The Grand Ethiopian Renaissance Dam:
An Opportunity for Collaboration and Shared Benefits in the Eastern Nile Basin

An Amicus Brief to the Riparian Nations of Ethiopia, Sudan and Egypt
From the International, Non-partisan Eastern Nile Working Group
Convened at the Massachusetts Institute of Technology on 13-14 November 2014
By the MIT Abdul Latif Jameel World Water and Food Security Lab

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MIT

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Introduction

On November 13-14, 2014 the International, Non-partisan Eastern Nile Working Group[1] met at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts (USA), to hold a workshop to discuss the Grand Ethiopian Renaissance Dam (GERD)[2] and its implications for regional cooperation and economic development in the Nile basin. The workshop included the Working Group, non-governmental participants from all Eastern Nile Countries, and local academics with an interest in the Nile Basin. It was convened by the MIT Abdul Latif Jameel World Water and Food Security Lab (J-WAFS) as part of its mission to address broad, high-level questions in water and food-supply scarcity and to coordinate the efforts of MIT's faculty, labs, and centers to work in partnership with other institutions, foundations, industry, and governments to develop regionally appropriate solutions for water security for sustainable development. This meeting was convened under MIT's own authority. It was not sponsored by any of the Nile riparian governments, nor did official representatives of any Nile riparian country or any other government attend. Funding at MIT was provided by multiple independent contributors. Participants at the meeting included individuals with many decades of experience working on water resource issues in the Nile basin, as well as MIT faculty with broad knowledge of global water resources policy and management. MIT has a long history in contributing to trans-boundary river issues including the President of MIT's role as a named umpire in the Court of Arbitration of the Indus Waters Treaty.

The Meeting

The discussions over the two days were wide ranging, covering technical aspects of the design of the GERD; the potential advantages of water storage in Ethiopia for regional economic development; filling and operating strategies for the reservoir; potential downstream consequences of the GERD for Sudan and Egypt; and opportunities and risks for future basin-wide cooperation and economic development. The right of Ethiopia to develop its water resources for the well-being of its citizens was a point of unconditional agreement at the meeting. There was also group-wide agreement on the advantages of water storage in Ethiopia and the economic attractiveness of hydropower developments in the Blue Nile gorge. The group also noted favorably that the official policy of the Government of Ethiopia is that the GERD will be constructed and operated so that downstream countries (Egypt and Sudan) are not harmed. This "no harm" policy of Ethiopia is consistent with both international law and best professional practice.

The group supports the Ethiopian strategy of developing its water resources in the Blue Nile basin, and acknowledges that the GERD (now under construction) is the first, major step in the implementation of this economic development strategy. At the same time, we have identified several areas of concern regarding the present situation that we wish to bring to the attention of policy makers in the Nile basin, especially those in the three Eastern Nile countries most affected by the GERD: Ethiopia, Sudan and

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[1] The International, Non-partisan Eastern Nile Working Group is a group of 17 world-renowned water resources scholars and practitioners who received no compensation to attend the workshop and have certified that they have no conflict of interest in participating in the workshop or preparing this report. The members of the Working Group and their bios are presented in Annex A.

[2] The GERD is currently under construction in Ethiopia near the border with Sudan. It is approximately 40% complete.

Egypt.

The purpose of this policy brief is to communicate our thoughts on four issues:

1) Need for an agreement on the coordinated operation of the GERD with the Aswan High Dam (AHD);
2) Technical issues regarding design of the GERD;
3) Need for an agreement on the sale of hydropower from the GERD; and
4) Potential downstream impacts on Egypt and Sudan, particularly in agriculture.

It is important to emphasize that, in making these assessments, we did not have access to some of the relevant information about the GERD. Thus, some of our concerns may be assuaged when Ethiopia makes more information about the GERD publicly available to the international community. If new information shows that some or all of our concerns are unfounded, we will quickly and publically acknowledge this.

Issue. 1 - Need for an agreement on coordinated operation of the GERD with the Aswan High Dam

Soon there will be two large, over-year storage reservoirs on the Nile: the GERD and the AHD. Globally there are few international rivers with large storage facilities in both an upstream and downstream riparian country. The Senegal River Basin Authority manages one large dam upstream and a second smaller facility downstream. The Zambezi Basin has a framework for managing the international cascade of Kariba and Cahora Bassa dams. The Colorado River is shared by the United States and Mexico. There are multiple large storage facilities (Lake Powell and Lake Mead) on this river, but the storage facilities are within the boundaries of the United States. Like the Colorado, the Murray-Darling has multiple large storage facilities operated in coordination, but the Murray-Darling is not an international river.

We are aware of no situation comparable to that which will be realized in the near future in the Nile, wherein two storage facilities that are so large relative to the annual flow of an international river will coexist without some institutional agreement in place. To achieve Ethiopia's "no harm" goal, it is important that the GERD, AHD, and Sudan's reservoirs be operated in coordination by Egypt, Ethiopia, and Sudan.[3] What makes the Nile situation especially unusual is that the two over-year storage facilities (AHD and GERD) have more combined water storage than is actually needed to provide sufficient drought protection for the downstream riparian (Egypt). When the GERD is completed, the Nile basin will have redundant storage capacity, i.e., reservoir managers will be able to choose where to store excess water for use during times of prolonged drought. It is important to emphasize that this redundancy does ***not*** mean that infrastructure in the Blue Nile gorge is a "mistake" or is "overbuilt" from an economic perspective. The GERD and any other future infrastructure facilities in the Blue Nile cascade are primarily hydropower facilities. Their economic justification does not depend on the value of the additional drought protection that they provide.

Although the Nile is thus unique in some respects, in all the existing similar situations with which we are familiar, there are agreements between the upstream and downstream countries as to how multiple water storage facilities are to be operated. Certainly if two such large reservoirs were built on a river in a single country (such as on the Colorado, Mississippi, and Murray-Darling), their operations would be carefully coordinated to ensure that economic and financial benefits are realized, and that the waters are equitably shared among all users. This type of coordination is likewise beneficial to all parties on an international river. To the best of our knowledge, there is currently no agreement for the coordinated operation of the

[3] The working group did not define what "no harm" means, nor do we offer any opinion on the magnitude of the water needs of downstream countries.

GERD and the AHD, as well as other infrastructure facilities in the Nile basin. Such an agreement is urgently needed to ensure that the Government of Ethiopia can fulfill its commitment that the GERD will be constructed and operated so that the downstream countries (Egypt and Sudan) are "not harmed" during the filling period or during periods of prolonged drought.

We are not able to offer specific advice on the articles such a joint operating agreement should contain, nor would this be an appropriate role for a group such as ours. But we would like to make a few general observations.

First, the agreement about filling the reservoir must be flexible enough to adapt to the actual sequence of Nile flows that occurs while the GERD reservoir is filling. It must be able to meet the agreed objectives given the many possible conditions of the Eastern Nile water resource each year: AHD reservoir storage level, the GERD storage level and Blue Nile flow. For example if during filling of the GERD reservoir the AHD is full, Egypt could draw down the AHD reservoir to meet its water requirements as Blue Nile flow is stored in the GERD reservoir, effectively shifting storage upstream and reducing evaporation losses from the AHD reservoir (while increasing evaporation losses from the GERD reservoir). However, if the AHD reservoir storage is low, then less Blue Nile flow could be stored in the GERD reservoir and agreed downstream releases could be made for Egypt and Sudan.

Any filling agreement must have provision for meeting the minimum water requirement for Egypt and Sudan. Storage in the AHD reservoir and the GERD reservoir would need to be managed especially wisely during a prolonged drought in order to meet Egypt's minimum water requirements.[4] Because of the over-year storage at the AHD, Egypt is concerned more about annual inflows into the AHD reservoir than it is in the monthly pattern of those inflows. Sudan also has minimum water requirements, but lacks an over-year storage facility. Sudan thus has limited ability to drawdown water in storage while the GERD reservoir fills. The policy for filling the GERD reservoir must provide for sufficient flow to Sudan to meet monthly water requirements for municipal, industrial, and agricultural use.

Ethiopia has already invested significant resources in developing hydropower capacity at the GERD and it is in their national interest to fill the GERD reservoir and produce electricity as soon as possible within the constraints of a cooperative filling policy.

Second, there will be a transition period as the filling of the GERD reservoir ends and "normal" operations commence. We believe most of the time there will be relatively little conflict between Ethiopia's desire to maximize the value of the GERD's hydropower production and the water requirements of downstream users. Generally Ethiopia will want to smooth the peaks of the Nile flood, shifting the natural flow pattern to increase summer low flows. This will also benefit Sudan by reducing floods, providing hydropower uplift at the Roseires, Sennar, and Merowe dams, increasing summer irrigation supplies, and improving navigation. There are also negative consequences to Sudan from the GERD, such as cessation of some recessional agriculture, long term changes in the geomorphology of the river and associated floodplains, and less silt for its brickmaking industry.

Precisely how the GERD should be operated to generate hydropower, including as a peaking plant, will depend in part on the characteristics of the regional load centers to which hydropower is transmitted. Because the AHD reservoir can buffer annual Nile fluctuations, Egypt should be more interested in the total quantity of water released during filling and during periods of prolonged droughts than with the annual pattern of releases from the GERD.

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[4] The Nile is famous for the autocorrelation in its annual floods, i.e., the tendency for a high flood to follow a high flood in the previous year, and for a low flood to follow a low flood in the previous year ("seven years of plenty, followed by seven years of famine").

Both Sudan and Egypt should be especially interested in GERD releases during filling and periods of drought, because at these times the interests of the downstream riparians differ from those of Ethiopia. Egypt and Sudan need releases from the GERD to meet minimum water requirements, but Ethiopia may prefer to increase the quantity of water stored in the GERD reservoir. A joint operating agreement is needed now to clarify how the Egypt, Sudan, and Ethiopia will juggle these tradeoffs. Such decisions require careful deliberation and negotiation. It is best to have these discussions in advance and not during times of crisis or under the pressure of extreme hydrological events.

Issue. 2: Technical issues regardin design of the GERD

Saddle Dam

The current design of the GERD requires that a "saddle dam" be built across a northwestern stretch of the boundary of the reservoir. This saddle dam is located approximately 10 kilometers from the main dam (Figure 1). It is planned to be 5 kilometers long and up to 50 meters high, making it one of the largest saddle dams in the world. There are no control works for the release of water from the saddle dam. Its sole purpose is to prevent water stored behind the GERD from spilling out of the northwestern end of the reservoir, where the elevation of the terrain is well below the dam's desired operating levels. The GERD's saddle dam is unusual in that it retains 89 percent of the live storage of the GERD reservoir, a volume in excess of the mean annual flow of the Blue Nile at the GERD site.

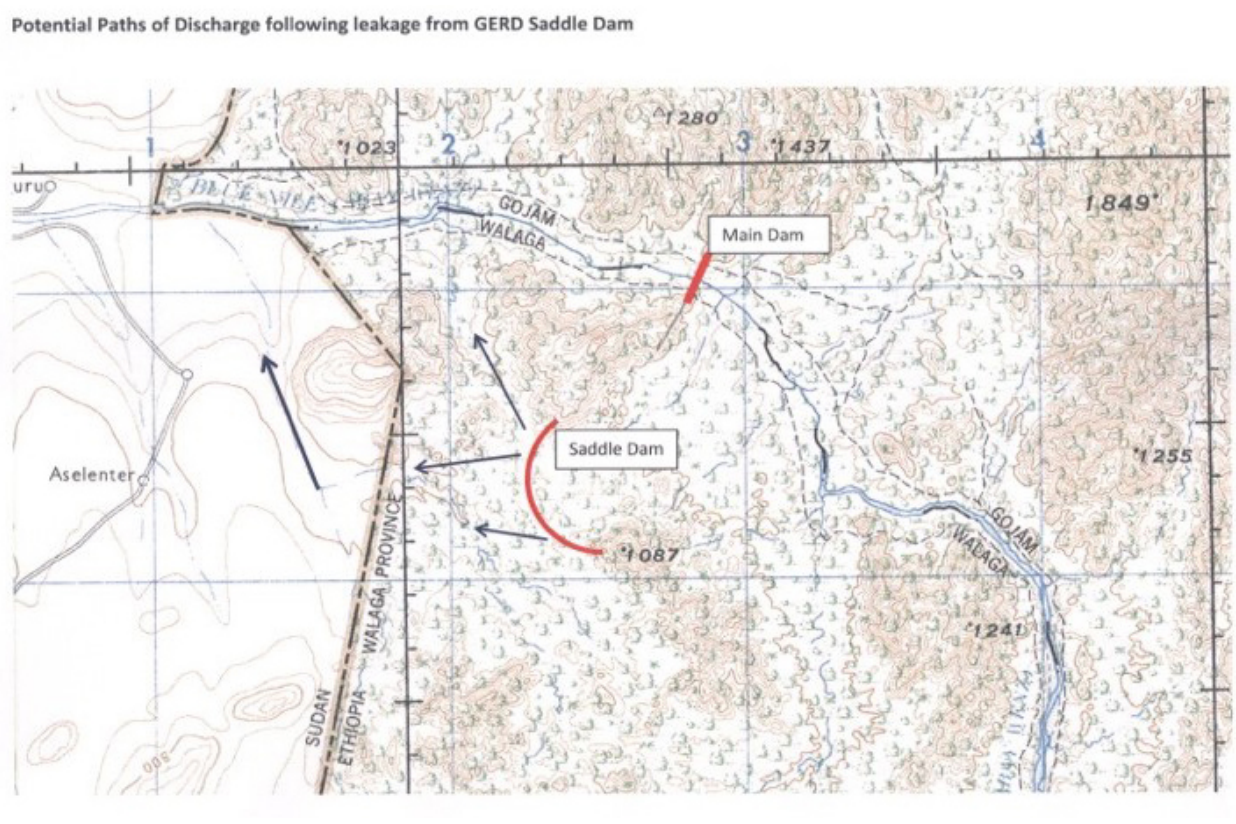

Figure 1. Location of Saddle Dam Relative to Main GERD Dam

The GERD's saddle dam will be constructed of rockfill with a bituminous surface facing. The foundation of the saddle dam is anticipated to be "weathered" rock in the valley between the hills which form the abutments. Given the long length of the saddle dam and the foundation of weathered rock, we believe that weak zones in the foundation are likely to be present. Such weak zones may give rise locally to increased seepage through the saddle dam foundations as well differential settlement of the rockfill embankment. In a saddle dam of this length, differential settlement or thermal movement may lead to cracking of the facing and increased leakage.

We are concerned that the risks posed by the GERD's extensive saddle dam may not have been fully appreciated or analyzed. The design, construction, safety features, and maintenance of the saddle dam need to be rigorously scrutinized by all parties potentially affected. A detailed plan is needed to carefully and continuously monitor the safety of the structure, and repair any problems as they arise.

Problems with the GERD's saddle dam would entail significant maintenance costs for Ethiopia, while a significant rupture of the dam would have potentially catastrophic consequences. The latter would be an economic disaster for Ethiopia, due to the loss of both hydropower and infrastructure, and an economic and humanitarian disaster for Sudan, where the waters released by a saddle dam failure would flow (see Figure 1).

Location and Capacity of the Release Outlets

In order to satisfy whatever agreements the three nations reach, the GERD must be constructed with outlet works that are capable of releasing the requisite flows. It is not clear from the information now available to us whether the current configuration of GERD outlets could release the required quantity of water under all conditions to meet reasonable downstream demands.

As with other large dams, there are various ways that water can be released from the GERD:

1) Bottom diversion used during the construction phase of the GERD to pass river flows;
2) Low-level release outlets;
3) Intakes to the hydroelectric power turbines; and
4) Spillways.

These are shown in Figure 2. The diversion outlets at the base of the dam structure are used to pass river flows during the construction of the GERD. These will have to be closed when the filling of the GERD reservoir begins, but might be wholly or partly retained to allow operation for lowering of the reservoir level in an emergency. We have no details on how this might be achieved, and it could prove critical in order to pass flows if a low flow period occurs during the initial filling of the GERD reservoir.

The majority of the financial benefits from the GERD will be from hydropower production and, under normal operating conditions, Ethiopia will want to maintain large releases of water through the turbines in order to maximize its hydropower revenues. Water can be released through the turbines when the level of the reservoir is El. 590 meters above sea level or higher. It is important to appreciate that water cannot be released through the turbines unless hydropower is in fact being generated. In other words, the turbines can only become operational when transmission lines are in place to transmit the hydropower generated to demand centers in the region. [We will return to the importance of this point below.]

The remaining outlets are necessary to meet other objectives of the GERD. The spillways on the left abutment and at the top of the GERD are designed to provide a way for excess floodwaters to be safely released so that water never "overtops" the dam structures because this could lead to catastrophic dam failure. Water released from the main spillway is regulated by the radial gates at the head of the spillway chute. Additionally, when the level of the reservoir reaches the height of the "low block" spillway (El. 640 meters above sea level), excess water automatically spills. The spillways would be used only when the reservoir levels are already high and an unexpectedly large flood occurs. There could be a long period of many years when the spillways are never used.

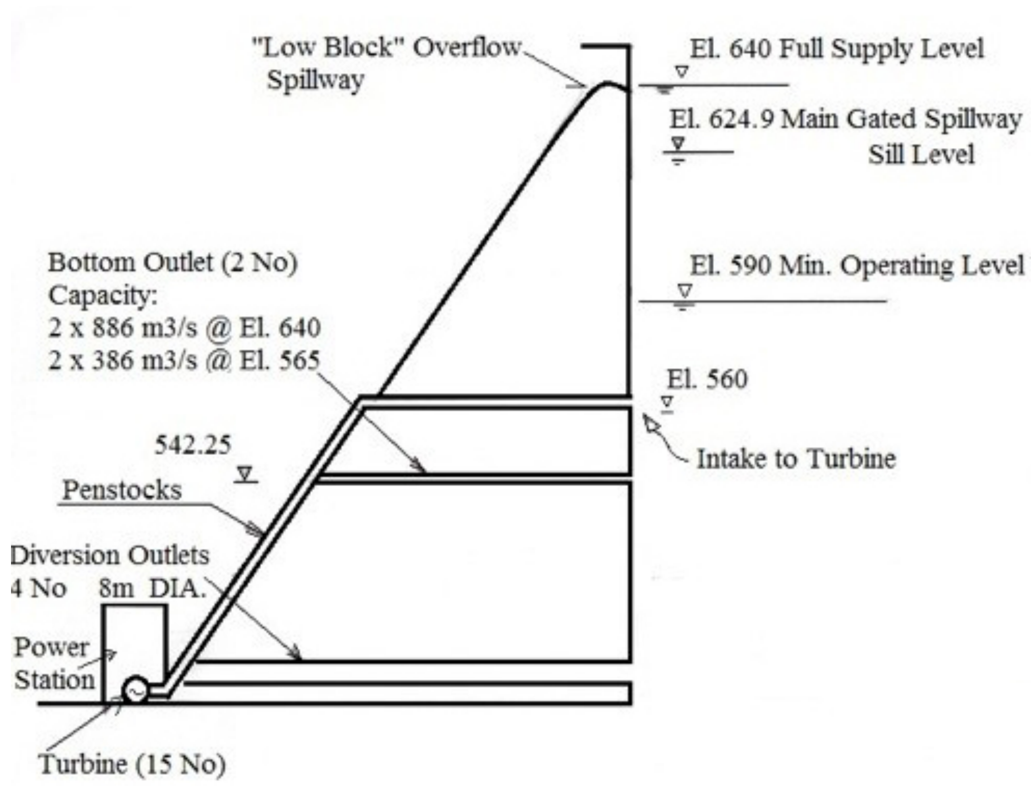

Figure 2. The current understanding of the GERD Outlet Works and Turbine Intakes

The final way that water can be released from the GERD is through the low-level release outlets. Our concern relates to the location and capacity of these low-level outlets (see Figure 2). The main purpose of these low-level outlets is to ensure that the operators of the GERD have the capability to release adequate water to downstream users to meet minimum downstream requirements in two situations:

1) During the period when the reservoir is filling prior to reaching the level at which water can be discharged through the turbines (El. 590 meters above sea level); and
2) After filling is complete and normal operations have commenced, when a prolonged drought occurs.[5]

With regard to point 1, the low-level outlets would also be required in the event that insufficient generation capacity was available to release the required downstream flow. Such a situation might arise during the early stages of reservoir operation, prior to installation and commissioning of the full set of turbines, or if transmission links to demand centers have not been constructed and commissioned. During periods of normal operation, the lower-level outlets may be needed when more water needs to be released to downstream users than can be released through the turbine outlets, or when the reservoir water level falls below the turbine intakes (e.g., during periods of prolonged drought).

At this time we do not know the elevation (location) or capacity of these low-level release outlets in the

[5] It is possible that the low-level release outlets might also be needed to lower the reservoir water level in order to make repairs to the turbines or the structure.

GERD, or how precisely they can be operated. If the capacity of these low-level outlets is too small, or the elevation at which water can be released is too high, the GERD may not have sufficient operational flexibility to meet reasonable downstream demands during both the period of filling and during periods of prolonged drought.

Issue No. 3 - Need for an agreement on the sale of hydropower from the GERD

As far as we know, Ethiopia is financing the construction of the GERD without international funds. The Ethiopian people are thus making substantial sacrifices to implement this project from domestic financing sources. The financial returns that they will receive in return are the revenues from the hydropower generated at the GERD, which will accrue for many years. It is thus essential from Ethiopia's perspective that the GERD's hydropower be sold as soon as it can be generated and at a good price.

When the GERD is completed, its average hydropower generation is expected to be about 15,000 GWh per year, roughly 50% more than the average hydropower generation from the Aswan High Dam over the past four decades. This is approximately equal to the entire current national electricity consumption in Ethiopia. In addition to the GERD, Ethiopia has other planned hydropower facilities coming online over the next decade (Table 1). Moreover, a second large water storage facility in the Blue Nile gorge would be the next step in a Blue Nile cascade and could generate even more hydropower.

Table 1: Planned Hydropower Projects in Ethiopia

Project	Capacity (MW)	Average Energy (GWh/yr)	Commissioning Year
Fan	100	212	2011
Gibe III	1870	6400	2013
Genale 3	258	1200	2014
Halele Werabesa	422	2233	2015
Chemoga Yeda	278	1250	2015
Genale 6	256	1000	2015
Geba 1 and 2	366	1788	2015
GERD	5250*	15000	2014-2015
Total	8800	29083	

Source: EEPCO "Highlights on Power Sector Development Program (2010 – 2015 G.C.) Oslo 2011

Notes:

1. Gibe III now expected to be commissioned in 2015
2. GERD capacity now reported as 6000 MW
3. GERD now expected to be commissioned in 2017

What this means is that over the short to medium term, the hydropower generated from the GERD cannot be fully utilized in Ethiopia's domestic power market, and will therefore need to be sold to regional markets outside Ethiopia. This requires that a power trade agreement be concluded soon and that transmission lines be built to deliver the GERD's hydropower to specific, identified regional markets. Without a power trade agreement, it is unclear where the transmission lines need to be built. The construction of high voltage direct current (HVDC) transmission lines to Kenya is likely to take at least 3 years. A transmission link to Sudan and Egypt is likely to take about 5 years to complete.

The hydropower revenues involved are substantial. If 15,000 GWh of power were sold for US$0.07 per kilowatt-hour, the annual revenue would be approximately US$1 billion. Annual revenues could be even higher if some of the hydropower from the GERD can be sold to meet peaking requirements in regional demand centers. In the long run, Ethiopia may have a sufficiently large domestic electricity market to use all the hydropower generated by the GERD, but this will only occur many years in the future. Any delay in the date when Ethiopia begins to receive these revenues from the sale of hydropower from the GERD will be costly to the Ethiopian people.

Not only will a delay have major financial consequences for Ethiopia, but also, if there is no power trade agreement in place and transmission lines are not ready when it becomes possible for the GERD to generate hydropower, then water cannot be released through the GERD's turbines. This has significant implications for a joint operating agreement for the GERD and the AHD (as discussed above).

To the best of our knowledge, a power trade agreement for the sale of the GERD's hydropower has not yet been negotiated. As a result transmission lines are not yet under construction. It is in the interests of Ethiopia, Sudan, and Egypt that a power trade agreement be negotiated as soon as possible. Importantly, Egypt and Sudan have legitimate interests in such a power trade agreement, even if the power is not sold to them, because the lack of a power trade agreement may affect the quantity of water that can be released from the GERD reservoir to downstream neighbors.

Issue 4 - Potential downstream impacts on Egypt and Sudan, particularly in agriculture

The potential downstream impacts of the GERD on Sudan and Egypt span a variety of socio-economic sectors and may be positive as well as negative. In Sudan, the GERD will allow for more hydropower generation, reduce flood damage, help reduce the cost of sediment control and removal, and improve navigation on the main and Blue Nile. Egypt faces potential negative impacts on irrigation water supply, hydropower generation, and navigation. While these impacts may be locally significant, most can be mitigated by financial or technological interventions

We want to highlight two potential negative impacts of particular concern, salinization of Egypt's agricultural lands and large-scale loss of recession agriculture in Sudan. These are highlighted because they require immediate study, both with respect to potential impacts and options for mitigation.

These two impacts are not of the same scale. The loss of recession agriculture lands will be on the order of tens of thousands of hectares, while salinization will potentially impact millions of hectares. The discussion below reflects the potential scale of these impacts

Increased salinization of Egypt's agricultural lands in the Nile Delta

All rivers carry dissolved salts, and the Nile is no exception. Compared to other rivers around the world, natural dissolved salt concentrations in the Blue Nile and the Main Nile upstream of the Aswan High Dam Reservoir are relatively low at approximately 200 mg/L. But when water is removed from the river, whether through evaporation from irrigation canals or reservoirs or evapotranspiration from crops planted in irrigated areas, salinity increases.[6] The salts contained in irrigation water that reaches fields are then either left behind in soils or carried away in drainage water return flows. Care must be taken to ensure that these salts do not build up in agricultural soils permanently, but are instead removed in the drainage water return flows, and eventually flushed out of the system.

Because of water losses through evapotranspiration, the salt concentration in the drainage water leaving agricultural fields is higher than it is in the irrigation water coming in. If drainage water is reused

6 Increased irrigation withdrawals upstream of the AHD and evaporation from new reservoirs (e.g., at Merowe in Sudan and the GERD in Ethiopia) will consequently lead to increases in the salinity of Nile water flowing into the AHD reservoir.

downstream for further irrigation, as is the case in Egypt, special care is required because the salinity of the irrigation water that is mixed with return flows of drainage water becomes higher and higher. Drainage water discharges are thus not "wasted"; they are used to supplement irrigation supplies and to serve an essential purpose: to prevent salt buildup in irrigated lands. In the case of the Nile, the "final" discharge of salt occurs when drainage waters in lower Egypt are discharged to the Mediterranean.

While we take no position regarding the 1959 Nile Waters Agreement, it is important to acknowledge that for the past two decades Egypt has had access to more water than anticipated under the Agreement. This is because Sudan has not been using its full allocation under the Agreement of 18.5 billion cubic meters (bcm) measured at Aswan, and because total flows in the Nile have been higher than the 84 bcm assumed in the Agreement (an average of 91 bcm from 1871-1999). Egypt has on average been releasing about 60-65 bcm annually from the AHD, about 10-15% more than its allocation under the Agreement of 55.5 bcm. This has enabled Egypt to achieve and maintain high discharges of agricultural drainage water, which has facilitated the movement of salts out of agricultural soils and eventually into the Mediterranean. The reasons for this recent excess supply notwithstanding, Egypt has come to rely on the water for salt removal.

As a result of the imminent filling of the GERD reservoir and other upstream developments, this period of excess water in Egypt is coming to an end. In particular, Sudan is now using more of its own allocation due to new evaporation from the Merowe Dam Reservoir (≈ 2 bcm annually) and the expansion of its irrigated lands. Moreover, when the GERD is completed, summer (pre-flood) flows will increase in Sudan as Ethiopian water managers smooth out the peak of the annual Nile flood. This will make available additional water supply for irrigation in Sudan. The result of GERD reservoir filling and the increase in water use in Sudan means that Nile flows into the AHD reservoir will be reduced substantially, especially in the short to medium term.

In the long run the AHD reservoir will run at lower levels, closer to what the AHD's designers originally envisaged, and evaporation losses from the AHD reservoir will be reduced as evaporation increases upstream at the GERD reservoir. A new equilibrium will be reached in which total system-wide evaporation from reservoirs could be reduced compared to the situation before the completion of the GERD. But water withdrawals upstream in Sudan and Ethiopia will have increased at the same time, and Egypt will therefore have less water overall to use for flushing salts from its agricultural lands. Water for flushing may be especially limited in Egypt during the filling of the GERD reservoir.

The issue here is twofold. First, if there is a fast and significant buildup of salts in Egypt's agricultural lands and in the Nile surface water in the Delta due to reduced flushing, Egyptian farmers and policymakers may be taken by surprise. They may be unprepared to respond quickly and effectively to address the problem. This salinization problem occurs in irrigated lands in all arid zones and can be managed provided that there is sufficient time to build infrastructure and implement the policies needed to address it.

Second, a rapid buildup of salts in Egyptian agricultural lands in the Nile Delta could create a political crisis in the basin if Egyptian farmers and policymakers blame their problems on Ethiopia and the GERD. In reality, the problem of salinization in Egypt would have occurred anyway as Egypt transitioned to reduced releases from the AHD due to increased upstream withdrawals that are independent of the GERD. But the filling of the GERD reservoir may accelerate this process, i.e., causing the salinization to occur more quickly. Also, the problem may coincide with the filling of the GERD reservoir, which would make it appear that the salinization of Egyptian agricultural lands was the direct result of the construction of the GERD.

In our opinion, both aspects of the salinization issue demand immediate attention and additional study.

Sudanese Recession Agriculture
Flood or recession agriculture is practiced in Sudan along some reaches of the Nile. The seasonally high flows spill onto the flood plains and infiltrate into the soil to provide the necessary soil moisture for an entire crop growing season. The practice currently provides both subsistence farming and regional economic benefits. Reduced Nile flows during the filling period of the GERD reservoir and subsequent operation of the GERD to maximize hydropower generation will likely reduce the magnitude and change the timing of peak flows. These significant changes will impact the areas flooded and thus the amount of land with sufficient soil moisture for crops. Lesson can be learned from the similar situation that occurred in the Senegal River basin after construction of the Manantali Dam.

In our opinion, these potential impacts also demand immediate attention as they will occur in the first growing season after filling of the GERD begins.

Conclusions

To summarize, we support Ethiopia's right to develop its water resources for the well-being of the Ethiopian people, and we believe that water storage facilities on the Blue Nile are economically and financially attractive investments. However, in order to maximize mutual gains of the GERD and other future reservoir developments, four principal issues must be addressed:

1) Need for an agreement on the coordinated operation of the GERD with the Aswan High Dam;
2) Technical issues regarding design of the GERD;
3) Need for an agreement on the sale of hydropower from the GERD; and
4) Potential downstream impacts on Egyptian and Sudanese agriculture

First, we believe that Egypt, Sudan and Ethiopia urgently need to reach agreement on the coordinated operation of the AHD and the GERD to ensure that they maximize the benefits of the GERD and equitably share Nile waters during periods of filling and prolonged drought. Nowhere in the world are two large over-year storage facilities operated without close coordination.

Second, we believe that the risks associated with the GERD's large saddle dam may not have been fully appreciated. We are also concerned about the location and capacity of the GERD's low-level release outlets, because of the important role that these will play in operation of the GERD, and in Ethiopia's commitment to do no harm to Sudan and Egypt.

The location and capacity of the low-level release outlets of the GERD define what is possible in terms of a joint operating agreement. If the level of the GERD's reservoir falls below the intakes for the turbines, downstream releases will be limited by the *level* of these outlets. This level will determine whether the outlets can be used to release water during filling or during periods of drought, while their *capacity* will limit the extent of releases that are possible in the event that they must be used.

Third, an agreement is urgently needed on the sale of hydropower from the GERD to ensure that:

1) The Ethiopian people receive a good financial return on their investment; and
2) Water can be released through the turbines to maintain downstream flow.

If there is no power trade agreement or if turbine installation and transmission line construction is not fully complete by the time the GERD becomes capable of generating hydropower, then water cannot be released through the turbine outlets. So without a power trade agreement and infrastructure in place to deliver the GERD's hydropower to users, the GERD's low-level release outlets will be the only means available to release water to downstream riparians, even if the reservoir level is above the intakes of the turbines. A power trade agreement and the agreement on the coordinated operation of the AHD and the GERD could be part of the same deal structure and could be negotiated simultaneously.

Fourth, we anticipate that ongoing salinization of the agricultural lands of the Nile Delta could rapidly accelerate due to increased upstream withdrawals (a large portion of which will be made possible by the change in seasonal Blue Nile flows resulting from GERD operation) resulting in Egypt having less water available to flush residual salts into the Mediterranean. In addition, changes in the seasonality of Blue Nile flows due to filling and operation of the GERD will affect soil moisture in areas of recession agriculture located in Sudan. Both of these changes, increased salinization in Egypt and the loss of flood recession agriculture in Sudan, demand immediate attention and additional study.

Our intention in writing this policy brief has not been to support one nation at the expense of the others. Rather the MIT-convened working group has strived to provide impartial, objective advice that we hope will be useful to all stakeholder nations. If any of the Nile riparians would like our group to clarify or elaborate on any of the issues described in this document, we stand ready to assist in any way possible.

Appendix A

Members of the International, Non-partisan Eastern Nile Working Group

Dr. Thinus Basson, Consultant , South Africa

Dr Thinus Basson, former General Director of BKS Consultants (South Africa) pioneered the development of the probabilistic management of water resources. He is senior author of the foundational textbook *Probabilistic Management of Water Resources and Hydropower systems*, published in Colorado, USA. Major contribution to the development of a National Water Resources Strategy for South Africa. He was a member of the International Advisory Group to the World Bank for development of the Nile River Basin Action Plan, chief advisor on Water Resource Issues for African Ministerial Council, advisor to the Government of Pakistan on management of the Indus River, The UNDP for the Mekong River, and the FAO for the Nile. He was a member of the International Panel of Experts for the Grand Ethiopian Renaissance Dam.

Alan Bates, Consultant, United Kingdom

Alan Bates has many years of experience in the planning, design and construction supervision of water development projects mainly in Africa and Asia. As Technical Director with an international consulting firm, Alan was responsible for a wide range of projects on major river systems, including the Nile and Zambezi/Kafue. He has extensive experience of private sector development of hydroelectric power and transmission projects including investment projects in Ethiopia, Kenya, Tanzania, Uganda and Zambia. His experience also includes environmental impact assessments of hydroelectric projects and transmission lines. Alan's involvement with the Nile started in 1983 with the Lake Victoria Basin and he has been worked on the Eastern Nile since late-2006, firstly as Team Leader for pre-feasibility studies of hydropower projects in Ethiopia and later as a Technical Adviser to ENTRO on wide-ranging simulation model studies of dam developments on the Blue Nile including operation and reservoir filling of the (GERD).

Dr Don Blackmore AM , Chair-eWater CRC & Chair-Water for a Healthy Country, Australia

Dr. Blackmore has had 40 years experience in water and natural resources management both in Australia and in many countries around the world. He was the Chief Executive of the Murray Darling Basin Commission for 15 years until he retired in March 2004. He has was Deputy Chair of Land and Water Australia for 9 years during the 1990's. He was a Commissioner on the World Commission on Dams. In 2004 he was made a Member of the Order of Australia (AM) for his service to the environment, particularly through the Murray-Darling Basin Commission and through the development of sustainable water management practices. He currently Chairs both eWater in Australia and the International Water Management Institute (IWMI) in Sri Lanka.. On the International front Don provides advice to the World Bank on the management of large river basins and has recently worked on the Nile, Indus, Mekong and Ganges Rivers.

Prof. Paul Block, University of Wisconsin, USA

Prof. Block is an Assistant Professor of Civil and Environmental Engineering, University of Wisconsin – Madison and Adjunct Associate Research Scientist, International Research Institute for Climate & Society (IRI), Columbia University, New York. Prof. Block has been Assistant Professor at Drexel University, Associate Research Scientist and Postdoctoral Research Scientist at IRI, Columbia University and Researcher, Columbia Water Center, Columbia University, Assistant Professor Adjunct, Civil, Environmental, and Architectural Engineering, University ofColorado and research, International Food Policy Research Institute. Prof. Block has been analyzing issues of water and agricultural development in the Nile Basin since 2003. His PhD research on downstream impacts of filling of proposed Eastern Nile reservoirs was some of the first work on the topic. He has been a consultant for the World Bank and other agencies working with the Nile Basin Initiative on issues of the filling of the GERD and climate change impacts on Nile development.

Dr. Brent Boehlert, Tufts University and Industrial Economics, Inc, USA
Dr. Boehlert specializes in applied economics and policy analysis, with a focus on water resources and climate change. He has extensive experience analyzing the effects of changes in water availability and allocation, climate change impacts and adaptation responses, the economic impacts of environmental regulations, and the costs of damages to natural resources. Drawing on his academic background in economics and engineering, he frequently employs analytical methods and tools from both fields in his often-interdisciplinary project work. Dr. Boehlert has worked on issues related to Economic Impacts to Egypt of Climate Change Impact on the Eastern Nile with Potential New Upstream Reservoir Development as well as major climate change analyses of Central Asia, Eastern Asia, Caucasus, Balkans, Sub-Saharan Africa and the USA. Dr. Boehlert holds an A.B. in Engineering from Dartmouth College, and a M.S. in Natural Resource Economics from Oregon State University and a PhD in Civil Engineering from Tufts University . Prior to attending graduate school, Mr. Boehlert worked as an engineer with an environmental consulting firm and as a hydrology intern with the U.S. Geological Survey.

Prof. Dara Entekhabi, MIT, USA
Dara Entekhabi received the Ph.D. degree from the Massachusetts Institute of Technology (MIT), Cambridge, in 1990. He is currently a professor in the MIT Department of Civil and Environmental Engineering with joint-appointment in the Department of Earth, Atmospheric and Planetary Sciences. Dara Entekhabi served as the director of the MIT Ralph M. Parsons Laboratory for Environmental Science and Engineering as well as the MIT Earth System Initiative. His research activities are in terrestrial remote sensing, data assimilation, and coupled land–atmosphere systems behavior. Dara Entekhabi is a fellow of the American Meteorological Society (AMS), fellow of the American Geophysical Union (AGU) and a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE). He is the Science Team Leader of the NASA Soil Moisture Active and Passive (SMAP) satellite mission.

Dr. Annette Huber-Lee, Stockholm Environment Institute, USA
Annette Huber-Lee is a senior scientist who focuses on water resource management and policy. She returned to SEI-US in May after serving as director of SEI Asia, in Bangkok, from mid-2012 until February 2013. She has more than 20 years of professional experience in international and domestic planning and management of environmental and water resources. She has also served as a research assistant professor and lecturer in the Department of Civil and Environmental Engineering at Tufts University. From 2006 to 2008, she served as science leader and theme leader for the Challenge Program on Water and Food and the International Food Policy Research Institute in, Washington, DC. From 2001 to 2006, she directed the Water Program at SEI-US in Boston. She has a Ph.D. in engineering sciences rom Harvard University, an M.S. in civil engineering from the Massachusetts Institute of Technology and a B.S. in agricultural engineering from Cornell University.

Prof. Henry Jacoby, MIT, USA
Henry "Jake" Jacoby is the William F. Pounds Professor of Management, Emeritus in the MIT Sloan School of Management. He is the Co-Director, Emeritus of the MIT Joint Program on the Science and Policy of Global Change; Jacoby has been Director of the Harvard Environmental Systems Program, Director of the MIT Center for Energy and Environmental Policy Research, Associate Director of the MIT Energy Laboratory, and Chair of the MIT Faculty. He has made extensive contributions to the study of economics, policy and management in the areas of energy, natural resources, and environment, writing widely on these topics including seven books. He currently serves on a National Academies Committee to Advise the U.S. Global Change Research Program and as a convening lead author on the U.S. National Climate Assessment.

Prof. Marc Jeuland, Duke University USA
Dr. Jeuland is an Assistant Professor in the Sanford School of Public Policy and the Duke Global Health Institute at Duke University, and a Senior Research Fellow at the Institute of Water Policy at the National University of Singapore. His research interests include nonmarket valuation, water and sanitation, environmental health, water resources planning and management, and the impacts and economics of climate change. Jeuland's recent research projects include analysis of the economic implications of climate change for water resources projects on transboundary river systems, and modeling of the costs and benefits of environmental health interventions in developing countries. Jeuland has worked with the World Bank, the Millennium Challenge Corporation, and the International Water Management Institute on projects involving economic modeling in the Ganges Basin in Asia, economic planning in the eastern Nile river basin, rural sanitation in Egypt, and wastewater reuse and water network improvements in the Middle East and Northern Africa. As part of this work, Professor Jeuland recently completed an economic analysis of possible dams (including the GERD) in the Blue Nile gorge for the World Bank (with Dale Whittington at UNC-Chapel Hill).

Prof. John H. Lienhard V, MIT, USA
John H. Lienhard V is the Abdul Latif Jameel Professor of Water and Food at MIT and Director of The Abdul Latif Jameel World Water and Food Security Lab (J-WAFS). During more than 27 years on the MIT faculty, Lienhard's research and educational efforts have focused on heat transfer, desalination, thermodynamics, fluid mechanics, and instrumentation. He has also filled a number of administrative roles at MIT. He joined MIT immediately after completing his PhD in the Applied Mechanics and Engineering Science Department at UC San Diego, Since coming to MIT, Lienhard has worked on desalination processes including humidification-dehumidification desalination, membrane distillation desalination, osmotic processes, solar-driven desalination, scale formation, electrodialysis, management of high salinity brines, thermodynamic and energy efficiency analysis of desalination cycles, and energy-water nexus issues. Lienhard is a recipient of the 1988 National Science Foundation Presidential Young Investigator Award, the 1992 SAE Teetor Award, a 1997 R&D 100 Award, and the 2012 ASME Technical Communities Globalization Medal. He has been the Director of the Rohsenow Kendall Heat Transfer Laboratory since 1997, and he is a Fellow of the American Society of Mechanical Engineers. He has also received several awards at MIT for his teaching. Professor Lienhard is currently the Director of the Center for Clean Water and Clean Energy at MIT and KFUPM.

Prof. David Marks, MIT, USA
Prof. Marks is the Goulder Professor of Civil and Environmental Engineering and Engineering Systems, Emeritus. Dr. Marks received his PhD in Environmental Engineering from the Johns Hopkins University. His expertise is in how large-scale infrastructure systems are organized and managed, with special concern for anticipating and mitigating larger scale, environmental and economic impacts. In the 1970s and 1980s, Prof. Marks led MIT research efforts on Water Management in the Nile Basin and Egypt jointly with Cairo University. Much of Dr. Marks' work is based on large-scale computer-based simulation and optimization modeling to help illuminate conflicts between competing objectives, goals, interest groups, and governmental organization. This work led to contributions in large-scale environmental systems, multi-objective analysis under uncertainty, and in new methods for increasing the interaction between scientific and technical knowledge and the difficult, diffuse, decision-making process involved in environmental management. Dr. Marks has worked closely with groups at MIT in the understanding of the interface between science, technology and society. This includes being a former director and co-director of MIT's Laboratory for Energy and the Environment and a founding member of the Technology, Management and Policy Program and MIT's Engineering Systems Division. He teaches and advises in the MIT Technology and Policy Program.

Dr. Sergey Paltsev, MIT, USA
Dr. Paltsev is the lead economic modeler in charge of the MIT Emissions Prediction and Policy Analysis (EPPA) model of the world economy. His research covers a wide range of topics including energy economics, climate policy, taxation, advanced energy technologies, and international trade. He was lead author of the MIT Joint Program's analysis of McCain-Liebermann 2003 Climate Stewardship Act, and analysis of the 2007 U.S. GHG Cap-and-Trade proposals. The results of the MIT studies are widely used in the U.S. Senate, U.S. Environmental Protection Agency and the U.S. Department of Energy. Before joining the MIT Program in 2002, Sergey Paltsev worked as a Consultant for International Management and Communication Corporation and the World Bank and as an Executive Director of the Program in Economics and Management of Technology at Belarusian State University.

Dr. Sherman Robinson International Food Policy Research Institute (IFPRI),USA
Visiting Research Fellow at the Institute of Development Studies (IDS), and Professor of Economics (emeritus) at the University of Sussex. He worked at the International Food Policy Research Institute (IFPRI) as Director of the Trade and Macroeconomics Division from 1993 to 2004 and from 2011 to present. Before joining IFPRI in 1993, he was: Professor of Agricultural and Resource Economics at the University of California, Berkeley; Economist, Senior Economist and Division Chief in the Research Department of the World Bank; Assistant Professor of Economics at Princeton University; and Lecturer in Economics at the London School of Economics. He has been a consultant to the World Bank and has held visiting senior-staff appointments at the Economic Research Service, U.S. Department of Agriculture; the U.S. Congressional Budget Office; and the President's Council of Economic Advisers (in the Clinton administration), where he largely worked on trade issues, including regional trade agreements, GATT/WTO negotiations, and the North American Free Trade Agreement (NAFTA). He has had extensive experience working with economy-wide models of Ethiopia and Egypt to analyze issues of long-run impacts of changes in water policy and climate change.

Dr. Kurt Sternlof, MIT, USA
Kurt Sternlof is the Executive Director of the new Environmental Solutions Initiative at MIT, having served in the same role for the MIT Earth System Initiative since 2009. In addition to his research expertise in structural geology, geomechanics and subsurface fluid flow, Kurt has worked extensively in the private sector as a consulting hydrogeologist, as a geologist for the U.S. Geological Survey, as a science journalist for The Tampa Tribune and Oregonian newspapers, and as senior science writer for Columbia University’s Earth Institute. Kurt is personally and professionally dedicated to the belief that solid science must inform how we choose to live on Earth, and that effective communication across human boundaries is critical to this effort. Besides having published research papers in a wide range of scientific journals—Kurt has authored hundreds of newspaper and other popular articles on topics ranging from mercury contaminated fish to cold fusion to seismic hazards, geothermal energy and the tree-ring dating of volcanic catastrophes. He holds degrees in Geology & Geophysics from Yale (B.S.), Earth & Planetary Sciences from MIT (S.M.), and Geological & Environmental Sciences from Stanford (Ph.D.).

Prof. Kenneth Strzepek, MIT, USA
Kenneth Strzepek is a Research Scientist at MIT’s Joint Program on the Science and Policy of Global Change and Professor Emeritus, University of Colorado, and Non-resident Senior Fellow at the UNU-World Institute for Development Economics Research. He has been working on water and agricultural issues of the Nile Basin since 1977. He is an advisor to the Nile Basin Initiative and a World Bank Consultant on modeling tools to assist policy analysis with a focus on hydro-economic and economy-wide modeling and climate change impact and adaptations in the Nile. Prof. Strzepek has a Ph.D. in Water Resources Systems Analysis from MIT, an MA in Economics from the University of Colorado. Professor Strzepek has spent over 35years as a researcher and practitioner at the nexus of engineering, environmental and economics systems. He has worked for a range of national governments as well as the United Nations: UNDP, UNU, FAO, WMO, UNIDO, UNESCO, and IAEA, the World Bank, Asian

Development Bank and the USAID. He was an Arthur Maass-Gilbert White Fellow at the Institute for Water Resources of the US Army Corps of Engineer and received the Department of Interior Citizen's Award for Innovation in the applications of Systems Analysis to Water Management.

Kevin Wheeler, University of Oxford, USA
Kevin Wheeler is a DPhil Candidate in Geography and Environment at the University of Oxford, United Kingdom. In 2012 he was awarded a MSc in Water Science, Management and Policy from University of Oxford, writing a thesis: "Distributing Costs and Benefits through Dam Operations: A Case Study of the Grand Ethiopian Renaissance Dam." He has over 15 years of experience as a consultant in water resources modeling and analysis. He worked as a Peace Corps Volunteer for two years and was a Young Summer Scientist at the International Institute for Applied Systems Analysis (IIASA) – Laxenburg, Austria where his research was awarded the Mikhalevich Scholarship for innovative research approaches to assist policy decisions. Kevin Wheeler was selected to construct a simulation model of the Eastern Nile for the Nile Basin Initiative's East Nile Technical Regional Office (ENTRO). He worked closely with personnel from Ethiopia, Sudan, and Egypt to build a decision support model for the Blue Nile. This new model will help the three countries explore collaboration opportunities for joint resource management. He continues to train individuals around the basin to operate and further develop this important decision support tool.

Prof. Dale Whittington, University of North Carolina, Chapel Hill, USA
Dr. Whittington is a Professor in the Departments of Environmental Sciences & Engineering, and City & Regional Planning, at the University of North Carolina at Chapel Hill (USA), and at the Manchester Business School (UK). Since 1986 he has worked for the World Bank and other international agencies on the development and application of techniques for estimating the economic value of environmental resources in developing countries, with a particular focus on water and sanitation and vaccine policy issues. Prof. Whittington has been working on Nile Basin management issues since 1977 and was a co-author (with Donald Blackmore) of the 2009 report of the Scoping Study Team to the Eastern Nile Council of Ministers, *Opportunities for Cooperative Water Resources Development on the Eastern Nile: Risks and Rewards.*