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Innovative Solution of the Irrigation System Management Between Aswan and Esna

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Abstract: The management of irrigation systems has gained importance over the last five decades due to a tremendous increase in irrigated land in Egypt. Climate change has negative impacts on management of irrigation water resources and agriculture sectors. This paper aims to suggest a strategy to adapt climate changes impacts in water resources irrigation. This could be achieved by use clean energy in irrigation in south of Egypt. There has been a growing realization of possible improvement of water irrigation management for the reach between Aswan High Dam (AHD) to Esna barrage at the south of Egypt. New water irrigation management strategies could provide water to the agricultural land, which facing increasing challenges in locating reliable water supplies for their cultivated land under climate change impacts. The existing irrigation system in this reach depends on usage of more than 82 irrigation pumps stations, which required high capital and energy costs on the east and the west side of the Nile River banks. The objective of this research is eliminated the existing irrigation pump stations on the east side of the riverbank and design a pipeline to convey the water from AHD reservoir (discharge point) to Esna barrage with total length 169 km. The research is carried out through three modules dependent on each other, Remote Sensing (RS) module, Geographic Information System (GIS) module, and hydraulic modeling of the proposed pipeline module. The Modis images were downloaded to develop vegetation map and calculate agriculture area. The total calculated cultivated area was estimated to be 206692 feddan (86810.64 ha) in East side of River Nile at year 2015. The data of irrigation pumps locations were collected. According to collected data, 34 outlets nodes were established to supply the water for different cultivated land zones. The pipeline was designed according to irrigation requirements at the irrigation nodes. Hydraulic modeling of the pipeline was carried out to properly size the pipeline based on its proposed alignment, and future water irrigation demands. The proposed pipeline solution will provide more reliable and less cost-effective strategy to meet future water supply needs and to adapt climate changes impacts in water resources by using clean energy. In additional, the pipeline will provide multiple benefits such as harvest renewable, low-cost electricity and will clearly help reduce energy consumption. The proposed solution needs to meet various requirements of operating authorities to satisfy crop water requirements.

Keywords: Climate Change, Renewable Energy, Geographic Information System, Hydraulic Modeling, Nile River, Pipeline, Pump Station, Remote Sensing

1. Introduction

The Nile River is considered the main source of irrigation water in Egypt. Control and management of the Nile water was achieved after the construction of a number of dams and barrages on the Nile and its branches. The old Delta barrages were completed in 1881 and the new ones in 1939. Recent barrages on the Nile were built at Esna, Naga-Hammadi, Assiut, Zifta and Edfina as shown in figure 1, [1]. As a result of the continuous population increase in Egypt and the need for further development in the agricultural and industrial sectors, it was necessary to have long term storage of the Nile water to reliably meet the demand. The Aswan High Dam (AHD) which is an earth-fill, multipurpose dam, was completed in 1965. The water is supplied to the irrigation system of Egypt through discharges from the High Aswan Dam [2]. Its construction resulted in the creation of the longest manmade lake in the world, extending in Egypt for about 300 km as Lake Nasser and for 180 km further south in Sudan as Lake Nubia. Released water downstream the AHD is distributed among regions through canals and pumps that divert water from the Nile River. The main features of the irrigation system are operation and control of the water based on the elevation of the water upstream or downstream of the off-take structures. Therefore, the irrigation systems usually use pump stations to lift water from the River Nile to the cultivated land. The first pump stations for irrigation were constructed in 1885 to feed the diversion canal "Raiyah El-Biheira", and the principal canal "El-Ibrahimiya Canal" during the period of low water levels in summer, [3]. Egypt has more than 560 irrigation pump stations (about 1600 pump units totally). They are consumed about 930 GWhr of the total electrical energy generated in Egypt (about 70000 GWhr), [4]. These pump stations consume considerable amount of the electrical energy. Accordingly, the issues of power management and energy saving in the pump station networks have a strong economic impact. This study suggests future national strategy to efficient use water for agriculture in Upper Egypt. The reach between AHD and upstream Esna barrage in Upper Egypt has been faced increasing challenges in locating reliable water supplies for irrigation of the cultivated land. Total cultivated lands cover (176,630 feddan) (74,185 ha) at year 2007 which represent of 2% of the total cultivated lands in Egypt (The Cabinet, Information and Decision Support Center (IDSC), 2010, [5]. Sugarcane cultivated area covers more than 50% of the total area, followed by dates then hibiscus. This reach zones is irrigated throughout pumping stations from the river which required high capital and energy costs. The existing water irrigation system depends on usage of more than (82) irrigation pump stations located on both sides of the Nile River banks, [6]. Since the pumping stations need a lot of construction material, energy, operation and maintenance cost, therefor there is growing realization of possible improvement for water irrigation management for this reach. The aim of this research is to eliminate the existing irrigation pump stations on the east Nile River bank (where the area of the agricultural land at the east side of the river in this reach represent more than 70% of the total cultivated area) and replace pump stations by pipeline to convey the water from AHD reservoir (Nasser Lake) (intake point) to Esna under pressure with total length 169 km. The proposed pipeline conveyance systems would reduce pump stations operation and maintenance costs, as well as the water losses due to seepage, evaporation, and spills. The proposed intake site was at the east side of AHD reservoir.

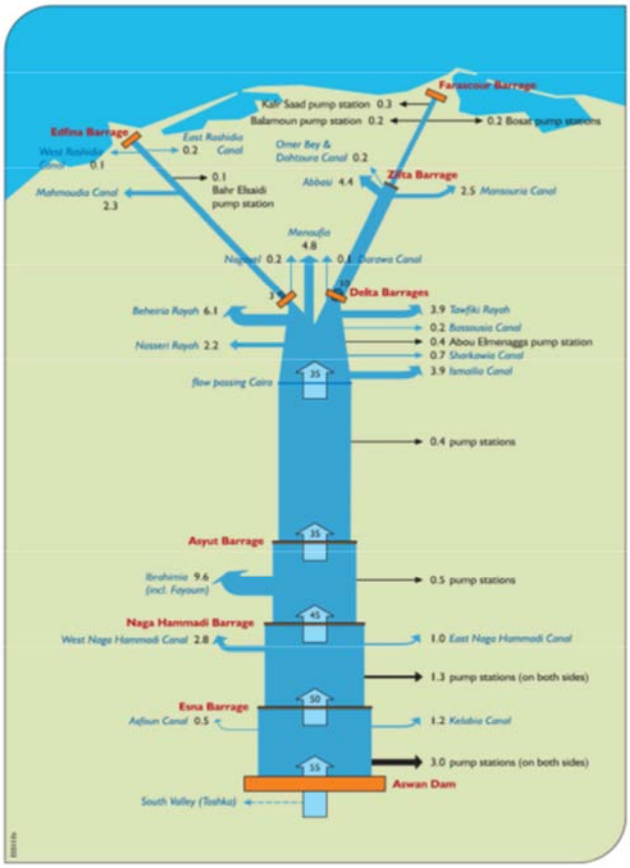


Figure 1. *Sketch of the hydraulic works on the Nile in Egypt, after NAWQAM.*

2. Objectives

The paper aims to propose a new solution for water conveys system at the study reach to meet future water supply needs through following steps:

a) Develop Remote Sensing (RS) application to determine the spatial distributions of cultivated lands nearby irrigation pipeline outlets.
b) Establish Geo-database for the existing irrigation pumps stations at the reach study to determine the future water irrigation demands.
c) Carry out the hydraulic modeling analysis of the proposed convey pipeline

3. Materials and Methods

3.1. Study Area

The study reach length extends from Aswan High Dam (AHD) until Esna barrage with total length 169 km north; which represents the border of Aswan governorate as shown in figure 2. The river valley in this area is narrow which varies from 3 to 18 km. It consists of 5 districts which are Aswan, Daraw, Komombo, Nasr, and Edfo. The drainage water returns to the river by gravity.

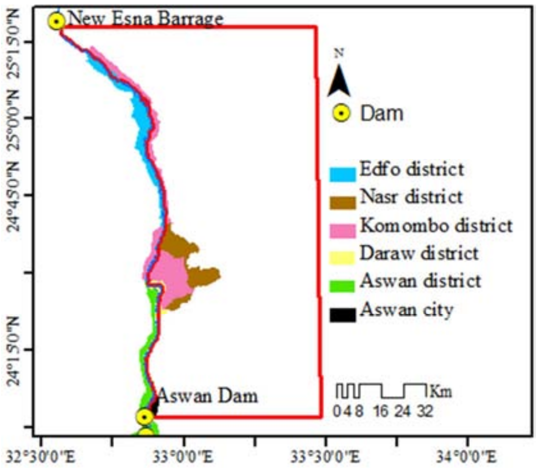


Figure 2. *The Study reach from AHD to Esna barrage.*

3.2. Methodology

The research is carried out through three modules dependent of each other; Remote Sensing module (RS), Geographic Information System (GIS) module, and hydraulic modeling of the proposed pipeline module. The RS module was used to determine the actual agricultural areas through satellite images. The GIS module was used to assemble the collected data of the existing irrigation pump stations. The hydraulic analysis of the proposed pipeline was carried out. The model simulation of the ultimate system was performed to properly size of the pipeline based on its proposed alignment, and future water irrigation demands. It was created more than 34 outlets on the pipeline route to supply the water for cultivated areas zones. Figure 3 shows the processing chart of the methodology.

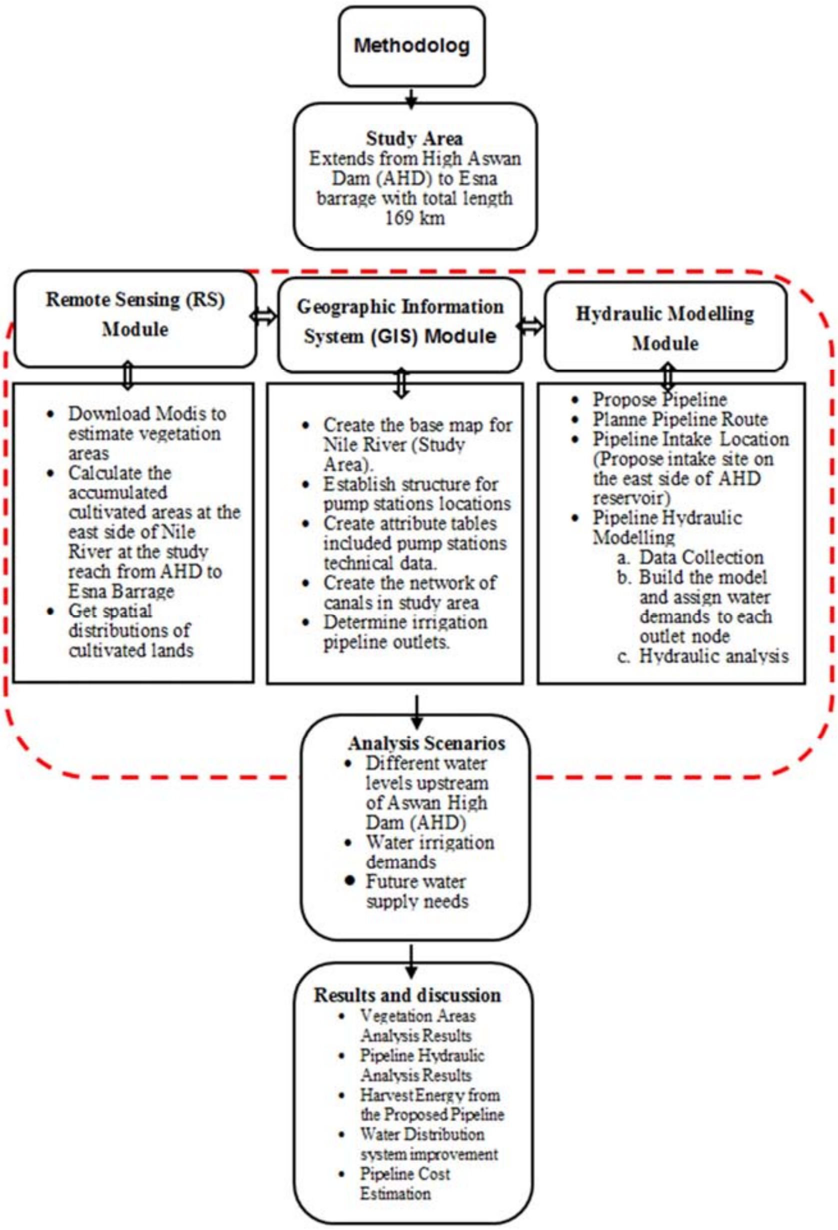


Figure 3. *The Study reach from AHD to Esna barrage.*

3.3. Remote Sensing (RS) Application

Remote Sensing (RS) application was carried out to get spatial distributions of cultivated lands nearby the proposed pipeline nodes. The Modis was used to estimate vegetation areas, [7]. The vegetation map with 250 m resolution of the east side of Nile River at the study reach from AHD to Esna Barrage had been developed. The studied area was covered by image in March 2015 representing winter harvesting season. The cultivated area at east reach is shown in figure 4 and table 1. The accumulated cultivated area at the east side of Nile River of the study reach from AHD to Esna Barrage has been calculated of about 206692 feddans, figure 5. The cultivated areas spread around the Nile from Aswan to Edfu and Komombo. Sugarcane is the most economic crop and covers about 57% of cultivated land. Palm date is the major fruit crop. Wheat covers about 15%, Sorghum covers about 10%, and the different crops as berseem, onion, garlic, beans, sesames, and barley represent 18%. Most of sugarcane cultivations are in Edfo, Komombo, and Nasr districts. Sugarcane cultivations lands are low in Daraw district and no cultivations in Aswan district. The areas of each farmer field are less than two (feddan). Farmers use traditional surface water irrigation more than modern drop and sprinkler methods that waste large amount of water. The irrigation water is pumped from River Nile to flood agriculture fields from 3 to 4 times within the month in summer season and one time in winter season, [8].

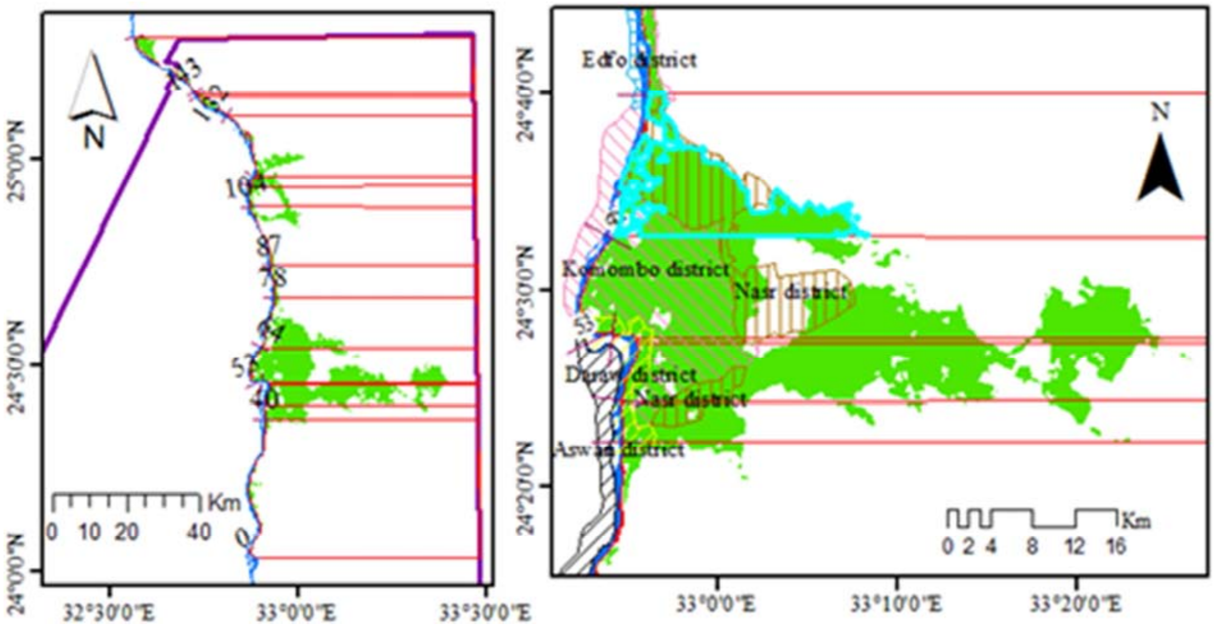


Figure 4. Cultivated areas between irrigation pipeline segments nodes at east side of Nile River.

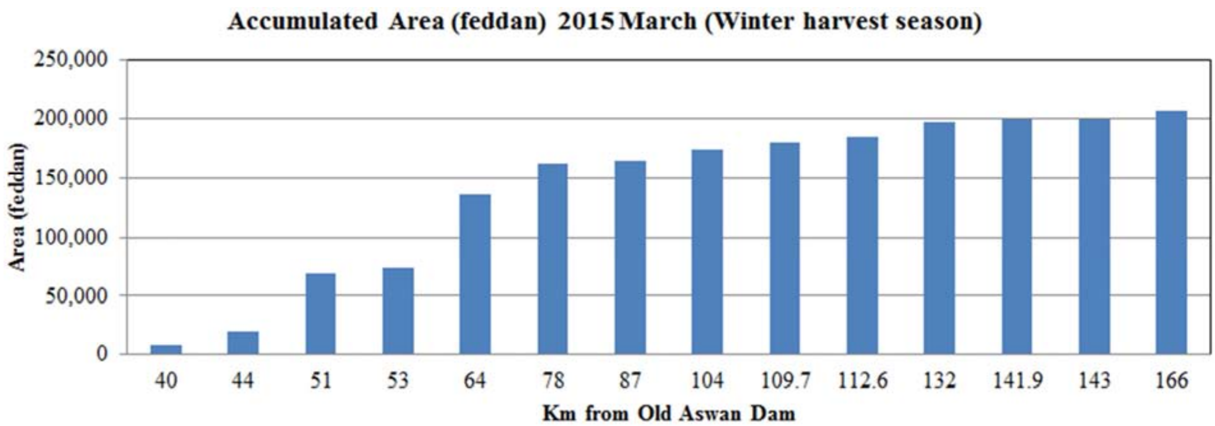
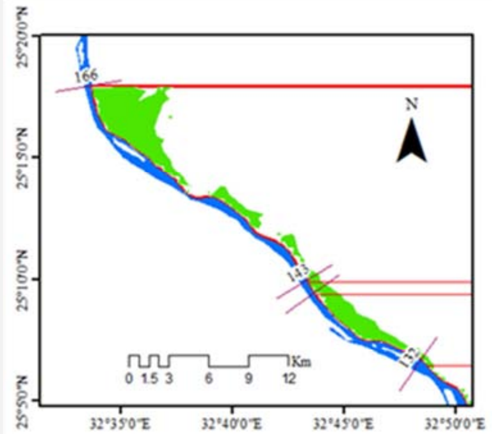
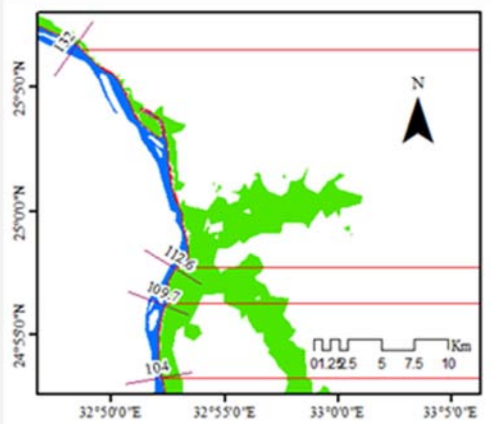
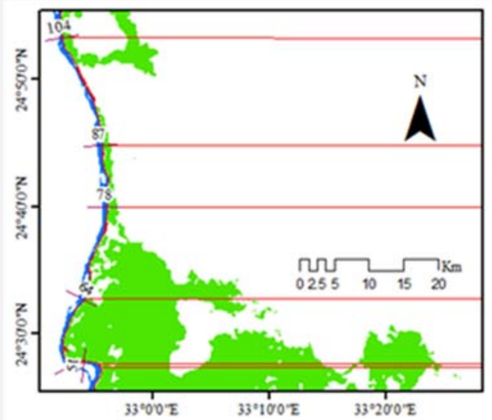
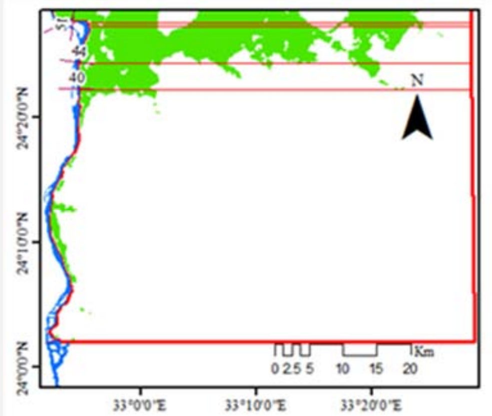


Figure 5. Accumulated cultivated area at east side of the study reach of River Nile, year 2015.

Table 1. *Total area of cultivated land at east side of River Nile from AHD to Esna Barrage (feddan).*

Km from AHD	from	To	Cultivated Area (feddan)	Total Cultivated Areas of Pipeline segments nodes (feddan)
143 - 169	Sebaaia	Esna Barrage	7014	
141.9 - 143	Hagz	Sebaaia	352	
132 - 141.9	Bosailia	Hagz	2287	
113 - 132	Kelh	Bosailia	12537	
110 - 113	Radisia	Kelh	4302	
104 - 110	Ramadi	Radisia	6044	
87 - 104	Salwa Behari	Ramadi	9085	
78 - 87	Salwa Kebli	Salwa Behari	2310	
64 - 78	Eklit	Salwa Kebli	26916	
53 - 64	Mansooria	Eklit	62268	
51 - 53	Komombo	Mansooria	4645	
44 - 51	Benban	Komombo	48363	
40 - 44	Daraw	Benban	12689	
0 - 40	HAD	Daraw	7880	
Total area			206692	

3.4. Geographic Information System (GIS) Application

Geo-database has been developed to evaluate and analyze the actual technical conditions of existing irrigation pump stations at the study reach. Four layers are developed and integrated with each other; first layer represents the Nile River in the study reach. Second layer is classifies the irrigation canals which are provide water to the cultivated lands. Third layer includes the pump stations data. The fourth layer establishes the cultivated area borders in the region. These layers are integrated to accomplish the GIS application module, there are many tasks have been undertaken as following:

a) Create the base map for Nile River.
b) Establish structure for pump stations locations along the study reach.
c) Create attribute tables included pump stations technical data.
d) Create the network of canals in study area.

This module utilizes and analyzes the data, through three steps, as following;

a) Assessment the status of pump stations; depending on the available data such as: the location, the consumed electric power, total discharge drawn, and operation periods depending on the commission date.
b) Specify the distribution outlets nodes of the proposed pipeline; depending on the discharge capacity of pump stations along the study area.
c) Estimation the annual flow as well as the power consumed of the pump stations according to the annual discharge for years from 1976, to 1984, and 2008 depending on these available distributed monthly data for these pump stations. Different classifications of pump stations are carried out based on the consumed power, the flow rate and served area depending on each the pump stations. Figure 6 shows the utilization the GIS module in classification of pump station according to the lifetime or the commissioned date of operation. It shows that more than 10 pump stations were commissioned since 1931 to 1950, 6 pump stations from 1967 to 1979, and 8 pump stations are commissioned from 1990 to 1999. There are only two pump stations are commissioned after year 2000, the remaining count of pump stations missing the commissioned dates. Table 2 shows the classification of pump stations in terms of consumed power, capacity of discharges and served areas.

Station_N	Side	Km_from_As	Km_from_Ru	Station_ty	No_of_Uni	Discharge	Consumed	Explusior	Explusio_1	Served_are	Governorat	Commission
		0	0		0	m3/sec	Power (kw)	(m)	Canal	Feddan		0
S. Gezert Aswan		6.5	920.5	Irrig./elec	1	0.15	20.360294118			50	Aswan	0
F. Abo Elresh qebly	Right	11	916	Irrig./elec	2	0.5	137.64705882	92.5		590	Aswan	1979
F. Gezert Baharief	Right	16	911	Irrig./elec	2	0.4	116.23529412	94.5		475	Aswan	1979
F. Saheil el khatara	Right	22	905	Irrig./elec	2	1.4	453.21568627	94.6		2000	Aswan	1952
F. Gezert el qobania qebly		22	905	Irrig./elec	2	0.3	79.529411765	92.2		175	Aswan	1971
F. Gezert el qobania bahary		23.5	903.5	Irrig./elec	2	0.2	53.019607843	92.2		110	Aswan	1974
F. El aaqab qebly	Right	24	903	Irrig./elec	2	0.2	50.980392157	92.5		400	Aswan	1950
F. El aaqab bahary	Right	28	899	Irrig./elec	2	0.4	121.33333333	93.5		440	Aswan	1950
F. Gezeret el tawiesa		40	887	Irrig./elec	2	0.3	62.705882353	92.6		290	Aswan	1952
F. Gezeret ballola	Right	43	884	Irrig./elec	2	0.3	62.552941176	92		270	Aswan	1952
F. Gezeret el arab	Right	47	880	Irrig./elec	2	0.2	49.450980392	90.5		110	Aswan	1973
S. El bayara 1	Right	48	879	Irrig./elec	4	1.5	1621.1764706	103.6	Casel	27850	Aswan	1953
S. El bayara 2	Right	0	0	Irrig./elec	6	2.9	5433.2352941	103.6	Casel	11318	Aswan	1953
S. El bayara 3	Right	48	879	Irrig./elec	4	2.4	2828.8	104	Casel	17100	Aswan	1995
S. Mechanical bayara		0	0	Irrig./dies	4	2.25	2747.2058824	103.5	Casel	2000	Aswan/kom ombo	1957
S. saheil meneiha el sabta	Right	50	877	Irrig./elec	2	0.8	183.52941176	89.1	Tard Meneiha	600	Aswan/kom ombo	1998
F. saheil meneiha	Right	50	877	Irrig./elec	2	0.8	183.52941176				Aswan/kom ombo	0
S. Gezeret meneiha		56.5	870.5	Irrig./elec	2	0.25	55.632352941			100	Aswan/kom ombo	0
S. Eqliet old	Right	60	867	Irrig./elec	3	0	0	87.2	Eqliet	2075	Aswan/kom ombo	1933
S. Eqliet new	Right	60	867	Irrig./elec	3	0.7	258.27941176		Eqliet	2700	Aswan/kom ombo	1987
F. Gezeret fares		66.8	860.2	Irrig./elec	2	0.5	105.01960784	89.8		620	Aswan/kom ombo	1952
S. Bowier new	Right	70	857	Irrig./elec	3	0.9	255.33529412	89.5	Tard elBowier	1000	Aswan/kom ombo	1977
S. El selsiela	Right	70	857	Irrig./elec	5	4.3	3233.4313725	90.5	El selsiela			0
S. Salwa qebly new	Right	75	852	Irrig./elec	2	0.8	218.19607843	83.4		450	Aswan/kom ombo	1998
S. Salwa qebly old	Right	75	852	Irrig./elec	3	0.4	147.74117647	87.2	salwa qeply old	1450	Aswan/kom ombo	1982
F. Salwa qebly old		81.5	845.5	Irrig./elec	1	0.5	68.18627451	90	salwa qeply old	450	Aswan/kom ombo	1874
S. Salwa el mostagada old		0	0	Irrig./elec	2	0.4	110.11764706			100	Aswan/kom ombo	1973
S. salwa bahary new		0	0	Irrig./elec	5	0.9	613.67647059	87.2	salwa bahary1	2450	Aswan/kom ombo	1982
S. salwa bahary old	Right	85	842	Irrig./elec	3	0.4	150.8	87.2	salwa bahary1	2450	Aswan/kom ombo	1933
S. El serag new		0	0	Irrig./elec	5	1	720.09803922	86.5	El Serag	5000	Aswan/Edfo	1986

Figure 6. *The GIS Classification of pump stations by Commissioned Date.*

Table 2. *Classification of the existing Pumps Stations (on East Side of the Nile River).*

Pump Stations Flow Rate Capacity (m^3/s)	Pumps Station Number	Total Flow Rate (m^3/s)	Served Area (ha)	Consumed Electric Power (Kw)
Small (0.15-0.80)	15	8.55	1457.4	1114.2
Medium (1.0 – 5.0)	28	34.00	5313.8	4165.6
Large (6.0-48.0)	13	146.00	60172.6	31308.4

Depending the available data from years 1976 and 1984, as shown at figure 7 which describe the monthly distribution of pump station such as (Hagz Station) for years 1984 and 2008. The maximum water demands for the 34 outlets nodes were calculated according to the maximum flow rate of the existing pump stations on the east side of the Nile River at the study reach. It was add 10% more for future water irrigation demands as shown in table 3.

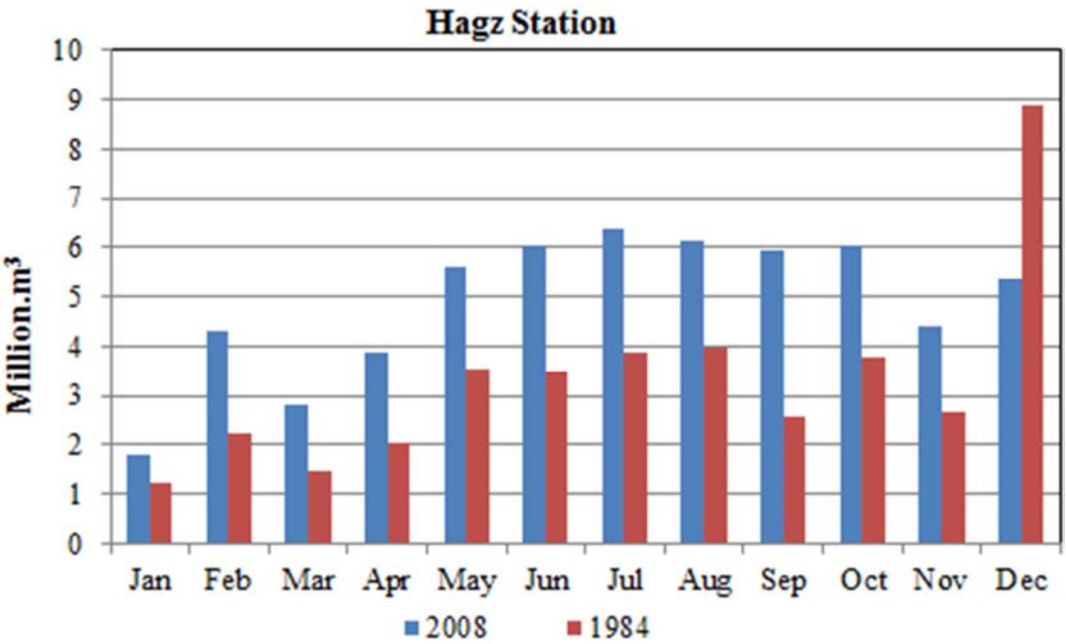


Figure 7. *Monthly Distribution of pump station flow rate (Hagz Station) for years 1984 and 2008.*

Table 3. *The maximum and future water irrigation demands for the proposed Pipeline Outlets.*

Nodes Outlets	Km from AHD	Flow Rate (m^3/s) for (24 Hours) Operation	Design Flow (m^3/s) with 10% future Extension	Accumulation Flow (m^3/s) for Pipeline
N1	6.50	0.05	0.06	68.77
N2	11.00	0.33	0.37	68.71
N3	16.00	0.27	0.29	68.35
N4	22.00	1.13	1.25	68.05
N5	23.50	0.13	0.15	66.81
N6	24.00	0.13	0.15	66.66
N7	28.00	0.27	0.29	66.51
N8	40.00	8.87	9.75	66.22
N9	43.00	0.2	0.22	56.47
N10	47.00	0.13	0.15	56.25
N11	48.00	12.07	13.27	56.10
N12	50.00	1.07	1.17	42.83
N13	56.50	0.17	0.18	41.65
N14	60.00	0.7	0.77	41.47
N15	66.80	0.33	0.37	40.70
N16	70.00	6.63	7.3	40.33
N17	75.00	0.93	1.03	33.04
N18	81.50	0.17	0.18	32.01
N19	85.00	2.17	2.38	31.83
N20	100.00	9.47	10.41	29.44
N21	102.00	0.67	0.73	19.03
N22	110.00	1.87	2.05	18.30
N23	111.00	0.27	0.29	16.24
N24	112.00	0.33	0.37	15.95
N25	116.00	1.57	1.72	15.58
N26	117.00	6.3	6.93	13.86
N27	122.00	1	1.1	6.93
N28	124.00	0.87	0.95	5.83
N29	125.00	0.67	0.73	4.88
N30	127.00	1.33	1.47	4.14
N31	130.00	0.47	0.51	2.68
N32	136.00	1.3	1.43	2.16
N33	140.00	0.53	0.59	0.73
N34	158.00	0.13	0.15	0.15
Total		62.52	68.77	

4. Hydraulic Modeling of the Proposed Pipeline

The proposed pipeline will convey the raw water from the AHD reservoir (discharge point) to the pipeline irrigation zones outlets. The driving force of the water movement inside the pipeline will be the pressure head of water upstream HAD reservoir. The key elements of design the proposed pipeline are: pipe materials, valves, pressure control devices, and automation system. The pipeline size and wall thickness are determined by flow rate, operating pressure, and trench conditions. It was established more than 34 irrigation outlets on the pipeline route to supply the water for different cultivated land zones. The pipeline was divided into four segments according to its design flow rate and pipe diameter. Table 4 describes the various pipeline segments, pipe diameters, and its design flow rates.

Table 4. *Pipeline Segments, Pipeline Diameters, and Design Flow Rate.*

Pipeline Segment	From	To	Pipeline Length (m)	Outlets Number	Flow Rate (m^3/s)	Duel Pipe Diameter (mm)
A	AHD	Komombo	53,913	11	12.68	(2 X D 3200)
B	Komombu	AR Raisiyyah	56,716	9	26.65	(2 X D 2800)
C	AR Raisiyyah	Edfo	30,283	8	23.60	(2 X D 1800)
D	Edfo	Esna	28,473	6	5.83	(1 X D 1800)
Total	AHD	Esna	169,385	34	68.76	

4.1. Pipeline Route

The proposed pipeline route is much less limited by the topography of the area rather than the case of canals. There is considerable freedom in selecting the pipeline alignment (run up and downhill) because of it is pressure pipeline. The pipeline route was located parallel to the Aswan to Luxor highway which would be preferred in order to facilitate inspection (for detection of any damage, leakage at pipe joints, faulty valves, etc.) and to provide ready access for maintenance and repair. The pipeline has been stationed beginning at AHD Reservoir (intake point) and ending at the Esna city with total length 169,385 m as shown in figures 8, 9, and 10. The pipeline profile and the surface ground elevations are shown in figure 11.

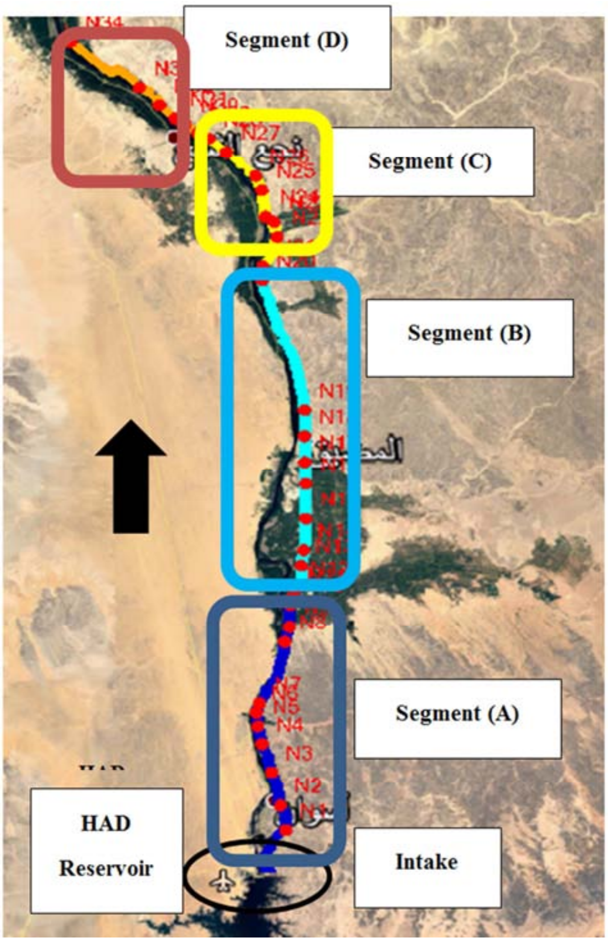


Figure 8. *Pipeline Route and the outlets points.*

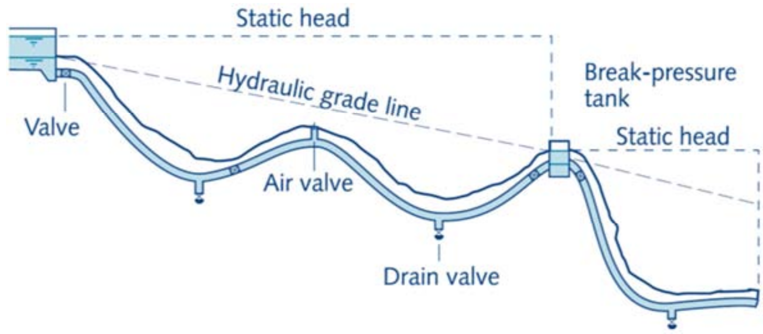


Figure 9. *Pipeline profile schematic.*

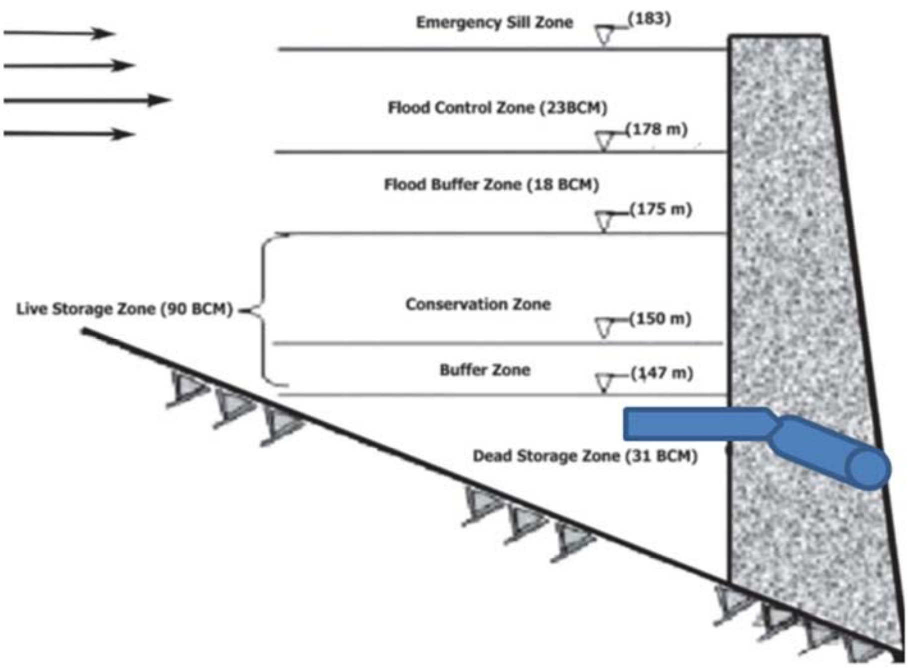


Figure 10. *Pipeline Intake water levels.*

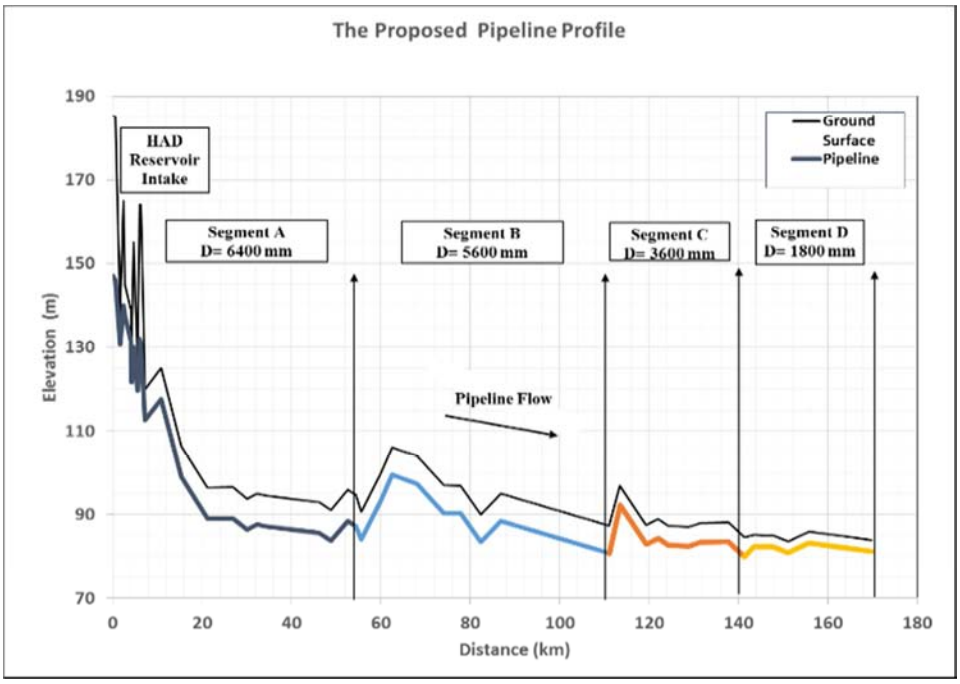


Figure 11. *Pipeline Route Profile.*

4.2. Pipeline Intake Location

The pipeline starts at a proposed intake site on the east side of AHD reservoir. The recommended location is approximately one kilometer east of AHD as illustrated in figure 12. The selected site is adjacent to deep water, has good foundation soils, access to roads, and has sufficient space to allow flexibility in the intake design. Deeper water at the intake location will increase reliability. The AHD reservoir bed elevation at the area of intake is 120 m. The AHD reservoir water levels are important design criteria influencing the location and layout of an intake site. The operation policy of the AHD reservoir is based on dividing the storage into six zones, illustrated in figure 12. The dead storage zone has a top elevation of 147 m with water volume of about 31 × 10^9 m^3. The live storage zone, which amounts to 90 × 10^9 m^3, includes the buffer zone and the conservation zone. The buffer zone lies between elevation (147 and 150) m. The conservation zone lies between (150 and 175) m. An additional storage volume of 40 × 10^9 m^3 is available for high flood waters. It is between elevation of (175 and 182) m, and brings the total lake volume up to 160 × 10^9 m^3 [1]. The water level of the reservoir changes depending on the rates of inflow and outflow. The lowest water level occurred in year 1988 at (151) m.

4.3. Pipeline Hydraulic Modeling

The pipeline is to supply irrigated water to the cultivated zones nodes at adequate pressure and flow. However, pressure is lost by the action of friction at the pipe wall. The modeling of the ultimate system was performed to properly size pipeline based on its proposed alignment and future water irrigation demands. It was evaluated the hydraulic performance of the proposed pipeline (pressure, flow rate, velocities, and hydraulic gradients) and other relevant design factors of the pipe diameters. The hydraulic modeling of the proposed pipeline was carried out. The process of the model application was achieved by:

a) Preliminary Data Collection
b) Building the model
c) Assigning water demands to each outlet node
d) Hydraulic analysis

The following data have been used for implementation the modeling of the pipeline as followings: maps with layout of the pipe route alignment; contour maps to determine the elevations of the consumption nodes; modes of operation the system (zoning); sources of water and available quantities (intake location); and future water demand patterns for the consumption outlet nodes. Once the spatial model is built, the parameters that need to be defined for each model components were determined. These parameters are: nodes (elevations and the base demands); pipe (pipe diameters, lengths and the friction coefficient factors).

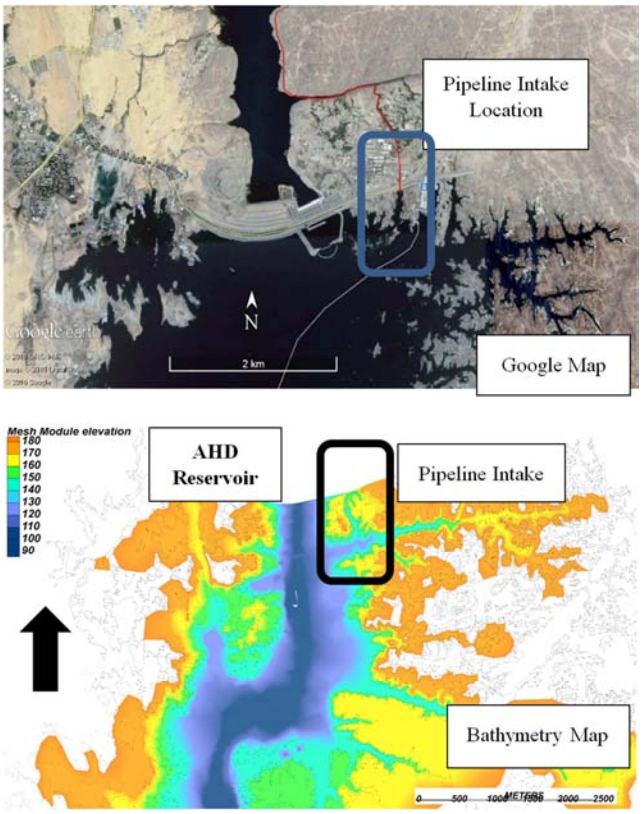


Figure 12. *The proposed pipeline intake location with reservoir bed elevation.*

The major factor to consider in pipeline hydraulic modeling is friction losses. Several empirical equations were established such as Hazen's Williams, [9]. The equation includes a roughness coefficient C, which accounts for pipeline hydraulic friction characteristics. The proposed pipeline material will be ductile iron having Hazen William friction coefficient factor of 130. The Hazen-Williams equation, which is applicable only for water in turbulent flow, expresses to calculate the head loss with the International System of Units (SI), the equation is:

$$Friction\ \ loss = 10.67\left(\frac{Flow\ rate}{Roughness}\right)^{1.85}\frac{Length}{Diameter^{4.87}} \tag{1}$$

$$H_L = 10.67\left(\frac{Q}{C}\right)^{1.85}\frac{L}{D^{4.87}} \tag{2}$$

Where HL = water head loss over the pipe length (m); L = pipe length (m); Q = flow rate, (m^3/s); C = pipe roughness coefficient; D = inside pipe diameter (m)

5. Results and Discussion

5.1. Pipeline Hydraulic Analysis Results

The pipeline hydraulic analysis was carried for various scenarios of water levels upstream of High Aswan Dam (AHD), and water irrigation demands, to determine flow velocities and pressure heads characteristics. The modeling scenarios were applied for the AHD reservoir water levels values as shown in the following table 5. The hydraulic grade lines and pipeline outlets pressure head of the proposed pipeline for different reservoir water levels scenarios were performed as shown in figure 13 and figure 14. The total head losses of the pipeline was calculated (49) m as shown in tables 6, and 7.

Table 5. *Modeling scenarios applied for the water levels.*

Scenario No.	Water Level upstream of High Aswan Dam (HAD) (m)	Notes
1	(147.00) m	Start of the buffer zone (live storage zone)
2	(150.00) m	Start of conservation zone (live storage zone)
3	(175.00) m	Start of flood buffer zone (flood storage zone)
4	(178.00) m	Start of flood control zone(flood storage zone)

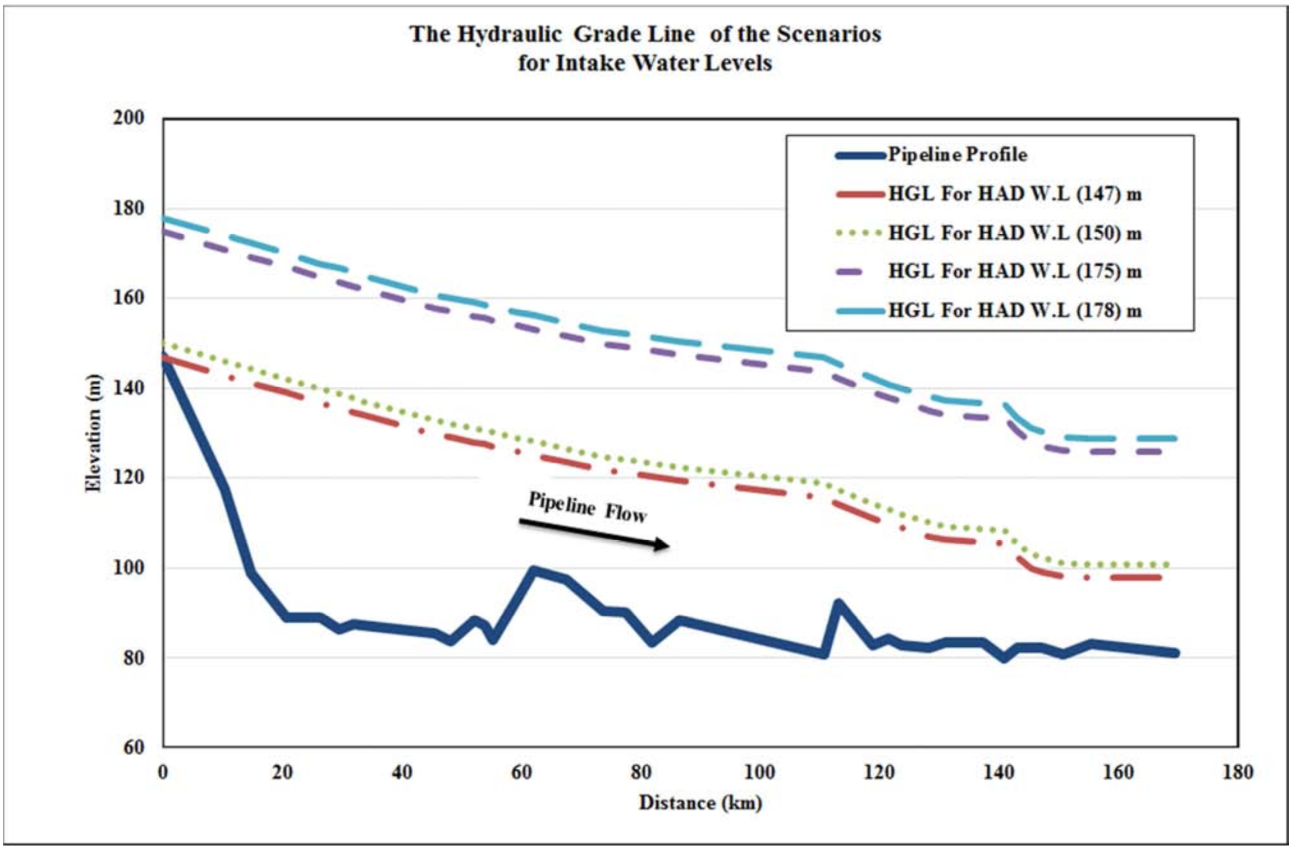


Figure 13. *Hydraulic Grade Line of the proposed pipeline for different reservoir water levels.*

Table 6. *The Pipeline Velocity and Head losses.*

Label	Pipe Length (m)	Diameter (mm)	Flow (m^3/s)	Velocity (m/s)	Pipe Head loss (m)
P-1	10,334	6400	68.76	2.14	4.02
P-2	4,509	6400	68.70	2.13	1.75
P-3	5,965	6400	68.33	2.12	2.30
P-4	5,609	6400	68.04	2.11	2.14
P-5	3,146	6400	66.79	2.08	1.16
P-6	2,362	6400	66.64	2.07	0.87
P-7	1,730	6400	66.49	2.07	0.63
P-8	12,001	6400	66.20	2.06	4.36
P-9	2,669	6400	56.45	1.75	0.72
P-10	3,774	6400	56.23	1.75	1.01
P-11	1,815	6400	56.08	1.74	0.48
P-12	1,279	5600	42.81	1.74	0.40
P-13	4,268	5600	41.64	1.69	1.26
P-14	2,669	5600	41.46	1.68	0.78
P-15	5,497	5600	40.69	1.65	1.55
P-16	6,065	5600	40.32	1.64	1.69

Label	Pipe Length (m)	Diameter (mm)	Flow (m^3/s)	Velocity (m/s)	Pipe Head loss (m)
P-17	3,704	5600	33.02	1.34	0.71
P-18	4,549	5600	31.99	1.30	0.82
P-19	4,492	5600	31.81	1.29	0.81
P-20	24,194	5600	29.43	1.19	3.76
P-21	2,405	3600	19.02	1.87	1.43
P-22	5,844	3600	18.29	1.80	3.24
P-23	2,672	3600	16.24	1.59	1.19
P-24	2,188	3600	15.95	1.57	0.94
P-25	4,636	3600	15.58	1.53	1.91
P-26	2,623	3600	13.86	1.36	0.87
P-27	6,274	3600	6.93	0.68	0.58
P-28	3,640	3600	5.83	0.57	0.24
P-29	2,044	1800	4.88	1.92	2.87
P-30	2,382	1800	4.15	1.63	2.48
P-31	1,923	1800	2.68	1.05	0.89
P-32	3,389	1800	2.17	0.85	1.06
P-33	4,650	1800	0.74	0.29	0.20
P-34	14,085	1800	0.15	0.06	0.03
					49.15

Table 7. *The Pipeline Outlet Pressure Head.*

Nodes	Elevation (m)	Demand (m/s)	Hydraulic Grade (m)	End Pressure (bar)
Reservoir	147.00	68.76	147.00	Free Surface
N1	117.6	0.06	142.98	2.49
N2	99.01	0.37	141.22	4.14
N3	89.05	0.29	138.93	4.89
N4	89.12	1.25	136.79	4.68
N5	86.36	0.15	135.63	4.83
N6	87.6	0.15	134.76	4.63
N7	87.15	0.29	134.12	4.61
N8	85.6	9.75	129.77	4.33
N9	83.71	0.22	129.05	4.45
N10	88.46	0.15	128.03	3.88
N11	87.22	13.27	127.55	3.96
N12	84.05	1.17	127.15	4.23
N13	93.27	0.18	125.89	3.20
N14	99.52	0.77	125.11	2.51
N15	97.40	0.37	123.56	2.57
N16	90.40	7.30	121.87	3.09
N17	90.29	1.03	121.16	3.03
N18	83.40	0.18	120.34	3.62
N19	88.40	2.38	119.53	3.05
N20	80.80	10.41	115.78	3.43
N21	92.27	0.73	114.35	2.17
N22	82.96	2.05	111.11	2.76
N23	84.4	0.29	109.92	2.50
N24	82.79	0.37	108.98	2.57
N25	82.41	1.72	107.07	2.42
N26	83.4	6.93	106.20	2.24
N27	83.55	1.1	105.63	2.17
N28	80.02	0.95	105.38	2.49
N29	82.33	0.73	102.51	1.98
N30	82.23	1.47	100.03	1.75
N31	82.25	0.51	99.14	1.66
N32	80.87	1.43	98.08	1.69
N33	83.20	0.59	97.88	1.44
N34	81.20	0.15	97.85	1.63

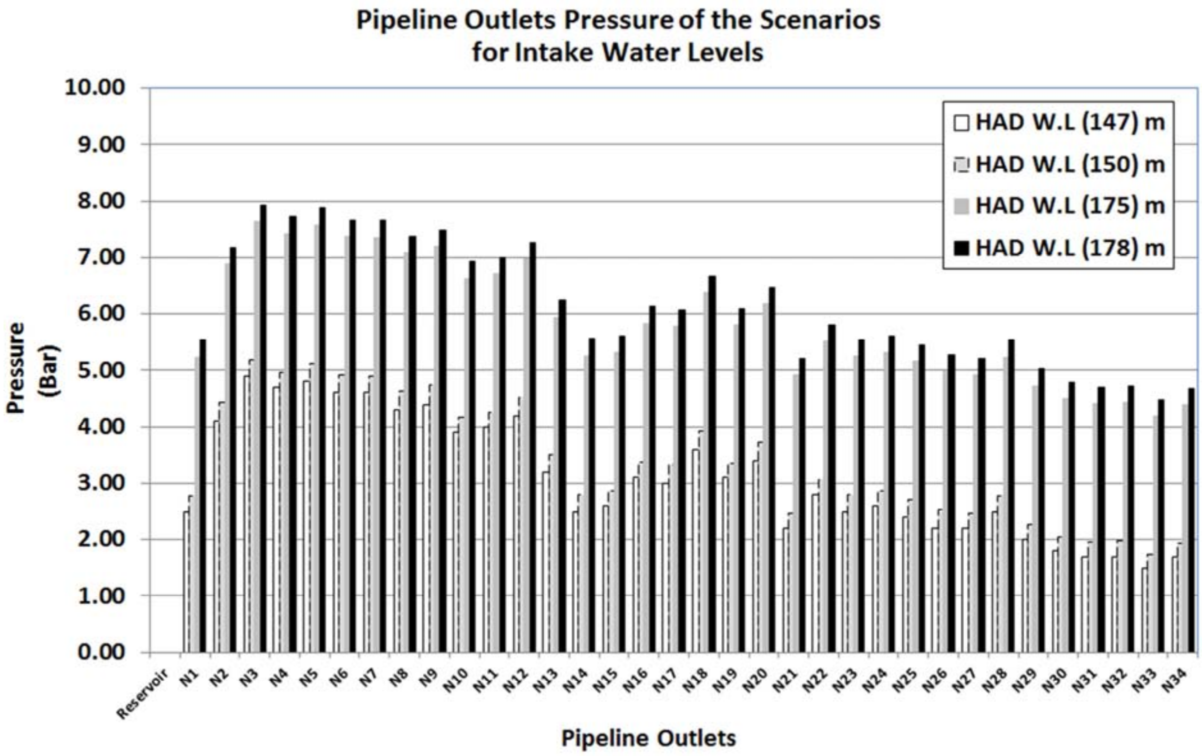


Figure 14. *Pipeline Outlets Pressure Head for different Reservoir Water Levels.*

5.2. Harvest Energy from the Proposed Pipeline

As a result of pass the part of the water from the reservoir through the pipeline intake, this will reduce the amount of water through the existing AHD hydropower plant. It was estimated that the reduction of the electricity power generated from AHD will be 4%. However; the energy produced from the proposed hydropower plant of pipeline intake will compensate the electrical power lost from the existing AHD hydropower plant. In Addition, the proposed pipeline will harvest energy from the outlets at irrigated zones. The energy system uses an in-conduit turbine that spins as water passes through it. It can produce clean, reliable, low-cost electricity with no impact on the environment or water delivery. The maximum hydropower power output at the pipeline outlets is entirely dependent on how much head and flow rate are available. The hydropower equation is:

$$P = m \times g \times H_{net} \times \eta \quad (3)$$

Where:

P: Power is the rate of producing energy which is measured in Watts;

m: Mass flow rate in kg/s;

g: the gravitational constant, which is 9.81in m/s^2;

H_{net}: the net head in m;

H: the overall system efficiency would be 90%.

Using data from the World Energy Council; the global average electricity consumption for households with electricity was roughly 3,500 kWh in 2010, [10]. The pipeline outlets energy generation and the number of houses homes powered were calculated for the future irrigation demands of different water levels upstream of AHD as shown in table 8.

Table 8. *The pipeline outlets energy generation and the number of houses homes powered.*

Scenario No.	Water Level upstream of High Aswan Dam (HAD) (m)	Pipeline outlets Energy Generation (kW hrs. /year)	No. of houses Powered
1	(147.00) m	26,382,741	6,040
2	(150.00) m	28,730,389	6,577
3	(175.00) m	48,294,124	11,056
4	(178.00) m	50,641,772	11,594

5.3. Water Distribution System Improvement

The proposed pipeline will improve the water distribution system of the study reach. There are two main systems of rotation (for distributary canal) at the study reach. The first is Two turn rotation (5 days on period and closed for another 5 days, or 4 days on and 6 days off for rice growing areas) and the second is Three turn-rotation (7 days on and 14 days off). Rotational system has negative effects such as: could not match irrigation intervals and crop or soil requirements; could not support channel storage capacity; could not stop high side slope damage within off periods and low bank level; and has high cost of canal cross sections and structures. The proposed pipeline will introduce the continuous flow all the time in the canal distribution system which leads to increase irrigation water efficiently. The advantage of pipeline is the continuous flow until the end of the canal; the irrigation could be adjusted according to the crops water requirements not according to the water availability in the canal; the irrigation is enhanced at the canals ends by reducing the soil salinity from the reuse of drainage water. However the pipeline irrigation needs skilled operating staff to adjust the flow rate and irrigation duration.

5.4. Pipeline Cost Estimation

The evaluation of water management strategies requires the development of cost estimates. The costs of the proposed pipeline and its intake are dependent on various factors, which include conveyed water quantity and quality, pipe length, operating pressure, soil properties and underground conditions, pipeline trench depth, appurtenances such as valves and automation system. The cost of the proposed pipeline was estimated for two components: Initial capital costs, including engineering and construction costs, and average annual costs, including annual operation and maintenance costs is shown in table 9. It is possible to set up the pipeline in stages, depending on the available of financial funding for the construction according to the following factors attached in table 10.

Table 9. *Pipeline capital costs and operation and maintenance costs.*

	Item	Costs US dollar ($)
A	Capital Costs	
1	Installed pipe, including appurtenances	437,963,000
2	Intake structures	27,900,000
3	Outlet structures	3,860,000
	Total	469,723,000
B	*Operation and Maintenance Costs/year*	
1	pipeline	3,850,000
2	Intake	4,100,000
	Total / year	7,950,000

Table 10. *Pipeline Segments Cost Percentage.*

Segment	From	To	Percentage of Length (%)	Percentage of Convey Flow (%)	Percentage of Total Cost (%)
A	HAD	Komombu	32%	18%	45%
B	Komombu	AR Raisiyyah	33%	39%	35%
C	AR Raisiyyah	Edfo	18%	34%	14%
D	Edfo	Esna	17%	7%	6%

6. Conclusion

This paper aims to suggest a strategic project to adapt climate changes impacts in water resources irrigation. This could be achieved by use pipeline in irrigation rather than fossil fuel pumps in Egypt. The case study is the eastern reach between Aswan High Dam and Esna barrage. The agriculture lands there are higher than Nile level, so irrigation pumps are used to lift water. These irrigation pumps could be replaced be pipeline at high level lands. The RS application was carried out to get spatial distributions of cultivated lands nearby irrigation pipeline outlets. The Modis was used to develop vegetation map for the east side of the river at the study reach. This map provides spatially detailed cultivated land distribution that support future plans of irrigation. It was estimated that the total cultivated areas are 206692 feddan at year 2015. The GIS module was used to assemble the collection data of the existing irrigation pump stations at the study reach in different layers through geo-database. Depending on the available data, it was established 34 outlets nodes on the pipeline route to supply the water for different cultivated land zones. The future water irrigation demands of the outlets nodes were computed according to the available data. The hydraulic modeling of the pipeline was carried out. The pipeline was divided to four segments according to its design flow rate and diameters. The model simulation of the ultimate system was performed to properly size the pipeline based on its proposed alignment, and future water irrigation demands. The results of the study show that the proposed solution would provide more reliable, less cost effective strategy to meet future water supply needs, and adapt climate changes impacts in water resources. This could be achieved by replacement the existing irrigation pump stations by water pipeline with total length 169 km. In additional, the pipeline would provide multiple benefits such as harvest renewable, low-cost electricity and clearly help reduce energy consumption and in turn reduce carbon emissions. For the future work, it will study the effect of the shortage of water release from AHD on the water levels at the Nile River of the study reach and its impact on navigation operation. In addition, it should be investigated the impacts on changing the irrigation rotation system (not only the flow rate, but also the flow irrigation duration) at the study reach as a consequence of continuous water flow all the time in the canals distribution system and its influence on the crop water requirements, operating authorities and the farmers.

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