TECHNICAL CONCEPT PAPER

REOPTIMIZATION OF DAMS IN THE MEKONG/LANCANG RIVER BASIN TO SAFEGUARD LIVELIHOODS AND AQUATIC ECOSYSTEMS

APRIL 2010

Problem Analysis:

The Mekong/Lancang is among the world's longest rivers, flowing 4,800 km from the Tibetan plateau through six nations to its delta in Vietnam and Cambodia (*see* map in Appendix 1). It supports some 60 million people, of which 40% live in poverty. Many of these people subsist on food derived from the river, its floodplain and its delta. The Mekong is very rich with freshwater fisheries producing 2.6 million tons annually, valued at some $2.5 billion. The Mekong is also the second most biodiverse river system in the world, with at least 1,200 species of fish and possibly as many as 1,700. A large portion of these fish have life cycles that require migrations of up to a thousand kilometers or more for reproduction. The engines of this exceptional natural productivity are the pulse flows of four elements: water, sediment, nutrient and carbon from the headwaters and tributaries all the way to the sea.

Global climate change will produce three physical alterations in the Mekong system with the potential to disrupt and diminish this natural productivity: (1) altered hydrology as a consequence of more extreme and variable monsoons, producing more frequent and severe floods and more profound and extended droughts in some reaches of the basin; (2) higher ambient temperatures, especially in the northern headwaters, which will accelerate the spring snow melt and stress many of the fish species; (3) sea level rise of as much as 1.5 meters within this century.

The expected ecological consequences of climate change in the basin are linked to these same factors. Species viability is closely intertwined with the natural variability in the flows. The seasonal flood pulse is a critical event that drives the high productivity of aquatic and wetland communities. According to the 4th assessment report of the Intergovernmental Panel on Climate Change[1], the mega-delta of the Mekong is particularly vulnerable. Over the time horizon of the next 2 to 3 decades, the combination of sea level rise, larger ocean surges and flood events, will likely increase both the inundation and seawater intrusion into the delta, causing massive changes in its highly productive land uses. One-third of the delta may be lost to

[1] The report forecasts:
- A basin-wide temperature increase which will be much more pronounced in the northern reaches, where the Himalayan glaciers are at risk of accelerated melting;
- an annual precipitation increase of 13.5 %, predominantly from increased wet season precipitation, resulting in increased delta inflows of as much as 20%;
- an increase in dry season precipitation in the northern catchments and a decrease in the southern catchments and coupled with increased water consumption could result in decreased delta inflows; and
- an increase in flooding in all parts of the basin, with the greatest impact in the Tongle Sap reach.

food production worsened by sediment starvation, leading to delta erosion and subsidence. This region of the basin has the highest population densities (500 people per km$^{2)}$ who depend on the high productivity of its coastal wetlands and estuary.[2]

Altered hydrology, elevated temperatures and sea level rise are probably inevitable, and there is not much the basin states can do to prevent their occurrence. But ***there is much these nations can do to either alleviate or exacerbate the effects in the decisions they make on the siting, design and operations of water development infrastructure, specifically hydropower and water supply dams.*** Some of these decisions have already been made and may be irreversible, such as the siting and design of the existing dams. Even these can be reoperated to counteract the effects of climate change, as discussed herein. At present, there are 25 hydropower and irrigation dams operating in the basin, including four in the Lancang reach.

The basin is positioned in a new era of accelerated dam building to meet essential power and food production needs. Eleven hydropower dams are being studied by private developers for the mainstem of the Lower Mekong. In Lao PDR, over 60 memorandums of understanding (MoU) have been signed for tributary projects up to the year 2020. In Cambodia, a master plan is being completed for 14 projects. China is planning to build 4- 14 additional dams on the Lancang reach (*see* Apppendix 2 for map of dams). For these dams, the options for creating resilience to climate change are quite substantial, particularly if the six basin states pursue them in a cooperative, synergistic and optimal manner. For example, dams can be operated in conjunction with aquifers and floodplains to enhance capacity to capture and attenuate larger flood events and to buffer longer periods of drought. On the other hand, dams sited, designed and operated in the wrong way can starve the delta of the sediment replenishment it needs to reduce the subsidence and erosion that make it vulnerable to sea level rise. Dams on both the mainstem and tributaries will trap sediments that are needed to keep the floodplains productive. As noted, the delta and Tongle Sap are the most vulnerable. By some estimates, the cascade of dams in the Lancang mainstem, when completed, will capture 40-50% of the sediment that now replenishes the Delta, with devastating effects on its sustainability. However, Chinese researchers believe that other sources of sediment in the Lower Mekong are more important. The sediment process modeling that will be conducted by this project should help settle that debate.

Today, the riparian nations have different and potentially conflicting strategies for the development and use of the river, and there is no institutional mechanism for collectively addressing climate change or for illuminating the optimal pathway. The Mekong River Agreement established the Mekong River Commission (MRC) in 1995 to foster "reasonable and equitable" utilization of the waters among the member countries, but it does not include China or Myanmar, which are merely observers. The MRC, as an intergovernmental organization, can share information with the non-member states only through official channels, which tend to be circuitous and rigid. The information flow needed to inform more optimal, climate wise decisions, like the water and sediment flows, is impeded by political barriers, in this case, those posed by national sovereignty.

[2] The Mekong delta is the most important agricultural area of Viet Nam, contributing more than 50% of the nation's food production.

The MRC has initiated a climate adaptation program in a forum held in 2009 (which included China and Myanmar) but this was limited to information sharing, identification of data gaps, and commitments to continuing the process. The climate adaptation programs of the riparian states are limited to emergency response measures, yet all recognize the importance of developing adaptive strategies. This project is designed to assist them in doing so.

Objectives

The objective of this project is to improve the capability of the riparian nations to counteract the negative effects anticipated from climate change through their coordinated decisions on the siting, design and operations of existing and prospective dams, while maintaining hydropower, water supply benefits and ecosystem services. We will do this by complementing initiatives already underway by the Mekong River Commission, NGOs such as WWF's Greater Mekong Initiative, and actions by the riparian states.

Methods

This project consists of a partnership in-the-making among governmental, non-governmental, and inter-governmental technical research institutions, both indigenous and international, including:

- **The hydrologic research agencies of five of the basin nations.**[3] Since China has not joined in the formal intergovernmental exchange of information, its Institute of Water Resources and Hydropower Research (IWHR) under the Ministry of Water Resources is authorized to join this project in a consulting capacity to review and provide feedback on project products. The confirmed non-governmental partner in China will be the Asian International Rivers Center (AIRC) at Yunnan University. We will also invite the Ecosystem Study Commission for International Rivers, and the Lancang Huageng Hydropower Company to join as full partners for China. The Department of Water Resources (DWR) of Thailand and the Water Resources and Environment Administration (WREA) of Lao PDR have expressed strong interest and are in the process of obtaining the necessary internal approvals, and are expected to confirm their participation by the first month of the program implementation. The counterpart governmental research agencies for Cambodia and Vietnam will be recruited into the project as an immediate task. Funding to support all of these local institutional partners is included in the cost proposal, and each is expected to provide equivalent in-kind co-financing.

- **Four international environmental NGO's** with freshwater conservation programs and with experience in the basin and/or the requisite technical expertise. WWF's Greater Mekong Program, the Nature Conservancy's Global Freshwater Initiative, and Conservation International will provide in-kind contributions of expert staff time to more than satisfy the 15% co-financing requirement, as reflected in the cost proposal, with the Natural Heritage Institute (NHI) managing the project.

[3] Because of USAID restrictions on funding institutions in Myanmar (Burma), we have not included its hydrologic research institutions in this project. However, only 3% of that nation is within the Mekong basin, so this will not diminish the project results.

The MRC will cooperate as a source of information, data and analytical tools, known as the Decision Support Framework (DSF). Consultations are ongoing with MRC regarding the approach for utilization of the DSF to evaluate climate adaptation scenarios that will be developed by this project. It may be necessary to purchase software licenses for the use of these tools, or to defray the costs of MRC modeling staff in operating the DSF for this purpose.

A detailed task table is attached as Appendix 3. It itemizes the sequence of activities that will be undertaken within the scope of this project, the task assignments to the project participants, and the timeline for their accomplishment. In this Technical Approach, we provide an overview.

1) Creating the analytical tools:

This project does not require highly precise predictions of how climate change will affect future hydrology, temperatures and sea levels in the basin. Fortunately, downscaling global climate circulation models to the river basin scale does not need a high degree of precision. The general direction of change is understood well enough to construct a range of credible assumptions regarding effects on hydrology and temperature, and to test how various adaptive scenarios involving infrastructure alternatives will perform to counteract these effects. We will also estimate the sediment process changes likely to occur in Mekong/Lancang basin as a result of climate change, in the context of the current state of development of the basin and current operational policies of dams.

We will gather the relevant data on historic hydrology, sediment regimes, and the associated geomorphic and ecological processes. We will organize these into a framework of planning models simulating the relevant hydrologic, sediment, and bio-physical processes of the entire integrated system. To do this, we will employ, link and enhance the existing models that have been built by the MRC, World Bank, AIRC, and others. We will utilize existing data as the time and resources available under this project are not sufficient to enable original data collection.

A major challenge is obtaining access to the data and models from the Chinese side. These are in possession of a number of institutions that are, or will be brought within the project, including:

- AIRC (a project partner), which is developing a model for simulating the water resources system of the Lancang River Basin. Climate change influences will be added to this model wth funding from this project.

- IWHR (a project consultant) will conduct a workshop of project partners, Chinese institutions and World Bank experts to update the World Bank's review of dam operations scenarios[4] in the basin to take account of the current state of dam development in the basin and climate change.

[4] "Modelled Observations on Development Scenarios in the Lower Mekong Basin" (November 2004).

- The Ecosystem Study Commission for International Rivers' "Compilation of Basic Data Concerning the Lancang-Mekong River Basin"

- The Lancang Huageng Hydropower Company, which is building the cascade of dams on the Lancang River, has detailed operational rules and how they can be modified to offset the effects of climate change.

- In the Yunnan Provincial Government: the Hydrology Bureau (for hydrologic data); the Institute for Investigation; Design and Research of Water Resources and Hydropower Energy (for hydropower dam operations), and the Meteorological Bureau (for predictions on the effects of climate change).

The project will then conduct a technical review of the functionality and limitation of these tools for investigating dam siting, design an operational scenarios for climate adaptation and develop an enhancement strategy. Our preliminary review of the MRC DSF indicates that the hydrological component is reasonably robust for the Lower Mekong.[5] However, there is no output related to sediment, temperature, water quality or environmental flow considerations. This project will fill these gaps. This may involve developing or selecting tools (models) to:

- Perform climate change analyses,
- Simulate basin-wide sediment processes,
- Add an ecological process module,
- Add an economic cost-benefit module

The linkage that this project will create to the Chinese models will be a major contribution toward creating a system-wide planning tool. This will be done through a menu-driven, graphics-based interface rather than combining models or building more complex ones. This will require significant software engineering and resources. These inputs will be provided by the local partners with training and advice from the NHI team.[6]

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[5] Current DSF models include (SWAT, IQQM and ISIS). SWAT is the rainfall – runoff model. Basin simulation is handled by the IQQM (Australian model) (DLWC [1995] Integrated Quantity-Quality Model (IQQM), Reference Manual. DLWC Report No. TS94.048, Parramatta, NSW, Australia.). The DSF seems to be capable of modeling hydropower, irrigation, water deliveries, flooding and inter-basin transfers, but the outputs are limited to hydrology and water use, including, river flow, river flows, stage, inundation, and salinity. These parameters are intended to provide inputs to fisheries, flood management, saltwater intrusion, navigation and environmental models. IQQM has some water quality simulation capability that does not seem to have been used here. ISIS (HR Wallingford) is the hydrodynamic model used to simulate flooding and inundation (as well as Tongle Sap). The testing of the DSF included evaluation of several scenarios including the impact of Chinese dams (2 existing run-of-river, and 2 larger storage dams that create significant redistribution of flow). The Decision Support Framework is also intended to have full socio-economic and environmental data and modeling capability when fully developed.

[6] The resulting system-wide tools will need to be tested for the purposes of calibration and validation. This will require significant data and operating policy inputs from local infrastructure managers and operators. It will be necessary to ascertain the availability of historical inflow data sets, sediment loadings, operating policies in effect or planned, constraints of operation limits (releases, power generation capacities, sedimentation rates, etc.).

2) **Formulate alternative scenarios for dam siting, design and operations:**

With the enhanced tools in hand, the project team will develop a suite of siting and design alternatives for proposed dams, and operational alternatives for both existing and prospective dams, designed to accomplish all of the following:

1) Maintain and enhance hydropower, water supply and flood control benefits;
2) Maintain or restore ecosystem functions, livelihoods and food production systems;
3) Manage sediment processes in the basin to avoid sediment deprivation in Tongle Sap and the delta, and reduce sediment accumulation in the reservoirs;
4) Buffer the anticipated adverse effects of climate change on all of the above objectives.

To formulate these scenarios will require several assessments to be conducted:

1) For reaches with high ecosystem, livelihood and food production value, assess flow requirements to understand the relationships between flow dynamics and ecosystem /ecosystem services responses. The assessment will generate "environmental flow" targets that the scenarios will be designed to maintain or achieve to the extent feasible.

2) Conduct sediment process alteration assessment for the entire basin to identify reaches where current state of development is causing sediment starvation or excessive sediment mobilization. The first step will be to focus on assessing risks associated with sediment reductions and increases. Building on existing information and expertise within MRC, World Wildlife Fund's Greater Mekong Program, and other organizations in the region, the effect of the various existing and possible future dams will be analyzed and quantified. These possible changes in sediment regime will then be linked to increased vulnerability of the system to climate change. For example, loss of total sediment load may be expected to decrease deposition in the delta, increasing its vulnerability to sea-level rise and storm surges. In addition, change in sediment regime would be expected to increase risk of reduced fishery resources through habitat loss; this would amplify the risk of catastrophic decline of fishery resources, exacerbating risk that would be expected from climate change through reduced basin water yield and increased droughts.

   The project team will then examine possible mitigation strategies to address sediment reduction caused by dam development. First, the siting of dams will be a critical variable. The project will compare scenarios involving mainstem dams with those involving only tributary dams. Possible infrastructure retrofits such as large volume sediment sluicing gates will be analyzed along with possible changes in the proposed operating rules for these dams.

3) Screen all existing and prospective hydropower and irrigation dams to ascertain which are the best prospects for improved operations to achieve the objectives. For the hydropower dams, we will apply the "REOPS model" (*see* Appendix 4) which was developed by NHI for the World Bank and field tested with the 141 hydropower dams currently operating in Africa to determine the best prospects for reoperation to restore ecosystems, livelihoods and food production systems in anticipation of climate change. A counterpart model for irrigation systems has been largely conceptualized and will be built and applied as a task in this project.

With the results of these assessments in hand, the project team will develop the siting, design and operations scenarios through a process of stakeholder consultations throughout the basin. These will include dam owners and operators, river basin planning officials, MRC experts, stakeholder and user communities, local and international NGOs, development assistance agencies (bilateral and intergovernmental).

3) Evaluate the scenarios using the linked-enhanced-system wide model:

The model will be applied by the regional research institutions, assisted by the NHI team, to evaluate the feasibility and efficacy of the scenarios to achieve the stated objectives and identify tradeoffs. The evaluation will be conducted iteratively, starting with a course-level, proof of concept approach to identify the best performing options and then progressively refined and optimized.

The team will first study the selected reservoirs individually to learn how to optimize siting, design and operations for the stated objectives. It will then evaluate the synergistic potential for coordinated operations system-wide. The developed scenarios will be translated into the inputs, infrastructure, operating policies, river flow and sediment constraints, and downstream water deliveries and flood protection needed for each scenario. This will be done in concert with the MRC and the regional hydrologic research centers.[7] It is unlikely that the modeling will result in any one solution or plan that is "optimal" in all respects. For instance, sediment management may have repercussions for the power, water supply and environmental performance objectives that will be taken into consideration. In addition, dams should be designed to flush sediment. However, that usually requires lower storage levels and foregoing some fraction of power generation. Even within objectives, there may be tradeoffs. For instance, it may be best to site dams as high as possible in the tributaries to minimize sediment starvation problems in the delta and at Tongle Sap. However, this siting alternative needs to be evaluated in light of the biodiversity consequences.[8]

4) Conduct economic feasibility analysis for best performing alternatives.

The team will conduct a cost-benefit analysis of the best performing scenarios emerging from the modeled evaluations of the dam siting, design and operational scenarios. This will not be highly precise, but will be useful to determine which of the scenarios are most implementable. These scenarios and the economic analysis will explore benefit sharing arrangements across boundaries to the extent that that will improve net benefits and is politically practical.

5) Vetting and disseminating the results

This project is not an academic study. It is intended lead to implementable and implemented improvements in dam siting, design and operation to achieve the objectives stated. Thus the results are addressed to the institutions that will make those critical decisions. This includes national governmental agencies that plan, manage and regulate river development, public and

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[7] We will identify a number of "efficient, non-dominated" alternatives where objectives are conflicting, as well as looking at the robustness of solutions to future uncertainties due to human activities and climate change. In this case, models can be used to explore the sensitivities of assumptions about the future rather than as predictive tools.

[8] Fish migration tends to be on the main channel, but some range restricted (endemic) species may be affected by tributary dams.

private sector dam developers and operators, the full range of institutions that finance dams, including public, private and foreign assistance agencies, and institutions that influence dam policies, including local and international civil society and environmental organizations.

Before the results of the technical investigations are disseminated, it is essential that they be vetted with these stakeholders and experts. The project team will therefore organize workshops of stakeholders and decision-makers in each riparian country to vet these results. We will then incorporating feedback from the workshops, prepare a final report, disseminate it broadly, and conduct briefings for water resources decision-makers, dam operators, and the development assistance community at the global scale.

For more information about this project, please contact:

Gregory A. Thomas

President, Natural Heritage Institute

Phone: 1-415-693-3000 ext. 101

E-mail: gat@n-h-i.org