Rapid Evaluation Tool for Screening the Potential for Reoptimizing Irrigation Systems

Adapted from Thomas, G. and DiFrancesco, K., 2009. Rapid Evaluation of the Potential for Reoptimizing Hydropower Systems in Africa. Final Report to The World Bank, Washington, DC.

As part of the ***Global Dam Reoperation Initiative,*** the Natural Heritage Institute (NHI) developed a "Rapid Evaluation Tool for Screening the Potential for Reoptimizing Irrigation Systems" (REOPS) to quickly and efficiently screen a large number of systems to identify those that are the most promising candidates for beneficial reoptimization. By reoperation, or reoptimization, we mean the implementation of environmental flows designed to restore downstream ecosystem functions and services (e.g., floodplain livelihoods, food production systems), without significantly decreasing the original benefits of the infrastructure.

REOPS is a “dichotomous key”, in which one proceeds through a logic pathway by answering a series of queries in either the affirmative or negative. Depending on the answer, one will either default out of the pathway, with the conclusion that the dam or irrigation system is not a good candidate for reoptimization, or will be directed to a succeeding cell.

It is also important to note that REOPS assesses only the physical requisites for successful reoptimization of irrigation systems. Facilities that survive this technical analysis must then also be subjected to an economic feasibility analysis that will weigh the costs and benefits of reoptimization to see where the break-even point may lie. That will often determine whether, and to what extent, reoperation is economically justified.

The subsequent pages display the REOPS schematic, followed by an explanation and guidance in the use of the tool, cell by cell.

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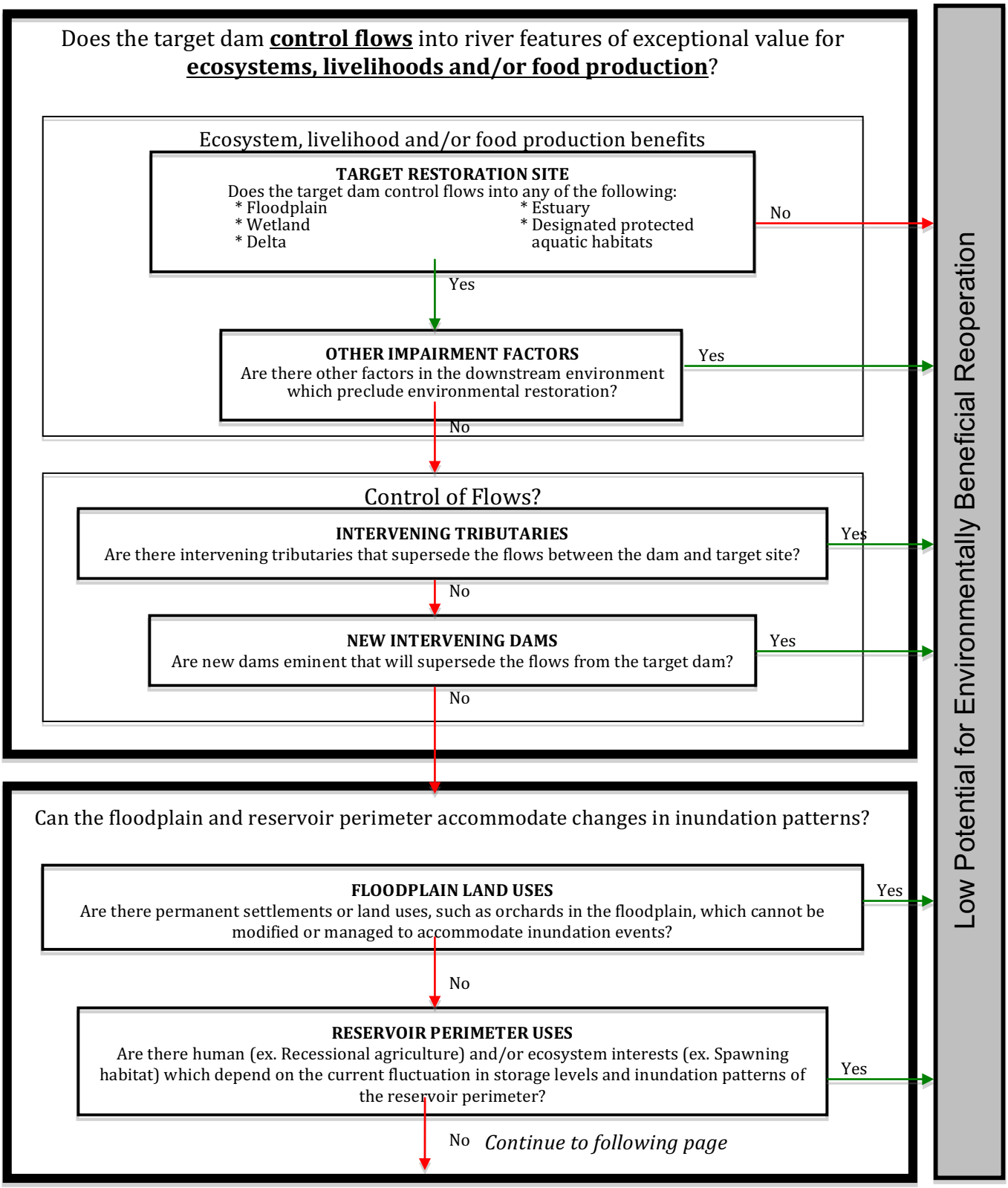

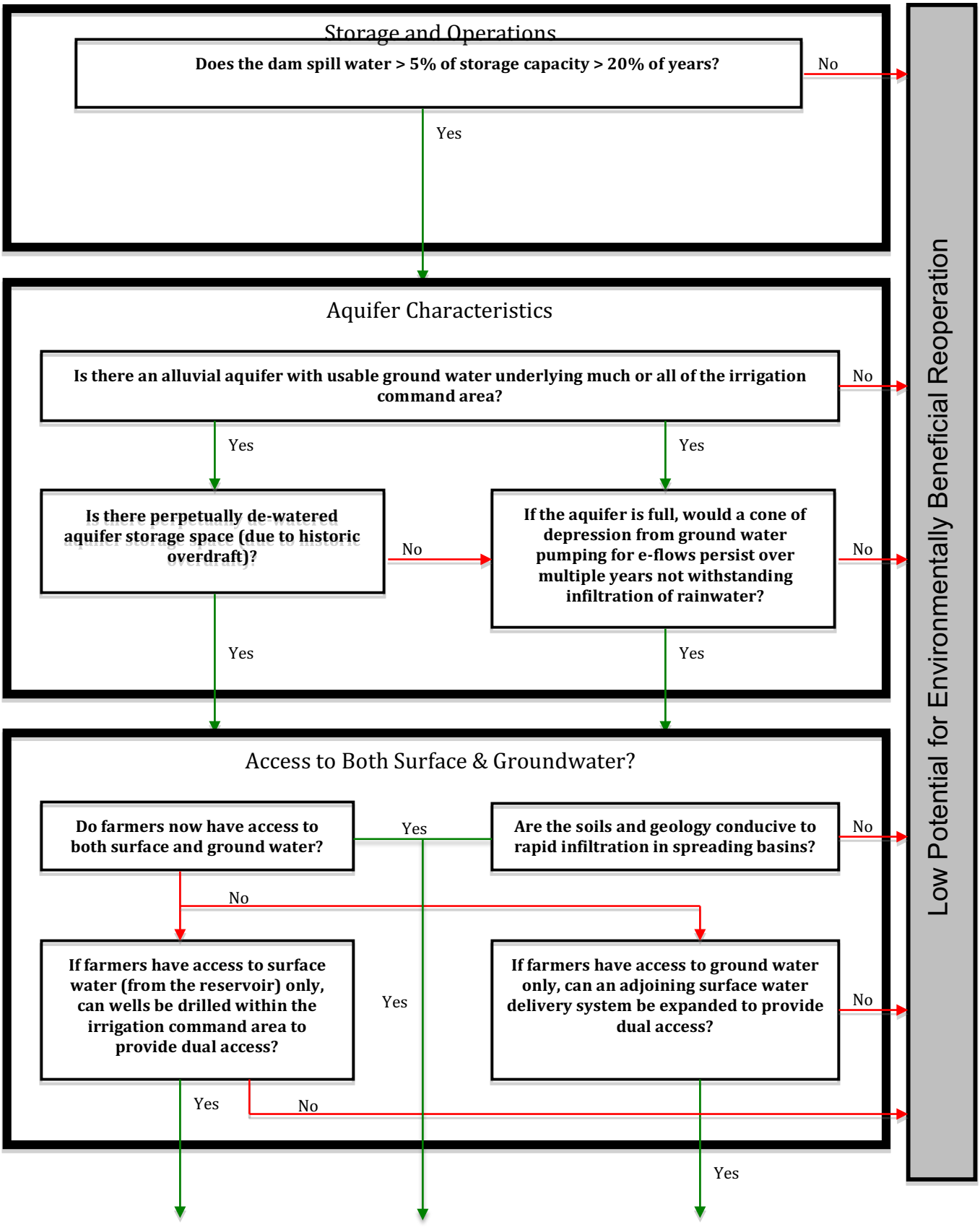

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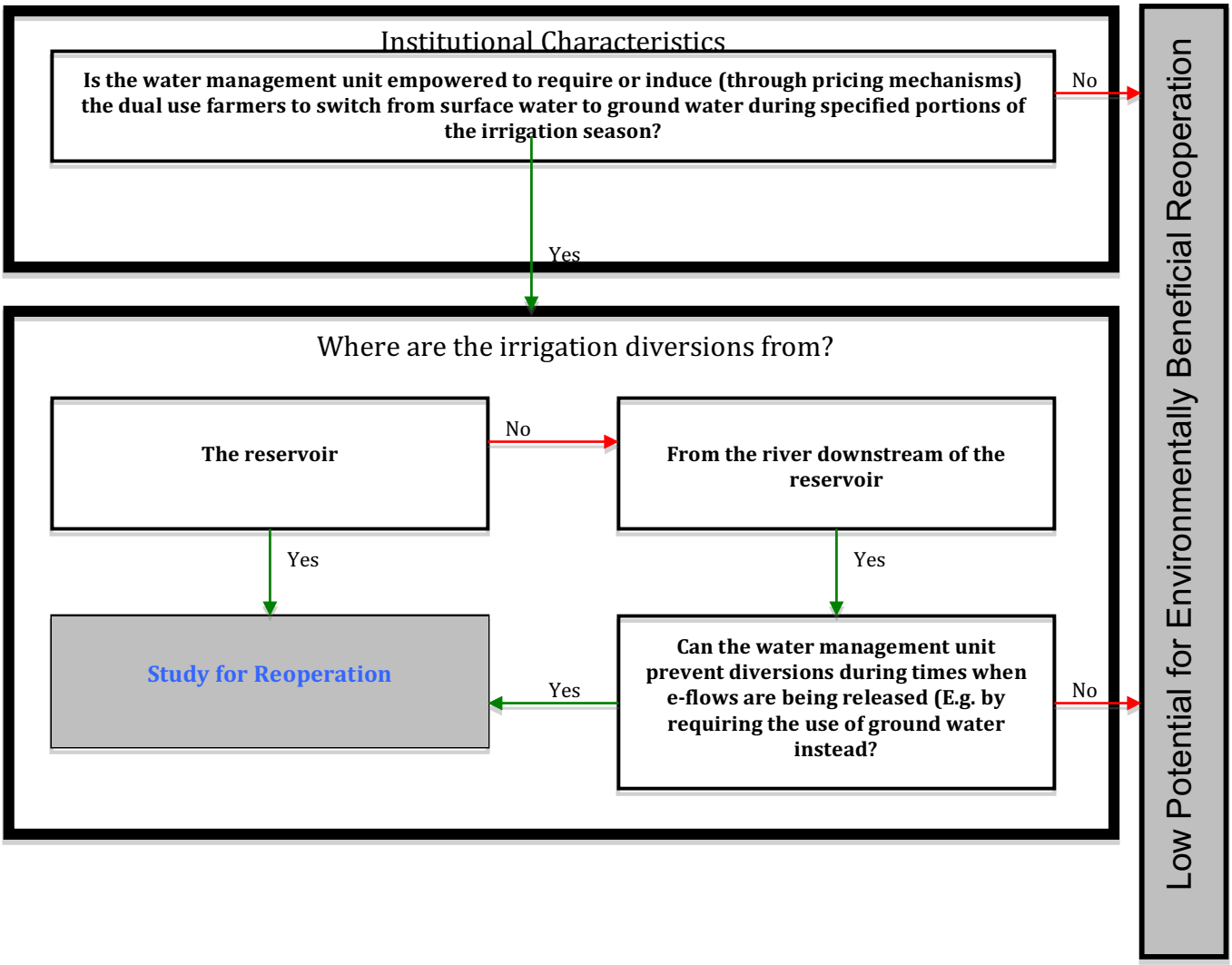

Ecosystem, livelihood and/or food production benefits

Target restoration site

Reoperation of existing dams to produce a more variable flow pattern that mimics natural conditions will only be worthwhile if that produces tangible improvements in the productivity of the downstream river system. The types of benefits of interest include both improvements in aquatic habitats and ecosystem functions, including morphological benefits, and improvements in river-dependent livelihoods and food productions systems, such as recessional cultivation, grazing, and fishing. The precise flow characteristics needed for these benefits—expressed in terms of magnitudes, duration, frequency and timing of flows—can only be ascertained through an environmental flow assessment, which is time and resource intensive and therefore appropriate as a result of, not a prerequisite to, a screening analysis. And, productivity benefits are a matter of degree.

Thus, a reliable and readily ascertainable proxy is needed to indicate whether a downstream river reach is likely to benefit from dam reoperation. In general, there are four types of river features that are particularly productive, both ecologically and in terms of human uses. These are: (1) broad, alluvial floodplains, (2) wetlands systems that are, or formerly were, seasonally connected to the river, (3) inland deltas, and (4) estuaries. By contrast, river canyons and gorges are less likely to yield large flow restoration benefits, unless they harbor species of special conservation value.

These types of river features are readily identifiable by looking at maps, utilizing remote imagery such as Landsat images or Google Earth, or learning where the dam is located relative to designated protected areas in the basin, such as Ramsar sites, World Heritage Sites, Important Bird Areas, designated habitat for endangered species, wildlife refuges, national parks, or other protected areas. Depending on the number and size of intervening tributaries, these features may be affected by flow regulation if they occur within a few hundred kilometers of the target dam.

If no such downstream features are found, the dam is probably not a strong candidate for reoperation.

Other Impairment Factors

Even if such river features are found, there are circumstances where the habitat values or human livelihood values are so compromised by other factors that flow restoration will not do much good. Examples may include mining operations in the river or riverbank, wastewater contamination from agriculture of urban runoff, overharvesting of fish, and massive sedimentation from deforestation or other erosive land uses. In such cases, again, it will not be worthwhile to improve the flow regime.[1]

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[1] *Information sources for target restoration site and other impairment factors:*

Bernacsek, G.M., 1984. Guidelines for dam design and operation to optimize fish production in impounded river basins (based on a review of the ecological effects of large dams in Africa). CIFA Tech. Pap., (11):98. Available from: <http://www.fao.org/docrep/005/AC675E/AC675E00.htm> (accessed Oct. 2008).

Birdlife International. Important Bird Areas. Datazone. Available from: <http://www.birdlife.org/datazone/index.html> (accessed Oct. 2008).

IUCN, 2008. Red List of Threatened Species. Available from: <http://www.iucnredlist.org/> (accessed March 2009).

Knaap, M. van der., 1994. Status of fish stocks and fisheries of thirteen medium-sized African reservoirs. CIFA Technical Paper. No. 26. FAO, Rome.

Shahin, Mamdouh., 2002. Hydrology and water resources of Africa. Dordrecht; Boston: Kluwer Academic.
Thieme, Michele L., 2005. Freshwater Ecoregions of Africa and Madagascar: A Conservation Assessment. Covelo, CA, USA: Island Press. Information. Available online at: http://www.feow.org/.

Vanden Bossche, J.P. & Bernacsek, G.M., 1990-1991. Source book for the inland fishery resources of Africa. Vols. 1-3. CIFA Technical Papers Nos. 18/1, 18/2,18/3. FAO, Rome.

Controlling Flows:

Where the desired riverine features are found, the next inquiry is whether the target dam actually *controls* the flows through those river reaches; that is to say, does the operation of the dam actually have a substantial impact on the magnitude, duration, frequency and timing of the flow patterns? The following considerations must be taken into account.

Intervening Tributaries

If there are other streams flowing into the river between the target dam and the river feature of concern, and if these provide substantial new flows, the effect of the target dam may be superseded. This will depend on the relative volume of flows contributed by these intervening tributaries, and whether they themselves are controlled by dams. In some cases, where the tributaries are not controlled, they may actually enhance the reoperation potential of the target dam because a relatively small additional season release from the target dam may be enough to produce a controlled seasonal flood event in the downstream river feature of interest. So this consideration factor can cut both ways.[2]

New Intervening Dams

Not infrequently, large new dams are being planned or are under construction in the river reach between the target dam and the river feature of interest for restoration. If it is a large dam, it is probable that the effect of that new dam will supersede the effects from the target dam. In that event, funding would be better spent on evaluating options for improving the siting, design or operation of the new dam.[3]

Storage and Operations:

The technique for generating environmental water supplies and counteracting the depletion from the irrigation diversion is to capture water that would otherwise be released for flood

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Wetlands International, 2008. Ramsar Site Database. Available from: <http://ramsar.wetlands.org/ (accessed Oct. 2008).

World Database on Protected Areas. Available from: <http://www.wdpa.org/ (accessed Oct. 2008).

[2] *Information sources for intervening tributaries:*

University of New Hampshire - Water Systems Analysis Group. Available from: <http://www.wsag.unh.edu/data.html> (accessed Oct. 2008).
USGS. Hydro 1k Africa dataset. Available from: <http://eros.usgs.gov/products/elevation/gtopo30/hydro/africa.html> (accessed Oct. 2008).

[3] *Information sources for new intervening dams:*

Africa Energy Intelligence. Available from: <http://www.africaintelligence.com> (accessed Oct. 2008).

Southern African Development Community (SADC). Status of the generation projects in the Southern African Power Pool. Available at: <http://www.sardc.net/Editorial/sadctoday/view.asp?vol=587&pubno=v10n4> (accessed Oct. 2008).

control purposes (operational spills). Unless the reservoir spills water frequently enough to provide this supply benefit, reoperation will not be worthwhile.

Aquifer Characteristics:

Only alluvial aquifers are generally suitable as storage basins. Other types of geologic formations tend to "leak" in ways that cannot be readily predicted.

If the aquifer is salty or contaminated, it will not be a suitable storage vessel for water that will ultimately be used for irrigation.

To use an aquifer to store water from a reservoir, it is necessary that it contain dewatered storage space. Over-drafted aquifers have this characteristic. If the aquifer fills every year from rainfall infiltration, notwithstanding some groundwater use, the reservoir water that is stored there will be, in effect, spilled. So high water tables can only be used if the pumping is sufficient to create a cone of depression that will persist for more than one year. That pumping can provide the desired environmental water supply.

Command Area Characteristics:

There are two categories of groundwater banking. In the active recharge category, reservoir water is imported and infiltrated into the aquifer using spreading basins. To do this, the soil and geology must be suitable for relative rapid infiltration to minimize evaporative losses and provide a feasible operational cycle. In the second category, "in lieu" recharge, water is banked in the aquifer by substituting surface water deliveries for irrigation instead of using the groundwater. This increases the "mass balance" of groundwater in storage due to infiltration of rainwater. In general, in lieu recharge is a more efficient and rapid method of banking groundwater, but can only be done where a substantial number of farmers in the command area have access to both surface and groundwater, and the water management unit (the water district) can compel the farmers to switch to surface water to recharge the aquifer and switch to groundwater to discharge the aquifer.

Institutional Characteristics:

As noted, in lieu groundwater banking entails the irrigation water management unit compelling farmers to switch from surface water to groundwater and vice versa in an orchestrated manner. Where the manager has the legal or contractual authority to mandate these practices, it will do so. In other cases, the manager can use financial inducements, such as changing the price it charges for its surface water (or groundwater) deliveries to induce the farmers to switch.

Location of the diversion works:

Reoperation of irrigation systems to restore downstream environmental flows is much simpler if the irrigation water is taken directly out of the reservoir, compared to the case where the downstream river is used a part of the irrigation water delivery system. In the latter case, there are two challenges. The first is to maintain environmentally beneficial flow patterns in the river reach between the reservoir and the point of diversion. Irrigation demands are such that the

reservoir will be operated to release high flows into this reach during the dry season, and low flows during the wet season. But environmental water requirements are exactly the opposite. There is no easy solution to this mismatch.

The second challenge is maintaining the desired environmental flow pattern below the point of diversion. One problem that can be prevented is the diversion of pulse flows for environmental purposes. This can be prevented by requiring the irrigation system to rely on groundwater at these times and bypass the environmental flows. This strategy will be essential, for instance, to restore the Colorado River delta.