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ADDIS ABABA UNIVERSITY SCHOOL OF EARTH SCIENCE

Comparative Evaluation of Shallow Groundwater Dynamics of Becho and Koka Plains, Upper Awash Basin, Central Ethiopia

Thesis Submitted to School of Graduate Studies of Addis Ababa University in
Partial Fulfillment for Degree of Masters of Science in Hydrogeology



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Jun, 22, 2018

Addis Ababa University School of Graduate Studies

This is to certify that the thesis prepared by Jebena Tafesse, entitled: Comparative Evaluation of Shallow Groundwater Dynamics of Becho and Koka plains, Upper Awash Basin, Central Ethiopia submitted in partial fulfillment of the requirements for the Degree of Master of Science in Hydrogeology complies with the regulations of the Addis Ababa University and meets the accepted standards with respect to originality and quality.

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By my signature below, I declare and confirm that this thesis is my own work. I have followed all ethical and technical principles of research in the preparation, data collection, data analysis and compilation of this thesis. Any scholarly article that is included in the thesis has been given acknowledgment through reference.

Jebena Tafesse

Signature: _____

Date: May, 2018

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Abstract

The target area (Koka and Becho plains) are situated in the upper reach of the Awash River basin, geographically, Koka plain located between $38.75^{\circ} - 39.12^{\circ}\text{E}$ and $8.38^{\circ} - 8.76^{\circ}\text{N}$ and Becho plain is located between $38.19^{\circ} - 38.61^{\circ}\text{E}$ and $8.54^{\circ} - 9^{\circ}00'\text{N}$. The main objective of this work is evaluating shallow ground water dynamics of Becho and Koka plains comparatively from water level fluctuation of monitoring wells and recharge estimation of the two plains by Water balance method. The shallow groundwater flow direction is identified from water table contour map and cross sectional map of well lithology in the target area. The water table contour map indicates that the groundwater flow direction of Becho plain is toward the Awash River from the recharge area. However, in Koka plain the groundwater flows toward Koka reservoir by the effect of topography and geological structures. The water balance method give recharge of the Becho plain is 235.029mm/yr., this means 23.38% of annual precipitation was recharged to groundwater and the recharge of Koka area is 22.2627mm/yrs., and i.e. only 2.65% of the annual precipitation is recharged to groundwater. The selected River gaging stations for baseflow separation are; Awash at Melka Kunture, Awash at Bello, Mojo at Mojo village and Mojo at Koka dam. Volume of baseflow, total volume and baseflow index were calculated from baseflow separation of the selected stations. The baseflow index of Awash at Melka Kunture, Awash at Bello, Mojo at Mojo village and Mojo at Koka dam are 0.65, 0.787, 0.18 and 0.343 respectively.

The index of base flow Calculated at Awash Bello and Awash at Melka Kunture was much greater than the estimated BFI at Mojo village and Koka Dam; this implies that the Awash river catchment has more stable flow regime and able to sustain river flow during extensive dry period. Piezometers were used to monitor groundwater from Grofutures project. Based on their distance from the surface water and effect of irrigation, monitoring wells of the study area are grouped into four; (i) piezometers located far from a surface watercourse and outside any irrigated area, (ii) piezometers close to a surface watercourse but outside any irrigated area, (iii) piezometers located far from any surface watercourse but located in irrigated areas and finally, (iv) piezometers close to a surface watercourse and located in irrigated areas. The piezometer data indicates that the temperature of the shallow groundwater is more or less the same with that of surface temperature and has an inverse relationship with water level.

Keywords: Becho, Koka, Upper Awash, Groundwater dynamics, Monitoring well

Acronyms and Abbreviations

EVDSA	Ethiopian Valleys Development Studies Authority
FAO	Food and Agriculture Organization
MER	Main Ethiopian Rift
UNEP	United Nation Environmental Programme.
Kg	Kilogram
SWL	Static Water Level
WD	Well Depth
MoA	Ministry of Agricultural
WWDSE	Water Works Design and Supervision Enterprise
ITCZ	Inter Tropical Convergence Zone
EIGS	Ethiopian institute of geological survey
BFI	Baseflow index
Qb	Groundwater flow
AET	Actual Evapotranspiration
Qt	Total flow
Vb	Volume of ground water
VT	Total volume
BFs	Baseflow separation.

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CHAPTER ONE

1. INTRODUCTION

1.1. Background

Groundwater is a very large significant part of the natural water resources. The occurrence, dynamics, origin, movement and chemical composition of groundwater is dependent on geology, lithology, geomorphology, landforms, drainage density, rainfall, geological structures or lineaments, slope, land use, land cover and soil cover of groundwater system. In the whole world, the number of population increase rapidly and the requirement for water supplies are significantly become greater. Shallow groundwater is significant sources of water for agricultural production especially during drought periods. Groundwater based irrigation is extremely rises in different parts of the country particularly in the upper Awash river basin. The particular study was focused on evaluation water dynamics of Becho and Koka areas, where farmer driven shallow groundwater utilization is increasing rapidly. The amount of land irrigated using shallow ground water and the corresponding number of shallow groundwater wells are increasing with time in the upper Awash River.

The Upper Awash river basin is located at the transient of the Main Ethiopian Rift (MER) and the central highlands of Ethiopia (**Andarge Yitbarek et al., 2012**). Becho and Koka areas are found in the upper part of Awash River basin situated in Oromia regional state, Central Ethiopia. Becho woreda is located in south western Shoa zone of Oromia Regional state, and its major town is Tulu Bolo. The Koka plain is located in the upper reaches of the Awash River basin approximately 75 km southeast of Addis Ababa. Awash River basin is actively and potentially utilizing for various levels of irrigation developments; its shallow groundwater potential, geography and its accessible condition makes the study area (Becho and Koka) more suitable for shallow groundwater based irrigation and utilization of ground water resources for different purposes than others. These active irrigation developments are mainly occurring in the upper Awash River basin where population density is high and crop productivity is good.

The Upper Awash basin is well-known by one of Ethiopia's aquifers providing water supply for different cities including Addis Ababa and small towns like Debrezeit, Modjo, Koka, Tulu bolo, Holeta, Sebeta and other smaller towns found in the area. Therefore, groundwater is extracted from aquifers and distributed through pumping wells and presented to the community for uses in domestic, agricultural, and industrial spheres. Ground water has been used as major water supply for agricultural, industrial, and domestic needs in both plains (Becho and Koka) because of the scarcity of surface water. The natural groundwater flow system has been turn on the other way round very much in case over-withdrawal or exploitation of groundwater, consequently in order to do more advanced and make effective use of groundwater resources fairly and prepare systematically water managing policies.

Groundwater dynamics reflect a complex natural process that is influenced by various factors in an environment (**Chen et al., 1988**). The dynamics of groundwater depend greatly on climate, geology, and topography, which are regarded as the three main factors that control subsurface water flow in the hydrologic landscape (**UNEP, 1996; Sophocleous, 2002**). In plain areas with shallow ground-water under a semi-arid climate, precipitation infiltration and evapotranspiration in the vertical direction are the major recharge and discharge processes of the water cycle.

The dynamics of the groundwater level and salinity interact intimately with each other during the recharge and discharge processes. Groundwater affects the soil formation processes and moisture and solute transport dynamics, and is one of the important factors ameliorating soil conditions (Kats 1976).

Groundwater dynamics and storage influence surface soil moisture and surface water flow. As there has been recent evidence that shallow soil moisture has a pronounced effect on atmospheric processes and weather prediction [**Chow et al., 2006; Holt et al., 2006; Patton et al., 2005**].

To utilize groundwater for, domestic and agricultural purpose; the occurrence, quantity Sustainability and quality are among the major factors.

Adaa and Becho groundwater resource evaluation project is designed for potential use of groundwater for irrigation. Three aquifer systems have been identified in the study area, namely alluvial and lacustrine deposits and the basaltic aquifer (**Semu Moges, 2012**)

1.2. Previous study

Various Studies on geology, hydrogeology and geomorphology have been conducted in the Upper awash basin, MER and the surroundings. Related articles, maps and reports in the area and the surrounding region have been reviewed. A number of studies have been conducted in relation to geological and hydrogeology of the upper awash and MER including the study area.

Tilahun. A (2008) conducted Hydrochemical characterization of aquifer system in upper Awash and adjacent plateau using geochemical modeling and Isotope hydrology. The research work addressed schematic conceptual model for special geochemical variations, evaluation and recharge area zonation for shallow and deep aquifer system along four groundwater flow path in geomorphic pattern (Plateau, transitional and rift).

The hydrogeological report of the Akaki-Beseka Sheet (NC 37-14) concluded that the geological, geomorphological, hydrogeological and hydrochemical data shows that the major groundwater flows are towards southeast (to the MER) and southwest.

Most water supply wells, especially shallow groundwater wells, have not had time drawdown tests performed on them. Therefore, to left the hydraulic parameter of the shallow aquifers especially for the hand dug wells (Robert, 2001).

The temperature of shallow ground water is approximately equal to the mean annual air temperature of the locale and is relatively constant year-round, typically varying by less than 2°C (Driscoll, 1986)

Groundwater from the upper and middle awash basin shows a clear spatial Hydrochemical distribution (Seifu Kebede, 2013)

WWDSE (2007-2008) has been conducted a study on the title of evaluation of water resources of the Ada'a and Becho plains groundwater basin for irrigation. This is comprehensive study and supported by geophysical investigation and deep well drilling. The work classified the main aquifers of the area in to upper and lower basalt aquifers and alluvial and lacustrine aquifers.

Groundwater depth has significant impact on the soil water budget and on the habitat condition of certain plants (Blom et al., 1996).

1.3. Problem of statement

For sustainable ground water management, shallow groundwater flow and groundwater recharge need an accurate and reliable evaluation. In fact Ethiopia has large enough quantity of fresh groundwater resources. However, detailed investigation on Groundwater (shallow Deep ground water) dynamics and groundwater management has not been done so far, except in MER (main Ethiopian rift valley) and in some interesting area for academic thesis. Groundwater monitoring has been given a very little consideration in the country. In the target area, groundwater resources are exploited traditionally without taking in consideration its potential and this may cause an adverse effect on this precious resources. Groundwater dynamics is the reflection of a complex process of nature influenced by various influencing factors in certain environments (Chen et al., 1988).

The natural groundwater flow system has been changed greatly due to over-exploitation of groundwater. In order to develop and utilize groundwater resources reasonably and formulate water managing and protecting policies for government, it is important to evaluate shallow groundwater dynamics.

1.4. Objective

1.4.1. General objective

The main objective of this work is to evaluate shallow groundwater dynamics of Becho and Koka plains comparatively from water level fluctuation of monitoring well and recharge estimation of the two plains.

1.4.2 Specific objective

- ❖ Preparing groundwater table contour map to understand shallow groundwater flow dynamics
- ❖ Recharge estimation of the two plains (Becho& Koka).
- ❖ Evaluate the baseflow towards understanding the hydrodynamics.

1.5 Methodology

To meet the objectives of the study, the methodological approach is based on the monitoring shallow groundwater level, pressure ,temperature and shallow groundwater fluctuation to understand the shallow groundwater dynamics of the study area, in addition to this base flow separation method is conducted by using BFI +3 tool and the recharge is estimated by using water balance method.

The study comprised three stages; desk study (pre- field work), fieldwork, and post field work (data analysis and interpretation Coupled with report writing.)

The desk study includes: Literature search, literature review and collection of available secondary data from different government office and non-Governmental organization. The sources of data used comprise published and unpublished reports, both local and international.

The field study; available data are collected directly from the field. The required data will be; measurement of static water level, well inventory of site features, Monitoring shallow ground temperature, pressure and depth of water of the observation well by BaroTroll and Rugged Troll.

Post field work; the analysis and interpretation of data will be carried out by using different software. These soft wares are: ArcGIS 10.3, Global mapper 17, surfer 10, excel spreadsheet program.

1.5.1 Shallow groundwater monitoring of Becho and Koka plains.

The study area is known by their flat topography and very shallow groundwater in the upper Aquifer. The shallow groundwater is monitored in the target area by BaroTroll, Rugged Troll and dipper. The Rugged TROLL is insitu most economical option for measuring and logging water level, water pressure and temperature. This non-vented (absolute)water level logger is ideal for flood prone or high humidity environments, allowing you to periodically download data with rugged troll docking station. These monitoring wells are drilled very systematically in the target area to address the effect of irrigation return water, effect of river water and rainfall on shallow groundwater dynamics.

1.5.2 Techniques of recharge estimation

Groundwater recharge is a fundamental component in the water balance of any watershed. However, because it is nearly impossible to measure directly, numerous methods have been used to estimate recharge. Determination of the base flow component of the stream flow is necessary to understand hydrologic budget of surface and groundwater (Yu and Schwartz). A common recommendation in various literatures is that recharge should be estimated from multiple methods and results, but in reality, comparing the result may be difficult because of difference inherence in the methods. Choice of the methods should also be guided by the objectives of the study, available data and the

possibility to get supplementary data. However, estimates are normally subject to large errors (Roohul Khan et al., 2016)

1.5.2.1 Base flow separation method

1.5.2.1.1 Base flow separation theory

In some cases base flow has been used as approximation of recharge. Base flow is the groundwater contribution to stream flow. Base flow is the portion of the stream flow that is sustained between precipitation events, fed to stream channels by delayed (usually subsurface) pathways. Many hydrograph separation techniques have been applied for identification of the different flow components of the total flow. The components are thought to represent different flow paths in the catchment; each characterized by different flow has traditionally been separated into flow that originates from overland (direct), unsaturated (thoroughflow) and saturated (groundwater) flow. Base flow indices have performed satisfactorily as catchment descriptions in many low flow studies because even a rough estimate of storage properties greatly increases the performance of the estimation model (Tallaksen & van Lannen, 2004).

Base flow indices are generally highly correlated to the hydrological properties of soils and geology and other storage related descriptions like lake percentage. BFI+3 programs perform a separation of a base flow from the total stream flow and calculate the base flow index (BFI). The algorithm is based on the calculation procedures introduced by Institute of hydrology (1980). The input data are time series of daily stream flow.

The time series must be continuous and should not contain missing data. The input data are inserted in to the first two columns of the spreadsheet. The dates are entered in column A and stream flow values are in column B. There are no restrictions for the units of the stream flow – the calculated base flow values will have the same units as the input data and the BFIs are relative measures without unit.

BFI: this gives the BFI for the whole stream *flow* series, calculated as

$$\text{BFI} = \frac{\sum_i \mathbf{bi}}{\sum_i \mathbf{di}}$$
 Where **bi**: base flow values (entire season) that are parts of the selected season

and **di**: total stream values that are parts of the selected season

$$\text{Mean annual BFIs} = \frac{\sum_a \text{BFIs}_a}{n}$$
 BFIs_a , annual or seasonal BFI where a denotes year/season

and n is total number of years/seasons

For the base flow separation a number of methods were created. Sloto & Crouse (1996) was presented three main methods ;(1) Fixed interval method, (2) Sliding interval method and (3) Local minimum method.

1.5.1.1.1 Fixed interval method

The fixed-interval method assigns the lowest discharge in each interval (N) to all days in that interval starting with the first day of the period of record. The method can be visualized as moving a bar $2N^*$ days wide upward until the bar first intersects the hydrograph. The discharge at that point is assigned to all days in the interval. The bar is then moved $2N^*$ days horizontally, and the process is repeated. The assigned values are then connected to define the base-flow hydrograph (Sloto & Crouse, 1996).

1.5.1.1.2 Sliding interval method

The sliding-interval method finds the lowest discharge in one half the interval minus 1 day [$0.5(2N^*-1)$ days] before and after the day being considered and assigns it to that day. The method can be visualized as moving a bar $2N^*$ wide upward until it intersects the hydrograph. The discharge at that point is assigned to the median day in the interval. The bar then slides over to the next day, and the process is repeated (Sloto & Crouse, 1996).

1.5.1.1.3 Local minimum method

The local-minimum method checks each day to determine if it is the lowest discharge in one half the interval minus 1 day [$0.5(2N^*-1)$ days] before and after the day being considered. If it is, then it is a local minimum and is connected by straight lines to adjacent local minimums. The base-flow values for each day between local minimums are estimated by linear interpolations. The method can be visualized as connecting the lowest points on the hydrograph with straight lines (Sloto & Crouse, 1996).

1.5.2.2 Recharge Estimation using water balance method.

Estimating groundwater recharge is often the primary purpose of conducting a water balance. Recharge largely determines the rate at which ground water can be withdrawn from the wells. Water balance is a balance between the incoming water in the form of precipitation and the outflow of water in the form of evapotranspiration, groundwater recharge and runoff. In some cases there might be a change in storage (Soil moisture, Groundwater or water bodies).The general formula of water balance is given by;

$P+G_i=AET+R_o+G_o+I\pm\Delta S$, where “P” is precipitation, “G_i” is groundwater inflow, “AET” is actual evapotranspiration, “R_o” Runoff, “G_o” groundwater outflow, ”ΔS” change in storag

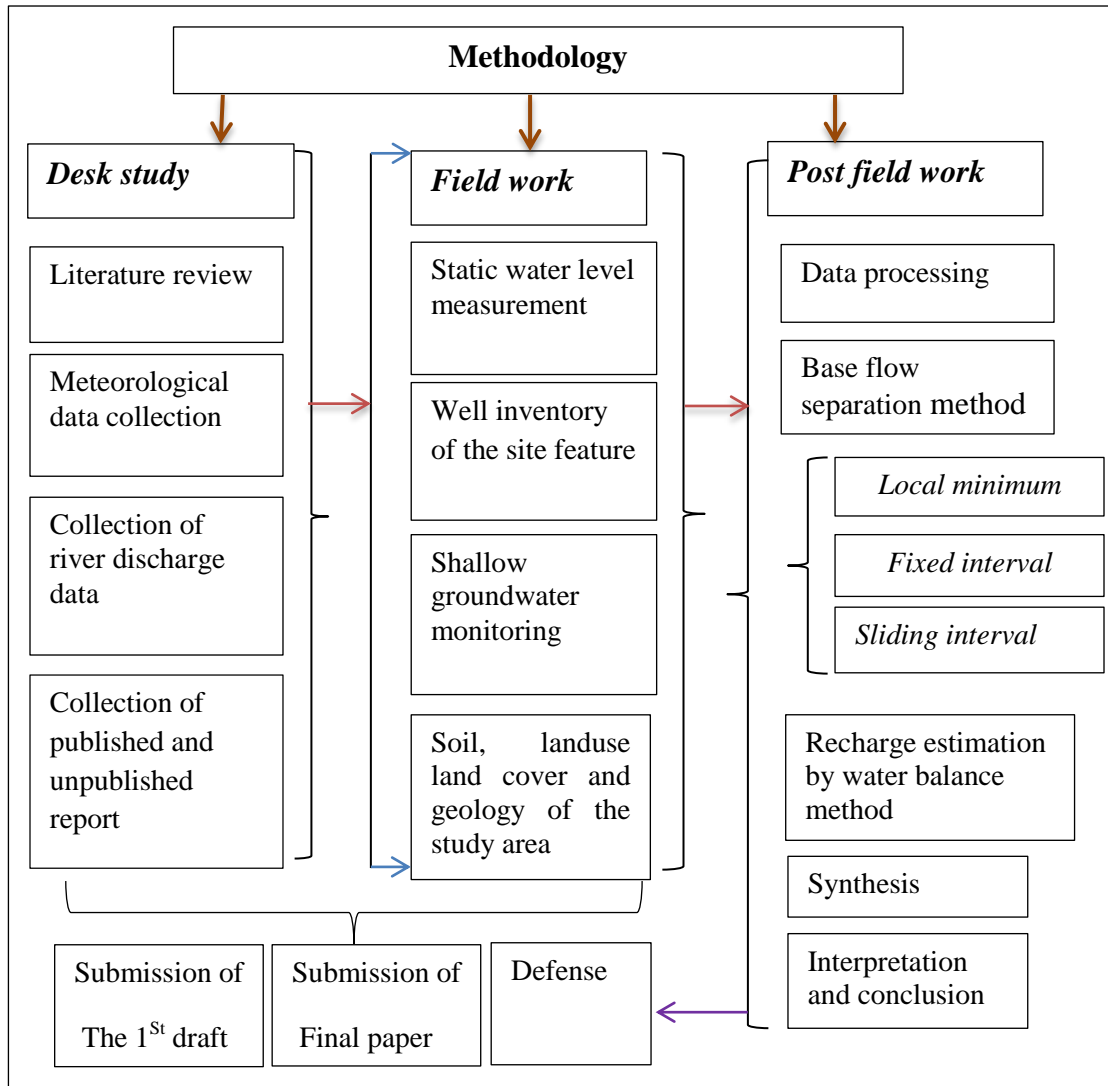


Figure 1.1: Flow diagram of the Approach/methodology

1.6 Material used

The materials used during field and post field to conduct this research are;

- ◆ 1:50,000 topographic map
- ◆ Deep meter to measure static water level
- ◆ Field laptop to down load recorded data from loggers
- ◆ Field cables
- ◆ Soft wares like, WIN_SITU5 to analyze seasonal water level fluctuation
- ◆ ARC GIS, strater 4, surfur10, global mapper, google earth
- ◆ Field camera to take photo of different features
- ◆ GPS and Compass

1.7 Overview of the thesis

This thesis is arranged in to five chapters starting with Background, previous study, statement of problem, objectives of the study, methodology and material used are discussed in an Introduction chapter (chapter1). The general overview of the study area is discussed in Chapter two which presents location, climate, physiography, drainage and land use and land cover of the study area. Chapter three covers regional geology, local geology. Chapter four presents hydrogeological characterization; which includes Recharge estimation, baseflow separation techniques, well inventories and piezometer data and finally, chapter five presents the conclusion and recommendation.

CHAPTER TWO

2 DESCRIPTION OF THE STUDY AREA

2.1 Location of the study area

Upper Awash River sub-catchment has an area of 11500km²(EVDSA, 1989) and is located between 8.2°and 9.3°N latitude and 38°and 39.3°E longitude. The target area (Koka and Becho plains) are situated in the upper reach of the Awash River Basin.

They are located in Central Ethiopia, in Oromia Regional State. Koka plain is crossed by Addis Ababa-Djibouti high way on 50km to 75km from Addis Ababa. The plain is bordered with Erer Mountain and Kesem river basin Water shed divide in the north, and Koka reservoir in the south. Geographically, koka plain located between 38.75⁰ – 39.12⁰E longitude and 8.38⁰ – 8.76⁰N latitude. Becho Plain is found at a distance range of 30 to 70 km from Addis Ababa along Addis Ababa-Jima road. The area is bordered in the north by the east-west trending rift escarpment (Ambo fault), in the east Wechecha Mountain and Melka Kunture horst, while in the south it is bordered by Guraghe highlands and in the west by Woliso highlands. Geographically becho plain is located between 38.19⁰ – 38.61⁰E and 8.54⁰ – 9⁰⁰'N. See (**Fig2. 1**). The total area of the study area (koka 1400km² and becho 1600km²) is approximately more than 3000 km². The area can be accessed through four-wheeled drive vehicle in two directions. The Becho area is located at south west of Addis Ababa and is reached by asphalt road from Addis Ababa through towns of Alem Gena, Sebeta, Tefki, Asgori and Tulu Bolo, while, Koka plain located at south east direction of Addis Ababa and is reached by via towns of Akaki Beseka, Dukem, Debrezeit, mojo and finally koka or by express way through towns of akaki Beseka, mojo finally koka. After that the study area is accessed through weathered gravel road and by local transport or by foot path.

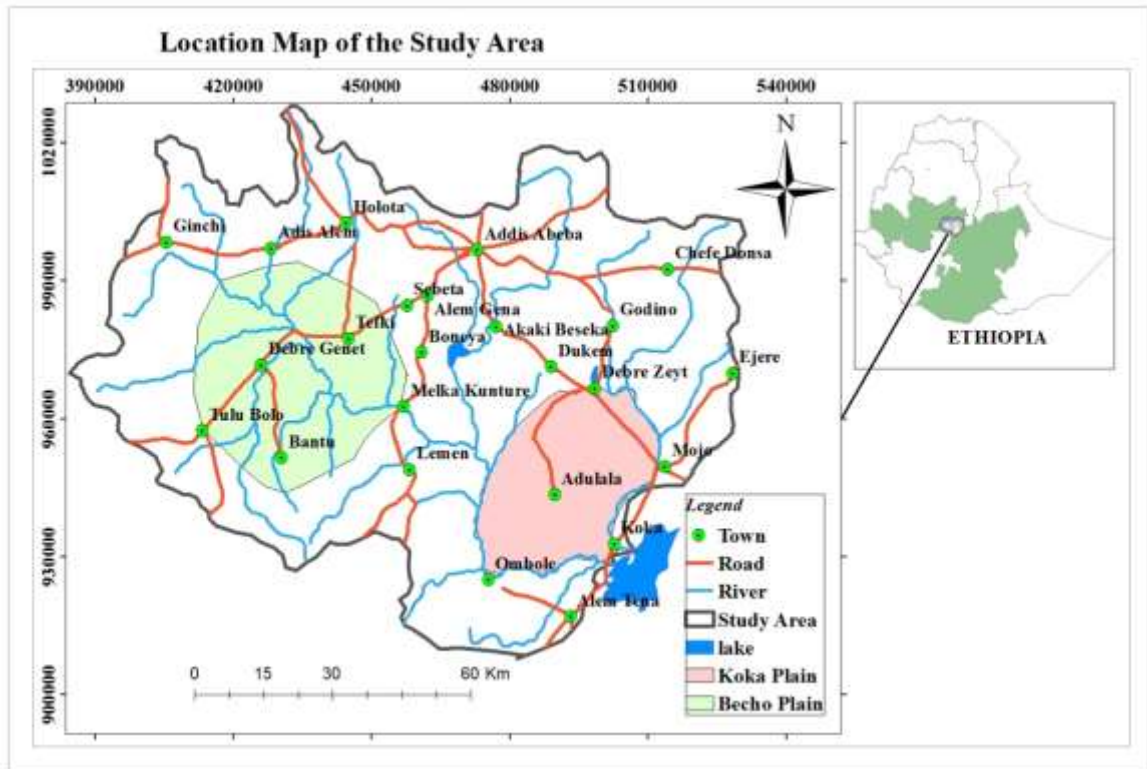


Figure 2.1: Location map of the study area

2.2 Topography and Drainage

2.2.1 Topography

The study area is located at the western margin of the main Ethiopian rift valley (MER) system and has three distinct geomorphologies; the plateau marginal area, the steep to gentle slope and the rift valley depression area. i) The plateau marginal area: is the area where the Awash River and its tributaries emerge and is supposed to be main recharge area for the groundwater and also is the western and North Western limit of the study area. ii) The steep to gentle slope is extending from the plateau to southeast of the area. iii) Rift valley depression area: including vicinity of towns like Modjo and koka and is extending to the North West and southeast of the area. See Fig.2.2

The study areas (becho and koka) are Flat Undulating Plains (characterized by flat low lying topographic surfaces superimposed on the low topographic basins and intervening ridges) and volcanic mountains and spatter cones (Wechecha, Furi, mt. Yerer and mt. Ziquala) land feature with gentle slopes, valleys and stream channels. Volcanic Mountains and Spatter Cones: this land form occurs near the western margin of Main Ethiopian Rift. It is characterized by low topographic basins and intervening ridges. The

rocks forming this geomorphic unit are basalts, rhyolitic and trachytic lava domes and welded to partially welded pyroclastic flows (Akaki Beseka geological report). The Becho plain has an average elevation of 2060 m and is surrounded by Wechecha Mountain in the east, the Guraghe highlands in the south and the Woliso highlands in the west (WWDSE, 2008). The Koka plain area is also characterized by a flat land having its boundary in the south eastern direction by Koka reservoir and by Awash River in the south direction with an average elevation of about 1590m a.s.l.

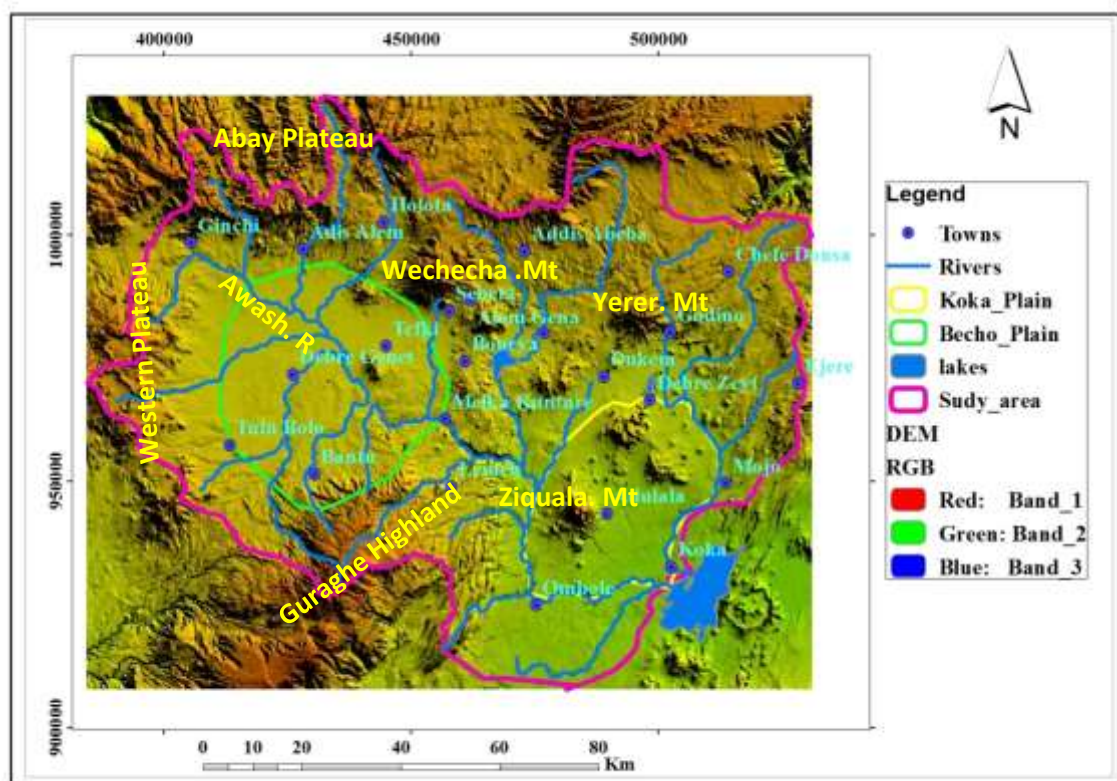


Figure 2.2: Physiographic map of the study Area

2.2.2 Drainage

The Awash River originates from the mountain range at an altitude of 3000m in the western most regions of the basin near Ginchi and the surrounding mountains and flow south east ward through becho plain and downstream of Teji bridge flow through the hilly mountainous area of Koka reservoir to koka plain. In Becho plain it forms an alluvial plain with an average altitude of 2,060m and form lacustrine deposit in koka plain along the low land of koka reservoir.

The Awash River and its several tributaries rise in the mountains that reach over 3300m.a.m.l. The Berga, Holeta, Kelina, Dilolo Dilu, Teji and Watira tributaries join the

Awash River in the Becho plain that flows towards Lake Koka in southeastern direction. The catchment of this upstream part of the upper Awash reach until the gauging station at Melka Kunture is 4541 km² (EVDSA, 1989).

Downstream of Melka Kunture the Akaki, Guracha and Dukem, Lemen and other smaller tributaries join the Awash River before it enters the plain surrounding Lake Koka. The Mojo River also flows into Lake Koka. This low-lying plain at the west shore of Lake Koka that is also surrounded by volcanic hills has a mean elevation of 1590 m (EVDSA, 1989).

The tributaries of Awash River also have a remarkably steep river bed slope in upper Awash River basin. This is one cause of the sedimentation in Becho plain (Nippon Koei, 1996).

Most of the areas in the Becho plain have drainage and seasonal flooding problems. Water from upland accumulates on flat lowlands, flood plains and enclosed bottom areas where slowly permeable soils are found. Soils with imperfect, poor to very poorly drainage sites require removal of excess water and proper drainage management system.

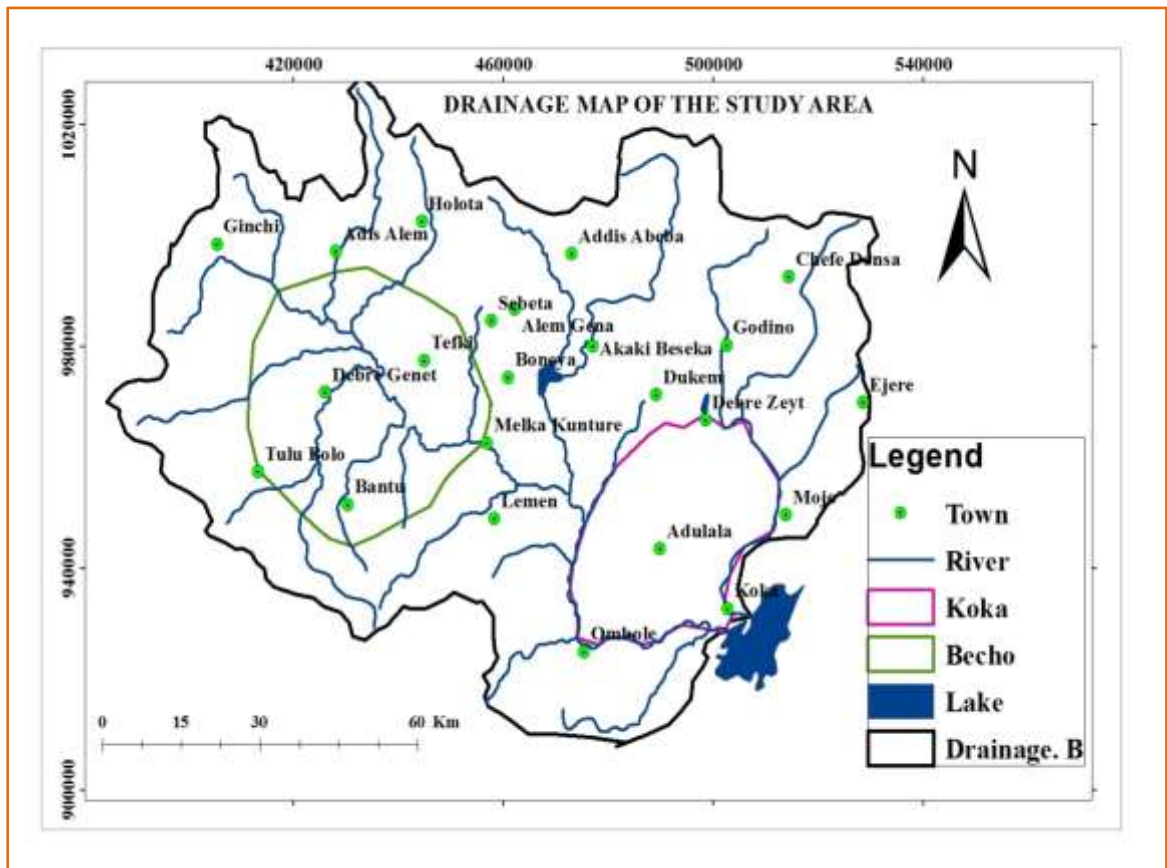


Figure 2.3: Drainage map of the study area.

2.3 Climate

The climatic condition of the Ethiopia is highly influenced by altitude, geomorphology, vegetation cover and other factors. The study area is characterized mainly by wet to semi-arid climatic condition. The climatic zoning of the area is done based on the Ethiopian climatic classification after Tesfaye Chernet (1993).

2.3.1 Rainfall

The seasonal rainfall distribution within the project area results from the annual migration of the ITCZ and lying in a tropical climate, classified as wet, humid region. The distribution of rainfall over the highland areas is modified by orographic effects and is significantly correlated with altitude. The main rainfall is experienced between June to September when moist winds from the Atlantic and Indian Oceans converge over the Ethiopian highlands (Gemechu, 1977). There are two seasons of rainfall in the specified study area. The first rainy season spans from late May to late September and the second from mid of March to mid of April. Between February and the end of April, the weather becomes more unsettled and a convergence of moist southeasterly air stream causes small rains. The study area is characterized by a major rainy season for 4 (Four) months, from June to September, about 73.6-75% of the annual rain falls is recorded in this season, followed by a relatively dry season for 4 (Four) months from late October to the end of January and the short rains season from February to the end of April. The mean annual rainfall of the koka plain is less than that of Becho plain, Koka plain is located in MER but becho plain is located at western margin of MER. The mean annual precipitation is computed to be 840.9517mm for Koka Area and 1050.145mm for the Becho Area. The average rainfall amount in December is 4.806272mm (the driest month) and 228.683mm in July (the wettest month). The key stations for Precipitation of koka area and becho areas are illustrated in table.1 and table.2 below.

Table 2.1: Mean monthly precipitation of koka area stations

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
Mojo	8	18	41	56	44	82	241	162	88	23	7	1	775
Hombole	6	34	54	56	45	86	208	180	70	27	8	4	783
D.zeit	10	20	51	56	42	100	222	209	99	28	6	6	852
Koka. D	14	24	54	57	61	71	241	266	115	29	11	7	953
Average	10	24	50	56	48	85	228	204	93	26	8	5	841

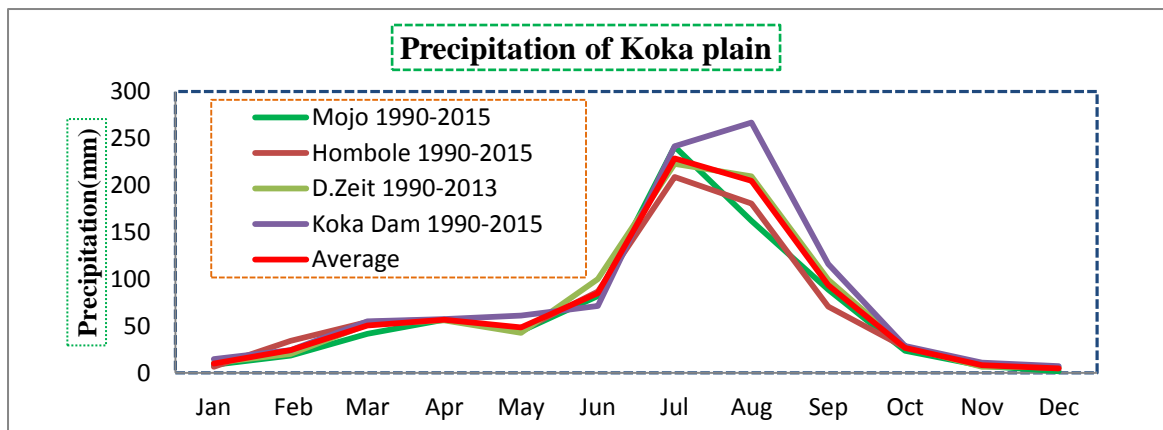


Figure 2.4: seasonal and spatial distribution of rainfall around koka stations

Table 2.2: mean monthly precipitation of Becho area station

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
Tulu Bolo	11	12	44	65	96	218	276	285	117	16	4	5	1150
Teji	12	26	52	67	74	138	217	215	100	22	8	5	939
Tefki	4	36	26	55	65	120	186	224	120	18	18	10	883
Bantu_liben	17	14	59	85	70	176	315	320	140	44	15	5	1263
Asgori	19	26	45	78	72	146	249	240	108	19	7	3	1015
Average	12	23	45	70	75	160	249	257	117	24	10	6	1050

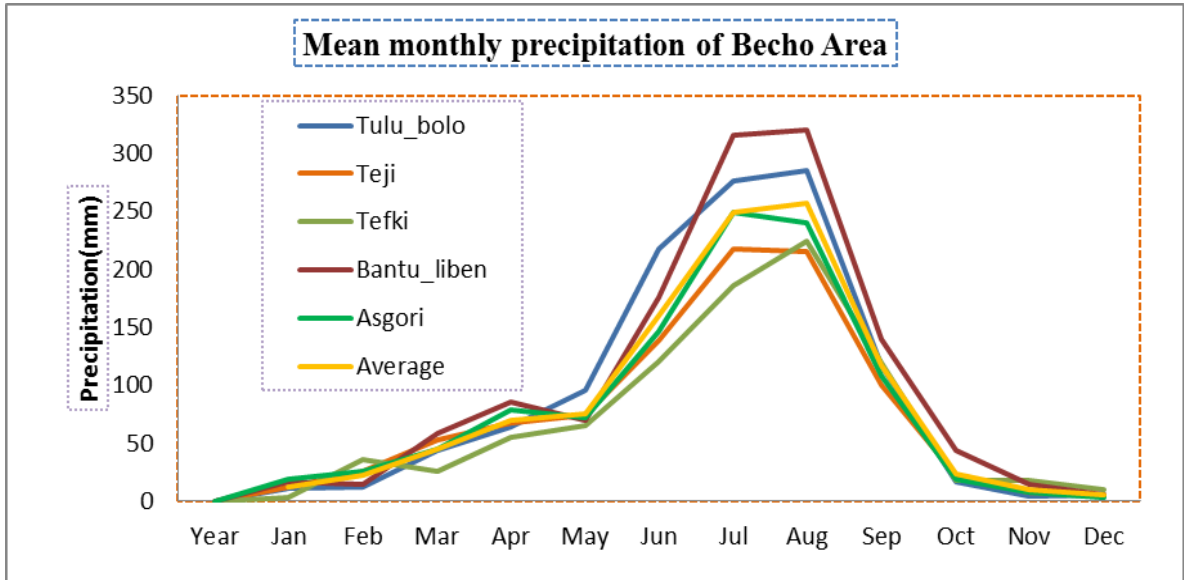


Figure 2.5: Seasonal and spatial rainfall distribution around Becho stations.

Table 2.3: Mean monthly precipitation of the study area

S.A	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Becho	13	23	45	70	75	160	249	257	117	24	10	6	1050
Koka	10	24	50	56	48	85	228	204	93	26	8	5	841

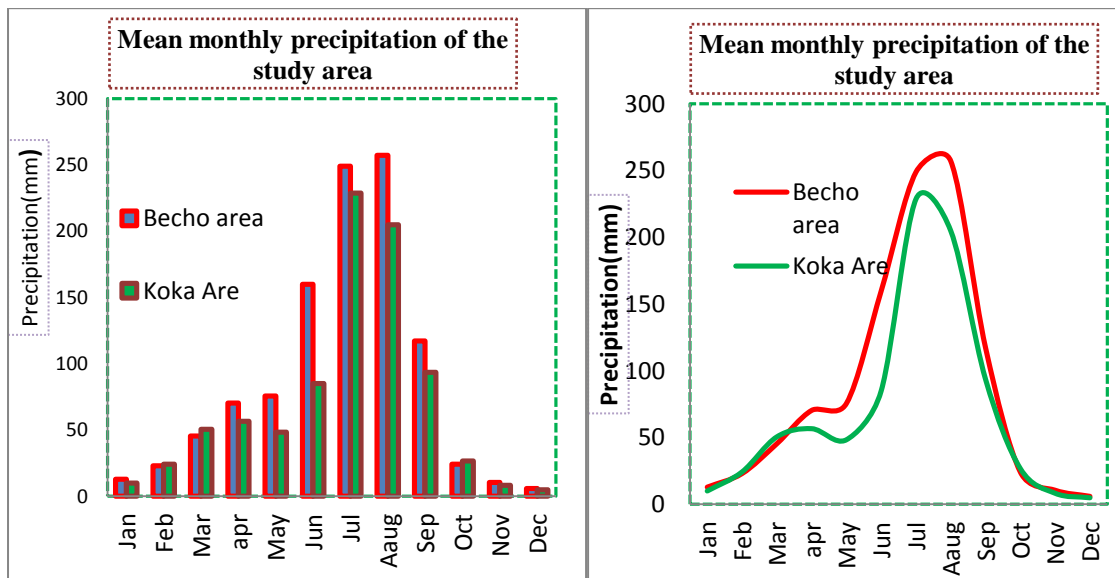


Figure 2.6: Mean monthly rainfall distribution of study area.

2.3.2 Temperature

The temperature, wind speed and relative humidity are variable with altitude and latitude (Tenalem Ayenew & Tamiru Alemayehu, 2001).

The mean temperature of the study area (Becho and Koka plains) is approximately 18 °C and 21 °C respectively according to temperature data collected from meteorological agency at different meteorological stations of the study area. The warmest months are from February to May while the coldest months are from October to December. During the coldest month specially in December temperature decreases to 5 °C in Becho plain And 9 °C in Koka plain, whereas during the warmest month temperature rises to 29 °C during March in Becho plain and 30 °C in May at Koka plain. The mean monthly temperature moderately varies within a year. The table 2.4 and 2.5 below give summary of the mean monthly temperature of the becho and koka area respectively.

Table 2.4: Mean monthly temperature of Koka area.

Temp	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Koka.D	21	22	23	23	24	23	22	22	23	21	21	20	22
D.zeit	18	19	20	21	21	20	19	19	19	18	17	17	19
Mojo	20	22	23	23	23	23	20	20	21	21	20	20	21
Koka	20	21	22	22	23	22	20	20	21	20	19	19	21

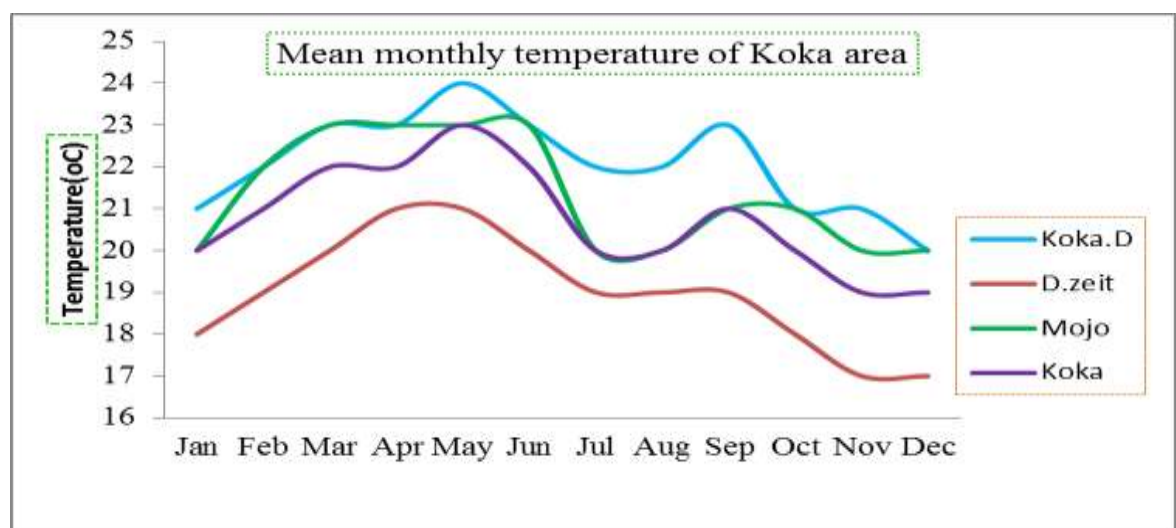


Figure 2.7: Graph of mean monthly temperature of koka area

Table 2.5: Mean monthly Temperature of Becho area

Temp	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Tefki	17	19	20	20	20	19	19	18	18	17	17	16	19
Asgori	17	19	19	20	19	19	18	18	18	16	16	16	18
Tulu.B	17	18	18	18	18	18	17	17	17	16	16	16	17
Becho	17	18	19	19	19	19	18	18	18	17	16	16	18

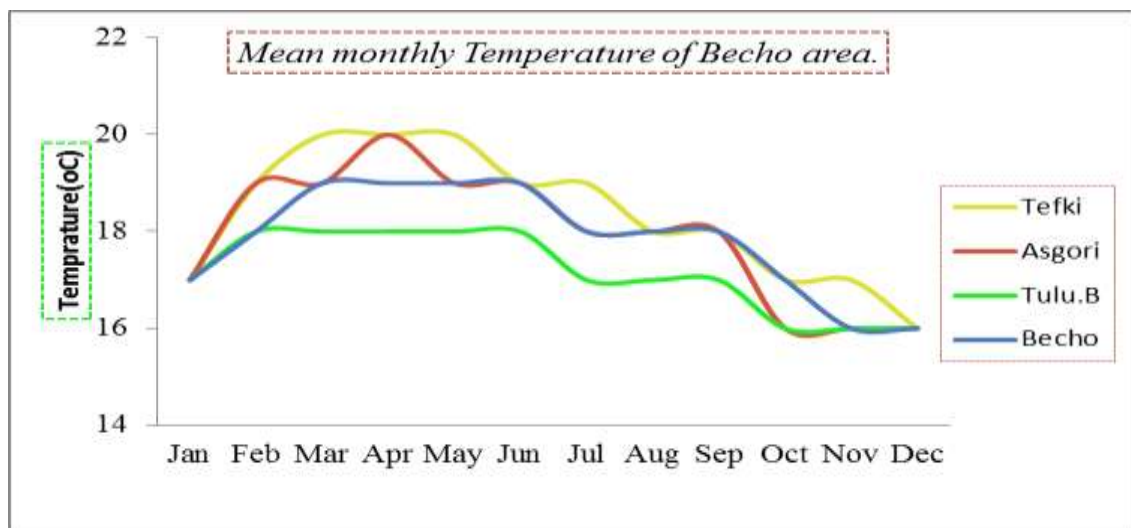


Figure 2.8: Graph of Mean monthly Temperature of Becho area

2.3.3 Wind speed, relative humidity and Actual evapotranspiration

Wind speed, or wind flow velocity, is the fundamental atmospheric quantity. The average wind speed of koka and Becho is 1.32m/sec and 0.7m/sec respectively at 2m heights from the ground surface. Relative humidity is calculated to be 56.85% and 57.05% respectively for the Koka and Becho areas (Abel Abebe, 2017). The annual Actual evapotranspiration rate value calculated Turc formula is 551.7404 mm and 614.55mm for Koka and Becho areas respectively.

Table 2.6: Mean Wind speed of Mojo and Debrezeit station

		Mojo	D/Zeit	Average
S/N	Months	Wind speed m/s	Wind speed m/s	Wind speed m/s
1	Jan	0.140323	1.363871	0.752097
2	Feb	0.207328	1.589957	0.8986425
3	Mar	0.417419	1.582814	1.0001165
4	Apr	0.433333	1.623	1.0281665
5	May	0.374758	1.623218	0.998988
6	Jun	2.005238	1.313889	1.6595635
7	Jul	0.408669	1.155914	0.7822915
8	Aug	0.434409	1.00879	0.7215995
9	Sep	1.60236	0.972727	1.2875435
10	Oct	0.266935	1.452458	0.8596965
11	Nov	0.361178	1.538056	0.9474918
12	Dec	0.401613	1.466129	0.893900473
13	Ave.	0.634553	1.386187946	1.010370473

2.4 Soil

In the study area the type and distribution of soil is not well studied. However there are some studies conducted for different purpose in the areas such as the soil map of Ethiopia produced by FAO and ministry of agriculture (MOA).

The type and distribution of soil is highly dependent on lithology (parent source), climatic factor and geomorphology. Dark clay soil occurs abundantly in the Northern, Western and eastern part of the study area. It's derived from lava flows, scoria cones and quaternary lacustrine sediments. In most places it is black clay loam soil but sometimes it has dark brown clay nature .The thickness of this soil is generally variable. Becho plain

i.e. from tefki to Tulu bolo the thickness reaches up to 10 meters. Usually this soil is a good media for water infiltration of the groundwater of basalt aquifers in the Koka, Becho -Woliso area. On the other hand they have high expanding and contracting characteristics when the soil gets wet and dry. This behavior of the soil results in the easily cracking of the ground which is the crucial problem in engineering structures. In the thick soil development of Addis Ababa- Awash Buni-Tulubolo road there is an intense ground cracking in response to the groundwater fluctuation of the area. This is resulting in the cracking of the Addis Ababa -Woliso asphalt road.

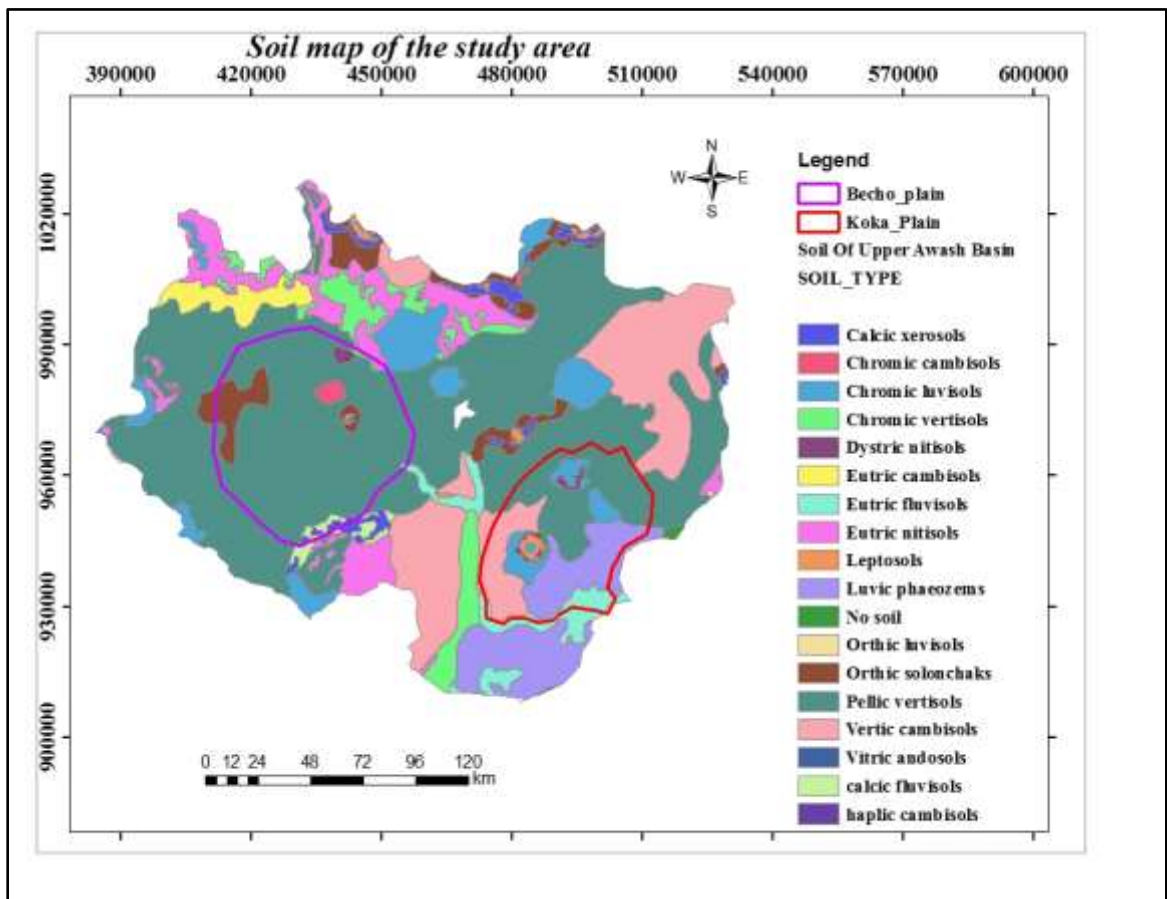


Figure 2.9: Soil map of the study area (modified from FAO, 1986)

2.5 Land use and land cover

The soil erosion and land degradation in the study area are highly controlled by proper land use and land management. The study area has a variable land cover land use property. Most of the study area especially the Becho plain and rift zones (koka plain) are dominated by intensively cultivated land which comprised 80 % of the entire area. The rest 20% are occupied by, the grass land, perennial swamp and open shrub land.

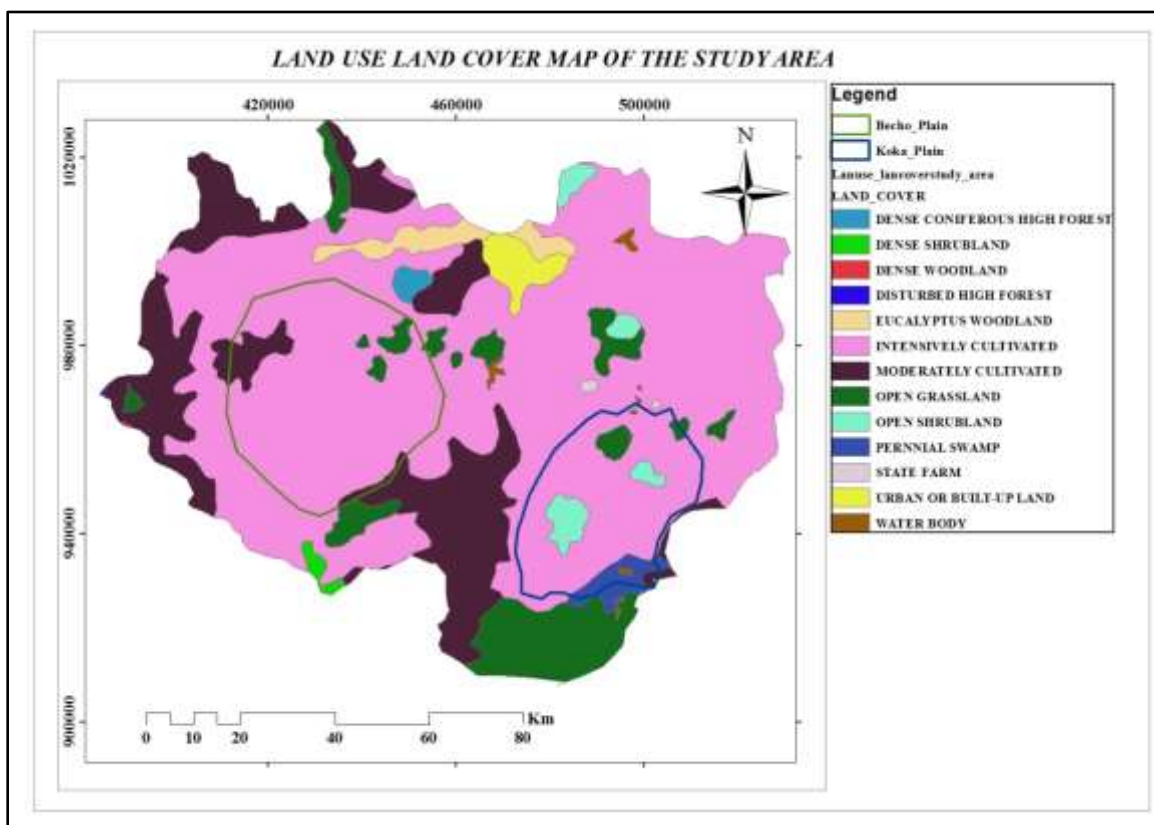


Figure 2.10: Land use land cover map (Modified from Ministry of water)

CHAPTER THREE

3 GEOLOGY AND HYDROGEOLOGY

3.1 Regional Geology.

The geological units in Ethiopia fall into one of the following three major categories; the Precambrian Basement, Late Paleozoic to Early Tertiary sediments and the Cenozoic volcanic and associated sedimentary rocks (EIGS, 1996).

The upper awash basin is located at the western margin of main Ethiopian rift and has a distinct geological units having separate time of formation. Mesozoic sedimentary succession, Tertiary and Quaternary age groups of acidic and basic volcanic rocks and Quaternary Lacustrine and alluvial deposits constitute the regional geologic arrangement of the study area.

3.1.1 Mesozoic sedimentary succession.

The Mesozoic sedimentary rocks comprise Adigrat Sandstone, Amba Aradam Sandstone, Antalo limestone and Muger mudstone. These sediments have the form of the transgression and regression of the Indian Ocean during Triassic to Cretaceous. This Mesozoic sedimentary succession is unconformably overly the crystalline basement rocks. Mesozoic sedimentary succession is exposed closed to kella, where unconformably overlay the crystalline basement rock (Mohr, 1967). The succession from lowest top lower most Triassic Adigrat sandstone, has a maximum exposed thickness of about 150m, it consists of reddish brown to medium fine grained sandstones, has high strength, fine to medium grained, light grey to dark grey color. According to (Kazmin, 1975) the highest in place unit, the Jurassic Antalo limestone, has high strength, yellowish grey in color with about 50 meters thick beds and maximum exposed thickness of 25 meters.

3.1.2 Tertiary volcanic rocks

This tertiary volcanic rock comprises of Addis Ababa Basalt, Addis Ababa Ignimbrite, and Nazareth Unit, and Central Volcanic Unit. The Tertiary volcanic composed of basalts and silicic of Miocene to Pliocene age. They unconformably line over top of the Mesozoic sediments. The Central Ethiopian plateau geology is controlling influence over by Tertiary volcanic made up of Aiba basalts, Alaji Rhyolites and basalts, Tarmaber basalts and Balchi Rhyolites (B. Zanettin et al., 1974).

3.1.2.1 Addis Ababa basalt

This subdivision is fine to coarse grained basalt constitute of olivine and plagioclase phenocrysts. In major component of the visible rocks observed in the area it is relatively thin (20m) lava flow overlying the ignimbrite. The length of time of the this basalt unit is 7.5-4.5Ma (Chernet et al., 1998 and Morton et al., 1979)

3.1.2.2 Addis Ababa ignimbrite

This rock unit is exposed in greater extent in part of the flat surface area around Addis Ababa and the Becho plane. It is made up of welded Tuff (ignimbrite) and non-welded pyroclastic fall (Ash and Tuff). In the area of Lega dadi plane and Melka Kunture area the thickness of this unit stretches up to 200m (exploration drilling data). The age of this Addis Ababa ignimbrite rock unit is 5.11-3.26 Ma (Morton et al., 1979).

3.1.2.3 Nazareth group

Nazareth rock unit composed of a thick succession of not welded tuffs, ignimbrite, ash flows, Rhyolites and trachyte out cropping for the most part on the rift floor reach a thickness of above 250m and to some degree in the rift escarpments and on the adjacent plateau border. As stated by (Kazmin and Seifmicheal Berhe, 1975) this class name was unofficially used for lower (older) welded Tuff (give an account of to Wechecha trachyte volcanism), Aphanitic Basalt (caused to be visible vertically curved columnar jointing close association with sub horizontal sheet jointing) and upper welded tuff (be connected to Yerer volcanism).

This unit is mainly exposed in the southeastern part of the area and forms rift floor. It comprised of a particular order of welded per-alkaline rhyolitic ignimbrite (Morton et al., 1979). The great distribution of rhyolitic domes is information indicating at hand to say silicic centers controlling influence over at the latest processes of Nazret volcanism which was occurring at the same time as by the Arba Gugu shield volcano and Chilalo and Badda Gebaba volcanoes which happened during the before expected time and after the expected stages of Nazret volcanism separately (Morton et al., 1979). The Nazret rock unit, division buried unconformably on the Addis Ababa Basalts and there is Bofa Basalt on the uppermost of the Nazret volcanic succession. This group has a close similarity to the young age of Addis Ababa Basalt and to the oldest age of Bofa Basalt within a specified age of 5.4 to 3.11ma (Morton et al 1979).

3.1.2.4 Akaki basalt

The Akaki basalt unit is visible (outcropped) at Daleti, Aba Samuel Dam, Akaki, Dukem area. It is coarse grained porphyritic olivine basalt. This basalt unit is highly vesicular and the vesicles or pore spaces are filled with carbonate minerals or secondary materials. Scoria and basalt quarried in Akaki and Dukem for construction purpose. The layer of this Akaki basalt unit around Akaki is 202m (drilling data). The age of the Akaki basalt is 2.9-2.0 Ma (Tesfaye Chernet et al 1998 and Morton et al., 1979).

3.1.2.5 Central volcanic unit

The central volcanic unit comprises Wechecha, Furi and Yerer Trachyte, Entoto ridge and Becho area Rhyolites, Tulu Rie Basalt and Chefa Donsa Unit. The Central Volcanoes rock units are for the most part are trachytic lavas visible at Wechecha, Furi, Yerer, Western and Southwestern narrow hill top of the investigation area forming an lift to higher ridges or mountain peaks. The Yerer trachyte is elevated about 1000 m from the surrounding plane area. The south and southern western narrow hill, tops is a watershed divide between the Omo-Gibe and Awash River basins. It is grayish color fine to medium grained trachyte with lower composition of ash falls and ignimbrite. The age of the central volcanoes rock unit is 10-3 Ma (Kazmin, 1979). It is also porphyritic in texture with phenocrysts of feldspar up to 1cm towards the other side. In fresh hand specimen it is grayish in color. Petrographic investigation studied by Tsegaye Abebe et al.,(1999) shows that Trachyte of Wechecha and Furi are comprised of plagioclase and sanidine phenocrysts predominating the trachyte, alkaline pyroxene and rare olivine. The crystals embedded in porphyritic rocks differ in size from glassy to microcrystalline and is be a part of by mostly by alkali feldspar, pyroxene, amphiboles and opaque minerals. The ages of the trachyte are different with Wechecha 4.6-3.7 Ma, Furi 4.0-3.7 Ma (Tesfaye Chernet et al., 1998), Yerer 3.9-3.3 Ma (Morton et al., 1979).

The Entoto Ridge is one part of central volcanoes unit which forms watershed divide of Abay and Awash River basins. The Entoto ridge forms steep slope in the direction of the Abay basin steep to gentle slope towards the awash river basin. Data (anything known) on the ages of the Rhyolites are not obtained; however from the crosscutting relationship they can be younger than the adjoining ignimbrite. The Wechecha trachytic rock unit is outcropped in the north and north east part of the mapped area and being composed of western rift shoulder central silicic volcanoes such as Wechecha, Furi and Yerer (Morton et al., 1979). The central volcano is preferentially trending in the direction of

E-W. It has medium to coarse-grained, light gray to dark-grey and very high strength and microscopically it is constituents of K-feldspar (Tsegaye Abebe et al., 1999). Tulu Rie Basalt is also one part of the central volcanoes unit outcropped in the southeastern part of the investigation area and forms NE trending escarpments. It is lava flow coarse grained basalt with olivine and plagioclase phenocrysts with very infrequent clinopyroxene. The age of this rock is 2.7 to 1.44 Ma (Morton et al., 1979). The Chefa Donsa volcanic rock units are visible at the surface in the east, north east south and west of not usual parts of Debrezeit. They are composed of fall deposits (ash, Tuff and pumice) and poorly welded ignimbrites of rhyolitic constituents. Therefore in the Dukem and Mojo river valleys they are outcropped under the lacustrine deposit. The age of this Chefa Donsa rock unit varies in between 2.24 to 1.71ma (Morton et al., 1979).

3.1.3 Quaternary volcanic rocks

This Quaternary volcanic rock contains Gash Megal Rhyolites, Woliso Ambo Basalts, Ziquala trachyte, and Bishoftu Volcanic unit.

3.1.3.1 Bishoftu volcanic unit

This Bishoftu volcanic rock unit configured a NNE trending belt outcropping for the most part in the central level surface areas of Debrezeit (Tsegaye Abebe et al., 1999). In the Bishoftu Volcanic splashed over the surface and cinder cones with conceptual connection with tabular basaltic lava flows and phreato-magmatic deposits are dignified in appearance. The basalt in this area is vesicular and coarse grained with olivine phenocrysts (Tsegaye Abebe et al., 1999). The phreato-magmatic deposits are for the most part composed of surges and highly broken off deposits make conceptual connections with maars and Tuff ring. Bora-Bericha Rhyolites rock units is also outcrops in the north east around Debrezeit area and eastern part of the investigation area (Tsegaye Abebe et al., 1999). The Bora-Bericha Rhyolites rock consists of younger rift floor volcanoes such as Bedegebaba, Gedemsa, Bericha, Bora and Tullu-Moye (Morton et al., 1979). Products of these centers are for the most part are per-alkaline trachyte. This rhyolitic rock unit has high strength, light gray to pink in color constituents of alkali feldspar, quartz and mica (Tsegaye Abebe et al., 1999).

3.1.3.2 Ziquala trachyte

This rock unit is exceptional, well maintained in its original cone standing about 1300m from the surrounding flat surface area, situated in the southern part of the detailed

investigation area. It has a highest point of hill caldera 1.5 km wide and existing only in part become full of water (Morton et al., 1979). This Ziquala trachyte is grayish pink in color, coarse grained and petro-graphically constituents of an orthoclase, sanidine, minor clinopyroxene phenocrysts and glassy alkali-feldspar embedded in a porphyritic rock (Tsegaye Abebe et al., 1999). The age of the Ziquala trachyte is 1.28-0.85 Ma (Morton et al., 1979).

3.1.3.3 Woliso Ambo basalts

The Woliso Ambo basalt rock unit is exposed at the western and northern extreme parts of the mapped area. It is lava flows make up of porphyritic basalt with relatively greater size crystals of plagioclase, olivine and pyroxene, basalt breccias' and little Tuff. (Tsegaye Abebe et al., 1999). In the area of Woliso it is Scoraceous basalt and in the Abay Master Plan report, this unit is mapped as a basalt lava flows join together to volcanic centers (QVCB) and its age is Pliocene to present.

3.1.3.4 Gash Megal rhyolites

This Gash Megal rock unit outcropped in a most important part of the detailed investigation area at the west of the Main Ethiopian Rift a point at which steep slope descends from highland area, on the top of Guraghe escarpment. This rock unit has medium strength, fine to medium grained, light gray color. This rock unit is constituents of feldspar, quartz, and Muscovite minerals (Tsegaye Abebe et al., 1999).

3.1.3.5 Chafe-Donsa pyroclastic deposit

This rock unit outcropped in the North -East central part of the study area. It has low strength, light to dark gray color, fine grained unwelded to poorly welded, fine volcanic ash flows and fall deposit composed of mainly Rhyolites and mainly exposed in the rift floor (Morton et al., 1979). Microscopically, it is composed of k-feldspar, quartz, plagioclase and hornblende having vitrophyric texture.

3.1.4 Quaternary lacustrine and alluvial deposit

3.1.4.1 Lacustrine deposits

The Lacustrine deposit is to higher degree dignified in appearance in the Adaa plain of the Lakes region. The Lacustrine sedimentations are the consequence of deposition in this large ancestral lake (Mohr, 1967) and (Tsegaye Abebe, et al., 1999). The age of the lacustrine rift sediments is occurring at the same time with the Wonji volcanic (Morton et al., 1979). They are fine grained outcrops in most cases brown-yellowish, thinly arranged

into strata and often hold within volcanic matrix; whose thickness varies from 5 to 8m. The thick layer of strata is written in the groundwater well drilling reports. They are for the most part of volcanoclastics sediments and tuffs with silts, clays and diatomite; silts and clays are the dominant once. Exposure of this the Eastern part of study area along the rift floor. The covers the largest area and forms flat topography and occur below an elevation of 1900 m.a.s.l. It consists of loose, light to yellowish grey color, sand and silt size sediments of volcanic origin such as pumice

3.1.4.2 Alluvial cover

Alluvial deposits are also common in the Rift, in connection with flood plains and at some places mixed with volcano clastic (Tsegaye Abebe, et al., 1999). The alluvial cover mainly outcropped above the Tertiary volcanic on the plateaus, Becho Plain, Mojo and its surrounding areas and composed of regolith reddish brown soils, talus and alluvium with maximum thickness of about 7 m (from area hand dug well data).and volcanic ash plus obsidian, Rhyolites and basaltic rock fragments (Morton et al., 1979).

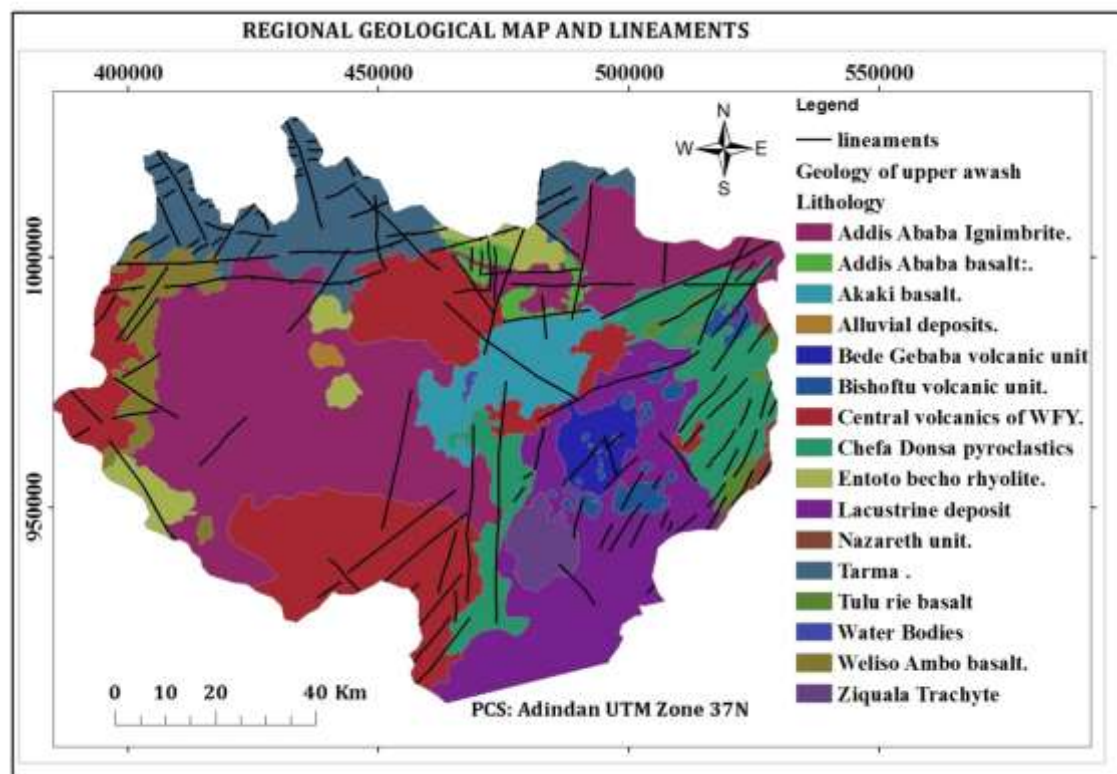


Figure 3.1: Geological Map of the Upper Awash Basin Modified from (WWDSE, 2008).

3.2 Geology of the study area

The study area (Becho and Koka) plains are covered by various geological units; including the dominant units which cover most of the study area and minor units which exposed in some part of the study area.

There are five exposures (Addis Ababa ignimbrite, alluvial deposits, Entoto Becho Rhyolite, central volcanic of Wechecha, Furi and Yerer and Terma ber basalt) which cover becho plains. Of these exposures approximately 90% of the becho plains are covered by Addis Ababa Ignimbrite (Nadl) and the rest of the plains were covered by minor exposures like Entoto becho rhyolite, alluvial deposits, central volcanic of Wechecha, Furi and Yerer and Terma ber basalt.

Koka plain is covered by five geological units; Bishoftu volcanic unit, Beda Gebaba volcanic unit, lacustrine deposit, and Ziquala trachyte and chafe Donsa pyroclastics. The dominant unit (exposure) of koka plain is lacustrine deposits approximately covers 75% of the plain and the rest 25% of the plain is covered by four minor units(Bishoftu volcanic unit, Beda Gebaba volcanic unit, Ziquala trachyte and chafe Donsa pyroclastics).

The geological units of the study area are discussed in detail with brief explanation of each unit as follows;

- a) .Chafe Donsa Pyroclastic Deposits (Ncp);** CDPU is exposed in central east, and northeastern part of the mapped area. It is light to dark-grey in fresh samples and reddish to yellow to pink in weathered ones. It is fine grained, poorly welded rock containing vitrophyric fiamme and lithic fragments with associated rhyolitic lava flows interleaved with ash and unwelded tuffs. Microscopically, it consists of crystals of 35 % K-feldspar (sanidine), 40% quartz, 20% plagioclase and 5% hornblende having vitrophyric texture.
- b). Ziquala Trachyte (Qtz);** this unit is exposed near Ziquala Mountain. Generally, it dark grey, moderately porphyritic to coarsely porphyritic with scarce deposits of pyroclastic material. Microscopically, it comprises crystals of 30% K-feldspar, 15 % sanidine), 15% pyroxene, 15% quartz, 20% and 5% opaque having trachytic to seriated textures.
- c).Addis Ababa ignimbrite;** Exposure of this unit is covering most of the becho plain. Is a tall deposit and poorly welded pyroclastic material. This unit is found to central western portion of the Becho area. It is light to dark-grey in fresh samples and reddish to yellow to

pink in weathered ones. It is fine grained, poorly welded rock containing vitrophyric fiamme and lithic fragments with associated rhyolitic lava flows interleaved with pumice, and unwelded tuffs. Microscopically, it consists of crystals of 35 % K-feldspar (sanidine), 40% quartz, 20% plagioclase and 5% hornblende having vitrophyric texture.

d). Lacustrine deposit (Qld); the exposure of this unit covers most of the koka plain along Koka Lake. This deposit is characterized by its thinly stratified brown to yellowish deposit with volcanic matrix. It is found to east and southeast occupying the rift floor of the map area. It forms flat-lying topography and marshy areas. It consists of loose, brown to grey colour sand, silt and calcrete.

e).Beda Gebaba volcanic unit (QbgPr): This unit exposed in koka plain of the study area. These units are rhyolitic to minor trachytic lava.

f). Bishoftu volcanic unit (QbiB): The Bishoftu unit are exposed in koka plain and characterized by spatter cones with basaltic lava flows.

g).Central volcanic of Wechecha, Furi, Yerer (NcvTy): The central volcanic of volcanic of Wechecha, Furi, and Yerer are porphyritic trachytic lava.

h). Entoto Becho Rhyolite (NebRy); Exposure of this unit is found near Debre Zeit and its environments. It is light grey to pink in color composed of alkali feldspar, quartz and mica. It forms unevenly distributed small domes and broad-based gentle sloping circular to elliptical hills. Locally, it shows intercalation of fine ash and unwelded tuffs. Microscopically, it consists of 35 % feldspar (sanidine), 40% quartz, 25% muscovite with rhyolitic textures. This geologic unit is exposed at southern and north eastern part of becho plain. As its name indicates the lithologic unit of Entoto Becho Rhyolite is obsidian rich rhyolites.

i). Alluvial deposits (Qal): This unit is alluvial bars and swamp areas surrounded by volcanics and exposed at north eastern corner of the becho plain

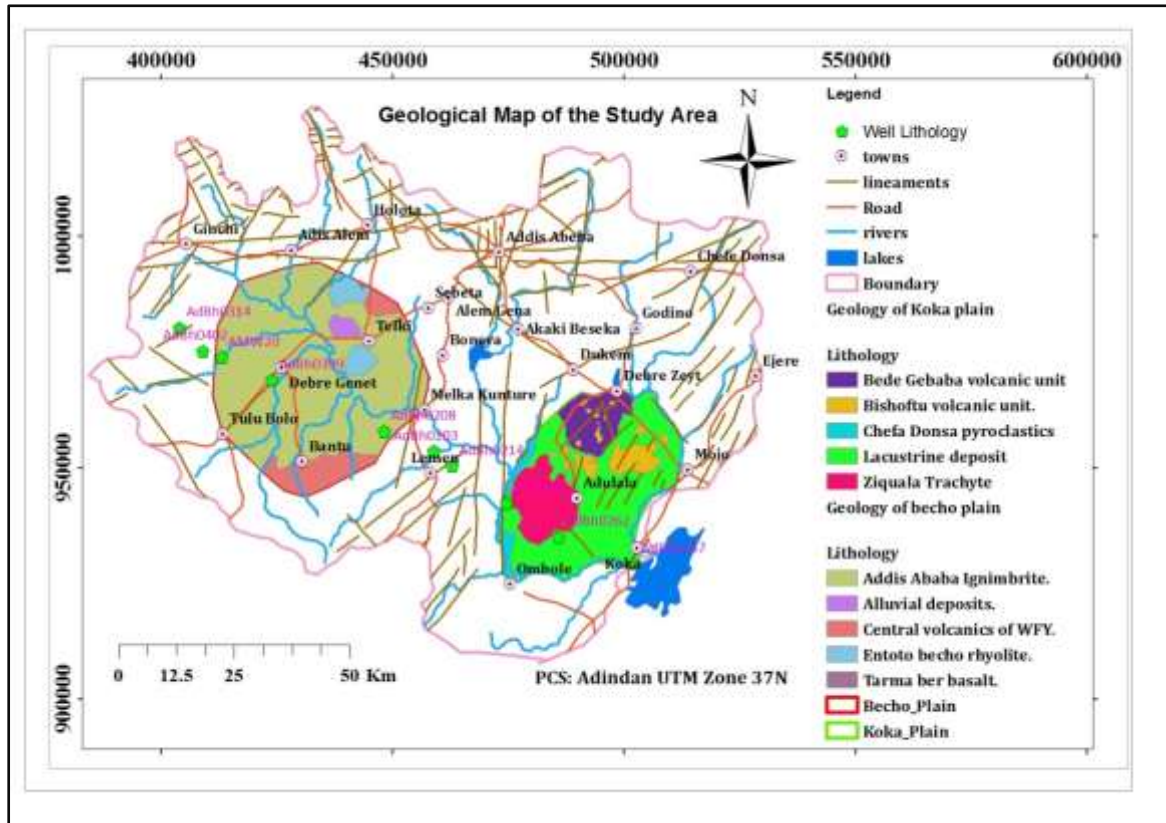


Figure 3.2: Geological Map of the study area.

3.3 Hydrogeology

The regional hydrogeological map is closely linked with geology and it may be expected to carry information on the hydrological and Hydrochemical nature of groundwater in different rocks as well as on the type and magnitude of the permeability of different rocks (Tesfaye Chernet, 1985). In the Akaki Beseka sheet (NC 37-14) The groundwater occurrence is affected by geomorphological setup, climatic conditions, lithology, degree and extent of fracturing and weathering of massive rocks, grain size, sorting and degree of cementing material for unconsolidated sediments and type and thickness of soil development. The porous and fissured rocks are responsible to store and transmit groundwater. The tectonic has dipped the bedding of the sedimentary formation to the south and north direction and the groundwater movement in the sedimentary as well as the volcanic aquifer are more probably governed by this effect.

The stratigraphy of the Ada-Becho Plains groundwater system shows a remarkable configuration. The northern part of the system, the Abay plateau is dominated by Paleogene Volcanic rocks, the transit zone (escarpment and local grabens) is composed of

Neogene volcanic units and the southern part of the basin is dominated by quaternary volcanic and sedimentary formation.

The stratigraphy of the area is briefly described below based on the geological survey and mapping carried out for the Ada-Becho project by WWDSE

Tertiary volcanoes: Paleogene and Neogene formations have wide distribution in the recharge area, transit zone and on the plains of the groundwater basin under study.

a).Paleogene volcanic is the most widely distributed on Abay Plateau and composed of dominantly basalt of different composition. Blue Nile Basalts (PbnB) have small distribution at the northern edge of the recharge area of the groundwater basin in Abay plateau. The formation is composed of columnar alkaline flood basalt of very low permeability. The thickness of this formation varies from 100 to 200 meters.

Basalt (PasB) and Alaji Ryholites have limited distribution in the area at the northeastern margin of the Abay plateau. These formations have low permeability.

Amba Aiba Basalt (PaaB) has wide distribution on the Abay Plateau on the northern part of the recharge area. The basalt is deeply weathered and favors water storage and movement. The thickness of this formation is more than 200 meters.

Tarmaber Basalt (PNtbB), covers more than 70% of the Abay Plateau have a thickness of more than 300 meters and underlies under the Neogene acidic and basic volcanic rocks in the upper Awash river basin. This has been proved by the drilling of mapping wells at Asgori (becho plain) AMW3, Legegadi AMW8, Melka Kunture AMW4, Sebeta AMW5, etc. This formation is lenticular basalt with large proportion of scoraceous lava flows. The formation is highly pervious, which highly favors groundwater storage and movement.

b).Neogene volcanic units are most widely distributed on the transit zone and fills Becho graben and east of Addis Ababa area. Volcanic tuff, ignimbrites and pyroclastic materials occupies the largest part of the area. Ryholites and Trachyte forms ridges and peaks in the area. The formations are:

Entoto-Becho Ryholites (NebRy) and Central Volcanics (NcvTy) of trachyte forms the Entoto ridges, Wechecha, Furi and Yerer mountains. The formations are practically impervious except the weathered and fractured zones.

Chefa Donsa Pyroclastic (NQcdPc), Nazareth group (NnuRI) welded tuff, Addis Ababa

Ignimbrites (NadI) forms a wide distribution and occupies more than 50 % of the area, the thickness of this formation varies from 150 to 300 meters. The formations have poor permeability except at the weathered and fractured zones.

Akaki basalts (NakB) scoria and basaltic lava, Addis Ababa Basalts (NadB) and Tulu Rie basalts (NtrB) occupies a small portion of the central part of Ada-Becho plains groundwater system. These formation favors groundwater storage and movement.

Quaternary volcanic and sedimentary formations: are most widely distributed on the southern part of the groundwater system (Koka plain). Trachyte and Ryholites form peaks and ridges while the alluvial plains and basic volcanic formation forms calderas and plains.

Ryholites and Trachyte (QzqTy, QbgPr) forms Ziquala and Bede Gebaba mountains. The formations are practically impervious.

Bishoftu volcanic units (QbiB) is composed of spatter cones and scoria which highly favors groundwater storage and movement

Alluvial and Lacustrine deposits (Qal and Qld) occupy large part of koka plain. The alluvial deposits are sandy clay and silty clay with gravel at the lower bed. The lacustrine sediments are distributed around koka lakes. This formation moderately favors groundwater storage and movement.

The hydrogeological classification system is done based on qualitative and quantitative approaches. On the bases of hydrogeological characteristics of different lithological units and different data collected during field inventory, the classification leads to the following aquifer/aquitared system (Akaki Beseka sheet (NC 37-14);. Moderate productive porous aquifers of lacustrine and alluvial sediments, High productive fissured aquifers of tertiary plateau and Quaternary rift basalts, Moderate productive fissured aquifers of silicic welded to partially welded pyroclastic flows, Low productive fissured aquifers of the acidic volcanic domes and flows of the syn-rift formations (rhyolite, trachyte and some unwelded pyroclastic flows), Localized aquifers with very limited outcrop (Mesozoic sediments) Aquitared or minor aquifers with very limited groundwater occurrence

The depth to groundwater in the most volcanic aquifers is in the range of 0 to 120 meters below ground level on average; however it reaches 200 meters in some places. Whereas in lacustrine and alluvial sediments the depth is not more than 40 meters (Akaki Beseka sheet (NC 37-14))

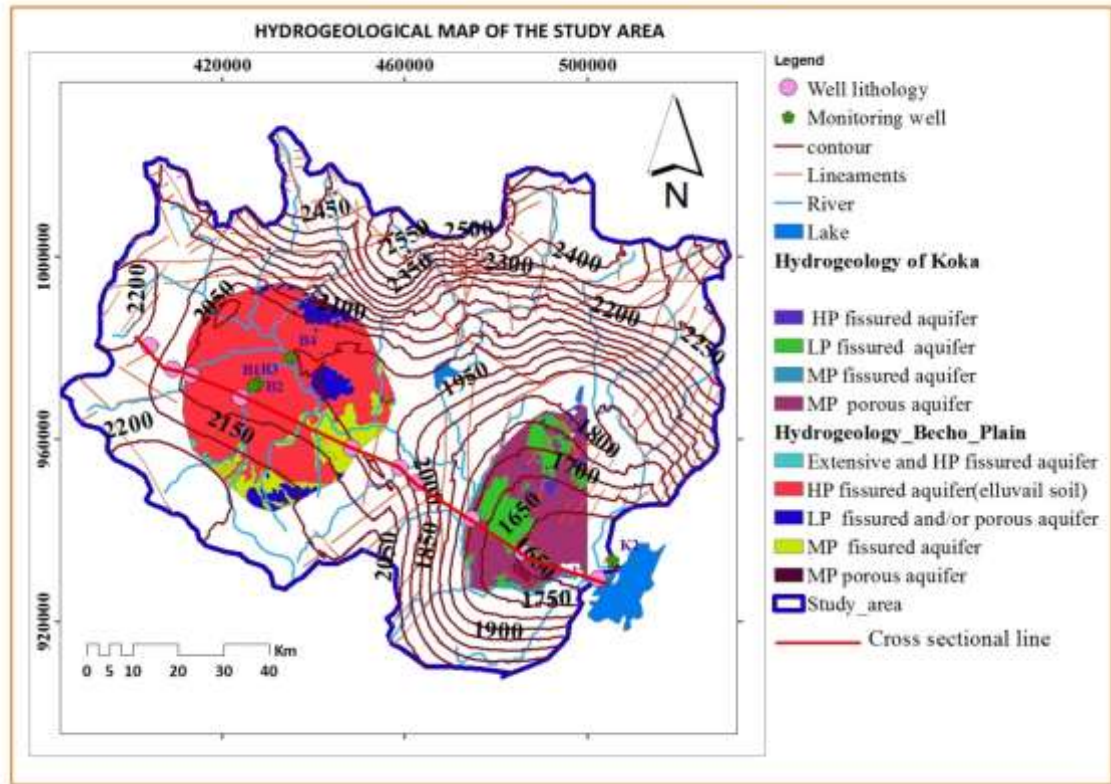


Figure 3.3: Hydrogeological map of the study area.

CHAPTER FOUR

4 HYDROGEOLOGICAL CHARACTERIZATION

4.1 Recharge estimation

4.1.1 General

Groundwater recharge is the fundamental component in the water balance of any watershed. However, because it is impossible to measure directly, numerous methods have been used to estimate recharge, and in some cases base flow has been used as an approximation of recharge (Lerner et al, 1990; Scanlon et al, 2002). A common recommendation in the literature is that recharge should be estimated from multiple methods and the results compared, but in reality comparing the results may be difficult because of difference inherent problems in the methods. While estimating natural groundwater recharge, it is essential to have a good idea of different recharge mechanisms and their importance in the study area. In the humid climate, where most streams are gaining and the water table is relatively shallow, recharge typically is estimated by an analysis of stream flow records, groundwater levels, or water balance for a watershed. Estimating ground water recharge is often the primary purpose for conducting a water balance. Recharge largely determines the rate at which ground water can be withdrawn from the wells.

Understanding ground water recharge is essential for the successful management of water resources and Modeling fluid and contaminant transport within the subsurface. Quantification of the rate of natural groundwater recharge is pre-requisite for efficient groundwater resource management. Estimation of recharge, by any method is normally subject to large uncertainties and errors. Estimating the rate of aquifer replenishment is probably the most difficult of all measures in the evaluation of groundwater resources. The methods available for the estimation of groundwater recharge directly from precipitation can be broadly divided in to three; inflow, aquifer response and outflow methods according to how the studies are conducted (Kumar C.P, 1977). The following methods are commonly in use for estimating natural groundwater recharge (Sathish Chandra, 1979); soil water balance method, zero flux plane method, one dimensional soil water flow model, inverse modeling technique, ground water level fluctuation method ,hybrid water fluctuation method, ground water balance method and isotope and solute

profile techniques. Here in this paper soil water balance method is used to estimate recharge. Water balance model were developed in the 1940 s by Thornthwaite (1984) and was later revised. The method is essentially estimates the balance between inflow and outflow of water. The soil water balance can be represented by:

Equation 4.1: $R = P - AET + \Delta S - R_o$

Where R is recharge, P is precipitation, AET is actual evapotranspiration, ΔS is change in soil water storage and R_o is runoff. (AET) Actual evapotranspiration is calculated by Turc formula as follows

Equation 4.2: $AET = P / [(1.9 + (P / J)^2)]^{0.5}$

Where; $J = 300 + 25 * T + 0.05 * T^3$, T = annual average temperature ($^{\circ}C$), P = the annual rate of precipitation in mm, ETA = Annual actual Evapotranspiration.

By using the above formula the recharge of the study area (Becho and Koka plains) are estimated as follows respectively.

Recharge estimation of becho plain.

The average annual rain fall of becho plain is 1050.145mm and actual evapotranspiration calculated by Turc formula and finally recharge is estimated by using soil water balance method as follows;

$$J = 300 + 25 * 17.97533 + 0.05 * (17.97533)^3$$

$$J = 300 + 449.38325 + 290.403$$

$$J = 1039.78625$$

$$ETA = 1050.145 \text{ mm} / [(1.9 + (1050.145 \text{ mm} / 1039.78625)^2)]^{0.5}$$
$$= 614.55 \text{ mm}$$

$$R = P - ETA + \Delta S - R_o$$

$$R = 1050.145 \text{ mm} - 614.55 \text{ mm} - 200.479 \text{ mm}$$

$$R = 235.029 \text{ mm/year}$$

By using the same procedure with that of becho plain, the recharge of koka plain is estimated as follows ; P=840.9517mm, J=1292.803, EAT=551.7404mm

$$R = 840.9517 \text{ mm /year} - 551.7404 \text{ mm /year} + 0 - 266.9486 \text{ mm} = 22.2627 \text{ mm/year.}$$

From the water balance method, 23.38% of the total rainfall of the becho plain directly recharges the ground water and only 2.6% of the total rainfall of koka plain recharges groundwater. The recharge of the study area is affected by Climate, geology and geography. Koka plain is located within main Ethiopian rift valley and the mean annual

rainfall of the area is less than that of becho plain. The mean monthly temperature of Koka area is greater than that of becho plain. Geography, climate and geology of the study area are completely different, that is why the recharge estimation values of both plain varies this much.

4.1.2 Base flow separation

Base flow is sustained low flow in a river during dry or fair weather conditions, but not necessarily all contributed by groundwater; includes contributions from interflow and groundwater discharge. Hydrograph is the graph showing the rate of flow (discharge) versus time past a specific point in a river, channel, or conduit carrying flow. Stream hydrograph increases in stream flow follow rainfall or snow melt.

Hydrograph is the continuous plot of instantaneous discharge versus time. It results from a combination of physiographic and meteorological conditions in a watershed and represents integrated effects of climate, hydrologic losses, surface runoff, inter flow and groundwater flow. Detailed analysis of hydrograph is usually important in flood damage mitigation, flood forecasting, or establishing design flows for structure that convey floodwater.

It is necessary to separate out the base flow from stream gage data, in order to determine the contribution from overland flow in a watershed to the stream in the watershed.

Calculation of baseflow index(BFI) is result of several steps and it is illustrated in Table 4.1 . The daily flows Q ($m^3.s^{-1}$) are divided into non-overlapping blocks of five days (Column 5 and 6). From this block is selected minima value (Q_{min}) of daily flows (Column 5). If central minima value (in between surrounding minima values) is ≤ 0.9 , than it is used for plotting base flow separation line and assigns to each day a base flow value Q_b , by linear interpolation between selected central values. Next step calculates the water volume (V_{base}) beneath base flow hydrograph between the first and last date of interest. The volume (m^3) is simply derived as the sum of the daily base flow values times the timespan in second per day. Calculating of corresponding volume water beneath the recorded hydrograph (V_{total}). The volume (m^3) is obtained by summing the daily flow values between the first and the last dates inclusive.

Calculating of BFI (V_{base}/V_{total})

Comparative Evaluation of Shallow Groundwater Dynamics of Becho and Koka Plains,
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Table 4.1: calculation of baseflow index (BFI) at Awash Bello.

Date	Discharge	Baseflow	BFI Index	Qmin(m ³ /s)	0.9Qmin(m ³ /S)
1/1/2011	0.492			0.492	0.4428
2/1/2011	0.492				
3/1/2011	0.907				
4/1/2011	0.776				
5/1/2011	0.713				
6/1/2011	0.682				
7/1/2011	0.652				
8/1/2011	0.623				
9/1/2011	0.511				
10/1/2011	0.433			0.433	0.3897
11/1/2011	0.384				
12/1/2011	0.361				
13/01/2011	0.338				
14/01/2011	0.315				
15/01/2011	0.294			0.294	0.2646
16/01/2011	0.272				
17/01/2011	0.252				
18/01/2011	0.213	0.21	1		
19/01/2011	0.213	0.21	0.97	0.213	0.1917
20/01/2011	0.232	0.2	0.86		
21/01/2011	0.213	0.19	0.91		
22/01/2011	0.195	0.19	0.96		
23/01/2011	0.213	0.18	0.84	0.213	0.1917
24/01/2011	0.272	0.17	0.64		
25/01/2011	0.252	0.17	0.66		

Only four river gaging stations are selected for base flow separation. The selected gaging stations are; Mojo at mojo village, Mojo at koka Dam, awash at Bello and Awash at Melka Kunture. The base flow separation was carried out by Sloto & Crouse (1996) methods (Fixed interval method, sliding interval method and Local minimum method). The base flow separation graphs of the selected stations are shown on figure below;

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Table 4.2: River gaging stations

River Gaging station	UTME	UTMN	Elevation(m)	Area(km ²)
Mojo at village	507050	945131	1725	1264.4
Mojo at Koka Dam	505718	933289	1595	1527
Awash at Melka K.	439200	940787	2050	4456
Awash at Bello	435067	977971	2024	2568.8

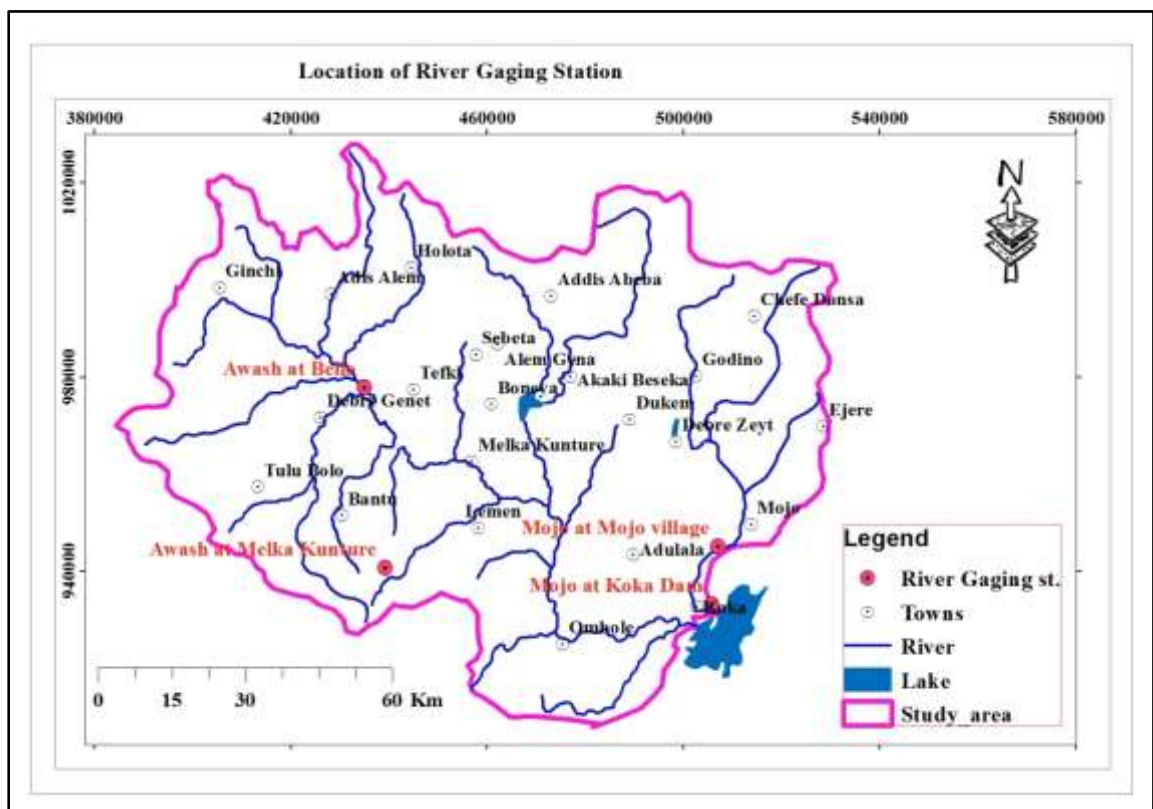


Figure 4.1: location Map of River Gaging station

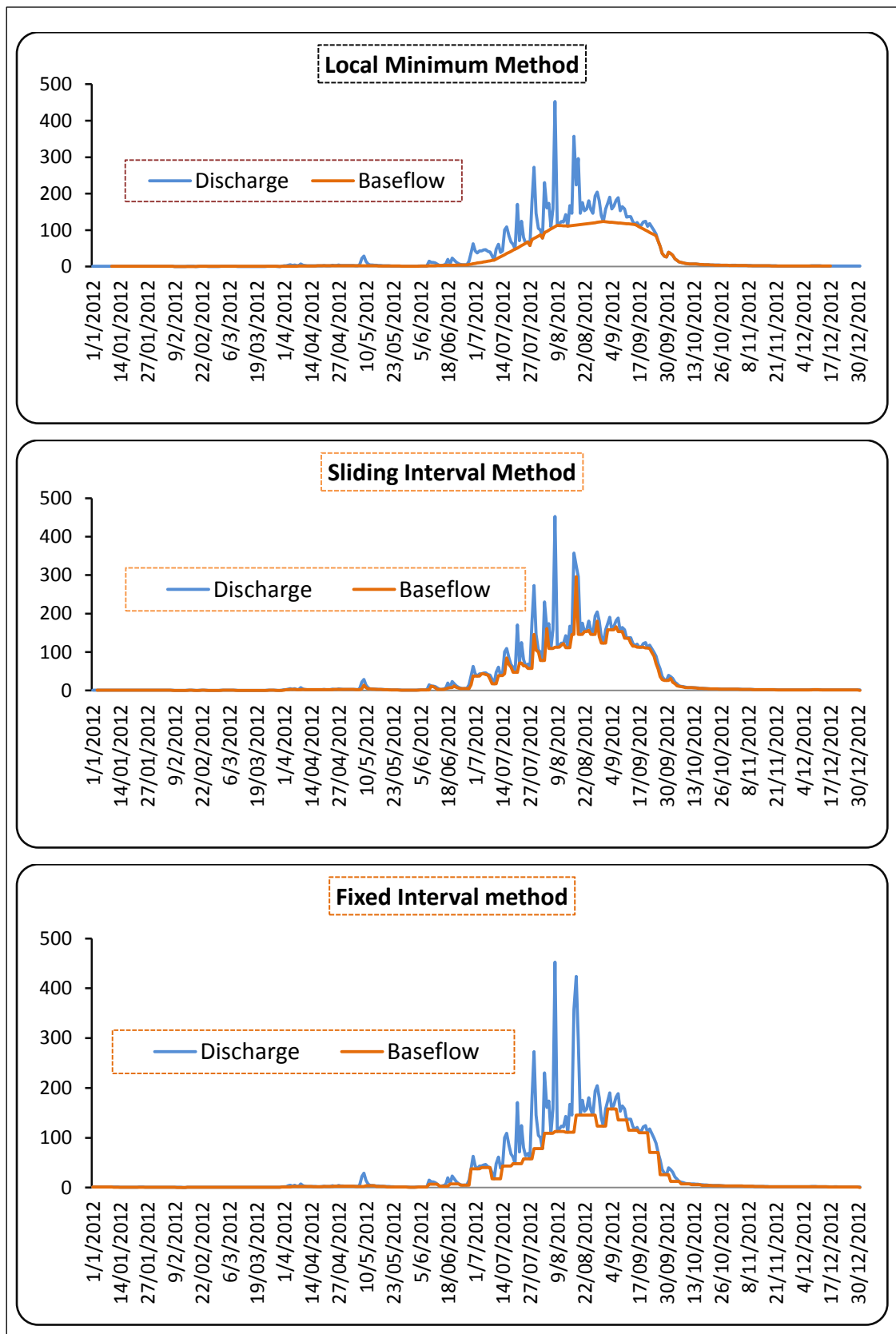


Figure 4.2: Baseflow separation of Awash at Melka Kunture by LM, FI and SI Methods.

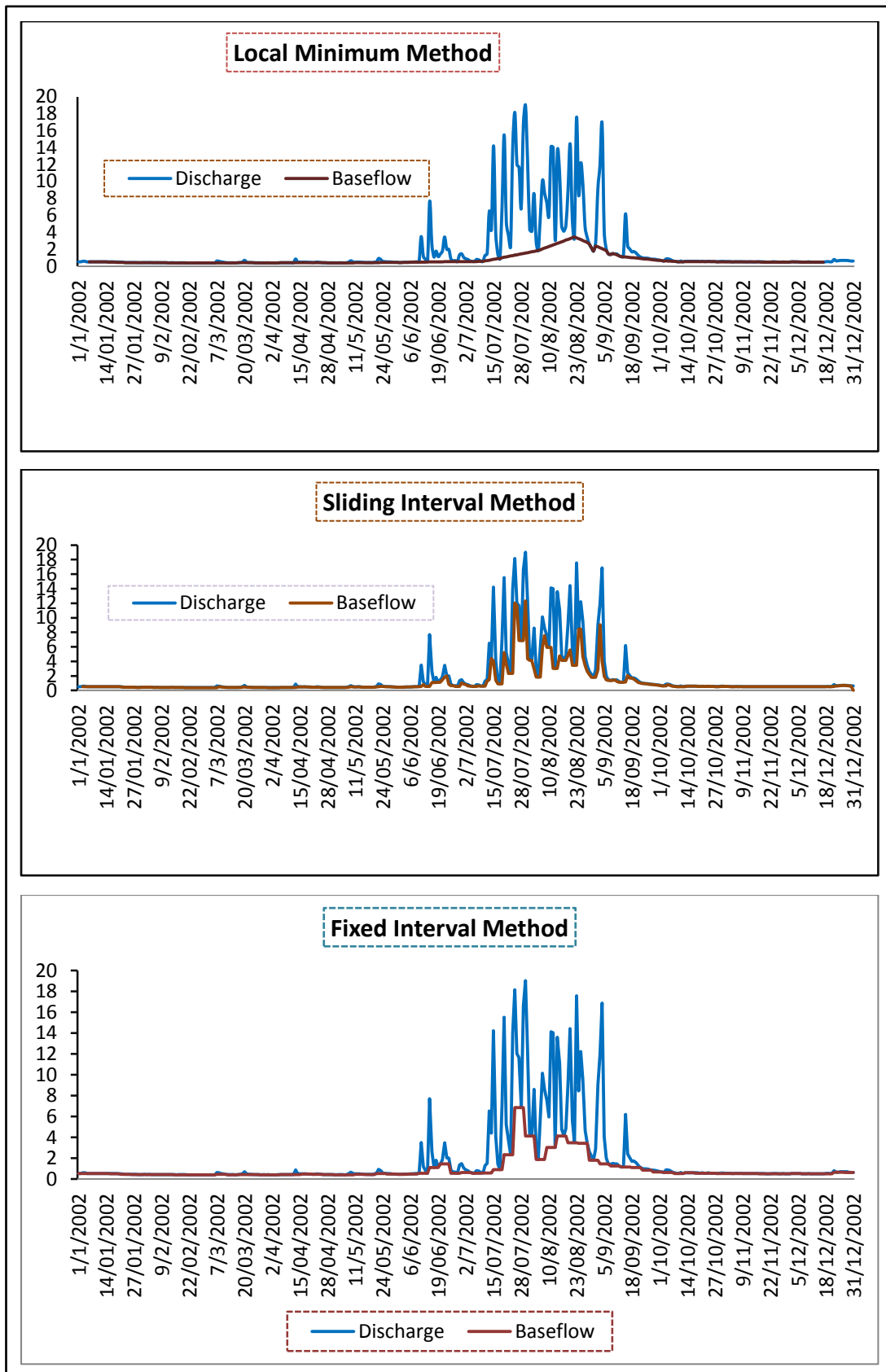


Figure 4.3: Baseflow separation of Mojo at koka dam by Lm, FI and SI methods

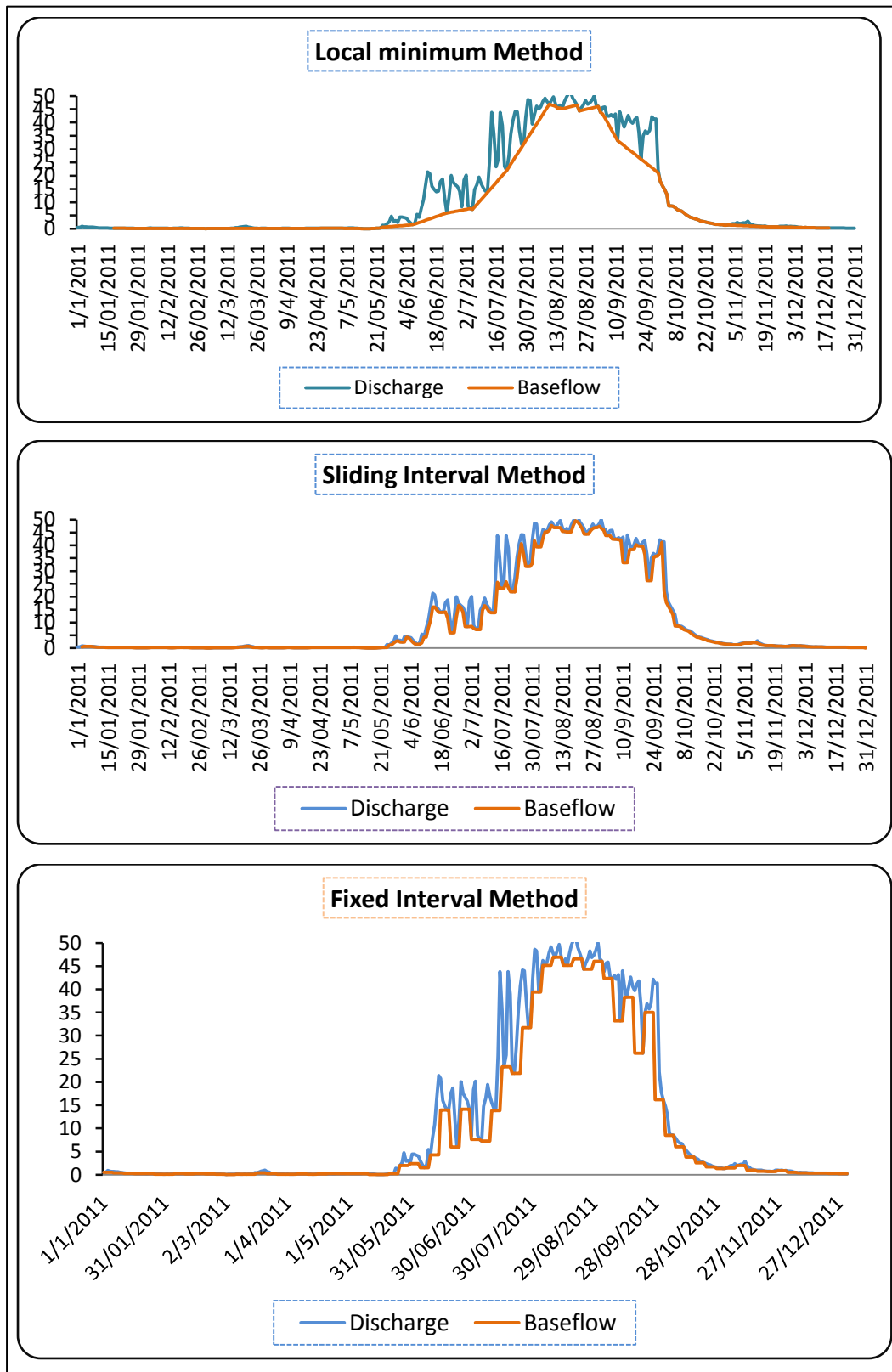


Figure 4.4: Baseflow separation of Awash at Bello by LM, FI, SI methods

Comparative Evaluation of Shallow Groundwater Dynamics of Becho and Koka Plains, Upper Awash Basin, Central Ethiopia

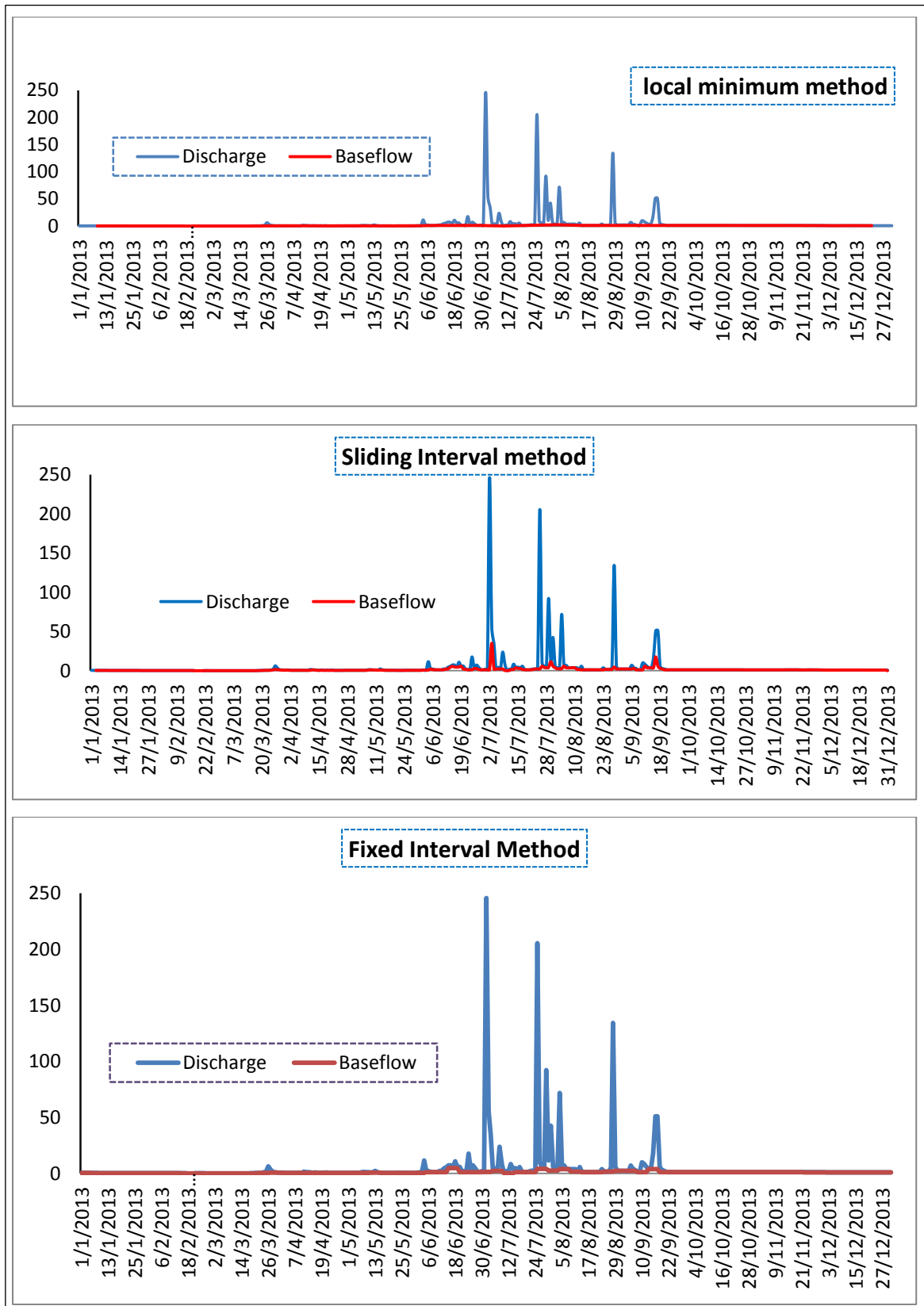


Figure 4.5: Base flow separation of mojo at Village by LM, FI and SI method

Table 4.3: Summaries of base flow separation techniques.

Station	Method	Total volume(VT) M ³	Vol.Baseflow(Vb) M ³	BFI(Qb/Q t)
Awash@Bello	Local minimum	1.298*10 ¹¹ M ³ /yr.	1.02*10 ¹¹ M ³ /yr.	0.787
	Sliding Interval	1.298*10 ¹¹ M ³ /yr.	1.166*10 ¹¹ M ³ /yr.	0.898
	Fixed interval	1.298*10 ¹¹ M ³ /yr.	1.093*10 ¹¹ M ³ /yr.	0.8418
Awash@Melka_Kunt ure	Local minimum	4.046*10 ¹¹ M ³ /yr.	2.613*10 ¹¹ M ³ /yr.	0.65
	Sliding Interval	4.046*10 ¹¹ M ³ /yr.	3.132*10 ¹¹ M ³ /yr.	0.774
	Fixed interval	4.046*10 ¹¹ M ³ /yr.	2.853*10 ¹¹ M ³ /yr.	0.7051
Mojo@Koka Dam	Local minimum	2.073*10 ¹⁰ M ³ /yr.	7.127*10 ⁹ M ³ /yr.	0.3438
	Sliding Interval	2.073*10 ¹⁰ M ³ /yr.	1.314*10 ¹⁰ M ³ /yr.	0.634
	Fixed interval	2.073*10 ¹⁰ M ³ /yr.	1.0645*10 ¹⁰ M ³ /yr.	0.5135
Mojo at Mojo Village	Local minimum	4.95683*10 ¹⁰ M ³ /yr.	8.7*10 ⁹ M ³ /yr.	0.18
	Sliding Interval	4.95683*10 ¹⁰ M ³ /yr.	1.5057*10 ¹⁰ M ³ /yr.	0.303
	Fixed interval	4.95683*10 ¹⁰ M ³ /yr.	1.1503*10 ¹⁰ M ³ /yr.	0.232

The baseflow index of Mojo at mojo village and Mojo at Koka Dam are small compared to BFI of Awash at Bello and Awash at Melka Kunture. Because at Mojo River the total volume of stream flow is much greater than volume of baseflow, however, at Awash River there is balance between volume of stream flow and baseflow. Imbalance between the stream flow and baseflow will leads to smaller value of BFI (baseflow index).

Time-series of base flow has been seen as useful as a measure of the dynamic behavior of groundwater in a catchment, whereas the base flow proportion of the total flow has an index of the catchment's ability to store and release water during dry weather. A high index of base flow would imply that the catchment has more stable flow regime and is thus able to sustain river flow during extensive dry periods. Baseflow index of Awash at

Bello and Awash at Melka Kunture from Local minimum method is 0.787 and 0.65 respectively. The index of base flow Calculated at Awash Bello and Awash at Melka Kunture was much greater than the estimated BFI at Mojo village and Koka Dam; this implies that the Awash river catchment has more stable flow regime and able to sustain river flow during extensive dry period than Mojo River. The total volume of flow and base flow were calculated by local minimum method, fixed interval method and sliding interval method at each station.

4.2 Water Point Inventory

The water point inventory has been commenced at office level by collecting all available information and data from different organizations. These information that are in the form of reports and data were evaluated to identify the data gap and resolute what to be done next. Hence, most of the obtained information and data were found to be incomplete, lacking co-ordinate, static water level, well log and others hydrodynamic parameters. Thus, the water points inventory were planned to collect hydrogeological information and direct measured data such as co-ordinates and dynamic or static water level. Prior and during field survey governmental and non-governmental organizations were visited to obtain all available written documents and verbal information.

In order to meet the objectives of the hydrogeological study, water point inventory has been planned to cover most part Becho and Koka plains. During field survey more than 200 numbers of water point inventoried from different Woredas of Oromia regional state found in the target areas.

As an outcome of both the field and office works about 768 water point data collected and a database organized. At each water point, data have been collected on hydrogeology, geomorphology, geology; water points properties and its use. The data were recorded by visiting the water point on spot by measuring co-ordinate and elevation using GPS and topographic map 1:50 000. By using deep meter water levels were measured where ever possible. The water point inventory was carried out from Jan, 10/2018 to march 30/2018.

The main constraints during the water point inventory were: The boreholes at most are on use and capped which could not allow to measure water level .The shallow wells and bore holes are also installed with hand pumps and no observation pipe to measure water level, Some water points were not accessible by vehicles except by walking on foot for long

time and The collected data such as well discharge, static water levels, draw downs and well depths look untrustworthy when compared with others surrounding water points.



plate 4.1: Photograph taken at the field during well inventories.

A total of 768 water points were inventoried including data collected from different organizations. Out of which 559 water points were boreholes with variable depth, 179 with very shallow depth or hand dug wells and 30 springs. Northern part of the study area has limited bore holes where most of the water points are springs. Deep boreholes are found at the Northeastern part of the study area surrounding Addis Ababa, Debrezeit and Modjo. In the western part of the study area there are few boreholes with variable depth. The distribution of water points in the area is given in the map below.

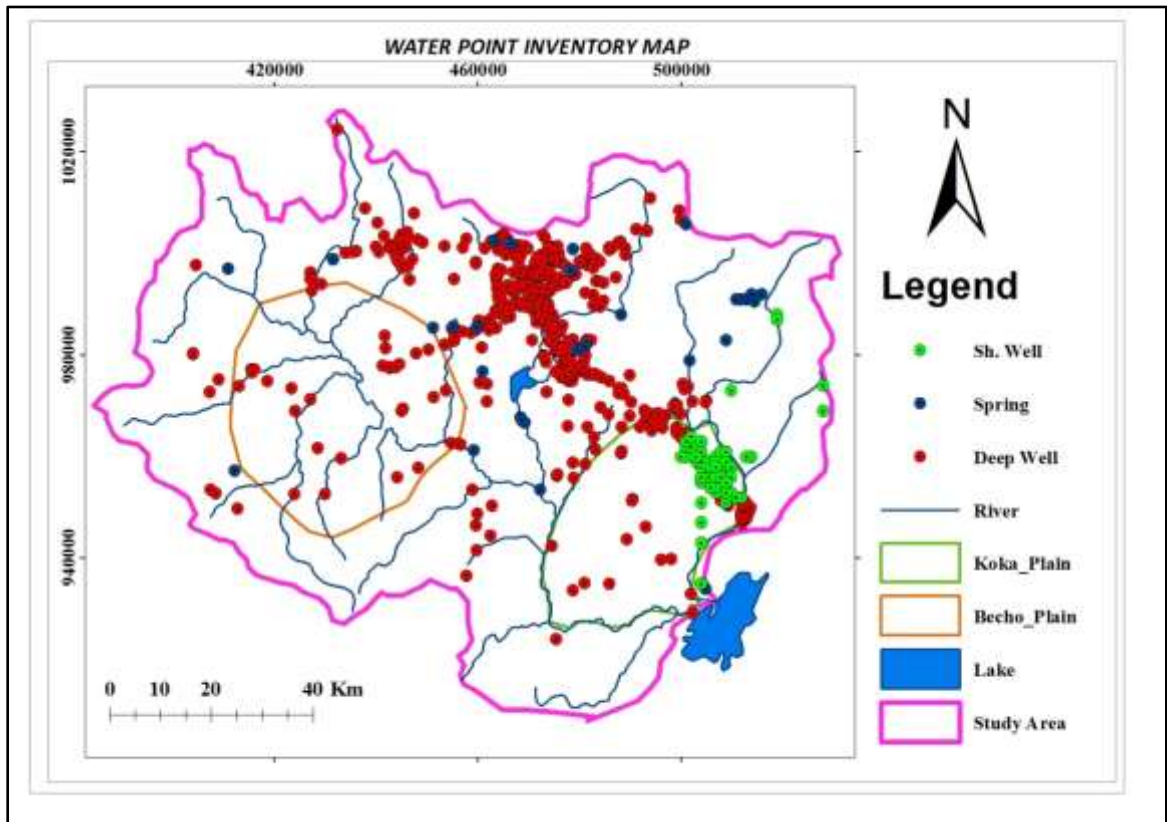


Figure 4.6: Water Point Inventory map

4.3 Groundwater flow

Ground water flow is the part of the stream flow that has infiltrated the ground, has entered the phreatic zone, and has been discharged into a stream channel, or spring and seepage water. The rate of groundwater flow depends on the permeability (the size of the space in the soil or rocks and how well the spaces are connected) and the hydraulic head (water pressure).

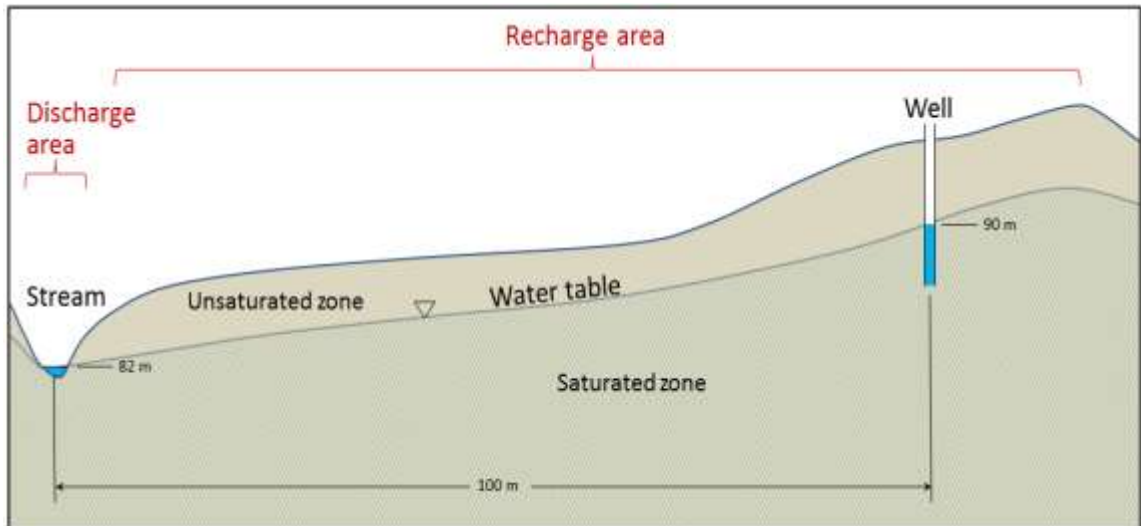


Figure 4.7: Water table in cross section, with saturated zone and unsaturated zone

The groundwater occurrence is affected by geomorphological setup, climatic conditions, lithology, degree and extent of fracturing and weathering of massive rocks, grain size, sorting and degree of cementing material for unconsolidated sediments and type and thickness of soil development. The porous and fissured rocks are responsible to store and transmit groundwater. In the study area, the Awash River emerges from the western and surrounding plateau especially from an average altitude of 3000m around Ginchi highland. The Awash River flows toward south eastern direction from western plateau (Ginchi&wonchi.mt) to Koka Lake (southeastern limit of the study area). Generally the western, north western and Guraghe highlands are the major recharge zone for both plains. The focus area (Becho & Koka plains) are discharge zones .the unconsolidated sediment in becho plains and lacustrine sediments in koka plains are known by their high potential shallow ground water. The local populations living around these two plains are highly dependent on these shallow ground water resources for irrigation, for domestic use and for factory. Here is the simple cross sectional view of the area that indicates recharge zone, discharge zone, ground water flow direction, subsurface geology and subsurface structure of the study area.

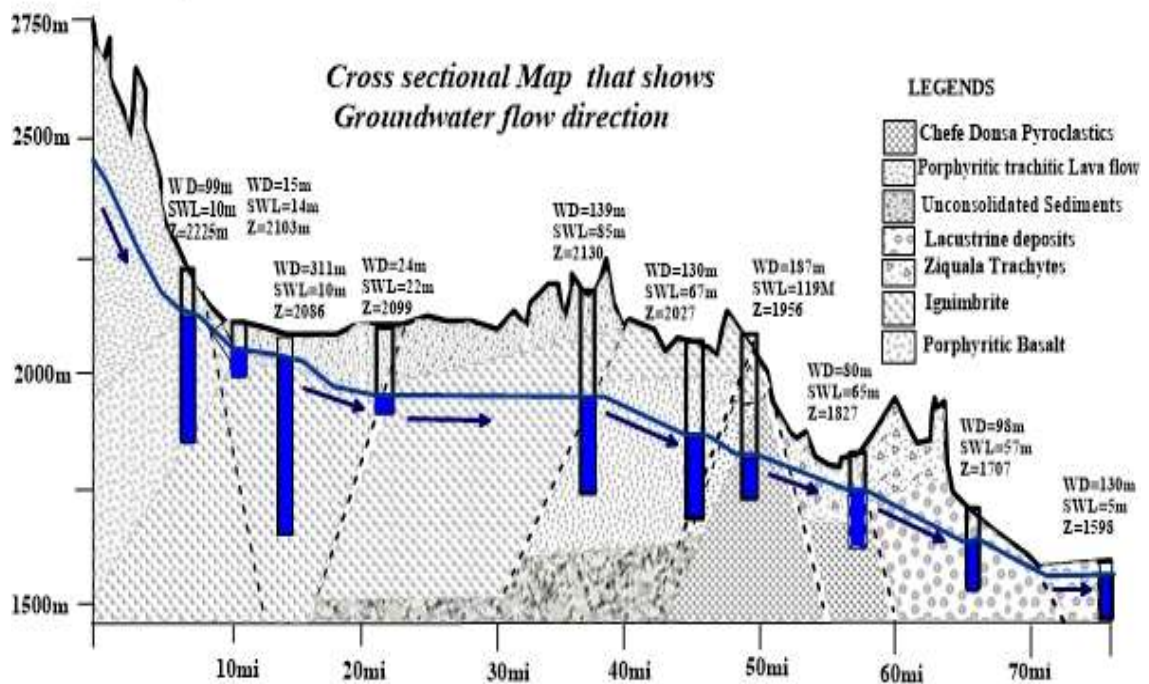


Figure 4.8: Well lithology cross sectional map

The ground water flow direction of the study area depends on topography, lithology and geological structures. The ground water flow direction of becho plain is toward Awash River and the ground water flow direction of the koka plain is toward the koka reservoir. The water table contour map of the study area shows clearly the ground water flow direction of the study area see fig below. The ground water flows from western and northwestern plateau, Guraghe highland, Wechecha and Furi mountain towards the becho plain because of topographic effect. Geological structures are one of the factors which govern groundwater storage and flow direction in the study area; especially in Koka plains. Koka plain is located in main Ethiopian rift valley (tectonically active area)

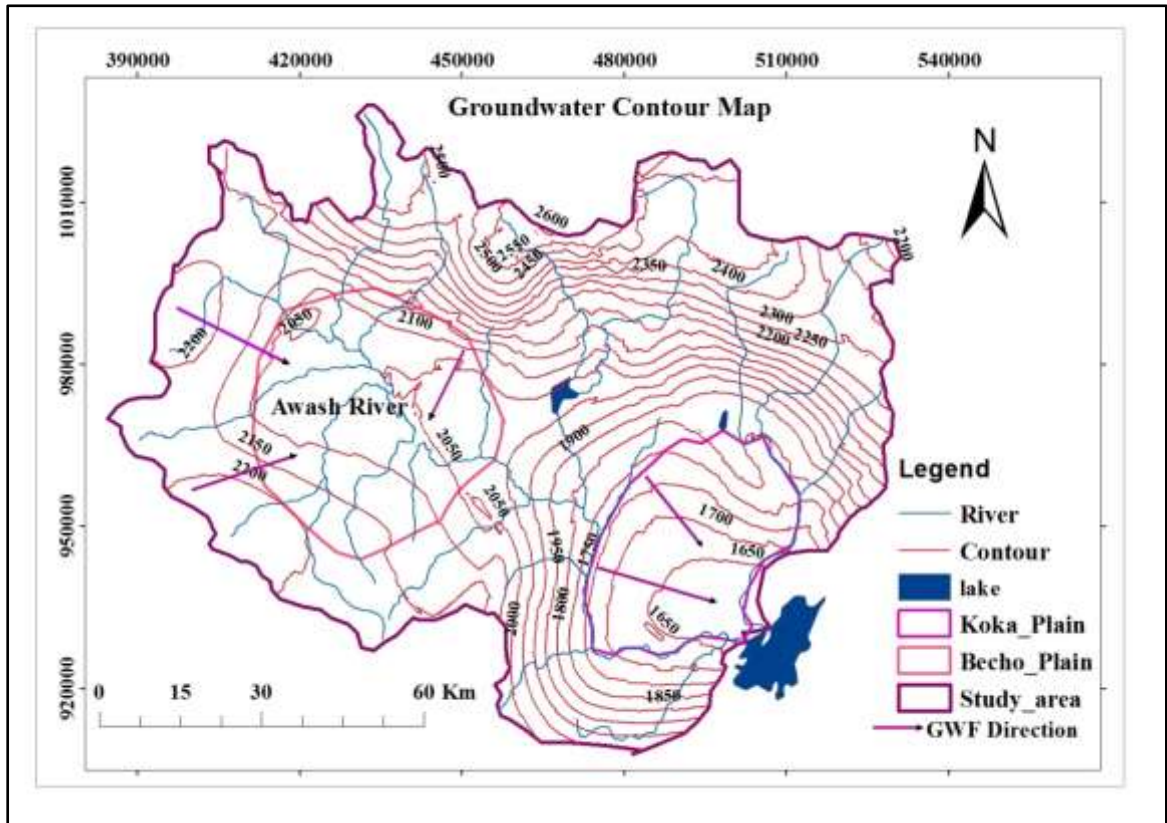


Figure 4.9: Groundwater table contour map

4.4 Hydrodynamic behavior of the shallow groundwater table

The study area is known by their flat topography and very shallow groundwater in the upper Aquifer. Piezometers were used to monitor groundwater from Grofutures project. In the specified location there are six monitoring wells; two monitoring wells (K1 and K2) are located in Koka plain and the rest four monitoring wells (B1, B2, B3 & B4) are located in Becho plain and their locations are illustrated in table 4.4 and Fig.4.9 below.

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Table 4.4: location of monitoring wells.

Id	Types of water source	Local name	W.point index	UTME	UTMN	Elevation m.a.s.l	SWL
1	Borehole	Koka	K1	505752	932604	1605m	2.69
2	Borehole	Koka	K2	505718	933289	1595	1.5
3	Borehole	Teji	B1	427190	971656	2122	7.39
4	Borehole	Teji	B2	427921	972156	2076	7.02
5	Borehole	Teji	B3	426867	971737	1796	7.37
6	Borehole	Bello	B4	435067	977971	2024	5.8

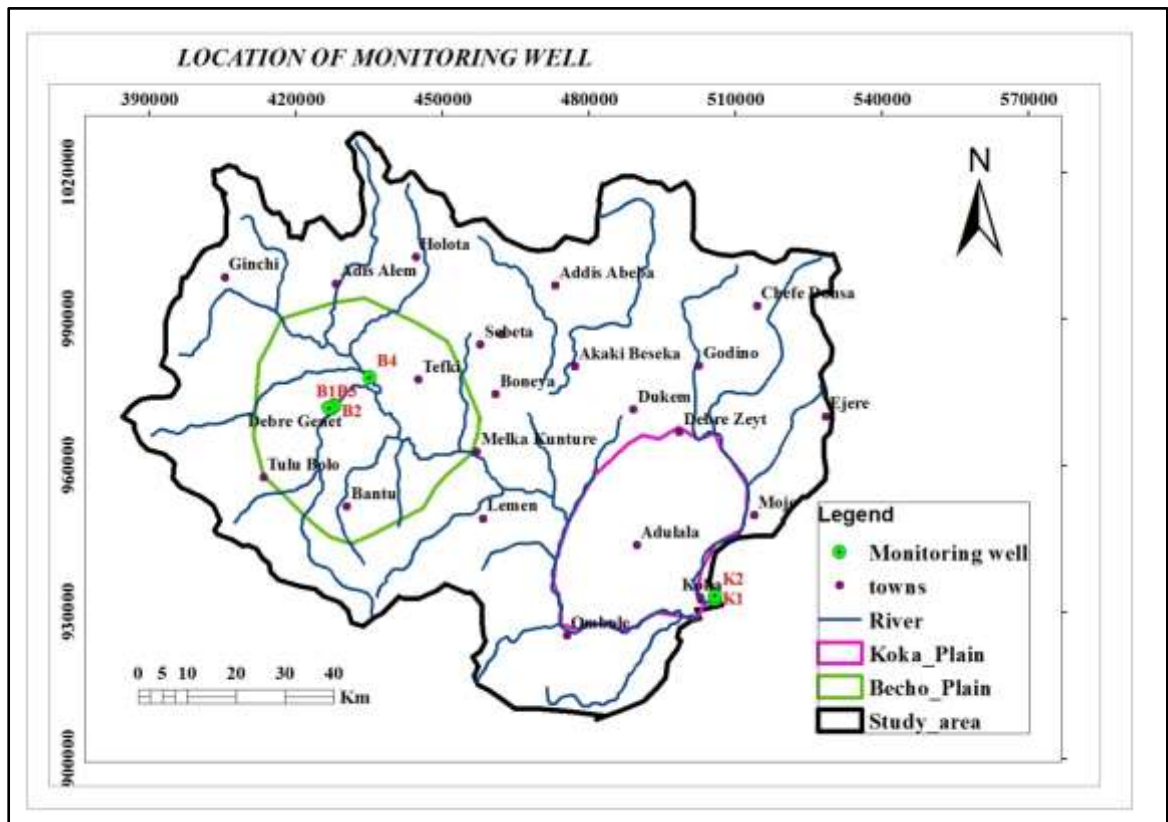


Figure 4.10: Location Map of Monitoring Well

These monitoring wells are drilled very systematically by Grofutures Project to address the effect of irrigation return water, effect of river water and the effect of rainfall on

shallow groundwater dynamics. Comparison between ground water level at monitoring points to rainfall data and surface water shows the piezometer can be classified based on the two main criteria.

- (1) .The distance to surface water courses (influence of surface water).
- (2).The location within or outside agricultural areas (influence of irrigation).

Based on the two above criteria, monitoring wells are classified in to four groups;

(i).Piezometers located far from a surface watercourse (beyond 1000 m from the river) and outside any irrigated area.

B2 and B1 located in Becho plain at about more than 1km distance from Teji River and also outside an irrigated field. On chart below the depth increases during the rainy season and gradually decreases during dry season. The water level respond to rainfall.

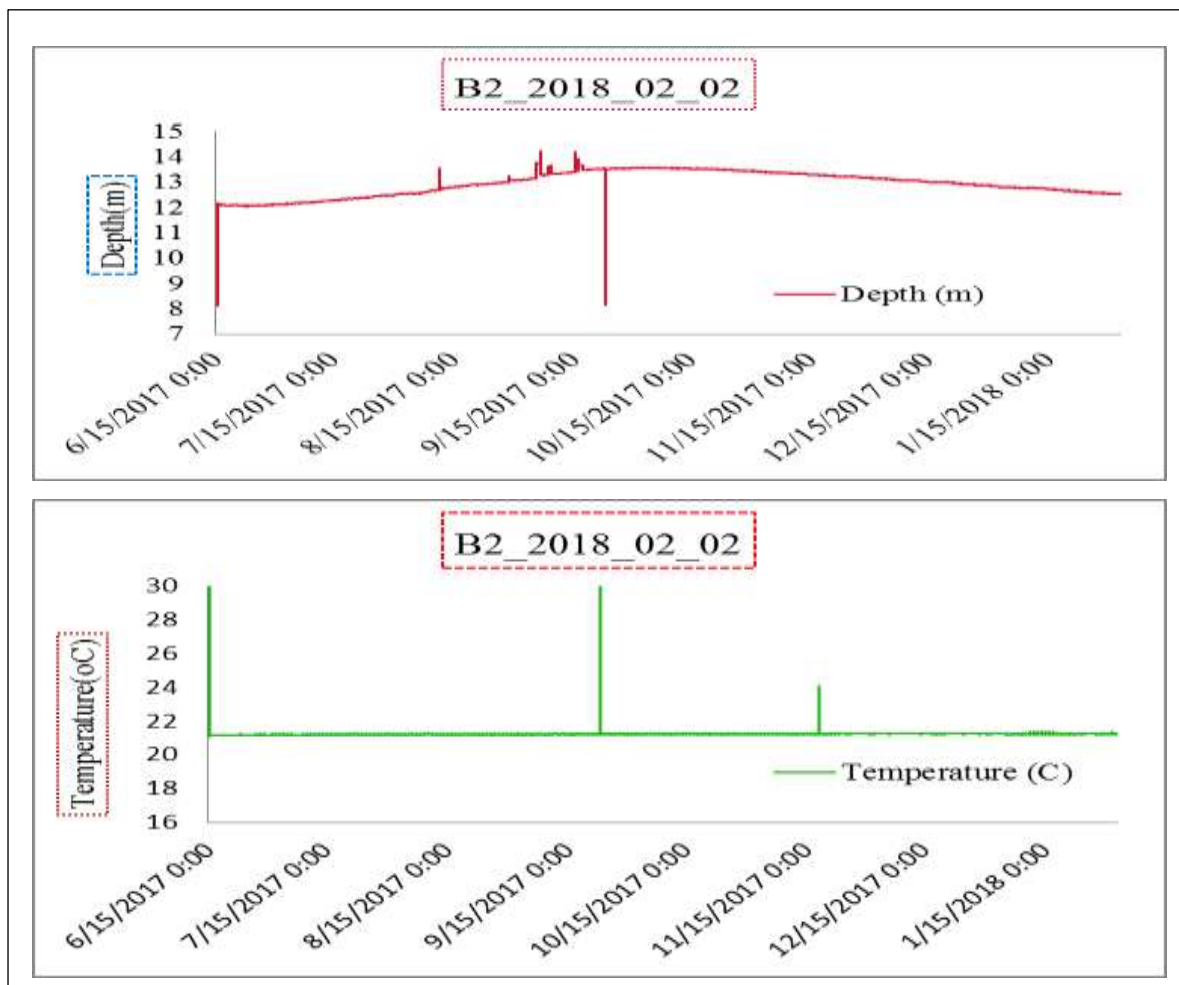


Figure 4.11: Piezometer located outside an irrigated field and at a distance from surface water courses (B2)

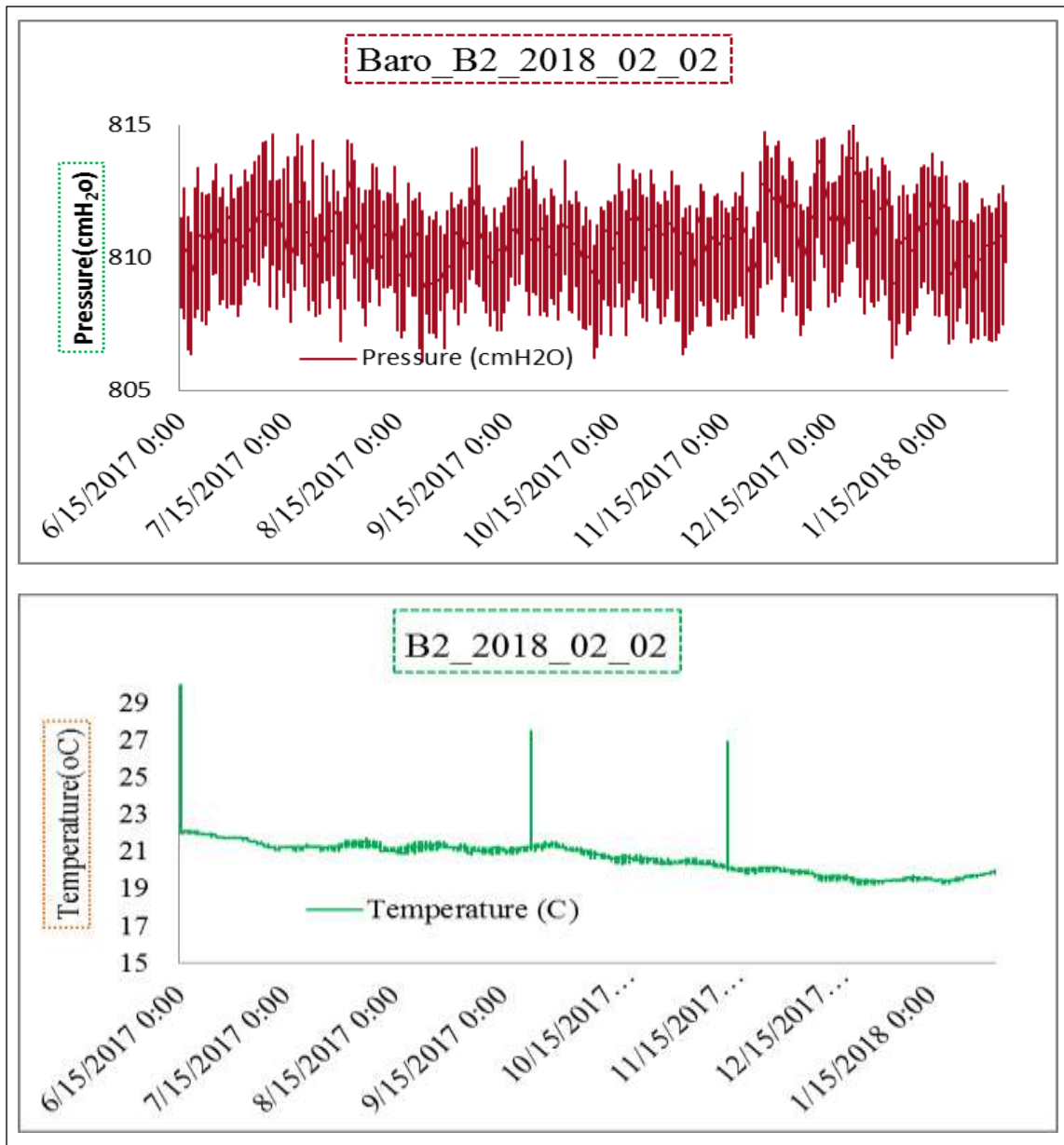


Figure 4.12: Temperature and Pressure graph from BaroTroll at Becho.

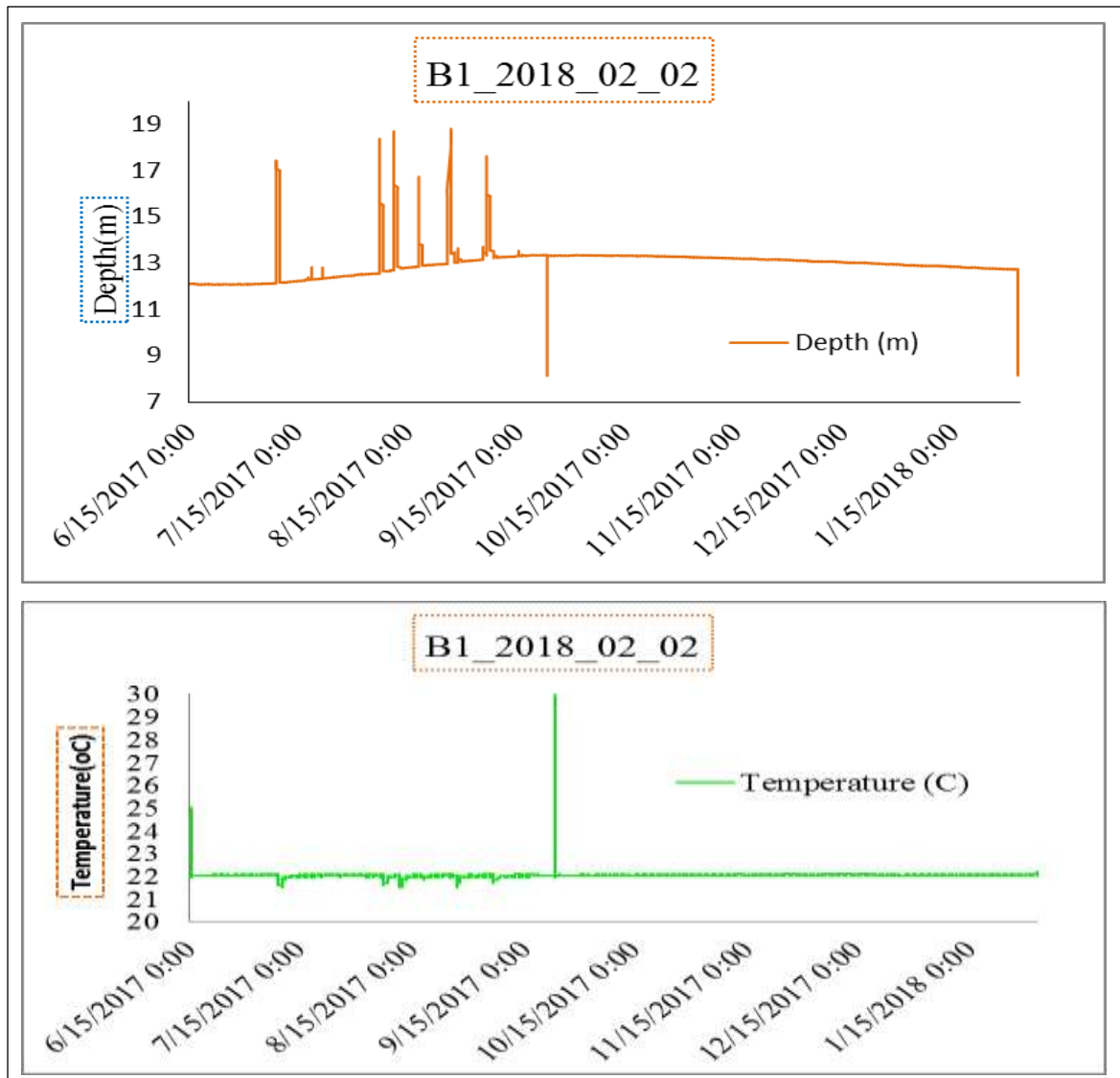


Figure 4.13: Piezometer located outside an irrigated field and at a distance from surface water courses (B1)

(ii). Piezometers close to a surface watercourse (Awash River and its tributaries) but outside any irrigated area.

The monitoring well (B4) located at Awash Bello and drilled very close to awash river, about 5m from the channel of awash river but outside an irrigated area. This monitoring well was drilled to understand the effect of surface water on shallow groundwater level. The piezometer data shows that the water level with in the well decreases gradually from the offset of rainy season (Onset of Dry season). Therefore, surface water doesn't contribute for shallow groundwater.

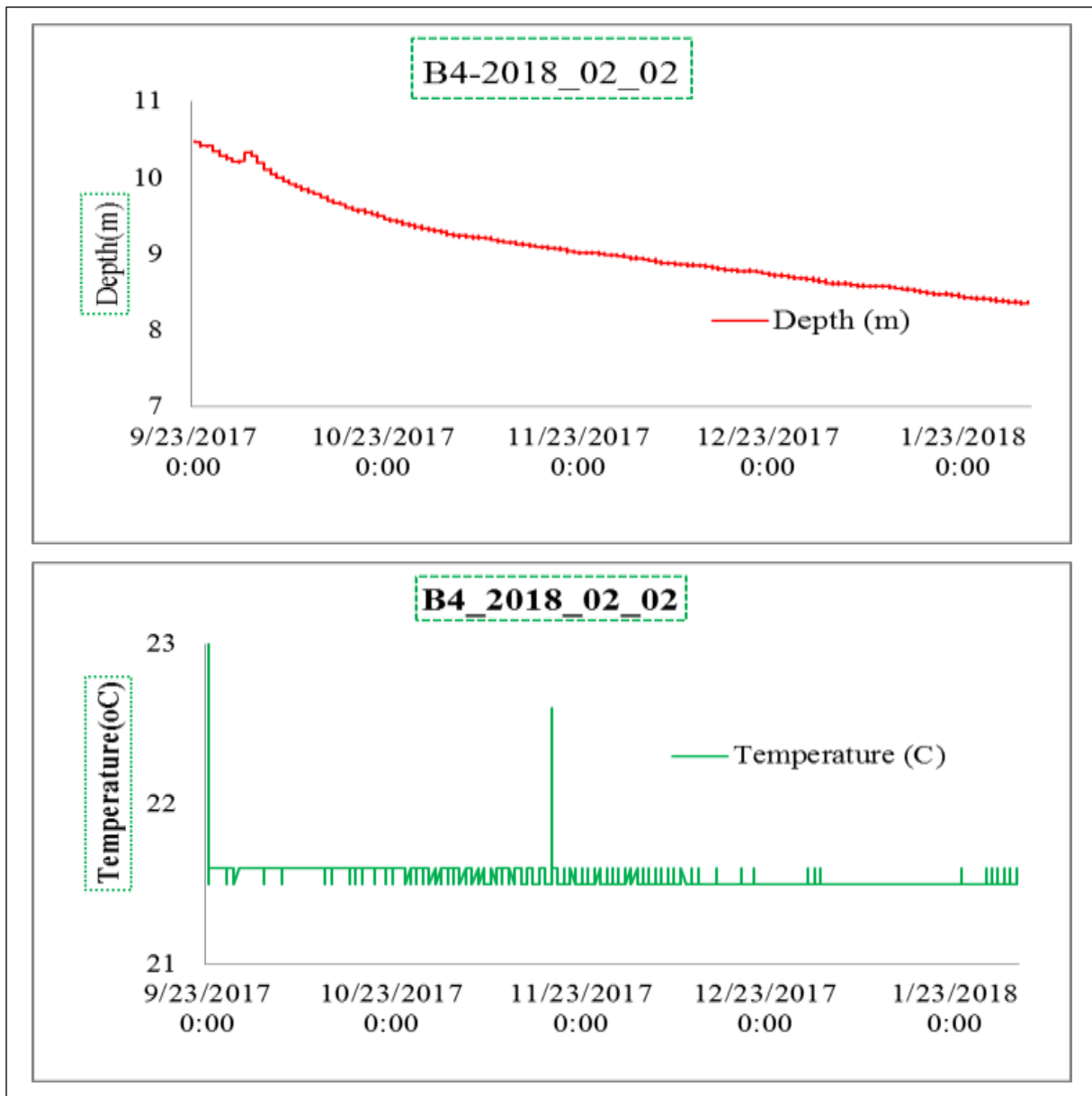


Figure 4.14: Piezometer close to surface water courses and but outside any irrigated area.

(iii).Piezometers located far from any surface watercourse but located in irrigated areas;

The monitoring well located in koka plain (K1and K2) are classified under this group. They are located in plain areas of koka at distance from surface water course but in irrigated area. Because of topographic effect, the groundwater of koka plain is shallower than that of becho plain. Since the soil in koka plain shows large cracking during dry season, it allows down ward infiltration of irrigation return water and contributes for shallow ground water. Both rainfall and irrigation return water contributes for groundwater in Becho plain.

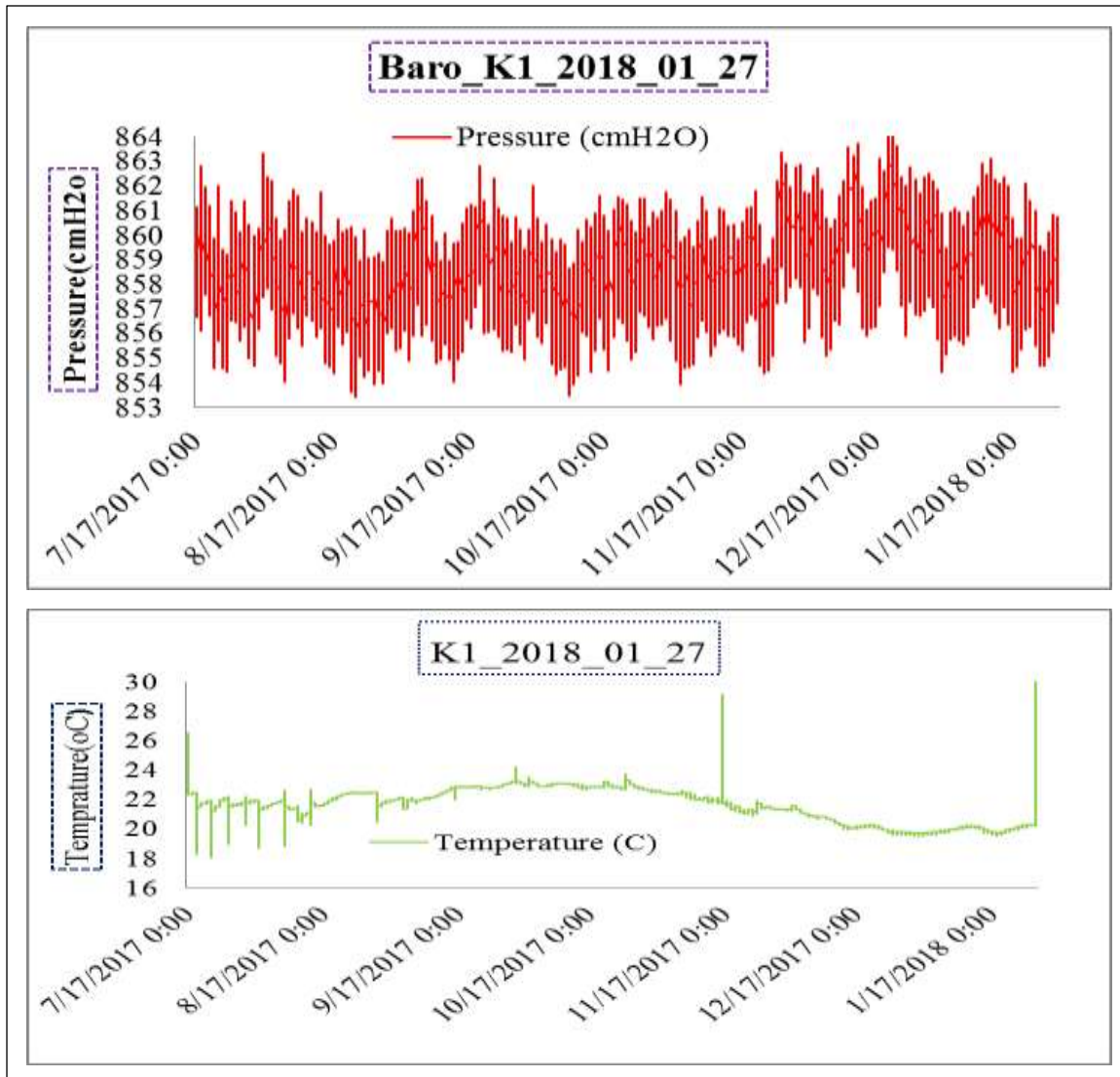


Figure 4.15: Temperatures and Pressure graph from Baro Troll at K1

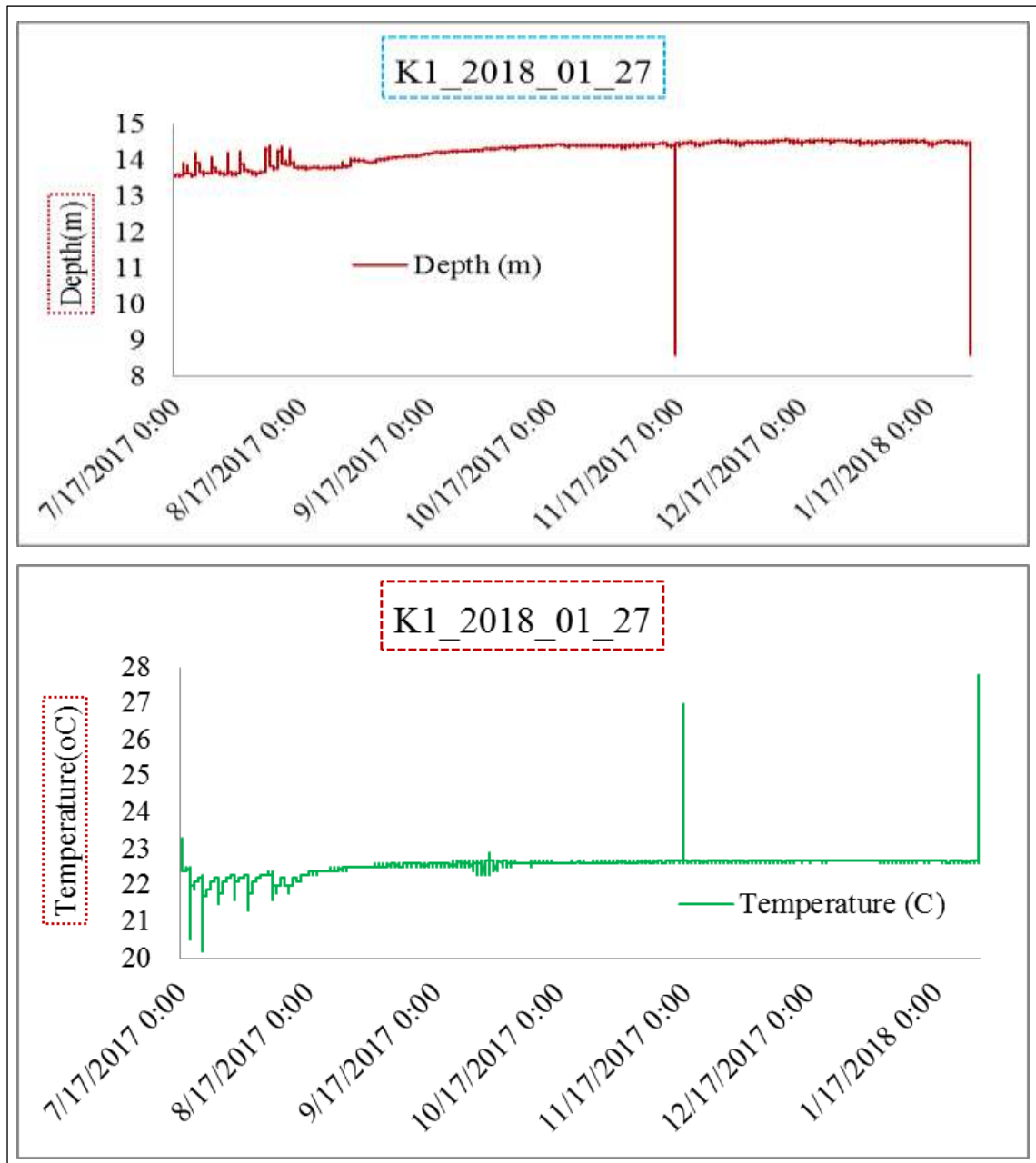


Figure 4.16: Piezometer Located irrigated area and at a distance from surface water course.

(iv). piezometers, both close to a surface watercourse and located in irrigated areas.

Well located in irrigated Area (B3) near Teji River is good example of this group. The depth of the water with in the well decreases sharply during dry season, even if its located very close to river and in irrigation field. This indicates that both irrigation return water and surface water doesn't contribute for groundwater.



plate 4.2: photograph of the well located in irrigated field and very close to Teji River

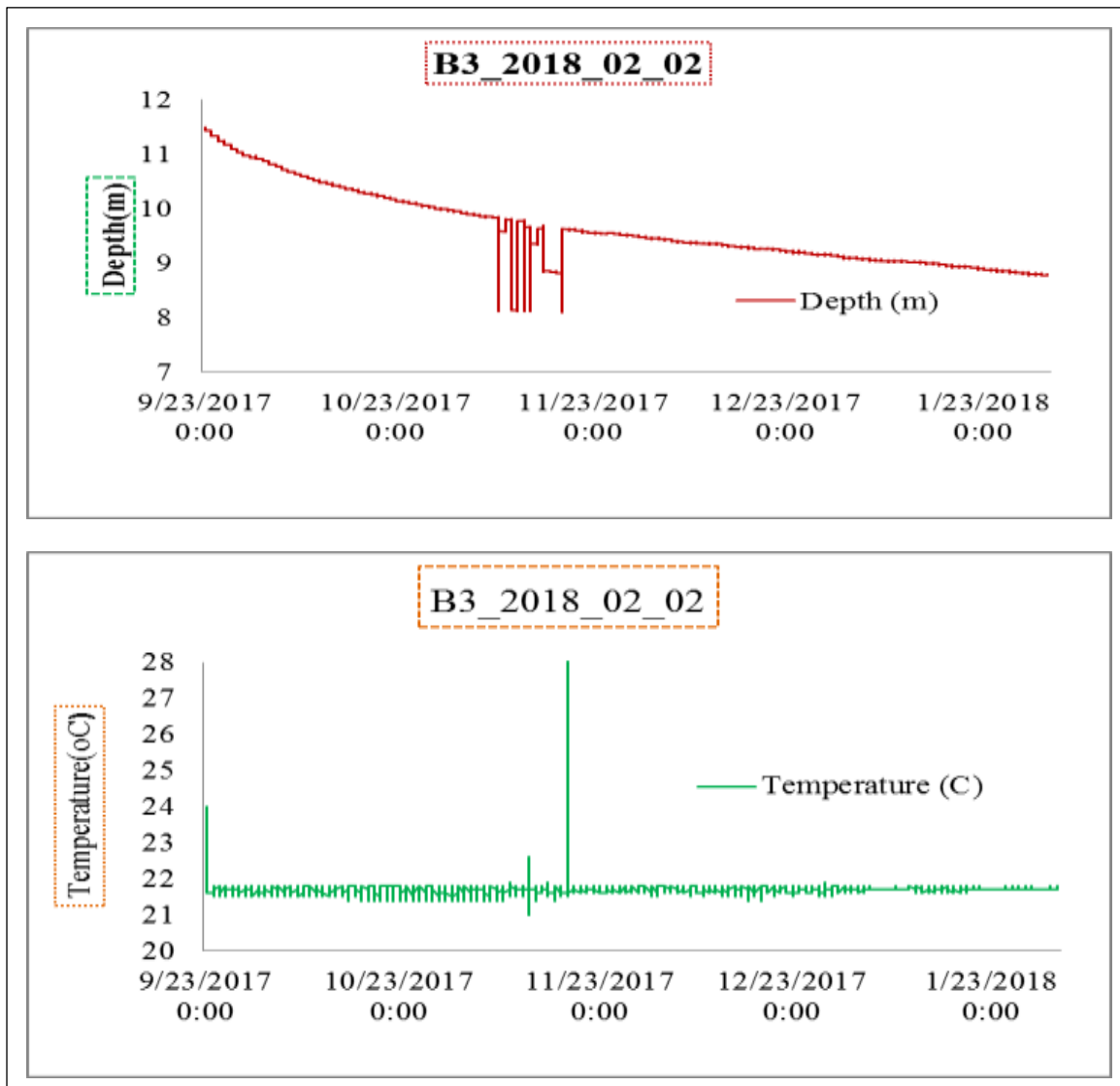


Figure 4.17: Piezometer very close to surface water and located in irrigated field

Generally, the piezometer data indicates that the temperature of shallow groundwater is more or less the same with that of surface temperature and has an inverse relationship with depth; i.e. when the water level increases the temperature of the groundwater decreases and when the water level decreases, the temperature of the ground water increases. Due to topographic effect, the groundwater is shallower in Koka plain than becho area. The lacustrine deposit of koka plain shows large cracking during dry season, and it permits infiltration of irrigation return water. The top most layer of becho plain is Clay (impermeable layer) which is a barrier for infiltration of water to groundwater table. This implies that both irrigation return water and surface water body has no contribution for shallow ground water in Becho area.

CHAPTER FIVE

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study area is located in Upper Awash River sub-catchment and has a total area of about 3000km². Geographically, becho plain is located between 38.19⁰ – 38.61⁰E and 8.54⁰ – 9⁰⁰'N whereas, koka plain located between 38.75⁰ – 39.12⁰E and 8.38⁰ – 8.76⁰N. The average altitude of the target area ranges between 2500m to 1598m m.a.s.l. The present study focuses on evaluation of comparative shallow groundwater dynamics of Becho and Koka plains. Characterization of shallow groundwater dynamics will provide vital information for future sustainable use of shallow groundwater resource.

The mean annual rainfall and mean monthly temperature of Becho plain is 1050 mm and 18 °C respectively, whereas, Koka plain gets 841mm mean annual rainfall and 21°C mean monthly temperature. There are two seasons of rainfall in the specified study area. The first rainy season spans from late May to late September and the second from mid of March to mid of April.

The dominant lithology that covers becho plain is Addis Ababa ignimbrite, alluvial deposits; central volcanics of Wechecha Furi Yerer and Entoto becho rhyolite are exposed in Becho_Plain. Lacustrine deposit, Ziquala trachyte, Beda Gebaba volcanic unit and Bishoftu volcanic units are exposed in koka plain. The Abay plateau and the Guraghe highlands are the surface water divide of the upper awash sub- basin.

Naturally occurring long-term mean annual ground-water recharge on a study area can be estimated using a water-balance approach coupled with an automated base flow separation techniques. Actual Evapotranspiration was computed by using Turc formula. The average actual evapotranspiration calculated by Turc formula is 614.55mm/yr. for Becho plain and 551.7404mm/yr. for Koka plain. Based on these evidences groundwater recharge was evaluated using the water balance method and base flow separation techniques. Therefore, the water balance method give recharge of the Becho plain is 235.029mm/yrs., this means 23.38% of annual precipitation was recharged to groundwater and the recharge of Koka area is 22.2627mm/yrs., and i.e. only 2.65% of the annual precipitation is recharged to groundwater. Time-series of base flow has been seen as useful as a measure of the dynamic behavior of groundwater in a catchment,

whereas the base flow proportion of the total flow has an index of the catchment's ability to store and release water during dry weather. Awash at Bello and Awash at Melka Kunture Comprises high index of baseflow that would imply that the catchment has more stable flow regime and is thus able to sustain river flow during extensive dry periods.

The rate of groundwater flow depends on the permeability (Effective porosity) and the hydraulic head (water pressure). In the study area, the awash river emerge from the western and surrounding plateau from an average altitude of 3000m around Ginchi highland, Guraghe highland, Furi, and Wechecha mountain. The Awash River flows toward south eastern direction from western plateau (Ginchi&wonchi.mt) to Koka Lake (southeastern limit of the study area). Generally the western, north western and Guraghe highlands are the major recharge zone for both plains. The unconsolidated sediment in Becho plain and lacustrine sediments in Koka plain is known by their shallow groundwater in the upper aquifer. The water table Contour map and the cross sectional map (see fig 4.8&4.9 above) clearly shows that the groundwater flow direction of the study area depends on topography, lithology and geological structures. Groundwater water flow direction of becho plain is governed by Topographic effect; i.e. ground water flows from western, northwestern plateau, Guraghe highland, Wechecha and Furi mountain toward the Awash river through becho plain. And the governing factor for ground water flow direction of the Koka plain is geological structures and topography. The ground water flows from Debrezeit and Mojo toward the koka reservoir by following geological structure and from hilly mountain of koka reservoir and Ziquala Mountain toward koka dam. Major factors affecting the dynamic patterns of groundwater, such as topography and landform, depth of groundwater level, exploitation or discharge extent, rivers and lakes, the dynamic regions of Becho and koka groundwater were gotten. The groundwater dynamics of study area is influenced by the climate, geology, hydrology, hydrogeology and human activities etc. The hydrodynamics behavior of the shallow ground water in the study area is monitored at six monitoring wells. These monitoring wells are drilled very systematically to address the effect of surface water, irrigation return water and rain water on shallow groundwater level, temperature and pressure. These monitoring wells are grouped into four based on their distance from surface water and effect of irrigation; (1) piezometers located far from a surface watercourse and outside any irrigated area, (2) piezometers close to a surface watercourse (Awash River and its tributaries) but outside any irrigated area, (3) piezometers located far

from any surface watercourse but located in irrigated areas and finally (4) piezometers close to a surface watercourse and located in irrigated areas.

Generally, the piezometer data indicates that the temperature of shallow groundwater is more or less the same with that of surface temperature and has an inverse relationship with depth; Due to topographic effect, the groundwater is shallower in koka plain than becho area. The lacustrine deposit of koka plain shows large cracking during dry season, and it permits infiltration of irrigation return water. The top most layer of becho plain is Clay (impermeable layer) which is a barrier for infiltration of water to groundwater table. This implies that both irrigation return water and surface water body has no contribution for shallow ground water in becho area.

5.2 Recommendation

Groundwater monitoring has been given a very little consideration in the study area. The local communities drill the shallow well for irrigation purpose and they kept open, this may leads to direct groundwater evaporation and make ground water susceptible to pollution.

In this study, it was also planned to test soil moisture variability of the target area, however due to political unrest and time constraints it becomes impossible. For the future, it is highly recommended to perform soil moisture variability test and identify its relation with shallow ground water of the area.

It is highly recommendable to perform pumping test for the shallow groundwater in the focused areas that will enable the researcher to detail characterization of the aquifers.

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APPENDIX

Appendix.1 Organization For data Source

Organization	Location
Oromia Water Resources Development Bureau	Addis Ababa
Oromia Water Works Construction Enterprise.	Addis Ababa
Addis Ababa University	Addis Ababa
Ethiopian Geological Survey	Addis Ababa
Water Well Drilling Agency	Addis Ababa
Ministry of Water Resources	Addis Ababa
Zonal Water Mines and Energy Offices	Project area

Appendix.2 Mean annual Rainfall of the study area.

St.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	An
Mojo	8.33	18.4	41.4	56.5	44.2	81.9	41	162	88.6	23.2	7.31	1.48	77 5.
Homb ole	6.45	34.1 7	54.1 3	56.5	45.4 4	86.6	208 .98	180. 43	70.4 1	26.7 6	8.35	4.7	78 2.9
D.zeit	10.3 7	20.1 1	51.5	55.9 5	42.4 14	99.9	222 .75	209. 7	99.1 35	27.7 4	6.3	6.05 6	85 1.9
Koka Dam	14.4 2	24	54.7	57.3 96	61.1 125	71.3	241 .67	266. 8	115. 85	28.6 9	10.7 4	7.02	95 3.8
Avera ge	9.89 6	24.1 78	50.4 5	56.5 9	48.2 96	84.9 5	228 .68	204. 8	93.5 1	26.6 2	8.17 5	4.8	84 0.9 5
Tulu bolo	11.4 1	11.8 56	43.9	64.7	96.1 32	217. 95	276 .35	285. 07	117. 14	16.3 1	4.21	5.08	11 50. 1
Teji	12.6 5	26.0 88	52.4 6	67.4 96	74.3 44	138. 4	217 .27	215. 4	99.9	22.1 3	7.94	5.07 6	93 9.1 5
Tefki	3.72	36.3 8	26.1 5	55.1 17	64.8 7	120. 17	186 .18	224. 3	119. 9	18.5 2	17.6	10.4 3	88 3.3 4
Bantu _liben	16.8 2	14.5 6	58.8 5	85.4 9	70.1 55	176. 23	315 .57	320. 59	140. 34	44.2 1	15.1 5	5.07	12 63

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Asgori	19.3	25.8	45.2	78.6	71.9	146.	249	240.	108.	19.2	7.35	3.69	10
		68	5	19	55	285	.17	12	21			5	15.0
Average	12.7	22.9	45.3	70.2	75.4	159.	248	257.	117.	24.0	10.4	5.87	10
	811	508	247	845	905	803	.90	097	101	783	499	279	50.
	7	2	7	2	3	9	9	5	2	6	6	2	1

Appendix.3 Mean maximum and minimum Temperature of the study area

Temp. (OC)	Jan	Fe	Mar	Apr	Ma	Jun	Jul	Aug	Sep	Oct	No	Dec	Ave
Koka. (min)	12.3	13.	14.8	15.5	15.7	15.2	14.7	14.84	14.89	13.2	12.8	11.7	14.2
Koka.D (Max)	29.5	30.	31.9	31.8	32.6	31.8	29.7	29.57	30.25	29.4	28.8	28.6	30.4
Koka (Ave)	20.9	22.	23.4	23.6	24.2	23.5	22.2	22.20	22.57	21.3	20.8	20.1	22.3
D.zeit (MaX)	26.6	28.	28.5	28.6	29.2	27.6	24.5	24.07	25.35	26.3	25.9	25.8	26.7
D.zeit (Min))	9.49	10.	12.3	13.5	13.1	13.0	13.5	13.68	12.53	10.0	8.85	8.62	11.6
D.zeit (Ave)	18.0	19.	20.4	21.0	21.1	20.3	19.0	18.88	18.94	18.1	17.4	17.2	19.2
Mojo (Max)	28.	29.	30.	30.	31.	29.	26.	25.9	27.3	28.	28.	28.	28.
Mojo (Min)	12.	13.	14.	15.	15.	15.	14.	14.8	14.8	13.	12.	11.	14.
Mojo (Ave)	20.	21.	22.	23.	23.	22.	20.	20.3	21.1	20.	20.	19.	21.
Koka	19.	21.	22.	22.	22.	22.	20.	20.4	20.8	20.	19.	19.	21.

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Area													
Tefki (max)	27.	28.	28.	29.	28.	26.	24.	24.3	25.2	26.	27.	26.	26.
Tefki (min)	7.4	8.9	11.	12.	12.	12.	12.	12.7	11.4	7.9	7.5	5.4	10.
Tefki (Ave)	17.	18.	20.	20.	20.	19.	18.	18.5	18.3	17.	17.	16.	18.
Tulu B (Max)	25.	25.	26.	26.	26.	25.	23.	23.6	23.9	24.	24.	24.	24.
Tulu B (Min)	8.9	9.4	10.	10.	10.	10.	10.	10.3	9.82	9.1	8.3	7.9	9.7
Tulu B (Ave)	17.	17.	18.	18.	18.	17.	17.	16.9	16.8	16.	16.	16.	17.
Asgori (max)	28.	28.	29.	28.	28.	27.	25.	25.0	25.7	26.	26.	26.	27.
Asgori i(min)	7.2	8.1	9.5	10.	10.	10.	11.	11.1	10.1	6.4	5.3	5.2	8.8
Asgori (Ave)	17.	18.	19.	19.	19.	19.	18.	18.1	17.9	16.	16.	16.	18.
Becho Area	17.	18.	19.	19.	19.	18.	17.	17.8	17.7	16.	16.	16.	17.

Appendix. 4 Shallow well used for groundwater table contour

ID	Local Name	UTME	UTMN	Z_DEM	W_DEP.	SWL	RWL__MASL
1	Girmi	519000	988000	2340	2	1	2339
2	Girmi Ademi	519000	987000	2314	1	1	2312.80005
3	Debre Zeit	510000	973000	1903	2	1	1902.69995
4	Ejere	528000	969000	2200	1	1	2199.3999

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5	Ejere	528000	974000	2335	1	1	2334.3999
6	Girmi	514000	960000	1913	34	32	1880.80005
7	Girmi	513000	960000	1899	33	32	1867.09998
8	Girnu	513000	960000	1899	28	28	1871.40002
9	Keraro,	512000	952000	1784	32	31	1753.30005
10	Keraro,	511000	952000	1804	35	33	1770.69995
11	Debandiba	510000	953000	1808	36	35	1773.09998
12	Momo,	509000	952000	1808	30	28	1779.5
13	Momo,	509000	951000	1799	30	29	1770.09998
14	Momo	509000	952000	1808	25	24	1783.90002
15	Momo	509000	952000	1808	26	25	1782.59998
16	Biyo	509000	953000	1815	21	20	1795.30005
17	Biyo	509000	953000	1815	18	18	1797.19995
18	Biyo	509000	953000	1815	18	17	1797.69995
19	Biyo	509000	955000	1833	19	17	1815.5
20	Biyo	509000	955000	1833	18	18	1815.19995
21	Biyo	507000	954000	1844	21	21	1823.40002
22	Biyo	507000	954000	1844	26	25	1818.90002
23	Biyo	507000	955000	1843	32	32	1811.5
24	Biyo	507000	955000	1843	37	35	1808.30005
25	Biyo	507000	954000	1844	32	31	1813.19995
26	Biyo	507000	954000	1844	30	29	1814.69995
27	Biyo	507000	954000	1844	29	29	1815.09998
28	Biyo	507000	953000	1835	29	28	1807.40002
29	Biyo	507000	953000	1835	23	23	1812.30005
30	Biyo	507000	954000	1844	45	44	1800
31	Amenese,	506000	954000	1864	55	53	1810.5

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32	Amenese	506000	954000	1864	52	51	1812.5
33	Amenese,	506000	954000	1864	52	51	1812.5
34	Amenese	506000	954000	1864	46	46	1817.90002
35	Amenese,	506000	954000	1864	45	44	1819.80005
36	Amenese,	507000	954000	1844	37	37	1807.30005
37	Amenese,	506000	954000	1864	43	42	1821.09998
38	Amenese,	504000	955000	1903	40	40	1863.80005
39	Amenese,	504000	955000	1903	40	39	1864.40002
40	Amenese,	504000	955000	1903	41	40	1863.09998
41	Amenese,	504000	955000	1903	41	40	1863.30005
42	Amenese,	506000	956000	1878	40	40	1838
43	Amenese,	506000	957000	1869	30	30	1839.5
44	Amenese,	507000	957000	1853	28	27	1825.80005
45	" Bahara dug w	505000	957000	1899	31	30	1869.19995
46	" Tesema	505000	957000	1899	31	31	1868.69995
47	" Negatua	505000	957000	1899	30	30	1869.40002
48	" Negatua	505000	957000	1899	34	33	1866.40002
49	" Bezunesh	504000	959000	1877	21	21	1856.40002
50	" Biro Bati	504000	951000	1961	21	21	1940.5
51	" Blacha	504000	956000	1907	25	24	1883
52	" Shiferaw	504000	956000	1907	24	24	1883
53	" Demu Tuffa	504000	956000	1907	28	28	1879.40002
54	" Yemane	504000	956000	1907	30	30	1877.19995
55	" Yilma	504000	958000	1898	37	32	1866.19995
56	" Bekele	504000	958000	1898	33	18	1880.59998
57	" Bayu Desta	504000	958000	1898	19	15	1883.59998

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58	Kujbursa,	503000	959000	1890	16	12	1878.19995
59	" Bizunesh d.w	504000	960000	1870	13	17	1853.30005
60	" Betru Wosen	503000	960000	1883	17	26	1857
61	" Yebdar Biru	502000	961000	1898	26	26	1871.09998
62	" Feyisa	501000	960000	1913	22	22	1891.09998
63	" "	500000	960000	1911	34	34	1877.59998
64	" Yiilma	501000	962000	1881	34	33	1848
65	" Lema Amine	501000	962000	1881	30	30	1851.69995
66	" Dejzasmach	502000	962000	1888	27	26	1861.19995
67	" Kidane	502000	962000	1888	28	28	1860
68	" Yai Hawassa	501000	963000	1877	30	30	1847
69	" Magra Abdi	501000	963000	1877	31	31	1846.09998
70	" Yimenu d.w.	502000	964000	1873	30	29	1843.5
71	" Major	504000	963000	1877	27	26	1851.40002
72	" Sofinas	504000	963000	1877	25	24	1852.80005
73	" Bekele	504000	963000	1877	24	24	1853.5
74	" Girma	504000	961000	1875	19	18	1857
75	" Asegid	504000	960000	1870	17	15	1854.69995
76	" Ayelech d.w.	504000	961000	1875	19	18	1856.80005
77	" Gashu	504000	959000	1877	18	17	1859.59998
78	" Betru Adafre	504000	959000	1877	17	17	1860.19995
79	" Senbetu	504000	959000	1877	16	15	1862
80	" Begashu d.w.	503000	960000	1883	19	18	1864.5
81	" Girmu Benti	503000	960000	1883	19	19	1863.90002
82	" Aboye	503000	960000	1883	18	17	1865.09998
83	" Yiheyis	506000	959000	1855	15	14	1840.69995
84	" Biyo Nadi	507000	960000	1856	15	13	1843.30005

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85	" Asefa	507000	960000	1856	13	13	1843.30005
86	Biyo, Taye	508000	961000	1849	10	10	1838.5
87	"	508000	961000	1849	9	9	1839.40002
88	"	509000	961000	1845	9	8	1836.80005
89	" Zewdneshe	509000	961000	1845	11	10	1834.90002
90	" Yisak	506000	958000	1859	27	26	1832.69995
91	" East	507000	956000	1851	23	21	1830.5
92	" East Belda	507000	956000	1851	21	20	1831.30005
93	" " Bajiga T	507000	956000	1851	23	22	1829.40002
94	" " Bizunesh	509000	958000	1849	19	19	1829.80005
95	" " "	509000	958000	1849	20	19	1830.5
96	" " Zebyider	509000	958000	1849	18	18	1831.40002
97	" " Dinku Ab	509000	958000	1849	16	15	1833.69995
98	" " Terefe W	509000	958000	1849	19	18	1830.90002
99	" " Terefe W	509000	958000	1849	20	19	1830.30005
100	Kumburse,	507000	959000	1854	18	17	1836.80005
101	" Ayele Jema	507000	959000	1854	17	15	1839.30005
102	Biyo N.	509000	959000	1844	10	8	1835.80005
103	Biyo N.	509000	959000	1844	14	13	1830.90002
104	Biyo	509000	959000	1844	15	15	1829.19995
105	Biyo N.	509000	959000	1844	19	18	1826.30005
106	Biyo N.	509000	959000	1844	21	21	1823.19995
107	Biyo N	509000	959000	1844	26	25	1818.90002
108	Biyo N.	509000	959000	1844	28	27	1816.59998
109	Biyo	509000	959000	1844	23	23	1821.30005
110	Biyo N.	510000	958000	1847	23	23	1824.30005
111	Biyo N.	510000	958000	1847	25	24	1823.40002

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112	Biyo N.	510000	958000	1847	21	20	1826.69995
113	Biyo	510000	958000	1847	24	23	1824.09998
114	Biyo	507000	958000	1854	39	39	1815.19995
115	Biyo	507000	958000	1854	37	36	1817.80005
116	Biyo	507000	958000	1854	34	33	1821.19995
117	Biyo	507000	958000	1854	32	31	1823.19995
118	Biyo	509000	956000	1884	25	24	1859.59998
119	Biyo	509000	956000	1884	26	25	1859.40002
120	Biyo	509000	956000	1884	26	25	1858.69995
122	Biyo	509000	956000	1884	25	25	1859.19995
123	Biyo	508000	956000	1869	25	24	1844.40002
124	Biyo	508000	956000	1869	26	25	1843.19995
125	Biyo	508000	956000	1869	26	26	1842.69995
126	Biyo	510000	956000	1839	23	23	1816.09998
127	Biyo	509000	955000	1833	18	17	1815.59998
128	Biyo	509000	955000	1833	21	20	1812.90002
129	Biyo	509000	955000	1833	19	18	1814.69995
130	Biyo	509000	955000	1833	20	19	1813.69995
131	Biyo	509000	955000	1833	19	18	1814.90002
132	Biyo	504000	943000	1692	58	57	1634.30005
133	Biyo	504000	947000	1732	40	39	1693.40002
134	Kimbib	504000	947000	1732	28	28	1704.5
135	Kake	504000	935000	1627	18	18	1609.19995
136	Koka	504000	935000	1627	19	18	1609.09998
137	Koka	504000	935000	1627	14	12	1615.19995

Appendix.5 Deep well used for groundwater contour map

ID	WATER_PO	UTME	UTMN	Z_DEM	WE_D	SWL_	RWL_MASL
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MSc Thesis School of Earth science, Hydrogeology stream

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0	AdBh0001	478772	958888	1906	220	102	1803.699951
1	AdBh0002	475705	956271	1902	220	104	1797.699951
2	AdBh0003	481178	958488	1848	140	58	1789.900024
3	AdBh0004	488305	960746	1956	180	121	1835
4	AdBh0019	475571	924071	1745	154	92	1653
5	AdBh0031	512159	946729	1770	141	73	1697.400024
6	AdBh0032	489485	943724	1723	140	75	1648.5
7	AdBh0036	493185	946241	1708	67	36	1671.699951
8	AdBh0037	480641	977009	2119	134	98	2020.5
9	AdBh0038	483567	976037	2133	173	125	2008.099976
10	AdBh0039	496479	965700	1907	104	57	1850
11	AdBh0044	493545	968537	1916	105	67	1848.900024
12	AdBh0045	482463	976154	2156	181	73	2082.800049
13	AdBh0049	483243	961360	1880	170	99	1780.599976
14	AdBh0050	488463	965890	1902	115	94	1808.5
15	AdBh0052	494320	965101	1982	153	110	1871.5
16	AdBh0053	495447	968060	1912	92	48	1863.5
17	AdBh0054	494054	968452	1925	130	66	1858.900024
18	AdBh0055	493179	968613	1912	108	74	1837.699951
19	AdBh0056	488798	972371	1957	132	30	1927
20	AdBh0057	487881	973470	1986	133	60	1926.400024
21	AdBh0060	492987	967055	1948	108	42	1905.099976
22	AdBh0062	501422	973727	1895	80	24	1871
23	AdBh0063	500766	973335	1894	80	23	1871.800049
24	AdBh0064	500494	974376	1902	81	25	1877.099976
25	AdBh0065	500424	974376	1903	82	31	1872
26	AdBh0067	500204	963672	1889	47	32	1857.300049
27	AdBh0068	499131	965767	1895	38	28	1867.400024
28	AdBh0069	499228	964796	1899	80	43	1856
29	AdBh0070	500909	964676	1885	36	24	1861.199951
30	AdBh0071	499148	965330	1898	62	34	1863.800049
31	AdBh0072	507491	952694	1827	102	40	1787.199951
32	AdBh0073	508079	952013	1818	115	8	1810.599976
33	AdBh0075	508995	951614	1804	150	31	1773
34	AdBh0078	509385	950325	1792	150	26	1765.900024
35	AdBh0079	509020	950736	1796	150	29	1767.099976
36	AdBh0080	508684	951058	1802	146	24	1777.699951
37	AdBh0081	507950	951364	1816	150	26	1790.5
38	AdBh0082	503886	958637	1887	37	30	1856.800049
39	AdBh0084	507722	955887	1851	50	32	1819
40	AdBh0085	507714	955875	1851	33	32	1819.300049
41	AdBh0087	512957	947774	1773	134	37	1736.099976
42	AdBh0089	512602	947821	1761	117	39	1721.800049
43	AdBh0090	511927	948292	1764	114	8	1755.599976
44	AdBh0091	511976	948671	1770	80	35	1734.400024
45	AdBh0092	512408	948682	1773	80	34	1739.199951
46	AdBh0093	512011	949196	1765	90	32	1733.099976
47	AdBh0094	513423	948940	1779	100	37	1741.900024
48	AdBh0095	513773	949998	1787	148	40	1747.400024
49	AdBh0101	474683	942441	1827	80	65	1761.900024
50	AdBh0147	502329	929321	1598	130	5	1592.900024

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51	AdBh0149	457823	1002833	2619	104	3	2616.5
52	AdBh0150	448290	1002698	2412	0	10	2402.100098
53	AdBh0152	449177	1002158	2477	0	0	2477.199951
54	Adbh0153	447200	998889	2295	126	0	2294.699951
55	AdBh0154	446338	997431	2259	125	13	2245.399902
56	AdBh0155	446632	994813	2242	80	1	2241.100098
57	AdBh0156	453522	1001474	2568	115	58	2510.199951
58	AdBh0157	457162	1001115	2625	115	7	2618.199951
59	AdBh0158	459689	998340	2593	48	0	2592.800049
60	AdBh0159	446266	1004147	2391	148	37	2354.5
61	AdBh0160	446155	1003073	2389	90	7	2382
62	AdBh0161	444997	1000718	2360	91	38	2322.100098
63	AdBh0162	444626	1001034	2386	0	40	2346.5
64	AdBh0163	444168	998992	2294	98	7	2286.300049
65	AdBh0165	445168	997226	2239	98	0	2238.600098
66	AdBh0166	445942	1001323	2395	99	0	2394.5
67	AdBh0167	445773	1001323	2388	75	30	2358.100098
68	AdBh0168	445099	1003816	2400	130	30	2370.5
69	AdBh0169	443050	1001649	2407	130	24	2383.300049
70	AdBh0170	442635	1001366	2409	220	25	2384.5
71	AdBh0171	443132	1000869	2386	116	30	2355.899902
72	AdBh0172	444677	998215	2288	100	6	2282.199951
73	AdBh0173	444677	998808	2309	100	21	2288
74	AdBh0174	444642	1002960	2426	66	49	2376.300049
75	AdBh0175	443984	999625	2311	70	10	2300.5
76	AdBh0176	444209	998733	2286	98	7	2278.5
77	AdBh0176A	481337	1001017	2637	135	23	2613.600098
78	AdBh0177	441584	1003445	2456	50	11	2444.699951
79	AdBh0178	437892	1008952	2591	13	4	2587.399902
80	AdBh0187	404656	997733	2232	81	22	2210.5
81	AdBh0190	427193	994953	2125	0	2	2122.699951
82	AdBh0191	427164	996290	2157	37	0	2156.800049
83	AdBh0193	434015	1000129	2341	147	5	2335.899902
84	AdBh0194	440110	1001337	2422	153	37	2384.899902
85	AdBh0195	465419	987294	2263	120	15	2247.899902
86	AdBh0196	460810	981473	2229	102	67	2162.100098
87	AdBh0197	460464	974637	2093	61	38	2054.800049
88	AdBh0198	461930	970844	2204	183	144	2059.699951
89	AdBh0199	456740	962388	2006	39	3	2003
90	AdBh0200	454852	962780	2005	56	2	2003.5
91	AdBh0203	458959	953532	2027	130	67	1960.300049
92	AdBh0208	448328	957872	2130	139	85	2044.900024
93	AdBh0210	460062	948743	2103	109	48	2055
94	AdBh0211	459658	946538	2126	103	50	2076
95	AdBh0212	444245	956023	2219	158	96	2122.199951
96	AdBh0214	462875	950361	2075	187	119	1956
97	Adbh0216	462554	944481	2111	127	91	2019.699951
98	AdBh0217	459928	941554	2167	134	78	2089.300049
99	AdBh0218	457905	936566	2263	211	134	2129.600098
100	AdBh0219A	479021	977596	2088	126	66	2022.300049
101	AdBh0236B	462743	1002521	2626	250	35	2590.699951

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102	AdBh0247	463635	988675	2283	83	27	2256.100098
103	AdBh0248	469672	993830	2324	167	17	2307.100098
104	AdBh0249	455450	983014	2110	120	15	2095.199951
105	AdBh0250	455426	982736	2105	150	16	2088.699951
106	AdBh0253	453850	973096	2055	59	56	1998.699951
107	AdBh0254	451420	971692	2066	60	58	2008.199951
108	AdBh0255	444624	978143	2064	65	10	2054.100098
109	AdBh0257	445354	969451	2092	71	39	2053.100098
110	AdBh0258	445144	969045	2088	86	45	2043.300049
111	AdBh0259	453538	982154	2088	80	8	2080
112	AdBh0261	497100	968198	1898	92	36	1861.300049
113	AdBh0262	485970	935007	1707	98	57	1650.599976
114	AdBh0263	481162	935226	1809	200	152	1657.300049
115	AdBh0264	478740	933707	1772	155	117	1654.900024
116	AdBh0290	488161	1002129	2475	102	63	2411.600098
117	AdBh0291A	494036	1010902	2541	154	21	2519.5
118	AdBh0293A	496646	967481	1896	60	20	1875.5
119	AdBh0295	509969	952000	1796	16	15	1781.300049
120	AdBh0295B	492803	969204	1907	116	64	1842.699951
121	AdBh0300	442842	977555	2067	100	14	2053
122	AdBh0301	442811	977625	2065	179	10	2055.100098
123	AdBh0312	408475	952876	2271	50	10	2260.699951
124	AdBh0313	407460	953526	2276	36	9	2267.399902
125	AdBh0314	404050	980200	2225	99	10	2215.199951
126	AdBh0315	404051	980357	2222	83	4	2218.300049
127	AdBh0318	407400	972711	2134	172	19	2114.899902
128	AdBh0323	447966	980422	2064	80	54	2010.099976
129	AdBh0324	461412	986324	2277	145	45	2232.199951
130	AdBh0325	459676	984947	2204	96	28	2175.600098
131	AdBh0326	460937	986565	2277	114	46	2230.5
132	AdBh0328	463599	988583	2283	130	19	2263.399902
133	AdBh0329	463742	985378	2363	125	18	2344.300049
134	AdBh0334	427635	994816	2119	125	7	2112
135	AdBh0335	429252	993949	2110	45	15	2095.399902
136	AdBh0339	436160	1000453	2360	153	37	2322.899902
137	AdBh0340	435382	1000251	2356	206	10	2345.699951
138	AdBh0347	488408	973431	1980	150	43	1937.5
139	Adbh0349	502364	970907	1884	74	24	1860.199951
140	Adbh0351	512282	951356	1774	150	7	1766.400024
141	AdBh0352	512282	951356	1774	123	7	1766.199951
142	AdBh0353	512355	951516	1776	125	9	1766.300049
143	AdBh0354	512356	947895	1753	114	26	1727.5
144	AdBh0355B	466050	993650	2366	137	71	2294.5
145	AdBh0357	445180	1002459	2390	101	23	2366.600098
146	AdBh0361B	471400	988250	2208	88	6	2202.300049
147	AdBh0362	432432	1024464	2607	161	11	2595.199951
148	AdBh0378	496234	939700	1659	12	6	1652.5
149	AdBh0379	498233	939885	1645	8	5	1639.800049
150	AdBh0386	494598	967157	1926	80	67	1858.699951
151	AdBH0393A	474125	1001050	2565	154	28	2536.600098
152	AdBh0395A	466200	1001008	2540	53	23	2517.399902

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153	AdBh0396A	467200	1001017	2536	152	35	2500.600098
154	AdBh0398	412826	949736	2261	50	0	2261.399902
155	AdBh0399	424094	968971	2099	24	22	2077
156	AdBh0400	428566	961644	2134	24	22	2113
157	AdBh0401	429969	952736	2161	0	0	2160.800049
158	AdBh0402	409122	975187	2103	15	14	2088.5
159	AdBh0403	415528	977263	2075	8	7	2068.399902
160	AdBh0403A	475000	1001300	2545	168	74	2471.100098
161	AdBh0404	416140	977209	2074	8	7	2067.899902
162	AdBh0404A	473400	999600	2498	58	21	2477.5
163	AdBh0405	415715	976666	2076	7	6	2070.699951
164	AdBh0406	418707	974898	2077	12	10	2066.899902
165	AdBh0407	423375	973439	2086	20	19	2067.300049
166	AdBh0408	441366	977899	2062	10	8	2054
167	AdBh0409	441901	981393	2064	7	6	2058.300049
168	AdBh0409A	474200	997400	2427	200	0	2426.800049
169	AdBh0410	441831	983807	2078	50	6	2072.199951
170	AdBh0410A	471300	998200	2453	88	17	2436.100098
171	AdBh0411A	469800	996300	2368	52	17	2351
172	AdBh0412A	469900	996000	2350	67	14	2336.300049
173	AdBh0413	491300	1004800	2448	95	5	2442.5
174	AdBh0413A	469800	996200	2369	60	7	2362.100098
175	AdBh0414	478007	971121	2183	186	137	2046
176	AdBh0414A	478450	995600	2358	171	87	2271.399902
177	AdBh0426	440595	1000333	2386	170	81	2305
178	AdBh0427	469725	994250	2328	142	17	2310.800049
179	AdBh0430A	472000	995100	2331	56	44	2287
180	AdBh0433A	471300	995050	2326	114	0	2325.899902
181	AdBh0439A	469700	994500	2339	152	7	2332.600098
182	AdBh0444	424000	952736	2176	112	5	2170.5
183	AdBh0446	474395	995211	2352	153	59	2292.5
184	AdBh0449A	468000	993200	2295	48	17	2278.699951
185	AdBh0451	471200	993700	2305	85	23	2281.899902
186	AdBh0453	473000	992700	2289	121	111	2178.300049
187	AdBh0456	472900	992500	2280	156	90	2190.100098
188	AdBh0458	474300	992700	2280	129	89	2190.699951
189	AdBh0459	475600	994500	2323	139	41	2282.600098
190	AdBh0461A	473200	992400	2287	72	40	2246.899902
191	AdBh0462A	473200	992400	2287	69	29	2257.800049
192	AdBh0463	473100	991900	2285	154	113	2172.399902
193	Adbh0468A	473848	990072	2255	100	39	2215.600098
194	AdBh0471A	473600	988300	2192	102	11	2180.5
195	AdBh0474	473900	989000	2225	201	35	2190.399902
196	AdBh0477	475000	987800	2164	172	28	2136
197	AdBh0485	475335	980717	2074	179	17	2057
198	Adbh0486	476500	981300	2065	53	4	2061.5
199	AdBh0487	476600	981500	2061	126	4	2057.699951
200	AdBh0489	481507	976220	2130	132	120	2010.5
201	AdBh0491	476400	980700	2062	126	53	2008.900024
202	AdBh0495	477400	979500	2084	96	27	2056.5
203	AdBh0497	477232	978999	2077	82	52	2024.800049

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204	AdBh0499	476600	978200	2071	79	46	2024.699951
205	Adbh0500	475300	983800	2122	93	0	2121.600098
206	AdBh0501	473900	1001050	2566	200	15	2551.199951
207	AdBh0501A	475300	984000	2115	129	0	2115.300049
208	AdBh0507	474300	1001005	2521	83	22	2499
209	AdBh0509	467200	1001017	2536	150	35	2500.600098
210	AdBh0510	468400	1001016	2548	192	3	2545.300049
211	AdBh0511	466600	1001003	2518	153	23	2495.5
212	AdBh0512	468300	1001003	2545	63	41	2504.399902
213	AdBh0513	468800	1001007	2540	42	18	2522
214	AdBh0514	468900	1001007	2548	116	72	2476.199951
215	AdBh0515	469900	1001000	2589	80	7	2581.5
216	AdBh0518	474000	999400	2475	50	7	2468
217	AdBh0522	473300	999300	2479	27	18	2460.5
218	AdBh0524	475600	998900	2422	90	20	2402.199951
219	AdBh0525	480400	998500	2458	47	30	2427.800049
220	AdBh0526	476500	998250	2448	58	22	2426.100098
221	AdBh0527	476450	998100	2437	85	11	2425.899902
222	AdBh0527A	463600	988200	2281	64	28	2253
223	AdBh0528	476100	998300	2435	54	17	2418
224	AdBh0536	486200	1001042	2472	100	18	2453.800049
225	AdBh0538	470000	996400	2353	44	14	2338.699951
226	AdBh0540	470100	996100	2351	45	30	2320.5
227	AdBh0548	473400	996400	2354	200	0	2353.5
228	AdBh0549	473400	996300	2352	249	0	2352.199951
229	AdBh0550	473100	996400	2348	249	0	2348.100098
230	AdBh0551	473200	996300	2347	0	57	2289.5
231	AdBh0552	473200	996400	2347	100	0	2346.600098
232	AdBh0553	473300	996100	2347	78	0	2347.399902
233	AdBh0554	473300	996200	2348	56	8	2340.699951
234	AdBh0555	473300	996300	2347	60	59	2288.5
235	AdBh0556	473400	995800	2347	50	6	2341.399902
236	AdBh0558	472900	995900	2359	32	2	2357.699951
237	AdBh0560	473000	996300	2348	80	2	2345.699951
238	AdBh0561	472700	996300	2355	20	7	2348.100098
239	AdBh0562	472500	996300	2361	41	9	2352.399902
240	AdBh0565	471400	995900	2346	67	26	2319.899902
241	AdBh0566	471600	995800	2352	34	19	2332.800049
242	AdBh0567	471500	995900	2349	34	17	2332.399902
243	AdBh0568	471400	995800	2344	64	12	2332.199951
244	AdBh0569	471400	996000	2348	32	23	2325.399902
245	AdBh0570	471500	996000	2350	46	19	2330.399902
246	AdBh0571	471550	995950	2352	44	23	2329
247	AdBh0572	471500	995800	2348	52	16	2331.899902
248	AdBh0573	471300	995800	2342	85	8	2334.800049
249	AdBh0575A	477162	976038	2066	135	42	2023.699951
250	AdBh0575B	477856	976402	2068	151	45	2023.599976
251	AdBh0579	471800	995500	2345	62	8	2337.399902
252	AdBh0580	471300	995400	2332	101	0	2331.600098
253	AdBh0582	471300	994800	2315	62	4	2310.5
254	AdBh0583	470900	994800	2307	119	1	2306.899902

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255	AdBh0584	471700	995100	2326	62	7	2318.800049
256	AdBh0585	471700	995000	2321	80	11	2310.300049
257	AdBh0587	471700	994900	2316	56	10	2305.699951
258	AdBh0588	469300	995500	2356	107	16	2339.5
259	AdBh0590	471700	986600	2259	81	26	2233.399902
260	AdBh0590A	481205	976968	2143	184	121	2022.300049
261	AdBh0591	471200	995700	2343	192	3	2339.600098
262	AdBh0593	471300	996200	2353	47	6	2347.300049
263	AdBh0596	471700	996300	2358	96	41	2317.399902
264	AdBh0598	466300	993100	2336	112	60	2275.800049
265	AdBh0600	466250	993050	2338	142	50	2288.5
266	AdBh0601	467200	993600	2331	84	48	2282.899902
267	AdBh0603	468100	993100	2303	80	50	2253.300049
268	AdBh0604	468100	993200	2299	83	45	2254.300049
269	AdBh0605	471000	993800	2306	76	68	2237.800049
270	AdBh0606	473334	997204	2371	355	4	2366.5
271	AdBh0607	472000	993500	2281	92	51	2230.300049
272	AdBh0609	473100	992600	2289	84	36	2253.199951
273	AdBh0610	473500	992900	2306	162	123	2183
274	AdBh0611	481650	997725	2416	145	43	2372.899902
275	AdBh0612	474300	993300	2319	214	126	2192.800049
276	AdBh0617	473100	991800	2283	94	56	2226.899902
277	AdBh0618	473100	991900	2285	154	113	2172.399902
278	AdBh0619	473050	991800	2281	136	94	2186.600098
279	Adbh0621	470465	991100	2223	124	16	2207.5
280	AdBh0623	470250	991500	2235	40	8	2226.5
281	AdBh0625	470300	991200	2229	20	10	2218.899902
282	AdBh0626	470400	992100	2240	91	11	2229.100098
283	AdBh0629	471400	991000	2248	38	26	2222.199951
284	AdBh0630	473800	990250	2260	75	38	2222.5
285	AdBh0633	473750	990050	2253	146	52	2201.800049
286	AdBh0634	473500	987900	2184	91	9	2175
287	AdBh0636	482770	997150	2387	137	35	2352
288	AdBh0638	473230	988879	2210	68	14	2195.899902
289	AdBh0639	473900	989000	2225	202	45	2179.5
290	AdBh0640	474000	989100	2226	58	18	2207.800049
291	AdBh0641	474100	989000	2221	126	35	2185.800049
292	AdBh0644	474050	996650	2382	400	10	2372.199951
293	AdBh0645	473300	987700	2160	103	45	2115.300049
294	AdBh0646	473300	987300	2157	120	35	2121.399902
295	AdBh0649	475000	985800	2164	120	0	2163.699951
296	AdBh0650	466050	993650	2366	140	71	2294.5
297	AdBh0652	475662	980783	2071	52	27	2043.900024
298	AdBh0656	476369	981717	2089	64	7	2082.399902
299	AdBh0658	476400	980600	2062	120	17	2045.099976
300	AdBh0660	465600	1001855	2555	83	56	2498.600098
301	AdBh0661	476400	984800	2133	90	12	2120.899902
302	AdBh0662	474800	984700	2146	71	1	2145
303	AdBh0666	477446	978851	2081	82	52	2028.5
304	AdBh0668	476500	981500	2062	79	73	1989
305	AdBh0671	476000	980900	2068	40	13	2054.5

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306	AdBh0675	465243	1003393	2635	115	26	2608.600098
307	AdBh0676	475200	999200	2450	51	39	2410.800049
308	AdBh0683	472400	998500	2458	43	5	2452.5
309	AdBh0689	472500	996600	2369	29	7	2361.899902
310	AdBh0694	465507	1002282	2562	178	2	2560.5
311	AdBh0703	470950	995225	2319	115	0	2319.399902
312	AdBh0706	472700	996500	2356	186	3	2353.600098
313	AdBh0708	480629	998771	2487	96	14	2473.699951
314	AdBh0710	470500	994500	2326	170	42	2284.300049
315	AdBh0711	466900	1001005	2537	150	20	2516.5
316	AdBh0713	471400	995900	2346	88	17	2329.199951
317	AdBh0715	478462	977721	2084	150	50	2034
318	AdBh0716	477608	978689	2082	116	58	2024.400024
319	AdBh0717	474225	982650	2155	178	31	2123.800049
320	AdBh0718	474429	986829	2183	187	41	2142.800049
321	AdBh0719	475300	983800	2122	140	0	2121.600098
322	AdBh0720	476350	981300	2068	65	7	2060.699951
323	AdBh0722	480431	998457	2455	181	15	2439.699951
324	AdBh0723	455000	985200	2238	126	51	2187.600098
325	AdBh0726	464300	990600	2292	52	14	2277.600098
326	AdBh0727	473000	992700	2289	90	24	2265.199951
327	AdBh0728	474050	1000875	2560	156	15	2545.600098
328	AdBh0729	473326	986813	2157	87	25	2132
329	AdBh0730	478462	977506	2081	123	50	2031.300049
330	AdBh0730A	474648	985501	2144	117	86	2058.600098
331	AdBh0731	476426	980749	2063	44	4	2058.899902
332	AdBh0732	476430	980669	2062	62	7	2055.800049
333	AdBh0736	489200	1001025	2446	0	31	2415.399902
334	AdBh0737	483093	976323	2156	207	138	2018.599976
335	AdBh0738	462500	987000	2309	137	84	2225.399902
336	AdBh0739	461900	974300	2127	0	38	2089.399902
337	AdBh0745	459700	998075	2581	67	10	2570.600098
338	AdBh0748	476200	998600	2473	66	10	2463
339	AdBh0750	464000	997000	2510	100	51	2458.600098
340	AdBh0751	463700	988500	2278	130	19	2259.199951
341	AdBh0752	486200	1001042	2472	100	10	2461.600098
342	AdBh0753	481200	980000	2159	150	11	2148.300049
343	AdBh0754	470800	982900	2109	114	0	2108.899902
344	AdBh0755	473566	978610	2066	122	24	2042.800049
345	AdBh0756	487300	995300	2364	120	88	2276.300049
346	AdBh0757	481600	982900	2211	120	35	2175.899902
347	AdBh0758	461500	1001023	2590	110	82	2507.899902
348	AdBh0759	466200	988800	2249	100	0	2248.600098
349	AdBh0760	466400	987600	2255	125	18	2237
350	AdBh0761	481200	980000	2159	173	9	2150.399902
351	AdBh0762	481600	982900	2211	120	37	2173.600098
352	AdBh0763	479400	981400	2130	100	3	2126.899902
353	AdBh0764	480900	978800	2134	160	86	2048
354	AdBh0765	479400	981400	2130	74	3	2126.800049
355	AdBh0766	479340	981400	2130	109	1	2128.899902
356	AdBh0767	481600	982850	2210	136	33	2176.5

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357	AdBh0768	479740	981400	2144	126	3	2140.800049
358	AdBh0769	473069	979881	2061	116	6	2055.5
359	AdBh0770	473108	979851	2063	103	7	2055.699951
360	AdBh0771	477972	974859	2084	133	59	2025.300049
361	AdBh0772	478399	975589	2078	122	53	2024.699951
362	AdBh0773	480517	977974	2106	170	65	2040.699951
363	AdBh0774	478713	974977	2087	130	64	2023.5
364	AdBh0775	477992	975552	2073	132	48	2024.5
365	AdBh0776	476574	975607	2074	142	51	2022.5
366	AdBh0777	479696	976936	2093	145	68	2025.699951
367	AdBh0778	479405	976735	2090	151	67	2023
368	AdBh0779	479061	976370	2091	144	67	2023.400024
369	AdBh0780	479246	977104	2081	146	59	2022
370	AdBh0781	479058	976020	2095	130	72	2023.099976
371	AdBh0782	478780	977307	2084	138	61	2022.400024
372	AdBh0783	478808	976867	2076	152	48	2028.599976
373	AdBh0784	478694	976490	2078	119	50	2028
374	AdBh0785	478580	976051	2085	130	59	2025.400024
375	AdBh0786	478347	976752	2071	148	48	2023.900024
376	AdBh0787	478199	976361	2070	144	46	2024.099976
377	AdBh0788	478154	975966	2079	140	54	2024.800049
378	AdBh0789	478019	977985	2077	150	52	2025.099976
379	AdBh0790	477945	976985	2073	148	50	2023.400024
380	AdBh0792	477651	975923	2072	142	48	2024
381	AdBh0793	477477	977216	2068	145	44	2024.300049
382	AdBh0794	477330	976793	2066	130	43	2023.099976
383	AdBh0796	477181	975680	2072	116	51	2021.400024
384	AdBh0797	476454	976951	2063	129	42	2021.199951
385	AdBh0798	476523	976374	2060	60	36	2024
386	AdBh0799	476972	976152	2065	120	40	2024.300049
387	AdBh0800	477185	975729	2071	114	47	2024.400024
388	AdBh0801	479942	977322	2088	0	64	2023.599976
389	AdBh0802	478450	979950	2117	0	56	2061.5
390	AdBh0803	479526	977468	2094	129	72	2022.099976
391	AdBh0804	479021	977596	2088	126	73	2014.900024
392	AdBh0805	478998	977937	2099	130	73	2025.099976
393	AdBh0807	477900	982875	2135	52	20	2114.899902
394	AdBh0808	478775	983133	2164	50	24	2139.800049
395	AdBh0811	486006	974882	2068	0	96	1972.099976
396	AdBh0812	487900	972421	1951	135	76	1874.800049
397	AdBh0814	481694	965913	1925	0	95	1829.400024
398	AdBh0815	484325	969692	1953	0	118	1834.599976
399	AdBh0822	488391	961066	1951	180	148	1802.800049
400	AdBh0833	499700	1008450	2517	0	4	2513.600098
401	AdBh0835	496147	967674	1888	0	40	1847.900024
402	AdBh0838	473350	1003000	2685	150	10	2675.300049
403	AdBh0849	496159	966870	1900	74	41	1859.400024
404	AdBh0855	484190	998500	2492	140	45	2447
405	AdBh0856	485925	1000975	2486	200	8	2478.600098
406	AdBh0857	486000	1001115	2483	130	10	2473.300049
407	AdBh0859	491300	1004800	2448	95	5	2442.5

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408	AdBh0860	482070	999823	2539	117	80	2459.899902
409	AdBh0863	466175	1001800	2566	0	26	2540.5
410	AdBh0864	465900	1002875	2613	110	16	2597
411	AdBh0868	464600	1003075	2633	96	14	2618.5
412	AdBh0869	483750	994550	2346	230	51	2295
413	AdBh0872	476750	985800	2142	86	53	2088.699951
414	AdBh0873	479450	995800	2353	0	32	2321.300049
415	AdBh0878	466440	1001760	2564	66	18	2546.800049
416	AdBh0879	474075	989600	2236	60	24	2212.399902
417	AdBh0881	473760	987300	2182	0	23	2158.600098
418	AdBh0882	473925	987175	2182	72	16	2166.100098
419	AdBh0884	455475	994995	2838	152	61	2777.300049
420	AdBh0886	475650	984750	2119	0	57	2061.800049
421	AdBh0887	467150	992150	2280	94	29	2251.300049
422	AdBh0888	455350	985100	2188	128	70	2118.300049
423	AdBh0889	455300	985250	2198	101	38	2160.800049
424	AdBh0890	455525	984000	2146	124	63	2082.5
425	AdBh0891	455550	983750	2138	181	47	2090.699951
426	AdBh0892	444000	977700	2068	100	17	2050.699951
427	AdBh0895	460850	985850	2251	106	43	2208.100098
428	AdBh0896	460500	986500	2296	100	27	2269.100098
429	AdBh0897	468650	995450	2342	126	26	2316.100098
430	AdBh0898	468650	999800	2488	172	69	2419.300049
431	AdBh0900	467100	1000550	2514	142	12	2502.399902
432	AdBh0901	464500	1003150	2629	0	6	2622.800049
433	AdBh0902	482400	983000	2243	83	56	2186.899902
434	AdBh0903	474500	995450	2346	201	66	2279.600098
435	AdBh0904	468800	996600	2372	124	50	2321.5
436	AdBh0905	468200	1001600	2572	150	46	2526.100098
437	AdBh0907	469050	994450	2329	120	27	2302.100098
438	AdBh0908	468425	996350	2329	68	20	2309.399902
439	AdBh0909	469280	993350	2303	122	20	2283.800049
440	AdBh0910	468875	993750	2304	130	11	2292.800049
441	AdBh0912	473900	993100	2313	201	118	2194.899902
442	AdBh0915	470950	993300	2298	120	19	2278.699951
443	AdBh0917	467250	999800	2513	70	59	2454.199951
444	AdBh0918	474250	996800	2386	205	40	2345.800049
445	AdBh0919	474175	996550	2377	120	40	2337
446	AdBh0920	472700	999800	2503	120	12	2491.399902
447	AdBh0922	476800	994200	2344	151	52	2291.600098
448	AdBh0927	476105	1000050	2477	105	50	2427.300049
449	AdBh0928	475050	985050	2124	24	5	2118.800049
450	AdBh0931	468100	1001625	2582	150	32	2550.399902
451	AdBh0932	463850	993100	2403	150	84	2318.899902
452	AdBh0933	466050	993650	2366	136	71	2294.5
453	AdBh0934	470450	990125	2224	0	15	2209
454	AdBh0935	480395	998100	2440	0	9	2431.899902
455	AdBh0936	471400	988250	2208	84	13	2195.800049
456	AdBh0937	472900	1003550	2710	0	4	2706.199951
457	AdBh0938	475750	993650	2313	149	97	2216
458	AdBh0940	487800	1002200	2478	80	25	2453.100098

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459	AdBh0946	465651	1001575	2545	76	7	2537.600098
460	AdBh0947	465600	1001855	2555	104	13	2541.5
461	AdBh0949	495447	968068	1912	70	50	1861.900024
462	AdBh0954	478347	976752	2071	200	48	2023.900024
463	AdBh0956	475402	976807	2053	63	31	2022
464	AdBh0957	482950	963800	1870	91	67	1803.300049
465	AdBh0958	475780	956477	1904	132	89	1814.5
466	AdBh0961	467853	999379	2467	0	3	2464.100098
467	AdBh0963	472150	993300	2278	150	51	2227.399902
468	AdBh0965	473576	972821	2095	150	74	2021.099976
469	AdBh0966	484475	975622	2110	220	100	2009.599976
470	AdBh0967	489950	976019	2071	220	91	1979.599976
471	AdBh0968	485798	968308	1905	217	69	1835.5
472	AdBh0969	463266	1001971	2604	111	53	2550.699951
473	AdBh0970	465243	1003930	2689	115	26	2662.699951
474	AdBh0971	470110	993850	2322	150	35	2287.199951
475	AdBh0977	474957	982383	2147	135	24	2123.300049
476	AdBh0978	483350	999064	2501	116	59	2441.800049
477	AdBh0979	466350	1001000	2541	153	16	2525.300049
478	AdBh0980	469727	993542	2314	120	22	2292
479	AdBh0981	460121	985966	2254	120	40	2214
480	AdBh0983	470316	991064	2228	170	10	2219
481	AdBh0984	467000	996300	2364	132	52	2312.5
482	AdBh0985	463908	995127	2463	147	40	2422.800049
483	AdBh0988	465410	1002944	2604	124	11	2593.199951
484	AdBh0989	476963	994106	2341	132	73	2268.5
485	AdBh0991	490000	968000	1905	115	95	1810.599976
486	AdBh0992	465161	1003103	2613	67	18	2595.100098
487	AdBh0993	472541	996743	2371	90	52	2319.600098
488	AdBh0994	464538	991302	2309	94	5	2304.199951
489	AdBh0995	475800	1001500	2570	210	97	2473.100098
490	AdBh0996	469804	993691	2322	170	27	2295.600098
491	AdBh0998	476235	995275	2353	151	84	2268.699951
492	AdBh1001	477463	994346	2328	170	92	2236.300049
493	AdBh1003	474556	983625	2162	219	39	2123.600098
494	AdBh1006	499500	964500	1898	72	31	1867.5
495	AdBh1020	494829	967088	1916	80	64	1852.300049
496	AdBh1022	495561	968574	1906	60	50	1856.5
497	AdBh1023	499320	970175	1891	68	19	1872.599976
498	AdBh1024	495765	966397	1905	94	47	1858.599976
499	AdBh1026	498633	970028	1889	74	34	1854.800049
500	AdBh1027	500078	968505	1905	56	15	1890.199951
501	AdBh1030	481878	1000148	2577	140	76	2500.600098
502	AdBh1032	474000	1001000	2570	201	40	2530
503	AdBh1036	488150	1002300	2476	175	26	2449.699951
504	AdBh1037	457030	984617	2218	140	89	2129.600098
505	AdBh1038	480895	977403	2124	104	85	2039.099976
506	AdBh1040	474788	982924	2159	124	24	2135.300049
507	AdBh1042	473466	987247	2170	65	9	2160.800049
508	AdBh1044	458646	984363	2190	161	44	2145.899902
509	AdBh1045	488243	1002102	2475	96	26	2448.699951

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510	AdBh1046	470983	992553	2261	96	33	2228.600098
511	AdBh1047	486000	1000707	2485	54	12	2473.5
512	AdBh1049	474645	985501	2144	68	92	2052.199951
513	AdBh1051	474641	985622	2154	68	8	2145.399902
514	AdBh1060	480965	977576	2129	132	99	2030.5
515	AdBh1063	471799	999371	2478	114	8	2469.800049
516	AdBh1068	481337	982304	2199	135	23	2175.300049
517	AdBh1069	479700	981700	2141	116	20	2120.899902
518	AdBh1070	479000	981400	2128	120	10	2117.600098
519	AdBh1071	500084	1006594	2502	10	9	2493.100098
520	AdBh1087	472200	995700	2358	67	15	2342.699951
521	AdBh1092	473209	996728	2355	300	0	2355.300049
522	AdBh1095	472500	998700	2479	0	14	2464.600098
523	AdBh1099	465600	1001855	2555	153	23	2532.100098
524	AdBh1100	473900	985100	2171	72	8	2163.5
525	AdBh1101	463972	1000788	2517	174	0	2517.100098
526	AdBh1102	464721	996788	2480	200	200	2280.199951
527	AdBh1103	462260	984901	2284	180	83	2201.5
528	AdBh1104	471500	990500	2224	200	12	2211.699951
529	AdBh1105	477515	997474	2405	216	19	2386.5
530	AdBh1106	464031	1002909	2586	200	0	2585.800049
531	AdBh1107	465578	999808	2471	193	0	2471.100098
532	AdBh1108	466050	993650	2366	200	71	2294.699951
533	AdBh1109	483453	994606	2337	182	1	2335.899902
534	AdBh1110	482896	991871	2248	205	14	2233.899902
535	AdBh1111	484152	989566	2206	182	0	2206.300049
536	AdBh1112	481230	992312	2262	200	22	2239.300049
537	AdBh1113	467135	989840	2243	213	3	2240.399902
538	AdBh1114	484900	990700	2233	177	4	2228.600098
539	AdBh1115	468261	990357	2240	213	4	2235.899902
540	AdBh1116	470277	989578	2218	230	13	2205.5
541	AdBh1117	469245	990260	2232	240	0	2232
542	AdBh1118	465741	989188	2254	134	3	2251.199951
543	AdBh1119	468512	989680	2230	130	0	2230.300049
544	AdBh1121	469458	990594	2233	181	0	2233.300049
545	AdBh1122	468196	990422	2241	180	5	2236.600098
546	AdBh1123	467723	990028	2236	161	4	2232.399902
547	AdBh1124	470790	990330	2219	240	0	2218.600098
548	AdBh1125	465591	989872	2267	257	8	2259.300049
549	AdBh1126	465295	990132	2273	200	10	2263.199951
550	AdBh1127	463985	991540	2323	185	25	2297.800049
551	AdBh1128	489127	999697	2441	280	39	2402.100098
552	AdBh1129	480029	998401	2466	144	20	2446.300049
553	AdBh1130	466600	1001250	2532	196	7	2524.600098
554	AdBh1131	486712	1001378	2448	133	0	2448.199951
555	AdBh1133	470450	990125	2224	140	16	2208
556	AdBh1134	471125	989636	2211	153	11	2199.800049
557	AdBh1135	470070	991000	2233	170	10	2223.699951
558	AdBh1136	469500	989600	2224	150	4	2220.199951
559	AdBh1137	463800	994650	2460	147	41	2419
560	AdBh1138	463595	995915	2486	158	66	2419.600098

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561	AdBh1139	482850	989900	2222	168	0	2222.100098
562	AdBh1140	466308	989421	2249	185	4	2245
563	AdBh1141	466200	988800	2249	100	0	2248.600098
564	AdBh1144	469322	1001428	2571	240	0	2570.699951
565	AdBh1145	464031	1002909	2586	200	0	2585.800049
566	AdBh1146	491980	965840	1958	250	140	1818
567	AdBh1148	468196	998300	2425	200	26	2399.800049
568	AdBh1151	470530	991988	2235	170	35	2200.600098
569	AdBh1152	460295	986769	2314	158	31	2282.800049
570	AdBh1153	447549	1007893	2509	203	24	2484.699951
571	AMW12A	477741	965964	2025	188	86	1938.900024
572	AMW12B	490336	970789	1930	282	89	1840.800049
573	AMW14	450359	981037	2076	280	11	2065.300049
574	AMW15	484821	994284	2324	368	42	2282.399902
575	AMW18	433200	959670	2112	194	0	2111.800049
576	AMW2	440274	1006055	2530	300	12	2517.5
577	AMW20	413137	973900	2086	311	10	2076.5
578	AMW21	506765	957179	1855	278	19	1836.099976
579	AMW22A	505014	970969	1884	126	21	1863.5
580	AMW22B	504878	970766	1883	300	20	1862.199951
581	AMW24A	490513	951595	1774	178	101	1672.599976
582	AMW24B	490444	951336	1772	225	98	1673.400024
583	AMW26	427395	992768	2101	220	6	2094.600098
584	AMW3	427126	971361	2084	308	4	2079.800049
585	AMW4	456314	962592	2019	290	0	2018.699951
586	AMW5	478990	955803	1834	330	38	1795.099976
587	AMW8	493518	1004421	2464	354	28	2436
588	AMW9	476790	981229	2078	328	0	2077.800049
589	19	512000	948000	1752	114	35	1716.699951
590	19	512000	948000	1752	114	39	1712.699951
591	22	513000	951000	1779	62	87	1692.099976
592	23	512000	951000	1779	70	58	1720.800049
593	42	502000	933000	1602	70	45	1556.900024

Appendix.6 spring used for shallow Ground water table contour.

ID	Local name	UTME	UTMN	RWL_MASL
1	Chefefonsa	513000	991000	2413
2	Chefedonsa	514000	992000	2358.800049
3	Girai Abo spr.	519000	987000	2314.100098
4	Chefedonsa,	512000	991000	2441.199951

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5	Chefedonsa, Ichicha	509000	983000	2252.199951
6	Chefedosa,	511000	991000	2428.699951
7	Chefedosa,	516000	992000	2336.300049
8	koka,	505000	934000	1613.099976
9	Adsp01	501798	978894	1994.5
10	Adsp06	431584	998853	2319.100098
11	Adsp07	431584	998853	2319.100098
12	Adsp08	410870	997013	2191.399902
13	adsp11	459831	985582	2226.5
14	Adsp12	455287	985619	2234.399902
15	Adsp13	459285	961268	2078.699951
16	Adsp44	412197	957215	2173.399902
17	Adsp45	451249	985378	2153.300049
18	Adsp57A	514504	990570	2307.800049
19	Adsp57B	488234	988003	2232.100098
20	Adsp59	460950	976800	2110.100098
21	Genda Ejara	501085	1005802	2500.899902
22	Fache Spring	481273	981768	2180
23	Eyasu Spring	466600	1001990	2572.600098
24	Megenagna	478350	996700	2373.300049
25	Kotebe Ankorach	478850	1000950	2736.699951
26	Burayu Water	463259	1002487	2605.300049
27	Meka Sprng	469300	966775	1953.5
28	Burka Spring	468500	967750	1967.400024
29	Fanta Spring	479600	981100	2145.399902
30	Kabo Shinare Spr	468750	967100	1963.199951
31	Abo Spring, Awash	472400	953500	1818.599976

