CHAPTER ONE

INTRODUCTION

1.1 Introduction

In January 2005 the Sudanese Government in Khartoum and the Sudan People's Liberation Army in South Sudan signed a Comprehensive Peace Agreement putting an end to twenty two years of continuous civil war. Following a referendum in 2011 the Republic of Southern Sudan was created and the northern part remains the Republic of Sudan.

1.2 Political and Administrative Structure:

The Republic of Sudan lies between latitudes 23.142863^{o} north & 8.641127^{o} south, and longitudes 38.590926^{o} east & 21.813157^{o} west. It covers an area of 1.9 million km^2. The population is estimated to be 30.9 million people. 50% of the populations live in the Nile River basin which represents about 15% of its landmass. It shares borders with Egypt, Libya, Chad, Central Africa, Ethiopia, Eritrea, and South Sudan.

It is administered as 17 federating States with a National Government based in Khartoum. The administration at local government levels in each State is organized into Mahalias or Localities.

The main economic activities in the rural areas are agriculture and livestock rearing with about two thirds of the population engaged in small holdings. Prior to the creation of South Sudan the country earned revenues from producing 500,000 barrels of crude oil per day. However it lost 75% of the oil reserves to South Sudan.

1.3 Relief and Drainage:

Most of Sudan is flatland with an altitude in the range of 300 – 600 m above sea level. Isolated highlands are found across the country. These include the Jebel Marra Plateau to the west of the country, the Nuba mountains to the south and the Red Sea Hills to the north east. The average elevation of these highlands is 1000 m above sea level.

The major drainage basin in Sudan is the Nile River, often described as the lifeline of the country because in an otherwise arid terrain, the Nile plays a crucial role in the country's various ecosystems. Its tributaries, the Blue Nile and the White Nile flowing from Ethiopia and Uganda respectively, meet in Khartoum before flowing north into Egypt and eventually into the Mediterranean sea. The western part of the country is drained by the Wadi Azum with its headwaters in the Jebel Marra in Darfur and eventually empties into the Chad basin. Sudan also has a 750 km long coastline and territorial waters in the Red Sea, north east of the country.

1.4 Climate and Vegetation:

Over 50% of Sudan lies within the desert or semi arid zone where rainfall is insufficient and highly variable and the temperatures are high. Average annual rainfall ranges between 400 mm in the south to much less than 100 mm in the north. Temperatures can be as high as 45^oC. Sudan like other countries in the Sahel belt has suffered episodes of devastating droughts in the past decades. The Sudan climate change study conducted in 2003 indicates an average annual temperature rise of between 0.5 to 1.5^oC and a 5% drop in annual rainfall. The implication is a major and potentially disastrous decline in crop production (UNEP, 2003).

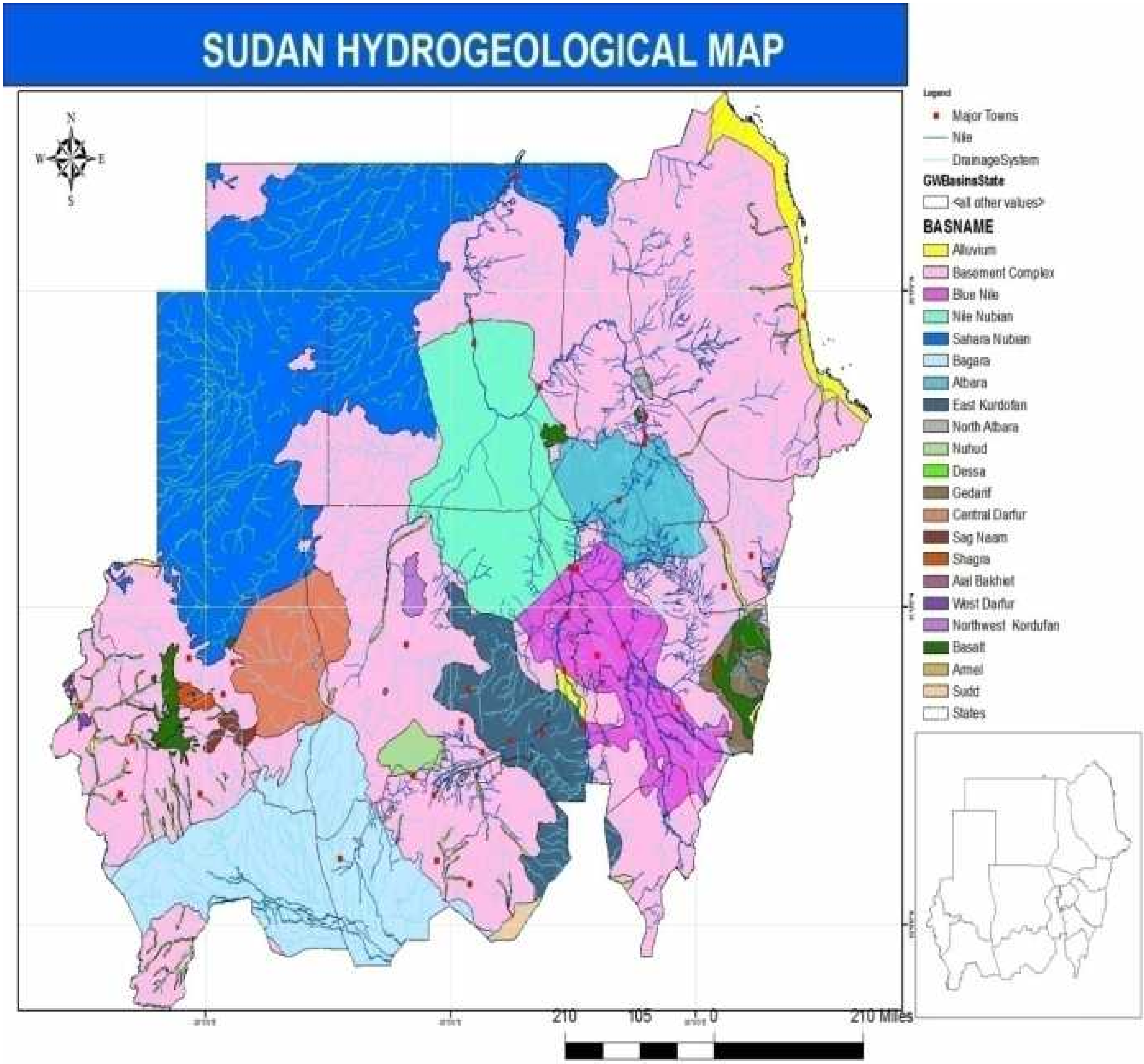

Figure (1.1): Sudan Hydro geological Map

1.5 Project Site:

South Darfur State is located in the western part of Sudan and covers an area of 127,300km^2 and administratively divided into 30 localities with the total population is 4,309,227 that expected to reach 5,026,709 persons by 2016 and estimated livestock load of 14,988,010 that expected to reach 17,785,839 by 2016. Due to the current emergency situation, the state has a total of 1,016,692IDPs. Access to improved water sources for the state population as per 2008 census was 52.1% (urban: 92.5%, rural: 41.2%) with the average daily per capita consumption of 13 l/c/d (urban: 16.1, rural: 12.2 l/c/d) as of 2010. About 90% of the state's IDPs have access to improved drinking water with the average daily per capita consumption of 13.0 L/C/d. For Nyala city, the population is about 519,677 persons and expected to be 606,202 persons on 2016.The average water consumption for one person is about 16 L/C/day, and expected to be 48.9L/C/Day. The production of the water is about 8,521m^3/day and expected to reach 29,636m^3/day on 2016 as per state strategic plan.

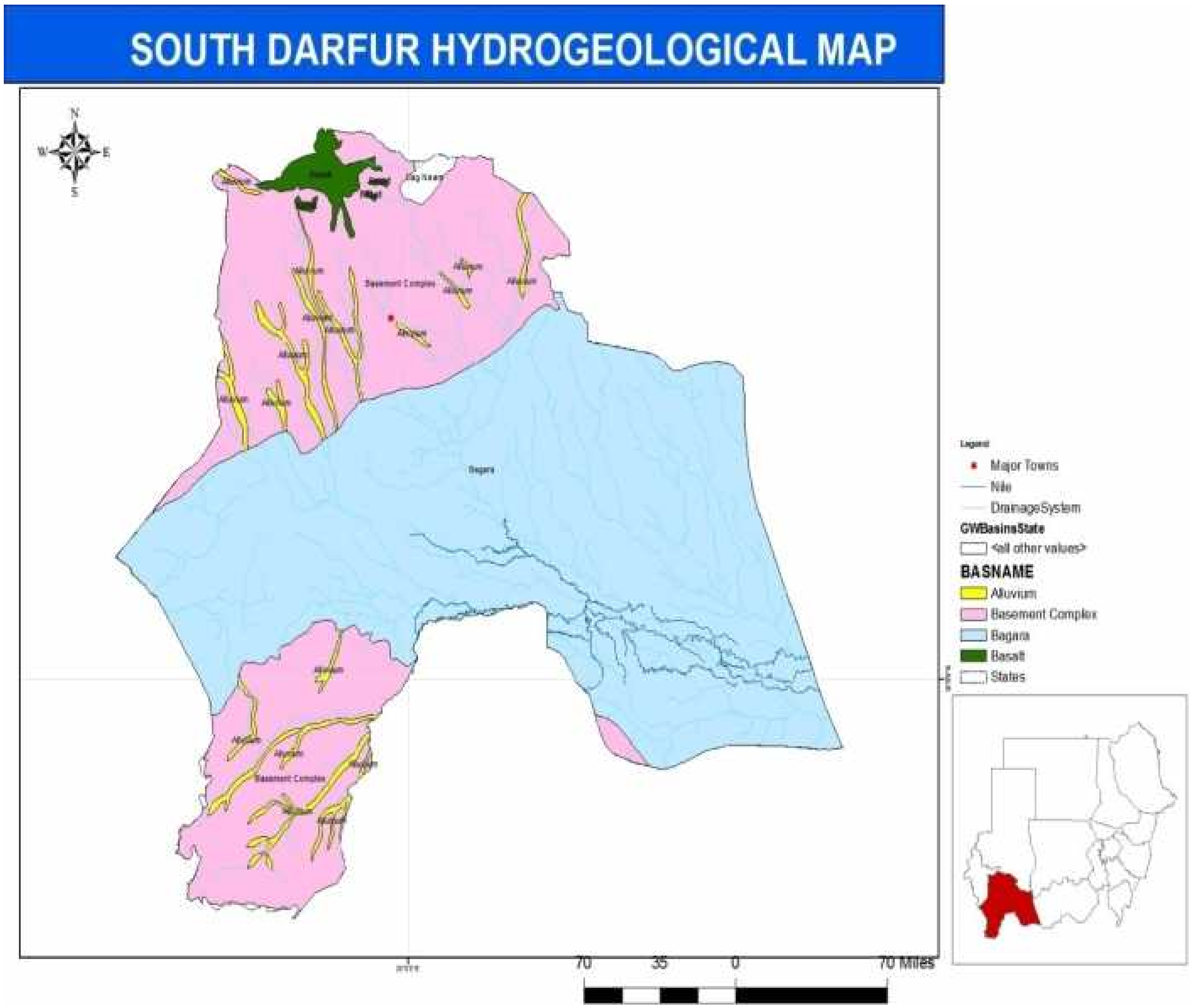

Figure (1.2): South Darfur Hydro geological Map

1.6 Problem Statement:

The Public Water Corporation (Drinking Water & Sanitation Unit now) is suggested to supply Nyala town by water pipeline from Geraida basin which was about 85 kilometer on the southern part of the state.

The project is already designed and under construction. The components of the project are as follows:

a) Water intake: well field, connection pipes, the design capacity for single well is $2000m^3$/day, and the total number of wells is 20.
b) The submersible pumps are of $80m^3$/hr., 100m head, and 37KW.
c) The elevation difference between Nyala & Geraida is about 218 meter above sea level.
d) First pump station has collecting reservoir from steel tank, boosting pump, power station, and $1500m^3$ tank. The working pressure in boosting is 1.4 MPa.
e) Other pump stations are with balancing reservoir tank of $800m^3$, three pumps (two in operation & one standby) of $850m^3$/hr, and 140m head.
f) Two Service reservoirs at Nyala city each $4000m^3$.
g) At each pump station there was 3 gen set of 750KW for each.
h) The pipe line was 700mm dia. And consisting of three pump stations.
i) Well field network pipe diameter is range from 200mm to 500mm.
j) The first pump station is located at 26Km from the well field, the 2nd booster is about 44Km, and the 3rd is about 72Km.
k) The fuel consumption for the total power stations is about $40m^3$/day.

1.7 Objectives of the Study:

The objective of this study is to review, evaluate and assess the existing components of the project design, identify the problems in the components of the existing design, and get suitable and sustainable design for the project.

1.8 Methodology:

1.8.1 Review of the available design

The available design was as follows:

a) The design proposed about twenty (20) boreholes, of $2000m^3$/day for each, will be drilled in Gerida area, each borehole will be equipped with a submersible pump of about $85m^3$/hr and 100m head, and water from these boreholes will be pumped and collected in one point and after that pumped by a booster pumps. In the collection point, the pumping unit was contain three pumps (2 in duty & 1 standby) of $850m^3$/hr, 140m head each, the source of the power is four diesel generators (3 in duty & 1 standby) of 750KW each was used.
b) The field pumping unit will pump up to kilo 26 and after that another pumping unit (first pump station) was designed to pump by 3 units, (2 in duty and 1 standby) and three power generators of 750KW accordingly (2 duty and 1 standby), up to kilo 44, and after that pumped by the second pumping station with same components (3 pumps and 3 generators) up to kilo 72, and after that again pumped by similar units up to kilo 85 , water collecting point, at Nyala town.
c) The pipe material used is ductile iron, with 700mm diameter. The diesel generators used in this project are of 750 KW and the fuel consumption of the well field pump station is about $14.61m^3$/day ($4.9m^3$/day for each generator) or about 608.75lit/hr, and for the other stations the fuel consumption is about $9.76m^3$/day or about 406.7lit/hr ($4.9m^3$/day for each generator).
d) From the above figures, the fuel consumption of the used 750KW generator is about 203.4 lit/h.

1.8.2 Data needed for the study:

The study was searching for solution for the hydraulic design of the project, so all data which used for this project was collected from available study and information from our colloquies at state water corporation and Drinking Water & Sanitation Unit.

First of all the researcher collected the elevation difference between well field and Nyala town by different distance intervals as follows:

Table (1.1): Pipeline Route Elevation Readings

Distance Point (Km)	**Elevation (m)**
00.00	489.50
25.00	530.32
26.00	532.36
27.00	534.21
28.00	535.48
29.00	536.26
30.00	537.86
31.00	538.46
32.00	544.44
33.00	547.20
34.00	543.77
35.00	549.19
36.00	552.46
37.00	557.34
38.00	562.39
39.00	569.22
40.00	576.34
41.00	584.61
42.00	588.54
43.00	592.80
44.00	598.54
45.00	602.05
50.00	604.46
55.00	606.38
56.00	614.45
57.00	616.20
58.00	622.57

59.00	623.16
60.00	617.97
65.00	622.50
66.00	623.18
67.00	632.26
68.00	632.36
69.00	634.19
70.00	632.17
71.00	628.65
72.00	630.47
74.00	641.70
76.00	638.20
78.00	637.49
80.00	641.57
85.00	707.80

* Source: Drinking Water & Sanitation Unit.

The above figures were used to calculate the head loss along the pipeline.

Also the researcher met the Public Water Corporation officials, state Water officials, Ground Water Directorate officials, and other related technical personnel to get the necessary data regarding to the ground water availability studies, boreholes production capacity, and design of the pumping stations& transmission line. From these discussions found that the aquifer is one of the successful aquifers in the country, and can be the solution for Nyala town water problem. The production of the borehole as mentioned in the studies done in this aquifer, about 2000m^3/day, and that was found by drilling test boreholes around the project proposed area.

CHAPTER TWO

Literature Review

2.1 Definition and Scope:

The term pipe is defined herein as a closed conduit, usually of circular cross section. It can be made of any appropriate material such as steel or plastic. The term pipeline refers to a long line of connected segments of pipe, with pumps, valves, control devices, and other equipment/facilities needed for operating the system. It is intended for transporting a fluid (liquid or gas), mixture of fluids, solids, fluid solid mixture, or capsules (freight-laden vessels or vehicles moved by fluids through a pipe).

2.2 Brief History of Pipelines:

The use of pipelines has a long history. For instance, more than 1,000 years ago, the Romans used lead pipes in their aqueduct system to supply water to Rome. As early as 400 B.C., the Chinese used bamboo pipes wrapped with waxed cloth to transport natural gas to their capital Beijing for lighting. Clay pipes were used as early as 4000 B.C. for drainage purposes in Egypt and certain other countries.

An important improvement of pipeline technology occurred in the 18th century when cast-iron pipes were manufactured for use as water lines, sewers, and gas pipelines. A subsequent major event was the introduction of steel pipe in the 19th century, which greatly increased the strength of pipes of all sizes. In 1879, following the discovery of oil in Pennsylvania, the first long-distance oil pipeline was built in this state. It was a 6-inch-diameter, 109-mi-long steel pipeline. Nine years later, an 87-mi-long, 8-inch-diameter pipeline was built to transport natural gas from Kane, Pennsylvania to Buffalo, New York. The development of high-strength steel pipes made it possible to transport fluids such as natural gas, crude oil, and petroleum products over long distances. Initially, all steel pipes had to be threaded together, which was difficult to do for large pipes, and they often leaked under high pressure. The development of electric arc welding to join pipes in the late 1920s made it possible to construct leak proof, high-pressure, large-diameter pipelines. Today, virtually all high-pressure piping consists of steel pipe with welded joints. Large seamless steel pipe was another major milestone achieved in the 1920s. Major innovations in pipeline technology made since 1950 include:

a) Introduction of new pipeline materials such as ductile iron and large diameter Concrete pressure pipes for water and PVC (polyvinyl chloride) pipe for sewers
b) Use of pigs to clean the interior of pipelines and to perform other functions
c) Batching of different petroleum products in a common pipeline
d) Application of cathode protection to reduce corrosion and extend pipeline life
e) Use of large side booms to lay pipes, machines to drill or bore under rivers and roads for crossing, machines to bend large pipes in the field, x-rays to detect welding flaws, and so forth.

Since 1970, major studies have been made in new pipeline technologies including trenchless construction (e.g., directional drillings, which allow pipelines to be laid easily under rivers, lakes, and other obstacles, without having to dig long trenches), pipeline integrity monitoring (e.g., sending intelligent pigs through pipes to detect pipe wall corrosion, cracks, and other pipe flaws), computers to control and operate pipelines, microwave stations and satellites to communicate between headquarters and remote stations, and new pipeline technologies to transport solids over long distances (e.g., slurry pipelines for transporting coal and other minerals, and capsule pipelines for bulk materials transport).

2.3 Existing Major Pipelines:

Most of the major oil and gas pipelines that exist today around the world were constructed either during or after World War II. In most cases, they were built to meet compelling national or international needs. For instance, the U.S. built the Big Inch and the Little Big Inch pipelines during World War II to counter the threat of German submarine attacks on coastal tankers. In the 1960s the Colonial Pipeline Company built a large product pipeline from Houston, Texas to New York City to counter a strike of the maritime union. The Arab oil embargo in 1973 prompted the construction of the Trans-Alaska pipeline to bring crude oil from the oil-rich fields of Prudhoe Bay located on the Aortic Ocean north of Alaska to an ice-free port at Valdez on the south shore of Alaska. The Big Inch was a 24-inch (61-cm) line designed to transport 300,000 bpd (barrels per day) of crude oil, and the Little Big Inch was a 20-inch (51-cm) product pipeline designed to deliver 235,000 bpd. Both lines extend from Texas to the East Coast. They were built between 1942 and 1943 (during World War II) by the U.S. government, but were sold after the war (in 1947) to the Texas Eastern Transmission Corporation (TETCO), and converted to transport natural gas. Later, TETCO expanded both lines, and converted the Little Big Inch back to petroleum products.

Although statistics on water pipes and sewers are lacking because they are too numerous, there is little doubt that the U.S. has the world’s most extensive network of water pipelines and sewers. According to estimates of the American Water Work Association (AWWA), the distribution network for large water supply systems in the U.S. comprises about 600,000 mi of pipe. Adding water pipelines for irrigation and various industrial uses, and adding pipelines of countless small distribution networks, it is reasonable to expect that the U.S. has well over 1 million mile of water pipelines, and about 1 million mile of sewers. Together they exceed the mileage of oil and natural gas pipelines combined. The largest diameter pipelines in the world are water pipelines. For instance, it is not uncommon to see penstocks (i.e., water pipe for hydropower generation) of diameter greater than 10 ft or 3 m. Aqueducts for long-distance transport of water may also use larger pipes either for the entire length of the aqueduct or portions of it. Note that aqueducts are mostly open channels (canals), which also use pipes (circular conduits) as inverted siphons to cross existing watercourses from beneath. These inverted siphons vary in length from 0.4 to 3.2 km. For example, a part of the aqueduct that brings water from the Colorado River to central Arizona uses pre-stressed concrete pipes of 6.4 m (21 ft) inner diameter. The “Great Man-Made River,” an underground pipeline built in Libya, uses pre-stressed concrete cylinder pipes of diameters varying from 1.6 to 4.0 m (5.2 to 13 ft). The total length of the pipeline is 1900 km (1180 mi). It was designed to transport water collected from aquifers in the southern part of Libya to the cities and agricultural area in the north. It is the world’s most ambitious and costly pipeline project for water supply and irrigation. The cost of the first half of the project exceeded $10 billion.

2.4 Types of Pipelines:

Pipelines can be categorized in many different ways. Depending on the commodity transported, there are water pipelines, sewer, natural-gas pipelines, oil pipelines (for crude oil), product pipelines (for refined petroleum products such as gasoline, diesel, or jet fuel), solid pipelines (freight pipelines) for various solids, etc. According to fluid mechanics or the types of flow encountered, pipelines can be classified as single-phase incompressible flow (such as water pipelines, oil pipelines, and sewers), single-phase compressible flow (natural gas pipelines, air pipelines, etc.), two-phase flow of solid-liquid mixture (hydro-transport), two-phase flow of solid-gas mixture (pneuma-transport), two-phase flow of liquid-gas mixture (oil-gas pipelines), non-Newtonian fluids, and finally, the flow of capsules. This type of classification is the best one from a scientific (analytical) standpoint since different pipelines of the same flow type are covered by the same fluid mechanic equations.

Other methods of classifying pipelines also exist. For instance, depending on the environment or where pipelines are used, there are offshore pipelines, inland pipelines, in-plant pipelines, cross-mountain pipelines, etc. Depending on the type of burial or support, pipelines may also be classified as underground, aboveground, elevated, and underwater (submarine) types. Depending on pipe material, there are steel, cast iron, plastic, concrete, and other types. Table 1.1 lists the classification of pipelines in various ways.

2.5 Components of Pipelines:

A pipeline is a complex transportation system. It includes components such as pipe, fittings (valves, couplings, etc.), inlet and outlet structures, pumps (for liquid) or compressors (for gas), and auxiliary equipment (flow meters, pigs, transducers, cathode protection systems, and automatic control systems including computers and programmable logic controllers).

2.6 Advantages of Pipelines:

For the transport of large quantities of fluid (liquid or gas), a pipeline is undisputedly the most favored mode of transportation. Even for solids, there are many instances that favor the pipeline over other modes of transportation. The advantages of pipelines are:

1. Economical in many circumstances. Factors that favor pipelines include large throughput, rugged terrain and hostile environment (such as transportation through swamps). Under ordinary conditions, pipelines can transport fluids (liquids or gases) at a fraction of the cost of transportation by truck or train. Solid transport by pipeline is far more complex and costly than fluid transport. Still, in many cases,

pipelines are used to transport solids because the cost is lower than for other modes of transportation, such as trucks.

2. Low energy consumption. The energy intensiveness of large pipelines is much lower than that of trucks, and is even lower than that of rail. The energy intensiveness is defined as the energy consumed in transporting unit weight of cargo over unit distance, in units such as Btu per ton mile.

3. Friendly to environment. This is due mainly to the fact that most pipelines are underground. They do not pose most of the environmental problems associated with trucks and trains, such as air pollution, noise, traffic jams on highways and at rail crossings, and killing animals that strayed on highways and railroads. Oil pipelines may pollute land and rivers when a leak or rupture develops. However, far more spills would occur if trucks and trains transported the same oil.

Table (2.1): **Classifications of Pipelines:**

#	**Pipeline Classifications**	
1	**According to commodity transported**	
		1- Water pipelines
		2- Sewage pipelines (sewer)
		3- Natural gas pipelines
		4- Oil pipelines (for crude oil)
		5- Product pipelines (for petroleum products such as gasoline, diesel, jet fuel, etc.)
		6- Solid pipelines (coal, other, minerals, and solid wastes, wood pulp, mail,

		parcels, consumer goods, etc.)
		7- Other (air, chemicals, hazardous waste, etc.)
2	**According to fluid mechanics**	
		1- Single-phase incompressible flow
		2- Single-phase compressible flow
		3- Two-phase flow solid-liquid mixture(hydro-transport)
		4- Two-phase flow solid-gas mixture(penumatransport)
		5- Two-phase flow liquid-gas mixture
		6- Two-phase flow of capsules
		7- Non-Newtonian fluids
3	**According to Environment**	
		1- Offshore pipelines
		2- Inland pipelines
		3- In-plant pipelines
		4- Mountain(or cross-mountain) pipelines
		5- Space pipelines (pipelines to be built in outer spaces, such as for space exploration on another planet)
4	**According to the type of Burial or Support**	
		1- Underground pipelines
		2- Aboveground pipelines
		3- Elevated pipelines

		4- Underwater (submarine) pipelines
5	**According to pipe Material**	
		1- Steel pipelines
		2- Cast-iron pipelines
		3- Plastic pipelines
		4- Concrete pipelines
		5- Others (clay, glass, wood stove, etc.)

4. Safe for humans: This is especially true for liquid pipelines and liquid solid pipelines. The safety of natural gas pipelines is always of strong concern. Gas pipelines under high pressure can explode; however, if trucks and trains transported the same natural gas, it would be much more dangerous to the public. So, in general, it can be said that pipelines are much safer than all other land-based modes of freight transport. For instance, based on statistics published by the U.S. Department of Transportation, during the 12-year period between 1988 and 1999, the average number of people killed (injured) by pipelines per year was 23 (107), which includes 21(92) for natural gas pipelines, and 2(15) for hazardous liquid pipelines. In contrast, the number of people killed (injured) by large trucks per year during the same period was 5,162 (133, 167). This shows that there were 200 times more people killed and 1000 times more people injured by trucks than by pipelines. It can be concluded that pipelines are enormously safer than trucks and trains.

5. Unaffected by weather: Weather does not affect pipelines because most of them are buried underground below the frostline.

6. High degree of automation: This makes pipelines the least labor-intensive of all transportation modes. Note that labor-intensive societies generally have low living

standards. The high living standard in the U.S. would not be possible without automation.

7. High reliability: Because pipeline operation is continuous, automatic, and unaffected by weather, pipelines are highly reliable. Furthermore, they are least affected by labor strikes, holidays, delivery schedules, etc. The system operates continuously around the clock without stop.

8. Less sensitive to inflation: Due to high capital cost and low operational cost, pipeline tariffs are less sensitive to inflation than tariffs for trucks and trains. However, high capital cost is great when the interest rate is high.

9. Convenience: Water and gas pipelines transport commodities directly to homes, a great convenience to the public. Oil pipelines bring crude oil to refineries and bring refined petroleum products, such as gasoline and diesel fuel, to the market without the products leaving the pipelines. Even when one puts gasoline in a car at a filling station, the gasoline moves through a short pipe (hose) fitted with a nozzle.

10. Less susceptible to theft: Because pipelines are mostly underground and enclosed, the commodities transported by pipelines are less susceptible to theft than those transported by truck and train.

11. Efficient land use: Underground pipelines allow surface land to be used for other purposes. This results in more efficient land use.

12. High degree of security: Because pipelines are underground and fixed to the ground, terrorists cannot hijack a pipeline, as they can trucks and aircraft, and use it as a lethal weapon to destroy a major building or other important target. Also, it is far more difficult for terrorists to attack an underground pipeline and inflict catastrophic damage to it than to an aboveground structure such as a bridge or a power plant. Moreover, underground pipelines are inaccessible to people except at the inlet and outlet. Thus, they can be more easily guarded against attack or

sabotage. Even though any unguarded long pipeline right-of way may be vulnerable to sabotage, the damage that can be achieved is rather limited. Pipeline companies have the ability to repair a damaged underground pipe and return it to service within hours. Such sabotage activities can also be detected easily by spy satellites and other means of remote sensing. For these reasons, pipelines must be low on the priority lists of targets of terrorists. This is not to say that security should not be of concern to pipeline companies. Two types of pipelines that require the greatest protection in terms of security are pipelines that supply drinking water, and natural gas pipelines that pass through densely populated areas.

CHAPTER THREE

Research Description and Data Collection Details

3.1 Introduction:

The project is named Nyala Water Supply Project, and its design capacity is $40,000m^3$/day. The project design is based on Nyala Water Supply Study (by Ministry of Irrigation and Water Resources, National Water Corporation, dated November 2000). The water capacity of single well is considered as equal. The chlorine content of water after being disinfected will reach the requirements of potable water standards of Sudan Standards and WHO. The linear distance of pipe will be considered as loose soil and easily be excavated.

3.2 Site condition:

3.2.1 Location & Access:

Nyala town is the capital of south Darfur state in the south western part of Sudan. The town is located at latitude 120 04 north, longitude 240 53 east and at distance of about 1000 Km from Khartoum. Topographically the town lies at 650m above the mean sea level and is divided into north and south residential area by Wadi Nyala. Nyala is linked to Khartoum and Port Sudan by a single tracked railway line.

Also linkage with Khartoum and other country parts is facilitated by satellite network of Sudan tel.

The town is also linked to Zalingei town via an asphalted road of 215 km passing via Jebael Marra in Central Darfur state, also Nyala town is linked with El-Fasher by an earth compacted road of about 205km which is currently under pavement by a Chinese company.

Being the capital of the state, Nyala is the most populated centre in the state and it is a big centre for agricultural and livestock marketing and with considerable light industries, such as a weaving factory, tannery, slaughter house and a number of groundnut processing and soap factories.

Geologically the town lies on abasement complex terrain which is anon-water bearing formation. Therefore the town depends for its water supply on groundwater storage of alluvium basin of wadi Nyala which divided the town into two parts northern and southern residential areas.

Based on the analysis of the collected information, the available water supply option that can meet the future demand of the town is the transmission of ground water from the Baggara basin requires.

3.2.2 Climate:

Nyala town and nearly most of the south Darfur state lies within the Sudan savanna belt which is controlled by the seasonal movement of the inter-tropical convergence zone (ITCZ). Rain falls occurs during the period June to October reaching its maximum in august. However rainfalls as early as May or as late as November are not uncommon. The annual rainfall of Nyala town is noticeably has declined from 195mm for the period 1921 – 1962 to 377mm for the period 1965 – 1992 with an average annual of 421mm.

The decrease seems to be more evident in July and August than other months. In recent history the year 1984 was the driest with a rainfall of about 197mm, or about 40% and 52% of the mean for the periods 1921 – 1964 and 1995 – 1992 respectively. Apparently the rainfall in Nyala town and its surroundings was below the long term mean indicating persistence of drought conditions since 1965. This implies that it’s only realistic to consider for designing and planning purpose rainfall data from year 1965 onward.

The average annual evaporation in Nyala town mounts about 2155mm or 5.9mm/day. However, the corrected estimate for the garden area is about 1932mm or 5.3mm/day (WRM, 1932).

3.2.3 Water Resources:

This project is based on development of ground water from the Baggara basin at Gereida area some 85km south of Nyala town. The Baggara basin is composed largely of multi-layered Nubian sandstone aquifer. Gereida Baggara basin attains a thickness up to 600m and composed of a variety of coarse, fine-grained, well sorted permeable and impermeable sediments, but they are hydraulically connected. Hydro-geologically the effective boundary of the basin may be taken as sedimentary isopach 100m contour line as shallower than this depth (100m) the sediments are mostly dry. Few kilometres south of Gereida the Nubian fill of the Baggara basin is overlain by the sediments of the Umm Ruwaba formation with general increase in the thickness east-south east wards.

Depth of the water (SWL) of the basin at Gereida area is about 55m (426m above mean sea level). The water quality has total dissolved solids (TDS) of about 300ppm, so the water is suitable for human and animal usage.

The western and north western parts of the Baggara basin receive annual recharge from wadi run off that originate from the high lands of Jebel Marra.

Probably the fault lines which characterized the area around Gereida may induce run off-ground water recharge of the Baggara basin. According to WRM (1993) the Baggara basin at Gereida area receives an annual recharge of about $20mm^3$. This annual recharge in addition to the huge permanent ground water sustains long term water supply to Nyala town and the neighbouring villages.

3.3 Battery Limit:

This project is started from the well field of Baggara basin at Gereida area, some 85km south of Nyala town, to water supply pump station of water plant at Nyala town.

3.4 Description of the Project Components:

The project compromised of water Intake works, water Transmission line, and water plant.

3.4.1 Water Intake Works:

This part is consists of well field, connection pipes for wells, and automatic control system.

3.4.1.1 Well Field & Intake Facilities:

Well field is located in Gereida area 85km south of Nyala. The design borehole depth is less than 400m. The upper part of the well (0-120m) is of diameter 325X8mm, the lower part of the well (120-400m) is of 219X6mm, the length of filter (John screen of stainless steel) is not less than 30m.

The design capacity of individual well is 2000m^3/day, 20 wells shall be arranged. The wells shall be arranged into two rows, the distance between the rows is 2000m. The well distance and row distance maybe changed in the construction period according to site conditions.

Intake facilities shall adopt submersible pumps of stainless steel with all necessary protection. The discharge of each pump is about 80m^3/hr, with 100m head, and 37kW power.

3.4.1.2 Connection pipeline for wells:

The out water of each well, through the discharge pipe, shall be collected to the connection pipes of wells, then collected to the main pipes, finally flow to the first stage pump station, boosted and entered into transmission pipeline.

The discharge pipe of the well in the field shall adopt DN200 steel pipe, connection pipes adopt Ductile Iron pipe, and the diameter shall be from 200mm to 500mm.

According to the arrangements of the wells, the length of the connection pipe shall be as follows:

DN200 steel pipe: 2000m;

DN200 – DN500 DI pipe: total of 22,000m

3.4.2 Transmission pipeline:

3.4.2.1 First Stage Pump Station:

In the pump station, the following buildings will be included:

Balancing water reservoir, boosting pump house and power distribution house etc., the ground elevation of the boosting station shall be ascertained according to the hydraulic calculation and the detailed landscape condition.

Due to the prominent function of the water hammer during the long distance transmission pipeline, two sets of self-closing water hammer eliminator shall be set at the start of outlet pipe of each pump station to eliminate the phenomenon of various water hammer while operation.

i- Balancing reservoir:

With the more stages of boosting station, considering the coordination of each pump stations operation, a balancing reservoir will be set in each stage of boosting pump station, which adopts tank of steel structure, regarding the first stage pump station; the capacity of balancing reservoir is 1500m^3.

ii- Boosting pump house:

Boosting pump house will be designed ground steel structure. In the house, 3 sets of pumps shall be adopted (2 sets for operation, 1 set for standby), and the auxiliary facilities, like maintenance valve, check valve, elevator, shall be set. Each pump shall be with the capacity of 850m3/h, delivery head of 140m.

iii- Water Hammer Protection Deign:

The working pressure of the pump in the boosting pump station is 1.4MPa, if the failure of the power and the shut-off the valve abruptly, the water hammer will form, the peak value of the water hammer will be 2 to 3 times of the normal working pressure, such a high pressure shall break the pipe and destroy the pump in the pump house, and the heavy accident of pump house submerging will happen. Considering the heavy harm of the water hammer, excepting the normal protection measurement of slowly-closed non-return valve shall be set at the outlet of the pump, water hammer preventing eliminating valve and air chamber water hammer eliminating tank shall be set in the pipe before its going out of the house, to carry out the duplex protection to the pump house.

3.4.2.2 Transmission Pipe:

The linear will be considered for the transmission pipe.

i- The pipe shall adopt Ductile Iron pipe, diameter shall be DN700mm.

The pipe shall be laid underground.

ii- Pipeline slope:

Preliminarily the linear distance of 85Km from well field to Nyala city is considered.

iii- Auxiliary facilities:

Since the project is with long distance transmission and complicated topography, considering the reliable water transmission, the maintenance valve, drainage valve, exhaust valve and water hammer elimination facilities shall be set in the pipeline.

The setting of the maintenance valve is considered according to the permitted water drainage time for the accident rush – to – repair time, and also the topography, pass-through the obstacle and the position of the connect pipe.

At the uplift point and the upper side of the inverse siphon pipe in the pipeline, the automatic inlet exhaust valve shall be set, to exhaust the air in the timely and not forming the air resistance. Meanwhile, air shall be imported when the pipe exhausted to empty and the water hammer happens, to prevent forming negative pressure in the pipe and the vacuum water – hit damage when the water hammer happens.

At the bottom point and the lower side of the inverse siphon pipe in the pipeline, the drainage pipe and drainage valve shall be set; drainage pipe shall be connected next to the bottom point of the pipe. Based on the actual landscape situation, when the drainage cannot be followed by itself, the drainage well shall be installed. The water shall be discharged by the submersible pump while drainage. The above valves will be put in valves pit with brick or stone.

3.4.2.3 Boosting Pump Station:

The transmission distance from well field to Nyala water plant is 85 Km,

This is belonging to high pressure transmission pipeline.

In the pump station, the following will be included:

i- Balancing Reservoir:

A set of balancing reservoir received water from the first stage pump house shall be set in boosting pump house in order to make the pumps normal and stable operation, the balancing reservoir is made of steel structure and capacity is $800m^3$.

ii- Boosting pump house:

Boosting pump house adopts ground steel structure, self-filling start and even water transmission. In the house, 3 sets of pumps shall be adopted (2 sets for operation, 1 set for standby), and the auxiliary facilities like, maintenance valve, non-return valve, elevator, drainage pump and vacuum pump shall be set. Each pump shall be with the capacity of $850m^3/h$, delivery head of 140m.

iii- Water Hammer Protection:

The working pressure of the pump in station is 1.4MPa, if the failure of the power and shut-off the valve abruptly, the water hammer will form, the peak value of the water hammer will be 2 to 3 times of the normal working pressure, such a high pressure shall break the pipe and destroy the pump in the pump house, and the heavy accident of pump house submerging shall happen. Considering the heavy harm of the water hammer, excepting the normal protection measurement of slowly-closed non-return valve shall be set at the outlet of the pump, water hammer preventing eliminating valve and air chamber water hammer eliminating tank shall be set in the pipe before its going out of the house, to carry out the duplex protection to the pump house.

3.4.3 Water Plant:

Water plant includes service reservoir, suction tank, conveying pumps and chlorine dosing etc.

3.4.3.1 Production Facilities:

(a) Service reservoir:

The quantity of the reservoir is two sets, and the volume of each one is 4000m^3, with in-situ-reinforced concrete structure; ventilation pipe; maintenance hole and guide wall shall be set in the reservoir.

(b) Suction tank:

In order to effective utilize the reservoir volume and improve the water absorbing effect of the pump, a suction tank is set between the reservoir and the pump house.

(c) Delivery pump house (secondary stage pump house):

Delivery pump house adopts semi-underground arrangement, self-filling pump start. The peak factor hour adopts 1.8. The pump house capacity is about 3000m^3/h, delivery head is 32-36m. 4 set of pumps shall be set and the auxiliary facilities of maintenance vale, non-return valve, elevator, drainage pump shall also be set.

(d) Chlorine Dosing:

The liquid chlorine disinfecting shall be set, 2 set with the capacity of 10kg/h, 2 sets with 5kg/h, the design dosage is 2.0mg/l. The chlorine dosing point is set in the entrance of the reservoir. Control method adopts close loop circuit method. The dosing chlorine is controlled by direct residual.

Chlorine titter and alarming apparatus shall be set in the dosing room and the chlorine storing warehouse, meanwhile, the gas mask, saving materials, accident pit and tools box shall also be equipped. The forced ventilation apparatus must be set; the gas exchange quantity is 10times/h.

3.5 Fuel Consumption:

3.5.1 General:

Diesel provided unit mainly includes two 50m^3 diesel tanks and two diesel pumps, which will provide diesel for generator in 1st pump station. The process flow consists of three parts:

(a) Unloading flow:

Diesel truck ⟶ pump ⟶ diesel tank

(b) Providing flow:

Diesel tank ⟶ pump ⟶ end user (generator)

(c) Inversing flow:

Tank A ⟶ pump ⟶ tank B

3.5.2 Capacity Calculation:

(a) For field pumping station (main pumping station):

The generator consume diesel about 12.42 ton every day. The diesel density is 0.85t/m^3, so the generator consumes 12.42/0.85=14.61m^3/day. Diesel trucks come once four days, so tanks should keep diesel: 4dx14.61m^3/day = 58.44m^3. In considering of the capacity coefficient 0.85 and the design coefficient 1.2, two diesel tanks (capacity 50m^{3}x2) are needed.

(b) For three pumping stations diesel tanks:

The generator consume diesel about 8.3 ton every day. The diesel density is 0.85t/m^3, so the generator consumes 8.3/0.85=9.76m^3/day. Diesel trucks come once four days, so tanks should keep diesel: $4d \times 9.76m^3/day = 39.04m^3$. In considering of the capacity coefficient 0.85 and the design coefficient 1.2, two diesel tanks (capacity $30m^3 \times 2$) are needed.

CHAPTER FOUR

Design and Calculations

4.0 Design Parameters:

4.1 Design Flow:

The water demand in a distribution area will fluctuate considerably during a day. Usually a service reservoir is provided to accumulate and even out the variation in water demand. The service reservoir is supplied from the transmission main, and is located at a suitable position to be able to supply the distribution system. The transmission main is normally designed for the carrying capacity needed to supply water demand on the maximum consumption day at a constant rate. All hourly variations in the water demand during the day of maximum consumption are then assumed to be evened out by the service reservoir. The number of hours the transmission main operates each day is another important factor. For a water supply with diesel engine or electric motor-driven pumps, the daily pumping often is limited to 16 hours or less. In such a case, the design flow rate for the transmission main as well as the volume of the service reservoir needed to be adjusted accordingly.

4.2 Design Pressure:

Pressure as a design parameter is only relevant pressurised pipelines. Consumer connections on transmission lines are rare, so the water pressure can be kept low, provided that the hydraulic grade line is poisoned above the pipe over its entire length and for all flow rates. A minimum of a few metres water column is also required to prevent intrusion of pollution through damaged parts of the pipe or faulty joints. In fact, nowhere should the operating pressure in the pipeline be less than 4 – 5 m (metre water column).

High pressures in transmission pipes occur as a result of long distances or specific topography. During supply by gravity the maximum pressure does not occur under operating conditions. It is the static pressure when the pipeline is shut. In order to limit the maximum pressure in the pipeline and thus the cost of the pipes, the route can be divided into sections separated by a break-pressure tank. The function of such a tank is to limit the static pressure by providing an open water surface at certain places along the pipeline. The flow from the upstream section can be throttled when necessary.

If water can be transported to higher elevations, the maximum pressures will occur in the vicinity of the pumping stations. High pressures in transmission pipe can be avoided in this case by application of multistage pumping along pipe route. Critical pressures may also develop as a result of pressure surge or water hammer in the pipeline. This phenomenon is caused by the instant or too rapid closure of valves, or by sudden pump starts or stops, e.g. due to electricity failure. A longitudinal water wave created in such a way causes over- and under-pressure well above the normal working pressure. This is potentially a very dangerous situation that may result in damage to the pipeline over long distances. Proper prevention includes construction of surge tanks, air vessels, or water towers as well as selection of suitable pipe materials that can withstand the highest pressure. Regarding valves, specific minimum shut-off times should be strictly respected.

4.3 Design Velocity and Hydraulic Gradient:

A velocity range is established for design purposes for two reasons. On the one hand, a certain minimum velocity will be required to prevent water stagnation causing sedimentation and bacteriological growth in the conduits. On the other hand, the maximum velocity will have to be respected in order to control head losses in the system as well as to reduce the effects of water hammer.

The velocity of flows in canals, aqueducts and tunnels usually ranges between 0.4 and 1 m/s for unlined conduits, and up to 2m/s for lined conduits. Flows in pressurised transmission mains have the velocity range between 1 and 2 m/s.

In the case of pressurised pipes, design values may also be set for the hydraulic gradient. This is done primarily to limit the head losses, i.e. to minimise the energy consumption for pumping the water. Common values of the hydraulic gradients for transmission pipes are around 0.005, which means 5 m of head loss per Km of the pipe length.

4.4 Hydraulic Design:

Flow Q (m^3/s) through a cross section area A (m^2) is determined as:

$$Q = AV \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where: Q=Flow Rate (m^3/s)

V= Velocity (m/s)

A=Pipe Cross sectional Area

Assumptions of ‘steady’ and ‘uniform’ flow apply in basic hydraulic calculations for the design of water transmission systems. The flow is steady if the mean velocity of one cross-section remains constant within a certain period of time. If the mean velocity between the two cross-sections is constant at a certain moment, the flow is uniform.

$$\frac{P}{\gamma} + Z + \frac{V^2}{2g} = \text{constant} \quad \text{(Bernoulli Equation)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(2)}$$

Where:

P/ γ =Pressure Head

Z= Potential Head

V/2g= Velocity Head

The Reynolds number indicates the flow regime:

$$Re = \frac{\rho V}{\mu} = \frac{V}{\gamma} , \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:

Re= Reynolds Number

μ = Fluid Viscosity

ν = Kinematic Viscosity

Kinematic Viscosity (ν) is dependent on the water temperature. For T in C^{o}

$$\nu = \frac{4 \quad X1 \quad ^{-6}}{(T+4 \quad .5)^{1.5}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The appropriate formulas for computing the head loss of water flowing through a pressurized pipeline are those of Darcy – Weisbach and Hazen Williams.

The Darcy – Weisbach formula states:

$$H_f = \frac{f}{d} x \frac{V^2}{2g} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where:

f = Friction factor

L= Pipe length

$f = 64/R_e$ (for smooth pipes) OR ($R_e \leq 2000$) ………………..(6)

For Rough pipes ($R_e \leq 4000$)

The friction factor can be calculated by the Colebrook – White formula:

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\frac{k}{D}}{3.7} + \frac{2.5}{R\ \sqrt{f}}\right) \text{ ………………………………….. (7)}$$

OR

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{5.1}{R^{\ 0.8}} + \frac{k}{3.7D}\right) \text{ ……………………………………….(8)}$$

Where k = pipe roughness

4.5 Power Requirements:

In order to calculate the pump power, the research have to know the operating pressure head (H) of the pump which is the total head. The total head is the sum of static head, friction head and velocity head. As velocity head is small in its magnitude, it is usually neglected. Therefore the total head is the sum of the static and friction heads.

The power output measured in watts (W) of a pump, P_w is given by

$P_w = \rho\ g\ Q\ H$ ……………………………………………………… (9)

Where:

ρ = is the density of water, 1000kg/m^3 or 1 kg/l

g = gravitational acceleration 9.81 m/s^2

Q = is the flow rate of water in m^3/s

H = operating pressure head (or total head)

The required input power to the pump P_p is given by:

$P_p = P_w/\eta$ ………………………………………………………………….. (10)

where η is the efficiency

4.6 Concept of Water Hammer:

Water hammer, or a pressure surge, is caused in pipelines as a result of changes in fluid flow velocities. A change in the flow velocity essentially causes the kinetic energy associated with velocity to be converted to pressure. This condition in a pipeline is termed one of hydraulic transients. The more rapid the change in flow velocity, the greater will be the magnitude of the resulting pressure surge. Pressure surges occur when valves are opened or closed, when pumps are started or stopped, or by sudden releases of entrapped air.

4.2.1 Hydraulics of Water Hammer:

The magnitude of pressure surges associated with water hammer is a function of:

i- System geometry.
ii- Magnitude of the velocity change.
iii- Velocity of the pressure wave for a particular system.

$\Delta H = (\frac{a}{g})\Delta v$ ……………………………………………………….. (11)

Where,

ΔH= surge pressure, m

a = pressure wave velocity, m/s

g = acceleration of gravity, m/s^2

Δv= change in fluid velocity, m/s

The velocity, or celerity, of the pressure wave is a function of both pipe material properties and fluid properties. The pipe material properties which affected the celerity are:

a- Modulus of elasticity
b- Diameter
c- Wall thickness

The fluid properties of major importance are:

a- Modulus of elasticity
b- Fluid density
c- Amount of air entrained in the fluid.

Applying the impulse – momentum equation and the principle of conservation of mass, the following equation for pressure wave velocity can be derived

$$a = \frac{K_1(K/\rho)^{1/2}}{[1+\left(\frac{K}{E}\right)\left(\frac{E}{t}\right)C_1]^{1/2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (12)$$

a = pressure wave velocity, m/s

k_1 = conversion constant dependent upon units

K = bulk modulus of elasticity of water, N/m^2

$\rho = d \quad o \quad w \quad , k \ /m^3$

D = inside pipe diameter, m

t = pipe wall thickness, m

E = pipe modulus of elasticity, N/m^2

C1 = pipe support coefficient

The pipe support coefficient is a function of the method of pipe constraint and the relationship between longitudinal and circumferential stress given by the Poission ratio. The function is given by the following equation (Watters, 1984):

$C_1 = 1.25 - \mu$, pipes anchored on one end only

$C_1 = 1 - \mu^2$, pipes anchored at both ends only

C1 = 1.0, pipes with expansion joints along the length

Where, μ = Poission ratio for pipe material

4.7 Hydraulic Calculations:

4.7.1: First Scenario: (replacing 2^{nd} & 3^{rd} stations by one station)

The available data are as follows:

i- Demand for Nyala town is estimated at 40,000 m^3 /day

$$Q = \frac{4\ ,0}{2\ X3} = 0.463 m^3/s$$

ii- The proposed boreholes are 20

iii- The required flow rate for each borehole = $\frac{0.4}{2}$ = 0.0232m^3/s

iv- The head for each borehole submersible pump(H_{SP}) =100m

v- The required power for each submersible pump(P_{SP})= ρ g Q H

$P_{SP})_{out} = 10^3 x 9.81 x 0.0232 x 100 = 22.7$ KW

$P_{SP})_{in}$ = $\frac{O}{P_1 \quad E}$ = $\frac{2\ .7}{0.6}$ = 34.0 KW

vi- The Total required input power for 20 BHL's =37.8x20 = 680.0KW

4.7.1.1Pumping from well field collection point to KILO **36**:

Given:

- Elevation difference between well field and Kilo 36 is: 552.46 - 489.50 = 63.0m=h_E
- Pipe type: Ductile Iron
- Pipe roughness ranges between (0.03mm – 0.06mm) for Ductile Iron.
- Pipe Inner Diameter =700mm=0.7m
- Water Flow rate (Q)=0.463m^3/s
- The flow velocity (V)= $\frac{Q}{A}$ =$\frac{Q}{\frac{\pi}{4}D^2}$ = $\frac{4X0.4}{\pi \quad 0.7^2}$ = 1.2m/s
- Reynolds Number(R_e) = $\frac{\rho}{\mu}$ = $\frac{V}{\nu}$,
- Kinematic Viscosity(ν) = $\frac{4 \quad X1 \ ^{-6}}{(T+4 \ .5)^{1.5}}$,
- T = water temperature, assumed to be 35^o C,

$\therefore \ \nu = \frac{4 \quad X1 \ ^{-6}}{(3 \ +4 \ .5)^{1.5}}$ = 0.7285x10^{-6} m^2/s

$\therefore R_e = \frac{1.2X0.7}{0.7 \quad X1 \ ^{-6}}$ = 1.15x10^6 (thus it is greater than 2000, the flow is turbulent)

Now from the Colebrook & White equation:

$$\frac{1}{\sqrt{f}} = -2\log(\frac{5.1}{R \ ^{0.8}} + \frac{k}{3.7D})$$

$$\therefore \frac{1}{\sqrt{f}} = -2\log(\frac{5.1}{(1.1 \ \ X1 \ \ ^6)^{0.8}} + \frac{0.0}{3.7X0.7}) = 8.8387$$

$$\therefore \ f = 0.0128$$

$h_f = \frac{f}{d} X \frac{V^2}{2g} = \frac{0.0 \quad X3 \;\; X1 \quad ^3}{0.7} X \frac{1.2^2}{2X9.8}$ = 48.315m,

The working Head of the Pump (h_p) = Elevation Head (h_E) + Friction Head (h_f)

$\therefore h_p = h_E + h_f$

$\therefore h_p = 63.0 + 48.315$ = <u>111.32m</u>

Power required from the pump:

Pw $=$ ρ g Q h_p

$\therefore$ Pw $=$ 10^3X9.81X0.46X111.32 = <u>502.34KW</u>

The power need to drive the pump:

$\therefore P_p = \frac{P_w}{\eta} = \frac{5 \quad .3}{0.6}$ = <u>749.8KW</u>

<u>Water Hammer Calculations:</u>

Given data:

Temperature = 35^o C,

From tables (10-7) & (10-8) the following data can be found

K = $2.272x10^9$ N/m^2

E = 165.47 $x10^9$ N/m^2

ρ = 998 kg/m^3

μ = 0.29

Based on units & pipe constraints, (anchored at one end)

K1= 1.0,

C1 = 1.25 - μ = 1.25 – 0.29 = 0.96,

t=19mm,

L= 36,000m,

$$a = \frac{k_1(K/\rho)^{1/2}}{[1 + \left(\frac{K}{E}\right)\left(\frac{D}{t}\right) C_1]^{1/2}}$$

$$a = \frac{1x\left(\frac{2.272x10^9}{994}\right)^{1/2}}{[1 + \left(\frac{2.272x10^9}{165.47x10^9}\right)\left(\frac{0.7}{0.019}\right) 0.96]^{1/2}}$$

$$\therefore a = p \qquad w \qquad v \qquad = \frac{1511.858}{1.21869} = 1240.6\, m/s$$

Time required for pressure wave to return to the valve:

$$T = \frac{2L}{a} = \frac{2x26x10^3}{1240.6} = 42\, s \quad .$$

The valve is completely closed by this time(42sec).

The change in velocity = $\Delta V = \frac{Q}{A} = \frac{0.4 \quad x4}{\pi \quad 0.7^2} = 1.2 m/s$

Pressure surge = $\Delta H = \left(\frac{a}{g}\right) \Delta V$

$$\therefore \Delta H = \left(\frac{1240.6}{9.81}\right) x1.2 = 151.8\, m$$

This is equal to: $10^3 x 9.81 x 151.8 = 1488.72 \frac{K}{m^2} = 14.9 B$

4.7.1.2 Pumping from KILO **36** up to KILO **66**:

Given:

- Elevation difference between Kilo 36 & Kilo 66 is: 623.18 - 552.46 =70.72m=h_E
- The pipe length = 30.00Km

$$\therefore h_f = \frac{f}{d} X \frac{V^2}{2g} = \frac{0.0 \quad X3 \;\; X1 \;\; ^3}{0.7} X \frac{1.2^2}{2X9.8} = 40.26\text{m},$$

$\therefore h_p = 70.72 + 40.26$ = <u>111.00m</u>

$\therefore$ Pw = 10^3X9.81X0.46X111.00 = <u>500.8KW</u>

The power need to drive the pump:

$\therefore P_p = \frac{P_w}{\eta} = \frac{5 \quad .8}{0.6}$ = <u>747.5KW</u>

<u>Water Hammer Calculations:</u>

Given data:

Temperature = 35^o C,

From tables (10-7) & (10-8) the following data can be found

K = 2.272x10^9 N/m^2

E = 165.47 x10^9 N/m^2

ρ = 998 kg/m3

μ = 0.29

Based on units & pipe constraints, (anchored at one end)

K1= 1.0,

C1 = 1.25 - μ = 1.25 – 0.29 = 0.96,

t=19mm,

L=46,000m,

$$\text{a} = \frac{k_1 (K/\rho)^{1/2}}{[1 + \left(\frac{\text{K}}{\text{E}}\right)\left(\frac{\text{D}}{\text{t}}\right) C_1]^{1/2}}$$

$$a = \frac{1x\left(\frac{2.272x10^9}{994}\right)^{1/2}}{[1 + \left(\frac{2.272\text{x}10^9}{165.47\text{x}10^9}\right)\left(\frac{0.7}{0.019}\right)0.96]^{1/2}}$$

$$\therefore a = p \qquad w \qquad v \qquad = \frac{1511.858}{1.21869} = 1240.6\,m/s$$

Time required for pressure wave to return to the valve:

$$T = \frac{2L}{a} = \frac{2x46x10^3}{1240.6} = 74.2\,s \quad .$$

The valve is completely closed by this time (74.2sec).

The change in velocity = $\Delta V = \frac{Q}{A} = \frac{0.4 \quad x4}{\pi \quad 0.7^2} = 1.2m/s$

Pressure surge = $\Delta H = \left(\frac{a}{g}\right)\Delta V$

$\therefore \Delta H = \left(\frac{1240.6}{9.81}\right)x1.2 = 151.8\,m$

This is equal to: $10^3x9.81x151.8 = 1488.72\frac{K}{m^2} = 14.9B$

4.7.1.3 Pumping from KILO **<u>66</u>** up to KILO **<u>85</u>**:

Given:

- Elevation difference between Kilo 66 & Kilo 85 is: 707.8 - 623.18 = 84.62m =h_E
- The pipe length = 19Km

$\therefore h_f = \frac{f}{d}X\frac{V^2}{2g} = \frac{0.0 \qquad X1 \quad X1 \quad ^3}{0.7}X\frac{1.2^2}{2X9.8}$ = 25.43m,

$\therefore h_p = 84.62 + 25.43$ = <u>110.05m</u>

$\therefore$ Pw = 10^3X9.81X0.46X110.05 = <u>469.62KW</u>

The power need to drive the pump:

$\therefore$ Pw $= \frac{4 \quad .6 \;\; X1^{\;3}}{0.6}$ = <u>741.22KW</u>

<u>Water Hammer Calculations:</u>

Given data:

Temperature = 35^{o} C,

From tables (10-7) & (10-8) the following data can be found

K = 2.272x10^{9} N/m^{2}

E = 165.47 x10^{9} N/m^{2}

ρ = 998 kg/m3

μ = 0.29

Based on units & pipe constraints, (anchored at one end)

K1= 1.0,

C1 = 1.25 - μ = 1.25 – 0.29 = 0.96,

t=19mm,

L=13,000m,

$$\mathrm{a} = \frac{k_1(K/\rho)^{1/2}}{[1+\left(\frac{\mathrm{K}}{\mathrm{E}}\right)\left(\frac{\mathrm{D}}{\mathrm{t}}\right)C_1]^{1/2}}$$

$$\mathrm{a} = \frac{1x\left(\frac{2.272x10^{9}}{994}\right)^{1/2}}{[1+\left(\frac{2.272\mathrm{x}10^{9}}{165.47\mathrm{x}10^{9}}\right)\left(\frac{0.7}{0.019}\right)0.96]^{1/2}}$$

$$\therefore a = p \qquad w \qquad v \qquad = \frac{1511.858}{1.21869} = 1240.6\, m/s$$

Time required for pressure wave to return to the valve:

$$T = \frac{2L}{a} = \frac{2x13x10^3}{1240.6} = 21\ s \quad .$$

The valve is completely closed by this time (21sec).

The change in velocity = $\Delta V = \frac{Q}{A} = \frac{0.4\ \ x4}{\pi\ \ 0.7^2} = 1.2 m/s$

Pressure surge = $\Delta H = \left(\frac{a}{g}\right)\Delta V$

$\therefore\ \Delta H = \left(\frac{1240.6}{9.81}\right) x1.2 = 151.8\ m$

This is equal to: $10^3 x 9.81 x 151.8 = 1488.72 \frac{K}{m^2} = 14.9B$

4.7.2: Second Scenario: (pumping through 2 stages)

4.7.2.1 Pumping from well field up to KILO **<u>43</u>**:

Given:

- Elevation difference between well field & Kilo 40 is = 592.8 - 489.5 = 103.3m=h_E
- The pipe length = 43Km

$\therefore\ h_f = \frac{f}{d} X \frac{V^2}{2g} = \frac{0.0\quad X4\ \ X1\ \ ^3}{0.7} X \frac{1.2^2}{2X9.8}$ = 57.7m,

$\therefore\ h_p$ = 103.3 + 57.7 = <u>161m</u>

$\therefore$ Pw = 10^3X9.81X0.46X161 = <u>726.53KW</u>

The power need to drive the pump:

$\therefore$ Pw $= \frac{7\quad .5\ \ X1\ \ ^3}{0.6}$ = <u>1084.4KW</u>

Water Hammer Calculations:

Given data:

Temperature = 35^{o} C,

From tables (10-7) & (10-8) the following data can be found

K = 2.272×10^{9} N/m^{2}

E = 165.47×10^{9} N/m^{2}

ρ = 998 kg/m3

μ = 0.29

Based on units & pipe constraints, (anchored at one end)

K1= 1.0,

C1 = 1.25 - μ = 1.25 – 0.29 = 0.96,

t=19mm,

L=43,000m,

$$\mathrm{a} = \frac{k_1 (K/\rho)^{1/2}}{[1 + \left(\frac{\mathrm{K}}{\mathrm{E}}\right)\left(\frac{\mathrm{D}}{\mathrm{t}}\right) C_1]^{1/2}}$$

$$\mathrm{a} = \frac{1x\left(\frac{2.272x10^{9}}{994}\right)^{1/2}}{[1 + \left(\frac{2.272\mathrm{x}10^{9}}{165.47\mathrm{x}10^{9}}\right)\left(\frac{0.7}{0.019}\right) 0.96]^{1/2}}$$

$$\therefore a = p \qquad w \qquad v \qquad = \frac{1511.858}{1.21869} = 1240.6\, m/s$$

Time required for pressure wave to return to the valve:

$$T = \frac{2L}{a} = \frac{2x43x10^{3}}{1240.6} = 69.4\ s \quad .$$

The valve is completely closed by this time (69.4sec).

The change in velocity = $\Delta V = \frac{Q}{A} = \frac{0.4\ \ x4}{\pi\ \ 0.7^2} = 1.2m/s$

Pressure surge = $\Delta H = \left(\frac{a}{g}\right)\Delta V$

$\therefore \Delta H = \left(\frac{1240.6}{9.81}\right)x1.2 = 151.8\ m$

This is equal to: $10^3x9.81x151.8 = 1488.72\frac{K}{m^2} = 14.9B$

4.7.2.2 Pumping from KILO 43 up to KILO 85:

Given:

- Elevation difference between KILO 43 & Kilo 85 is = 707.8 - 592.8 = 115m=h_E
- The pipe length = 42Km

$\therefore h_f = \frac{f}{d}X\frac{V^2}{2g} = \frac{0.0\ \ \ \ \ X4\ \ X1\ \ ^3}{0.7}X\frac{1.2^2}{2X9.8}$ = 56.4m,

$\therefore h_p = 115 + 56.4$ = 171.4m

$\therefore$ Pw = 10^3X9.81X0.46X171.4 = 773.5KW

The power need to drive the pump:

$\therefore$ Pw $= \frac{7\ \ \ .5X1\ \ ^3}{0.6}$ = 1154.5KW

Water Hammer Calculations:

Given data:

Temperature = 35^o C,

From tables (10-7) & (10-8) the following data can be found

K = $2.272x10^9$ N/m^2

E = 165.47 $x10^9$ N/m^2

ρ = 998 kg/m^3

μ = 0.29

Based on units & pipe constraints, (anchored at one end)

K1= 1.0,

C1 = 1.25 - μ = 1.25 – 0.29 = 0.96,

t=19mm,

L=42,000m,

$$a = \frac{k_1(K/\rho)^{1/2}}{[1 + \left(\frac{\mathrm{K}}{\mathrm{E}}\right)\left(\frac{\mathrm{D}}{\mathrm{t}}\right) C_1]^{1/2}}$$

$$a = \frac{1x\left(\frac{2.272x10^9}{994}\right)^{1/2}}{[1 + \left(\frac{2.272\mathrm{x}10^9}{165.47\mathrm{x}10^9}\right)\left(\frac{0.7}{0.019}\right) 0.96]^{1/2}}$$

$$\therefore a = p \qquad w \qquad v \qquad = \frac{1511.858}{1.21869} = 1240.6\, m/s$$

Time required for pressure wave to return to the valve:

$$T = \frac{2L}{a} = \frac{2x42x10^3}{1240.6} = 67.7\, s \quad .$$

The valve is completely closed by this time (67.7sec).

The change in velocity = $\Delta V = \frac{Q}{A} = \frac{0.4 \;\; x4}{\pi \;\; 0.7^2} = 1.2 m/s$

Pressure surge = $\Delta H = \left(\frac{a}{g}\right) \Delta V$

$$\therefore \Delta H = \left(\frac{1240.6}{9.81}\right) x1.2 = 151.8\, m$$

This is equal to: $10^3 x 9.81 x 151.8 = 1488.72 \frac{K}{m^2} = 14.9B$

4.7.3: Third Scenario: (pumping through one booster only)

Given:

- Elevation difference between well field & Kilo 85 is = 707.8 - 489.5 = 218.3m=h_E
- The pipe length = 85Km

$$\therefore h_f = \frac{f}{d} X \frac{V^2}{2g} = \frac{0.0 \quad X8 \;\; X1 \;\; ^3}{0.7} X \frac{1.2^2}{2X9.8} = 114\text{m},$$

$\therefore h_p = 218.3 + 114$ = <u>332.3m</u>

$\therefore$ Pw $= 10^3 X9.81X0.46X332.3$ = <u>1500KW</u>

The power need to drive the pump:

$\therefore$ Pw $= \frac{1 \quad X1 \;\; ^3}{0.6}$ = <u>2,238.8KW</u>

<u>Water Hammer Calculations:</u>

Given data:

Temperature = 35^o C,

From tables (10-7) & (10-8) the following data can be found

K = $2.272x10^9$ N/m^2

E = 165.47 $x10^9$ N/m^2

ρ = 998 kg/m3

μ = 0.29

Based on units & pipe constraints, (anchored at one end)

K1= 1.0,

C1 = 1.25 - μ = 1.25 – 0.29 = 0.96,

t=19mm,

L=85,000m,

$$a = \frac{k_1 (K/\rho)^{1/2}}{[1 + \left(\frac{\mathrm{K}}{\mathrm{E}}\right)\left(\frac{\mathrm{D}}{\mathrm{t}}\right) C_1]^{1/2}}$$

$$a = \frac{1x\left(\frac{2.272x10^9}{994}\right)^{1/2}}{[1 + \left(\frac{2.272\mathrm{x}10^9}{165.47\mathrm{x}10^9}\right)\left(\frac{0.7}{0.019}\right) 0.96]^{1/2}}$$

$$\therefore a = p \qquad w \qquad v \qquad = \frac{1511.858}{1.21869} = 1240.6\, m/s$$

Time required for pressure wave to return to the valve:

$$T = \frac{2L}{a} = \frac{2x85x10^3}{1240.6} = 137.0\, s \quad .$$

The valve is completely closed by this time (137.0sec).

The change in velocity = $\Delta V = \frac{Q}{A} = \frac{0.4 \ \ x4}{\pi \ \ 0.7^2} = 1.2 m/s$

Pressure surge = $\Delta H = \left(\frac{a}{g}\right) \Delta V$

$\therefore \Delta H = \left(\frac{1240.6}{9.81}\right) x1.2 = 151.8\, m$

This is equal to: $10^3 x9.81x151.8 = 1488.72 \frac{K}{m^2} = 14.9B$

4.8 Cost Analysis:

From the annex tables (1 to 10) the researcher have analysed the cost breakdown (cost of the labour, operation and maintenance, and fuel consumption)for the selected scenario and the existing design and other scenarios and the results has been summarised and tabulated below:

4.5 Cost Analysis Tables:

Table(4.1): Operation & Maintenance Staff cost for working by diesel generators: (existing design)

Site Location	Position Description	Qty.	Cost/man (SDG)	Cost /month	Cost/Year (SDG)
well field	Manager	**1**	**1500**	1500	18000
	Electro-mech. techn.	4	1000	4000	48000
	PLC Specialist	2	1000	2000	24000
	Operators/Technicians	6	900	5400	64800
	Laboratory Staff & well observers	4	900	3600	43200
	Finance & Admin. Officers	3	900	2700	32400
	Communication Staff	2	900	1800	21600
	Store keeper	2	750	1500	18000
	Labours	4	500	2000	24000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			8100	25500	306000
1 st Booster	Supervisor Engineer	1	1000	1000	12000
	Electro-mech. techn.	4	900	3600	43200
	Operators/Technicians	6	800	4800	57600
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			5350	14700	176400
2nd Booster	Supervisor Engineer	1	1000	1000	12000
	Electro-mech. techn.	4	900	3600	43200
	Operators/Technicians	6	800	4800	57600
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			5350	14700	176400
3rd Booster	Supervisor Engineer	1	1000	1000	12000
	Electro-mech. techn.	4	900	3600	43200
	Operators/Technicians	6	800	4800	57600

	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			5350	14700	176400
Water Plant at Nyala	Technical Manager	1	1500	1500	18000
	Laboratory Staff	4	900	3600	43200
	Operators/Technicians	4	900	3600	43200
	Finance & Admin. Officers	3	900	2700	32400
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
Sub Total			6850	16700	200400
Total				**86300**	**1035600**

Table(4.2): Operation & Maintenance Staff cost for working with electricity: (existing design)

Site Location	**Position Description**	**Qty.**	**Cost/man (SDG)**	**Cost /month**	**Cost/Year (SDG)**
well field	Manager	**1**	**1500**	1500	18000
	Electro-mech. techn.	2	1000	2000	24000
	PLC Specialist	2	1000	2000	24000
	Operators/Technicians	3	900	2700	32400
	Laboratory Staff & well observers	4	900	3600	43200
	Finance & Admin. Officers	3	900	2700	32400
	Communication Staff	2	900	1800	21600
	Store keeper	2	750	1500	18000
	Labours	4	500	2000	24000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			8100	20800	249600
1 st Booster	Supervisor Engineer	1	1000	1000	12000
	Electro-mech. techn.	2	900	1800	21600
	Operators/Technicians	3	800	2400	28800

	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			5350	10500	126000
2nd Booster	Supervisor Engineer	1	1000	1000	12000
	Electro-mech. techn.	2	900	1800	21600
	Operators/Technicians	3	800	2400	28800
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			5350	10500	126000
3rd Booster	Supervisor Engineer	1	1000	1000	12000
	Electro-mech. techn.	2	900	1800	21600
	Operators/Technicians	3	800	2400	28800
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			5350	10500	126000
Water Plant at Nyala	Technical Manager	1	1500	1500	18000
	Laboratory Staff	4	900	3600	43200
	Operators/Technicians	3	900	2700	32400
	Finance & Admin. Officers	3	900	2700	32400
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
Sub Total			6850	15800	189600
Total				**68100**	**817200**

Table(4.3): Operation & Maintenance Staff cost for working by diesel generators: (selected design)

Site Location	Position Description	Qty.	Cost/man (SDG)	Cost /month	Cost/Year (SDG)
well field	Manager	**1**	**1500**	1500	18000
	Electro-mech. techn.	4	1000	4000	48000
	PLC Specialist	2	1000	2000	24000
	Operators/Technicians	6	900	5400	64800
	Laboratory Staff & well observers	4	900	3600	43200
	Finance & Admin. Officers	3	900	2700	32400
	Communication Staff	2	900	1800	21600
	Store keeper	2	750	1500	18000
	Labours	4	500	2000	24000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			8100	25500	306000
1 st Booster	Supervisor Engineer	1	1000	1000	12000
	Electro-mech. techn.	4	900	3600	43200
	Operators/Technicians	6	800	4800	57600
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			5350	14700	176400
2nd Booster	Supervisor Engineer	1	1000	1000	12000
	Electro-mech. techn.	4	900	3600	43200
	Operators/Technicians	6	800	4800	57600
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			5350	14700	176400
3rd Booster	Supervisor Engineer		1000	0	0
	Electro-mech. techn.		900	0	0
	Operators/Technicians		800	0	0
	Communication Staff		900	0	0
	Labours		500	0	0

	Driver		750	0	0
	Guard		500	0	0
SUB TOTAL			5350	0	0
Water Plant at Nyala	Technical Manager	1	1500	1500	18000
	Laboratory Staff	4	900	3600	43200
	Operators/Technicians	4	900	3600	43200
	Finance & Admin. Officers	3	900	2700	32400
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
Sub Total			6850	16700	200400
Total				**71600**	**859200**

Table(4.4): Operation & Maintenance Staff cost for working with electricity: (selected design)

Site Location	Position Description	Qty.	Cost/man (SDG)	Cost /month	Cost/Year (SDG)
well field	Manager	**1**	**1500**	1500	18000
	Electro-mech. techn.	2	1000	2000	24000
	PLC Specialist	2	1000	2000	24000
	Operators/Technicians	3	900	2700	32400
	Laboratory Staff & well observers	4	900	3600	43200
	Finance & Admin. Officers	3	900	2700	32400
	Communication Staff	2	900	1800	21600
	Store keeper	2	750	1500	18000
	Labours	4	500	2000	24000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			8100	20800	249600
1 st Booster	Supervisor Engineer	1	1000	1000	12000
	Electro-mech. techn.	2	900	1800	21600
	Operators/Technicians	3	800	2400	28800
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000

	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			5350	10500	126000
2nd Booster	Supervisor Engineer	1	1000	1000	12000
	Electro-mech. techn.	2	900	1800	21600
	Operators/Technicians	3	800	2400	28800
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
SUB TOTAL			5350	10500	126000
3rd Booster	Supervisor Engineer		0	0	0
	Electro-mech. techn.		0	0	0
	Operators/Technicians		0	0	0
	Communication Staff		0	0	0
	Labours		0	0	0
	Driver		0	0	0
	Guard		0	0	0
SUB TOTAL			0	0	0
Water Plant at Nyala	Technical Manager	1	1500	1500	18000
	Laboratory Staff	4	900	3600	43200
	Operators/Technicians	3	900	2700	32400
	Finance & Admin. Officers	3	900	2700	32400
	Communication Staff	2	900	1800	21600
	Labours	2	500	1000	12000
	Driver	2	750	1500	18000
	Guard	2	500	1000	12000
Sub Total			6850	15800	189600
Total				**57600**	**691200**

Table(4.5): Operation & Maintenance Cost (Labour, Fuel , and Oil Consumption) used design

#	Pumping Station Name	Fuel & Oil Consumption			Litre Cost Price (SDG)			fuel & oil cost/month	labour cost/month	total (labour & Fuel, oil)
		lit/day	lit/month	lit/year	Unit Cost	Total Cost/Year	cost/month			
1	Main Pump Station fuel consumption	14610	438300	5259600	3.11	16357356	1363113			
2	Main Pump Station oil consumption	9	270	3240	3.11	10076.4	839.7	1363953	25,500	1389452.7
3	1st Booster fuel consumption	9760	292800	3513600	3.11	10927296	910608			0
4	1st Booster oil consumption (3lit X 2 engines)	6	180	2160	3.11	6717.6	559.8	911167.8	14,700	925867.8
5	2nd Booster fuel consumption	9760	292800	3513600	3.11	10927296	910608			0
6	2nd Booster oil consumption (3lit X 2 engines)	6	180	2160	3.11	6717.6	559.8	911167.8	14,700	925867.8
7	3rd Booster fuel consumption	9760	292800	3513600	3.11	10927296	910608			0
8	3rd Booster oil consumption (3lit X 2 engines)	6	180	2160	3.11	6717.6	559.8	911167.8	14,700	925867.8
	Total Fuel & Oil Consumption	43917	1317510	15810120		49169473.2	4097456.1			4167056.1

Table(4.6): Operation & Maintenance Cost (Electricity Consumption) for used scenario

#	Pumping Station Name	Electricity Consumption			KWh Cost (SDG)			labour cost/month	total O&M , labour /month
		KWh/day	KWh/month	KWh/year	Unit Cost	Total Cost/Year	cost/month		
1	Main Pump Station consumption (750Kwx3 setx24h=54,000KWh)	54,000	1620000	19440000	0.26	5054400	421200	25,500.00	446,700.00
3	1st Booster consumption (750Kwx2setx24h=36,000KWh)	36,000	1080000	12960000	0.26	3369600	280800	14,700	295,500.00
5	2nd Booster consumption(750KWx2setx24h=36,000KWh)	36,000	1080000	12960000	0.26	3369600	280800	14,700	295,500.00
7	3rd Booster consumption (750KWx2setx24h=36,000KWh)	36,000	1080000	12960000	0.26	3369600	280800	14,700	295,500.00
	Total Consumption cost	162,000	4860000	58320000		15163200	1263600		1,333,200.00

Table (4.7): Operation & Maintenance Cost (Labour, Fuel , and Oil Consumption) selected design

#	Pumping Station Name	Fuel & Oil Consumption			Litre Cost Price (SDG)			cost/month (fuel&oil)	labour cost /month	total cost/month
		lit/day	lit/month	lit/year	Unit Cost	Total Cost/Year	cost/month			
1	Main Pump Station fuel consumption	14610	438300	5259600	3.11	16357356	1363113			
2	Main Pump Station oil consumption	9	270	3240	3.11	10076.4	839.7	1363953	25,500	1389453
3	1st Booster fuel consumption	9760	292800	3513600	3.11	10927296	910608			0
4	1st Booster oil consumption (3lit X 2 engines)	6	180	2160	3.11	6717.6	559.8	911167.8	14,700	925867.8
5	2nd Booster fuel consumption	9760	292800	3513600	3.11	10927296	910608			0
6	2nd Booster oil consumption (3lit X 2 engines)	6	180	2160	3.11	6717.6	559.8	911167.8	14,700	925867.8
7	3rd Booster fuel consumption	0	0	0	3.11	0	0			0
8	3rd Booster oil consumption (3lit X 2 engines)	0	0	0	3.11	0	0	0	0	0
	Total Fuel & Oil Consumption	34151	1024530	12294360		38235459.6	3186288.3			3241188

Table (4.8): Operation & Maintenance Cost (Electricity Consumption) for 1st scenario

#	Pumping Station Name	Electricity Consumption			KWh Cost (SDG)			staff cost/month	total staff & elect.
		KWh/day	KWh/month	KWh/year	Unit Cost	Total Cost/Year	cost/month		
1	Main Pump Station consumption (750Kwx3 setx24h=54,000KWh)	54,000	1620000	19440000	0.26	5054400	421200	20,800	442,000
3	1st Booster consumption (748Kwx2setx24h=35,904KWh)	35,904	1077120	12925440	0.26	3360614.4	280051.2	10,500	290,551
5	2nd Booster consumption(742KWx2setx24h=35,616KWh)	35,616	1068480	12821760	0.26	3333657.6	277804.8	10,500	288,305
7	3rd Booster consumption		0	0	0.26	0	0	0	0
	Total Consumption cost	125,520	3765600	45187200		11748672	979056	41,800	1,020,856

Table (4.9): Operation & Maintenance Cost (Electricity Consumption) for 2nd scenario

(pumping up to kilo 43, then up to 85)

#	Pumping Station Name	Electricity Consumption			KWh Cost (SDG)			labour	total
		KWh/day	**KWh/month**	**KWh/year**	**Unit Cost**	**Total Cost/Year**	**cost/month**		
1	Main Pump Station consumption {(750Kw x 2set) + (1085Kwx1set)}x24h=62,040KWh)	62,040	1861200	22334400	0.26	5806944	483912	20,800	504,712
3	1st Booster consumption (1155Kwx2setx24h= 55,440KWh)	55,440	1663200	19958400	0.26	5189184	432432	10,500	442,932
5	2nd Booster consumption(641KWx2setx24h=30,768KWh)	0	0	0	0.26	0	0	0	0
7	3rd Booster consumption	0	0	0	0.26	0	0	0	0
	Total Consumption cost	117,480	3524400	42292800		10996128	916344	31,300	947,644

Table(4.10): Operation & Maintenance Cost (Electricity Consumption) for 3rd scenario

#	Pumping Station Name	Electricity Consumption			KWh Cost (SDG)		cost/month	labour	total
		KWh/day	KWh/month	KWh/year	Unit Cost	Total Cost/Year			
1	Main Pump Station consumption {(750Kwx2set) +(2239Kwx1 set)}x24h=89,736KWh)	89,736	2692080	32304960	0.26	8399289.6	699940.8	20,800	720,741
3	1st Booster consumption (1146Kwx2setx24h=55,008KWh)	0	0	0	0.26	0	0	0	0
5	2nd Booster consumption	0	0	0	0.26	0	0	0	0
7	3rd Booster consumption	0	0	0	0.26	0	0	0	0
	Total Consumption cost	89,736	2692080	32304960		8399289.6	699940.8	20,800	720,741

CHAPTER FIVE

Results & Discussions

5.1: Table (5.1) Calculations Results:

#	Scenario Name	Pumping	Power Requirements (KW)/Head(m)			
		Flow Rate(Q),m^3/s	Well Field	1st station	2nd station	3rd station
1	**Used Scenario**	**0.46**	**750/140**	**750/140**	**750/140**	**750/140**
2	**1st Scenario**	0.46	750 / 111.3	748 / 111.0	742 /110.1	N/A
4	**2nd Scenario**	0.46	1085/161	1055/171.4	N/A	N/A
5	**3rd Scenario**	0.46	2239/332	N/A	N/A	N/A

5.2: Results Analysis:

From table (5.1), and by analyzing the scenarios, the following analysis has been conducted:

Table: (5.2) Comparison of Operation and Maintenance (O& M) cost for existing project Design and the selected scenario (with diesel)

		well field	1st boost	2nd boost	3rd Boost	Plant	total cost/month
Ex. SC	cost/month	1,389,452.70	925,867.80	925,867.80	925,867.80	0	4,167,056.10
1st SC	cost/month	1,389,453	925,868	925,868	0	0	3,241,188

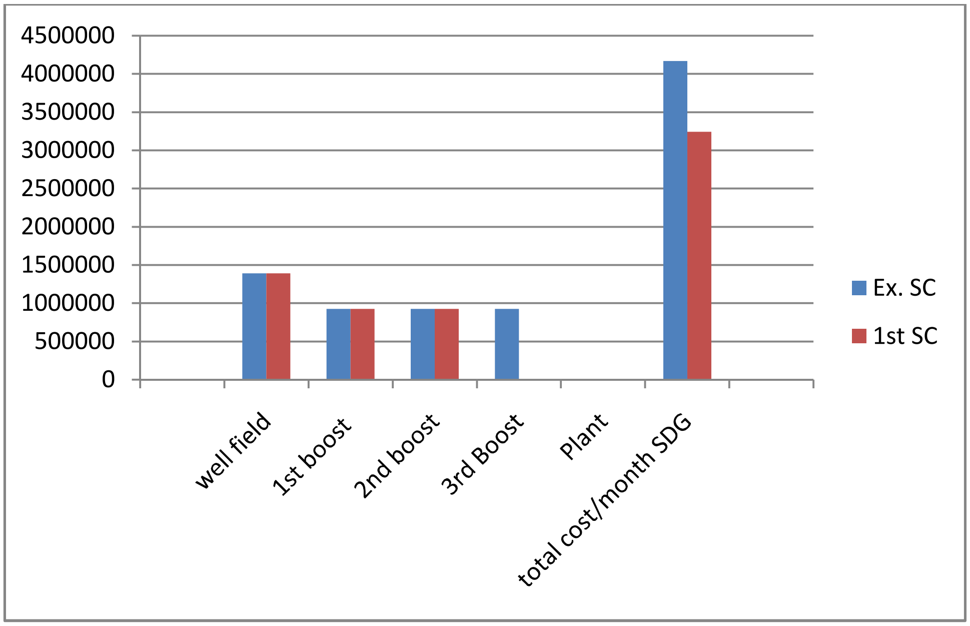

Figure:(5.1) Comparison of O& M cost for existing project design & the selected scenario (with diesel)

Table: (5.3): Comparison of O& M cost for the selected scenario between diesel and electricity

		well field	1st boost	2nd boost	3rd Boost	Plant	total cost/month
Diesel	cost/month	1,389,453	925,868	925,868	0	0	3,241,188
Electricity	cost/month	442,000	290,551	288,305	0	0	1020856

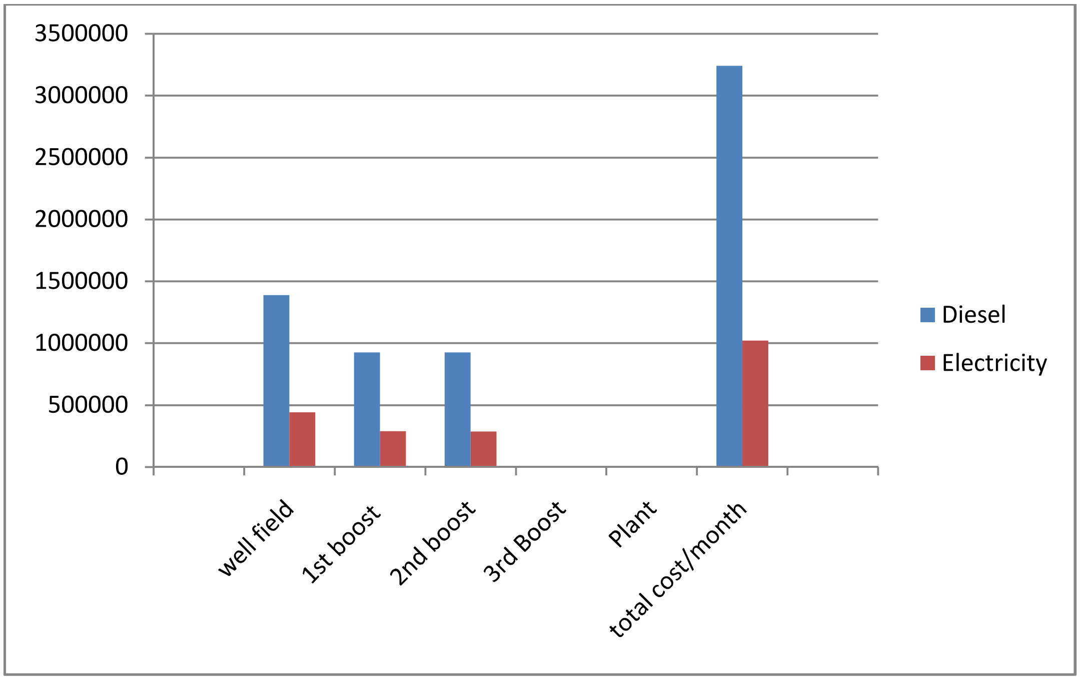

Figure:(5.2) Comparison of O& M cost for the selected scenario between diesel and electricity

Table: (5.4) Comparison of O& M cost for Existing project Design and 1st scenario (with electricity)

		well field	1st boost	2nd boost	3rd Boost	Plant	total cost/month
Ext. SC.	cost/month	446,700.00	295,500	295,500	295,500	0	1333200
1 st SC.	cost/month	442,000	290,551	288,305	000,000	0	1020856

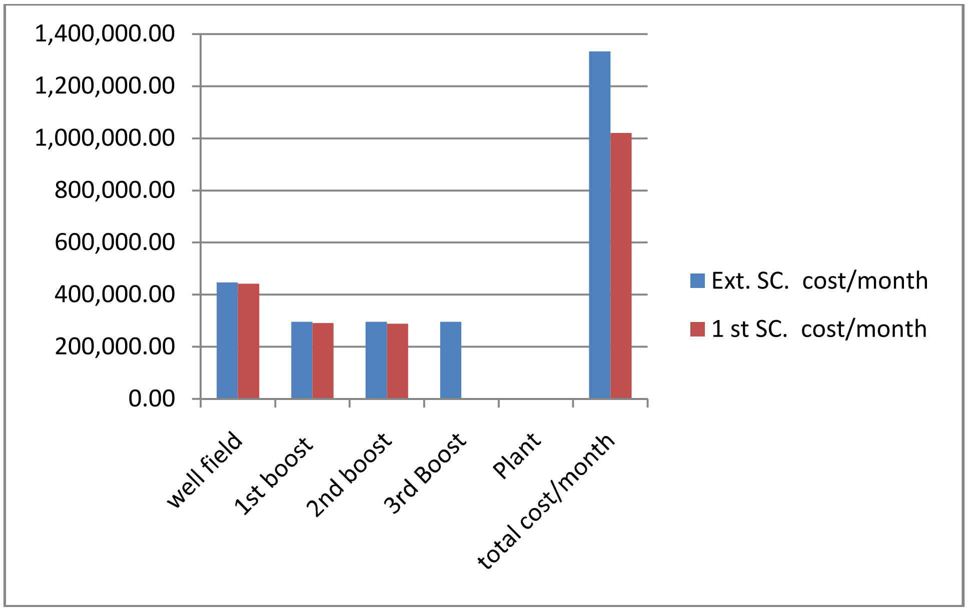

figure: (5.3) Comparison of O& M cost for Existing project Design and 1st scenario (with electricity)

Table: (5.5) Comparison of O& M cost for selected project Design and 2nd scenario

		well field	1st boost	2nd boost	3rd Boost	Plant	total cost/month
Select. SC.	cost/month	442,000	290,551	288,305	0	0	1,020,856
2nd SC.	cost/month	504,712	442,932	0	000,000	0	947,644

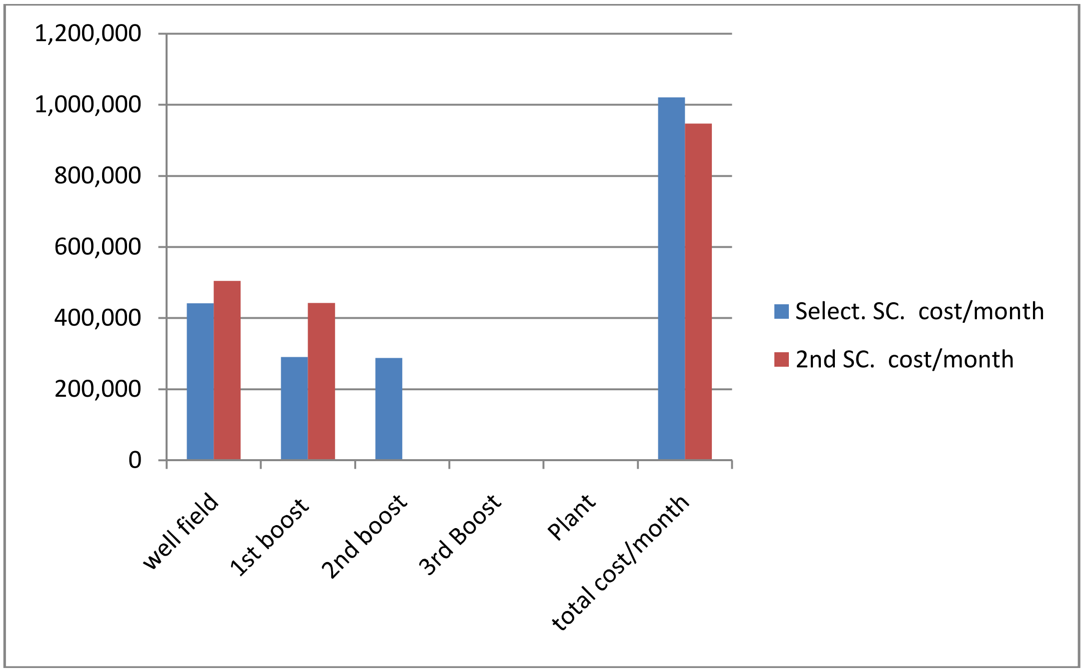

figure: (5.4) Comparison of O& M cost for selected project Design and 2nd scenario

Table: (5.6) Comparison of O& M cost for selected project Design and 3rd scenario

		well field	1st boost	2nd boost	3rd Boost	Plant	total cost/month
Select. SC.	cost/month	442,000	290,551	288,305	0	0	1020856
3rd SC.	cost/month	720,741	0	000,000	000,000	0	720,741

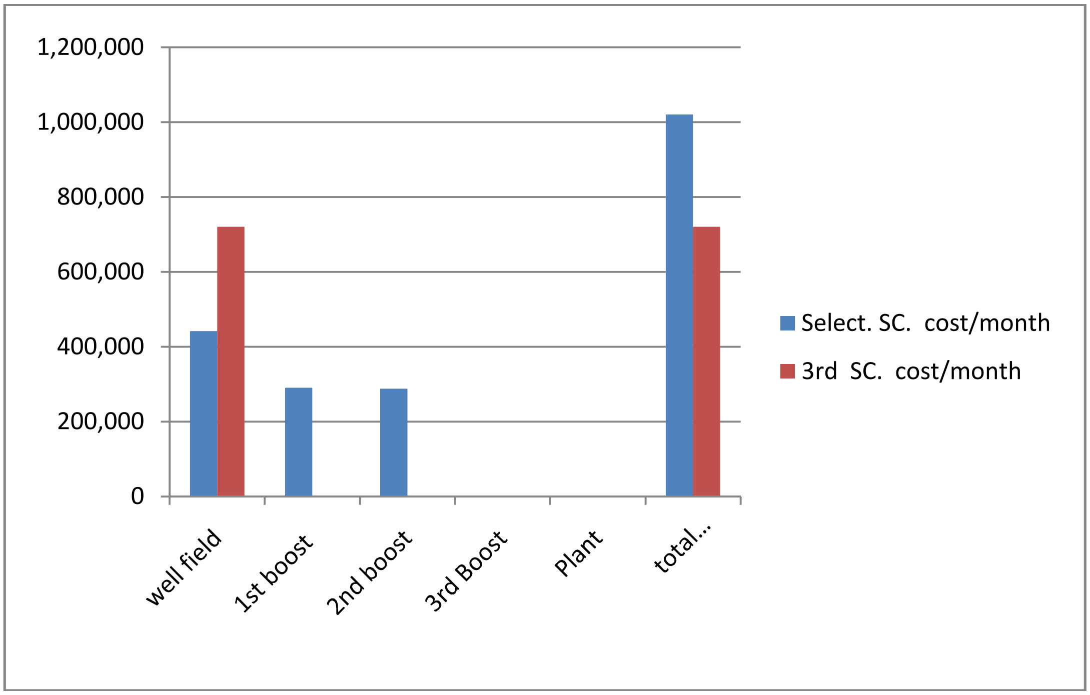

figure: (5.5) Comparison of O& M cost for selected project Design and 3rd scenario

Note:

1- Ex. Sc. means Existing Scenario (old design)
2- Selected Sc. means selected design Scenario
3- 2nd Sc. means second option design
4- 3rd Sc. means third option design

5.2.1 First Scenario:

By pumping through three stages, main pump station and two boosters, the first booster can be shifted up to kilo 36 and then pumping from there to kilo 66 and then up to kilo 85, its appear that can be done with the same pumps (flow rate 850m^3/h, and head 140m) and it can reduce the cost of pumping, which is represent in the fuel consumption, and other operational costs, and reduce the personnel cost of the operation.

5.2.2 Second Scenario:

In this case, new pumps and power generators are needed to pump through two stages, main pump station up to kilo 43 and then up to kilo 85, (new pumps of flow rate 850m^3/h, and head 171m & power generators of 1160Kw). This also can reduce the number of pumping stations, and operational costs, but the cost of new units is very high and need additional budget.

5.2.3 Third Scenario:

In this case we need to pump the water from the field to the end of the pipeline(up to kilo 85) by only one pumping station, and this need bigger size pumps with head about 332.3m, and then bigger size generating sets (2239KW) accordingly.

5.3: Discussions:

5.3.1 The first scenario is to cancel the first pump station and boost from collecting point up to kilo 36 and then from that point up to kilo 66, then to kilo 85, the end of the pipeline, and this scenario can be done by the existing pumps and power generators without any additional cost.

5.3.2 For the third scenario, it need to pump by new pumps through two stations and that need more budget to replace the existing pumps, with about 1200KW generating set & 170m head pumps, so that is additional cost to the project, but this can be new study to know whether it is efficient or not.

5.3.3 From the results analysis, it is clear that the fourth scenario is not practical solution, because pumping through one pumping station of 40,000m^3/day, and 332m head is difficult and it needs huge type of pumps with about 2250 KW power generating set, this also consume diesel and other operational costs will be very high. So this scenario also can be studied to know if it is possible or not and it's efficiency.

5.4 Fuel Consumption Analysis:

The project was designed to pump the water through pumps driven by electrical motors, and it equipped by diesel power generators to supply them with power. The generators are about 12 sets, and each about 750KW.

The first station (main pumping station) was designed to supply by 4 units of generators, which will consume about 14.61m^3/day (608.75lit/h), and the other 3 stations are with 3 units in each of them, and consume 9.76m^3/day (406.7 lit/h).

The total fuel consumption was about 24.37m^3/day (1015.42 lit/h), and it’s a huge quantity of fuel which is need to be available at pumping stations.

CHAPTER SIX

Conclusion and Recommendations

6.1 Conclusion of the Study:

This research is set out to understand of how to plan, design, and implement the water supply facilities in South Darfur State, and in all over the country through the Drinking Water & Sanitation Unit (national authorized agency in the country for water sector). The research also reflects the weakness of the Drinking Water and Sanitation Unit on planning and designing of the new drinking water projects which need more revision and acceptance of the final design. Additionally it ~~was~~ reflect the importance of the suitable policies and strategies relating to water resources management and selection of the best solutions for the drinking water services.

6.2 Recommendations:

From the discussions and analysis of the calculations, and the need of Nyala town to this project to solve the problem of safe drinking water, the research strongly recommend the following:

i. The best solution for this project is, to pump as per first scenario.

ii. Instead of working with three generating sets (two on duty and one standby) in each pump station, the suggest to only use two sets as standby and work with general electricity from Nyala town. This can be done by agreement between State Water Corporation (SWC) and Electricity Distribution Co. (SEDC), because of the high fuel cost, the pumping stations can be supplied by electricity instead of diesel which is difficult to transport due to security reasons, and high transportation cost from Khartoum to Nyala and then to site locations. This can open the door to do researches and studies to know the best and efficient design for the project.

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