Responding to the Crisis of the Filling of the GERD: An International Insurance Approach?

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Outline of Presentation

• Overview of Nile Hydrology
• The Crisis of GERD Filling
• A Primer on Hydropower
• Uncertain Future of Nile Flows
  – Natural Variability
  – Impacts of Filling Policies
• Modeling Approach
• Engineering Impacts and Risks
• Economics Impacts and Risks
• Sharing the Risks: A Case for Insurance
Nile Hydrology

<table>
<thead>
<tr>
<th>Nr</th>
<th>River and Station Name</th>
<th>Data Period</th>
<th>Avg Ann Flow [km³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Nile at Dongola</td>
<td>1890 - 1995</td>
<td>84.1</td>
</tr>
<tr>
<td>2</td>
<td>Atbara at mouth</td>
<td>1903 - 1994</td>
<td>11.1</td>
</tr>
<tr>
<td>3</td>
<td>Main Nile at Tamaniat</td>
<td>1911 - 1995</td>
<td>72.7</td>
</tr>
<tr>
<td>4</td>
<td>Blue Nile at Khartoum</td>
<td>1900 - 1995</td>
<td>48.3</td>
</tr>
<tr>
<td>5</td>
<td>White Nile at Mogren</td>
<td>1911 - 1995</td>
<td>26.0</td>
</tr>
<tr>
<td>6</td>
<td>Dinder at mouth</td>
<td>1907 - 1997</td>
<td>2.8</td>
</tr>
<tr>
<td>7</td>
<td>Blue Nile at Diem</td>
<td>1912 - 1997</td>
<td>48.7</td>
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</table>
Grand Ethiopian Renaissance Dam

- The GERD (the 8th largest reservoir on Earth) will soon join Egypt’s High Aswan Dam (3rd largest) in the unprecedented combination of
  - two major, multipurpose dams operating on the same river system with
  - no agreement for coordination in place.
Grand Ethiopian Renaissance Dam

• At 6,000 MW, the dam will be the largest hydroelectric power plant in Africa when completed, as well as the 8th largest in the world.

• No IRRIGATION JUST HYDROPOWER

• The reservoir at 70 billion cubic meters will be one of the continent's largest. Able to hold the 1.4 times he mean annual flow of the Blue Nile with is 75% of Nile flow reaching Egypt and Sudan.

• According to the Ethiopian government, as of Summer 2016, the dam is 70% complete. Could start filling in less than a year !!!!!!!
Why is it a CRISIS?
The GERD’s Location
High Aswan Dam

Filling the GERD with IMPACT EGYPT
BUT HOW AND BY HOW MUCH?
A PRIMER on RESERVOIRS AND HYDROPOWER
RESERVOIR ZONES

- Total Storage
- Top of Conservation
- Top of Buffer
- Top of Inactive

Flood Control Zone
Conservation Zone
Buffer Zone
Inactive Zone

DEAD STORAGE
GERD STORAGE FEATURES

Volume

74 BCM

47 BCM

15 BCM

3.5 BCM

1 BCM

0 BCM
Converting Potential to Mechanical to Electrical Energy

\[ HP = a \times H(t) \times Q(t) \]

\[ H = \text{Elevation Difference} \]

\[ Q = \text{Flow through Turbines} \]
Assessing the Impact of the GERD in light of the uncertainty of Future Nile Flow

- The sequence of flows in the Nile for the period over which filling will take place is uncertain and a stochastic process.
- A Risk Based Assessment must be undertaken.
- A modeling Framework was developed to take a monte carlo modeling risk based approach.
Nile Flow Ensemble Creation

- Prof Paul Block at Univ of Wisc
- Developed a KNN-Wavelet Model of Nile Precipitations
The KNN-WAVELET MODE

• Performed well in reconstructing History
• Generated 100 sequences of possible future 20 years of monthly precipitation over the Basin
Water Systems Modeling
DHI – MIKE HYDRO SYSTEM used to model Rainfall to Runoff and Nile Water System
GERD FILLING POLICY ASSESSED

• Minimum Release of 30 BCM per Year
  – The Blue Nile flow exceeded 95% of the time
  – The 1 in 20 year Drought

• 4 rates of Filling to Top of Conservation Pool
  – Unconstrained
  – 3 years
  – 5 years
  – 10 years
Simulated Inflow Sequences

Inflow to GERD

Billion Cubic Meters per year

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
GERD STORAGE
GERD STORAGE

Mean over first 10 years

Billion Cubic Meters

GERD FILLING POLICY

NoGERD  NoPolicy  3Yr  5Yr  10Yr
GERD RELEASE

Inflow to GERD

GERD RELEASE FOR No Policy

GERD RELEASE FOR 3 Yr FIl
IMPACTS TO EGYPT

• IMPACT ON INFLOW
• IMPACT ON STORAGE
• IMPACT ON HYDROPRODUCTION
IMPACT ON STORAGE

The diagram illustrates the impact on storage with different GERD filling policies. The box plots show the distribution of meters for NoGERD, NoPolicy, 3Yr, 5Yr, and 10Yr policies. The data indicates that policies with GERD have a wider range of storage impacts compared to the NoGERD policy.
IMPACT on HAD HydroPOWER

![Box plot showing the impact of different GERD filling policies on HydroPOWER generation.](image)
Trade Off

• How Much is Ethiopia Impacted by a slower fill policy?

• Let’s look at impacts on GERD Hydropower
What is the Value if GERD Hydrower

- Average Annual Generation for a minimum annual release of 30 BCM is estimated at 11,000 GWh
- At $0.10 per kwh give an annual revenue of $1.1 billion
- Power in Kenya was selling at $0.14 per kwh
From Engineering to Economics

- The previous was reporting on Engineering Indicators
- What if we look at Economic Indicator
- We performed a Hydro-Economic Analysis
UNU-WIDER Sacred Framework
Linking Engineering Systems Models with Economy-Wide CGE Modeks

Multi-sector Modeling Framework

- Global change (temperature, rainfall, world product prices)
  - Rivers (runoff, streamflow)
  - Flooding (frequency, severity)
  - Sea level rise (land loss, salination)
  - Cyclones (storm surges)

- Energy (hydropower)
- Agriculture (food, exports)
- Infrastructure (roads, ports, houses)
- Economy (growth, jobs, welfare, inequality)
High Aswan Dam model

Mediterranean
- Egypt M&I
- Egypt Irrigation

Low Aswan and Other Egyptian Reservoirs
- Sudan M&I and Irrigation (lumped)
- Ethiopia M&I and Irrigation (lumped)

Toshka Depression

High Aswan Dam

Sudd Wetland and Lake Victoria

NILE
- WHITE NILE
- BLUE NILE

GERD

ATBARA

Lake Tana
Objective function formulation

Objective function maximizes annual revenues, with a penalty:

$$Maximize \ Z = \sum_{i}^{n^c} p^c_i x_i + \sum_{j}^{n^h} \sum_{m}^{12} p^h y_{jm} - p^r (H_{12} - 175)^2$$

Where:

- $p^c_i =$ Price per crop
- $x_i =$ Yield per crop
- $n^c =$ Number of crops
- $p^h =$ Hydropower price
- $y_{jm} =$ Hydro per facility per month
- $n^h =$ Number of facilities
- $p^r =$ Penalty price
- $H_{12} =$ End of July elevation

Subject to:

$$V_t - V_{t-1} = Q_t - R_t - D_t - Tosh_t - Evap_t - Seep_t; \ \forall \ t$$
EGYPT - CGE

Factor Markets

Households

Government

Savings & Investment

Exports

Imports

Exports

Sales

Intermediate demand

Sales

Intermediate demand

Factor costs

Wages & rents

Domestic private savings

Direct taxes

Public savings

Public consumption

Investment demand

Foreign savings or capital inflows

Private consumption

Firms

Product Markets

Foreign Markets

Wages & rents

Social transfers

Private consumption

Sales

Wages & rents

Product Markets

Wages & rents

Direct taxes

Public consumption

Firms

Product Markets

Wages & rents

Firms

Product Markets

Wages & rents
Effect on Hydropower Generation

Mean Annual Difference in Hydro Generation relative to the Median No GERD Scenario, Over the First 10 Years

Effect on Hydro Generation (%)
Effect on GDP (relative)

Mean Annual Difference in GDP relative to the Median
No GERD Scenario, Over the First 5 Years

GDP: 272 billion USD (2013)
Population: 82.06 million (2013)
GDP growth rate: 2.1%
GDP/CAP: $3,314.46 (2013)
Mean Annual Difference in Ag GDP relative to the Median No GERD Scenario, Over the First 5 Years
IMPACT ON WAGES
What is the Impact on Average

• On the Average 1,480 Gwh lost at HAD

<table>
<thead>
<tr>
<th></th>
<th>HAD LOSS $million</th>
<th>GERD GAIN $milion</th>
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</thead>
<tbody>
<tr>
<td>NoGERD</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NoConst</td>
<td>30,661,294</td>
<td>1,198,101,444</td>
</tr>
<tr>
<td>3yr Fill</td>
<td>29,218,073</td>
<td>1,186,879,117</td>
</tr>
<tr>
<td>5yr fill</td>
<td>27,654,801</td>
<td>1,154,409,000</td>
</tr>
<tr>
<td>7yr Fill</td>
<td>19,141,106</td>
<td>1,039,181,599</td>
</tr>
</tbody>
</table>

• Room for Compensation
The Extreme Event

The Problem is below and Not above
The Risks to Egypt of the GERD Filling

- Loss Hydropower and Irrigation Flow
  - On average small much less that gains at GERD
- Significant increase in the Risk of Extreme Impacts
- The Economy-wide impact are very minor due to substitution in the economy and limited role of water in GDP (Ag 11% of GDP, Hydro ~ 10% of total generation)
- BUT impacts are on low income and Farmers a very politically volatile segment of the Egyptian Economy
- Poor Society Wide understanding of the greatly reduced role the Nile plays in Egypt Economy
- The Incredible Role it plays in national identity, psyche, and pride.
- Is there Room for Cooperation?
The Risks to Ethiopia
GERD Filling Policies

• Loss Hydropower Revenues & Repayment Issues
• And slowing of Economic Growth
• The GERD has been significantly by domestic bonds
• Society-Wide understanding of an inflated role the GERD will play in Ethiopian Economy
• The Incredible Role GERD plays in national identity, psyche, and pride. JUST LOOK AT THE NAME
• Is there Room for Cooperation
A proposal

• The international community develop an insurance scheme similar to the Hydrologic Risk Fund of the Senegal River Basin or Crop Insurance.

• This will insure Both Egypt and Ethiopia against the losses they both fear from extreme events and allow them to develop an agreement based upon the clear win-win of the “mean-state” of the Nile.

• What do you think?