TECHNICAL BRIEF

CGIAR RESEARCH PROGRAM ON Water, Land and Ecosystems

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Re-operating large dams to benefit all – experiences from Akosombo and Kpong dams in Ghana

Results from the Reoperation and reoptimization study of Akosombo and Kpong dams project

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SPILLWAY OF AKOSOMBO DAM GHANA.PHOTO: THOR WINDHAM-WRIGHT (IWMI)

KEY MESSAGES

- Large dams affect upstream and downstream ecosystems and livelihoods
- Dam reoperation can in principle reintroduce a near natural flow regime while increasing overall annual hydropower production but it requires significant adjustments elsewhere to cope with the seasonal variability in energy supply
- The feasibility of reoperating a dam is therefore dependent on a balance of trade-offs between technical, economic and social benefits and challenges
- For the Akosombo and Kpong dams, reoperation is not economically and socially feasible, it is therefore more cost effective to focus instead on improving alternative livelihood sources

BACKGROUND

Development of rivers for hydropower has conventionally come at a high cost to riverine livelihoods and ecosystems. Ecosystems are adapted to the natural flow dynamics so changes to the flow will affect these ecosystems and the livelihoods dependent on the services they provide. Hydropower dams tend to release steady flow regimes, regardless of the natural flow regime, to optimize turbine energy generation and provide a steady flux of energy. Providing environmental flow that better supports downstream ecosystems can increase total hydropower production, albeit not in a continuous manner. Reoperating dams is an innovative way of addressing these challenges while potentially increasing total annual hydropower production. However, before implementing dam reoperation, all aspects for feasibility should be assessed, including technical, economic and social. This brief presents the concept of dam reoperation as well as application of this concept to the Akosombo and Kpong dams in Ghana.

Dam reoperation concept

The dam reoperation concept is summarised in the Dam Operation Concept graphic overleaf. When conventionally operating a hydropower dam, dynamic flows fill the dam and a steady flow regime is released. Due to seasonal differences in inflow and outflow water levels in the reservoir change as well. During the dry season water levels drop as less water flows in than out. During the wet season the reservoir fills up as more water flows into the dam than is released through the turbines. Hydropower production is then relatively steady throughout the year based on water levels and outflows. The reoperated dam, however, releases flows that aim to mimic the natural flow regime. In this scenario, as inflow and outflow are almost equal, the water level in the dam remains relatively constant. A continuous high water level means that hydropower production can be more efficient (more MWh per m^3). However, hydropower production from a reoperated dam fluctuates throughout the year, and depending on the contribution of the dam towards firm or peak production this may have an impact on reoperational feasibility.

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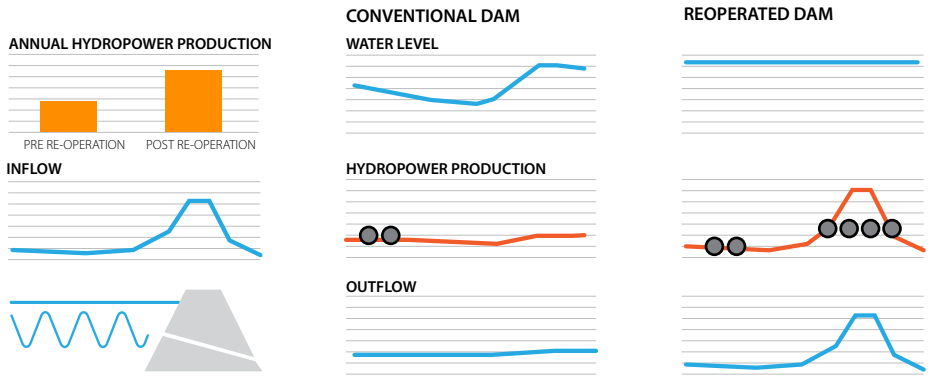
Feasibility assessment of reoperating dams

The main objective of dam reoperation is to improve the environmental conditions downstream, however this will impact the system in a number of other ways. The feasibility of reoperating a dam is therefore not only dependent on the improvement of the environmental conditions, but it is also dependent on technical, economic and social aspects.

DAM REOPERATION CONCEPT



Technical requirements

Optimally harnessing hydropower production in the wet season requires significant technical adjustment of the dam. Water released through the spillway during the flood season is not normally used productively. Producing electricity from these releases requires the spillway to be equipped with additional turbines. Ensuring the structural stability of the dam is of utmost importance when considering such alterations to an existing dam. Equally, to ensure a stable power supply during the dry season, reductions in hydropower production need to be compensated for by increasing electricity generation in other ways.

Economic feasibility

The primary goal of dam operation is to increase livelihoods among downstream communities. Yet it is also important to consider holistically what the combined effects, of different affected sectors, will be. If large economic losses are predicted overall in a reoperation scenario it is unlikely that decisions will be taken to reoperate the dam merely in favor of downstream communities. Economic feasibility not only considers the total benefits for all sectors but also provides insight into the trade-offs between the different stakeholders in each scenario.

Social feasibility

Reoperating a dam to allow for more natural downstream flows will impact downstream communities. The hypothesis is that this will be beneficial to them, as natural flows support ecosystem services. Natural floods however would also bring different challenges. It is therefore important that communities are engaged and fully support reoperation implementation.

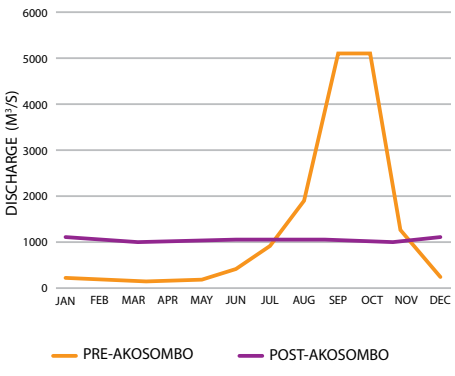
The case study: Akosombo and Kpong dams

The dam reoperation concept was explored through a case study of Akosombo and Kpong dams on the Lower Volta in southern Ghana. The construction of these dams (in the 1960s and 1980s respectively) radically changed the hydrological regime in the Lower Volta. The historically highly dynamic system, with peak flow in September and October and low flows in the long dry season was replaced with a steady flow regime (see flow regime graph opposite). During the dry season the flow is more than 10 times higher than the natural flow, affecting the natural salt and freshwater dynamics in the estuary.

Historical flow regime benefits

Historical floods inundated large areas of the floodplain and connected creeks to the river, offering good fish spawning grounds and thus good fish yields. Low flows allowed for saltwater intrusion up to 95km from the estuary, supporting a healthy clam industry mainly operated by women. Pre-dam conditions provided several livelihood opportunities to downstream communities, including fishing, farming, clam picking, petty trading, craftwork and net and fish trap manufacture. Post-impoundment the resulting dwindling resource base contributed to household impoverishment.

PRE- AND POST-DAM FLOW REGIME IN THE LOWER VOLTA



Current flow regime challenges and benefits

The current flow regime does not adequately support ecosystem services that formerly underpinned many of these downstream livelihoods. Additionally, increasing downstream community populations combined with limited sanitation facilities have resulted in higher than normal water nutrient levels. Together with slow flowing water, this makes the Lower Volta an excellent environment for aquatic weeds. The unintended release of Water Hyacinth (Eichhornia crassipes), an invasive species, into the environment

FISH MONGERS IN THE LOWER VOLTA.
PHOTO: NANA KOFI ACQUAH/IWMI

AQUACULTURE IN THE LOWER VOLTA.
PHOTO: MARLOES MUL/IWMI

AQUATIC WEEDS IN KPONG HEADPOND.
PHOTO: MARLOES MUL/IWMI

has led to its proliferation. This has a big impact on local fishing, blocking access to clear water and damaging fishing nets. Water Hyacinth also has an impact on the health of downstream communities, serving as a habitat for the bilharzia snail. More positively, the steady flow regime provides year-round freshwater supply for domestic, industrial and agricultural use in most parts of the Lower Volta. Hydropower production by Akosombo has been credited for the economic development of Ghana. Even today it contributes more than 50% of Ghana's energy supply.

Scenarios

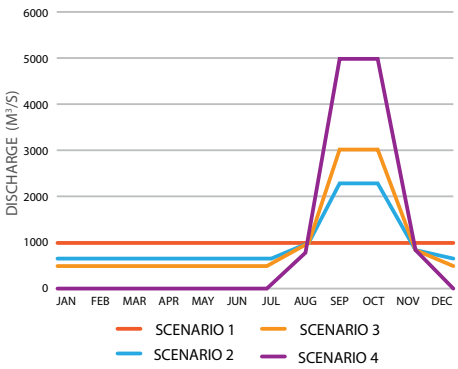
To assess the feasibility of reoperating Akosombo and Kpong dams, key national experts on the flow requirements for fish, agriculture, groundwater and aquatic weeds, were consulted and four flow scenarios developed. These were:

- Scenario 1 (S1): Maximizing hydropower generation by maintaining the current flow
- Scenario 2 (S2): Reinstating the current flow dynamics up to the 2010 spillway levels
- Scenario 3 (S3): Maintaining sufficient water for irrigation while introducing natural flow
- Scenario 4 (S4): Maximizing ecosystem services by introducing natural flow

A scenario has been added to S3 (S3b), which includes adding turbine capacity to harness the water released through the spillway during peakflow conditions for electricity generation.

Feasibility for reoperating

RESTORATION HYDROGRAPH SCENARIOS



Akosombo and Kpong dams

The technical feasibility of each scenario was assessed using the water allocation model WEAP, developed by the Stockholm Environment Institute. The model provided information on the average hydropower production (GWh/a) and on what percentage of hydropower production this represents compared to the current flow regime scenario. Furthermore, the model indicated what percentage of firm power (6 GWh/day) would be met in this scenario and for how many months of the year. Firm power refers to the actual energy guaranteed to be available. These model scenarios showed that as the flow regime comes closer to the natural one hydropower production will decrease.

It also showed that even if additional turbines were installed in the spillway (S3b), which would increase hydropower production to 3,149 GWh/a, this would still only meet around 60% of current hydropower production.

The economic feasibility of reoperating the two dams was assessed by identifying the costs and benefits resulting from the different flow scenarios. It showed that the highest cost-benefit ratio is obtained from the baseline scenario (S1). The highest income is generated by hydropower, which contributes 60-78% of total benefits. It is therefore not surprising that scenarios highly affected by a reduction in hydropower likewise see a reduction in overall benefits.

The scenario with the highest total benefits provides the least benefits in the activities that support downstream community livelihoods, such as flood recession farming, river fishing and clam harvesting. This scenario also results in the largest drawback in the form of increasing aquatic weeds. Downstream communities would also be affected by reintroducing a natural flow regime as they now have investments in the floodplains that would be at risk from flooding. During community consultation researchers found that these communities are most interested in addressing the issues of health and aquatic weeds, but not necessarily through dam reoperation.

Net Present Value for selected scenarios

At the macro level the lack of social support combined with the low overall economic value associated with the reoperation scenarios indicates that reoperation

HYDROPOWER PRODUCTION

	% of FIRM power met	No. of months	Average hydropower production	
			GWh/a	% w.r.t Ref.
S1	100%	12	5,248	100%
S2	76%	9	5,259	54.9%
S3	33%	4	2,880	41.7%
S3b	33%	4	3,146	59.9%
S4	17%	2	2,186	26.5%

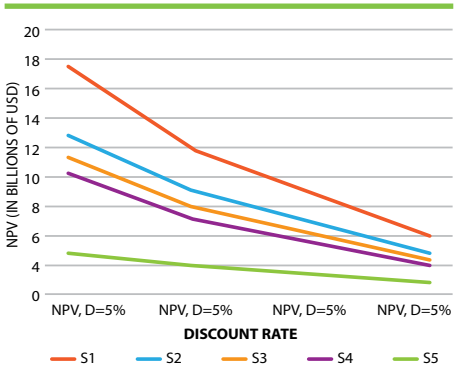
of Akosombo and Kpong dams is not advisable. To compensate for hydropower losses in the reoperation scenario, large investments would be required to upgrade both the dams and the energy network to maintain the network stability. Even with these large investments the economic benefit analysis is not in favour of reoperating Akosombo and Kpong dams.

Policy implications

Akosombo and Kpong dams generate over 50% of the electricity in Ghana. Any reduction, at any time of the year, would require substantial investment in additional electricity generation capacity elsewhere in the grid. The high natural seasonal variability of the flows in the Lower Volta are difficult to mimic and significant ecosystem benefits would only be attained by restoring the flow regime to very close to the natural one. Slight modifications to increase some of the natural dynamics would have limited impact. This study has found that reoperating Akosombo and Kpong dams, can only reproduce the natural flow regime to a limited extend due to technical constraints. This would not generate the intended benefit of improved local livelihoods and so is not advisable. Rather than reoperating existing dams, instead making further efforts to involve riparian communities and integrate their needs at the on-set of the dam planning and design would help reduce future negative impacts.

The concept of reoperating dams could support downstream ecosystems and ecosystem services, however careful considerations are needed before dam reoperation is implemented. Reestablishing natural or near-natural flow regimes may come with negative consequences to communities who have adjusted to the new flow regime and high investments are required to increase hydropower production and to minimize the effects of variable energy production. Therefore it is important to identify dams where reoperation is feasible.

NET PRESENT VALUE FOR SELECTED SCENARIOS



Further information

Ntiamoa-Baidu, Y., Ofosu, E.A., Ampomah, B., 2017 *Dams, Development and Downstream Communities. Implications for re-optimising the operations of Akosombo and Kpong dams in Ghana.* Digibooks, 435 pages

Acknowledgements

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The WLE Briefing series presents WLE research outputs in an accessible format to different users (policy makers, developers practitioners, investors or regional managers. The focus in repackaging research down to its essential points and appeals to the needs and interests of specific groups of decision-makers. Each brief offers evidence and gives the minimum required background. They briefs also provide concrete recommendations as to what can be done and is actionable.

ABOUT WLE

The CGIAR Research Program on Water, Land and Ecosystems (WLE) promotes a new approach to sustainable intensification in which a healthy functioning ecosystem is seen as a prerequisite to agricultural development, resilience of food systems and human well-being. WLE combines the resources of 11 CGIAR centers, the Food and Agriculture Organization of the United Nations (FAO), the RUAF Foundation and numerous national, regional and international partners to provide an integrated approach to natural resource management research. This program is led by the International Water Management Institute (IWMI) and is supported by CGIAR, a global research partnership for a food-secure future. We would like to thank all donors who supported this research through their contributions to the CGIAR Fund (http://www.cgiar.org/about-us/our-funders/).

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