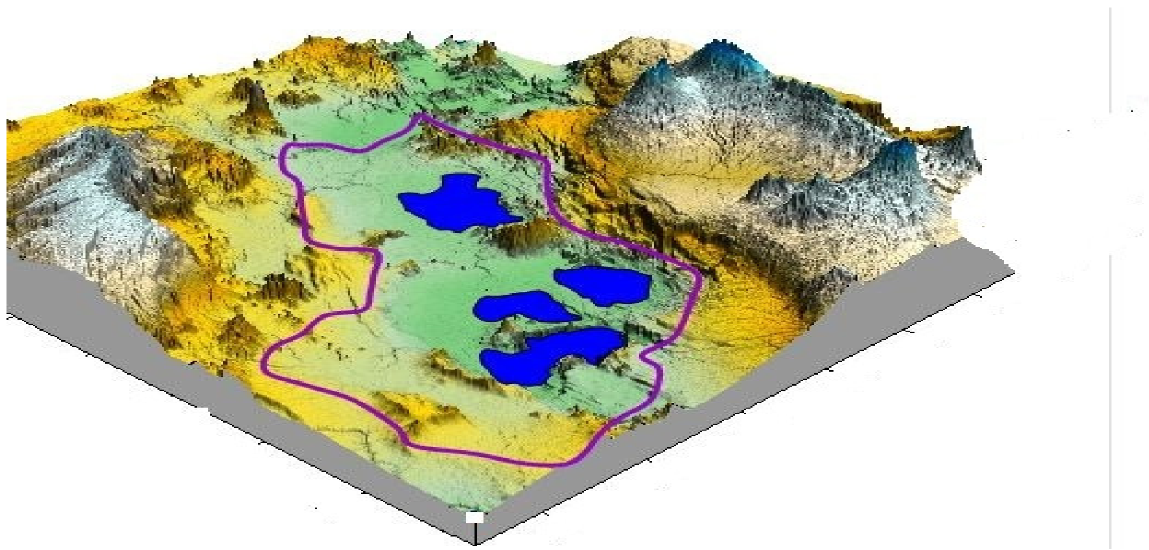
ADDIS ABABA UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCE

SCHOOL OF EARTH SCIENCE

HYDROGEOCHEMISTRY OF ZIWAY-SHALA AREA, MAIN ETHIOPIA RIFT



A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE IN HYDROGEOLOGY

By: Engdasew Temere

July, 2013

Addis Ababa

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ADVISOR: Prof. Tenalem Ayenew

December, 2013

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DECLARATION

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in any other university and that all sources of materials used for the thesis have been duly acknowledged.

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ABSTRACT

Ground water is the main source for domestic, agriculture and industries used in Ziway-Shala Lake area .The study area is found in the main rift valley, in rift floor which include the four main lakes Ziway, Langano, Shala and Abijata. The climate condition of the area is characterized by alternating wet and dry seasons. In the area there water quality problems. The main objective the study is to investigate hydrogeochemistry of the Ziway-Shala Lake area system using water chemistry (chemical composition).

The water samples for analysis of major anions and cations are 56 water samples of boreholes, hand dugs, springs, Lake Waters and River waters. Of which 31 water samples are newly analyzed and the rest are secondary data from water work design and supervision enterprise and zonal office of water and energy in the study area. Prior to using the water chemistry results for the intended application, charge balance evaluation is done and those with an error greater than 10 were not used.

The water types of most ground water in the area is Na- HCO3 specially found in Ziway area but a few samples shows water types of Na- Ca- HCO3 in Meki area and Na-HCO3- Cl in Shala and Abijata area which is similar water type with the Lakes which indicates surface water – ground water interaction. The Na-HCO3 and Na-HCO3-Cl water types are common in the study area.

The major drinking water quality problems in the area are TDS and fluorides in which the values exceed the WHO standards. This water quality problem is high towards Shala which have high fluoride, chlorides and TDS value which follow ground water flow. The water type in the area is fresh, Brackish and saline based on TDS classification. In the area there is water quality problem for irrigation purpose. In terms of SAR the surface waters (Rivers) are highly preferable for irrigation than ground water .The surface water quality shows variation seasonally. They have high TDS and major ions concentration in dry season than wet season. The agricultural activities in the area are not alarming on water quality problems but the floriculture activities have some impact on Lake Ziway, even if the change in chemistry of the lake at present due to floriculture is not significant.

Key words: water quality, ground water, Surface water, hydrogeochemistry, rift floor

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ACRONYMS

AWSA- Addis Ababa Water and sewage Authority

BH - Borehole

CER- Central Ethiopian Rift

CS - Cold Spring

DEM - Digital Elevation Model

EC - Electrical Conductivity

GIS - Geographical Information System

GPS - Global Position Space Elevation

HD - Hand Dug

HS - Hot Spring

ICTZ - Inter- Tropical Convergence Zone

m.a.s.l - Meter above Sea Level

MER - Main Ethiopia Rift

MoWE - Minister of Water and Energy

PH - Negative Logarithm of Power of Hydrogen

RSC - Residual Sodium Carbonate

SAR - Sodium Adsorption Ratio

SW - Surface Water

TDS - Total Dissolved Solid

(UNESCO)- United Nation Educational, Scientific and Cultural organization

USAD- United State of America Development

WFB - Wonji Fault Belt

WHO - World Health Organization

WW - Waste Water

CHAPTER ONE
INTRODUCTION

1.1. Background

The proposed research area is part of Ethiopian rift system which is known to be Ziway Shala Lake area found in central Main Ethiopian Rift Valley. The central part is the floor of the rift occupied by Lakes Ziway, Langano, Abijata and Shala. The major incoming rivers are the Ketar River and Meki River to Lake Ziway. A major part of the water inflow of Lake Abijata originates from Lake Ziway through the Bulbula River. Lake Shala and its catchment do not have a surface water connection with the other lakes in the CER valley .The climate condition of the area is mainly characterized by alternating wet and dry season. In the area the people get water from groundwater resources like wells and springs as well as from rivers for drinking and for irrigation purpose. The available water resources in the study area have water quality problems.

Thus, hydrogeochemistry has found a wide spectrum of applications for hydrological problems encountered in water resources development and management. Thus, the major objective of this research is to investigate hydrogeochemistry of Ziway-Shala lake area.

The research is expected to give insight in characterization of hydrogeochemistry and evaluation of surface and ground water quality of the area which is very important in water resource management and development methods.

1.2. Research Problem Descriptions

The rift and the bordering highlands in the study area is one of the most populated regions of the country. The water supply source in the region is mainly from groundwater wells (dug wells and boreholes), unprotected springs (cold springs and sometimes hot springs) and rivers. Majority of the population depend on agriculture. Irrigation is practiced by diverting rivers and abstracting from Lake Ziway. Until recently, water from the lakes mainly supported agriculture and commercial fishery, domestic use, industrial soda extraction and recreation, while the lakes and surrounding wetlands supported a wide variety of endemic birds and wild animals. Recently, large-scale foreign and national horticulture and floriculture enterprises have been settling down in the area. Water quality aspects will be increasingly at stake as a consequence of agricultural developments and settlements in the area, and the input use (pesticides and fertilizer nutrients) associated with the production of high value agricultural crops like vegetables and cut-flowers. So these agricultural and other activities introduce pollutants to the surface water and ground water. Human activities, in Combination with changes in climate and geology, have influenced the hydrological setting and the water quality of the lakes, with the salinity and major ion composition dramatically changed in some of them. Without water of sufficient quantity and acceptable quality, sustainable socio-economic development of a country is unlikely. So the main objective of this research is hydrogeochemistry characterization (chemical composition) of ground water and surface water. This water chemistry enables to identify source of pollutants, concentration of major ions (water quality) which is very important for sustainable use of the water resources.

1.3. Research Objectives

1.3.1. General Objective

The general objective of the research is to investigate hydrogeochemistry of Ziway – Shala lake area using the chemistry of water (chemical composition).

1.3.2. Specific Objectives

- To identify the chemical composition of ground water, surface water and see their variations.
- To determine the source of water quality problems.
- To see time variation of the surface water in chemical composition.

1.4. Methodology and Material

To conduct the proposed research the following approaches were conducted:

1.4.1. Methodology

1.4.1.1. Pre-field work

Before field work the following activities were conducted:

- Collecting and reviewing available maps like topographical, geological, and hydrogeological and hydrogeochemical maps.

- Collecting metrological data like precipitation, temperature and others from metrological agency to understand the climate condition of the area.
- Collecting secondary physico-chemical data from the respective organization.
- Geo-referencing different relevant maps and digitizing the local catchments.
- Understand the general geological and hydrological condition of the basin to identify location where representative sample to be collected.
- Reviewing previous researches that were conducted in the area.

1.4.1.2. Field work

The field work was done to get primary data and prove the ground truth that useful for objective of the research. In general during field work the following activities were conducted:

- Observation of different geological formations and structures to describe outcrop formation types, degree and frequency of weathering and fracturing.
- Measuring in-situ field parameters of water samples like PH, EC, and temperature.
- Collecting water samples for laboratory analysis at representative sites selected during the office work.
- Collecting well completion reports that includes physico-chemical analysis from respective zonal and district offices.

1.4.1.3 .Post field work

Here, the primary and secondary data collected during the pre-field and field work stages are analyzed and interpreted. The water samples collected during the fieldwork are analyzed and interpreted for the major cations and anions to understand the geochemical properties and the results of the laboratory analysis are processed and presented using AQUACHEM 4.0 Software, and Surfer 8, and Global Mapper 11were used for mapping purpose.

The research is conducted using scientific procedure and technique of Hydrogeochemical to analyze and interpret the Hydrochemical data to meet the research objectives. Groundwater chemistry is basic tool to understand or to characterize the hydrogeochemistry of ground water .Therefore, to meet the objectives of the research the following classical techniques ways of chemical analysis were used:

- **Piper diagram**

The piper diagram is used for graphically displaying a large number of chemical analyses of groundwater using Aqua chem. Software .The piper diagram can be used to classify waters .The percentage composition of the major ionic species of natural water can be shown using piper diagram (Fitter, 1998). This kind of diagram is especially appropriate for representing simultaneously three components. It consists of an equilateral triangle where each vertex represents 100% of each component.

This way, points are represented as ternary mixtures. Ions must be reduced to%. Usually, the major anions and cations (HCO_3), SO_4, Cl and Na, K, Ca, Mg) are represented. The main advantage of those graphics is that they can represent a lot of different analysis without confusion. Those waters of similar composition stay grouped into very definite zones. Those diagrams can also reflect mixtures of water.

- **Stiff diagram**

This is a polygon shape diagram created from four parallel horizontal axes extending on either sides of a vertical zero axes. Cations are plotted in mill equivalents per liters on the left and anions plotted on the right.

Stiff diagrams are used to display concentration ratio of individual ion for each samples. The larger the area of polygonal shapes the grater the concentrations of the various ions (Fetter, 1998).Stiff diagrams can also useful in making a rapid visual comparison between water from different sources.

- **Scatter Plot**

The X-Y scatter plots are the simplest initial approach to the interpretation of geochemical data. Single plots of ion relationship and parameters that show significant data can be easily created and patterns are quickly identified and easily understood.

- **Schoeller diagram**

This is logarithmic diagram of major ion analyses in meq/l demonstrate different water types on the diagram. Sample concentrations are displayed not ratios are displayed and compared. Similar waters exhibit similar ‘‘fingerprints’’ in chemical identity.

1.4.2. Materials and Equipment

To achieve the objective of the research and the required data were collected and a number of materials and equipments were used during the fieldwork and office work phases of the research.

The materials used during the investigation were:

- Geological map, hydrogeological map.
- DEM, GARMIN GPS-72, EC meter, pH meter.
- Bottles for sampling collecting.
- For data inputs the following were used: Aqua chem., Microsoft Excel and Access and for map preparation: Arc GIS soft ware version 9.3, Global Mappe-11and Surfer 8 were used.

1.5. Frame of the Research

To meet the objectives the research is framed by three parts. The first is preparation for field in office. The second is field work for in-suit measure and the last is post field work. Generally the research frame work is given in Figure 1.1

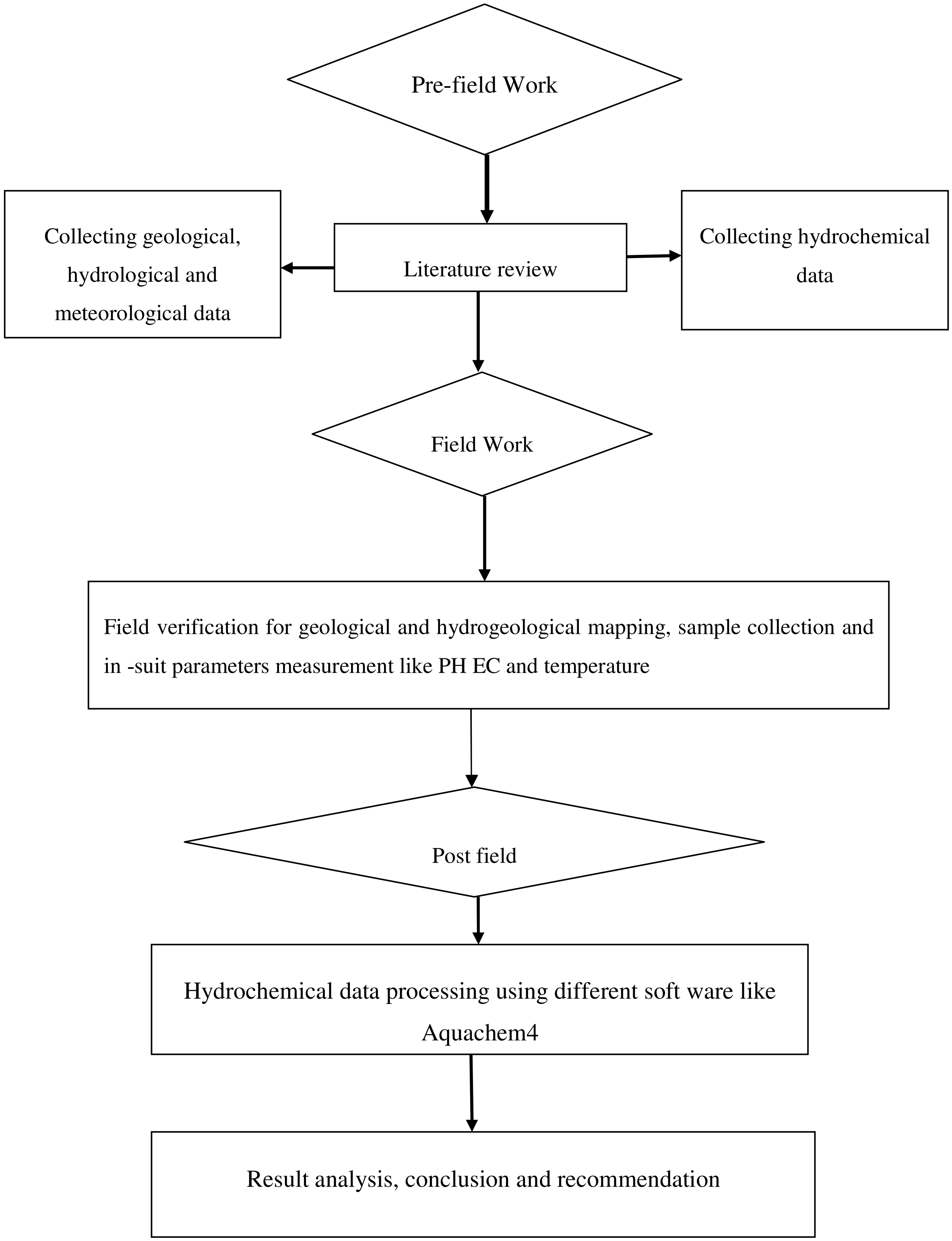


Figure2.1 : Major research out lines

CHAPTER TWO

LITERATURE REVIEW AND PREVIOUS STUDY

2.1. Literature Review

Most water in our planet occur as a saline water in the ocean and deep underground or is contained in polar ice caps and permanent ice cover of high mountain ranges. So 2% of all water plays active parts in hydrological cycle. Water on land mass is always on motion, either moving quickly (vapor transport, precipitation, and surface flow) or slowly (ground water flow).The slowness of ground water flow means that most fresh water is in the form of ground water. Consequently, ground water is the main storage reservoirs of fresh water, while surface water can be considered as surplus precipitation that could not infiltrate or that has been rejected as over flow from the ground water reservoir (spring and other out flow) (UNESCO, 2004).The ground water is vital resource in steady increase demand by man, but man threaten its quality and mishandle its quantity.

Water contains dissolved salts , dissociated in to cations (positively charged ions) and anions (negatively charged ions) .The most common dissolved cations and anions are sodium (Na), calcium (Ca) ,magnesium(Mg) , potassium (k) . The most common anions are chloride (Cl), bicarbonate (HCO_3), nitrate (NO_3) and sulfate .Composition of ground water that is concentration of different ions varies over a wide range of values. These cations and anions normally comprise over 90% of the total dissolved solids content (Hiscock, 2005).

The source of the major cations is different. Calcium in natural aqueous system is generally governed by the availability of more soluble calcium containing solids and by solution and gas phase equliberia that involve carbon dioxide species. .The most common forms of calcium in sedimentary rock are carbonate like dolomite. The amount of sodium held in evaporates sediments and in solution in the ocean is an important part of the total. Sodium is retained by adsorption on mineral surface, especially by minerals having high cation-exchange capacities such as clays. Potassium is slightly less common than sodium in igneous rock but more abundant in all sedimentary rocks. The principal potassium minerals of silicate rocks are the feldspars orthoclase and microcline. Magnesium is typically a major constituent of the dark –colored ferromagnesian mineral. Specifically, this includes olivine, the pyroxenes, the amphiboles and the dark-colored micas along with various less common species (Hem, 1989).

The anions have also different source. Bi carbonate (HCO_3) and Carbonate (CO_3) Sources are products of carbonate rocks, mainly limestone ($CaCO_3$) and dolomite ($CaMgCO_3$), by water containing carbon dioxide. The HCO_3^- content in ground water is normally derived from soil zone CO_2 and from dissolution of calcite and dolomite. On the other hand, carbonate minerals do react quite readily with water, and they play an important role in the evolution of many ground waters. Since carbonates are present in many different carbonate reactions types of rock , including most sedimentary rocks , and even some ingenious and metamorphic rocks , carbonates chemistry is relevant to the evolution most ground waters . The main mechanism for the dissolution of calcite can be shown as;

$$\mathbf{CaCO_3 + CO_2\ (g) + H_2O = Ca^{2+} + 2HCO_3} \text{.. Equation…1}$$

Calcium Fluoride (CaF2) is a common fluoride mineral. This mineral has rather low solubility and occurs in both igneous and sedimentary rocks. Apatite, CaS (Cl, F, OH) $(PO4)_3$, commonly contains fluoride. Fluoride is commonly associated with volcanic or fumarelic gases, and in some areas these may be important Sources of fluoride for natural water (Hem, 1989).

The composition of rocks and soils has a direct bearing on the quality of water. Hydro chemically a rough classification in to three rock group seems practical: Rocks in which fresh ground water is common, that is, rocks that contribute extremely small amounts salts to the water. The second group is rocks that contribute dissolved matter but maintain good potable quality .The third group is rocks that enrich the water with significant amounts of dissolved salts, often making them non potable. The litho logical parameter is only one of the several parameters that control ground water quality. Water moves underground and its salts or minerals content is determined by all soil and rock type it passes through (Mazor, 2004).

Ground water quality is based on the physical and chemical soluble parameters due to weathering from source rocks and anthropogenic activities. In general, the quality of ground water depends on the composition of recharge water, the interaction between the water and the soil, the soil-gas, the rock with which it comes in to contact in the unsaturated zone, and the residence time and reaction that takes place within the aquifer. Thus, the principal processes that influence the quality of water in an aquifer are physical, geochemical and biochemical. Changes in the concentration of certain constituent due to natural or anthropogenic causes alter the suitability of ground water (Hem, 1989).

The processes of rock weathering are strongly influenced by temperature and by amount and distribution of precipitation. An arid climate is unfavorable for rapid rates of solvents, but concentration of dissolved weathering products in the soil by evaporation can give rise to water high in dissolved –solids content .Climate characterized by altering wet and dry season may favor weathering reaction that produce considerable large amounts of soluble inorganic matter at some seasonal of the year than at other season (Hem, 1989).

As groundwater moves along flow lines from recharge to discharge areas, its chemistry is altered by the effects of a variety of geochemical processes. As groundwater moves along its flow paths in the saturated zone, increases of total dissolved solids and most of the major ions normally occur. Shallow groundwater in recharge areas is lower in dissolved solids than the water deeper in the same system and lower in dissolved solids than water in shallow zones in the discharge areas (Freeze, 1979).

Hydrogeochemical processes that are responsible for altering the chemical composition of ground water vary with respect to space and time. These geochemical processes are responsible for the spatiotemporal in the ground water chemistry. The quality of water is the resultant of all the processes and reactions that acted on the water from the moment it condense in the atmosphere to the time it is discharge by a well. Therefore ,the quality of ground water varies from place to place with the depth of water table, and from season to season and is primarily governed by the extent and composition of dissolved solids presents in (Hem, 1989).

The ultimate source of most dissolved ions is the mineral assemblage in rocks of the land surface. The purity and crystal size of minerals ,the rock texture and porosity ,the regional structure ,the degree of fissuring ,the length of previous exposure time ,and a good number other factors might influence the composition of water passing over and through the rock (Freeze, 1979).

Rock temperature increase with depth below the land surface .When water circulates to a considerable depth; it attains a substantially higher temperature than water near the land surface. Increased temperature raises both the solubility and the rates of dissolution of most rock minerals .Most thermal ground water (hot spring) is found in areas where the temperature gradient with depth is abnormally steep. The solute of content of such water is commonly higher than that of that of a non thermal water .Some thermal water may be notably high in dissolved –solids concentration and may contain unusual amounts of metals ions (Hem, 1989).

The chemical composition of groundwater is the combined result of the composition of water that enters the groundwater reservoir and reactions with minerals present in the rock that may modify the water composition (Postma, 2005).

2.2. Previous Study

In the Main Ethiopia Rift valley there are a numbers of studies have been carried out in which the study area is found. The studies focus on geology, hydrogeology, water quality, water resource investigation, and modeling which are very important for the current study. From the previous studies some of them are the following:

Di Paola (1972): Descriptions of different types and geothermal Conditions in the area and gave a brief description of hydrothermal areas in the lakes and presented an overall account of the geology, stratigraphy and structural Patterns of the Main Ethiopian Rift within 7°00'to 8°40'N latitudes.

Tesfaye Chernet (1982): presented a regional geological and hydrogeological map of the lakes region (which includes Ziway-Shalla and Awassa lake basins) at a scale of 1:250,000 based on geologic, meteorologic, hydrologic, chemical and geothermal investigations. The report includes regional classifications of different types of rocks of the area into different permeability groups and water balance of the region.

MoWE (2012): The study of ground water resource assessment in the rift valley lakes region. It describes the meteorological and hydrological explanation of the area. It also describes the general geology and hydrogeology of the Ethiopian rift valley lakes system that cooperate surface water and ground water potential of the basin. The report describes the general overview of the area.

Le Turdu (1999): Influence of volcanism, tectonics, and climatic forcing on basin formation and sedimentation on Ziway Shala lake basin system, Main Ethiopian Rift. It briefly describes model of basin formation and sediment accumulation for this system of lakes, in order to separate the effects of climatic change from environmental variations induced by local or regional factors such as volcano-tectonic forcing.

Tibebeu Terefe (2007): Effects of irrigation practices and lacusterine aquifer development on water availability in Ziway Abijata cordial.

Tenalem Ayenew (1998): In his PhD thesis entitled "The Hydro geological System of the Lakes District Basin, Central Ethiopian Rift"; he analyzed general hydrology and hydrogeology of Ziway-Shalla basin. The study includes evaluation of groundwater and surface water interaction, water balance and recharge estimation of sub catchments and hydrogeochemistry and isotope hydrology of the Main Ethiopian Rift system.

Shemelis Fikre (2006): This Msc thesis hydergeological system analysis in Ziway Shala lake area using hydrogeochemistry and isotope techniques for determination of ground water and surface water interaction.

Alemu Direbsa (2006): Ground water surface water interaction and analysis of recent change in hydrogeological environment of Lake Ziway cachement.

Nesant Kassa (2007): Ground water resource evaluation and in Dugda wereda, central rift valley, Ethiopia.

Tenalem Ayenew (2009): Hierarchal clusteral hyderochemical analysis of hydrochemical data as a tool for assessing the evolution and dynamics of ground water across the Ethiopian rift.

MoWR (2008): With collaboration of Ethiopian Water Technology Centre presented an overall account of the Geology, Hydrogeology and Ground water modeling of Butajera Ziway area.

MoWR (2008): Butajira Ziway areas development. This literature generally explains the water quality aspects around Butajera and Ziway areas. It describes that there is a water quality problems in the area for irrigation and drinking purpose. The paper describes defluoridation techniques to reduce the fluoride amount.

Tewodros Geodebo (2009): Geochemical and isotope composition of natural water in the central main Ethiopia rift: emphasis on the study and of source and genesis of fluoride.

Halcrow (2009): Rift Valley Lake basin integrated resource development master plan study which describes the Geology, hydrogeology, and water quality and Natural resources of the area. Generally it describes the overall aspect of the rift valley lake basin system.

Hail Gashaw (1999): hydrogeochemistry of water in Lake Ziway area – this paper describe water problem around Ziway area and says that, the major problem for drinking water quality in the area is its fluoride content, in most cases above the recommended limit (1.5 mg/l).

Tewodros Geodebo (2012): Groundwater quality and its health impact. It is an assessment of dental fluorosis in rural inhabitants of the Main Ethiopian Rift. - It explains about dental fluorosis and the results show that the distribution of fluoride (7.8–18 mg/L) in the local groundwater is associated with high levels of fluorosis. The effect of this consumption is manifest in the very high observed prevalence of advanced dental fluorosis (DF).

Tewodros Geodebo (2013): The Impact of Climate Change on Water Resources, Agriculture and Food Security in the Ethiopian Rift Valley: Risk Assessment and Adaptation Strategies for Sustainable Ecosystem Services. The paper give brief explanation on impact of climate change on water resource and generalized that climate related shocks are linked with lack of rainfall and variability in time. As a result, crop failure is the most common consequence of changing climate in MER.

CHAPTER THREE

GENERAL DESCRPTION OF THE STUDY AREA

3.1 Location of the area

Ziway-Shala Lake area is found in the Ziway-Shala basin in the lakes region of the Main Ethiopian Rift. The study was conducted in central Ethiopia and within the Main Ethiopian Rift Valley in the northern sector of the lake region in regional state of oromiya within the limits of 38° 13' - 39° 06' East longitude and 7° 16' - 8° 20' North latitude, and covers a total area of 6013 km^2.

It is located at the centre of the Main Ethiopia Rift Valley some 200 km south of the capital Addis Ababa to Addis Ababa–Ziway road. The area is accessible by two routes from Addis Ababa. One route is the asphalt road that runs from Addis Ababa-Mojo-Ziway with a distance of163 km; and another route is Addis Ababa Alem Gena- Butajera-Ziway asphalt road with distance of 174km. The Ziway-Shala area represents the rift floor portion. All weather roads, secondary and tertiary roads connect different part of the study area. The area contains the following werdas Meki, Adami Tulu, Arsi Negela, Ogolco, kersa and Bulbula.

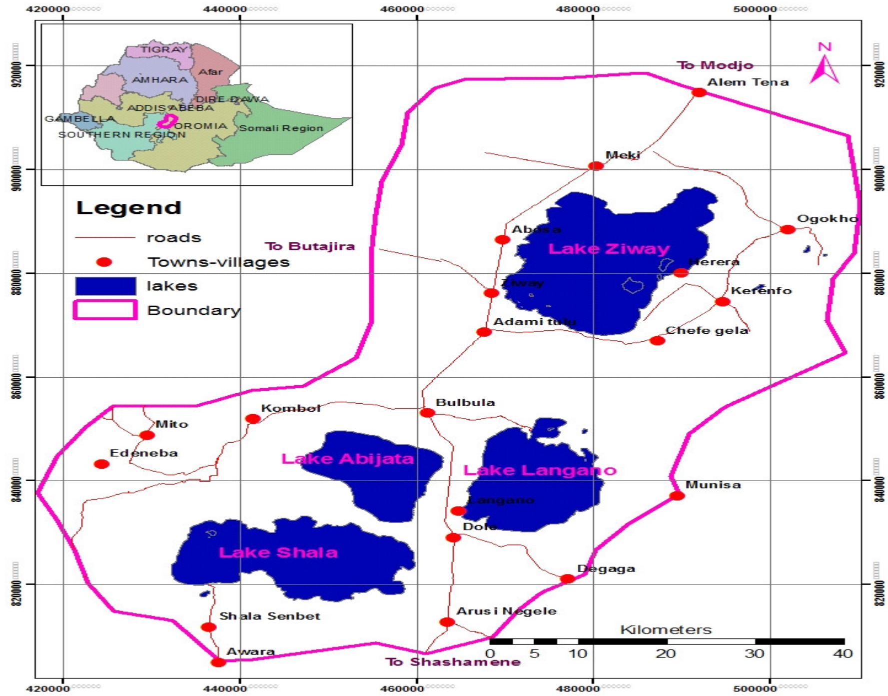


Figure3.1: Location Map of the Study Area (Source: Halcrow, 2008)

3.2. Topography

The Ziway-Shala lake area consists of the rift floor of the lake basin, an internal drainage basin located at the central part of the main Ethiopian rift valley. The physiographic of the area is, therefore the result of volcano-tectonic activities that occurred in the past and also deposition of sediments which are largely of lacusterine origin. As a result the main landscape features in the area include the volcano tectonically formed Ziway, Langano, Abijata and Shala lakes, fault scarps, and fault controlled depressions, volcanic domes, calderas and ridges. The eastern section particularly east of Lake Ziway is characterized by distinctive fault system, known as the Wonji Fault Belt. The intense fault system resulted in formation of minor grabens and horsts and volcanic domes.

Elevation of the cordial varies from around 1550m a.s.l at Lake Abijata to more than 2328m a.s.l on mount Aluto. The rift floor is more or less flat except in some areas where several small volcanic hills above the surrounding plains. The four main lakes are separated from each other by volcanic ridges, hills and caldera rim in structure.

Each of the three lakes (Ziway-Langano-Abijata) has an elongate shape parallel to the main trend of the MER and can be defined as tectonically controlled lakes. Unlike the other three lakes Shala occupies a large caldera. As a result of difference in geomorphologic setting they vary considerably in depth, in shape and size. Basic hydrological data of the four lakes are given below in Table3.1.

Table3. 1: Basic hydrological data of major lakes (Tenalem Ayenew, 1998)

Lakes	Altitude (m.a.s.l)	Lake area (km2)	Catchment area (km2)	Maximum depth (m)	Mean depth (m)	Volume (m3)
Ziway	1636	440	7380	8.9	2.5	1466
Langano	1585	230	2000	47.9	17	3800
Abijata	1580	180	10740	14.2	7.6	957
Shala	1550	370	2300	266	8.6	3700

Lake Abijata is the smallest lake which lies in a saucer-shaped hollow with in a deep down faulted trough at elevation 1580 .It is a terminal lake without surface out let and its lake level fluctuation rang is 6.88m. Lake Langano, is located at 1585m.a.s.l, occupies a large depression bounded by a well fault system. Its northeastern and southwestern shores lap against the horsts and grabens of the Wonji Fault Belt. Its lake level fluctuation rang is 2.50.

Lake Ziway is located at a relatively higher elevation (1636m.a.s.l) than the other three lakes. It is the largest and the shallowest lake in the central Main Ethiopian Rift with elevation of 1636m. It lies in a shallow down –faulted basin flanked in the east by a large basalt field. Its lake level fluctuation range is 2.7m (Halrcrow, 2008).

Lake Shala (1550m.a.s.l) is a separate terminal lake. The lake possesses the distinction of being one of the deepest lakes in the Eastern African Rift system, partly owing to its location owing to its location in a big caldera bounded by a steeply dipping rim.

3.3 .Drainage

There are a number of different scales of perennial and intermittent streams originate from the sides of Sloppy scarps, ridges and domes of the area and converge towards the lakes. The three Northernmost lakes, Ziway, Langano, and Abijata are connected by a surface network .The feeders of lake ziway are Meki and Keter river which start from the western and eastern high land respectively. Lake Ziway out flow to Lake Abijata through Bulbula River, Lake Langano over flows in to Abjiata through Hora Kelo River. Dijo River which originates from the western highland enters in to Lake Shala.

Within the floor and the neighboring escarpments and highlands the courses of the streams is highly controlled by the geological structures. Rift faults have affected the drainage of the area both by influencing the river courses and by impounding river water and causing some marshy areas.

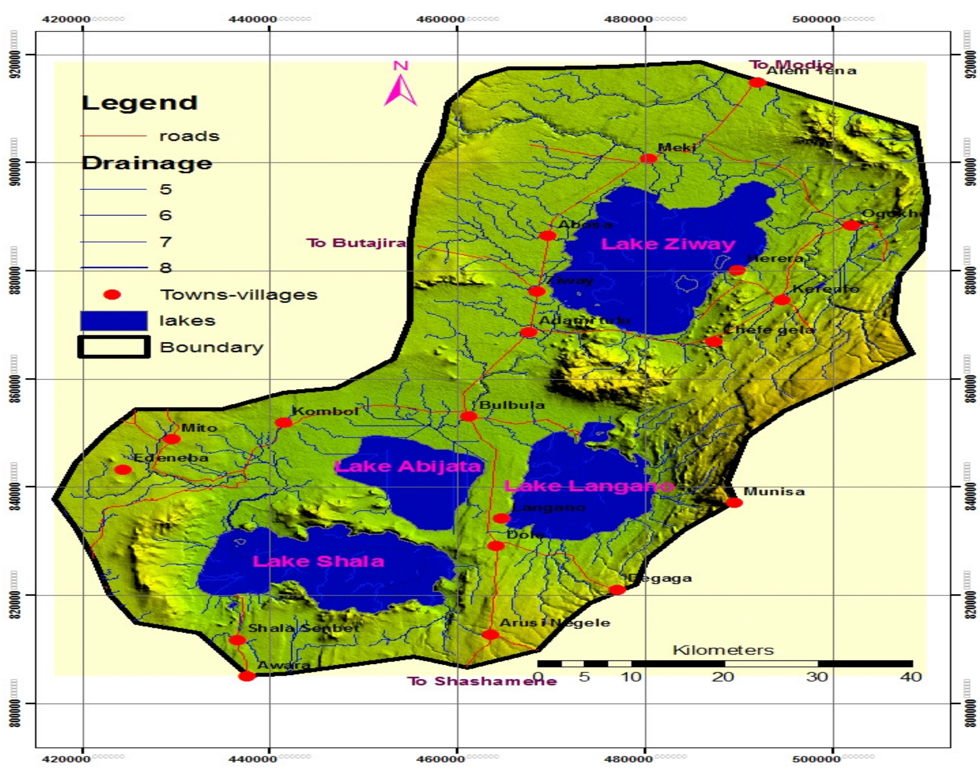


Figure3.2: Drainage and Topography map (Source: Halcrow, 2008)

The drainage density is high in the plateau and escarpment area and very low in the rift floor. In many places small streams disappear in the rift, before reaching the rift lakes, by transmission losses in large faults and volcanic vents (Tenalem Ayenewe, 1998).

3.4. Soil

The soil type in the rift valley is closely related to parent material and the degree of weathering (Makin et al, 1976). The main parent materials in the basin are basalts, acidic lavas, volcanic ash and pumice, riverine and lacusterine alluvium. Weathering varies from deeply weathered basalt in humid highland areas to unweathered recent alluvial deposits in the drier central part of the rift valley.

About 10 major soil groups and 13 soil units were identified In Rift valley Lakes Basin. Luvisols, Cambisols, Nitisols, Vertisols, Solonetz, Solonchaks, Arenosols, Andosols, Fluvisol and Leptosols are the dominant soil groups identified in the Basins (Halcrow, 2008). But in the study area the major soil types are: Luvisols, Leptosols, vertisols, Fluvisol and Solonetz.

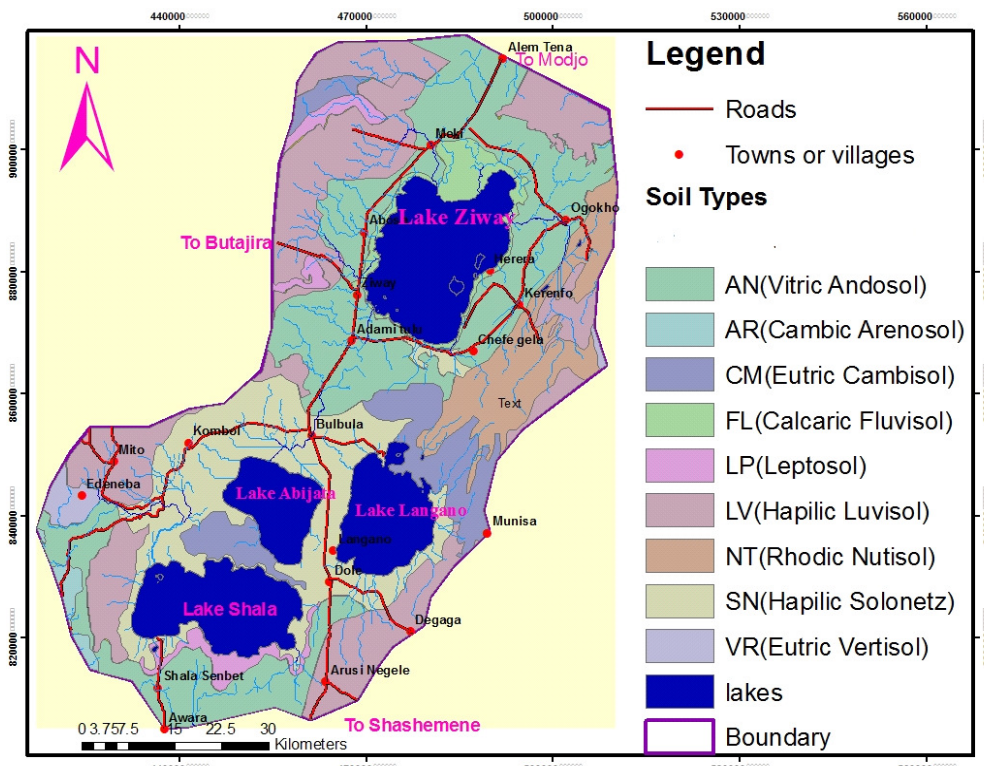


Figure3.3: Soil Map of the Study Area (Source: Halcrow, 2008)

Around lake Ziway the soils are Vitric and sols (derived from volcanic materials, generally well drained, deep and medium to coarse textured) with Calcaric and Eutric Fluvisols (developed from recent Alluvial deposits, imperfectly drained, deep and fine to medium textured) associated with the Meki delta. Around the northern lakes of Shala, Abijata and Langano the soils are HaplicSolonetz (Sodic soils) with a small area of Cambisols between Lake Abijata and Shala.

3.5 .Land use land cover of the study area

The land cover of the study area has been changed for the past years due to different activities occurred by the people. The land cover of the area mainly contains Grasse land, intensively cultivated, and moderately cultivated, shrubs land, wood land and Riparian vegetations. In the area forest is very small. Grass land is found in south of lake Ziway. Around Ziway and Meki the area is intensively cultivated area. The area around Abijata Lake and between Abijata and Langano lakes are mainly covered by wood land. Shrub is found around Lake Shala and between Shala and Abijata Lake.

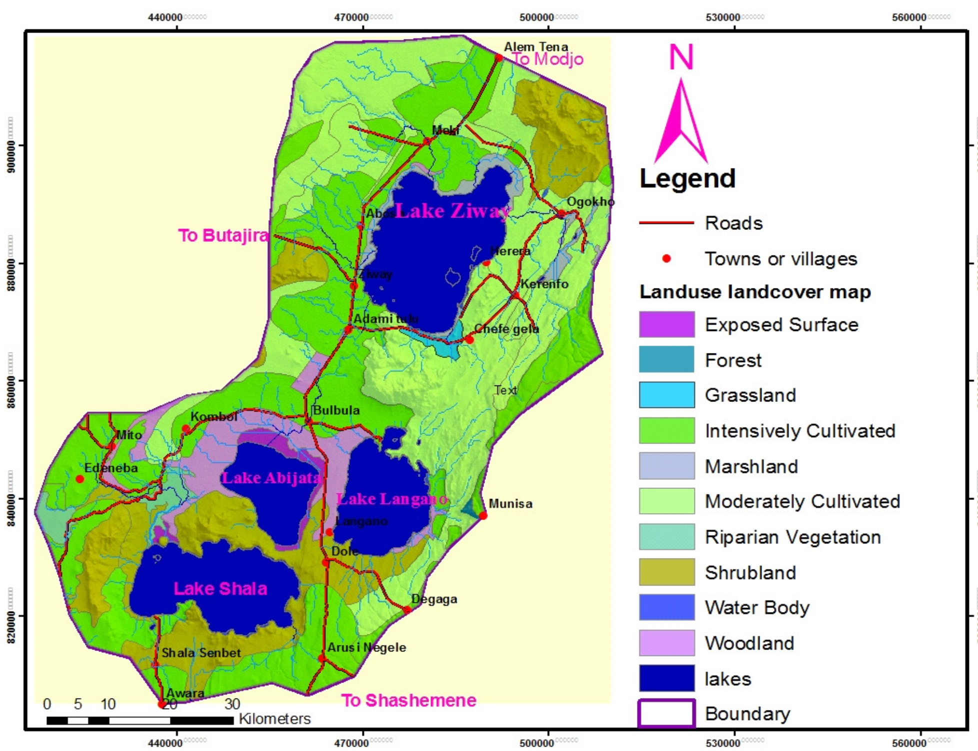


Figure3.4: Land use and Land Cover (Source: Halcrow, 2008)

3.6. Climate

The modern climate of the Ziway–Shala region is mainly characterized by alternating wet and dry seasons following the annual movements of the Inter tropical Convergence Zone (ITCZ) which separates the air streams of the northeast and southeast monsoons (Nicholson, 1996 cited in Tenalem 1998). Different climatic conditions characterize the highlands, the escarpment and the rift valley. Annual rainfall ranges from around 650mm in the rift valley to 1100 mm in the highlands. Mean annual temperature is less than 15ºC in the highlands and more than 20ºC in the lowlands and evaporation ranges from more than2500 mm on the rift floor to less than 1000 mm in the highlands (Tenalem Ayenew, 1998).

The mean annual rain fall data of some stations is given in Figure 3.5 and average temperature of selected area is illustrated in Table 3.2.

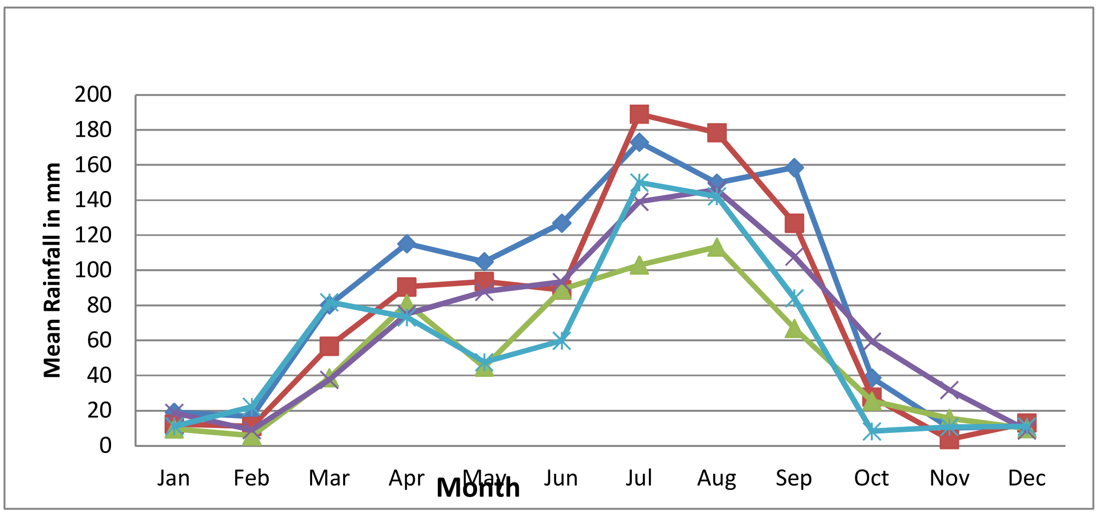


Figure3.5: Mean monthly rain fall data

Table3.2: Summarizing of Temperature's Basic Characteristics in °c (MoWE, 2012)

Station	Duration	Average	Max	Min
ArsiNegala	1987-2010	18.6	36.1	3.4
Langano	1981-2010	21.4	38.0	6.5
Ogolcho	1994-2010	20.5	38.0	0.0
Ziway	1981-2010	20.6	34.0	2.4

3.7. Geology

3.7.1. Regional Geology

The present day geological and geomorphic features of the region are the result of Cenozoic volcanic –tectonic and sedimentation processes. The Precambrian basement complex upon which all younger formation were deposited contains the oldest rocks, which are mainly located in peripheral regions of the country (Tenalem Ayenew, 1998).

The MER development is related to volcanism. They believed that the initial rifting began in the Oligocene –early Miocene. In the late Oligocene nearly Miocene the first tertiary volcanism dominated by basaltic rock occurred, which forms a series of half garble with opposed border faults of greater than 60 dip . In middle Miocene an important volcanic event occurred. In late Miocene Early Pliocene another very large volume basaltic eruption occurred, which was associated with the full development of the MER by forming or evolved in to symmetrical grabens, finally in the Pleistocene volcanism dominated by Rhyolitic rock occur which is the youngest and associated with the rift reorientation and the formation of the Wonji Fault Belt which is the active axis of the main Ethiopian Rift (Giday Woidegebriel et al. 1990).

In Pleistocene Wonji Fault Belt (WFB), which is the main spreading axis of MER, is formed at the rift floor, and floor basalt and rhyolite are erupted along WFB. The volcanic activities are characterized by peralkaline fissure basaltic eruption and Rhyolitic eruptions which make volcanoes and caldera. MER was formed symmetrical depression zone in this period and many Lakes appeared and disappeared by obstruction of volcanic deposit and /or climate change (MoWE, 2012).

An intense tectonic event occurred in the Pleistocene-Pliocene in the Main Ethiopian Rift related to the Wonji Fault (Mohr, 1967). With the formation of the Wonji Fault Belt, tectonic movements and volcanic activity produced step-like structures and associated volcanic activity, represented by ignimbrites, basalts and unwedded pyroclastics. The fault zone is straddled by central volcanoes disposed along the axial zone of the Wonji Fault Belt. The main products were rhyolite, trachyte lava flows, pumice, unwedded tuffs, obsidians and pitch stones. The products of the Wonji fault are referred as Wonji Group (Kazmin at al., 1978 and others).

Another type of volcanic activity in Wonji Fault Belt was the eruption from fissures of Pleistocene to recent basalt lava flows. The basalts are controlled by extensional fractures. These basalts are particularly prominent in the northern part of the rift, from Lake Ziway northwards, but also occur in the Lake Abaya area. Recent flows in many cases follow pre-existing topographic low relief areas although the development of the rift was dominated by volcanic activity, sedimentation also occurred by volcanic activity. Wonji Group rocks are intimately associated with lacusterine sediments related to the ancestral Lake in the rift floor in the Pleistocene -Holocene times. Alluvial deposits also occur in the rift. They are mostly recent. Commonly they occupy depressions, such as grabens, calderas, crater floors, the bases of escarpments and wide nearly flat basins (MoWE, 2012).

Specifically most of the MER rift floor is covered by silicics pyroclastics materials (rift floor ignimbrites, Early to Middle Pliocene (4.2–3 Ma, Giday Woldegabriel et al., 1990) mainly consisting of peralkaline Rhyolitic ignimbrites, inter layered with basalts and tuffs, associated with layered and unwelded pumices (Di Paola, 1972; Giday Woldegabriel et al., 1990). Ashes are frequently found inter-bedded with ignimbrites and pumice layers.

3.7.2. Stratigraphy

3.7.2.1. Nazareth Group and Dino Formation Undifferentiated

A thick succession of stratoid silicics, ignimbrites, unwelded tuffs, ash-flows, rhyolite and trachytes form a large part of the rift floor and also outcrops in the rift escarpments and on the adjacent plateau margins (Kazmin et. al., 1980). In the northern parts of the rift the Nazret silicics appear from below the younger volcanic which form most of the rift floor. They represent an event of fissural eruption which immediately followed a major faulting event (Kazmin, 1980).

Dino formation includes typically ignimbrites “sillar” and layered pumice and it is the oldest formation out cropping in the rift floor .The typical ignimbrite is the most common of the three rock types in the rift pyroclastics formation. The “sillar” type of ignimbrite is coarse and less welded and it is found locally around Lake Shala, western shore of Lake Langano and east of Lake Ziway. This rock has abundant pumice fragments and xenolite.

3.7.2.2 Afar Group

The bulk of the lower afar series is contemporaneous with the bofa baslts and volcanic of the Wonji group of the rift .The Bofa basalts occur west and north west of Lake Langano (Tenalem Ayenew, 1998). They are mildly alkaline transitional basalt.

3.7.2.3. Basalt and associated flows of the rift floor

This group is dominated by baslalts of different generations ranging in age from pleistocene to Holocene . The recent basalts outcrop in the floor of the rift ; the ones include basltic flowes ,cones and hyaloclastics.Afew outcrop of basaltic hyaloclastic which were produced by subaqueous basaltic volcanism are located south east of Lake Ziway and southwest of Shala (Tenalem Ayenew ,1998). The basalts are alkaline or transitional, mostly mildly alkaline. The alkali basalts consist of magnesian olivine, augitic clinopyroxene, labradorite and opaque phenocrysts, while in the groundmass these minerals are sometimes accompanied by alkali feldspar (MoWE, 2012).

3.7.2.4. Central Rift Volcanic Complex

This group includes the rift valley hills and small volcanics cones, and is characterized by Rhyolitic lava flows and domes associated with the rift floor ignimbrites. Alkaline silicics are the last volcanic products of the group. The pyroclastics are unwelded pumice and tuff, obsidian, pitchstone and Rhyolitic lava flows. According to Tenalem (1998) .Some of the central rift volcano groups are:

- **Aluto volcanics**

Aluto volcanics are of late pleistocene –Holocene age representing multiple flows dominated by pumice, ash and recent obsidian flows. Before volcanism commenced at Aluto center the Langano-Ziway basin was well developed and occupied by ancestral Lakes. Coarse pumice inter bedded with sediments encountered in drill holes at Aluto caldera represents subaqueous ignimbrite flows.

- **Gedamota rhyolite**

This is an early alkaline and per alkaline Rhyolitic lava flow and bedded tuff located west of Ziway. The Gedamota ridges the relict of a large caldera.

- **Corbetti Volcano**

The Corbetti- Post caldera activity is represented by two very recent volcanoes of Uriji and Chabbi mostly formed of pumice flows and falls with subordinate obsidian lava flows.corbetti has not been dated, but it is likely that some of the pumice layers in the Shala lake beds are derived from the dominant chabbi centers of Corbetti.

- **Fike Mountain**

Mount Fike located on the isthmus between Shala and Abijata lakes, is a double cone of stratified pumice resulting from eruptions of base surege type. Similar sub-aqueous volcanic is outcrop in the denuded cones of the Lencha Mountains on the south shore of Lake Abijata.

3.7.3. Volcano-sedimentary rocks and lacusterine sediments

The volcano –sedimentary are lacusterine predominantly volcano clastic sediments and tuff associated with lacusterine sediments. The lacusterine sediments include silts, clays, diatomite, and materials of ash and tuff associated with rock fragments derived from a wide variety of volcanic rocks. Silt and clay dominant; the only significant diatomite deposit is located between Lake Shala and Abijata.

Alluvium in valleys is also a common feature, varying considerably in thickness and composition .Thin coarse alluvium is present in many river beds; locally thick soil is associated with fans and flood plains.

The following lithostratigraphic units of this group were identified in the study area:

- Pelite dominated lacusterine deposit: deposits of pelitte and peat.
- Colluviums: gravels, sands, silts and volcanic pyroclastics (mid Pleistocene-Recent).
- Deltaic and fluvio- deltaic: deposits of sand, silt, and clay (Holocene).

- Meki deltaic deposite: Pumaceous volcanic fall deposits are evident along Meki river bank. Sand, silt and clay (Holocene).
- Ziway terrace and volcano-lacusterine deposite: Pyroclastics derived from ash and tuff. Also included are pelite, diatomite, silt, and clay with occasional shore sand and Shell beds (Holocene).
- Bulbula deposite: volcano-lacusterine deposits, mainly pyroclastics derived from ash and tuff and subordinate shell beds and sand.
- Meki and Katar deltic deposite (MK):- sand, silty and clay (Holocene).

Figure3.6 : Lacusterine Deposite around Bulbula River

3.8. Regional Structure of the Study Area

Tertiary volcanism and rift faulting are responsible for basin evolution in the Main Ethiopian Rift (Halcrow et al., 2008). The main geologic structures that have been observed in the area Include: faults, joints, fractures, calderas and craters.

In Ethiopia, rift system consists of the Lake Rudolf rift, the Main Ethiopian rift and the Afar depression. The afars represent the intersection of Africa rift system and the Gulf of Aden and the Red sea rift; both the last two rift being much broader the typical rift system

(Mohr, 1961). The Main Ethiopian rift to which the project area lies is south of the afar depression.

Large-scale normal block faulting has disrupted the volcanic rocks and formed step-faults and horst and graben topography. These structures impose an important control of the movement of ground water. In Ethiopia the rift valley is distinctly separated from adjacent plateaux by a series of normal step- faults usually trending parallel to the NNE-SSW rift axis (Tenalem Ayenew, 1998).

The rift valley is asymmetry in the study area and its greater number of faults on eastern half. One reason for the difference in faulting characterics on the two rift margin, the other being the effect of young fault the Wonji Fault Belt which is close to the eastern escarpment of the four lakes in the area, three are of tectonic origin and these are Ziway, Langano and Abijata. These lakes show elongation in north-south direction parallel to the general trend of the tectonic of the rift valley and they have shallow depths, less than a few tens of meters. However, Lake Shala seems to have a different origin as it is probably a volcanic tectonic sinking (Tesfaye Chernet, 1982).

The margins of the MER are characterized by a few widely spaced faults with very large vertical displacements to the rift floor. The eastern margin is well developed and it is defined by a more or less continuous system of boundary faults, whereas the western border is marked by only a few major faults in the Mt. Guragie area. The MER attains a width of about100 km in its centre, between Fonko and lake Langano, but narrows southward in the Lake Abaya region, where it is bifurcated by the N-S striking Amaro horst. This separates the Ganjuli basin in the west from the Gelana depression in the east (Halcrow.2008).

The WFB affecting the rift floor are closely spaced, commonly en-echelon and linear or curved in plain view over distances of up to a few tens of km. They delineate many fault bounded blocks. Associated with these faults are open fissures with or without vertical displacement, splay patterns, aligned cinder cones and complex rhomb-shaped structures (Halcrow, 2008).

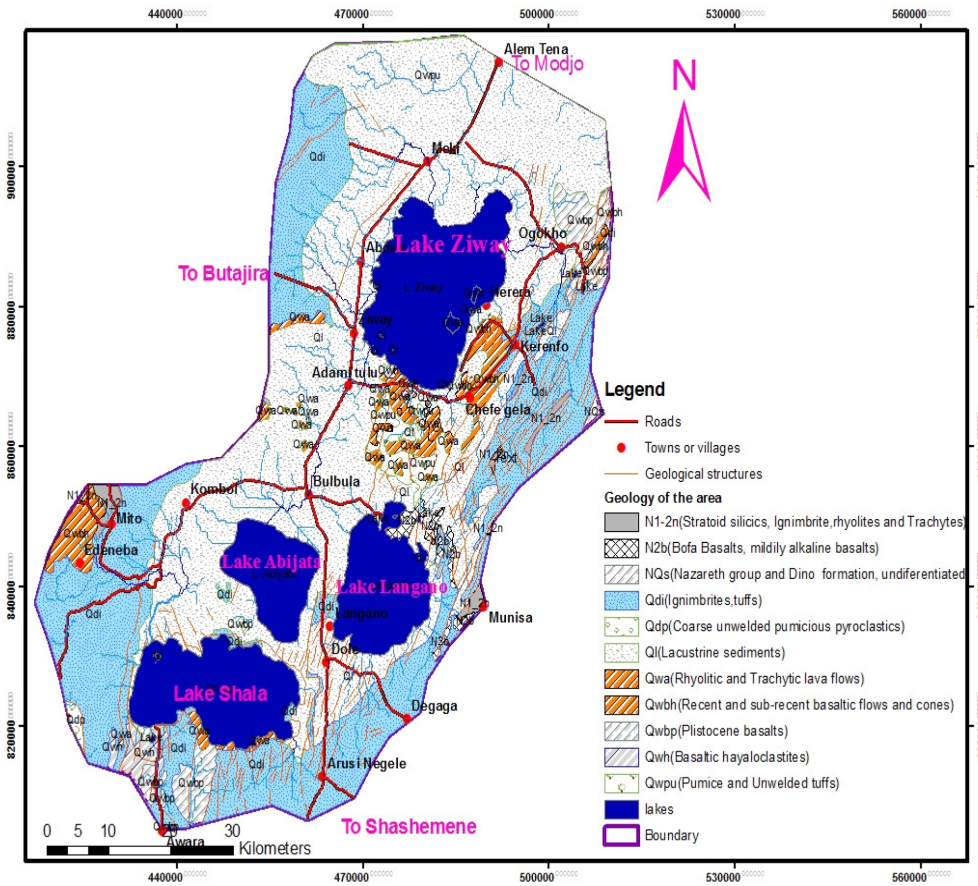


Figure3.7: Geological and Structural Map of the Study Area (Source: Halcrow, 2008)

3.9. Hydrogeology of the Study Area

The existing hydrogeology units in the study area are volcanic rocks that are subjected to Varying degrees of secondary activities like weathering, fracturing and faulting which intensively divided the area by a number of minor and major normal Faults. Comparing to the primary structure, secondary one has a significant role in the circulation and distribution of groundwater in the study area.

The various formation in the area have been classified in to three groups of High, Moderate and low permeability. Most permeabilities fall in the moderate range. The basalt is expected to have high permeability in the area (Tesfaye Cherent, 1982). The permeability of the rocks is highly variable based on the degree of weathering and faulting .The hydraulic conductivities varies in a wide range between 0.1 and 140m/d, the highest being in the rift floor (Tenalem Ayenew, 1998).

According to Tenalem (2009) Hydraulic conductivity data shows that there is a large variation in the permeability of the rock. In ignimbrite and tuffs the range is 0.02m/day to 41.6m/ day and in lacusterine deposit it ranges from 3.1m/day to 71.1m/day .The transmiissivity in tuff and ignimbrite varies over a wide range between 1 and 1300m^2/day; in lacusterine deposit it ranges from 10 to 520m2/day.

According to Tenalem (1998) -In the Ziway-Shala basin six hydraulic conductivity zones are identified. From the six three are fall in the study area. These are:

- Zone 1 (10 – 20 m/d): Recent basaltic fields and highly fractured rift floor ignimbrites with thin permeable volcano-clastic sediments and local lacustrine soils.
- Zone 2 (2.5 – 5 m/d): includes lacustrine deposits underlain by rift and escarpment. Moderately fractured acidic volcanics of the Katar valley and western escarpment covered with moderately and highly permeable soils.
- Zone 3 (0.01 – 0.1 m/d): These are acidic volcanic plugs and caldera rims with very low permeability and with little or no soil cover.

The lacusterine sedimentary basement of the Lake Abijata is characterized by a multi layered aquifer in which two main levels are exploited: (1) the alluvial shallow aquifer of the Bulbula plain connected to the lake and supporting most of the local village water supply well and (2) a deeper system exploited by the soda ash plant. Despite some clayey lens which can cause the deeper aquifer to be locally confined, these two producing levels can be considered hydraulically connected at the basin scale (Tesfaye Cherent, 1982).

In the rift floor there are recent basaltic fields and highly fractured rift floor ignimbrites with thin permeable volcano clastic sediments and local lacusterine soils which have (10-20m/day).

Alkaline basalts, trachytes, and trachytes basalts – These rocks have a variable degree of jointing and often they have a variable degree of joining and often they are massive to moderate joined. Springs discharge at contacts of jointed and massive flows.

Some of these springs are starting point's perennial streams which flow down to the lakes (Tesfaye Cherent, 1982).

Pumice falls and acidic volcanic - The pumice falls are characterized by a high inter-granular permeability which becomes highest when stored. The acidic volcanic shows moderate to high jointing (Halcrow.2008).

Ground water moves from all sides towards the center the basin in center of the basin in to the lakes .The rift-floor ground water is strongly controlled by the axial faults (Tenalem Ayenew, 2009). The axial faults control the subsurface hydraulic connection of the rift lakes and the river-groundwater relations. Ground water flow paths move towards Lake Shala, which has the lowest elevation (Tesfaye Cherent, 1982). From the ground water contour in Fig 3.9 the ground flow is in to the lake, towards Shala.

In the rift floor, significant groundwater flows through local palaeo channels. An example to this is the palaeo channel along the Bulbula River, which connects lakes Ziway and Abijata. In contrast to the high hydraulic conductivity of the rift fractured volcanics, some faults act as barriers of groundwater flow. This is a common case in areas of rift-in-rift structures where the faults deep against the topographic slope forming local grabens and horsts. Beyond the barrier faults most volcanic rocks do not form large extended aquifers, even if they are highly permeable. The barrier faults form local swampy areas. The typical examples are the Shetemata swamp east of Ziway. Large groundwater barrier zones exist west of the Gedamota ridge also southwest of Lake Ziway. In these areas, the groundwater reserve is extremely low, if present it is deep and with very low yield. Due to high groundwater residence time, the water has high total dissolved solids (Tenalem Ayenew, 1998).

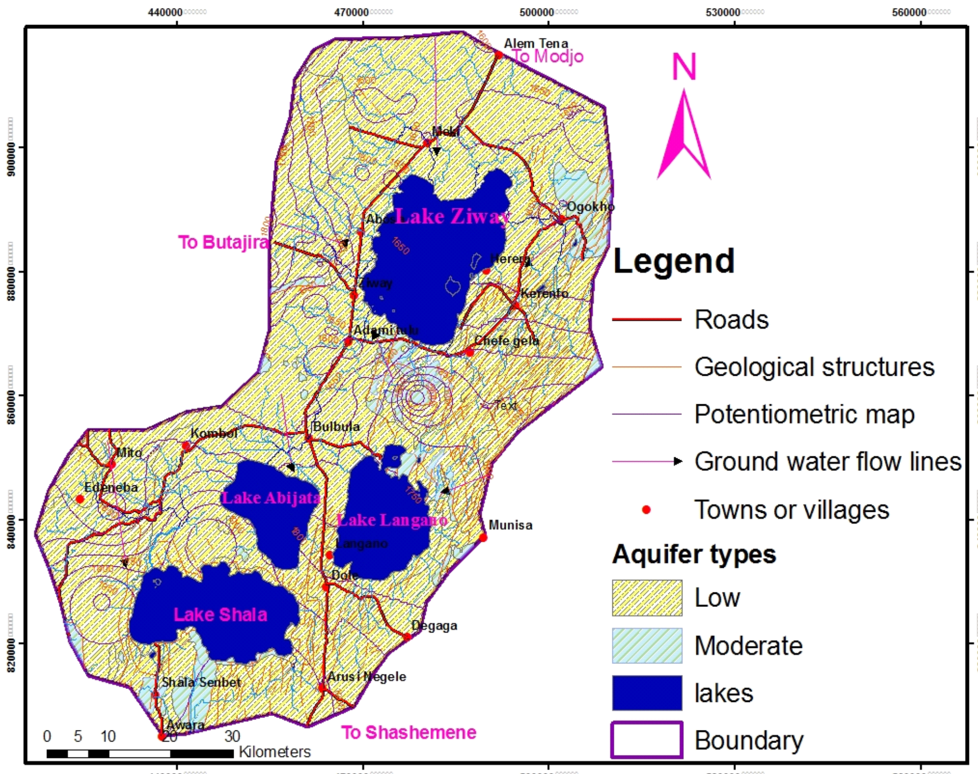


Figure3.8: Hydrogeological Map of the study of the Area (Source: Halcrow, 2008)

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1. Hydrogeochemistry

Only a small percentage of the world's total water supply is available to humans as free water. More than 98% of the available fresh water is ground water which far exceeds the volume of surface water. At any given time, only 0.0001% of the total water supply is in the atmosphere (Fetter, 1998).

The geochemistry of natural waters involves the study of the composition and sources of chemical elements as well as the understanding of processes that control the composition of geochemical anomalies in waters (Tewodros Geodebo, 2008). Chemistry of ground water is an important factor determining its use for domestic, irrigation and industrial purposes.

Ground water quality is based on the physical and chemical soluble parameters due to weathering from source rocks and anthropogenic activities. In general, the quality of ground water depends on the composition of recharge water, the interaction between the water and the soil, the soil-gas, the rock with which it comes in to contact in the unsaturated zone, and the residence time and reaction that takes place within the aquifer (Hem, 1985). Thus, the principal processes that influence the quality of water in an aquifer are physical, geochemical and biochemical. Change in the concentration of certain constituent due to natural or anthropogenic causes alter the suitability of ground water.

Fundamental data used in the determination of water quality are obtained by the chemical analysis of water samples in the laboratory or in suite sensing of chemical properties in the field. Interpretation of the distribution of Hydrochemical parameters in groundwater can help in the understanding of hydrogeological conditions and can also aid decisions relating to the quality of water intended for drinking water. Hydro chemical processes and Chemical analyses may be grouped and statistically evaluated by means, medians, frequency distributions, or ion correlations to summarize large volumes of data. Graph of groups of analyses aids to show chemical relationships among water, probable sources of solutes, areal water-quality regimen, temporal and spatial variation, and water-resources evaluation. Graphs may show water type based on chemical composition, relationships among ions, or groups of ions in individual waters or many Waters considered simultaneously are also Significant in attenuating groundwater contaminants (Hiscock, 2005).

The natural process and human activities vary in time and places in the area which reflect ground water chemistry variation of spatial and temporal. The quality of groundwater primarily refers to the type and concentration of dissolved substances in the water. These substances can be dissolved gases and inorganic and organic solids. The term "potable" water refers to water that meets standards for drinking water and includes physical, biological, inorganic, and organic parameters.

Standardization and comparing of water quality based on World Health Organization (WHO) helps to categorize the suitability of for the intended purpose of water for Drinking, industrial and irrigation purpose.

4.2. Sampling and Hydrochemical Analysis of water Sample

Sampling is a vital part of studies of natural-water composition and is perhaps the major source of error in the whole process of obtaining water-quality information. The sampling of a completely homogeneous body is a simple matter, and the sample may be very small. The extent to which a small sample maybe considered to be reliably representative of a large Volume of material depends on several factors. These include, first, the homogeneity of the material being sampled and, second, the number of samples, the manner of collection, and the size of the individual samples (Hem, 1989).

A sample integrated by taking small portions of the material at systematically distributed points over the whole body represents the material better than a sample collected from a single point. The more portions taken, the more nearly the sample represents the Whole (Hem, 1989).

The sampling devices and bottles should be rinsed with a sample of the water being sampled if they are not thoroughly dry. This will prevent the mixing of rinse water with the final samples. A good geographical distribution of wells is needed.

In studies of chemical hydrogeology, wells located in both recharge and discharge should be sampled (Fetter, 1998).

Mixing of water from different strata in a well, and in some instances exposure of the water to the atmosphere, may bring about chemical instability, even though the original water in place was in equilibrium with its surroundings (Hem, 1989).

In sampling groundwater contamination and disturbance of natural conditions by drilling are the first concern. Water from boreholes where drilling mud has been used or where clay Layers are sealed with betonies displays cation exchange with the clay .Wells which have been out of production for some time may yield a water chemistry that is different from the composition during pumping. The main reason is the presence of stagnant water above the screen in the well and it is therefore necessary to empty the well flora number of volumes. On the other hand, excessive pumping may draw waters with a different composition towards the screen and cause mixing waters (Appelo and Postma, 2005).

Water stored in lakes and reservoirs commonly is not uniformly mixed. Thermal stratification and associated changes in water composition are among the most frequently observed effects. The effect of stratification on water composition is noticeable in concentrations of ions whose behavior is influenced by oxidation and reduction, the reduced species commonly increasing in concentration with depth below the surface and assuming particulate form in oxidizing shallower water (Hem, 1989).

In-situ measurement of water sample like boreholes, hand dugs, springs, Lakes and Rivers was conducted by measuring like PH, EC, and temperature. In-suit measurement was conducted due to change of the physical properties of water which is time sensitive until it reaches in the laboratory for analysis. Field measurement of water can also use to get immediate water quality data and to compare with the laboratory result. A total of 56 samples were used .From 56 samples 31 were primary and the rest were secondary.

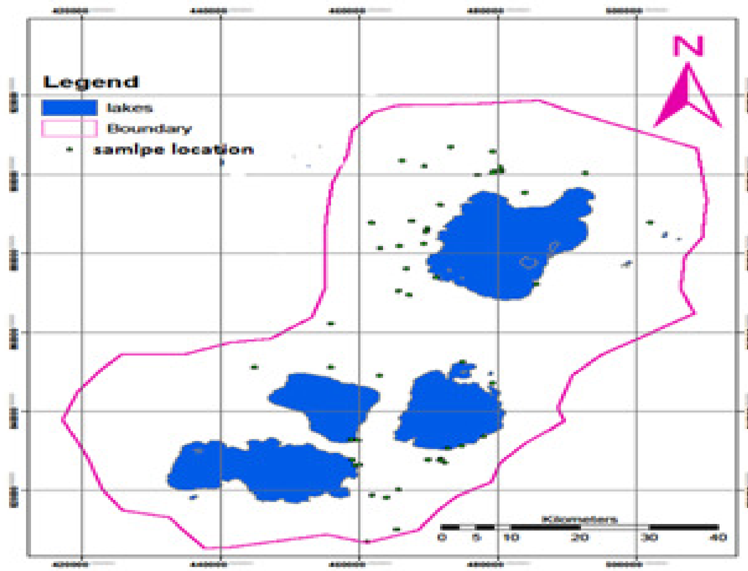


Figure4.1: Sampling Location

4.3. Reliability of Chemical Analysis Result

Before to analyze of the data, the water quality results of the samples should be checked. In order to evaluate the correctness of the laboratory results various methods of reliability check are undertaken as per Hounslow (1995). Water is naturally balanced in its cations and anions so that the principle of the cation-anion balance was used to check electro neutrality of the analyzed data.

Standard method states that "the anion and cation sum, when expressed as mill-equivalents per liters, must balance because all potable waters are electrically neutral." The anion-cation balance check is based on: a percentage difference between the total positive charge and the total negative charge.

Electro neutrality $= \sum(\text{cation} - \sum\text{anions}) / \sum(\text{cation} + \text{anion})$………Equation 2

In any solution, the total number of anions tends to balance with the total number of cations. Water fulfills the Principle of electro neutrality and is therefore always uncharged. Based on the electro neutrality, analysis of water samples with a percent balance error -5% or +5% is regarded as acceptable (Fetter, 2001). But in very dilute or saline water, up to10% error may be considered as acceptable due to the errors introduced in measuring major ions in dilute groundwater or in the multiple dilutions require for analysis of Concentrated groundwater (Fetter, 2001; cited in Alema, 2009). In accurate analyses are either due to analytical error or some ions that are presumed to be minor are not included in the chemical analysis (e.g., Appelo and Postma, 2005, cited in, Jan Marten journal).

From this point of view 91.08% of the samples that were analyzed is fall within the acceptable range of -5% or +%5 %. 8.92% of the samples fall with the range of -10% or +10%. Reliability of the sample can also be check by using the ion ratio.

Table 4.1: Reliability Check of sets Used in this Work Hydrochemical Data

Reliability test	Permissible value	Theoretical facts	comments
K/ K+Na	< 20 %	Na >>k; because K+ is more rapidly removed from solution by plants And clays than Na+.	7.317 % of the data are > 50%
Mg/ Mg+Ca	< 40 %	Ca > Mg, unless provided by the dissolution of dolomite	9.756 % of the data are >> 40%
Ca/ Ca+SO4	< 50 %	Most SO4 concentration can be attributed to the dissolution of Gypsum. Therefore the Ca/SO4 ratio must be 1:1 or lower, if some Ca is also provided by the dissolution of carbonate	58.53 % of the data are > 50%
Na / Na+ Cl	> 50 %	Chloride is mainly provided by the Dissolution of Halite (NaCl). Therefore the ratio Na/Cl is 1 or higher, if some Sodium is added from silicates or by ion exchange	All the data are greater than 50%

The ionic balance can also be checked by the sum of cations and anions comparing with the electrical conductivity divided by 100.

∑cations (meq/l) = ∑ anions (meq/l) = EC/100 (µs/cm)

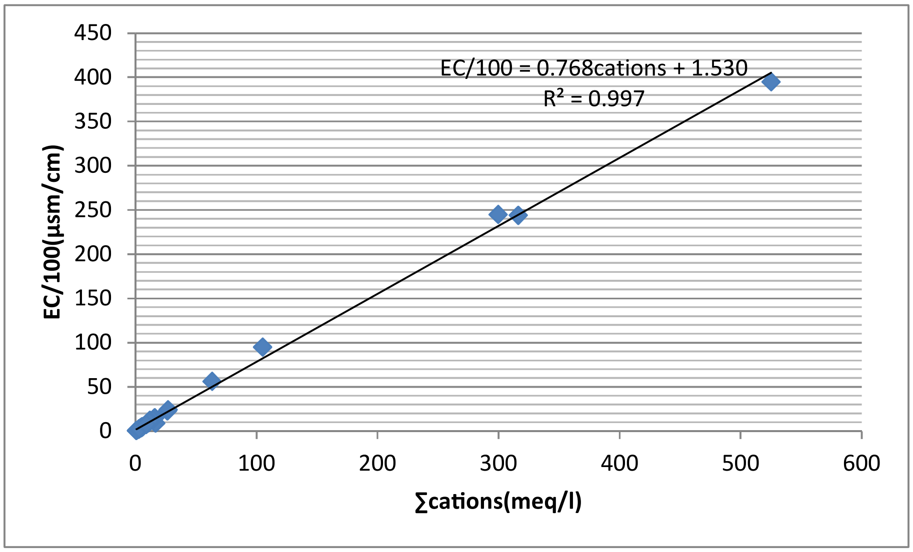


Figure 10 (a)

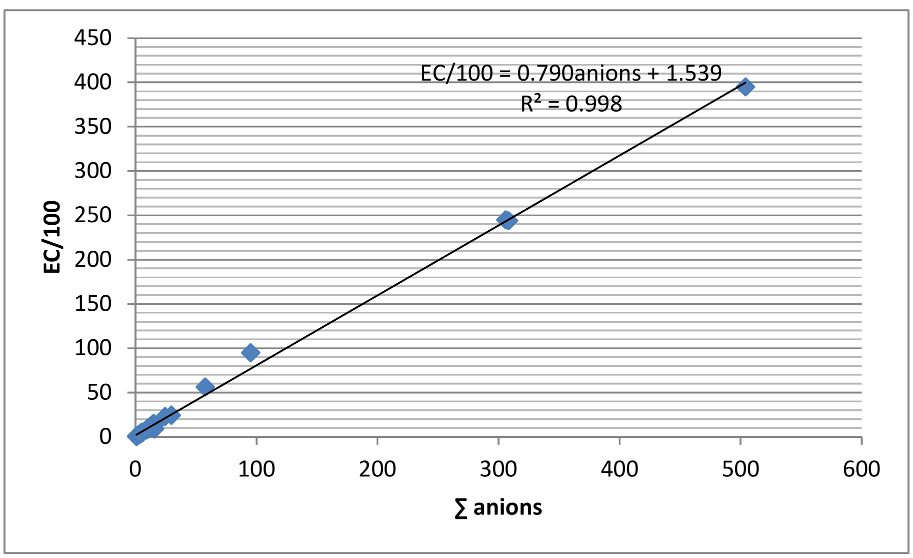


Figure10 (b)

Figure4.2: ∑cations Vs EC/100 (a) and ∑anions Vs EC/100(b)

Table 3:2: Descriptive Statistics of Hydrochemical Parameters in the Study Area

Parameter	unit	max	min	range	average	Std.dev	variance
PH		9.68	5.7	3.98	7.72	0.983	0.967
EC	µs/cm	39500	59	39421	3708.811	8598.439	73881573
TDS	Mg/l	27840	41	27799	2529.424	5961.099	35534705
Na	Mg/l	11800	3.2	11896	1008.551	2525.624	6378778
K	Mg/l	465	2.9	462.1	38.089	89.034	7929.04
Ca	Mg/l	91	1.37	89.63	13.99359	10.519	110.646
Mg	Mg/l	27.84	0.48	27.36	6.44	6.562	43.058
F	Mg/l	282.05	0.59	281.46	21.111	60.664	3680.072
Cl	Mg/l	3727.73	0.91	3726.77	389.182	100.859	1003721
No3	Mg/l	104	0.16	103.8	4.22785	5.039	25.596
So4	Mg/l	456	0.19	455.81	31.398	46.58125	2169.813
Co3	Mg/l	8640	4.8	4635.2	2290.2	3141.314	9867851
Hco3	Mg/l	5612	29.28	5582.72	857.8874	1248.194	1557989.01
Alkalinity	Mg/l	19000	24	1873	1602.167	38856	15097.891

The parameters considered for analysis of the water sample are physical and chemical parameters:

The physical parameter includes:

- Total hardness as mg/l of CaCO3
- Total alkalinity as mg/l ofCaCO3
- Electrical conductivity(EC)
- Total dissolved Solids (TDS) and
- PH

The Chemical Analysis includes the parameters:

- The majors cations (Na^+, K^+ Ca^{2+},Mg^{2+})
- The minors anions (Cl^-,NO_3^-, F^-, HCO_3^- ,CO_3^{2-} SO_4^{2-})

4.4. Physical Parameters

The results of a water analysis typically include physical parameters like pH, conductivity, TDS, hardness, and alkalinity. The physical parameters which are changed with time such as PH, EC and temperatures are under taken in-suit measurement.

4.4.1 .PH

PH is a measure of the hydrogen ion concentration of the water. The pH of water indicates whether the water is acid or alkaline. PH is the best physical parameters that determine the quality of water. It is directly related to the geochemical and biochemical reaction in water. The pH of water has a profound effect on the mobility and solubility of many substances. Most metallic elements are soluble as cations in acid groundwater but will precipitate as hydroxides or basic salts with an increase in PH (Neven kresic, 2009). In-suit measurement of PH was conducted in the field.

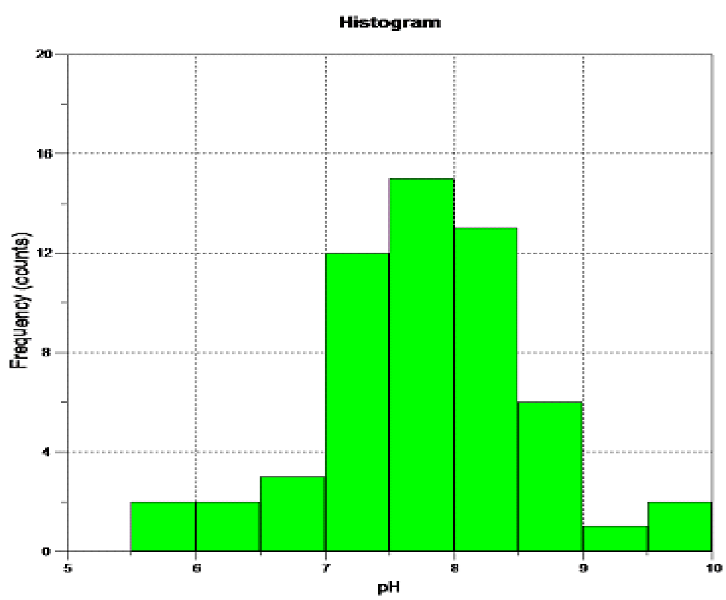


Figure4.3: Histogram Diagram of PH

According to WHO (2011) standard the PH of the water should ranges between 6.5-8.5. In the study area pH ranges from 5.7 to 9.7. The lowest PH is recognized in Kersa Ellala River and the highest PH is observed in Abjiata and Shala lakes. In ground water the PH range is from 6.1- 8.6. The lowest PH recorded in borehole is 6.1 in Alleweyoo area.

From the Figure 4.3 most of the samples PH are in the range of 6.5- 8.5 which fulfill the WHO requirement.

4.4.2 .Total Dissolved Substance (TDS)

TDS is total concentration of dissolved material in water which is determined by weighting the dry residual after heating the water samples. The TDS value does not necessarily equal the sum of the concentrations of all dissolved constituents, because some elements react and/or enter the gas state during evaporation (Charles R. Fitts, 2002). Total Dissolved Solids (TDS) signifies the salinity behavior of water because it is the index of the concentration of the dissolved ion in the water. Shallow groundwater in recharge areas is lower dissolved solids than the water deeper in the same system and lower in dissolved solids than water in shallow zones in the discharge areas (Freeze and Cherry, 1979). This implies that as the water goes from the highland through fractured and unconsolidated sediments it acquires dissolved solids more and more depending on all the parameters that govern the evolution of groundwater chemistry.

Table 4.3: Water Classes Based on TDS Value

Water class	TDS (mg/l)
Fresh	0 - 1,000
Brackish	1,000 - 10,000
Saline	10,000 - 100,000
Brine	>100,000

Based on these Criteria Lake Shala and Abijata are saline lakes but Lake Ziway is fresh and Lake Langano is brackish. Water from open hand dug well in Kolkola, Elkelcha, Abusara and Abosa which are found around Ziway and hot spring around Shalla and Aluto shows brackish water type.

Deep borehole around Ziway also classified as brackish water types. The poatability of water with a total dissolved solids (TDS) level of less 1000 mg/l.

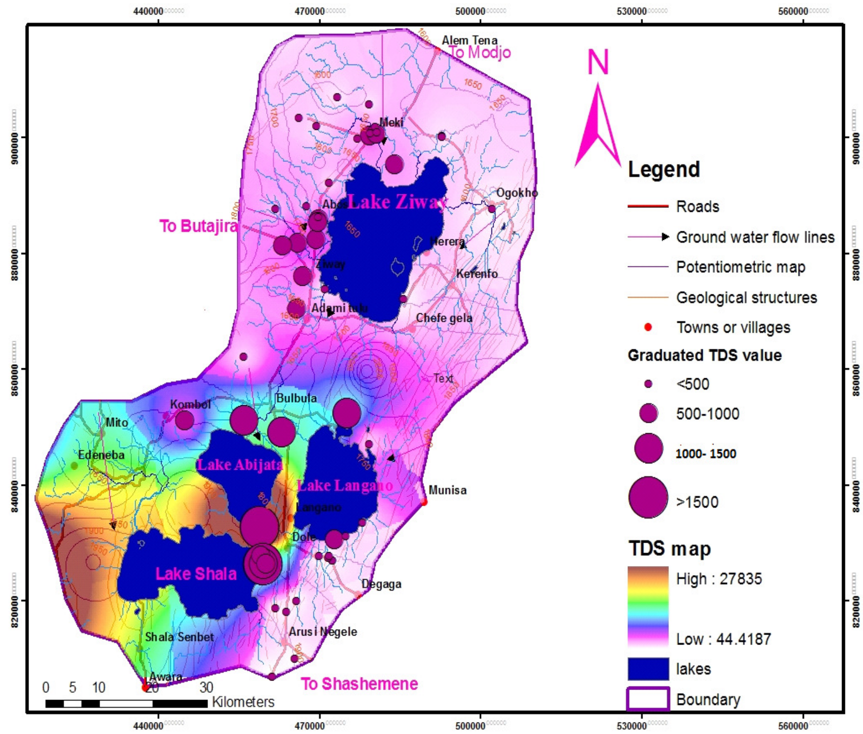


Figure4.4 : TDS Map of the Study Area

Drinking-water becomes significantly and increasingly not potable at TDS levels greater than about 1000 mg/l. From the TDS map in the Figure 4.4 the TDS is increasing towards Shala Lake following ground water flow path.

4.4.3. Electrical Conductivity (EC)

Electrical conductance is the ability of a substance to conduct an electric current that expressed in micro Siemens per centimeter (μ s/cm). It can also be expressed in siemens per meter (S/m) and mili siemens per meter (mS/m). The conductivity of most fresh waters is in the range of 5 to 50 mS/m and for highly mineralized waters goes up to 1000 and even higher.

The presence of charged ionic species in solution makes the solution conductive. As ion Concentrations increase, conductance of the solution increases; therefore, the conductance measurement provides an indication of ion concentrations.

The values of EC increase with temperature, between 20^0c and 30 ^{0}c, an increase in 10 ^{0}c, increases the EC by two percent on the average (Hem, 1992). Electrical conductance of groundwater commonly increases in the flow direction (Mazor, 1997).

The optimum values are much higher than the maximum permissible range of the standard EC value set by World Health Organization (WHO, 2011) for drinking water, which is 1,400 µs/cm. In the study area the water from spring in Shalla and Aluto area, borehole in Ziway Dugda, the hand dug in Kolkola and Abusara shows high EC value. The EC value for Horakelo River is 5630µs/cm which is larger than from previous data reported by Tenalem , in 1998 as 3850µs/cm.EC value for Shalla and Abijata lakes are greater than 20, 000 µs/cm and 30, 000 µs/cm respectively. From the hot springs, spring near to Lake Shala has high EC value .The high EC value in the area is due to geo thermal heating and rock water interaction due to long residence time (Tenalem, 1998). EC and TDS are highly correlated and EC can be used to estimate TDS multiplying EC by an empirical factor that ranges from 0.55 to 0.99.

The EC against TDS from all sources of water measured in Laboratory shows a straight correlation line (R2 = 0.995).

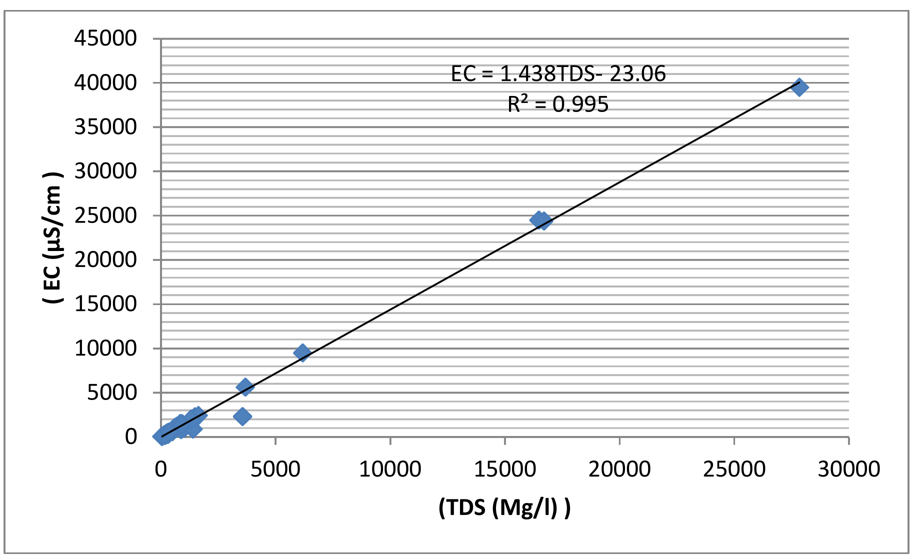


Figure4.5: TDS Vs EC

4.4.4 .Temperatures

Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. Chemical and biochemical reactions induced at higher temperatures produce undesirable tastes and an odor. Water temperature is an important factor of the usage of water (http://www.env.gov.bc.ca/wat/wq/BCguidelines/temptech/temperature.html).

Temperature is also affecting the various parameters such as alkalinity, salinity, electrical Conductivity. Rock temperatures increase with depth below the land surface. Where water circulates to a considerable depth, it attains a substantially higher temperature than water near the land surface. Increased temperature raises both the solubility and the rate of dissolution of most rock minerals. The solute content of thermal water is commonly higher than that of non thermal water. Some thermal water may be notably high in dissolved-solids concentration and may contain unusual amounts of metal ions (Hem, 1989). In the study area range of temperature is 21.5^0c and 78 ^{0}c.

The cold springs which have low temperature have low TDS than hot springs which have high temperature. From hot springs there are high variations in temperature that cause different TDS values.

4.5. Major Ion Chemistry

Minerals substance contained in natural water in the dissolved states (in the form of ions) are conventionally sub divide in to two major ions and minor ions. The major ions compromise cations like Na, K, Ca, Mg and anions Cl, SO_4, HCO_3 and CO_3. These ions account 95% for fresh water and 99% for mineralized water and determine water chemical type. Major ions constitute a significant part of the total dissolved solids present in ground water. The concentrations of these ions in ground water depend on the hydrogeochemical processes that take place in the aquifer system. These processes occur when the groundwater moves toward equilibrium in major ion concentration.

4.5.1. Sodium

The sources of sodium in waters are deposite of various salts (rock salts), weathering products of lime stone rocks and displacement from the absorbed complex of rocks and soil by calcium and magnesium. Cations exchange is a reaction in which the calcium and magnesium in the water are exchanged for sodium that is adsorbed to aquifer solids such as clay minerals, resulting in higher sodium concentrations (Hem, 1985). The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution. At room temperature, the average taste threshold for sodium is about 200 mg/l (WHO, 2011).

There is a variation of Na ions concentration in ground water and surface water .The amount of sodium is larger in the ground water than in the surface water due to rock water interaction process occur in the ground water .The concentration of sodium in the study areas varies from maximum of 11800Mg/l in Abijata lake and minimum of 3.2 Mg/l in Kersa Ellala River. Borehole around Horakelo and Hand dug in Abusar area shows 2900Mg/l and 600 Mg/l respectively.

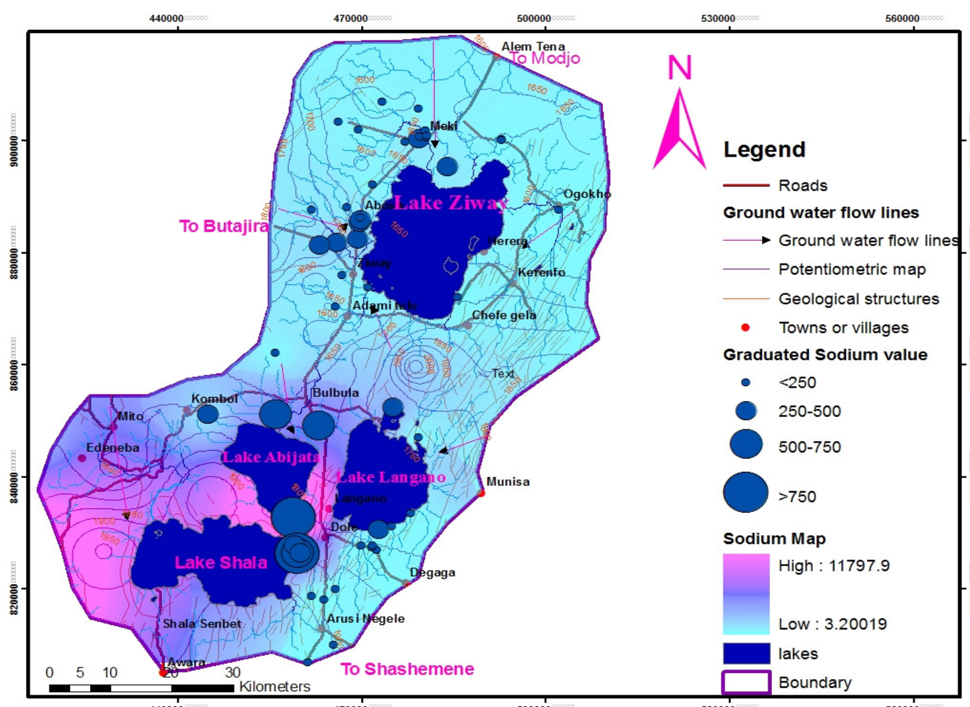


Figure4.6: Sodium Map of the Study Area

Na is the dominant cation in the study area due to Na is more abundant in the host rock and high water rock interaction with lacusterine deposite. From the Na distribution map given in Figure 4.6, the concentration of Na increase towards Shala Lake along ground water path. Na is less around Meki area and Keter area relative to Ziway and Shala area.

4.5.2. Calcium

The basic sources of calcium in water are carbonate rocks (limestone and dolomite) that are dissolved by carbonic acid dissolved in water. Another source of calcium is gypsum which is common in sedimentary rocks. Calcium ions dominated in low mineralized water.

The maximum calcium concentration is observed in boreholes in Ziway with a value of 91 Mg/l due to irrigated drained water and from the hand dug the maximum calcium is 69Mg/l. This may be the interactions of the hand dug with the nearby Meki river that have maximum calcium from all surface water found in the area and minimum value is observed of 1.37 mg/l in borehole found in korka area. Of the surface water, Meki River with a Ca value 26 Mg/l and Lake Shalla with Ca value of 1.6Mg/l show the maximum and minimum value respectively.

4.5.3. Magnesium

Magnesium is typically a major constituent of the dark –colored ferromagnesian minerals specifically, these includes olivine, the pyroxenes, the amphiboles and the dark-colored micas along with various less common species (Hem, 1989).

The concentration of Mg is less than 27.84 Mg/l which is recorded in Ziway Kolkola hand dug and greater than 0.48 which is observed in hot spring around Shalla Lake. Around Shalla small concentration of magnesium is observed. In all samples magnesium concentration is smaller than calcium. This is probably due to the low abundance of Mg^{2+} in the outcropping rocks.

4.5.4. Potassium.

The principal potassium minerals of silicate rocks are the feldspars, orthoclase and microcline (KALS&OH), the micas, and the feldspathoid leucite (KAlSizOs).

The maximum concentration and the minimum concentration of potassium are 465Mg/l and 2.9Mg/l respectively in Abijata Lake and Kersa Ellala River. Relative to ground water surface water in the area has high potassium concentrations. In ground water samples boreholes in Ziway and hot springs in Aluto have maximum value of 67Mg/L. According to Tewodros (2008), Na^+ is always higher than K^+, because K-minerals in primary volcanic par ageneses are more resistant to weathering than Na-minerals (i.e. plagioclase is more Alterable than K-feldspar); moreover K^+ is easily stabilized in neo-formation minerals (clay minerals).

4.5.5. Nitrate

Nitrates (NO3) are an essential source of nitrogen (N) for plants. When nitrogen fertilizers are used to enrich soils, nitrates may be carried by rain, irrigation and other surface waters through the soil into ground water. Human and animal wastes can also contribute to nitrate contamination of ground water. Although any well can become contaminated by nitrates, shallow, poorly constructed, or improperly located wells are more susceptible to contamination. Nitrate levels in drinking water can also be an indicator of overall water quality. Elevated nitrate levels may suggest the possible presence of other contaminants such as disease-causing organisms, pesticides, or other inorganic and organic compounds that could cause health problems. 98% of the sample analyzed falls within the acceptable ranges which are less than 50Mg /l .In the area nitrate concentration is very low in boreholes and hand dug wells but in borehole around Meki shows 104 Mg/l which is high from all ground water samples. This is may be contamination of borehole due to anthropogenic activities or agricultural activities.

4.5.6. Chloride

Chlorides have very high migration ability in connection with very high solubility of chlorides salts. Their presence in water is associated leaching from minerals. .The high chloride concentration is associated with type of Lithology and pollution from surface water. Lake Abijata and lake Shalla shows high concentrations of chloride which shows the very high salinity of the lakes .In boreholes around Horakelo area has maximum of chlorides concentration of 966Mg/l. This may be interaction of the borehole with high chlorides concentration saline river Horakelo.

In the area there is high variation of chlorides from the ground water. This indicates that the main source of chloride in the area is leaching of chlorine from acidic igneous rocks (Hail Gashaw, 1999). From Figure 4.5 the concentrations of chlorides increase towards Lake Shala.

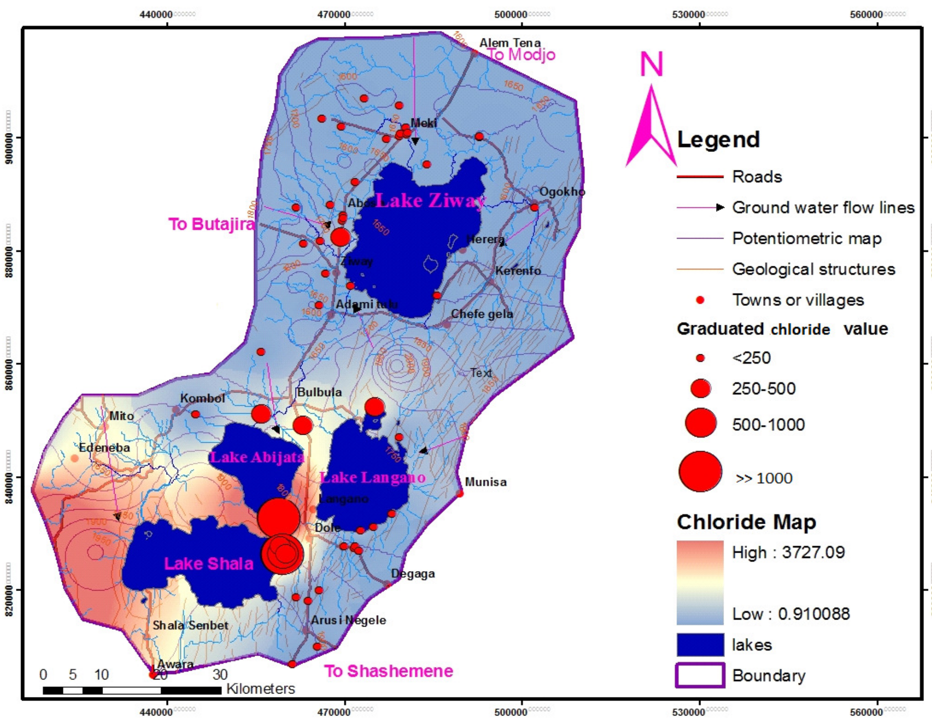


Figure4.7: Chloride Map

4.5.7. Sulphates

The main source of sulphate in water is various sedimentary rocks which includes gypsum and anhydride. The presence of sulphate in the area is related to volcanic activities.

In the study area the SO_4 ions concentration varies from a minimum of 0.19Mg/l to a maximum of 191Mg/l borehole in Alleweyoo and Horakelo rivers respectively. From the ground water boreholes in Meki areas shows a maximum value of 456Mg/l.

4.5.8. Carbonate and Bi-carbonate

The presence of carbonates and bicarbonate influences the hardness and alkalinity of water. The source of HCO_3 and CO_3 is various carbonate rocks like dolomite, limestone and magensite form which dissolution takes place with which precipitation carbon dioxide. In the study area the source of bicarbonate is not calcite dissolution since carbonate are not present in the study area. So the source of bicarbonate is magmatic CO2. When the PH is from 7 to 8.5 hydro carbonate is dominated. When pH is less than 5, hydro carbonate less than zero. Carbonate ions are dominated with pH greater than8. From correlation matrix pH and HCO_3 is moderately correlate (r =0.596) .From Figure 3.8 , most sample with PH 7 up to 8.5 are dominated by HCO_3 ion and sample with PH less than 7 are not dominated by HCO_3.

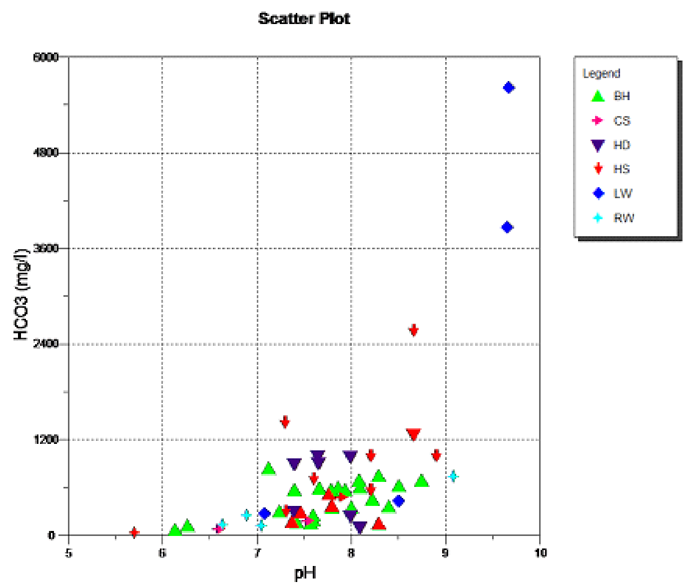


Figure4.8: PH Vs HCO3

The maximum carbonate and bi-carbonate observed is 8640 and 5612 in Lake Abijata and hot springs around Shalla respectively and maximum alkalinity observed in the area is 2700 Mg/L CaCO3.

4.5.9. Fluoride

Since fluoride is highly soluble in water, it can be subsequently transferred in the water system if the volcanic deposits are leached by water during water-rock interactions. The fluvio-volcano lacustrine sediments are the main reservoir of fluorine in the area and that they can release it into the water system (Tewodros Geodebo, 2008). The natural concentration of fluoride in groundwater depends on many factors, like the geologic, chemical and physical characteristics of the aquifer, the porosity and acidity of the rocks, the temperature, and the action of other chemical elements and the depth of the wells (Tamiru Alemayehu, 2006).

There are about 150 fluoride bearing minerals however villiaumite, fluorspars, flour apatite and cryolite are the most abundant ones. Many rocks of the rift are enriched in those minerals. Especially amorphous rocks, like pumice, tuffs, pyroclastics and porphyry or other easily weather able materials, like volcanic ash or sediments of salt. Lakes are concentrated by washing out the fluoride component into the surface and groundwater. Leaching out the fluoride from easily weather able volcanic rocks is thought to be the main source of high fluoride levels in water sources of the area. High fluoride water sources are characterized by high sodium and bicarbonate as well as high alkaline media (Tebebeu Terefe, 2007).

The weathering products of the volcanic rocks, i.e. the clay-rich fluvio/volcanolacustrine sediments, are enriched in F^- with respect to the original mother rocks. Coherently, the higher concentrations of F^- in groundwater have been recorded in those wells drilled on the fluvio/volcano lacustrine sediments (Tewodros Geodebo, 2008).

The maximum fluorine concentration is observed in Lake Abijata and the minimum fluoride concentration is observed in boreholes around Ziway. Rivers have low fluorine concentration expect Horakelo River. Around Horakelo area high fluoride concentration is recorded in borehole.

The source of high fluoride concentration in the area is related with three causes: addition of fluoride by active volcanic and fumarelic activities, high water-rock interaction (particularly interaction of water with volcanic ash) and low calcium concentration, which restricts the precipitation of fluoride as fluorite (CaF_2) (Hail Gashaw, 1999). This Ca and F correlation can be shown by using the following scatter diagram given in Figure 4.9.

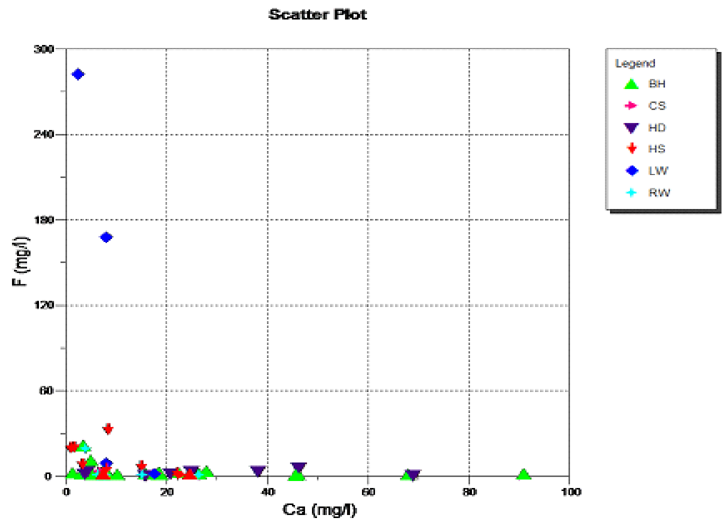


Figure4.9: Ca vs. F

The more Ca the less the F (r = -0.184). So those samples with high calcium concentrations have low fluorides amounts. But Na and F are directly related as shown below in Figure 4.10 (r= 0.976). That is why in the study area one of the reasons of the higher fluoride concentrations is due to Na dominated water type.

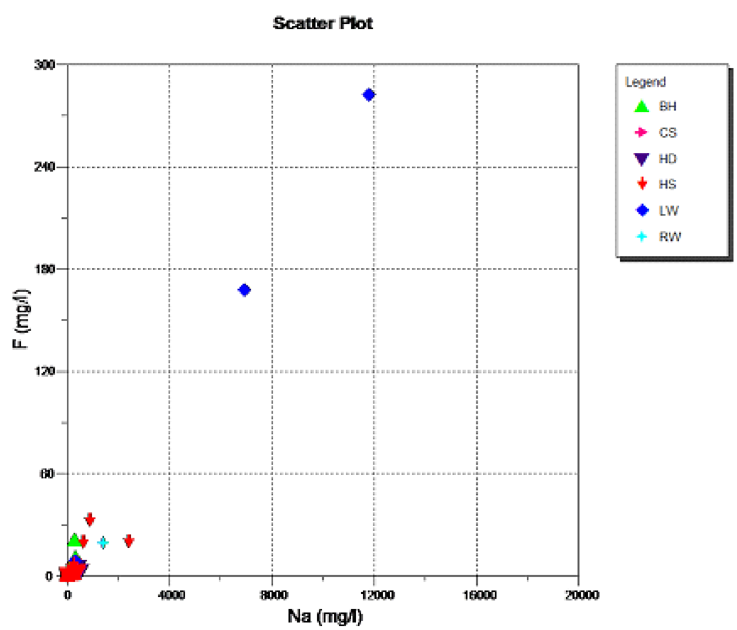


Figure4.10: Na vs. F

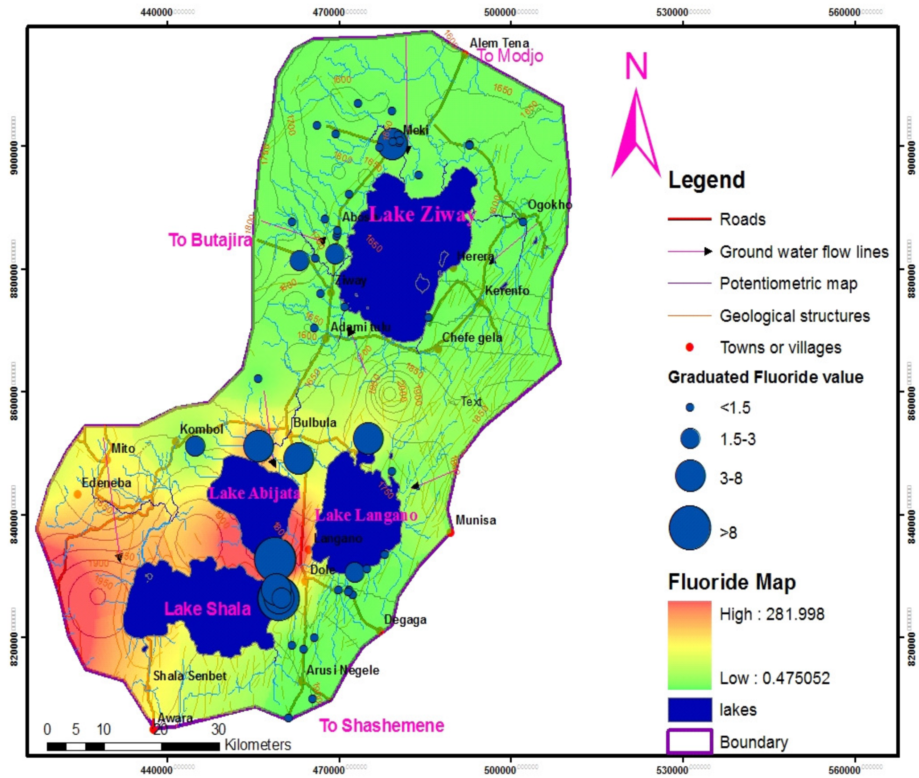


Figure4.11: Fluoride Map

From the Figure 4.11, the fluoride concentration around Shala is high along ground water path.

4.6. Surface Water Chemistry

Surface water is usually rain water that collects in surface water bodies, like oceans, lakes, or streams etc. The most important substance for humans in their surrounding materials world is natural water. Natural water is a dynamic chemical system containing in its compositions a complex group of gases, minerals and organic substance in the form of true solution and suspended and colloidal matter as well.

The concentration of all minerals is related to two main factors - the abundance of chemical elements on the earth crust and the solubility of their compounds. http://www.eolss.net/SampleChapters/C07/E2-03-04-02).

A major impact of the environmental factors influencing the composition of water may also come from human activities.

Climatic patterns tend to produce characteristics plant communities and soil types, and the composition of waters of streams draining such areas could be influenced by the ecological balance. Bicarbonate (HCO_3^-), for example, tends to predominate in water in areas where vegetation grows profusely.

4.6.1. Rivers Chemistry

Water samples from different rivers were taken and physico-chemical parameters were analyzed. The rivers are Meki, Keter, Bulbula, Kersa Ella, Gedemso and Horakelo. Meki and Keter are drained from western and eastern highlands and flows in to Lake Ziway. Bulbula River out flows from Lake Ziway and enter in to Lake Abijata and Horakelo river flows from Lake Langano to Abijata. Kersa Ellala River enters in to Lake Shalla and Gedemso river flow in to Langano lakes.

The sources of streams water are base flow fractions from ground water infiltration to the channel water and the surface run-off fraction during and after precipitations. The direct run-off has short contact with soli and vegetations. The interactions of the direct run-off with the soil enable the run –off to have higher dissolved substances than the original rain or snow. The base flow fraction also has considerable higher dissolved substances.

Rivers that drained from the high land like Meki and Keter have low total dissolved but river like Horakelo have high Total Dissolved Substance and has high salinity. Gedemso River has low Total Dissolved Substances from all rivers. The PH of the rivers ranges from 5.7 – 9.08. River Kersa Ella and Gedemso have PH 5.7 and Horakelo is alkaline river with PH 9.08. Rivers like Gedemso, Kersa Ellala and Meki are acidic. This may be pollution of the rivers due to human activities.

Table 4.4: Physico –Chemical Parameters of Rivers

		Name of the river					
Parameters	Unites	Bulbula	kersa ellala	Gedemso	Horakelo	Meki	Keter
PH	-	6.8	5.70	5.70	9.08	6.64	7.05
EC	µs/ cm	444.5	68	59.0	5630	200.0	232
TDS	Mg/ l	280	49	41.0	3680	130.0	152
Na	Mg /l	66.5	3.20	3.30	1420	13.0	23
K	Mg/l	12	2.90	3.0	48.00	5.10	5.40
Mg	Mg/l	7.68	3.36	2.40	1.44	5.76	4.56
Ca	Mg/l	22.4	6.40	8.00	4.00	26.40	15.20
Cl	Mg/l	12.74	0.91	1.82	587.92	3.64	0.91
SO4	Mg/l	12.35	9.98	7.70	191.90	8.74	1.81
HCO3	Mg/l	241.56	29.28	29.28	732	122.0	120.29
CO3	Mg/l	Nil	Nil	Nil	720.00	Nil	Nil
NO3	Mg/l	5.08	6.79	6.52	1.48	1.35	0.62
F	Mg/l	0.925	0.59	0.80	19.74	0.89	0.75
Total hardness	(Mg/l CaCO3)		30	30.00	16.00	90.0	57.0
Alkalinity	(Mg/l CaCO3)		24	24.00	1800.00	100.0	98.60

Rivers have different major ion chemistry. For example Meki River has high calcium other than rivers and Horakelo River is Na dominated river. This is may be due to the Lithology difference in which the river drains. Most rivers have less Na unlike most ground water .This is due to the main source of Na is rocks containing Na minerals and rivers have not long time interaction with the rocks . Except Horakelo the other rivers have fluoride concentrations of less than 1.5 Mg / L.

The rivers have different water types. These water types can be classified by using different diagrams. From the diagrams piper plot, stiff diagrams and Durov`s diagram are the common one. Classifification of the water can be used to differentiate the origin of various water bodies and to examine the ground water surface water bodies' interaction.

The surface water has different water types. The water types are Na-HCO3, Na-CO3-Cl-HCO3, Na-Ca-HCO3, Ca-Mg-HCO3, and Na-CO3- Cl. The water types of the rivers are different from the lakes. The Rivers show uniformity in anion that is HCO_3 but differ in cation.

4.6.1.1. Water Type of Bulbula River

Bulbula River is flow out from Ziway Lake and flow in Lake Abijata. The river has nearly the same chemistry with Lake Ziway .The dominant cation and anions are Na and HCO_3 respectively .The water type of the Bulbula River is Na-Ca-HCO_3.

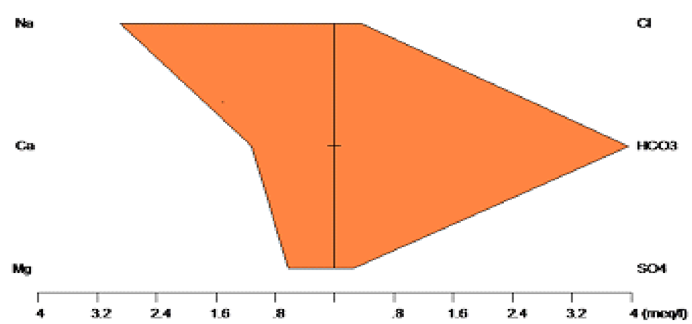


Figure4.12: Stiff Diagram of Bulbula River

4.6.1.2. Water Type of Kersa Ellala River

Kers Ellala River enters Shala Lake which is acidic river with PH 5.7 due to may be pollution. The water type of Kersa Ellala is Ca-Mg-HCO3-SO4.

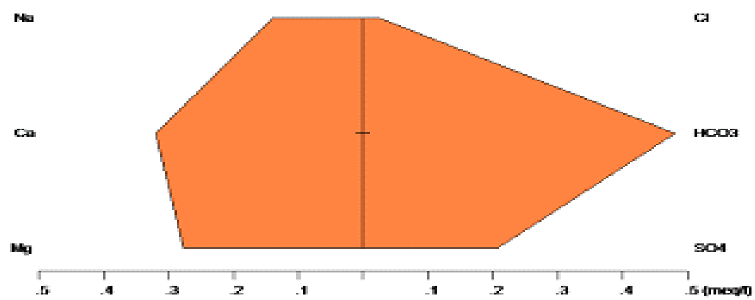


Figure4.13: Stiff Diagram Kersa Ellala River

4.6.1.2 .Water type of Horakelo River

Horakelo River flows out from Lake Langano and enters to Lake Abijata. The river has different chemistry with Lake Langano. It has high Electrical Conductivity and high saline water from all other rivers and has the same water type like Lake Abijata. The water type is Na-CO_3-Cl.

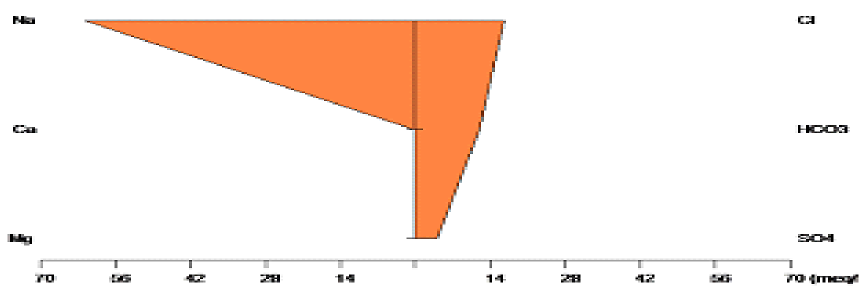


Figure4.14: Stiff Diagram of Horakelo River

4.6.1.4 .Water type of Meki River

Meki River flows from Goragi –Highland and enters to Lake Ziway. The PH of the river is 6.64 which is acidic but the local people used for irrigation. The river has water type of Ca-Na –HCO3 .The hand dug near to Meki River has similar water type like the Meki River. This significance that ground water and surface water are inseparable entities they feed each other.

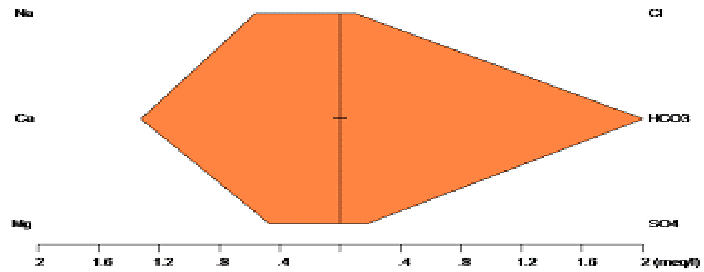


Figure4.15: Stiff Diagram of Meki River

4.6.1.5. Water type of Keter River

Keter River is flows from Arsi-Highland and enters in to Lake Ziway .The River is neutral relative to other rivers. The other rivers are either acidic or basic. The water type of the river is Na-Ca-HCO3.

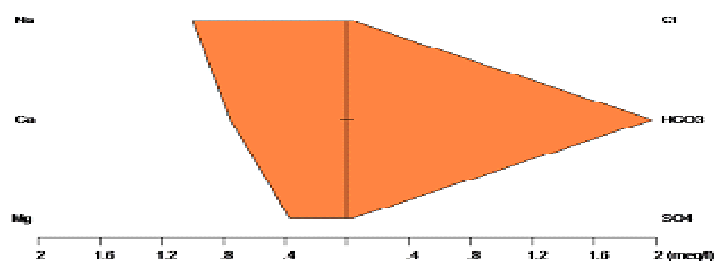


Figure4.16: Stiff Diagram of Keter River

4.6.1.6. Gedemso River

The river is flows in to Lake Langano and has a PH of 5.7 which shows acidic river and has low TDS relative to other rivers. The water type of the river is Ca-Mg-HCO_3.

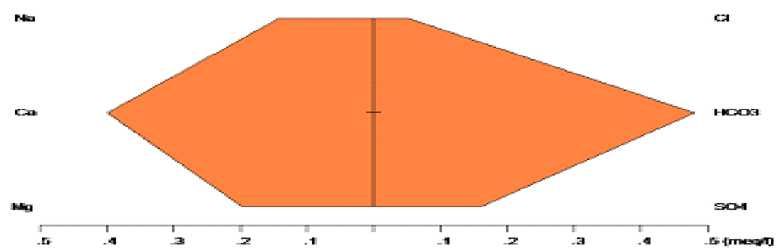


Figure4.17: Stiff Diagram of Gedemso River

The water types of all rivers can be represented by using the piper plots. From Figure 4.18, the rivers have mainly Na-HCO3 and Ca-Mg-HCO3 water type. The river shows uniform in anion distribution but shows different in cation distribution.

The concentrations of major ions can be compare be by using Schoeller diagram given in Figure 4.19.

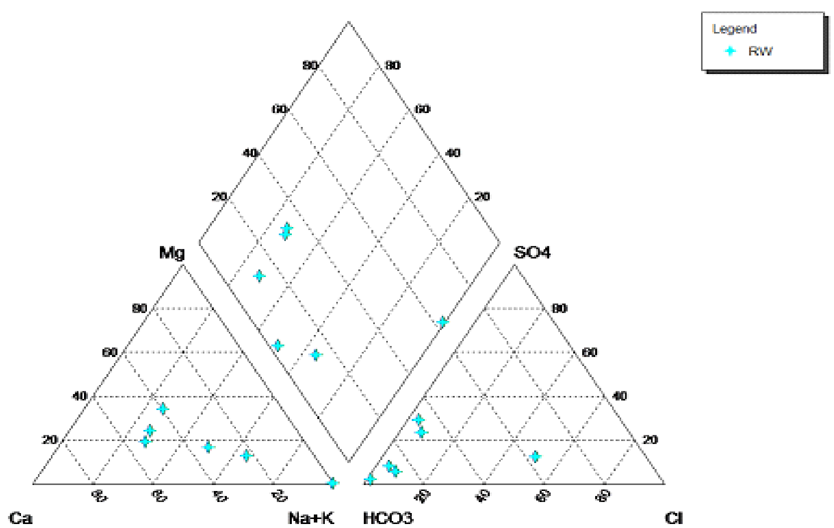


Figure4.18: Piper Plot of Rivers

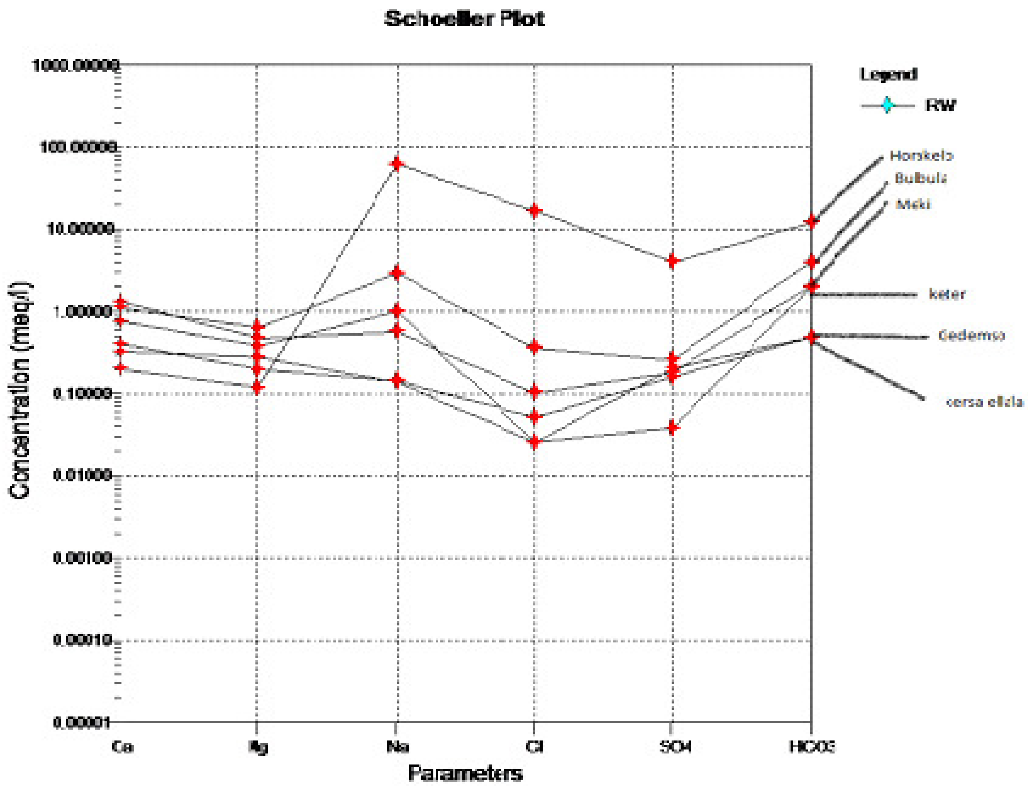


Figure4.19: Schoeller Diagram of the Rivers

4.6.2. Lake Water Chemistry

In the study area there are four main lakes. These are Ziway, Langano, Shala and Abijata. The lakes have been subjected to strong changes in water level and water salinity .Lake Ziway is fresh water with TDS of 289.11 and Lake Abijata and Lake Shala are saline water but Lake Langano is brackish water. Except Lake Ziway the other three lakes are alkaline lakes. The three lakes are connected by surface water with exception of Lake Shala .Lake Shala and Abijata are terminal lakes with no outlet other than evaporation. These terminal lakes accumulate solute from rivers and ground waters and become alkaline.

Table 4.5: Physico Chemical Parameters of the Lake

Name of the lake	PH	EC	TDS	Na	K	Ca	Mg	Cl	SO_4	HCO_3	F	NO3
Ziway	7.1	453	289	73.5	13	18	10.1	13.6	7.25	262.2	1.5	2.75
Langano	8.5	1700	1105	340	23	8	2.4	143	21	424.6	8.5	4.1
Shala	9.6	24450	16590	6950	207	8	0.96	3309	25	3855	167	0.75
Abijata	9.7	39500	27840	11800	465	2.4	0.96	3727	160	5612	282	0.36

Like the rivers the lakes also have different water types. The water types of the lakes are also varies with water types of the river.

4.6 .2.1.Water Type Lake Shala

Lake Shala is highly saline-alkaline-Sodic waters, containing high pH, high EC and sodium. The lake is not connected with other lakes and it is a terminal lake. The water types of Lake Shala is Na- Cl-HCO3with the dominant cations of Na.

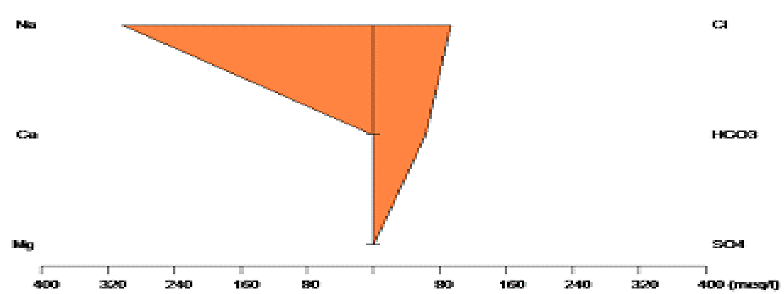


Figure4.20: Stiff Diagram of Shala Lake

4.6.2.2. Water type of Lake Abijata

Lake Abijata is also highly saline-alkaline-Sodic waters, containing high pH; high EC and sodium .The type of water for Lake Abijata is Na-CO3-Cl. Like Lake Shalla the dominant cations in Abijata is Na.

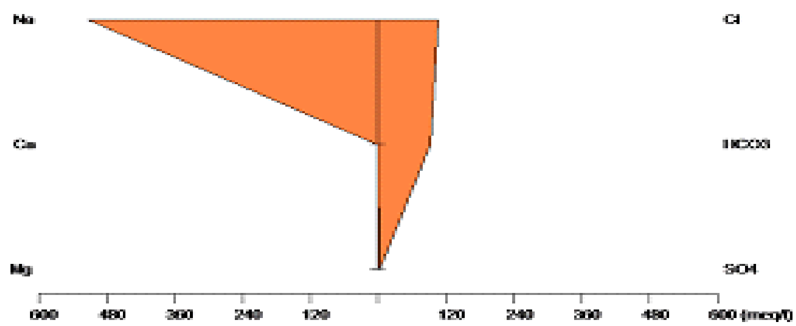


Figure4.21: Stiff Diagram of Abijata Lake

4.6.2.3 .Water type of Lake Langano

Lake Langano is Brackish water .The water type of the lake is Na-HCO3-Cl. The major cations and anions are Na and HCO3 respectively.

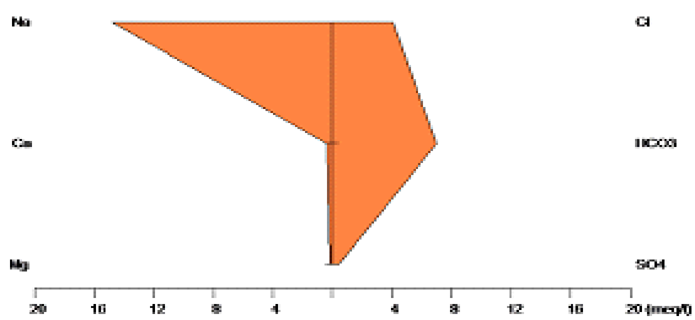


Figure4.22: Stiff Diagram of Lake Langano

4.6.2.4 .Water type of Lake Ziway

The water type of Ziway Lake is Na- HCO3, with the dominant cation of Na and anion of HCO3. Ziway is fresh water with TDS of 289due to it is flushed and open water bodies and a PH of on average 7. Lake Ziway has low fluoride content and TDS (1.4 and 289 mg/l) respectively because of the dilution from the surface waters Keter and Meki rivers with Fluoride content of less than 1mg/l and TDS less than 200 mg/l.

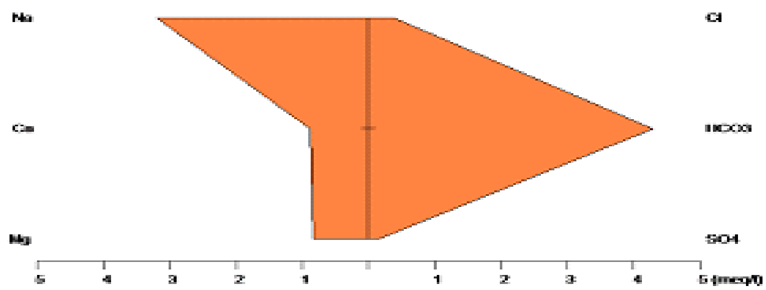


Figure4.23: Stiff Diagram of Lake Ziway

The water types of the lakes can be represented by using the piper diagram below in Figure 4.24. The lakes water types are Na- HCO_3 and Na- HCO_3-Cl which is a characterics of water type of rift floor unlike the highland and escarpment water type. The major ion concentration variability of the lakes is shown from in Figure 4.25

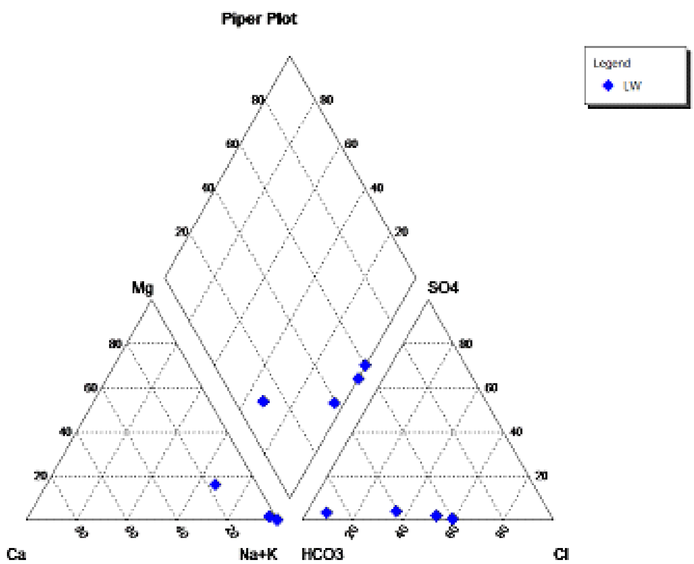


Figure4.24: Piper of diagram the lakes

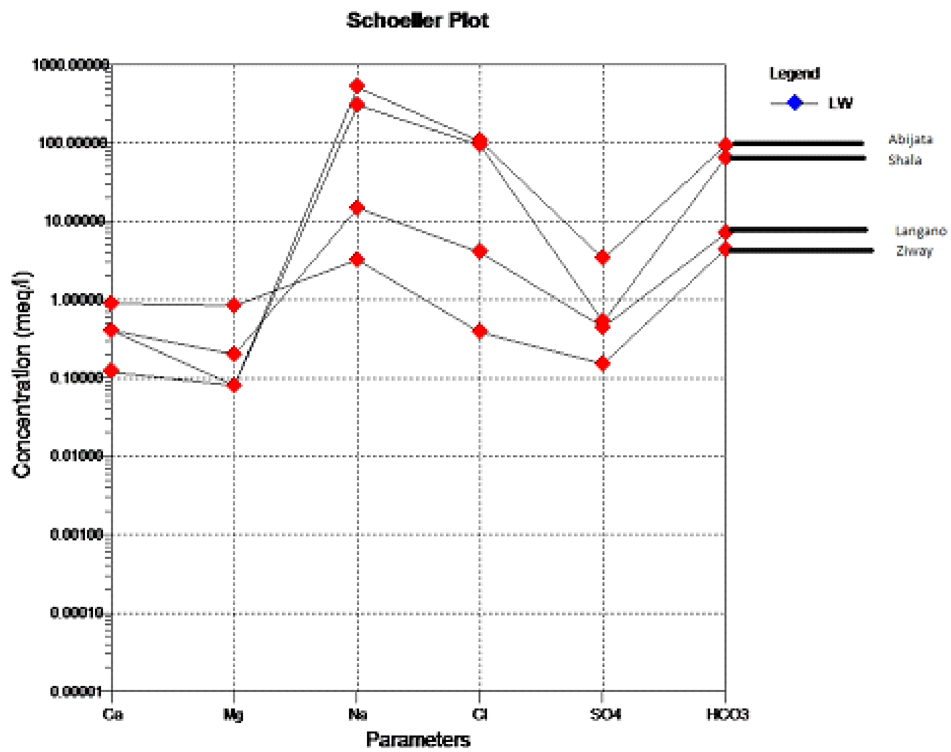


Figure4.25: Schoeller diagram of the lakes

Generally the water types of the surface water is shown in Figure 4.26

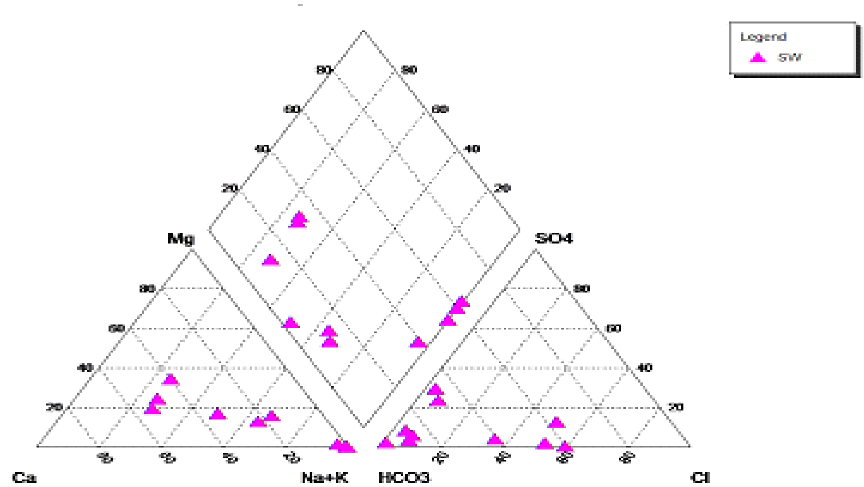


Figure4.26: Piper diagram of the surface water

4.6 .3.Impact of the floriculture on Ziway Lake

Lake Ziway and its surrounding area are of commercial and tourist interest and support a large livestock population. Over-exploitation of the natural resources and increasing use of agrochemicals threaten the environment.

There is no control over effluent discharges from floriculture into the Lake Ziway and the lake is over abstracted. These activities may change the chemistry of the lake.

Eight samples of Ziway lake water were taken from starting of near to Shear Ethiopia effluent (Z1) up to out- let of Ziway Lake (z9) in the name of Bulbula River. Sample from near Shear Ethiopia effluent was also took in order to investigate the impact of the floriculture wastes in the lake. The result of the physico- chemical analysis result is given below the Table4.6. From the table the nitrate concentration of the lake near to the effluent is higher than far from the effluent. Even if the concentration of nitrate is not above the WHO standards; there is an increase of the nitrate. This effect can be shown indirectly due to growth of plants in the lake. If the waste discharge continues like this the lake will be polluted. Because the waste is not treated and has nitrate concentration of 126Mg/l .This value is above the WHO standards.

Nitrate is the product of the biochemical oxidation of ammonium using nitrite as an intermediary (nitrification), or can be supplied direct (for example as ammonium nitrate fertilizer). Nitrate is commonly found in soil and water and is one of the main forms by which plants obtain their nitrogen. In excess, nitrate can also be responsible for eutrophication (i.e. the disturbance of ecology of waters by causing excessive plant growth.) The nitrate form is most effective in promoting plant growth, but is also most readily lost from soil by leaching in drainage.

The concentration of nitrate in the lake is low as compared to the waste .Because of the dilution of the effluent with the fresh water of the lake and may be due to the intake of the nutrient by plants that grow in the lake and due to high solubility of nitrate .The growth of the plants indicate that there are nutrients that enable to grow macrophyte in the lake. This shows that there is nitrate load in the lake that enable grow the plant.

Table 4.6: Physico- Chemical Parameters of Lake Ziway Sample at Different Location

			Code									
Parameters	Units	ZL 1	ZL 2	ZL 3	ZL 4	ZL 5	ZL 6	ZL 7	ZL 8	ZL 9	ZL 10	WW
PH	-	6.83	6.9	7.1	7.1	7	7	7.3	7.1	7.2	7.4	7.84
EC	µs/cm	329	407	470	477	469	473	463	464	525	474	1409
TDS	Mg/l	240	260	300	306	300	304	290	280	343	309	915
Na	Mg/l	50.5	68	75	80	78	72	80	77	88	74	335
K	Mg/l	9.7	12	13.1	13	13.4	13.2	13.2	13.3	18	13	48
Ca	Mg/l	17.6	18.4	18.4	16,8	16	18.4	16.8	18.4	19	15.2	19
Mg	Mg/l	7.68	8.64	9.12	10.6	11	11	9.6	12.5	12.3	9.12	77
Cl	Mg/l	11.8	10.9	14.6	14.6	14.6	15.4	13.7	14.6	16.4	10	27.3
SO4	Mg/l	1.33	1.71	2.57	2.95	2.38	2.28	2.76	3.23	26.9	21.4	12
F	Mg/l	0.91	1,56	1.04	1.08	1.61	1.16	1.43	1.36	3.86	0.97	3.
NO3	Mg/l	7.72	5.67	1.62	0.72	11.9	0.76	1.05	5.88	0.76	0.56	126
HCO3	Mg/l	190	236.7	268.4	273.3	258	268	270	273.3	307	271.6	658.4
Total hardness	Mg/l (CaCO3)	76	82	84	86	86	92	82	98	98.8	76	79

ZW- Lake Ziway, WW- waste water

Figure4.27: Image showing untreated effluent discharge from share Ethiopia

Figure4.28: Plant that grown in the Ziway Lake

4 .6.4.Seasonal Variations of physico chemical parameters of surface waters

The chemical composition and characteristics of surface have been shown to vary with seasonal regimes. This is usually associated with variations in precipitation, surface run-off, interception and abstraction of Surface water Discharge.

Results from analysis of selected parameters (physical and chemical) for the dry (April) and wet seasons (August) are presented in Table 4.7 and 4.8.

4.6.4.1. Variation in ionic composition of the lakes with time

For lakes TDS and EC is recorded maximum in April. There is also alkalinity difference due to seasonal difference. . The PH also changes even if the variation is not high. The major cations also show difference as the seasons is different. This variation may be due to high dilution occurring in August which is rainy season.

Table 4.7: Time variation of chemical compositions lakes Langano and Ziway

Parameters	PH	TDS	EC	Ca	Total alkalinity	Cl	F	Na
Units	-	mg/l	µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l
Ziway , April	8.68	220	460	22.4	194	12.5	1.51	63.5
Ziway ,August	8.05	212	442	20.8	152	12.0	1.62	59
Variation (%)		3.6	3.9	7.2	21.6	4	7.3	7.1
Langano , April	8.89	923	1932	4.8	574	166	9.6	445
Langano , August	9.07	853	1786	4.8	530	187	7.2	405
Variation (%)		7.58	7.56	0	7.7	12.65	25	8.99

Source, (Halcrow, 2007)

Table.4. 8: Time Variation of Chemical Composition Lake Abijata and Shala

Parameters	PH	TDS	EC	Ca	Total alkalinity	Cl	F	Na
Unit	-	gm/l	mS/cm	mg/l	mg/l	mg/l	mg/l	mg/l
Abijata– Apr	10.05	41.52	83.58	3.2	25,900	10,778	370	12,940
Abijata–Aug	10.00	41.60	84.25	4.0	26,000	10,900	370	13,100
Variation %	-	0.2	0.8	25	0.4	1.1	0	1.2
Shala – Apr	9.77	23.16	48.15	Nil	10,700	3,123	156	6,000
Shala - Aug	9.83	21.30	44.00	6.4	11,000	3,150	220	6,950
Variation %	0.6	8.0	8.6	-	2.8	0.9	41	15.8

Source, (Halcrow, 2007)

4.6.4 .2. Variation in ionic composition of the rivers with time

From the rivers Meki, Keter and Bulbula are highly abstracted for irrigation and these rivers have different chemistry in different seasons. The river has high TDS in April than in August. Not only TDS almost all parameters have significant difference in variation of the season. The reasons the rivers have less TDS in August is due to dilution. Bulbula River has consistent major ion concentration in the two seasons.

Table 4.9: Time Variation of Chemical Composition of Rivers

Parameters	Meki		Keter		Bulbula		Gedemso	
	April	August	April	August	April	August	April	August
TDS (mg/l)	142	43	94	39	231	211	79	26
EC (µS/cm)	294	90.4	197	83.3	482	442	165	58
TSS (mg/l)	530	3600	94	312	96	122	32	298
Na (mg/l)	29	15	16	5.2	54	60	12.7	4.4
K (mg/l)	10.1	5.9	5.1	3.5	12.3	10.6	6.8	2.5
Ca (mg/l)	25.6	4.8	15.2	8.0	21.6	20.8	10.4	3.2
Mg (mg/l)	6.804	0.486	4.86	1.944	8.748	6.6	3.4	1.944
HCO_3 (mg/l)	131.76	29.28	100.04	12.2	246.44	190.32	63.44	7.32
Cl (mg/l)	8.5	2.0	2.5	2.5	14	12.5	5.5	6
SO_4 (mg/l)	18.62	2.4	1.27	3.04	6.14	0.4	3.28	2.6
SAR	1.3	1.74	0.92	0.43	2.47	2.93	0.87	0.46

Source (Halcrow, 2007)

4.6.4.3 .Variation in chemical composition of the lakes in Long term

The lakes also have significant variation annually in chemistry. This is shown in Table 4.10, 4.11, 4.12 and 4.13. From Tables 4.10, 4.11, 4.12, and 4.13 the salinity of the lake are increase from time to time specially Abijata and Shala. The increase in the salinity of Abijata are due to the abstraction of water for soda manufacturing and the decrease of flow of Bulbula river to the Abijata by abstraction of the river for irrigation .But in the tables the salinity is decrees in 2012 . This is may be the reason that the sample taken is in July which is rainy seasons that dilution is high. The salinity of Ziway is somewhat increase even if it is not significant as compare with Abijata and Shala.

The increase in salinity of Lake Ziway is because of high abstraction of water for irrigation and the effluent that is flow in the lake which have high TDS than the lake. Lake Langano has also some change in TDS although the change is insignificant.

Table 4.10: Long term variation of chemical composition of Shala Lake

		Name of the lake	Sources				
Parameters	Units	Shala	Tesfaye , 1982	Tenalem , 1995	AAWSA ,2004	Halcrow , 2007	Recent ,2012
PH	-		9.6	-	9.92	9.83	9.6
EC	µs/cm		-	-	41, 300	44000	24450
TDS	Mg/l		-	-	19975	21300	16590
Na	Mg/l		5600	6850	8800	6950	6950
K	Mg/l		200	275	288.5	244	207
Ca	Mg/l		1	0.5	7.2	4	8
Mg	Mg/l		1	0.45	Nil	Nil	0.96
CO3	Mg/l		3090	5350	-	141.6	4224
HCO3	Mg/l		3569	1650	9272	6344	3855
Cl	Mg/l		2663	2880	3098	10900	3309
SO4	Mg/l		100	650	Nil	15.75	2408
F	Mg/l		175	190	285	370	167.4
NO3	Mg/l		-	0.5	Nil	0.29	0.8

Source, Halcrow (2008)

From the Table 4.10 the Na concentration of the lake Shala is increasing. Note only Na all major ion has been changed.

Table 4.11: Long term variation of chemical composition of Abijata Lake

		Name of the lake	Source				
parameters	units	Abijata	Tesfaye ,1982	Tenalem , 1995	AAWS, 2004	Halcrow, 2007	Recent ,2012
PH	-		9.6	-	10		9.7
EC	µs/cm		-	-	51950	89250	39500
TDS	Mg/l		13480	-	25100	41600	27870
Na	Mg l		4700	7950	11251	13100	11800
K	Mg/l		250	390	169	630	465
Ca	Mg/l		1	0.4	3.2	4	2.4
Mg	Mg/l		5	0.3	0.49	Nil	0.96
CO3	Mg/l		311	6780	-	141.6	8640
HCO3	Mg/l		2367	2100	11078	6344	5640
Cl	Mg/l		2095	2980	3530	10900	3727
F	Mg/l		130	190	228	370	282.05
SO4	Mg/l		140	1250	57	15.75	160.08
NO3	Mg/l		-	-	1.5	0.29	0.36

Source, Halcrow (2008)

Table 4.12: Long term variation of chemical composition of Langano Lake

		Name of the lake	Source				
Parameters	Units	Langano	Tesfaye ,1982	Tenalem ,1995	AAWSA, 2004	Halcrow ,2007	Recent , 2012
PH	-		9.2	-	-	9.17	8.5
EC	µs/cm	-	-	-	1815	1737	1700
TDS	Mg/l		1733	-	887	853	1105
Na	Mg/l		390	430	338	405	340
K	Mg/l		26	27	23	11.2	23
Ca	Mg/l		4.5	0.8	5.6	20.8	8
Mg	Mg/l		2	1	0.97	1.46	2.4
CO3	Mg/l		96	180	-	141.6	91.2
HCO3	Mg/l		586	510	634.4	436.7	424.2
Cl	Mg/l		182	190	162	188	143
F	Mg/l		13	14.2	13.1	17.2	9.5
SO4	Mg/l		-	30	6.7	0.75	21
NO3			-	0.4	1.6	0.3	4.1

Source (Halcrow, 2008)

Table 4.13: Long term variation of chemical composition of Ziway Lake

		Name of the lake	Source				
parameters	Units	Ziway	Tesfaye 1982	Tenalem. 1995	AAWS, 2004	Halcrow, 2007	Recent, 2012
PH	-		7.6		8.31	8.03	7.1
EC	µs/cm		416		498	445	453
TDS	Mg/l		-		238	214	289
Na	Mg/l		63	70	66.5	59	73.5
K	Mg/l		10	13	12.4	11.2	13
Ca	Mg/l		18	17	16.8	20.8	17.7
Mg	Mg/l		9	8.4	8.26	6.32	10.1
CO3	Mg/l			60	-	Nil	Nil
HCO3	Mg/l		244	145	222	185.44	262.2
Cl	Mg/l		14	4.1	24	12	13.6
F	Mg/l		1.3	1.9	3.2	1.62	1.4
SO4	Mg/l		1	13	7	25.4	7.25
NO3	Mg/l		-	2.3	0.32	1.58	2.75

Source, Halcrow (2008)

The TDS of the lake Ziway is increasing even if the change is not significant like Shala and Abijata. The PH of the lake is decreasing from alkaline to neutral. This shows the lake becomes acidic.

4.7. Hydrogeochemistry of ground water

Natural Groundwater Quality is mostly affected by Total Dissolved Solids, gases and pollutants and is controlled by presence of soluble or reactive minerals in aquifer/s such as Soluble minerals: halite (NaCl), anhydrite ($CaSO_4$) or gypsum ($CaSO_4 \cdot 2H_2O$), calcite (CaCO3) etc.

In higher lying areas, Ca $(HCO_3)_2$ type waters are prevalent, while in topographical flat areas NaCl type waters dominate. Recharge: recently recharged groundwater rich in calcium and/or magnesium and carbonate. Stagnant: relatively old groundwater at the end of chemical development, with high sodium, chloride and/or sulphate values. Static coordinate: groundwater that can be classified as stagnant and is actively being mixed. This water is generally rich in Ca, Mg, Na, Cl and SO_4. Dynamic coordinated: water rich in bicarbonate with increasing sodium and potassium concentrations (Plummer et.al, 1990).

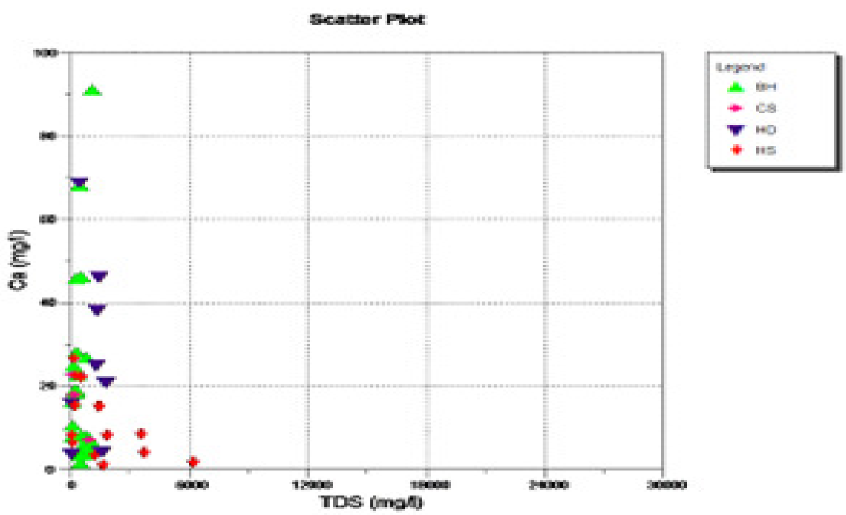
According to Paul M. Heisig (2002), the residence time Na-Ca –HCO3 water probably is intermediate between that of relatively young Ca-HCO3 water and that of the relatively older Na-HCO3 which undergoes the cation exchange processes and the water represents an intermediate step in the natural evolution of Ca-HCO3 water toward Na-HCO3water, or the mixing of CaHCO3 water with Na-HCO3. The Ca-HCO3 water type is considered as fresh waters of natural replenishment through the limestone, sandstones and other carbonate rocks.

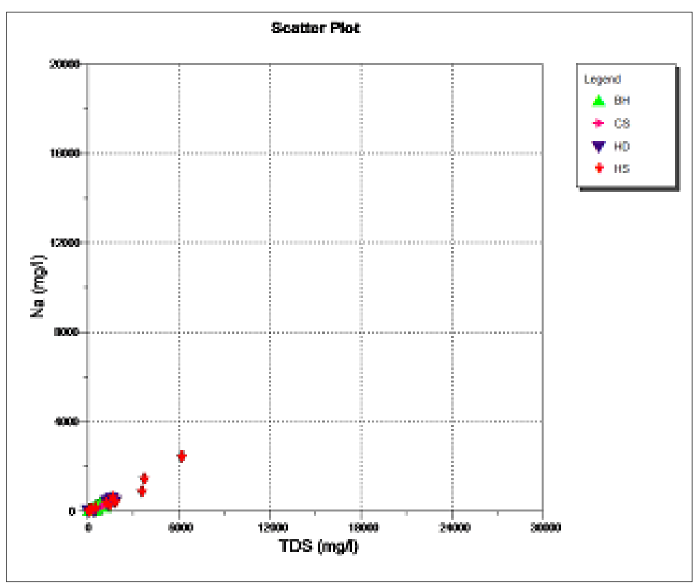
Ca-Na –HCO3 Water type has no dominant ion. Their spatial distribution represents a wide transition zone from fresh water recharge to in mixed water type (Appelo and postma, 1993). This show water rock interaction is in progress.

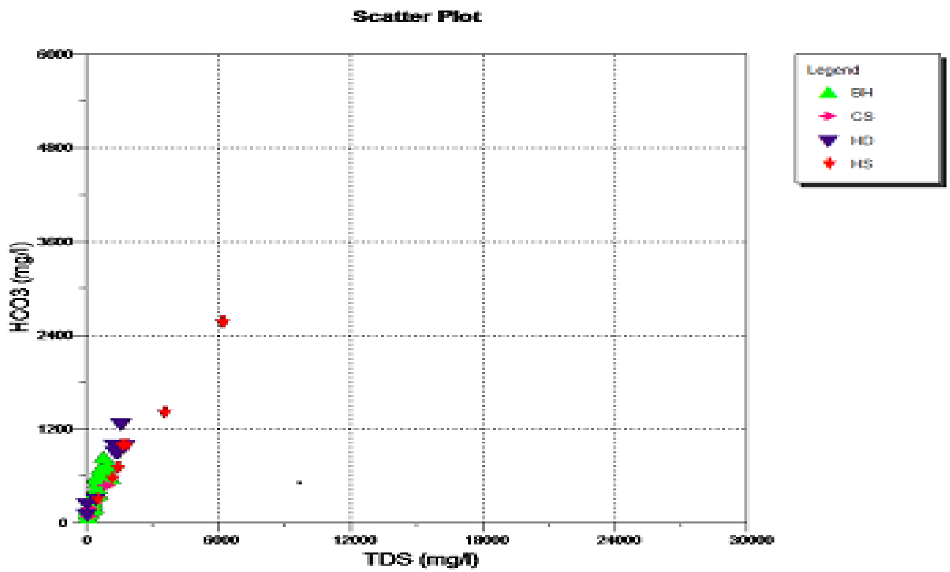
The chemical water types are distinguished and grouped by their position on a Piper diagram (Piper, 1944). In the study area the ground water shows different water types such Na-Ca-HCO3, Na-HCO3 ,Na-HCO3-CO3, Ca –Na –HCO3, Na-HCO3-Cl, From the ground waters samples 58.54% are Na-HCO3 type which indicates the area is discharge with the dominant ion of Na .This is due to high rock - water interaction within lacustrine sediments and which is lower in welded ignimbrites and basalts.

4.7.1. Composition Diagram

Composition Diagrams of major elements of the chemical analysis versus the TDS (TDI) of groundwater from the study area that plotted scatter in x-y plane may indicate the groundwater chemistry evolution and water contact with the rock body.







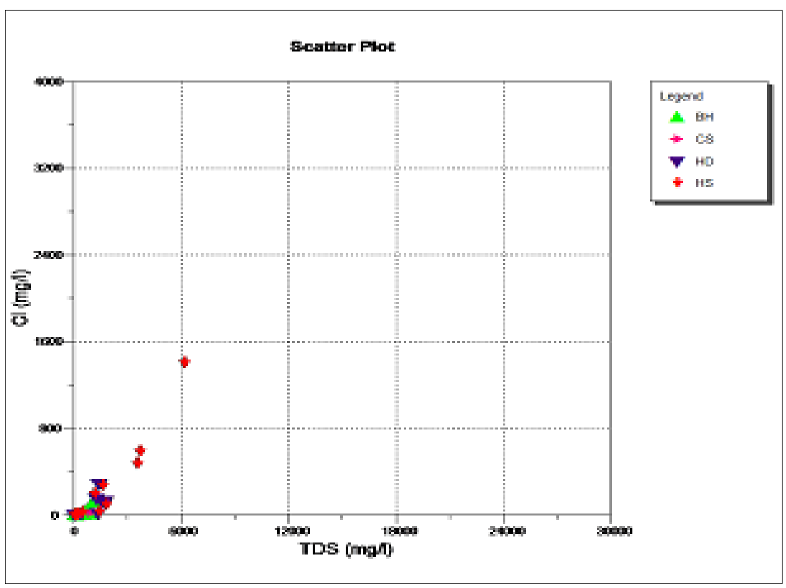


Figure4.29: Composition Diagram; TDS vs. Ca, Na, HCO3, Cl respectively

From Figure 4.29 TDS and Na. TDS and HCO_3, TDS and Cl are highly correlated but TDS and Ca is not highly correlated. This indicates the main ions contributor for the salinity of the ground is the one with highly correlation with TDS. Na, HCO3 and Cl are the main ions that contribute for the salinity of the ground water .The correlation can also show by using correlation matrix in table 4.14.

4.7.2 Correlation Matrix

Samples showing $r > 0.7$ are considered to be strongly correlated whereas $0.5 < r < 0.7$ shows moderate correlation at a significance level (p) of < 0.05. Strong Correlations have seen between TDS and the major elements of Na, K, Cl, and HCO3; $r > 0.7$, in Table4.14.These relationships clearly identify the main elements contributing to the groundwater salinity and their tendency to follow a similar trend (E.g. due to concentration by evaporation, dissolution/precipitation).

Table 4.14: correlation matrix of ground water in the study area all values are in mg/l

Correlation coefficient

	pH	TDS	Na	K	Mg	Ca	Cl	SO4	HCO3	NO3	F	F
pH	1	0.531	0.517	0.474	-7.6E-02	-0.194	0.525	0.381	0.596	-0.395	0.493	
TDS		1	**0.998**	**0.971**	-0.173	-0.173	**0.974**	0.451	**0.959**	-0.16	**0.987**	
Na			1	**0.97**	-0.182	-0.191	**0.973**	0.442	**0.948**	-0.148	**0.989**	
K				1	-0.117	-0.184	**.9070**	0.467	**0.907**	-0.152	**0.976**	
Mg					1	0.35	-0.192	-7.60E-03	-9.40E-02	-0.149	-0.187	
Ca						1	-0.185	-4.00E-02	-0.201	-0.116	-0.184	
Cl							1	0.386	0.947	-0.155	**0.952**	
SO4								1	0.461	-3.30E-02	0.404	
HCO3									1	-0.218	0.917	
NO3										1	-0.121	
F											1	

Strong correlation between Cl and HCO3 indicates that these ions tend to increase in concentration as the salinity of the water increases. The parameter with bolded has high correlation with other parameters.

4.7.3. Hydrogeochemistry of Boreholes and Hand dugs

4.7.3.1. Hydrochemistry of Boreholes

The EC of the boreholes ranges from 210 Mg/l to3969Mg/l. The borehole that show highest EC is found near to Horakelo River with high EC value from all rivers and the one that show lowest EC is shallow borehole in alleweyoo around arsi negela. From the observation of the PH value falls within 6.1- 8.6 ranges which is from acidic to alkaline properties. Alkalinity increases towards Shala that follows the ground water path flow.

The boreholes show different types of water. The different water types are Na-HCO_3, Ca -HCO_3, Na-Ca-HCO_3, Na-Ca-HCO_3-Cl, and Na –Ca-Mg-HCO_3. From the water type 60% are Na-HCO3 which indicate large residence time and are discharge area. But there is one sample with water type Ca-HCO3. Almost in all boreholes the dominant cation is Na.

Some boreholes that are near the surface water body's shows similar hydrochemical identity like the surface .Water sample 29 and 30 show similar chemical identity like Lake Ziway, in annex 2. Borehole found proximate to Horakelo river shows similar Chemical signature with the river in which both are the saline borehole and the saline river from the boreholes and the rivers. But there is anomalies chemical identity with boreholes found nearby surface water.

The water types of the boreholes can be represented by using piper diagram. From the piper diagram in Figure 4.30 one can show the dominant cation is Na and anion HCO3. A few samples have water type of Ca- HCO_3 with the dominant ion of Ca.

The key geochemical process in MER that controls the groundwater chemistry is the silicate hydrolysis of the Rhyolitic rocks that was initiated by high mantle CO2 gas flux. The silicate hydrolysis generates dissolved sodium and bicarbonate together with solid weathering products (e.g., clay minerals and oxides) that enhance Base Exchange reactions for removal of Ca^{2+} and Mg^{2+} and further release of Na^{+}. The end product is saline groundwater predominantly composed of a sodium-bicarbonate water type in Gizaw, 1996 cited in Tewodros 2013).

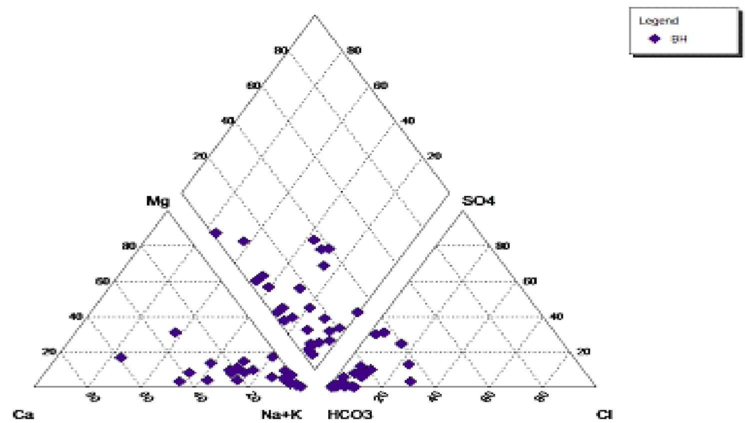


Figure4.30: Piper Plot of Boreholes

4.7.3.2. Hydrogeochemistry of the hand dugs

In the study area there are hand dugs that the local people use for irrigation and for drinking. The hand dugs have different EC with maximum of 2778 Mg/l and a minimum of 124 Mg/l. The PH of the hand dugs is almost alkaline. The water types of the hand dugs are Na-HCO3 but in Meki there is a hand dug with Na-Ca –HCO3. The EC of the hand dug is small as compared to the boreholes.

The high EC value of boreholes is due to high water rock interaction occur in boreholes that have high depth than the hand dug. The water types of the hand dugs can be show with the help of piper diagram in Figure 4.31.

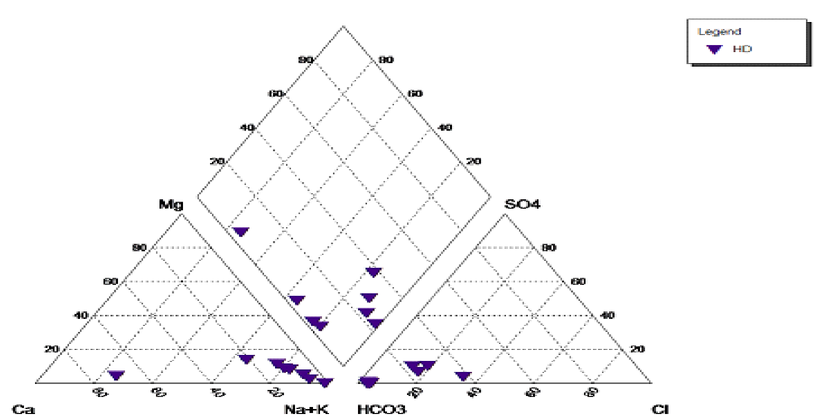


Figure4.31: Piper Plot of Hand Dugs

4.7.4. Hydrogeochemistry of Hot Spring

The hydrogeochemistry of the hot springs are spatially different in ionic concentration. Two hot spring samples from Ziway highland, two hot spring samples from Langano area and two hot springs samples from Shala area were taken. The hot springs around Shala have large total dissolved solid and are alkaline in nature with water type of Na-HCO3-Cl and have high chloride concentrations but hot springs around Ziway have low total dissolved solid and are neutral with water type of Na-HCO3. The hot springs around Langano also have high total dissolved solids especially around Aluto Langano area and the PH shows it is nearly neutral. From Figure 4.32 the hot spring shows Na-HCO3 and Na-HCO3-Cl water types.

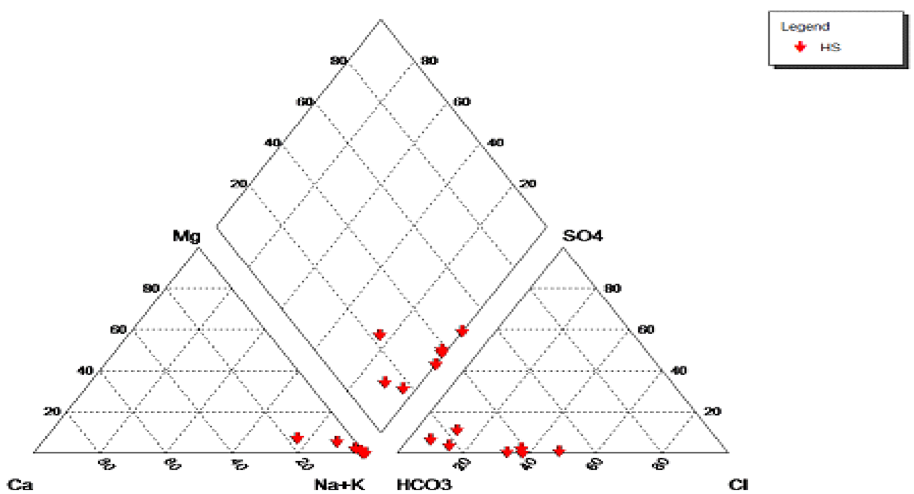


Figure4.32: Piper Plot of Hot Springs

4.7.5 .The Hydrogeochemistry of Cold Springs

Unlike the hot springs the cold springs have low TDS with different acidity properties. They shows a maximum TDS of 930mg/l .The three cold springs show different water types of Na- HCO3, Na-Ca- HCO3 and Ca-Na-HCO3 with different major cation but with the same major anions .The hydrogeochemistry of the cold springs have nearly similar hydrochemical identities. The water types of the cold springs can show by using the piper plots in Figure 4.33.

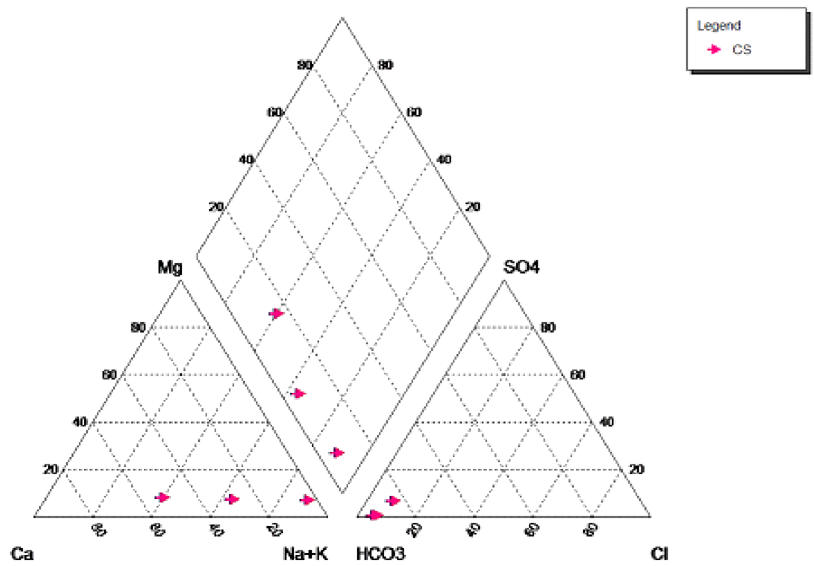


Figure4.33: Piper Plot of Cold Springs

Generally in the study area most water samples have water types of Na-HCO_3 as shown in Figure 4.34 of piper plot.

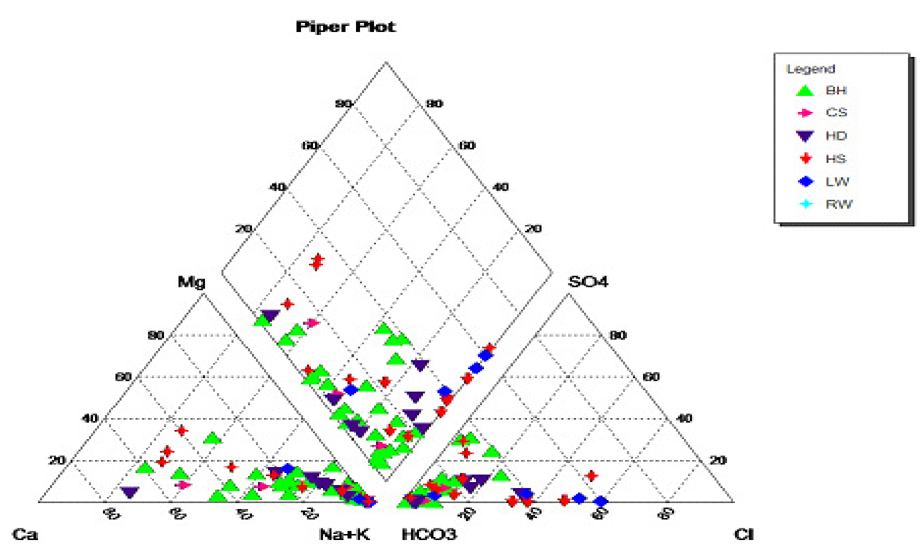


Figure4.34: The Piper Plots of All Samples

4.8 .Water quality of ground water

4.8.1. Drinking water quality of ground waters

The data on chemistry of the groundwater have been used for the evaluation of quality of water for drinking, industrial and irrigation purposes. Discharge of toxic chemicals, over-pumping of aquifers, long-range atmospheric transport of pollutants and contamination of water bodies with substances that promote algal growth (possibly leading to eutrophication) are some of today's major causes of water quality degradation (MoWR , 2008). So Water quality gives a clear picture about the usability of water for different purposes.

As a result of chemical and biological interaction between groundwater and contaminants from various sources related to natural or anthropogenic sources through which it flows, it contains a wide variety of dissolved inorganic chemical constituents in various concentrations.

The quality of water is very important to the mankind, because it has a direct link with human health. The water to be used for drinking purposes must meet very high standards of physical, chemical and biological purity. Water quality affects the daily lives of everyone and thus it is one of the most important topics addressed in water-supply studies. Besides being chemically safe for human consumption, water to be used in the home should be free of undesirable physical properties such as color or turbidity and should have no unpleasant taste or odor (Hem, 1985).

According to the WHO (2011) the PH of water must be in the range of 6.5-8.5 for drinking water. In terms of PH two samples are acidic and three samples are basic which are not fulfilling the WHO standards. The acidic sample is a shallow well Alleyweyo and a cold spring in Ziway area. The alkaline samples are boreholes from Bulbula area, a hand dug from Abusara area and a hot spring around Shala Lake.

In terms of TDS two boreholes from Ziway area, four hand dugs in Ziway and all hot springs except one spring do not fulfill the WHO standards. The TDS must be less than 1000Mg/L (WHO, 2011).

According to WHO (2011), the concentration of the Na should not exceeds 200Mg/l. but since the area is dominated by sodium, there is a water quality problems regarding to sodium concentration. From the ground water samples eight boreholes, five hand dugs and all hot springs are not fulfill the WHO standards.

The concentrations of chlorides in hot springs around Shala and Langano have high chlorides concentration and a hand dug in Ziway shows high chloride amount which are higher than the WHO requirement.

The concentration of nitrate and sulphate is very small in the study area but borehole in Langano shows 41.3Mg/l even if, it is not above the WHO standards. One borehole in Meki exhibits 104Mg/l and 456Mg/l concentration of nitrate and sulphate respectively. This shows a pollution of water due to agricultural activities or anthropogenic activities.

The study area faced water quality problems due to fluoride .From the Ground water samples, 25 samples have fluoride concentration above WHO requirement .Generally the water quality data are given below.

Table 4.15: Drinking Water Quality of Ground Water Comparing with WHO

S/N	Parameters	% above WHO	WHO (2011) guide lines	Remarks
1	TDS(Mg/l)	26.1	1000	4.3% (BH), (8.7% HD)and (13.04%) HS
2	PH	13.04	6.5-8.5	4.35 %(BH), 2.17% (CS) , 2.17% (HD)and 4.35% (HS)
3	Na	43.5	200	17.4% BH, 10.9 CS % and 15.21(all HS)
4	F	54.3	1.5	21.3(BH), 4.3 %(CS), 13.04% (HD) and 15.21 (all HS)
5	Cl	8.7	250	2.17% (HD)and 6.52% (HS)
6	NO3	2.17	50	2.17 %(BH)
7	SO4	2.17	250	2.17 %(BH)

From the Table 4.15, the area is highly in problems in TDS, Na and F relative to other parameters. Problems in nitrate and sulphate are insignificant but one borehole around Meki has NO_3 concentration above the WHO standards.

4.8.2. Irrigation Water Quality of Ground Water

Overall, large fraction of the MER groundwater have a significant water quality problem that could jeopardize the agricultural sector, particularly of the horticulture and floriculture sector that are the most vulnerable as they mainly depend on groundwater for irrigation . The low adaptive capacity coupled with other environmental factors including precipitation variability, population pressure, natural resource degradation and water quality and supply will continue to harm the agricultural sector. With regard to water resources, any changes in hydrological balance such as change in runoff due to climate change may limit surface water supply for irrigation which is already in high demand and may force shifting to poor quality groundwater resources (Tewodros Geodebo, 2012).

Water quality studies in the Main Ethiopian Rift (MER) revealed that the groundwater and surface water resources of the region are characterized by high salinity (e.g., Na, Cl, and B) that determine their use for irrigation (Tewodros Geodebo , 2012).

The most critical parameters that potentially constrain soil permeability and crop yields are salinity (as electrical conductivity; EC), sodium adsorption ratio (SAR) or sodium (Na %) and residual sodium carbonate (RSC). The parameters are expressed by the following formulas and concentrations are in equivalent unit.

The suitability of groundwater for irrigation use is evaluated by calculating Sodium Adsorption Ratio (SAR)

SAR= $Na^{+} / Ca^{2+} + Mg^{2+}) / 2$, can be used to classify water as excellent , good , fair and unsuitable for irrigations .According to USAD(1954) , the water having SAR values less than 10 are considered to be excellent 10 to 18 as good, 18 to 26 as fair, and above 26 are unsuitable for irrigation use.

Table 4.16: Irrigation Water Quality Data of Ground Water

S/N	Parameters	USAD (1954) Guidelines	% Within the limit
1	SAR	< 10 (excellent)	39.96 % (BH), 4.35 %(CS), 8.69 %(HD) and 2.17 %(HS)
2	SAR	10-18 (good)	21.73%(BH),2.17%(CS) ,2.17%(HS) % 4.34% (HD)
3	SAR	18-26 (fair)	4.34 %(HD)
4	SAR	>26 (unsuitable)	4.34% (BH), 2.17% (HD) and 18.68 %(HS)

From the Table 4.16 hot springs around Shala and some hand dugs around Ziway are not good for irrigations. But hand dugs and boreholes around Meki are suitable for irrigations relative to Ziway area. From all sample 82% are ground waters and 18% are surface water. From the ground water 60.8% are BH, 17.39% are HD, 15.22% are HS and 6.52% are CS.

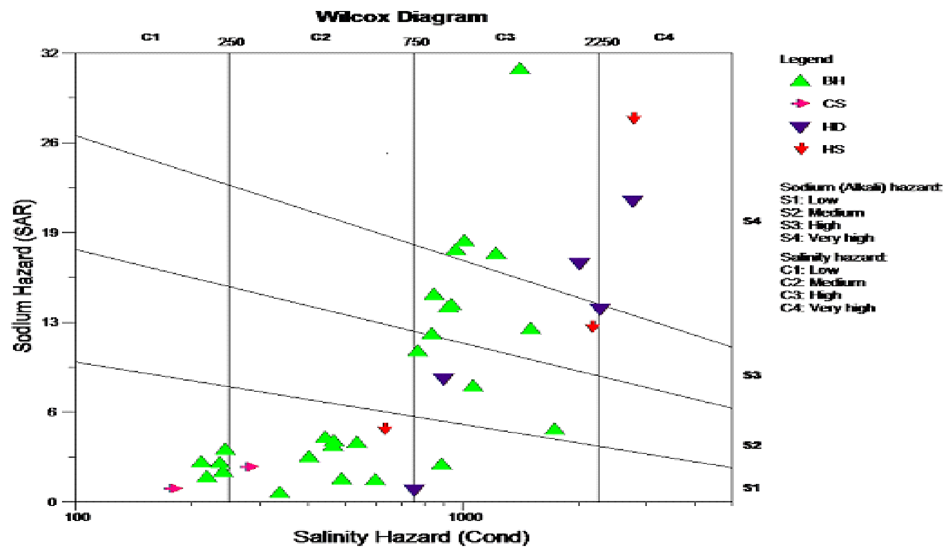


Figure4.35: Wilcox Diagram of Ground Water

4.9. Surface water quality

4.9.1. Drinking water quality of surface water

Table 4.17: Drinking Water Quality of Surface Water

S/N	Parameters	% above WHO	WHO (2011) guide lines	Remarks
1	TDS(Mg/l)	40%	1000	30% (LW) and 10 %(RW)
2	PH	60%	6.5-8.5	30 %(LW) and 30 %(RW)
3	Na	40%	200	30 %(LW) and 10 %(RW)
4	F	40%	1.5	30 %(LW) and 10 %(RW)
5	Cl	30%	250	20 % (LW) and 10 %(RW)
6	NO3	-	50	-
7	SO4	10%	250	10% RW

Note that LW (Lake water) and RW (River water)

4.9.2 .Irrigation Water Quality of Surface Water

Except Ziway the other three lakes (Langano, Shala and Abijata) are alkaline in natures so, the lakes do not use for irrigations. In rivers like Meki, Kersa Ellala and Gedemso rivers have acidic properties and Horakelo River have alkaline properties. According to WHO, the PH should be 6.5-8.4 for irrigation.

In the study area the people use surface water for irrigations especially Meki, Keter and Bulbula .Depending to SAR except Ziway from lakes, the other cannot be used for irrigations and from rivers Horakelo River cannot use for irrigations.

Table41.8. Irrigation water quality of surface water

S/N	Parameters	USAD(1994) Guidelines	% within the limit
1	SAR	< 10 (excellent)	10 % LW(ziway) , 50% RW(except Horakelo)
2	SAR	10-18 (good)	0
3	SAR	18-26 (fair)	0
4	SAR	>26 (unsuitable)	30% LW and 10% RW

From Tables 4.18 the surface water is based on SAR value is either excellent or unsuitable for irrigation.

From the Wilcox diagram in Figure44, Lake Ziway is suitable for irrigation because it falls in S1 which is low in sodium hazards and C2 with medium in salinity hazards. Even if most of the boreholes and hand dugs are suitable for irrigations there are boreholes and hand dugs that are not suitable for irrigations in Ziway area.

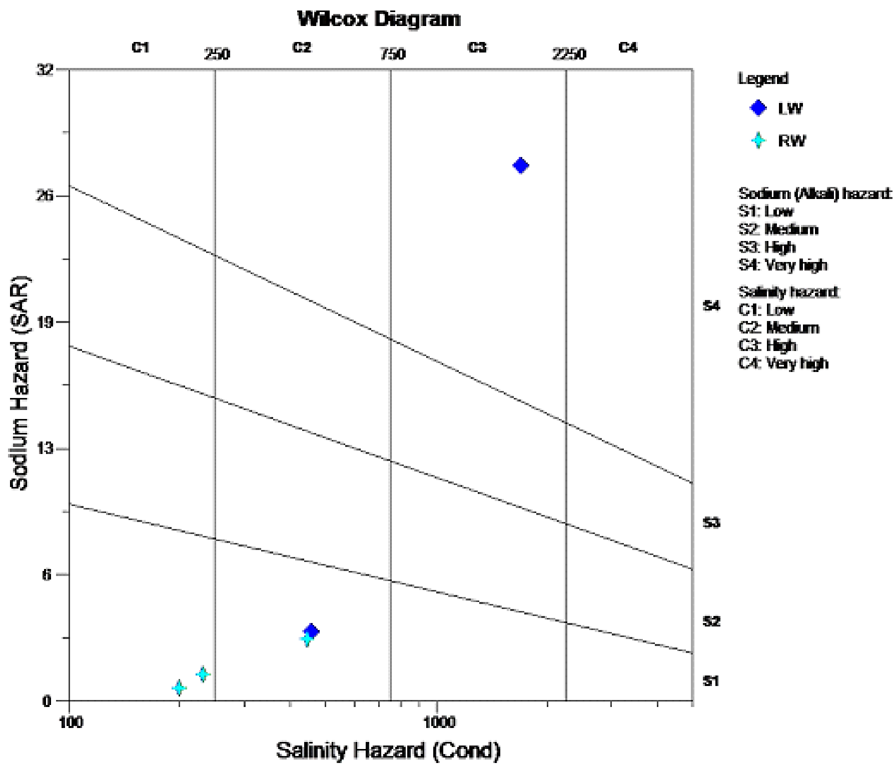


Figure4.36: Wilcox Diagram of Surface Water

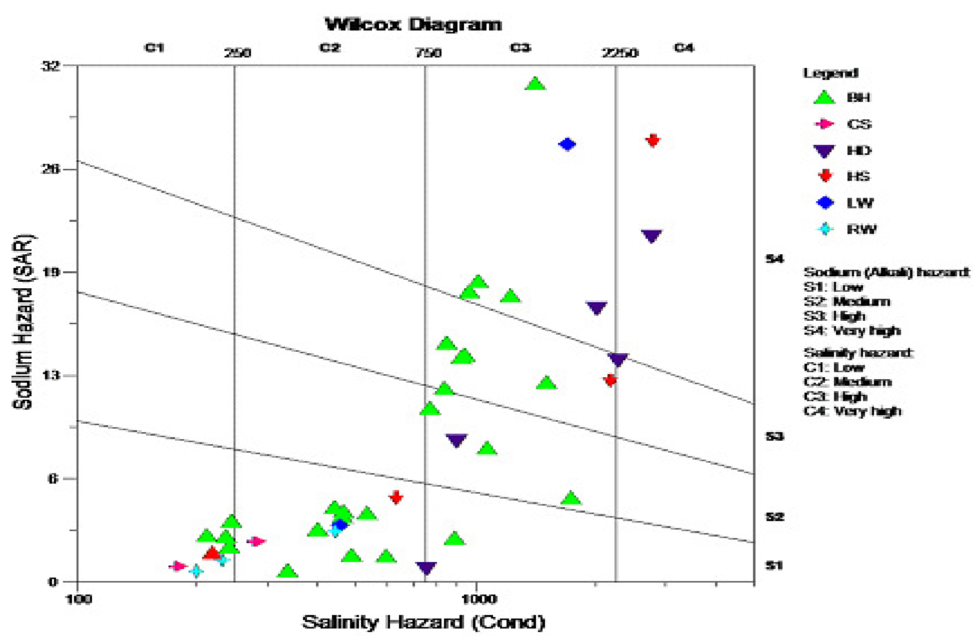


Figure4.37: Wilcox Diagram for All Samples

Table4.19. Water quality of waste water from share Ethiopia Company

S/N	PH	EC	TDS	Na	K	Ca	Mg	Cl	SO4	F	NO3	HCO3	TH	Alkalinity
ww	7.8	1409	915	335	48	19	7.75	27.3	126.5	3.9	126.3	658.4	79.8	539

From Table 4.19, the waste water is not treated because the nitrate and sulphate concentration is high that shows the water is not pure. The effluent also has high TDS than the Ziway lake .This untreated waste water has impact on the water quality of Lake Ziway. Lake Ziway near to the effluent has high nitrate concentration, than away from the effluent.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The ground water in the area is characterized by high alkalinity and high sodium content. The increase in alkalinity is enables to increase in the PH. Most ground water also has TDS value greater than 1000 mg/l. From the ground water the hot springs have high TDS. Unlike the ground water the rivers have low TDS which is less than 300 Mg /l except Horakelo River. But the lakes except Ziway have high TDS value. The TDS are increasing towards Lake Shala. So salinity of the ground water is increasing towards the ground water flow direction.

The water types of the ground water of the area are almost sodium bicarbonate. This is because the dominant cation is sodium and the dominant anion is bi-carbonate. But some boreholes around Meki show Calcium sodium bicarbonate like Meki River which indicates surface water ground water interaction. Rivers shows a different water type from the ground water .This is due to high water rock interaction occur in the ground water.

There is annual variation in the chemistry of the surface water. The salinity of the surface water specially the lakes like Shala and Abijata is increasing .The reason that increasing the salinity of lake Abijata is the abstraction of the lake for soda manufacturing and decreasing of water flow to the lake through Bulbula river .The chemistry of the surface water also show change as the season change . The surface water shows high TDS and EC during the dry seasons.

The major drinking water quality problems in the study area are high TDS, Na and fluoride concentrations. Especially above 50% of the ground water exceeds the WHO limits (1.5 mg/l) in fluoride amount. The main causes of high fluoride concentration are the addition of fluoride by active volcano, the higher rock water rock interaction and the low calcium concentration. The Rivers have low TDS and F than the ground water and the lakes. Except lake Ziway the others lakes cannot uses for drinking water.

When we considered the water quality for agriculture purpose the rivers except Horakelo are suitable for irrigation. The only lake that is used for irrigation purpose is Lake Ziway.

The ground water in Keter and Meki area has high water quality for irrigation. Some Ground water in ziway area has water quality problems.

The source of water quality problems are anthropogenic activities and agricultural activities and natural (Geological) condition.

5.2 Recommendation

In the towns and villages near to perennial rivers and Ziway Lake, and exploitation of the water resources is very recommendable since they have relatively good chemical qualities and great water potentials for different purposes.

The area is   high agricultural and industrial activities which are potential pollutant of the ground water and surface water. So, in order to protect water from pollution give awareness for the local people and the organizations which are uses chemical for agriculture.

Treating the waste that floriculture factory dispose the waste directly in to the lake Ziway and use these treated water for different purpose.

Use different defluoridation techniques to minimize the fluoride concentration in the water and uses water with high fluoride concentration for washing purpose

Drilling new wells that have high quality by investigating detailed hydrogeochemical investigations in the study area.

Impact of agrochemicals in Lake Ziway and ground water around Ziway and Meki area should be investigate in order to examine the impact of floriculture and agricultural activities on the water quality.

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Annexes

Annex 1::Water type and SAR value of the samples

Sample number (Sample type)	SAR value	Water type	Sample number (Sample type)	SAR value	Water type
RV 1 (Bulbula)	3.09	Na-Ca-CO3	Borehole 1	2.14	Na-Ca-HCO3
RV2 (Kersa ellala)	0.26	Ca-Mg-HCO3-SO4	Borehole 2	3.74	Na-HCo3

RV3 (Gedemso)	0.26	Ca-Mg-HCO3	Borehole 3	13.87	Na-HCO3
RV4 (Horakelo)	154	Na-CO3-Cl	Borehole 4	14.04	Na-HCO3
RV5 (Meki)	0.60	Ca-Na-HCO3	Borehole 5	17.97	Na-HCO3
RV6 (Keter)	1.33	Na-Ca-HCO3	Borehole 6	17.70	Na-HCO3
Lake 1(Ziway)	3.46	Na-HCO3	Borehole 7	12.36	Na-HCO3
Lake 2(Shala)	618	Na-CO3-Cl-HCO3	Borehole 8	4.60	Na-HCO3
Lake 3(Abijata)	1628	Na-CO3-Cl	Borehole9	4.0	Na-HCO3
Lake 4(Langano)	27	Na-HCO3-Cl	Borehole 10	3.20	Na-Ca-HCO3-SO4
Hot spring 1	427	Na-HCO3-Cl	Borehole 11	14.77	Na-HCO3
Hot spring 2	12.45	Na-HCO3	Borehole 12	8.72	Na-HCO3
Hot spring 3	172	Na-HCO3-Cl	Borhole13	10.73	Na-HCO3
Hot spring 4	53.26	Na-HCO3-CL	Borehole 14	2.83	Na-HCO3-NO3
Hot spring 5	27.33	Na-HCO3	Borehole 15	11.97	Na-HCO3
Hot spring 6	5.19	Na-HCO3	Borehole 16	0.65	Ca-HCO3
Hot spring 7	59.43	Na-HCO3	Borehole 17	2.69	Na-Ca-HCO3
Cold spring 1	12.01	Na-HCO3	Borehole 18	1.57	Na-Ca-Mg-HCo3
Cold spring 2	0.92	Ca-Na-HCO3	Borehole 19	30.87	Na-HCO3
Cold spring 3	2.45	Na-Ca-HCO3	Borehole 20	5.21	Na-Ca-HCO3-Cl
Hand dug 1	13.76	Na-HCO3-Cl	Borehole 21	1.63	Ca-Na-HCO3
Hand dug 2	8.79	Na-HCO3	Borehole 22	1.76	Na-Ca-HCO3
Hand dug 3	58.31	Na-HCO3	Borehole 23	18.59	Na-HCO3
Hand dug 4	21.47	Na-HCO3	Borehole 24	4.21	Na-Ca-HCO3
Hand dug 5	17.04	Ca-Na-HCO3	Borehole 25	4.34	Na-Ca-HCO3-SO4
Hand dug 6	2.43	Na-HCO3	Borehole 26	1.76	Na-Ca-HCO3
Hand dug 7	2.72	Na-K-CO3	Borehole 27	2.79	Na-HCO3

Annex 2: Physico- chemical analysis results

C/N	sample ID	X – coordinate	y-coordinate	PH	EC	TDS	Na	K	Mg	Ca	Cl	SO4	HCO3	NO3	F	CO3
1	RW1	448634	879556	*6.89*	444.5	280	66.5	12.85	7.68	22.4	12.74	12.355	241.56	5.085	0.925	0
2	RW2	461142	806893	*5.7*	68	49	3.2	2.9	3.36	6.4	0.91	9.98	29.28	6.79	0.59	0
3	RW3	471742	827814	*5.7*	59	41	3.3	3	2.4	8	1.82	7.7	29.28	6.52	0.8	0
4	RW4	462918	849048	*9.08*	5630	3680	1420	48	1.44	4	587.92	191.9	732	1.48	19.47	720
5	RW5	480599	900940	*6.64*	200	130	13	5.1	5.76	26.4	3.64	8.74	122	1.35	0.89	0
6	RW6	502024	887711	*7.05*	232	152	23	5.4	4.56	15.2	0.91	1.81	120.29	0.62	0.75	0
7	LW	459439	826337	*9.65*	24450	16,590	6950	207	0.96	8	3309.1	24.75	3855.2	0.72	167.36	0.75
8	LW	458825	832793	*9.67*	39500	27840	11800	465	0.96	2.4	3727.7	160.08	5612	0.36	282.05	8640
9	LW	472751	830566	*8.5*	1500	920	340	23	2.4	8	142.9	20.9	424.5	4.01	8.53	91.2
10	LW	471026	873831	*7.08*	455	289	73.5	13.1	10	17.6	13.5	7.2	262.1	2.75	1.485	0
11	HS	459439	826337	*8.66*	9500	6180	2400	25	0.48	1.6	1407	21.09	2562	0.55	20	360
12	HS			*7.6*	2160	1404	240	25	8	15	31	40	704	0	7	0
13	HS	458976	827744	*8.9*	2750	1600	593	18	0	0.9	279	3.3	988	0	19.6	0
14	HS	459969	826417	*8.2*	1780	1141	346	26	0	3.2	196	0	561	0	8.4	0
15	HS			*8.2*	2775	1804	400	38	5	8	95	31	988	0	5	0
16	HS	479160	847093	*7.3*	630	499	105	11	5.5	22	27	32.6	293	0.3	1.9	0

17	HS	474961	852428	*7.29*	2316	3560	860	67	4.56	8.36	474.16	38.78	1409.1	0.51	32.71	0
18	CS	480402	900580	*7.9*		934	200	15	8.5	7	18	2.5	473	0	3.2	12.2
19	CS	471664	827524	*6.6*	180	137	17	5	2.1	22.7	5	4.8	79	24	0.7	0
20	CS	485555	872111	*7.55*	283.58	190	42	6.3	2.7	17.8	5.8	1.05	176.8	10.7	1.9	0
21	BH	463869	818147	*7.43*	242	160	38	3.8	4.8	16	5.46	0.19	153.72	1.37	1.06	0
23	BH	461112	921101	*7.58*	246	164	50	2.9	3.36	8	5.46	0.19	146.4	4.6	1.06	0
24	BH	449265	870613	*7.94*	923	580	220	11	6.72	8	14.56	6.08	561.2	1.56	3.33	0
25	BH	467538	888146	*7.79*	944	560	198	12.3	4.56	7.6	14.56	8	561.2	3.28	1.39	0
26	BH	461779	887647	*7.77*	966	580	220	11.8	2.28	7.6	26.39	42.08	517.28	0.47	1.61	0
27	BH	469795	886242	*8.09*	1229	700	250	12.6	4.56	7.6	37.31	2	683.2	1.78	1.16	0
28	BH	483932	895266	*7.13*	1514	840	300	20	10.94	26.6	14.56	38.65	829.6	0.22	1.38	0
29	BH	473265	906931	*7.25*	446	270	86	5.6	5.02	18.24	3.64	0.19	290.36	0.16	1.05	0
30	BH	479292	905765	*7.47*	464	280	80	5.4	6.84	19	5.46	4.66	280.6	0.18	0.8	0
31	BH	492763	900233	*7.38*	402.98	270	60	9.9	4.86	18.7	7.8	63.29	166.5	11.5	2.2	0
32	BH	477064	899798	*7.67*	852	526	200	8.5	7.6	1.37	10.01	0.95	581.57	0.267	1.98	0
33	BH	479438	900702	*7.87*	1073	616	200	17.5	23.56	5.45	39.13	30.559	589.26	0.3791	0.8471	0
34	BH	466200	903424	*8.23*	770.14	516	172	15	9.88	3.192	19.112	49.885	448.35	0.3568	1.5	0
35	BH	461835	818752	*6.14*	213	140	40	4.5	4.56	7.6	9.1	20.16	64.05	41.26	0.67	0
36	BH	465703	870416	*8.1*	840	876	180	67	5.7	7.8	9	4	598	0.4	4.2	0
37	BH	474863	831173	*7.6*	340	323	18	6	7.7	45.7	2	0	244	0.5	0.4	0
38	BH	463026	881252	*8.51*	1354	900	350	12.9	2.04	5.04	48.25	59.9	614.9	4.4	10.56	57.6
39	BH			*8.9*	9710	6650	2900	50	2.7	6.2	966.1	133	3891	31	158	1454.9
40	BH	471682	892227	*8.4*	600		54.4	13.2	27.2	46.3	22	nil	354	3.4	0.9	24

41	BH			*8.75*	1413	918	334	9.3	3.2	3.6	25.2	48.1	679	19	21	596.434
42	BH			*7.4*	1741	1132	190	10	6	91	119	88	561	0	1.5	0
43	BH	480351	901817	*7.8*	490	489	55	2	11.2	68	4	5.8	342	0.1	0.9	0
44	BH	477951	833606	*8.3*	210	188	31	5	0.8	7.3	1	1	140	0.2	1.2	0
45	BH	466804	876055	*8.3*	1020	1013	232	18	3.1	6.7	12	2	738	1.3	2.1	0
46	BH	469448	901986	*8.01*	537.31	360	94	10.3	5.9	28	2.9	1.53	348.3	7	3.3	0
47	BH	492689	900276	*7.6*	470	367	81	8	2.4	22.5	4	63.5	183	6.4	2.4	0
48	BH	469929	827729	*6.27*	238	150	40.5	8.4	3.36	10.4	8.19	8.08	119.56	24.72	0.74	0
49	HD	469295	882451	*7.4*	2290	1480	480	37.5	27.84	46.4	287.59	52.92	902.8	3.9	6.47	0
50	HD	469764	885793	*7.66*	900	1400	282	17	24	38.4	19.11	0.76	915	2.09	3.93	0
51	HD	465779	881853	*8.67*	2435.82	1632	600	19.5	2.2	4.4	131.9	138	1268.9	7.5	3.96	57.6
52	HD			*8*	2778	1806	456	20	8	21	129	74	996	0	2.1	0
53	HD	469643	885338	*7.65*	2020	1317	450	47.5	16.87	25.08	152.9	120..79	999.18	5.22	4.03	0
54	HD			*7.4*	758	493	28	2	3	69	8	2	300	0	0.7	0
55	HD	465424	810049	*8*	124	81	46	19.5	6.8	16	6	0.5	244	0	0.9	0
56	HD	465705	820049	*8.1*	175	114	27.6	15.6	2.3	4	2.1	1.1	109	0	1.6	0

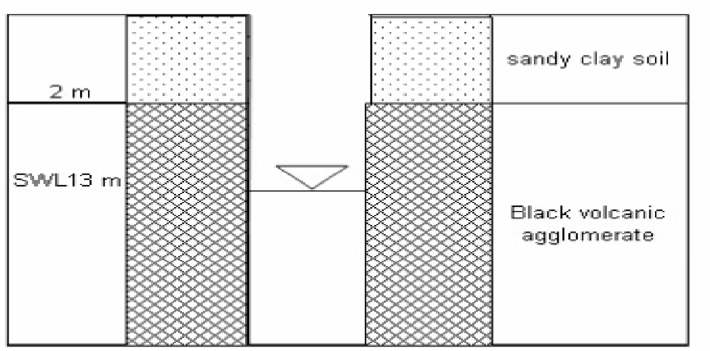
Note that RW-river water , LW- Lake water , HS-Hot spring, CS-Cold spring , BH- Borhole and HD- hand dug , and C/N 1- Bulbola river, 2- kersaellala, 3 -Gedemso , 4- Horakello 3 -Gedemso , 4- Horakello, 5 –Meki and 6 Keter river . From the lake C/N 8-Shala , 9- Abijata , 10- Langano and 11- Ziway .

Annex 3: Mean annual rainfall data

Station	Month											
	Jan	Feb.	mar	April	may	June	July	August	Sept	Oct	Nov	Dec
Adami Tulu (2000-2009)	12.38	11.0	56.7	90.55	93.58	88.8	189	178.4	126.8	27.8	3.54	13
Arsi Negela (2000-2009)	19.07	16.7	80.21	115.1	104.8	126.9	173	149.7	158.5	38.7	10.1	11
Bulbula (2000-2009)	9.68	5.59	38.75	81.06	44.92	89	103	113.2	66.91	25.49	15.63	9.8
Langano(2000-2009)	18.76	8.86	37.58	75.06	87.81	93.27	139	145.9	107.9	59.37	31.79	8.6
Meki (2000-2009	11.07	22.2	81.78	73.16	47.66	59.79	150	142.1	84.03	8.22	10.69	10.9

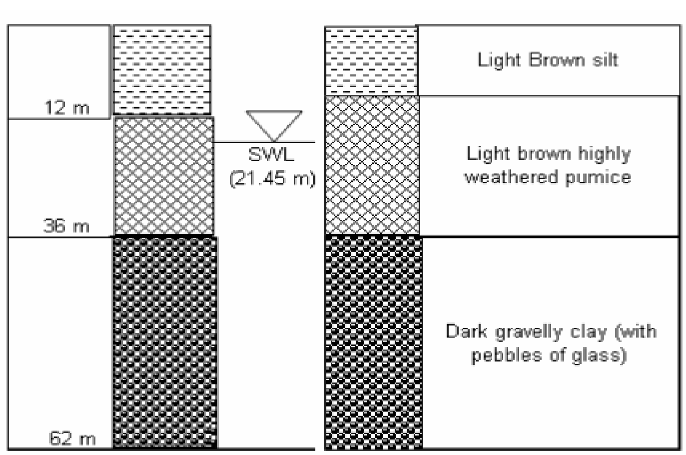
Annex 4: well log -lithology for Gerbi farm well (Near to lake Ziway)

Depth Lithology well Lithology Formation name



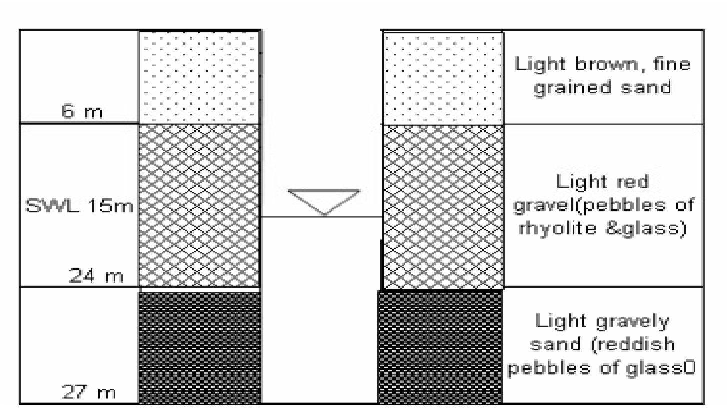
Annex 5 : well log –lithology for Bulbula well (In Bulbula town)

Depth Lithology Well Lithology Formation name

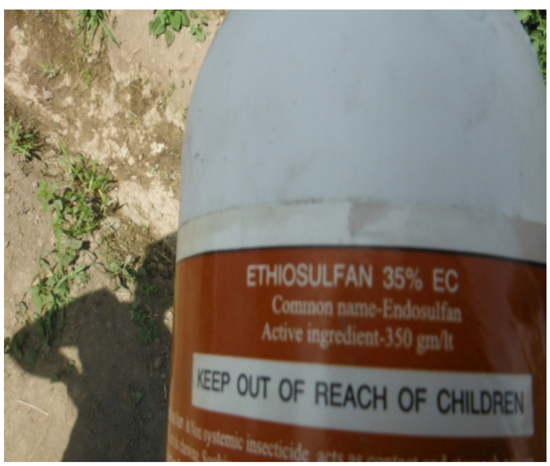


Annex 6 : well log- lithology for Doka horakelo well (near lake Abijata)

Depth Lithology Well Lithology Formation name



Annex 6: plates



A-Chemicals that local farmers use B-In-situ measurement of sample

C- Bulbula River that Human and animal use together