ADDIS ABABA UNIVERSITY SCHOOL OF

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URBANIZATION & WATER SUPPLY CHALLANGES IN ADDIS ABABA; WITH SPECIAL REFERENCE TO JEMO CONDOMINUM SITE

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URBANIZATION & WATER SUPPLY CHALLANGES IN ADDIS ABABA; WITH SPECIAL REFERENCE TO JEMO CONDOMINUM SITE

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Lists of abbreviation

UN-HABITAT	United Nations Centre for Human Settlements
AAU	Addis Ababa University
UN	United Nations
WHO	World Health Organization
UNICEF	United Nations Children's Fund
IAHS	International Association of Hydrological Sciences
MOWE	Ministry of Water and Energy
AAWSA	Addis Ababa Water Supply and Sewerage Authority
CSA	Central Statistical Agency of Ethiopia
A.A	Addis Ababa
TDS	Total Dissolved Solute
EC	Electrical Conductivity of Water
GWIACCES	Global Water Institute for Africa Climate Change, Environment & Security
EWRMP	Ethiopian Water Resources Management Policy

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Abstract

Achieving Quantitative & qualitative Water service is both basic and democratic rights of human beings to assure sustainable urban and other development activities. However, different setbacks such as lack of appropriate management and rapid urbanization failing to provide this service.

Geographically, Jemo condominium site is located in Addis Ababa at latitude 8°57′28.7748″ and longitude 38°42′43.8222″. It is accessible from three main directions by the highways stretching to different destination of Addis Ababa.

The main objective of conducting this research is to identify, the major water supply challenges of Addis Ababa with special reference to Jemo condominium site, and also to recommend possible solutions.

Methods that used to conduct this research were based on both secondary and primary data analysis using qualitative and quantitative techniques. The Secondary data include Journals, thesis and reports. Were as, the primary data include water sampling, photographs, questionnaires on some concerned bodies and experts who were involved in water supply service.

The major procedure that used in this research was given as follow: gathering related secondary information, collecting primary data & finally analysis & presentation of result.

The researches of many authors have reviewed to conclude the strong relationship between urbanization & water supply challenges in the study area.

The significance of the study was to identify the water supply challenges and recommending possible means to enhance the quality and quantity of water supply.

From customers, decision makers, experts response, Basic Human water requirement index and water scarcity index analysis result indicate: There is a limitation of fresh water supply in the study area .This is due to rapid population growth, power interruption, city expansion, frequently pipeline breakage due to different infrastructure, lack of water scheme rehabilitation, and lack of awareness to use water economically.

The present TDS, SO_4, NO_3, Co, Ni, Cd, Cu, Zn, , Pb, Mn ,pH & EC of the water samples analysis which has been taken takes from two streams near to the study area has shown that very high hazardous lead metal concentration, nitrate, EC compared to WHO standards. The groundwater analysis result also showed there is consecutive increasing of sulphate concentration in some productive groundwater wells & decreasing of pH value.

Frequently pipeline breakage due to different infrastructure, the system of water distribution to end users ,accessibility of roads ,developing new sources compatible to the growth of the city both population and construction, leakage control for physical loss and unaccounted water for financial loss are the major water supply challenges of study area .

To improve quantity and quality of water supply : we can use different methods: such as reducing water supply loss through appropriate rehabilitation and increasing awareness for economical use of water , creating good integration between different institutions, development of new water scheme and waste water treatment .

Keywords: Urbanization, water supply challenges, water resource management models, basic human water requirements and water stress and scarcity index.

CHAPTER ONE INTRODUCTION

1.1Background

Urbanization is a process and has caused by many factors. Even the term urbanization can have different meanings with different context. The term urbanization in this paper refers to the process of urban growth which is due to increasing of population in cities and expansion of urban centres. In other word, Urbanization is a cyclical process through which the nation passes as they evolve from agricultural activity to industrial societies. It may be caused by Rural to urban migration (result of push and pull factors) and natural increase (high levels of births and falling death rates). Urban populations are not only growing but also 'growing-up', which is disproportionately increasing both domestic and industrial water demand, and also generating more wastewater. Unless adequately managed these trends are likely to impact negatively on urban water supply.

According to European Commission (2012) assessment, urban growth has been leading to reduction of groundwater availability. As the population increased so did water deficiency .By 2030, Africa's urban population is forecasted to rise to around 654 million people. However, Water supply is shrinking, and water quality is deteriorating**.** As water demand grows, cities are forced to rely on water sources that are further from the city and more expensive to tap. (World Bank, 2013).

No doubt that demand for water is dramatically growing from time to time. Population growth in cities is driving this demand, but economic growth will add to it. More industry requires more water, and prosperity raises expectations for the quality of water services (World Bank, 2012).

Between 2010 and 2015, 200,000 people on average will be added to the world's urban population each day. From this 91% from developing countries (UNHSP, 2012) in Ethiopia the Percentage of population obtaining drinking-water from an improved source is less than 50% in 2010 (UNICEF/WHO, 2012) .

Improving adequate, reliable and clean water supply and sanitation services are the main objective of Ethiopia water resource management (EWRMP, 1999). However World

Academy of Science, Engineering and Technology (2010) study showed that Addis Ababa Water supply and sanitation has become serious problem.

Addis Ababa is established in 1878 by the Empire Menilik II. Before 1893 residents of Addis Ababa and its surrounding used River and spring waters which were relatively free from pollution. However, after 15 years Addis Ababa faced water scarcity due to increasing population and drought. Thus, Minilk II was forced to establish the modern water supply in 1893(AAWSA, 2001). Currently the water supply capacity of Addis Ababa is estimated around 307,328m^3/day and out of this 184,473m^3/day Revenue water and 122,855m^3/day (39.98) Non Revenue water (AAWSA, 2013).

The study area: Jemo condominium site, one of the main urbanization areas in Addis Ababa city. It is the second largest condominium site after Lideta, which has 20,000 households (Ashenafi, 2013). The source of fresh water is mainly groundwater and indirectly the residents have used unprotected water like stream. According the residents, officials and experts, the site has accessed pipe water not more than four days per week. This means there is no water supply for the rest three days because of power interruption, rapid increase population and expansion of the city, lack of quick maintenance and breakage of pipe line. The residents and surrounding community have also used unprotected stream water for domestic cattle consumption, micro irrigation and other washing purposes.

Based on common understanding of surface and ground water interaction relation, we can draw that the groundwater has probability to be polluted by contaminated surface water and vice versa. Above all, the current study has revealed that there is quality and quantity of water problem in the study area.

Therefore, In the future the demand for industry, construction, domestic water resources use is expected to increase and mitigate the impact we should have use our resource wisely so as to reduce quality water scarcity on the socio-economic activity.

1.2 Statement of Problem

Fresh water is indispensable for human life, development and environment. However, fresh water is a scarce and vulnerable in quantitative and qualitative. Life is strongly tied to water, air and food. Above all shortage of water is becoming a global issue. (Lalzad, 2007)

Even the UN Human Rights Council has affirmed that the right to get water and sanitation is derived from the right to an adequate standard of living. Consequently, this can take human life to the highest attainable standard of physical and mental health, as well as to the right to life and human dignity (The UN Human Rights Council, 2010,). The combined effect of the two resolutions has been the anchor of the right to water and sanitation in the framework of the right to an adequate standard of living, making it legally binding like any other of the rights inscribed in UN treaties (WHO/UNICEF, 2012).

In Ethiopia the percentage of population obtaining clean drinking-water from an improved source is less than 50% in 2010 (UNICEF/WHO, 2012). Between 2010 and 2015, 200,000 people on average will be added to the world's urban population each day. From this, 91% from developing countries (UNHSP, 2012).

The population of Addis Ababa has grown from 2 million to about 4 million in the last fifteen years with the administrative area expansion from 220 to 540 square kilometers. This has resulted in a heavy pressure on the Addis Ababa City Administration and the Addis Ababa Water and Sewerage Authority to extend safe drinking water supply and sanitation services (GWI, 2011).

Addis Ababa is one of the fastest growing cities on the continent. Its population has nearly doubled every decade. In 1984 the population was 1, 412, 575, in 1994 it was 2,112, 737, and this number will continue to rise, reaching 12 million in 2024. Lack of water scheme maintenance and lack of new facilities combined with rapid population growth has brought water shortage in many parts of Addis Ababa. High volume of water wastage due to faulty piping and needs priority given to industries, also contribute to the shortage (UN-Habitat, 2008). Thus, this study focused on the improvement of water supply service of Addis Ababa with special reference Jeom Condominium site.

1.3 Research Questions

- What is the current status of water supply services in Jemo condominium site?
- What are the major challenges in water supply in Jemo condominium site now and in the future?
- What measures should be taken to insure sustainable water supply services in Jemo condominium site?

1.4 Objective of the Study

The objective of conducting this research was to identify, the major water supply challenges of Addis Ababa with special reference to Jemo condominium site, and also to recommend possible solutions.

1.4.1 Specific Objectives

- To evaluate the current status of water supply services of Jemo condominium site.
- To identify the major challenges in water supply of Jemo condominium site.
- To recommend the possible measures to insure sustainable water supply services Jemo condominium site.

1.6 Significance of the Study

The significance of the study is to identify the water supply challenges and recommending possible means to enhance the quality and quantity of water supply.

1.7 Methods and Materials

Methods that used to conduct this research were based on both secondary and primary data. It was analysed using qualitative and quantitative techniques. The secondary data include journals, books, thesis, existing water quality data, and reports. Where as, the primary data include field geological observation, water sampling, photographs, questionnaires. Moreover, water samples were collected from two different streams and user pipe water about 2000ml clean plastic containers and send to Addis Ababa City Government Environmental protection agency and Saba Engineering PLC within 24 hours to determine (TDS), Pb, Mn, NO3, SO4, Cd, Zn, Co, Cu, Ni and other physiochemical analysis . In addition, I used different materials to carryout this study such as different software's

(Arc GIS, Aquachem, Surfer and Excel), digital camera, and geologic hammer, GPS and plastic water sample bottle.

1.8. Limitation of the Study

This study faced some limitations. These include: some officials and Experts were not happy to give response for the relevant questionnaire. In addition to that, during the study some of the resident's respondents were not willing due to lack of confidence. Another problem is limitation of time and budget so as to see seasonal variation of heavy metals concentration of the study area.

1.9 Work Procedure

The procedure that was used in this research is gathering related secondary information, field data sampling & measurement, laboratory water quality analysis, preparation of questioner & filling of questionnaires by the concerned bodies & finally analysis of data & presentation of the research result.

1.10 Organization of the Study

This paper is organized into four chapters. The first chapter covered an introduction part including back ground, statement of problem, research questions, objectives, significance of the study. It also includes methods and materials, limitation of the study, work procedure, location, climate, geological and hydrogeological setting of the study area. The second chapter discusses the literature review. The third chapter focuses on data presentation and interpretation and the fourth chapter deals with the discussion, conclusions and recommendation**.**

1.11 Location of the Study Area

Geographically Jemo condominium site is located in Addis Ababa at latitude 8°57′28.7748″ and longitude 38°42′43.8222″. It is accessible from two main direction by the highways stretching to different destination of the country`s boarder.

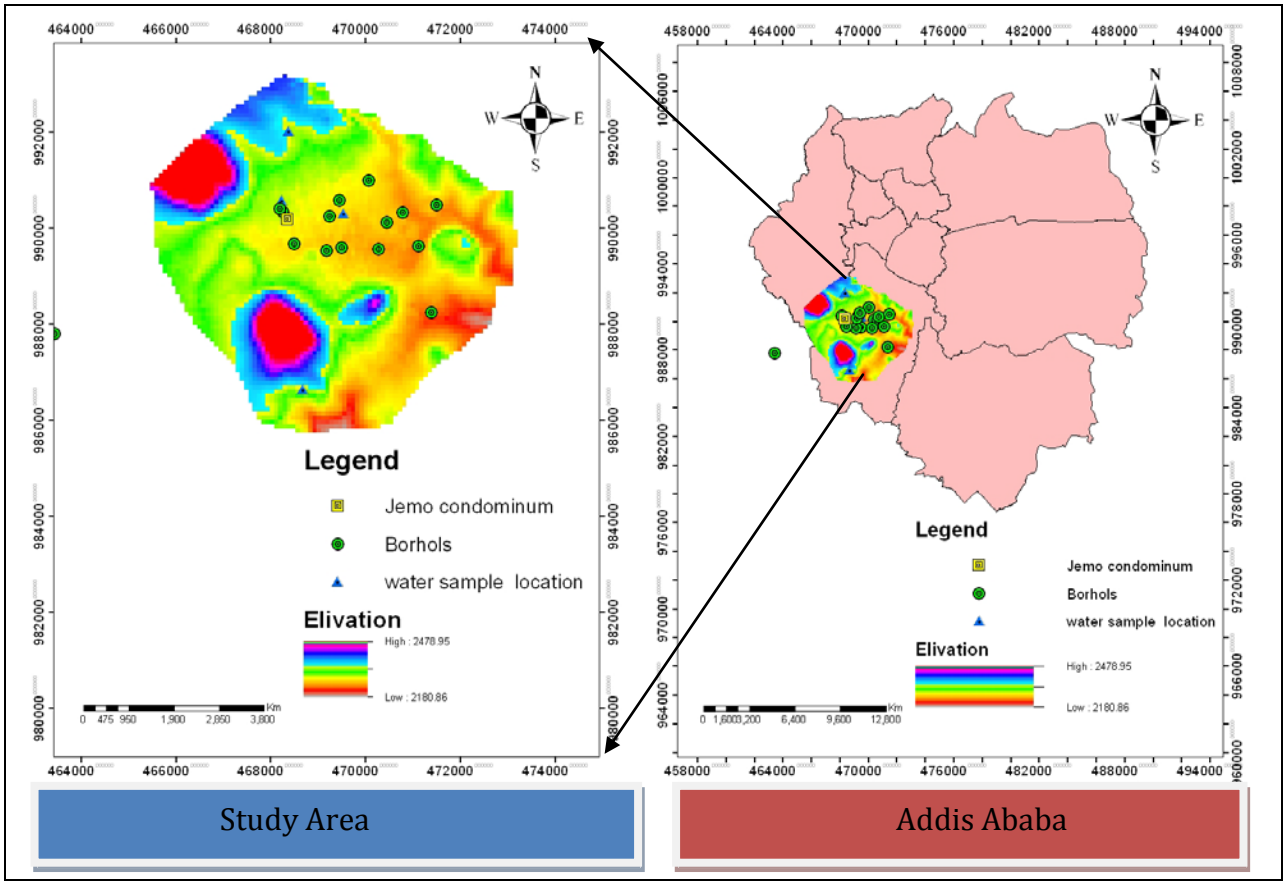

Figure 1: Location of Jemo condominium Site

1.12 Climate

The study area is characterized by two distinct seasonal weather patterns .The wet season starts from June and runs up to September and contributes about 70% of the annual rainfall. Where as the dry season starts from October up to May with minor rain season in March and April. Long term mean annual rainfall is 1052 mm. The average daily temperature is around 15.6 degree centigrade. Moreover, the average annual potential evapotranspiration of Addis Ababa is about 1226 mm (Tenalem et al., 2008).

Table 1 : Rainfall and Temperature of Selected Stations in Addis Ababa Area

Parameter	Station(periods)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Rainfall, mm	Intoto(1989-2004)	15.6	38.3	61	87.2	43.2	102.2	265.3	317.1	138.4	27.2	9.9	9.8	1115.2
	Sendafa(1991-2004)	20.8	18.5	47.7	52.4	43.7	118.6	328.8	308	106.1	49.1	3.6	3.8	1101.1
	Akaki (1975-2004)	14.1	29.8	76.7	86.1	68.5	115.2	255.4	258.5	118.8	25.1	3.6	3.2	1055.0
	AA Bole(1980-2004)	11.8	33.6	68	93	71.1	122.5	235.9	240.3	133.5	30.9	3.2	4.9	1048.8
	AA Obs(1980-2005)	14.2	39.1	68.9	91.5	83.7	136.2	262.4	272.9	168.7	34.9	5.8	9.2	1187.4
Mean		**15**	**32**	**64.4**	**82**	**62**	**119**	**270**	**279**	**133**	**33**	**5**	**6**	1100.5
Temp.^{0}c	Entoto (1989-2004)	19.1	19.7	19.9	19.4	20.1	17	15.9	15.9	15.8	16.8	18.6	17.5	18.0
	AA Obs (1980-2005)	23.9	24.9	25	24.5	25.1	23.4	21	20.9	21.7	22.7	23.1	23.2	23.3
	AA Bole(1980-2004)	23.8	23.8	26.3	24.8	25.3	23.5	21.2	21.1	21.8	22.9	23.2	23.2	23.4
	Akaki (1997-2004)	26.3	27.3	27.4	27.3	28	26.3	24.3	23.8	25.3	25.8	25.9	25.9	26.1
Mean		**23.3**	**24**	**24.7**	**24**	**24.6**	**15.9**	**20.6**	**20.4**	**21.2**	**22.1**	**22.7**	**22.5**	22.2

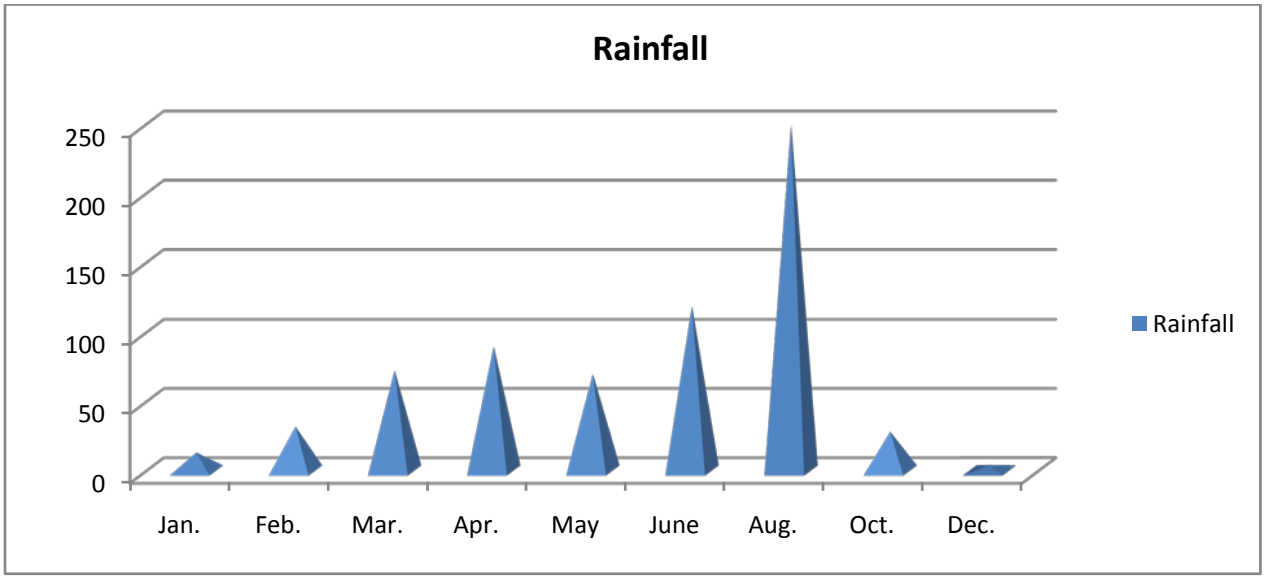

Figure 2: Average Annual Rainfall Pattern of the Study Area

1.13 Geological Setting of the Study Area

Generally, as per Zanettin et al. 1974 and Morten et al, 1974/79 the geology of Addis Ababa comprises Miocence- Pleistocene succession which consists of:

- ✓ Alaji series (flood basalts, Rhyolites, ignimbrite and tuff of 36-12 million years)
- ✓ Entoto Silicis (Rhyolite and Trachyits with minor tuff and obsidian of 22 million years)

Addis Ababa basalts of 7 million years

- ✓ Nazareth group (lower welded tuff, Aphanatic basalt, and upper welded tuff of 4.6 million years.
- ✓ Bofa basalts of 2.8 million years which are located along the Debrezeit road

Based on field observation and available drilling well log data, the study area comprise of: Basalts, ignimbrite and tuff, tuff, Trachyite or the combination of them.

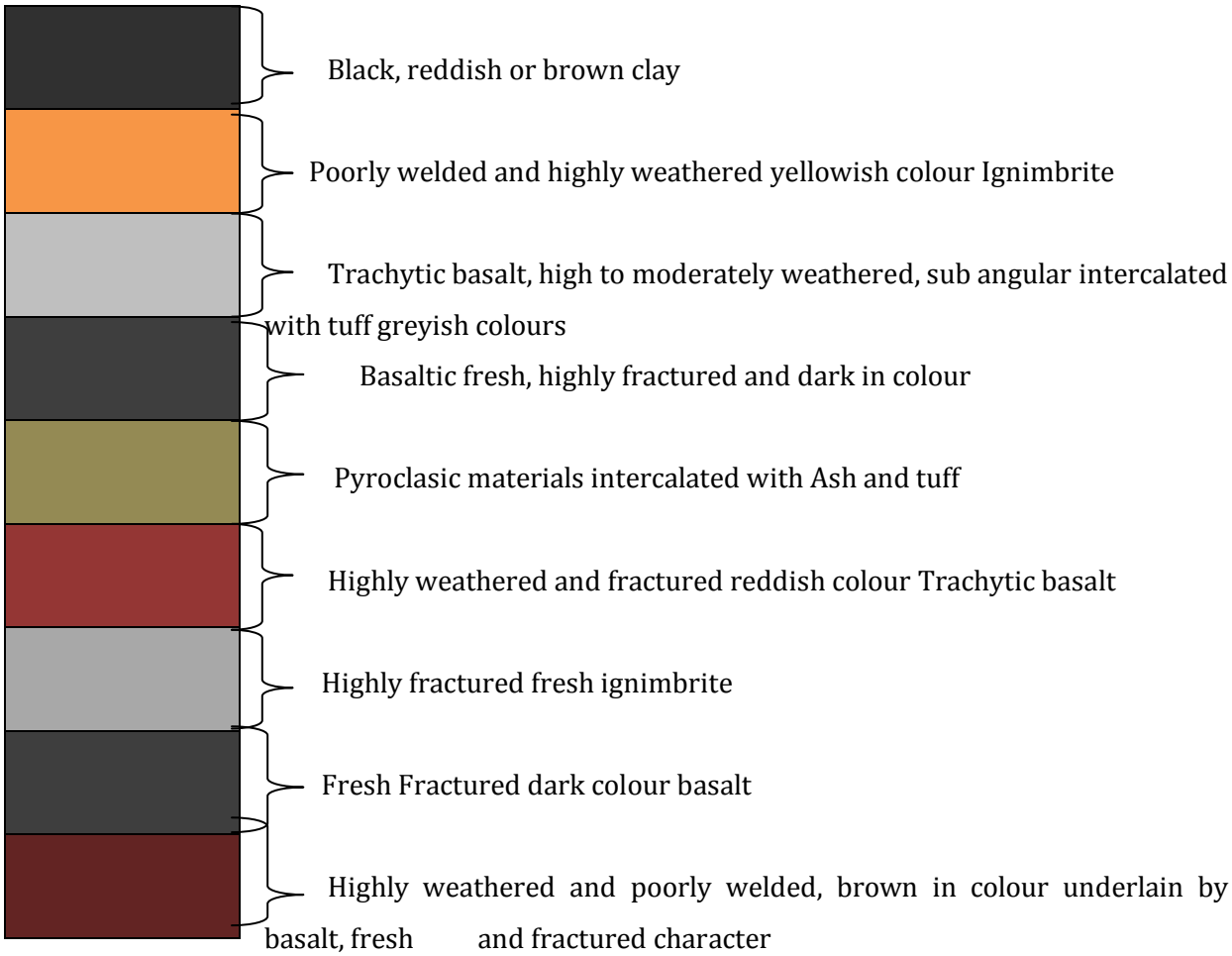

Figure 3: The Vertical Litology of Study Area (source from water well drilling report of the study area)

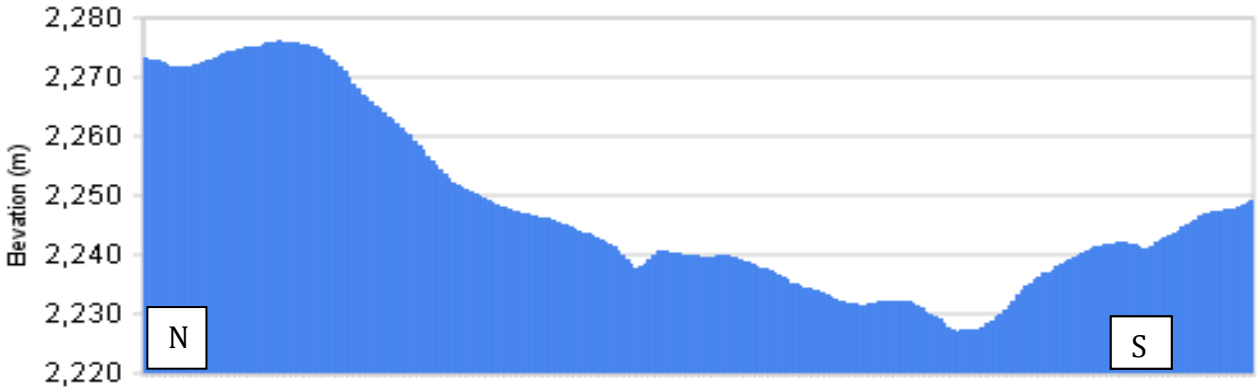

Figure 4: Topographic Profile of Study Area

1.14 Geologic Structure of the Study Area

The geological structures in the study are has been studied by different scholars for a variety of purposes .The area is characterized by both primary and secondary geological structure. Some of the structure which is found in the study area is fracture, mud cracks (Fig.4) and contacts within the different volcanic rocks. This structure may control the groundwater movement, contaminant movement, age, recharge and evaporation of groundwater. The geological structure also shows the type of geologic formation and ages.

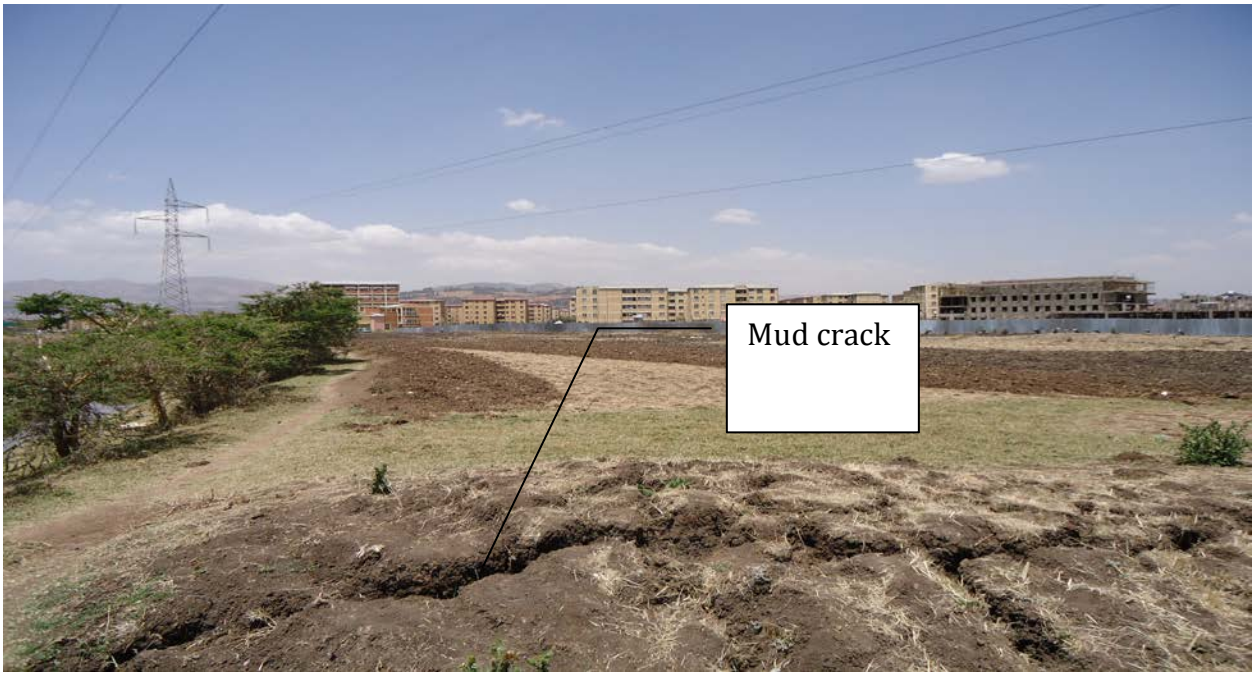

Figure 5*:* Mud Cracks Produced by Drying of clays/silts during dry season

1.15 Hydrogeology and Groundwater Quality of the Study Area

Addis Ababa terrain is characterized by multi–layer aquifers which have different hydro geological characteristics. All types of aquifers are found in Addis Ababa (unconfined, semi-confined and confined) including perched aquifers .For the confined and semi confined aquifers the confining layers are clays and fresh and massive and /aphanitic basalts and welded tuffs/ ignimbrites (Dereje , 2006).

Older volcanic rocks consists of Trachytes, Tuff, Ignimbrites and ash flows as well as older basalts are characterized by low to moderate permeability and productivity aquifers while the younger volcanic rocks of mainly vesicular and scoracious basalts are known to high to very productive aquifers (AAWSA, 2008).

The hydraulic conductivity value ranges from 0.09 m/day in the homogeneous less fractured highland volcanic rocks to around 550 m/day in the highly fractured volcanic and permeable alluvial and lacustrine deposits, the mean annual aerial groundwater recharge from the rainfall is estimated 106 mm and the transmissivity value range from 0.3 to 105408 m^2/day (Tenalem et al, 2008).

The existing water well drilling data shows the study area is composed of both inter-granular and fractured (secondary) porosity aquifers. It is also characterized by both consolidated and unconsolidated volcanic aquifer.

The source of freshwater in the study area is: groundwater and indirectly they use stream water for different purpose. The Total depth of boreholes are from the range of 84 to 240 m, average depth of static water level is 6.76 m below the ground, average optimum yield 16.81 liter per second and average working time per day is 16.19 hours, average dynamic water level is 48.68 m(source : drilling well completion report).

As far as ground water quality is concerned, most of the well completion data show less mineralized (TDS less than 500 mg/lit) (AAWSA, 2008). In addition, most of the study area productive groundwater well finds along the polluted stream bed and within the condominium buffer zone (AAWSA data base, 2014).

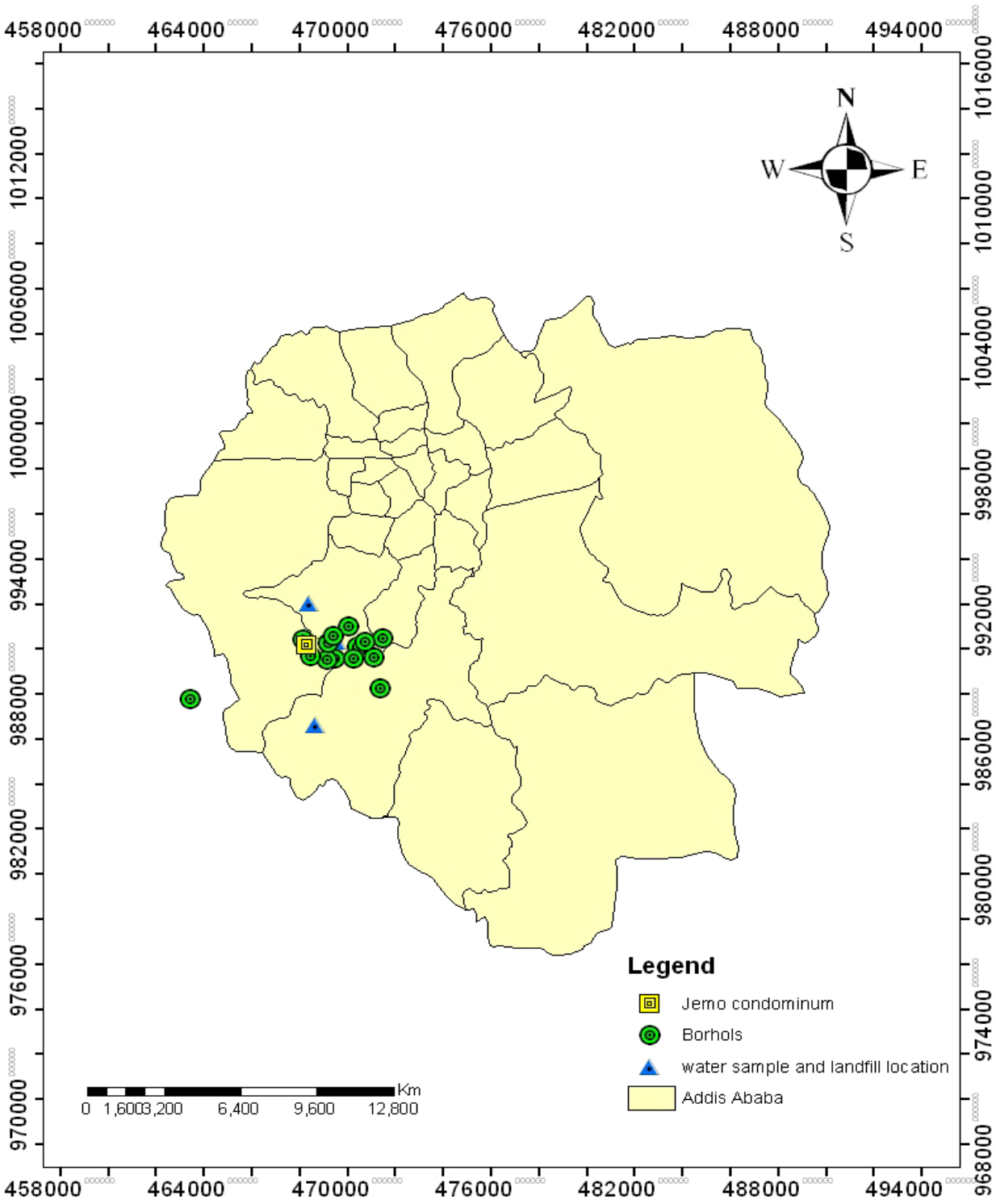

Figure 6 : Borehole, Water Sample, Jemo Condominium & Reservoir Location.

1.16 Physiography of the Study Area

The study area is characterized by flat land and surrounded by mountain from south and west. The overall view of this topographic high gives half depressed volcanic vent (caldera). The major volcanic centers are Mt. Wechecha (3384 m) western side and Mt. Furi (2838m) a.m.s.l from south. Mt Wechecha which forms the surface water divides in to the eastern and western basin.

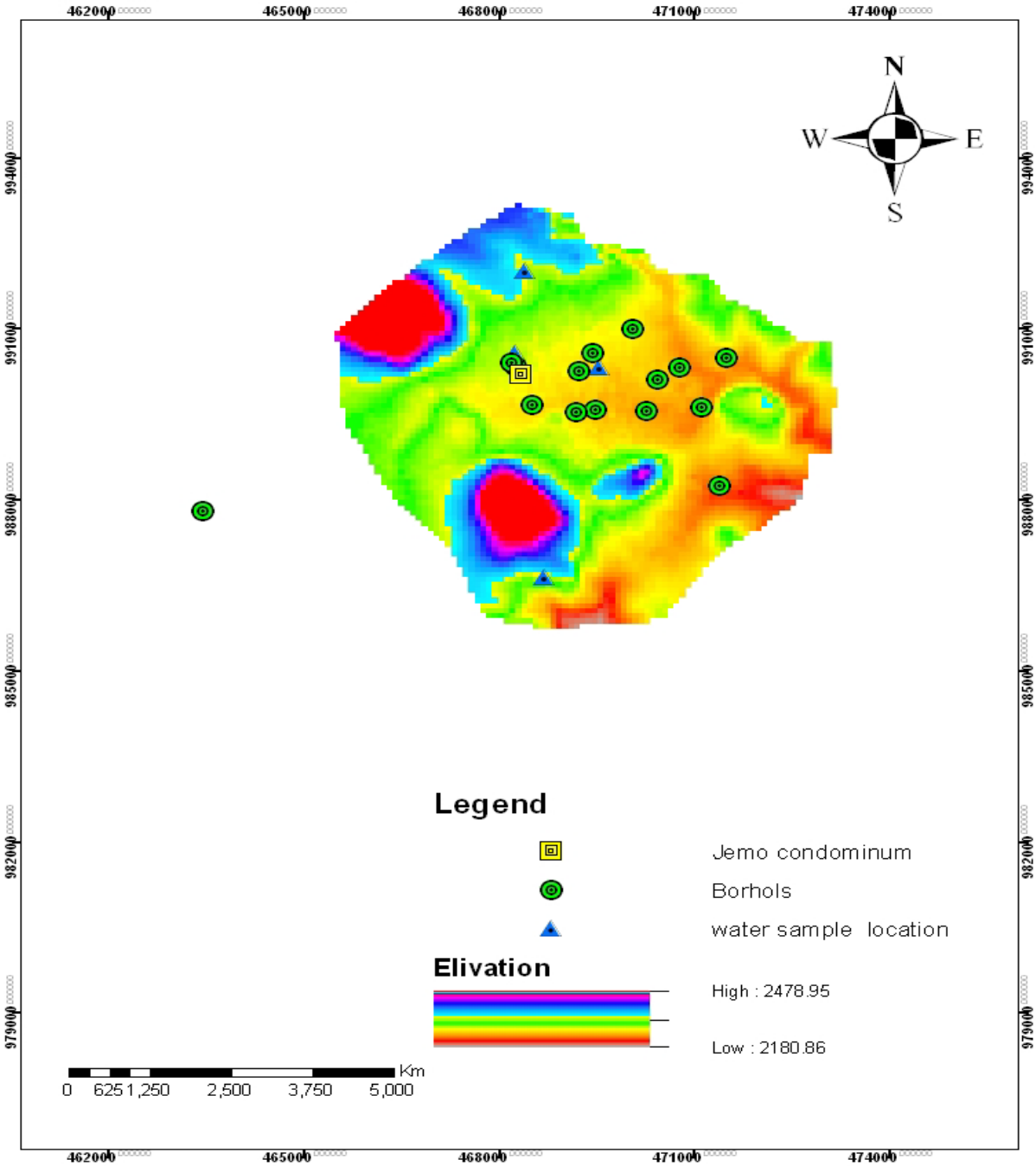

Figure 7: Digital Elevation Model of the Study Area

1.17 Drainage

The study area is located at little Akaki River catchment which is a tributary of Akaki River. The western part of this area has high elevation compare to the study area and form a water divide between the study areas to western part of Ethiopia. As a result the flow of water is directed towards the Akaki well field area.

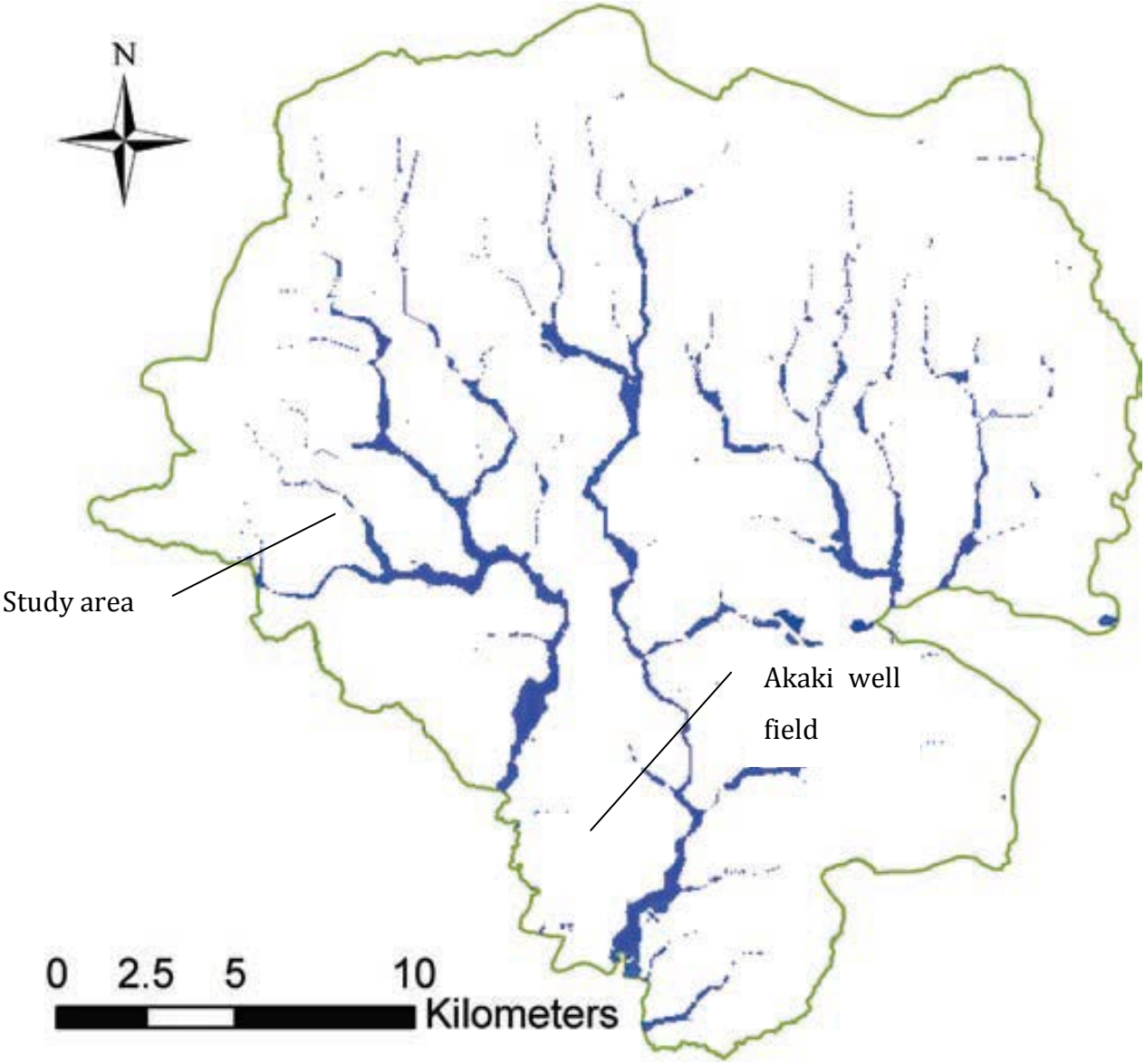

Figure 8: Drainage System of Addis Ababa (Source: free encyclopedia)

1.18 Land Use

Land resource in the study area has been used for condominium house, industry, agriculture, agriculture, and landfill and quarry site. However, some of the activities such as poor landfill have negative impact on the quality of water resource. Hence, effective land resource management needs to improve the sustainable clean water supply.

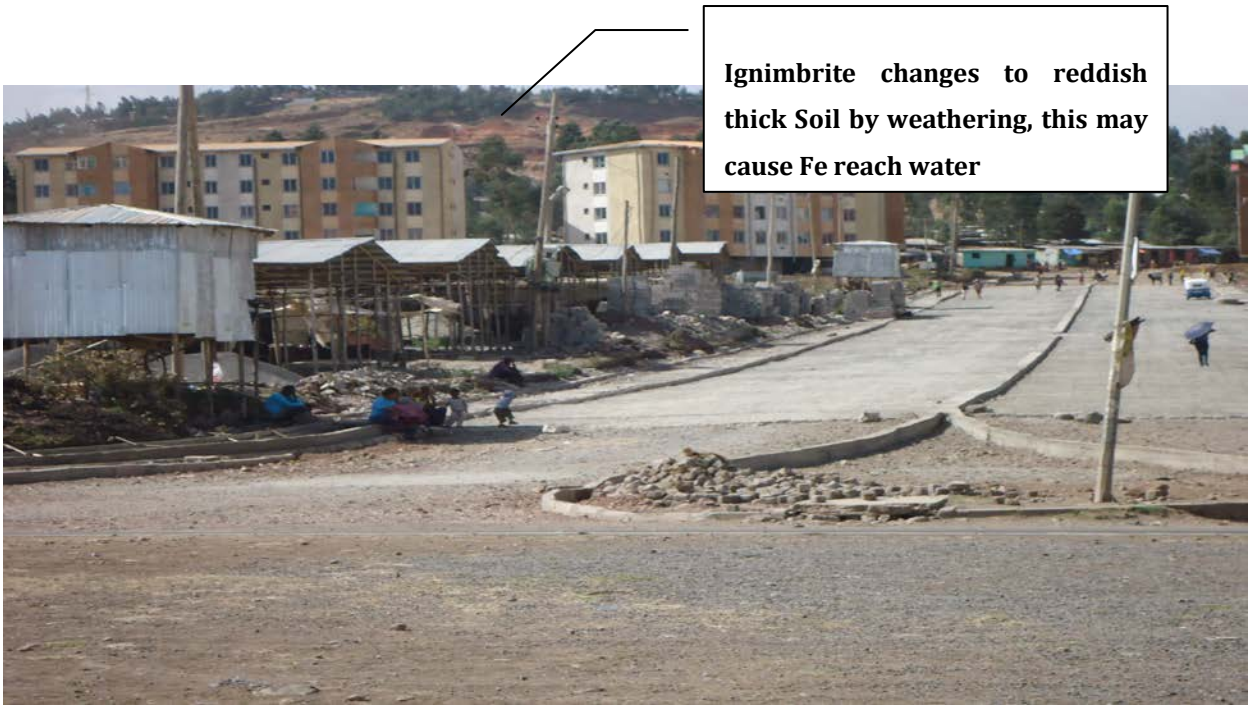

Figure 9 : Ignimbrite Changes to Reddish Thick Soil by Weathering

1.19 Population Growth in Addis Ababa

Previously the populations of the Addis Ababa city were mainly settled in the center of the city. Increasing population and industry can cause expanding fast in all directions except to the northern part due to topographic barrier and has an estimated population of 3,147,000 with an estimated area of 530.14 square kilometers with an estimated density of 5936.2 inhabitants per square kilometer (CSA, 2007) .The population of Addis Ababa is also strongly affected by migration so as to look for better income, education and facility. The percentage of immigration is 9.2% and outmigration is 5% result a net addition is 4.2% of the current population of the city during 2007-2012. The proportion of migration much higher in urban population (49%) compared to rural population (9 %) and rural to rural migration (37%) of all migrates while rural to urban migration formed 33% (CSA, 2013).

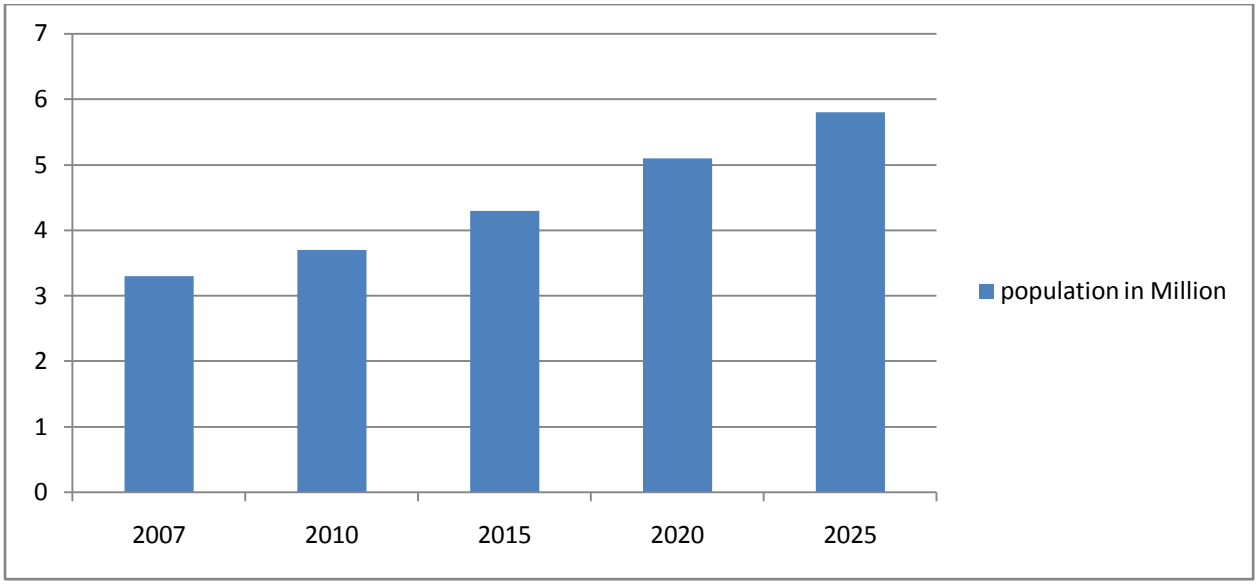

Figure 10 : Population Growth (AAWSA, 2013)

	unit	2007	2009	2010	2012	2013	2014	2015
Population growth	million	3.3	3.6	3.7	4.0	4.2	4.4	4.6
Water supply production capacity	m3/day	237,380	265000				365,000	
Water demand	m3/day	363000	396,000	407000	440000	462000	484000	506000
Per capita water supply	In litter	110	110	110	110	110	110	110

Table 2 : Population Growth and Water Demand

Table 3: Water Production, Distribution and Consumption in Addis Ababa for the Year 2005 to 2009(Addis Ababa City government finance and economic development Bureau, 2010)

No.	Indicators	Unit of measurement	Annual Trend				
			2005	2006	2007	2008	2009
1.	water loss	%	17.62	17.81	18.12	17.68	18.44
2.	Annual growth rate of water distribution	%	3.98	4.57	3.63	4.12	5.97
3.	Water production capacity	M3/day	220,000	230,000	237,380	248,000	265,000
4.	Annual growth rate of water production capacity	%	4.35	2.95	4.44	6.42	10.17
5.	Per capita water supply	Litter/person	--	110	110	110	110
6.	Water demand	m3/day	341,5467	352,110	363,000	373890	385,106.7

CHAPTER TWO LITERATURE REVIEW

In relation to urbanization and water supply problems a number of researches have been done in the last decades. Of course, their particular interest and focus areas varied based on their contexts. I tried to examine some of them and I have observed clear gaps that should be fulfilled in the present and future researches. Some of them are briefly discussed below:

Roy and Saha (2011) study factors related to urban growth and emerging challenges in the case of West Bengal. They concluded the rate of urbanization is rapid in the developing countries due to lack of proper planning and strategy. Some of the problems related to urbanization are:

1. Formation of new Sewage.

2. Dumpsites may locate indiscriminately.

3. Domestic waste water which contains organic and inorganic matter which may be harmful to the environment or to public health.

4. River and sub-surface waters are vulnerable to pollution which may cause diseases.

5. High rate of population growth and urban expansion bring Infiltration problems.

6. Improper organized system of water supply may result drinking water problem.

7. Cities may be suffered by social problems.

8. Urbanization may bring housing and services shortage.

However, Roy and Saha (2011) did not much emphasis about impact of urbanization on geology and hydrogeology which have to the integral part their research.

In addition ,the International Journal of Security and Development (2013) argues that the accelerated growth of urbanization change the demand for key services such as shelter and basic services (water and sanitation, education, public health, employment and transport) in sub-Sahara Africa. Above all accelerated and poorly managed urbanization has resulted in various types of atmospheric, land, water pollution and social problems.

This journal provides information about the relationship between urbanization, sustainable development and human security within the context of Sub-Saharan Africa. It also recommends possible measures and policy options to mitigate the negative impacts of rapid urbanization in the region. However, this journal did not give emphasise to the importance of primary data.

Moreover, the impact of industrialization and urbanization was discussed by two known scholars. According to Christopher and Mohd (2011), the main impacts are ground water pollution and occurrence of Insects, rodents, snakes and scavenger birds, dust, noise, bad odour. However, they did not give much attention the importance of local community and health experts' response.

Daniel (2011) also tried to explain about Vulnerability of surface water supply systems of Addis Ababa due to climate change and other factors such as meteorological, hydrological and demographical data. he also draws the supplied water quantity per capita from surface sources in Addis Ababa is reduced because of increase in temperature, water losses, increase in groundwater level and population. But he did not emphasis the impacts geologic condition and catchment nature on groundwater level increment.

It is clear that regarding Addis Ababa water supply and sewerage a number of researches have been done. Particularly modern water supply of Addis Ababa was started by constructed masonry ducts along Kebena River during Emperor Minilik.

A major departure was taken place by Ras Dests Damtew in 1926. He under took a revised water supply project. Consequently, the water from the springs near Menbere kibbre was collected in one reservoir and distributed by means of 3-inchs pipes to Genete Leul palace and surrounding. The Franco- Ethiopia railway company also had contribution to construct the water supply pipe line from Wochecha spring up to station and to the settlement of Keranio Medhanialem church, Lidetta and surrounding residents (AAWSA, 2012)

Italian force also built a reservoir of 1500 m3 capacity at the site close to Ras desta Damtew residence. This was augmented by another system constructed on Kogole River at Gullele, on the way to Addis Alem, producing 300 cubic meter of water per day.

Moreover, After the Italian occupation, Hile Selassie I launched reconstruction and rehabilitation programs in every sphere of development activity. In 1971 water supply was augmented by extracting water from springs, wells and fusing them in to the system using motor pumps. Based on the evaluation of previous water production and water scarcity The Geferssa dam was made. This is the beginning of a big water supply system in Addis Ababa with water capacity 1.5 million cubic meters constructed in 1952. However, the increasing water demand pressured on the management caused the construction of Legedadi dam in 1971.

According to Wuha Lehiywet Special Issue Magazine (2001), Addis Ababa water and sewerage authority was established as an autonomous body by order No 68/1971, proclamation no 10/1995. The main objective of AAWSA is to supply safe and adequate water and provision of wastewater and sludge disposal service.

Water Supply Stress Indexes

There is different water scarcity or water stress index (WSI) that shows the current water supply situation of a certain area in the world (Brown and Matlock, 2011). Some of them are:

a) Basic Human Water Requirements index: Freshwater scarcity is commonly described as a function of available water resources and human population. These figures are generally expressed in terms of annual per capita water and mostly on a national scale.
b) Water Scarcity index: use when annual water supplies drop below 1 000 m3 per person.

From the above mentioned indexes the researcher used Basic Human Water Requirements and Water Scarcity index

Water Resource Management Models

To represent the real management of water resource, there are different types of water resource management policy models in the world: according to Haakon Lein and Matthias Tagseth (2009) water resource management discussed as follow:

A, State Centre Water Resource Management Model

This model is characterized by state centred approach to manage the water resource. It is carried out based on the notion of administrative and political institutions to manage water resources in the interest of the common good. Planning, management and conflict resolution can be carried out by special water management authorities, having superior knowledge and overview of available resources. In this model water management organizations are to be governed by boards, often involving different "stakeholders", understood to represent various interests groups or sectors (civil administration, ministries, economic actors, farmers, women, etc.)

B, Market centre Management Model

According to the market-based water resource management argue that "water has an economic value in all its competing uses and should be recognized as an economic good" .It can be used to recover the cost of providing the service; it can provide an incentive for the efficient use of scarce water resources; and water charges can be used as a benefit tax on those receiving water services to provide potential resources for further investment for the benefit of others in society.

C, Community Water Resource Management Model

The idea that local communities can manage resources which states that "Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels" . A "water management community" may be a village or a group of water users sharing a scheme or a source of water. The "members" of the community have the right to utilize the resource, but there is usually no individual ownership.

The above overview tried to show the works of some scholars and their focuses regarding urbanization and water supply challenges and their gaps. Of course, the main objective of this thesis is to identify the major water supply challenges of Addis Ababa with special reference to Jemo condominium site .In the following chapter the collected data are interpreted and analyzed based on basic human water requirement index, water scarcity index , water resource management model and mixed approaches (qualitative and quantitative).

CHAPTER THRE DATA PRESENTATION AND INTERPRITATION

This chapter basically interpret and analyse data using quantitative and qualitative methods in relation with basic human water requirement index, water scarcity index and water resource management models.

3.1 Groundwater Quality Analysis

The provision of quality water supply is the main responsibility of Addis Ababa water supply and sewerage authority. Since it is established as an autonomous body based on proclamation No 10/1995 so as to supply safe and adequate water service in Addis Ababa. The Authority also has the duty to test biological, chemical and physical properties of surface and groundwater supply source before distributing to community water supply system. The ground water sample laboratory analysis result has indicated that the study area is characterized by average EC, TDS, P^H ,Ca, Mg, Na, Cl, $HC0_3$and S04 in mg/lit are 303.6, 160.1, 7.258, 44.95, 8.73, 30.1, 5.2, 211.458 and 2.173 respectively .However, some of the groundwater well show relatively increasing of sulphate concentration and decreasing of P^H value.

	Jemo 27,24		Jemo 28		Jemo 29		Mekanisa			
	2011	2014	2011	2014	2011	2014	2006	2010	2012	2014
TDS	140	131	184	174	143	150	194	187	196	102
pH	7.73	6.29	6.98	6.93	8	7.27	7.71	7.66	7.44	7.12
EC	140	275	386	386	303	315	295	391	411	216
sulfate	1	1.6	1.84	2.5	0.5	1.2	0.74	1.8	2.5	3.4

Table 4 : TDS, P^H, EC, and Sulphate Concentration of Groundwater Well of the Study Area (source AAWSA, 2014)

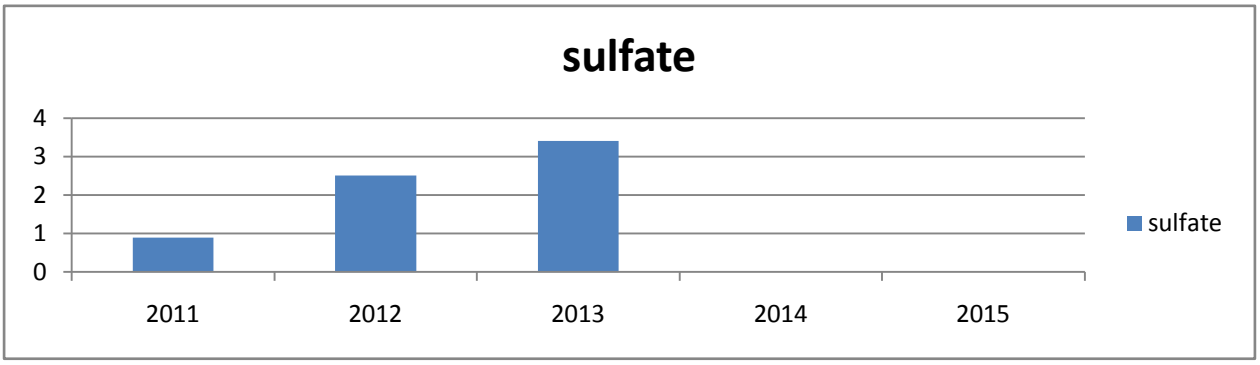

Figure 11: Increasing of Sulfate Concentration from 2006 to 2014 of Mekanisa Well

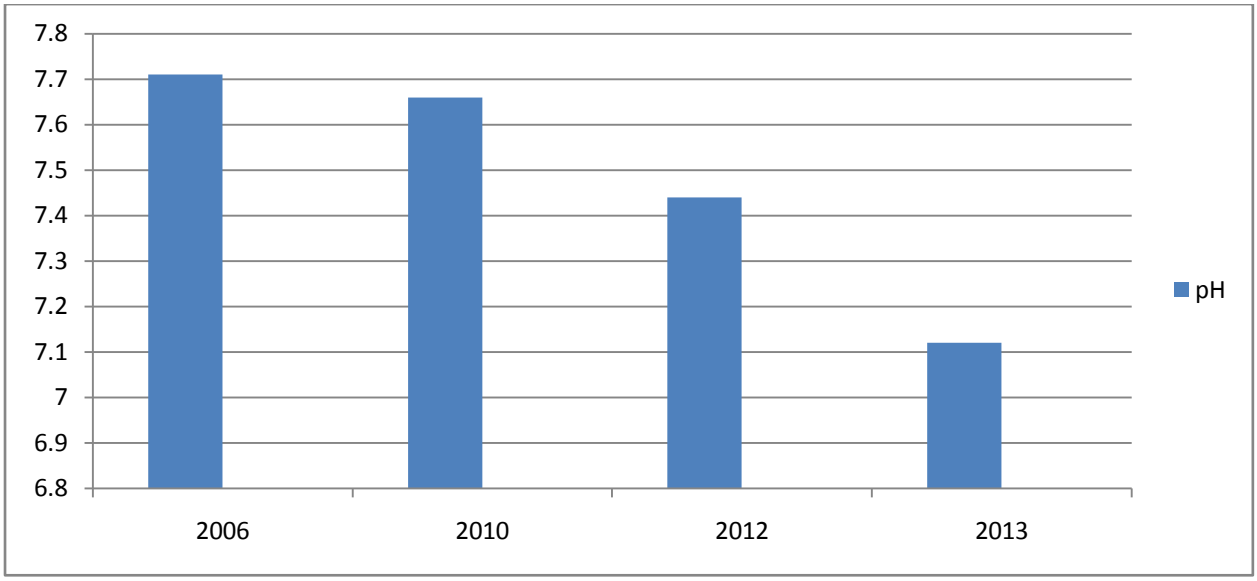

Figure 12: Variation of pH from 2006 to 2014 of Mekanisa Well

Number of Samples: 5
Unit mg/l

Parameter	Min	Max	Average	St. Dev.	Dev. Coef	Q25	Q50	Q75
Ca	20.4	65.63	44.95	16.59	36.908	25.86	42.96	50.52
Mg	7.15	10.26	8.73	1.323	15.155	7.253	8.37	9.42
Na	11.6	93.1	30.1	35.281	117.213	12.15	14.15	16.75
Cl	1.99	9.93	5.2	3.147	60.524	2.393	3.68	5.98
HCO3	173.97	245.95	211.458	31.982	15.125	173.97	197.64	228.27
SO4	0.74	3	2.173	1.012	46.572	0.74	2.2	2.75
TEMP	105	105	105	0	0	105	105	105
pH	6.92	7.71	7.258	0.321	4.42	6.94	7.12	7.375

Table 5: Hydrogeochemical Characteristics of the Study area Calculated by Aquachm Software (source: study area water well drilling completion reports and current water sample analysis)

Borehole	X UTM	Y UTM	Depth,bgl (m)	Pump Test Yield(l/s)	DWL	SWL	Optimum Yield	Average / Current Q(l/s)	Daily Production
Mek1/96	469500	989600	150	3	39	4	3	3	108
Mek 2/96	470070	991000	170	10	66	10	10	10	576
Mek 1/97	471125	989636		26		11	26	26	1684.8
Mek 1/98	470453	990127	140	50	25.36	22	17	17	1075.7
Site No.1	463453	987806	184	47	14	1	30	27	1652.4
Site No.18	469191	989547	230	8	106	3	7	5	324
Site No.19	468261	990357	196	17	113	7	10	6	345.6
Site No.20	470277	989578	230	15	89	13	5	14	856.8
Site No.21	469245	990260	240	30	50	1.8	20	26	1310.4
Site No.24	468512	989680	230	60	14	Flow	30	26	1591.2
Site No.25	471500	990500	200	17	20	12	16	17	734.4
Site No.26	469458	990594	181	15	25	0	15	9	648
Site No.27	468196	990422	180	18	19	5	10	10	504
Site No.29	470790	990330	240	40	45	0	30	18	907.2
Lafto old	471400	988250	84	21.3		9	20	18	1166.4

Table 6: Groundwater Well in the Study Area

From the above data we can calculate the value of specific capacity.

Specific capacity: Is the ratio of discharge to maximum drawdown

Specific Capacity = (Yield/Drawdown)

Well Yield: Volume of water per unit time discharged from a well by pumping or free Flow, Units of discharge: Gallons/Minute or m_3/day

Drawdown= (SWL-PWL); Length difference between the SWL (water table or potentiometric) and the PWL

Static Water Level (SWL) is the Equilibrium level of water in well (confined or unconfined aquifer) when no water is being removed from the aquifer via pumping or free flow. SWL in well at equilibrium with aquifer is a reflection of the total hydraulic head of the water table (unconfined) or potentiometric surface (confined)

Pumping Water Level (PWL): Level at which water stands in a well when pumping/removal is in progress

Average pump position, optimum yield and drawdown of the study area =117 m, 16.60l/s and 35.1m respectively

Given

Q= 16.6 /s, D= 35 m

Required Sc

Sc = Q/D in l/s/m = 16.60l/s/35m = 0.47 lit/s/m

Where Q is discharge (yield) in l/s and D is drawdown in m.

Therefore, the average specific capacity of boreholes in the study area is 0.47 lit/s/m = 40.608 m2/day

From this we can conclude the specific capacity of an aquifer is directly proportional to yield and inversely proportional to drawdown.

3.2 Surface Water (stream) Quality Analysis

The main assumption to analyze the surface water samples in the study area is to identify the major hazardous chemicals which may affect the groundwater and surface water. Two different water samples were taken and analyzed for physicochemical parameters including pH, electrical conductivity, TDS, SO4, NO3, Co, Ni, Cd, Cu, Zn, , Pb, and Mn. The laboratory results indicated; the levels of Cd 0.2791to 0.5602 µg/lit, Cu 9.687 to 8.699 µg/lit, cobalt (Co) 59.03 to 65.15 µg/lit, Pb 131.7 to 407.1 µg/lit, Mn 0.5851 to 21.81 µg/lit, zinc (Zn) 4.743 to 11.65 µg/lit, SO4 55 to 10mg/lit , NO3 121.25 to 82.5mg/lit, nickel (Ni) 13.68 to 27.44 mg/lit, PH 7.29 to 8.22, TDS 351 to 1200 mg/lit, and E.C704 to 2430 µs/cm at 25 degree centigrade. From this we can see the concentration of lead increased by 40.7 times compare to WHO standards.

Figure 13 : Junction of streams in the study area

Sample No.	Pb	Zn	Mn	Ni	Cd	Cu	Co
Standard	20 µg/l	6000 µg/l	800 µg/l	70 µg/l	3 µg/l	5000 µg/l	
Sample1	131.7	4.743	0.5851	13.68	0.2791	9.687	59.03
Sample2	407.1	11.65	21.81	27.44	0.5602	8.699	65.15

Table 7: Stream Water Quality Analysis of Study Area

Sample No.	PH	SO4	NO3	TDS	EC
Standard	6.0-8.5	200mg/l	50 mg/l	1200 mg/l	1000µs/cm at 25 0c
Sample1	7.29	55	121.25	351	704
Sample2	8.25	10	82.5	1200	2430

Table 8: Stream Water Quality Analysis of Steady Area

Key finding

From the above data analysis we can conclude that the concentration of Lead, electrical conductivity of water is very high compare to WHO standard.

Figure 14: Importance of Stream for Local Community

3.2.1 Landfills at Jemo Condominium Site

This is one of the landfill sites in Addis Ababa .The satellite image shows that the landfill is found 2270 m above sea level and 40m elevated from the groundwater well filled area. In this site huge both organic and inorganic waste materials gathered from different parts of the city and dump there. Consequently, very high polluted leach has released and joins to the surrounding streams and well field without treatment. And also cause the occurrence of Insects, rodents, snakes and scavenger birds, dust, noise, bad odor.

Figure 15: landfill Near the Study Area

Key finding: Very high polluted leach has released and joins to the surrounding streams and well field area without treatment. And also cause the occurrence of Insects, rodents, snakes and scavenger birds, dust, noise, bad odor.

3.3 Evaluation of Water Supply Using Water Supply Index

Water stress or water scarcity is a condition where an imbalance occurs between water demand/need and water availability. Determination of *water scarcity* in an area will be determined by using index that is called *water stress Index* (UNESCO, 2009).

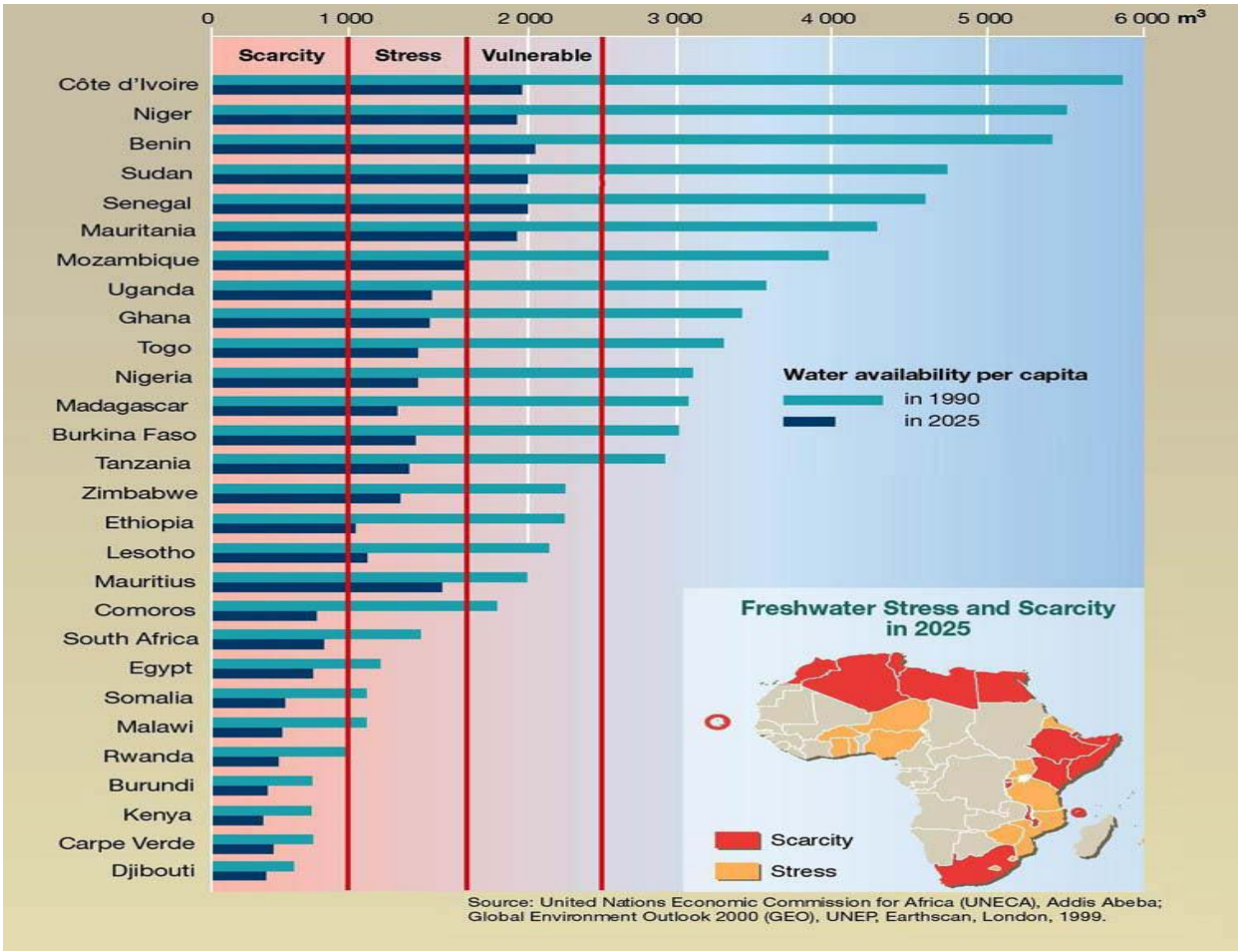

Figure 16: Water Availability Per capita for African Countries (IWMI 2007a)

3.3.1 Basic Human Water Requirement Index

As Gleick (1996) developed that a water scarcity index is a measurement to meet all water requirements for basic human needs that is for drinking water for survival 5 liters per person per day, for hygiene 20 liters per person per day, for sanitation services 15 liters per person per day And also average household water needs for preparing food 10 liters per person per day. The proposed minimum amount needed to sustain is 50 liter per person per day. Hence, the total population that can benefit from the existing water supply of Addis Ababa can be calculated as:

The study area water supply district has 74,646 customer and 12 boreholes and some additional water from the surrounding district. Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA, 2007), Addis Ababa has an average of 4.1 persons per household.

Hence, the total population of the study area can be calculated by the number of household multiplied by average number of people in household = 74646 x 4.1 = 306,048.6 populations in the water supply district.

From 15 boreholes the total water production = 13,484.9 m^3/day

Water loss 30% = 13,484.9 m^3/day – 30% = 4045.47

Estimated population in the district is 306,048.6

Net water production & Water demand = 9439.43 m^3/day and 15,302.43 m^3/day respectively

Water deficit = 15302.43- 9439.43 m^3/day = 5863 m^3/day

Based on this analysis only 61.7% population is served with the existing water supply system.

3.3.2Water Scarcity Index: use when annual water supplies drop below 1000 m^3 per person.

Average water demand per person per day = 110 lit/cap/day

Estimated population of the district and total water demand 306,048.6 and 33,665.346 m^3/day

Total water supply capacity and water deficit of the study area are: 9,439.43 m^3/day and 24,225.916 m^3/day correspondingly.

To get annual water consumption of each person in m3/year = total water supply/ total population = 9, 439.43 / 306,048.6 = 30.84lit/cap/day or 11.26m^3 /person/year

Since 11.26 11.26m^3/person/year is less than 1000 m^3 person/year shows the presence of water scarcity in the study area.

3.4 Water Resource Management Model of Study Area

The current water supply management structure of AAWSA is organized from relevant Ministers, organization of the federal government, Addis Ababa city administration, Oromia regional states and representative of the AAWSA worker association structure and the absence of community participation to manage the water scheme show the water supply management models (approach) of Addis Ababa are similar to state centred.

3.5 Customer Water Supply Satisfaction Analysis

Data which are collected through questionnaires are analysed on the basis of % that corresponds with the number of respondents who have provide similar answer for the given questions. Different groups of respondents analyze separately before merging all groups in to one big group.

General Characteristics of Respondents

Lists of participants	Gender in %		age		Educational states in %			
	M	F	min	Max	Uneducated	Below grade 10	Diploma	Degree
AAWSA project office	100	00			00	00	00	100
Clinic Jemo site area	80	20	25	45	00	10	30	60
Jemo condominium site residents	10	90	15	70	26	6	62	6
School response			25	35	00	00	00	100
AAWSA Mekanisa branch	100	00			00	00	00	100

Table 9 : General Characteristics of Respondent

Lists of respondents	questionnaires distributed		questionnaires returned and fully answered	questionnaires not returned	questionnaires not fully answered
	No.	%			
AAWSA project office	7		6	0	1
Clinic Jemo site area	20		15	5	O
Jemo condominium site residents	20		16	0	4
School Jemo site response	25		20	4	1
AAWSA Mekanisa branch	6		4	0	2
Total	78		61	9	8

Table 10 : Lists of Participants Distributed and Returned Questionnaires in the Study Area

From table 6, we can draw that out of 78 questionnaires distributed to the residents and related organization 78% of them fully completed and returned. The rest 11.54% questioners are not returned and 10.25% questioner is returned but not fully answered.

Figure 17: Water Leakage in Addis Ababa

Lists of questions	**Response in %**				**Response in word and figure or %**
	Strongly agree	Agree	Strongly disagree	disagree	
Average number of days in a week with out pipe water supply in Addis Ababa					2 days
There is a limitation of awareness to use water economically	20	80	00	00	
Rapid expansion of the city, and waste material from domestic and industry may affect the water quality and location of the Addis Ababa.	20	60	00	20	
There is limitation budget and skilled manpower in AAWSA.	20	20	20	40	
Average water losses in the distribution in A.A					32-40%
The total none domestic water consumption in A.A					< 20 %
The total domestic water consumption in A.A					>71%
What are the major water supply challenges in A.A?					

Table 11: AAWSA Project Office Response

Key finding

From the above table one can conclude that More than 80 % response showed the limitation of awareness to use water economically, more than 80 % respondents believed that the rapid expansion of the city brought waste material from domestic and industry may affect the water supply.

Lists of questions	Response in %				Response in word and figure or %
	Strongly agree	Agree	Strongly disagree	disagree	
Average number of days in a week with out pipe water supply in the district					3 days
There is some user which can get better water supply in the district		75		25	
There is a limitation of awareness to use water economically	25	75			
Rapid expansion of the city, and waste material from domestic and industry may affect the water quality and location of the district.	25	25	00	50	
There is limitation budget and skilled manpower in your district.	25	25		50	
The maximum water supply to your district from the total water production of Addis Ababa					< 10 %
Average water losses in your districts					32-40%
The total none domestic water consumption in Jemo site					< 20 %
The total domestic water consumption in Jemo site					>71%
water supply source of the area					Groundwater
What are the major water supply challenges in your district?					

Table 12: AAWSA Mekanisa Branch Office Response

Key finding

From the above analysis we can draw that More than 80 % respondents said that the Average three days in a week are with out pipe water supply in the district. And more than 75 % respondents are informed that there is limitation of awareness to use water economically.

Lists of questions	Response in %				Response in word and figure or %
	Strongly agree	Agree	Strongly disagree	disagree	
There is a limitation of clean water in Jemo area.	38	42.3	0	19	
Based on the current waste disposal to the environment, there is the possibility of water born dieses in Jemo area.	11.5	46	3.8	38.46	
The awareness of using water Economically is low in Jemo area.	7.6	46	8.33	37.5	
Rapid expansion of the city, population and industry may affect the water supply in Jemo area.	19	38	30.77	11.5	
There is limitation water supply in public organization.	50	30.77	15.38	3.85	
Some times there is unclean water comes from water tap to Jemo area.	15	53.8	30.76	00	
The coordination between user and water provider in Jemo area.					65 % say unsatisfactory
Active technical participation of user on water scheme maintenance can reduce water loss.	19	57.77	0	15.38	
Average daily water consumption per person per day in Jemo area					20-60 lit/day
Response of water supplier during fault is supply.					More than 65 % unsatisfactory
Quality and quantity water supply is increasing from time in Jemo area.	11.5	19	26.9	42.3	
What do you Suggest to improve the water supply of your area?					

Table 13: Responses of School Teacher and Director, and Clinics Staffs of Study Area

Key finding: From the above table we can understand that More than 80 % respondents showed that there is limitation clean water supply; more than 76 .77 % respondents suggested the need of active participation of consumers so as to minimize water loss. And more than 69 % responses indicated the decline of clean water; more than 65 % of responses explained the problem of coordination between users and water provider .Above 80 % response show the limitation water supply in public organization.

Lists of questions	Response in %				Response in word and figure or %
	Strongly agree	Agree	Strongly disagree	disagree	
Main source of water supply					% 99 private indoor
Average Water Use Per Person Per Day in Addis Ababa					20-60 liter
Number of days in a week with out pipe water supply					3-4 days
There is some water user which can get better water supply within a Jemo condominium site	19	38	30.77	11.5	
There is a possibilities of diharhea and typhoid dieses within Jemo condominium site	25	50.77	15.38	3.85	
There is no sufficient water in hotel , cafe , school, health within Jemo condominium site	15	53.8	30.76	00	
Participation of the water user in water Scheme maintenance can improve the water supply loss	50	30.77	15.38	3.85	
Some times there is turbidity water supply at Jemo condominium site	19	57.77	0	15.38	

Table 14: Responses of Residents

Key finding: From the above data analysis we can draw that more than 80 % respondents pointed out that on average 3 days per week are with out pipe water supply, above 80 % responses suggested the need for Participation of the water users in water Scheme maintenance .

CHAPTER FOUR CONCLUSION & RECOMMENDATION

4.1 Results and Discussion

Many researches and the above analysis have made clear that the rapid urbanization and population have brought series challenges on quality and quantity of water supply. This study tried to point out the problems based on laboratory experiment, water supply stress index, and water resource management models and data interpretation. For instance, the ground water sample laboratory Analysis result has indicated most of the hydrochemical characteristics are within the WHO standards. However, some of the ground water well revealed variation of sulphate and P^H in consecutive years.

Where as, the surface water(stream) sample analysis result indicated; the levels of Cd 0.2791to 0.5602 µg/lit, Cu 9.687 to 8.699 µg/lit, cobalt (Co) 59.03 to 65.15 µg/lit, Pb 131.7 to 407.1 µg/lit, Mn 0.5851 to 21.81 µg/lit, zinc (Zn) 4.743 to 11.65 µg/lit, SO_4 55 to 10mg/lit , NO_3 121.25 to 82.5mg/lit, nickel (Ni) 13.68 to 27.44 mg/lit, P^H 7.29 to 8.22, TDS 351 to 1200 mg/lit, and E.C 704 to 2430 µs/cm at 25 degree centigrade . From this we can draw very high concentration of lead, EC, nitrate compare to WHO standards. Excess lead concentration in water may result toxic effects of lead include: Anaemia, kidney damage, hypertension, and cardiac disease, Immune system suppression (antibody inhibition) neurological damage (Quaterman, 1986)

Since the structure of AAWSA similar to state centered approach ,this may make the user passivne and activnes of the state only. In addition, basic human water requirement and water scarcity index result show the existing water supply serve not more than 60% of the population.

Interpretation *which* was done in table 6 and 7 made clear that more than 75 % responses showed the existence lack of awareness to use water economically. While more than 75 % respondents believed that the rapid expansion of the city brought waste material from domestic and industry may affect the water supply and average three days in a week are with out pipe water supply.

Moreover, Table 8 we can understand that more than 80 % the respondents indicated that the presence of limitation of clean water supply. One can also grasp more than 76 .77 % respondents suggested the need of active participation of consumers so as to minimize water loss. And more than 69 % responses showed the decline of clean water where as more than 65 % of responses explained the problem of coordination between users and water provider. Table 9 analyses also indicated 80 % respondents pointed out that average 3 days per week are with out pipe water supply; above 80 % responses suggested the need for Participation of the water users in water Scheme maintenance.

In generally, lack of integration between different stakeholder frequently pipeline breakage, lack of water scheme rehabilitation & maintenance, system of water distribution to end users ,accessibility of roads ,developing new sources compatible to the growth of the capital city both population and construction, power interruption ,Insufficient source of water and Water quality constraints are some of the major water supply challenges of the study area .Because of this , there is no clear pipe water supply at least three days per week.

4.2 Conclusion

This conclusion is basically drowned from the literature review, data interpretation and analysis. It is also drown from laboratory result , water scarcity index and water resource management models .The research revealed scarcity of water & majority of the respondents agreed that there is no clear pipe water supply at least three days per week in the study area. This is mainly due to population growth, lack of integration between different stakeholders and breakage pipeline. The other main causes of shortage of clean water are lack of water scheme rehabilitation, lack of awareness to manage and use water economically.

Moreover, from the ground water sample laboratory Analysis of AAWSA result one can conclude most of the area hydrochemical is within the WHO standards. However, some of the ground water well showed variation of sulfate and P^H in consecutive years. Where as, the surface water samples analysis indicated that the levels of lead ,Cadmium , Cobalt , Manganese, Zink, Sulfate ,Nitrate , nickel , P^H and TDS within the WHO standards . But the level of lead and electrical conductivity of surface water above the WHO standards .This may cause toxic impact on central and peripheral nerves systems especially pregnant women and children are the primary victims of this impact.

4.3. Recommendation

Rapid urbanization and population faced challenges on provision quality water supply. These problems cannot be solved using one technique or method. They need multifaceted solutions. Fore instance, to improve quantity and quality of water supply in the study area we have to use different methods: such as reducing water supply loss by appropriate rehabilitation and increasing awareness, using alternative power source, creating good integration between different institutions, development of new water scheme. However the ultimate solution of improving water supply is improving our water resource management capacity. Other wise water scarcity and groundwater and surface water pollution are the major water supply challenges of the future.

In addition, the present hydro chemical and physical properties of water sample analysis which takes from the two streams near to the study area show very high hazardous lead metal concentration and E.C compare to WHO standards results from landfill. Thus it needs some modification wasting mechanism so as to protect hydro-geological contamination impacts on the area.

The AAWSA groundwater laboratory analysis data also show there is consecutive increase of sulphate concentration in some productive groundwater wells. These increment probably the results of surface contamination of the area. Thus attention is required to protect associated impact on healthy.

Ingenerall, so as to mitigate these crucial challenges all stakeholders particularly Addis Ababa water and sewerage authority including nongovernmental organizations and the direct beneficiaries should give immediate and holistic action.

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Appendix 1

Questioners

These questioners are use only for the purpose of completing MSc. Thesis Research on the topic: ``Urbanization and Water Supply challenges in Addis Ababa: special reference Jemo condominium site``. Please tick one from Q1- Q16

Full Name: _____

_____Block No. _____House No.

1. Gender

☐ Male ☐ Female

2. Age:

☐ under 16 ☐16-25 ☐26-35 ☐ 36-45 ☐above 46

3. Educational status

☐ Upto Grade 6 ☐ grade 6 to 10 ☐ grade 10- diploma ☐ university degree

4. Family status

☐ Single ☐Married ☐ Divorce ☐ Widow

5. Household size

☐ 1 ☐ 2 ☐ 3 ☐4 ☐5 ☐ >6

6. Age of Children

☐ Age < 4 ☐ Age 4 - 12 ☐> 12

7. Purpose of the house

☐ Residence ☐ Shop ☐ Micro enterprise ☐ Bekery

9. Main source of water supply

☐ Communal ☐ private indoor ☐ private outdoor

10. Average Water Use per Person per Day in Addis Ababa

☐ <20 lit ☐20 – 60 lit ☐60 – 100 lit ☐> 100 lit

11. Number of days in a week with out water supply

☐ 0 ☐ 1 ☐ 2 ☐3 ☐ > 4

12 There is some water user which can get better water supply within a Jemo condominium site.

☐ Strongly agree ☐agree ☐ disagree ☐ strongly disagree

13. There is a possibility of diarrhea and typhoid diseases within Jemo condominium site.

☐ Strongly agree ☐agree ☐ disagree ☐ strongly disagree

14. There is no sufficient water in hotel, cafe, school, health within Jemo condominium site

☐ Strongly agree ☐agree ☐ disagree ☐ strongly disagree

15. Participation of the water user in water Scheme maintenance can improve the water supply loss.

☐ Strongly agree ☐agree ☐ disagree ☐ strongly disagree

16. Some times there is turbidity water supply at Jemo condominium site.

☐ Strongly agree ☐agree ☐ disagree ☐ strongly disagree

17. If you have any other comments on the water supply service please include below.

Thank you for your kindly response!!

Appendix 2

Questioners

These questioners are use only for the purpose of completing MSc. Thesis Research on the topic: ``Urbanization and Water Supply challenges in Addis Ababa special reference Jemo condominium site ``. please tick one from Q1- Q12

Name : _____Position _____

1. 1.Age:

☐ under 16 ☐16-25 ☐26-35 ☐ 36-45 ☐above 46

2.Educational status

☐ Up to Grade 6 ☐ grade 6 to 10 ☐ grade 10- diploma ☐ university degree

3. There is limitation of clean water in this area.

☐ strongly agree ☐agree ☐ disagree ☐ strongly disagree

4. Average number of days in a week with -out water supply in this area.

☐ 0 ☐ 1 ☐ 2 ☐3 ☐ > 4

5. Based on the current waste disposal to the environment, there is a possibility of outbreak water born disease in this area.

☐ strongly agree ☐agree ☐ disagree ☐ strongly disagree

6. The awareness of using water economically is lo in Jemo area.

☐ strongly agree ☐agree ☐ disagree ☐ strongly disagree

7. Rapid expansion of the city, population and industry may affect the water supply of in Jemo area.

☐ strongly agree ☐agree ☐ disagree ☐ strongly disagree

8. There is limitation of water supply in public organization (e.g. school, health centre) of Jemo area.

☐ strongly agree ☐agree ☐ disagree ☐ strongly disagree

9. Sometimes there is high turbidity (unclean) of water comes from water tap to Jemo area.

☐ strongly agree ☐agree ☐ disagree ☐ strongly disagree

10. The coordination between user and water provider in Jemo area.

☐ unsatisfactory ☐satisfactory ☐ good ☐ ≥ very good

11. Active technical participation of user on water scheme maintenance can reduce water loss.

☐ strongly agree ☐agree ☐ disagree ☐ strongly disagree

12. Average daily water consumption per person per day in Jemo area.

☐ <20 lit ☐20 – 60 lit ☐60 – 100 lit ☐ 100 - 200 lit ☐> 200 lit

13. Response of water supplier during fault is :

☐ unsatisfactory ☐satisfactory ☐ good ☐ ≥ very good

14. Quality and quantity water supply is increasing from time in Jemo area.

☐ strongly agree ☐agree ☐ disagree ☐ strongly disagree

15. What do you suggest to improve the water supply of your area?

Thank you for your kindly response!!

Appendix 3

Questioners

These questioners are use only for the purpose of completing MSc. Thesis Research on the topic: ``Urbanization and Water Supply challenges in Addis Ababa special reference Jemo condominium site ``. please tick one from Q1- Q11

Name : _____Position _____

1.Gender

☐ Male ☐ Female

2.Educational status

☐ Up to Grade 6 ☐ grade 6 to 10 ☐ grade 10- diploma ☐ university degree

3. There is limitation of budget and skilled manpower in AAWSA.

☐ strongly agree ☐agree ☐ disagree ☐ strongly disagree

4. Average number of days in a week with -out water supply in AA.

☐ 0 ☐ 1 ☐ 2 ☐3 ☐ > 4

5. Rapid expansion of the city and waste material from domestic and industry affect the location and water quality of A.A.

☐ strongly agree ☐agree ☐ disagree ☐ strongly disagree

6. The average water loss in water distribution in AA.

☐ <20% ☐21-34% ☐ 35-40 ☐ > 40%

7. There is limitation of awareness of customer to reduce the water supply losses in A.A .

☐ strongly agree ☐agree ☐ disagree ☐ strongly disagree

8.the total none domestic water consumption in A.A

☐ <20% ☐21-34% ☐ 35-40 ☐ > 40%

9.the total domestic water consumption in A.A

☐ <20% ☐21-34% ☐ 35-40 ☐ > 40%

10. Average daily water consumption per person per day in AA.

☐ <20 lit ☐20 – 60 lit ☐60 – 100 lit ☐ 100 - 200 lit ☐> 200 lit

11 what is the major water supply challenges in A.A?

Thank you for your kindly response!

Appendix 4

Questioners

These questioners are use only for the purpose of completing MSc. Thesis Research on the topic: ``Urbanization and Water Supply challenges in Addis Ababa special reference Jemo condominium site ``. Please tick one from Q1- Q11

Name: _____Position _____

1. Gender

☐ Male ☐Female

2. Educational status

☐ Up to Grade 6 ☐ grade 6 to 10 ☐ grade 10- diploma ☐ university degree

3. There is limitation of budget and skilled manpower in your district.

☐ Strongly agree ☐agree ☐ disagree ☐ strongly disagree

4. Average number of days in a week with -out water supply in your district.

☐ 0 ☐ 1 ☐ 2 ☐3 ☐ > 4

5. The awareness of using water economically is low in Jemo area.

☐ Strongly agree ☐agree ☐ disagree ☐ strongly disagree

6. Rapid expansion of the city, population and industry may affect the water supply of in Jemo area.

☐ Strongly agree ☐agree ☐ disagree ☐ strongly disagree

7. The average water loss in water distribution in your district.

☐ <20% ☐21-34% ☐ 35-40 ☐ > 40%

8. There is limitation of awareness of customer to reduce the water supply losses.

☐ Strongly agree ☐agree ☐ disagree ☐ strongly disagree

9. The total none domestic water consumption in Jemo area.

☐ <20% ☐21-34% ☐ 35-40 ☐ > 40%

10. The total non domestic water consumption in Jemo site

☐ <20% ☐21-34% ☐ 35-40 ☐ > 40%

11. The total domestic water consumption in Jemo site

☐ <20% ☐21-34% ☐ 35-40 ☐ > 40%

12. Average daily water consumption per person per day in your district.

☐ <20 lit ☐20 – 60 lit ☐60 – 100 lit ☐ 100 - 200 lit ☐> 200 lit

13. What are the major water supply challenges in your district?

Thank you for your kindly response!!

Altitude in m	Rainfall mm/year	Station
2900	1320	
2,700	1230	
2,500	1,150	
2,300	1,080	
2,100	1000	Bole,Entoto,Sendafa

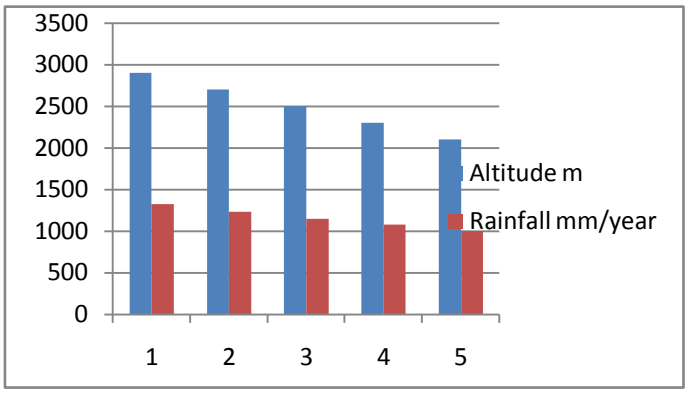

Figure 18: Rainfall variation with altitude in Addis Ababa

			rate per 1000 current population of the region			
	all migrants			recent migrants		
Region	In migrant	out migrants	net migrants	in migrants	out migrants	net migrants
Tigray	26	43	-17	8	11	-4
Affar	81	15	66	33	12	21
Amhara	7	71	-64	4	14	-11
Oromia	25	24	1	8	8	1
Somalia	17	16	1	2	4	-2
Benishangulgumuz	209	31	178	44	10	34
SNNP	20	47	-27	10	13	-3
Gambella	220	12	209	82	9	73
Harari	224	181	43	76	45	31
Addis Ababa	452	22	430	96	51	45
Dire dawa	334	45	289	106	24	82

Table 15: Immigrants, out migrants and net -migrants by region among all migrants and recent migrants, ICPS 2012

Figure 19: Relation B/n glass factory and Jemo condominium site

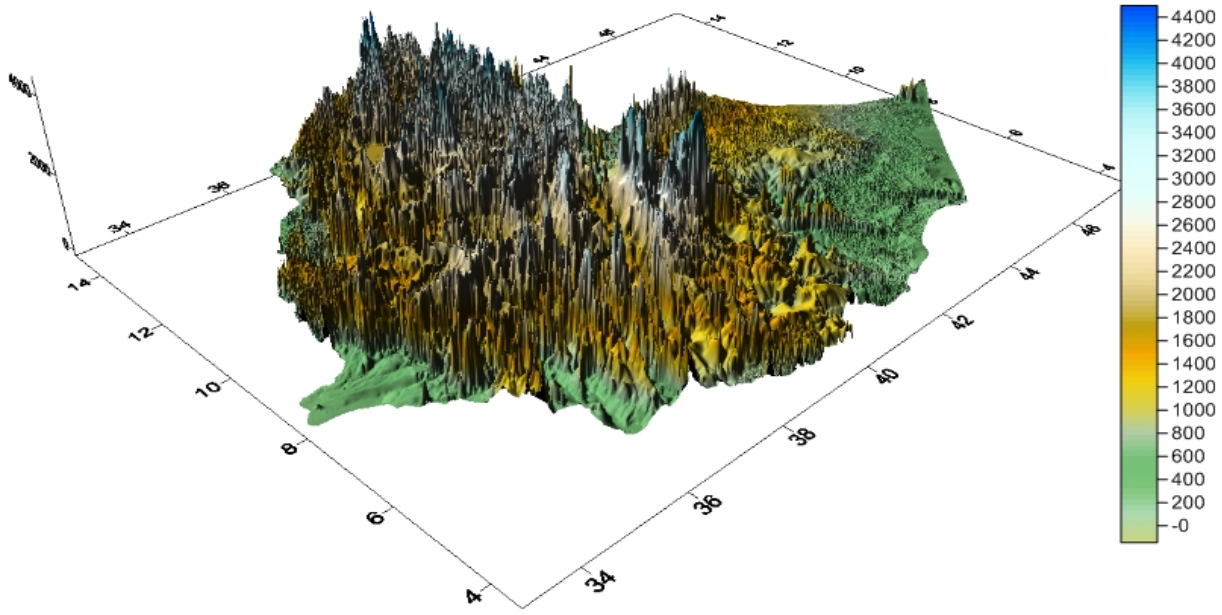

Figure 20 :3D Surface area model of Ethiopia

Table 14 : Rock source from water quality analysis

Parameter	Attention Value	Conclusion	Value	Result
SiO2 (mmol/l)	> 0.5	Volcanic Glass or hydro thermal water possible	n.d.	
HCO3-/SiO2	>10	Carbonate weathering	n.d.	
	>5 and <10	Ambiguous		
	<5	Silicate weathering		
SiO2/(Na+K-Cl)	<1	Cation exchange	n.d.	
	>1 and <2	Albite weathering		
	>2	Ferromagnesian Minerals		
(Na+K-Cl)/(Na+K-Cl+Ca)	> 0.2 and < 0.8	Plagioklase weathering possible	n.d.	
	< 0.2 or > 0.8	Plagioklase weathering unlikely		
(Na/(Na+Cl)	>0.5	Sodium source other than halite - albite, ion exchange	0.918	Sodium source other than halite - albite, ion exchange
	0.5	Halite solution		
	<0.5 TDS >500	Reverse Softening, seawater		
	<0.5 TDS <500 and >50	Analysis Error		
	<0.5 TDS <50	Rainwater		
Mg/(Ca+Mg)	=0.5 and HCO3-/Si>10	Dolomite Weathering	n.d.	
	<0.5	Limestone-dolomite weathering		
	>0.5	Dolomite dissolution, calcite precipitation or seawater		
	<0.5 and HCO3-/Si<5	Ferromagnesian Minerals		
	>0.5	Granitic weathering		
Ca/(Ca+SO4)	0.5	Gypsum dissolution	0.993	Calcium source other than gypsum - carbonate or silicates
	<0.5 and pH <5.5	Pyrite oxidation		
	<0.5 and pH neutral	Calcium removal - ion exchange or calcite precipitation		
	>0.5	Calcium source other than gypsum - carbonate or silicates		
TDS	>500	Carbonate weathering or brine or seawater	194	Silicate weathering
	<500	Silicate weathering		
Cl-/Sum Anions	>0.8 and TDS>500	Seawater or brine or evaporites	0.016	Rock weathering
	>0.8 and TDS<100	Rainwater		
	<0.8	Rock weathering		
HCO3-/Sum Anions	>0.8	Silicate or carbonate weathering	0.952	Silicate or carbonate weathering
	>0.8 sulfate high	Gypsum dissolution		
	<0.8 sulfate low	Seawater or brine		
SI Calcite	>0	Oversaturated with respect to calcite	1.354	Oversaturated with respect to calcite
	0	Saturated with respect to calcite		

Declaration

I here by declare that the thesis entitled "urbanization and water supply challenges in Addis Ababa with special reference Jemo condominium site `` has been carried out by me under the supervision of Dr. Dessie Nedaw, School of Earth Sciences, Addis Ababa University, during the year 2013-2014 to fulfill Master of Science in Hydrogeology. I further declare that this work has not been submitted to any other University or Institution for the award of any degree and that all sources of material used for the thesis have been duly acknowledged.