Chapter 9

Basic Survey for Water Supply Planning of Small Towns

9 Basic Survey for Water Supply Planning of Small Towns

9.1 Introduction

9.1.1 Background and objectives

Water demand projection for provisional water supply planning are carried out introducing appropriate assumptions of population and social structure at a predetermined target year.

Provisional water supply plan are prepared for small towns whose relevance for planning is confirmed. The plan is prepared based on the results of survey on actual water usage conditions, groundwater potential evaluation and water demand projections. The following items are included in the provisional water supply plan.

Provisional water supply plans are evaluated from the viewpoints of water potential (quality / quantity), coverage rate, benefits, O&M capacity, environmental and social impacts, etc. Some 10 priority plans are selected in accordance with the evaluation results.

In order to collect necessary information, data, etc. for above works, survey on existing water supply facilities' conditions and its' operation & maintenance situations and water use survey in 30 small towns are conducted.

9.1.2 Methodology and survey items

a. Survey on existing water supply facilities' conditions and its' operation & maintenance situations in 30 small towns

The team should have a thorough knowledge and expertise on water supply to understand the actual status of existing water supply facilities and management situation. Inaccurate information or data are expected if the survey is implemented only by the local sub-contractor. Therefore, it will be supervised directly by [Small Town Water Supply Scheme Development/ Water Use Planning/ O&M Planning] expert to the local staffs. The survey will be an interview towards the mayor or leader of the small town, operator of the facility, Woreda office, etc. The survey items are shown in Table 9.1.1.

Table 9.1.1: Survey Items on Existing Water Supply Facilities

Classification	Contents
Basic information	Administrative section (town, woreda, zone and region), coordinates, distance from paved road, interviewee
1. Population benefited by water supply facilities	1-1 Population / users in the target town 1-2 Number of satellite village / population / user 1-3 Total number of users of water supply facility 1-4 Population growth situation 1-5 Distribution of ethnic groups
2. Situation of existing water supply facilities i) mainly from Woreda office, ii) information from the operator such as photos, water resources, power supply	2-1 Water sources 2-2 (1) Operation situation (operational/non-operational) and time (2) Time and position of the latest break down/ What is the cause of break down? 2-3 (1) Type of power generating equipment (2) Manufacturer of power generating equipment (3) Model & specification of equipment (4) Output of engine (HP) or electric generator (kVA) (5) Period of usage (6) Condition of equipment

Classification	Contents
	2-4 (1) Type of pump (2) Manufacturer of pump (3) Model and specification of pump (4) Output (kW) (5) Cycle(Hz)、Speed(rpm) (6) Total head（m） (7) Period of usage (8) Condition of pump (9) Diameter of riser pipe/ material of riser pipe (10) Unit length of riser pipe/ total number of pipes (11) Existing of water flow meter 2-5 (1) Year of borehole construction/ finance(donor) (2) Depth and material of borehole (3) Depth and diameter of pumping chamber (4) Depth, diameter and material of screen (5) Geology of aquifer (6) Static water level (7) Pumping rate and draw down (8) Setting position of pump (9) Problem of borehole (10) Problem of water quality 2-6 (1) Specification of distribution reservoir (2) Diameter, length and material of transmission pipe (3) Diameter, length and material of distribution pipe (4) Existing water taps (5) Situation of installation of water meter
3. System of the water supply facilities management (Take a photo if there is evidence)	3-1 (1) Organization system for management of water supply facilities (2) Establishment period of the organization system (3) Contacts (mobile phone/name/position) 3-2 (1) Meeting situation of the Water Committee (2) Record of revenue and expenditures (3) Resident general meeting situation (4) Year of experience (operator) (5) Training attendance situation and contents of the operator 3-3 (1) Collecting method of the water tariff (2) Collecting rate of water usage fee (3) Is the water tariff set reasonable to conduct operation and maintenance for water supply facilities? 3-4 (1) Management method of savings (where savings are kept) (2) Bank name, account establishment date and holder name (3) Savings situation and balance in the account 3-5 Hygiene condition of the water service area and faucet, with reasons if no hygiene activities are taken. 3-6 When was the latest breakdown of the water supply facility? What was the cause of breakdown? How did it be repaired? 3-7 (1) How to provide the fund for repairing facilities? (2) Existence of particular contractors (private) for the repairs during breakdowns 3-8 (1) At the latest breakdown, to whom did you ask to repair? (2) How much did you pay for the cost of its repairing? (3) In case you cannot repair the facility, what is the reason that you cannot repair?
4. Motivation on the management	4-1 Participation interest as if the water supply facilities construction project is going to be implemented. 4-2 (1) Possibility of sharing the construction costs (2) Willingness to pay (how much can they pay for construction at one time)

Classification	Contents
	4-3 (1) Intention on establishing and managing the Water Committee (2) How much do you set the price per cubic meter? (3) The establishment of the bank account as if the establishment of a Water Committee can be agreed upon. 4-4 Intention of paying the cost for the equipment in case it needs to be replaced in the future.
5. Other problems	Do you have any other problems of water supply facilities and operation & maintenance, etc.?
6. Other donor's project	Is there any water supply project by other donors on going or in future?
7. New spring water source	Is there any spring which is available as water source for drinking water supply around the town?
8. Remarks	Any remarks

The survey was executed in accordance with the schedule shown in the Table 9.1.2.

Table 9.1.2: Actual Survey Schedule

Date	Day	Town
21-Jan, 2014	Tue	Wonji Shewa Alemtena (ES-1)
22-Jan, 2014	Wed	Geldiya (ES-2)
23-Jan, 2014	Thu	Bofa (ES-4)
24-Jan, 2014	Fri	Bole (ES-5)
25-Jan, 2014	Sat	Golegota (AR-5)
26-Jan, 2014	Sun	
27-Jan, 2014	Mon	Biyo (ES-11)
28-Jan, 2014	Tue	Kamise (ES-8)
29-Jan, 2014	Wed	Ude Dhankaka (ES-6)
30-Jan, 2014	Thu	Dire (ES-3)
31-Jan, 2014	Fri	Adulala (ES-12)
1-Feb, 2014	Sat	Bekejo (ES-7)
2-Feb, 2014	Sun	
3-Feb, 2014	Mon	Chefe Donsa (ES-9)
4-Feb, 2014	Tue	Areda (ES-10)
5-Feb, 2014	Wed	Sire (AR-1)
6-Feb, 2014	Thu	Arbe Gebeya (AR-7)
7-Feb, 2014	Fri	Gonde (AR-6)
8-Feb, 2014	Sat	
9-Feb, 2014	Sun	Bolo (AR-2)
10-Feb, 2014	Mon	Aseko (AR-4)
11-Feb, 2014	Tue	Mieso (WH-5)
12-Feb, 2014	Wed	Hargeti (WH-6), Kenteri (WH-8), Kora (WH-11), Aneno (WH-9)
13-Feb, 2014	Thu	Chorora (WH-1), Belo (WH-4)
14-Feb, 2014	Fri	Bordede (WH-7)
15-Feb, 2014	Sat	Hardim (WH-3), Bube (WH-4)
16-Feb, 2014	Sun	
17-Feb, 2014	Mon	Bedeyi (WH-2)

b. Water use survey in 30 small towns (sub-contracted)

The actual status survey on water use will be implemented as described in the Table 9.1.3 to understand the water resources in small towns at present. The task of this survey is to gather the small town water use status for the existing water resource facilities within the study area.

This work was entrusted to a local sub-contractor.

Table 9.1.3: Contents of Water Use Survey

Items	Contents
Purpose	・ Understand the water use status in the candidate towns for planning
Target	・ 30 candidate towns
Survey method	・ Interview by questionnaire
Number of sample	・ 23 samples each for target towns (20 samples at households and 3 samples at water point survey)
Target Interviewee	・ Head or member of household and person who fetches water at water point
Survey item	・ Water source, water fetching, purpose of use, water consumption, payment for water, need of water supply facility, etc.

9.2 Small town profiles

a. Confirmation and identification of target towns

Preliminary survey for 30 towns which were proposed by the Ethiopian Government at ”The Preliminary Study for the Project for Groundwater Resources Assessment in the Middle Awash River Basin” were conducted. According to the report of the study issued on November 2012, it was found a water supply project on going in some target small towns. It is also found that one of target small towns was located in Amhara Region where is outside of target region i.e. Oromia region. The study team of this project also found that some of target towns are located outside of the middle Awash river basin.

Considering such situation, the study team requested to OWMEB to submit the final list of target small towns after selecting and replacing target towns based on the following criteria by the end of November 2013.

- The target town shall be located in the middle Awash river basin area.
- The population of the small town shall be between 2,000 and 15,000. The town shall be authorised as the town not the Kebele officially.
- There is no water supply project on going in the town.
- The rate of water supply coverage is low compared to other small towns.

According to the above mentioned procedure, Target towns, which are officially requested as the Technical Notes dated December 20, 2013 and signed by as attached have been confirmed and identified during the survey. The list of target towns after confirmation and identification is shown in Table 9.2.1.

Table 9.2.1: List of Target Towns

ID	Zone	Woreda	Town	Coordinates (UTM, Datum: Adindan)			
				Zone	X (m)	Y (m)	Elevation (m)
ES-1	East Shewa	Adama Zuria	Wonji Shewa Alemtena	37 P	523983	927885	1539
ES-2		Adama Zuria	Geldiya	37 P	537805	957201	1561
ES-3		Ada	Dire	37 P	488864	961034	1958
ES-4		Boset	Bofa	37 P	549706	935610	1426
ES-5		Boset	Bole	37 P	582430	956118	1174

ID	Zone	Woreda	Town	Coordinates (UTM, Datum: Adindan)			
				Zone	X (m)	Y (m)	Elevation (m)
ES-6		Ada	Ude Dhankaka	37 P	504593	959074	1869
ES-7		Ada	Bekejo	37 P	493382	952238	1820
ES-8		Lume	Kamise	37 P	512241	963884	1938
ES-9		Gimbichu	Chefe Donsa	37 P	513210	991145	2414
ES-10		Gimbichu	Areda	37 P	529573	1004272	2520
ES-11		Lume	Biyo	37 P	507829	956072	1846
ES-12		Liben Zikuala	Adulala	37 P	489099	943666	1729
AR-1	Arsi	Sire	Sire	37 P	553789	914629	1989
AR-2		Jeju	Bolo	37 P	563663	911085	2548
AR-3		Jeju	Arboye	37 P	575105	926450	2115
AR-4		Aseko	Aseko	37 P	612898	940113	2115
AR-5		Merti	Golegota	37 P	582942	955787	1163
AR-6		Tiyo	Gonde	37 P	521176	888123	2262
AR-7		Lodehetosa	Arbe Gebeya	37 P	547813	898826	2441
WH-1	West Hararge	Anchar	Chorora	37 P	641097	971517	1691
WH-2		Anchar	Bedeyi	37 P	627376	954910	2149
WH-3		Guba Qoricha	Hardim	37 P	656277	975905	1632
WH-4		Guba Qoricha	Bube	37 P	662813	979936	1991
WH-5		Mieso	Mieso	37 P	692799	1021080	1323
WH-6		Mieso	Hargeti	37 P	674221	1003489	1349
WH-7		Mieso	Bordede	37 P	652603	996461	1100
WH-8		Mieso	Kenteri	37 P	670893	1005689	1279
WH-9		Mieso	Aneno	37 P	665114	1010056	1319
WH-10		Mieso	Belo	37 P	644399	983865	1232
WH-11		Mieso	Kora	37 P	668599	1006889	1263

Figure 9.2.1: Location Map of Target Towns

b. Profile of target towns

The profiles of the target towns are mentioned below.

b.1 East Shewa Zone

1) Wonji Shewa Alemtena (ES-1)

Water is taken from Awash River, treated and distributed by the Adama Town Water Supply and Sewerage Service Enterprise (hereafter referred to as "TWSSSE") which is 20 km away from the town and supplied by two (2) public taps and thirty one (31) private connections.

Town is located at the end of distribution network so that water is sometimes not coming out due to the lack of water pressure.

Activities of operation and maintenance such as management of revenue and expense, repairing pipelines, etc. are conducted by the Adama TWSSSE, therefore there is no official water committee in the town; however, there are two (2) tariff collectors at public taps.

2) Geldiya (ES-2)

Water is pumped up by submersible pump from the borehole constructed by World Vision in 2003. The power for submersible pump is purchased from Ethiopian electric Power Corporation (hereafter referred to as "EEPCO"). Water is pumped up to the distribution reservoir, which has a capacity of twenty five (25) m^3, and is distributed by gravity.

There are four (4) public taps, two hundred and fifty (250) private connections and two (2) cattle troughs as water points. The material of pipes for transmission and distribution is galvanized steel pipes (hereafter referred to as "GSP"). Operation and maintenance of the water supply facilities is executed by a local water committee. As the result of interviews, yield of the borehole is decreasing so that they can only pump up water from the borehole for a maximum of 6 hours a day.

3) Dire (ES-3)

There are two (2) water supply systems constructed by NGOs in 1987 and 1997 in the town. Both systems consist of a borehole, a submersible pump, transmission pipes, a distribution reservoir, distribution pipelines and water points. The power for the submersible pumps is purchased from EEPCO. As for the capacity of the distribution reservoirs, the older one is fifteen (15) m^3 and the newer one is thirty (30) m^3. There are seven (7) public taps, ninety (90) private connections and two (2) cattle troughs in total.

The interviews found that the yield of the boreholes is decreasing, the water contains some sand and operation of the submersible pumps sometimes stops. There is concern regarding the deterioration of the borehole.

Water committee is organized and established at each water supply system separately.

4) Bofa (ES-4)

There are also two (2) water supply systems. Old system was constructed by China's aid in 1982 and new system was constructed by World Vision in 2005. Both systems consist of a borehole, a submersible pump, transmission pipes, a distribution reservoir, distribution pipelines and water points. The power is supplied by EEPCO. There are three (3) distribution reservoirs, which capacity of fifty (50) m^3 exists in old system and fifty (50) m^3 and twenty five (25) m^3 exist in new system. There are eleven (11) public taps and two hundred and thirty two (232) private connections in total. There are no cattle troughs.

Operation and maintenance of both water supply systems is executed by only one (1) Town Water Supply Service Office (hereafter referred to as “TWSSO”).

5) Bole (ES-5)

Only one (1) water supply system which covers both Bole town of East Shewa Zone and Golegota town of Arsi Zone exists. Both towns are adjacent across the river. Water source is the borehole drilled by Italian aid in September 2010 that is located in Golegota Town. The power source of the submersible pumps, which have an output of 30 kW, is from diesel generators, which have an output of 100 kVA. There are two (2) distribution reservoirs. Fifty (50) m^3 capacity elevated tank is located in Bole town and 10 m^3 on ground is in Golegota Town. There are eleven (11) public taps and two hundred and fifty one (251) private connections in total.

Operation and maintenance of the water supply systems is executed by only one (1) TWSSO, the office of which is located in Bole Town.

6) Ude Dhankaka (ES-6)

There are three (3) sets of borehole with hand pump, which are all functioning, constructed by an NGO in 2011. There are two (2) types of hand pump, India Mark II and AFRIDEV. There are also four (4) sets of hand dug well with hand pump which were all broken and abandoned before 2011. There are also many unprotected hand dug wells in this area. Water committee exists for every borehole with hand pump.

7) Bekejo (ES-7)

Water supply system which was constructed in 1987 consists of a borehole, a submersible pump, transmission pipes, a distribution reservoir with a capacity of forty (40) m^3, distribution pipelines and water points. Power source of the submersible pump is a diesel generator with an output of 38 kVA. There are four (4) public taps and twenty six (26) private connections in total.

Both submersible pump and diesel generator have been used for twenty seven (27) yeas and are much deteriorated. Water committee desires to switch power source from a diesel generator to public electricity supply earnestly in order to reduce operation cost.

8) Kamise (ES-8)

Water is supplied at two (2) public taps, one (1) private connection and one (1) cattle trough by Gimbichu - Fentale Rural Water Supply Enterprise, which source is a spring in Gimbichu Woreda, to the villages along 300 km distance from Gimbichu Woreda to Fentale Woreda.

Activity of operation and maintenance such as management of revenue and expenses, repairing pipelines, etc. is conducted by the Gimbichu - Fentale Rural Water Supply

Enterprise so that the activity of water committee of the town is limited.

There is crossing of Mojo River on the way to the town from the paved road which distance is about 11 km. It is impossible to access to the town from June to August when the water level of the river increases in rainy season.

9) Chefe Donsa (ES-9)

Water is pumped up from the collecting chamber of spring constructed by the Government in 1983 which is located 1 km away from the centre of the town. Power is purchased from EEPCO. There is a standby diesel generator. Water is pumped up to the distribution reservoir which capacity is ninety (90) m^3 and distributed by gravity. There are ten (10) public taps and nine hundred and twenty (920) private connections in total. There is no cattle trough. New collecting chamber of new spring, which yield is 4.6 litres/sec is under construction at a location 200 m away from the existing collecting chamber.

Operation and maintenance of the water supply system is conducted by TWSSO.

10) Areda (ES-10)

The town is newly established so that the area where exists public buildings such as school, health centre, agricultural centre, etc. is located more than 1 km away from the commercial area where there is a market, etc.

Water is supplied to the area of public buildings by the water supply system which was constructed in 2001 consisting of a borehole, a submersible pump, transmission pipes, a distribution reservoir, distribution pipes and water points. Power source for the submersible pump is a diesel generator. There are two (2) public taps and three (3) private connections in total.

Commercial area is not covered by the water supply system and people living there is fetching water from an unprotected spring underneath the cliff.

Operation and maintenance of the water supply system is conducted by water committee.

11) Biyo (ES-11)

Water was distributed through the reservoir tank besides the borehole with a windmill pump, constructed by an NGO in 1999, before the facility became no longer functional in January 2013.

There are four (4) sets of hand dug wells with hand pumps which types are India Mark II and AFRIDEV. But all of them are broken and not functioning. There are also many unprotected hand dug wells.

There is a water committee only for the borehole with a windmill pump, which was no longer functional as of January 2013.

12) Adulala (ES-12)

Water supply system which was constructed in 1989 consists of boreholes, submersible pumps, transmission pipes, two distribution reservoirs, distribution pipelines and water points.

Power for the submersible pump is purchased from EEPCO. There is a standby generator which has an output of 27 kVA. There are two (2) distribution reservoirs with capacities of fifty (50) m^3 and twenty five (25) m^3, which are abandoned due to a lack of water pressure.

There are three (3) public taps and three hundred and ninety three (393) private connections in total.

Operation and maintenance of the water supply system is conducted by TWSSO.

b.2 Arsi Zone

1) Sire (AR-1)

There are two (2) water supply systems in the town. The old system which water source is spring was constructed in 1981 and the new system which water source is borehole was constructed by UNICEF in June 2010. For the spring system, water is pumped up by submersible pump, the power for which is purchased from EEPCO to the distribution reservoir that has a capacity of sixty five (65) m^3, and distributed by gravity.

For the borehole system, there is booster pumping station due to the great difference (214 m measured by GPS) in elevation between the borehole and the distribution reservoir, which has a capacity of fifty (50) m^3. Both pumps for borehole and pumping station are submersible pump which power supplied by diesel generator which outputs are both 85 kVA. There are twenty one (21) public taps and five hundred and sixteen (516) private connections in total. There are no cattle troughs.

Operation and maintenance of both water supply systems is conducted by TWSSO. TWSSO desires to switch power source from a diesel generator to public electricity supply earnestly in order to reduce operation cost of two (2) generators for the borehole system. A power supply line with transformer was installed besides the pumping cabin of the borehole. But it is still not available to use power of EEPCO because the capacity of the transformer is not enough.

2) Bolo (AR-2)

Water supply system, which was constructed by the Oromia Regional Government in 2000, consists of a borehole, a submersible pump, transmission pipes, distribution reservoir which capacity is forty (40) m3, distribution pipelines and water points. Power source of submersible pump is a diesel generator with an output of 27.5 kVA. There are four (4) public taps, fifty six (56) private connections and one (1) cattle trough in total.

Operation and maintenance is conducted by water committee.

3) Arboye (AR-3)

Water is transmitted to the town by gravity from the collecting chamber of spring constructed by the Government in 1983 which is located about 5 km away from the center of town. There are seven (7) public taps and five hundred and twenty nine (529) private connections. Operation and maintenance of the facility is conducted by a water committee.

There were seven (7) springs where water flowed out in the past. But there are only three (3) springs out of the seven (7) where water is still flowing. Total yield of springs has been reduced up to fifty (50) % of the original. It is difficult to find new spring sources around the town.

4) Aseko (AR-4)

Water is pumped up from the collecting chamber of spring constructed by the Oromia Regional Government in 2009 which is located 1.5 km away from the center of the town. Water is pumped up to the distribution reservoir which capacity is twenty five (25) m^3 and distributed by gravity. Power is purchased from EEPCO since 2011 after switching the power source from a diesel generator. There are six (6) public taps and sixty six (66) private connections in total.

There is another protected spring intake facility on spot. But it is worried about the contamination of the water because water source exists just besides the main road of the town.

Operation and maintenance of the water supply system is conducted by water committee.

5) Golegota (AR-5)

The profile of water supply facility of this town is already mentioned in “Bole (ES-5)”.

6) Gonde (AR-6)

There is a vast area, where a lot of spring intake facilities exist, located 1km east from the center of the town. Those spring intake facilities are owned by various organizations. Gond-Iteya Water Management Board owns four (4) sets of intake facilities in the area and the potable water is distributed by gravity system, one (1) for Gonde Town, one (1) for Agricultural Research Center in Khulumusa Kebele located 5 km south-west from Gonde Town and remaining two (2) for 16 Kebeles downstream of the town.

In Gonde Town, water is distributed to five (5) public taps and two hundred and eighty three (283) private connections directly from the spring intake facility which was constructed in 2006 without a distribution reservoir.

It is impossible to distribute water in higher areas, which is around seventy (70) percent of the town, due to lack of water pressure caused by a too low elevation difference from the intake facility.

There is a project on going that is constructing new water supply system consisting of a spring intake facility, a submersible pump, transmission pipes, distribution reservoir, distribution pipelines and water points, which distribution area is planned to include a part of Gonde Town where water is not distributed yet.

7) Arbe Gebeya (AR-7)

Water is transmitted to the distribution reservoir which capacity is fifty (50) m^3 by gravity from the collecting chamber of spring constructed by the Oromia Regional Government in 1995 which is located about 4 km away from the center of town. There are five (5) public taps and three hundred and forty (340) private connections. Operation and maintenance of the water supply system is conducted by a water committee.

There is another protected spring intake facility in this town with a yield of about 0.7 litre/sec, near the above mentioned collecting chamber.

b.3 West Hararge Zone

1) Chorora (WH-1)

Water supply system, which was constructed by the Oromia Regional Government in 2002, consists of a borehole, submersible pump, transmission pipes, distribution reservoir which capacity is one hundred (100) m^3, distribution pipelines and water points. Power source of submersible pump is a diesel generator with an output of 30 kVA. There are three (3) public taps and one hundred and forty two (142) private connections in total. Operation and maintenance is conducted by a water committee.

2) Bedeyi (WH-2)

Water supply system, which was constructed by the Oromia Regional Government in 2007, consists of a borehole, a submersible pump, transmission pipes, a distribution reservoir with a capacity of fifty (50) m^3, distribution pipelines and water points. Due to the great difference in elevation between the borehole and the distribution reservoir (379 m measured by GPS), there is a booster pumping station with a reservoir with a capacity of twenty five (25) m^3. The pump for the borehole is a submersible pump and the pump for the booster station is a line shaft pump. The power of both pumps is supplied by diesel generators, which both have an output of sixty (60) kVA. There are five (5) public taps and one hundred and one (101) private connections in total. Operation and maintenance of both water supply systems is conducted by water committee.

Water tariff is forty two (42) birr / m^3 which is most expensive among the thirty (30) target towns because of the high cost of having to run two (2) diesel generators. The water committee desires a switch of power source from diesel generator to public electricity supply earnestly.

3) Hardim (WH-3)

Water supply system, which was constructed by the Oromia Regional Government in 1994, consists of a borehole, a submersible pump, transmission pipes, a distribution reservoir with a capacity of fifty (50) m^3, distribution pipelines and water points. Power source of the submersible pump is a diesel generator with an output of thirty eight (38) kVA. There are seven (7) public taps and eighty eight (88) private connections in total. Operation and maintenance is conducted by a water committee. The water committee desires a switch of power source from diesel generator to public electricity supply earnestly.

4) Bube (WH-4)

Water is pumped up from the collecting chamber of a spring, constructed by the Oromia Regional Government in 2006, and which is located 1.5 km away from the center of the town. Water is pumped up to the distribution reservoir with a capacity of fifty (50) m^3 and is distributed by gravity. Power source of the submersible pump is a diesel generator with an output of forty (40) kVA. There are four (4) public taps and sixteen (16) private connections in total. Operation and maintenance of the water supply system is conducted by a water committee.

5) Mieso (WH-5)

There are also two (2) water supply systems, each consisting of a borehole, a submersible pump, transmission pipes, a distribution reservoir, distribution pipelines and water points. The old system, with a seventy (70) m^3capacity distribution reservoir, was constructed by the Government in 1977. Construction of a new system including a distribution reservoir with a capacity of fifty (50) m^3, was completed by an NGO in 2004 with the borehole drilled and donated by the Chinese contractor for a road construction project in 2001.The power for both systems is purchased from EEPCO. The new system has a standby diesel generator with a capacity of seventy (70) kVA. There are ten (10) public taps and seven hundred and twelve (712) private connections in total. There are no cattle troughs.

Operation and maintenance of both systems is conducted by the Mieso Town Water Supply Service Office.

6) Hargeti (WH-6)

There is no facility to supply safe drinking water in the town. Population fetches water at the Arba River about 2 km away from the center of the town. Water level decreases much in the dry season so that it becomes difficult to fetch water. Water flow increases very much in the rainy season so that it becomes dangerous to fetch water. The is no water committee.

7) Bordede (WH-7)

The water supply system, which was constructed by the Government of Ethiopia in 1976, consists of a borehole, a submersible pump, transmission pipes, a distribution reservoir with a capacity of fifty (50) m^3, distribution pipelines and water points.

Power source of the submersible pump is a diesel generator with an output of sixty (60) kVA for the time being, after previous pumps were was burned three (3) times due to the bad quality of power supply by EEPCO.

There are nine (9) public taps and one hundred and sixty eight (168) private connections in total. Operation and maintenance is conducted by a water committee.

8) Kenteri (WH-8)

There is no facility to supply safe drinking water in the town. Residents fetch water at Kora River about 1 km away from the center of the town. There is no water committee in the town.

9) Aneno (WH-9)

There is no facility to supply safe drinking water in the town. Residents fetch water at Kora River about 7 km away from the center of the town. There is no water committee in the town.

10) Belo (WH-10)

Water supply system, which was constructed by the Oromia Regional Government in 2004, consists of a borehole, a submersible pump, transmission pipes, a distribution reservoir with a capacity of eighty (80) m^3, distribution pipelines and water points. Power source of the submersible pump is a diesel generator with an output of forty (40) kVA. There are three (3) public taps and one (1) cattle trough in total. Operation and maintenance is conducted by a water committee.

11) Kora (WH-11)

Water supply system, which was constructed by the NGO in 2004, consists of a borehole, a submersible pump, transmission pipes, a distribution reservoir with a capacity of fifty (50) m^3, distribution pipelines and water points. Power source of the submersible pump is a diesel generator with an output of forty (40) kVA. There are four (4) public taps and seventy five (75) private connections in total. Operation and maintenance is conducted by a water committee.

9.3 Results of water use survey

9.3.1 Interview survey of water supply situation in Woreda

A list of the interview survey results of the water supply situation in Woreda is shown in Table 8.4.3 in Chapter 8, Socio-economic Survey.

The name of 15 Woreda, where 30 target small towns exist, are shown in Table 9.3.1, which also shows the population, number of users of water supply facilities and water supply coverage rate. Table 9.3.2 shows the number and type of existing water sources in Woreda. For Aseko and Merti, the Water, Mineral and Energy Office did not possessed data regarding number of users and water supply ratio.

Table 9.3.1: Population, Number of Users and Water Coverage Rate in Woreda

No.	Woreda	Population	Number of Users	Water Supply Ratio (%)
1	Adama Zuria	173,372	95,040	72
2	Ada	137,296	113,172	81
3	Boset	132,779	69,178	52
4	Lume	95,656	70,919	74
5	Gimbichu	105,509	88,228	86
6	Liben Zikuala	90,637	61,543	68
7	Sire	94,995	53,568	58
8	Jeju	132,465	64,908	49
9	Aseko	95,929	68,536	71
10	Merti	104,270	34,376	33
11	Tiyo	102,102	28,589	28
12	Lodehetosa	127,699	88,856	71
13	Anchar	75,155	26,150	24
14	Guba Qoricha	135,626	143,599	40
15	Mieso	153,182	65,052	42

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

Table 9.3.2: Number and Type of existing Water Source in Woreda

No.	Woreda	Motorized system with borehole	Hand pump with borehole	Hand dug well	Spring	Reservoir pond	River
1	Adama Zuria	12	0	0	0	0	1
2	Ada	16	83	45	15	52	0
3	Boset	19	0	0	12	0	1

No.	Woreda	Motorized system with borehole	Hand pump with borehole	Hand dug well	Spring	Reservoir pond	River
4	Lume	16	33	0	18	10	2
5	Gimbichu	11	7	107	25	20	0
6	Liben Zikuala	14	0	72	1	0	0
7	Sire	6	0	15	12	0	0
8	Jeju	11	35	0	7	0	0
9	Aseko	1	0	0	32	0	0
10	Merti	7	1	0	8	0	2
11	Tiyo	3	0	1	12	0	4
12	Lodehetosa	0	0	7	40	0	5
13	Anchar	0	2	0	57	0	0
14	Guba Qoricha	4	5	0	8	0	0
15	Mieso	17	0	0	0	0	0
	Total	137	166	247	247	82	15

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

9.3.2 Interview survey of water supply situation in small Towns

A list of the interview survey results of the water supply situation in a small Town is shown in Table 8.4.4 in Chapter 8, Socio-economic Survey. The population, number of households, and number of users are shown in Table 9.3.3. The number of the existing water supply facilities by a water source type of the Town is shown in Table 9.3.4. The number of existing water taps and water meter is shown in Table 9.3.5.

The population information has been obtained from the survey made on 2013 at the town office and rural office. Both offices do aggregate the population independently but never publish it officially. The only official population data in Ethiopia was made by CSA which was calculated in according to 2007 census.

Table 9.3.3: Population, Number of Households and Number of Users

ID	Town	Population	Household	Original source
ES-1	Wonji Shewa Alemtena	12,300	4,200	Town Admin. 2013
ES-2	Geldiya	2,320	562	Town Admin. 2013
ES-3	Dire	6,462	1,293	[1]WWMEO 2013
ES-4	Bofa	5,360	1,092	[2]TWSSO 2013
ES-5	Bole	14,350	2,050	TWSSO 2013
ES-6	Ude Dhankaka	2,753	580	Town Admin. 2013
ES-7	Bekejo	11,000	2,200	Town Health Office 2013
ES-8	Kamise	1,896	212	Town Admin. 2013
ES-9	Chefe Donsa	13,074	2,600	Town Admin. 2013
ES-10	Areda	2,100	240	Town Admin. 2013
ES-11	Biyo	2,500	254	Town Admin. 2013
ES-12	Adulala	6,000	970	Town Admin. 2013
AR-1	Sire	15,936	3,188	TWSSO 2013
AR-2	Bolo	1,485	297	[3]CSA projection 2013
AR-3	Arboye	10,600	878	Town Admin. 2013
AR-4	Aseko	7,905	528	WWMEO 2013

1 WWMEO: Woreda Water, Mineral and Energy Office
2 TWSSO: Town Water Supply Service Office
3 CSA: Central Statistical Agency

ID	Town	Population	Household	Original source
AR-5	Golegota	4,201	488	Town Admin. 2013
AR-6	Gonde	2,598	687	Town Admin. 2013
AR-7	Arbe Gebeya	6,473	660	Town Admin. 2013
WH-1	Chorora	3,000	453	Town Admin. 2013
WH-2	Bedeyi	5,520	850	Town Admin. 2013
WH-3	Hardim	5,500	556	Town Admin. 2013
WH-4	Bube	5,920	1,232	Kebele manager 2013
WH-5	Mieso	16,620	3,120	CSA projection 2013
WH-6	Hargeti	3,287	685	Town Admin. 2013
WH-7	Bordede	2,765	990	CSA projection 2013
WH-8	Kenteri	2,093	460	Town Admin. 2013
WH-9	Aneno	2,382	500	CSA projection 2013
WH-10	Belo	4,530	774	CSA projection 2013
WH-11	Kora	2,360	731	Town Admin. 2013

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

Table 9.3.4: Number of existing Water Supply Facilities by Water Source Type of the Town

ID	Town	Motorized borehole	Borehole with hand pump	Hand dug well	Motorized Spring	Spring with gravity system	Spring on spot	River
ES-1	Wonji Shewa Alemtena	0	0	0	0	0	0	1
ES-2	Geldiya	1	0	0	0	0	0	0
ES-3	Dire	2	0	0	0	0	0	0
ES-4	Bofa	2	0	0	0	0	0	0
ES-5	Bole	1	0	0	0	0	0	0
ES-6	Ude Dhankaka	0	7	0	0	0	0	0
ES-7	Bekejo	1	0	0	0	0	0	0
ES-8	Kamise	0	0	0	0	1	0	0
ES-9	Chefe Donsa	0	0	0	1	0	0	0
ES-10	Areda	1	0	0	0	0	0	0
ES-11	Biyo	1	0	20	0	0	0	0
ES-12	Adulala	1	0	0	0	0	0	0
AR-1	Sire	1	0	0	1	0	0	0
AR-2	Bolo	1	0	0	0	0	0	0
AR-3	Arboye	0	0	0	0	1	0	0
AR-4	Aseko	0	0	0	1	0	0	0
AR-5	Golegota	[4](1)	0	0	0	0	0	0
AR-6	Gonde	0	0	0	0	1	0	0
AR-7	Arbe Gebeya	0	0	0	0	1	0	0
WH-1	Chorora	1	0	0	0	0	0	0
WH-2	Bedeyi	1	0	0	0	0	0	0
WH-3	Hardim	1	0	0	0	0	0	0
WH-4	Bube	0	0	0	1	0	0	0
WH-5	Mieso	2	0	0	0	0	0	0
WH-6	Hargeti	0	0	0	0	0	0	0
WH-7	Bordede	1	0	0	0	0	0	0
WH-8	Kenteri	0	0	0	0	0	0	0
WH-9	Aneno	0	0	0	0	0	0	0
WH-10	Belo	1	0	0	0	0	0	0
WH-11	Kora	1	0	0	0	0	0	0
	Total	20	7	20	4	4	0	1

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

[4] One motorized borehole supplies water to both ES-5 and AR-5.

Table 9.3.5: Number of existing Water Taps and Water Meters

ID	Town	Water Points					Water Meter
		House Connection	Public Office	Public Fountains	Cattle Trough	Total	
ES-1	Wonji Shewa Alemtena	27	4	2	0	33	33
ES-2	Geldiya	244	6	4	2	256	256
ES-3	Dire	87	3	7	5	102	102
ES-4	Bofa	224	8	11	0	243	243
ES-5	Bole	243	8	11	0	262	262
ES-6	Ude Dhankaka	0	0	0	0	0	0
ES-7	Bekejo	24	2	4	0	30	30
ES-8	Kamise	1	0	2	1	4	4
ES-9	Chefe Donsa	881	39	10	0	930	930
ES-10	Areda	0	3	2	0	5	5
ES-11	Biyo	0	0	1	0	1	1
ES-12	Adulala	365	28	3	0	396	396
AR-1	Sire	499	17	21	0	537	537
AR-2	Bolo	52	4	4	1	61	61
AR-3	Arboye	526	3	7	0	536	536
AR-4	Aseko	61	2	6	0	72	72
AR-5	Golegota	243	8	11	0	262	262
AR-6	Gonde	273	5	5	0	283	283
AR-7	Arbe Gebeya	332	8	5	0	345	345
WH-1	Chorora	136	3	3	0	142	142
WH-2	Bedeyi	96	5	5	0	106	106
WH-3	Hardim	54	4	7	0	65	65
WH-4	Bube	12	4	4	0	20	20
WH-5	Mieso	712	0	10	0	722	722
WH-6	Hargeti	0	0	0	0	0	0
WH-7	Bordede	161	7	9	0	177	177
WH-8	Kenteri	0	0	0	0	0	0
WH-9	Aneno	0	0	0	0	0	0
WH-10	Belo	0	0	3	1	4	4
WH-11	Kora	70	5	4	0	79	79

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

9.3.3 Sample household survey

A list of the sample household survey results of small towns are shown in Table 8.4.5 in Chapter 8, Socio-economic Survey. The average of the results among 30 small Towns and its analysis are mentioned as follows.

a. Existing water sources in rainy and dry seasons

Existing water sources in both rainy and dry seasons are shown in Table 9.3.6. There is no significant difference between the rainy and dry seasons. About 20% of the population uses unprotected water sources. The piped water supply system is about 70% out of remaining about eighty (80) %. Remaining 10% are boreholes with hand pumps, protected springs and so on.

Table 9.3.6: Existing Water Sources in Rainy and Dry seasons

Category	Rainy season (%)	Dry season (%)
Piped water supply (public fountains)	40	41
Piped water into compound (private)	19	18
Piped water into dwelling (private)	5	5
Piped water from vendors	4	5
Protected well/spring	9	10
Unprotected well/spring	5	6
Unprotected surface water (such as river, pond & etc)	16	13
Others	2	2

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

b. People who fetch water

Table 9.3.7 shows a list of people who have been responsible for fetching water for households. About 60% of people who fetch water are adult women, and 26% are children. Water fetching is a burden to women and children.

Table 9.3.7: People who Fetch Water

Category	%
Men adult (Age >15 Years)	14
Women adult (Age >15 years)	60
Male Child (Age <15)	13
Female Child (Age <15)	13

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

c. Container for fetching water

Table 9.3.8 shows the type of container used for fetching water. Most of the people used jerry cans for fetching water.

Table 9.3.8: Type of Container for Fetching Water

Category	%
Plastic Jerry can	88
Donkey carried canvas/leather bag	7
Bucket	2
Pot	1
Others	2

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

d. Distance, time and frequency for fetching water

Table 9.3.9 shows the distance, time, and frequency, which are increasing in the dry season, for fetching water. As shown in Tables 6.7, 6.8 and 6.9 in Chapter 6, Socio-economic Survey, the longest distance is 3,783 m of Hargeti (WH-6), where people go to fetch water from the river, and the shortest is 11 m of Bolo (AR-2).

The maximum time for fetching water is 255 min in Aneno (WH-9), where there is no water supply facility, and thus people go to fetch water from the river, and the minimum is 3 min in Arbe Gebeya (AR-6).

The maximum frequency of fetching is 4.5 times/day in Geldiya (ES-2), and the minimum is 1.0 times/day in Dire (ES-3), Bofa (ES-4), Golegota(AR-5) and Gonde(AR-6).

Table 9.3.9: Distance, Time and Frequency for Fetching Water

ID	Town	Distance to water source (m)		Time for each travel (min)		Number of travel per day (times)	
		Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
ES-1	Wonji Shewa Alemtena	659	654	85	40	1.6	1.8
ES-2	Geldiya	199	199	9	8	3.4	4.5
ES-3	Dire	1,105	750	70	59	1.0	1.5
ES-4	Bofa	226	264	19	17	1.0	2.1
ES-5	Bole	217	215	30	30	1.5	2.0
ES-6	Ude Dhankaka	282	242	28	22	1.7	2.8
ES-7	Bekejo	1,389	1,217	57	53	1.1	2.2
ES-8	Kamise	604	506	36	36	1.6	2.2
ES-9	Chefe Donsa	121	119	13	13	1.2	2.2
ES-10	Areda	535	489	64	63	1.7	1.7
ES-11	Biyo	383	363	76	56	2.3	3.1
ES-12	Adulala	507	548	11	10	1.3	2.3
AR-1	Sire	368	368	32	32	1.8	1.9
AR-2	Bolo	11	12	7	15	1.4	1.6
AR-3	Arboye	19	42	8	12	2.1	2.8
AR-4	Aseko	92	80	14	16	2.2	2.6
AR-5	Golegota	213	213	28	27	1.0	1.4
AR-6	Gonde	197	201	17	17	1.0	2.3
AR-7	Arbe Gebeya	26	26	3	3	1.1	2.8
WH-1	Chorora	149	149	25	24	3.2	2.2
WH-2	Bedeyi	39	38	35	27	1.6	1.7
WH-3	Hardim	146	143	19	19	1.3	1.7
WH-4	Bube	405	405	20	20	2.3	2.8
WH-5	Mieso	134	140	13	14	1.7	2.4
WH-6	Hargeti	3,726	3,783	156	162	1.6	1.7
WH-7	Bordede	305	306	29	31	1.7	2.4
WH-8	Kenteri	836	960	105	113	1.2	1.2
WH-9	Aneno	1,122	2,548	121	255	1.1	1.3
WH-10	Belo	1,553	1,584	101	110	1.4	1.7
WH-11	Kora	21	21	7	7	2.1	2.1
Average		520	553	41	44	1.6	2.2

Source : the Project Team, Data: Result of local consultant and water supply survey in this Project

e. Water consumption by purpose

The water consumption per household is shown in Table 9.3.10. The minimum volume consumed per household is 23 liters in Arebe Gebeya (AR-7) in rainy season, and the maximum is 187 liters per household in Geldiya (ES-2) in the dry season.

Table 9.3.10: Water Consumption by Purpose

ID	Town	Drinking & Cooking		Washing & Bathing		Livestock		Total	
		Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
		L/day/ household	L/day/ household	L/day/ household	L/day/ household	L/day/ household	L/day/ household	L/day/ household	L/day/ household
ES-1	Wonji Shewa Alemtena	25	27	22	25	5	8	52	60
ES-2	Geldiya	51	58	46	58	20	71	117	187
ES-3	Dire	23	31	24	30	4	19	50	80
ES-4	Bofa	14	26	13	25	0	7	28	58
ES-5	Bole	23	24	24	28	5	6	52	58
ES-6	Ude Dhankaka	40	53	43	60	7	39	90	153
ES-7	Bekejo	24	38	25	44	3	18	53	100
ES-8	Kamise	33	40	38	42	11	27	82	109
ES-9	Chefe Donsa	24	39	22	36	1	6	47	81
ES-10	Areda	20	26	18	25	2	9	40	60
ES-11	Biyo	44	59	43	41	41	35	128	135
ES-12	Adulala	20	32	19	31	0	15	39	78
AR-1	Sire	36	35	40	43	7	7	82	85
AR-2	Bolo	29	43	44	66	25	42	97	152
AR-3	Arboye	34	50	41	59	24	38	99	147
AR-4	Aseko	49	48	70	77	45	40	163	166
AR-5	Golegota	11	16	12	14	0	7	24	37
AR-6	Gonde	18	32	17	30	0	9	35	71
AR-7	Arbe Gebeya	11	29	11	30	0	4	23	63
WH-1	Chorora	36	45	40	57	36	36	112	137
WH-2	Bedeyi	57	53	45	53	37	33	139	139
WH-3	Hardim	29	42	32	45	43	47	104	135
WH-4	Bube	33	43	42	53	41	48	116	143
WH-5	Mieso	15	46	30	39	13	21	58	106
WH-6	Hargeti	27	32	30	34	30	30	87	97
WH-7	Bordede	33	45	42	44	37	42	111	130
WH-8	Kenteri	28	29	37	32	32	34	96	95
WH-9	Aneno	34	38	27	29	19	16	80	84
WH-10	Belo	25	30	26	38	33	36	85	103
WH-11	Kora	25	28	31	28	33	33	89	90
Average		29	38	32	41	18	26	79	105

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

f. Intention to pay and amount to pay

Table 9.3.11 shows the amount to pay for water. On average, 79% of households pay for water. The amount to pay is zero in Hargeti (WH-6), Kenteri (WH-8), and Aneno (WH-9), where there is no water supply facility. All respondents in nine small Towns responded that they pay for water.

The maximum amount of payment is 313 Birr/month/household in Bedeyi (WH-2), where the water tariff is more than twice of other Towns, which is because they have to use two sets of generators for submersible and booster pumps due to the high difference of elevation between the borehole and reservoir tank.

Table 9.3.11: Amount to Pay for Water

ID	Town	Respondent for water payment		Amount	
		Yes	No	Rainy season	Dry season
		%	%	Birr/month/ household	Birr/month/ household
ES-1	Wonji Shewa Alemtena	100	0	27	53
ES-2	Geldiya	96	4	38	60
ES-3	Dire	96	4	131	143
ES-4	Bofa	100	0	34	62
ES-5	Bole	96	4	54	60
ES-6	Ude Dhankaka	70	30	25	38
ES-7	Bekejo	78	22	35	64
ES-8	Kamise	87	13	151	152
ES-9	Chefe Donsa	100	0	39	48
ES-10	Areda	30	70	9	9
ES-11	Biyo	57	43	11	15
ES-12	Adulala	96	4	75	83
AR-1	Sire	96	4	41	43
AR-2	Bolo	100	0	54	96
AR-3	Arboye	100	0	13	21
AR-4	Aseko	100	0	56	57
AR-5	Golegota	91	9	33	36
AR-6	Gonde	100	0	34	34
AR-7	Arbe Gebeya	96	4	21	21
WH-1	Chorora	83	17	72	64
WH-2	Bedeyi	91	9	233	313
WH-3	Hardim	100	0	48	64
WH-4	Bube	96	4	100	116
WH-5	Mieso	87	13	62	95
WH-6	Hargeti	0	100	0	0
WH-7	Bordede	100	0	77	91
WH-8	Kenteri	0	100	0	0
WH-9	Aneno	0	100	0	0
WH-10	Belo	39	61	34	27
WH-11	Kora	96	4	30	37
Average		79	21	51	63

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

g. Need for a new or additional improved water supply system

Table 9.3.12 shows the percentage of respondents who replied to the need for a new or additional improved water supply system. 100% of respondents stated that they need the system in 13 small Towns. The minimum is 48% of respondents in Bedeyi (WH-2). More than 70% of respondents stated that they need the system in the remaining Towns.

Table 9.3.13 shows the water supply situation to be improved. 77% of respondents stated that the water supply volume shall be increased.

Table 9.3.12: Percentage of Respondents who Need Improved Water Supply System

ID	Town	Need improved water supply (NA included)	
		Yes (%)	No (%)
ES-1	Wonji Shewa Alemtena	96	0

ID	Town	Need improved water supply (NA included)	
		Yes (%)	No (%)
ES-2	Geldiya	91	4
ES-3	Dire	100	0
ES-4	Bofa	100	0
ES-5	Bole	83	13
ES-6	Ude Dhankaka	100	0
ES-7	Bekejo	96	0
ES-8	Kamise	96	0
ES-9	Chefe Donsa	100	0
ES-10	Areda	87	4
ES-11	Biyo	100	0
ES-12	Adulala	96	4
AR-1	Sire	100	0
AR-2	Bolo	100	0
AR-3	Arboye	100	0
AR-4	Aseko	100	0
AR-5	Golegota	100	0
AR-6	Gonde	100	0
AR-7	Arbe Gebeya	100	0
WH-1	Chorora	83	4
WH-2	Bedeyi	48	43
WH-3	Hardim	83	13
WH-4	Bube	78	17
WH-5	Mieso	96	0
WH-6	Hargeti	96	0
WH-7	Bordede	96	4
WH-8	Kenteri	87	0
WH-9	Aneno	91	4
WH-10	Belo	100	0
WH-11	Kora	96	4
Average		93	4

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

Table 9.3.13: Water Supply Situation to be Improved

ID	Town	Item to be improved (Multiple answer allowed) (%)					
		Increase supply of water	Improve water quality	Shorter distance in water source	Lower cost of water	Improved system	Other
ES-1	Wonji Shewa Alemtena	52	30	35	0	4	4
ES-2	Geldiya	39	39	9	22	9	0
ES-3	Dire	91	57	57	22	35	0
ES-4	Bofa	61	39	22	22	9	0
ES-5	Bole	78	17	17	13	22	0
ES-6	Ude Dhankaka	96	57	52	52	48	0
ES-7	Bekejo	91	30	17	17	13	0
ES-8	Kamise	91	22	0	0	4	0
ES-9	Chefe Donsa	100	17	0	0	74	0
ES-10	Areda	87	4	0	0	43	0
ES-11	Biyo	74	39	22	17	26	0
ES-12	Adulala	96	91	87	87	74	4

ID	Town	Item to be improved (Multiple answer allowed) (%)					
		Increase supply of water	Improve water quality	Shorter distance in water source	Lower cost of water	Improved system	Other
AR-1	Sire	100	9	0	4	0	0
AR-2	Bolo	65	0	0	35	0	0
AR-3	Arboye	83	13	0	9	0	0
AR-4	Aseko	100	4	0	9	22	0
AR-5	Golegota	78	13	17	9	78	0
AR-6	Gonde	96	9	0	0	17	0
AR-7	Arbe Gebeya	100	0	0	0	61	0
WH-1	Chorora	74	52	0	35	0	0
WH-2	Bedeyi	30	52	13	9	4	4
WH-3	Hardim	74	35	0	43	0	0
WH-4	Bube	57	52	4	35	0	0
WH-5	Mieso	91	91	48	57	0	0
WH-6	Hargeti	74	57	30	52	0	0
WH-7	Bordede	78	43	4	35	0	0
WH-8	Kenteri	70	30	17	65	0	0
WH-9	Aneno	70	39	35	57	9	0
WH-10	Belo	70	43	4	35	0	0
WH-11	Kora	52	96	13	65	17	0
Average		77	36	17	27	19	0

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

h. Water storage conditions at home

Table 9.3.14 shows the cleanliness of the water storage at home. 75% of respondents cover the water storage and maintain it clean.

Table 9.3.14: Water Storage Conditions at Home

Category	Percentage (%)
Covered and kept well	75
Uncovered & kept in unclean	22
Others	3

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

i. Experience of hygiene education

Table 9.3.15 shows that 87% of respondents were trained in hygiene education.

Table 9.3.15: Percentage of Respondents Trained in Hygiene Education

Category	Percentage (%)
Yes	87
No	13

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

j. Water Treatment Method

Thirty six (36) % of respondent treat water. Chlorination is the commonest treatment method. Table 9.3.16 shows method of water treatment.

Table 9.3.16: Water Treatment Method

Category	Percentage (%)
Add chlorine/bleach	15
Filter with clean cloth	12
Boil	6
Use homemade sand filter	2
Other	9

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

k. Patients of diarrhea

Table 9.3.17 shows that 17% of respondents or their families suffered diarrhea within two weeks.

Table 9.3.17: Percentage of Respondents or their Families who Suffered Diarrhea within Two Weeks

ID	Town	Percentage of Respondents or their Families who Suffered Diarrhea within Two Weeks (%)		
		Yes	No	Unknown
ES-1	Wonji Shewa Alemtena	30	61	9
ES-2	Geldiya	22	78	0
ES-3	Dire	30	39	30
ES-4	Bofa	17	83	0
ES-5	Bole	17	83	0
ES-6	Ude Dhankaka	9	52	39
ES-7	Bekejo	35	43	22
ES-8	Kamise	17	83	0
ES-9	Chefe Donsa	4	96	0
ES-10	Areda	26	61	13
ES-11	Biyo	22	78	0
ES-12	Adulala	26	43	30
AR-1	Sire	4	91	4
AR-2	Bolo	39	57	4
AR-3	Arboye	26	70	4
AR-4	Aseko	52	48	0
AR-5	Golegota	9	91	0
AR-6	Gonde	4	96	0
AR-7	Arbe Gebeya	0	35	65
WH-1	Chorora	13	87	0
WH-2	Bedeyi	43	22	35
WH-3	Hardim	0	100	0
WH-4	Bube	0	100	0
WH-5	Mieso	17	83	0
WH-6	Hargeti	22	78	0
WH-7	Bordede	4	96	0
WH-8	Kenteri	4	96	0
WH-9	Aneno	4	96	0
WH-10	Belo	13	87	0
WH-11	Kora	0	96	4
Average		17	74	9

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

l. Intention to pay for the contribution of a new water supply project

In an average, 92% of respondents stated that they have the intention for contributing to a new water supply project. Table 9.3.18 shows the amount of respondents who had the intension to pay.

Table 9.3.18: Amount of Respondents who Have the Intention to Contribute

ID	Town	Intention to contribute (%)		Amount for contribution
		Yes	No	Birr/household
ES-1	Wonji Shewa Alemtena	100	0	67.72
ES-2	Geldiya	100	0	96.22
ES-3	Dire	96	4	128.24
ES-4	Bofa	100	0	200.23
ES-5	Bole	61	39	271.02
ES-6	Ude Dhankaka	96	4	206.25
ES-7	Bekejo	100	0	289.47
ES-8	Kamise	100	0	200.00
ES-9	Chefe Donsa	100	0	156.30
ES-10	Areda	100	0	250.00
ES-11	Biyo	78	22	311.76
ES-12	Adulala	96	4	202.47
AR-1	Sire	100	0	226.74
AR-2	Bolo	100	0	85.48
AR-3	Arboye	100	0	82.17
AR-4	Aseko	96	4	273.33
AR-5	Golegota	100	0	95.31
AR-6	Gonde	96	4	102.95
AR-7	Arbe Gebeya	100	0	90.74
WH-1	Chorora	91	9	138.50
WH-2	Bedeyi	96	4	253.16
WH-3	Hardim	87	13	115.75
WH-4	Bube	78	22	150.00
WH-5	Mieso	43	57	181.00
WH-6	Hargeti	100	0	1,112.95
WH-7	Bordede	100	0	116.09
WH-8	Kenteri	100	0	109.78
WH-9	Aneno	65	35	84.00
WH-10	Belo	100	0	92.00
WH-11	Kora	96	4	85.45
Average		92	8	192.50

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

m. Intension to pay for water tariff

In an average, 90% of respondents stated that they have the intention to pay for water, as shown in Table 9.3.19. The minimum is 65% in Kenteri and Aneno, and the maximum is 100% in eight small Towns. Table 9.3.20 shows the amount of respondents who have the intention to pay for water. The respondents of ES-9, ES-10, AR-1 and AR-6 have requested the amount for per jerry can and not monthly.

Table 9.3.19: Percentage of Respondents with the Intension to Pay for Water

ID	Town	Intension to pay for water (%)	
		Yes	No
ES-1	Wonji Shewa Alemtena	96	4
ES-2	Geldiya	78	22

ID	Town	Intension to pay for water (%)	
		Yes	No
ES-3	Dire	96	4
ES-4	Bofa	96	4
ES-5	Bole	83	17
ES-6	Ude Dhankaka	83	17
ES-7	Bekejo	87	13
ES-8	Kamise	100	0
ES-9	Chefe Donsa	100	0
ES-10	Areda	91	9
ES-11	Biyo	96	4
ES-12	Adulala	91	9
AR-1	Sire	100	0
AR-2	Bolo	100	0
AR-3	Arboye	100	0
AR-4	Aseko	91	9
AR-5	Golegota	91	9
AR-6	Gonde	100	0
AR-7	Arbe Gebeya	100	0
WH-1	Chorora	91	9
WH-2	Bedeyi	78	22
WH-3	Hardim	100	0
WH-4	Bube	91	9
WH-5	Mieso	78	22
WH-6	Hargeti	87	13
WH-7	Bordede	96	4
WH-8	Kenteri	65	35
WH-9	Aneno	65	35
WH-10	Belo	83	17
WH-11	Kora	74	26
Average		90	10

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

Table 9.3.20: Amount of Respondents with the Intension to pay for Water

ID	Town	Amount of contribution	
		per jerry can	Monthly
		Birr/20L	Birr/month/household
ES-1	Wonji Shewa Alemtena	0.34	26.22
ES-2	Geldiya	0.30	38.70
ES-3	Dire	0.78	38.81
ES-4	Bofa	3.00	35.15
ES-5	Bole	2.81	61.34
ES-6	Ude Dhankaka	1.06	24.40
ES-7	Bekejo	3.00	46.00
ES-8	Kamise	0.17	21.47
ES-9	Chefe Donsa	0.39	N.A.
ES-10	Areda	0.46	N.A.
ES-11	Biyo	0.23	33.54
ES-12	Adulala	3.02	25.11
AR-1	Sire	0.36	N.A.
AR-2	Bolo	13.02	71.43
AR-3	Arboye	8.21	13.23
AR-4	Aseko	0.29	27.16
AR-5	Golegota	0.48	43.76

ID	Town	Amount of contribution	
		per jerry can	Monthly
		Birr/20L	Birr/month/household
AR-6	Gonde	0.38	N.A.
AR-7	Arbe Gebeya	0.26	21.00
WH-1	Chorora	0.39	42.38
WH-2	Bedeyi	9.79	183.50
WH-3	Hardim	0.46	31.52
WH-4	Bube	0.34	35.95
WH-5	Mieso	0.31	55.82
WH-6	Hargeti	0.42	33.75
WH-7	Bordede	0.55	47.27
WH-8	Kenteri	0.41	44.60
WH-9	Aneno	0.40	52.87
WH-10	Belo	0.38	26.59
WH-11	Kora	0.45	49.73
Average		1.75	43.51

Source: the Project Team, Data: Result of local consultant and water supply survey in this Project

9.4 Analysis of survey results on existing water facility conditions

Results of the survey on existing water supply facilities' conditions and its' operation & maintenance situation are shown in Table 9.4.1.

Table 9.4.1: Survey Results on existing Water Supply Facilities' Conditions and its' Operation & Maintenance Situation (1/7)

No.	ID No.	Administrative Section				Coordinates by GPS			Accessibility	Interviewee (Representative of the Town)		1-1	1-2	1-3	1-4	1-5	2-1	2-2(1)	2-2(2)
		Town	Woreda	Zone	Region	UTM-E (Adindan)	UTM-N (Adindan)	Altitude (m)	Distance from Paved Road (km)	Name	Position/ Title	Total Population of the Town/ Total Number of the Users of the Facility in the Town	Number/ Population/ Users of Satellite Village using the Facility	Total Number of Users	Is the population increasing after construction of water supply facility?	Distribution of ethnic group in the town	Water Source	Operation of pumping (operating/ break down)・operation time	Time and position of the latest break down/ What is the cause of break down?
1	ES-1	Wonji Shewa Alemtena	Adama Zuria	East Shewa	Oromia	523983	927885	1539	17	Sisay Hailu/ Abebe Yohaness/ Debritu Tefera	Deputy Kebele Chairman Technician/ Public Tap Tariff Collector	12300/ 12300	3 kebeles/ no data/ 5060	17,360	increasing	Amhara (40%), Oromo (35%), Others (25%)	Adama Town Water Supply Service Enterprise (treated river water)	2 days/week and 3 hrs/day (both season)	not applicable
2	ES-2	Geldiya	Adama Zuria	East Shewa	Oromia	537805	957201	1561	7	Tilaye Gebele Kidan/ Megerssa Mobissa/ Jima Degefa	Chairman Water Committee/ Fianace Head of Water Committee/ Plumber	2320/ 2320	2 kebeles/ no data/ 1200	3,520	increasing	Oromo (80%), Amhara (20%)	motorized borehole (1)	7 days/week and 6 hrs/day (both season)	switch board damaged (twice in 2013)
3	ES-3	Dire	Ada	East Shewa	Oromia	488864	961034	1958	12	Worku Dadi/ Negusu Legese	Chairman, Dire Medhanyalem Water Committee/ Chairman, Dire Alerti Water Committee	6462/ 6462	3 Kebeles/ no data/ 850	7,312	increasing	Oromo (97%), Amhara (3%)	motorized borehole (2)	4 days/week and 4 hrs/day (both BH1 and BH2 for both season)	pump damaged (BH1)
4	ES-4	Bofa	Boset	East Shewa	Oromia	549706	935610	1426	9	Abebech Yadeta/ Tessema Tuffa	Manager/ Finance Head of Bofa Town Water Supply Service Office	5460/ 5460	7/ no data/ 11000	16,460	increasing	Oromo (85%), Amhara (10%) & others (5%)	motorized borehole (2)	7 days/week and 12 hrs/day (rainy season), 7 days/week and 24 hrs/day (dry season)	control panel for submersible pump burned
5	ES-5	Bole	Boset	East Shewa	Oromia	582430	956118	1174	24	Tesfaye Mulatu	Manager of Bole Golegota Town Water Supply Service Office	14350/ 14350	1 town + 2 kebeles/ 23452/ 23452	37,802	increasing	Oromo (75%), Amhara (10%) & others (15%)	motorized borehole (1)	7 days/week and 14 hrs/day (both season)	generator broken down
6	ES-6	Ude Dhankaka	Ada	East Shewa	Oromia	504593	959074	1869	0	Amauel Dadi/ Tessema Tufa	Chairman, Water Committee I/ Chairman, Water Committee II	2753/ 2753	0/ 0/ 0	2,753	increasing	Oromo (85%), Amhara (15%)	borehole with hand pump (3)	7 days/week and 24 hrs/day	4 sets of hand dug well with hand pump are breakdown and abandoned.
7	ES-7	Bekejo	Ada	East Shewa	Oromia	493382	952238	1820	25	Guchi Tulu/ Bejiga Beyene/ Beshoda Balcha/ Buzu Bulto/ Kano Negash	Finance Head, Water Committee/ Secretary, Kebele Administration/ Members, Water committee	11000/ 11000	0/ 0/ 0	11,000	increasing	Oromo (95%), Amhara (5%)	motorized borehole (1)	7 days/week and 2 hrs/day (water is finished after 2 hours pumping)	pump can not start since yesterday
8	ES-8	Kamise	Lume	East Shewa	Oromia	512241	963884	1938	11	Kassa Zewdie/ Tilahun Teshome/ Melkamu Tadesse/ Yalemshet Tadesse	Chairman, Water Committee/ Chairman, Kebele Administration/ Secretary, Water Committee/ Members, Water Committee	1896/ 1896	3 kebeles/ no data/ 2600	4,496	increasing	Oromo (80%), Amhara (20%)	Gimbichu-Fentale Town Water Supply Service Enterprise (spring)	5-6 days/week and 9 hrs/day (rainy seson), 4days/week and 7 hrs/day (dry season)	breakdown of pipeline
9	ES-9	Chefe Donsa	Gimbichu	East Shewa	Oromia	513210	991145	2414	34	Belete Taye	Manager, Water Supply Service office	13074/ 13074	2 kebele/ no data/ 2000	15,074	increasing	Oromo (75%), Amhara (16%) and Others (9%)	motorized spring (1)	7 days/week and 9 hrs/day (both season)	control panel burned, June 2012
10	ES-10	Areda	Gimbichu	East Shewa	Oromia	529573	1004272	2520	64	Tsegaye Biftu/ Almaz Tariku/ Andualem Mersha/ Yeshi Shiferaw	Secretary/ Cashier/ Store Keeper/ Members of water committee	2100/ 2100	4kebeles/ no data/ 1750	3,850	increasing	Amhara (90%) and Oromo(10%)	motorized borehole (1)	3 days/week and 4 hrs/day (both season)	breakdown of gate valve, Dec. 2013
11	ES-11	Biyo	Lume	East Shewa	Oromia	507829	956072	1846	0	Mitiku Mamo/ Shewangezaw Tsegaye	Member, Water Committee (for Windmill)/ Secretary, Water Committee	2500/ 2500	0/ 0/ 0	facility not functioning	increasing	Oromo (84%), Amhara (10%) & others (6%)	borehole with windmill pump (1), hand dug well with hand pump (4)	no data	breakdown of windmill pump spindle, Jan. 2013
12	ES-12	Adulala	Liben Zikuala	East Shewa	Oromia	489099	943666	1729	34	Sisay Lemma	Head, Town Water Ssupply Service Office	6000/ 6000	2 kebeles/ 5816/ 5816	11,816	increasing	Oromo (95%) and Amhara (5%)	motorized borehole (1)	7 days/week and 5 hrs/day (rainy season), 7 days/week and 8 hrs/day (dry season)	pump burned, March 2013
13	AR-1	Sire	Sire	Arsi	Oromia	553789	914629	1989	17	Belihu Bogale/ Beyene Negeo	Chairman, Sire-Merfe Water management Board/ Administration & Finance Head, Water Management Board	15,936/ 15936	1 kebele/ no data/ 1000	16,936	increasing	Amhara (60%) and Oromo(40%)	motorized borehole (1), motorized spring (1)	7 days/week-9 hrs/day (rainy season), 7 days/week-6 hrs/day (dry season)	Nov 2013, burning of the electric cable (BH)
14	AR-2	Bolo	Jeju	Arsi	Oromia	563663	911085	2548	37	Teha Turku/ Abe Menza/ Mustefa Kelil	Mayor, Bolo Town Administration/ Chairman, Bolo Town Water Committee/ Finance & Administration, Water Committee	2705/ 2705	4 kebeles/ no data/ 5000	7,705	increasing	Oromo（98%）, Amhara（2%）	motorised borehole (1)	7 days/week-6 hrs/day (rainy season), 7 days/week-6 hrs/day (dry season)	2013, switch board burned
15	AR-3	Arboye	Jeju	Arsi	Oromia	575105	926450	2115	70	Kamilo Aliyi/ Sefi Mohamed	Chairman, Arboye Town Water Committee/ Finance Head, Arboye Town Water Committee	10600/ 10600	9 kebeles/ no data/ 24400	35,000	increasing	Oromo（90%）, Amhara（8%）, Others（2%）	spring with gravity system (1)	7 days/week-24 hrs/day (rainy season), 7 days/week-24 hrs/day (dry season), (available water collection time 1-3 hrs/day)	Feb 2014, transmission pipeline disjointed
16	AR-4	Aseko	Aseko	Arsi	Oromia	612898	940113	2115	91	Johar Haji/ Kedir Amda/ Abebech Mekonnen/ Hussein Bale/ Johar Haji	Deputy Head, Woreda WME office/ Purchaser, Water Committee/ Cashier, Water Committee/ Team Leader, Facility Section, Woreda WME Office	7905/ 7905	0/ 0/ 0	6,905	increasing	Oromo（56%）,Amhara（36%), Others（8 %）	motorised spring (1), spring on spot (1)	7 days/week-4 hrs/day (rainy season), 7 days/week-4 hrs/day (dry season)	Jan 2014, pipeline disjointed
17	AR-5	Golegota	Merti	Arsi	Oromia	582942	955787	1163	24	Tesfaye Mulatu	Manager of Bole-Gologota Town Water Supply service Office	11000/ 11000	1 town + 2 kebeles/ 26802/ 26802	37,802	increasing	Oromo (75%), Amhara (10%) & others (15%)	motorized borehole (1)	7 days/week and 14 hrs/day (both season)	breakdown of generator
18	AR-6	Gonde	Tiyo	Arsi	Oromia	521176	888123	2262	0	Debele Geno/ Tekle Bejiga/ Kelil Gelete	Mayor, Gonde Town Administration/ Finance Head, Gonde-Iteya Water Management Board/ Head, technical Services (Gonde-Iteya WMB)	2598/ 2598	0/ 0/ 0	2,598	increasing	Oromo（43%）, Amhara（32%）, Silte（10%）, Others（15%）	spring with gravity system (1)	7 days/week-24 hrs/day (rainy season), 7 days/week-24 hrs/day (dry season)	never broken down in the past
19	AR-7	Arbe Gebeya	Lodehetosa	Arsi	Oromia	547813	898826	2441	28	Muktar Mohamed/ Demis Hailiye	Mayor, Arbe Gebeya Town Administration/ Chairman, Arbe Gebeya Town Water Committee	6473/ 6473	2 kebeles/ no data/ 5000	11,473	increasing	Oromo（85%）, Amhara（10%）, Others（5 %）	spring with gravity system (1), spring on spot (1)	7 days/week-24 hrs/day (rainy season), 7 days/week-24 hrs/day (dry season)	2012, pipeline broken down
20	WH-1	Chorora	Anchar	West Hararge	Oromia	641097	971517	1691	82	Siraj Shiekadem/ Derebe Mandefro/ Tahir Mohamed/ Rashid Hussein	Chairman, Kebele Administration/ Secretary, Kebele Administration/ Deputy Chairman, Kebele Administration/ Member, Water Committee	3000/ 3000	3 kebeles/ no data/ 2000	5,000	increasing	Oromo（85%）, Argoba（14%）, Amhara（1%）	motorized borehole (1)	7days/week-11hrs/day (rainy season), 7days/week-11hrs/day (dry season)	From Dec, 2013 to Jan 2014 , generator broken down
21	WH-2	Bedeyi	Anchar	West Hararge	Oromia	627376	954910	2149	73	Efrem Belay/ Abebe Aytenfisu/ Abdujebar Geda	Mayor Town Administration/ Chairman, Bedeye Town Water Committee/ Chairman Kebele Administration,	5520/ 5520	4 kebeles/ no data/ 1950	7,470	increasing	Oromo（70%）, Amhara（25%）, Argoba（5%）	motorized borehole (1)	7 days/week-9 hrs/day (rainy season), 7 days/week-9 hrs/day (dry season)	May 2013, Break-down of Generator
22	WH-3	Hardim	Guba Qoricha	West Hararge	Oromia	656277	975905	1632	51	Kedir Mohamed/ Hussiem Ahmed/ Mohamed Nuryasin	Mayor, Hardim Town Administration/ Chairman , Hardim Town Water Committee/ Finance & Administration, Water Committee	8000/ 8000	2 kebeles/ no data/ 3000	11,000	increasing	Oromo（80%）, Amhara（20%）	motorized borehole (1)	7 days/week-10 hrs/day (rainy season), 7 days/week-10 hrs/day (dry season)	Jan. 2014, burning of switch board
23	WH-4	Bube	Guba Qoricha	West Hararge	Oromia	662813	979936	1991	26	Nure Ahemed/ Ahmedsani Abrahim/ Nuran Saide	Chairman, Kebele Town Administration/ Chairman , Bube Town Water Committee/ Finance & Administration, Bube Town Water Committee	5920/ 2420	2 kebeles/ no data/ 400	2,820	increasing	Oromo（90%）, Amhara（7%）, Somali（3%）	motorised spring (1)	2.3 days/week-4 hrs/day (rainy season), 1.8 days/week-4 hrs/day (dry season)	2010, generator broken down
24	WH-5	Mieso	Mieso	West Hararge	Oromia	692799	1021080	1323	0	Almaz Mekonnen	Manager, Town Water Supply Service Office	17000/ 17000	6 kebeles/ no data/ 975	17,975	increasing	Oromo（60%）, Amhara（20%）, Somali (10%), Others (10%)	motorized borehole (2)	7 days/week-24 hrs/day (rainy season), 7 days/week-24 hrs/day) (dry season)	2012, pump burned (BH2)
25	WH-6	Hargeti	Mieso	West Hararge	Oromia	674221	1003489	1349	14	Noma Wako	Chairman, Hargeti Kebele Administration	3287/ no facility	no facility	no facility	increasing	Oromo（100 %）	no facility, surface water (Arba river)	not applicable	not applicable
26	WH-7	Bordede	Mieso	West Hararge	Oromia	652603	996461	1100	2	Ayele Daba/ Getnet Geremew	Store Keeper, (Operator) Water Committee/ Delegate, Mayor (Town Administration)	5000/ 5000	4 kebeles/ no data/ 1550	6,550	increasing	Oromo（97%）, Other（3%）	motorized borehole (1)	7 days/week-10 hrs/day (rainy season), 7 days/week-11 hrs/day (dry season)	June 2013, pump burned (3 times)
27	WH-8	Kenteri	Mieso	West Hararge	Oromia	670893	1005689	1279	10	Mohamed Abdela	Chairman, Kinteri Kebele Administration	2093/ no facility	no facility	no facility	increasing	Oromo（100 %）	no facility, surface water (Kora river)	not applicable	not applicable
28	WH-9	Aneno	Mieso	West Hararge	Oromia	665114	1010056	1319	0	Ume Aliumer/ Ibrahim Adem	Chairman, Kebele Administration/ Civil Service Officer, Aneno Kebele Adminstration	2115/ no facility	no facility	no facility	increasing	Oromo（100%）	no facility, surface water（Kora river）	not applicable	not applicable
29	WH-10	Belo	Mieso	West Hararge	Oromia	644399	983865	1232	18	Usman Hasano/ Shemsu Yusuf	Chairman, Water Committee/ Finance Head, Water committee	3730/ 3730	3 kebeles/ no data/ 0	3,730	increasing	Oromo（97%）, Argoba（3%）	motorized borehole (1)	7 days/week - 9 hrs/day (rainy season), 7 days/week - 9 hrs/day (dry season)	never broken down in the past
30	WH-11	Kora	Mieso	West Hararge	Oromia	668599	1006889	1263	6	Nejib Jadido	Chairman, Water Committee	2360/ 2360	5 kebeles/ no data/ 4250	6,610	increasing	Oromo（95%）, Others（5%）	motorized borehole (1)	7 days/week - 2.5 hrs/day (rainy season), 7 days/week - 2.5 hrs/day (dry season)	Dec 2012, radiator of generator broken down

Source: the Project Team, Data: Result of water supply survey in this Project

Table 9.4.1: Survey Results on existing Water Supply Facilities' Conditions and its' Operation & Maintenance Situation (2/7)

No.	ID No.	2-3(1)	2-3(2)	2-3(3)	2-3(4)	2-3(5)	2-3(6)	2-4 (1)	2-4 (2)	2-4 (3)	2-4 (4)	2-4 (5)	2-4 (6)	2-4 (7)	2-4 (8)	2-4 (9)	2-4 (10)	2-4 (11)	2-5 (1)	2-5 (2)	2-5 (3)	2-5 (4)
		Type of power generating equipment	Manufacturer of power generating equipment	Model & specification of equipment	Output of engine (HP) or electric generator (kVA)	Period of usage (installation month / year)	Condition of equipment(good / bad)	Type of pump	manufacturer of pump	Model and specification of pump	Output (kW), voltage(V)	Cycle(Hz)、Speed(rpm)	Total head (m)	Period of usage (installation month/ year)	Condition of pump (good / bad)	Diameter of riser pipe/ material of riser pipe	Unit length of riser pipe/ total number of pipes	Existing of water flow meter	Year of borehole construction/ finance(donor)	Depth and material of borehole	Depth and diameter of pumping chamber	Depth, diameter and material of screen
1	ES-1	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
2	ES-2	public power supply	not applicable	not applicable	not applicable	not applicable	not applicable	submersible pump	no data	no data	11kW	no data	no data	9 years (since 2005)	the pump requires frequent maintenance	50mm (GS)	6m/ 22.5 pieces	installed and functioning	2003/ World Vision	150m/ uPVC	150m/ 150mm (6")	no data
3	ES-3	public power supply (both)	not applicable	not applicable	not applicable	not applicable	not applicable	submersible pump (BH1 and BH2)	no data	no data	15kW	no data	no data	3 years since Jan. 2011 (BH1), 17 years since 1997 (BH2)	BH1 is good and BH2 is bad	50mm (BH2)	6m/ 23 pieces (BH2)	not exist (BH1 and BH2)	BH1/ 1997/ NGO (Medical Sisters Mission), BH2/1987/ Goverment	180m-BH1-steel, 180m-BH2-	180m-300mm (BH-1) and 180m-200mm (BH-2)	no data
4	ES-4	public power supply (both)	not applicable	not applicable	not applicable	not applicable	not applicable	submersible pump (BH1 and BH2)	no data	no data	18.5kW	no data	no data	8 years since 2006 (BH1) and 9 years since 2005 (BH2)	good	no data	6m-9pcs (BH1), 6m-14pcs (BH2)	installed and functioning for both	1982-China (BH1), 2005-World Vision (BH2)	steel (both)	no data	no data
5	ES-5	diesel generator	Perkins	1006-6TG	100 kVA	3 years and 4 months (since Sep. 2010)	good	submersible pump	Caprari	E6VX27/31+MC64 0-9V	30kW, 400V	50 Hz、2850rpm	195 m	4 years since Sep. 2010	good	65mm/ GSP	6m/ 32pcs	installed and functioning	2010, Ethio-Italy	steel	no data, 7"	steel
6	ES-6	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	hand pump	various	India Mark 2 and AFRIDEV	not applicable	not applicable	not applicable	3 years for 3 hand pumps with borehole	3 hand pumps with borehole are good.	no data	no data	not applicable	2011/ Catholic Church	PVC	52m, no data	no data
7	ES-7	diesel generator	Deutz	F4L912	38 kVA	27 years (since 1987)	acceptable but very old	submersible pump	Grundfoss	no data	7.5kW	50 Hz	no data	27 years	bad, can not start since yesterday	50mm/ GSP	6m-16pcs	not intalled	1987/ no data	103.5m-steel	no data/ 8"	no data
8	ES-8	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
9	ES-9	public power supply (standby diesel generator)	Deutz	F4L912	40 kVA	no data	good	submersible pump	no data	no data	18.5kW	no data	no data	2 years (August 2012)	good	65mm/ GSP	no data	installed but not working properly	1983, governmnet of Ethiopia	no data	no data	no data
10	ES-10	diesel generator	no data	no data	no data	10 years (2002)	good	submersible pump	no data	no data	15kW	no data	no data	12 years (2012)	good	2"/ GSP	6m-17pcs	not istalled	2001, no data	180m, steel	no data	no data
11	ES-11	windmill	no data	no data	no data	15 years (1999)	windmill pump is broken and not functioning	windmill pump	no data	no data	no data	no data	no data	15 years (1999)	breakdown and not functioning	no data	no data	installed/ not working	1999	48m, steel	no data	no data
12	ES-12	public power supply (standby diesel generator)	Deutz	F4M1011F	27 kVA	18 years (July 1999)	available but much fuel consumption	submersible pump	Pleuger	no data	7.5 kW, 400 V	50 Hz	190m@7m^3/hr	21 years (Oct. 1993)	good	50mm, GSP	6m/ 15.5pcs	installed and working	1989, Government	96m, steel	no data, 6"	no data
13	AR-1	public power supply (spring), 2 diesel generators (borehole and booster station)	IVECO (2)	F4GE0485C*F650 (2)	85 kVA (2)	3 years since June 2010 (2)	good (2)	3 submersible pump (spring, borehole and booster station)	no data	no data	no data	50 Hz	no data	33 years since 1981(spring), 3 years since June 2010	old (spring), good condition (borehole and booster)	50mm-GSP (spring), 65mm-GSP (borehole and booster)	6m-0.5pieces (spring), 6m-26pieces (borehole)	installed and working (3)	no data (spring), Jun 2010, UNICEF (borehole)	172m, steel	6"	no data
14	AR-2	public power supply (standby diesel generator)	Deutz	F3L912	27.5 kVA	14 years since 2000	bad	submersible pump	no data	no data	no data	50 Hz	no data	14years since 2000	Good	50mm/ GSP	no data	installed and working	2006/ Oromia regional goverment	no data/ steel	no data/ 6"	no data
15	AR-3	not applicable (gravity system)	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not installed	1982, Arsi Rural Development Unit (ARDU)	not applicable	not applicable	not applicable
16	AR-4	public power supply (standby diesel generator)	IVECO	30591	30 kVA	6 years since 2008	unknown	submersible pump	Grundfoss	no data	no data	no data	no data	5 years, 2009	good	65mm	1.5 m/ 1piece	not installed	2009, Oromia Regional Goverment	not applicable	not applicable	not applicable
17	AR-5	diesel generator	Perkins	1006-6TG	100 kVA	3 years and 4 months (since Sep. 2010)	good	submersible pump	Caprari	E6VX27/31+MC64 0-9V	30kW, 400V	50 Hz、2850rpm	195 m	4 years since Sep. 2010	good	65mm/ GSP	6m/ 32pcs	installed and functioning	2010, Ethio-Italy	steel	no data, 7"	steel
18	AR-6	not applicable (gravity system)	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not installed	Mar 2006, Town Administration and Water Board	not applicable	not applicable	not applicable
19	AR-7	not applicable (gravity system)	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not installed	May 1995, Oromia government	not applicable	not applicable	not applicable
20	WH-1	diesel generator	VM	SUN3105	30 KVA	12 years since 2002	Good (much fuel consumption)	submersible pump	no data	no data	11 kW, 400V	50Hz, 2890rpm	170	12 yeas since 2002	good	2"	no data	not installed	2002, Oromia Regional Government	99.7m, steel	99.7m, 200mm	no data
21	WH-2	2 diesel generators (1 for borehole, 1 for booster pumping station)	Perkins (borehole), John Deere (booster PS)	1103A-337 (borehole) and 60JD (booster PS)	60 kVA (both)	7 years since 2007 (both)	Good (fuel consumption becomes high)	submersible pump (borehole), turbine pump (booster PS)	CMS (borehole) and KSB (booster)	QB 25 (borehole) and 20619146/10 (booster PS)	18.5 kW/ 22 kW, 400V	50Hz, 2890rpm	no data	7 years since 1995	good (both)	65mm/ no data	no data (both)	installed and working (2)	May 2007, Oromia Regional Government	87.65m, steel	87.65m, 6"	no data
22	WH-3	diesel generator	Deutz	F4L912	38 kVA	2 years since 2012 (second hand)	good	submersible pump	Pleuger	no data	14.5 kW, 400V	50Hz, 2890rpm	170m	19 years since 1995	good	65mm/ GSP	6m, 12pieces	installed (not functioning)	1994, Oromia Regional Government	78m, steel	78m, 200mm	no data
23	WH-4	diesel generator	Perkins	2320/1500	40 KVA	4 years since 2010	good	submersible pump	no data	no data	18.5 kW, 400V	50Hz	no data	4 years since 2010	good (both)	2"/ 4"	no data	not installed	2006, Zonal Water Mineral & Energy Office of West Hararge	not applicable	not applicable	not applicable
24	WH-5	public power supply (BH1), public power supply (standby diesel generator) (BH2)	FPT (BH2)	F4GE0455A-F650	70 KVA	2 years since 2012	good	submersible pump (2)	Grundfoss (BH1), CMS (BH2)	AF11-1A (BH-1) CMSE-10909 (BH-2)	11kW-380V (BH-1) 22kW-400V	50Hz (both)	no data	6 years since March 2008 (BH1), 2 years since 2012 (BH2)	good (both)	50mm-GSP (BH-1), 100mm-GSP (BH-2)	no data (BH1), 6m-11.5pieces (BH2)	installed and working (2)	1977-Government (BH1), 2001-China (BH2)	94m-steel (BH1) and 120m-steel	94m-5" (BH1), 120m-10" (BH-2)	no data
25	WH-6	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
26	WH-7	diesel generator (quality of public power supply is very poor so that pumps were burned 3 times)	IVECO	F4GE0455C*F600	60 KVA	5 years since 2009	available but sometimes difficult to start engine	submersible pump	Flankline	no data	15 kW	50Hz, 2860rpm	225m @ 30m^3/hr	9 month since June 2013	good	2"/ GSP	no data	installed and working	1976/ Government	130m, steel	130m, 200mm	no data
27	WH-8	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
28	WH-9	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
29	WH-10	diesel generator	Tianjin Lovol	1003TG14	40 KVA	8 months since June 2013	good (capacity is small)	submersible pump	Grundfos	no data	13 kW,400V	50Hz, 2890rpm	no data	10 years since 2004	good	65mm/ GSP	no data	not installed	2004, Oromia Regional Government	130m, steel	130m, 150mm	no data
30	WH-11	diesel generator	Sisu Diesel	320 DRG (DN3-AJ48PSCI)	40 KVA	1 year 2 month since Dec. 2012	good (difficult to get the spare parts)	submersible pump	Grundfos	no data	13 kW,400V	50Hz, 3950rpm	170m	10 yeas since 2004	good	50mm/ GSP	no data	installed but not working	2004, IRC (International Rescue Committee)	40m, steel	40m/ 150mm	no data

Source: the Project Team, Data: Result of water supply survey in this Project

Table 9.4.1: Survey Results on existing Water Supply Facilities' Conditions and its' Operation & Maintenance Situation (3/7)

ID No.	2-5 (5)	2-5 (6)	2-5 (7)	2-5 (7)	2-5 (8)	2-5 (9)	2-5 (10)	2-6 (1)	2-6 (2)	2-6 (3)	2-6 (4)	2-6 (5)	3-1 (1)	3-1 (2)	3-1 (3)	3-2 (1)
	Geology of aquifer	Static water level (construction/ now)	Pumping rate and draw down (construction)	Pumping rate and draw down (now)	Position of pump (depth)	Problem of borehole (pumping volume decreased/ operation stops often/ containing sand in pumped water) / since when?	Problem of water quality (smell/ taste)	Specification of distribution reservoir	Diameter, length and material of transmission pipe	Diameter, length and material of distribution pipe	Existing water taps	Situation of installation of water meter	Who is responsible for managing the operation and maintenance of water supply facility?	When did the organization/committee been established?	Contact person (name/ position/ phone number)	Is the meeting of water committee held periodically?
ES-1	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	no problem	not applicable	no data	no data	2 public taps, 31 private connection	installed and functioning	water committee not formally established & Adama Town WSSSE	2008	Sisay Abebe, Deputy Head of Kebele Administration, 0911-838107	no
ES-2	no data	no data	no data	no data	137m	decreasing pumping rate since 2010	no problem	$25m^3$	50mm, 65mm/ no data/ GSP	50mm, 40mm, 25mm/ no data/ GSP	4 public taps, 250 private connection and 2 cattle troughs	all installed and 1 piece not functioning	water committee	2003	Tilaye Gebre Kidan, Chairman, 0921-727779	yes (4 times/year)
ES-3	no data	148m(BH1)/ 120m(BH2)	no data	no data	160m(BH1)/ 140m(BH2)	decrease pumping rate and often stops (BH2)	no problem	$25m^3$ (BH1) and $10m^3$ (BH2)	3", 900m, GSP (BH1) / 2", no data, GSP (BH2)	2", 1.5km, GSP (BH1), no data (BH2)	7 public taps, 90 private connection and 5 cattle troughs	all installed (all functioning)	2 water committees for each borehole (BH1and BH2)	1996 (Dire Medhanyalem, WC1) for BH1, 1987 (Dire Arerti, WC2) for BH2	Worku Dadi (WC1), Kassahun Negusu (WC2), 0926-850523	no for WC1, yes (24 times/year) for WC2
ES-4	no data	no data	no data	$14.4m^3$/hr, no data (BH1) and $19.8m^3$/hr, no data (BH2)	56m (BH1) and 86m (BH2)	contains sand (BH1), decreasing pumping rate (both)	no problem	$25m^3$, $50m^3$, $50m^3$	3", 10396m, GSP	2.5"-2200m-GSP and 2", 2"-900m-HDP	11 public taps and 232 private connections	all installed (all functioning)	Bofa Town Water Supply Service Office	2008	Abebexh Yadete, Manager of Town Water Supply Service Office, 0921-728219	yes (12 times/year)
ES-5	no data	no data	no data	$25.2m^3$/hr, no data	194m	no problem	no problem (high concentration of flouride?)	$50m^3$, $10m^3$	3", 3800m, GSP	no data	11 public taps and 251 private connections	all installed (all functioning)	Bole-Golegota Town Water Supply Service Office	Sep, 2013	Tesfaye Mulatu, Manager, Water Suply Service office, 0912-217684	yes (12 times/year)
ES-6	no data	no data	no data	no data	no data	no problem	no problem	not applicable	not applicable	not applicable	not applicable	not applicable	water committee	Aug. 2011	Bekele Shume, Secretary of Water Committee, 0911-081670	yes (12 times/year)
ES-7	no data	no data	no data	no data	no data	decrease pumping rate, sometimes stops and gravel & sand are observed since 2013	no problem	$25m^3$	65mm, 800m, GSP	2", GSP	4 public taps and 26 private connection	all installed (all functioning)	water committee	1987	Guchi Tulu, Chairman, Water Committee, 0921-719609	yes (12 times/year)
ES-8	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	no problem	not applicable	not applicable	75mm, 65mm, and 40mm, no data and PVC	2 public taps, 1 private connection and 1 cattle trough	all installed (all functioning)	Water Committee/ Gimbichu-Fentale Rural Water Supply Service Enterprise	Aug, 2010	Kassa Zewdie, Chairman, 0911-944549	yes (12 times/year)
ES-9	no data	no data	no data	10.8 m^3/hr, no data	no data	not applicable	no problem	90 m^3	2000m, 75mm, GSP	no data	10 public taps and 920 private connections	all installed (all functioning)	Chefe Donsa Town Water Supply Service Office	Oct. 2010	Belete Taye, Manager of TWSS office, 0913-950132	yes (24 times/year)
ES-10	no data	no data	no data	16.7 m^3/hr, no data	no data	decrease pumping rate since 2002	no problem	$25m^3$	50mm, no data, GSP	50mm, no data, GSP	2 public taps and 3 private connections	all installed (all functioning)	Water Committee	2002	Chara Dugma/ chairman/ 0920-465080	yes (24 times/year)
ES-11	no data	no data	14.3 m^3/hr	no data	no data	unknown	unknown	$10m^3$	no data	no data	1 public tap	installed and functioning	Water Committee	1999	Bahiru Begashaw, Chairman, 0931-299302	yes (12 times/year) before breakdown of windmill borehole
ES-12	no data	no data	no data	14.4 m^3/hr	93 m	decrease pumping rate since 2011	no problem	50 m^3 and $25m^3$ (abandoned)	3", 1090m and GSP	2.5"-370m-GSP, 2"-322m-GSP, 1.5"-1300m-GSP	3 public taps and 393 private connection	all installed (all functioning)	Adulala Town Water Supply Service Office	Oct, 2010	Sisay Lemma/ Manager/ 0911-866658	yes (24 times/year)
AR-1	no data	no data	21.6 m^3/hr (borehole)/ $14.4m^3$/hr (spring)	12.5 m^3/hr (borehole)	156 m (borehole)	no problem	no problem	$65m^3$, $50m^3$, $50m^3$(booster station)	4500m-3.5"-GSP, 2500m-3"-GSP	4"-400m-GSP, 2.5"-GSP, 2"-GSP, 1.5"-HDP	21public taps, 516 private connections	all installed (all functioning)	Sire-Merfe Water Management Board	Jun. 2010	Belihu Bogale/ Chairman/ 0913-047753	yes (12 times/year)
AR-2	no data	no data	no data	around 13m^3/hr	no data	no problem	no problem	$40m^3$	65mm, 1000m, GSP	2", no data, GSP	4 public taps, 56 private connections, 1 cattle trough	all installed (1not functioning)	water committee	2000	Abe Menza/ Chairman/ 0920-394377	yes (12 times/year)
AR-3	not applicable	not applicable	no data	no data	not applicable	decrease pumping rate by around 50% from original yield	no problem	$10m^3$, $40m^3$	no data, 3.5", GSP	GSP, uPVC	7 public taps (3 no functioning) and 529 private connections	all installed (3 non functioning)	water committee	2006	Kamilo Aliyi, Manager, 0911-700786	yes (48 times/year)
AR-4	not applicable	not applicable	3 m^3/hr	12.5 m^3/hr	1.5 m	no problem	no problem	$25m^3$	65mm-2300m-GSP, 50mm-150m-GSP	3"-300m-GSP, 2.5"-GSP, 2"-552m-GSP, 1.5"-793m-GSP	6 public taps (2 not functioning) and 66 private connections	all installed (2 not functioning)	water committee	Apr. 2009	Negash Mekennen, Chairman, 0920-932920	yes (24 times/year)
AR-5	no data	no data	no data	25.2 m^3/hr, no data	194 m	no problem	no problem (high concentration of flouride?)	$50m^3$, $10m^3$	3", 3800m, GSP	no data	11 public taps and 251 private connections	all installed (all functioning)	Bole-Golegota Town Water Supply Service Office	Sep, 2013	Tesfaye Mulatu, Manager, Water Suply Service office, 0912-217684	yes (12 times/year)
AR-6	not applicable	not applicable	no data	no data	not applicable	seasonal variation in volume	no problem	not exist	not exist	75mm-100m-GSP, 65mm-500m-GSP, 40mm-400m-HDPE, 25mm-HDPE, 15mm-HDPE, 12mm-HDPE	5 public taps and 278 private connections	all installed (all functioning)	Gonde-Iteya Water Management Board	1999	Wado Kedir, Manager, 0912-064354	yes (12 times/year)
AR-7	not applicable	not applicable	no data	no data	not applicable	no problem	no problem	$50m^3$	100mm-GSP, 75mm-GSP/uPVC	75mm-GSP, 65mm-GSP	5 public taps and 340 private connection	all installed (4 not functioning)	water committee	May 1995	Demis Hailiye, Chairman, 0913-745174	yes (12 times/year)
WH-1	no data	36.32 m	21.6 m^3/hr	16.7 m^3/hr, no data	83 m	decreasing pumping rate and often stops since 2013	no problem	$50m^3$	50mm-GSP	40mm-GSP	3 public taps and 139 private connections	all installed (all functioning)	water committee	2002	Tahir Mohamed, Chairman, 0913-185947	yes (12 times/year)
WH-2	no data	34.10m	18.0 m^3/hr	8.3 m^3/hr, no data	no data	no problem	no problem	50 m^3 and $25m^3$ (booster PS)	100mm, GSP 75mm, GSP	80mm-GSP, 75mm-GSP, 65mm-GSP, 50mm-GSP	5 public taps and 101 private connections	all installed (all functioning)	water committee	May 2007	Abebe Aytenfisu, Chairman, 0932-406431	yes (24 times/year)
WH-3	no data	18.10m	no data	8.3 m^3/hr	72 m	decreasing pumping rate since 2008	no problem	$25m^3$	75mm-GSP	75mm-GSP, 50mm-GSP	7 public taps and 88 private connection	all installed (all functioning)	water committee	1995	Husein Ahmed, Chairman, 0924-169999	yes (24 times/year)
WH-4	not applicable	not applicable	3.5liter/sec	no data	no data	no problem	no problem	$50m^3$	50mm-GSP	no data	4 public taps and 16 private connection	all installed (all functioning)	water committee	2006	Ahmedsani Abrahim, Chairman, 0919-215340	yes (12 times/year)
WH-5	no data	30m (BH-1), 78m (BH-2)	8.3 m^3/hr - no data (BH1), 21.6 m^3/hr - no data (BH2)	8.3 m^3/hr - no data (BH1), 19-20 m^3/hr - no data (BH2)	no data (BH1)/ 69m (BH2)	stop pumping water 2009-2011(BH1), decreasing pumping rate since 2001(BH2)	no problem	$70m^3$ (1977), $50m^3$ (2001)	65mm, no data, GSP (BH1), 75mm, no data,	no data	10 public taps (4 not functioning) and 712 private connection	all installed (all functioning)	Mieso Town Water Supply Service Office	2005	Almaz Mekonnen, Manager, 0913-997881	yes (12 times/year)
WH-6	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
WH-7	no data	120 m	10.8 m^3/hr	8 m^3/hr	120m	decreasing pumping rate since 2009	no problem	$50m^3$	no data, 65mm, GSP	100mm-GSP, 75mm-GSP, 65mm-GSP, 50mm-GSP, 25mm-GSP	9 public taps and 168 private connection	all installed (all functioning)	water committee	2005	Mohamed Yuya, Chairman, 0920-932333	yes (12 times/year)
WH-8	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
WH-9	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
WH-10	no data	no data	no data	2.6 m^3/hr	105 m	decreasing pumping rate since Dec. 2013	no problem	$80m^3$	no data, 75mm, GSP	no data-75mm-GSP, no data-50mm-GSP, no data-40mm-GSP	3 public taps and 1cattle trough	all installed (all functioning)	water committee	2004	Usman Hasano, Chairman, 0926-641723	yes (52 times/year)
WH-11	no data	20 m	$18.7m^3$/hr	20 m^3/hr	37 m	no problem	salty taste	$50m^3$	no data, 75mm, GSP	no data, 65mm, GSP	4 public taps (1 not functioning) and 75 private connection	all installed (all functioning)	water committee	2004	Nejibo Jadido, Chairman, 0920-364079	yes (10 times/year)

Source: the Project Team, Data: Result of water supply survey in this Project

Table 9.4.1: Survey Results on existing Water Supply Facilities' Conditions and its' Operation & Maintenance Situation (4/7)

No.	ID No.	3-2 (2)	3-2 (3)	3-2 (4)	3-2 (5)	3-3 (1)	3-3 (2)	3-3 (3)	3-4 (1)	3-4 (2)	3-4 (3)	3-5	3-6
		Is the record of income and expenditure of water committee issued monthly?	Is the general assembly by all of users held annually?	Period of experience of the operator	Operator has ever been trained?	System of water tariff	The rate of collection of water tariff is 100%?	The water tariff is set reasonable to conduct operation and maintenance for water supply facilities?	Where to keep the collected amount of money?	If you keep in the bank, date of opening account, name of the bank and name of the registered person.	If there is not much expenditure for repairing cost etc., collected amount of cash is deposited to the bank account? How much is remaining amount of the fund now?	Water supply facilities and water taps are kept clean? In case no, what is the reason?	When was the latest breakdown of the water supply facility? What was the cause of breakdown? How did it be repaired?
1	ES-1	no	yes	no operator	not applicable	5 birr/m^3	yes	too cheap	cash in the village	not applicable	not applicable	yes	Nov. 2013, damage of distribution pipeline
2	ES-2	yes	yes	17 years	yes (on site) for 1 week	7 birr/m^3	yes	reasonable	bank	2003/ Oromia Credit & Saving Association/ Chora Chore Water Committee	yes/ 320,000 birr (bank) and 2,000 birr (cash)	yes	Sep, 2013 (pipeline damage)
3	ES-3	yes (both WC1 and WC2)	no for both WC1 and WC2	unknown for WC1, 5 years for WC2	no for WC1, yes (2 days by Woreda office) for WC2	6 birr/m^3 (WC-1) and 8 birr/m^3 (WC-2)	yes (both WC1 and WC2)	too cheap for both WC1 and WC2	bank for both WC1 and WC2	1997, CBE-Bishoftu Branch, Dire Medhanyalem Water Committee for WC1, 1987, CBE-Bishoftu Branch, Dire Arerti Water Committee for WC2	yes/ 70,000 birr (bank) and 1,500 birr (cash) for WC1, unknown for WC2	no for both BH1 and BH2	2012-breakdown of submercible pump for WC1, 2012-maintenance of submersible pump for WC2
4	ES-4	yes	no	3 operators with experience of 13years, 2years and 1years	yes (7 days in Mojo) for 3 operators	4.0 birr/m^3 (public tap), 5.20 birr/m^3 (0-3m^3), 5.8 birr/m^3 (4-6m^3), 6.2 birr/m^3 (7-10m^3), 7.1 birr/m^3 (over 11m^3)	yes	too cheap	bank	Sep. 2000, CBE Adama Branch, Bofa Town Water Supply Service Office	yes/ 532,000 birr (bank) and 3,000 birr (cash)	yes	Nov. 2013, distribution pipeline disjointed by the flood
5	ES-5	yes	yes	16 years	yes (15days at Arsi zonal WME office)	16.0 birr/m^3 (public tap), 17.0 birr/m^3 (0-5m^3), 17.5 birr/m^3 (6-10m^3), 18.5 birr/m^3 (11-30m^3), 20.0 birr/m^3 (over 30m^3)	no (90 to 95%)	too cheap	bank	Sep. 2010, Cooperative Bank of Oromia Bole branch, Bole Golgota water supply service office	yes/ 464,647 birr (bank) and 500 birr (cash)	yes	Dec, 2013, breakdown of generator
6	ES-6	no	yes (2 times/year)	no operator	no operator	10 birr/ month/ household	yes	reasonable	bank	2003, Cooperative Bank of Oromia Bishoftu branch, water committee	yes/ 3,000 birr (bank) and 600 birr (cash)	yes	no breakdown in the past
7	ES-7	yes	yes	5 month	yes (2 days on site by Woreda office)	22 birr/m^3	yes	reasonable	bank	unknown, CBE Bishoftu Branch, Bekejo water committee	yes/ 57,000 birr (bank) and 4,500 birr (cash)	yes	Jan. 2014, pump not started
8	ES-8	no	no	not in the town	not in the town	6.25 birr/m^3	yes	reasonable	Gimbichu-Fentale Rural Water Supply Service Enterprise	not applicable	not applicable	yes	Jan, 2014, damage of PVC pipeline
9	ES-9	yes	yes	2 person, 10years and 3years	old operator trained 2 weeks by East shewa zonal office/ new operator never trained	5 Birr/m^3	no (90%)	too cheap	bank	Oct. 2010, CBE Chefe Donsa branch, Chefe Donsa Town Water Supply Service office	yes/ 140,000 birr (bank) and 5,000 birr (cash)	yes	June 2012, switch board burned
10	ES-10	yes	yes (1 time/year)	1 year	1 day OJT on site by Woreda office	25 Birr/m^3	yes	too cheap	bank	Apr. 2013, Cooperative Bank of Oromia Chefe Donsa branch, Areda Wera water committee	yes/ 2,229 birr (bank) and 103 birr (cash)	yes	Dec. 2013, damage of gate valve
11	ES-11	yes	no	no operator	not applicable	12.5 birr/m^3	yes	too cheap	cash in the village and bank	no data	no data	yes	Jan. 2013
12	ES-12	yes	yes	21 years	1month at East Shewa zonal office	5.0 birr/m^3 (public tap), 5.5 birr/m^3 (0-3m^3), 6.3 birr/m^3 (4-6m^3), 7.5 birr/m^3 (7-10m^3), 8.7 birr/m^3 (over 11m^3)	no (98%)	too cheap	bank	1993, CBE Adulala branch, Adulala Town Water Supply Service Office	yes/ 330,719.72 birr (bank) and 5,000 birr (cash)	yes	March, 2012, pump burned
13	AR-1	yes	yes (twice a year)	2years (borehole), 5years (spring), 9years (booster pump)	3 days on the job training	22 birr/m^3	yes	too cheap	bank	Oct. 2012, CBE and Oromia Credit & Saving Bank, Sire-Merfe Water Management Board	yes/ 381,072 birr (bank) and 1,000 birr (cash)	not clean around the spring water source	Nov. 2013, burning of electric cable of submercible pump at borehole
14	AR-2	yes	yes	4 years	no	14 birr/m^3 for public taps and 18 birr/m^3 for private connection	yes	too cheap	bank	2000, Commercial Bank of Ethiopia Dera branch, Bolo Town Water Supply Station	yes/ 0.00 birr (bank) and 0.00 birr (cash)	yes	Feb. 2013, switch board is burned
15	AR-3	yes	yes	no operator	not applicable	2 birr/m^3 for public taps, 2.75 birr/m^3 for private connection	yes	too cheap	bank	2006, CBE Arboye branch, Arboye Town Water Committee	yes, 10,500 birr (bank) and 0 birr (cash)	yes	Feb 2014, transmission pipeline disjointed
16	AR-4	yes	no	5 years	no	9 birr/m^3	yes	too cheap	bank	2012, Oromia Credit & Saving Association and CBE, Aseko branch, Aseko Town Water Committee	yes, 27,400 birr (bank) and 0 birr (cash)	yes	Jan. 2014, transmission and distribution pipeline disjointed
17	AR-5	yes	yes	16 years	yes (15days at Arsi zonal WME office)	16.0 birr/m^3 (public tap), 17.0 birr/m^3 (0-5m^3), 17.5 birr/m^3 (6-10m^3), 18.5 birr/m^3 (11-30m^3), 20.0 birr/m^3 (over 30m^3)	no (90 to 95%)	too cheap	bank	Sep. 2010, Cooperative Bank of Oromia Bole branch, Bole Golgota water supply service office	yes/ 464,647 Birr (bank) and 500 birr (cash)	yes	Dec, 2013, breakdown of generator
18	AR-6	yes	no	no operator	not applicable	5 birr/m^3 (public taps), 4.25 birr/m^3 (0-30m^3) 5 birr/m^3 (over 30m^3)	yes	too cheap	bank	1999, CBE Asela branch and Cooperation Bank of Oromia Iteya branch, Gonde-Iteya Town Water Management Board	yes, 1,300,000 birr (bank) and 500 birr (cash)	yes	2012, damage of pipeline by flood
19	AR-7	no, 4 times/year	no	no operator	not applicable	1.5 birr/m^3 plus 2 birr/month/connection as water meter rental fee	no (85%)	too cheap	bank	May 1995, CBE Huruta branch, Jimata Lode Water Committee	yes, 10,200 birr (bank) and 5,000 birr (cash)	yes	Aug. 2012, damage of transmission pipeline
20	WH-1	yes	yes	4 years	no	18 birr/m^3 for public taps and 21 birr/m^3 for private connection	yes	too cheap	bank	May 2005, CBE Gelemso branch and Oromia Credit & Saving Bank Cheleleka branch, Chorora Town Water Committee	yes, 36,500 birr (bank) and 4,000 birr (cash)	yes	Dec. 2013, breakdown of generator and swith board
21	WH-2	yes	yes	2 operators with 7years and 2months experience	3-4 days on the job training at Woreda Office	38 birr/m^3 for public taps and 42 birr/m^3 for private connections	yes	too cheap	cash in the village	not applicable	no, 10,000 birr (cash)	yes	May 2013, generator broken down
22	WH-3	yes	yes	19 years	10.5 month at Zonal WME office	19 birr/m3 for public taps and 25 birr/m3 for private connection	yes	too cheap	bank	May 1997, CBE Gelemso branch	yes, 10,000 birr (bank) and 15,000 birr (cash)	yes	Jan 2014, switch board burned
23	WH-4	yes	no	8 years	no	20 birr/m^3 for public taps and 21 birr/m^3 for private connections	no (100% only for public taps)	too cheap	bank	2013, CBE Gelemso branch, Bube Town Water Committee	yes, 15,000 birr (bank) and unknown (cash)	yes	May 2010, generator broken down and replaced with new one
24	WH-5	yes	yes	10 years both 2 operators	no (both)	7.5 birr/m^3 for public taps and 6.0 birr/m^3 for private connection plus 2 birr/ month/ connection as water meter rental fee	no (72%)	too cheap	bank	June 2005, CBE Mieso branch, Mieso Town Water Supply Service Office	yes, 314,586.24 birr (bank) and 2,000 birr (cash))	yes	Jan 2012, pump burned and replaced
25	WH-6	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
26	WH-7	yes	no	8 years	1 month and 5 days by IRC in 2004	20 birr/m^3 (6 birr/m^3 when using public power supply in the past)	yes	too cheap	bank	CBE Mieso Branch, Bordede Town Water Committee	yes, 50,000 birr (bank) and 5,000 birr (cash)	yes	June 2013, pump burned
27	WH-8	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
28	WH-9	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
29	WH-10	no (4 times/year)	yes	11 years	yes, 1 week on the job site by Woreda WME office	20 birr/m^3	yes	too cheap	bank	CBE Mieso branch, Gololcha Water Committee	yes, 11,000 birr (bank) and 5,000 birr (cash)	no, users don't follow the instruction of water committee	never broken down in the past
30	WH-11	yes	yes	2 years	no	19 birr/m^3 for public taps and 20 birr/m^3 for private connection	yes	reasonable	bank	CBE Mieso branch, Kora Rural Town Water Committee	yes, 87,000 birr (bank) and 5,000 birr (cash)	yes	Dec. 2013, problem on radiator of generator

Source: the Project Team, Data: Result of water supply survey in this Project

Table 9.4.1: Survey Results on existing Water Supply Facilities' Conditions and its' Operation & Maintenance Situation (5/7)

No.	ID No.	3-7 (1)	3-7 (2)	3-8 (1)	3-8 (2)	3-8 (3)	4-1	4-2 (1)	4-2 (2)	4-3 (1)	4-3 (2)
		How to provide the fund for repairing facilities? (Is it possible to cover the costs of repair by remaining amount of water committee?)	Is there any private company to ask repairing facilities?	At the latest breakdown, to whom did you ask to repair?	How much did you pay for the cost of its repairing?	In case you cannot repair the facility, what is the reason that you cannot repair?	In case water supply project will be implemented, do you have intension to participate in the project?	In case water supply project will be implemented, can you pay for any part of construction cost?	If yes, maximum how much amount can you pay for?	Do you have intension to operate and maintain water supply facility by establishing Water Management Committee, setting water tariff by volume and opening bank account to save collected tariffs?	In case you agree to establish Water Management Committee, the water tariff shall be paid depending on the consumed water volume. How much do you set the price per cubic meter?
1	ES-1	temporary collection	no	Adama Town WSSSE	200 birr	shortage of money for purchase of fittings	yes	yes	50,000 - 60,000 birr	yes	6 birr/m^3
2	ES-2	remaining fund	no	operator	60 birr	none	yes	yes	10-20% of the total project cost	yes	7-10 birr/m3
3	ES-3	remaining fund for WC1 and WC2	no for both WC1 and WC2	Woreda WME office	33,000 birr for WC1 and 8,083 birr for WC2	lack of qualified technician for both WC1 and WC2	yes for WC1 and WC2	yes for WC1 and WC2	20% of the total project cost for WC1 and WC2	yes for WC1 and WC2	8 birr/m^3 for WC1 and WC2
4	ES-4	remaining fund	no	operator	2,738 birr	none	yes	yes	129,000 birr or more	yes	same as existing tariff
5	ES-5	remaining fund	no	Zonal WME office	49,000 birr	beyond the capasity of town water supply service office	yes	yes	50% of the remaining fund	yes	the water supply service office has plan to reduce tariff in case public electric power will be supplied by Ethiopian Electric power Corporation (EEPCO)
6	ES-6	remaining fund	no	no breakdown in the past	no breakdown in the past	no breakdown in the past	yes	yes	no idea	yes	12.5 birr/m^3
7	ES-7	remaining fund	no	Woreda WME office	12,000 birr	lack of qualified technician	yes	yes	whatever amount is asked by the project	yes	22 birr/m^3 unless public power supply is connected
8	ES-8	temporary collection	no	Gimbichu-Fentale Rural Water Supply Service Enterprise	1500 birr	lack of qualified technician	yes	yes	200,000 birr	yes	10 Birr/m^3
9	ES-9	remaining fund and temporary collection in case remaining fund is not enough	no	Zonnal WME office	1,000 birr	lack of qualified technician	yes	yes	200,000 birr	yes	7 Birr/m^3
10	ES-10	remaining fund	no	Woreda WME office	990 birr	lack of qualified technician	yes	yes	no idea	yes	25 birr/m^3
11	ES-11	no data	no	Woreda WME office	4,000 birr	lack of qualified technician and spare parts	yes	yes	100 birr/ household	yes	25 birr/m^3
12	ES-12	remaining fund	no	Zonnal WME office	121,771.32 birr	lack of qualified technician	yes	yes	300,000 birr	yes	same as existing tariff
13	AR-1	remaining fund	no	Zonal WME office	4,000 birr	lack of major equipment and qualified technician	yes	yes	500,000 birr	yes	7-10 birr/m^3 in case connected to public power supply at borehole and booster station
14	AR-2	remaining fund	no	Zonal WME office	3000 birr	lack of qualified technician	yes	yes	40% of project cost	yes	10 birr/m^3
15	AR-3	remaining fund	no	water committee	6,000 birr	water committee has technician who can repair the water supply facilities	yes	yes	5% of the total project cost	yes	3.5 birr/m^3
16	AR-4	remaining fund	no	Woreda WME office	4,000 birr	lack of qualified technician	yes	yes	50,000 - 100,000 birr	yes	13 birr/m^3
17	AR-5	remaining fund	no	Zonal WME office	49,000 birr	beyond the capasity of town water supply service office	yes	yes	50% of the remaining fund	yes	the water supply service office has plan to reduce tariff in case public electric power will be supplied by Ethiopian Electric power Corporation (EEPCO)
18	AR-6	remaining fund	no	Zonal WME office	no data	lack of qualified technician	yes	yes	200,000 birr	yes	7 - 8 birr/m^3
19	AR-7	remaining fund	no	Woreda WME office	5,000 birr	lack of qualified technician	yes	yes	10% of the project cost	yes	3.0 birr/m^3
20	WH-1	remaining fund	no	Zonal WME office through Woreda WME office	1,500 birr	lack of qualified technician	yes	yes	50,000 birr	yes	20 birr/m^3
21	WH-2	remaining fund and temporary collection	no	Regional WME bureau via Zonal WME office via Woreda WME office	18,000 birr	lack of qualified technician	yes	yes	20,000 - 25,000 birr	yes	42 birr/m^3 (in case of generator) or 8 birr/m^3 (in case of public power supply)
22	WH-3	remaining fund	no	Zonal WME office through Woreda WME office	2,000 birr	lack of qualified technician	yes	yes	100,000 birr	yes	19-25 birr/m^3 (in case of generator) or 5-6 birr/m3 (in case of public power supply by EEPCO is available)
23	WH-4	remaining fund	no	Zonal WME office through Woreda WME office	0 birr (new generator supplied by Regional WME bureau free of charge)	lack of qualified technician	yes	yes	5% of the project cost	yes	20-21 birr/m^3 (in case of generator) or 8 birr/m^3 (in case of public power supply by EEPCO will be available)
24	WH-5	remaining fund	no	Zonal WME office through Woreda WME office	20,000 birr (pump supplyed by OWMEB free of charge)	lack of qualified technician	yes	yes	50,000 birr	yes	10 birr/m^3
25	WH-6	not applicable	not applicable	not applicable	not applicable	not applicable	yes	yes	no idea	yes	no idea
26	WH-7	remaining fund	no	Zonal WME office through Woreda WME office	25,000 birr (new submersible pump supplied by OWMEB as free of charge)	lack of qualified technician	yes	yes	no idea	yes	20 birr/m^3 (in case of generator) and 5-6 birr/m3 (in case of publich power supply)
27	WH-8	not applicable	not applicable	not applicable	not applicable	not applicable	yes	yes	200 birr/ household	yes	25-50 birr/m^3
28	WH-9	not applicable	not applicable	not applicable	not applicable	not applicable	yes	yes	10,000 birr or more	yes	25 birr/m^3
29	WH-10	remaining fund	no	maintenance by Woreda WME office	400-500 birr for maintenance	lack of qualified technician	yes	yes	20% of the project cost	yes	20 birr/m^3 (in case of generator) and 15 birr/m3 (in case of public power supply)
30	WH-11	remaining fund	no	repaired at private garage in Awash Town	2,200 birr	lack of qualified technician	yes	yes	no idea	yes	20 birr/m^3 (if case of generator), reducing tariff in case public power supply will be connected

Source: the Project Team, Data: Result of water supply survey in this Project

Table 9.4.1: Survey Results on existing Water Supply Facilities' Conditions and its' Operation & Maintenance Situation (6/7)

No.	ID No.	4-3 (3)	4-4	5
		In case you agree to establish Water Management Committee, it is necessary to open the account to save the collected amount of water tariff and fund. Where do you intend to open the account?	When the equipment such as pumps, generators, etc become old and necessary to replace with new equipment, do you have intension to pay for the cost of new equipment?	Do you have any other problems of water supply facilities and operation & maintenance, etc.? If yes, please mention detail of the problem.
1	ES-1	Comercial Bank of Ethiopia (CBE) , Wonji branch	yes	1. no water supply during the day time due to the low water pressure, 2. shortage of water from the source
2	ES-2	CBE, Adama branch	yes	1. shortage of water from the source, 2. need additional $50m^3$/day water supply, 3. new borehole, distribution reservoir, 4 public fountaines and 250 private connection shall be needed.
3	ES-3	same as existing bank	yes for WC1 and WC2	1. shortage of water from the source, 2. low water pressure at the water point, 3. capsity of submercible pump is low, 4. pumping yield decreased much, 5. lack of office for the staff, 6. capasity and experience of technicains and opreators are not enough
4	ES-4	same as existing bank	yes	1. water shortage, 2. generator shall be needed due to frequent interupption of public electric power supply, 3. shortage of office and storage space, 4. lack of trainig for staff
5	ES-5	same as existing bank	yes	1. water is short and necessary to construct additional borehole, 2. not enough money (1.3 million birr) to pay for EEPCO to get electric power supply, 3. low pressure in the pipeline most places do not get water, 4. worring about water quality for fluoride contamitation, 5. lack of qualified manpower
6	ES-6	same as existing bank	yes	1. shortage of water, 2. operation of the hand pump is difficult for women and children, 3. cattle trough is needed, 4. water tap is necessary 8 points (6 pouints for Ude side and 2 points for Dhankaka side)
7	ES-7	same as existing bank	yes	1. shortage of water from the source, 2.water in the borehole is finished after 2 hrs pumping, 3. lack of public fountains (4 additional needed) and distribution reservoir, 4. replace diesel generator with electric power supply, 5. no training is given to the staff, 6. lack of ofice space
8	ES-8	Cooperative Bank of Oromia Mojo branch	yes	1. water shortage from the source, 2. time of water supply is not sure due to the lack of water pressure, 3. PVC distribution pipeline get broken very easily, 4. additnal 6 public fountaines and distribution reservoir shall be needed, 5. lack of capasity of manpower
9	ES-9	same as existing bank	yes	1. shortage of water from the source, 2. low pressure at water point, 3. extension of distribution pipeline to newly developed area shall be needed, 4. there are some damages of pipeline by vehicles
10	ES-10	same as existing bank	yes	1. replace the generator with electric power supply of EEPCO because fuel cost is too much expensive, 2. there are few numbers of private connection and hence small revenue from water sales so that more private connection shall be neededd, 3. capasity no office space for the water committee
11	ES-11	CBE Mojo branch	yes	1. water shortage in some areas of the town, 2. low income households are not able to construct hand dug wells in their compound, 3. frequent break-down of water supply facility (windmill borehole), 4. lack of pipeline to connect to water points, 5. five public fountaines and private connection shall be needed
12	ES-12	same as existing bank	yes	1. shortage of water from the source, 2. reservoir becomes empty quickly before filling up, 3. extention of distribution pipeline shall be needed 4. lack of office for the staff, 5. lack of staff training, 6. Lack of tools for maintenance, 7. lack of transportation vehicle, 8. lack of pipe and fittings in the store
13	AR-1	same as existing bank	yes	1. shortage of water from the source, 2. twice of existing water supply volume shall be needed, 3. electric power suppy (by EEPCO) is not connected to the borehole and booster pump station, 4. lack of office for the staff, 5. lack of staff training (capacity building), 5. lack of transportation vehicle
14	AR-2	Commercial Bank of Ethiopia, Dera Branch	yes	1. shortage of water due to high population increase (the water supply system was originally designed for half the current population size), 2. shortage of water due to population increase in saterite kebeles, 3. additional borehole shall be needed, 4. capasity of distribution reservoir is too small, 5. investigation of existing borehole to check the yield variation in dry and wet season shall be neeeded, 6. corrosion of transmission pipeline
15	AR-3	same as existing bank	yes	1. shortage of water from the source, 2. study for borehole or spring with motorized scheme is required, 3. the reservoir capacity is very small, so additional larger capacity reservoir is required
16	AR-4	CBE, Aseko branch	yes	1. shortage of water from the source (yield obtained from the spring is very small) so that water is finished after 2 hours from the commencement of supplying water every morning, 2. construction of cattle trough for livestock using the spring source located on the vicinity of the town shall be needed, 3. Additional public taps are needed, 4. Povide private connections to households (up to 200 numbers)
17	AR-5	same as existing bank	yes	1. water is short and necessary to construct additional borehole, 2. not enough money (1.3 million birr) to pay for EEPCO to get electric power supply, 3. low pressure in the pipeline most places do not get water, 4. worring about water quality for fluoride contamitation, 5. lack of qualified manpower
18	AR-6	same as existing bank	yes	1. water shortage from the source (Gonde spring) so that there is no water at some water tap in dry season, 2. only 30% of the area of town is coverd by water supply system, 3. motorized system (borehole or spring) will be acceptable if there is no spring source with gravity flow, 4. the income level of the population is low so cannot afford construction cost
19	AR-7	same as existing bank	yes	1. replacement of GSP pipeline with PVC or HDPE hsall be needed due to the corrosion of GSP pipe, 2. capacity of existing distribution reservoir is not enough (continuous overflow from the existing reservoir), 3. lack of office for the water committee, 4. upgrade to water management board, 5. lack of transportation means, 6. lack of good quality maintenance tools,
20	WH-1	Commercial Bank of Ethiopia, Awash branch	yes	1. There is water shortage from the water source, so it is necessary to rehabilitate existing well and construct one additional borehole, 2. The generator, when operated more than 10 hours, become very hot, 3. The number of public taps are not enough, so construction of additional 2 public taps shall be needed, 4. The storage capacity of existing distribution reservoir is not enough, so construction of additional 100m3 distribution reservoir shall be needed, 5. More private connection shall be needed, 6. The water committee does not have office building, so construction of office block, 7. There is no transportation facility, so 2 motor bikes are required, 8. One computer is needed for bill preparation
21	WH-2	Commercial Bank of Ethiopia, Metehara branch	no, difficult to pay for pumps and generators	1. diesel generator set is consuming much fuel, so better to replace it with public electric power supply by EEPCO (EEPCO request payment of 240,000 birr for electric line to booster pump station, 2. two (2) sets of additional distribution reservoir which capacity is 100m3 shall be needed, 3. five additional public taps are required for the rural kebeles, 4. provision of private connection to the households (250 connections are required)
22	WH-3	same as existing bank	yes	1. there is water shortage from the water source, so one additional borehole is required to increase water supply volume up to twice of existing capasity, 2. Water cannot be supplied to some areas (including health centre) in the town due to location of reservoir is on lower ground, 3. pressure in the distribution pipeline is very low, so some areas cannot get water, 4. high fuel cost of generator so it is better to replace the diesel generator with electric power form EEPCO, 5. as some areas in the town are not covered with public taps, it is necessary to construct additional 4 public taps and additional 150 private connections
23	WH-4	same as existing bank	yes	1. the transmission pipeline is block by silt which further decrease flow of water, so it needs to be flushed, 2. extension of water supply system to the 3 rural kebeles (Goro-Bate, Goro-Amhara and Ella) shall be needed, 3. the diesel generator set is consuming much fuel, so better to replace it with public electric power supply form EEPCO, 4. access road to the spring site requires for rehabilitation
24	WH-5	same as existing bank	yes	1. water supply area is rotated day by day due to the lack of water so that water is available only 1-2 days a week in average, 2. three (3) more boreholes are required to satisfy water demand of the population of the town, 3. distribution reservoir capacity is very low, so one additional reservoir is required, 6. the number of private connection can be increased by 1000 new connections, 7. additional 20 public taps are required, 8. there are no computers, printers to prepare bill and carry out other office works, 9. the existing water supply service office is made from CIS and better office block for the staff, 10. lack of transportation vehicle for the office staff, 11. the office does not have a ware house
25	WH-6	Commercial Bank of Ethiopia, Mieso branch	yes	1. long time fetch water from the surface water sources as it is located 2 km from the Kebele, 2. during rainy season it is difficult and dangerous to collect and fetch water from the river source as the river water level increases, 3. the community requires a motorized borehole or spring water pipeline system with public taps and private connection
26	WH-7	Commercial Bank of Ethiopia, Mieso branch	no, difficult to pay for pumps and generators	1. water users are complaining about the current water tariff (too high), 2. water is finished within 2 hours after filling up distribution reservoir even they fill up it twice a day, 3. the town needs additional water source (2 sets of borehole), as the existing one is very old, 4. shortage of public taps and cattle troughs (so additional 4 public taps and 4 cattle troughs are needed), 6. the water committee needs office building to provide quality service, 7. office material such as office furniture and printer and printer are also needed
27	WH-8	Commercial Bank of Ethiopia, Mieso branch	yes	1. the water fetched from spring does not have good quality so that people gets water borne disease, 2. women spend more time collecting water than working at home, 3. motorised borehole or motorized spring with distribution system with public taps and private connections is required, 4. no idea about water source, 5. the inhabitants of the town have capacity to connect to the water supply system
28	WH-9	Commercial Bank of Ethiopia, Mieso branch	no, difficult to pay for pumps and generators	1. it takes long time to fetch water from Kora river which is around 7km far from village, 2. women spend more time for fetching water than working at home, 3. during rainy season people collect rain water, 4. motorized borehole or spring with distribution system is required, 5. around five public taps are needed, 6. the inhabitants of the town have capacity to make private connection to the water supply system for 100 households
29	WH-10	same as existing bank	yes	1. Shortage of water from the source, so addional borehole shall be needed, 2. Elevation of distribution reservoir is not high as it is unable to supply water whole area of the town, 3. The exisitng public taps are not enough, so additional 6 public taps are required, 4. additional 4 cattle trough shall be constructed to provide water to livestock in the town
30	WH-11	same as existing bank	no, difficult to pay for pumps and generators	1. water hardness problem (salty taste), 2. water pressure in the distribution system is low in some areas of the town, 3. reservoir is not storing sufficient water (low capacity), 4. cost of fuel for running the generator is high so that minimize pumping time, so necessary to replace it with public electric power supply, 5. public taps are not available in some area of the town, so additional 4 public taps are required

Source : the Project Team, Data: Result of water supply survey in this Project

Table 9.4.1: Survey Results on existing Water Supply Facilities' Conditions and its' Operation & Maintenance Situation (7/7)

No.	ID No.	6	7	8
		Is there any water supply project by other donors on going or in future? If yes, please mention the title and scope of the project.	Is there any spring which is available as water source for drinking water supply around the town? If yes, please mention the number and the location, And also please explain that is it no dry-up whole year?	Remark
1	ES-1	no	no	Water tariff is set by Adama TWSSSE, living condition of the population is very low
2	ES-2	no	no	
3	ES-3	no	no	
4	ES-4	no	no	
5	ES-5	no	no	Awash river flows close to the town and people use the water for different purposes, due to low pressure in the pipeline most places do not get water
6	ES-6	no	no	
7	ES-7	no	no	
8	ES-8	no	no	
9	ES-9	no	no	ccollection chamber of new spring water source (yield, 4.6 l/sec) is under construction
10	ES-10	no	there is one spring which yield is estimated to be around 0.36 l/sec	
11	ES-11	no	no	
12	ES-12	no	no	
13	AR-1	no	no	
14	AR-2	no	no	
15	AR-3	no	no information	
16	AR-4	no	There are two spring sources • the first spring is not provided wi th structure (yield is estimated to be around 0.75 l/s) • the second spring is inside the town and provide on-spot supply (yield is around 0.5 l/s)	additional distribution reservoir with 2 public fountaines were constructed in 2013 by oromia Regional government without any water source
17	AR-5	no	no	Awash river flows close to the town and people use the water for different purposes, due to low pressure in the pipeline most places do not get water
18	AR-6	there is one project on going to supply water to some kebeles including some area of Gonde town by motorized spring pipeline scheme	there is possibility to find new springs far from the town but not identified yet	
19	AR-7	no	there are three (3) springs around the existing spring site which yields are approximately 0.67 l/sec, 0.17-0.33 l/sec and 0.17-0.33 l/sec	
20	WH-1	no	no	New road construction project from Bordede to Bedeyi by Oromia Road Autority is on going.
21	WH-2	no	no	It is not accessible at Arba river crossing from Metehara during rainy season (June to September). It is accessible from Bordede whole year.
22	WH-3	no	no	
23	WH-4	no	small size springs (4 number) exist far from the town, which are providing water to local people (on-spot supply0	
24	WH-5	no	no	
25	WH-6	no	There are two springs located beside the Arba river. Water sources are covered by the stream when water level of the river becomes higher during rainy season.	
26	WH-7	no	no	There was a conflict with Obenisa village in where Somali trive is majority 11 years ago.
27	WH-8	There is Pastral Community Development Project (PCDP) including health center and school but not including water supply.	There is only one spring. It is available whole year but volume is not much.	
28	WH-9	no	no	
29	WH-10	no, USAID/OFDA donated a generator for motorized borehole as Emergency Response on WASH Project in 2013, which is already	no	
30	WH-11	no	no	

Source: the Project Team, Data: Result of water supply survey in this Project

9.4.1 Water supply conditions and hardship

a. Population

Table 9.4.2 shows the comparison of four (4) population data as of 2013, sourced from the Town Water Supply Service Office/Water Committee, Town Administration Office, Woreda Administration Office and Central Statistical Agency (hereafter referred to as "CSA"). CSA data is projected by the population data and the population growth rate obtained from the results of the census in 2007. The population growth rate of Oromia Region is 2.9%.

Table 9.4.2: Comparison of Population Data

ID	Town	Population (as of 2013)			
		TWSSO / Water Committee	Town Admin. Office	Woreda Admin. Office	CSA Projection
ES-1	Wonji Shewa Alemtena	12,300	12,300	7,255	7,639
ES-2	Geldiya	2,320	2,320	3,520	No data
ES-3	Dire	6,462	6,462	6,462	6,103
ES-4	Bofa	5,460	5,460	5,460	3,750
ES-5	Bole	14,350	14,350	7,983	4,727
ES-6	Ude Dhankaka	2,753	2,753	5,468	5,164
ES-7	Bekejo	11,000	11,000	No data	6,571
ES-8	Kamise	1,896	1,896	4,470	4,342
ES-9	Chefe Donsa	13,074	13,074	13,074	7,514
ES-10	Areda	2,100	2,100	2,100	2,466
ES-11	Biyo	2,500	2,500	2,500	2,426
ES-12	Adulala	6,000	6,000	6,000	3,478
AR-1	Sire	15,936	15,936	11,275	9,943
AR-2	Bolo	2,705	1,485	2,700	1,415
AR-3	Arboye	10,600	10,600	10,600	6,516
AR-4	Aseko	7,905	7,905	No data	4,734
AR-5	Golegota	4,201	4,201	3,860	6,610
AR-6	Gonde	2,598	2,598	2,598	3,077
AR-7	Arbe Gebeya	6,473	6,473	2,272	2,413
WH-1	Chorora	3,000	3,000	3,000	2,707
WH-2	Bedeyi	5,520	5,520	2,770	2,639
WH-3	Hardim	8,000	5,500	2,335	5,291
WH-4	Bube	5,920	5,920	5,920	No data
WH-5	Mieso	17,000	16,620	16,620	15,835
WH-6	Hargeti	3,287	3,287	3,251	3,338
WH-7	Bordede	5,000	2,765	2,765	2,634
WH-8	Kenteri	2,093	2,093	1,692	1,738
WH-9	Aneno	2,115	2,382	2,382	2,828
WH-10	Belo	3,730	4,530	7,591	4,652
WH-11	Kora	2,360	2,360	2,728	2,356

Source: the Project Team, Data: Result of water supply survey in this Project

b. Number of users

Table 9.4.3 shows the number of users of the water supply facility based on the result of the interview from the Town Water Supply Service Offices (hereafter referred to as "TWSSO") and Water Committees (hereafter referred to as "WC") for the targeted small towns.Number of users is calculated by adding the population of target small town (population of the water supply area) with number of users coming from outside of the town. Number of users from outside is calculated by Town Water Supply Service Office and Water Committee based on the counting person coming from satellite Kebeles or population data of Kebele administration office.

Because there is no water supply facility in WH-6, WH-8 and WH-9 among 30 small towns, user of water supply facility does not exist. 1,000 people out of total population, who live in the area where water tap is not available, do not use water supply facility in AR-4. Due to the village is divided into two areas across the valley in WH-4. It is assumed that 2,500 inhabitants do not use the water supply facility. Water supply coverage can be calculated as 100% in the remaining 25 towns assuming that the total population use the water supply facility though the water supply volume are insufficient at many towns due to reason mentioned later.

The ground of assuming 100% coverage of water supply is the information from the Town Water Supply Service Offices and Water Committees is reliable, because those offices comprehend the water supply conditions sufficiently. Also, town as defined in administrative zone category are established in population concentrated area, although there is a town where the water distribution is not sufficient such as WH-4 which is still categorized as village (Kebele) under administrative zone category. For that reason, the water supply pipes are mostly planned/ constructed to be circulated throughout the town. Therefore, the number of users for the target town can be assumed by basing it on the population. On the other hand, the number of users coming from outside to fetch water at public fountains is very difficult to grasp. The number of users at the house connection can be estimated based on the registration book of TWSSO and WC. But the number of users at the public fountain cannot be estimated because anybody can use the public fountains if they pay a water tariff. Most of the users from outside are supposed to be residents of satellite Kebeles. But it is very difficult to estimate the exact number of users from the outside. Therefore, the number of users of satellite Kebele shown in the table is a rough estimate by TWSSO and WC.

Due to the number of users from the outside it is not accurate. Examinations of this data shall be continued and discussed with C/P and JICA to determine how to estimate for the water supply planning.

Table 9.4.3: Number of Users

ID	Town	Population of water supply area	Number of Users		
			Water supply area	Outside of water supply area	Total
ES-1	Wonji Shewa Alemtena	12,300	12,300	5,060	17,360
ES-2	Geldiya	2,320	2,320	1,200	3,520
ES-3	Dire	6,462	6,462	850	7,312
ES-4	Bofa	5,460	5,460	11,000	16,460
ES-5	Bole	14,350	14,350	12,452	26,802
ES-6	Ude Dhankaka	2,753	2,753	0	2,753
ES-7	Bekejo	11,000	11,000	0	11,000
ES-8	Kamise	1,896	1,896	2,600	4,496
ES-9	Chefe Donsa	13,074	13,074	2,000	15,074
ES-10	Areda	2,100	2,100	1,750	3,850
ES-11	Biyo	2,500	2,500	0	2,500
ES-12	Adulala	6,000	6,000	5,816	11,816

ID	Town	Population of water supply area	Number of Users		
			Water supply area	Outside of water supply area	Total
AR-1	Sire	15,936	15,936	1,000	16,936
AR-2	Bolo	2,705	2,705	5,000	7,705
AR-3	Arboye	10,600	10,600	24,400	35,000
AR-4	Aseko	7,905	6,905	0	6,905
AR-5	Golegota	4,201	4,201	6,799	11,000
AR-6	Gonde	2,598	2,598	0	2,598
AR-7	Arbe Gebeya	6,473	6,473	5,000	11,473
WH-1	Chorora	3,000	3,000	2,000	5,000
WH-2	Bedeyi	5,520	5,520	1,950	7,470
WH-3	Hardim	8,000	8,000	3,000	11,000
WH-4	Bube	5,920	2,420	400	2,820
WH-5	Mieso	17,000	17,000	975	17,975
WH-6	Hargeti	3,287	0	0	0
WH-7	Bordede	5,000	5,000	1,550	6,550
WH-8	Kenteri	2,093	0	0	0
WH-9	Aneno	2,115	0	0	0
WH-10	Belo	3,730	3,730	0	3,730
WH-11	Kora	2,360	2,360	4,250	6,610

Source: the Project Team, Data: Result of water supply survey in this Project

c. Overall water consumption volume

Table 9.4.4 shows the overall water consumption (including safe water other from water supply facilities) obtained from the result of the sample household survey. For small towns it is considered that enough volume from the water is not obtained by the people living in the town where the water consumption is less than 20 - 25 l per capita per day, which is defined as use of portable water for urban population in the "Revised UAP (Rural Water Supply) Final Report / Ministry of Water and Energy / April 2011 (hereafter referred to as "UAP2").

Table 9.4.4: Water Consumption Volume

ID	Town	Rainy season		Dry season	
		Household	Person	Household	Person
		(l/ day)	(l/ capita/ day)	(l/ day)	(l/ capita/ day)
ES-1	Wonji Shewa Alemtena	51.9	8.5	59.5	9.8
ES-2	Geldiya	117.0	19.8	187.4	31.7
ES-3	Dire	50.2	7.9	80.2	12.6
ES-4	Bofa	28.0	4.3	58.3	9.0
ES-5	Bole	51.7	10.7	58.3	12.1
ES-6	Ude Dhankaka	89.6	16.3	152.7	27.8
ES-7	Bekejo	52.7	8.2	100.2	15.5
ES-8	Kamise	82.3	16.5	108.7	21.7
ES-9	Chefe Donsa	47.0	7.2	80.9	12.3
ES-10	Areda	40.0	7.9	60.2	11.9
ES-11	Biyo	128.0	25.0	134.6	26.2
ES-12	Adulala	38.6	7.5	77.9	15.1
AR-1	Sire	82.2	15.1	84.8	15.5
AR-2	Bolo	97.2	13.1	151.6	20.5
AR-3	Arboye	99.1	23.8	147.2	35.3
AR-4	Aseko	163.5	36.2	165.9	36.7
AR-5	Golegota	23.9	4.6	36.5	7.1
AR-6	Gonde	35.4	7.4	70.9	14.8

ID	Town	Rainy season		Dry season	
		Household (l/ day)	Person (l/ capita/ day)	Household (l/ day)	Person (l/ capita/ day)
AR-7	Arbe Gebeya	22.6	3.7	63.5	10.3
WH-1	Chorora	111.7	20.5	137.0	25.1
WH-2	Bedeyi	138.9	25.7	139.3	25.7
WH-3	Hardim	104.3	16.6	134.8	21.4
WH-4	Bube	115.7	20.6	143.5	25.6
WH-5	Mieso	57.9	12.0	106.0	22.0
WH-6	Hargeti	87.4	15.5	96.5	17.1
WH-7	Bordede	110.9	22.4	130.1	26.2
WH-8	Kenteri	96.1	17.1	94.8	16.9
WH-9	Aneno	80.0	15.6	84.0	16.4
WH-10	Belo	84.6	12.6	103.5	15.5
WH-11	Kora	89.1	17.7	90.2	17.9

Source: the Project Team, Data: Result of water supply survey in this Project

d. Water consumption volume from water supply facility

Table 9.4.5 shows the water consumption from the water supply facility. The data is obtained from the interview from the TWSSO and WC, which are based on the records of the annual water consumption of the TWSSO and WC. If they could not find the data of the water consumption then the water consumption is calculated by the water sales income and the water tariff. The method is the water sales income divided by the water tariff.

There is no data of water consumption at ES-6 because its water supply facility is borehole with a hand pump without a water meter. There is no water supply facility in WH-6, WH-8 and WH-9. A TWSSO conduct a water supply service to both ES-5 and AR-5, so the data is combined in the table.

It is considered that the people living in the target small towns except AR-6 do not obtain enough volume of potable water. Because the water consumption is less than 20 l per capita per day, which is defined as use of portable water for urban population in the UAP2.

The water consumption volume, which is calculated by water sales income and water rate, is not so accurate because generally the water rate at a house connection is not same as the water rate at public fountains. Also the water rate at a house connection varies depending on the consumed volume in some towns where block rate is applied.

Regarding ES-11, the water consumption volume of the water supply facilities is excessively lower than the overall water consumption. There is one (1) wind pump broken currently, which causing the water to be supplied on the spot. Water consumption volume is based on this wind pump. There are also hand-dug wells with hand pump in this town but every hand pumps are broken. On the other hand, overall water consumption volume is high because of the numbers of hand-dug well (though the water is not safe) which can be obtained due to shallow groundwater level.

Table 9.4.5: Water Consumption Volume from Water Supply Facility

ID	Town	Number of users	Water Consumption Volume		Calculation basis
			Total Annual (m^3/year)	Per person (l/ capita/ day)	
ES-1	Wonji Shewa Alemtena	17,360	1,006.0	0.2	Total amount / tariff
ES-2	Geldiya	3,520	17,400.0	13.5	Total amount / tariff
ES-3	Dire	7,312	19,148.0	7.2	Water Consumption Volume
ES-4	Bofa	16,460	69,932.3	11.6	Water Consumption Volume
ES-5/ AR-5	Bole Golegota	37,802	57,785.0	4.2	Water Consumption Volume
ES-6	Ude Dhankaka	2,753	No data		
ES-7	Bekejo	11,000	5,748.0	1.4	Total amount / tariff
ES-8	Kamise	4,496	4,789.0	2.9	Total amount / tariff
ES-9	Chefe Donsa	15,074	54,354.0	9.9	Water Consumption Volume
ES-10	Areda	3,850	1,287.0	0.9	Water Consumption Volume
ES-11	Biyo	2,500	502.5	0.6	Water Consumption Volume
ES-12	Adulala	11,816	58,386.0	13.5	Water Consumption Volume
AR-1	Sire	16,936	29,105.7	4.7	Water Consumption Volume
AR-2	Bolo	7,705	5,883.0	2.1	Total amount / tariff
AR-3	Arboye	35,000	52,736.0	4.1	Total amount / tariff
AR-4	Aseko	6,905	6,229.7	2.5	Total amount / tariff
AR-6	Gonde	2,598	37,344.0	39.4	Water Consumption Volume
AR-7	Arbe Gebeya	11,473	14,538.7	3.5	Total amount / tariff
WH-1	Chorora	5,000	4,030.0	2.2	Total amount / tariff
WH-2	Bedeyi	7,470	2,939.0	1.1	Total amount / tariff
WH-3	Hardim	11,000	11,940.0	3.0	Total amount / tariff
WH-4	Bube	2,820	1,864.0	1.8	Total amount / tariff
WH-5	Mieso	17,975	80,503.7	12.3	Water Consumption Volume
WH-6	Hargeti	0	0.0	0.0	Total amount / tariff
WH-7	Bordede	6,550	17,566.7	7.3	Water Consumption Volume
WH-8	Kenteri	0	0.0	0.0	Total amount / tariff
WH-9	Aneno	0	0.0	0.0	Total amount / tariff
WH-10	Belo	3,730	521.0	0.4	Total amount / tariff
WH-11	Kora	6,610	4,423.0	1.8	Total amount / tariff

Source: the Project Team, Data: Result of water supply survey in this Project

9.4.2 Current conditions of existing water supply facilities and its issues

a. Water supply facilities

a.1 Water supply system

Table 9.4.6 shows the types and the numbers of existing water supply systems in thirty (30) target small towns.

Table 9.4.6: Types of Water Supply System

ID	Town	Water Supply System			
		Water source	Intake	Transmission	Distribution
ES-1	Wonji Shewa Alemtena	Piped water supply from outside of the town			Public tap, public tap, house tap
ES-2	Geldiya	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap, livestock tap
ES-3	Dire	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap, livestock tap
ES-4	Bofa	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
ES-5/ AR-5	Bole/ Golegota	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
ES-6	Ude Dhankaka	Groundwater	Borehole	Hand pump	On spot
ES-7	Bekejo	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
ES-8	Kamise	Piped water supply from outside of the town			Public tap, house tap, livestock tap
ES-9	Chefe Donsa	Spring	Collecting chamber	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
ES-10	Areda	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
ES-11	Biyo	Groundwater	Borehole	Windmill pump	On spot
		Groundwater	Hand dug well	Hand pump	On spot
ES-12	Adulala	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
AR-1	Sire	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
		Spring	Collecting chamber	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
AR-2	Bolo	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap, livestock tap

ID	Town	Water Supply System			
		Water source	Intake	Transmission	Distribution
AR-3	Arboye	Spring	Collecting chamber	Gravity	Reservoir, pipes, public tap, public tap, house tap
AR-4	Aseko	Spring	Collecting chamber	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
AR-6	Gonde	Spring	Collecting chamber	Gravity	Reservoir, pipes, public tap, public tap, house tap
AR-7	Arbe Gebeya	Spring	Collecting chamber	Gravity	Reservoir, pipes, public tap, public tap, house tap
WH-1	Chorora	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
WH-2	Bedeyi	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
WH-3	Hardim	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
WH-4	Bube	Spring	Collecting chamber	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
WH-5	Mieso	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
WH-6	Hargeti	-			
WH-7	Bordede	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap
WH-8	Kenteri	-			
WH-9	Aneno	-			
WH-10	Belo	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, livestock tap
WH-11	Kora	Groundwater	Borehole	Motorized pump	Reservoir, pipes, public tap, public tap, house tap

Source: the Project Team, Data: Result of water supply survey in this Project

a.2 Intake facilities

a.2.1 Spring

Most of the intake facilities are collecting chambers where the water is flowing from the springs.

a.2.2 Borehole

Diameters of boreholes are mostly between 6” to 8” where the material of the casings is steel except for ES-2 and ES-6, which is by Poly Vinyl Chloride (hereafter referred to as “PVC”). It is very difficult to obtain the data of the boreholes. Such as borehole depth, screen position, hydrogeological condition, static water level, specific capacity, maximum pumping rate with drawdown, actual pumping rate with drawdown, pump setting depth, pump total head, etc. In case such data will not be obtained, it is very difficult to determine the capacity, specification, setting position and so on for the submersible pumps to replace the existing broken down pumps. For that reason, data acquisition of the water supply facilities mentioned in item 9.5.4will be included in the operation and maintenance management plan of this study.

a.3 Treatment Facilities

Water is not treated by any filtration or disinfection in the target towns except ES-1 where water is distributed by Adama City Water Supply and Sewerage Service Enterprise.

a.4 Intake pump

Most of the existing pumps are submersible pumps except the line shaft pump used for the booster pumping station at WH-2. Most of riser pipe materials are galvanized steel pipes (hereafter referred to as “GSP”), which has a diameter of 50 mm or 65 mm. Table 9.4.7shows the identified brand of the existing pumps, which are from European countries or the USA.

a.5 Power supply

There are twelve (12) water supply systems using a public power supply purchased from Ethiopia Electric Power Corporation (hereafter referred to as “EEPCO”) as the power source for the pumping. Out of the twelve (12), there are five (5) systems with standby diesel generators set up.

There are eleven (11) systems using a diesel generator as the power source for the pumping. Output of the generators, which could be identified, varies between twenty-seven (27) kilovolt-amps (kVA) and one hundred (100) kilovolt-amps (kVA).

The identified brand of the engine installed in the generators and pumps is shown in the Table 9.4.7. Four (4) brands of Deutz, IVECO, Perkins and VM Motori are popular in African countries so that it seems that it is not difficult to get consumable materials such as filters, oil and more, as well as spare parts such as fan belts, etc.

Public power is more economical than the power generated by fuel. Therefore, most of the TWSSO and WC who use generators desire to switch the power source from a diesel generator to public electricity supply earnestly, in order to reduce the operation cost. The diesel generator is set in some systems as a standby in case there is a power cut. In WH-7 the power source of a submersible pump is a diesel generator for the time being after the previous pump were burned three (3) times due to the bad quality of the public power supply.

Table 9.4.7: Brand of Existing Engine of Generators and Pumps

ID	Town	Pump		Power Supply	
		Type	Brand	Commercial power supply /Generator	Brand of Generator
ES-1	Wonji Shewa Alemtena	not applicable	not applicable	not applicable	not applicable
ES-2	Geldiya	submersible pump	no data	public power supply	not applicable
ES-3	Dire	submersible pump (BH1 and BH2)	no data	public power supply (both)	not applicable
ES-4	Bofa	submersible pump (BH1 and	no data	public power supply (both)	not applicable

ID	Town	Pump		Power Supply	
		Type	Brand	Commercial power supply /Generator	Brand of Generator
		BH2)			
ES-5/ AR-5	Bole/ Golegota	submersible pump	Caprari	diesel generator	Perkins
ES-6	Ude Dhankaka	hand pump	various	not applicable	not applicable
ES-7	Bekejo	submersible pump	Grundfoss	diesel generator	Deutz
ES-8	Kamise	not applicable	not applicable	not applicable	not applicable
ES-9	Chefe Donsa	submersible pump	no data	public power supply (standby diesel generator)	Deutz
ES-10	Areda	submersible pump	no data	diesel generator	no data
ES-11	Biyo	windmill pump	no data	windmill	no data
ES-12	Adulala	submersible pump	Pleuger	public power supply (standby diesel generator)	Deutz
AR-1	Sire	3 submersible pump (spring, borehole and booster station)	no data	public power supply (spring), 2 diesel generators (borehole and booster station)	IVECO (2)
AR-2	Bolo	submersible pump	no data	public power supply (standby diesel generator)	Deutz
AR-3	Arboye	not applicable	not applicable	not applicable (gravity system)	not applicable
AR-4	Aseko	submersible pump	Grundfoss	public power supply (standby diesel generator)	IVECO
AR-6	Gonde	not applicable	not applicable	not applicable (gravity system)	not applicable
AR-7	Arbe Gebeya	not applicable	not applicable	not applicable (gravity system)	not applicable
WH-1	Chorora	submersible pump	no data	diesel generator	VM
WH-2	Bedeyi	submersible pump (borehole), turbine pump (booster PS)	CMS (borehole) and KSB (booster)	2 diesel generators (1 for borehole, 1 for booster pumping station)	Perkins (borehole), John Deere (booster PS)
WH-3	Hardim	submersible pump	Pleuger	diesel generator	Deutz
WH-4	Bube	submersible pump	no data	diesel generator	Perkins
WH-5	Mieso	submersible pump (2)	Grundfoss (BH1), CMS (BH2)	public power supply (BH1), public power supply (standby diesel generator) (BH2)	FPT (BH2)
WH-6	Hargeti	not applicable	not applicable	not applicable	not applicable
WH-7	Bordede	submersible pump	Flankline	diesel generator (quality of public power supply is very poor so that pumps were burned 3 times)	IVECO
WH-8	Kenteri	not applicable	not applicable	not applicable	not applicable
WH-9	Aneno	not applicable	not	not applicable	not applicable

ID	Town	Pump		Power Supply	
		Type	Brand	Commercial power supply /Generator	Brand of Generator
			applicable		
WH-10	Belo	submersible pump	Grundfos	diesel generator	Tianjin Lovol
WH-11	Kora	submersible pump	Grundfos	diesel generator	Sisu Diesel

Source: the Project Team, Data: Result of water supply survey in this Project

Table 9.4.8: Operating Hour of Existing Pump

ID	Town	Operating hour of existing pump
ES-1	Wonji Shewa Alemtena	not applicable
ES-2	Geldiya	7 days/week and 6 hrs/day (both season)
ES-3	Dire	4 days/week and 4 hrs/day (both BH1 and BH2 for both season)
ES-4	Bofa	7 days/week and 12 hrs/day (rainy season), 7 days/week and 24 hrs/day (dry season)
ES-5/ AR-5	Bole/ Golegota	7 days/week and 14 hrs/day (both season)
ES-6	Ude Dhankaka	not applicable
ES-7	Bekejo	7 days/week and 2 hrs/day (water is finished after 2 hours pumping)
ES-8	Kamise	not applicable
ES-9	Chefe Donsa	7 days/week and 9 hrs/day (both season)
ES-10	Areda	3 days/week and 4 hrs/day (both season)
ES-11	Biyo	not applicable
ES-12	Adulala	7 days/week and 5 hrs/day (rainy season), 7 days/week and 8 hrs/day (dry season)
AR-1	Sire	7 days/week-9 hrs/day (rainy season), 7 days/week-6 hrs/day (dry season）
AR-2	Bolo	7 days/week-6 hrs/day (rainy season), 7 days/week-6 hrs/day (dry season）
AR-3	Arboye	not applicable
AR-4	Aseko	7 days/week-4 hrs/day (rainy season), 7 days/week-4 hrs/day (dry season)
AR-6	Gonde	not applicable
AR-7	Arbe Gebeya	not applicable
WH-1	Chorora	7days/week-11hrs/day (rainy season）, 7days/week-11hrs/day (dry season）
WH-2	Bedeyi	7 days/week-9 hrs/day (rainy season）, 7 days/week-9 hrs/day (dry season)
WH-3	Hardim	7 days/week-10 hrs/day (rainy season）, 7 days/week-10 hrs/day (dry season）
WH-4	Bube	2.3 days/week-4 hrs/day (rainy season）, 1.8 days/week-4 hrs/day (dry season）
WH-5	Mieso	7 days/week-24 hrs/day (rainy season）, 7 days/week-24 hrs/day）(dry season)
WH-6	Hargeti	not applicable
WH-7	Bordede	7 days/week-10 hrs/day (rainy season）, 7 days/week-11 hrs/day (dry season）
WH-8	Kenteri	not applicable
WH-9	Aneno	not applicable
WH-10	Belo	7 days/week - 9 hrs/day (rainy season）, 7 days/week - 9 hrs/day (dry season)
WH-11	Kora	7 days/week - 2.5 hrs/day (rainy season）, 7 days/week - 2.5 hrs/day (dry season）

Source: the Project Team, Data: Result of water supply survey in this Project

a.6 Flow meter

Flow meters are installed at seventeen (17) pumps out of the twenty-four (24) pumps, in which three (3) flow meters were broken down. Therefore, only fourteen (14) flow meters are functioning for the time being.

The flow meter is very important to measure the production volume. It is possible to check unaccounted water, such as leakage water by comparing the production volume with the consumed volume measured by the water meter at water points. Therefore, a flow meter shall be installed at every pumping system.

a.7 Transmission pipes

All of the transmission pipes in target towns are GSP with a maximum diameter of 100 mm. Basement rock is shallow or exposed on the ground in target towns so that excavation for the installation of the pipes in the ground is not easy. Due to such a situation it is seen that the cover of the backfill is not enough or the pipes are exposed on the ground. Excavation works shall be carefully examined for the design of the water supply facilities and the estimation of the Project cost.

a.8 Booster pumping station

The booster pumping station is constructed at WH-2 due to the great difference in elevation between the boreholes and the distribution reservoirs. Diesel generators are used for the power source of the pumps for station so that the water tariff is much more expensive than other towns. The tariff for towns using generator is 16~25 Birr/m^3, while tariff for the public tap is 38Birr/m^3 and house tap is 42Birr/m^3 in WH-2.

a.9 Distribution facilities

a.9.1 Distribution reservoirs

The capacity of the distribution reservoirs is between 10 m^3 and 100 m^3. There is one (1) elevated reservoir tank where the structure is reinforced concrete in E-5. Others are constructed directly on the ground where the structure is reinforced concrete with an exterior wall by stone masonry.

It is investigating how many percent of daily water supply volume is the capacity of the reservoir equivalent to. It is planned to be described into the Interim Report.

a.9.2 Distribution pipes

The PVC pipes and Polyethylene (hereafter referred to as "PE") pipes are used in some areas but mostly GSP is used for the distribution pipes, which has a maximum diameter of 100 mm. Basement rock is shallow or exposed on the ground in target towns so that excavation for the installation of pipes in the ground is not easy, as well as transmission pipes. Due to such a situation it is seen that the cover of the backfill is not enough or the pipes are exposed on the ground. Excavation works shall be carefully examined for the design of the water supply facilities and the estimation of the Project cost.

a.9.3 Water points and water meters

Table 9.4.9 shows the number of existing water points and water meters. The types of water points are public taps, private connections and cattle troughs. Private connections include not only house connections but also a connection to the public buildings such as schools, health centers, etc.

Mostly water meters are installed and function at every water point while the readings of the water meters are recorded for collecting water tariffs by the TWSSO and WC.

Table 9.4.9: Numbers of Water Points and Water Meters

ID	Water point				Water meter	
	Public tap	Private connection	Cattle trough	Total	Installed	Broken
ES-1	2	31	0	33	33	0
ES-2	4	250	2	256	256	1
ES-3	7	90	5	102	102	0
ES-4	11	232	0	243	243	0
ES-5/ AR-5	11	251	0	262	262	0
ES-6	0	0	0	0	0	0
ES-7	4	26	0	30	30	0
ES-8	2	1	1	4	4	0
ES-9	10	920	0	930	930	0
ES-10	2	3	0	5	5	0
ES-11	1	0	0	1	1	0
ES-12	3	393	0	396	396	0
AR-1	21	516	0	537	537	0
AR-2	4	56	1	61	61	1
AR-3	7	529	0	536	536	3
AR-4	6	66	0	72	72	2
AR-6	5	278	0	283	283	0
AR-7	5	340	0	345	345	4
WH-1	3	139	0	142	142	0
WH-2	5	101	0	106	106	0
WH-3	7	88	0	95	95	0
WH-4	4	16	0	20	20	0
WH-5	10	712	0	722	722	0
WH-6	0	0	0	0	0	0
WH-7	9	168	0	177	177	0
WH-8	0	0	0	0	0	0
WH-9	0	0	0	0	0	0
WH-10	3	0	1	4	4	0
WH-11	4	75	0	79	79	0

Source: the Project Team, Data: Result of water supply survey in this Project

b. Issues of existing water supply facilities

b.1 Lack of water volume

There are many demands for the construction of additional water sources such as boreholes, collecting chambers of springs and so on with the distribution reservoirs and the expansion of water supply areas with distribution pipes, public taps and private connections among the TWSSOs and WCs.

In case the population of water supply area is much more than population of the town, population coming to fetch water from satellite Kebele is included.

Sufficiency rates based on the intake capacity is much higher than 100 % in ES-10 and almost 100% in WH-1. Those data will be carefully examined by examining water supply population, comparing with water consumption volume based on the record of water meter reading, etc. based .on the results of supplementary survey.

Due to most of the existing facilities been constructed a long time ago, the supply capacity of the existing facilities is mostly not sufficient for the water demand, which is increasing by the population growth with the progress of time. The ratio rate of existing water supply facilities to water demand is shown in Table 9.4.10. Most of ratio rate for both reservoir capacity and capacity to obtain from water source are less than 100%, which showing that the capacity of water supply is insufficient. In addition, as shown in the Table 9.4.11, safe water volume supplied from the facilities is lower than 20 L/capita/day (UAP2) in every town excluding AR-6. As the result above, it can be concluded that the supply for safe water is insufficient.

Table 9.4.10: The Sufficiency Rate of Existing Water Supply Facilities to Water Demand

ID	Town	Population	Numbers of Users	Population by supplied water	Effective water volume	Ineffective water volume	Average daily water consumption	Maximum daily water consumption	Consideration of the water supply capacity based on existing water intake capacity from water source			Consideration of the water supply capacity based on existing water supply reservoir		
				Household	Household	15% of effective water volume		1.2 times of average daily water consumption	Hourly water intake	Daily water intake	Sufficiency rate	Water reservoir capacity needed	Existing water supply reservoir capacity	Sufficiency rate
				*Using larger number from population or numbers of users	(20 l/ capita/ day)					[5]8 hours operational for motorized pump, 24 hours operational for motorized system		12 hours of water intake (Population more than 10,000), 15 hours of water intake (Population less than 10,000)		
					(m^3/day)	(m^3)	(m^3)	(m^3)	(m^3/hr)	(m^3/day)	(%)	(m^3/day)	(m^3)	(%)
ES-1	Wonji Shewa Alemtena	12,300	17,360	17,360	347.2	52.1	399.3	479.2	0.0	0.0	0.0	239.6	0.0	0.0
ES-2	Geldiya	2,320	3,520	3,520	70.4	10.6	81.0	97.2	6.3	50.4	51.9	60.8	25.0	41.1
ES-3	Dire	6,462	7,312	7,312	146.2	21.9	168.1	201.7	No Data	No Data	No Data	126.1	35.0	27.8
ES-4	Bofa	5,460	16,460	16,460	329.2	49.4	378.6	454.3	34.2	273.6	60.2	227.2	125.0	55.0
ES-5/ AR-5	Bole/ Golegota	18,551	37,802	37,802	756.0	113.4	869.4	1,043.3	25.2	201.6	19.3	521.6	60.0	11.5
ES-6	Ude Dhankaka	2,753	2,753	2,753	55.1	8.3	63.4	76.1	No Data	No Data	No Data	47.6	0.0	0.0
ES-7	Bekejo	11,000	11,000	11,000	220.0	33.0	253.0	303.6	No Data	No Data	No Data	151.8	25.0	16.5
ES-8	Kamise	1,896	4,496	4,496	89.9	13.5	103.4	124.1	0.0	0.0	0.0	77.6	0.0	0.0
ES-9	Chefe Donsa	13,074	15,074	15,074	301.5	45.2	346.7	416.0	10.8	86.4	20.8	208.0	90.0	43.3
ES-10	Areda	2,100	3,850	3,850	77.0	11.6	88.6	106.3	16.7	133.6	125.7	66.4	25.0	37.7
ES-11	Biyo	2,500	2,500	2,500	50.0	7.5	57.5	69.0	0.0	0.0	0.0	43.1	10.0	23.2
ES-12	Adulala	6,000	11,816	11,816	236.3	35.4	271.7	326.0	14.4	115.2	35.3	163.0	50.0	30.7
AR-1	Sire	15,936	16,936	16,936	338.7	50.8	389.5	467.4	26.9	215.2	46.0	233.7	115.0	49.2
AR-2	Bolo	2,705	7,705	7,705	154.1	23.1	177.2	212.6	13.0	104.0	48.9	132.9	40.0	30.1
AR-3	Arboye	10,600	35,000	35,000	700.0	105.0	805.0	966.0	6.0	144.0	14.9	483.0	50.0	10.4
AR-4	Aseko	7,905	6,905	7,905	158.1	23.7	181.8	218.2	12.5	100.0	45.8	136.4	25.0	18.3
AR-6	Gonde	2,598	2,598	2,598	52.0	7.8	59.8	71.8	No Data	No Data	No Data	44.9	0.0	0.0
AR-7	Arbe Gebeya	6,473	11,473	11,473	229.5	34.4	263.9	316.7	No Data	No Data	No Data	158.4	50.0	31.6
WH-1	Chorora	3,000	5,000	5,000	100.0	15.0	115.0	138.0	16.7	133.6	96.8	86.3	50.0	57.9
WH-2	Bedeyi	5,520	7,470	7,470	149.4	22.4	171.8	206.2	8.3	66.4	32.2	128.9	50.0	38.8
WH-3	Hardim	5,500	11,000	11,000	220.0	33.0	253.0	303.6	8.3	66.4	21.9	151.8	25.0	16.5
WH-4	Bube	5,920	2,820	5,920	118.4	17.8	136.2	163.4	12.6	100.8	61.7	102.1	50.0	49.0
WH-5	Mieso	16,620	17,975	17,975	359.5	53.9	413.4	496.1	32.5	260.0	52.4	248.1	120.0	48.4
WH-6	Hargeti	3,287	0	3,287	65.7	9.9	75.6	90.7	0.0	0.0	0.0	56.7	0.0	0.0
WH-7	Bordede	2,765	6,550	6,550	131.0	19.7	150.7	180.8	8.0	64.0	35.4	113.0	50.0	44.2
WH-8	Kenteri	2,093	0	2,093	41.9	6.3	48.2	57.8	0.0	0.0	0.0	36.1	0.0	0.0
WH-9	Aneno	2,115	0	2,115	42.3	6.3	48.6	58.3	0.0	0.0	0.0	36.4	0.0	0.0
WH-10	Belo	3,730	3,730	3,730	74.6	11.2	85.8	103.0	2.6	20.8	20.2	64.4	50.0	77.6
WH-11	Kora	2,360	6,610	6,610	132.2	19.8	152.0	182.4	20.0	160.0	87.7	114.0	50.0	43.9

Source: the Project Team, Data: Result of water supply survey in this Project

[5]Actual pumping hours by towns are shown in Table 9.4.8. Standard pumping hours are set as 8 hours herewith.

Table 9.4.11: Safe Water Consumption

ID	Town	Number of users	Water Consumption		Base of calculation
			Annual usage (m^3/year)	Daily/person (l/ capita/ day)	
ES-1	Wonji Shewa Alemtena	17,360	1,006.0	0.2	Total amount / tariff
ES-2	Geldiya	3,520	17,400.0	13.5	Total amount / tariff
ES-3	Dire	7,312	19,148.0	7.2	Water Consumption
ES-4	Bofa	16,460	69,932.3	11.6	Water Consumption
ES-5/ AR-5	Bole Golegota	37,802	57,785.0	4.2	Water Consumption
ES-6	Ude Dhankaka	2,753	No data		
ES-7	Bekejo	11,000	5,748.0	1.4	Total amount / tariff
ES-8	Kamise	4,496	4,789.0	2.9	Total amount / tariff
ES-9	Chefe Donsa	15,074	54,354.0	9.9	Water Consumption
ES-10	Areda	3,850	1,287.0	0.9	Water Consumption
ES-11	Biyo	2,500	502.5	0.6	Water Consumption
ES-12	Adulala	11,816	58,386.0	13.5	Water Consumption
AR-1	Sire	16,936	29,105.7	4.7	Water Consumption
AR-2	Bolo	7,705	5,883.0	2.1	Total amount / tariff
AR-3	Arboye	35,000	52,736.0	4.1	Total amount / tariff
AR-4	Aseko	6,905	6,229.7	2.5	Total amount / tariff
AR-6	Gonde	2,598	37,344.0	39.4	Water Consumption
AR-7	Arbe Gebeya	11,473	14,538.7	3.5	Total amount / tariff
WH-1	Chorora	5,000	4,030.0	2.2	Total amount / tariff
WH-2	Bedeyi	7,470	2,939.0	1.1	Total amount / tariff
WH-3	Hardim	11,000	11,940.0	3.0	Total amount / tariff
WH-4	Bube	2,820	1,864.0	1.8	Total amount / tariff
WH-5	Mieso	17,975	80,503.7	12.3	Total amount / tariff
WH-6	Hargeti	0	0.0	0.0	Total amount / tariff
WH-7	Bordede	6,550	17,566.7	7.3	Water Consumption
WH-8	Kenteri	0	0.0	0.0	Total amount / tariff
WH-9	Aneno	0	0.0	0.0	Total amount / tariff
WH-10	Belo	3,730	521.0	0.4	Total amount / tariff
WH-11	Kora	6,610	4,423.0	1.8	Total amount / tariff

Source: the Project Team, Data: Result of water supply survey in this Project

b.2 Lack of water pressure at water point

It seems that the diameter of the distribution pipes was calculated based on the quantity of public taps without the private taps that were planned to be constructed in order to keep the minimum head (pressure) at the water taps.

However, since the completion of construction, the private taps started to be connected by the users and increased during the progress of time thus some distribution pipes were extended to install new public taps and private taps without any consideration about the increasing loss of the water head (pressure). Then the water pressure at the water taps became low. In some cases the water is not coming through due to the lack of water pressure, especially at peak times.

For the countermeasure the distribution pipeline where the diameter is too small shall be replaced with pipes of an appropriate diameter, which is determined by hydraulic calculation based on the projection of the number of the private connection and population.

The distribution pipeline network shall also be designed by the hydraulic calculation based on the projection of the number of the private connections and the population for new construction and rehabilitation works as well.

b.3 Deterioration of the facilities

It is specified that the life of boreholes in hard rock is twenty-five (25) years in the "Urban Water Supply Design Criteria/ Ministry of Water Resources/ January 31, 2006". But some boreholes are very old as shown in Table 9.4.12. As a result of interviews to operators, the yield of boreholes is decreasing, water contains some sand and operation of the submersible pumps sometimes stops in some boreholes. It is a worry for the deterioration of the boreholes.

For the establishment of water supply plan in this study, re-excavation of the well will be considered for the broken and old wells.

Table 9.4.12: Construction Ages of Borehole

Construction age	Number of borehole	Town
1970s	2	WH-5, WH-7
1980s	4	ES-3, ES-4, ES-7, ES-12
1990s	3	ES-3, ES-11, WH-3
2000s	9	ES-2, ES-4, ES-10, AR-1, AR-2, WH-1, WH-2, WH-5, WH-10, WH-11
2010s	2	ES-5

Source: the Project Team, Data: Result of water supply survey in this Project

It is specified that the life of electromechanical equipment from pumping stations and boreholes is ten (10) years in the "Urban Water Supply Design Criteria/ Ministry of Water Resources/ January 31, 2006". As some of the identified existing pumps and diesel generators are very old, shown in Table 9.4.13 and Table 9.4.14, it is worrying about the deterioration.

Table 9.4.13: Used Years of existing Pump

Used years	Number
1-5	7
5-10	7
10-15	5
15-20	3
20-	3

Source: the Project Team, Data: Result of water supply survey in this Project

Table 9.4.14: Used Years of existing Diesel Generator

Used years	Number
1-5	8
5-10	4
10-15	3
15-20	2
20-	1

Source: the Project Team, Data: Result of water supply survey in this Project

b.4 Delay of the electrification

Table 9.4.15 shows the water tariff of the target small towns. The water tariff for water supply facility using a diesel generator is about twice of that, which uses a public power supply. There are many demands to change from a diesel generator to the public electricity supply.

But there are target small towns located in areas that have still not received electricity supply. The Government and EEPCO shall give priority to expedite the electrification to the water supply systems.

The cost for commercial power supply installation in town without electricity shall be expected upon establishment of water supply plan.

Table 9.4.15: Water Tariff by Power Type

Water source	Power	Number of motorized pump	Town ID	Tariff		
				System	Min.	Max.
Spring	Gravity	ー	AR-3, AR-6, AR-7	Volumetric	1.50	5.00
Spring	Public power supply	1	ES-9, AR-4	Volumetric	5.00	9.00
Spring	Generator	1	WH-4	Volumetric	20.00	21.00
Borehole	Public power supply	1	ES-2, ES-3, ES-4, ES-12, AR-2, WH-5	Volumetric	6.00	8.70
Borehole	Generator	1	ES-5, AR-5, ES-7, ES-10, WH-1, WH-3, WH-7, WH-10, WH-11	Volumetric	16.00	25.00
Borehole	Generator	2	WH-2	Volumetric	38.00	42.00
Borehole	Windmill	ー	ES-11	Volumetric	8.00	10.00
Borehole	Manual	ー	ES-6	Fix	10.00	10.00
Outside	ー	ー	ES-1, ES-8	Volumetric	5.00	6.25

Unit (volumetric): birr/m^3

Unit (fix rate): birr/month/household

Source: the Project Team, Data: Result of water supply survey in this Project

9.4.3 Water sources

a. Existing water source

Water sources of 27 towns, not including the three towns where the water supply facilities do not exist are shown in Table 9.4.16. The main water source of seven towns is a spring and the main water source of 19 towns is the groundwater. Water sources of both the spring and the groundwater are used in AR-1. There is no water source in the town for ES-1 and ES-8 where the water is distributed from outside of the town by Adama City, Water Supply and Sewerage Service Enterprise and Gimbichu-Fentale Town Water Supply Service Enterprise.

Table 9.4.16: Main Water Source of Water Supply System in Target Small Town

Main water source	Target town	Number
Spring	ES-9, AR-1, AR-3, AR-4, AR-6, AR-7, WH-4	7
Groundwater	ES-2, ES-3, ES-4, ES-5, ES-6, ES-7, ES-10, ES-11, ES-12, AR-1, AR-2, AR-5, WH-1, WH-2, WH-3, WH-5, WH-7, WH-10, WH-11	19
Not in the town	ES-1, ES-8	2

Source: the Project Team, Data: Result of water supply survey in this Project

b. Existence of new spring water source

There are some springs for the new water source in ES-10, AR-4 and AR-7. But the yield is too small (maximum 0.75 litter per sec) to distribute by a piped water supply system.

9.5 Operation and Maintenance (O&M) of Water Supply Facilities

9.5.1 Policies, rules, and regulations on O&M

a. Policy on operation and maintenance

a.1 Regulation and policy by National, Regional, Zonal and Woreda level

The policy on operation and maintenance of water supply facility is included in the "Ethiopian Water Sector Policy" (Ministry of Water and Energy, 2001). Every regional government sets their own policy in accordance with it.

Recently, the following documents were issued by the Ministry of Water and Energy as the national standards of policies or the manual for operation and maintenance of water supply facilities.

1) Recommended Guideline on Technical Service Provision to Customers by Urban Water Supply Utilities (First Draft) (Ministry of Water and Energy, September 2005 EFY)
2) National Guideline for Water Utilities Categorization (Draft) (Ministry of Water and Energy, September 2012)
3) Organization Setup Proposals for Town Water Supply and Sewerage Services (Ministry of Water and Energy, October 2012)
4) Operation and Maintenance Manual for Water Supply, Sanitation and Hygiene Project (WaSH P)-Urban Component (Ministry of Water and Energy, September 2012)
5) Guideline Proposals for Water Tariff Setting for Town Water Supply and Sewerage

Services (Draft) (Ministry of Water and Energy, October 2012)

a.2 Regulation, policy, and manual on operation and maintenance in the Oromia Region

There are two kinds of organizations that conduct water supply service in the Oromia region.

"Urban Water Supply and Sewerage Service Enterprise" legislated by the "Proclamation No.78/2004: A Proclamation to provide for the Establishment of Urban Water Supply and Sewerage Service Enterprises of the Oromia Regional State" of 2004 is the organization that supplies urban areas.

"Portable Water Service Organization" legislated by the "Proclamation No.152/2009: A proclamation to provide for the Establishment and Administration of Oromia National Regional State Rural potable water service Organizations" of 2009 is the organization that supplies rural areas.

The roles and responsibilities of water supply service organization and regional government are ruled in those proclamations.

b. Category of target water supply system to be operated and maintained

Table 9.5.1 shows the type of existing water supply system in Oromia region. Those can be categorized into big city, small town, and rural areas.

Operation and maintenance is generally conducted by the Urban Water Supply and Sewerage Service Enterprise in case of a big city, the Town Water Supply Services Office in case of a small town, and by the Water Committee in rural areas.

A single water supply system is generally operated and maintained by a single organization in case of rural area, whereas multiple water supply systems are operated and maintained by one organization in case of a big city and a small town.

Table 9.5.1: Comparison of existing Water Supply System Type

Type	Big City	Small Town	Rural Area
Facility	• System to supply water to a big city and its surrounding areas after purified huge volume of river water (e.g., Adama city) • System to supply water to a big city and its surrounding areas after pumping up huge volume of groundwater (e.g., Bishoftu city, Mojo city) • System to supply water to small towns and Kebeles in wide areas after drawing huge volume of spring	• System consisting of motorized pump, transmission pipes, reservoir, distribution pipes, public fountains, and private taps with borehole or spring intake. • System comprising transmission pipes, reservoir, distribution pipes, public fountains, and private taps with spring intake by gravity water flow	• Borehole with hand pump • Hand-dug well with hand pump • Spring intake on spot • System consisting of motorized pump, transmission pipes, reservoir, distribution pipes, public fountains, and private taps with borehole or spring intake. • System comprising transmission pipes, reservoir, distribution pipes, public fountains, and private taps with spring intake

Type	Big City	Small Town	Rural Area
	water (e.g., Gimbichu—Fentale Water Supply and Service Enterprise)		by gravity water flow
Water source	River, Groundwater, Spring	Groundwater, Spring	Groundwater, Spring
Number of users	Twenty thousand–hundreds of thousand people	Several thousand–twenty thousand people	Several hundred–several thousand
O&M organization	Urban water supply and sewerage service enterprise	Town water supply service office	Water committee

Source: the Project Team, Data: Result of water supply survey in this Project

Operation and maintenance is generally conducted by the Urban Water Supply and Sewerage Service Enterprise in a big city, Town Water Supply Services Office (hereafter referred to as TWSSO) in small towns, and by the Water Committee (hereafter referred to as WC) in kebeles. A single water supply system is generally operated and maintained by a single organization in case of a rural area, whereas multiple water supply systems are operated and maintained by a single organization in case of a big city and a small town.

c. Organizations related to water supply and its relationship

The organization that controls and supervises the field of water supply and water resource is the Oromia Regional Water, Mineral and Energy Bureau (hereafter referred to as OWMEB), which supports operation and maintenance conducted by the TWSSO and WC together with the Zonal Water, Mineral and Energy Office (hereafter, ZWMEO) and the Woreda Water, Mineral and Energy Office (hereafter, WWMEO), who are affiliated with OWMEB.

Table 9.5.2 shows main organizations concerned with Water Supply Service in the Oromia region.

Table 9.5.2: Organizations related to Water Supply Service

Name of Organization	Administrative Body	Role	Activity
Oromia Regional Water, Mineral and Energy Bureau	Regional Government	-Making regional water supply plan -Implementation of major water supply project -Technical guidance to substructure -Supporting major maintenance works	-Procurement of pumps, diesel generators, water meter, etc. -Dispatch borehole maintenance team -Dispatch submersible pump removal and installation team
Zonal Water, Mineral and Energy Office	Regional Government	-Making zonal water supply plan -Implementation of water supply project -Technical guidance to substructure -Supporting major maintenance works	-Repairing major breakdown such as・borehole, pump, diesel generator, etc. -Supporting management of Town water Supply Service Office
Woreda Water, Mineral and Energy Office	Woreda Administration Office	-Making Woreda water supply plan -Implementation of water	-Repairing minor breakdown such as hand pumps etc.

Name of Organization	Administrative Body	Role	Activity
		supply project -Supporting minor maintenance works -Monitoring and supporting management	-Supporting management of water committee
Urban Water Supply and Sewerage Service Enterprise	City Administration Office	-Providing water supply and sewerage service to big cities	-Operation and maintenance of facility
Town Water Supply Service Office	Town Administration Office	-Providing water supply service to small towns	-Operation and maintenance of facility
Water Committee	Community (Residents)	-Providing water supply service to rural Kebeles	-Operation and maintenance of facility

Source: the Project Team, Data: Result of water supply survey in this Project

d. Outline of each organization

d.1 Oromia Regional Water, Mining and Energy Bureau

OWMEB comprises the following 15 departments, whose organization chart is shown in Figure 9.5.1. Table 9.5.3 shows staff strength and budget.

Water Supply Sector

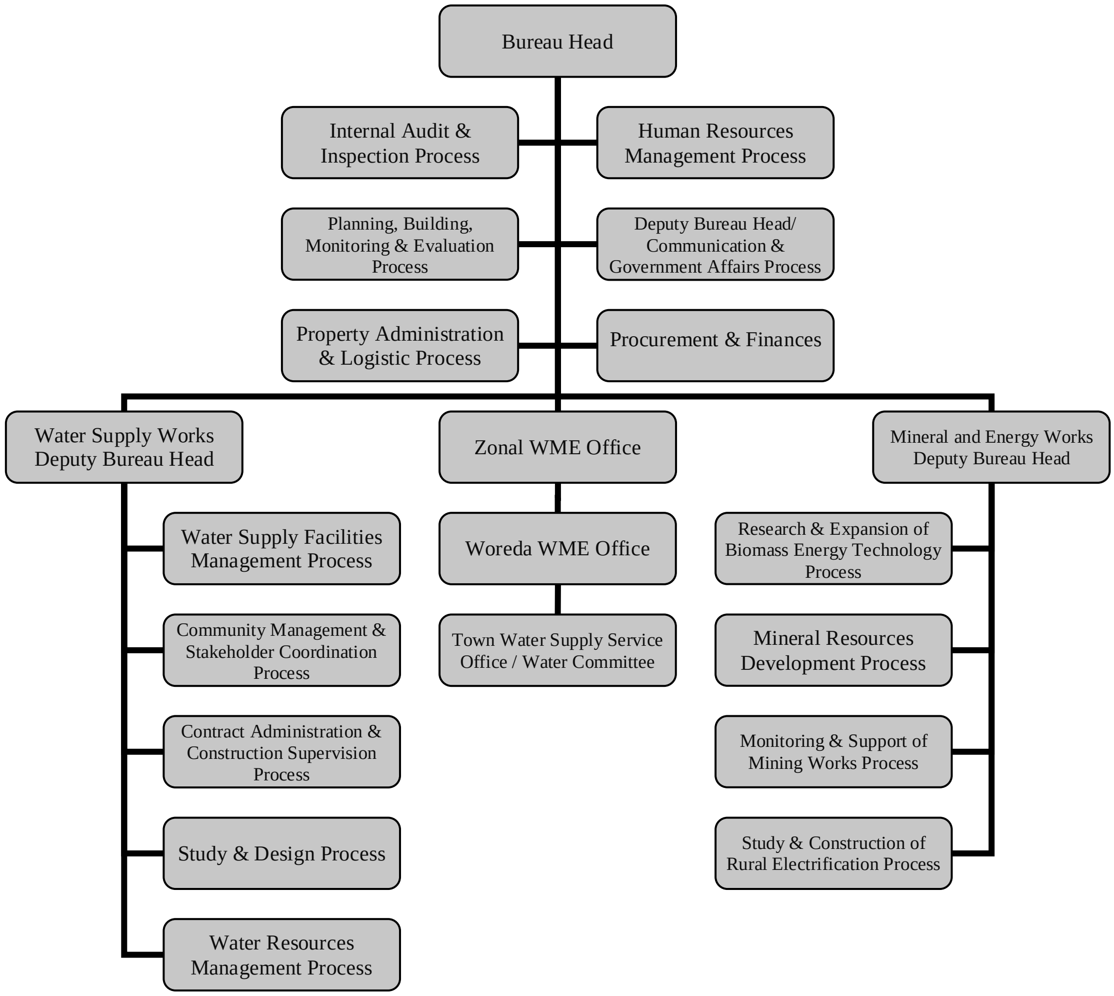
1) Water supply & facility management process
2) Community management & stakeholder coordination process
3) Contract administration & construction supervision process
4) Study & design process
5) Water resource management process

Mineral and Energy Sector

1) Research and expansion of biomass energy technology process
2) Mineral resources development process
3) Monitoring & supporting of mining works process
4) Study & construction of rural electrification process

Other Sectors

1) Internal auditing & inspection process
2) Human resource management process
3) Planning, building, monitoring & evaluation process
4) Communication & government affairs process
5) Property administration & logistic process
6) Procurement & finance administration process



Source: OWMEB

Figure 9.5.1: Organization Chart of OWMEB

Table 9.5.3: Number of Staff and Budget of OWMEB

Number of staff	Budget (Birr)					
	Recurrent (Overhead)			Capital (Project)		
	2011/2012	2012/2013	2013/2014	2011/2012	2012/2013	2013/2014
275	NA	66,790,000	104,611,877	NA	1,723,809,297	1,654,888,090

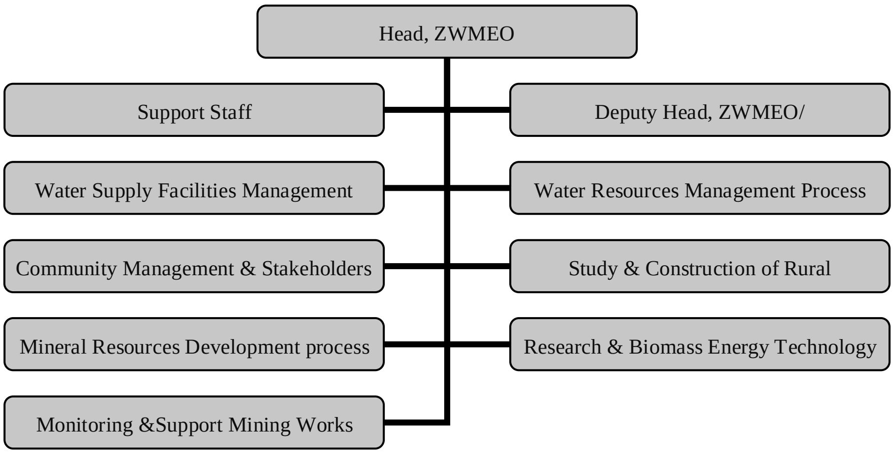
Source: the Project Team, Data: OWMEB

d.2 Zonal Water, Mineral and Energy Office

The ZWMEO comprises the following eight departments, whose organization chart is shown in Figure 9.5.2. Table 9.5.4 shows number of staff and budget.

1) Facility management of water supply
2) Stakeholders and community management
3) Study, design and contract
4) Water resource management
5) Biomass energy

6) Electrification
7) Mineral resource management
8) Mineral support and monitoring



Source: the Project Team, Data: ZWMEO

Figure 9.5.2: Organization Chart of ZWMEO

Table 9.5.4: Number of Staff and Budget of ZWMEO

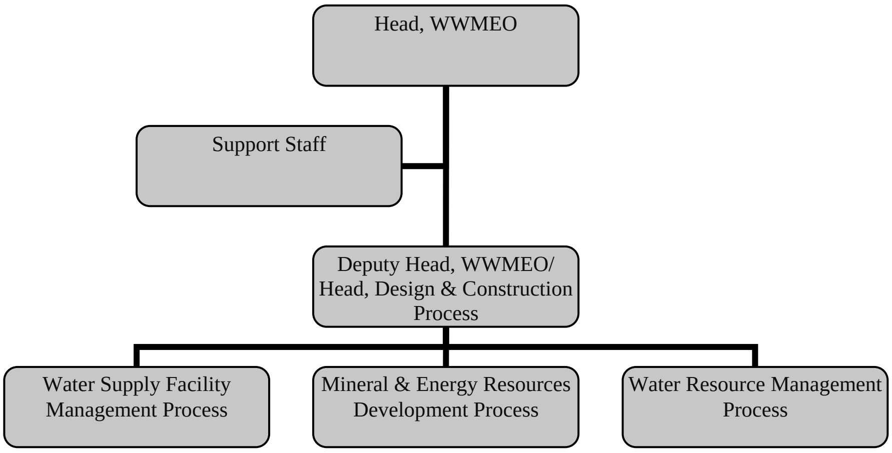
Zone	Number of staff	Budget (Birr)					
		Recurrent (Overhead)			Capital (Project)		
		2011/2012	2012/2013	2013/2014	2011/2012	2012/2013	2013/2014
East Shewa	44	1,875,582	1,984,650	1,939,319	NA	NA	NA
Arsi	52	NA	1,751,020	2,475,361	NA	16,843,211	23,508,337
West Hararge	44	NA	NA	NA	NA	NA	42,100,000

Source: the Project Team, Data: Result of water supply survey in this Project

d.3 Woreda Water, Mineral and Energy Office

The WWMEO comprises the following four departments, whose organization chart is shown in Figure 9.5.3. Table 9.5.5 shows staff strength and budget. Table 9.5.6 shows the list of equipment both office equipment and equipment for operation and maintenance owned by WWMEO.

1) Study, design and contract
2) Facility management
3) Water resource management
4) Mineral and energy



Source: the Project Team, Data: WWMEO

Figure 9.5.3: Organization Chart of WWMEO

Table 9.5.5: Number of Staff and Budget of WWMEO

Woreda	Number of staffs	Budget (Birr)					
		Recurrent (Overhead)			Capital (Project)		
		2010/2011	2011/2012	2012/2013	2010/2011	2011/2012	2012/2013
Adama Zuria	13	285,504	533,145	577,991	200,000	260,000	141,693
Ada	22	315,288	486,140	612,967	45,000	75,000	260,000
Boset	17	350,000	520,577	513,351	NA	408,880	200,000
Lume	11	110,000	250,000	334,072	NA	43,280	23,924
Gimbichu	15	241,372	371,350	653,512	75,000	208,180	704,000
Liben Zikuala	21	158,000	73,000	388,050	NA	63,000	30,000
Sire	14	118,362	255,574	347,498	44,431	300,000	100,000
Jeju	17	203,806	NA	NA	304,683	NA	NA
Aseko	16	218,785	NA	NA	61,000	NA	NA
Merti	13	239,676	NA	NA	200,389	NA	NA
Tiyo	15	NA	155,859	474,275	105,000	62,000	200,000
Lodehetosa	20	362,000	408,000	704,650	NA	205,000	85,000
Anchar	12	195,179	406,495	456,408	0	0	200,000
Guba Qoricha	11	228,100	456,770	419,181	100,000	226,882	399,322
Mieso	19	293,385	NA	NA	80,000	NA	NA

Source: the Project Team, Data: Result of water supply survey in this Project

Table 9.5.6: Equipment in WWMEO

Woreda	Office Equipment (Number)	O&M Equipment (Number)
Adama Zuria	Desktop computer (1), Laptop computer (1), Printer (1), Telephone (1), Scanner (1)	None
Ada	Desktop computer (3), Printer (1), Telephone (2),	Tripod (1), Chain block (1), Motor cycle (2)
Boset	Desktop computer (2), Printer (2), Telephone (1)	Tripod (1), Motor cycle (2), Spanner set (4)
Lume	Desktop computer (2), Printer (1), Telephone (1)	Motor cycle (1), Spanner set (1)
Gimbichu	Desktop computer (1), Printer (1), Telephone (1), Digital camera (1)	Tripod (1), Motor cycle (2)
Liben Zikuala	Desktop computer (1), Printer (1), Telephone (1)	Motor cycle (1), Spanner set (1), Hand pump spare parts (20), Chlorination agent (8kg)

Woreda	Office Equipment (Number)	O&M Equipment (Number)
Sire	Desktop computer (1), Printer (1), Telephone (1), Digital camera (1)	Tripod (1), Motor cycle (2), Water meter (2), PVC pipe (16), Galvanized Steel Pipe (120)
Jeju	Desktop computer (1), Printer (1), Telephone (1)	Generator (1), Chain Block (1), Hand pump spare parts set (1)
Aseko	Desktop computer (4), Laptop computer (1), Printer (2), Telephone (1)	Hand pump spare parts (5)
Merti	Desktop computer (3), Laptop computer (1), Printer (2), Telephone (2), Digital Camera (1)	Generator (8), Motor Cycle (1)
Tiyo	Desktop computer (2), Printer (1), Telephone (1), Digital camera (1)	Motor cycle (1), Spanner set (1)
Lodehetosa	Desktop computer (3), Printer (2), Telephone (2)	Chain block (2), Motor cycle (4), Spanner set (1), Water meter (10)
Anchar	Desktop computer (1), Laptop computer (1), Printer (1)	Generator (3), Motor cycle (1), Chlorination agents (10)
Guba Qoricha	Desktop computer (1), Laptop computer (1), Printer (1), Telephone (1), Digital camera (1)	Generator (6), Tripod (1), Motor cycle (1), Spanner set (1)
Mieso	Desktop computer (1), Laptop computer (1), Printer (1), Telephone (1)	Generator (17), Water meter (500)

Source: the Project Team, Data: Result of water supply survey in this Project

e. Organization for operation and maintenance of water supply facility in small Towns

e.1 Town water supply service office

The Town Water Supply Service Office is considered to be the same organization as the "Urban Water Supply and Sewerage Service Enterprise," which is legislated by the "Proclamation No.78/2004: A Proclamation to provide for the Establishment of Urban Water Supply and Sewerage Service Enterprises of the Oromia Regional State" of 2004. However, the magnitude of a small town system is relatively smaller than of cities like Adama city, and there is no generally sewage system in a small town; thus, seems that the organization is called as the Town Water Supply Service Office.

The Town Water Supply Service Office is established by the Town Water Board, whose members comprise the representative of the Town Administration Office, one person from OWMEB or the ZWMEO or the WWMEO, one person from the Health office, one person from the Women's Affair Office, one person from the Finance and Economic Development Office, one person from the branch of EEPCO in the town, one person from Education Office, two person from water users of the water supply service, and the general manager of the Town Water Supply Service Office. The manager and staff of the Town Water Supply Service Office are selected and employed by the Town Water Board.

e.2 Water committee

The "Portable Water Service Organization," which is legislated by the "Proclamation No.152/2009: A proclamation to provide for the Establishment and Administration of Oromia National Regional State Rural potable water service Organizations" of 2009, and generally called the "Water Committee," is the organization of water users in rural Kebeles who establish the committee to operate and maintain water supply facilities.

Members of the committee are elected among water users. Generally, the number of the committee members is approximately seven, which comprises a chairperson, secretary, cashier, auditor, store keeper, purchaser, and member. The term of office of the committee is two years; committee members are generally volunteers, but committee employees, such as operators, water fee collectors, and guards, are paid.

9.5.2 Current conditions of O&M in target small towns

a. Organization of operation and maintenance

TWSSO is organized in eight towns (ES-4, ES-5, ES-9, ES-12, AR-1, AR-5, AR-6, and WH-5). Only one TWSSO exists for both town ES-5 and AR-5, whose name is "Bole-Golegota Town Water Supply Service Office," thus, the total number of TWSSO is seven out of 30 target towns.

There is no organization for operation and maintenance in three towns (WH-6, WH-8, WH-9) where water supply facilities do not exist.

WCs exist in the remaining 17 towns. There are two WCs that were established for every water supply system in ES-3. There are three WCs that were established for every borehole with hand pump.

b. Meeting, record and general assembly

Periodic meetings are held in all of TWSSOs and water committees except one water committee—ES-3. Meetings are usually held monthly. However, there is a water committee that holds weekly meetings.

Revenue and expense was not recorded by the three WCs for borehole with hand pump of ES-6. Revenue and expense was not recorded monthly but every three months by the WCs of AR-7 and WH-10. Revenue and expense was recorded by other TWSSOs and WCs.

General assembly was not held in nine towns (ES-3, ES-4, ES-8, ES-11, AR-4, AR-6, AR-7, WH-4, and WH-7).

Table 9.5.7: Operation and Maintenance Management Organization, Meeting Situation and Income Record Documentation Situation

ID	Town	Operation and Maintenance Management Organization	Meeting Situation (Yes/No) (frequency)	Monthly documentation of income record (Yes/No)
ES-1	Wonji Shewa Alemtena	water committee not formally established & Adama City WSSSE	no	no
ES-2	Geldiya	water committee	yes (4 times/year)	yes
ES-3	Dire	2 water committees for each borehole (BH1and BH2)	no for WC1, yes (24 times/year) for WC2	yes (both WC1 and WC2)
ES-4	Bofa	Bofa Town Water Supply Service Office	yes (12 times/year)	yes
ES-5/ AR-5	Bole/ Golegota	Bole-Golegota Town Water Supply Service Office	yes (12 times/year)	yes
ES-6	Ude Dhankaka	water committee	yes (12 times/year)	no

ID	Town	Operation and Maintenance Management Organization	Meeting Situation (Yes/No) (frequency)	Monthly documentation of income record (Yes/No)
ES-7	Bekejo	water committee	yes (12 times/year)	yes
ES-8	Kamise	Water Committee/ Gimbichu-Fentale Rural Water Supply Service Enterprise	yes (12 times/year)	no
ES-9	Chefe Donsa	Chefe Donsa Town Water Supply Service Office	yes (24 times/year)	yes
ES-10	Areda	Water Committee	yes (24 times/year)	yes
ES-11	Biyo	Water Committee	yes (12 times/year) before breakdown of windmill borehole	yes
ES-12	Adulala	Adulala Town Water Supply Service Office	yes (24 times/year)	yes
AR-1	Sire	Sire-Merfe Water Management Board	yes (12 times/year)	yes
AR-2	Bolo	water committee	yes (12 times/year)	yes
AR-3	Arboye	water committee	yes (48 times/year)	yes
AR-4	Aseko	water committee	yes (24 times/year)	yes
AR-6	Gonde	Gonde-Iteya Water Management Board	yes (12 times/year)	yes
AR-7	Arbe Gebeya	water committee	yes (12 times/year)	no, 4 times/year
WH-1	Chorora	water committee	yes (12 times/year)	yes
WH-2	Bedeyi	water committee	yes (24 times/year)	yes
WH-3	Hardim	water committee	yes (24 times/year)	yes
WH-4	Bube	water committee	yes (12 times/year)	yes
WH-5	Mieso	Mieso Town Water Supply Service Office	yes (12 times/year)	yes
WH-6	Hargeti	not applicable	not applicable	not applicable
WH-7	Bordede	water committee	yes (12 times/year)	yes
WH-8	Kenteri	not applicable	not applicable	not applicable
WH-9	Aneno	not applicable	not applicable	not applicable
WH-10	Belo	water committee	yes (52 times/year)	no (4 times/year)
WH-11	Kora	water committee	yes (10 times/year)	yes

Source: the Project Team, Data: Result of water supply survey in this Project

c. Operator

Operators exist only for water supply facilities with motorized pump, whose total number is 26 persons. There are nine operators who have more than 10 years of experience, five operators who have less than three years of experience, and two of them have less than a year of experience, where the shortest period is two months. Twenty two operators were trained in the past, whose training period was various between two days and 10 months.

d. Collection of water tariff

Table 9.5.8 shows the water tariff of target small towns. The charging system is volumetric except for borehole with hand pump, of which the charging system is a fixed rate. In case a motorized pump is used, it will require some costs for power supply so that water tariff becomes more expensive than the gravity system. The tariff for water supply facilities using diesel generator is approximately two times its using public power supply. The tariff for water supply facilities using two sets of motor pump with a diesel generator is approximately two times than its use of only one set.

The rate of collection of water tariff is 100%, except for seven towns—ES-5, ES-9, ES-12, AR-5, AR-7, WH-4, and WH-5.

Interviewees of 22 towns answered that water tariff is very feasibly set to conduct operation and maintenance.

TWSSOs and WCs besides four towns—ES-1, ES-8, ES-11 and WH-2—maintain their funds at the local bank.

Table 9.5.8: Water Tariff of Target Towns

Water source	Power source	Number of pumps	Town ID	Tariff (birr)		
				System	Min.	Max.
Spring	Gravity	0	AR-3, AR-6, AR-7	Volumetric	1.50	5.00
Spring	Public power supply	1	ES-9, AR-4	Volumetric	5.00	9.00
Spring	Generator	1	WH-4	Volumetric	20.00	21.00
Borehole	Public power supply	1	ES-2, ES-3, ES-4, ES-12, AR-2, WH-5	Volumetric	6.00	8.70
Borehole	Generator	1	ES-5, AR-5, ES-7, ES-10, WH-1, WH-3, WH-7, WH-10, WH-11	Volumetric	16.00	25.00
Borehole	Generator	2	WH-2	Volumetric	38.00	42.00
Borehole	Windmill	0	ES-11	Volumetric	8.00	10.00
Borehole	Manual	0	ES-6	Fixed rate	10.00	10.00
Outside	—	—	ES-1, ES-8	Volumetric	5.00	6.25

Unit (volumetric): birr/m^3
Unit (fix rate): birr/month/household
Source: the Project Team, Data: Result of water supply survey in this Project

e. Supporting system for operation and maintenance

In case the WC requires support for operation and maintenance, the water committee requests the WWMEO first. In case the WWMEO does not have a capacity to solve the problem, the WWMEO will request support from the ZWMEO.

In case the TWSSO requires support for operation and maintenance, the TWSSO will directly request the ZWMEO.

f. Procedure of repairing works

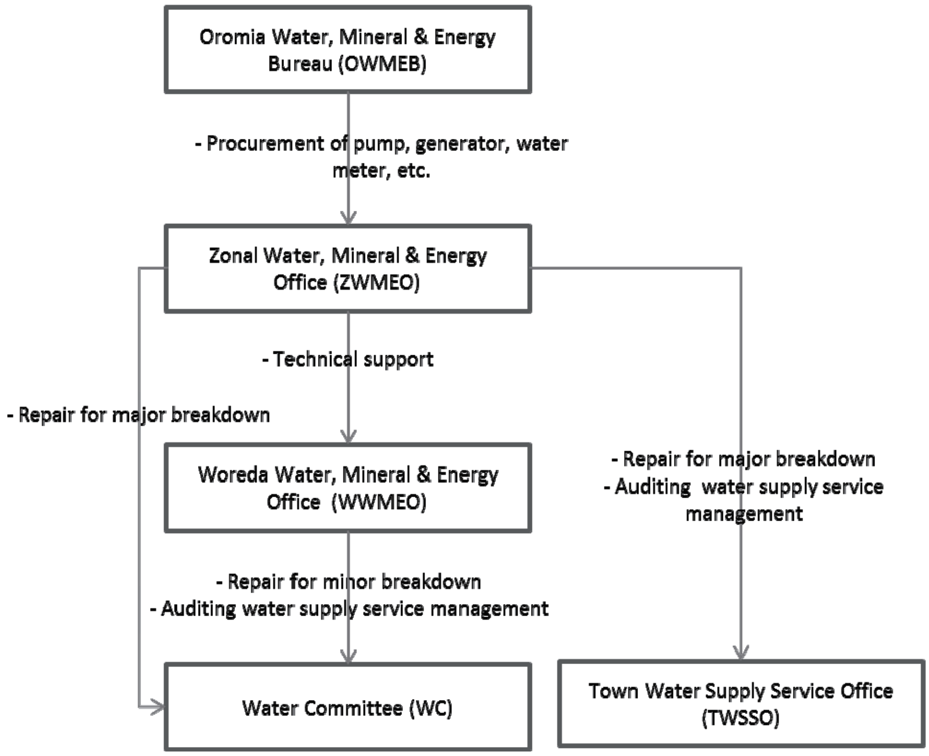
There are barely any mechanical and electrical technicians who can repair pumps, generators, electric control panels, etc. in the WWMEO; thus, most of the repairing work is conducted by the ZWMEO.

The ZWMEO does not have equipment, such as cranes for dismantling and installation submersible pumps and service rigs for rehabilitation of boreholes. In case such equipment is required, ZWMEO request OWMEB to dispatch crane and service rig teams.

TWSSOs and WCs will incur for the costs of necessary materials and fuels for transport and repair.

Most new pumps and generators for replacement are purchased by the OWMEB because those are expensive and shall be imported.

In case TWSSOs and WCs have insufficient funds for the equipment, the OWMEB supplies the equipment free of charge. In this case, the OWMEB sometimes supplies used equipment.



Source: the Project Team, Data: Result of water supply survey in this Project

Figure 9.5.4: Support Structure for Maintenance Management

9.5.3 Ability and actual performance of water committee/office for O&M

Table 9.5.9 shows type and number of staffs of O&M organization in small towns. Staffs of water committee are operators, accountants, guards, water fee collector at public taps, etc.

Table 9.5.10 shows revenue and expense for the past three years and remainder of the funds for water supply and facilities as of January 2014.

Seven water supply systems are operated and maintained by TWSSO among target small towns. The remainder of the funds for water supply and facilities for every office is over 300,000 birr. It seems that good management of water supply service is maintained; however, the remainder of funds for water supply and facilities of every WC except ES-2 is less than 100,000 birr, including a WC whose remainder is zero. There is some difference of magnitude of water supply service between the TWSSO and the WC. Judging remaining amount, it seems that management of water supply service is not good in most of the WC.

The term of office of the committee members elected among water users by democratic way is two years. Due to change of the members, the management know-how is not accumulated. In case taking over the management from the old to the new committee is not proper, some past records may be missing. The management of water supply service by the WC seems like management by amateurs because the management know-how is not accumulated.

The entire staff of the TWSSO, including the manager, is semi-permanently employed by the Water Management Board, and the management know-how is accumulated depending on the experience. The management of water supply service by the TWSSO seems professional. It is considered that this difference between the TWSSO and the WC appears in a management of water supply service.

Table 9.5.9: Type and Number of Staff of O&M Organization

ID	Town	Organization	Committee member	Staff	Total	Remark
ES-1	Wonji Shewa Alemtena	None	0	3	3	Water supplied by Adama City Water Supply and Sewerage Service Enterprise
ES-2	Geldiya	WC	7	7	14	
ES-3	Dire	WC	14	7	21	There are two water supply systems. A WC exists at every system.
ES-4	Bofa	TWSSO	0	11	11	
ES-5/ AR-5	Bole/ Golegota	TWSSO	0	24	24	One TWSSO supplies to two towns.
ES-6	Ude Dhankaka	WC	21	3	24	There are three boreholes with hand pump. WC exists at every borehole.
ES-7	Bekejo	WC	7	6	13	
ES-8	Kamise	WC	5	2	7	Water supplied by Gimbichu-Fentale Water Supply Service Enterprise
ES-9	Chefe Donsa	TWSSO	0	18	18	
ES-10	Areda	WC	7	3	10	
ES-11	Biyo	WC	7	3	10	
ES-12	Adulala	TWSSO	0	11	11	
AR-1	Sire	TWSSO	0	11	11	
AR-2	Bolo	WC	7	3	10	
AR-3	Arboye	WC	7	14	21	
AR-4	Aseko	WC	7	10	17	
AR-6	Gonde	TWSSO	0	18	18	
AR-7	Arbe Gebeya	WC	7	7	14	
WH-1	Chorora	WC	7	4	11	
WH-2	Bedeyi	WC	7	9	16	
WH-3	Hardim	WC	7	6	13	
WH-4	Bube	WC	7	3	10	
WH-5	Mieso	TWSSO	0	11	11	
WH-6	Hargeti	None	0	0	0	Water supply system does not exist.
WH-7	Bordede	WC	7	7	14	
WH-8	Kenteri	None	0	0	0	Water supply system does not exist.
WH-9	Aneno	None	0	0	0	Water supply system does not exist.
WH-10	Belo	WC	7	4	11	
WH-11	Kora	WC	7	5	12	

Source: the Project Team, Data: Result of water supply survey in this Project

Table 9.5.10: Revenue, Expense and Remaining Funds (unit: birr)

ID	Town	2011		2012		2013		Remaining funds as of Jan. 2014
		Revenue	Expense	Revenue	Expense	Revenue	Expense	
ES-2	Geldiya	118,140	61,768	120,900	53,506	151,535	93,449	322,000
ES-3	Dire	NA	NA	NA	NA	244,805	225,048	71,500
ES-4	Bofa	355,588	260,324	356,873	594,025	578,727	461,405	535,000
ES-5/ AR-5	Bole/ Golegota	589,138	449,392	795,501	640,118	1,068,191	851,937	465,147
ES-6	Ude Dhankaka	NA	NA	NA	NA	7,200	3,600	3,600
ES-7	Bekejo	NA	NA	NA	NA	84,309	71,326	61,500
ES-9	Chefe Donsa	230,265	229,030	279,487	207,305	279,525	286,812	145,000
ES-10	Areda	NA	NA	NA	NA	35,790	33,438	2,332
ES-11	Biyo	NA	NA	5,708	6,667	NA	NA	NA
ES-12	Adulala	222,687	156,347	239,088	448,303	258,774	291,711	335,720
AR-1	Sire	208,167	140,612	279,698	198,421	435,322	233,566	382,072
AR-2	Bolo	NA	7,440	NA	NA	94,122	NA	0
AR-3	Arboye	165,840	145,527	135,389	135,354	75,308	118,527	10,500
AR-4	Aseko	16,439	16,439	49,933	41,693	100,428	82,109	27,400
AR-6	Gonde	527,865	673,039	651,153	358,640	581,297	353,885	1,300,500
AR-7	Arbe Gebeya	19,429	9,408	24,187	11,634	NA	NA	15,200
WH-1	Chorora	54,195	52,680	85,000	78,230	111,290	89,142	40,500
WH-2	Bedeyi	NA	NA	100,084	100,399	135,014	99,032	10,000
WH-3	Hardim	318,075	NA	265,560	119,469	132,780	NA	25,000
WH-4	Bube	NA	NA	NA	NA	NA	NA	15,000
WH-5	Mieso	392,033	101,439	384,336	147,034	76,221	152,642	316,586
WH-7	Bordede	309,520	53,088	158,030	27,084	184,334	283,160	55,000
WH-10	Belo	NA	NA	NA	NA	NA	NA	16,000
WH-11	Kora	NA	NA	NA	NA	88,469	70,929	92,000

Remark: The revenue and expense of ES-6 is for one Water Committee of borehole with hand pump. The Town Water Supply Service Office of AR-6 supplies water to wide areas including Gonde Town and surrounding 16 Kebeles.

Source: the Project Team, Data: Result of water supply survey in this Project

9.5.4 Overall identified issues on management and O&M of water supply facilities

a. Capacity of water committee

Most WCs do not maintain a proper record of consumed volume read by water meter, record of revenue and expense, etc. Therefore, the situation of management of water supply service cannot be evaluated in a timely manner.

The term of office of the members of committee is two years. Due to change of the members, the know-how of the management is not accumulated.

1) Therefore, capacity development for new members of water committee is necessary every two years as mentioned below. Capacity on documentation of water consumption volume and water tariff record based on water meter
2) Capacity on water tariff bill and receipt preparation.
3) Capacity on collecting water tariff and accounting management

4) Capacity on preparing monthly and annually income report
5) Capacity on understanding and improving ineffective water volume by comparing water consumption volume and water production record

b. Operation record

Most of operators do not maintain operation records of water supply facilities such as operated hours with time of start and stop, consumption of fuel, oil, electricity (kWH), and flow meter readings at start and stop; thus, unaccounted water can be estimated by comparing with consumed volume recorded by water meter.

Therefore, capacity development for operations is necessary as mentioned below.

1) Capacity on preparation of operation record
2) Capacity on preparation of water production record
3) Capacity on maintenance management and inspection of water supply facilities

c. Data of water supply facility

The data of water supply facilities is very difficult to obtain. Such data is not found in the WC and TWSSO. The WWMEO has some of the data of water supply facilities; however, they do not have the data of borehole such as static water level, specific capacity, and screen position. The ZWMEO and OWMEB stock documents of construction such as drilling report, pumping test record, specifications, and as-built drawings. However, it is difficult to obtain data because the ZWMEO has no system to maintain, arrange, and manage those documents and data; therefore, some of the documents might be lost in the past.

Data of water supply facilities are necessary for operation and maintenance, including selection of equipment such as submersible pump and diesel generator, replacing submersible pump, rehabilitation of borehole (e.g. air lift), and repairing transmission and distribution pipes.

Therefore, a system for maintenance, arrangement, and management of essential data of water supply facilities must be established by OWMEB.

Therefore, following are quite important for proper operation and maintenance.

1) Establish a library in OWMEB and employ a person in charge to keep and manage hard copies of construction reports, as-built drawings, other related documents, etc.
2) Extract essential data from these documents and make the database of the water supply facility inventory
3) Make the technical information sheet of every water supply facility and share it in four (4) organizations of TWSSO or WC, WWMEO, ZWMEO and OWMEB

If one page of technical information sheet consisting of essential data of water supply facilities showing in Table 9.5.11 is shared among TWSSSO, WC, WWMEO, ZWMEO, and OWMEB, the repairing work for breakdowns can be started rapidly. OWMEB shall provide such technical information sheet and distribute to the abovementioned organizations related to water supply services.

Table 9.5.11: Sample of Technical Information Sheet

Technical Information Sheet

Data:

Town/Kebele:		Woreda office:
Borehole Code:	UTM-E (m):	UTM-N (m):
A: Administration Information		
Town/Kebele:		Zone:
Woreda:		Population:
B: Water Source		
Type: Borehole/ spring	Max. yield: m^3/h	**Screen**
Drilling date:	Draw down: m	Material/type:
Contractor:	Specific capacity: $m^3/h/m$	Diameter: mm
Operation start date:	**Casing**	Position(top) m
Aquifer:	Material:	Position(bottom) m
Ground level: m	Diameter: mm	
Static W. L.: m	Depth: m	
C: Pump		
Submersible	**Booster pump 1**	**Booster pump 2**
Installation date:	Installation date:	Installation date:
Brand:	Brand:	Brand:
Model:	Model:	Model:
Output: kW	Output: kW	Output: kW
Volt/Hz/phases:	Volt/Hz/phases:	Volt/Hz/phases:
Speed: rpm	Speed: rpm	Speed: rpm
Pumping rate: m^3/h	Pumping rate: m^3/h	Pumping rate: m^3/h
Dynamic W. L. m	Total head: m	Total head: m
Total head: m	Contractor:	Contractor:
Setting depth: m		
Riser pipe dia. mm		
Contractor:		
D: Power Source		
Generator		**Transformer**
Installation date:		Installation date:
Motor	**Alternator**	Power company:
Brand:	Brand:	Brand:
Model:	Model:	Model:
No. of cylinder:	Output(standby): kVA	Output: kVA
Speed:	Output(prime): kVA	Voltage(prime): V
Supplier:	Volt/Hz/phases:	Voltage(second): V
E: Reservoir and Pipelines		
Project:	Year:	Contractor:

Reservoir					
Type:	Capacity (m^3)	Elevation (m)			
		Ground	Bottom	Height	Top
Reservoir					
Booster					

Pipelines					
Transmission			Distribution		
Material	Diameter (mm)	Length (m)	Material	Diameter (mm)	Length (m)
Total			Total		

Source: the Project Team, Data: Result of water supply survey in this Project

Chapter 10

Environmental and Social Consideration

10 Environmental and Social Consideration

10.1 Introduction

The purpose of the environment and social consideration study is to estimate the environmental and social impact of the installation of facilities designed by The Project for Groundwater Resources Assessment in the Middle Awash River Basin in the Federal Democratic Republic of Ethiopia (hereafter, the Project), based on the JICA Environmental and Social Consideration Guidelines and the Ethiopian Environmental Impact Assessment (EIA) Guidelines. Alternative plans and mitigation strategies will also be studied if the impacts are inevitable.

10.2 Outline of the Project components

This Project is carried out in the middle Awash River Basin based on the results of the Record of Discussions (R/D) agreed and signed by the Federal Democratic Republic of Ethiopia and Japan International Cooperation Agency (JICA) in May 2013

The Project consists of components such as drawings of geographic and hydrogeological maps in the middle awash basin area, evaluation of groundwater potential, and water supply plan for target towns in the Oromia region and selection of high-priority small towns for further assistance.

As mentioned above, the purpose of environment and social consideration study is to estimate environmental and social impacts caused by the implementation of the water supply plans drawn up by the Project.

10.3 Outline of the water supply plans

The initial (pre-Project) water supply plan was to supply water to 30 rural towns in 16 Woredas. However, for various reasons, outlined below, the target number of towns—for which JET developed water supply plans in the Project—was reduced to 19. Among the 11 excluded towns, several were found to already be on the receiving end of water supply projects such as by the government of Oromia and the One WASH program by UNICEF. Other towns were excluded because the groundwater showed high fluoride concentrations exceeding Ethiopian water quality standards, as well as towns that already had a water supply exceeding the targeted water supply for the estimated population in 2020. The water source for all of the 19 target towns of the plan is groundwater.

The water supply plans consist of renewal of current water supply facilities and construction of new facilities reflecting current conditions in each rural town. The table below shows a summary of the water supply population in target year, the daily maximum water supply amount and allocation of the water supply amount between new and current facilities.

Table 10.3.1: Allocation of water supply amount between new and current facilities

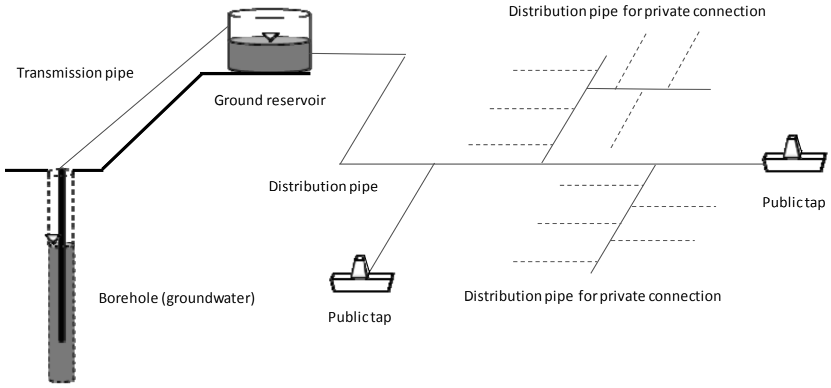
ID	Rural town	Total amount		Allocation	
		Water supply population in 2020 (person)	Maximum water supply amount (m^3/day)	Current Current water supply (m^3/day)	New Necessary amount (m^3/day)
ES-2	Geldiya	2,873	162.9	93.8	69.1
ES-4	Bofa	5,326	299.3	229.8	69.5
ES-6	Ude Dhankaka	7,334	413.3	0.0	413.3
ES-8	Kamise	6,167	343.6	11.5	332.1
ES-10	Areda	3,502	197.2	11.0	186.2
ES-11	Biyo	3,446	195.9	0.0	195.9
AR-2	Bolo	2,010	114.6	24.2	90.4
AR-3	Arboye	9,254	550.4	271.7	278.7
AR-4	Aseko	6,724	386.9	46.3	340.6
AR-6	Gonde	4,370	248.0	116.2	131.8
WH-1	Chorora	3,183	117.3	21.2	96.1
WH-2	Bedeyi	3,748	219.0	16.8	202.2
WH-3	Hardim	7,515	428.1	18.1	410.0
WH-4	Bube	7,286	258.9	18.1	240.8
WH-6	Hargeti	3,926	138.3	0.0	138.3
WH-8	Kenteri	2,044	73.2	0.0	73.2
WH-9	Aneno	3,326	116.6	0.0	116.6
WH-10	Belo	5,471	189.9	12.2	177.7
WH-11	Kora	2,771	99.0	37.8	61.2

Source: the Project Team
Data source: field survey by JET

Water supply plans were developed with the following conditions:

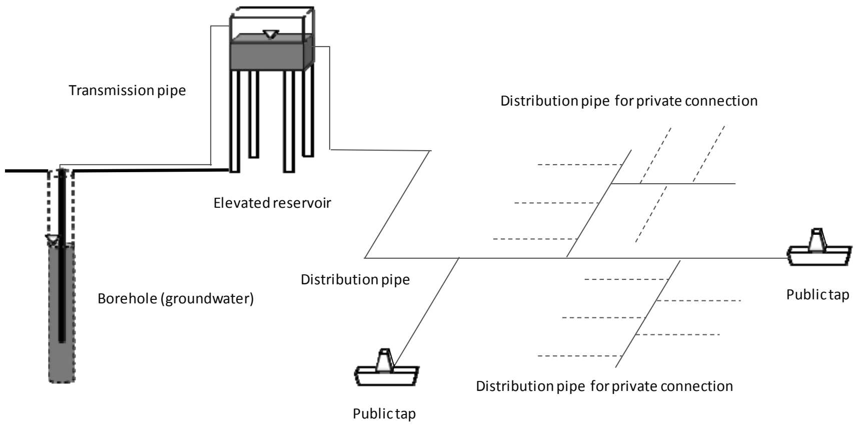
- Target Year : 2020
- Design supply amount : 40 litter/capita/day (urban), 25 litter/capita/day (rural)
  5 litter/capita/day (school), 25 litter/capita/day (medical station)
- Design usage : Domestic household use
  (Educational and medical institutes use are also concerned)
- Components of facility : Refer below

The plans drawn by the Project consist of electric generators, submersible pumps, pipe line to water reservoirs, elevated water tanks, public water taps and so on (Figure 10.3.1, Figure 10.3.2).



Source: the Project Team

Figure 10.3.1: General scheme on water supply system with water tank on the ground



Source: the Project Team

Figure 10.3.2: General scheme on water supply system with elevated water tank

In view of the conditions above, the water supply plans with new facilities and renewal of current facilities were estimated as below.

Table 10.3.2: Outline of construction plan of new water supply facilities

ID	Small town	Intake facility							Transmission facility	Distribution facility				
		Borehole		Submersible motor pump		Diesel generator		Pumping cabin	Transmission pipes	Distribution reservoir			Distribution pipes	Public taps
		Quantity (set)	Depth (m)	Quantity (set)	Output (kW)	Quantity (set)	Output (kVA)	Quantity (set)	Quantity (m)	Quantity (set)	Type	Capacity (m3)	Quantity (m)	Quantity (set)
ES-2	Geldiya	1	200	1	4	1	10	1	1,225	1	Ground	50	3,025	1
ES-4	Bofa	1	250	1	4	1	10	1	2,120	1	Elevated	50	8,290	1
ES-6	Ude Dhankaka	1	300	1	15	1	34	1	965	1	Ground	300	6,850	13
ES-8	Kamise	1	350	1	19	1	42	1	1,750	1	Ground	250	5,100	10
ES-10	Areda	1	250	1	19	1	42	1	4,275	1	Elevated	150	3,330	6
ES-11	Biyo	1	300	1	11	1	26	1	285	1	Ground	150	5,120	6
AR-2	Bolo	1	250	1	8	1	18	1	1,345	1	Elevated	100	2,540	2
AR-3	Arboye	2	250	2	11	2	26	2	650	2	Elevated	100	4,910	4
AR-4	Aseko	2	250	2	22	2	50	2	1,210	2	Ground	150, 100	3,500	9
AR-6	Gonde	1	150	1	8	1	18	1	2,175	1	Ground	100	5,935	2
WH-1	Chorora	1	150	1	4	1	10	1	625	1	Ground	100	1,870	2
WH-2	Bedeyi	1	250	1	22	1	50	1	1,130	1	Ground	150	2,750	4
WH-3	Hardim	1	150	1	13	1	30	1	1,645	1	Ground	300	3,820	10
WH-4	Bube	3	200	3	3	3	8	3	530	3	Ground	50	3,530	11
WH-6	Hargeti	1	250	1	8	1	18	1	1,070	1	Ground	100	1,575	7
WH-8	Kenteri	1	200	1	4	1	10	1	1,205	1	Elevated	50	745	4
WH-9	Aneno	2	300	2	6	2	14	2	1,495	2	Ground	50	1,555	6
WH-10	Belo	2	200	2	4	2	10	2	150	2	Ground	100, 50	3,005	9
WH-11	Kora	1	200	1	4	1	10	1	585	1	Ground	50	1,350	2

Source: the Project Team

Table 10.3.3: Outline of renewal plan of existing water supply facilities

ID	Small town	Intake facility							Transmission facility	Distribution facility				
		Borehole		Submersible motor pump		Diesel generator		Pumping cabin	Transmission pipes	Distribution reservoir			Distribution pipes	Public taps
		Quantity (set)	Depth (m)	Quantity (set)	Output (kW)	Quantity (set)	Output (kVA)	Quantity (set)	Quantity (m)	Quantity (set)	Type	Capacity (m3)	Quantity (m)	Quantity (set)
ES-2	Geldiya	-	-	1	4	-	-	-	-	-	-	-	-	-
ES-4	Bofa	1	250	2	4	1	10	-	-	-	-	-	-	11
ES-6	Ude Dhankaka	-	-	-	-	-	-	-	-	-	-	-	-	-
ES-8	Kamise	-	-	-	-	-	-	-	-	-	-	-	-	-
ES-10	Areda	-	-	1	19	-	-	-	-	-	-	-	-	-
ES-11	Biyo	-	-	-	-	-	-	-	-	-	-	-	-	-
AR-2	Bolo	-	-	1		-	-	-	-	-	-	-	-	-
AR-3	Arboye	-	-	-	-	1	26	-	-	-	-	-	-	7
AR-4	Aseko	-	-	1	22	-	-	-	-	-	-	-	-	-
AR-6	Gonde	-	-	-	-	-	-	-	-	-	-	-	-	-
WH-1	Chorora	-	-	1	4	-	-	-	-	-	-	-	-	-
WH-2	Bedeyi	-	-	1	22	-	-	-	-	-	-	-	-	-
WH-3	Hardim	1	150	1	13	1	30	-	-	-	-	-	-	7
WH-4	Bube	-	-	1	3	-	-	-	-	-	-	-	-	-
WH-6	Hargeti	-	-	-	-	-	-	-	-	-	-	-	-	-
WH-8	Kenteri	-	-	-	-	-	-	-	-	-	-	-	-	-
WH-9	Aneno	-	-	-	-	-	-	-	-	-	-	-	-	-
WH-10	Belo	-	-	1	4	-	-	-	-	-	-	-	-	-
WH-11	Kora	-	-	1	4	-	-	-	-	-	-	-	-	-

Source: the Project Team

10.4 Alternative for rural kebeles

If the piped water supply system will be applied for WH-6, WH-8, and WH-9, the following issues are of concern regarding sustainability:

(1) The beneficial effect may be low because of an insufficient population.

(2) Cost performance may be low because the target small towns are kebele (village) where the population is very scattered.

(3) Capability of operation and maintenance is unforeseen because the towns do not currently have water supply facilities

For this reason, the borehole with hand pump is considered recommendable as an alternative water supply plan.

The implementation cost for piped water supply was estimated as in the table below.

Table 10.4.1: Implementation cost

Exchange rate: 1 US$ = 20.6298 Birr

ID	Small town	Borehole with hand pump		Piped water supply system
		Quantity (set)	Implementation cost (Birr)	Implementation cost (Birr)
WH-6	Hargeti	12	11,542,579	8,182,575
WH-8	Kenteri	6	5,938,701	6,693,520
WH-9	Aneno	10	9,645,979	11,835,317

Source: the Project Team

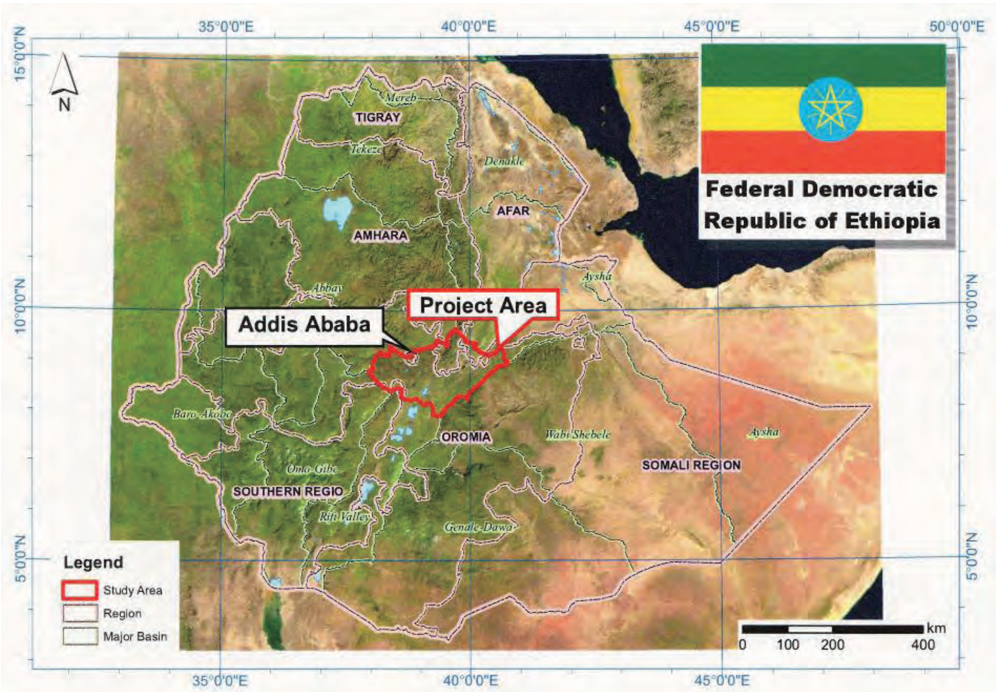
In comparison with the implementation cost of the piped water supply system, the implementation cost of borehole with hand pump is cheaper in WH-8 and WH-9. But the implementation cost of piped water supply system is cheaper in WH-6.

10.5 Environmental and social conditions in the Project area

10.5.1 Natural environment

a. Geographical feature

The study area is located about 180 km east of the capital Addis Ababa. It is bounded by the limits of 38^{0}00' – 40^{0}00' east longitude and 8^{0}00' – 9^{0}30' north latitude. The area is topographically characterized by a depression zone with steep marginal faults along its edges. The study area is an independent basin; therefore it is called middle Awash River Basin.



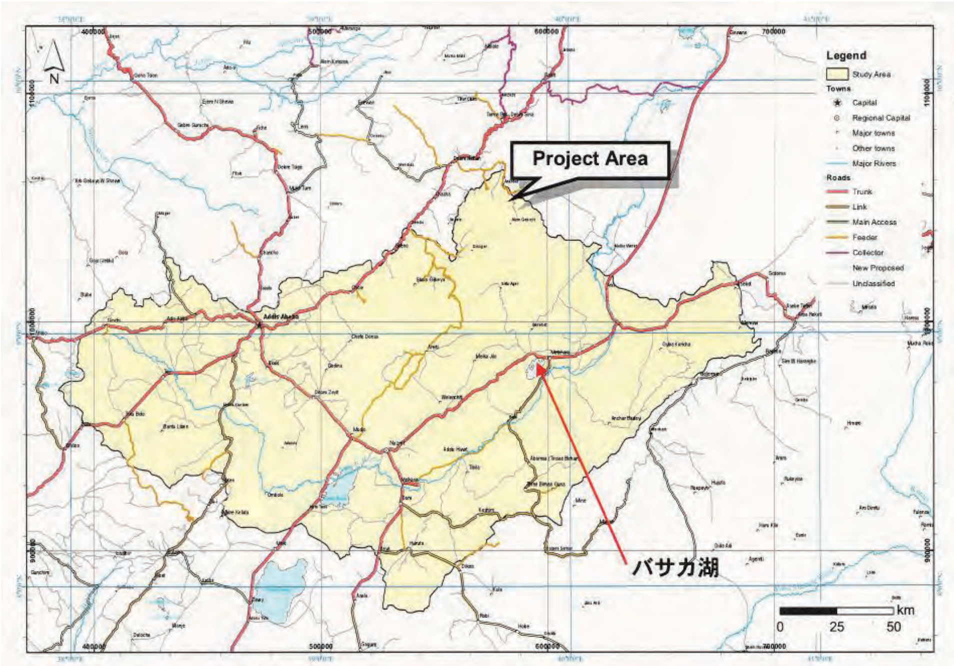


Figure 10.5.1: Location of the study area

b. Weather

Maximum and minimum temperatures and relative humidity in and around the Middle Awash River Basin is summarized in Table 10.5.1.

Table 10.5.1: Data on air temperature, relative humidity and sunshine hours from weather stations in and around the Middle Awash River Basin

Station	Elevation (m a.m.s.l)	Max. Temperature (°C)	Min. Temperature (°C)	Annual Mean Temperature (°C)	Annual Mean Relative Humidity (%)	Annual Mean Sunshine Hours (hours/day)
Abomsa	1,630	31.0 (Jun.)	13.2 (Dec.)	21.9	59.3	7.5
Addis Ababa Obs	2,386	24.9 (Mar.)	7.7 (Dec.)	16.5	60.4	6.6
Ambo Agriculture	2,068	28.4 (Mar.)	10.5 (Nov.)	18.9	61.2	6.4
Awash Arba	780	38.9 (Jun.)	14.3 (Dec.)	26.8	-	-
Debre Berhan	2,750	22.0 (Jun.)	2.8 (Nov.)	13.1	64.7	-
Debre Zeit	1,900	28.6 (May)	8.6 (Dec.)	18.9	-	-
Gelemso	1,739	28.1 (Mar.)	10.0 (Nov.)	20.0	64.0	6.7
Kulumsa	2,211	25.2 (Mar.)	7.8 (Dec.)	16.6	65.8	7.0
Melka Werer	740	38.1 (Jun.)	15.3 (Jan.)	26.7	-	-
Melkasa	1,540	31.2 (May)	10.6 (Nov.)	21.2	64.8	8.4
Metehara	944	36.9 (Jun.)	13.6 (Dec.)	25.8	30.4	8.5
Mieso Mission	1,332	33.3 (Jun.)	10.5 (Dec.)	22.7	-	-
Shola Gebeya	2,500	22.0 (May)	6.5 (Dec.)	14.7	-	-
Wilso Giyon	2,058	27.6 (Mar.)	11.7 (Sep.)	18.9	62.3	-

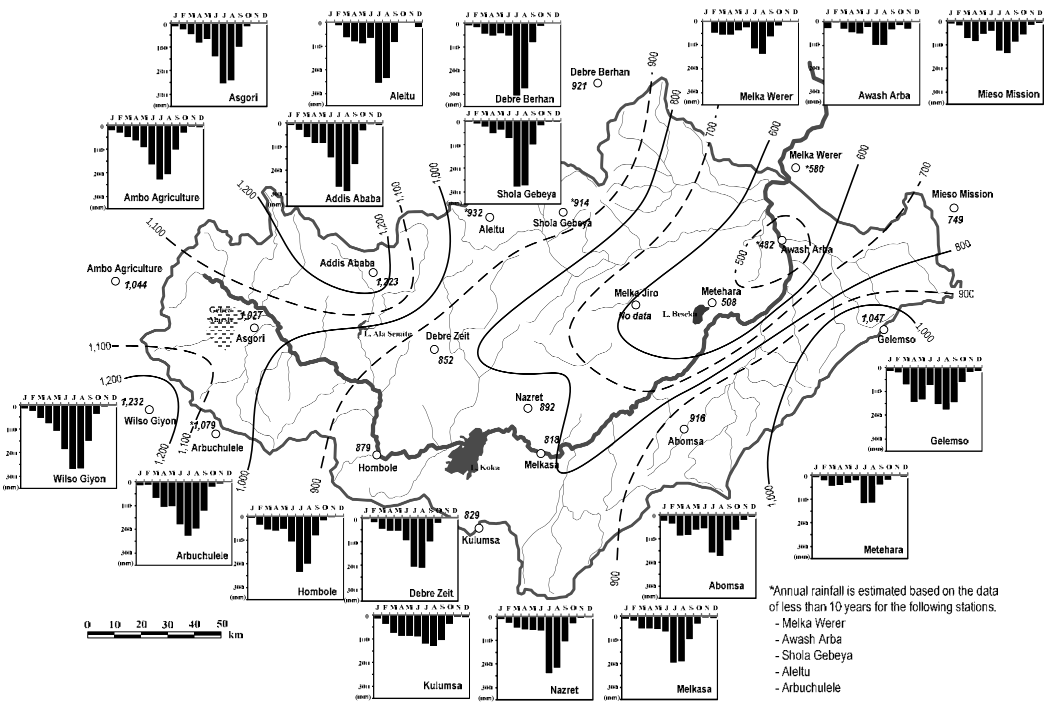
- : Data is not available or has not been collected.
Source: the Project Team. Data source: meteorological data from NMA.

The maximum temperatures are observed late in the small rainy season or in the beginning of the main rainy season, i.e. from May to June, at every observatory. In the main rainy season, although the daily temperature highs are lower than this abovementioned maximum, the daily temperature lows are higher. That is, the daily temperature fluctuation is minimal in the main rainy season. The maximum temperature reaches more than 36 °C at the stations of downstream regions such as Awash Arba, Melka Werer, and Metehara. The temperature drops less than 10 °C in the high lands such as Addis Ababa, Debre Zeit, Kulumsa, and Shola Gebeya.

In terms of relative humidity, the peak is observed in the main rainy season and the annual mean value ranges from 60–65% except for the points in dry regions such as Metehara, where annual mean relative humidity is only 30%.

c. Rain fall

Isohyetal map of the Middle Awash River Basin is generated as shown in Figure 10.5.2.



Source: project team, Data source: meteorological data from NMA

Figure 10.5.2: Isohyetal Map of the Middle Awash River Basin

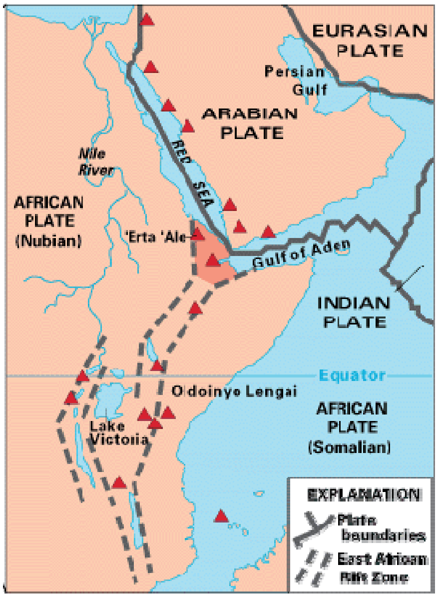
The annual rainfall is greater in the northwestern (i.e., upstream) part of the basin. The areas with low annual rainfall are found in the downstream. Annual rainfall in the western and northwestern areas reaches more than 1,000 mm. The annual rainfall in the middle reaches of the Middle Awash around Lake Koka is 800–900 mm. Rainfall of 500 mm or less is observed in the downstream of the Middle Awash from Metehara.

d. Physiography

The study area is within the African Rift. The African Rift originates from the Aden Junction (Figure 10.5.3) and traverses SW- SSW longitudinally through the eastern African countries such as Djibouti, Eritrea, Ethiopia, Kenya, Uganda, and Tanzania.

Generally the valley is characterized by the geological occurrence of active faults, active volcanoes and hot springs, which indicates it is a geothermal area. Geophysical and petrological data show that lithosphere is thinning from the intrusion of hot mantle below the valley.

The valley is considered to be a separation boundary of the African Plate. The eastern plate is called the Somalian Plate and the western plate is the Nubian Plate. The two plates are separating at a speed of 5 mm/year (Stamps et. al, 2008).



Source: http://people.dbq.edu/faculty /deasley/ Essays/EastAfricanRift.html

Figure 10.5.3: Distribution of African Rift Valley

10.5.2 Environmental pollution

There is no information on systematic services of waste collection and management in the Project area. Based on the results of on-site review in the target towns, it is estimated that waste generated from households and business establishments is either buried, left on a vacant lot naturally or possibly burned in a field.

Health centers in the target towns owned small incinerators for medical waste management. However, those facilities did not appear to be currently in use.

Source: taken by the Project Team

Figure 10.5.4: Small incinerators at HCs, out of use (Areda town)

10.5.3 Social environment

In this clause, an overview of social environment is described for only the Oromia region. Most of the area belongs to the Oromia region in the Project and all target rural towns are selected from Oromia although the Project area cuts across three regions (Oromia, Amhara and Afar regions).

a. Population

The population and land area of the Oromia region are the largest in Ethiopia.

Table 10.5.2: Population Census Data of each Ethiopian Regional State in 1994, in 2007, and in 2013

Region	Population (1994)	Population (2007)	Population (2013)*1)	Area (km^2)	Remarks
Addis Ababa	2,112,737	2,739,551	3,104,000	527	City
Afar Region	1,106,383	1,390,273	1,650,000	72,053	Regional Capital: Asayita
Amhara Region	13,834,297	17,221,976	19,212,000	154,709	Regional Capital: Bahir Dar
Benishangul-Gumuz Region	460,459	784,345	1,028,000	50,699	Regional Capital: Asosa
Dire Dawa	251,864	341,834	395,000	1,559	City
Gambela Region	181,862	307,096	406,000	29,783	Regional Capital: Gambela
Harar	131,139	183,415	215,000	334	City
Oromia Region	18,732,525	26,993,933*2)	32,220,000	284,538	Regional Capital: Adama
Somali Region	3,152,704	4,445,219	5,318,000	279,252	Regional Capital: Jijiga
Tigray Region	3,136,267	4,316,988	5,062,000	84,722	Regional Capital: Mek'ele
SNNPRs	10,377,028	14,929,548	17,887,000	105,476	Regional Capital: Awasa
Total	53,477,265	73,750,932	86,614,000	1,063,652	

Source: CSA, Britannica Book of the Year (1999)
*1) Preliminary figures in 2013

b. Ethnic group, religion and language

Ratio of ethnic groups in the Oromia Region is Oromo people (around 88%), Amhara (around 7%), Gurage (around 1%), and others (4%).

Table 10.5.3: Ethnic composition in each woreda in the Project area

			Ratio of Ethnic group (%)				
No	Zone	Woreda	Oromo	Amhara	Gurghie	Somali	Others
1	East Shewa	Adama Zuria	87	10	0	0	3
2		Ada	95	3	0	0	2
3		Boset	90	5	3	0	2
4		Lume	80	8	0	0	12
5		Gimbichu	80	15	0	0	5
6		Liben Zikuala	95	3	2	0	0
7	Arsi	Sire	60	30	0	0	10
8		Jeju	90	8	0	2	0
9		Aseko	80	N.A	N.A	N.A	N.A
10		Merti	80	10	0	0	10
11		Tiyo	90	8	0	0	2
12		Lodehetosa	85	10	0	0	5
13	West Hararge	Anchar	77	13	0	0	10
14		Guba Qoricha	93.5	5	0	1.5	0
15		Mieso	90	8	0	2	0
		Average	84.8	9.7	0.4	0.4	4.4

Source: the Project team. Data source: field survey by the Project Team.

The Muslim is the largest religion (around 48 %) in the Oromia Region followed by Ethiopian orthodox (around 30%) and protestant (around 18%), and others (around 4%).

Table 10.5.4: Religion in the Oromia region

Religions	Ratio in Oromia	Ratio in Ethiopia
Muslim	47.6%	33.9%
Orthodox Christians	30.4%	43.5%
Protestants	17.7%	18.6%
Traditional religions	3.3%	2.6%
Others	1%	1.4% (Catholic 0.7% and the others 0.7%)
Total	100 %	100 %

*Source: CSA

In the Oromia Region, the local people mainly speak the Oromiffa language (around 84%) though there are some people who speak the Amhara language (around 11 %) as the common language.

Table 10.5.5: Language spoken in the Project area

Languages	Ratio	Remarks
Oromo(Oromiffa)	83.5%	
Amharic	11.0%	Especially in East Welega & North Shewa
Others	5.5%	Gurage, Hadiya, Gedeo, Tigrigna, Somali Language etc.
Total	100 %	

*Source: CSA

c. Regional economy

Agriculture is the basic industry in the Oromia region. In 2012, 80% of the regional population was engaged in agriculture, and agriculture contribution reaches 42% of total regional GDP.

The main crops of agriculture production in the Oromia Region are cereals. Production of other grains such as pulses and oilseeds is relatively small. The agricultural products in large quantities are sugarcane, coffee, potatoes, and cut flowers.

Table 10.5.6: Planted area of agriculture productions

	Cropland Area (unit: ha)			Ratio in 2013/14
	2011/12	2012/13	2013/14*	
Teff	1,293,514	1,256,565	1,418,205	
Barley	460,545	448,545	502,206	
Wheat	740,811	872,972	927,015	
Maize	1,102,256	1,115,957	1,083,148	
Sorghum	743,379	675,657	783,547	
Finger Millet	87,062	92,307	95,675	
Oats/Aja	27,344	21,889	27,053	
Rice	2,165	2,270	-	
A: Total Cereals	4,457,075	4,486,163	4,840,711	85.74 %
Faba Beans	185,911	237,163	218,830	
Field Peas	85,959	99,941	116,958	
Haricot Beans	153,814	171,667	51,111	
Chick-Peas	87,721	90,757	41,766	
Lentils	36,827	37,050	27,156	
Grass Peas	58,086	67,423	20,688	
Soya Beans	10,679	14,118	12,770	
Fenugreek	17,348	15,739	9,036	
Gibto	-	-	1,104.40	
B: Total Pulses	636,575	734,045	499,420	8.84 %
Neug	193,175	188,558	175,978	
Linseed	69,997	73,863	63,850	
Groundnut	42,348	56,950	34,967	
Sunflower	-	2,070	-	
Sesame	78,749	42,220	27,425	
Rapeseed	13,953	14,901	2,668	
C: Oilseeds	399,075	378,563	305,557	5.42 %
Total Grains	5,492,726	5,598,772	5,645,689	100 %

*Source: CSA
http://www.csa.gov.et/images/general/news/livestock%20report%202005&20ec_2012_13.pdf

In the middle of Awash River Basin, large-scale national farms for sugarcane lie in

Wonji/Wonji Shewa and Metehara.

More than 80% of the male population is engaged in agriculture. The female population is engaged in other industries excluding agriculture.

In addition to agriculture, there are tourism resources such as the Awash National Park, Sodere hot springs and the Rift Valley lakes region.

10.6 Classification of environmental category

10.6.1 JICA category

The Project is regarded as "Category B" according to the JICA Guidelines (April 2012) for environmental and social consideration.

The project area is not situated in any sensitive areas as designated by the JICA guidelines and the Project does not possess any sensitive characteristics in accordance with the JICA guideline (Table 10.6.1).

Table 10.6.1: Applicability of Sensitive Characteristics and Areas on the Environment and Society Designated by JICA Guidelines (April 2010)

Sensitive characteristics and areas on the environment and society	Yes/No
(1) Sensitive Characteristics	
1) Large-scale involuntary resettlement	No
2) Large-scale groundwater pumping	No
3) Large-scale land reclamation, land development, and land clearing	No
4) Large-scale logging	No
(2) Sensitive Areas	
1) National parks, nationally-designated protected areas	No
2) Areas that are thought to require careful consideration by the country or locality	
・ Primary forests or natural forests in tropical areas	No
・ Habitats with important ecological value (coral reefs, mangrove wetlands, tidal flats)	No
・ Habitats of rare species that require protection under domestic legislation, international treaties, etc.	No
・ Areas in danger of large-scale salt accumulation or soil erosion	No
・ Areas with a remarkable tendency towards desertification	No
・ Areas with unique archeological, historical, or cultural value	No
・ Areas inhabited by ethnic minorities, indigenous peoples, or nomadic peoples with traditional ways of life, and other areas with special social value	No

10.6.2 Category by Ethiopian guideline

The Project is regarded as "Category B" according to the Ethiopian EIA Guidelines (2011).

10.7 Environmental system and organizations in Ethiopia

The enabling legislation for the EIA in Ethiopia is the EIA proclamation of 2002 (Environmental Impact Assessment Proclamation, Proclamation No.299/2002). In Ethiopia, some of the authorities involved in environmental management, including the EIA, have been transferred to the regional government from the federal government because of decentralization. Projects across regions are still under the management of MEF (Ministry of Environment and Forest).

For projects in the Oromia Region, the Environment Protection Core Process (EPCP) within the Oromia Land and Environmental Protection Bureau (OLEPB) reviews the EIA and makes a decision on whether the EIA meets the necessary standards.. The OLEPB of the Oromia Regional government is the final decision maker; and the federal MEF will not review the report for this Project.

Furthermore, there are environmental offices at 18 towns, which also implement receiving, reviewing of applications and consulting with the EPCP as needed. The organizational chart is shown in the figure below:

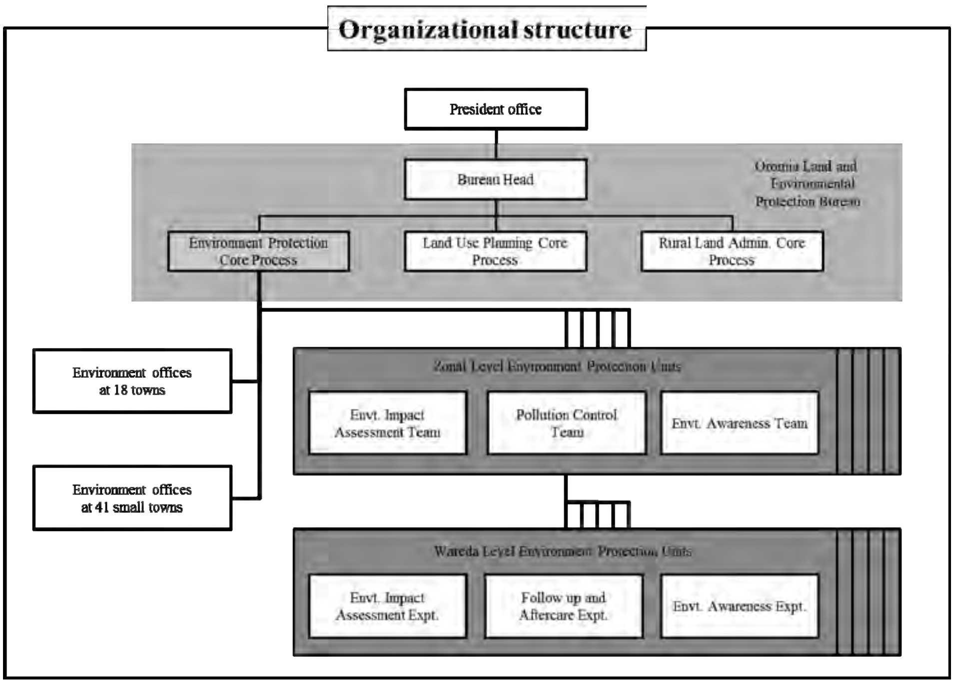


Figure 10.7.1: Organogram of OLEPB and agencies concerned

The OLEPB does not have their own official guidelines for the EIA yet (as of Aug. 2015) so the projects in the Oromia region shall follow the Federal guideline for the EIA. In the Federal guidelines, projects focusing on water supply and hygiene are divided into Schedule 1 and Schedule 2 shown in Table 10.7.1. According to Table 10.7.1, the Project corresponds to Schedule 2 which is required for the preliminary environmental impact study.

Table 10.7.1: List of projects that require a preliminary study

Schedule 1 (Full EIA required)	Schedule 2 (Preliminary EIA required)
♦ Construction of dams, impounding reservoirs with a surface area of 100 hectares ♦ Groundwater development for industrial, agricultural or urban water supply of greater than 4,000 m^3/day ♦ drainage plants in towns close to water bodies	♦ Rural water supply and sanitation ♦ Rain water harvesting ♦ Land drainage (small scale)

*Source: Ethiopia EIA Guideline (2011)

The maximum water supply amount among the plans drawn by the Project is 550 m^3 per day in Arboye town, Jeju Wareda. All the water supply plans do not correspond to the contents of Schedule 1. A full EIA is not required for the water supply plans drawn by the Project.

10.8 Alternatives including zero options

As mentioned above, the water supply plans were drawn with multilateral considerations such as geographical conditions, natural environmental conditions and the current water supply system in each target site. The Project team evaluated that there are no alternatives for planning but recommended monitoring after donation.

As alternatives to the proposed water supply plan, the zero option case (do nothing scenario) is examined in Table 10.8.1.

Table 10.8.1: Impacts comparison between with- and without Project

	S/N	Impacts	Without project		With project	
			Description	Impact	Description	Impact
Social Environment	1	Involuntary Resettlement	(no change)	―	(no change)	―
	2	Local economy such as employment and livelihood	There is a possibility of a negative impact on the local economy due to a water shortage crisis.	(-)	Fostering job opportunities for villagers is expected, however, current water retailers may go out of business due to lack of demand.	(+/-)
	3	Land use and utilization of local resources	(no change)	―	Increase of the land value is expected.	(+)
	4	Local communities and decision-making institutions	There is a possibility of damaging the relationship of mutual trust with the local community, the city government and the OWMEB.	(-)	There is a positive impact on the local communities and decision makers as a result of the buildup of a relationship among them.	(+)

	S/N	Impacts	Without project		With project	
			Description	Impact	Description	Impact
	5	Existing infrastructures and services	(no change)	—	There is a positive impact, especially on the supply of drinking water as a basic public service	**(+)**
	6	The poor/ indigenous/ ethnic minority/ women/ children	Vulnerable groups will be suffering from water shortage in the future.	**(-)**	Living environment of vulnerable groups will be improved as a result of water supply.	**(+)**
	7	Misdistribution of benefits and social cost	(no change)	—	Unnecessary confusion or dispute over managing the water source and distribution can be avoided.	**(+)**
	8	Historical/ cultural heritage	(no change)	—	(no change)	—
	9	Local conflict of interests	Conflict over limited water supplies may increase in the local community in the future.	**(-)**	The chance of local conflict may be decreased, but other conflicts caused by water may also increase	**(+/-)**
	10	Water usage, Water rights, Communal rights	No change. Water shortage rather has negative impacts for communal rights.	**(-)**	The water facilities can highly contribute to the communal rights of villages	**(+)**
	11	Sanitation	Human health and hygienic environment will deteriorate due to the continual water shortage.	**(-)**	Sanitation conditions will improve through safe water.	**(+)**
	12	Health Hazards/Risk, Infectious Diseases such as HIV/AIDS	The same with "11" above.	**(-)**	Decrease of infectious diseases and water related diseases is expected.	**(+)**
Natural Environment	13	Important/ valuable geographical and geological features/ resources	(no change)	—	(no change)	—
	14	Soil erosion	(no change)	—	(no change)	—
	15	Amount and quality of groundwater	(no change)	—	Groundwater level may be decreased in the long-term.	**(-)**
	16	Amount of natural reservoir/ flow	(no change)	—	(no change)	—
	17	Coastal zone	(Not applicable)	—	(Not applicable)	—
	18	Flora, Fauna, Biodiversity	(no change)	—	(no change)	—

	S/N	Impacts	Without project		With project	
			Description	Impact	Description	Impact
	19	Meteorology/ climate	(no change)	—	(no change)	—
	20	Aesthetic landscape	(no change)	—	(no change)	—
	21	Global warming	(no change)	—	(no change)	—
	22	Air pollution	(no change)	—	There will be some exhaust emissions from trucks and machineries.	**(-)**
	23	Water pollution	(no change)	—	(no change)	—
	24	Soil contamination	(no change)	—	(no change)	—
	25	Solid waste amount increase	(no change)	—	Solid waste will be generated in the construction phase.	**(-)**
	26	Increase of noise and vibration	(no change)	—	Noise and vibration will occasionally occur in the construction phase.	**(-)**
	27	Ground level subsidence	(no change)	—	(no change)	—
	28	Offensive odor	(no change)	—	(no change)	—
	29	Sedimentation	(no change)	—	(no change)	—
	30	Increase of Accidents	(no change)	—	(no change)	—

*Source: the Project Team. Data source: Field survey by the Project team

Rating

(+) Positive impact might be expected.

(-) Negative impact might be expected.

(+/-) Both positive and negative impacts could occur.

— No change or not applicable to the Project

In a business-as-usual scenario, there may be possibilities of causing negative impacts such as an increase of waterborne diseases and deterioration of hygiene conditions in the target areas resulting from lack of safe water.

In the project implementation, there may be possibilities of causing negative impacts such as creation of unemployment, increase in the amount of groundwater use, generation of noise and vibration during facility construction as well as. On the other hand, the Project implementation also might be expected to improve the drinking water shortage, lead to the creation of employment opportunities resulting from the water committee, increase social capital and improve hygiene conditions in the area. Furthermore, it can be expected to mitigate the negative effects by taking appropriate measures.

However, the Project implementation has some possibilities to adversely affect the natural and social environments in the area but serious negative impacts are not foreseen, and great benefits can be expected. Consequently, it is concluded that the Project implementation case is a more appropriate choice compared to the do nothing scenario.

10.9 Scoping

As described above, there may be possibilities of causing negative impacts socially and environmentally. Expected negative impacts during the construction and operation phase are summarized in the scoping matrix (Table 10.9.1). The "●" marks in the table show the possibilities of causing negative impacts.

Table 10.9.1: Scoping matrix

	No.	Impacts	Phase	
			Construction	Operation
Social Environment	1	Involuntary Resettlement		
	2	Local economy such as employment and livelihood		●
	3	Land use and utilization of local resources		
	4	Local communities and decision-making institutions		
	5	Existing infrastructures and services		
	6	The poor/ indigenous/ ethnic minority/ women/ children		
	7	Misdistribution of benefits and social costs		
	8	Historical/ cultural heritage		
	9	Local conflict of interests		●
	10	Water usage, Water rights, Communal rights		
	11	Sanitation		
	12	Health Hazards/Risk, Infectious Diseases such as HIV/AIDS		
Natural Environment	13	Important/ valuable geographical and geological features/ resources		
	14	Soil erosion		
	15	Amount and quality of groundwater		●
	16	Amount of natural reservoir/ flow		
	17	Coastal zone		
	18	Flora, Fauna, Biodiversity		
	19	Meteorology/ climate		
	20	Aesthetic landscape		
	21	Global warming		
	22	Air pollution	●	
	23	Water pollution		
	24	Soil contamination		
	25	Increase of solid waste amount	●	
	26	Increase of noise and vibration	●	
	27	Ground level subsidence		
	28	Offensive odor		
	29	Sedimentation		
	30	Increase of Accidents		

*Source: the Project Team

10.10 TOR of environmental and social consideration

The survey on environmental and social consideration was conducted based on the scoping matrix shown above. As described before, involuntary resettlement and expropriation of land will not happen in the water supply plans. Furthermore, it is not necessary to carry out additional surveys on the groundwater level because the results of the drilling survey and pumping test are available.

Negative impacts such as air pollution caused by heavy vehicles and noise/vibration caused by construction works are expected to occur in the construction phase. Negative impacts such as creation of unemployment for water retailing and local conflict caused by water are anticipated to occur in the operation phase. The table below shows the summary of survey items for evaluation of the extent of the negative impacts. A quantitative survey was not conducted in the Project due to time constraints. It is recommended to carry out the survey according to Ethiopian environmental standards of the implementation process.

Table 10.10.1: Summary of items of environmental and social consideration

Impact	Phase	Survey area	Contents
Local economy (creation unemployment)	Operation	Bolo, Golegota, Anneno towns and surrounding areas	Interviews with water retailers
Local conflict (caused by water)	Operation	Towns where ethnic conflict is a concern	Interviews with citizens in the town and personnel at the public office
Air pollution from construction vehicle	Construction	Surrounding areas of water supply plan	Sighting survey
Construction waste from construction work	Construction	Surrounding areas of water supply plan	Sighting survey
Noise and vibration by construction vehicle	Construction	Surrounding areas of water supply plan	Sighting survey

*Source: the Project team

10.11 Result of environmental and social impact assessment

10.11.1 Local economy (creation of unemployment)

People in some target towns have to buy drinking water from water retailers because of constraints on the water supply amount and water supply time. They need water supply from water retailers even though the situation can vary by towns and by season. The impact to these retailers through the improvement of the water supply was studied.

The study method was interviews with water retailers on how to buy, how to sell and questions about prices. Based on the interviews, it was found that there were two types of water retailers in the Project area:

1. Individual proprietors

   They have their main business and buy/sell water for people in the area additionally

2. Reseller

   They have their own tap water system in their houses and resell it as required.

People of Group 1 got water when they purchased daily items which they sell in their own shops. The prices were varied due to distances from the towns where they got water. They got one jerry can of water worth about 3 -5 ETB and sold the water for about 10 – 20 ETB.

Source: Taken by the Project Team

Figure 10.11.1: Water retailer in Aneno town

People of Group 2 had their own tap water system in their houses. They supplied water as requested by the neighbors, and the neighbors paid for the water. They resold one jerry can of the water for about 3 -5 ETB.

These two groups are selling water to respond to the requests from people in towns although they receive money from the activities. According to the interviews, there are no water retailers who retail water as a main business nor were there any retailers who were deeply dependent on the business.

In conclusion, the negative impacts for the local economy seem to be slight and very limited.

10.11.2 Environmental and social impact by heavy vehicle

Conditions of arterial roads in the area are shown as below (Figure 10.11.2). Those roads are sufficiently wide and do not have much traffic. Construction vehicles are not expected to interrupt traffic.

A quantitative survey on air pollution caused by heavy vehicles and noise/vibration caused by construction works was not conducted in the Project due to time constraints. It is recommended to carry out the survey according to the Ethiopian environmental standards (Environmental Policy of Ethiopia, 1997) in the implementation process.

A sighting survey found that there were few houses along roads between towns. In addition, roads in towns were sufficiently wide and traffic volume was not so heavy.

In conclusion, the negative impacts from heavy vehicles seem to be avoided by complying with regulations of traffic in Ethiopia such as the speed limit and load capacity.

1-1. Road in town (Bolo town)

1-2. Road in town (Golegota town)

2-1. Road between towns (near Bofa town)

2-2. Road between towns (near Belo town)

Source: Taken by the Project Team

Figure 10.11.2: Road condition

Ethiopian national standards on air pollution and noise/vibration are shown as below.

Table 10.11.1: Standards on air pollution and noise/vibration in Ethiopia

Sr. No	Element	Requirement		
		Parameter	Standard $(\mu g/m^3)$	Averaging Time
1	Ambient Air Quality	SO2	500	10 min
			125	24 hr
			50	1 yr
		NO2	200	24 hr
			40	1 yr
		CO	100,000	15 min
			60,000	30 min
			30,000	1 hr
			10,000	8 hr
		PM10	50	1 yr
			150	24 hr
2	Noise quality	Category of area	Day Time 1	Day Time 2
a	Noise standards where people live or work	Industrial	75	70
		Commercial	65	55
		Residential	55	45
	Note	1. Day time reckoned from 6 to 1m to 9 pm 2. Night time reckoned from 9 pm to 6 am		
b	Vibration and Air Overpressure in Quarrying			
	Peak particle vibration	Level of 12 mm/sec, measured in any three mutually orthogonal directions at a receiving location when blasting occurs at a frequency of once per week or less Level of 8 mm/ sec2 for more frequent blasting 1, 2: For vibrations <40 Hz		
	Air Overpressure	Blasting should not give rise to air overpressure values in excess of 125 dB(Lin) max peak at sensitive locations		

Source: Environmental Policy of Ethiopia, 1997

10.11.3 Local Conflict

Field survey on local conflict was conducted as described below.

a. Purpose

To confirm the presence or absence of ethnic conflict in the target area and the reason

b. Method

Interviews with citizens and personnel of public office in the concerned area

c. Result

The results of the survey are summarized as below.

- Sometimes there are conflicts between Oromo and Somali, Oromo and Afar
- Conflicts were mainly caused by land matter and theft of livestock
- Personal troubles may escalate into ethnic conflict, but not for a long period
- People in the area had a cooperative relationship with regard to water
- During operation, misdistribution of benefits and social costs should be avoided

Interview 1

Organization	Water committee
Name	Mr. Shemshedin
Job title	Chairman
Town/Woreda	West Hararge Woreda, Bordede town
Date	August 24, 2015
Outline of interview	➢ Conflict happens between Oromo and Somali, Oromo and Afar ➢ Conflicts between Oromo and Somali are caused by land issues, conflicts between Oromo and Afar are caused by theft of livestock ➢ Somali people live in the surrounding areas of Bordede town and have access to public tap water in the town under same conditions of Oromo. There is no conflict on the issue ➢ Conflict due to water issues is unlikely to occur

Interview 2

Organization	Bordede town administrative office
Name	Mr. Kedir Kama
Job title	Town mayor
Name	Mr. Zeade Adam
Job title	Head of social sector
Town/Woreda	West Hararge Woreda, Bordede town
Date	August 24, 2015
Outline of interview	➢ There are tribes such as Oromo, Amhara, Somali and Afar in Bordede town ➢ Somali people live in the surrounding area of the town and have their own water well. Oromo people sometimes use the water well. Somali people also use the water well in the town. The relationship between Oromo and Somali is good

	➢ Troubles happen mainly due to theft of livestock, especially in the rainy season. Such personal troubles sometime escalate into conflict between tribes. ➢ Disputes caused by water are rare ➢ There is no religious conflict

Interview 3

Organization	Mieso Wareda Administrative office
Name	Mr. Adujeri Mohammed
Job title	Office Head
Town/Woreda	West Hararge Woreda, Bordede town
Date	August 24, 2015
Outline of interview	➢ There is no ethnic conflict and no religious conflict in Mieso town ➢ There are small conflicts between a few tribes in seven rural towns ➢ Everyone needs water. No one conflicts with others over water. People can cooperate with each other for water even if their relationship is not good ➢ Most of the conflicts are caused by theft of livestock

As mentioned above, construction of new water facilities does not seem to escalate local conflict. In conclusion, there is no need to change the target towns and contents of the plan out of concern of local conflict. However, ethnic conflict does exist, even if on a small scale so misdistribution of benefits and social costs should be avoided.

10.12 Environmental impact assessment (Preliminary EIA)

The likely adverse impacts that may be caused by implementation of the proposed water supply plan are summarized in Table 10.12.1. The evaluation and rating are based on reference data and field data by the Project Team. The final rating was discussed with the person below and approved.

- Name: Fekadu Lebecha
- Organization: Oromia Water, Mine and Energy Bureau
- Job title: Division Head of Water Resource Management

Impact is assessed for two periods: impacts may occur during the construction period and during the operation period. For rating the degree of significance, “a”, “b”, “c” and “d” are used. The definition of each is as follows:

- a: Significant negative impact is expected.
- b: Negative impact is expected to some extent.
- c: Extent of negative impact is unknown. (A further examination is needed, or the impact could be clarified as the study progresses)
- d: No impact or negligibly small impact is expected.

Table 10.12.1: Assessed impacts by the water supply plan

	No.	Impacts	Rating		Brief description
			Construction Phase	Operation Phase	
Social Environment	1	Involuntary Resettlement	**d**	**d**	Resettlement of residents will never occur.
	2	Local economy such as employment and livelihood	**d**	**d**	There would be some job opportunity provided to locals by water users' groups. No adverse serious impacts are expected on current retailers.
	3	Land use and utilization of local resources	**d**	**d**	No adverse impacts are expected on land use and utilization of local resources, but positive impacts from installation of the water supply facility such as increasing of the land value are expected.
	4	Local communities and decision-making institutions	**d**	**d**	No negative impacts are expected on local society; new water supply facility is going to give positive and profound impacts to the local community since securing water is one of the most significant needs in their community. Unnecessary confusion or disputes over managing the water source and distribution should be avoided.
	5	Existing infrastructures and services	**d**	**d**	The public drinking water supply service is improved. Severe impacts on existing infrastructures are not expected based on traffic density in the area.
	6	The poor/ indigenous/ ethnic minority/ women/ children	**d**	**d**	Highly positive impacts are expected for women, children and the poor by saving their time for fetching water and allowing them to spend that time for other productive work.
	7	Misdistribution of benefits and social costs	**d**	**d**	The same with "4" above.
	8	Historical/ cultural heritage	**d**	**d**	There is no cultural and historical heritage at the proposed project site.
	9	Local conflict of interests	**d**	**c**	There is no conflict caused by water thus far. However, there are several ethnic and tribal conflicts caused by land issues so emotional conflict may occur due to installation of the water supply facility near the border of ethnic tribes. The way in which the facility is run must also take into account the concerns of neighboring tribes.
	10	Water usage, Water rights, Communal rights	**d**	**d**	Since the water supply facility will provide water, there will be a positive impact on water usage for the community. The facility will contribute to the respective town as a whole because the distribution is managed by the village water committee or water users group.
	11	Sanitation	**d**	**d**	Water quality is checked in the test drilling phase. The facility allows for a certain amount of water supply to be used for sanitation purposes. It will give a highly positive impact to the community health.
	12	Health Hazards/Risk, Infectious Diseases such as HIV/AIDS	**d**	**d**	Public health and sanitation conditions will be improved by improving accessibility to clean water. New infections of the HIV/AIDS problem will not occur during water facility installation work.
Natural Environment	13	Important/ valuable geographical and geological features/ resources	**d**	**d**	There is no such place in the target area. No impact is expected.
	14	Soil erosion	**d**	**d**	No soil erosion is expected by installation and use

No.	Impacts	Rating: Construction Phase	Rating: Operation Phase	Brief description
				of water supply facility.
15	Amount and quality of groundwater	**d**	**c**	There would be no negative impact on quality of groundwater by installation and operation of the facility. The quality of ground water will be tested at the first place, and the water is utilized only if the water quality is appropriate. Like-wise, the amount is also measured to judge if there is enough ground water supply at the test. However, the groundwater level may decrease in the long-term. Periodical monitoring is necessary in order to assure the planned amount of water supply.
16	Amount of natural reservoir/ flow	**d**	**d**	Extracting deep groundwater has almost no impact on the flow rate of river at the surface.
17	Coastal zone	**d**	**d**	There is no coastal area in the target Regions.
18	Flora, Fauna, Biodiversity	**d**	**d**	Game Reserve or Forest Reserve is excluded from the project area.
19	Meteorology/ climate	**d**	**d**	There is no plan of large scale construction or facilities that would have a negative impact on the climate.
20	Aesthetic landscape	**d**	**d**	There will be no large scale facility that may affect the surrounding landscape. Surge tank of Level-2 facility may change the surrounding view; however, it will not have much impact.
21	Global warming	**d**	**d**	Diesel motor pumps emit CO_2; however, there will be no large scale generators installed that would have a negative impact on global warming.
22	Air pollution	**c**	**d**	There will be some exhaust emission from trucks and machineries during the construction work, and the diesel generator of the Level-2 facility emits exhaust gas, which contain SO_X and NO_X gases. Therefore, it is recommended that the OWMEB monitors ambient air quality regularly in conformity to Pollution Control -proc # 300/2002.
23	Water pollution	**d**	**d**	Water is supplied after the water quality check so that there will be a positive impact on water quality. Water pollution during the construction phase is easily avoidable with the proper work supervision. There is no waste water discharge from the facilities during operations.
24	Soil contamination	**d**	**d**	Falling down of some oil droplets from heavy machineries is expected during the construction phase, which is a negligible impact; and no soil contamination will occur during the operation phase either.
25	Solid waste amount increase	**d**	**d**	Excavated soil is properly disposed in a routine manner. There is no solid waste produced by the water supply facility during the operation phase.
26	Increase of noise and vibration	**d**	**d**	Since heavy machineries will be operated during the construction phase, noise and vibration will occur; however, the duration is quite limited.
27	Ground level subsidence	**d**	**d**	The capacities of pump motors are extremely small compared to those that cause ground subsidence.
28	Offensive odor	**d**	**d**	There will be no odor sources at the water supply facility.
29	Sedimentation	**d**	**d**	No sedimentation on river beds or reservoir beds will occur from installation of the water supply facility.
30	Increase of Accidents	**d**	**d**	There are no circumstances to cause accidents by installation of the facilities

The three impacts marked as C in the table above are considered for mitigation measures.

10.13 Mitigation

There are only minor impacts marked as C in Table 10.12.1. It is possible to mitigate and minimize their effects by taking proper measures. Table 10.13.1 shows the mitigation measures and monitoring for key adverse impacts.

Mitigation measures in the construction phase shall be conducted by the OWMEB as the project owner and by the construction companies.

Table 10.13.1: Mitigation measures for negative impacts

Impact	Effect	Mitigation
Air pollution	• Dust occurs from heavy vehicles • Exhaust gasses from heavy vehicles for construction works	• Complying with regulations of traffic in Ethiopia such as the applicable legal speed limit and load capacity • Setting of complaints counter at the OWMEB
Local conflict	• Conflict between tribes	• Pay attention to avoid misdistribution of benefits and social costs • Meeting among tribes as necessary
Amount and quality of groundwater	• Deterioration of groundwater level due to use over a long period	• Setting of proper pump discharge • Monitoring the water level

10.14 Environmental monitoring plan

Environmental monitoring is recommended for air pollution, noise/vibration and groundwater level. The negative impacts that may occur by the Project implementation are foreseen in both the construction and operation phase. Proper mitigation measures and monitoring plans are necessary as shown in Table 10.14.1.

Table 10.14.1: Environmental monitoring plan

Air Quality (Ambient Air Quality)

Item	Averaging Time	Unit	Measured Value (Mean)	Measured Value (Max.)	National Standards (Max.)[*1]	Remarks: Location	Remarks: Frequency	Remarks: Implementation	Remarks: Supervision
SO_2	10 min.	μg/m³			500		Construction stage 4 times/year Operation stage 2 times/year	Constructor through approved monitoring agency	SRWDB
	24 hours 24 hours				125				
	1 year				50				
NO_2	24 hours 24 hours	μg/m³			200				
	1 year				40				
CO	15 min. 24 hours	μg/m³			100,000				
	30 min.				60,000				
	1 hours 24 hours				30,000				
	8 hours				10,000				
PM10	24 hours	μg/m³			150				
	1 year				50				

Noise

Item	One hour L_Aeq	Unit	Measured Value (Mean)	Measured Value (Max.)	National Standards (Max.)[*1]	Remarks: Location	Remarks: Frequency	Remarks: Implementation	Remarks: Supervision
Noise	Daytime (6:00 – 21:00)	dB(A)			55		Construction stage: 4 times/year Operation stage: 2 times/year	Constructer through approved monitoring agency	SRWDB
	Night time (21:00 – 6:00)				45				

Vibration

Item	National Standards		Measured Value (Mean)	Measured Value (Max.)	Implementation	Supervision
Vibration	Peak particle vibration	Level of 12 mm/sec, measured in any three mutually orthogonal directions at a receiving location when blasting occurs at a frequency of once per week or less than a level of 8 mm/sec for more frequent blasting 1, 2: For vibrations < 40 Hz			Constructor through approved monitoring agency	SRWDB
	Air overpressure	Blasting should not give rise to air overpressure values in excess of 125 dB (Lin) max peak at sensitive locations				

Groundwater Level

Item	Unit	Stage	Measured Value (Mean)	Measured Value (Max.)	Remarks			
					Location	Frequency	Implementation	Supervision
Groundwater level	m	Construction stage				two times during dry and wet seasons	Constructor through approved monitoring agency	SRWDB
		Operation stage				two times with an interval of six months for three years	SRWDB through approved monitoring agency	

10.15 Discussions with stakeholder

There is no water committee in the following five towns in the target area: Hargeti Town, Kenteri Town, Kamise Town, Aneno Town and Wonji Shewa Alemtena Town. These towns have no water committee because there are no public water services or very limited water services. Water committees should be formed as needed in the future for appropriately operating water supply facilities based on their ownership.

In the plans drawn by the Project, no serious impacts like involuntary resettlement and/or land expropriation are foreseen, therefore necessity of a stakeholder meeting is likely not high.

10.16 Conclusion

The environmental and social assessment found that the construction and operation phases are categorized as having an unknown or negligibly small negative impact. Appropriate mitigation measures and monitoring will be conducted as necessary.

The water supply plans proposed by the Project do not foresee any serious impacts such as compensation for involuntary resettlement, the occurrence of a secondary pollution source (generation of new environmental pollution sources derived from hazardous substances and heavy metals), damage or loss of ruins and cultural assets, and/or adverse impact on natural protected areas.

In conclusion, implementation under the proposed water supply plan is unlikely to significantly degrade the social environment or the natural environment in the Project area.

Chapter 11

Hydrology and Hydrogeology Analysis around Lake Beseka

11 Hydrology and Hydrogeology Analysis around Lake Beseka

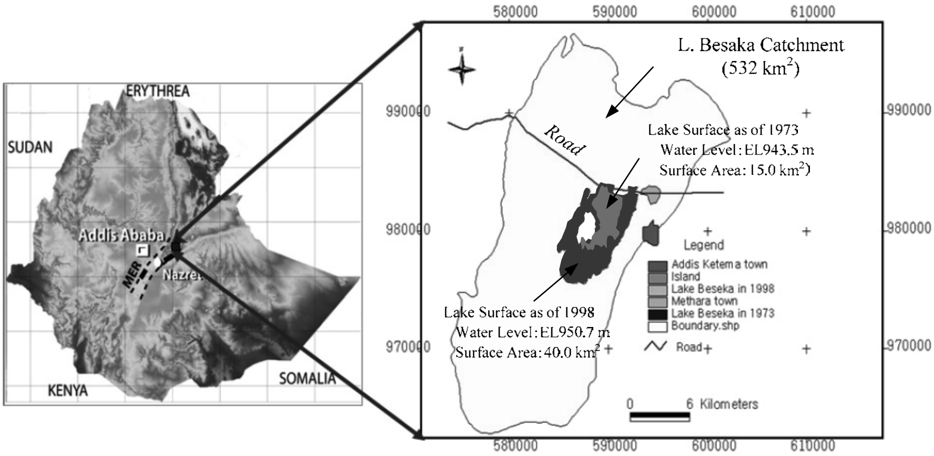
11.1 Introduction

Results of the survey and analysis on topography, geology, geological structures and hydrogeology around Lake Beseka are reported in this chapter. In addition to this, i) analysis on surface temperature of the Lake Beseka, ii) water quality analysis for water samples in and around the Lake Beseka, and iii) water balance analysis with estimated irrigation return flow are undertaken in order to validate the rationality of the widely recognized cause of lake expansion, i.e. excess irrigation water inflow. The results of these analyses are also explained in this chapter.

11.2 The Lake Beseka Issues

11.2.1 Current situation of Lake Beseka

Lake Beseka is located in Fentale District of Oromia Region at about 130 km east from Addis Ababa. The lake has a watershed area of 532 km^2 and is topographically isolated from the Middle Awash River Basin.



Source: Reference ⑩

Figure 11.2.1: Location Map of Lake Beseka

The water surface level of the lake started rising from the 1960s and adverse effects thereby have been reported since 1970s. The national highway, railway, irrigated farms and residential areas around the lake have submerged due to the lake level rise. The lake water level has increased about 12 m and the lake surface area has expanded from 3.6 km^2 to 55 km^2 since late 1960s.

Measures have been implemented to mitigate the effect of the lake level rise, including the heightening and/or shifting existing roads and railways. Measures for lowering the lake levels have also been implemented. In 2004, discharging the lake water to the Awash River was commenced with 8 pump units with total capacity of 1.73 m^3 per second. However, all pumps were submerged by the lake and became dysfunctional in 2009. Also a gravity canal system was installed to discharge the lake water level to the Awash River in 2011. In 2012, the operation of the system ceased by closing outflow regulation gate responding to complaints raised by downstream water users. The lake water now overflows the embankment of the canal system and control gates and is spilling into the Awash River without control.

Submerged Railway

Outlet Channel from the Lake

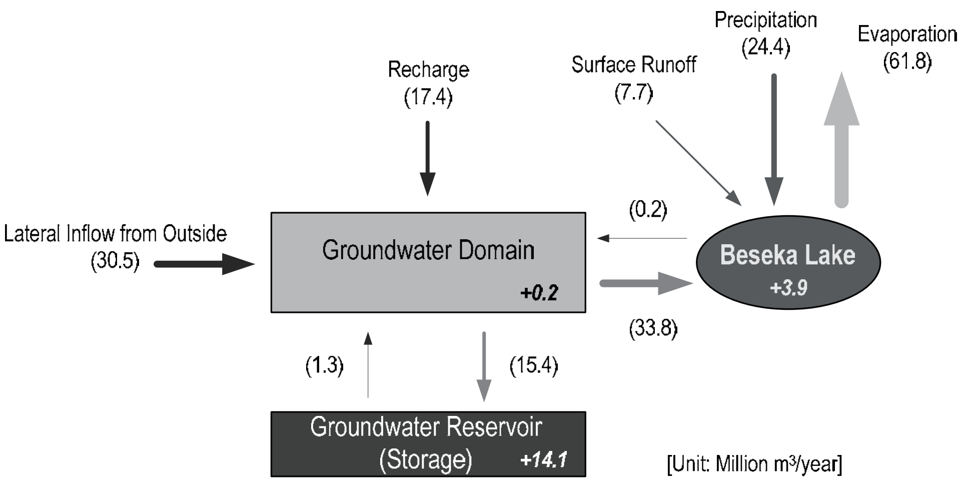
Source: the Project Team

Figure 11.2.2: Current Situation of Lake Beseka

Several studies have been undertaken to reveal the causes and mechanisms of the lake level rise. Reports of the following studies are available and collected:

- Study of Lake Beseka, May 1999 (by Ministry of Water Resources)
- Growing Lake with Growing Problems: Integrated Hydrogeological Investigation on Lake Beseka, Ethiopia, 2009 (by Eleni Ayalew Belay)
- Study and Design of Lake Beseka Level Rise Project II, August 2011 (by Water Works Design and Supervision Enterprise, WWDSE)
- Assessment and Evaluation of Causes for Beseka Lake Level Rise and Proposed Immediate Mitigation Measures, July 2013 (by Oromia Water Works Design & Supervision Enterprise, OWWDSE)

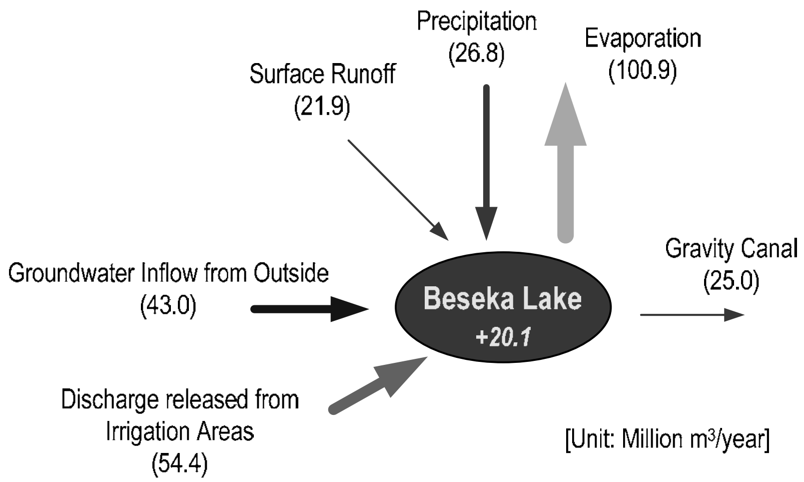
The water balance of Lake Beseka and its watershed has been analyzed by the above studies. The following figure shows the annual water balance analyzed by Ayalew (2009). The figure suggests the inflow from outside watershed of 30.5 million m^3 annually.



Source: the Project Team, Data: Reference ⑩

Figure 11.2.3: Long-term Annual Water Balance of Beseka Lake and its Watershed (Ayalew, 2009)

The water balance analysis results for the years of 2010 and 2011 undertaken by WWDSE are schematically shown in Figure 11.2.4 below. The numerical values shown in the figure are simple averages of the results for the years of 2010 and 2011. Large amount (43.0 million m^3) of inflow from outside Lake Beseka catchment is suggested in this result too.



Source: the Project Team, Data: Reference ⑥

Figure 11.2.4: Water Balance of Beseka Lake (WWDSE, 2011)

According to the previous studies, conceivable causes of lake level rise are as follows:

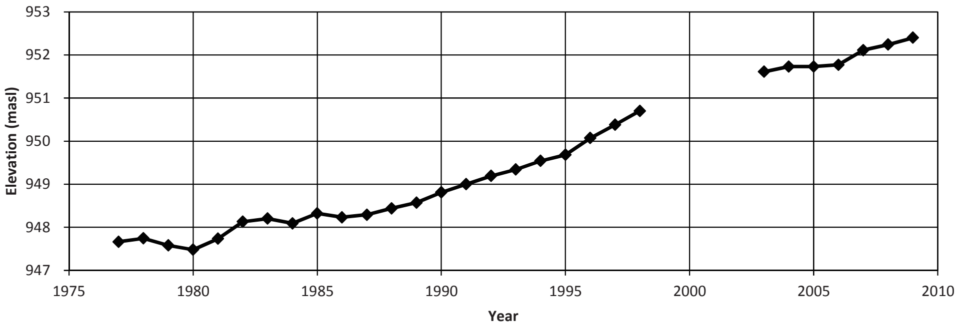
- Irrigation return water flow from older farms;
- Leakage from unlined irrigation canals;
- Inter-basin groundwater transfer triggered by new tectonic activities;
- Disturbance of water table around the irrigation farms and water pressure build-up in the upstream;
- Increase in rainfall.

In terms of mitigation measures, the following are proposed:

- Reduction of inflow to the lake by i) lining of irrigation canals; ii) improvement of water use efficiency in irrigation farms; and iii) control of waste water release from sugarcane farms;
- Increase of outflow from the lake by increasing the outlet size; and
- Reclamation of degraded areas.

11.2.2 Water level of Lake Beseka and change in outflow

Water level of Lake Beseka has been recorded since July 1976 since problems on lake expansion was recognized. Time series of water level in December of each year is plotted based on the MoWIE's data as in Figure 11.2.5.

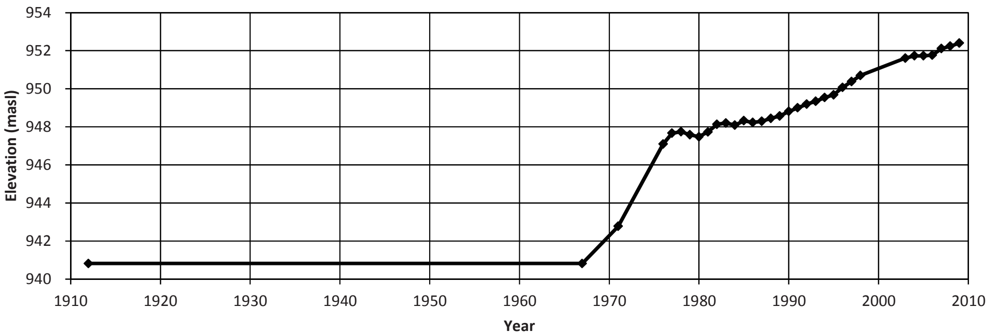


Source: the Project Team, Data: Reference ⑥

Figure 11.2.5: Time Series of Water Level of Lake Beseka (1977–2009)

Previous studies indicate that the lake water level was stable although some seasonal fluctuations were observed. The lake was reported to be about 3 km^2 during dry season and about 5 km^2 during rainy seasons during the period from 1912[1] to 1967 at its smallest extent. This is almost equivalent to the surface water level of 941 m above mean sea level. In addition, water level data of the lake in January 1972 are available in the report prepared by Ministry of Water, Irrigation and Energy (hereafter referred to as “MoWIE”) in 1999.

Figure 11.2.6 provides the historical trend of surface water level in Lake Beseka by incorporating the information above.

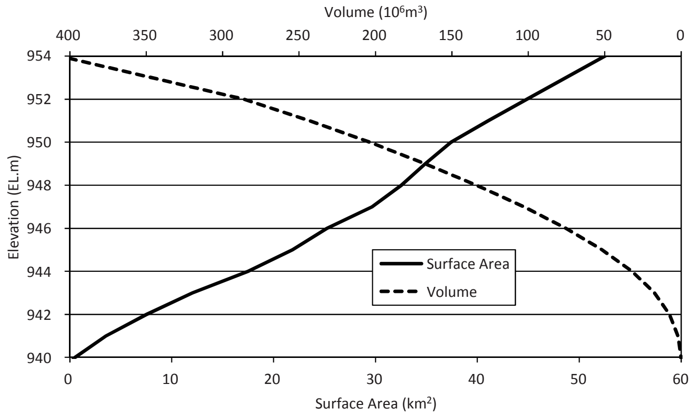


Source: the Project Team, Data: Reference ⑤ and ⑥

Figure 11.2.6: Time Series of Water Level of Lake Beseka (1912–2009)

The graph shows sharp increment in the water level for a decade from the late 1960s to late 1970s. The water level increment became smaller after the late 1970s, although continuous increase in the water level is observed. MoWIE developed the relationship of lake water level (H) with water surface area (A) and lake water volume (V), i.e., H–A and H–V curves, based on the 1:5,000 topographic map. The curves are provided in Figure 11.2.7.

[1] Water level in 1912 is based on the topographic map prepared by French Engineers for construction of Addis Ababa–Djibouti railway.

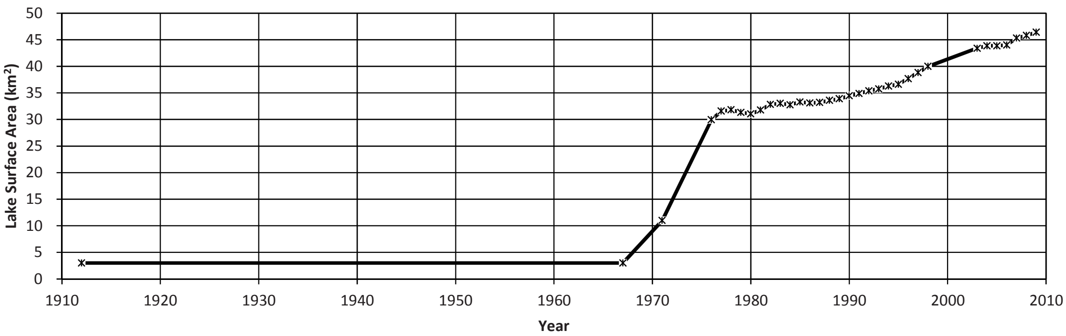


Elevation [EL.m]	Water Surface Area [km^2]	Volume [10^6m^3]	Mean Water Depth [m]
939.74	0.000	0.000	-
940.00	0.520	0.068	0.13
941.00	3.535	2.095	0.59
942.00	7.527	7.626	1.01
943.00	12.032	17.406	1.45
944.00	17.486	32.165	1.84
945.00	21.845	51.830	2.37
946.00	25.228	75.367	2.99
947.00	29.674	102.818	3.46
948.00	32.541	133.925	4.12
949.00	34.888	167.640	4.81
950.00	37.426	203.797	5.45
951.00	41.059	243.039	5.92
952.00	44.870	286.004	6.37
960.00	75.358	766.916	10.18

Source: the Project Team, Data: Reference ⑤

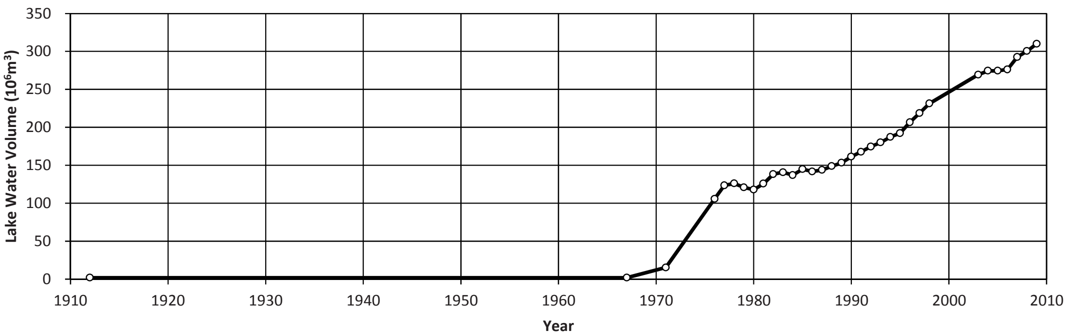
Figure 11.2.7: Area-Elevation and Volume-Elevation Curves of Lake Beseka based on 1:5,000 Topographic Map

Figure 11.2.8 and Figure 11.2.9 shows the historical trend of lake surface area and lake water volume, respectively, calculated using the water level information and the H–V curve shown in Figure 11.2.7.



Source: the Project Team, Data: Reference ⑤ and ⑥

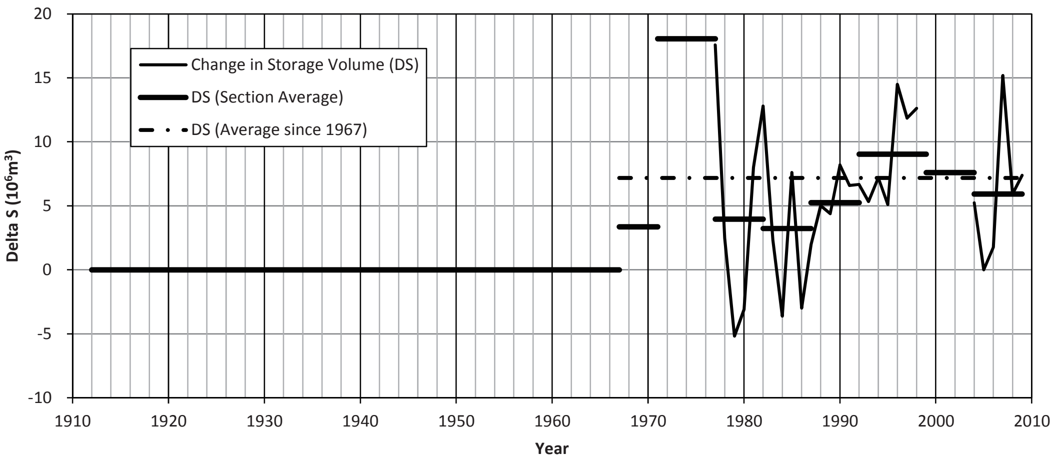
Figure 11.2.8: Time Series of Water Surface Area of Lake Beseka (1912–2009)



Source: the Project Team, Data: Reference ⑤ and ⑥

Figure 11.2.9: Time Series of Stored Water Volume in Lake Beseka (1912–2009)

Figure 11.2.10 shows annual change in the lake water volume (solid line) together with average volume change for consecutive several years (about 5 years; thick solid line) and for 1967–2009 (dashed line).

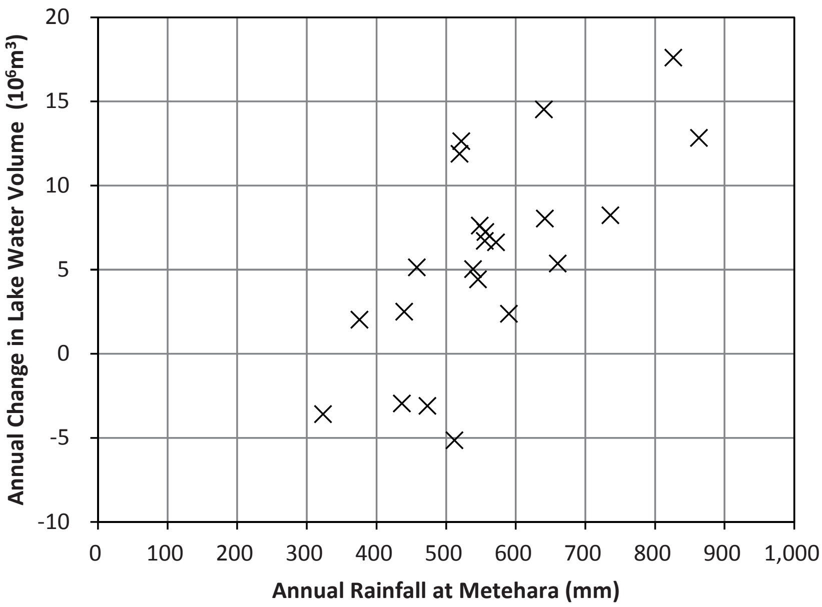


Source: the Project Team, Data: Reference ⑤ and ⑥

Figure 11.2.10: Changes in Water Volume in Lake Beseka

The graph shows the annual mean increment in the lake water volume of 7.17 million m^3 since 1967. The most abrupt change in the volume was from 1971 to 1977 with an average increment of more than 18 million m^3, followed by that from 1992 to 1999 with an average increment of 9 million m^3. Average increment during the period from 1967 to 1977 was 11.07 million m^3 per annum, and that was 5.83 million m^3 per annum subsequently up to 2009.

The relationship between annual rainfall at Metehara observatory, which is the representative station in the Lake Beseka watershed, and annual change in lake water volume is shown in Figure 11.2.11. The data for 1977–1998 are plotted in the graph because neither drainage channel nor pump from the lake was installed in those years.

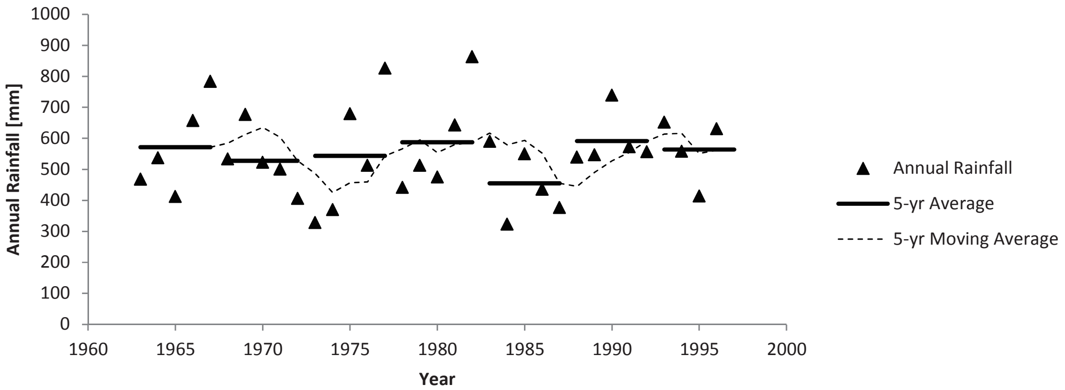


Source: the Project Team, Data: Reference ⑥

Figure 11.2.11: Annual Rainfall at Metehara versus Lake Volume Change (1977–1998)

A reasonably positive correlation is found between rainfall at Metehara and change in lake volume. There are, however, wide range of values in volume change for a value of annual rainfall. This may be caused by the combinations of i) difference between point rainfall at Metehara and areal rainfall over the lake basin, ii) accuracy of rainfall data and topographic data (H–V curve), and iii) the influence of factors other than rainfall on lake water volume.

Rainfall is indeed one of the factors that control the lake water volumes. However, as explained in Chapter 2, no drastic changes in annual rainfall are found in accordance with long-term point rainfall record in the Middle Awash River Basin. Figure 11.2.12 shows the annual rainfall data at the sugar estate in Metehara area from 1963 to 1996. Although rainfall data before the 1960s are not available, no remarkable increment in annual rainfall is observed.



Source: the Project Team, Data: Reference ⑤

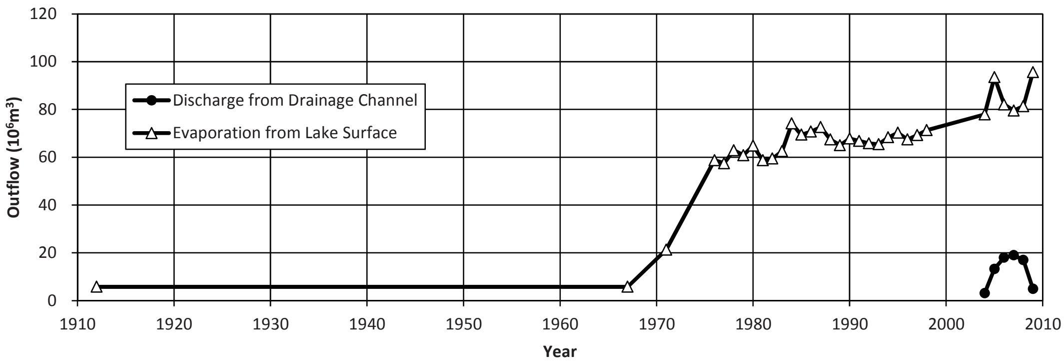
Figure 11.2.12: Long-term Annual Rainfall at the Sugar Estate in Metehara Area

Before the installation of drainage facilities in 2004, watershed of Lake Beseka was closed and not connected to the Awash River. Therefore, loss of lake water was formed by lake evaporation provided that percolation and infiltration to the groundwater domain were negligible. Evaporation from the lake has been simply estimated by the following formula:

$$VE_{lake} = A_{lake} \times C_{pan} \times E_{pan} / 1000$$

where VE_{lake}: Evaporation from the lake [million m^3]
A_{lake}: Water surface area of the lake [km^2]
C_{pan}: Pan coefficient (0.80 is applied here referring to MoWIE (1999))
E_{pan}: Pan evaporation at Metehara [mm]

Figure 11.2.13 shows the estimated evaporation from the surface of Lake Beseka together with the discharge from drainage facilities since 2004 onward.



Source: the Project Team, Data: Reference ⑥

Figure 11.2.13: Estimated Outflow from Lake Beseka

Surface evaporation increases as water surface area of the lake expands according to the above-mentioned formula. Considering the annual mean evaporation at Metehara of approx. 3,000 mm as explained in Chapter 1, increment in annual surface evaporation reaches 2.4 million m^3 if the lake surface area expands by 1 km^2 (in case with pan coefficient of 0.80).

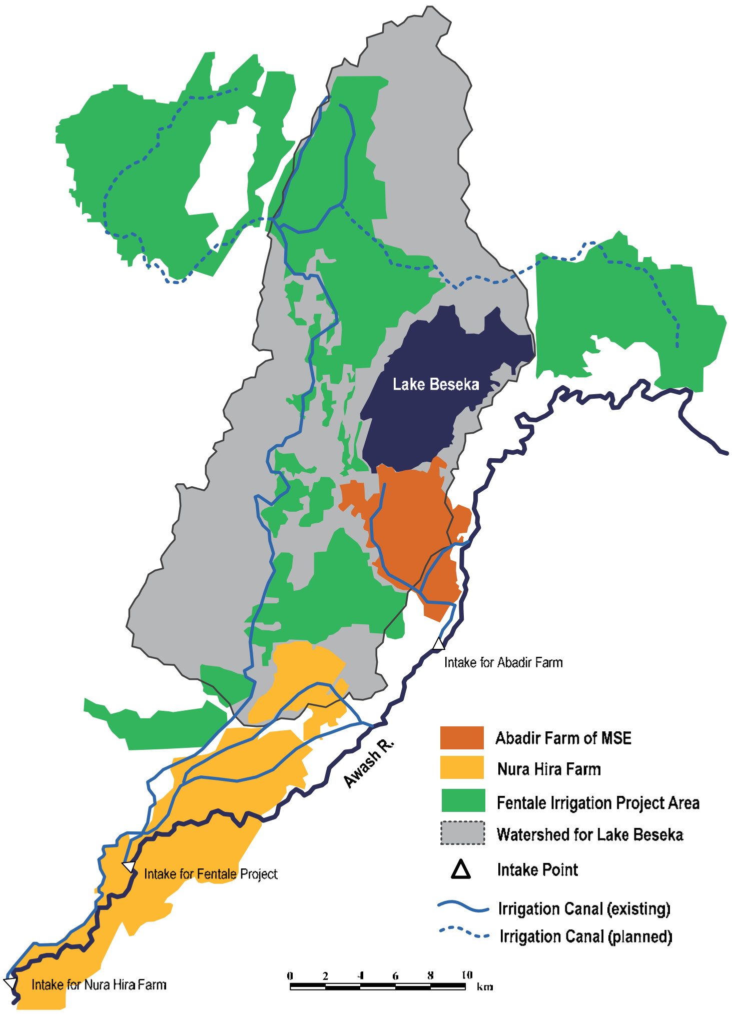
11.2.3 Irrigation plan and current situation around Lake Beseka

As mentioned in the above subsection, expansion of Lake Beseka is reported to have started from the late 1960s. This is corresponsive in timing with intensive development of irrigation projects in the lake watershed diverting the Awash River water. Almost all of existing studies and researches conclude that excess water from large-scale irrigation projects have caused this lake expansion to some extent[2].

Indigenous people in the Lake Beseka area are nomadic and depend mainly on cattle and camel rearing. Cultivation is not a common practice in the area, although scattered and insignificant patches of land area are used by semi-nomads for rainfed cultivation of sorghum and maize. In the lake watershed, cultivation is mainly confined to the state owned farms in Metehara Sugar Estate (hereafter referred to as “MSE”) in south of the lake, Nura Hira citrus farm in the south end of the watershed, and Fentale irrigation project, as shown in Figure 11.2.14. They are the large-scale irrigation schemes in and around the Lake Beseka watershed.

Outlines of these irrigation schemes are mentioned below:

[2] Based on the hydrochemical and isotopic analyses undertaken, Ayalew (2009) concluded that the effect of irrigation water release on the lake expansion is negligible. All other available studies regard excess irrigation water as the dominant cause.



Source: the Project Team, Data: Reference ⑥ and existing 1:50,000 topographic maps

Figure 11.2.14: Irrigation Projects in and around the Lake Beseka Watershed

a. Abadir farm

MSE is a large state-owned agro-industrial company established in the late 1960s. Irrigation farming has been practiced in this area since 1968 with cultivation of cotton and citrus fruits. Crops then changed to sugarcane in 1978.

Currently, the total area of MSE is 10,218 ha. The irrigation area for sugarcane plantation is divided into three parts; i) Abadir block (left side of the Awash), ii) main Estate (largest block in the right side of the Awash), and iii) North block (left side of the Awash). The Abadir irrigation farm is located on the west of the Awash with irrigation area of 3,158 ha. Water is supplied to this block from the Awash through an intake structure. The Abadir farm lies directly south of Lake Beseka. Out of the total irrigation area of Abadir farm, land 2,315 ha is located in the Lake Beseka watershed and drains into the lake.

The irrigation system of the Abadir farm comprises the intake, main canal (unlined), supply canal, branch canal, night storage reservoirs, laterals, sub-laterals, feeder ditches, and furrows. The length of main canal is 8 km.

The volume of irrigation water intake by Abadir Farm measured by MSE is shown in Table 11.2.1 below. Annual mean water intake from 1977 to 2009 was about 102 million m^3 (3.24

m^3/sec).

Table 11.2.1: Water Intake Volume by Abadir Farm

Year	Water Intake (10^6 m^3)	Year	Water Intake (10^6 m^3)	Year	Water Intake (10^6 m^3)
1977	111.9	1988	91.4	1999	No data
1978	87.0	1989	91.4	2000	104.5
1979	100.4	1990	91.4	2001	104.4
1980	90.3	1991	109.0	2002	103.8
1981	125.9	1992	109.0	2003	81.7
1982	119.6	1993	109.0	2004	84.2
1983	130.3	1994	92.7	2005	100.9
1984	129.0	1995	97.1	2006	111.9
1985	83.7	1996	107.0	2007	104.7
1986	93.9	1997	102.7	2008	115.5
1987	87.9	1998	92.7	2009	103.2

Source: the Project Team, Data: Reference ⑥

b. Nura Hira farm

Total irrigation area of Nura Hira is 6,335 ha. Out of this, 1,529 ha lies in southwest of Lake Beseka and drains into the lake. The irrigation system of the farm comprises the intake, main canal (unlined), supply canal, branch canal, night storage reservoirs, laterals, sub-laterals, feeder ditches, and furrows. The length of main canal is 34.5 km. The farm cultivates different types of crops such as orange, mandarin, maize, tomato, onion, and cotton by diverting the Awash River water.

The volume of irrigation water intake by Nura Hira Farm measured by the farm is shown in Table 11.2.2. Annual mean water intake from 1977 to 2009 was about 105 million m^3 (3.34 m^3/sec).

Table 11.2.2: Water Intake Volume by Nura Hira Farm

Year	Water Intake (10^6 m^3)	Year	Water Intake (10^6 m^3)	Year	Water Intake (10^6 m^3)
1977	107.1	1988	117.7	1999	No data
1978	95.8	1989	111.3	2000	No data
1979	139.9	1990	86.5	2001	91.4
1980	116.7	1991	86.8	2002	98.4
1981	139.4	1992	88.9	2003	90.2
1982	86.2	1993	95.7	2004	98.2
1983	101.7	1994	91.2	2005	100.6
1984	109.4	1995	94.8	2006	99.8
1985	141.0	1996	70.7	2007	97.9
1986	166.1	1997	85.2	2008	108.9
1987	160.8	1998	89.4	2009	102.6

Source: the Project Team, Data: Reference ⑥

c. Fentale irrigation project

Fentale irrigation is a large community based project. Various crops such as maize, groundnut, sugarcane, onion, and animal forage are cultivated. The main canal run along the periphery of Nura Hira farm and extends to the foot of Mt. Fentale. The length of the main canal is 46 km. The main canal is lined with masonry and geomembrane to minimize seepage. The secondary and tertiary canals receive water from the main canal through underground pipes.

The gross irrigation area of the project is approx. 18,000 ha and net irrigation area is about 16,000 ha. So far, the net area of 6,000 ha is irrigated and all of the current irrigation areas locate in the Lake Beseka watershed.

Summary of the major irrigation schemes in the Lake Beseka watershed is given in Table 11.2.3.

Table 11.2.3: Major Irrigation Schemes in the Lake Beseka Watershed

Scheme	Commencement of Irrigation	Total Area (Gross)	Area drains to Lake Beseka	Crops
Abadir Farm	1968	3,158 ha	2,315 ha	Sugarcane
Nura Hira	Late 1960s	6,335 ha	1,529 ha	Orange, Mandarin, Maize, Tomato, Onion, Cotton, etc.
Fentale	2007 (not completed)	18,000 ha	6,000 ha	Maize, Groundnut, Sugarcane, Onion, Forage, etc.

Source: the Project Team, Data: Reference ⑤ and ⑥

11.3 Topography, geology and geological structure

11.3.1 Topography

An elevation map around Lake Beseka created with the DEM data of the ALOS satellite image purchased by the project (Resolution 5 m, vertical accuracy 5 m) is shown in Figure 11.3.1. In addition, a topographic classification map around Lake Beseka created through the field work and analysis of the obtained data (ASTER DEM shaded relief map, SPOT satellite image and existing geological map) is shown in Figure 11.3.2.

The topography around Lake Beseka is divided into seven classes, such as alluvial lower plain, Basalt lower plain, middle plain, upper plain, acidic rock dome, gorge and lake taking volcanic ejecta, deposits and geological structure into consideration. Each characteristic is explained in Table 11.3.1.

Table 11.3.1: Classification and Characteristics of Topography around Lake Beseka

Classification	Characteristics
Alluvial lower plain	This is mainly composed of the flood plain of Awash River and the flat plain formed by young ignimbrite of Mt. Fentale. It is the lowest topographic plain in the area located at the center of the rift.
Pleistocene basalt lower plain	This is mainly formed by the numerous lava flows of Pleistocene basalts and has an undulating land surface. Although this plain is one step higher than the alluvial lower plain, it is also distributed in the central part of the rift.
Middle plain	This plain is one step higher than the alluvial lower plain and the Pleistocene basalt lower plain, and bounded from them by the NE-SW or NNE-SSW faults. It is composed of volcanic ejecta of the Oligocene to the early Pleistocene (Dino ignimbrite and Bofa basalts) and the plain surface which is relatively flat slightly inclines towards the center of the rift.
Upper plain	This plain is mainly composed of older basalts (Miocene) and the major fault escarpments of the MER are developed in this area.
Acidic rock	This is dome topography composed of Tertiary to Quaternary rhyolites and

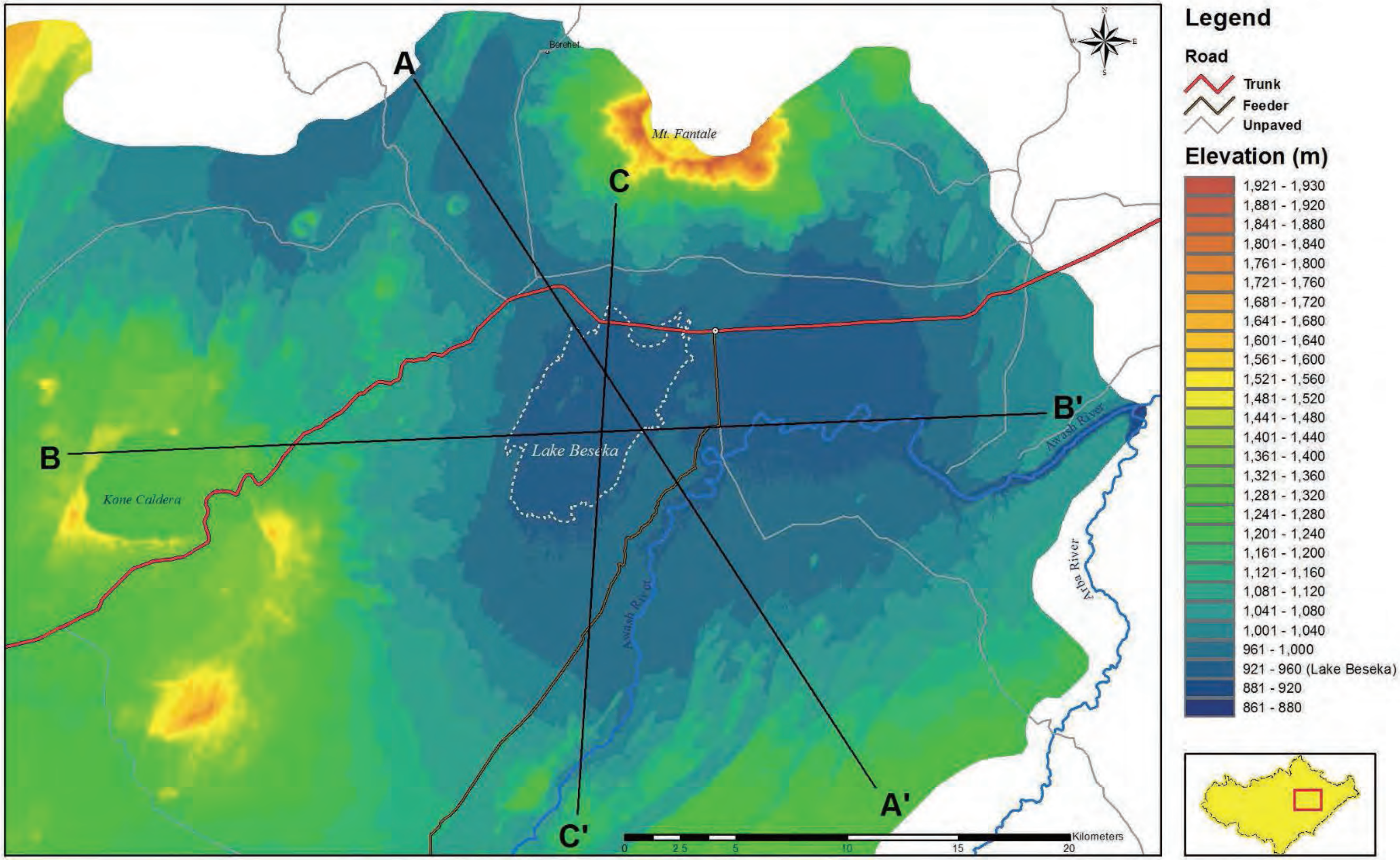
Classification	Characteristics
dome	trachytes which form the major part of Mt. Fentale, Kone caldera, Mt. Birenti, Mt. Hada etc. or lava plateau of these rocks.
Gorge	This is topography formed in the middle plain through the dissection by the Awash River and the Arba River. The gorge developed along the Arba River is parallel to the NE-SW faults but that along the Awash River has been developed free from any fault trends.
Lake	Lake Beseka

Source: the Project Team

The elevation becomes lower from the rift margin hills or plateaus composed of Tertiary basalts and pyroclastic rocks through the major MER fault escarpments and numerous normal faults which form repeated small horsts and half grabens until it comes to the center of MER. Lake Beseka is a structural lake which has been formed at the very center of the MER. One of the possible causes of the formation of the lake could be that the groundwater which used to be gathering and flowing at the center of the MER was banked up by the emersion of Mt. Fentale, which resulted in the rise of groundwater level and ultimately the lake was formed at the present location.

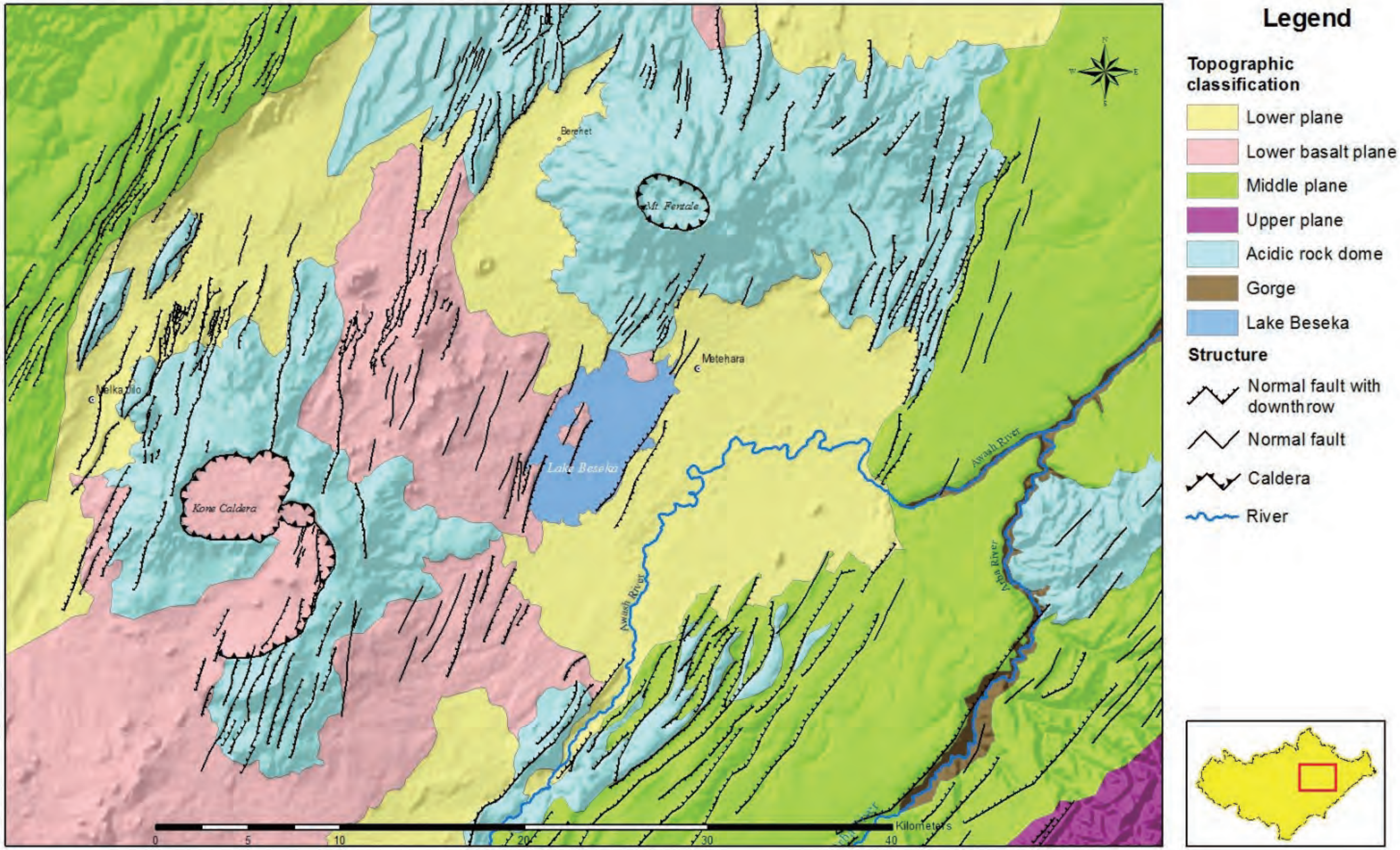
The surface water that is the Awash River is also considered to have previously flowed along the central part of the MER, which is lowest in elevation. However, after the emergence of the Fentale volcano the route of the Awash River changed to the east to bypass Mt. Fentale. This hypothesis is supported by the existence of a deep gorge (elevation gap reaches up to about 170 m at maximum) dissected in the middle plain which is one step higher than the lower plain by the Awash River. This gorge has been developed free from any fault trends unlike that of Arba River which is almost parallel to a fault trend.

This detour of the Awash River around Mt. Fentale starts from the east edge of Metehara sugar plantation at the east of Lake Beseka extends about 50 km until the river goes back to the lower plain of MER in the north of Mt. Fentale.



Source; Project Team Data: ALOS, Resolution 5 m, vertical accuracy 5 m

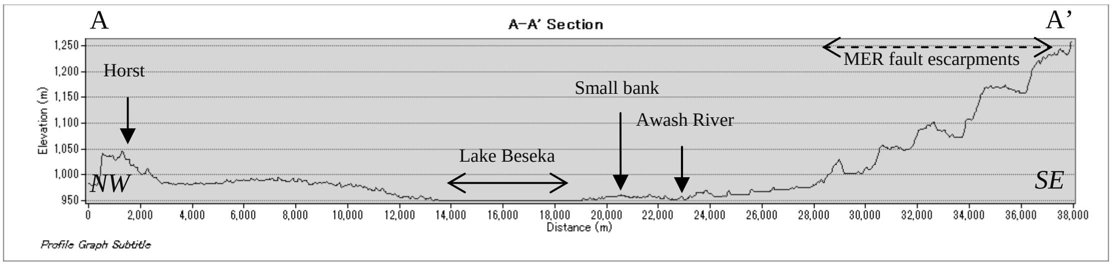
Figure 11.3.1: Elevation Map around Lake Beseka



Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.2: Topographic Classification Map around Lake Beseka (background: shaded relief map created from ASTER DEM data)

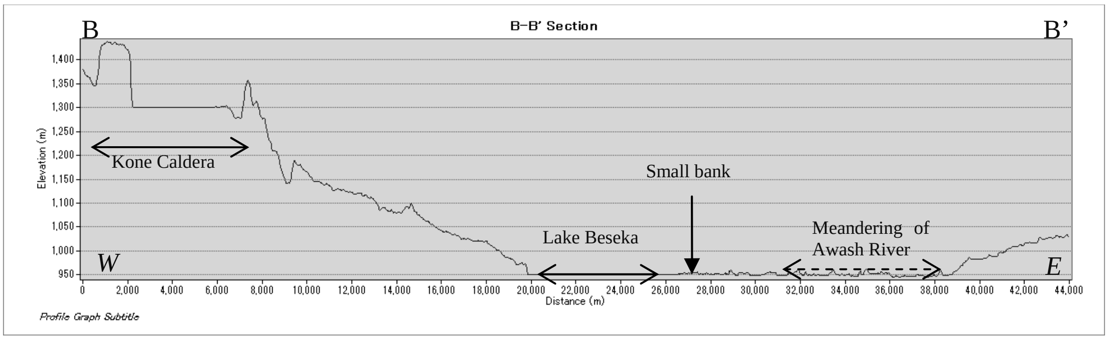
NW-SE section (A-A’) in the elevation map (Figure 11.3.1) shows that the elevation of the surface of Lake Beseka is the lowest and there is a small bank, 10 to 15 m high between the lake and the Awash River existing at the east side of the lake (Figure 11.3.2). In the southeastern part of the section, it is observed that horsts and grabens are repeated and the height is gradually increasing towards the southeast. In the northwest part of the section, there is a gentle depression between the Fentale mountain and the Kone Caldera but it is separated from the depression area distributed at the north of the Kone Caldera by a horst extending NNE direction.



Source: the Project Team, Data: ALOS, Resolution 5 m, vertical accuracy 5 m

Figure 11.3.3: NW-SE Topographic Section around Lake Beseka (A-A’)

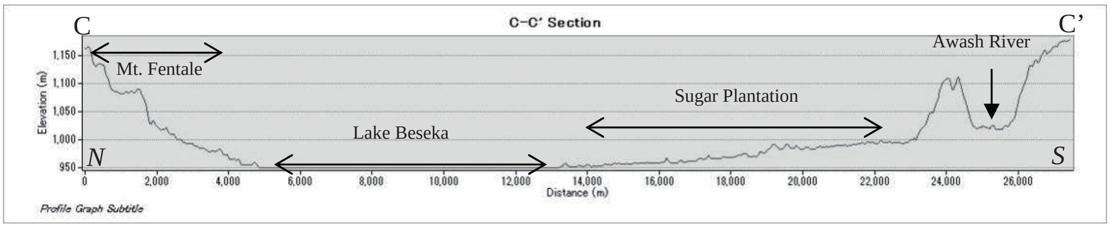
E-W section (B-B’) shows the bank at the east of Lake Beseka is very small and the elevation of Lake Beseka and the Awash River is almost the same or the latter is a little lower (Figure 11.3.4). Towards the west of Lake Beseka, basaltic lavas continue to increase in elevation gradually until the Kone Caldera.



Source: the Project Team, Data: ALOS, Resolution 5 m, vertical accuracy 5 m

Figure 11.3.4: E-W Topographic Section around Lake Beseka (B-B’)

N-S section (C-C’) shows that the lake and the sugar plantations located at the south of the lake are topographically continuous. It is assumed that the surface water from the plantations pours into the lake directly, considering the slope direction (Figure 11.3.5). However, inflow of the surface water from the plantations to the lake was not observed when the project team visited the site in May 2015 because of the dry season.



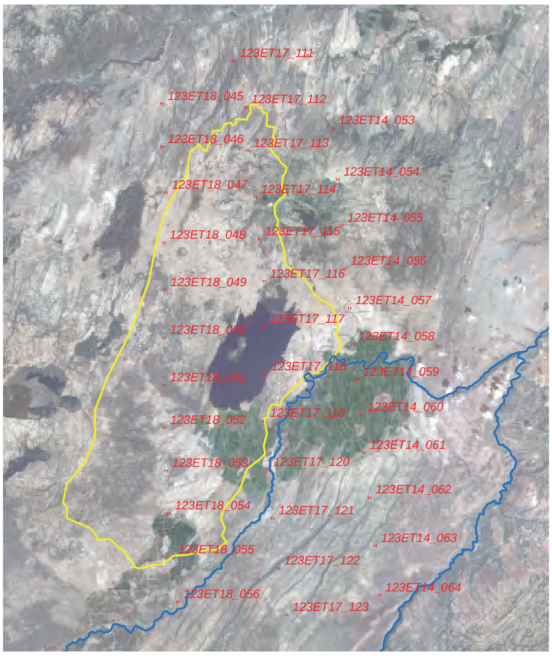
Source: the Project Team, Data: ALOS, Resolution 5 m, vertical accuracy 5 m

Figure 11.3.5: N-S Topographic Section around Lake Beseka (C-C')

Distribution of faults around Lake Beseka indicates that the lake is a tectonic lake considering the shape of the lake and the dominating northeast trending structure. This is particularly evident in the micro topography of the northeast trending normal faults on the north of the lake. Among such faults, normal faults with openings of about 20 m, which extend towards the eastern shoulder of the Fentale volcano, are also observed at the site. These faults are assumed to be extending into Lake Beseka.

Topographical analysis around Lake Beseka through aerial photos

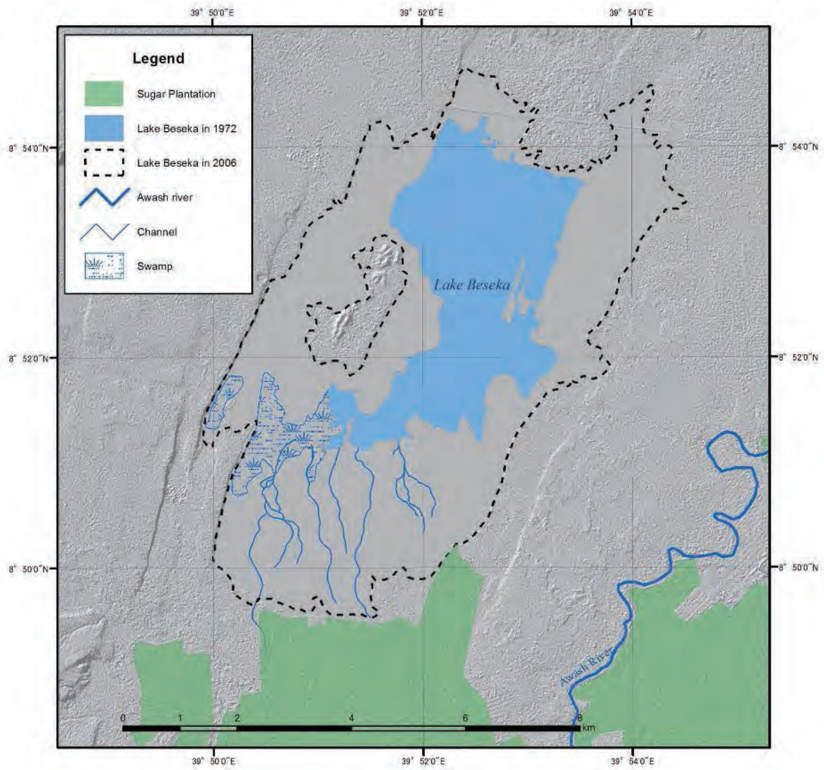
Using the 37 obtained aerial photos (Figure 11.3.6), topographical classification, fault topography analysis and analysis for paleo-channel flowing into Lake Beseka were conducted. The result of topographical classification and fault topography analysis were reflected to the geological map around Lake Beseka.



Source: the Project Team, Data: SPOT satellite image

Figure 11.3.6: Index map of aerial photos used for the topographical analysis

The aerial photos were taken in January 1972 (dry season), which was around the time when the water level of Lake Beseka began to rise. The outline shape of Lake Beseka at that time, adjacent swamp area and distribution of paleo channels were traced through the stereoscope as shown in Figure 11.3.7. The outline shape of Lake Beseka (black dot line) and the sugar plantation area (green) obtained from ALOS captured in 2008 are superimposed in the same map. The area of Lake Beseka in 1972 (11.7 km^2) was about 28% of that in 2008 (42.3 km^2). There are swampy areas at the southwest of the lake and 6 to 7 lines of paleo-channels flowing into the lake from the south to the north are also observed. From these photos it was not possible to confirm that there was water in the channels at that time, although vegetation was developed along the channels. The paleo-channels appear to start from the northern edge of the sugar plantation, causal relationship between the channel and the plantation was unclear only from these aerial photos. However, the inflow of surface water to Lake Beseka was observed only from the southern part.



Source: the Project Team, Data: ALOS DEM

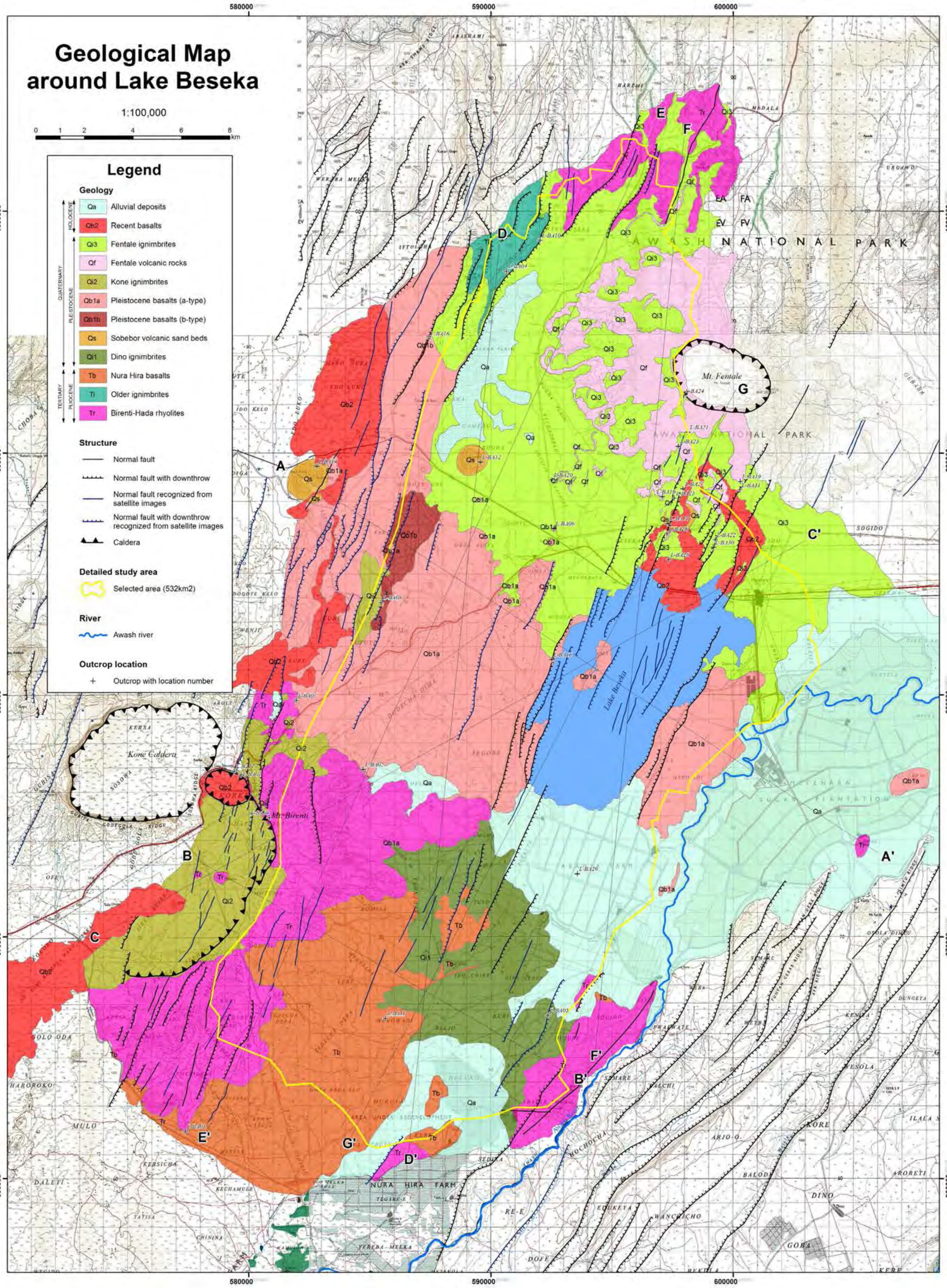
Figure 11.3.7: Paleo-channel flowing into the southern part of Lake Beseka

11.3.2 Geology

a. Geological units

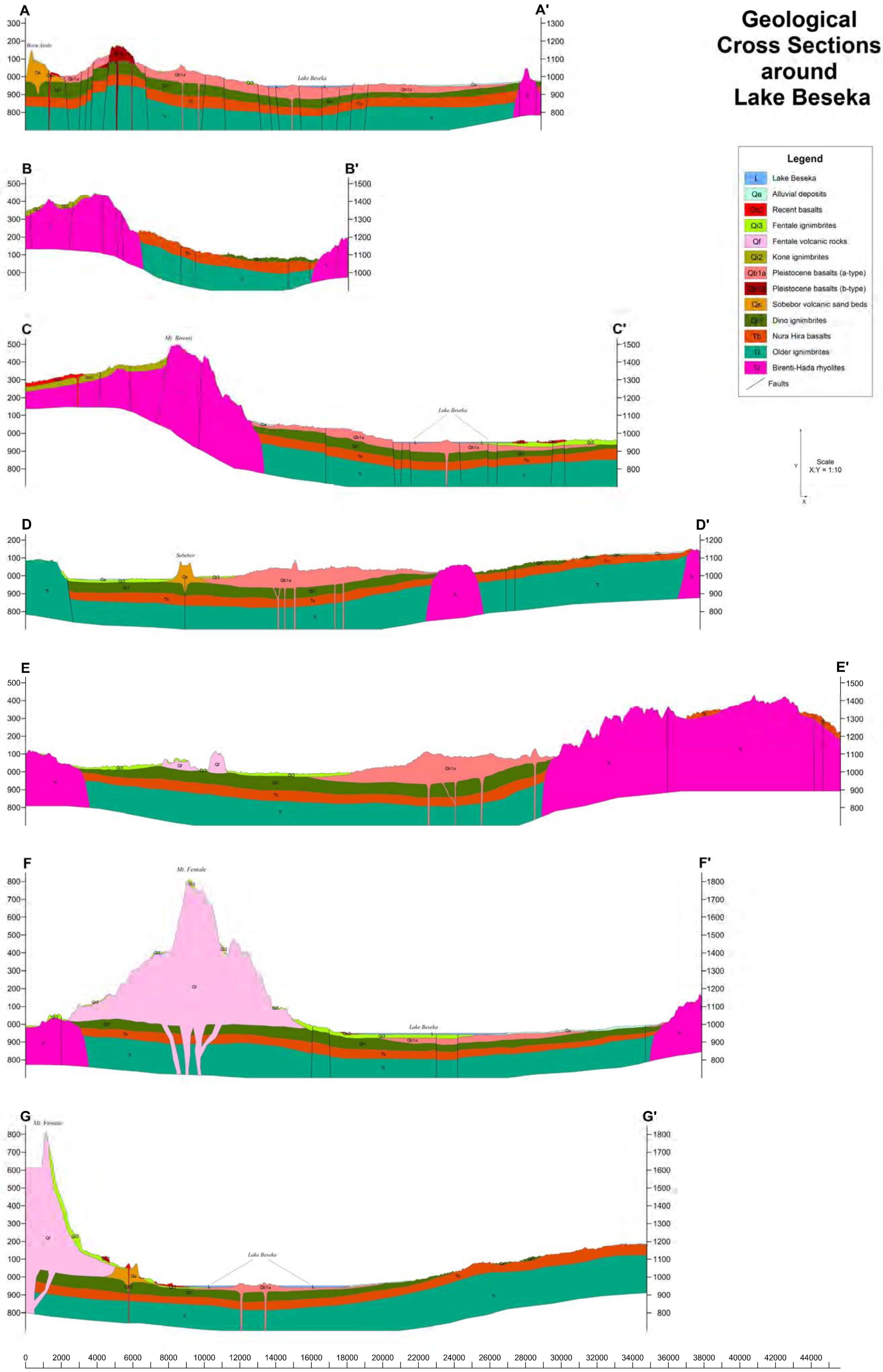
A detailed geological map of an Awash River sub-basin which extends from the northwestern foot of Mt. Fentale to the Nura Hira farm including Lake Beseka (hereinafter referred to as the detailed study area) was prepared at a scale of 1:100,000 (532 km^2). As for existing geological maps of this area, there is a map of 1:250,000 compiled by Kazmin and Berhe (1978) and a map of 1:100,000 by EIGS and ELC (1987). The former includes a larger area from around Nazret to Metehara and the established stratigraphy and the described names of each geological unit are still often quoted in other research papers and reports. The latter is an output of a comprehensive geothermal study including petrological analysis. However, there still needed a further detailed study and discussion for the geological boundaries and stratigraphy of the area around Lake Beseka. Therefore, a detailed geological field survey was conducted and the geological map of the area was revised. A geological map and sections of the detailed study area are shown in Figure 11.3.8 and Figure 11.3.9.

The locations of outcrops expressed by the location numbers (L-BA**) in this chapter are expressed in the geological map around Lake Beseka.



Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.8: Geological Map around Lake Beseka



Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.9: Geological section around Lake Beseka

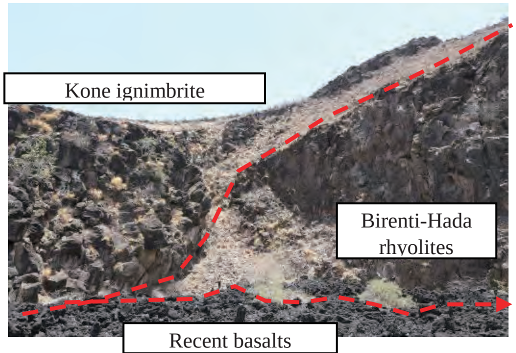
1) Birenti-Hada rhyolites

This unit is fine to coarse grained rhyolites mainly distributed in Mt. Birenti and Mt. Hada in the west to the southwest of the detailed study area. In addition, the rhyolites distributed around Mt. Abadir and Mt. Dekaki in the south and north of the detailed study area, respectively are also considered as the same horizon due to the characteristics of the rock facies and topography.

The rhyolites are gray to greenish gray in color, and the matrix is fine grained and often glassy with flow structures, and scattered with hornblende and feldspar phenocrysts. Generally platy joints develop around the surface and the inside of the lava body is massive. Obsidian bands develop from around Mt. Bilenti to the southwards. Coarse grained rhyolites with feldspar phenocrysts 1 to 3 mm in size are distributed at Mt. Mekidera exceptionally.

It is observed that these rhyolites are unconformably overlain by the Kone ignimbrite at the east wall of Korke caldera (L-BA01), by the Pleistocene basalts at the northeast foot of Mr. Birenti (L-BA02) and by the Nura Hira basalts at the south foot of Mt. Hada (L-BA03).

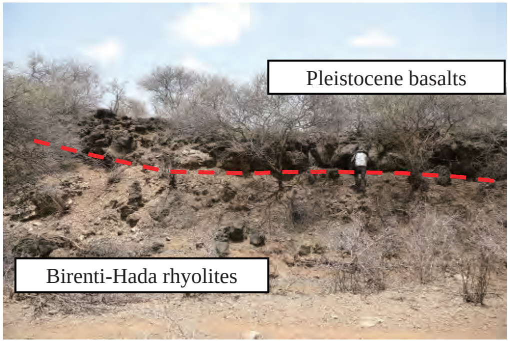
In the existing geological maps, Kazmin and Berhe (1978) and EIGS and ELC (1987) have shown “Unwelded rhyolitic pumice and unwelded tuff” or “Welded tuff” around Mt. Birenti. However, this study revealed that rhyolites are distributed wider and the stratigraphical position is lower than previously considered. Therefore, this unit is newly named as Birenti-Hada rhyolites.



The Birenti-Hada rhyolites overlain by the Kone ignimbrite (north wall of Korke caldera). L-BA01


Obsidian bands developed around the peak of Mt. Bilenti. L-BA09


Platy joints of the Birenti-Hada rhyolites.



The Birenti-Hada rhyolites overlain by the Pleistocene basalts. L-BA02

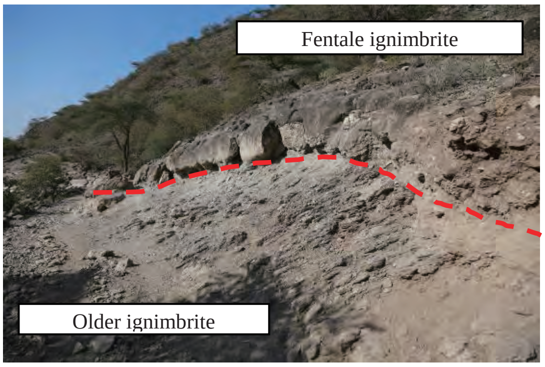
Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.10: Outcrop photos of Birenti-Hada rhyolites

2) Older ignimbrite

This is widespread ignimbrite composed of greenish to greenish gray highly welded tuff to slightly welded tuff and pumice. In the detailed study area this geological unit outcrops in the NNE-SSW trending, east-facing fault escarpment (60 to 100 m in height) located at the northwest area of the detailed study area and is expanding out of the detailed study area further westwards. In the southwest part of the fault escarpment, it is observed that the Fentale ignimbrite overlie unconformably the fault slope formed by the old ignimbrite (L-BA04). The older ignimbrite are composed of several flow units with different welding grades. The characteristics of this welded tuff is similar to those of the Fentale ignimbrite and it is often difficult to distinguish. However, this unconformable contact between the two units allows them to be differentiated (photo).

This unit is correlated with welded tuffs of Nazret Group of Kazmin and Berhe (1978) which is widespread to the west of the detailed study area.



The Fentale ignimbrite unconformably overlie inclined welded tuff of the older ignimbrite (Haro Gersa). L-BA04

A NNE-SSW trending fault escarpment on which the older ignimbrite are exposed (Haro Gersa). L-BA10

Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.11: Outcrop photos of the older ignimbrite

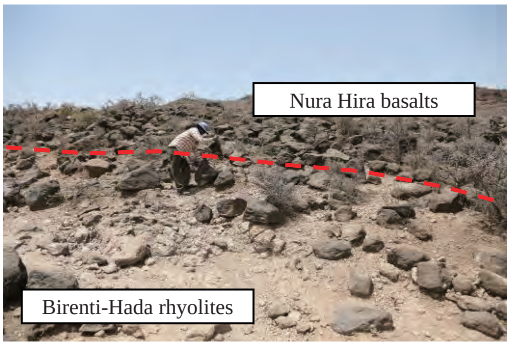
3) Nura Hira basalts

This unit is composed of black aphyric basalt lavas distributed around the north of Nura Hira farm. Although the area covered by these basalts was an extension of the Pleistocene to sub-recent basalts according to Kazmin and Berhe (1978), considering the characteristics of petrological characteristics, topography and stratigraphy, this unit was distinguished and newly named as Nura Hira basalts.

The topography formed by this unit is relatively flat and continuous and covered by relatively thicker shrubs. Most of the basalts of this unit are aphyric but sometimes pyroxene and plagioclase phenocrysts of about 1mm in size are observed. Olivine and pyroxene phenocrysts (about 0.5 mm in size) are included in the fine graind basalt distributed in some areas such as the north of Kubi Dimtu. The lava is usually vesicular near the surface.

It is observed that this unit overlies the Birenti-Hada rhyolites unconformably at the south foot of Mt. Hada (L-BA03) and is overlain by the Kone ignimbrite unconformably along the road connecting Nura Hira farm and Abadir farm (L-BA05).

Flat plain formed by the Nura Hira basalts (northwest of the Nura Hira farm).



The Birenti-Hada rhyolites unconformably overlain by the Nura Hira basalts (southern foot of Mt. Hada). L-BA03

Source: the Project Team, Data: Result of geological survey in this Project

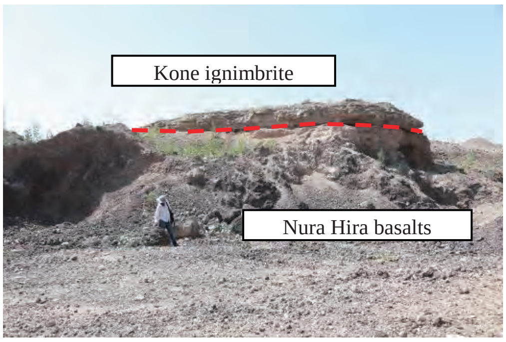
Figure 11.3.12: Outcrop photos of the Nura Hira basalts

4) Dino ignimbrite

This unit is an extension of the widely distributed welded tuff (Dino ignimbrite, Kazmin and Berhe (1978)) mainly distributed southeast out of the detailed study area between the right bank of the Awash River and Arba River. In the detailed study area, it is thinly (maximum about 5 m thick) distributed at the southwest of Lake Beseka in a limited area. It forms relatively flat topography. The tuff is greenish gray colored and weakly welded. It includes hornblende. The rock facies of this unit resembles that of Kone ignimbrite and Fentale ignimbrite, but they are separated due to discontinuity of distribution and topography.

It is observed that this unit overlays the Nura Hira basalts along the road connecting Nura Hira farm and Abadir farm. (L-BA05)

Dino ignimbrite exposed along the irrigation channel at the north of Nura Hira farm. L-BA11



Nura Hira basalts overlain by the Kone ignimbrite. L-BA05

Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.13: Outcrop photo of Dino ignimbrite

5) Sobebor volcanic sand beds

This unit is represented by the Sobebor hill (L-BA12) located at the southern part of the Alaka plain and observed at only three locations such as Sobebor hill, Dinbiba (L-BA13) on the southern foot of Mt. Fentale and Boru Arole hill (L-BA14) about 6 km westwards from Sobebor. This unit forms an independent hill (tuff ring) at each location and three locations are arranged so as to draw a gentle arc shape. The size of the hills is vast and they have big craters with a diameter of 0.5 to 1 km at the center, which makes the appearance different from other scoria cones.

This unit is composed of thick layers of yellowish brown volcanic sand and silt with lamina with a thickness of 2 to 10 cm. Sometimes lapilli and boulders with a diameter of 1 to 30 cm are also included. The lamina inclines towards the outside from the center 20 to 30 degrees. At Dinbiba, some parts of the crater rim have remained and fresh basalt lavas (recent basalts) spilled out from the center. Fresh basalts came out from a collapsed hillside at Boru Arole.

Previous reports such as Kazmin and Berhe (1978) and EIGS and ELC (1987) mentioned this unit as basaltic hyaloclastites. However, it seems that they were either confused with the cause of hyaloclastite or the definition of the term was different at that time. The term "hyaloclastite" is generally used for the pyroclastic rocks formed when magma gets into water and is crushed due to rapid cooling. There is no evidence of these causes in the sediment of this unit. Moreover, it does not include original magma fragments (direct products of magma) in the sediment unlike scoria and pumice, which indicates that this sediment could be the remnant of a continuous phreatic eruption.

This unit is overlain by the Fentale ignimbrite at Dinbiba (L-BA13).

Sobebor tuff ring from a distance.

Sand beds inclined towards outside of the hill (Sobebor).

Sedimentary structure (parallel lamina) in the sand beds (Sobebor)

Inside the Sobebor crater. L-BA12

Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.14: Outcrop photos of Sobebor volcanic sand beds

6) Pleistocene basalts

This unit is composed of basalts and scoria distributed mainly in the west and partly in the east of Lake Beseka. Taking the rock type into consideration, it is divided into two parts; olivine-pyroxene basalts (a-type) and alteration between porphyritic pyroxene basalts and aphyric basalts (b-type).

Within the distribution area of this unit, a-type occupies most of the area. The basalts of a-type contain a lot of olivine and pyroxene phenocrysts with a size of 0.5 to 1 mm with black with fine grained matrix. The lava is very vesicular near the surface and often filled with the secondary mineral (zeolite). The lava is aa-type and it remains the original undulated topography of lava flow. Most of the scoria cones distributed in the detailed study area are located within the distribution area of this unit. In addition, with the analysis of topography and satellite images, it is observed that most Pleistocene basalts spouted out from these cones. Generally, a scoria cone was formed first and then, lava erupted from the center or the side of the cone. The scoria cones are aligned in an NNE-SSW direction which is the same as the Wonji fault trend. This indicates that the magma erupted along the weak zones of faults.

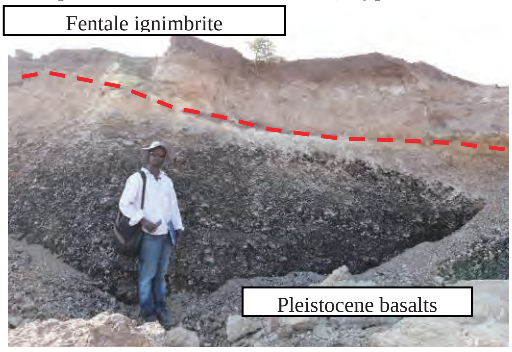
B-type basalts are distributed only in the west part of the detailed study area along the hills extending in a NNE-SSE direction between Dodote and Tututi about 6 km long and 0.5 to 1 km wide, and in the west of Alaka plain along a fault escarpment. The basalts of b-type are composed of porphyritic basalts and aphyric basalts. The former contains plagioclase phenocrysts with pyroxene reaching a prominent size of 5mm and olivine averaging a smaller size of 1 to 3 mm. Porphyritic basalts and aphyric basalts are distributed in the same area but the relationship of these two could not be observed directly.

Because a-type is distributed on a part of the hill formed by b-type, it is considered that a-type is younger than b-type.

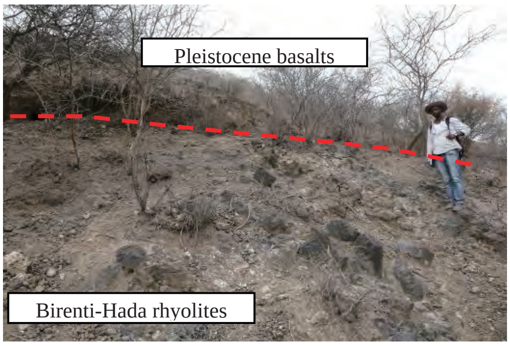
It is observed that this unit overlies Birenti-Hada rhyolites unconformably at the northeast of the Korke caldera (L-BA07) and is overlain by Fentale ignimbrite unconformably at the scoria cone (Ilala) located at the southwest foot of Mt. Fentale (L-BA06). Although a direct relationship between this unit and Kone ignimbrite was observed, this unit is considered younger than Kone ignimbrite from the view point of topography and distributional characteristics.

Olivine-pyroxene basalt exposed on the fault escarpment west of Lake Beseka (a-type). L-BA15

Porphyritic basalt exposed on the fault escarpment in the west of the Alaka plain (b-type). L-BA16



Scoria of the Pleistocene basalts (a-type) overlain by the Fentale ignimbrite (Ilala). L-BA06



The Birenti-Hada rhyolites overlain by scoria of the Pleistocene basatlt (a-type) (northeast of the Korke caldera). L-BA07

Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.15: Outcrop photos of the Pleistocene basalts

7) Kone ignimbrite

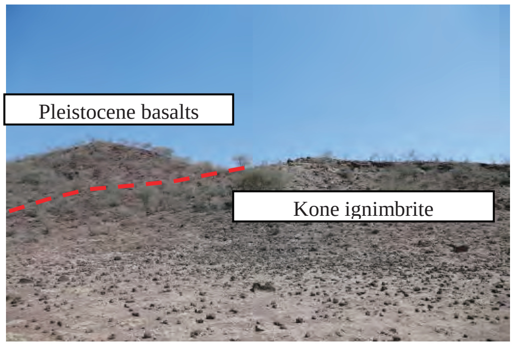
This unit is composed of greenish gray to gray colored highly welded tuff to unwelded tuff and pumice mainly distributed east of Kone caldera. The tuff contains relatively higher numbers of hornblendes 1 to 3 mm in size and foreign lapilli of up to several centimeters in size.

Continuous welded tuff with about 70 m in thickness forms a caldera wall on the south edge of the Korke caldera subordinately situated besides the Kone caldera. EIGS and ELC (1987) described several flow units of welded tuff on the wall of the Korke caldera. On the east wall of the Korke caldera, it is observed that several layers of unwelded pumice including obsidian lapilli 1 to 5 cm in size continue for about 20 m below the welded tuff.

The characteristics of the welded tuff of this unit is similar to the Fentale ignimbrite and Dino ignimbrite, which makes identification through facies difficult. Therefore, these units were distinguished from the view point of distributional continuation.

It is observed that this unit unconformably overlies Birenti-Hada rhyolites at the east wall of Korke caldera (L-BA01) and the Pleistocene basalts at the east of Kube (L-BA08).

The Kone ignimbrite exposed on the west wall of Korke caldera. L-BA17



Kone ignimbrite which overlay the Pleistocene basalts (east of Kube). L-BA08

Source: the Project Team, Data: Result of geological survey in this Project

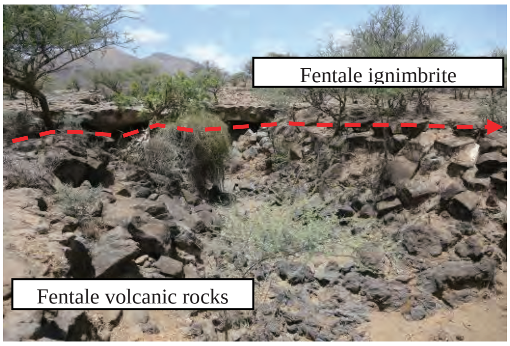
Figure 11.3.16: Outcrop photo of Kone ignimbrite

8) Fentale volcanic rocks

Mt. Fentale (2,007 m) is located just north of Lake Beseka and has an elevation gap of about 1,050 m between the surface of the lake. It has a caldera with a diameter of about 4 x 2.5 km on the top of the mountain. This unit is composed of acidic rocks which form the main body of Mt. Fentale.

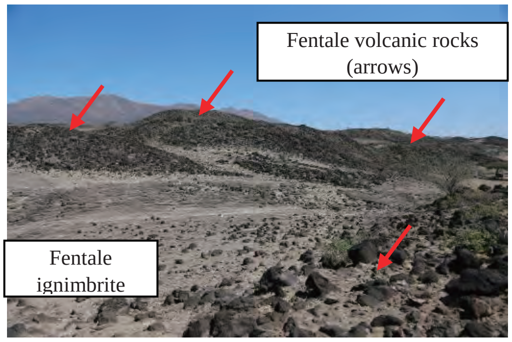
In the detailed study area, the west part of Mt. Fentale is included. Within the detailed study area, the volcano is composed of rhyolite and trachyte lavas in which phenocrysts of alkali feldspar and hornblende are scattered. The lava surface is block type with a diameter from several dozen cm to about 1 m. The lavas are generally very glassy and are black to deep green in color.

The lavas distributed on the foot of the mountain remain in the original topography of the lava flow and each lava flow can be distinguished through the analysis of satellite images and digital elevation model. However, since the characteristics of the lavas distributed in the detailed study area are almost similar to each other, they are grouped as the Fentale volcanic rocks in this report.



Trachyte of the Fentale volcanic rocks overlain by the Fentale ignimbrite (southern foot of Mt. Fentale). L-BA18

Block lava of glassy trachyte (south foot of Mt. Fentale). L-BA19



Glassy trachytes (arrow) exposed after the erosion of the Fentale ignimbrite (southern foot of Mt. Fentale). L-BA20

Glassy rhyolites exposed on the southern slope of Mt. Fentale. L-BA21

Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.17: Outcrop photos of the Fentale volcanic rocks

9) Fentale ignimbrite

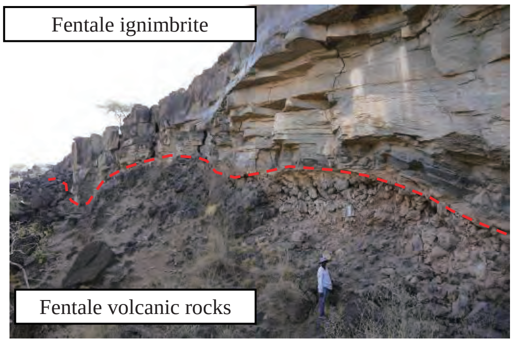
This unit is composed of greenish gray to whitish gray welded to unwelded tuff and pumice which erupted from Mt. Fentale. It is distributed at the slope of Mt. Fentale, foot of the mountain and widely around the surrounding area. It includes a lot of lapilli with a diameter of a few mm to several cm and develops glassy (obsidian) lens structure (fiamme). The size of the fiamme is variable from several mm to more than 50 cm. There is unwelded pumice at the bottom of the welded tuff.

This unit covers 15 to 18 km towards south to west directions from Mt. Fentale and more than 30 km towards east direction according to Kazmin and Berhe (1978). On the slope of Mt. Fentale, welded tuff thinly are deposited in the gentle valleys and plains (about 1m thick). At the southwestern to western side around the mountain peak of Mt. Fentale, it is observed that pumice and welded tuff are deposited from the top of the caldera wall towards the outside overlaying rhyolites of the Fentale volcanic rocks.

At the southern foot of Mt. Fentale, there is a thick deposit of pumice. This is considered the secondary sediment of collapsed pumice which originally was deposited on the mountain slope. This pumice is assumed to be a part of pyroclastic rocks of the Fentale ignimbrite. This pumice is covered by the Holocene basalts.

The maximum observed thickness of this unit is about 10m in the outcrops, but a borehole log record shows about 30 m of welded tuff for the horizon assumed as the Fentale ignimbrite (AW BH-5).

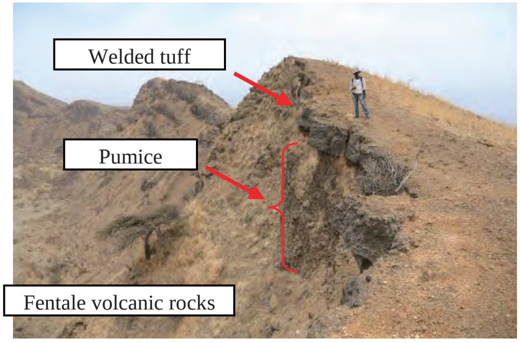
There is a report about the age of this unit as 1.1±0.1 Ma (Gibson (1970)). However, EIGS and ELC (1987) indicated a possibility of a much younger age for the unit due to its topographical characteristics.



The Fentale ignimbrite which overlies the trachyte of the Fentale volcanic rocks. (Southern foot of Mt. Fentale). L-BA22

Glassy lens structure (fiamme) of the Fentale ignimbrite.

Welded tuff of the Fentale ignimbrite which cover the southern slope of Mt. Fentale. Black oval patterns are fiammes seen from above. L-BA23



Pumice and welded tuff deposited out of the caldera rim of Mt. Fentale. L-BA24

Source: the Project Team, Data: Result of geological survey in this Project

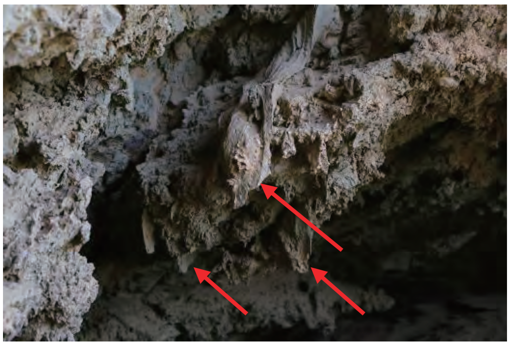
Figure 11.3.18: Outcrop photos of the Fentale ignimbrite

There is a remarkable topographic feature on the surface of the Fentale ignimbrite that is called “Blister”. The blister is a small rise of welded tuff surface forming a conical shape. The existence of the blisters is limited to an area near Mt. Fentale (within about 10 km) and many of them can be observed especially in the west and the south of Mt. Fentale where there is a flat plain. The size of a blister is normally from 5 to 30 m in diameter and reaches up to 100 m when a couple of blisters are combined. Relatively larger blisters tend to have been collapsed at the center and only their rims have remained.

Blisters are considered to have been formed by the presence of steam pockets which caused a bulge to the surficial portion of the still hot and plastic material (EIGS and ELC, 1987). To support this idea, the inside of a blister is hollow and it is observed that half melted material is hanging down from the ceiling made of welded tuff, and then cooled and consolidated. In addition, the cracks developing on the surface of the blister do not reach deep inside (photo).

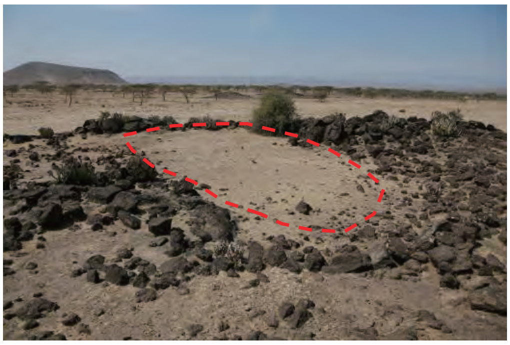
EIGS and ELC (1987) mentions the cause of the blister as steam produced by the sudden vaporization of water from swampy areas or shallow lakes trapped beneath the flow at the moment of deposition. However, blisters are observed on the lava plateau formed by the trachyte block lava of the Fentale volcanic rocks and sometimes on the slope of the plateau edge. It is difficult to assume that these places were all swamps or lakes. Moreover, there is no trace of lake deposits beneath the Fentale ignimbrite and the tuff deposited on water would be cooled rapidly so that it cannot be welded strongly. Generally pyroclastic flow contains a large volume of volatiles and degassing structures are observed in the unwelded deposits. Probably the volatiles included in the original pyroclastic flow deposits of the Fentale ignimbrite lost a way out for degassing due to welding of the deposits, and then they gathered and combined at certain places increasing the volume. At last, the shape of present blisters was formed.

A blister with its original cavity remaining without collapsing (southern foot of Mt. Fentale). L-BA25



Ceiling of the cavity of a Blister. Melted parts of the welded tuff are hanging down like stalactite (southern foot of Mt. Fentale).

Cracks observed on the surface do not reach the inside (southern foot of Mt. Fentale)



Remnant of a collapsed blister (a diameter of about 20m) (southern foot of Mt. Fentale)

Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.19: Outcrop photos of the blisters of the Fentale ignimbrite

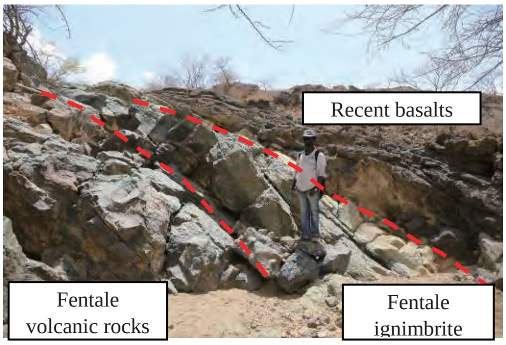
10) Recent basalts

This unit distributed in the detailed study area is black vesicular aphyric basalt and it is the youngest volcanic ejecta in the area (1810 to 1830, Buxton (1949)). It is located at the southern foot of Mt. Fentale and the southern tip of the lava reaches Lake Beseka. Since it is a very recent basalt, there is little vegetation on the lava and the lava flow maintains its original shape without weathering or erosion. The viscosity of the lava is very low and spatter cones and lava tunnels are developed and a few ropy structures are observed near the eruption center. These characteristics of pahoehoe lava turn into those of aa lava after some distance from the eruption center. There are several eruption centers along the faults (in and out of the tuff ring of the Sobebor sand beds and at the southern foot of Mt. Fentale)

Since there is little vegetation and soil developed on these lavas, their distribution is clearly demarcated from other units. Many other recent basalts are distributed west of the detailed study area at Boru Arole, Kube, Korke and Kokoro, etc. At all these locations, the basalts generally contain olivine and pyroxene. Most of them are aa lava but the basalt distributed at Boru Alole shows pahoehoe characteristics such as lava tunnels and ropy structures. The mineral composition of these basalts are different from that of the detailed study area, they are considered to be the basalts of a similar age due to the freshness of their surface.

Lava tunnel observed near the eruption center of the recent basalt lava (Dinbiba). L-BA26

Spatter cone developed at the spout of the recent basalt lava (Dinbiba). L-BA26



The recent basalts over the Fentale ignimbrite and the Fentale volcanic rocks. L-BA27

The recent basalts reaching Lake Beseka. L-BA28

Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.20: Outcrop photos of the recent basalts

11) Alluvial deposits

This unit is mainly a flood plain deposit of the Awash River and is composed of sand and silt. Most of the area is now utilized for sugar plantations. In addition, alluvial deposits are distributed at the Alaka plain on the west of Mt. Fentale and eastern foot of Mt. Bilenti.

Alluvial plain utilized for a sugar plantation (Abadir farm). L-BA29

Section of alluvial deposits (northeast of Mt. Bilenti)

Source: the Project Team, Data: Result of geological survey in this Project

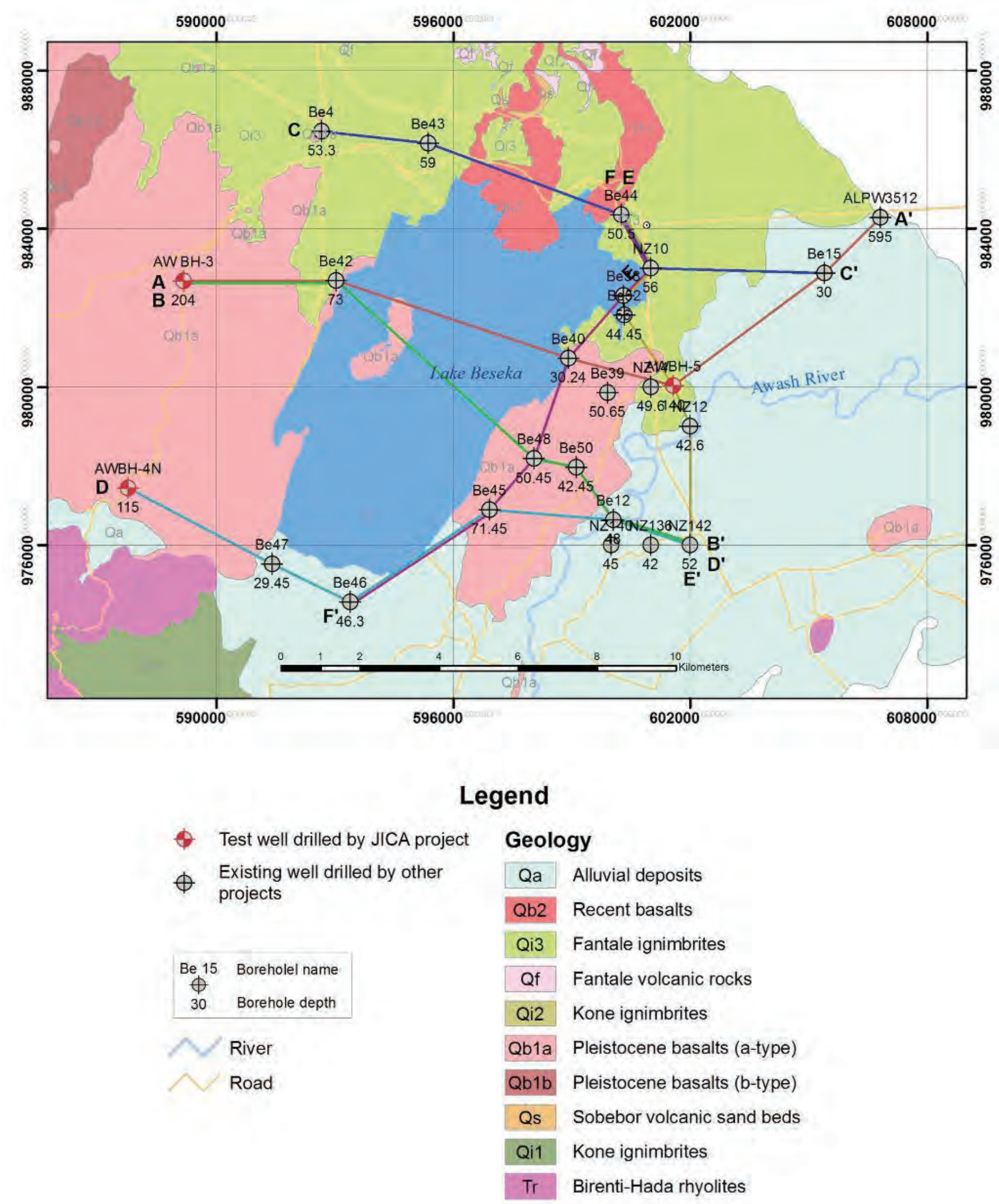
Figure 11.3.21: Photos of alluvial plains and deposits

b. Borehole log analysis

The geological log information of 22 existing wells and three observation wells constructed through this project around Lake Beseka were examined to analyze the correlation of geology and thickness of each geological unit. Most of the existing wells are relatively shallow (40 to 73 m) but the geological information of the deep part was compensated by the three observation wells of this project (114 to 204 m) and a deep well (595 m) constructed by MoWIE for irrigation purposes 6km east of Metehara Town, in 2014 . The results of analysis of those geological logs was almost consistent with the result of the field work. When a large gap of geological unit is observed within adjacent wells, effects of previous topographical features or displacement by fault activity were considered although a description error cannot be completely ruled out.

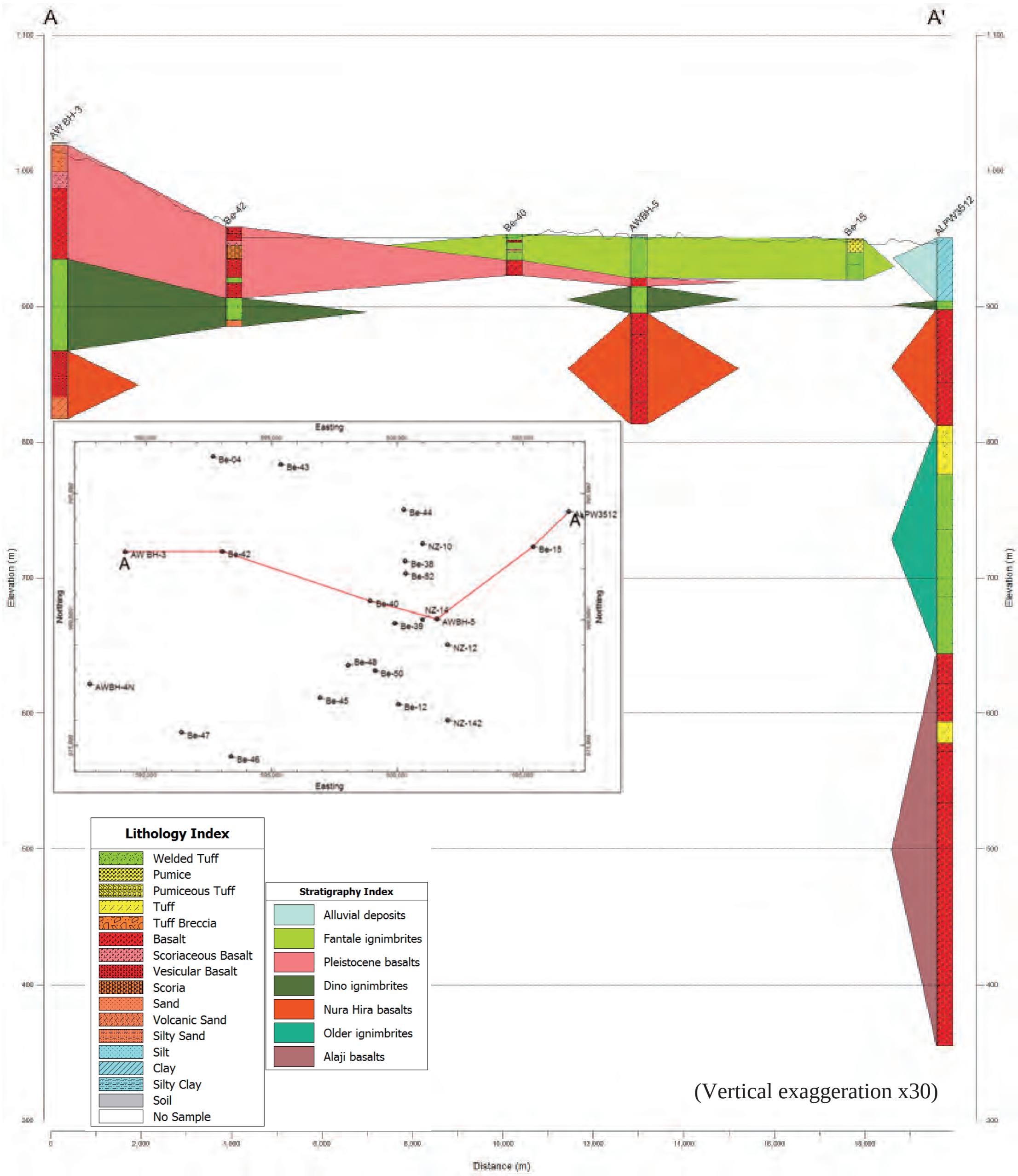
In each profile section the position of wells are arranged according to the ground elevation of the wells and the continuation of each horizon is schematically shown.

The location of the existing wells and observation wells and profile lines are shown in Figure 11.3.22, and profile sections are shown in Figure 11.3.23, Figure 11.3.24, Figure 11.3.25, Figure 11.3.26, Figure 11.3.27, Figure 11.3.28. The results of this analysis are reflected in the attached geological section (Figure 11.3.9).



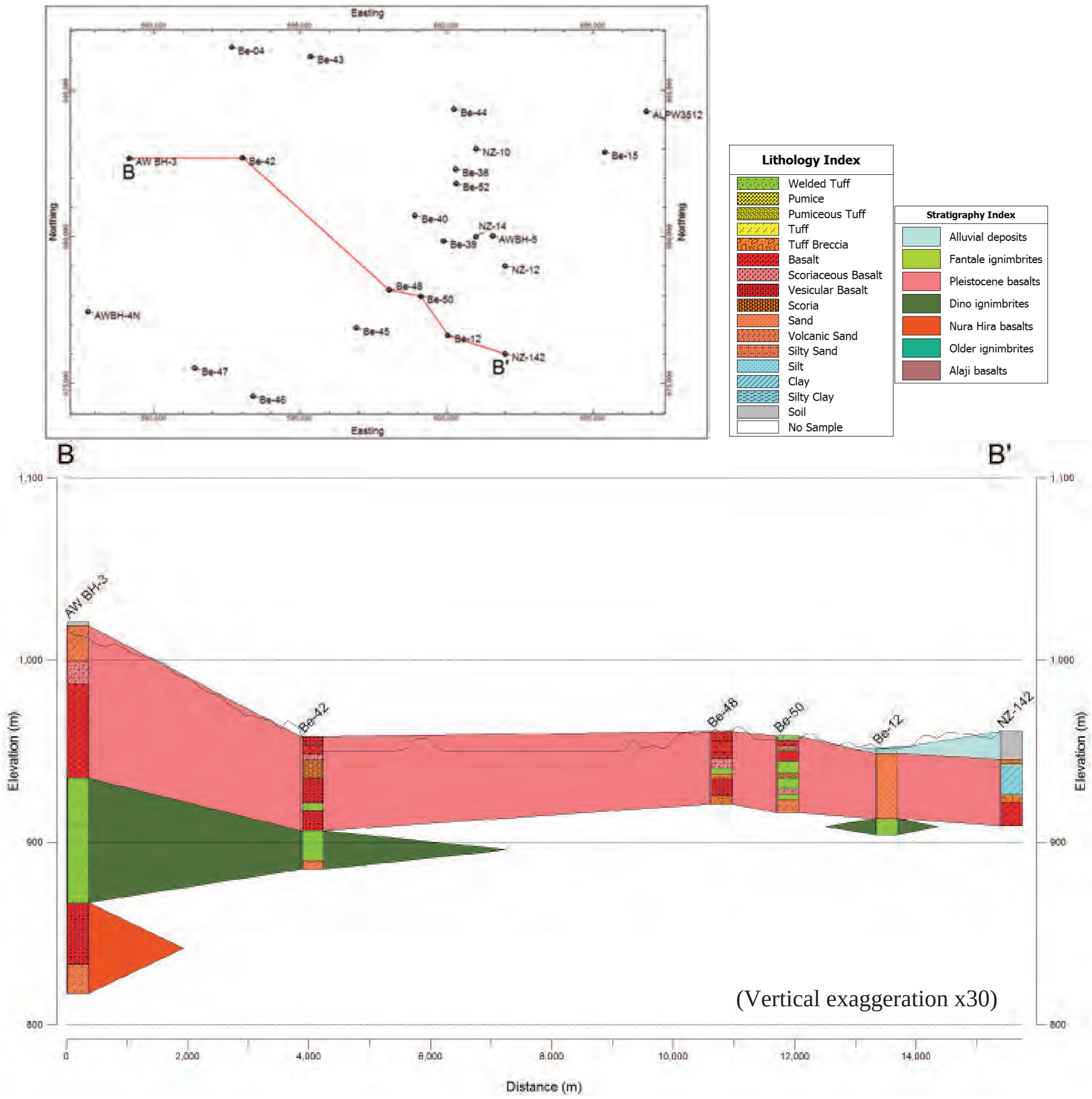
Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.22: Location of existing wells and observation wells constructed by this project and profile lines around Lake Beseka



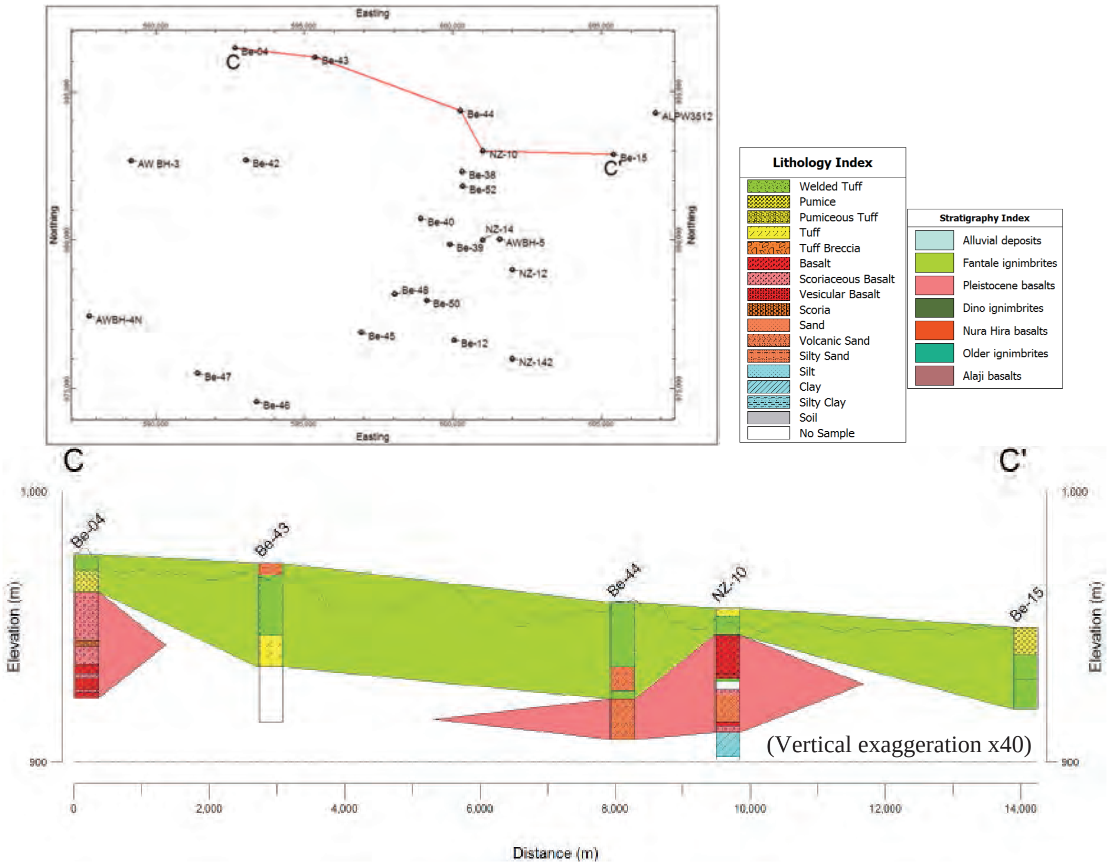
Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.23: Borehole log profile A-A' section



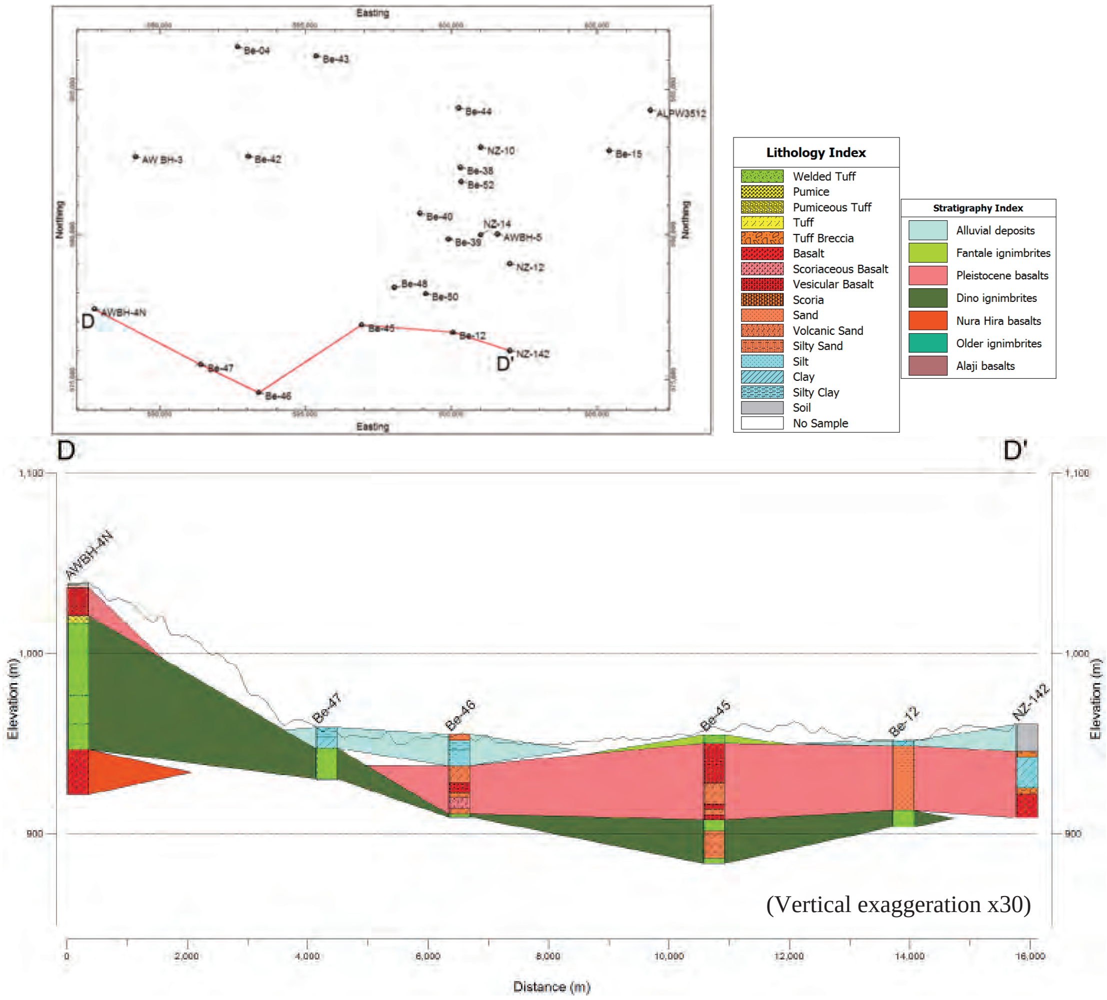
Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.24: Borehole log profile B-B' section



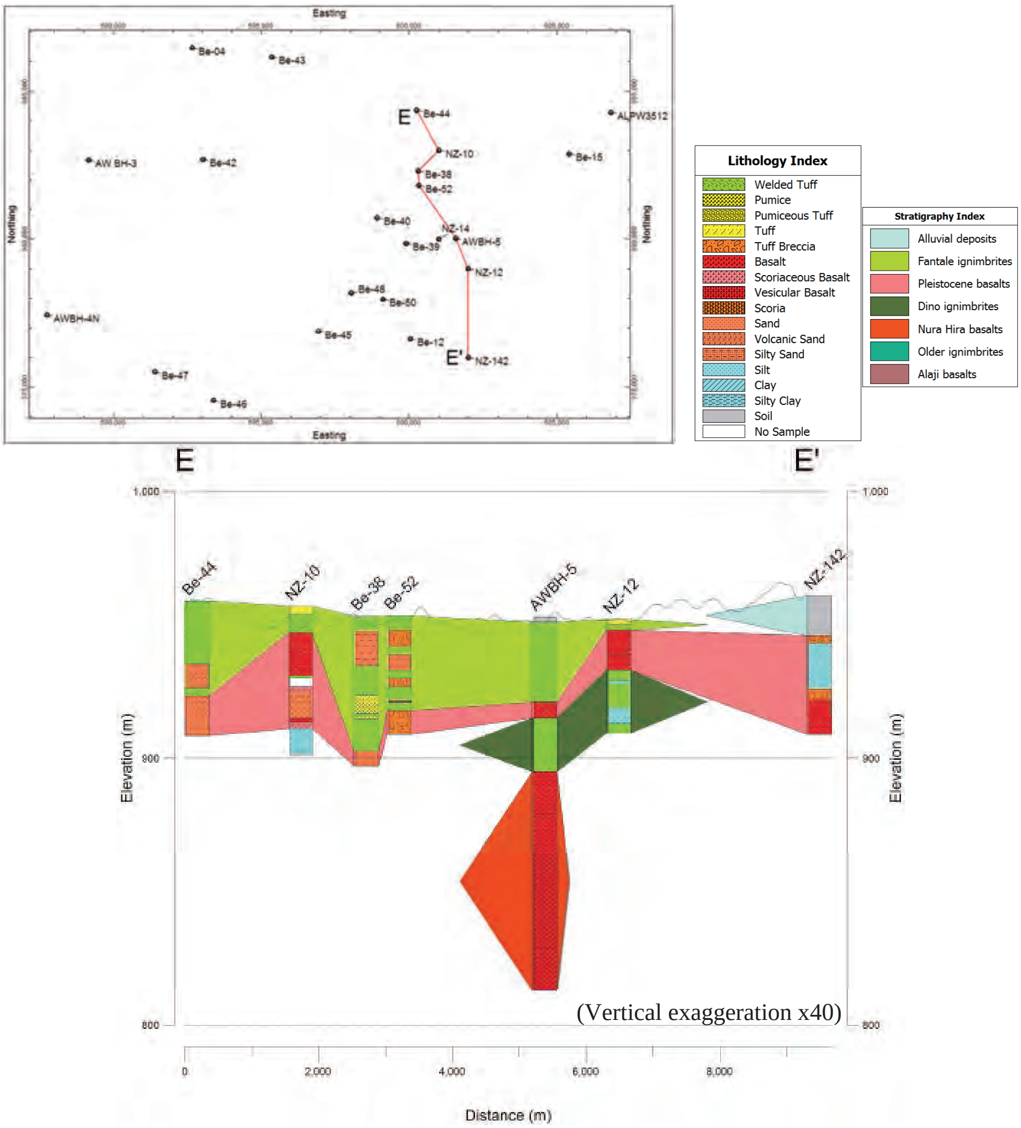
Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.25: Borehole log profile C-C' section



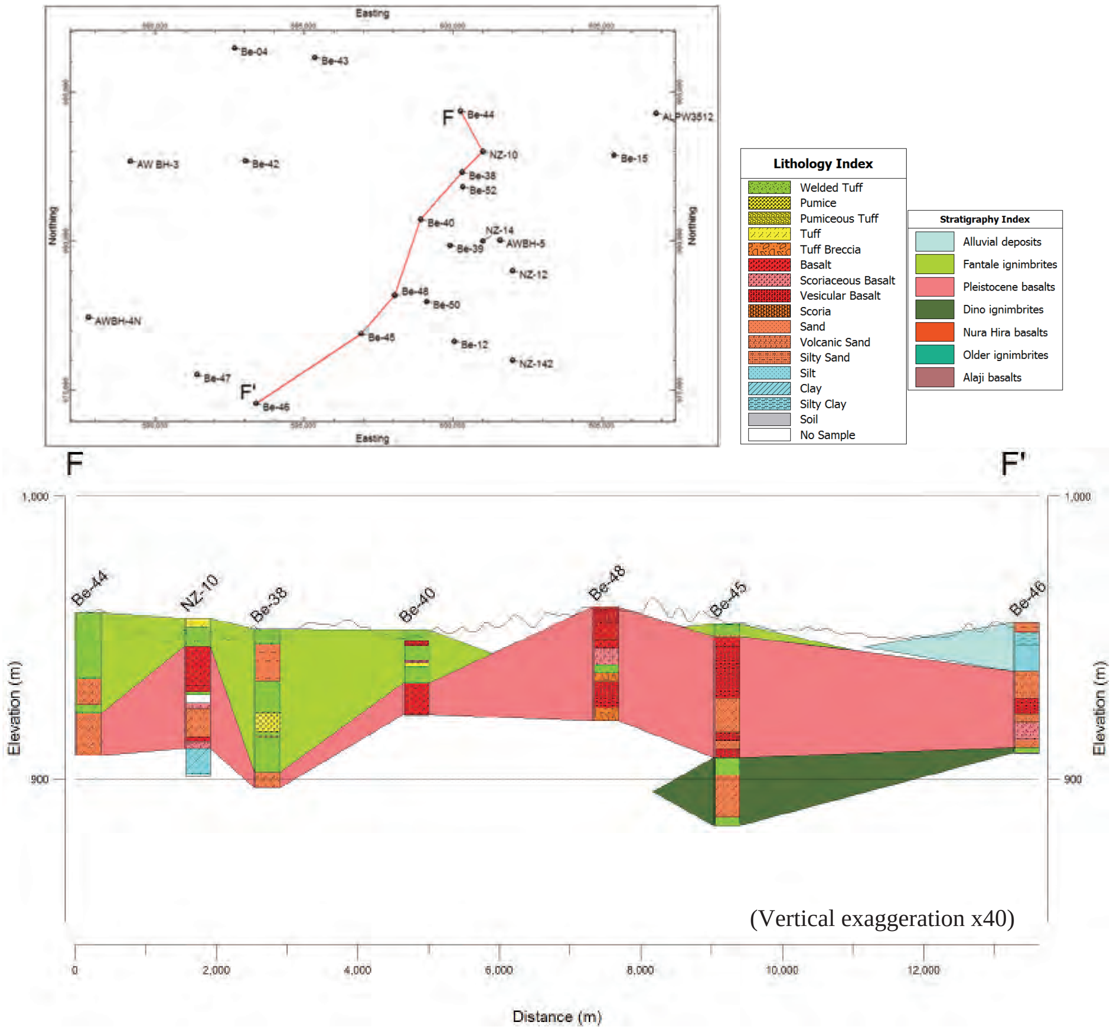
Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.26: Borehole log profile D-D' section



Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.27: Borehole log profile E-E' section



Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.28: Borehole log profile F-F' section

c. Stratigraphy

A stratigraphy of the detailed study area and correlation with other areas as a result of field survey and borehole log analysis is summarized in Table 11.3.2.

Table 11.3.2: Geological stratigraphy around Lake Beseka and correlation with other areas

Age			Stratigraphy	Legend	Kazmin and Berhe (1978)	Dating
Cenozoic	Quaternary	Holocene	Alluvial deposits	Qa	Alluvium	
			Recent basalts	Qb2	Recent aphyric basalts	Between 1810 and 1830 (Buxton, 1949)
		Pleistocene	Fentale ignimbrite	Qi2	Young ignimbrite of Fentale	1.1±0.1Ma (Gibson 1970)
			Fentale volcanic rocks	Qf	Pantelleritic volcanics of Fentale rhyolites, trachytes, tuffs and agglomerates	
			Kone ignimbrite	Qi2		
			Pleistocene basalts	Qb1a Qb1b	Pleistocene-subrecent basalts	
			Sobebor volcanic sand beds	Qs	Basaltic hyaloclastites	
			Dino ignimbrite	Qi1	Dino ignimbrite	1.51Ma (Kazmin and Berhe (1978))
	Tertiary	Pliocene	Nura Hira basalts	Tb	Bofa basalts	
			Older ignimbrite	Ti	Nazret Group	
			Birenti-Hada rhyolites	Tr	Older alkaline and paralkaline rhyolitic domes and flows	

Source: the Project Team, Data: Result of geological survey in this Project

11.3.3 Geological structure

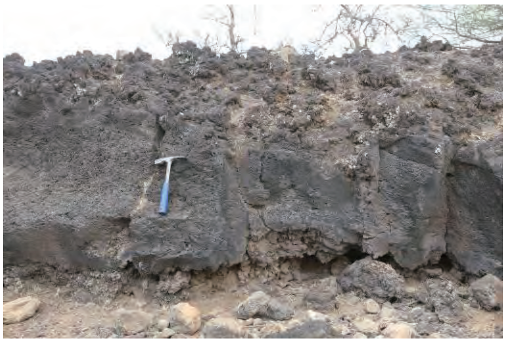
The vicinity around Lake Beseka is located at the very center of Main Ethiopian Rift and the geological structure is dominated by the Quaternary still active NNE-SSW trending normal faults (Wonji Fault Belt, Mohr (1960)). The faults distributed in the detailed study area are divided into two segments; one is the area around Kone caldera and the other is around Lake Beseka (EIGS and ELC (1987)). From the view point of topography and geological structure, since the area around Lake Beseka is located in the lower position of the rift, it may indicate that the active center has shifted from the Kone caldera area to the Lake Beseka area. The youngest fault in the detailed study area is observed on the recent basalt (1810 to 1830, Buxton (1949) north of Lake Beseka (L-BA31).

Although the displacement of the normal faults observed in the detailed study area is relatively small, mostly less than 10 m, the displacement gap becomes larger when the faults get closer to the main fault escarpment of MER (NE-SW trend). The largest displacement is observed at the Haro Gersa area for about 100 m. The inclination angle of the faults observed in the field is almost vertical.

In addition, some of the normal faults show open cracks within the dFetailed study area. A relatively long extending normal fault passing through the northeast of Mt. Fentale up to Lake Beseka has an open crack with a width of about 10 m in addition to the 10m displacement about 2 km north of the lake (L-BA30).

Open crack with a width of more than 10 m at 2 km north of Lake Beseka. L-BA30

A normal fault extending from Lake Beseka towards Mt. Fentale



Recent basalt lava section cut by a fault. L-BA31

NNE-SSW trending fault escarpment at the western part of the detailed study area (Haro Gersa)

Source: the Project Team, Data: Result of geological survey in this Project

Figure 11.3.29: Outcrop photos of faults distributed in the detailed study area

11.4 Hydrogeology

11.4.1 Aquifer classification and groundwater flow

As mentioned in Chapter 3, the existing wells data around Lake Beseka was mainly collected from the following reports.

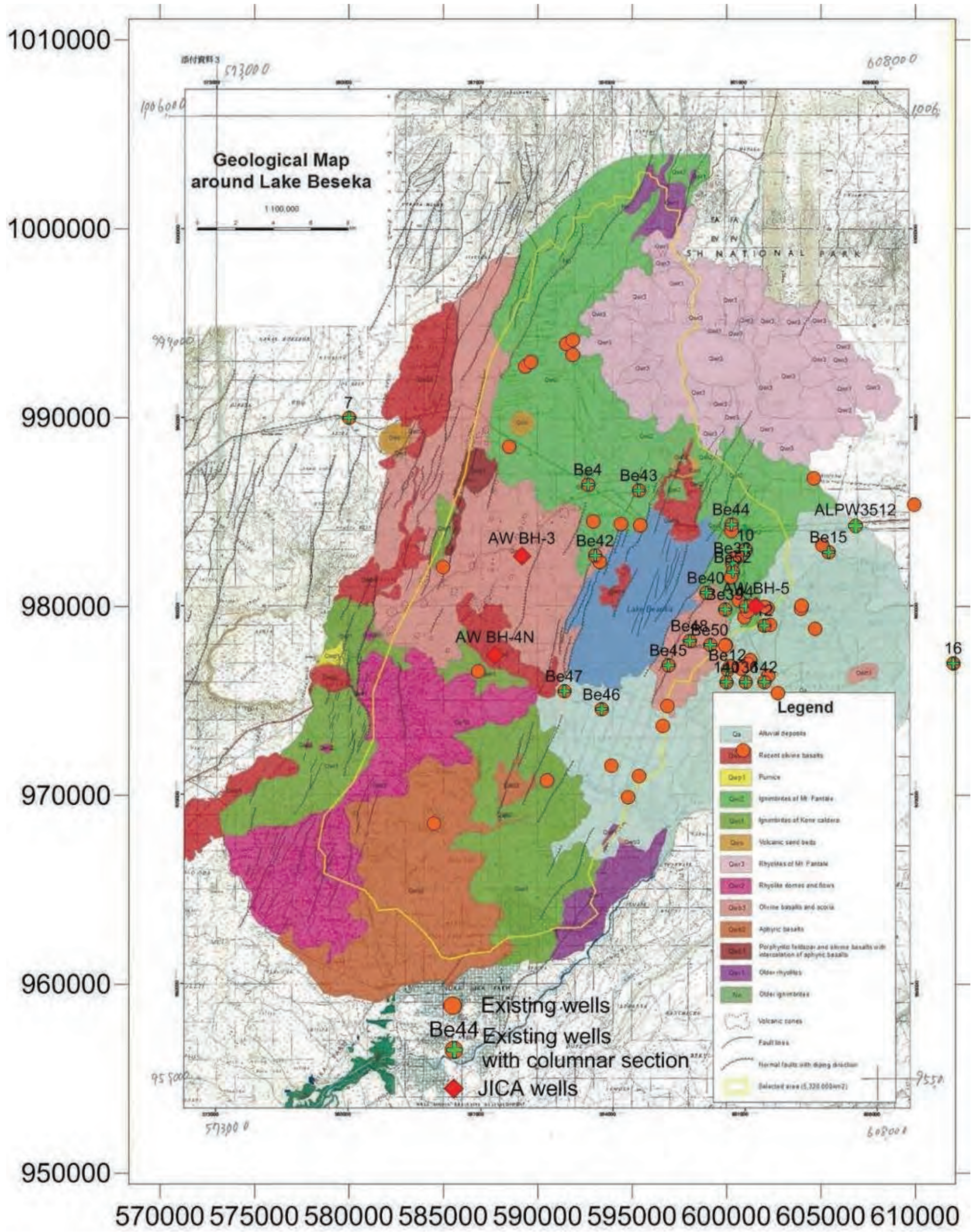
- Hydrogeology (Map) of the Nazret, EIGS, 1985
- Study and design of Lake Beseka level rise project II, WWDSE, planned by MoWE, 2011

All existing wells around Lake Beseka, were plotted on the geological map created after making P/R2 around Lake Beseka (refer to Figure 11.4.1). Lithological conditions of JICA wells were clarified by the chip sampling of drilling, so the columnar sections of JICA wells are able to correlate with the geology around Lake Beseka (refer to Figure 11.4.2 to Figure 11.4.4). Table 11.4.1 shows the results of geological interpretation for each existing well by using the geological map and the columnar section for each of the existing wells.

The depth of almost all existing wells around Lake Beseka was less than 70 m; the geological conditions of these existing wells can be correlated with the geology of JICA wells with depths less than 100 m. The geology of JICA wells more than 100 m deep was correlated with the results of a geological survey and geological map. Transmissivity and Specific capacity are shown in Table 11.4.1. The aquifer of each existing well is estimated in reference to the groundwater level and the depth of screen.

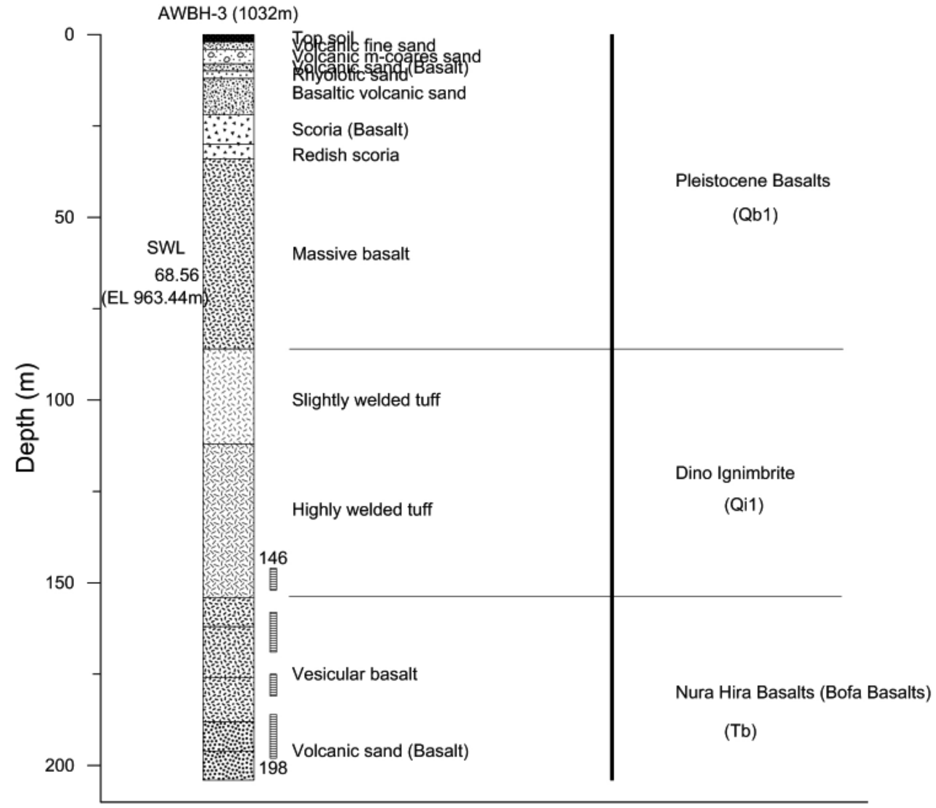
The groundwater flow was discussed around Lake Beseka by the two categories, using the existing wells of less than 100 m deep or more than 100 m deep because of the differences of groundwater level by the geology and depth of aquifer speculated. Figure 11.4.5 shows the groundwater level contour map for existing wells less than 100 m deep, and Figure 11.4.6 shows that of wells more than 100 m deep. The former shows a SW to NE flow direction, and the latter shows a south to north flow direction. There is a difference of groundwater flow by the aquifer depth. The aquifers are classified by the correlation with each geological layer, and the classification of aquifers was conducted and is shown in Table 11.4.2 in accordance with the Table 11.4.1.

As mentioned in Chapter 3, fluoride concentration in the water around Lake Beseka is high and exceeds the Ethiopian standard. There is no correlation between fluoride concentration and depth as Figure 11.4.7 shows.



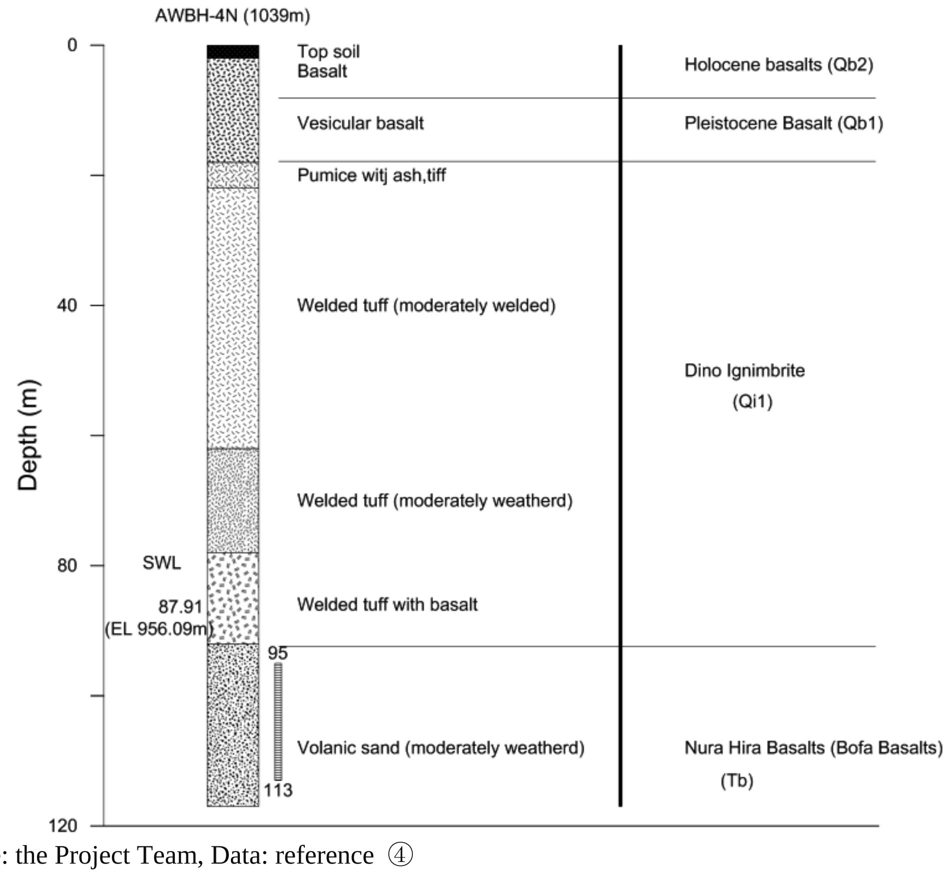
Source: the Project Team, Data: reference 1) & 4) of ① and ④

Figure 11.4.1: Geological Map, Existing Wells and JICA Wells around Lake Beseka



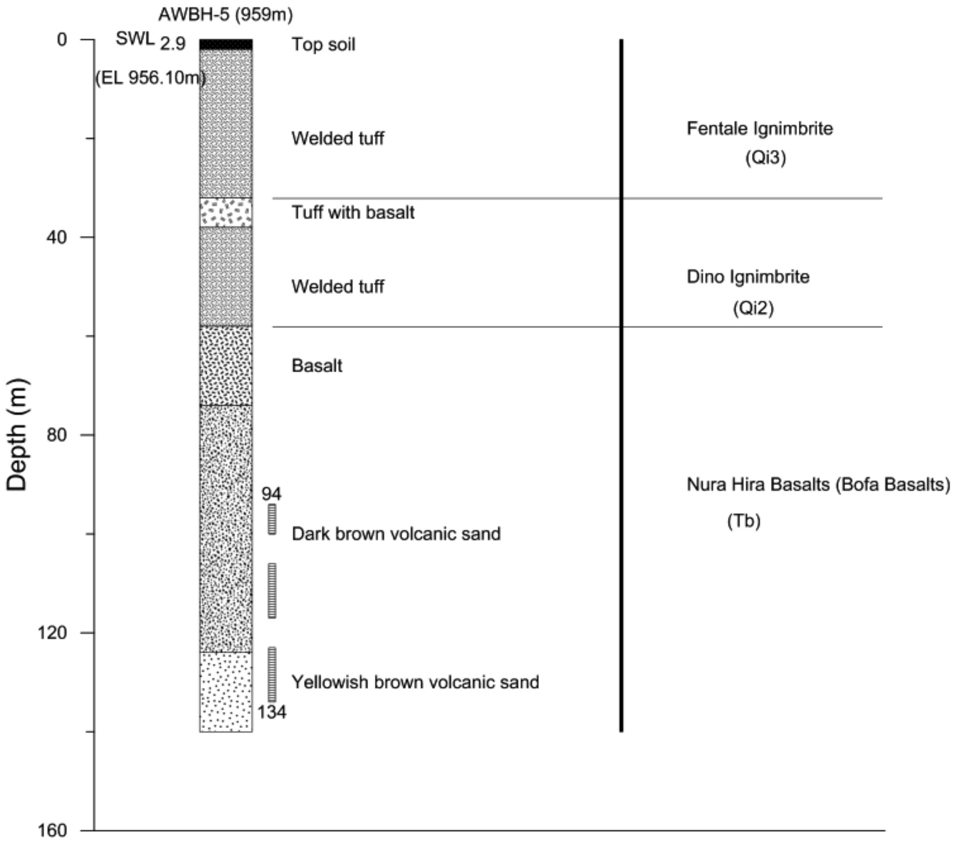
Source: the Project Team, Data: reference ④

Figure 11.4.2: Columnar Section of JICA Well (AW BH-3) and Geological Correlation



Source: the Project Team, Data: reference ④

Figure 11.4.3: Columnar Section of JICA Well (AW BH-4N) and Geological Correlation



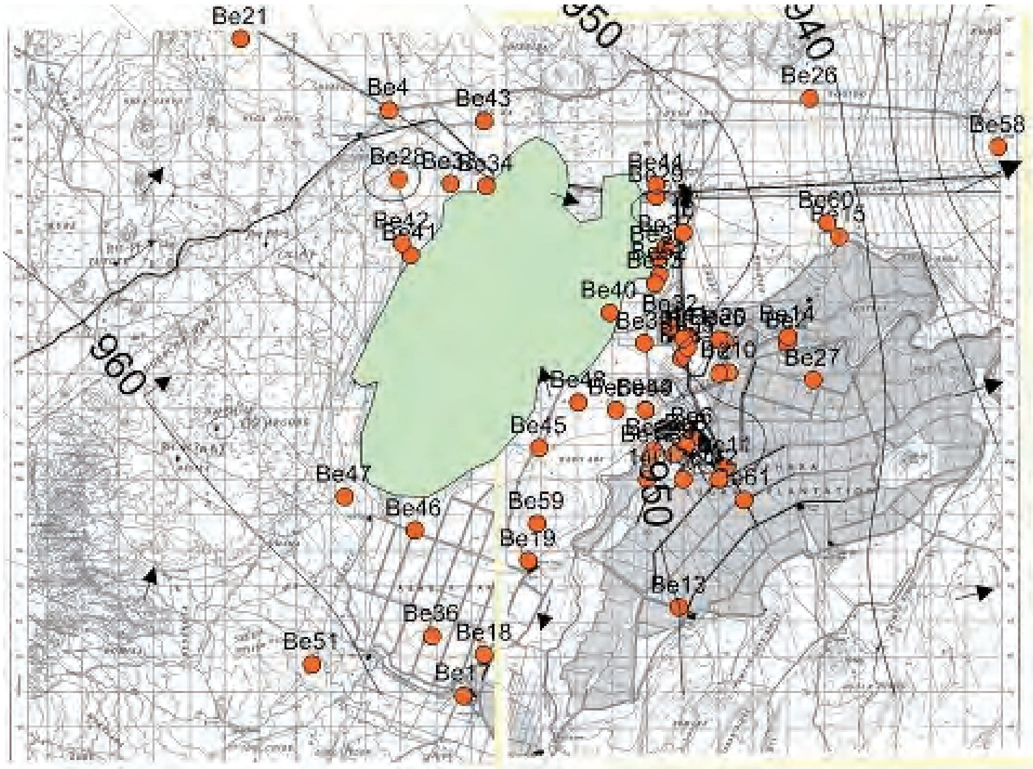
Source: the Project Team, Data: reference ④

Figure 11.4.4: Columnar Section of JICA Well (AW BH-5) and Geological Correlation

Table 11.4.1: Existing Wells and JICA Wells with Columnar Section around Lake Beseka

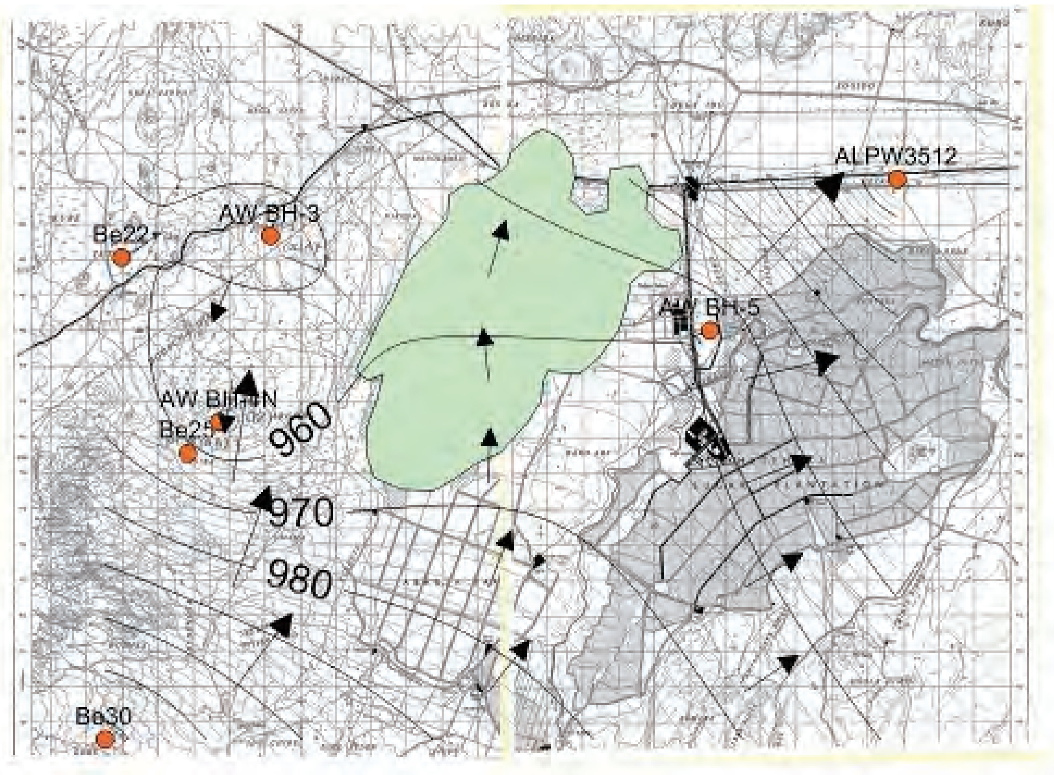
X	Y	No	H	SWL	GWL	GWL2010	Total D (m)	Q(L/sec)	Existing name	Top of Screen(m)	Top of Screen (Elevation)	T (m2/day)	Geology	Aquifer
592664	986463	Be4	981.29	30.94	950.35	953.09	53.3	-	BHI-02	29.3	951.99	8088	Geological map: Fentale Ignimbrite (Qi3), Lower part: Pleistocene basalt(Qb1)	Qb1
600048	976634	Be12	959	15.32	943.68	955.36	48	6.5	BHMR-20	12	947	965	Geological map: Alluvium, Lower part: Fentale Ignimbrite(Qi3)	Alluvium sand
605405	982881	Be15	949.8	6.15	943.65	945	30	4	BHG-32	15	934.8	60.4	Geological map: Alluvium, Lower part: Fentale Ignimbrite(Qi3)	Qi3
600305	982301	Be38	953.21	3.7	949.51	951.31	56	-	BH-59	-	-	-	Geological map: Alluvium, Lower part: Fentale Ignimbrite(Qi3)	Alluvium sand
599903	979853	Be39	953.93	4.43	949.5	951.3	50.65	-	BH-23	18.65	935.28	2681	Geological map: Fentale Ignimbrite(Qi3)	Qi3
598914	980723	Be40	953.02	3.24	949.78	951.58	30.24	-	BH-37	11	942.02	502	Geological map: Between Holocene basalt(Qb2) and Fentale Ignimbrite(Qi3), Columnar section: Fentale(Qi3)+Pleistocene basalt(Qb1)	Qi3
593035	982691	Be42	958.32	8.18	950.14	952.88	73	-	BH-50B	17.25	941.07	-	Geological map: Basalt & Scoria (Qb1), Lower part: Tuff (from 50m deep).Tuff belongs to Dino Ignimbrite(Qi1)	Qb1
595362	986153	Be43	973.83	23.16	950.67	953.42	59	-	BH-57	24	949.83	217.8	Geological map: FentaleIgnimbrite (Qi3). Columnar section is same lithology.	Qi3
600252	984352	Be44	958.93	8.62	950.31	951.91	50.5	-	BH-58	-	-	-	Geological map: Fentale Ignimbrite (Qi3)	Qi3
596921	976889	Be45	955.14	4.2	950.94	953.44	71.45	-	BH-63	-	-	-	Geological map: Basalt & Scoria (Qb1), Lower part: Tuff (from 50m deep).	Qb1
593389	974555	Be46	955.53	4.54	950.99	954.79	46.3	-	BH-62	-	-	-	Geological map: Alluvium (Depth to 17m), Lower part: Scoria, Basalt(Qb1), Tuff (from about 44m deep)	Qb1
591413	975520	Be47	959.35	7.7	951.65	955.35	29.45	-	BH-60	-	-	728	Geological map: Alluvium (Depth to 12m), Lower part: Tuff(Qi2)	Qi2(Fissure)
598043	978183	Be48	965.16	14.25	950.91	953.42	50.45	-	BH-66	28.75	936.41	189	Geological map: Basalt and Scoria (Qb1), to about 40m depth	Qb1
599118	977968	Be50	958.64	8.08	950.56	952.36	42.45	-	BH-64	-	-	-	Geological map: Basalt and Scoria (Qb1), and many tuff layers (Dino ignimbrite (Qi1) from 14m deep)	Qi1
600331	981811	Be52	953.42	3.65	949.77	951.57	44.45	-	BH-05	23	930.42	996	Geological map: Fentale Ignimbrite(Qi3)	Qi3のBreccia
580000	990000	7	1000	25	975	975	50.6	6.7	-	25	975	-	Geolgical map: Kone Ignimbrite (Qi2)	Qi2(Fissure)
601000	983000	10	1000	13.6	986.4	986.4	56	12	-	-	-	-	Geological map: Fentale Ignimbrite (Qi3), Depth to about 10m, Lower part: Basalt(Qb1)	Qb1
602000	979000	12	950	8.8	941.2	941.2	42.6	12	-	-	-	-	Geologicalmap: Alluvium deposit, Basalt(Holocene basalt)(Qb2), Lower part: Fentale Ignimbrite(Qi3)	Breccia (Qi3, fissure)
601000	980000	14	950	11.19	938.81	938.81	49.6	7	-	-	-	Sc: 3.1(l/sec/m)	Fentale Ignimbrite	Qi3
601000	976000	136	960	20.6	939.4	939.4	42	6	-	32	928	Sc: 0.6	Geological map: Alluvium, Lower part: Basalt(Qb1).	Qa
600000	976000	140	960	25.6	934.4	934.4	45	8	-	24.5	935.5	Sc: 2.3	Geological map: Alluvium, Lower part: Basalt(Qb1).	Qa
602000	976000	142	966	42.8	923.2	923.2	52	8	-	30	936	Sc: 4.7	Geological map: Alluvium, Lower part: Basalt(Qb1).	Qa+Qb1
606822	984277	ALPW3512	942	46.65	895.35	895.35	595	100	-	111.41	830.59	703, Sc:6.5	Qi3, Pleistocene basalt(Qb1), Dino Ignimbrite (Qi1), Bofa basalts (Tb3), Nazret G (Ti3), Alaji Basalt (Tb1)	Qi1, Basalt(Tb1)
589168	982673	AW BH-3	1032	68.56	963.44	963.44	204	6.3	-	158	874	-	Qb1(Pleistocene Basalt), Dino Ignimbrite, Bofa besalts	Bofa(Tb3)
587744	977436	AW BH-4N	1044	87.91	956.09	956.09	117	4.43	-	96	948	3.52	Qb2(Recent Basalt), Qb1, Dino Ignimbrite, Bofa basalts	Bofa (Tb3)
601567	980025	AW BH-5	959	2.90	956.10	956.10	140	7.6	-	94	865	-	Fentale Ignimbrite, Dino Ignimbrite, Bofa basalts	Bofa (Tb3)

Source: the Project Team, Data: reference 1), 4) of ①, 5) of ②and ④



Source: the Project Team, Data: reference 1) & 4) of ① and ④

Figure 11.4.5: Groundwater Level Contour Map around Lake Beseka (Less than 100 m depth of Existing Wells)



Source: the Project Team, Data: reference 1), 4) of ①, 5) of ②and ④

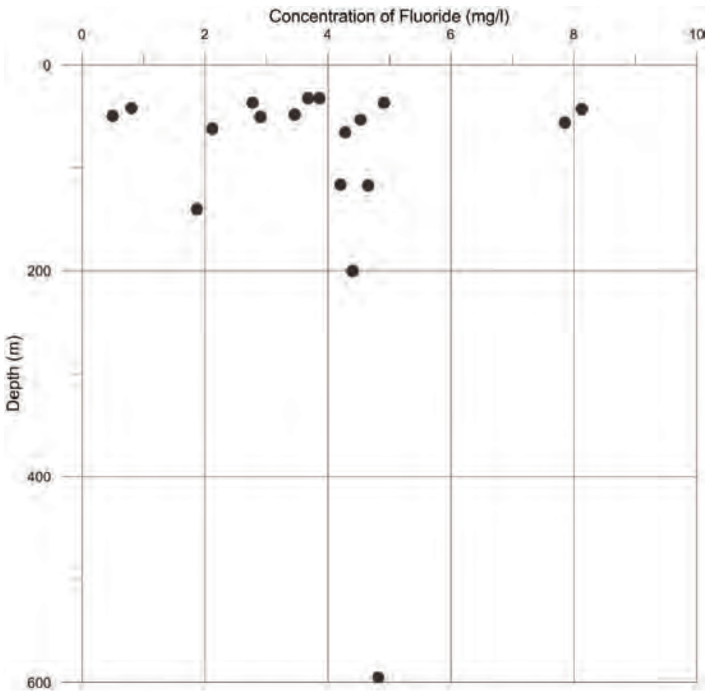
Figure 11.4.6: Groundwater Level Contour Map around Lake Beseka (More than 100 m depth of Existing Wells)

Table 11.4.2: Aquifer Unit Classification and Characteristics around Lake Beseka

Geologic age	Aquifer unit name	Code	Hydrogeological characteristics
Quaternary Pleistocene -Holocene	Holocene deposits	Qal (including Lacustrine deposits)	• Along the Awash River, alluvial sediment covers a small area. • The Alluvium around Lake Beseka consists of sand, mud and gravel, and the thickness of alluvium reaches about 11-40 m. Most of the boreholes in these areas have yield from 3 to7 L/sec.
	Recent Basalts	Qb2	• They are products of fissure eruption • They are highly vesicular, and can store an appreciable quantity (amount) of groundwater. • They are considered to have a high permeability. However it is difficult to predict whether or not an impermeable layer exists below.
	Fentale Ignimbrite	Qi3	• "Fentale Group of Ignimbrites (Qwi2)" shows different hydrogeological characteristics in different areas. • To the west and south of the Fentale volcano, this welded tuff is greyish green, fresh, columnar jointed with blisters and crevasses. So these fractures act as groundwater conducts, some existing boreholes have a yield of 7 L/sec. Such layers in this area have high permeability. • Depth of existing boreholes is 30-60 m. Although the yield data are limited, there is a record of 7 L/sec.
	Pleistocene Basalts	Qb1	• They are vertically and horizontally jointed. • Drawdown is small by the existing borehole and specific capacity is more than 7 L/sec/m in some areas. Other yields are 1.4 and 1.6 L/sec respectively. • The basalt layer occurs at 50 m to 70 m depth of the existing wells around Lake Beseka. The record of yield is sparse, but there are partial records of 8 to 12 L/sec. • Therefore, these groups of basalt are considered to have moderate permeability.
	Dino Ignimbrite	Qi1	• "Dino Ignimbrites (Qwi)" corresponded to this layer are jointed and faulted. • Yield data from existing boreholes are limited around Lake Beseka. • Although there is a layer correlate with Dino in JICA well, the groundwater was taken from the lower layers. • According to the information in other area, the average of specific capacity of the existing well gives 2.2 L/sec/m. It is grouped as moderately permeable formation. The average of the yield indicates more than 6 L/sec.
Tertiary Pliocene	Nura Hira Basalts	Tb (correlate with Bofa baslts)	• Columnar jointing is very well developed with openings of 2-3 cm joints and a distance of 1 m between joints in the outcrop. • There are no outcrops around Lake Beseka, but JICA wells correlated with the Bofa horizon, the yield ranges from 6 to 11 L/sec and specific capacity is 0.15 to 9.3 L/sec/m. • In general Bofa basalts are expected to have high to medium permeability.
	Older Ignimbrite	Ti (correlate with upper Naret Pyroclastic deposits)	• "Nazret Group of Ignimbrites (Nn)" shows variable permeability in different areas. • Geology consists of Ignimbrites, welded tuffs, ash flows, rhyolites and tuffs. • The group to the northeast of Melka Jilo and north of Kone Caldera is jointed and faulted and a borehole drilled in this formation has a yield of 6.7 L/sec. • The average yield is 15 L/sec as a whole, specific capacity is more than 2 L/sec/m. There are highly productive areas in the Study

Geologic age	Aquifer unit name	Code	Hydrogeological characteristics
			area. • In the other areas, they predominantly consist of ash flow and tuff, and bore holes drilled in this formation have low yields according to the information.
	Birenti-Hada Rhyolites	Tr (correlate with Pliocene rhyolite)	• Mainly consists of rhyolites with pumice tuff. • They are generally grouped as formations of middle permeability by fractured aspects.

Source: the Project Team, Data: reference 1), 4) of ① and ④



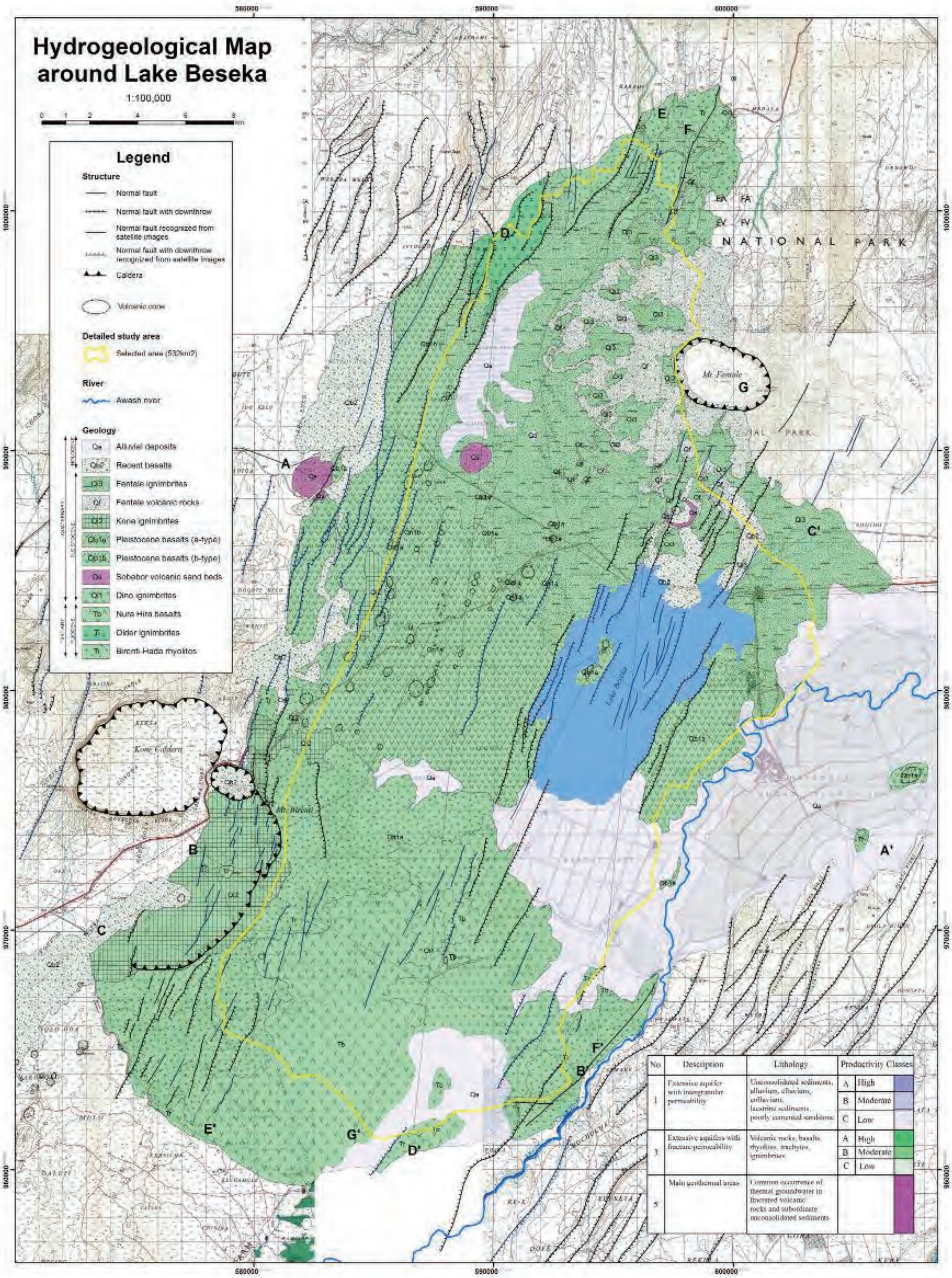
Source: the Project Team, Data: reference 1), 4) of ①, 5) of ②and ④

Figure 11.4.7: Well Depth and Fluoride Concentration around Lake Beseka

11.4.2 Hydrogeological map and cross-sections

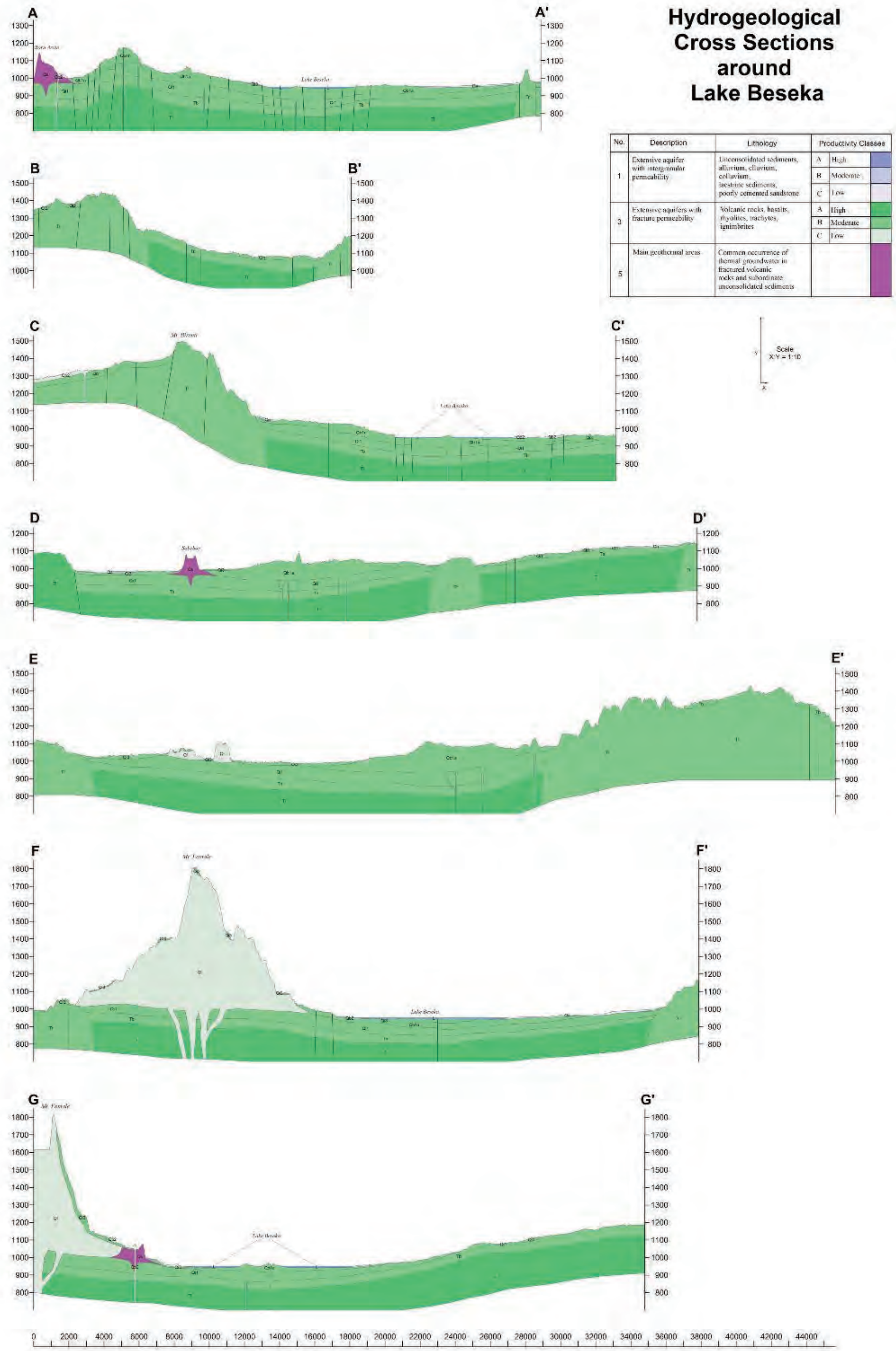
Aquifer units in the Middle Awash river basin were classified based on the existing information in Ethiopia such as a hydrogeological map with scale of 1:2,000,000 prepared by GSE (aquifer unit classification and definitions). The productivity of aquifer units were estimated through the aquifer information obtained on the hydrogeological survey in this Project. Based on these units, a hydrogeological map and cross-sections were prepared for the Middle Awash river basin. The hydrogeological map and cross-sections for the Lake Beseka area were then prepared referring to the geological survey results for the Lake Beseka area as shown below.

Most of the aquifer units distributed in the surface area, except for the surrounding area of the Mt. Fentale, are considered to have medium permeability, and these reach up to around 150 m in depth. In the deeper area than this, pyroclastic deposits of Tertiary Pliocene are distributed and the aquifer unit in this area is considered to have high productivity.



Source: the Project Team, Data: reference 1), 4) of ①, ④and⑬

Figure 11.4.8: Hydrogeological Map around Lake Beseka



Source: the Project Team, Data: reference 1), 4) of ①, ④and⑬

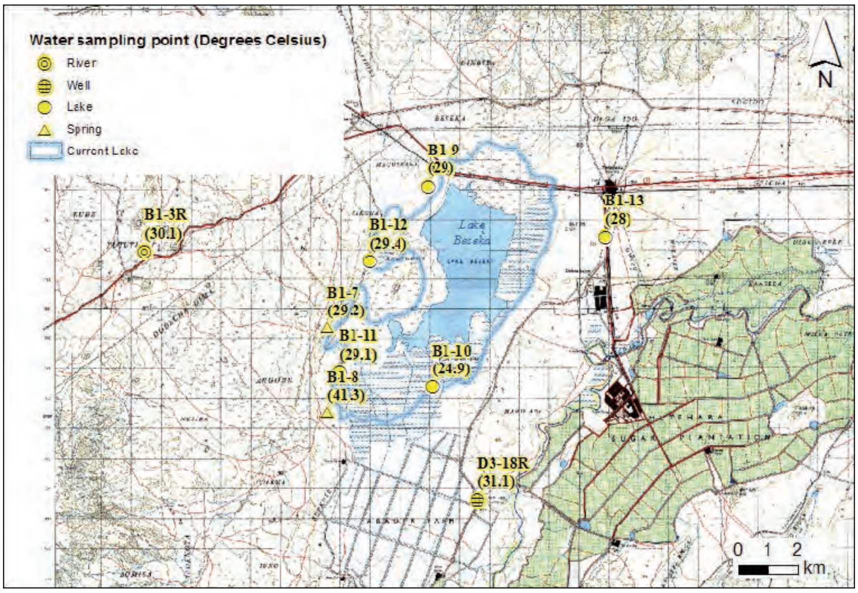
Figure 11.4.9: Hydrogeological Section around Lake Beseka

11.5 Inflow situation of springs and irrigation water

11.5.1 Ageing of spring inflow by satellite image analysis

a. Background and Objective

Figure 11.5.1 shows the current boundary of Lake Beseka and the result of water sampling on a topographic map from 1975. The numbers inside the brackets at each of the sampling points show the temperature of the water samples. From this figure, high temperature springs (hot springs) can be confirmed at the west side of Lake Beseka.



Source: the Project Team, Data: Result of survey in this Project

Figure 11.5.1: Result of Water Temperature Study around Lake Beseka

There are two types of water which are likely to flow into Lake Beseka:

A) High temperature groundwater from the west side of the lake
B) Excess water discharged from Abadir irrigation area etc.

There might be a clue on the cause of surface expansion in Lake Beseka if the changes in the surface temperature of the lake can be traced for the past years. However, there is no past continuous record of surface temperature measurements in Lake Beseka Therefore, satellite images have been utilized to estimate the changes of surface temperatures over the past few years.

The surface temperature of Lake Beseka will be calculated using the Landsat data from various years.

b. Data and method of analysis

The satellite data used in the analysis are shown in Table 11.5.1. Also, the flow of the analysis is shown in Figure 11.5.2.

Table 11.5.1: Data used for the Analysis

No.	Satellite	Date of acquisition
1	Landsat 5	21st January 1986
2	Landsat 5	13th December 1994
3	Landsat 5	30th January 1995
4	Landsat 5	24th December 1998
5	Landsat 5	25th January 1999
6	Landsat 5	27th December 1999
7	Landsat 5	6th December 2009
8	Landsat 5	9th December 2010

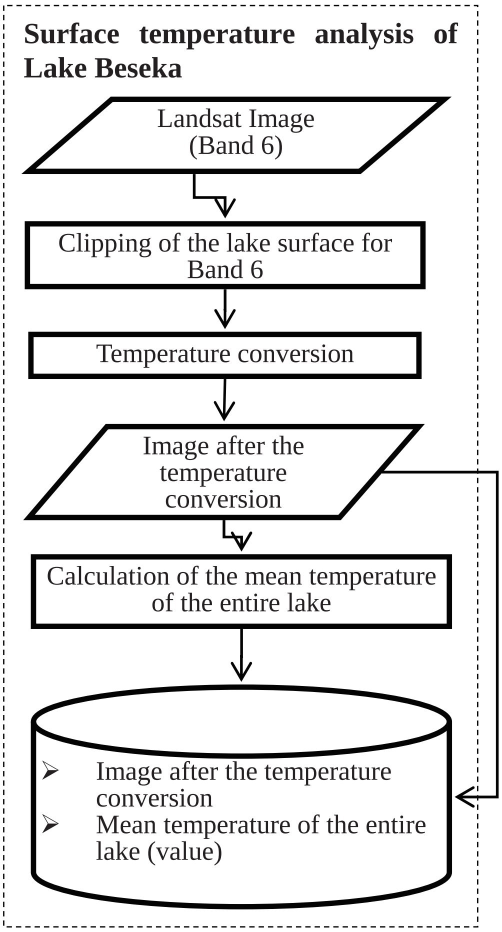
Source: the Project Team

There are some advantages of utilizing the Landsat data as mentioned below:

- Thermal Infrared (TIR) data from Landsat can be used to estimate the surface temperature of the lake
- Landsat has been operating since the 1970's and provides relatively old data compared to the other satellite data
- The spatial resolution of TIR (30 m) is sufficient to analyze the surface of the lake
- The Landsat data can be obtained free of charge

The data above has been selected/acquired from the archive of United States Geological Survey (http://earthexplorer.usgs.gov/). The selection of which took into consideration the points below:

- No clouds above Lake Beseka
- No noise or error in the data
- Standardized observation period: Data from December and January (dry season and less clouds) have been selected in this analysis.
- Thermal Infrared (TIR) data of Band 6 (around 0.701 - 0.833 μm) which was acquired from the Thematic Mapper (TM) sensor for the analysis of surface temperatures
- The data taken from the same sensor (TM) of the Landsat 5 were used to avoid the analysis error

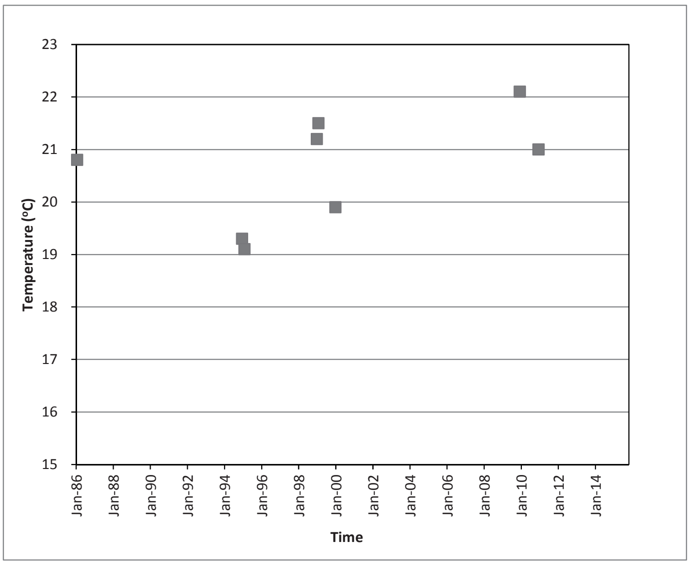


Source: the Project Team

Figure 11.5.2: The Analysis Flow of Surface Temperature using Landsat Data

c. Result of analysis

The surface temperature (average of the entire lake surface) of Lake Beseka for each scene are as follows.



Source: the Project Team, Data: Result of analysis in this Project

Figure 11.5.3: Changes of Surface Temperature in Lake Beseka

From the figure above, no obvious trends are found in the surface temperature of the lake due to the reasons mentioned below;

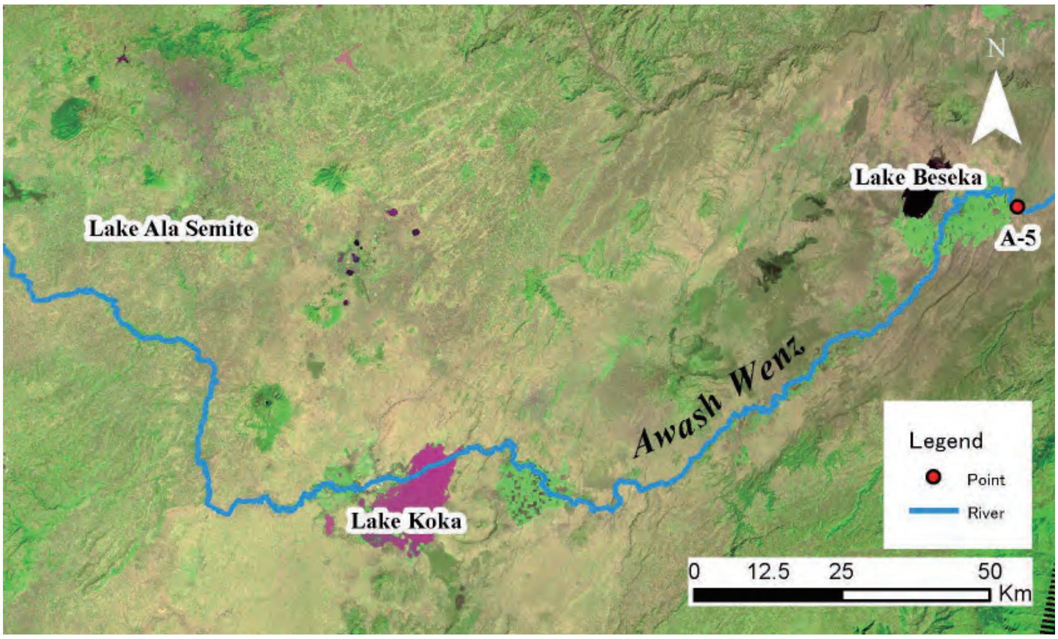
- Error caused by the atmospheric noise, etc.
- The surface temperature of the Landsat data is estimated by converting the surface brightness (not an actual surface temperature)

Therefore, the result of the analysis needs to go through the calibration process to obtain a more accurate result. However, the calibration process could not be undertaken since there is no continuous record of surface temperatures for Lake Beseka in the past.

Since it is problematic to compare the actual measured temperature and the result of the analysis, another analysis has been undertaken to find the trends of the surface temperature of Lake Beseka.

- Area: Lake Koka and the Awash River around the Abadir irrigation farm (Figure 11.5.4)
- Method: Same method as the analysis of Lake Beseka
- Data: Same data which was used in the analysis of Lake Beseka (= same date)

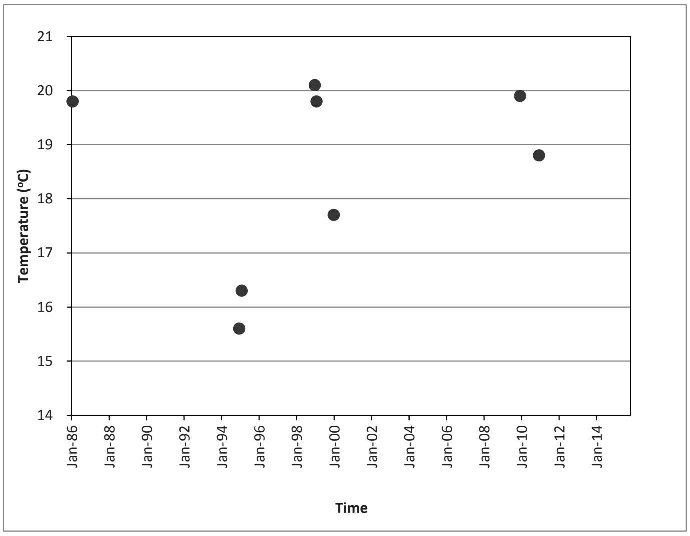
The same coordinates of the actual sampling point (A-5) in this study were used for the point along the Awash River around the Abadir irrigation farm



Source: the Project Team

Figure 11.5.4: Location of Lake Beseka, Lake Koka and the sampling point on the Awash

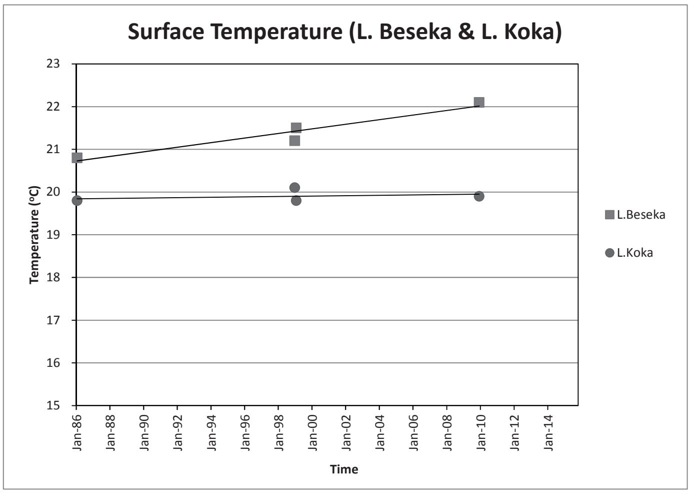
The changes in Lake Koka are shown in Figure 11.5.5. The result of the analysis was the same as Lake Beseka, which showed the surface temperature of the lake scattering over previous years and no obvious trend was found from the graph. On the other hand, the origin of Lake Koka is the Awash River and the annual temperature cycle is almost equal, which means the actual surface temperature from December to January must also be stable



Source: the Project Team, Data: Result of analysis in this Project

Figure 11.5.5: Changes of Surface Temperatures in Lake Koka

Therefore, four scenes (1986/1/21, 1998/12/24, 1999/1/25, 2009/12/6) of Lake Koka which are relatively stable around 20 °C, were selected to be compared with Lake Beseka.

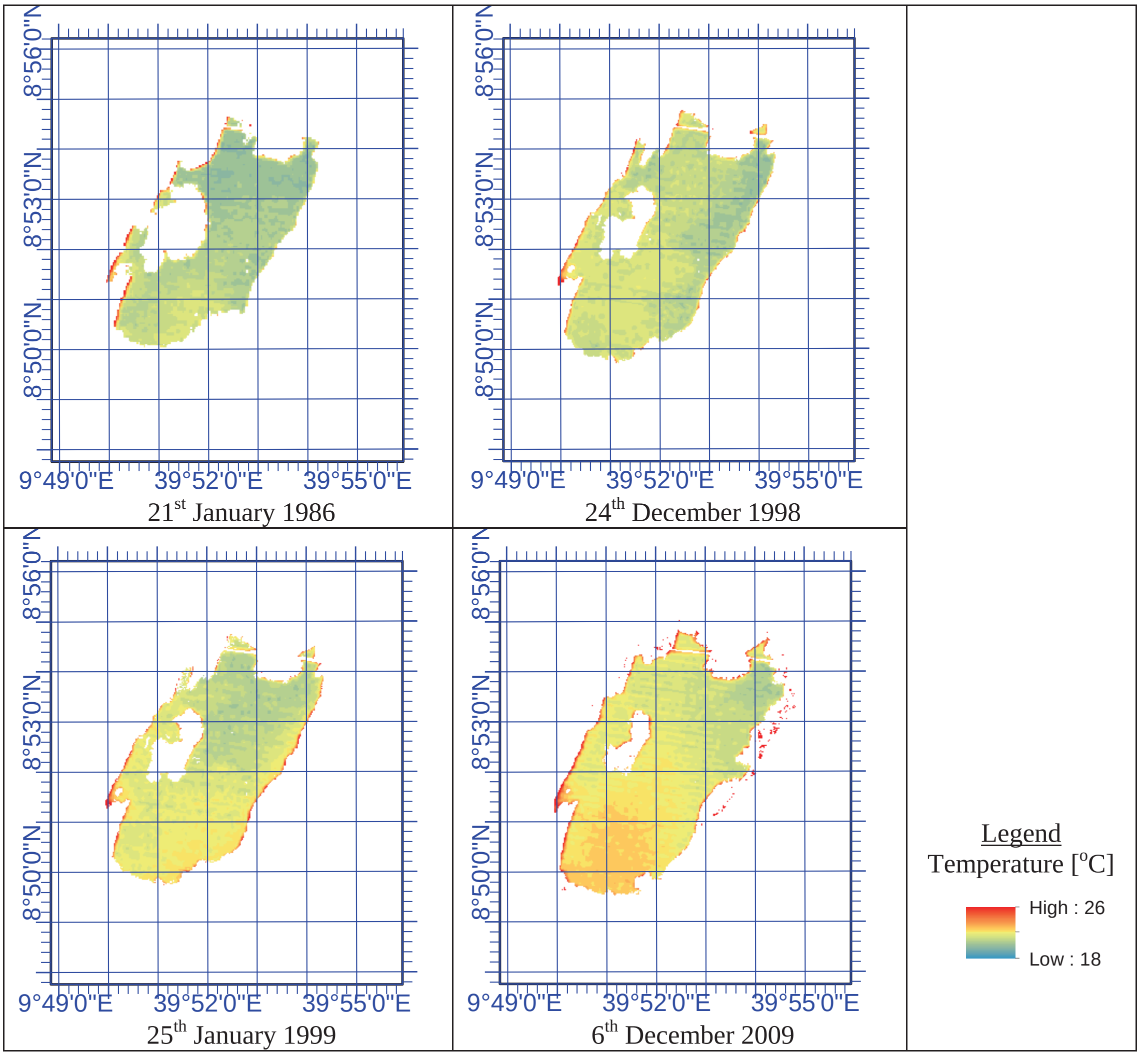


Source: the Project Team, Data: Result of analysis in this Project

Figure 11.5.6: Comparison of Surface Temperatures between Lake Beseka and Lake Koka

The surface temperature of Lake Beseka is higher than Lake Koka as shown in the figure above. In addition, the surface temperature of Lake Beseka seems to be in rising trend. It is conceivable that the inflow of the high temperature spring from the west side of Lake Beseka is causing the increase in the lake's surface temperature.

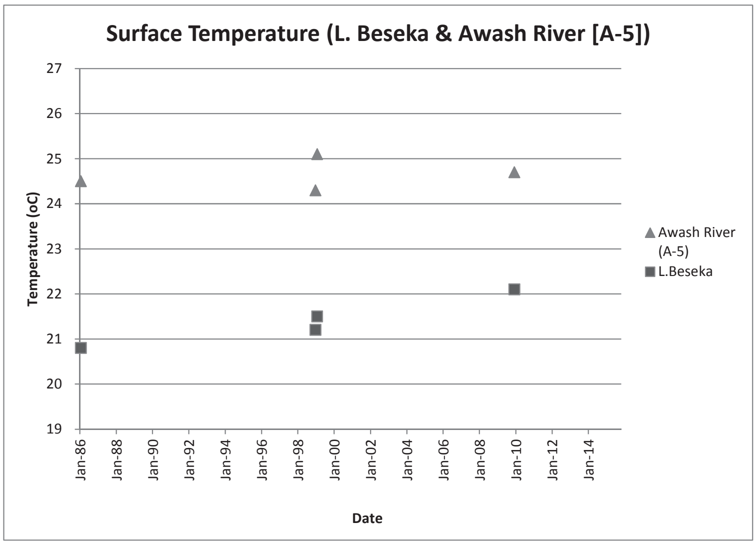
The figure below shows the surface temperature distribution of the four scenes in Lake Beseka. It is clear that the surface temperature at the west side of the lake is higher than the other areas.



Source: the Project Team, Data: Result of analysis in this Project

Figure 11.5.7: Surface Temperature Distribution of Lake Beseka

Figure 11.5.8 shows the surface temperature of Lake Beseka and the Awash River around the Abadir irrigation farm for the same four scenes (1986/1/21, 1998/12/24, 1999/1/25, 2009/12/6) as the above. The figure shows that the temperature of the Awash River is constantly higher (24 - 25 °C) than the surface temperature of Lake Beseka. Therefore, it can also be interpreted that the expansion of Lake Beseka was caused by the massive inflow from the irrigation water provided that the detected temperature values are accurate enough.



Source: the Project Team, Data: Result of analysis in this Project

Figure 11.5.8: Surface Temperature of the Awash around Abadir Farm and Lake Beseka

d. Discussion

Although only a limited number of scenes were used for the analysis, it is conceivable that the surface temperature of Lake Beseka has been increasing over the previous years as the surface temperature of Lake Koka was stable in the same scenes. This means, there is no contradiction in the theory of the increase in the surface temperature caused by the inflow of the hot spring from the west side of the lake since the lake volume was also expanding during this period.

However, there are limits in this analysis and the result cannot be directly linked to a specific cause.

- The number of scenes used for the analysis was small and it does not absolutely prove the increasing trend of the surface temperature of Lake Beseka.
- Even if the increasing trend of the lake is proven, there is still a possibility of inflow caused by the water from the river (irrigation water) if the temperature of Lake Beseka was somehow lower than the river when the lake and the river were not connected by the irrigation farm.

Actual temperature measurements were taken during the water quality survey for this Project. The thermometer measurement results of Lake Beseka, Lake Koka and the Awash River are shown in Table 11.5.2.

Table 11.5.2: Temperature Result during the Water Quality Survey (9th March 2014)

Point	Temperature	Remarks
Lake Beseka	28.3 ^{o}C	Arithmetical average of six points at the lake
Tone spring	41.3 ^{o}C	Spring at the west bank of Lake Beseka
Awash River (East side of Metehara Plantation)	25.1 ^{o}C	Point A-5 of Figure 11.5.4
Lake Koka	21.3 ^{o}C	Data of a point at the lake

Source: the Project Team, Data: Result of survey in this Project

The table above shows that the temperature of Lake Beseka is higher than the Awash River, which means the theory that Lake Beseka's increase in surface temperature is caused by the inflow of hot springs is more rational.

Hence, the considerations mentioned below will be necessary in the future to investigate the cause of the expansion of Lake Beseka from the point of view of temperature.

- Continuously monitoring of the temperature at Lake Beseka and Awash River.
- The temperature in Table 11.5.2 was measured on 9th March 2014 and it shows that the surface temperature of Lake Beseka is affected by the inflow of the hot spring. Of course caution is needed when making such a simple interpretation as other factors such as solar radiation and atmospheric temperature increases are also likely to play a role in the high surface temperature of Lake Beseka. However, further discussion can be made by continuously acquiring such data.

11.5.2 Results of water quality testing

The water quality testing around Lake Beseka was carried out for the purpose of understanding the recent inflow conditions from the surrounding area to Lake Beseka. The testing involved comparing the water quality of Lake Beseka with that of wells, springs, and river & irrigation water. As mentioned in the second phase, the water quality of water resources around Lake Beseka have specific properties compared to the other areas in terms of the main seven ions and fluoride concentration. The sampling points around Lake Beseka conducted by the Study team are shown in Table 11.5.3. Moreover, the existing water quality data around Lake Beseka is utilized as the reference data (refer to Table 11.5.4).

Table 11.5.3: List of Sampling Points around Lake Beseka

Zone or Region	Detailed Place	Type of Water Sources	Number of Sampling Points		SL. No.	Location ID (Sample ID)	Reference Coordinate		Remarks
			For Physio-chemical Analysis	For Isotope Analysis			Easting	Northing	
East Shewa	Around Lake Besaka	Awash River Water	1	0		B1-2R	587,951	968,181	From BH-53 to River/Canal
		Existing Well	1	0		B1-4	604,677	978,810	From BHM-12 to R28
		Existing Well	1	0		B1-5	604,309	975,247	From BH-41to M21
		Existing Well	1	0		B1-6	601,234	972,270	From BH-64 to L11
	Near the Tone spring	Spring	1	0		B1-7	591,607	979,363	Lake water?
	Spring of Southwest Side of Lake Besaka	Spring	1	0		B1-8	591,608	976,552	
	North-western part of the Lake Besaka	Lake Besaka Water	1	0		B1-9	594,960	984,098	
	South-eastern part of the Lake Besaka	Lake Besaka Water	1	0		B1-10	595,100	977,400	Same point with suggestion
	South-western part of the Lake Besaka	Lake Besaka Water	1	0		B1-11	592,000	977,900	Same point with suggestion
	Central-western part of the Lake Besaka	Lake Besaka Water	1	0		B1-12	593,000	981,600	Same point with suggestion
	Drainage Channel of Lake Besaka	Lake Besaka Water	1	0		B1-13	600,905	982,406	Lake outlet
	Along Wast of Lake Beseka	Spring	1	1		B1-14	592,612	981,509	
	In Metehara Plantation	Awash River Water	1	1		B1-15	598,077	972,974	
	From Nura Hera Farm	Awash River Water	1	1		B1-16	592,729	967,092	Irrigation water
	Middle Awash River	Awash River Water	1	1		B1-17	596,078	965,762	River intake point
	Metehara SP	Awash River Water	1	1		B1-18	601,502	978,505	
	South of Lake Besaka	Lake Besaka Water	1	1		B1-19	595,246	975,723	
	Tone Spring	Spring	1	1		B1-20	591,674	978,734	
	Around Lake Besaka (AW BH-3)	New Well	1	1		E1-1	589,167	982,682	
	Around Lake Besaka (AW BH-4N)	New Well	1	1		E1-2	587,754	977,437	
	Around Lake Besaka (AW BH-5)	New Well	1	1		E1-3	601,565	980,024	
	West of Lake Beseka	Lake Water	1	1		B1-21	592,146	980,409	
	West of Lake Beseka	Spring	1	1		B1-22	591,536	979,199	
	West of Lake Beseka	Lake Water	1	1		B1-23	591,532	979,193	
	South of Lake Beseka	Lake Water	1	1		B1-24	593,045	975,249	
	South of Lake Beseka	Lake Water+Irrigation	1	1		B1-25	593,044	975,228	
	South of Lake Beseka	Lake Water	1	1		B1-26	594,247	974,998	
	South of Lake Beseka	Irrigation Water	1	1		B1-27	593,243	972,517	
	East of Lake Beseka	Lake Water	1	1		B1-28	598,897	980,437	
	East of Lake Beseka	Lake Water	1	1		B1-29	596,741	978,173	
	East of Lake Beseka	Lake Water	1	1		B1-30	598,698	984,130	
			31	**20**					

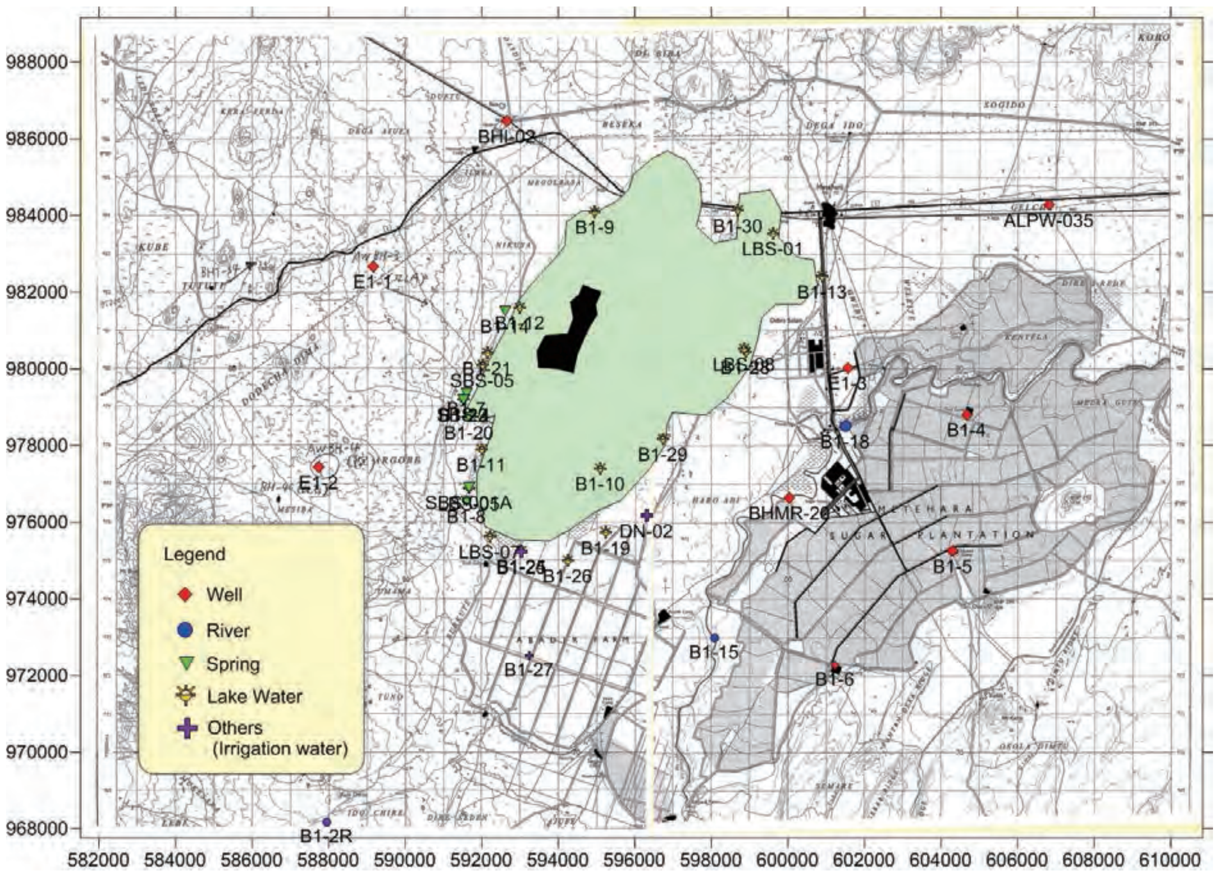
Source: the Project Team, Data: reference ④

Table 11.5.4: List of Existing Water Quality Data (around Lake Beseka)

Code	Easting	Northing	Resource	Remarks
LBS-01	599,618	983,534	Lake water	North East of Lake Beseka
LBS-08	598,860	980,515	Lake water	East of Lake Beseka
DN-02	596,308	976,168	Irrigation	South East of Lake Beseka
LBS-07	592,218	975,624	Lake water	South of Lake Beseka
LBS-05	591,670	976,881	Lake water	South West of Lake Beseka
SBS-4	591,533	979,204	Hot spring	West of Lake Beseka
SBS-05	592,019	980,096	Lake water	West of Lake Beseka
SBS-001A	591,669	976,913	Hot spring	South West of Lake Beseka
ALPW-035	606,822	984,277	Existing well	Depth; 595m (WWDSE,2015)
BHMR-20	600,048	976,634	Existing well	Same to Be12, Depth;48m
BHI-02	592,664	986,463	Existing well	Same to Be4, Depth; 53m

Source: the Project Team, Data: reference 4) of ①, 5) of ②

The sampling points and existing water quality testing points are shown in Figure 11.5.9.



Source: the Project Team, Data: reference ④

Figure 11.5.9: Location Map of Water Quality Testing Points around Lake Beseka

a. Characteristic of water quality by Trilinear Diagram

The results of the water quality testing around Lake Beseka are seen in the annex of this chapter. The Trilinear Diagram is shown in Figure 11.5.10 using the main ions. Figure 11.5.10 shows the following results and interpretations.

- The river and irrigation water (this canal water is classed as “others”) belong to the

$CaHCO_3$ type of water quality, and shows the same behaviour as surface water. Irrigation water sampled near Lake Beseka indicates a $NaHCO_3$ type due to the effects of Lake water.

- Both existing and JICA wells around Lake Beseka have been located in the west and east of Lake Beseka, and the depth of each well is different. However, with the exception of a few wells, those wells belong to the $NaHCO_3$ type of retarded deep groundwater. In the Trilinear Diagram, one well is plotted at a range of shallow groundwater by the effect of the shallow well, and a well belong to the Na_2SO_4 type containing the SO_4 and Cl ions. The water quality of the groundwater of each well is not affected by Lake Beseka's water because the water quality of both existing and JICA wells do not change as a whole even if the location of each well is different.

- The (hot) springs are located in the west and south west of Lake Beseka. It is difficult to find out the accurate points of the springs in the current situation because the springs have been submerged under the Lake. However it can be assumed to spring the groundwater along the flow line from the west and south west of Lake Beseka based on the groundwater level contour map as mentioned above. The characteristic of the springs belongs to the same type of both existing and JICA wells plotted in the $NaHCO_3$ type.

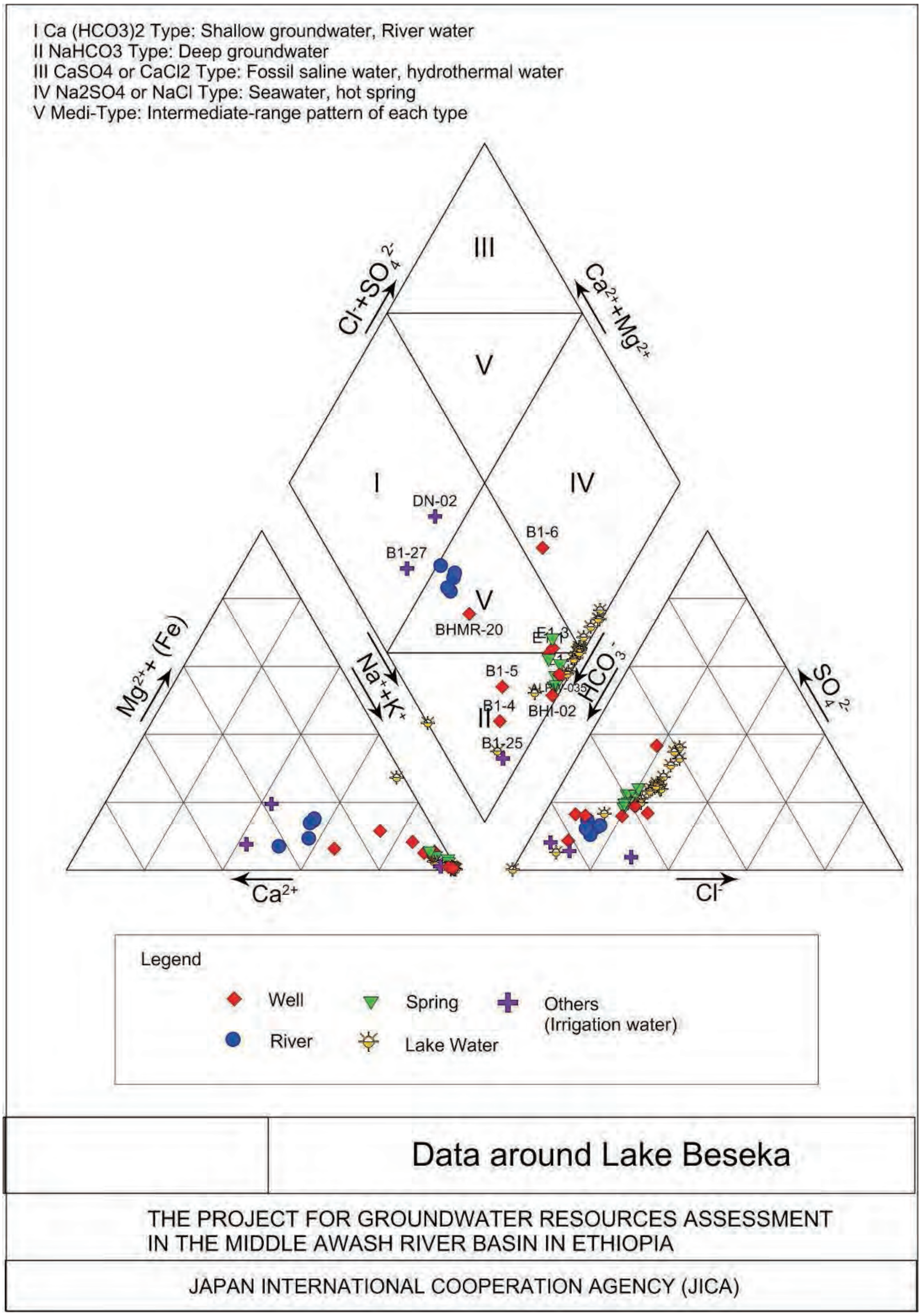
- The lake water shows the $NaHCO_3$ and Na_2SO_4 or NaCl types in the Trilinear Diagram, and the water quality of the lake water has the retarded deep groundwater characteristics as well as hot spring characteristics (near the component of the sea water). The lake water is affected by the spring, clearly having the same component. In other words, according to the assortment of the main ions, the water quality of the lake water is directly affected by the groundwater and spring.

- The change of anion and cation appears like the trace below in response to the retarded time and flow distance of the groundwater. This is generally called "the water quality evolution of the groundwater".

  Anion: $HCO_3^- \rightarrow HCO_3^- + SO_4^{2-} \rightarrow SO_4^{2-} + HCO_3^- \rightarrow SO_4^{2-} + Cl^- \rightarrow Cl^- + SO_4^{2-} \rightarrow Cl^-$

  Cation: $Ca^{2+} \rightarrow Ca^{2+} + Na^+ \rightarrow Na^+$

  In the Trilinear Diagram, the type of the water quality is changed from I to II and IV. This is the change of the water quality of the groundwater in accordance with the retarded time, and Figure 11.5.10 shows the change of ion from river water to spring and lake water. The river water is plotted near I type, the groundwater and spring is plotted in II type and almost all of the lake water belongs to the IV type. In other words, the lake water is strongly affected by the water quality of the groundwater and spring compared to that of river and irrigation water.

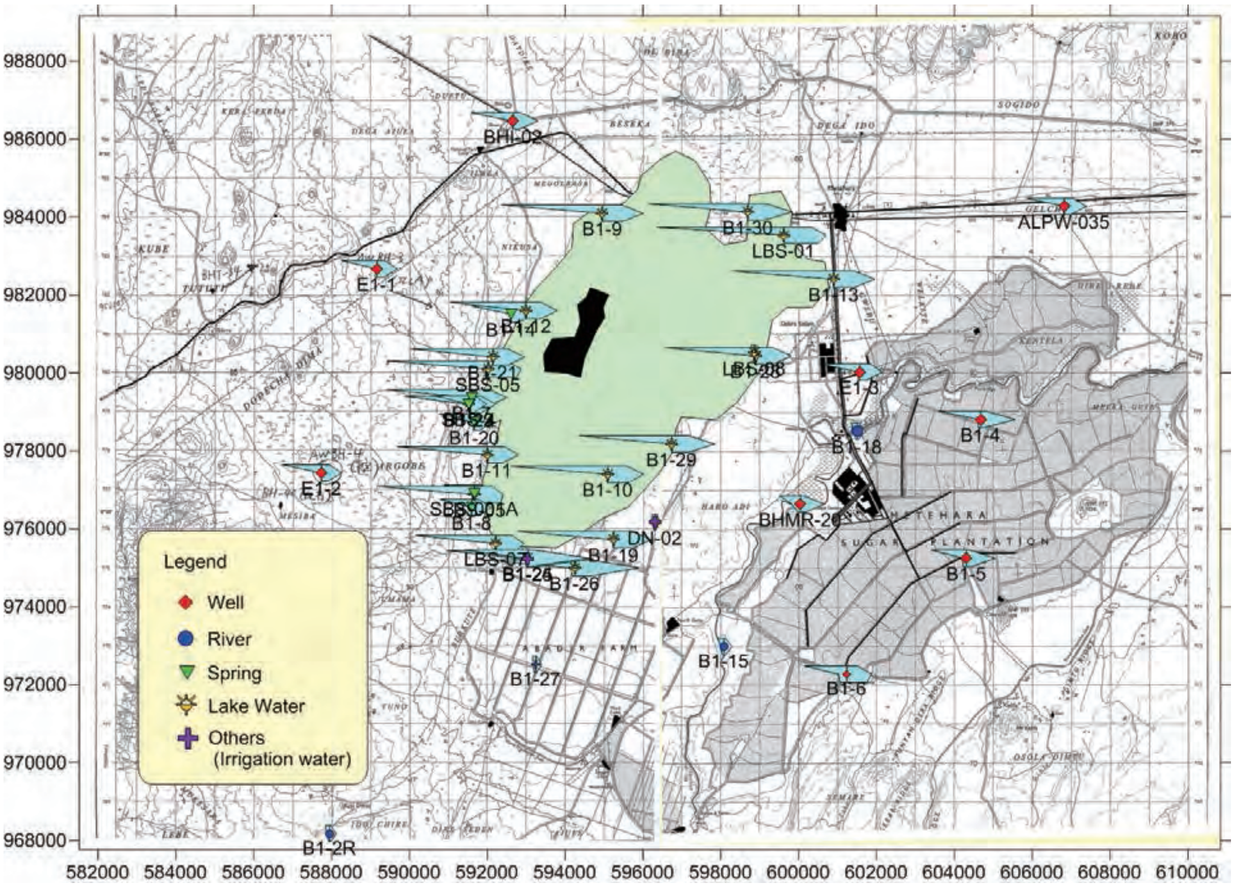


Source: the Project Team, Data: reference ④

Figure 11.5.10: Trilinear Diagram around Lake Beseka

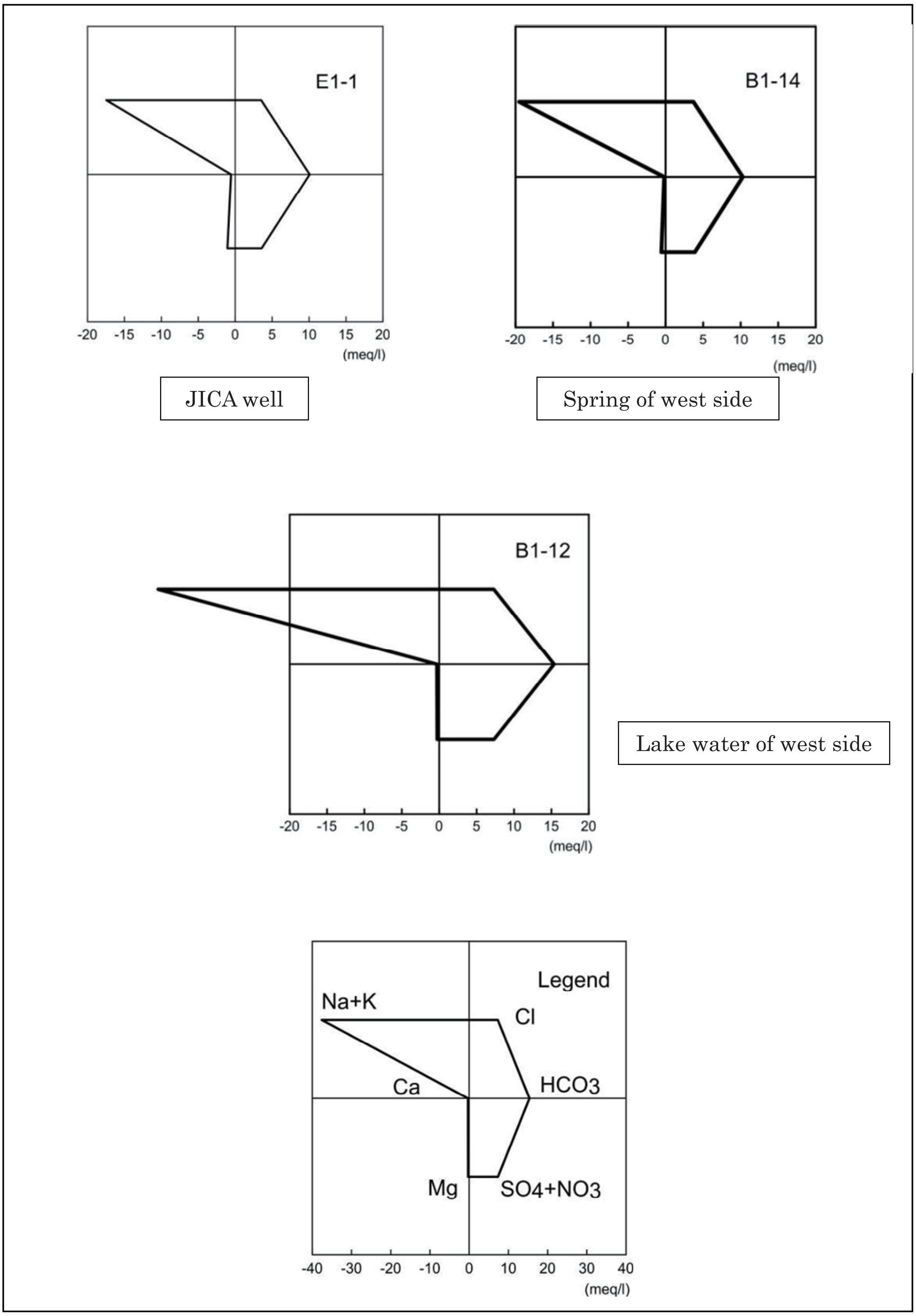
b. Characteristic of water quality by hexadiagram

The hexadiagram contains concentration information and total salinity weight, and can be used to represent water quality visually as mentioned in Chapter 2. The sampling points and existing data points with the hexadiagram are shown in Figure 11.5.11. The hexadiagrams at points of west to south west and south of Lake Beseka having possibilities for inflow into Lake Beseka from its surrounding area are shown in Figure 11.5.12, Figure 11.5.13 and Figure 11.5.14, respectively.



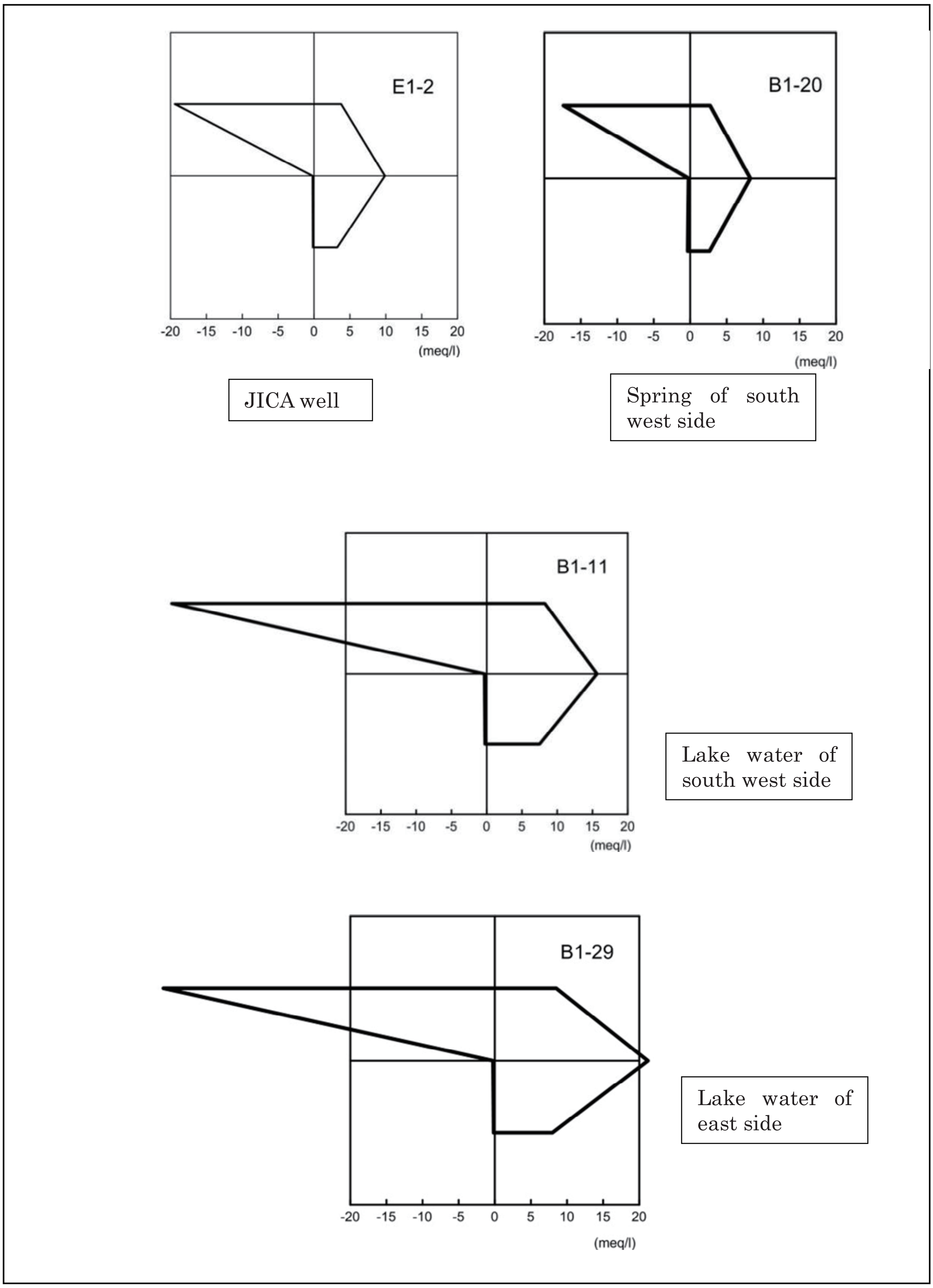
Source: the Project Team, Data: reference ④

Figure 11.5.11: Hexadiagram at Sampling Points around Lake Beseka



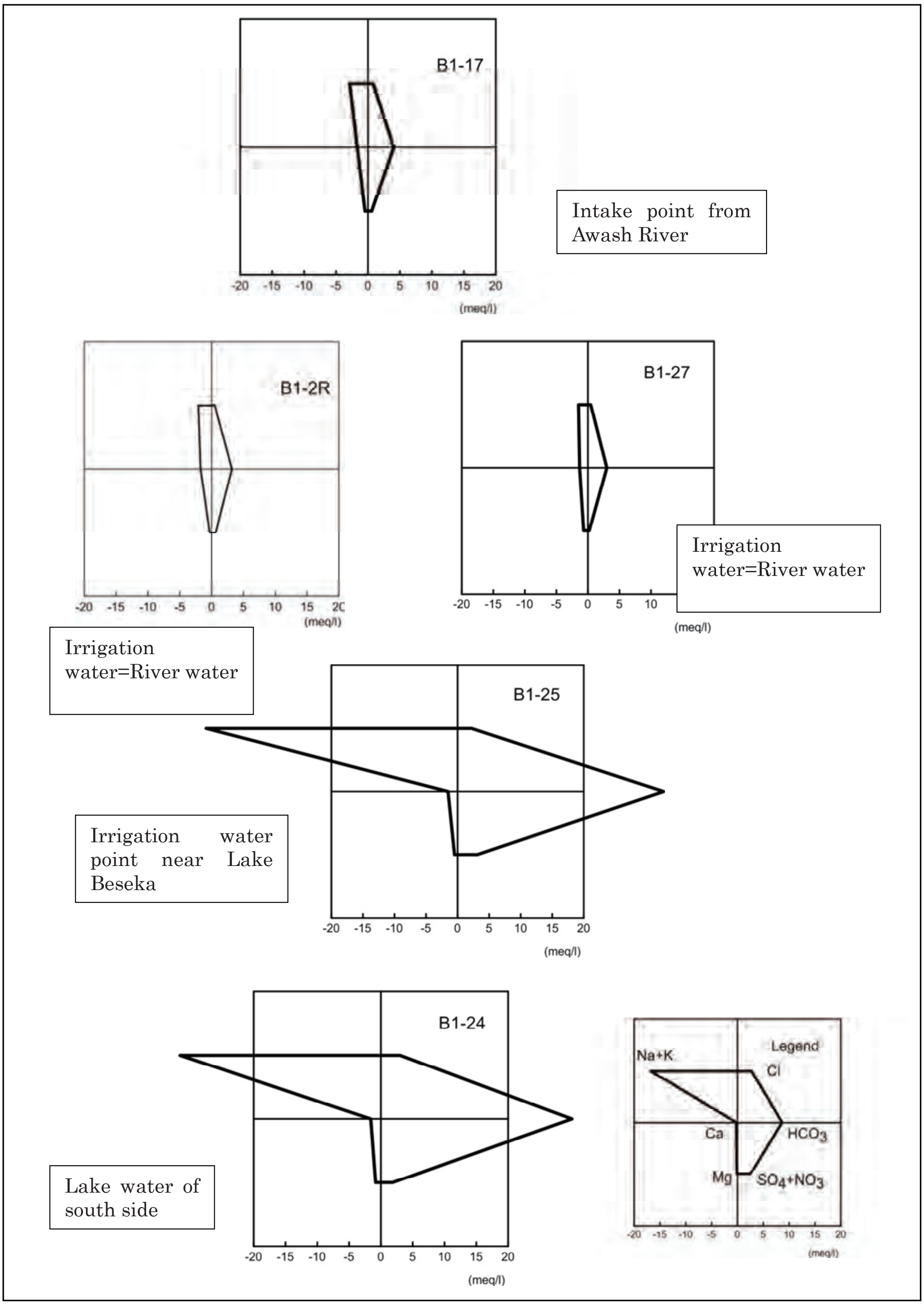
Source: the Project Team, Data: reference ④

Figure 11.5.12: Hexadiagram of Main Sampling Points at West of Lake Beseka



Source: the Project Team, Data: reference ④

Figure 11.5.13: Hexadiagram of Main Sampling Points at South West of Lake Beseka



Source: the Project Team, Data: reference ④

Figure 11.5.14: Hexadiagram of Main Sampling Points at South of Lake Beseka

These figures show the following results and hypotheses:

- The results of the hexadiagram for the groundwater from nine wells around Lake Beseka are shown in Figure 11.5.11. The water quality of these nine points belong to the

NAHCO$_3$ type. One point (B1-6) out of nine contains a high concentration of Cl$^-$and SO$_4^{2-}$ ions compared to the that of other points. This point is plotted in the area of IV in the Trilinear Diagram and this is indicated by the effect deep groundwater. The depth of each well is 50 m to 595 m deep and there is considerable width. The main aquifer consists of basalt, and the groundwater of the each well indicates the retarded deep groundwater type. The river and irrigation water (this canal water is classed as “others”), belong to the CaHCO$_3$ type of water quality like the Trilinear Diagram, and the concentration is also thin compared to the other resource. The concentration and visual type of the spring are similar to that of the groundwater from wells. The type of the springs belongs to the retarded deep groundwater type, and the springs are affected by the groundwater from the west and south west of Lake Beseka. Figure 11.5.11 shows the lake water belongs to the Na-HCO$_3$ type and has a high concentration including high amounts of SO$_4^{2-}$ and Cl$^-$ ions,. As just described, the water quality of the lake water is affected by the inflow of the springs (groundwater), according to the hexadiagram. Generally, in the deep groundwater, the oxygen is consumed when the decay of organic matter and NO$_3$ and SO$_4$ disappear in the reductive environment. However, in the groundwater of wells around Lake Beseka, the NO$_3$ and SO$_4$ do not disappear. So the oxygenation may be slow (the retarded time is not so long).

- Figure 11.5.12 shows the hexadiagram of the groundwater of wells and springs around Lake Beseka as well as lake water. The hexadiagrams of the springs resemble the groundwater of wells in shape and concentration. The Na of springs increases a little bit because the springs retain the Na during the inflow of groundwater to springs because Na has a soluble aspect in water. The Na, SO$_4$, Cl and HCO$_3$ ions increase in the Lake water keeping the characteristic of the springs. In particular, the concentration of the HCO$_3$ ion increases in the Lake water due to carbon dioxide existing as the atmosphere in the air reacts with the water. Figure 11.5.13 also shows the same situation like Figure 11.5.12. In the east of Lake Beseka, HCO$_3$ and other anions also tend to increase because of the long retarded time in Lake Beseka.

- The change of the water quality in the lake water at the south area of Lake Beseka is shown in Figure 11.5.14. In this figure, the water quality among the river water, irrigation water, and lake water is compared. The water quality of the river water and irrigation water include the Ca ion compared to that of the groundwater, springs and lake water at the west and south-west of the Lake Beseka. Therefore, Ca is found in the Lake water and the water between the lake and the irrigation area (refer to the points of B1-24 and B1-25 belonged to the NaHCO$_3$ type). B1-25 was collected between the lake and the irrigation area, but the water quality of B1-25 is affected by that of the lake water. The HCO$_3$ has high values while SO$_4$ & Cl have low values at the south area of Lake Beseka. It is highly probable that it is affected by the vegetation of the sugar cane at the irrigation area of southern Lake Beseka.

- The lake water is affected in totality by the groundwater and springs according to the hexadiagram. On the other hand, lake water at the south area is affected by the river and irrigation water due to the existence of Ca ion. However, according to the hexadiagram, aside from the south area of Lake Beseka, the entire lake water is not affected by the river water because there is no Ca ion in the water throughout the whole of Lake Beseka.

- The component and visual type of the lake water is very similar to that of springs even if there is a difference of the concentration according to the hexadiagram. It is hypothesized that the springs are concentrated from evaporation and the concentration of the lake water is made in these environments. As mentioned above, the analysis results indicate the present lake water is not influenced by the river water regardless of the existence of Ca ion.

- Although this conclusion mentioned above cannot directly account for Lake Beseka's dramatic water rise, the water quality of almost all the lake water suggests the effect of the groundwater (springs) from the characteristic of the hexadiagram.

c. Isotope analysis

Isotope analysis was conducted by the IAEA in regard to the groundwater of JICA wells. On the contrary, isotope analysis of the river waters (including irrigation water), springs and lake waters around Lake Beseka were carried out in AAU and the analysis results were utilized for useful information for tracing the source of waters. The sampling points analysed and the results of the isotope analysis are shown in the Table 11.5.5.

Table 11.5.5: Results and List of Isotope Analysis

Detailed Place	Type of Water Sources	Location ID (Sample ID)	Reference Coordinate		Date of Sampling	δ ^{2}H (‰)	δ ^{18}O (‰)
			Easting	Northing			
Around Ombole (Hombole)	Awash River Water	A1-1(D)	475,873	925,842	2015/1/16	-2.69	-1.31
Around North of Gefersa	Awash River Water	A1-2(D)	525,365	937,096	2015/1/10	5.81	-0.16
Around Awash Melkasa	Awash River Water	A1-3(D)	536,207	927,203	2015/1/10	9.11	0.35
Around Doni	Awash River Water	A1-4(D)	562,223	940,652	2015/1/15	8.43	-0.07
East of Metehara Sugar Plantation	Awash River Water	A1-5(D)	611,191	977,348	2015/1/15	15.39	1.89
Lake Koka	Mojo River Water	A1-7(D)	506,888	929,588	2015/1/16	6.08	0.36
Along Wast of Lake Beseka	Spring	B1-14	592,612	981,509	2014/7/7	-14.38	-2.76
In Metehara Plantation	Awash River Water	B1-15	598,077	972,974	2014/7/8	-12.78	-1.42
From Nura Hera Farm	Awash River Water	B1-16	592,729	967,092	2014/7/8	-11.22	-0.86
Middle Awash River	Awash River Water	B1-17	596,078	965,762	2014/7/8	-3.88	-1.06
Metehara SP	Awash River Water	B1-18	601,502	978,505	2014/7/9	-12.58	-1.02
South of Lake Besaka	Lake Besaka Water	B1-19	595,246	975,723	2014/7/9	31.64	3.29
Tone Spring	Spring	B1-20	591,674	978,734	2014/7/9	2.55	-1.74
West of Lake Beseka	Lake Water	B1-21(D)	592,146	980,409	2015/1/8	16.41	2.69
West of Lake Beseka	Spring	B1-22(D)	591,536	979,199	2015/1/8	-9.56	-2.68
West of Lake Beseka	Lake Water	B1-23(D)	591,532	979,193	2015/1/8	9.79	1.04
South of Lake Beseka	Lake Water	B1-24(D)	593,045	975,249	2015/1/9	25.55	2.97
South of Lake Beseka	Lake Water+Irrigation	B1-25(D)	593,044	975,228	2015/1/9	34.28	4.81
South of Lake Beseka	Lake Water	B1-26(D)	594,247	974,998	2015/1/9	21.64	2.94
South of Lake Beseka	Irrigation Water	B1-27(D)	593,243	972,517	2015/1/9	6.45	0.19
East of Lake Beseka	Lake Water	B1-28(D)	598,897	980,437	2015/1/9	25.77	4.55
East of Lake Beseka	Lake Water	B1-29(D)	596,741	978,173	2015/1/9	25.41	4.49
East of Lake Beseka	Lake Water	B1-30(D)	598,698	984,130	2015/1/9	26.26	4.44
Around Lake Besaka (AW BH-3)	New Well	E1-1	589,167	982,682	2014/8/9	-9.79	-2.65
Around Lake Besaka (AW BH-4N)	New Well	E1-2	587,754	977,437	2014/11/12	-9.75	-2.72
Around Lake Besaka (AW BH-5)	New Well	E1-3	601,565	980,024	2014/4/2	1.65	-1.08
Around Feto (AW BH-6)	New Well	E1-4	552,789	958,778	2015/8/11	-33.1	-6.24
Between Doni and Bofo (AW BH-9)	New Well	E1-6	555,025	936,983	2014/9/22	-12.87	-3.55
Around Sire (AW BH-11)	New Well	E3-2	553,313	916,009	2015/4/3	-12.2	-3.03
Around Balchi (AW BH-1)	New Well	E4-1	542,642	985,361	2015/4/8	-11.78	-3.11
Around Melka Jiro (AW BH-2)	New Well	E4-2	567,414	980,822	2015/7/21	-27.3	-6.10
Around Dehaye (AW BH-12)	New Well	E4-3	550,405	1,027,427	2014/10/20	-30.59	-5.41

Source: the Project Team, Data: reference ④, analyzed by AAU and IAEA

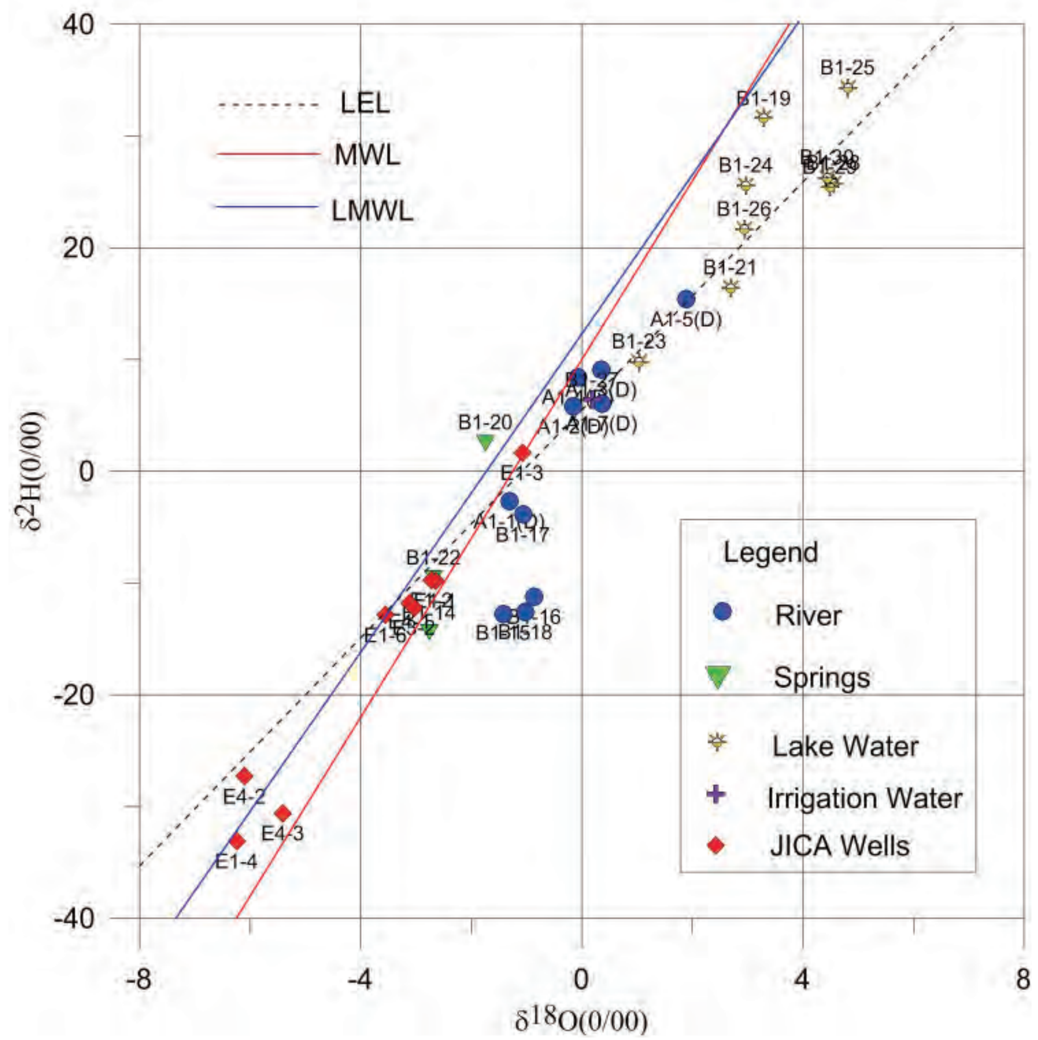
In stable isotopes in water, ^{2}H (D) of mass number 2, and ^{18}O of mass number 18 were used for the analysis. A water molecule consists of these atoms, and these are contained in the river and groundwater in high concentration (high compared to the other concentrated components). These isotope molecules are ideal tracers for the comprehension of groundwater flow in the hydrologic cycle because they do not have a chemical reaction with other matter like dissolved matter.

The results of the analysis for the stable isotopes are shown in Figure 11.5.15 as delta (δ) diagram. Generally, the straight line for precipitation and surface water is made using plotted points of precipitation around the world. This line is called the Meteoric Water Line (hereafter refer to as "MWL") as $\delta D = 8\delta^{18}O+10$.

As the formation temperature decreases and the latitude increases, the isotopic ratio of precipitation decreases along the MWL. This is called the temperature effect or latitude effect. Moreover, when the precipitation increases, the isotopic ratio decreases in what is called the precipitation effect. Isotopic ratio at higher elevations decreases or when the precipitation moves toward continental regions, isotopic ratio has a tendency to decrease. The former is called the altitude effect, and the latter is called the continental region effect.

Meteoric waters do not always plot on MWL, as they are affected by various local and regional factors such as source of moisture, extent of evaporation during rainfall, altitude, and so on. For instance, the line that is formed by plotting δ^2H and $\delta^{18}O$ for specific regions is called the Local Meteoric Water Line (hereafter referred to as "LMWL"). Records from 1964 to 2004 were used to establish the LMWL, and the line defined by the relation $\delta D = 7.12\delta^{18}O+12.3$ with a regression coefficient (r^2) of 0.93. Figure 11.5.15 includes MWL and LMWL.

The isotopic ratio of the precipitation or groundwater and river water derived from rainfall is plotted near the MWL. The δ value of the groundwater is similar to that of precipitation as the weighted mean near the point of groundwater. For the isotopic ratio of springs, one outcrop of groundwater was plotted near the LMWL. It is possible it was derived from the Addis Ababa rainfall in Figure 11.5.15. The isotopic ratio of river water can be plotted with three groups as a whole in Figure 11.5.15. The river waters marked by (D) including A1-5 (D) sample are plotted at a relatively high isotopic ratio. As these samples were collected in the dry season, it is possible to recognize the precipitation effect. Also, sample A1-5 (D) is influenced by the lake water because the sampling point of is located downstream of Lake Beseka. The low isotopic ratio group of the river waters is located below MWL. This group reflects the precipitation effect because of the sampling was done in the rainy season. The lake waters are plotted in the lower right below the MWL. The lake is characterized by an enriched composition compared to their inflows due to the isotopic fractionation during the evaporation process. Consequently, the isotopic ratio of evaporating lake plots below the MWL, along a line called Local Evaporation Line (hereafter referred to as "LEL"). The slope of LEL is found mainly from 3.5 to 6, and depends on local climate factors. The lake waters with some river waters plot along the LEL are defined by the relation $\delta D = 5.1\delta^{18}O+5.5$ in reference to Eleni, 2009. The LEL intersects the LMWL at the isotopic value of -3.40‰ in $\delta^{18}O$ and -11.84‰ in δ^2H (refer to Figure 11.5.15). As this isotopic value is comparable to the isotopic ratio of the groundwater in the up watershed, it was discussed in the flow system of the western part of the watershed. The average δ values of the groundwater in JICA wells (AW BH-1, 3, 4N, 9, and 11) taken in the western part of the watershed is characterized by an isotopic ratio of -3.01‰ in $\delta^{18}O$ and -11.28‰ in δ^2H (refer to Figure 11.5.15).This value is similar to that of the intersected point of LEL. This suggests that the inflow to Lake Beseka comes from the groundwater at the western and northwest part of the watershed. For example, Eleni, 2009 described the isotopic value of -2.8‰ in $\delta^{18}O$ and -10.7‰ in δ^2H as the average of the groundwater system in the western part of the lake watershed.



Source: the Project Team, Data: reference 5) of ①, and ④

Figure 11.5.15: Delta Diagram of Stable Isotope around Lake Beseka

d. Tritium Analysis

The results of the tritium analysis and sampling points are shown in Table 11.5.6 below. The sampling of groundwater with JICA wells will be carried out from now. A1-1 (D) to A1-7 (D) are samples from the Awash River, B1-21 to B1-30 are almost all lake waters and B1-22 and B1-27 are sampled from spring and irrigation water respectively.

Table 11.5.6: List of Points for Tritium Analysis

Detailed Place	Type of Water Sources	SL. No.	Location ID (Sample ID)	Reference Coordinate		Final Result TU±0.5σ
				Easting	Northing	
Around Ombole (Hombole)	Awash River Water	1	A1-1(D)	475,873	925,842	**2.33**
Around North of Gefersa	Awash River Water	2	A1-2(D)	525,365	937,096	**2.25**
Around Awash Melkasa	Awash River Water	3	A1-3(D)	536,207	927,203	**2.23**
Around Doni	Awash River Water	4	A1-4(D)	562,223	940,652	**2.17**
East of Metehara Sugar Plantation	Awash River Water	5	A1-5(D)	611,191	977,348	**2.19**
Lake Koka	Mojo River Water	6	A1-7(D)	506,888	929,588	**2.32**
West of Lake Beseka	Lake Water	7	B1-21	592,146	980,409	**2.21**
West of Lake Beseka	Spring	8	B1-22	591,536	979,199	**2.35**
West of Lake Beseka	Lake Water	9	B1-23	591,532	979,193	**2.30**
South of Lake Beseka	Lake Water	10	B1-24	593,045	975,249	**2.26**
South of Lake Beseka	Lake Water+Irrigation	11	B1-25	593,044	975,228	**2.14**
South of Lake Beseka	Lake Water	12	B1-26	594,247	974,998	**2.27**
South of Lake Beseka	Irrigation Water	13	B1-27	593,243	972,517	**2.25**
East of Lake Besek	Lake Water	14	B1-28	598,897	980,437	**2.13**
East of Lake Besek	Lake Water	15	B1-29	596,741	978,173	**2.36**
East of Lake Besek	Lake Water	16	B1-30	598,698	984,130	**2.29**
Around Lake Besaka (AW BH-3)	New Well	17	E1-1	589,167	982,682	-
Around Lake Besaka (AW BH-4N)	New Well	18	E1-2	587,754	977,437	-
Around Lake Besaka (AW BH-5)	New Well	19	E1-3	601,565	980,024	-
Around Feto (AW BH-6)	New Well	20	E1-4	552,789	958,778	**2.43**
Between Doni and Bofo (AW BH-9)	New Well	21	E1-6	555,025	936,983	-
Around Sire (AW BH-11)	New Well	22	E3-2	553,313	916,009	-
Around Balchi (AW BH-1)	New Well	23	E4-1	542,642	985,361	-
Around Melka Jiro (AW BH-2)	New Well	24	E4-2	567,414	980,822	**3.01**
Around Dehaye (AW BH-12)	New Well	25	E4-3	550,405	1,027,427	-

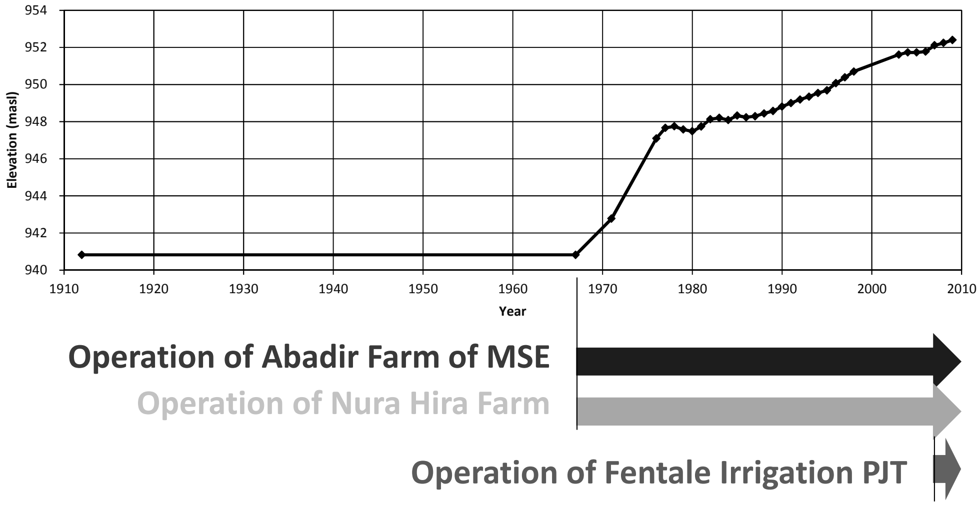
Source: the Project Team, Data: reference ④, analyzed by AAU and IAEA

Tritium (^3H) is a radioactive hydrogen isotope with a half-life of 12.43 years and changes to ^3He by beta-decay. The tritium concentrations are almost parallel in the vapor of the troposphere. The usual concentration in the mid-latitude rainfall was 10 tritium units (hereafter refer to as "TU"). However, following atmospheric detonation of thermonuclear bombs after 1952, a large amount of tritium, in particular, 1000 TU was released into the atmosphere in the peak period between 1963 to 1964,. After that, the tritium concentration was back to a natural level of 5 to 10 TU in 1990 due to decreasing tritium concentrations year on year after the experiments were finished. The tritium content of lake waters is 2.245 TU on average, that of river waters indicates 2.248 TU on average and that of springs is 2.35 TU for one point. Seifu Kebede, et al, 2008 says the tritium concentration of the groundwater around Lake Beseka is 1.5 and 5.8 TU, and that of a hot spring in the Fentale volcano is 0.7 TU. Eleni Ayalew Belay, 2009 shows the tritium content of the rainfall in Addis Ababa is transitional from 5 to 15 TU from1984 to 1997. The value of tritium contents in this Study indicates a mixture of recharge from sub-modern (prior to 1953) and modern (after 1953) meteoric waters.

11.5.3 Estimation of irrigation return flow

a. General

The purpose of the analysis here is to assess the extent of the irrigation return flow's contribution to the expansion of the Lake Beseka which started in the late 1960s. Currently, the developed irrigation projects in and around the Lake Beseka catchment are the Abadir farm, Nura Hira farm and Fentale project (see Figure 11.2.14).



Source: the Project Team, Data: Reference ⑤ and ⑥

Figure 11.5.16: Lake Water Level and Timing of Operation of Irrigation Projects

Irrigation efficiency as well as the possible irrigation return flow amount from the Abadir farm are tried to be estimated in this analysis based on the available data. The relevancy of widely recognized cause of the lake expansion, that is irrigation return flow, is reviewed from the following viewpoints:

- Evaluation of the irrigation efficiency in Abadir farm and estimation of possible return flow amount into the Lake Beseka
- Review of consistency of water balance of the Lake Beseka under the scenario with possible return flow

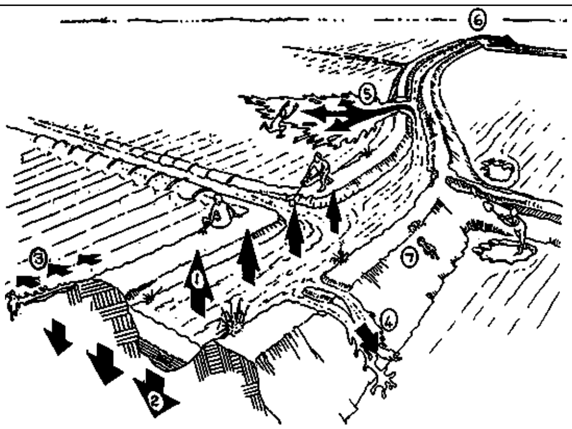
According to Water Works Design and Supervision Enterprise (WWDSE, 2011), no return flow has flowed into the Lake from Nura Hira farm owing to the construction of a diversion structure in 1984. Therefore, the irrigation efficiency in Nura Hira farm is not estimated in this analysis. On the other hand, water balance analysis is undertaken incorporating the possible return flow of 11.2 million m^3 from Nura Hira farm during the period between 1977 and 1983, which was estimated by Ministry of Water Resources (MoWR, 1999).

In terms of the ongoing Fentale project, it is nothing to do with the sharp increment of the Lake Beseka size since the late 1960s because the project was partly completed in 2007. Therefore, this project is omitted from this analysis.

b. Irrigation efficiency in Abadir farm

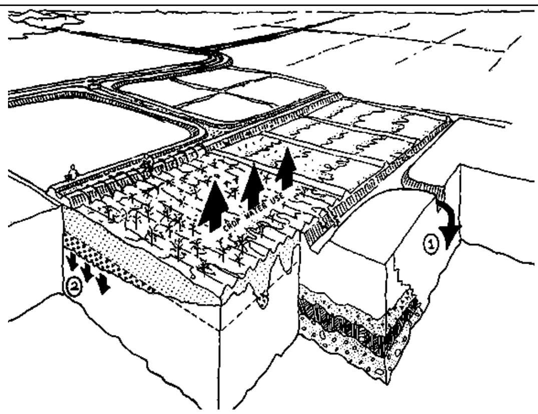
b.1 Irrigation water losses and standard for efficiency evaluation

Typical irrigation water losses are shown in Figure 11.5.17 below. The water which is lost during the irrigation, evaporates, infiltrates or flows into the drainage canal without the direct contribution to crop growth.



① Evaporation from the water surface
② Deep percolation to soil layers underneath the canals
③ Seepage through the bunds of the canals
④ Overtopping the bunds
⑤ Bund breaks
⑥ Runoff in the drain
⑦ Rat holes in the canal bunds

Irrigation water losses in canals (conveyance losses)



① Surface runoff, whereby water ends up in the drain
② Deep percolation to soil layers below the root zone

Irrigation water losses in the field (application losses)

Source: Reference ⑦

Figure 11.5.17: Irrigation Water Losses

Irrigation efficiency is generally estimated by multiplying the conveyance efficiency and application efficiency. According to the Food and Agriculture Organization of the United Nations (FAO, 1989), the irrigation efficiency is evaluated as ‘Good’ for 50-60%, ‘Reasonable’ for the 40% level and ‘Poor’ for 20-30%.

b.2 Irrigation efficiency estimated in the past surveys

The MoWIE has estimated the irrigation efficiency of Abadir farm several times employing methods that include field investigations and measurements.

Table 11.5.7: Irrigation Efficiency of Abadir by Previous Surveys

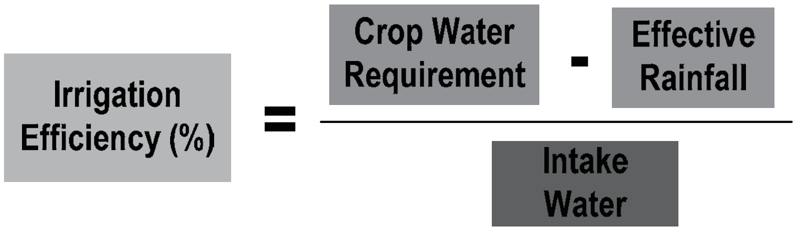
Year	Conveyance (A)	Application (B)	Efficiency (A x B)
1977	—	—	30%
1997	82%	65%	53%
2010	87%	65%	56%

Source: Reference ⑤ and ⑥

According to the table above, the poor irrigation efficiency in the farm of 30% had been improved up to more than 50% by 1997, and the good irrigation efficiency has been kept since then.

b.3 Estimation of irrigation efficiency in this Project

In this JICA Project, a different approach from the past surveys is taken for the estimation of irrigation efficiency in Abadir farm. The water requirement for cultivation (crop water requirement) in the farm is estimated first and then the irrigation efficiency is estimated comparing the water requirement that is actually taken from the Awash River with the amount of effective rainfall over the farm fields. Namely, the crop water requirement minus the effective rainfall is divided by the water intake from Awash River to obtain the irrigation efficiency.



Source: the Project Team

Figure 11.5.18: Irrigation Efficiency Calculation Used in this Project

b.3.1 Volume of water intake by Abadir farm

The water intake by Abadir farm from 1977 to 2009 is shown inTable 11.2.1. The intake amount varies between 80 and 130 million m^3 and annual mean water intake is approx. 102 million m^3 (3.24 m^3/sec). The total area of Abadir is 3,158 ha and cultivation area reaches 2,842 ha if 90% of the total area is for cultivation. The annual mean water intake is therefore converted in the height of 3,589 mm (= 102 / 2,842 x 10^5).

b.3.2 Estimation of crop water requirement

Crop water requirement for cultivation of sugarcane, which has been cultivated in Abadir farm since 1978, is estimated by the following formula:

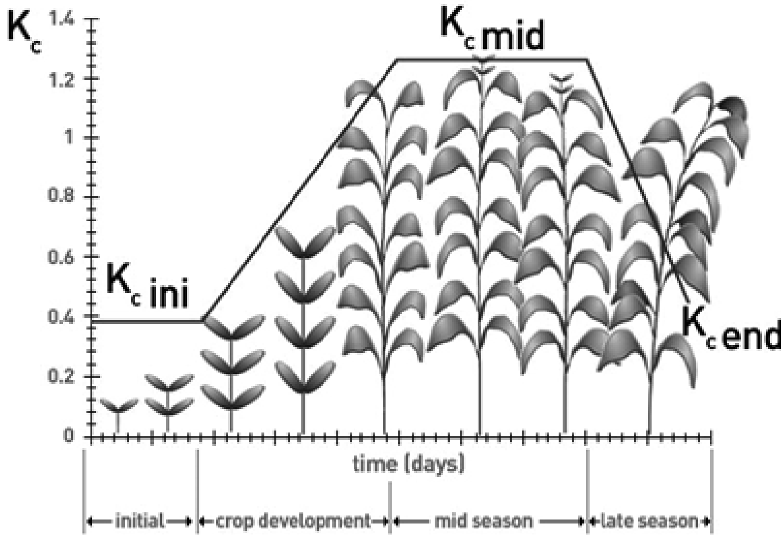
$$ET_{sugarcane} = ETo \times Kc$$

where, $ET_{sugarcane}$: Water requirement for sugarcane (mm/year)
ETo: Reference evapotranspiration (mm/year)
Kc: Crop coefficient

ETo is calculated as 2,224 mm/year based on the meteorological data at Metehara station employing Penman-Monteith method[3].

The typical growth stages of sugarcane and associated duration and Kc values are as presented in Figure 11.5.19 and Table 11.5.8 in accordance FAO.

[3] http://www.fao.org/docrep/x0490e/x0490e00.htm#Contents



Source: Reference ⑦

Figure 11.5.19: Growth Stages of Sugarcane

Table 11.5.8: Duration and Kc Values by Growth Stages

Stages	Durations (days)	Kc Values
Initial	35	0.40
Crop Development	60	*0.825
Mid-Season	190	1.25
Late Season	120	0.75

Remark: Kc value for crop development stage is the simple average of Kc for initital and mid-season stages.

Source: Reference ⑦

The annual mean Kc value is then calculated as follows:

$$K_c = \frac{35 \times 0.40 + 60 \times 0.825 + 190 \times 1.25 + 120 \times 0.75}{35 + 60 + 190 + 120} = 0.965$$

The crop water requirement for sugarcane is estimated at 2,146 mm/year (= 2,224 x 0.965).

b.3.3 Estimation of effective rainfall

The effective rainfall is defined as the rainfall which contributes to the crop growth. This is estimated based on the total rainfall amount applying the following empirical formula proposed by the FAO-AGLW (FAO Water Resource, Development and Management Services):

$$P_{eff} = 0.6 P_{month} - 10 \quad (P_{month} \le 70mm)$$
$$P_{eff} = 0.8 P_{month} - 24 \quad (P_{month} > 70mm)$$

where, P_{month}: Monthly total rainfall (mm)
P_{eff}: Effective rainfall (mm)

Table 11.5.9 shows the mean monthly effective rainfall based on the mean annual rainfall data at Metehara observatory station:

Table 11.5.9: Effective Rainfall in Abadir Farm

Month	Total Rainfall (mm)	Effective Rainfall (mm)	Month	Total Rainfall (mm)	Effective Rainfall (mm)
January	11	0	July	121	73
February	25	5	August	118	70
March	47	18	September	43	16
April	46	18	October	22	3
May	35	11	November	6	0
June	26	6	December	8	0
			Total	508	220

Source: the Project Team, Data: Result of hydrology survey in this Project

The mean annual effective rainfall is estimated at 220 mm.

b.3.4 Estimation and evaluation of irrigation efficiency

The above calculation results are summarized below:

Mean annual water intake by Abadir farm: 3,589 mm
Mean annual crop water requirement in Abadir farm: 2,146 mm
Mean annual effective rainfall in Abadir farm: 220 mm

The irrigation efficiency in Abadir farm is estimated at about 54% (= (2,146 – 220) / 3,589). It is evaluated as 'Good' irrigation practices according to the FAO's criteria. The irrigation efficiency elaborated here is consistent with the results of the previous surveys shown in Table 11.5.7.

Table 11.5.10 below presents the irrigation efficiency in Abadir farm per each year estimated by the same manner as explained above. The efficiency range is 40% to 60%, which is a reasonable level.

Table 11.5.10: Annual Irrigation Efficiency in Abadir Farm

Year	Intake Volume (10^6m^3)	Cultivation Area (ha)	Effective Rainfall (mm)	ETo (mm)	Kc	Required Water (10^6m^3)	Ineffective Intake Water (10^6m^3)	Irrigation Efficiency	FAO's Evaluation
1977	111.9	2,842	428	2,224	0.965	48.83	63.07	43.6%	Reasonable
1978	87.0	2,842	188	2,224	0.965	55.65	31.35	64.0%	Good
1979	100.4	2,842	229	2,224	0.965	54.50	45.90	54.3%	Good
1980	90.3	2,842	221	2,224	0.965	54.73	35.57	60.6%	Good
1981	125.9	2,842	326	2,224	0.965	51.72	74.18	41.1%	Reasonable
1982	119.6	2,842	442	2,224	0.965	48.44	71.16	40.5%	Reasonable
1983	130.3	2,842	298	2,224	0.965	52.53	77.77	40.3%	Reasonable
1984	129.0	2,842	78	2,224	0.965	58.78	70.22	45.6%	Reasonable
1985	83.7	2,842	334	2,224	0.965	51.52	32.18	61.5%	Good
1986	93.9	2,842	132	2,224	0.965	57.24	36.66	61.0%	Good
1987	87.9	2,842	198	2,224	0.965	55.36	32.54	63.0%	Good
1988	91.4	2,842	256	2,224	0.965	53.73	37.67	58.8%	Good
1989	91.4	2,842	248	2,224	0.965	53.96	37.44	59.0%	Good
1990	91.4	2,842	362	2,224	0.965	50.70	40.70	55.5%	Good
1991	109.0	2,842	266	2,224	0.965	53.43	55.57	49.0%	Reasonable
1992	109.0	2,842	287	2,224	0.965	52.83	56.17	48.5%	Reasonable
1993	109.0	2,842	318	2,224	0.965	51.95	57.05	47.7%	Reasonable
1994	92.7	2,842	309	2,224	0.965	52.22	40.48	56.3%	Good

Year	Intake Volume (10^6m^3)	Cultivation Area (ha)	Effective Rainfall (mm)	ETo (mm)	Kc	Required Water (10^6m^3)	Ineffective Intake Water (10^6m^3)	Irrigation Efficiency	FAO's Evaluation
1995	97.1	2,842	215	2,224	0.965	54.88	42.22	56.5%	Good
1996	107.0	2,842	336	2,224	0.965	51.46	55.54	48.1%	Reasonable
1997	102.7	2,842	218	2,224	0.965	54.82	47.88	53.4%	Good
1998	92.7	2,842	233	2,224	0.965	54.39	38.31	58.7%	Good
1999			254						
2000	104.5	2,842	242	2,224	0.965	54.13	50.37	51.8%	Good
2001	104.4	2,842	200	2,224	0.965	55.31	49.09	53.0%	Good
2002	103.8	2,842	95	2,224	0.965	58.28	45.52	56.2%	Good
2003	81.7	2,842	224	2,224	0.965	54.63	27.07	66.9%	Good
2004	84.2	2,842	284	2,224	0.965	52.93	31.27	62.9%	Good
2005	100.9	2,842	273	2,224	0.965	53.24	47.66	52.8%	Good
2006	111.9	2,842	198	2,224	0.965	55.37	56.53	49.5%	Reasonable
2007	104.7	2,842	310	2,224	0.965	52.19	52.51	49.8%	Reasonable
2008	115.5	2,842	264	2,224	0.965	53.50	62.00	46.3%	Reasonable
2009	103.2	2,842	176	2,224	0.965	55.99	47.21	54.3%	Good

Source: the Project Team, Data: Result of hydrology survey in this Project

b.3.5 Estimation of return flow to the Lake Beseka

When the irrigation efficiency in Abadir farm is 54%, the remaining 46% of intake water disappears without contributing to the crop growth. Since the annual water intake by Abadir farm is approx. 102 million m^3, the annual irrigation water loss is approx. 47 million m^3.

Out of the total area of Abadir farm of 3,158 ha, 2,315 ha (73.3%) is within the lake catchment. Therefore, the irrigation water losses occur in the lake catchment and it can be estimated at approx. 35 million m^3 (= 47 million m^3 x 73.3%), and it is considered as the possible maximum return flow to the Lake Beseka.

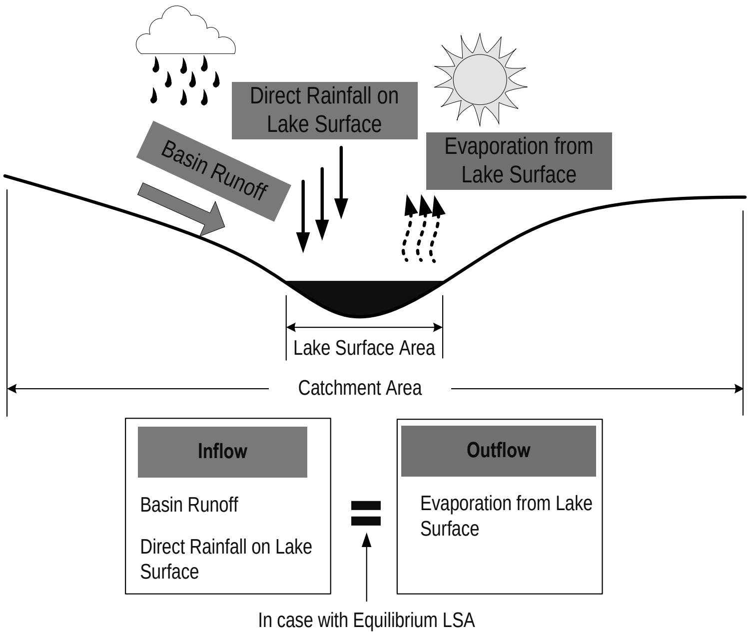
Actually, a substantial amount of this possible maximum return flow may be lost before reaching the lake by evaporation, etc. (see Figure 11.5.17). Since it is not possible to estimate the proportion of return flow that does not reach Lake Beseka, the subsequent analyses will be conducted by assuming that the total amount of return flow reaches Lake Beseka.

c. Effects of irrigation return flow on the lake water balance

The effects of the possible maximum return flow from the irrigation area elaborated above on the annual water balance in the lake are assessed here. The annual water balance in the lake without return flow is estimated first, and then the water balance is analyzed adding the return flow in order to check whether or not this will sufficiently explain the sudden expansion of the lake.

c.1 Definition of equilibrium lake surface area and conditions for the analysis

The lake catchment is reported to be isolated from the Awash River Basin before the construction of drainage facilities in 2004. Water balance situation in the lake catchment is schematically shown in Figure 11.5.20 below:



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.20: Water Balance in Isolated Lake Catchment

The inflow to the Lake Beseka consists of the direct rainfall on the lake surface and the runoff from the lake catchment. The lake outflow consists only of evaporation from the lake surface. The volume of the surface evaporation increases in proportion to the lake surface area. So, in the long term, if the hydrometeorological conditions remain unchanged, the lake surface area shall converge at a size in which the surface evaporation amount is balanced with the inflow components, namely direct rainfall plus basin runoff. This converged lake surface area is defined as the equilibrium lake surface area (ELSA) in this analysis.

The following relationship is realized if the surface area of the Lake Beseka is ELSA:

$$E \cdot ELSA = R \cdot ELSA + Q$$

where,
- ELSA: Equilibrium lake surface area
- E: Mean annual evaporation (height)
- R: Mean annual rainfall (height)
- Q: Mean annual runoff from the catchment (volume)

Although there shall be minor fluctuations of the lake surface area due to the occurrence of floods/draughts, seasonal variation of rainfall or other reasons, the surface area may not deviate from ELSA in the long term.

Hydrometeorological analysis in this Project figured out the mean annual rainfall and evaporation at Metehara observatory station of 508 mm and 3,023 mm, respectively. The data at this observatory station is applied to the lake catchment. Applying the pan coefficient of 0.8 which was used in the past similar studies, the annual evaporation from the lake surface is 2,418 mm (= 3,023 x 0.8)

Runoff from the lake catchment (Q) is calculated by multiplying the mean annual rainfall (R) with runoff coefficient (C). Following formula proposed in the hydrological analysis is used for estimation of C:

$$C = 1.090(A - ELSA)^{-0.236}$$

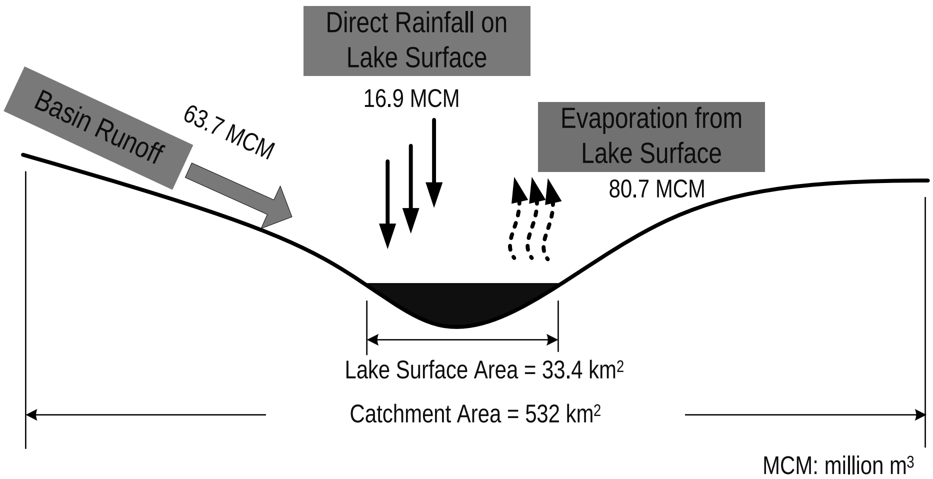
where, ELSA: Equilibrium lake surface area (km^2)
A: The lake catchment area (= 532 km^2)

The calculated ELSA in the above condition is 33.4 km^2.

Table 11.5.11: Mean Annual Water Balance in the Lake Beseka (ELSA＝33.4 km^2)

Items	Volume	Calculation / Remarks
Inflow		
Direct Rainfall on the Lake Surface	16.9 (10^6m^3)	508 mm x 33.4 km^2
Runoff from the Lake Catchment	63.7 (10^6m^3)	508 mm x 1.090 (532 km^2 – 33.4 km^2)$^{-0.236}$ x (532 km^2 – 33.4 km^2)
Total Inflow	**80.7 (10^6m^3)**	
Outflow		
Evaporation from the Lake Surface	80.7 (10^6m^3)	3,023 mm x 0.8 x 33.4 km^2
Total Outflow	**80.7 (10^6m^3)**	
Balance	**0.0 (10^6m^3)**	

Source: the Project Team, Data: Result of hydrology survey in this Project



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.21: Mean Annual Water Balance in the Lake Beseka (ELSA＝33.4 km^2)

On the other hand, the existing information says that the Lake Beseka kept its surface area in the range of 3 – 5 km^2 before 1970. In other words, it means that the ELSA was 3 – 5 km^2 before and that the water amount cannot be balanced only with the outflow by surface evaporation. Table 11.5.12 shows the water balance calculation with 4 km^2 of ELSA.

Table 11.5.12: Mean Annual Water Balance in the Lake Beseka (ELSA＝4 km^2)

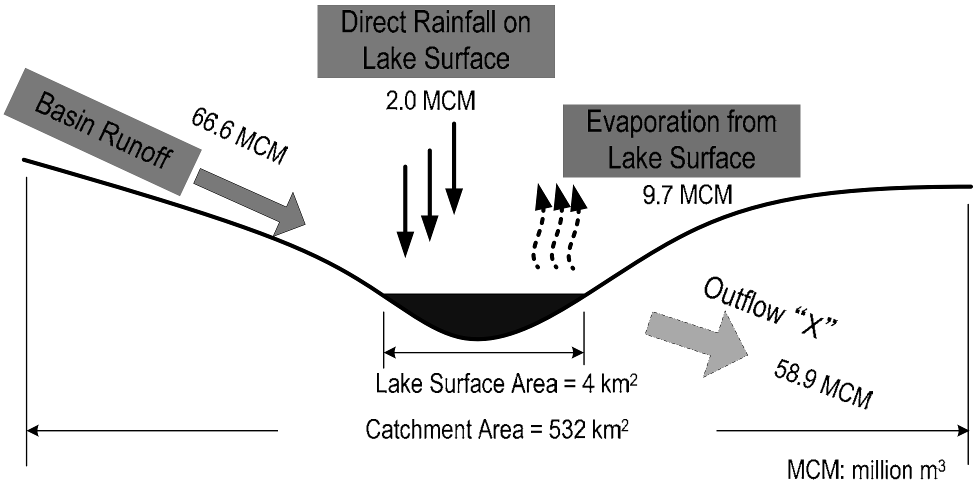
Items	Volume	Calculation / Remarks
Inflow		
Direct Rainfall on the Lake Surface	2.0 (10^6m^3)	508 mm x 4 km^2
Runoff from the Lake Catchment	66.6 (10^6m^3)	508 mm x 1.090 (532 km^2 – 4 km^2)$^{-0.236}$ x (532 km^2 – 4 km^2)
Total Inflow	**68.6 (10^6m^3)**	
Outflow		

Items	Volume	Calculation / Remarks
Evaporation from the Lake Surface	9.7 (10^6m^3)	3,023 mm x 0.8 x 4 km^2
Total Outflow	**9.7 (10^6m^3)**	
Balance	**58.9 (10^6m^3)**	

Source: the Project Team, Data: Result of hydrology survey in this Project

The total outflow is only 9.7 million m^3, while the total inflow amounts to 68.6 million m^3. It is an inflow excess of 58.9 million m^3 on terms of water balance. This suggests the necessity of the introduction of one of the following assumptions in order to stabilize the water in the lake area of 4 $km^{2.}$

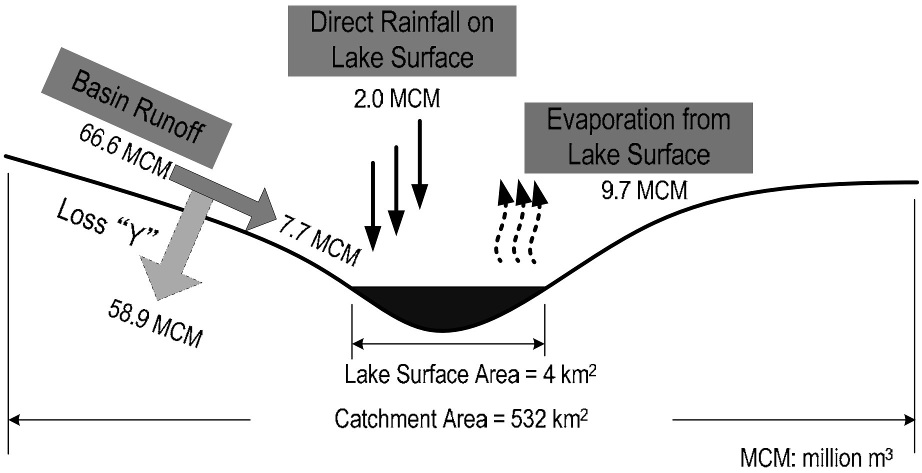
[Assumption 1]
An additional outflow of 58.9 million m^3 is occurring to keep the lake size of 4 km^2. This additional outflow is called outflow “X”.



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.22: Mean Annual Water Balance in the Lake Beseka with Outflow “X” (ELSA＝4 km^2)

[Assumption 2]
The amount of 58.9 MCM out of the basin runoff (66.6 MCM) is lost due to deep percolation, etc. before reaching the Lake. This is called loss “Y”.



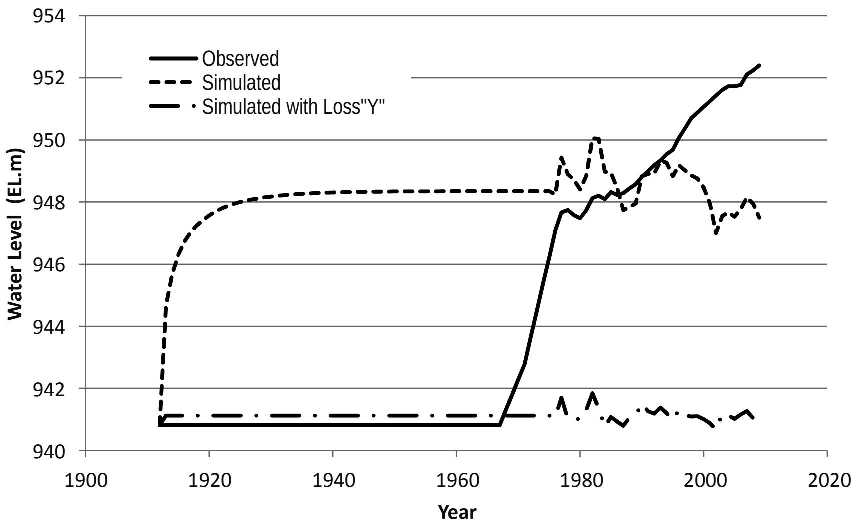
Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.23: Mean Annual Water Balance in the Lake Beseka with Loss "Y" (ELSA＝4 km^2)

There will be no difference in the result of water balance analysis in either assumption. On the other hand, considering that the salinity of the Lake Beseka was extremely high before starting the expansion, it is more reasonable that the basin runoff to the Lake was limited and therefore salinity had been concentrated.

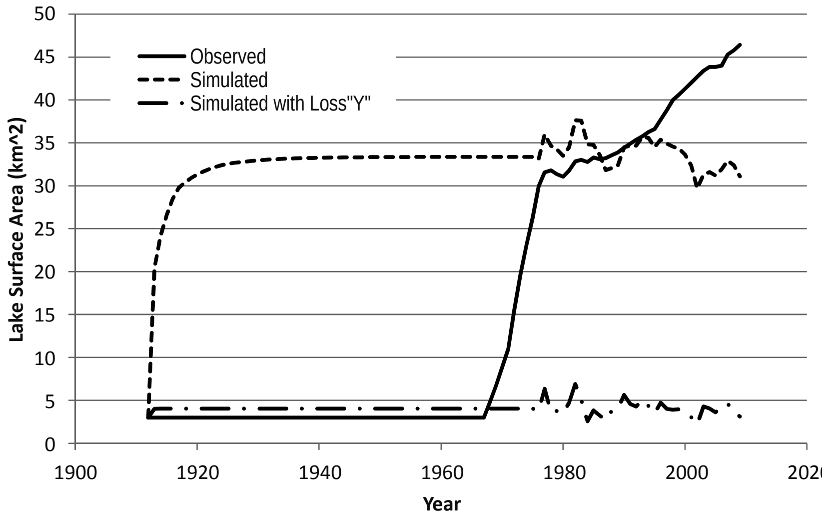
Assumption 2 is therefore incorporated in the subsequent water balance analysis.

Historical changes of the lake water level and surface area are calculated using the annual rainfall data in the basin. Time series of the lake water level and surface area are presented in Figure 11.5.24 and Figure 11.5.25, respectively.



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.24: Observed and Simulated Historical Changes of the Lake Water Level



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.25: Observed and Simulated Historical Changes of the Lake Surface Area

As seen in the figures above, without loss “Y”, the lake water level rapidly rises at the beginning (Year 1912) and reaches up to around EL. 948 m. The Lake Beseka surface area becomes approx. 33 km^2. This does not explain the lake size as of the late 1960s.

When the loss “Y” is considered, the Lake surface area is in a stable condition with an approximate size of about 4 km^2, though minor variation of area due to the rainfall amount is found. This adequately explains the situation before the expansion of the Lake Beseka.

An additional analysis is undertaken to check the sensitivity of the ELSA to variations of climatic conditions. Following changes are assumed for this sensitivity analysis:

- Varying 610% from original rainfall amount (508 mm/year)
- Varying 610% from original evaporation amount (2,418 mm/year)

Results are shown in Table 11.5.13.

Table 11.5.13: Sensitivity of ELSA to Climatic Conditions

		Rainfall		
		-10% 457 mm/year	60% 508 mm/year	+10% 559 mm/year
Evaporation	-10% 2,176 mm/year	0.7 km^2 (33.4 km^2)	4.5 km^2 (37.9 km^2)	8.5 km^2 (42.7 km^2)
	60% 2,418 mm/year	0.7 km^2 (29.4 km^2)	4.0 km^2 (33.4 km^2)	7.5 km^2 (37.5 km^2)
	+10% 2,660 mm/year	0.6 km^2 (26.4 km^2)	3.6 km^2 (29.8 km^2)	6.7 km^2 (33.4 km^2)

Note: ELSA values in parentheses are the results without loss “Y”.
Source: the Project Team, Data: Result of hydrology survey in this Project

As seen in the table above, the ELSA increases only up to 8.5 km^2 even if 10% increase of rainfall together with 10% decrease of evaporation is assumed. It is therefore not possible to explain the actual rapid expansion of the lake from 4 km^2 to more than 50 km^2 only by fluctuation of climatic conditions.

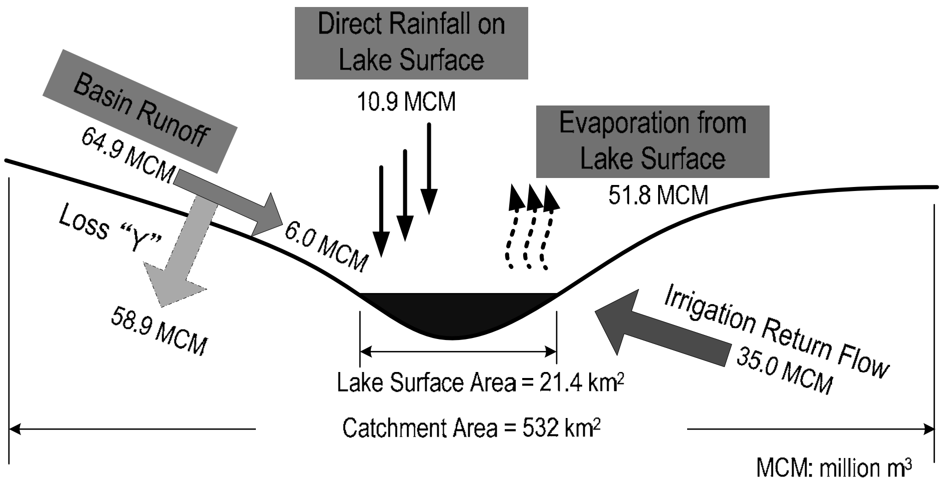
c.2 Water balance calculation with return flow (with loss "Y")

The possible maximum return flow from Abadir farm is estimated at approx. 35 million m^3 per annum as explained in b.3.5 above. The ELSA is 21.4 km^2 if this return flow is taken into account for the water balance calculation (see Table 11.5.14 and Figure 11.5.26).

Table 11.5.14: Mean Annual Water Balance in the Lake Beseka with 35 MCM Return Flow

Items	Area/Volume	Calculation / Remarks
ELSA	21.4 km^2	
Inflow		
Direct Rainfall on the Lake Surface	10.9 (10^6m^3)	508 mm x 21.4 km^2
Runoff from the Lake Catchment	64.9 (10^6m^3)	508 mm x 1.090 (532 km^2 – 21.4 km^2)$^{-0.236}$ x (532 km^2 – 21.4 km^2)
Loss "Y"	-58.9 (10^6m^3)	
Irrigation Return Flow	35.0 (10^6m^3)	
Total Inflow	**51.8 (10^6m^3)**	
Outflow		
Evaporation from the Lake Surface	51.8 (10^6m^3)	3,023 mm x 0.8 x 21.4 km^2
Total Outflow	**51.8 (10^6m^3)**	

Source: the Project Team, Data: Result of hydrology survey in this Project



Source: the Project Team, Data: Result of hydrology survey in this Project

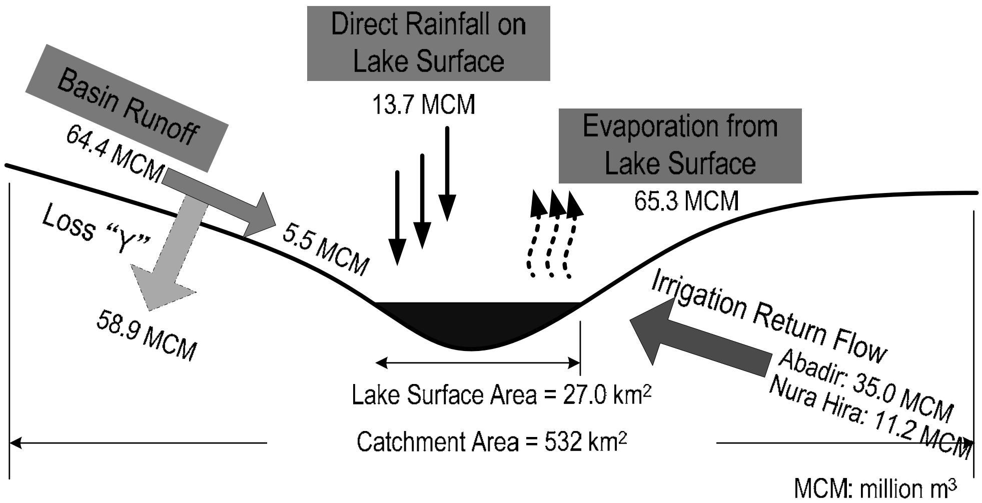
Figure 11.5.26: Mean Annual Water Balance in the Lake Beseka with 35 MCM Return Flow

As described in the item "a" above, previous surveys state that 11.2 million m^3 of return flow reached the Lake Beseka annually from Nura Hira farm during the period from 1977 to 1983. The calculated ELSA is 27.0 km^2 if the return flows from both Abadir and Nura Hira farms (46.2 million m^3 per annum in total) are taken into account.

Table 11.5.15: Mean Annual Water Balance in the Lake Beseka with 46.2 MCM Return Flow

Items	Area/Volume	Calculation / Remarks
ELSA	27.0 km^2	
Inflow		
Direct Rainfall on the Lake Surface	13.7 (10^6m^3)	508 mm x 27.0 km^2
Runoff from the Lake Catchment	64.4 (10^6m^3)	508 mm x 1.090 (532 km^2 – 27.0 km^2)$^{-0.236}$ x (532 km^2 – 27.0 km^2)
Loss "Y"	-58.9 (10^6m^3)	
Irrigation Return Flow (Abadir)	35.0 (10^6m^3)	
Irrigation Return Flow (Nura Hira)	11.2 (10^6m^3)	
Total Inflow	**65.3 (10^6m^3)**	
Outflow		
Evaporation from the Lake Surface	65.3 (10^6m^3)	3,023 mm x 0.8 x 27.0 km^2
Total Outflow	**65.3 (10^6m^3)**	

Source: the Project Team, Data: Result of hydrology survey in this Project



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.27: Mean Annual Water Balance in the Lake Beseka with 46.2 MCM Return Flow

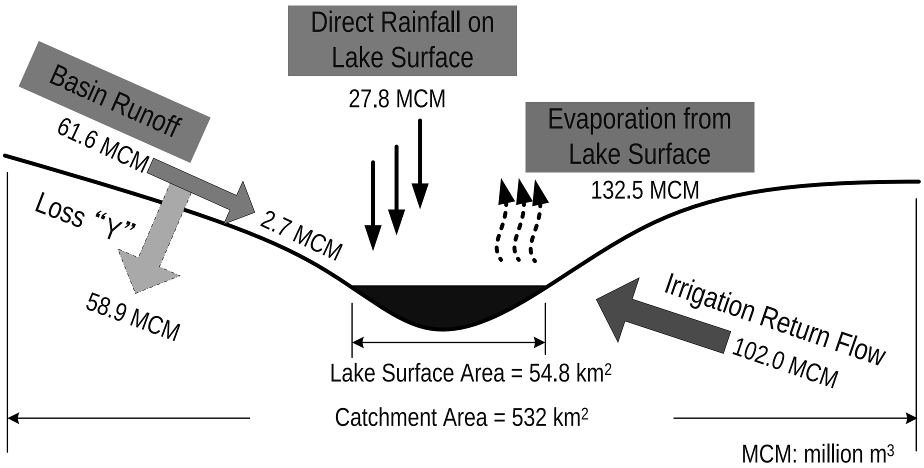
Another extreme case is considered. In this case, all intake water of Abadir farm (102 million m^3 per annum, see b.3.1 above) is supposed to discharge into the Lake Beseka without any uses or losses. The result is provided in Table 11.5.16 and Figure 11.5.28 below:

Table 11.5.16: Mean Annual Water Balance in the Lake Beseka with 102 MCM Return Flow

Items	Area/Volume	Calculation / Remarks
ELSA	54.8 km^2	
Inflow		
Direct Rainfall on the Lake Surface	27.8 (10^6m^3)	508 mm x 54.8 km^2
Runoff from the Lake Catchment	61.6 (10^6m^3)	508 mm x 1.090 (532 km^2 – 54.8 km^2)$^{-0.236}$ x (532 km^2 – 54.8 km^2)

Items	Area/Volume	Calculation / Remarks
Loss “Y”	-58.9 (10^6m^3)	
Irrigation Return Flow	102.0 (10^6m^3)	
Total Inflow	**132.5 (10^6m^3)**	
Outflow		
Evaporation from the Lake Surface	132.5 (10^6m^3)	3,023 mm x 0.8 x 54.8 km^2
Total Outflow	**132.5 (10^6m^3)**	

Source: the Project Team, Data: Result of hydrology survey in this Project

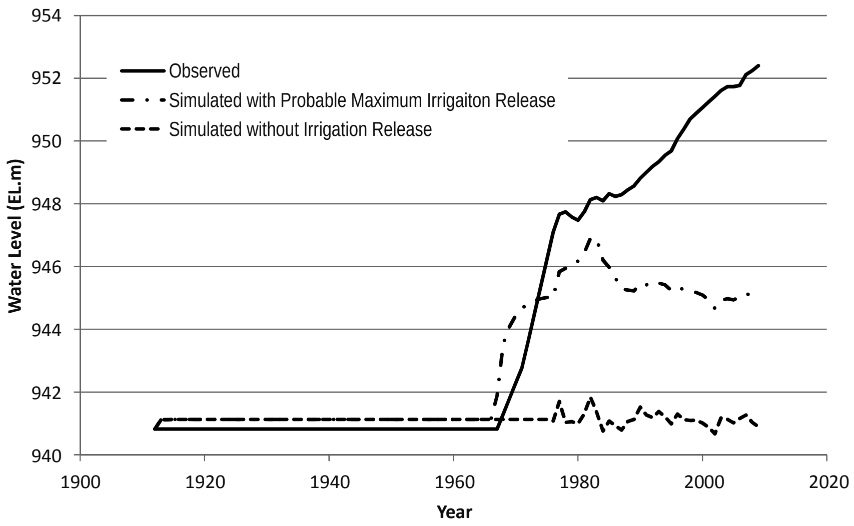


Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.28: Mean Annual Water Balance in the Lake Beseka with 102 MCM Return Flow

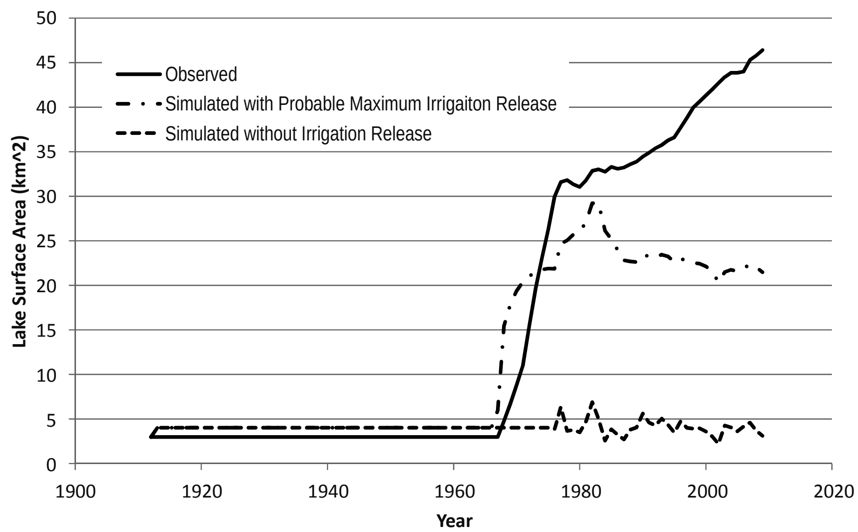
According to the above, possible maximum lake surface area would be around 20 km^2 in case with the return flow from Abadir farm. It would be around 27 km^2 even if the return flow from Nura Hira farm, which is actually no longer reaching the lake (as a result of the countermeasure works), is added. If the lake size of 50 km^2 is kept by the irrigation return flow, the required scale of the return flow is some 100 million m^3 per annum.

The following graphs show the historical changes of the water level and surface area of Lake Beseka assuming that all return flow from Abadir and Nura Hira farms discharge into the lake.



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.29: Simulated Time Series of the Lake Water Level with Irrigation Return Flow



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.30: Simulated Time Series of the Lake Surface Area with Irrigation Return Flow

The lake water level rose sharply after the start of the Abadir farm operation. The water level reached up to EL. 947 m (surface area: 30 km^2) in 1983 due to additional return flow from Nura Hira farm. The water level finally converged at around EL. 945 m (surface area: 23 km^2).

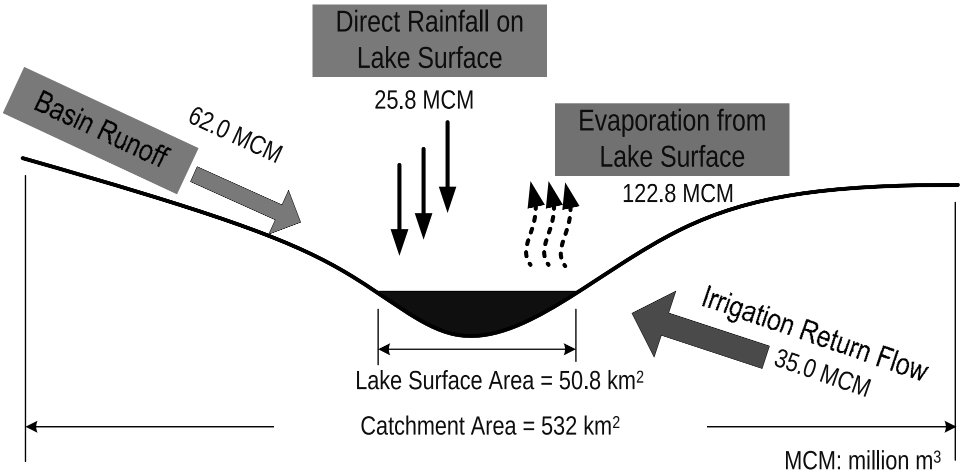
c.3 Water balance calculation with return flow (without loss "Y")

The annual water balance calculation is again made without supposing loss "Y" (58.9 million m^3 per annum) which is introduced to keep the ELSA of 4 km^2. The results with return flow of 35 million m^3/year are shown in Table 11.5.17 and Figure 11.5.31, and those with return flow of 102 million m^3/year are in Table 11.5.18 and Figure 11.5.32.

Table 11.5.17: Mean Annual Water Balance in the Lake Beseka with 35 MCM Return Flow (without loss "Y")

Items	Area/Volume	Calculation / Remarks
ELSA	50.8 km^2	
Inflow		
Direct Rainfall on the Lake Surface	25.8 ($10^6 m^3$)	508 mm x 50.8 km^2
Runoff from the Lake Catchment	62.0 ($10^6 m^3$)	508 mm x 1.090 (532 km^2 – 50.8 km^2)$^{-0.236}$ x (532 km^2 – 50.8 km^2)
Irrigation Return Flow	35.0 ($10^6 m^3$)	
Total Inflow	**122.8 ($10^6 m^3$)**	
Outflow		
Evaporation from the Lake Surface	122.8 ($10^6 m^3$)	3,023 mm x 0.8 x 50.8 km^2
Total Outflow	**122.8 ($10^6 m^3$)**	

Source: the Project Team, Data: Result of hydrology survey in this Project



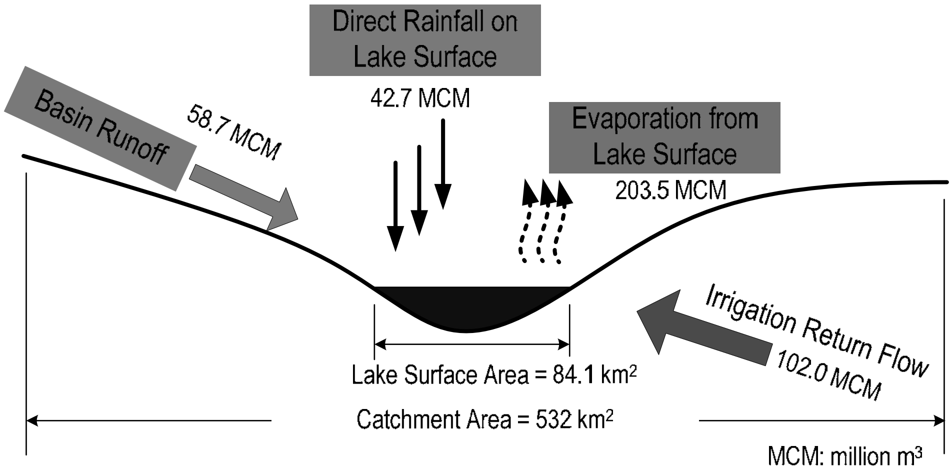
Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.31: Mean Annual Water Balance in the Lake Beseka with 35 MCM Return Flow (without loss "Y")

Table 11.5.18: Mean Annual Water Balance in the Lake Beseka with 102 MCM Return Flow (without loss "Y")

Items	Area/Volume	Calculation / Remarks
ELSA	84.1 km^2	
Inflow		
Direct Rainfall on the Lake Surface	42.7 ($10^6 m^3$)	508 mm x 84.1 km^2
Runoff from the Lake Catchment	58.7 ($10^6 m^3$)	508 mm x 1.090 (532 km^2 – 84.1 km^2)$^{-0.236}$ x (532 km^2 – 84.1 km^2)
Irrigation Return Flow	102.0 ($10^6 m^3$)	
Total Inflow	**203.5 ($10^6 m^3$)**	
Outflow		
Evaporation from the Lake Surface	203.5 ($10^6 m^3$)	3,023 mm x 0.8 x 84.1 km^2
Total Outflow	**203.5 ($10^6 m^3$)**	

Source: the Project Team, Data: Result of hydrology survey in this Project



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.32: Mean Annual Water Balance in the Lake Beseka with 102 MCM Return Flow (without loss “Y”)

The above results show, if the loss “Y” is ignored, the possibility of the expansion of the lake area up to 50 km^2 due to the return flow from Abadir farm. However, it shall be noted that the lake situation before the 1960s cannot be explained properly in this case as shown in Figure 11.5.24 and Figure 11.5.25.

d. Discussions

The analyses made in this subsection 11.5.3 are summarized below:

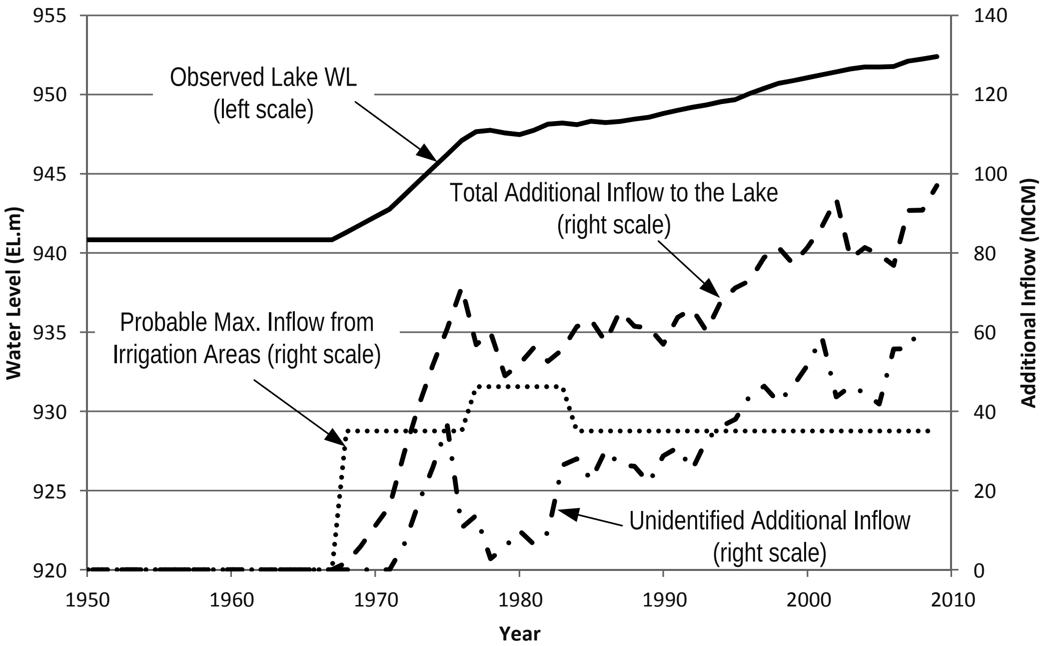
- The irrigation efficiency in Abadir farm is estimated based on 1) water intake record, 2) crop water requirement for sugarcane and 3) effective rainfall. The estimated efficiency is about 54% and this is high enough.
- The possible maximum return flow from Abadir farm is 35 million m^3 per annum. However, since this includes water losses which should actually occur before arriving to the Lake Beseka in the form of evaporation and so on, the actual annual return flow must be much smaller than 35 million m^3.
- The hydrological equilibrium state before 1960s, in which the Lake Beseka surface area was approx. 4 km^2, cannot be explained without considering 58.9 million m^3/year of loss “Y” from the basin in addition to the evaporation from the lake surface.
- Under the condition with loss “Y”, the possible maximum Lake Beseka surface area is around 20 km^2 with Abadir farm’s return flow. The area reaches up to 27 km^2 considering the Nura Hira farm’s return flow additionally. Regardless, these areas are far below the actually observed lake surface area of 50 km^2.
- Under the condition without loss “Y”, the possible maximum Lake Beseka surface area is comparative to the actual size (about 50 km^2) due to the Abadir farm’s return flow (35 million m^3/year). However, the original Lake Beseka surface area should be 33.4 km^2 in this condition and it is inconsistent with the fact that the Lake Beseka was in the stable condition with the surface area of 3 – 5 km^2 before.

The following can be said from the above findings:

- Considering the fact that the timing of the Lake Beseka level rise coincides with that of commencements of large irrigation projects (see Figure 11.5.16) and water balance calculation results, we cannot conclude that there are definitely no effects by irrigation return flow on the Lake Beseka expansion.

- However, the expandable area due to return flow is limited far below the actual area, even if we introduce the extreme assumption in which all irrigation losses reach the lake and form the lake water.
- Other key factors besides irrigation return flow such as sudden decrease or disappearance of loss "Y", sudden emergence of trans-basin flow from adjacent catchment, etc. shall be considered for explaining the expansion of Lake Beseka.

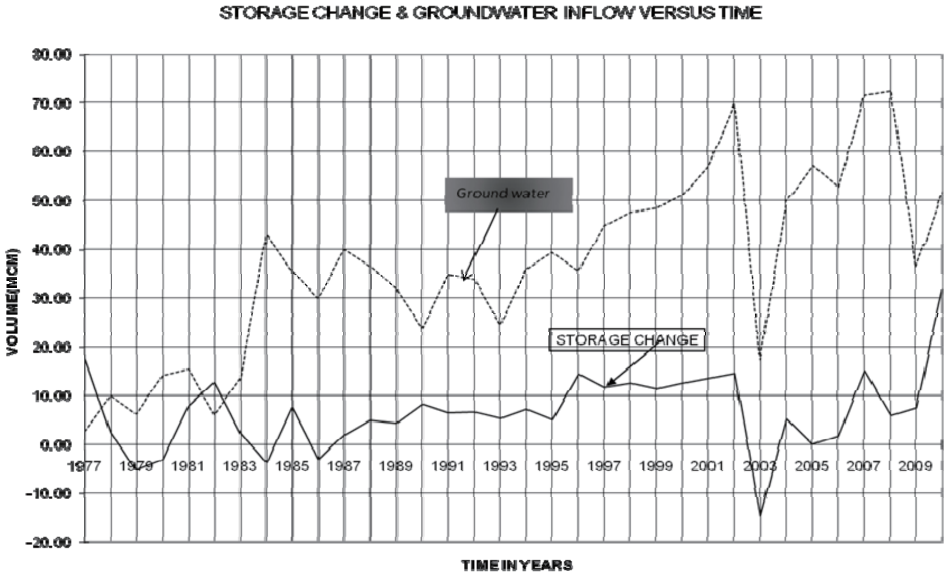
Figure 11.5.33 estimates the required additional inflow to the lake to explain the actual observed lake level rise after late 1960s. This strongly implies the existence of some kind of additional inflow (or decrease in loss "Y") in an upward trend other than uniform irrigation return flow.



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 11.5.33: Annual Additional Inflow to the Lake required for Explanation of Actual Lake Rise

Similar analysis has been made in WWDSE (2011) as shown in Figure 11.5.34. In that analysis, existence of groundwater flow in an upward trend is denoted.



Source: Reference ⑥

Figure 11.5.34: Annual Groundwater Inflow to the Lake estimated in WWDSE (2011)

In terms of the countermeasures against irrigation return flow, the following points shall be kept in mind:

- It is not realistic to force Abadir farm to improve irrigation efficiency because the farm already has high efficiency.
- Countermeasures in Nura Hira farm have already been taken.
- It is not realistic to abandon the existing Abadir and Fentale irrigation projects.
- It is almost impossible to trap irrigation return flow before reaching the Lake Beseka because the flow shall pass through broad areas such as soil layers and shallow groundwater domains.

The most practical way to mitigate the influence of irrigation return flow is to install drainage facilities (eg. drainage pump, channel, etc.) in the Lake Beseka and strive, as far as possible, to release the same amount as there is incoming in the return flow. Possible maximum annual return flow is estimated as follows:

Abadir farm: 35 million m^3/year

All irrigation losses are assumed to become the lake water from the conservative view.

Fentale project: 91 million m^3/year

The return flow is estimated at a rate proportion to the area of Abadir farm in the Lake Beseka catchment (2,315 ha). The irrigation area of Fentale project in the Lake Beseka catchment is about 6,000 ha. So, the possible maximum annual return flow from Fentale project is 91 million m^3 (= 35 million m^3 x 6,000 ha / 2,315 ha)

The required drainage capacity is therefore 126 million m^3 per annum (4 m^3/sec). Drainage facilities from the Lake Beseka have been installed since 2004. According to the reconnaissance by the Project Team, the capacity of the existing drainage channel is at least

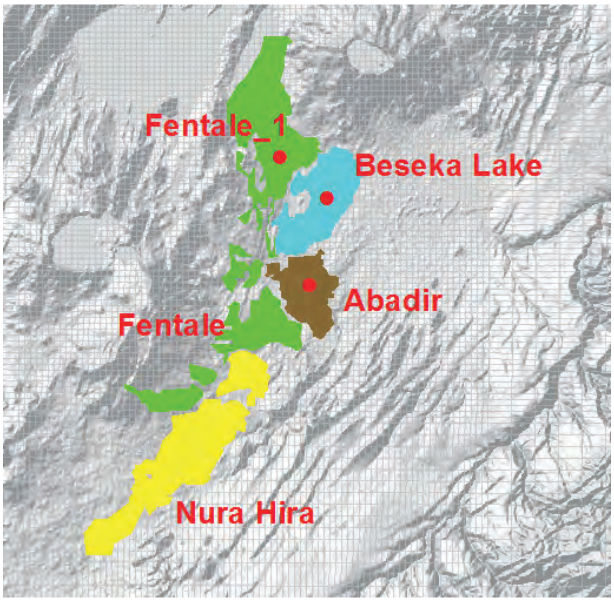
4.20 m^3/sec (= 7 m (width) x 1.2 m (depth) x 0.5 m/sec (velocity)). The existing drainage facilities therefore have sufficient capacity as the countermeasure against irrigation return flow.

11.6 Analyses on Groundwater Recharge and Movement for Lake Beseka Area

11.6.1 Irrigation farms around Lake Beseka

There are several factors which are believed to be the cause of water level rise of Lake Beseka including the inflow of the irrigation water from the sugarcane plantation farms which started from 1960's. The possibility of the water level rise by the irrigation water has been considered using the model.

Figure 11.6.1 shows the location of the irrigation farms and Lake Beseka (including the topography acquired from the SRTM). However, Fentale_2 and Fentale Vast are not in operation.



Source: the Project Team

Figure 11.6.1: Location of Irrigation Farms around Lake Beseka

Abadir farm is built adjacent to the Lake Beseka in the south of the lake and has the higher altitude (irrigation area) than the lake itself. This means there is a possibility of irrigation return flow to the lake.

11.6.2 Return flow from the irrigation area

It is difficult to estimate the amount of water used inside in the irrigation area. However, there is a data of return flow from the irrigation farms (excess water) into Lake Beseka from 1977 to 2011 prepared by MoWIE as shown in Table 11.6.1.

Table 11.6.1: Estimated Return Flow from Irrigation to Lake Beseka by MoWIE

Year	Nura Hira	Abadir	Fentale	Total (MCM)
1977	13.4	20	0	33.4
1978	12	20	0	32

Year	Nura Hira	Abadir	Fentale	Total (MCM)
1979	17.5	2.9	0	20.4
1980	14.6	2.6	0	17.2
1981	10.8	3.6	0	14.4
1982	12.7	3.4	0	16.1
1983	13.7	3.8	0	17.5
1984	0	3.7	0	3.7
1985	0	2.4	0	2.4
1986	0	2.7	0	2.7
1987	0	2.5	0	2.5
1988	0	2.2	0	2.2
1989	0	2.2	0	2.2
1990	0	2.2	0	2.2
1991	0	2.8	0	2.8
1992	0	2.8	0	2.8
1993	0	2.8	0	2.8
1994	0	2.4	0	2.4
1995	0	2.5	0	2.5
1996	0	2.8	0	2.8
1997	0	2.7	0	2.7
1998	0	2.4	0	2.4
1999	0	1.8	0	1.8
2000	0	1.2	0	1.2
2001	0	1.2	0	1.2
2002	0	1.2	0	1.2
2003	0	0.9	0	0.9
2004	0	1	0	1
2005	0	1.2	0	1.2
2006	0	1.3	0	1.3
2007	0	1.2	0	1.2
2008	0	1.4	0	1.4
2009	0	1.2	31.7	32.9
2010	0	1.1	42.2	43.3
2011	0	1.1	64.3	65.4

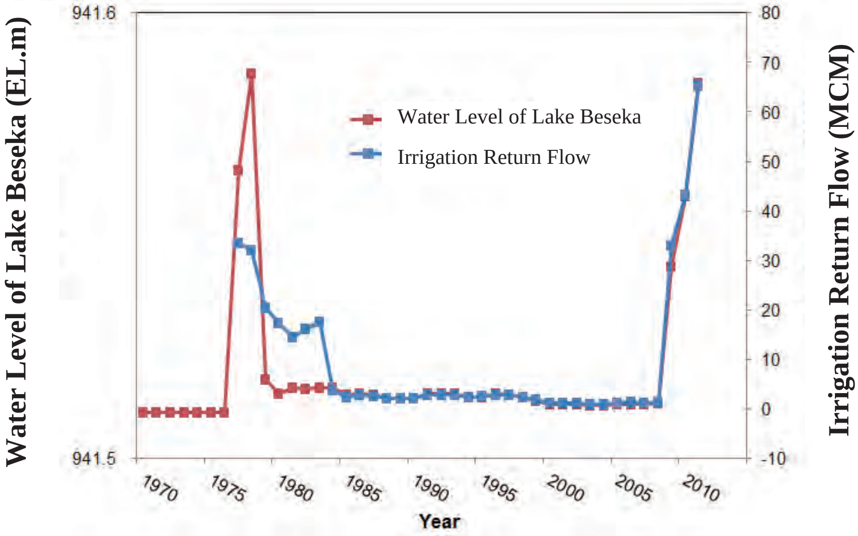
Source: MoWIE (2011)

The method of model specification (consideration) is by dividing the total cell area of the irrigation farms with the irrigation return flow before calculating the average amount in each farm.

For example, there are 873 cells in the groundwater model extracted from the area of Fentale farm. From the cell size (500 x 500 m), the total area of the irrigation farm will be 218,250,000 m^2. The recharge value of each cell will be 0.29m/year when estimated flow of Fentale farm in 2011 (64.3 MCM) divided by the total area of the farm. It is the same with the Abadir farm where the recharge value of each cell will be 0.04m/year when estimated flow of Abadir farm in 2011 (1.1 MCM) divided by the total area (27,750,000 m^2) of the farm. After the calculation of the recharge amount in each farm, the groundwater model was calculated with the three criteria listed below.

11.6.3 The result of 1st analysis (criteria)

Figure 11.6.2 shows the analysis results of the first criteria. The fluctuation of the water level in Lake Beseka seems to match the fluctuation in the irrigation farms.



Source: the Project Team

Figure 11.6.2: Results of Irrigation Return Flow and Water Level (50% of Irrigation Return Flow)

As mentioned above, the irrigation farms have started operating from 1960's which means the return flow from the irrigation farms are likely to have started at the same period. However, there is no related data available before 1977. Therefore, the data later than 1977 was used to set the recharge amount for the analysis.

The data above indicated the return flow of irrigation was observed only from 1977 to 2008 in Abadir farm and Nura Hira. Among these two farms, the return flow at Nura Hira farm was observed only until 1983 which means the period of return flow at these farms was from 1977 to 1983. This might be the reason in the significant difference of fluctuation between 1979 and 1983 in the results.

The return flow from the irrigation farm until 2008 was considered assuming the Abadir farm as the main cause. The return flow from 1977 to 1978 was 20MCM though the amount has decreased drastically after 1978 (Min: 3.8, Max: 0.9, Average: 2.1MCM) which is 1/10 of the return flow between 1977 and 1978. This is the reason of water level decrease after 1979 as shown in Figure 11.6.2. Nevertheless, the water level is higher compared to the initial water level (before the irrigation became operational).

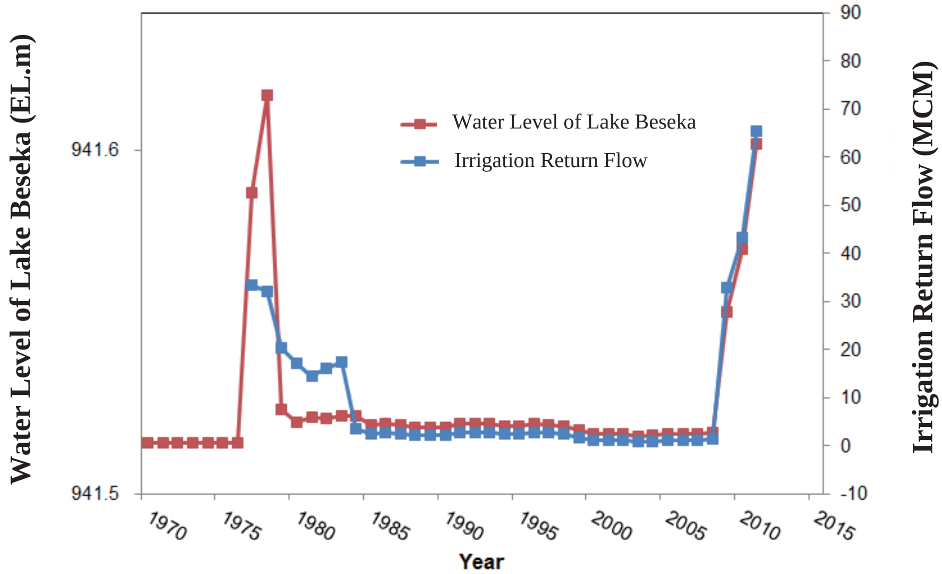
The largest increase in water level was seen in 1978 which matches the maximum return flow period of Abadir farm (0.026m higher than the initial water level). On the other hand, the minimum increase in water level was seen in 2003 which assumed to be caused by return flow from the Abadir farm only (0.005m higher than the initial water level).

11.6.4 The result of 2nd analysis (criteria)

The analysis results of the second criteria (same recharge amount with the estimated irrigation return flow) is shown in Figure 11.6.3.

The trend of the water level seems to be the same as the result of the first analysis where the fluctuation is dominated by the return flow of irrigation farms. The largest increase in water level was seen in 1978 where the water level was 0.05 m higher than the initial water level. This is two times of the result calculated in the first analysis (the return flow amount was

50% in the first analysis). The minimum increase in water level was seen in 2003 (same as the first analysis) where the water level is 0.0009 m higher than the initial water level.



Source: the Project Team

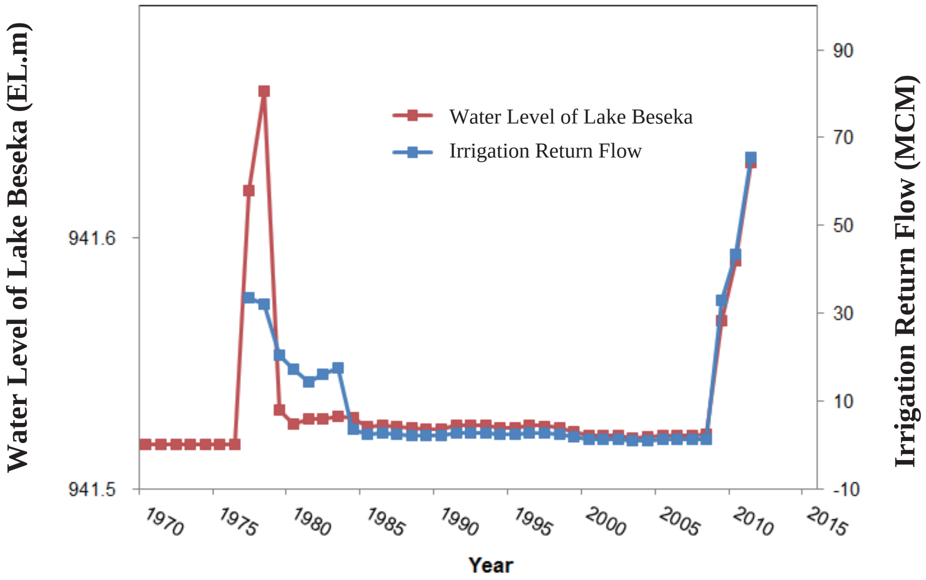
Figure 11.6.3: Result of Irrigation Return Flow and Water Level (Equal to the Irrigation Return Flow)

11.6.5 The result of 3rd analysis (Criteria)

The analysis result of the third criteria (estimated irrigation return flow is set as double that of the 2nd analysis) is shown in Figure 11.6.4.

The trend of the water level seems to be the same as the result of the first and second analysis where the fluctuation is dominated by the return flow of irrigation farms. The largest increase in water level was seen in 1978 where the water level was 0.1 m higher than the initial water level. The minimum increase in water level was seen in 2003 where the water level 0.0018 m higher than the initial water level. These values are double the results of the second analysis and four times higher than the first analysis.

Judging from the results of the abovementioned groundwater model analysis, it seems the return flow of the irrigation water is hardly affecting the rise of the water level in Lake Beseka. The water level could rise only 0.1 m even though the return flow of the irrigation water is set to be twice as high as that of the groundwater model. This means that the irrigation water can hardly be considered as the main reason for the rise in water level at Lake Beseka.



Source: the Project Team

Figure 11.6.4: Result of Irrigation Return Flow and Water Level (Double of Irrigation Return Flow)

In addition, the return flow amount from Awash River to the irrigation farms are shown in Table 11.6.2.

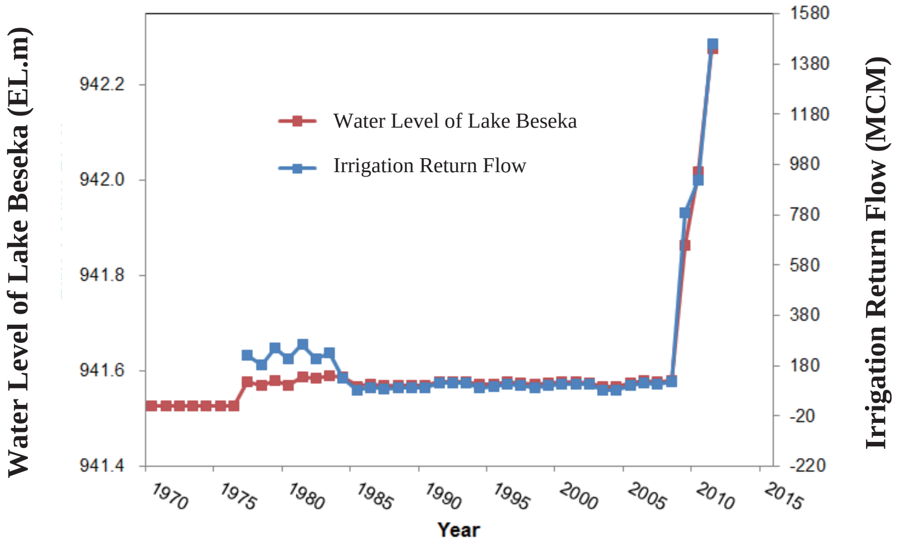
Table 11.6.2: Water Intake Amount from Awash River to Each Irrigation Farm

Year	Nura Hira	Abadir	Fentale	Total (MCM)
1977	107.1	111.9	0	219
1978	95.8	87	0	182.8
1979	139.9	110.4	0	250.3
1980	116.7	90.3	0	207
1981	139.9	125.9	0	265.8
1982	86.2	119.6	0	205.8
1983	101.7	130.3	0	232
1984	0	129	0	129
1985	0	83.7	0	83.7
1986	0	93.9	0	93.9
1987	0	87.9	0	87.9
1988	0	91.4	0	91.4
1989	0	91.4	0	91.4
1990	0	91.4	0	91.4
1991	0	109	0	109
1992	0	109	0	109
1993	0	109	0	109
1994	0	92.7	0	92.7
1995	0	97.1	0	97.1
1996	0	107	0	107
1997	0	102.7	0	102.7
1998	0	92.7	0	92.7
1999	0	99.83	0	99.83
2000	0	104.5	0	104.5
2001	0	104.4	0	104.4
2002	0	103.8	0	103.8
2003	0	81.7	0	81.7
2004	0	84.2	0	84.2
2005	0	100.9	0	100.9

Year	Nura Hira	Abadir	Fentale	Total (MCM)
2006	0	111.9	0	111.9
2007	0	104.7	0	104.7
2008	0	115.5	0	115.5
2009	0	103.2	684.1	787.28
2010	0	16.17	900.3	916.5
2011	0	99.83	1359.8	1459.68

Source: MoWIE (2011)

Although this return flow shown above is hardly to flow directly into the Lake Beseka. the comparison with the fluctuation of the lake water level will be as shown in the figure below asssuming that the whole amount of water shown in Table 11.6.2 flows into Lake Beseka



Source: the Project Team

Figure 11.6.5: Results of Water Level of the Lake and River Inflow (Same as Return Flow)

The fluctuation trend of water level is dominated by the irrigation return flow. The maximum value until 2008 was seen in 1983 where the water level 0.062 m higher than the initial water level. The minimum increase of the water level of lake was seen in 2003 (seen in the return flow of Abadir farm) here the water level is 0.038 m higher than the initial water level. As an utmost example, there is only a little difference in the water level even though it is assumed that all of the water flows from the river into the lake (maximum value of 0.6 m in 2011).

11.6.6 Estimation of the groundwater fluctuation in the irrigation farms by model

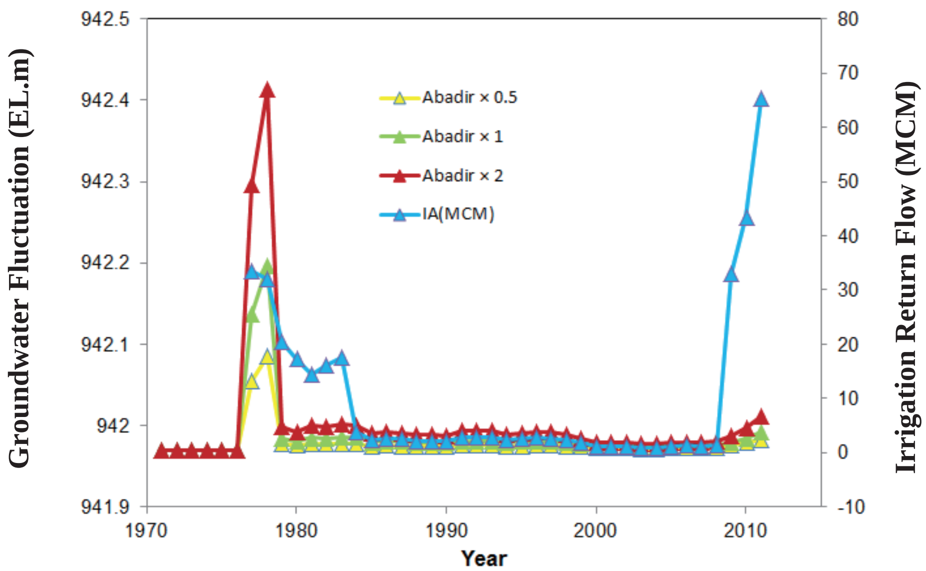
The fluctuation of the groundwater has been considered not only at the Lake Beseka but also in its the surrounding area particularly in the irrigation area. The groundwater in the Abadir farm (located in the south of the lake) was considered using the groundwater model since it has the longest period of return flow to the lake.

a. Groundwater fluctuation at Abadir farm (calculated according to the return flow from irrigation)

Abadir farm is located in the upstream adjacent to Lake Beseka. The result of the groundwater fluctuation calculation using the groundwater model is shown in Figure 11.6.6.

The groundwater fluctuation of Abadir farm seems similar to the fluctuation of Lake Beseka. In particularly, the groundwater fluctuation seems to match the estimated recharge amount from 1984 to 2008 where there was only the return flow from Abadir farm.

Furthermore, part of the Fentale farm (started to operate from 2009 to 2011) in the upstream of Abadir farm as shown in Figure 11.6.1 may affect the return flow of the irrigation return flow in the Abadir farm. Therefore, the rise of the water level from 2009 to 2011 may have been caused mostly by the Fentale farm while the return flow of irrigation water from Abadir was constant at that period. However, the rate of the rise in this groundwater model is small compared to the maximum return flow recorded from 1977 to 1978.



Source: the Project Team

Figure 11.6.6: Model Estimation of Groundwater Fluctuation in Abadir Farm (Irrigation Return Flow)

The groundwater fluctuation by the irrigation return flow undertaken with three criteria as follows;

1) When assuming the estimated irrigation return flow as 50%, the maximum value was seen in 1978 where the groundwater is 0.116 m higher than the initial groundwater level. While the minimum value was seen in 2003 where the groundwater is 0.0019 m higher than the initial groundwater level.

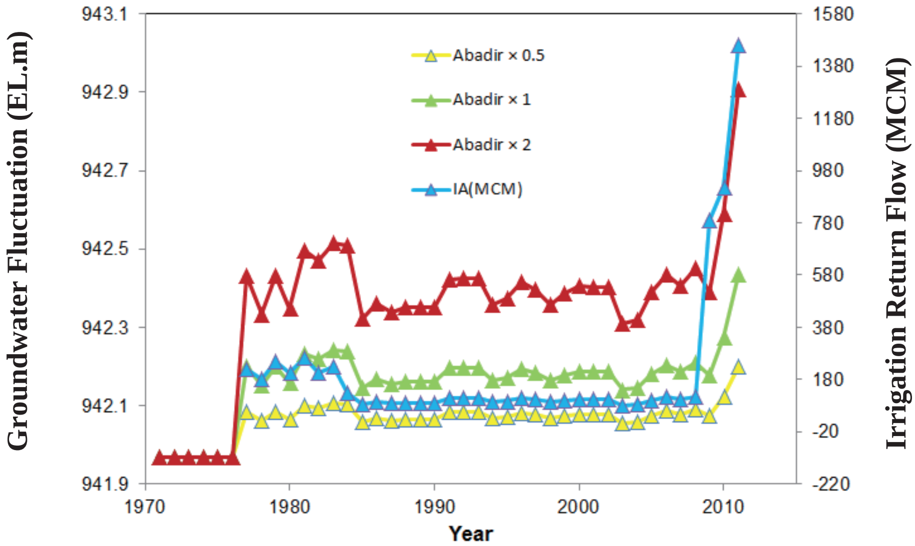
2) When assuming the recharge amount to be the same as the estimated irrigation return flow, the maximum value was seen in 1978 where the groundwater is 0.227 m higher than the initial groundwater level. While the minimum value was seen in 2003 where the groundwater is 0.0038 m higher than the initial groundwater level.

3) When assuming the irrigation return flow to be double that of the estimated irrigation return flow, the maximum value was seen in 1978 where the groundwater is 0.443 m higher than the initial groundwater level. While the minimum value was seen in 2003 where the groundwater is 0.0075 m higher than the initial groundwater level.

Comparing the maximum value of groundwater fluctuation of the three results above and the results of the fluctuation at Lake Beseka in 1978 (maximum amount of irrigation return flow), the estimation result of water level rise will be 0.09, 0.176 and 0.344 m.

b. Groundwater fluctuation at Abadir farm (calculated according to the return flow from the river)

Figure 11.6.7 shows the groundwater fluctuation when assuming the return flow originates from the river.



Source: the Project Team

Figure 11.6.7: Model Estimation of Groundwater Fluctuation of Abadir Farm (by the Return Flow from the River)

The groundwater fluctuation by the river return flow undertaken with the three criterions in Abadir farm is as follows;

1) When assuming the estimated river return flow as 50%, the maximum value was seen in 1983 where the groundwater is 0.136 m higher than the initial groundwater level. While the minimum value was seen in 2003 where the groundwater is 0.0085 m higher than the initial groundwater level.

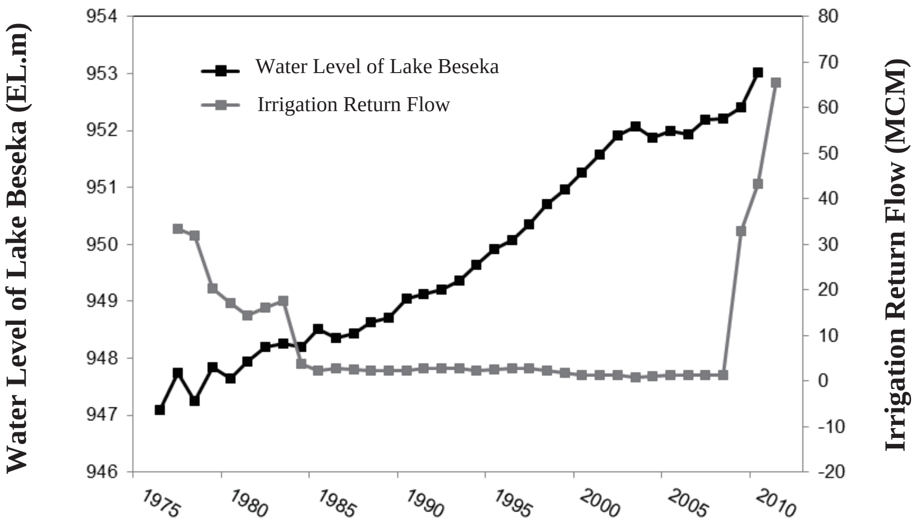
2) When assuming the recharge amount as same as the estimated river return flow, the maximum value was seen in 1983 where the groundwater is 0.273 m higher than the initial groundwater level. While the minimum value was seen in 2003 where the groundwater is 0.171 m higher than the initial groundwater level.

3) When assuming the river return flow as double the recharge amount, the maximum value was seen in 1983 where the groundwater is 0.545 m higher than the initial groundwater level. While the minimum value was seen in 2003 where the groundwater is 0.341 m higher than the initial groundwater level.

Comparing the maximum value of groundwater fluctuation of the three results above and the result of the water level fluctuation at Lake Beseka in 1983 (maximum amount of river return flow), the estimation result of water level rise will be 0.101, 0.211 and 0.422 m .

11.6.7 Comparison between the irrigation return flow and water level rise in Lake Beseka

Figure 11.6.8 shows the comparison of the water level at Lake Beseka and irrigation return flow.



Source: the Project Team

Figure 11.6.8: Comparison of the Water Level at Lake Beseka and Irrigation Return Flow

As shown in the analysis results by the groundwater model, the water level of Lake Beseka is dominated by the irrigation return flow, which means the irrigation return flow does somehow affect the fluctuation of water level in Lake Beseka.

However, as shown in Figure 11.6.8, no matter how much the irrigation return flow is reduced or maintained, the water level of the lake will keep increasing. From 1984 to 2008, the irrigation return flow was only confirmed only at the Abadir farm which is located at the south of the Lake Beseka. The maximum return flow was 2.8 MCM, the minimum return flow was 0.9 MCM and the average was 2.0 MCM. The analysis result by the groundwater model shows that the water level has decreased.

On the other hand, the data of MoWIE shows the increase of the water level where the water level was increase at least 4.98 m in 2003. From the groundwater model, there is no increase of the water level of Lake Beseka even though there is a return flow from the irrigation. The results of three criterions (refer to Table 11.6.1) shows that the water level is 0.0018 m (maximum), 0.00009 m (intermediate) and 0.0005 m (minimum) higher than the initial water level. This shows that there is not much difference from the initial water level. Based on the groundwater model analysis, the return flow from the irrigation does not much affect the rise in the water level of Lake Beseka, which means there is a possibility of other factors causing the water level rise monitored by MoWIE.

11.7 Discussions

Results of the surveys and analyses on topography, geology, geological structures and hydrogeology are reported in this chapter. In addition to these, i) analysis on surface temperature of the Lake Beseka, ii) water quality analysis for water samples in and around the Lake Beseka, and iii) water balance analysis with estimated irrigation return flow are undertaken in order to validate the rationality of widely recognized cause of the Lake Beseka expansion, i.e. excess irrigation water.

Temperature analyses based on the infrared data of Landsat images suggest the continuous rise of the lake surface temperature. This strongly implies the continuous inflow of high-temperature spring water from western or southwestern side of the Lake Beseka Basin as the cause of Lake Beseka expansion rather than intrusion of excess irrigation water.

Water quality analysis in and around the Lake Beseka revealed that the current water quality of the lake, classified into $NaHCO_3$ or Na_2SO_4/NaCl type, is very similar to those of surrounding groundwater and springs, mainly classified into $NaHCO_3$ type. In view of chemical evolution, the lake water has clearly evolved from spring water and no effects of river water (irrigation water) are found. The trace of intrusion of irrigation water (or Awash River water) can be found from the slightly detected calcium ion only in the southern shore where the Lake Beseka faces the Abadir farm. This result also suggests the importance of other factors for explanation of the lake expansion than irrigation return flow.

The irrigation efficiency in Abadir farm is high enough in accordance with the FAO's standard, and the farm has practiced effective irrigation. On the other hand, as long as the irrigation projects in the Lake Beseka Basin involve water transmission from outside of the basin, the return flow theoretically contributes to the lake expansion. The water balance analysis is undertaken to see whether or not the return flow from the irrigation projects developed in late 1960s can explain the lake expansion without contradiction. The result shows that the lake surface area cannot reach up to currently observed level even if the possible maximum return flow is applied with extreme assumptions.

Based on the above results, the Project Team considers the process of expansion of Lake Beseka as follows:

- The scale of Lake Beseka has remained stable with a surface area of around 4 km^2 until the 1960s.
- The groundwater inflow to the lake began to increase after the late 1960s.
- The lake water level sharply rose due to groundwater inflow promoted by the return flow from the irrigation projects which were developed around the same time.
- The amount of groundwater inflow to the lake has been in upward trend year after year making the lake the current size.
- The source of the groundwater inflow is the same as that of hot springs in the western and southwestern shores of the lake because the lake surface temperature is in upward trend.

Since the following points are difficult to evaluate, further scientific investigations are expected.

- What triggered the increase in groundwater inflow since the late 1960s?
- To what extent the groundwater inflow will eventually increase? Will it be in static condition or it will turn into a downward trend?

References

① Data on existing wells presented in existing research papers

1) Hydrogeology (Map) of the Nazret, EIGS, 1985
2) Evaluation of water resources of the Ada'a and Becho plans groundwater basin for irrigation development project, WWDSE, planned by MoWR, 2009
3) Allaidege plain groundwater resources assessment project, WWDSE planned by MoWR, 2009
4) Study and design of Lake Besaka level rise project II, WWDSE, planned by MoWE, 2011
5) Growing lake with growing problems: integrated hydrogeological investigation on Lake Beseka, Ethiopia, ELENI AYALEW BELAY, 2009
6) Assessment and evaluation of causes for Beseka Lake level rise and design mitigation measures Part II: Study for medium and long term solutions (Main report final), MoWIE and OWWDSE, 2014

② Well development records, borehole logs and pumping test results

1) Existing well data (incl. borehole logs and pumping test results) from West Hararge Zone Water Office
2) Existing well data (incl. borehole logs and pumping test results) from Arsi Zone Water Office
3) Existing well data (incl. borehole logs and pumping test results) from East Shewa Zone Water Office
4) Well development records and individual well data in Arerti Woreda (Amhara Region) and Lomme Woreda (Oromia Region)
5) Data from irrigation well by WWDSE, 2014 (depth: 595 m)

③ Others

1) Hydrogeological map of Ethiopia (1:2,000,000) compiled by Tesfaye Chernet and the Regional Geology Department, EIGS, 1988

④ Data including photographs taken by the Project Team though field survey, analysis and interviews etc.

⑤ Study of Lake Beseka, Ministry of Water, 1999

⑥ Study and Design of Lake Beseka Level Rise Project II, WWDSE, planned by MoWIE, 2011

⑦ Irrigation Water Management: Irrigation Scheduling, 1989 (http://www.fao.org/docrep/t7202e/t7202e00.htm#Contents)

⑧ FAO Crop Water Information (http://www.fao.org/nr/water/cropinfo_sugarcane.html)

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⑩ Growing Lake with Growing Problems: Integrated Hydrogeological Investigation on Lake Beseka, Ethiopia, Eleni Ayalew Belay, 2009

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⑫ EIGS (Ethiopian Institute of Geological Survey) and ELC (Elc electroconsult milano and Geotermica italiana pisa, Italia) (1987): Geothermal reconnaissance study of selected sites of the Ethiopian rift system, Geotherm. Report, Milan, Italy.

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⑮ Mohr, P.A. (1960): Report on a geological excursion through southern Ethiopia. Geophys. Observatory of Addis Ababa Bull., 3, 9-20.

Appendix (Minutes of Meting)

KOKUSAI KOGYO CO., LTD.
Overseas Operations Department:
2 Rokubancho, Chiyoda-ku, Tokyo 102-0075, Japan
TEL:**81-3-6361-2452 FAX:**81-3-3237-5477

The Project of Groundwater Resource Assessment in the Middle Awash River Basin in The Federal Democratic Republic of Ethiopia

Date: 1st August 2014

Ref: No.21/TM/14

Ministry of Water Irrigation & Energy (MoWIE)
Attention to Ato. Tesfaye Tadesse (Groundwater Directorate Director)

Re: Handing over of JICA funded equipment

Dear Sir,

This is evidence that the following items procured by The Project of Groundwater Resource Assessment in the Middle Awash River Basin in The Federal Democratic Republic of Ethiopia were certainly handed over to the Groundwater Directorate of Ministry of Water Irrigation & Energy (MoWIE). The equipments are listed in the attachment.

Groundwater Directorate surely received these items and promised to sustainably implement the project activities using the provided equipment.

as Provider	as End User
Mr. Toshiyuki MATSUMOTO Team Leader/Groundwater Resources Development & Management for JICA Study Team Kokusai Kogyo Co., Ltd.	Ato. Tesfaye Tadesse Groundwater Directorate Director Ministry of Water Irrigation & Energy (MoWIE)

KOKUSAI KOGYO CO., LTD.
Overseas Operations Department:
2 Rokubancho, Chiyoda-ku, Tokyo 102-0075, Japan
TEL:**81-3-6361-2452 FAX:**81-3-3237-5477

The Project of Groundwater Resource Assessment in the Middle Awash River Basin in The Federal Democratic Republic of Ethiopia

List of Equipment

No.	Item	Quantity
1	Handy GPS	4
2	Automatic Water Level Gauge / Data Logger	12
3	Portable Water Level Gauge (200m)	1
4	Portable Water Level Gauge (300m)	1
5	Electrical Conductivity Meter (EC)	2
6	pH Meter	2
7	Oxidation Reduction Potential Meter (OPR)	2
8	GIS Software (ArcGIS)	1
9	Groundwater Modelling Software (Processing Modflow)	1
10	Cross View for ArcGIS	1
11	Cross View Editing Software (Surfer / Digger)	4
12	GPS Data Editing Software (MxGPS)	1
13	Multifunction Printer	1
14	Desktop PC	2
15	Laptop PC	2
16	External Storage Device	2
17	Microsoft Office	1

KOKUSAI KOGYO CO., LTD. Addis Ababa Ethiopia

The Federal Democratic Republic of Ethiopia Ministry of Water, Irrigation & Energy

Date: 9th August 2014

Ministry of Water, Irrigation & Energy (MoWIE)

Temporary Handover of Equipment

The Groundwater Directorate has temporarily transferred the following equipment for project office of the Middle Awash Basin Groundwater Resource Assessment which were procured by The Project and was handed over to the Groundwater Directorate of Ministry of Water Irrigation & Energy (MoWIE). The equipment are listed below.

List of Equipment

No.	Item	Quantity
1	Handy GPS	4
2	Automatic Water Level Gauge / Data Logger	12
3	Portable Water Level Gauge (200m)	1
4	Portable Water Level Gauge (300m)	1
5	Electrical Conductivity Meter (EC)	2
6	pH Meter	2
7	Oxidation Reduction Potential Meter (OPR)	2
8	GIS Software (ArcGIS)	1
9	Groundwater Modelling Software (Processing Modflow)	1
10	Cross View for ArcGIS	1
11	Cross View Editing Software (Surfer / Digger)	4
12	GPS Data Editing Software (MxGPS)	1
13	Multifunction Printer	1
14	Desktop PC	2
15	Laptop PC	2
16	External Storage Device	2
17	Microsoft Office	1

as Receiver

For Mr. Toshiyuki MATSUMOTO
Team Leader/Groundwater Resources Development & Management for JICA Study Team
Kokusai Kogyo Co., Ltd.

as Provider

Tesfaye Tadesse
Director, Groundwater Directorate

Ato. Tesfaye Tadesse
Groundwater Directorate Director
Ministry of Water Irrigation & Energy (MoWIE)

The Federal Democratic Republic of Ethiopia Ministry of Water, Irrigation & Energy

Date: 2nd November 2015

Ministry of Water, Irrigation & Electricity (MoWIE)

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as Provider

For Mr. Toshiyuki MATSUMOTO
Team Leader/Groundwater Resources
Development & Management for JICA Study Team
Kokusai Kogyo Co., Ltd.

as Receiver

Ato Tesfaye Tadesse
Groundwater Directorate Director
Ministry of Water, Irrigation &
Electricity (MoWIE)

The Federal Democratic Republic of Ethiopia Ministry of Water, Irrigation & Electricity

Appendix (Confirmation Letter)

KOKUSAI KOGYO CO., LTD.
Overseas Operations Department:
2 Rokubancho, Chiyoda-ku, Tokyo 102-0075, Japan
TEL:**81-3-6361-2452 FAX:**81-3-3237-5477

The Project of Groundwater Resource Assessment in the Middle Awash River Basin in The Federal Democratic Republic of Ethiopia

Date: 1st August 2014

Ref: No.21/TM/14

Ministry of Water Irrigation & Energy (MoWIE)
Attention to Ato. Tesfaye Tadesse (Groundwater Directorate Director)

Re: Handing over of JICA funded equipment

Dear Sir,

This is evidence that the following items procured by The Project of Groundwater Resource Assessment in the Middle Awash River Basin in The Federal Democratic Republic of Ethiopia were certainly handed over to the Groundwater Directorate of Ministry of Water Irrigation & Energy (MoWIE). The equipments are listed in the attachment.

Groundwater Directorate surely received these items and promised to sustainably implement the project activities using the provided equipment.

as Provider	as End User
Mr. Toshiyuki MATSUMOTO Team Leader/Groundwater Resources Development & Management for JICA Study Team Kokusai Kogyo Co., Ltd.	Ato. Tesfaye Tadesse Groundwater Directorate Director Ministry of Water Irrigation & Energy (MoWIE)

KOKUSAI KOGYO CO., LTD.
Overseas Operations Department:
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KOKUSAI KOGYO CO., LTD. Addis Ababa Ethiopia

The Federal Democratic Republic of Ethiopia Ministry of Water, Irrigation & Energy

CONSULTING ENGINEERS; GROUND WATER DEVELOPMENT, SOLID WASTE MANAGEMENT, AGRICULTURE & FOREST RESOURCES DEVELOPMENT, ENVIRONMENT CONSERVATION, PHOTOGRAMMETRY & GIS AND OTHERS

Date: 9th August 2014

Ministry of Water, Irrigation & Energy (MoWIE)

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as Receiver

For Mr. Toshiyuki MATSUMOTO
Team Leader/Groundwater Resources Development & Management for JICA Study Team
Kokusai Kogyo Co., Ltd.

as Provider

Tesfaye Tadesse
Director, Groundwater Directorate

Ato. Tesfaye Tadesse
Groundwater Directorate Director
Ministry of Water Irrigation & Energy (MoWIE)

Date: 2nd November 2015

Ministry of Water, Irrigation & Electricity (MoWIE)

Handover of Equipment

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as Provider

For Mr. Toshiyuki MATSUMOTO
Team Leader/Groundwater Resources
Development & Management for JICA Study Team
Kokusai Kogyo Co., Ltd.

as Receiver

Ato Tesfaye Tadesse
Groundwater Directorate Director
Ministry of Water, Irrigation &
Electricity (MoWIE)

The Federal Democratic Republic of Ethiopia Ministry of Water, Irrigation & Electricity