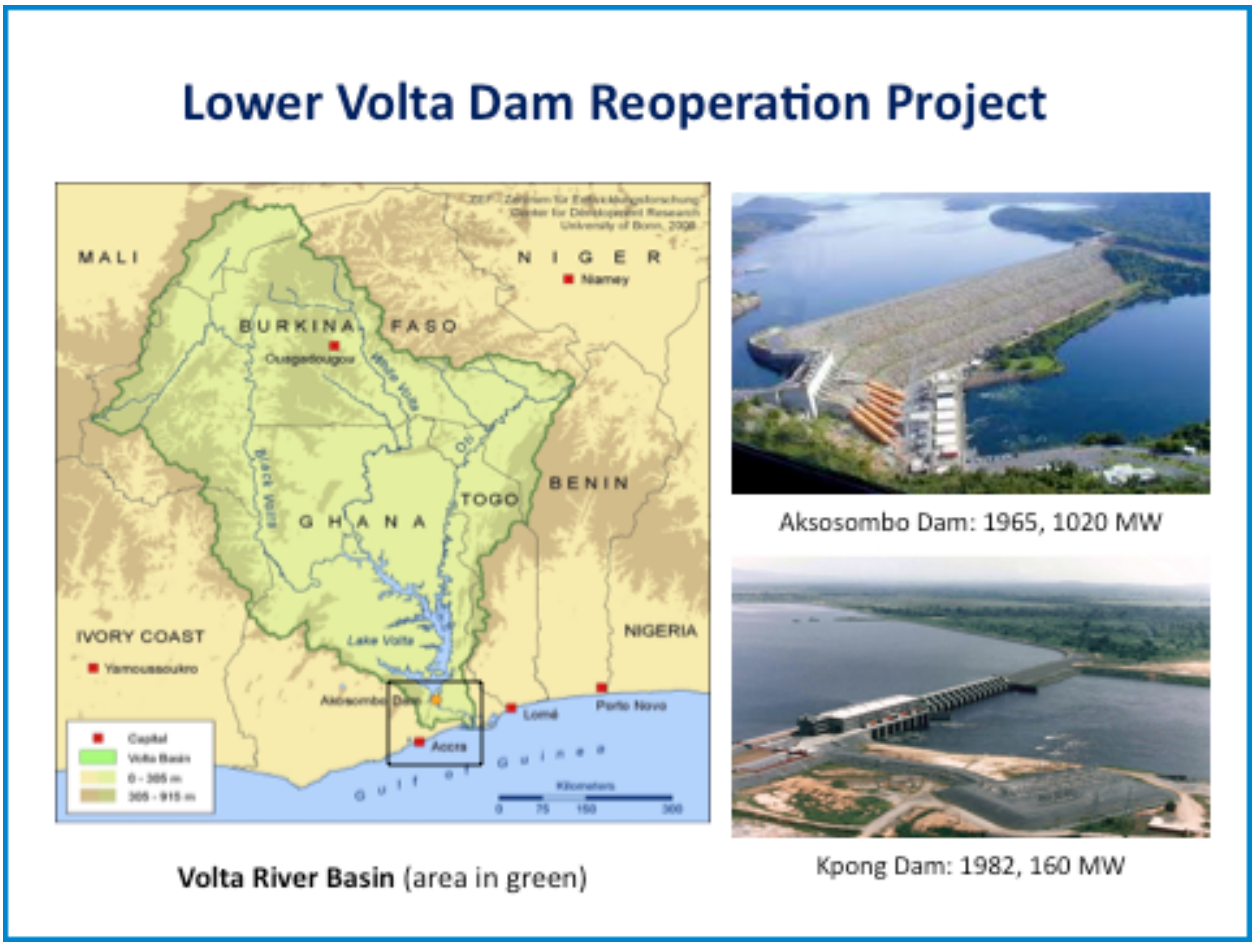
Reoptimization and Reoperation Study of Akosombo and Kpong Dams

Project Summary & Key Elements

The Akosombo and Kpong Dams Reoptimization and Reoperation Study has been established to examine options for reoperating Akosombo and Kpong hydropower dams and the electrical grid they supply to enable a more natural flow pattern to be re-established into the Lower Volta River. This will restore the human food production systems and livelihoods and the ecological functions that depend upon natural flow variability, and it may also be possible to accomplish these improvements while increasing the reliability of and access to water and power and reducing flood risks. The ultimate output from the project is a technically and economically feasible reoperation plan. The project will also contribute to a global process of shared learning on the techniques and benefits of dam reoperation.



Project Team:
The project team is comprised of an impressive partnership of Ghanaian and international organizations, with a high level of technical capacity and field research skills and project execution experience. The Reoptimisation and Reoperation Study of the Akosombo and Kpong Dams originated with the Natural Heritage Institute (NHI), but it was developed and designed by the project partners in 2007. The Water Resources Commission (WRC) is acting as the Executing Agency and is a recipient of a grant from the African Water Facility on behalf of the entire project team. NHI is playing the lead role in specific tasks, including: environmental flow process & modeling; building dam and river basin operations models; constructing a model of the power generation and distribution system (Grid) to evaluate technical and economic feasibility; and knowledge-sharing and global learning. The NHI team comprises of directors and staff of the organization as well as key experts (consultants) in hydrology, water resources modeling and engineering, fluvial geomorphology and sedimentation, and systems evaluation.

PROJECT PARTNERS

GHANA	EXTERNAL
Ministry Of Water Resources Housing And Works *	**Natural Heritage Institute**
Water Resources Commission – Executing Agency	**Cornell University**
Ministry Of Energy *	**Consultants from the Purdue University Energy Center**
Volta River Authority	**University Of Stuttgart**
GRIDCo	**International Water Management Institute**
Environmental Protection Agency *	
Water Resources Institute CSIR	
University Of Ghana • **Institute For Environmental And Sanitation Studies** • **Center For African Wetlands**	
Traditional Chiefs	

* Members of the Project Steering Committee

Study Area:

The geographic focus is the Lower Volta River from Lake Volta to the mouth of the river near Ada. This reach of the river is of interest to the project because Akosombo and Kpong dams, built in 1965 and 1982, respectively, have distorted the natural river flows by storing and releasing water to meet electricity demand patterns rather than in rhythm with the seasonal patterns of rainfall and runoff in the catchment area. The Akosombo dam formed Lake Volta, one of the largest water storage reservoirs in the world. Twenty-five kilometers downstream, the Kpong dam operates as a run-of-the-river facility with minimal storage to re-turbine the Akosombo releases. Akosombo and Kpong dams were designed to generate an average of 6,100 GWh/year, which is 95% of Ghana's electricity consumption. In addition to power generation, Akosombo provides some degree of flood protection due to its very large storage capacity relative to inflow, and Kpong supplies a small amount of irrigation (only about 100 ha) for rice cultivation. Navigation and a robust lake fishery are important additional benefits of the reservoir.

Rationale for the Project:

Like storage reservoirs in general, the function of Akosombo is to store water during seasons and years of high inflow for power generation during seasons and years of lower inflow. In Ghana, the demand pattern causes Akosombo to be operated to generate a relatively constant output of power daily and seasonally. Thus, Akosombo distorts the natural river flows by storing and releasing water in rhythm with the patterns of electricity demand in the service area rather than the seasonal patterns of rainfall and runoff in the catchment area. The effect on the downstream flow pattern is to reduce the peak flows and increase the base flows, effectively eliminating the dynamic interactions between the river and its floodplains, wetlands, deltas, estuaries, mangrove and beach environments. These are the great engines of riverine and marine biodiversity and the environmental services that they provide for the myriad of human livelihoods that are dependent upon a fully-functioning river system.

By eliminating the annual floods in the Lower Volta River floodplain and estuary, the Akosombo and Kpong dams have devastated the historic livelihoods of the downstream communities and the physical and ecosystem processes on which they depend. The results have been a drastic reduction in sediment flushing and an explosion in the growth of exotic weeds that have choked off the once lucrative shell fishery, increased the snail vectors for the debilitating bilharzias, and fostered the formation of a permanent sandbar at the estuary. As sediments accumulate in the channel, they are no longer replenishing the beaches in Ghana, Togo and Benin, resulting in massive beach erosion, loss of mangrove habitats and reductions in the productivity of the Guinea Current and its pelagic fishery. The loss of the annual flood pulse has also reduced floodplain agriculture as natural flooding no longer leaves rich alluvial deposits that improve soil fertility in the overlying upland areas.

The overall effect of the loss of agriculture, clam picking, and fishing activities has created intense poverty and led to a dramatic shift in income generating activities. Some 80,000 people are directly adversely affected by the change in livelihood. The Volta Basin Research Project

has found that the decline in river-based incomes triggered an increase in prostitution, crime, sexually transmitted diseases, and the widespread migration of young people to urban areas.

The goal of the Ghana Dam Reoptimisation and Reoperation Project is to contribute to economic growth and poverty reduction through restoration of downstream ecosystems, food systems and livelihoods by reoperating the Akosombo and Kpong dams. It will specifically examine techniques for optimizing major hydropower dams and the electrical grids into which they feed to enable a more natural flow pattern to be re-established into the Lower Volta River. This project will improve the reliability of and access to water, food and energy, thereby improving livelihoods on a local, regional and transboundary level. The beneficiaries of this dam reoperation project will include: riparian communities downstream of the dam whose food production, livelihoods, and access to groundwater will be markedly improved, and whose flood risks will be reduced; residents of Togo and Benin who will benefit from the arrested erosion of their beaches and mangrove ecosystems, and from the improved production of the ocean fisheries that depend upon recruitment in the Volta estuary; and consumers of power from Akosombo and Kpong dams whose reliability will be improved by the hydropower and grid reoperations.

Project history:

The project is one of a suite of regional investigations to demonstrate the technical and economic feasibility of re-optimizing the world's major irrigation, hydropower and flood management systems to enable their storage dams to be reoperated to restore their formerly productive floodplains, wetlands, deltas and estuaries in ways that maintain - and can often even enhance - the existing water supply, power generation and flood control benefits.

Significant milestones in the project history include:

- Akosombo/Kpong dam reoperation project was developed and designed by the International and Ghanaian project partners in a workshop conducted in May 2007 at the Kofi Annan Center in Accra.

- The project application was submitted to the African Water Facility (AWF) for funding consideration in August 2008.

- The proposal was considered eligible for support under the AWF Operational Procedures in 2009. The AWF deployed a multi-disciplinary team to carry out a field appraisal mission to Ghana from 29th September to 6thOctober, 2009 including a field visits to Akosombo hydropower station and the Lower Volta estuary at Ada. The mission furthermore met and discussed with partners, such as officials of the Volta River Authority, academic and research institutes, traditional authorities, community representatives and other stakeholders.

- The project was approved for funding in July 2010. The first funding disbursement was made in January 2011.

- The project was officially launched during a partners workshop held in August 2012 in Accra.

- A series of meetings were held from March 7-11, 2013 in Accra and around the project site. In addition to re-confirming support for the project from key Ghanaian Ministries; NHI and WRC introduced the project to GRIDCo (power transmission company of Ghana); and began discussions with VRA and the model developers on data gathering and populating the WEAP model for the Lower Volta Basin.

- Project Steering Committee meeting held in Accra on May 7, 2013. VRA (Charles Addo) participated in the meeting. In addition, NHI and colleagues from the Purdue Energy Center held a more in-depth conversation with GRIDCo technical staff and the role they can play in the project.

- On August 12-13, 2013 a partners' workshop was held to discuss the progress so far and the methodology for establishing target flows that will be able to restore the downstream ecosystem using the data and information which have been collected by partners.

- The WRC organized a Mid-Term Review program from January 13-24, 2014 "to assess how well the project is progressing in achieving its objectives." The program included several meetings with the AWF and the project partners; facilitated by an independent consultant to "take stock of work undertaken (by the project) and help make informed decisions with regards to the achievement of the development objectives," including the need for mid-course corrections in the workplan and roles to reflect the learning that has been achieved in the project so far. […] Findings of the MTR will contribute to refinement, adjustments and re-allocation of resources for the success of the project" (Terms of Reference for Mid-Term Review).

Elements of the Project:

1. **Determine the flow pattern that will be most advantageous to bring back the downstream ecological functions and livelihoods.**

   Project partners set out to determine the pattern(s) of downstream flows that would result in restoring an array of environmental benefits that have been impaired by the operation of the dams since 1965. Due to limited empirical data, the likely method to be utilized will be to assume that the pre-dam hydrograph provided the physical conditions conducive to the full range of benefits that we now seek to restore, and then to eliminate features of that hydrograph that either cannot be re-created, or are deemed to be undesirable. Findings presented at a project workshop in August 2013 suggest that the environmental restoration objectives will best be achieved through improvements in flow patterns in combination with physical improvements (e.g. mechanical removal of weeds and reducing riverbank gradient) in the downstream floodplain.

Proposed new methodology: Following the August 2013 partners' workshop, NHI proposed a series of new and/or enhanced activities for setting the environmental flow targets and achieving the project objectives:

- **Conduct a Dam Retrofit Feasibility Study:** The capacity of the dam to discharge water through the powerhouse limits the magnitude of flow that can be released into the downstream river and floodplain without sacrificing power generation (the goal of the project is to restore downstream conditions without impairing power generation or reliability). So, the project objectives can only be achieved by increasing the discharge rate for power generation. A proposal from a US-based firm was submitted to carry out a study on the feasibility of retrofitting Akosombo Dam. This may be included in the next phase of the project.

- **Carry out Additional Fieldwork:** To determine the extent of the natural hydrograph that can be re-established without creating flood risk, it is necessary to develop a detailed understanding the relationships between discharge rates at the dam(s) and the floodplain inundation patterns that would result. This requires additional transects (cross sections) of the river from the dams to the estuary and floodplain geometries. NHI team members from the University of Stuttgart will develop a training manual and provide a training workshop for Ghanaian partners at the CSIR/WRI to carry out the necessary fieldwork.

- Once the relationship between dam releases and floodplain inundation is understood, it will be possible to make decisions regarding the extent to which the historic inundation patterns can be established. That, in turn, will define the restoration flow target(s). There are two considerations here. First, existing structures or land uses may not be compatible with a season flood regime. If those structures can be moved or protected with berms or levees, that would permit the floodplain to be reactivated. The high-value resorts at the mouth of the river may be an example. Second, it would be highly desirable to reconnect historic flood retention areas to the river where possible.

- **Enhanced Community Consultations:** The community preferences regarding a more dynamic river should also be considered in selecting the restoration flow target, or range of targets, before developing the reoperation scenarios. There is no sense in assessing flow restoration hydrographs that are adamantly opposed by the local residents. NHI devised a work plan with proposed methodology for conducting a more intensive community assessment where we will bring in maps generated by University of Stuttgart from their floodplain analysis and discuss openly with the local stakeholders their desires, the options and the tradeoffs.

2. **Construct operational models to evaluate a range of scenarios to generate restoration flows.**

The project is building a planning model to simulate the hydrology of the Lower Volta River system from Lake Volta to the sea and the operations of Akosombo and Kpong dams on the WEAP platform. This model is being developed in collaboration with the **Volta River Authority** as they hold much of the required data, and they will be the ultimate beneficiaries/users of the final product. In additional, the Lower Volta planning model can be merged with an existing WEAP model of the Upper Volta River to represent the entire basin. In this project, the model will enable all of the partners to simulate, assess and compare a range of scenarios for reoperating the dams to generate downstream flow patterns that will achieve (as closely as possible) the environmental restoration targets set in Project Element 1.

We will operate the model to:

- Ascertain the physical and economic limitations on the ability of Akosombo and Kpong dams to release water and generate power. Specifically, we need to ascertain the feasibility of retrofitting the dam with additional turbines to permit larger releases of water during the times when a controlled flood is desired.

- Quantify the magnitude of the controlled flood events that can be released from Akosombo and through Kpong to the estuary without causing catastrophic inundation downstream that will damage property or endanger lives. Thus, it is also necessary to ascertain the flood reservation requirements in Lake Volta. This will be accomplished by changes in land uses in the floodplain to accommodate these larger flow events. That should allow Lake Volta to retain higher storage levels than it does under current operations, and thereby increase power output. The challenge is to figure out how much additional storage it can maintain without creating risks of floods larger than the targeted controlled floods (bearing in mind, however, that, axiomatically, there is always some probability of a flood larger than design). The operations model should allow us to ascertain this storage level.

- Estimate the size of pulses needed to create the hydraulics that will mobilize sediments downstream of the Kpong dam so that downstream geomorphic processes can be re-established, including beach accretion.

- The NHI team will determine whether these scenarios provide climate adaptation benefits in a future of more intense droughts and floods in the Volta River system. Climate change will require greater capacity to store and channel water in the Volta river system. This project will test whether Akosombo dam can do a better job of managing larger floods by utilizing the capacity of downstream floodplain to accommodate (store and attenuate) controlled flood flows, provided that floodplain land uses are adapted to this purpose. This work is of vital importance in Africa, the continent that is already most ravaged by droughts and floods, with often devastating consequences for the food production systems that are here, particularly, so intimately connected to natural river functions.

The scenarios will be evaluated and compared using the computer model to identify those that are hydrologically feasible and most robust in achieving the objectives. Hydrologic feasibility means both physically achievable and desirable from the vantage point of the stakeholders. This is an optimization study, not a reallocation study. We intend to identify the scenarios that increase the water service benefits for all interests.

3. **Redefining role of the dams in the power generation mix for the Ghana Grid and WAPP.**

   To explore the potential for reoperating Akosombo/Kpong to reintroduce annual controlled flood events into the downstream river system, the project will explore the range of freedom in the scheduling of power generation at those facilities relative to the demand requirements of the integrated grid system and the supplies of power from other generators. The WEAP model outputs will feed into a power system operations model that is being developed by consultants from the Purdue Energy Center with input from GRIDCo. The model will cover the grid system at its current state of integration with Nigeria, Benin, Burkina Faso, Cote d'Ivoire, Niger, Nigeria and Togo (West Africa Power Pool Zone A). The model will also account for current hydro and thermal generation connected to that grid, including plants now under construction, as well as future additions to electrical supplies, which are also dynamic.

4. **Generating the Reoperation Scenarios.**

   Generating the reoperation scenarios that will be assessed for feasibility and effectiveness (in achieving the project goals while maintaining or improving power system reliability) will be done jointly by all of the project partners, including at least the entire NHI Team, VRA, GRIDCo and WRC. This essential task will require a day or two of interaction among the project team. However, it cannot be done until the previously mentioned tasks have been completed.

5. **Assessing the Reoperation Scenarios using the WEAP Planning Model and the WAPP System Operations Model**

   These models will be used to assess (1) physical feasibility and (2) efficacy of the scenarios to achieve the dual objectives of (A) achieving the restoration flow targets, in whole or in part, and (B) maintaining or improving power system reliability. The model runs will be conducted iteratively. After the initial runs, the outputs should reveal which of these are most robust in terms of the objectives and also suggest how the best performing can be fine-tuned to improve outcomes. This process should reveal the optimal reoperation scenario to incorporate into a reoperation plan.

6. **Economic Assessment of the Best Performing Scenarios.**

   This will be an economic cost-benefit analysis of the “finalist” scenarios run through the planning models. The NHI Team (the Purdue group) will carry out the power-system cost-benefit analysis. The costs include the additional capital costs of the reoperation

scenario: spillway retrofit, increased transmission capacity from Akosombo, additional thermal generation to buffer the change in scheduling of power generation; and the additional O&M costs. The baseline for comparison should be the facilities already included in the 10-year power generation and transmission plans of GRIDCo. The relevant metric will be the increase in costs per KWh for the West African demand center. The power generation benefits will include factors such as increased annual power output from Akosombo/Kpong, improved power system reliability, reduced operating costs due to reduction in the need for dredging at the mouth of the river.

The additional benefits that can be quantified are the increases in food production and livelihoods, which will be analyzed by IWMI. However, the challenge here will be establishing the causal relationships between improved flow patterns and biological productivity of the estuary—the same problem encountered in attempting to set empirically-based restoration flow targets.

7. **Global Learning Component.**

This project is one of a suite of regional reoperation investigations around the world to demonstrate a toolbox of techniques that can be widely applied to the current inventory of major dams and to the next generation of dams to make them more environmentally compatible. Thus, this project has the dual objective of improving the environmental performance of the major infrastructure on the Lower Volta River and also of contributing to a global process of shared learning. We expect this work to result in a transformation in how dams are sited, designed and operated at the global scale.

The knowledge sharing and dissemination of project results, outputs and lessons learned, will take place through an online platform; a process of structured workshops; and high level briefings to the development assistance agencies, dam operators, national governments, non-governmental organizations and the academic community. The project will produce reports and workshop presentations for major international water conferences (i.e. World Water Week) that will show case the project results and to demonstrate the analytic tools best employed to develop dam reoperation plans and the broadly replicable reoperation techniques. In addition, both training and knowledge sharing among the Ghanaian and international partners will be an ongoing, integral part of the entire project.

The current completion deadline for the project is May 2015.

Expected Outcomes of the Project:

- Improved downstream ecosystems and human livelihoods. This will include:
  - ✓ Increased flood plain agricultural production as a result of controlled downstream flooding;
  - ✓ Increased human livelihoods namely due to employment in agriculture, fishing and related businesses;

- ✓ Reduced coverage of exotic aquatic weeds;
- ✓ Groundwater availability as a result of recharge due to annual flooding;
- ✓ Resumed shell fishing due to re-establishment of the salinity regime;
- ✓ Improved sediment transport which would reduce the build-up of sand bar at the estuary and possibly reduce shoreline erosion

- Continued protection of the downstream communities from the larger flood events that would jeopardize human settlements while accommodating seasonal inundation of farmlands. This is entailed by the reintroduction, to the extent possible, the natural flow patterns. In effect, the floodplain storage would augment the reservoir in attenuating flood pulses, allowing the reservoir to be maintained at higher storage levels year around.
- Increased total electric power output of the dams, while altering the generating schedule. This would be accomplished by maximizing the hydrologic head and thus increasing electricity output through simulation of the planning model.
- Increased reliability of water supply for hydropower generation. This would be accomplished by investigating the optimum reservoir levels that will keep the reservoirs full during the early years of an extended drought, thereby reducing the potential for power shortages in later years.
- Reduced incidence of water borne disease vectors. Re-operating Akosombo and Kpong will reduce the static water levels and therefore exotic weeds that are the breeding grounds of bilharzia and malaria, thus improving the health and productivity of millions downstream of those dams.

Expected Outputs of the Project

The expected outputs comprise the following:

- A computer simulation of the physical processes and infrastructure operations in the entire Volta River system developed;
- A power system planning model constructed for the grid system at its current state of integration with Nigeria, Benin, Burkina Faso, Cote d'Ivoire, Niger, Nigeria and Togo (West Africa Power Pool Zone A). The model also accounts for current hydro and thermal generation connected to that grid, including plants now under construction, as well as future additions to electrical supplies, which are also dynamic);
- An Economic model developed that estimates economic incentive structure to induce users and dam operators and stakeholders to implement reoperation;
- A feasibility report prepared on the legal, institutional and political implications of reoperating dams according to the natural flow patterns;
- A report on the effects of reoperation of Akosombo and Kpong dams on Public Health prepared. If the model proves successful there will be the need for follow-on study to define down streamactivities that shall be necessary.
- A recommended reoperation plan for Akosombo and Kpong dams.