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Grand Ethiopian Renaissance Dam (GERD)

An Interactive Qualifying Project Report

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Abstract

The development of Great Ethiopian Renaissance Dam (GERD) is causing political escalation of tensions between Ethiopia and Egypt based on current issues and the expectations for requirements that must be met before the completion of the dam construction. These include: engineering design, funding, political agreement, and thorough consideration of all possible options. This study reviews existing alternative solutions and proposes a methodology to assess their relative merits. It also provides suggestions for the efficient use of the water efficiency through reductions in physical losses, re-utilization of drainage and municipal water, and less waste in irrigation.

Acknowledgements

I would like to thank Professor Salazar F. Guillermo of the Civil and Environmental Engineering Department for his contribution and as well his guidance during the course of the project.

Executive Summary

Background:

The Nile River is the source of lifeline to about 300 million residents of Africans in 11 different countries. Over the years, there have been many dams built over the river of varying size and capability. These dams were small enough not to cause political upheaval. The construction of the Greater Ethiopian Renaissance Dam (GERD) is causing substantial changes to the water utilization of the river that would significantly impact water supply to Egypt. The GERD is currently in the midst of a large-scale political battle between Ethiopia, Sudan, and Egypt. If the construction of the dam is completed, Egypt may have to find new ways to support the water security for the Egyptian people. Egypt is considered one of the biggest countries in the world suffering from the water supplies, because of its natural conditions, Egypt's total geographic area 1.1 million kilometer square about 90% of Egypt area is desert and10% is of the area is inhabited and agricultural. Egypt's main source of fresh water is the River Nile which provides about 96% of fresh water supplies; the other sources of fresh water are the aquifers. Egypt has high population of around 95 million people and there is growing demands of fresh water every day (Abdin and Gaafar, 2008).

Objective and Scopes:

The purpose of this project is to outline the current situation surrounding the construction of the GERD. This project describes requirements that must be met before the completion of the dam construction among these strong engineering design, sufficient funding, political agreement, and thorough consideration of all possible options. The report also describes the political atmosphere that surrounds the issue from the influences of the British Colonial Rule to the current situation among the three basin nations on the Nile River. This study reviews existing alternative solutions and proposes a methodology to assess their relative merits. It also provides suggestions for efficient use of the water efficiency through reductions in physical losses, re-utilization of drainage and municipal water, and less waste in irrigation.

Results and Recommendations:

Egypt needs a revolution to conserve and manage the fresh water supplies in the face of the growing demands from the population growth, irrigation agriculture, and growth of industries and cities. Solving the water problem will require coordinated response to the problem from local, national and international levels. There are several ways to solve the problem.

1. Water Saving Techniques:

There are number of measures can be used towards the rational use of water for different activities. Some of these measures could be applied to domestic water systems and industrial requirement. However, agriculture being the major consumer of water has the largest share of these measures. Following water saving techniques are some of measures applied to agriculture (Abdin and Gaafar, 2008):

A. Use of modern irrigation systems in newly cultivated land (Sprinkler and drip irrigation systems must be used in the desert lands)
B. Change from surface irrigation to drip irrigation in the orchards and vegetable farms in the old lands.

C. Land leveling to decrease the amount of water needed to irrigate higher land
D. Night irrigation reduces evaporation losses
E. Modification of the cropping pattern
F. Introduction of short-age varieties the reduction in the number of days is immediately reelected on the number of irrigation gifts and consequently on the quantity of water supplied.
G. Irrigation improvement projects in the old land
H. The change from the earth field ditches named Misqas into canals or pipelines.

2. Optimum Use of Resources

A. Reuse of drainage water and treated wastewater
B. Desalination of sea water
C. Importance of international co-operation between the River Nile basins
D. Nile Basin Initiative (NBI) projects water policy good practice guides and support, project planning and management good practice guides, Nile Basin decision support system, and regional coordination and facilitation.
E. ENSAP relevant projects can be described as follows: The project may offer opportunities for win-win multipurpose development. Important water conservation gains may be possible through improved water management, storage and flood routine.
F. Eastern Nile Planning Model has been proposed as a common analytical basis for identifying, and assessing options, quantifying benefits and impacts, evaluating tradeoffs, and analyzing and managing information to support complex decision making processes on the Eastern Nile.
G. NELSAP Project: The Regional Agricultural Program will promote opportunities for cooperation in the Nile Basin through private investment, public- private partnerships and enhanced trade, in the field of high value crops and products. It will also identify steps to increase food security through increased investment, income generation and pro-poor growth.

3. **Development of National Water Resources Plan for Egypt 2017**:

The Egyptian governmental institution represented by Ministry of Water Resources and Irrigation (MWRI) has developed what is called a National Water Resources Plan (NWRP) to support the country's development until the year 2017. Specifically, NWRP has three major pillars:

- Increasing water use efficiency;
- Water quality protection;
- Pollution control and water supply augmentation.

4. **Legislation Improved Enforcement** of regulations this law puts more emphasis on four important points:

- Increased penalties for water miss-users or those who cause waste in different fields.
- Strengthening of "Polluter Pay" principal.
- Encouragement of participation both at the low level through water users associations in old and new lands as well as at the higher level of supply canal through the setting up of water federations.
- Introduction of water extension services represented by the Irrigation Advisory Services "IAS" Which provide farmers with the advice they need for a better and rational use of irrigation water. Other users, such as for domestic supply, are made aware by publicity through different media (newspapers, radio, television.).

5. **Institutional Reform** Egypt now to create an irrigation district which includes all the above disciplines and practice real integrated water management.
6. **Participatory Irrigation Management (PIM)** Farmers in developed countries enjoy high levels of education, and strong support services through both the private market and the public sector.
7. **National Water Quality Monitoring Program** the main objectives of this program are covering Egypt with water quality network to assess decisions of water use, to enhance the human resources capacity building and to unify the standards.
8. **Role of The Private Sector and Privatization** encourage the private sector in invest on the water infrastructures.
9. **Link The Nile to The Congo River** Recommendations for future research to link the two Rivers.

Conclusions:

Since the Egyptian population keeps growing rapidly, this requires more demands of water, so the Egyptian government should intensify the efforts to reduce the population growth rate. The Egyptian government should also establish an adequate legal framework as empowerment of the existing water use and water pollution laws seems crucial.

The Egyptian government should strengthen the cooperation ties through better cultural, social, economic and political relations with the Nile Basin countries as well as to support the Upper Nile projects, which will increase the Nile water quota, adding to encourage governmental and private investments in the Nile basin countries. An increased number of governmental and private sector interventions are needed to raise the public's awareness of the water scarcity problems, the rationalizations of water use in the domestic and industrial sectors as well as the protection of water recourses from pollution.

The Egyptian government should also support the role of scientific research to develop new affordable desalinization techniques and to introduce new agriculture seeds that have high productivity, high diseases resistance and low water consumption. Push forward the decentralization process of water management up to district level but it should be accompanied by serious capacity building programs. Establish a well-coordinated information system to support decision makers for making an effective water resources management on an environmentally sound basis.

Finally, Egypt should agree that Ethiopia has right to construct the GERD and three countries Ethiopia, Egypt and Sudan should come to an agreement on rules for filling the GERD reservoir and on operating rules during periods of drought.

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1. Introduction

Approximately 70% of the surface our globe is covered with water, saltwater accounts for 97.5% of that amount and only 2.5% would be considered fresh water. (Ward, 2003)

The fresh water is distributed as following:

- 68.9% is in the "form of ice and permanent snow cover in the Arctic, the Antarctic, and in the mountainous regions.
- 29.9% exists as fresh groundwater.
- Only 0.26% of the total amount of fresh waters on planet Earth is easily accessible. It is found in lakes, reservoirs and river systems are available for humans and other organisms for drinking. Figure 1-1 below illustrate fresh water distribution in the globe (Shiklomanov and Rodda, 2004):

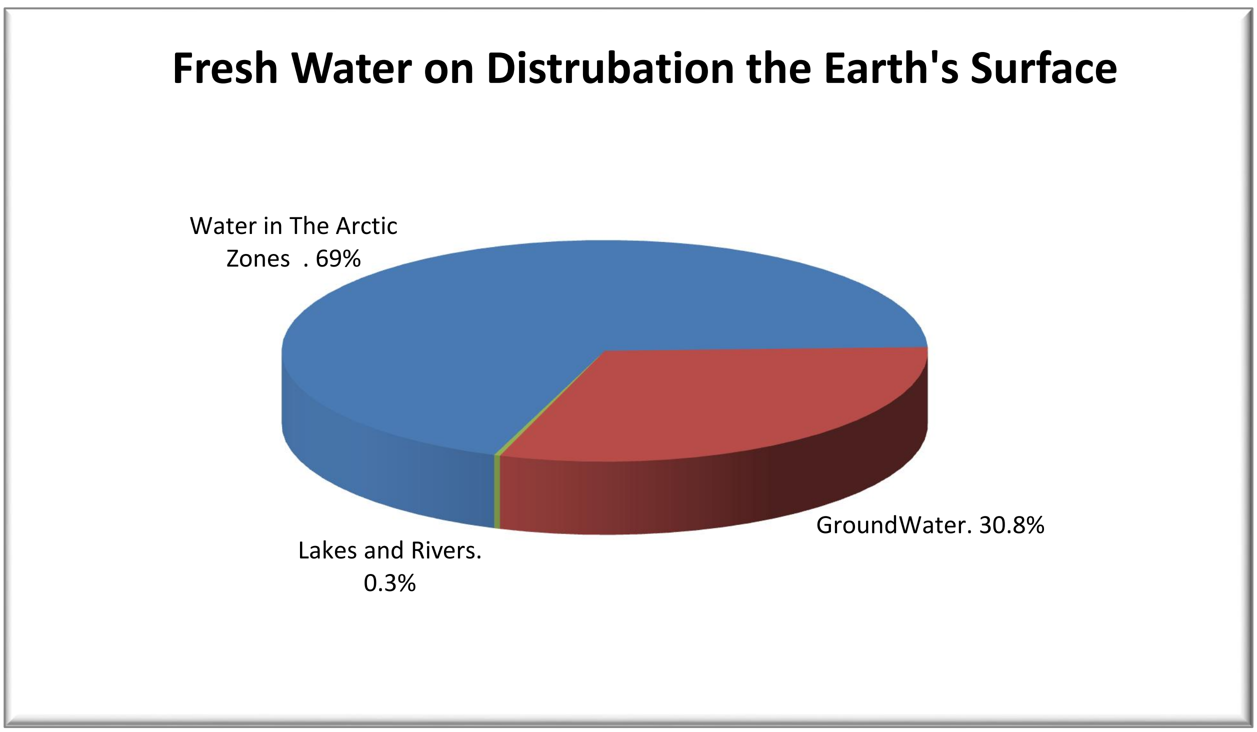

Figure 1-1: Fresh Water Distribution in the Globe

Every drop of water wasted by actual generations becomes priceless for our future generations. The whole globe must be concerned about the reality of water scarcity. Consciousness should be created among these world habitants. There will be a time in the future in which the available amount of fresh water to human consumption will gone forever, and returning this valuable resource to its original level is hard and in many cases impossible.

Water problems not only occur on developing countries, it occurs all around the world as it could be seen above. This is an issue that has concerned the population for more than decades; even the most developed countries experience some type of concern about their water resources. As predicted that due the climates changes and water scarcity in the near future will lead to war over water resources. Developed countries would be able to secure the water resources using advanced technology; this is not the case for undeveloped countries which they lack in use the technology and they lack to secure the funding to buy the technology to secure the water resources their people. Two-thirds of African population is threatened by Water scarcity and famine. There are more international river basins in Africa than in any other of the fifty seven countries. But nowhere in Africa are the tensions of drought, inadequate water supply, and water politics felt more acutely than along the Nile River. During the study I will concentrate on the Nile River Basin Countries to present the current situation surrounding the construction of the Grand Ethiopian Renaissance Dam which cause big conflict between Egypt and Ethiopia.

The conflict over the Nile waters

While the Nile being one of the most important rivers in the world and there are 11 countries sharing the river basin. There is no water sharing agreement between the basin countries for how the water should be distributed among them, only Egypt has historical rights under the Nile Water Agreement signed with Britain in 1929. This agreement gave Egypt the right to veto any project in upstream countries affecting Egypt's share of water flowing to it. It is worth mentioning that the 1929 agreement is binding for the three upstream countries Tanzania, Kenya and Uganda on the grounds that Britain, which colonized these countries, was their legal representative and could sign binding international agreements on their behalf. Egypt codified its legal status in an agreement with Sudan in 1959.

The construction of the Grand Renaissance Dam started in 2011 caused huge conflict between the downstream countries and the upstream countries the two groups fighting over the right waters the first group are the downstream countries, it includes Egypt and Sudan. The other group is the upstream countries which includes Ethiopia, Eritrea, Uganda, Congo, Burundi, Tanzania, Southern Sudan, Rwanda and Kenya. The downstream countries argue that they were not a party to those agreements at the time, and therefore do not recognize their legitimacy. The upstream countries want to modify the water-sharing agreement and keep more of the water by building dams, which will directly affect the water share of the downstream states, Egypt and Sudan. The problem is compounded by the projected large population increase in the Nile basin. The UN projects that the population in the 11 basin states will reach 860 million people by 2050. This is pressuring both sides to try to improve their positions in the conflict over the Nile waters. In May 2010, Ethiopia drafted the Entebbe Agreement to modify the historical and legal basis for the sharing of water. Most upstream countries supported the agreement but Egypt and Sudan refused it. The Entebbe Agreement will necessarily affect Egypt's share in the Nile waters and thus represent an existential threat to Egypt (Al-Labbad, 2013)

The populations of the Nile River basin countries usually have concerns such as: Why do other regions receive more drinkable water than us? Is this a political issue? Is the government searching for possible solutions? Are our resources used in an effective way? Is that water lack exist because financial issues? Is the Civil War in Sudan affecting the possibilities of developing water storage and resources? What happens to Egypt and Sudan water supplies while the reservoir behind the GERD dam is being filled? The dam will be able to hold back more than a year's flow of the Blue Nile as it leaves Ethiopia. In theory, while filling the reservoir for the first time, Ethiopia could cut off the entire flow for that year. Even filling over five years would significantly impact Egypt, especially if they are dry years. These are some of the questions that I will be approaching in this project to outline the construction of the GERD and the requirements that must be met before the completion the GERD construction. Among these: strong engineering design, sufficient funding, political agreement between the basin countries, and thorough consideration of all possible options. The study will review existing alternatives solutions, proposes a methodology to rank them and provides suggestions for the efficient use of the water resources to what may become a breach in the water security of the Egyptian people.

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Egypt needs a revolution to conserve and manage the fresh water supplies in the face of growing demands from the population growth, irrigation agriculture, and growth of industries and cities. Solving the water problem will require coordinated response to the problem from local, national and international levels. There are several ways to solve the problem.

2. Background

The Nile River is the longest river in the world. It is approximately 4,160 miles (6,670 km) long. There are eleven countries the Nile and its tributaries flow through. These countries are Burundi, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda. The Nile River flows from the high mountains in the middle regions of Africa north to the Nile Egypt delta. Near the Mediterranean Sea the river splits into two branches, the Rosetta Branch (to the west) and the Damietta (to the east). Both flow into the Mediterranean Sea. The name of the river (Nile) is derived from the Greek word "neilos" which means "river". There are two major branches of the Nile; they are the White Nile and the Blue Nile. The White Nile originates in East Africa, and the Blue Nile originates in Ethiopia. The two branches join at Khartoum (the capital city of Sudan located in North East Africa). The two major sources of the river are Lake Victoria which feeds the White Nile branch, and Lake Tana which feeds the Blue Nile branch. The rivers average discharge is approximately 300 million cubic meters per day. Ancient Egypt may have never become one of the greatest civilizations in history if it had not been for the Nile. Ancient Egypt relied on agriculture for its wealth and power. The Ancient Egyptians called the river Ar or Aur which means "black". They named it this because the annual flood left black sediment along the river banks.

2.1 The Sources of The Nile:

The origin of the great river was a mystery until the middle twentieth century. Herodotus speculated that the Nile arose between the peaks of Crophi and Mophi, south of the first cataract. In 140 C.E. Ptolemy suggested the source was the Mountains of the Moon, in what are now called the Ruwenzori Mountains in Uganda (Carlson, 2013).

In the 11th century Arab geographer al-Bakri claimed the Nile arose from West African origins, confusing the Niger River, which empties into the Atlantic Ocean, with the Nile River.

In 1770 the Scottish explorer James Bruce claimed his discovery of the source in Ethiopia, while in 1862 John Hanning Speke thought he found it in Lake Victoria and the equatorial lakes. The river's limited navigability only increased its mystery. The Blue Nile River descends 4501 feet in 560 miles from Lake Tana in the Ethiopian highlands through a deep gorge with crocodiles, hippopotamuses, and bandits to the Sudan border and the savannah. Despite the efforts of scores of intrepid adventurers, the Blue Nile in Ethiopia was not successfully navigated until 1968 by a team of British and Ethiopian soldiers and civilians equipped by the

Royal Military College of Science (Carlson, 2013). Figure 2.1-1 below shows the Nile River sources:

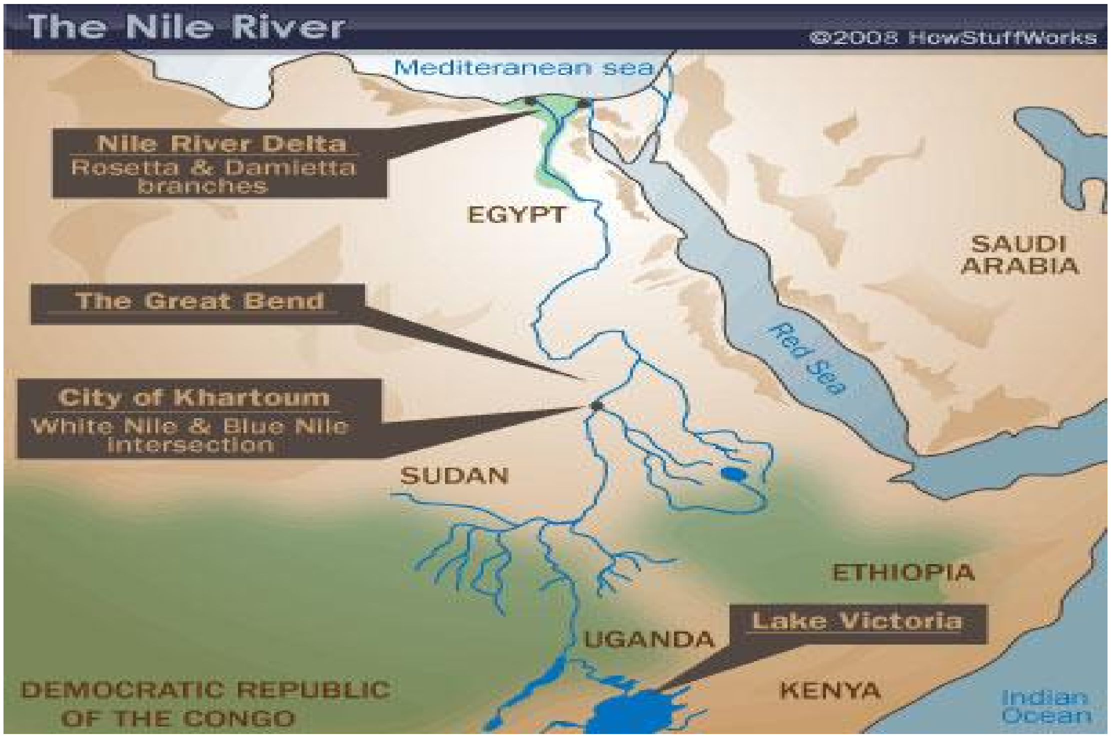

Figure 2.1-1: Map showing Nile River Sources

The source 2008 How Stuff Works:http://adventure.howstuffworks.com/nile-river1.htm

Further south up the White Nile in the lakes and rivers of Burundi, Rwanda, Kenya, Tanzania, and Uganda, the Egyptian cultural influence is less pronounced, due to the Sudd, a gigantic and impassable swamp which absorbs waters from the equatorial lake tributaries. the 20th century did it become clear that the Nile is part of a vast river system with dozens of tributaries, streams, and lakes, stretching from the Mediterranean Sea to the remote mountains of Burundi, in tropical central Africa, and to the highlands of Ethiopia, in the Horn of Africa. Spanning more than 4,200 miles, it is the longest river in the world. It has also become clear that the volume of water which flows through the Nile is relatively smaller two percent in volume of the Amazon's and fifteen percent of the Mississippi in table 2.1-1 below shows the World's Major River systems (Carlson, 2013).

Table 2.1-1: World's Major River Systems

River	Length (Km)	Drainage Area (10^3 Km^2)	Annual Discharge (10^9 m^3)	Discharge/unit area (10^3 m^3/Km^2)
Nile	6,850	3,110	84	28
Amazon	6,700	7,050	5518	728
Congo	4,700	3,820	1248	326
Mekong	4,200	795	470	590
Niger	4,100	2,274	177	78
Mississipi	970	3,270	562	170
Danube	2,900	816	206	252
Rhine	1,320	224	70	312
Zambezi	2,700	1,200	223	185

Source: water sharing in the Nile River valley:
http://www.grid.unep.ch/activities/sustainable/nile/nilereport.pdf

2.2 Egypt and the Nile:

The Nile has been essential for civilization in Egypt and Sudan. Without that water, there would have been no food, no people, no state, and no monuments.

For millennia peoples have travelled along the banks of the Nile and its tributaries. Scores of ethnic groups in Egypt, Ethiopia, and Sudan share architecture and engineering, ideas and traditions of religion and political organization, languages and alphabets, food and agricultural practices. In 3000 B.C.E., when the first Egyptian dynasty unified the lower and upper parts of the Nile River, there were no states in Eastern or Central Africa to challenge Egypt's access to

Nile waters. The Nile was a mysterious god: sometimes beneficent, sometimes vengeful. Floods between June and September, the months of peak flow, could wipe out entire villages, drowning thousands of people. Floods also brought the brown silt that nourished the delta, one of the world's most productive agricultural regions, feeding not only Egypt but many of its neighbors (Carlson, 2013).

The Nile's seasonal flooding is a central theme in Egyptian history. The river flow follows regular patterns, increasing between May 17 and July 6, peaking in September, and then receding until the next year. But the river volume is very unpredictable, as documented by (nilometers) (multi-storied structures built in the river to measure water heights). Successive empires of Pharaohs, Greeks, Romans, Christian Copts, and Muslims celebrated the rising waters of the Nile and dreaded floods or droughts (Carlson, 2013).

Five millennia of Nile history show how years with high water have produced ample food, population growth, and magnificent monuments, as during the first five dynasties from 3050 B.C.E. to 2480 B.C.E. Periods with low water have brought famine and disorder. The Book of Genesis describes seven years of famine that historians associate with the drought of 1740 B.C.E. From the time of the Pharaohs until 1800 C.E., Egypt's population rose and fell between 2 to 5 million, due to food availability and epidemics. The irrigation projects of the 19th century built under the Ottoman ruler Mohammad Ali allowed year-round cultivation, causing population growth from 4 to 10 million. Since the opening of the Aswan High Dam in 1971, Egypt's population has increased from about 30 to 95 million.

2.3 The Nile River:

The Nile River is one of the most important rivers around the world. There are eleven nations depending on the Nile's river water; Burundi, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda. All of those countries are completely dependent on the River's water, especially Egypt and Sudan. Figure 2.3-1 shows the Nile River basin:

Figure 2.3-1: Map Showing River Neil Basin Countries

Source: World Bank, 1998:

http://siteresources.worldbank.org/INTAFRNILEBASINI/About%20Us/21082459/Nile_River_Basin.htm

Egypt's population is nearly ninety five million people, and they are all concentrated along the Nile's Bank, in about ten percent of Egypt's land. The other ninety percent is desert. "The Nile river Valley has an average of 3820 people per square mile, ranking it as one of the world's most densely populated areas, and some 95 percent of the population of Egypt lives near the Nile's banks (Hoyt, 2007)

Only Egypt and Sudan have historical rights to the Nile's water. It is well known that the Egyptian civilization originated around the Nile River. As Herodutus famously wrote in the 5th century B.C.E., "Egypt is the gift of the Nile". Because the Egyptian civilization was depending on the resources of the great river" (Dowling, 2015).

Over last two centuries, the other nations rose and claimed their ownership of the water because the water of the River is originated in their land. However, Egypt and Sudan claim that the law on their side according to 1929 and 1959; treaties when Great Britain controlled much of the areas. Great Britain had granted Egypt and Sudan a full utilization of the Nile and the power to veto any development projects in the catchment area in East Africa (Rice, 2010).

The 1959 treaty gave Egypt three quarters of the Nile's River water; 55.5 billion cubic meters per year, and it gave about quarter of the water flow; 18.5 billion cubic meters.

These 79 billion cubic meters represented 99% of the calculated average annual river flow. The treaty also allowed for the construction of the Aswan High Dam, completed in 1971, in Egypt. However, the population of Egypt had doubled since 1959; the water portion has not changed. (Carlson, 2013).Great Britain agreed to the 1959 treaty on behalf of the upstream states. However, the upstream states refused to agree to this treaty after their independence in 1960s.

In 1984, the rains failed in Ethiopia causing a drought, which killed about one million Ethiopians. Meanwhile in Egypt, the Aswan turbines failed causing a power crisis in Egypt. In 1990s, President Hosni Mubarak doubled the pace of construction of another project in Egypt on the Nile River to build the Toshka Canal. It is one of the most expensive water resources project in the world, to turn an area of land in the western desert into Greenland (Carlson, 2013).

In response, Ethiopia objected and began plans for the Grand Renaissance Dam. In 2013, the visit of the ousted president Mohamed Morsi helped Ethiopia to begin the construction of the Renaissance Dam. The Renaissance Dam is located about twenty five miles away from the Ethiopian Sudanese Border. A failure of this Dam will be disaster for Sudan and Southern parts of Egypt. The construction's anticipated completion in 2017; this Dam will dramatically affect life in Sudan and Egypt.

The issue between the upstream and downstream countries is very complex, and it is not anticipated to be solved soon. Egypt's government and leaders are on the mission impossible; trying to race the time to find a solution while the Dam is under construction.

2.4 Nile's Water Cycle:

The Nile really begins with the water cycle, every year the water on the Nile rise and fall with seasons. These changes in the river level are tied to water cycle that brings rain to highlands of Africa. The water cycle is "vital component on the Earth's ecosystems. It redistributes itself through different a natural cycle that contributes in the climate control and the hydrologic cycle. The Water Cycle is a way of explaining how the water travels in different ways. These ways can be seen more clearly in Figure 2.4-1 below:

As a part of the water cycle, Earth's surface-water bodies are generally thought of as renewable resources, although they are very dependent on other parts of the water cycle. The amount of water in rivers and lakes is always changing due to inflows and outflows. Inflows to these water bodies will be from precipitation, overland runoff, groundwater seepage, and tributary inflows. Outflows from lakes and rivers include evaporation, movement of water into groundwater, and withdrawals by people. Humans get into the act also, as people make great use of surface water for their needs.

Water is exchanged between the Earth and its atmosphere in an endless cycle. When the sun warms water in rivers, lakes and the oceans, some of this water becomes **water vapour** and rises into the atmosphere. This process is called **evaporation**. The rest of the moisture found in the atmosphere is given off by plants, with water escaping through the surface of the leaves. This form of evaporation is known as **transpiration**. Water vapour is invisible. When it cools, water vapour becomes liquid water again. This is called **condensation**. The water vapour rises it cools to form clouds. Clouds are made up of millions of tiny drops of water so light that they float in the air. Rain falls when clouds become over-saturated or too heavy to carry the moisture in them. The water then returns to the Earth as rain, hail or snow. This is called **precipitation**. Rain is the best known form of precipitation. Hail and snow eventually melt, and join rainwater to form streams and rivers that flow back to the oceans. All these processes are repeated over and over again. (Evans and Howard, 2005).

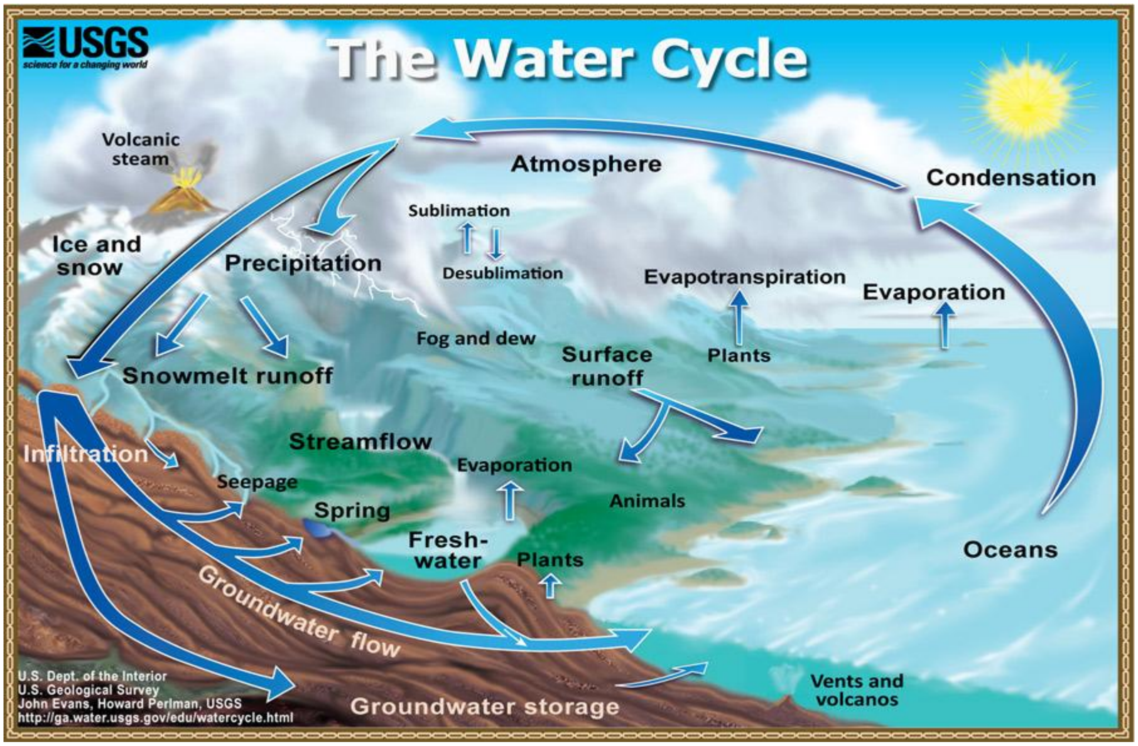

Figure 2.4-1: The Water Cycle

Source: USGS, http://water.usgs.gov/edu/watercycle.html

2.5 Existing Dams over the Nile:

A **dam** is defined as a barrier or structure across a stream, river or waterway to confine and then control the flow of water. Dams vary in size from small earth embankments often for farm use to high massive concrete structures generally used for water supply, hydropower and irrigation.

The construction of a dam usually requires the relocation of existing villages, individual houses, farms, highways, railroads and utilities from the river valley to a higher elevation above the reservoir. The principal types of dams in the world are embankment, gravity and arch. The appurtenant or additional structures of a dam include a spillway, outlet works, hydropower plants and a control facility. Dams are constructed to store and control water for domestic water supply, irrigation, navigation, recreation, sedimentation control, flood control or hydropower. Some dams serve one purpose and are therefore known as a **“single purpose dam”.** Today, dams are being built to serve several purposes and are therefore called **"multipurpose dams"**. A multipurpose dam is a very important and cost effective project for developing countries because the population receives several domestic and economic benefits from a single investment. It is the cornerstone in the water resources development of a river basin. (ICOLD, 2007).

In 1843 Egypt decided to build a series of diversion dams (barrages or weirs) across the Nile at the head of the delta about 12 miles downstream from Cairo, so as to raise the level of water upstream to supply the irrigation canals and to regulate navigation. This delta barrage scheme was not fully completed until 1861, after which it was extended and improved; it may be regarded as marking the beginning of modern irrigation in the Nile valley. The Zifta Barrage, nearly halfway along the Damietta branch of the deltaic Nile, was added to this system in 1901. In 1902 the Assiuṭ Barrage, more than 200 miles upstream from Cairo, was completed. This was followed in 1909 by the barrage at Isna (Esna), about 160 miles above Assiuṭ, and in 1930 by the barrage at Naj Hammadi, 150 miles above Assiuṭ. (El-Kammash, Hurst and Smith, 2006)

The first dam Egypt constructed was Aswan low dam between 1899 and 1902; it has a series of four locks to allow navigation. The dam has twice been enlarged first between 1908 and 1911 and again between 1929 and 1934 thus raising the water level and increasing the dam’s capacity. It is also equip with a hydroelectric plant with an installed power of more than 345 megawatts. (El-Kammash, Hurst and Smith, 2006). Figure 2.5-1 shows the placement of early dams on the Nile:

Figure 2.5-1: Map Showing Early Dams on The Nile

Source:http://www.gwp.org/Global/ToolBox/Case%20Studies/Asia%20and%20Caucasus/the_nile_river_basin-water_agriculture_governance_and_livelihoods.pdf

The Aswan High Dam is located about 600 miles upstream from Cairo and 4 miles upstream from the first Aswan dam. It is built at a place where the river is 1,800 feet wide and has steep banks of granite. The dam is designed to control the Nile water for the expansion of cultivation and for the generation of hydroelectric power and to provide protection downstream for both crops and population against unusually high floods. The work began in 1959 and was completed in 1970. The Aswan High Dam is 12,562 feet long at crest level and 3,280 feet wide at the base, with a height of 364 feet above the riverbed. It has a hydroelectric plant with an installed capacity of 2,100 megawatts. Lake Nasser stretches some 310 miles upstream from the dam site, extending 125 miles into Sudan. (El-Kammash, Hurst and Smith, 2006). Figure 2.5-2 shows the Aswan High Dam and Lake Nasser:

Figure 2.5-2: Map Showing Aswan High Dam and Lake Nasser

Source: http://www.somalipress.com/static/aswan_tourist_map.gif

The objective behind the construction of the Aswan High Dam is to store sufficient water in the reservoir in order to protect Egypt from the dangers of a series of years when the Nile flood is above or below the long-term average and thus to guarantee a steady flow of water from the Nile for both Egypt and Sudan. An agreement concluded in 1959 between the two countries sets a maximum amount that can be drawn per year and apportions it in a ratio of three to one, with Egypt receiving the larger share. The quantities of water maintained and apportioned are based on the estimated worst possible sequence of flood and drought events over a period of 100 years;

and generally, one-fourth of the total capacity of Lake Nasser is reserved as relief storage for the highest anticipated flood during such a period. (El-Kammash, Hurst and Smith, 2006)

The Aswan High Dam was a source of considerable controversy during its construction, and since it began operation it has continued to have its critics. Opponents have charged that silt-free water flowing below the dam has caused erosion of the downstream barrages and bridge foundations; that the loss of silt downstream has caused coastal erosion in the delta; that the overall reduction in the flow of the Nile resulting from the construction of the dam has caused the inundation of the lower reaches of the river by saltwater from the Mediterranean Sea, with resulting deposition of salt in the delta soils; and that the creation of Lake Nasser has caused the water table along the river to rise, resulting in water logging and an increase in soil salinity in some areas. The dam has maintained that these harmful effects are worth the security of dependable water and power supplies, and, indeed, Egypt would have suffered severe shortage in 1984–88 without the dam. Table 2.5-1 below shows the Major dams and barrages finished, unfinished and planned in the Nile Basin countries (Awulachew, Smakhtin, Molden and Peden, 2012)

Table 2.5-1: Major Dams and Barrages Finished, Unfinished and Planned in The Nile Basin:

Country	*Name of dam*	*River*	*Year completed (or to be started)*	*Power (MW)*	*Storage (m^3)*	*Contractor*
1900s to 1970 post-independence						
Egypt	Assiut barrage	Main Nile	1902	Irrigation		
Egypt	Esna barrage	Main Nile	1908	Irrigation		
Egypt	Nag-Hamady barrage	Main Nile	1930	Irrigation		
Egypt	Old Aswan Dam	Main Nile	1933		450,000	
Egypt	High Aswan Dam	Main Nile	1970	2100	1,110,000	
Ethiopia	Tis-Abay	Lake Tana	1953	12		
Sudan	Sennar	Blue Nile	1925	48	0.93	
Sudan	Jebel Aulia	White Nile	1937	18		
Sudan	Khashm El Gibra	Atbara	1964	35	1.3	
Sudan	Roseires	Blue Nile	1966	60	2.386	
Uganda	Owen/Nalubaale	White Nile	1954	180	0.230	
1970 to present						
Ethiopia	Tekeze 5	Tekeze	2009–2010	300	9.2	
Sudan	Merowe	Main Nile	2009–2010	350	12	
Ethiopia	Finchaa	Finchaa	1971/2013	134	1050	
Ethiopia	CharaChara	Blue Nile	2000	84	9126	
Ethiopia	Koga	Blue Nile	2008	Irrigation	80	
Ethiopia	Tana Beles	Blue Nile	2011	460		
Kenya	Sondu Miriu	Victoria	2007	60	1.1	Japan
Uganda	Kiira/extension	White Nile	1993–2000	200		
Under construction (date gives completion date)						
Sudan	Roseires heightening	Blue Nile	2013			Multi-national
Sudan	Burdana	Setit/Atbara		135		China/ Kuwait
Sudan	Rumela	Atbara		135		China/ Kuwait
Sudan	Shiraik	Main Nile		300		
Ethiopia	FAN	Finchaa	2011			China/ Italy
Ethiopia	Tekeze II	Tekeze	2020			
Ethiopia	Megech	Abay		Irrigation		Multi-national
Ethiopia	Ribb	Abay	2011			
Ethiopia	Grand Millennium	Blue Nile	2017	5250		China/ Italy
Rwanda	Nyabarongo	Nyabarongo	2011	27.5		Australia/ India
Uganda	Bujagali	White Nile	2011	250		Italy

Continue of Table 2.5-1: Major Dams and Barrages Finished, Unfinished and Planned:

Country	*Name of dam*	*River*	*Year completed (or to be started)*	*Power (MW)*	*Storage (m^3)*	*Contractor*
Dams proposed (date gives potential start date)						
DRC	Semliki	Semliki				
Ethiopia	Jema	Jema				
Ethiopia	Karadobi	Blue Nile	2023	1600		ENSAP
Ethiopia	Border	Blue Nile	2026	1400		ENSAP
Ethiopia	Mabil	Blue Nile	2021			
Ethiopia	Beko Abo	Blue Nile		2000		ENSAP
Ethiopia	Mendaya	Blue Nile	2030	1700		ENSAP
Ethiopia	Chemoda/Yeda five dams proposed	Chemoga/ Yeda rivers	2015	278		China
Ethiopia	Baro I	Sobat				
Ethiopia	Baro II	Sobat				
Sudan	Nimule	Nile				
Sudan	Dal-1	Nile		400		
Sudan	Kajbar	Nile		300		
South Sudan	Bedden	Bahr el Jebel				Italy/NBI
South Sudan	Shukoli	Bahr el Jebel				Italy/NBI
South Sudan	Lakki	Bahr el Jebel				Italy/NBI
South Sudan	Fula	Bahr el Jebel				Italy/NBI
Uganda	Isimba	White Nile	2015	87		
Uganda	Kalagala	White Nile	2011	300		India
Uganda	Karuma	White Nile	2017	200		
Uganda	Murchison	White Nile	600			
Uganda	Ayago North	White Nile	2018	304		
Uganda	Ayago South	White Nile		234		
Uganda	15 small run-of-the river	Kagera				
Rwanda	Kikagate	Kagera	2016	10		
Rwanda	Nyabarongo	Kagera	2012	27		
Rwanda/ Tanzania/ Burundi	Rusumo I & II	Kagera	2012	60		NELSAP
Kenya	Goronga	Mara				
Kenya	Machove	Mara				
Kenya	Kilgoris	Mara				
Kenya	EwasoNgiro	Mara	2012	180		UK

Note: ENSAP = Eastern Nile Subsidiary Action Program

Sources: Ofcansky and Berry, 1991; Nicol, 2003; Scudder, 2005; Dams and Agriculture in Africa, 2007; McCartney, 2007; World Bank, 2007; UNEP, 2008; African Dams Briefing, 2010; Dams and Hydropower, 2010; Kizza et al., 2010;Verhoeven, 2011; Sudan Dams Implementation Unit, undated

2.6 Similar Case Situation: Hoover Dam on Colorado River

Description of Hoover dam:

Hoover Dam is located on Colorado River, the natural Canyon border between Arizona state and Nevada state. The name of the dam is taken from the name of 31^{st} USA president, Mr. Herbert Hoover. The amount of water is shared among seven states. The Colorado River basin states are Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming. Hoover dam is a concrete Arch Gravity type dam that is 379 m high, 221m tall and 201 wide at its base. Lake Mead is the reservoir of the dam .The dam cost was about 49 million US dollars to build. Hoover dam is a huge dam that it is consider the 1st ranked largest dam in the world right after it construction completed in 1935, and at the present time, it is being ranked as 38^{th}. Figure 2.6-1 shows aerial photograph of the of hoover dam.

Figure 2.6-1: Aerial Photograph of The of Hoover Dam

Source: http://the-wanderling.com/hoover_dam.html

Impact of Hoover Dam:

Construction of Hoover Dam has advantages and disadvantages, the advantages for Hoover dam to store water for irrigation, flood control along the Colorado River, to generate electricity and for other purposes, the disadvantages of Hoover dam caused negative effects on environment due to the construction of the dam lowered the groundwater table because of the lowering of Colorado riverbed and over the years the water stored in Lake Mead kept digging the riverbed below the dam, so the plants couldn't reach the new depth of the ground water table.
Also, the dam affected on the electricity output and caused shrinking electrical output where it record low reservoir levels. Researchers at the University of California in San Diego predict that Hoover Dam has a 50% chance of decreasing to a point too low for power generation by 2017, and an equally high chance of going dry by 2021.

I used comparison between Hoover dam and Grand Ethiopian Renaissance Dam because the Hoover dam has disadvantages similar the ones created by Grand Ethiopian Renaissance Dam construction. The critical disadvantages of Hoover dam is the sharing of the amount of water between the seven states. It was so hard for the seven states of the Colorado River Basin are to decide how to divide the waters of the River. Most of the states were afraid about which state was going to get more water so they managed to agree on a document, called the Colorado River compact. The Compact under the Act of the Congress of the United States of America approved in August 19, 1921. The major purposes of this compact are to provide for the equitable division and apportionment of the use of the waters Of the Colorado River System; to establish the relative importance of different beneficial uses of water, to promote interstate comity; to remove causes of present and future controversies; and to secure the expeditious agricultural and industrial development of the Colorado River Basin, the storage of its waters, and the protection of life and property from floods. The Colorado River Compact divided the Colorado River Basin into the Upper Basin and the Lower Basin. The division point is Lees Ferry, a point in the main stem of the Colorado River about 30 river miles south of the Utah-Arizona boundary. The "Upper Basin" includes those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters naturally drain into the Colorado River system above Lees Ferry, and all parts of these States that are not part of the river's drainage system but may benefit from water diverted from the system above Lees Ferry. The "Lower Basin" includes those parts of the States of Arizona, California, Nevada, New

Mexico, and Utah within and from which waters naturally drain into the Colorado River system below Lees Ferry, and all parts of these States that are not part of the river's drainage system but may benefit from water diverted from the system below Lees Ferry figure 2.6-2 shows the location of Less Ferry. The purpose of the compact was to divide and apportion the use of water in the Colorado River basin. The compact estimated the river's annual flow and divides the waters among the seven basin states and establish the apportionment of the waters between the states. While there is agreement that divides the waters among the seven basin states there are areas in the basin facing huge economic challenges to get water. For example, Las Vegas has spent a billion dollars to build a new intake valve, because their intakes are so dangerously close to the water level at Lake Mead, so the rivers are facing the same challenge, as well as keeping the water. The main question that the seven basin states on the Colorado River under controls of one country USA so they were able to work together to come up with agreement to divide the water among them. On the other hand, after Grand Renaissance Dam is building there are a very important questions need to be answered such as that which countries of Egypt, Sudan, and Ethiopia can get the largest amount of water? Would this amount of water assign each country satisfying all its needs? Could the Nile River basins countries come up with agreement to divide the water among them?

The reason for Ethiopia construction the dam is to make history, get rid of poverty, increasing electricity and prosperity the agriculture, but what about the other countries and their needs of the water. The main purpose here in the comparison to show that not only the Grand Renaissance Dam will have problems about the water sharing within the basin countries, but there are other dams have the same problems, for instance Hoover dam. Also, this means the Grand Renaissance Dam can cause other negative effects on the other countries and will face similar problems as Hoover Dam does. Ethiopia should look at the dam's impacts on the downstream neighbors and work with them to come up with solution that would benefit all the basin countries. Nile basin countries should try to come up with agreement that all basin countries would support the construction of the GERD and finalize an agreement to explain how the water would be divided among all basin countries.

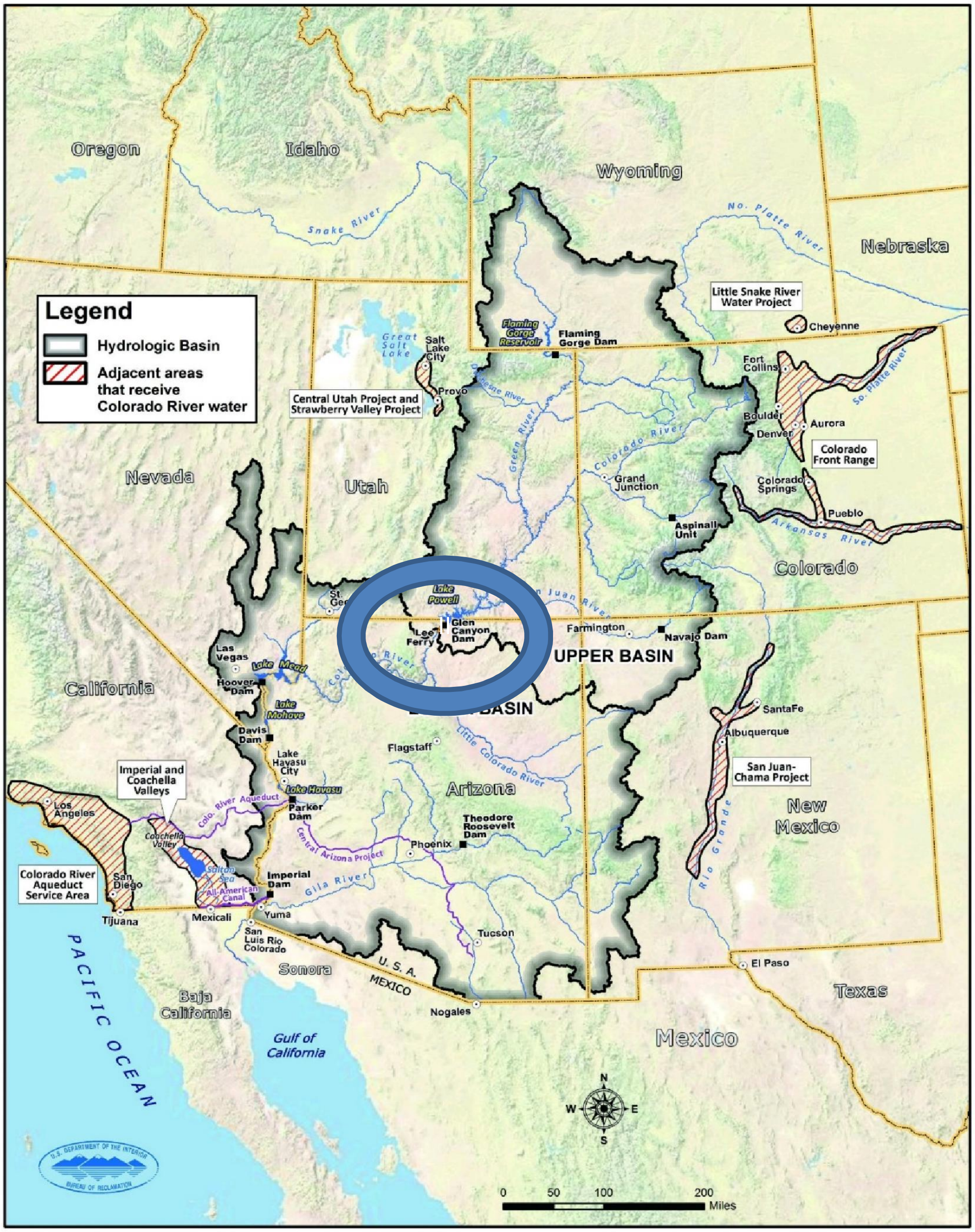

Figure 2.6-2: Lees Ferry Divided Colorado River Basin into Upper and Lower Basin

Source: http://www.crb.ca.gov/images/content/colorado-river-lrg.jpg

3. The Grand Ethiopian Renaissance Dam:

The following data was obtained by the IPOE (International Panel Experts) committee. This committee was put together by Egypt, Sudan and Ethiopia. The final report was submitted on May 31, 2013.

3.1 Project Location and Description:

The Grand Ethiopian Renaissance Dam is located in Ethiopia; on the Blue Nile about 20 Km away from the Ethiopian Sudanese Border. This Dam will be the largest hydropower project in Africa. The main body of the Dam is Roller Compacted Concrete (RCC). The Dam is currently under construction, where about 33% of the project is completed. The Dam is anticipated to operate within the next two years, by 2017, with a height of 145 meter above the foundation level, and a crest length is 1780 meter. The reservoir area will cover 1874 square Kilometer at full supply level of 640 meter above sea level. The expected average energy production is 15,692 GWh per year. Figure 3.1-1 shows the location of the dam area.

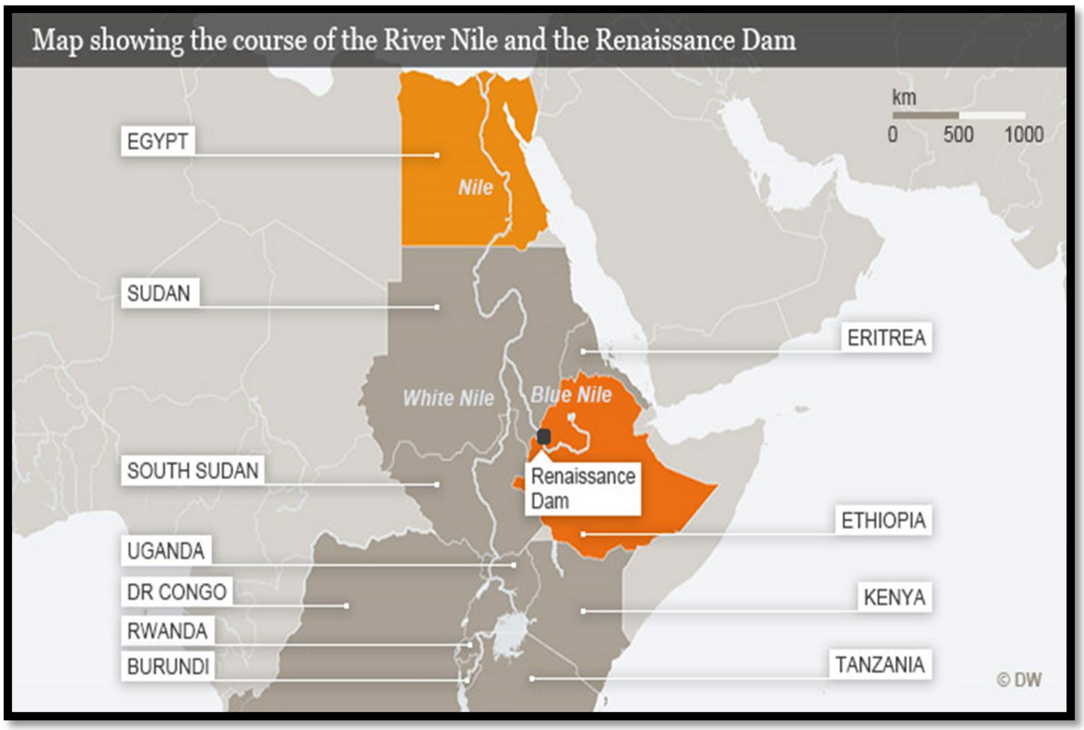

Figure 3.1-1: General location Map and The Nile's river Basin Area

Source: http://www.dw.deegypt-and-ethiopia-argue-over-dam-projecta-16880722

The main dam, which will have a volume of approximately 10MCM, will be divided in three sections; Right bank, central section and left bank. The central section will be used as a stepped spillway, and it will be kept at a lower level than the left and right banks to allow maintenance of the Dam body and allow for flood in raining season. The power houses will be on the downstream of the dam; one on the left bank and the other on the right bank of the dam. Figure 3.1-2 shows the main dam body with power houses and reservoir area.

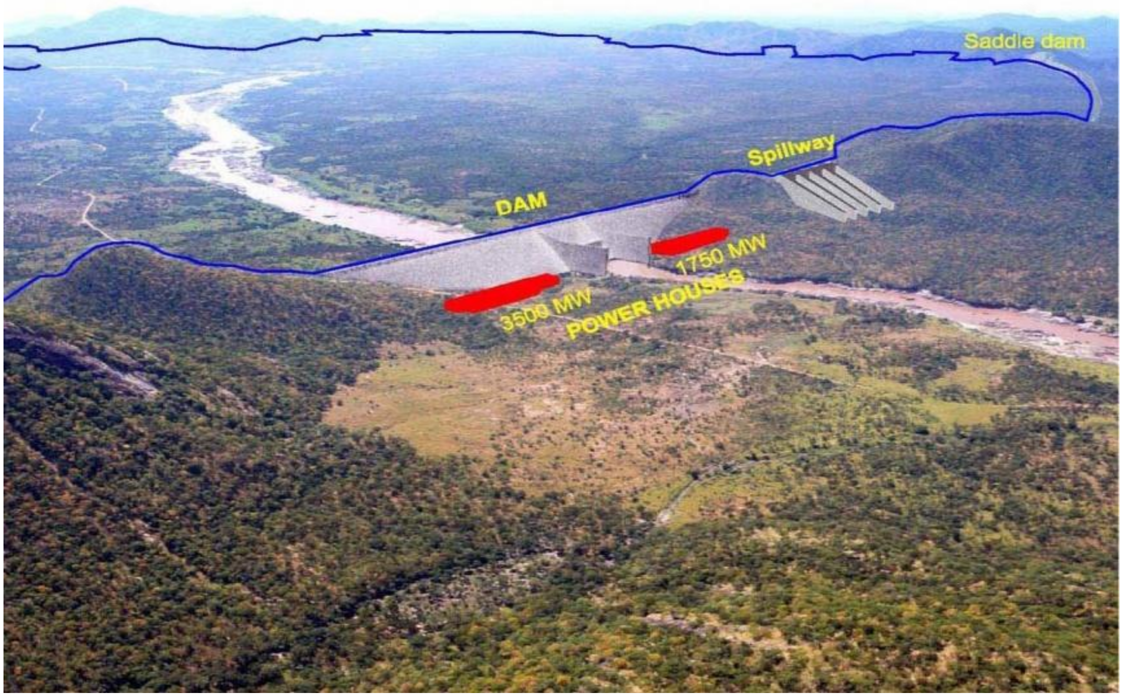

Figure 3.1-2: Aerial Photograph of The GERD Project Area

Source: http://www.internationalrivers.org/resources/the-grand-ethiopian-renaissance-dam-fact-sheet-8213

3.2 Dam and Reservoir:

Based on multiple factors like average energy productivity and Location of Dam site a sensitivity analysis was done within certain range. The range for the crest elevation was 630-660 asl; meanwhile the sensitivity analysis showed that the optimum elevation is 640 asl. Other measures were picked based on the energy requirements like the length and the volume; creating a 74 billion cubic meters reservoir (IPoE, 2013).

The studies were conducted to choose the least-cost dam that will meet the international safety standards. Based on the location, soil type and hydrological data, the decision was made to pick the rolled compacted concrete (RCC). RCC was chosen because the flows which needed to be diverted are large, and only this type of construction will withstand the corrosion. A traditional Earth-fill dam will require flow diversion through tunnels and therefore the construction would take longer time and would cost more (IPoE, 2013).

As mentioned in section 2.1 the Dam will be consisted of 2 major parts; central section and the shoulders plus the powerhouses on the shoulders. There are four gates on the shoulders; 2 on each side. These gates will operate during the river conversion and during reservoir operation. The central section will be used as a spillway, and there will be no spill over the shoulders during normal circumstances (IPoE, 2013).

The saddle dam the main function of this dam is to raise the water level in the reservoir at 600 m asl o 646 m asl. The body of this dam is a rock fill with a bituminous upstream face. It is 5.2 km long and 50 m high. It, also, includes the emergency spillway, which allows flood flow to be directly discharged into the Blue Nile (IPoE, 2013).

The reservoir will extend over the Blue Nile gorge for 246 Km with a surface area of 1874 Km^2. This massive reservoir has a total capacity of 74 billion cubic meters with active storage of 59.22 billion cubic meters. The minimum operating level is 590 asl. The reservoir level will rise during the rain fall season between June and September, and it draws down during the dry season (IPoE, 2013).

River diversion plays an important role in the construction and operation of the project and therefore the production of energy. There are four outlets on the shoulders; each outlet is steel lined with 8 m diameter. These outlets will be used for diversion during construction, and they will be used for de-watering purposes in the unusual circumstances during operation (IPoE, 2013).

The cost of the project is estimated to be 47 billon US dollars; where about two thirds of that is going to civil workers and one third for equipment. The project owner is the Ethiopian electric power corporation (IPoE, 2013).

4. Hydro-Politics Surrounding the Grand Ethiopian Renaissance Dam

In order to prevent devastating crises like the droughts to the extent of that in 1984 that killed millions Ethiopians, 2 April 2011 Ethiopian government decided to go ahead with the construction of the $4.7 billion Grand Ethiopian Renaissance Dam. The dam, which has been halted from construction, is approximately 30% complete and after waiting for further funding and agreement, is beginning to proceed once again. While it was being constructed, there were a reported 8,500 workers on the job with work being done 24 hours a day (BBC News 2013, June 10). This dam, which could eventually provide 6,000 MW of power has experienced tremendous political quarrel over the effects that it could have on Sudan and Egypt.

4.1 British Involvement

In the later part of the 19th century and well into the 20th century, Egypt and Sudan were under British rule. The most attractive asset to the British was the accessibility to the Red Sea and to India. Egypt's affluent citizens proved to be a viable market for the British, but those in the lower economic echelons despised them and wanted nothing more than their independence. British rule in Egypt became absolute in 1883 under Lord Cromer and was passed down until the mid-twentieth century. Following the First World War, there was resurgence in the cotton industry and as a result, a decline in the food industry in Egypt. This began to harm the Egyptians with poverty and malnutrition. Their despair was exacerbated and their hopes of independence dampened by U.S. President Woodrow Wilson's decision to recognize Britain's "protection" of Egypt.

In February of 1922, Egypt became an independent sovereignty with only four restrictions from the United Kingdom of Great Britain and Ireland. The restrictions were: foreign relations, communications, the military, and Anglo-Egyptian Sudan (Wucher, 1989). Seven years later, the two powers co-signed a treaty, without consulting the upper riparian nations, which allowed both of them to utilize the Nile's water resources. The agreement gave a large amount of power to the government of Egypt stating, "Except with the prior consent of the Egyptian Government, no irrigation works shall be undertaken nor electric generators installed along the Nile and its branches nor on the lakes from which they flow if the lakes are situated in Sudan or in countries under British administration which could jeopardize the interest of Egypt either by reducing the quantity of water flowing into Egypt or appreciably changing the date of its flow or causing its level to drop."

Ethiopia is the only African nation to have never fallen under colonial rule. They were also not included in the 1929 Nile Water Agreement between Egypt and Sudan. For these reasons, they have not been, nor are they currently under any legal obligations to abide by the regulations set forth in these previous agreements. They have thus been able to utilize the rivers resources in order to develop their own nation, something the Egyptian government has never fully approved of and continues to contest to this day. This quarrel is evidenced by the on-going debates over the Grand Renaissance Dam on the Blue Nile.

4.2 Post-Colonial Rule

Thirty years after the Egyptians first major Nile water agreement that was done on 1929 as an independent sovereignty, Egypt and Sudan established an agreement at the 54th session of the Permanent Joint Technical Commission for Nile Waters that stated Egypt would receive 55.5 billion cubic meters a year of the 84 billion cubic meters produced by the Nile, Sudan would receive 18.5 billion cubic meters, and the fate of the remaining 10 evaporates. Again, Ethiopia was not included in the agreement. Naturally, Ethiopia was not pleased with this agreement either and their discontent reflected that of former Emperor, Haile-Selassie who proclaimed in 1957, “Ethiopia has the right and the obligation to exploit its water resources of the Empire, for the benefit of the present and future generations of its citizens, in anticipation of the growth in population and its expanding needs. Therefore, reassert and reserve now and for the future, the right to take all such measures in respect of its water resources, namely those waters providing so nearly the entirely of the volume of the Nile.” Because Ethiopia had zero representation in both 1929 and 1959, it is not a surprise that they rejected both agreements because they are, as a critic from The Reporter stated, “baseless.”

4.3 Current Situation

It comes as little surprise why in May of 2013 however, Ethiopia began diverting the flow of the Blue Nile River without the consent of Egypt or Sudan. This diversion of the Blue Nile, a main tributary of the Mother Nile, and the new dam that Ethiopia has begun building has caused the two downstream nations concern that their shares may be infringed upon. Former Egyptian President, Hosni Mubarak, declared that he would not let the Egyptian share of the Nile be disrupted. Again, standing to defend the “historical rights” that leads Egyptians to believe that they deserve nearly 75% of the Nile’s total annual yield. In a BBC article from June of 2013, Mubarak stated that, “all options are open,” and elaborated on the fact that other nations are free to develop upon the Nile, “but on condition that those projects do not affect or damage Egypt’s legal or historical rights.” An Aljazeera article from April of 2014 stated that Mohammed Morsi, who gained the Egyptian presidency following the Arab Spring, made a much more aggressive statement a national conference stating, “We will defend each drop of the Nile River with our blood if necessary.”

Although Egypt currently receives a significant portion of water from the Nile under the 1959 contract, some still fear that this dam has potential to significantly disrupt their water security and in turn their agriculture, which for many is the difference between life and death. According to an Egyptian water official, a difference of 10 billion kiloliters, the amount that some predict the new dam would withhold from Egypt, could devastate approximately one million acres of farmland. Yet other claims from the helm of Egyptian water resources seem far less realistic such as, “Then you might cross the Nile on the back of a camel.”

There is no doubt that Egypt is heavily dependent on the water that the Nile provides. The nation gets 85% of their water from the Nile and has expressed concerns with the water they obtain from elsewhere. A report from the International Development Research Centre claims that 17,000 children die annually due to diarrhea diseases caused by, “sub-standard drinking water quality, inadequate sanitation facilities and inadequate personal, food and domestic hygiene behavior.” The sanitation of the water is a paramount concern, but does not seem to pose as great of a threat to the country as population growth does. This same report points out that the population in Egypt has doubled in the last 40 years from 37 million people in 1970 to 72 million in 2005; the current population is 83 million. By their estimates, the population will continue to grow and may reach 95 million by 2025. Currently the per capita water supply is at $1000m^3/year$ and may decrease to 600 $m^3/year$ if and when the population approaches nearly 100 million in 2025. Ethiopia, whose population is currently 83 million, could see an influx of up to 150 million in the next 40 years. The continent of Africa has a population of over 1 billion and is growing at a rate of nearly 24 million per year; their population could double by 2050.

The water available must remain clean or its uses will dwindle, posing greater threats to the people of Egypt. There has been a decrease in the amount of cultivated land per capita which also supports this argument. The amount of cultivated land decreased from 0.23 acres per capita in 1960 to 0.1 acres in 2000 according to the IDRC. A continuation of this decline could manifest the worst nightmare of millions, decreasing food stocks at the individual level.

Economically, these losses could amass to a 4.8% decrease in the nation's GDP, 1% of which are directly from water resource degradation and pollution.

Although it is clear that the arid nation of Egypt may be at risk if their water supply is significantly reduced, the validity of some of the contention of the dam came under greater scrutiny when the final report produced by an International Panel of Experts was leaked in March of 2014. Upon the request of the Ethiopian government, two elected experts from each of the three riparian nations as well as a group of international experts constituted this panel. The panel consists of Dr. Sherif Mohamady Elsayed and Dr. Khaled Hamed of Egypt, Eng. Gedion Asfaw and Dr. Yilma Seleshi of Ethiopia, and Dr. Ahmed Eltayeb Ahmed and Eng. Deyab Hussien Deyab of Sudan. The international members of the panel are, Dr. Bernard Yon, Environmental Expert, Mr. John D. M.Roe, Socio-economics Expert, Mr. Egon Failer, Dam Engineering Expert, and Dr. Thinus Basson, Water Resources and Hydrological Modeling Expert.

Their final report, dated May 31, 2013 was intended to, "provide transparent information sharing and to solicit understanding of the benefits and costs accrued to the three countries and impacts if any to the GERD on the two downstream countries so as to build trust and confidence among all parties" (IPoE, 2013).

In their attempts to build confidence, the panel met six times to consult with one another on both their visits to the dam site as well as their consultation of documents. The report lists 12 documents that have been submitted and reviewed. Their related subjects included: water resources, dam engineering, the environment, socio-economics, and two conglomerates. An extension of the panel into May was requested and approved.

Following the leakage of this report, there were still disbelievers who claimed the report did not explain the project well enough to instill the level of confidence it had hoped to. Some of the contentions include the lack of detail about the downstream effects of the dam as well as the potential 6% decrease in production of the Aswan High Dam, which provides 15% of Egypt's power according to The Guardian news source. These discrepancies are rivaled however by those who feel the report is a good indication of the benefits of this new dam. One claim is that the dam could actually reduce the sediments that would reach the Aswan High Dam and actually benefit its power production. The fact that this report had to be leaked and not publically released 10 months after its completion is indicative of the fact that some did not want it to be seen and may also support its validity.

There have been several other benefits that the dam could potential have on the smaller surrounding dams and the areas. According the report released by the Consulate General of Ethiopia in Los Angeles, "the project will also enhance other areas, including navigation on the river, tourism and fisheries as well as improve the climate of the area. It will create numerous job opportunities and improve local livelihoods. Clean and renewable energy at cheaper prices will be made available to the region." Additionally, they believe the dam will have far greater social and environmental benefits than it will costs. Environmentally, the dam is supposed to reduce the amount of water evaporation that occurs in other dams that are located in downstream, desert settings like the Aswan High Dam. Estimates say that the GERD is likely to only lose 0.4 billion cubic meters annually compared to 14.3 BCM lost by the Aswan High Dam.

The productivity of the Aswan High Dam is a point of discrepancy between the Ethiopian and Egyptian governments. The consulate reports that the reduction in the productivity of the Aswan would actually save 6 BCM of water in the Nile annually. This could prove to be mutually beneficial if the water allocations are agreed upon by the two nations. As mentioned in defense of the IPoE report, this report also defends that the GERD dam would reduce the amount of sediments that are permitted to travel down river and interfere with the production of smaller dams.

Some of the greatest benefits of this dam are the ways in which it can control the flow of the river by means of retention and otherwise. It is believed that the capacity of the GERD could sustain minimum flow levels for the entire year, something uncommon to these arid and semi-arid nations. The Consulate also reports that the project will help with the climate in these arid nations by mitigating drought and offering flood management. Some droughts and hydrological events that are believed to be affected by the climate will be more favorable to Ethiopia and possibly Sudan and Egypt. The retention of water and mitigation of flooding will also make a huge difference in the agricultural economy, "Sustainable and regulated flow will also allow for increased agricultural production, ensuring reliable all season supply to DS irrigation schemes, thus, reducing harvest losses caused by water shortages during critical growing periods."

As Ethiopia pushes to gain the recognition and approval that they desire for the GERD, they must also succeed in winning the local approval of those that will most directly affected by the dam. In comparison to the Gibe III dam, another large dam under construction that is located further south, the GERD seems to have achieved far greater local support for its production. This approval must however be carefully considered because the country of Ethiopia has gained a poor reputation for their actions and policies on public outcry against government action, especially those which oppose major dam projects like the Gibe III. Because this Renaissance Dam is to be funded solely by the Ethiopian government and domestic supporters, it would make sense for there to be public acclaim of people buying bonds to fund the project.

As is the case in the construction of the Gibe III dam, on the Omo River, there are several environmental and socio-economic issues that must be addressed in relation to the construction of the GERD. Among the design aspects of the project, Jon Abbink points out in his essay Dam Controversies: contested governance and developmental discourse on the Ethiopian Omo River Dam, the major issues that will affect the population included the significant environmental changes (biodiversity, agrarian land, land slide, and water seepage), proper compensation of those displaced by the dam, and the increased health problems that may occur as the result induces disease such as malaria. The GERD is set to be located in a less populated area of the country, which mitigates the negative effects on those in its immediate surroundings. There appears to be much less of a threat to the biodiversity in the planned area, unlike the Gibe III, which is expected to harm the ecosystem of the Omo River and Omo River Valley.

Abbink also points out those structures on the scale of the Gibe III, which is comparable to that of the GERD, maintenance may fall short and major problems arise years later. He continues, Studies of the aftermath of various large Ethiopian dam projects (like the T'ana-Beles and the Tekkeze), however, have made clear that they were not an unmitigated success and have had disturbing social and environmental effects." Proponents of the dam are confident that the success of this project will reduce future need for other large dam projects.

As this debate wages on, Egypt seems to be losing strength in their argument against the project and Ethiopia is gaining positive attention. In the last two months, Egypt has been pushing to "internationalize" this project. As reported by Al-Monitor, in response to Ethiopia "rejecting initiatives to solve the crisis," 87% percent of responding to a poll on one of the nation's most read news websites, voted yes to internationalizing the issue. The Egyptian Minister of Water, Mohamed Abdul Muttalib has been travelling around to different nations to try and gather support for this cause. An Egyptian government official was quoted on behalf of

Mr. Muttlib as saying the project's tracks, "aim to persuade the international community to reject the dam's construction because it may lead to further conflict and instability in the region of the Nile Basin."

Mr. Muttalib and Nabil Fahmy, the Minister of Foreign Affairs first visited Italy, who is one of the larger supporters of the GERD project; Salini Corporation is the contracting company that is working on the dam. Muttalb is expected to visit Norway soon because they are a strong support system for the dam project as well. According to the same government official that spoke to Al-Monitor, plans to internalize the effort have been supported by The Supreme Committee of Nile Waters. As the Egyptian government continues their effort to "raise awareness in the world" about the threat that this dam poses to the Nile River Basin, Ethiopia does not seem concerned with it having any effect. The website of Ethiopia's Foreign Ministry inferred this stating, "There is no internal court responsible for investigation or arbitrating in issues of water…. and that is why the Egyptian move to internationalize won't have any effect."

There is clearly a lack of constructive communication between the three basin countries, a problem some attribute to the Mubarak era of Egyptian government. Muhammad Mizanur Rahaman, a professor of international water law at Asia Pacific University in Bangladesh points out that, "Egypt, Ethiopia, and Sudan should all agree on the principles they agree on before trying to seek refuge or shelter from the principles of international water law." In 1999 the Nile Basin Initiative was formed as a collaboration of Nile riparian states. Egypt has not signed anything that would alter their 55.5 billion cubic meters of annual inflow.

Sudan, who has been much less vocal than Egypt about the issue, has slowly begun to side with the Ethiopians in support of the GERD project and recently accused Egypt of complicating the matter and jeopardizing their nation's safety. The location of the Renaissance Dam is 40 km away from the border of Sudan. In the event of something like a collapse, Sudan could be devastated. Because Ethiopia is self-funding this project, money shortage could pose a serious safety problem. Hussein Ahmad, Sudan's top official of Eastern Blue Nile State, has recently accused Egypt of, "threatening Sudan's safety by blocking international loans for Ethiopia's hydro-dam." Ahmad also added that the Sudanese capital will, "hold Egypt fully responsible if structural failure of the dam results in Sudan's flooding." Sudan has displayed their support for the new dam's potential stating, "The dam's benefits outweigh any potential issues," according to Somaliland Press.

5. The Toshka Project

The Toshka project was initiated in 1997 by former president Mubarak; the Toshka project was created as a means to solve various problems in Egypt. The Toshka project or otherwise known as the New Valley Project is system consisting of a pump and canals in order to reclaim desert land. Egypt is facing many different geological, social and economic problems. One of these is a result of a rapidly growing population. As of 2010 there are 83 million Ethiopians and is expected to increase to 95 million by the year 2025 with a birth rate of 6.7 per woman (The Guardian). Another problem is the rapid demand for wheat. As Egypt being the world's largest wheat importer shipping 11.5 million tons in 2012, there is not enough land to keep up with demand (Bright Bulb Engineering). This proves to be difficult when a total of 11, 76 hectares or twenty-nine thousand acres are lost due to desertification, urbanization, and salination per year. With the rising demand Egypt also faces the fact that there is a lack of means to transport large quantities of wheat from their new agricultural land in Toshka to other parts of the country.
In addition to land being reclaimed by the desert annually, the demand for water remains very high. Problems such as these appear in the drought and famine cause by rain failing in the Ethiopian highlands. In the middle of the 1980s there was a water crisis upriver and downriver claiming around one million Ethiopians lives. During this water crisis crops failed in the delta and the turbines in the Aswan High Dam were nearly shut down, creating an electric power catastrophe (Carlson, 2013)

Egypt's climate and the surrounding area's geology make the demand for water vast. It is characterized by its long summer and warm winters with very low rainfall. Egypt is 95% desert and has large amounts of heavy clay soils that act like an impervious bed which could lead to water-logging (JWARP). Also characterized for having large losses of water due to being evaporated rapidly, the water is becoming more susceptible to salinization. As a result of salinization, the land takes around three years to convert into soil usable for crops (npr.org).

5.1 Toshka Project Goals:

The Toshka Project's ultimate goal is to reclaim desert land and reduce the amount of arable land. To make this possible, the project plans to cultivate half-million acres of farmland in order to deal with Egypt's rising demand for food and to also decrease the uninhabitable land by ten percent. When the land is completely cultivated, the climate conditions may change. This could result in the overall reduction in temperature over the project area and ultimately reducing the evaporation of the lake (JWARP). When this project is completed, it hopes to attract sixteen million people by the potential 2.8 million new jobs and to relocate them to Toshka to alleviate the population living near the Nile (water-technology). Figure 5.1-1 shows the location of Toshka project:

Figure 5.1-1: Map Showing The Location of Toshka Project

Source: http://www.eosnap.com/tag/toshka-lakes/page/2/

The second and third stages of the Toshka Project have been delayed, mostly due to financial constraints, ecological problems and political issues. Egypt's debts increased due to the projects very high price tag. The water from the Nile needed to irrigate would need to be increased even if the treaty share of 1959 of fifty-five billion cubic meters was maintained (who owns). During a time of drought such as the epidemic claiming one million lives in 1980, the water in Lake Nasser would decrease exponentially. This would therefore result in no water to use for the Toshka Project. Consequently this may lead to a loss of agricultural land near the Toshka Lakes because these areas need a constant supply of water. The loss of land leads to losses in crops such as wheat which ultimately hurts the economy as well. Throughout the project, the migration of the population was fairly slow and production of agricultural goods was also limited.

After the former president was dethroned in 2011, Egypt was engulfed by political woes. In this time there was a land dispute between the Egyptian government and Saudi Arab's Kingdom Holdings that put a temporary hold on the project (irinnews.org). The current president of Egypt, Mohammed Morsi greatly opposes the project. Chances of revival for the project were halted and this delay may result in the completion date of the Toshka Project in 2020 to be pushed back a few years.

5.2 Toshka Components:

The Toshka Project consisting of a three part system in order to take advantage of the water located in Lake Nasser. The Toshka Project is comprised of the Mubarak Pumping Station, the Sheikh Zayed Canal and the three Toshka Lakes. With an anticipated cost of around 70 billion when completed, water is pumped from Lake Nasser and transported to the Toshka Lakes via the Sheikh Zayed Canal. This project plans to take ten percent of the water from Lake Toshka in order to irrigate the desert (who owns the Nile). The Toshka project, funded by the government of Egypt's ministry or water resources and irrigation is a joint effort of many different companies. The design of the great Mubarak Pumping Station, that is said to be one of the greatest civil engineering feats by the American Society of Civil Engineers, was done by Hamza Associates and Lahmeyer. Construction was performed by Arabian International, Skanska and Hitachi. Also project development and management was done by a partnership of KADCO and Sun World (water-technology.net)

At the center of the Toshka project the Mubarak Pumping station which named one of the five most outstanding civil engineering achievements of the year is designed to have a discharge capacity of 1.2 million cubic meters per hour (Toshka Project). Completed in March 2005 and costing roughly 436 million dollars this station is located in Lake Nasser. Per year the Mubarak Pumping Stations is planned to take 5 billion cubic meters of water out of Lake Nasser per year. This pump is designed to lift water from Lake Nasser to the lowest level of lake storage via the Sheik Zayed Canal (JWARP).

The Mubarak pumping station was built with a total of twenty-four vertical pumps which are installed in two parallel lines along both sides of the station. Only eighteen of the pumps are running at a given time while three pumps are kept for maintenance and the last three pumps are kept in reserve. All of these pumps have speed settings and are load-controlled with a 50 meter deep intake channel (asce.org). The Mubarak Pumping Station is made up of steel mini-piles which are very effective and are praised by civil and mechanical engineers for being cost-effective and earthquake resistant compared to the very costly concrete piles. The structure also excludes joints below the normal high water lake level and provides joints above it in order to eliminate thermal effects in the overall structural design of the pump station because it is subjected to temperatures ranging from zero to fifty-five degrees Celsius (asce.org).

The Sheikh Zayed Canal is the second element of the project. In junction to the Mubarak Pumping Station, the Sheikh Zayed Canal was made instead of the use of a pipe to transport the water. It is an open channel with 4.5 kilometer in length and ten meters in width with side slopes ratio of 2:1. (iwtc.info) Named for the person who donated 100 million to the project, this canal was made primarily with layers of cement and sand, concrete and polymer sheeting (water-technology.net). The Sheikh Zayed Canal is feed by the Mubarak Pumping Station and at the end of the canal it is divided into two main sub-canals. Each of those sub-canals then splits into two branches with lengths of around 24km or 59.5km. (JWARPPDF) The Sheikh Zayed Canal is designed to transport five billion cubic meters per year of water from the Mubarak Pumping Station to the Toshka Lakes (water-technology.net).

6. Possible solutions for water scarcity in Egypt:

Water resources in Egypt are limited to the Nile River, rainfall and flash floods, deep groundwater in the deserts and Sinai, and potential desalination of sea and lakes water. Each resource has its usage limitation, whether these limitations are related to quantity, quality, space, time, or exploitation cost. Egypt receives about 98% of its fresh water resources from outside its national borders. The Agriculture is the largest consumer of water resources worldwide and in Egypt as well. The annual freshwater withdrawals for agriculture in 1991 amounted to 83 % of Egypt water resources and this percent keep increasing due to the increase or land reclamation, increase in the global warming. Table 6-1 shows the water allocation among water users.

Table 6 -1: The Water Allocation among Water Users

Water Users	Worldwide %	Egypt %		
Year	1999	1990	1991	2001
Agriculture	65	84	83	78
Industry	25	7.8	10	14
Domestic use	10	5.2	6	8
Total water use in *BCM	-	59.2	67.47	68.67

*BCM stand for **billion cubic meter**

Source: Abu-Zeid, 1991, UN CCA, 2001

So Agriculture can be affected by increasing water scarcity due to growing demands from other sectors such as industries, domestic use due to the increase of population. The consideration about water reallocation becomes relevant taking into account the decrease of Egypt water supply from the Nile River. Table 6-2 and figure 6-1 presenting the current and projected water resources in Egypt.

Table 6-2: Present and Projected Water Resources in Egypt in BCM:

Source	2001	2017
The Nile	55.5	57.5*
Renewable ground water	4.8	7.5
Agricultural drainage water	4.5	8.4
Treated domestic waste water	0.7	2.5
Treated industrial waste water	6.7	6.7
Desert aquifers	0.57	3.77
Rainfall and lush harvesting	-	1.5
Saving from management	-	1.5
Total water resource in BCM	72.77	89.37

BCM stand for **billion cubic meter**

*Including the 2 BCM possible yields from Jonglei project. Jonglei project in Sudan intended to increase availability from Nile water reducing the evaporation from Sudan's Sudd swamps. Project has not been completed due to conflict in the region. Source: (UN CCA, 2001)

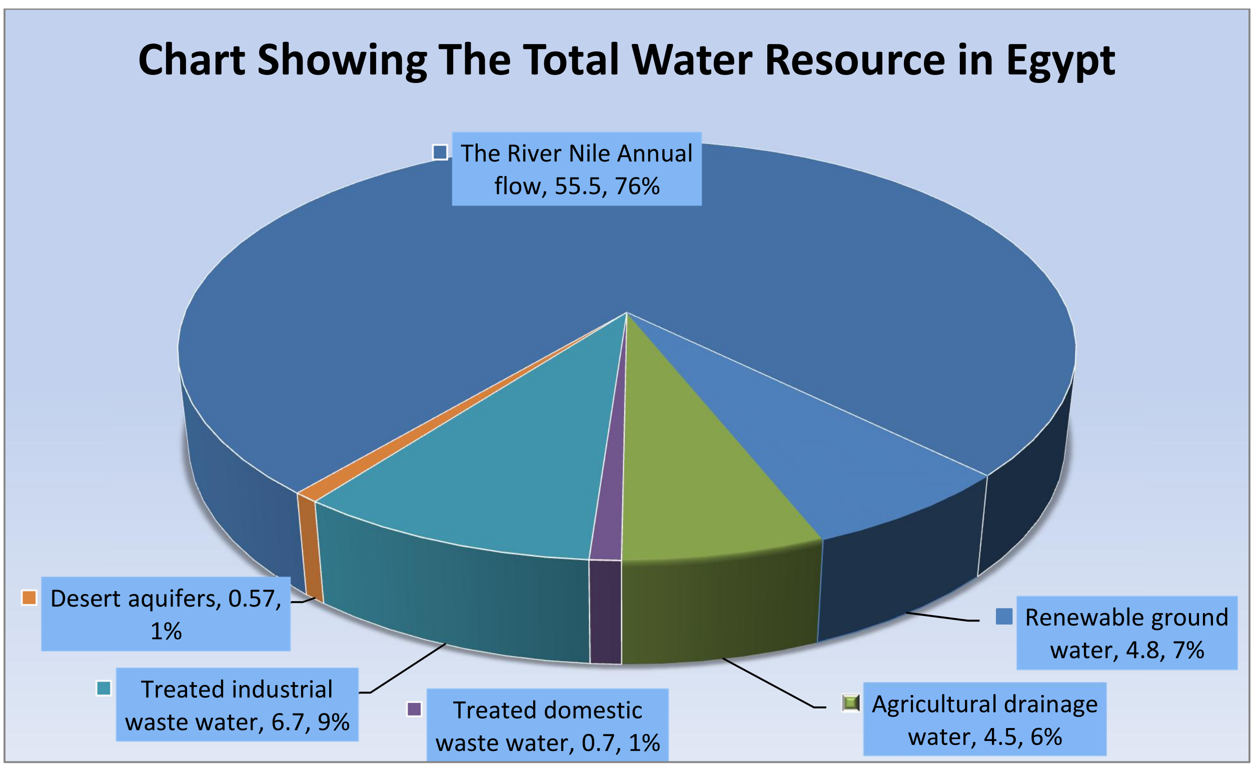

Figure 6-1: The Total Water Resource in Egypt

6.1 Water saving techniques

There are number of measures can be used towards the rational use of water for different activities. Some of these measures could be applied to domestic water systems and industrial requirement. However, agriculture being the major consumer of water has the largest share of these measures. Following water saving techniques are some of measures applied to agriculture (Abdin and Gaafar, 2008)

A. Use of modern irrigation systems in newly cultivated land

Sprinkler and drip irrigation systems must be used in the desert lands converted into agricultural production through reclamation. Gravity or flood irrigation in these areas is prohibited by law. This is obvious because of the high permeability of these soils and their high capacity of natural drainage. (Abdin and Gaafar, 2008)

B. The change from surface irrigation to drip irrigation in the orchards and vegetable farms in the old lands

Some 700,000 feddans[1] in the old lands of the Nile Valley and Delta are occupied with different types of fruit trees, citrus and grape yards in addition to the area cultivated with summer and winter vegetables. These areas are currently irrigated traditionally with surface irrigation. It is the plan of the country to change the irrigation system in these areas into drip irrigation. The cost of the irrigation system and the running cost of operation are expected to be borne jointly by the farmers and the state. (Abdin and Gaafar, 2008). Table 6.1-1 shows the total cultivated and reclaimed agriculture land areas in Egypt and the expected areas of reclaimed by 2017 and 2030.

Table 6.1-1: Total Areas of Cultivated and Reclaimed Lands in Egypt (in Million Feddans[1])

Area of The Nile Valley and Delta (surface irrigated lands)	6.5
Area of the new reclaimed land (Pressurized irrigated lands (sprinkler and localized Sys.)	2.1
Total Cultivated Land Areas	8.6
Expected area of reclaimed land until 2017	1.5
Expected area of reclaimed land until 2030	3

Source: Ministry of Agriculture and Land Reclamation Egypt

http://www.ustda.gov/egyptforward/presentations/ag_el-gindydr.abdel-ghanymohamedpresentation.pdf

[1] **Feddan** is a unit of area. It is used in Egypt, Sudan(1 feddan=1.038 Acre)

C. Land leveling

Land leveling has a positive impact on the reduction of water supply since it reduces surface run-off to a minimum. Special attention is always paid to the major water consuming crops like sugar cane and rice. (Abdin and Gaafar, 2008).

D. Night irrigation

Farmers are encouraged to practice night irrigation since it reduces evaporation losses if irrigation is carried out during day time, in addition to the reduction of tail end losses taking place directly from irrigation to drainage canals if fresh water is not abstracted at night. It is worth mentioning that the Egyptian irrigation network is designed for 24 hours a day abstraction, there is no storage capacity in the system. (Abdin and Gaafar, 2008).

E. Modification of the cropping pattern

The cropping pattern in Egypt is governed by a number of factors which include: the country's need for food and natural fiber, the export requirement, the availability of land and water, the employment needs, the climate conditions, status of soil salinity. Egypt's government desire is to bring the agricultural water requirements to a minimum in order to make sufficient quantities available for other activities that might be of higher priority (such as drinking water supply) or of higher return per unit volume of water (such as industry or tourism). For this reason, the area of sugar cane is kept constant while sugar beet is increasing. The area cultivated with rice is limited to about one million feddans[1] deviation from these two rules cause farmers to be heavily penalized by the law. (Abdin and Gaafar, 2008)

F. Introduction of short-age varieties

Growing crops which have a shorter period in the fields by reducing their growing age. A good example is represented by the shortage varieties of rice which stay in the field only 150 days compared with the traditional variety that need 180-210 days. The reduction in the number of days is immediately reelected on the number of irrigation gifts and consequently on the quantity of water supplied. Other examples are wheat, maize, cotton and legumes. (Abdin and Gaafar, 2008)

G. Irrigation improvement projects in the old lands

The alluvial soils of the Nile Valley and Delta reduce the possibility of changing the existing gravity irrigation into modern systems. The reasons for this are illustrated below (Abdin and Gaafar, 2008). Figure 6.1-1 shows surface irrigation in the old land.

Figure 6.1-1: The Surface Irrigation in the Old Land

Source: Ministry of Agriculture and Land Reclamation Egypt

http://www.ustda.gov/egyptforward/presentations/ag_el-gindydr.abdel-ghanymohamedpresentation.pdf

- The very low permeability of the soils and the high possibility of acre soil salinization;
- The high initial cost of the imported material (sprinklers, drippers, filters, fertilizers) and the high cost of energy, maintenance and spare parts;
- The need for skilled labor which might not be available in rural areas while there is ample number of laborers acquainted with surface irrigation systems;
- The need to raise crops of relatively low return like wheat and corn. Other cash crops like vegetables and flowers are not easily marketed in the surrounding area. For these reasons, the state has supported the improvement of surface irrigation in the old lands. A number of water and energy saving techniques are implemented through the Irrigation Improvement Projects (IIP) table 6.1-2 shows total water savings using Modified Irrigation System. Some of these techniques are:

  a. The change from the earth field ditches named Misqas into canals or pipelines. This change reduces seepage, aquatic weeds and evaporation from free water surface due to the reduction of the area of this surface. Figure 6.1-2 Show the Irrigation Improvement Projects to Irrigation System used on old land.

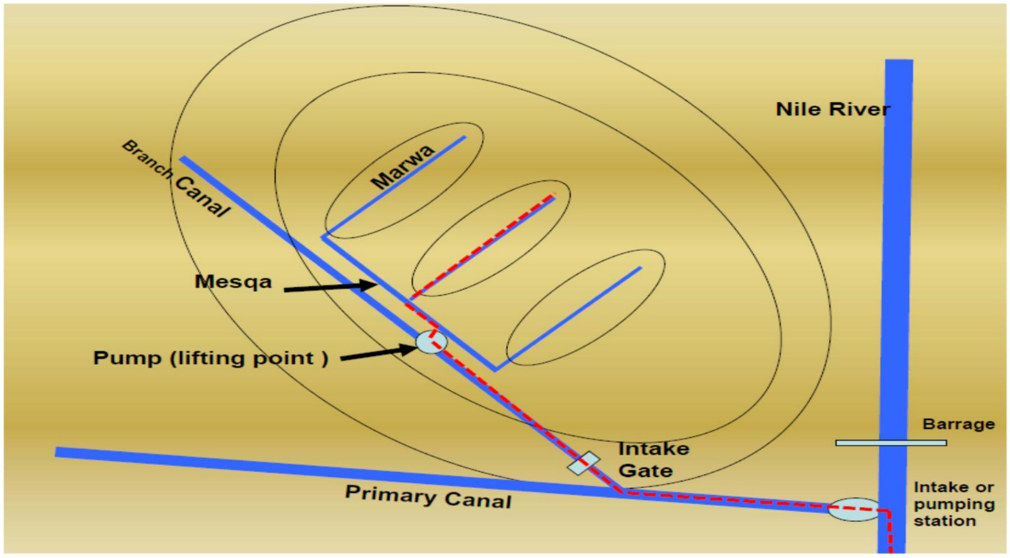

Figure 6.1-2: The Irrigation Improvement Projects used on The Old Land

Source: Ministry of Agriculture and Land Reclamation- Egypt
http://www.ustda.gov/egyptforward/presentations/ag_el-gindydr.abdel-ghanymohamedpresentation.pdf

b. The change from multi point abstraction of water from the mesqa into one point lift on the top end of a raised mesqa. This is necessary for better steady and uniform mesqa low plus the saving in energy needed to operate the lifting pumps. One of the major advantages of the above concept is the setting up of water users.

c. The change from upstream control into downstream control. The distribution system in Egypt is based upon upstream control. The Irrigation Improvement Project has introduced downstream control at the level of the supply canals as one of the measures that initiate demand management. The traditional head regulators operated manually or mechanically on the basis of upstream control are replaced by regulators equipped with automatic gates capable of providing the required low when demand is in progress, reduced low when demand decreases and complete shut off when demand is stopped. In the meantime this type of system allows for storage build up during periods of no abstraction to permit heavy abstraction afterwards. Figure 6.1-3 Show the change from the earth field ditches Misqas into Pipelines Marws.

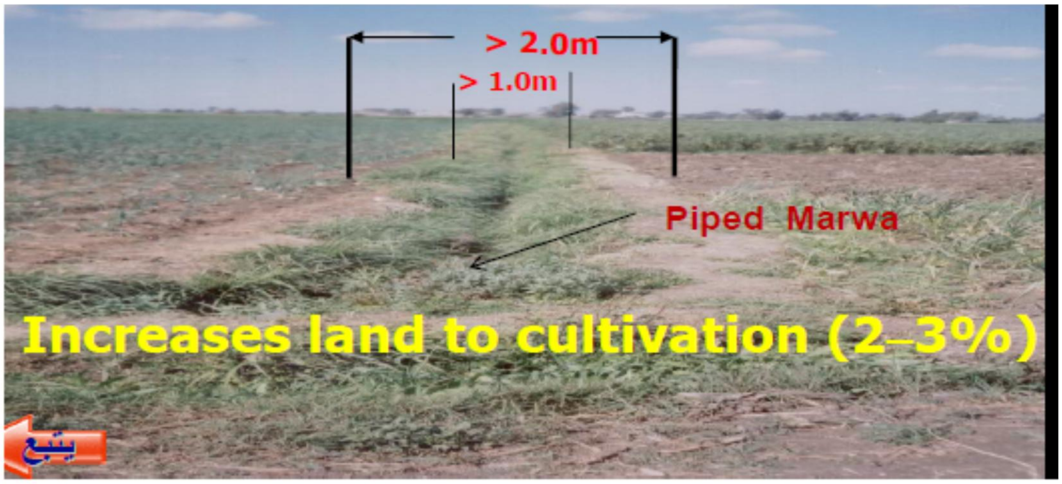

Figure 6.1-3: The Change from The Earth Field Ditches Misqas into Pipelines Marws

Source: Ministry of Agriculture and Land Reclamation- Egypt

http://www.ustda.gov/egyptforward/presentations/ag_el-gindydr.abdel-ghanymohamedpresentation.pdf

Table 6.1-2: Total Water Savings Using Modified Irrigation System

Crop	Area	Water savings (m^3/ha/[m^3/feddan[1]])		Total water savings (million m^3)	
	(1,000 ha/ [1,000 feddan])	Localized irrigation system	Modified irrigation system	Localized irrigation system	Modified irrigation system
Sugarcane	126/[300]	9,524/[4,000]	8,095/[3,400]	1,200	1,020
Maize	714/[1,700]	3,119/[1,310]	2262/[950]	2,227	1,615
Faba bean	126/[300]	2,193/[921]	674/[283]	276	85
Wheat	1,260/[3,000]	-	833/[350]	-	1,050
Fruit trees	273/[650]	4,048/[1,700]	1,190/[500]	1,105	325
Total	2,499/[5,950]	-	-	4,808	4,095

Source Suttles et al. 1999

6.2 Optimum use of resources

The scarcity of natural resources in Egypt, which are limited and the rate of increase these resources is much less than the rate of population growth and the increase in the demand side has burdened Egypt. This is why the Egyptian Government is accordingly integrating activities towards optimizing benefits from its scarce resources and adapting long-term strategy for the optimum use of all available water resources. This strategy includes long term programs that all focus on the reduction of losses and better allocation of Promoting water availability in Egypt through the aforementioned measures necessitates investigating the optimum allocation of extra supplies of water. In this context, the best alternative use of a new supply of water is envisaged through one of the following procedures:

A. <u>Reuse of drainage water and treated wastewater</u>

Egypt is one of the leading countries in the reuse of water. This process started as early as the 1920's and the water multiplier now stands at 150-200%. All drainage water of the Upper Egypt returns back to the River Nile raising its salinity from about 200 ppm at Aswan to less than 300 ppm near Cairo. Four more billion cubic meters of drainage water generated in the southern part of the Delta are mixed with fresh water and reused for different purposes. It is the plan of the country to reuse another three billion cubic meter per year for the irrigation of Al Salam Canal Project (620,000 feddans[1] or 250,000 hectares) and for the feeding of Nubaria Canal (one of the largest irrigation canals in the Western Delta which serve an area of more than seven hundred thousand feddans of newly reclaimed lands.), the canal will be fed with one billion cubic meter of drainage water from Omoum Drain (El Quosy, 2005). At present, treated sewage and industrial effluent can supply about seven million cubic meters per day or about two billion cubic meters per year. Plans to use this water for the cultivation of special crops (timber trees, industrial crops such as cotton, lax, lowers, etc.) are under preparation. (Abdin and Gaafar, 2008).

B. <u>Desalination of sea water</u>

Desalination has long been confined to situations where no other alternatives were available to produce drinking water (some coastal towns, islands, remote industrial sites), or where energy was abundantly available (power stations, gas and oil production fields). Today, desalination is becoming a serious option for the production of drinking- and industrial water as an alternative to traditional surface water treatment and long distance conveyance. The desalination capacity in Egypt has grown to some 150,000 m3/day. Most of the plants treat seawater, but a growing number of installations use brackish water. The capacity of individual plants is generally small and ranges between 500 and 10,000 m3/day (MWRI, 2005). There is unlimited potential for further development of seawater desalination in Egypt along the long shoreline. Sectors of application are the tourist sector and the industries along the coast. Considering the vast reserves of brackish groundwater in Egypt, there is also great potential for brackish water desalination which can be applied at much lower cost. Desalination of inland brackish groundwater requires special attention for the discharge of the brine (the highly saline byproduct of desalination). Treatment of domestic waste water and of drainage water is a potential new field of application for which vast quantities of water are available in Egypt. (Abdin and Gaafar, 2008)

C. Importance of international co-operation

The international aspect is a crucial factor in Egyptian water policy. Because Egypt's water resources are 90% produced outside the country (upstream of Lake Nasser), the planned expansion of supply has to be undertaken in collaboration with upstream governments. This places Egypt in a very difficult planning situation, since it simply does not possess control over the speed of the implementation of the water conservation projects along the White Nile. It is estimated that the inflow to Lake Nasser could be increased by as much as 18 billion m3 per year to be shared by Egypt and Sudan by implementing the four phases of the upper Nile projects (Jonglei I, Jonglei II, Machar Marshes and Bahr El-Ghazal). And, as it looks now, Egypt will increasingly come to rely on the implementation of these projects (Abdin and Gaafar, 2008).

D. Nile Basin Initiative (NBI) projects

The NBI intervention seeks to build confidence and capacity across the basin through a Shared Vision Program (SVP), and to initiate concrete investment and action on the ground through a Subsidiary Action Program (SAP). The NBI plans to implement projects, in partnership with member states that will contribute to strengthening the cooperation mechanism and to long-term sustainable development, economic growth and regional integration (Sileet et al., 2007).

The SVP contributes to the creation of an enabling environment for investments and action on the ground and will promote the shared vision through a set of effective basin-wide activities. An initial set of basin-wide SVP projects has been endorsed by Nile-COM. They include: environmental action, power trade, efficient water use for agriculture, water resources planning and management, coordination, applied training, and socio-economic development and benefit sharing. Following are the SVP projects contributing to water efficiency, integrated water resources management (IWRM), confidence building and awareness and their objectives and expected impacts(Abdin and Gaafar, 2008):

Nile Trans-boundary Environmental Action Project (NTEAP) with its five components (Institutional strengthening, community level land, forest and water conservation, environmental education and public awareness, wetlands and biodiversity conservation, and basin-wide water quality monitoring) aims to provide a strategic framework for environmentally sustainable development and to support basin wide environmental action. The water quality monitoring component contributes to the enhancement of water quality in Nile Basin Countries. Water Resources Planning and Management (WRPM) project has four components: water policy good practice guides and support, project planning and management good practice guides, Nile Basin decision support system, and regional coordination and facilitation. These components contribute to achieving the project's goals in enhancing analytical capacity for basin wide perspective to support the development, management and protection of Nile Basin water resources in an equitable, optimal and sustainable manner. Efficient Water Use for Agricultural Production (EWUAP) project with its four components (water harvesting, community managed irrigation, public and private managed irrigation and project coordination and facilitation) aims to establish a forum to assist stakeholders to address issues related to efficient use of water for agricultural production in the Nile Basin, and to provide an opportunity to develop a sound conceptual and practical basis for Nile Riparian countries to increase the availability and efficient use of water for agricultural production. Some of the SVPs have an indirect impact and contribution in the IWRM in the Nile Basin through strengthening the capacity for practitioners and post graduates in subjects of water resources planning and management in public and private sectors (Applied Training project), developing confidence in regional cooperation at both Basin and local levels (Confidence Building and Stakeholder Involvement project) and enhancing the process of integration and cooperation to further socio economic development in the Nile Basin (Socio economic Development and Benefit Sharing).

SAPs plan and implement action on the ground at the lowest appropriate level. They comprise actual development projects at sub-basin level, in order to address the challenges of regional co-operation and development opportunities with trans-boundary implications. Two groups of countries have been formed to investigate the development of investment projects on the Nile Basin. These are the Eastern Nile Group (ENSAP), which includes Egypt, Sudan and Ethiopia; and the Nile Equatorial Lakes Group (NELSAP) comprising Uganda, Tanzania, Kenya, Rwanda, Burundi and the Democratic Republic of Congo and Egypt. (Abdin and Gaafar, 2008)

E. <u>ENSAP relevant projects can be described as follows</u>

Integrated Watershed Management; Obvious regional benefits of this project will be erosion control leading to decreased siltation and sedimentation in downstream river/reservoir reaches, which will increase reservoir life, improve hydropower production and irrigation efficiency, leading to an overall increase in land productivity, which will yield higher agricultural outputs, and thus enhance food security and alleviate poverty. Baro-Akobo-Sobat Multipurpose: The project may offer opportunities for win-win multipurpose development. Important water conservation gains may be possible through improved water management, storage and flood routine. (Abdin and Gaafar, 2008)

F. <u>Eastern Nile Planning Model</u>

An Eastern Nile Planning Model (ENPM) has been proposed as a common analytical basis for identifying, and assessing options, quantifying benefits and impacts, evaluating tradeoffs, and analyzing and managing information to support complex decision making processes on the Eastern Nile. Flood preparedness and Early Warning: Climate and river lows in the Eastern Nile of water (EN) are highly variable. The region is thus prone to extremes of droughts and floods. While there is some flood warning activity in individual countries, there is no integrated or cooperative flood warning system for the Eastern Nile basin.

Irrigation and Drainage: Among other factors, unpredictable seasonal and spatial distribution rainfall in some regions is a factor contributing to low agricultural productivity. The development of irrigation and intensification of existing agricultures offer the potential to increase food security, enhance agricultural productivity and improve livelihoods. The regional benefits of this project are expected to be maximized through the integrated development of different components, as well as building different sub-projects under the integrated development of the Eastern Nile Project. Eastern Nile Joint Multipurpose Program: Integrated and joint basin management offers the greatest opportunity to unlock economic growth, promote regional integration, and realize peace and stability. Investments in new storage capacity and improvising watershed management have the potential to improve irrigation and agricultural productivity in all countries by reducing sedimentation in reservoirs, mitigating drought impact and flood damage, and supplying substantial hydropower electricity to meet rapidly expanding demand. (Abdin and Gaafar, 2008).

G. NELSAP project

The Regional Agricultural Program will promote opportunities for cooperation in the Nile Basin through private investment, public- private partnerships and enhanced trade, in the field of high value crops and products. It will also identify steps to increase food security through increased investment, income generation and pro-poor growth. (Abdin and Gaafar, 2008)

6.3 Development of national water resources plan for Egypt 2017

The Egyptian governmental institution represented by Ministry of Water Resources and Irrigation (MWRI) has developed what is called a National Water Resources Plan (NWRP) to support the country's development until the year 2017. Specifically, NWRP has three major pillars (Abdin and Gaafar, 2008):

- Increasing water use efficiency;
- Water quality protection;
- Pollution control and water supply augmentation.

NWRP is based on a strategy that has been called .Facing the Challenge. (FtC). FtC includes measures to develop additional resources, make better use of existing resources, and measures in the field of water quality and environmental protection. Improving the performance of the water resources system; more water will be available for the various uses and the water quality will improve significantly. The agricultural area will increase by 35% as a result of horizontal expansion and of the two mega projects in Toshka and Sinai. Space for living will be created in the desert for more than 20% of the population as a result of these projects. The implementation of the strategy will support the socio-economic development of the country and provide safe drinking water to its population. The access of the population to safe sanitation facilities will double from the present 30% to 60%. Summarizing and as stated in the objectives, the strategy will safeguard the water supply up to the year 2017.

The FtC strategy follows an integrated approach to cope with the increasing pressure on the water resources system in Egypt and contains a wide range of measures and policy changes up to the year 2017. The implementation of this strategy is a real challenge. Further development of the system after 2017 may require some drastic policy decisions at the national level, e.g. accepting some limitations in growth of the agricultural sector and increasing the developments and corresponding employment in the industrial and services sectors. An increase in the Nile water supply will ease the situation somewhat and should be pursued. A limited increase is not unrealistic, either as a result of water conservation projects in Sudan, changes in reservoir operation of Lake Nasser or (in the very long run) as a result of climate change.

The integrated approach of FtC assumes that all measures are really implemented. Failure to implement some measures may have severe consequences for the overall strategy. This is in particular the case for the expected improvement of the water quality. An insufficient improvement of the water quality will mean that the increase in the reuse of water will be much less than expected with the consequence that there will be less water available for agriculture, leading to less water available per feddan[1] and a further lowering of cropping intensities(Abdin and Gaafar, 2008).

6.4 Legislation

New implementation concepts need laws and regulations updates. Generally, water laws in Egypt are as old as the country itself. They were never static, they always have dynamic nature. However, at this stage of history, when demand is pressing supply heavily, a need for strict laws is probably more than any previous time. A new water law is being developed at the present time. This law puts more emphasis on four important points (Abdin and Gaafar, 2008):

- Increased penalties for water miss-users or those who cause waste in different fields.
- Strengthening of "Polluter Pay" principal.
- Encouragement of participation both at the low level through water users associations in old and new lands as well as at the higher level of supply canal through the setting up of water federations.
- Introduction of water extension services represented by the Irrigation Advisory Services "IAS" Which provide farmers with the advice they need for a better and rational use of irrigation water. Other users, such as for domestic supply, are made aware by publicity through different media (newspapers, radio, television.).

6.5 Institutional reform

Egypt as one of the oldest country in the world practicing river-fed agriculture depends on a strong central organization working on conveyance and distribution of water. All these agencies should change from the old regime of complete government control to the new concept of user's participation. In the meantime, the vital approach and concept of integrated water resources management should also be part of this reform. This means that separate entities such as irrigation, drainage, structures, survey, mechanical and electrical divisions are no longer acceptable and even separation between water, soil, crop, and climate is not the correct way of management. It is the opinion of the officials in Egypt now to create an irrigation district which includes all the above disciplines and practice real integrated water management. (Abdin and Gaafar, 2008)

6.6 Participatory irrigation management (PIM)

The objective should be to transform the competition between stakeholders into a form of cooperation that achieves the highest overall revenue. Private stakeholders associations can provide a counterweight to the government departments own technical agencies to enhance water use efficiency. Most of the developed countries adopted PIM policies some time ago, as a matter of fiscal necessity. Farmers in developed countries enjoy high levels of education, and strong support services through both the private market and the public sector. (Abdin and Gaafar, 2008).

6.7 National water quality monitoring program

Water quality deterioration is one of the most contributed factors in water losses in Egypt. Egypt releases 12.5 BCM per year of drainage water to the Mediterranean Sea because of its unsuitable quality (MWRI, 2005). The National Water Quality Monitoring Program has been launched based on the integrated approach for water resources management. It was developed by the National Water Research Center to serve as the solid scientific foundation for Egypt's policy development and decision making. The main objectives of this program are covering Egypt with water quality network to assess decisions of water use, to enhance the human resources capacity building and to unify the standards. (Abdin and Gaafar, 2008).

6.8 Role of the private sector and privatization

There is always a mix between privatization and the role of the private sector in irrigation. Although irrigation in Egypt is practiced though a strict central governmental authorities, the private sector is heavily involved in the provision of services such as construction (through private as well as public sector contractors), engineering consultants, selling irrigation equipment, management of large-scale modern irrigation systems, drilling of groundwater wells,...etc. Privatization of the irrigation system in Egypt has already started by the establishment of water users associations and water federations.

The following step would be the establishment of management boards capable of conveying and distributing water from one end of the system to the fields. This type of service provider will be in place in the very near future as soon as government agencies give green light by contracting complete commands to water boards. It is not necessary that water boards be responsible for large or small areas. The exercise may start with very small areas and grow up with time and experience. (Abdin and Gaafar, 2008).

6.9 Linking the Nile to the Congo River

The following information was obtained according to Walaa Hussein; the editor-in-chief of the parliamentary news division at Rose al-Yusuf. She is an expert in African affairs. Hussein has collaborated with the Nile Channel, writing and preparing newscast.

This Idea has been always the last hope for Egyptian people to get more water for their dry land. The idea goes back 100 years ago. It was written in book written by, Apata Basha, Egypt's former chief irrigation engineer in Sudan. In 1980, the Idea emerged again when the Egyptian president Anwar Al-Sadat sent a committee to the Democratic Republic of Congo to study the feasibility of the Idea. The project died with the assassination of Anwar Al-Sadat in 1981.

The idea came back again to life when the conflict between Egypt and Ethiopia intensified in 2013 when Ethiopia initiated the construction work; immediately, after the visit of the ousted Egyptian Mohamed Morsi. This idea was extracted from the Suez Canal which links between the Red sea and the Mediterranean Sea.

The linking Canal would link the White Nile in South Sudan to the Congo River in the Democratic Republic of Congo. It is estimated that this canal would supply Egypt with 95 billion cubic meters per year which is almost double the current portion of Egypt's of water. Gamal el-Kalyouby, a professor of petroleum and energy at the American University of Cairo, said that "linking the Nile with the Congo River would divert Congo River water that washes into the Atlantic Ocean into the Nile River Basin." The Congo River's water that enters the Atlantic Ocean is estimated to be 1000 billion Cubic meters per year. There are few technical and political difficulties facing the project. On the technical side the two rivers have a huge difference in altitudes which requires more dams and canals to overcome this issue. On the Political side, the Egyptian government has been ignoring the proposed studies. On top of that, Egyptian leaders claimed that by doing so, they would be violating the international law which prevents the transfer of rivers' water from one country to another. From figure 6.9-1, it can be seen that both White Nile and the Congo River go through the Democratic republic of Congo.

Thus, by connecting the two waterways, there will be no violation for the international law because both watersheds lie in the same country.

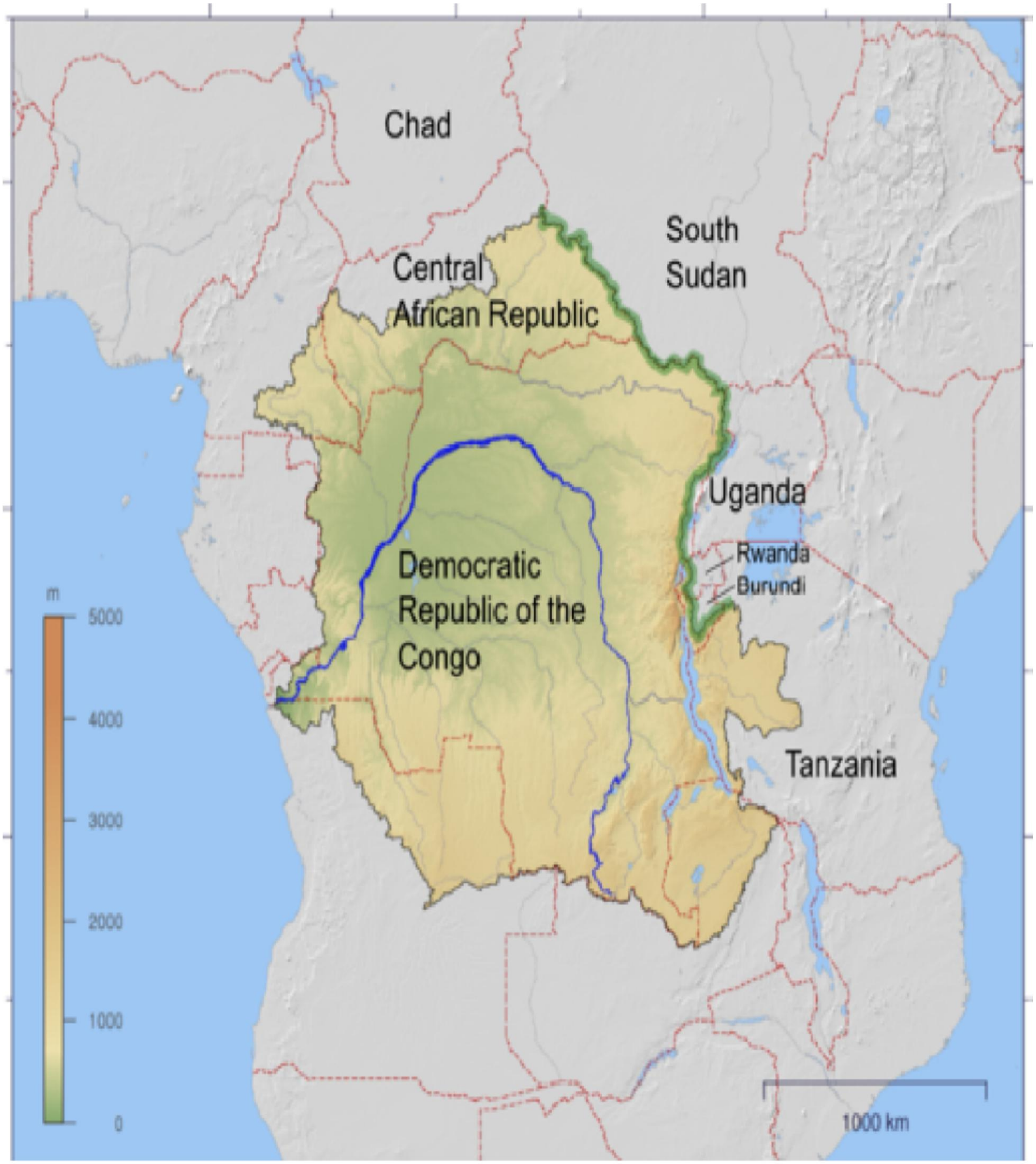

Figure 6.9-1: White Nile and the Congo River Go through The Democratic Republic of Congo

Source: Congo-Nile Divide.svg (png version): https://en.wikipedia.org/wiki/File:Congo-Nile_Divide2.png

The study was conducted by the Egyptian Mineral Resources Authority to link the Nile with the Congo River has three different proposed scenarios for the Linking Canal in order to find the best possible path for the water. Each scenario has different alignment to where the two rivers should be connected and each scenario has different elevation between the two rivers as following:

A. The First Scenario:

The length of the canal would be 263 miles with a water-level altitude differential of 0.9 of a mile between the two rivers, which would be impossible to implement due to the huge difference in altitude in such a short distance.

B. **The Second Scenario**:

The Canal length would be 584 miles, with an altitude differential of 0.4 mile.

C. The Third Scenario:

The Proposed Canal length is 373 miles with an altitude different 218 yards. "The last scenario has the best chances of being implemented, through the use of four consecutive water-pumping stations. As a bonus, the project would also have the ability to generate 300 trillion watts of electricity per hour, enough to satisfy all of Africa's lighting needs.

7. Assessing Relative Merits of Proposed Solutions:

In the previous chapter I illustrated that there are many possible solutions to the water problem in Egypt. In order to identify what decisions or solutions are the most viable, in evaluating which solutions or decisions are the most viable I decided to use a decision matrix for the evaluation.

Let's first start with defining the decision matrix as an evaluation tool used by decision makers to systematically identify, analyze, and rate the strength of relationships between sets of information. The matrix is especially useful for looking at large numbers of decision factors and assessing each factor's relative importance. These are evaluated with respect to a list of criteria which are weighted by their respective importance in the final decision. The decision matrix may be utilized using the COWS method as follows:

C – Criteria. Develop a hierarchy of criteria, also known as decision model. Place these on one axis.

O – Identify the options, also known as solutions or alternatives. Place these on the second axis.

W – Assign a weight to each criterion based on its importance in the final decision.

S – Rate each option on a ratio scale by assigning it a score or rating against each criterion.

The following steps were used to create the evaluation decision matrix showing in table 7-1:

- All of the possible solutions were listed as the rows labels on the table, and the performance criteria were listed as the column headings such as (cost, time, ease of implementation, quality of life and benefit index)
- Each option in performance criteria was assigned score from 1 (low) to 5 (high).
- Weighting the possible solutions based on the importance of the solution. The Weighting numbers from 1 to 10, where 1 means that the factor is absolutely not important in the final decision, and 10 means that it is very important.
- Sum of all the performance criteria scores.
- Multiply each of sum of all the performance criteria scores from step 4 by the values for relative importance of the factor that you calculated in step 3. This will give you total scores for each option/factor combination.
- Finally, compare the total scores for each of options; the option that scores the highest is the best option. Table 7-1 shows the total scores for each options.

- Rankings were assigned to each possible solutions based on the total scores the ranking showing in figure 7-2.

Table 7-1: Evaluation Decision Matrix

Evaluation Matrix

Performance Criteria

Possible Solutions / Ranking Scores	Cost	Time	Ease of Implementation	Quality of Life	Political Impact	Benefit Index	Sum	Weight	Total score	Rank
	(Low = 1 & High = 5)	(short = 1 & Long = 5)	(Low = 1 & High = 5)	(Low = 1 & High = 5)	(Low = 1 & High = 5)	(Low = 1 & High = 5)	Σ of Criteria	(Low = 1 & High =10)	Σ of Criteria X Weight	From (1-9)
6.1 Water Saving Techniques										
A. Use of modern irrigation systems B. The change from surface irrigation to drip irrigation C. Land leveling D. Night irrigation G. Irrigation improvement projects in the old lands	1	1	2	4	2	2	12	7	84	9
E. Modification of the cropping pattern F. Introduction of short-age varieties	1	1	3	4	1	2	12	7	84	9
								Total	84	
6.2 Optimum Use of Resources										
A. Reuse of Drainage Water and Treated Wastewater B. Desalination of brackish and sea water C. Importance of international co-operation D. Nile Basin Initiative (NBI) projects E. ENSAP relevant projects F. Eastern Nile Planning Model G. NELSAP Project	4	2	4	3	3	4	20	7	140	2
								Total	140	
6.3 Development of National Water Resources Plan	1	3	2	4	3	3	16	8	128	3
								Total	128.00	
6.4 Legislation	3	2	3	4	2	2	16	7	112	5
								Total	112	
6.5 Institutional Reform	3	2	3	4	3	2	17	7	119	4
								Total	119	
6.6 Participatory Irrigation Management (PIM)	2	1	3	4	2	2	14	7	98	7
								Total	98	
6.7 National Water Quality Monitoring Program	3	1	3	4	3	2	16	6	96	8
								Total	96	
6.8 Role of The Private Sector and Privatization	3	2	3	4	3	2	17	6	102	6
								Total	102	
6.9 Linking the Nile to the Congo River										
A. The First Scenario B. The Second Scenario C. The Third Scenario	5	5	5	4	5	5	29	10	290	1
								Total	290	

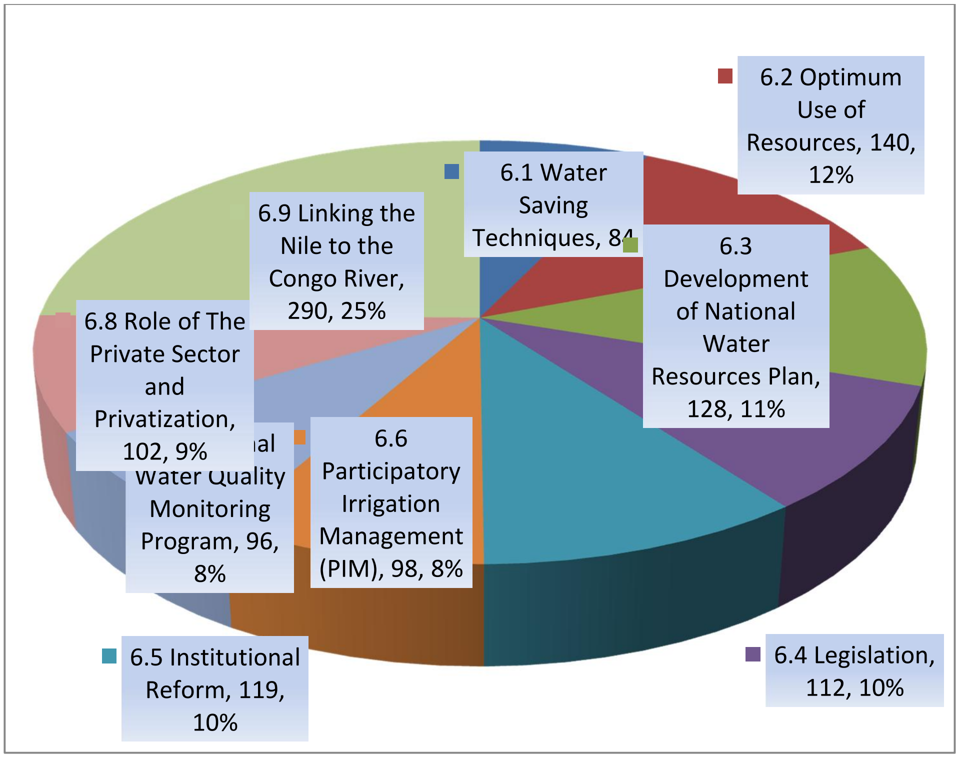

Figure 7-1: Total Scores of Possible Solutions for Water Scarcity in Egypt

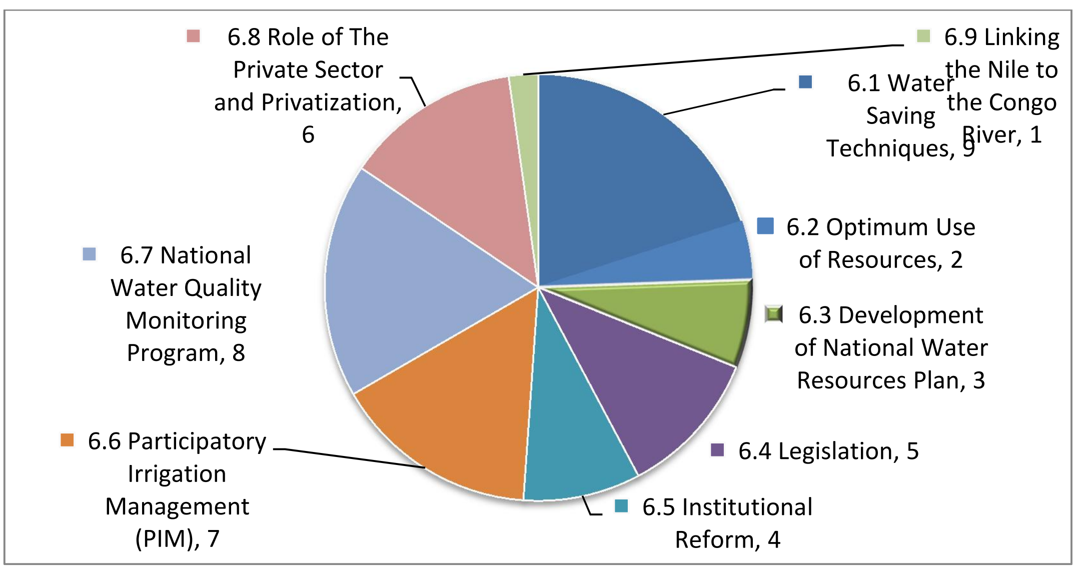

Figure 7-2: Ranking of Possible Solutions for Water Scarcity in Egypt

From the evaluation decision matrix table 7.1 and figures 7-1 &7-2 we could conclude the following solutions were ranked from high to low based on the total scores as permanent solutions:

1. Linking the Nile to the Congo River is the best solution while the cost of the solution is very high and it needs collective corroboration between multi nations in order to implement the solution.
2. Optimum use of resources ranked as 2nd as the second best solution.
3. Development of national water resources plan ranked 3rd best solution.
4. Institutional reform ranked 4th best solution.
5. Legislation ranked 5th best solution.
6. Role of the private sector and privatization ranked 6th best solution.
7. Participatory irrigation management (PIM) ranked 7th best solution.
8. National water quality monitoring program ranked 8th best solution.
9. Water saving techniques ranked 9th best solution.

The solutions with low ranking could be considered as temporary solutions and could be implemented quickly and with low cost compared to solutions with high ranking that consider as permanent solutions that would require long time to implement and would require securing financial before implementation. Implementing any of these solution would require collective effort from the government and the private sectors and even the world-bank.

- First the government should start with increasing the public awareness about the problem using some media programs such as of the television and radio.
- Second the government should pass a new environmental law. This law will require the plant owners to clean up their discharges. Industrial wastewater will improve with penalties, and the plant owners will pay an amount of money if the plant does not utilize equipment to clean the discharge.
- Encourage the private sectors to share in building and developing of Water contamination treatment plans. The private sectors will make a profit from the project through distribution of table water; they will make sure the water will be available to each person in the country.
- The most important solution is to build bigger plants to turn waste of the industrial and agricultural to useful materials instead of dumping it to the River Nile.
- The last solution is to build a new sewerage system as well as build a bigger treatment plant to accommodate the large amounts of sewerage from the areas, which do not have access to sewerage. This will help in protecting the aquifer water from the pollution. The last solution that Egypt could possibly use is to desalinate to the seawater, again another expensive

procedure.

- Taring the farmer to use modern irrigation system and to use crops pattern to reduce the amount of water loss in the field of irrigation.
- Egypt has to work with other basins country to reduce the loss of water in the Nile due to evaporation.
- Egypt should consider the study of liking the Congo River to The River Nile, they should work the Congo basins countries to develop plan how to link the two rivers could be beneficial for both basins by building dam to convert the water from Congo River to the Nile.

8. Conclusions

Given the background information and current situation of this magnificent dam project in Ethiopia, it is evident that proper management water is crucial in these three Nile basin countries. The Great Ethiopian Renaissance Dam will substantially influence the flow of water to Egypt. Egyptians are concerned that if their current 55 billion cubic meters of annual flow is altered, their people will be in grave danger. The dam, which is already 30% complete, will very likely be completed in its entirety. When the dam is complete, Egypt may need to seek alternatives for supplying the people with clean water and supporting their agricultural livelihood. Exploring options such as the "New Valley Project" and the linkage to the Congo River may manifest as viable solutions. In order for them to come to completion, they will require a great deal of planning, design, and funding especially. All of these projects are substantially intertwined in the politics of the governments of the three nations most directly affected and these issues are beginning to gain international recognition. Millions of people will be affected by the outcome of this project so pragmatic measures must be taken so that the outcome is one that causes the greatest good for the greatest amount of people, regardless of which nation they call home. Egyptian water resource planning is given the task of satisfying the ever-increasing water demands which are dictated by a rapidly growing population, increased urbanization, higher standards of living, and an agricultural policy which emphasizes expanded production in order to feed the growing population. There is, and probably always will be, enough water to satisfy municipal and industrial water use. From the analysis of water resource planning in Egypt, the planning emphasis can be characterized by the following eight points:

A. Shift from water abundance to water deficit.
B. The importance of international co-operation
A. Supply bias.
B. Environmental concern
C. Lack of data
D. Established priority to non-agricultural uses of water
E. Delayed implementation
F. The establishment of an administrative framework for water resource planning.

Thirst for water will become one of the most pressing resource issues of the 21st Century. Egypt water consumption is rising and continues to grow rapidly. The scope and extent of water conservation is decisively shaped by the shift to a demand-oriented water management strategy in other words a demand-managed water culture. Such a policy is imperative for Egypt and for other arid countries facing similar water constraints. The agricultural sector is considered as critical for tackling poverty in developing countries. Egypt is not an exception as its large population is engaged in agricultural activities. In the future, irrigation water, which is the absolutely crucial part of Egypt's agriculture, has to satisfy demands of even larger population and increasing living standards. Till now, the water shortages have been tackled by increasing extractions of resources and developing new supply options for the irrigation system. However, most of the supply options are already exhausted and cannot maintain significant enlargements. Some improvements can be achieved through efficiency increase. The demand side management entails some potential for water saving which might be possible through cost recovery as one of the financial instruments for water conservation.

The main objections rose by efficiency and cost recovery measures are negative social effects and environmental implications. Without building favorable preconditions for cost recovery, the introduction of user charge at this stage might face inevitable problems. Preconditions imply community involvement in canal management, well-defined rights, responsibilities for quota violations in case of drainage water reuse and rice cultivation. Whatever conservation measure will be applied, the main problem for the environment will remain the same. Soil salinization due to drainage water reuse or reduced water applications on fields will be a threat. Balanced approach in pricing and adequate knowledge of the soil salinity itself can ease the task. This would mean intensive awareness campaigns enriching farmer's information about salinity management, spreading the information about new water-saving and salinity resistant crops. Water scarcity is not an easy issue to deal with but still there are hopes that its negative effects can be minimized. To this end, an inclusive picture of the problems with all the factors involved has to be realized. In this study, an attempt has been made to view just some aspects of the whole picture. However, for a further understanding of the issue, other factors need to be added, which might be the subject for future study. Egypt water resource planning is facing a number of problems - such as the lack of funds and no rational governance - which predominate in less-developed economies. Establishing a planning system, in general, is expensive; therefore, it is developed only if needed. Egypt in fact might have had too much water at one time, a surplus which has severely hindered the necessity to implement a planning system. Emphasis on water resource planning depends on the scarcity of the resource. The greater the scarcity, the more planning is needed to counteract it. According to that argument, Egypt is expected to strengthen its water resource planning capability in the near future, following a greater scarcity of its water supply (Hvidt, 2000)

The sources of the conflict over Nile waters are old and cannot be dealt with merely through short-term agreements specific to the GERD. But the escalation of tensions between Ethiopia and Egypt over the construction of the GERD is at least partly based on a misunderstanding of the nature of the risks this dam poses to Egypt. The GERD does not spell disaster for the downstream riparians because hydropower generation is largely a non-consumptive water use. After the GERD is filled, the dam itself will not appreciably reduce the total water supply available to Egypt and Sudan. There is a win–win deal that can defuse tensions between Egypt and Ethiopia over the GERD. First, Ethiopia needs to agree with Egypt and Sudan on rules for filling the GERD reservoir and on operating rules for the GERD during periods of drought. Second, Egypt needs to acknowledge that Ethiopia has a right to develop its water resources infrastructure for the benefit of its people based on the principle of equitable use, and agree not to block the power trade agreements that Ethiopia needs with Sudan. Because the economic feasibility of the GERD and other Ethiopian hydropower projects will depend on such agreements, Sudan has leverage with both Ethiopia and Egypt to encourage this win–win deal .A broader cooperative framework for use of the Nile would require some accommodation on the part of both Egypt and Ethiopia, but it need not cause ‘appreciable’ harm to either. The combined efforts of Saudi Arabia and the GCC more generally, Sudan, and the United States may be required to encourage Egypt and Ethiopia toward a shared vision and cooperative framework. We recognize that the default position in the Nile basin, as elsewhere, is to seek self-sufficiency at the expense of cooperation, but participation by the Nile riparians in the Nile Basin Initiative (NBI) showed at least some willingness on their part to move beyond that kind of thinking. The failure of the NBI also shows the challenges that the riparians are likely to continue to encounter. If Egypt acknowledges the legitimacy of the equitable use criterion for Ethiopia, this may have implications for upper basin riparians on the White Nile. In the long run the creation of regional watermarkets may permit more flexibility in water allocations, allowing limited water supplies to move to the highest value uses. But given the present dispute over the GERD, the trust required for regional water markets to function seems far away.

Even without any change in the 1959 Agreement and without any concessions by Egypt and Sudan to the other nine upstream riparians, Egypt will need to make major adjustments in its current use of water. This is because its current use of Nile water is based on two 'windfalls'. The first is the unused portion of the Sudan's share under the 1959 Agreement, which has recently been in the order of 5 bcm per year. The second is that the average annual flow of the Nile has been above the 84 bcm assumed in the 1959 Agreement, and this long term mean has not been adjusted as the provisions of the 1959 Agreement require. It is likely that Sudan will use its full share within a decade. As global warming increases evaporation losses and crop water requirements, and possibly also reduces the average discharge of the Nile, supplies will tighten further. Taken together, these changes mean that Egypt will likely have to get along with less water in the future. Egypt's experience in the past few decades indicates that it is capable of engineering much greater water efficiency through reductions in physical losses, re-utilization of drainage and municipal water, and less waste in on field irrigation.

Bibliography:

- Abdin, E. & Gaafar, I., 2008, "Rational water use in Egypt", CIHEAM, retrieved from: <http://om.ciheam.org/article.php?IDPDF=801177>
- Abdel-Gawad, S., 2007, "Actualizing the Right to Water: An Egyptian Perspective for an Action Plan", International Developmental Research Centre.
- Al-Labbad, M., 2013 "Egypt, Ethiopia Headed for War Over Water", Al-Monitor: the Pulse of the Middle East. Al-Monitor. Retrieved March 24, 2013, retrieved from: < http://www.al-monitor.com/pulse/politics/2013/03/egypt-ethiopia-water-war.html#>
- Aman, A., 2014, "Egypt seeks to halt Ethiopian dam", Al-Monitor: the Pulse of the Middle East. Al-Monitor. Retrieved April 23, 2014, retrieved from: < http://www.al-monitor.com/pulse/originals/2014/02/egypt-lobby-renaissance-dam-ethiopia.html#ixzz2zfdPWaAx>
- Awulachew, S., Smakhtin, V., Molden, D. & Peden, D., 2012, "THE NILE RIVER BASIN Water, Agriculture, Governance and Livelihoods", Routledge, 711 Third Avenue, New York, NY10017, retrieved from: <http://www.gwp.org/Global/ToolBox/Case%20Studies/Asia%20and%20Caucasus/the_nile_river_basin-water_agriculture_governance_and_livelihoods.pdf>
- Carlson, A., 2013, "Who Owns the Nile? Egypt, Sudan, and Ethiopia's History-Changing Dam", Origins: Current Events in Historical Perspective Changing Dam, retrieved from: <.http://origins.osu.edu/article/who-owns-nile-egypt-sudan-and-ethiopia-s-history-changing-dam
- Consulate General of Ethiopia, 2012, "Grand Ethiopian Renaissance Dam" Los Angeles, CA.
- Dowling, M., 2015, "Egypt: the Gift of the Nile", mrdowling.com. www.mrdowling.com. Retrieved from: <http://www.mrdowling.com/604egypt.html>
- Egypt to 'escalate' Ethiopian dam dispute, 2014 –Aljazeera News, retrieve from: <http://www.aljazeera.com/news/middleeast/2014/04/egypt-escalate-ethiopian-dam-dispute-201448135352769150.html>
- Egypt warning over Ethiopia Nile dam, 2013, BBC News, retrieved from: < http://www.bbc.com/news/world-africa-22850124>
- El-Kammash, M., Hurst, H. & Smith, C., 2006, "Nile River (river, Africa)", Encyclopedia Britannica Online Academic Edition. Encyclopedia Britannica, n.d., retrieved from: http://www.britannica.com/place/Nile-River/Plant-and-animal-life>
- Evans, J. & Howard, P., 2005, "The Water Cycle", USGS, retrieved from: <http://water.usgs.gov/edu/watercycle.html>
- Hoyt, A., 2007, "How the Nile River Works", HowStuffWorks.com. Retrieved from: <http://adventure.howstuffworks.com/nile-river.htm>
- Hvidt, M., 2000, "Water Resource Planning in Egypt", the Middle Eastern Environment, St. Malo Press, Denmark, retrieved from: <http://www.netcomuk.co.uk/~jpap/hvidt.htm>
- ICOLD, 2007, "Dams and the World's Water", International Commission on Large Dams 151 Boulevard Haussmann F-75008 Paris , FRANCE, retrieved from: <www.icold-cigb.org>
- Igunza, E., 2014, "Will Ethiopian dam dry up the Nile?", BBC News, retrieved from: <http://www.bbc.com/news/world-africa-26679225>
- International Panel of Experts (IPoE), 2013, "Grand Ethiopian Renaissance Dam Project", Addis Ababa, Ethiopia. retrieved from: <http://www.internationalrivers.org/files/attached-files/international_panel_of_experts_for_ethiopian_renaissance_dam-_final_report_1.pdf>
- Jon, A., 2012, "Dam Controversies: Contested Governance and Developmental Discourse on the Ethiopian Omo River Dam" Social Anthropology Wiley-Blackwell
- Kingsley, P., 2014, "Nile dam study fails to stem the tide of Egyptian indignation towards Ethiopia" theguardian.com. Retrieved April 23, 2014, retrieved from: <http://www.theguardian.com/global-development/poverty-matters/2014/apr/16/nile-dam-study-egyptian-indignation-ethiopia>
- Rice, X., 2010, "Battle for the Nile as rivals lay claim to Africa's great river", The Guardian, retrieved from: <http://www.theguardian.com/environment/2010/jun/25/battle-nile-africa-river-resources>
- Shiklomanov, A. & Rodda, J.,2004, "World Water Resources at the Beginning of the Twenty-First Century", the Press syndicate of the University of Cambridge, the Pitt building, Trumpington street, Cambridge, UK,
  Retrieved from :< http://catdir.loc.gov/catdir/samples/cam034/2002031201.pdf>

- Ward, A., 2003, "Weighing Earth's Water from Space", NASA, Earth Observatory, retrieved from: <http://earthobservatory.nasa.gov/Features/WeighingWater/>
- Wucher, J., 1989, "Historical Dictionary of Egypt". Books of Lasting Value, American University in Cairo Press.