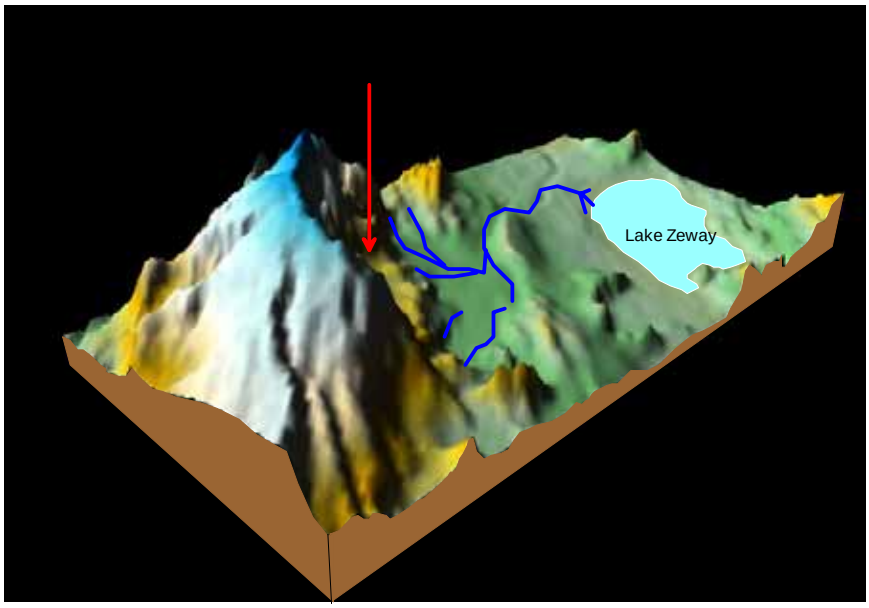
FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

MINISTRY OF WATER RESOURCES
ETHIOPIAN WATER TECHNOLOGY CENTRE

BUTAJIRA – ZIWAY AREAS DEVELOPMENT STUDY



DRILLING AND PUMPING TEST

JANUARY 2008

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Acronyms

EWTEC = Ethiopian Water Technology Centre

MoWR /MWR = Ministry of Water Resources

MER = Main Ethiopian Rift

UTM = Universal Transverse Mercator

m.a.m.s.l = Meter above mean sea level

T = Transmissivity

K = Hydraulic Conductivity

m = meter

l/s = liters per second

m/sec = meter per second

m/day = meter per day

m2/day = square meter per day

m2/sec = square metre per second

m3/sec = cubic metre per second

m3/day = cubic meter per second

mcm = million cubic meter

mg/l = milligram per liter

1 BACKGROUND

One component of the Butajira-Ziway Development project is the verification of the available groundwater source. The geological and hydrogeological and geophysical investigations in the project area indicated the occurrence of different geological formations of groundwater potential. Therefore, in order to verify the potential of the aquifers and their extent test-drilling program was considered.

The purpose of the test drilling was to study the aquifers located in different geological setups and to collect data on the aquifer conditions (such as occurrence, extent, potential, parameters and quality of the groundwater) that can be used for further evaluation of groundwater availability and application for the development of the area.

1.1 DRILLING PROGRAM AND LOCATION OF DRILLING SITES

The drilling program comprised of 6 test boreholes. The boreholes are located to test the aquifers in the following places;

- The alluvial and talus deposit of Butajira Crescent,
- The cinder and basaltic aquifers of Cinder cone and basaltic areas,
- The alluvial lacustrine and pyroclastic deposits of the Kuntane-Inseno Kella Plain,
- The pyroclastic formation of Tora-Koshe Dugda Ridge,
- To understand the water level elevation difference between Inseno plain and Koshe area and,
- The lacustrine deposit in the Gademotta caldera

The locations of the test drilling sites are shown on figure 1.

The test borehole at Butajira Crscent was planned to test the alluvial and talus deposit and shallow test borehole was drilled.

The test borehole for the cinder cone areas was planned to test the scoria and basaltic aquifer of this area and therefore, drilling of shallow well was planned.

At Inseno plain all the existing wells are shallow wells. The vertical extent of the aquifer is not known. The geophysical investigation conducted indicated thick formation of potential for groundwater. Therefore, it was planned to test the aquifer at deeper levels as indicated from the geophysical investigation with borehole of 200 m to 250m depth.

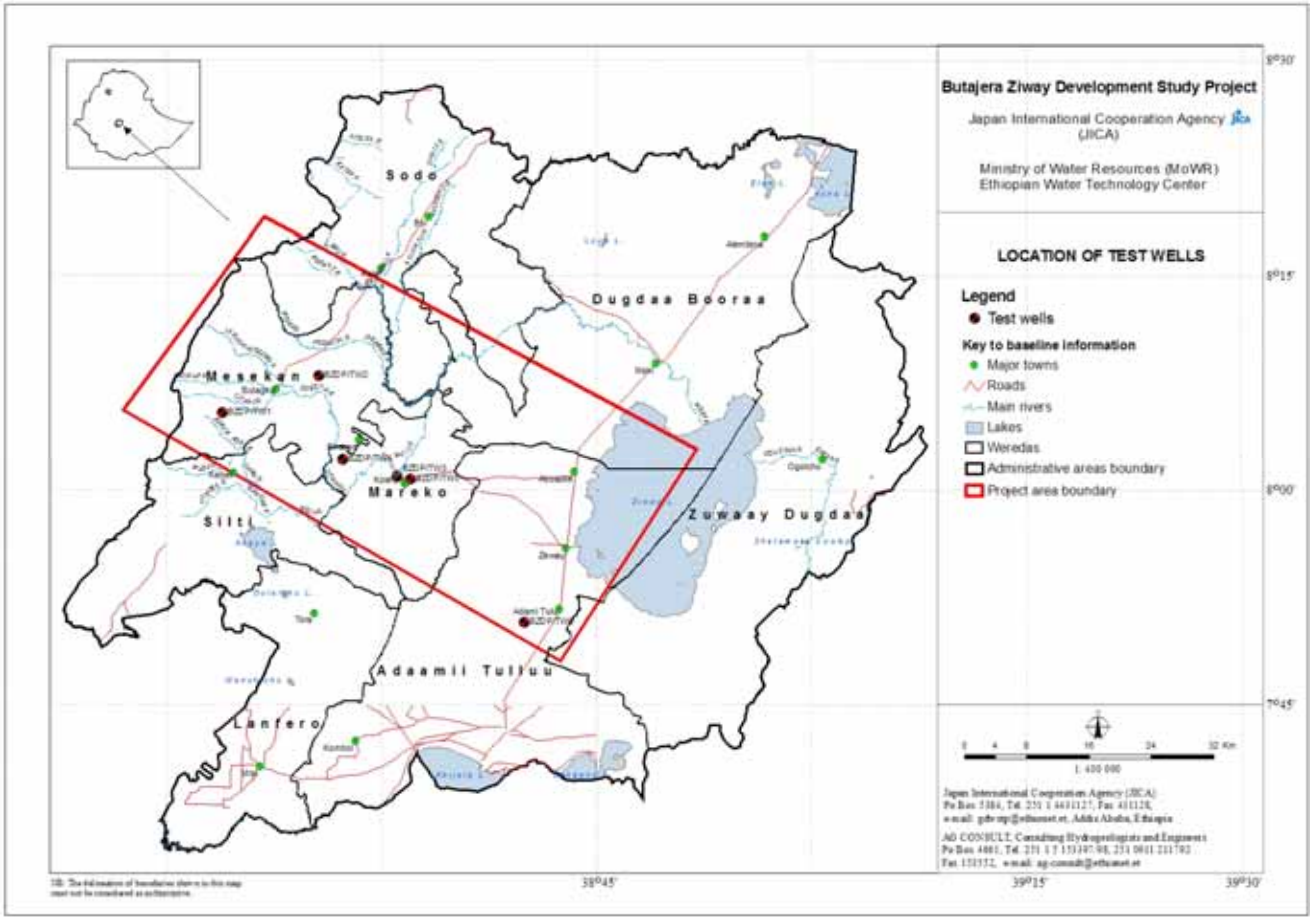


Figure 1. Location of the study area and the test drilling sites

From existing data it was understood that there is difference in aquifer as well as water level elevation between Inseno plain aquifer and Tora-Koshe-Dugada ridge. Therefore to understand this difference one test borehole was planned at the fault zone separating Koshe area and Inseno plain.

It is known from existing information and the geophysical survey that the aquifer at Koshe is deep. Therefore, to understand the deep aquifer at this ridge and its relation with Inseno plain one deep borehole of up to 250 m depth was planned.

In Gademotta caldera occurrence of lacustrine deposit is explained from the geophysical as well as geological investigation. Therefore, one test borehole drilling was planned in order to test the aquifer in this area.

In accordance to the planning all the test wells were drilled. The shallow test wells were drilled by EWTEC and the deep test wells were outsourced to a drilling contractor.

Drilling of two deep boreholes was outsourced to SABA Engineering PLC and the drilling team of the Ethiopian Water Technology Centre (EWTEC) has drilled four shallow boreholes.

- One deep borehole with 244 m depth (BZDP/TW5) drilled in Tora-Koshe-Dugda ridge at Koshe Town.
- The second deep borehole with 168 m depth (BZDP/TW4) drilled in Inseno Plain at a locality known as Kuno Kertafa.

The shallow boreholes are drilled in the following places

- Butajira pediment/crescent at Kacha Ber 123.8 m deep (BZDP/TW1),
- Scoria cones region at Semen Shershera 86 m deep (BZDP/TW2),
- Kontane-Inseno-Kela plain at Weja Kebele 64 m deep (BZDP/TW3) and
- Gademotta caldera / Ziway plain at Shisho Tora 128 m deep (BZDP/TW6).

1.2 DRILLING METHODS

Two types of drilling methods were used. Down the Hole Hammer (DTH) and drilling with mud circulation. DTH drilling used in areas of non-collapsing formations and / or in area where collapsing is not a problem.

DTH drilling is efficient and time saving in non-collapsing formations. However, in collapsing formations such as unconsolidated sediments, collapsing fracture zones, sediments between lava layers drilling with DTH becomes difficult. Therefore, when such difficulties are encountered mud circulation drilling is the safest drilling operation.

Initially in all areas drilling commenced with 12 to 13 inches diameter for the purpose of installation of surface casing. Following installation of surface casing drilling continued with DTH method. Wherever collapsing formations encountered which makes difficult to continue drilling with DTH, the drilling changed to mud circulation method. Therefore two wells well drilled fully with DTH (BZDP/TW4 & BZDP/TW5) and the other four wells were drilled in combination of the two methods.

For logging the geological formations penetrated samples were collected every 2 m and at locations of changes in the geological formation.

After completion of drilling and before installation of casing the wells were logged with electrical, gamma and calliper logs. Based on this and sample logs the screen locations were determined and casings and screens were installed. In shallow wells PVC casings were used on for the two deep wells (BZDP/TW4 & BZDP/TW5) steel casings and screens were used. Wherever the wells are suitable, with the installation of the casing observation pipes were installed in some of the wells.

Following the casing and screen installation, the annular spaces are filter (gravel) packed and development continued until clear water is obtained from the wells.

The wells were test pumped. Water samples were collected for chemical analysis after sufficient duration of testing in order to obtain representative water from the aquifer further away from the well. Therefore, water samples were collected during the end time periods of the test pumping before switching off the pump.

Finally after recovery test sanitary seals and wellheads constructed and the well is sealed with capping.

2 DRILLING RESULTS

2.1 BZDP/TW1 BUTAJIRA PEDIMENT/CRESCENT AT KACHA BER

Location

This test well is situated in Butajira pediment/crescent at Kacha Ber Village.

- Geographic coordinates UTM: 424544 E, 894351 N
- Altitude: 2179 m.a.s.l

Purpose

This borehole has been drilled in order to test the hydrogeological condition underlying the Butajira pediment plain.

Drilling

The well was drilled using DTH and mud circulation system. The first 38 m drilled with DTH and the remaining part with mud circulation after protecting the collapsing part with temporary casing. The total depth of the well below ground surface is 123.83m. The drilling was completed with 252 mm (10 inches) diameter. After completion of drilling 6 inches PVC casing and screens were installed up to 119.38 m. There was no major drilling problem except the collapse encountered in upper unconsolidated sediment.

Well Construction

ND 6 inches PVC casing and screen has been installed down to 119.38 m depth. The screen casings were installed between 39.5 - 45.19, 62.38 - 68.06, 73.79 - 79.47, 85.2 - 102.24, and 107.97 - 113.65. The remaining part is blind casing.

Formation Penetrated

The geological formations penetrated are mainly talus and alluvial deposits alternating with some basalt and ignimbrite. These deposits extend down to about 108 m below ground. These rock layers are probably big blocks, which slide down from the escarpment. It is difficult to explain occurrence of layers of basalt and ignimbrite within layers of gravel and clay deposits in the context of the local geological conditions. The parent rock made up of ignimbrite underlain by basalt started somewhere around 108 m and extended down to 123 m.

It is apparent that the geology penetrated well fits to the geological evolution of the area. The area is a down faulted block receiving flood and sediment deposit from the up thrown block of the escarpment. The variation in the sediment deposit from clay to gravel indicates different stages of faulting or changes in the course of the sediment flux.

The electrical logging result of the borehole shows the alternating sediments up to about 108 m and sharp increase below 108 m depth indicating the bedrock depth.

The gamma log indicates variation in the clay content in the formation penetrated. Higher values are indicated adjacent to weathered rocks and clay deposits. Higher gamma log values correspond with low SP logs indicating clayey layers.

The temperature log indicates the temperature of the water is below 23 ^{o}C, however it has gradually increased from about 20 ^{o}C to 21.5 ^{o}C with depth.

The caliper log shows that the well has irregular diameter. Wide diameter (up to 40 cm or 15.7 inches) is measured between 66 m and 70 m

For details see the Appendix .

2.2 BZDP/TW2 SCORIA CONES REGION AT SEMEN SHERSHERA

Location

This test well is situated in Scoria cones region at Semen Shershera. It is situated close to the road from Butajira to Ziway .

- Geographic coordinates UTM; 436926 E, 899128N
- Altitude 1981 m.a.s.l .

Purpose

This borehole has been drilled in order to test the hydrogeological condition underlying the Basaltic flow and scoria cone region.

Drilling

The total depth of the well below ground surface is 86m. After completion of drilling 6 inches PVC casing and screens installed up to 86 m. There was no major drilling problem except loss of circulation and sampling difficulties. The well was drilled using mud circulation system.

Well Construction

ND 6 inches PVC casing and screen has been installed down to 86 m depth. The screen casing has been installed between 50 - 56, 61-73, 77-83. The remaining part is blind casing.

Formation Penetrated

The geological formations penetrated are mainly vesicular basalt alternation with scoria. This is quite similar with the geology of the area. It is difficult to explain occurrence of layers of basalt below an ignimbrite layer. Normal succession should be vesicular basalt underlain by ignimbrite or alluvial deposit. The geological log of the old borehole of semen Shershera water supply shows vesicular basalt and scoria underlain by ignimbrite/rhyolite. The geological log of Debub Shershera indicates vesicular basalt underlain by ignimbrite, and the well at Shershera ele shows vesicular basalt underlain by alluvial deposit. The geology indicated as basalt below 56 m depth is probably ignimbrite/rhyolite weathered to different degrees.

It is apparent that the geology penetrated well fits to the geological evolution of the area. The area is a down faulted block which has received flood and sediment deposit from the up thrown block of the escarpment and latter on covered by basic volcanic eruption forming the vesicular lava flows and cinder cones. Absence of the alluvial deposits at some localities and presence at some places indicates that sedimentation took place at some spots where some river or stream channel has developed. Occurrence of sediment deposit within the basaltic flow layers is quite possible, because both the lava flow and sedimentation were possible within the down faulted block.

The electrical logging result of the borehole shows low resistivity layer between 58 m and 72 m depth. Probably this belongs to the weathered ignimbrite/rhyolite layer. The SP log indicates area affected with mud invasion below 57 m. in addition between 57 to 60 and 71 to 70 m depths there is an open area with deep invasion of mud. This could be the reason for non-recovery of samples at some spots. In addition this zone is the main aquifer zone. The electrical log indicates that the depth to groundwater level is at about 46 m below ground.

The gamma log is quite uniform and indicates very low clay content in the formation penetrated.

The calliper log shows the well diameter is uniform except at 12 m to 16 m and 20 m to 24 m. The area from 20 to 27 m is area of no sample recovery.

The temperature log indicates the temperature of the water is about 25 ^{o}C, and doesn't show increase or decrease with depth.

For details see the Appendix .

2.3 BZDP/TW3 KONTANE-INSENO-KELA PLAIN

Location

This test well is situated at Weja Kebele close to Weja River north of Koshe town.

- Geographic coordinates UTM; 446999 E, 886227 N
- Altitude 1798 m.a.s.l

Purpose

This borehole has been drilled in order to test the aquifer and the water level differences between Tora-Koshe-Dugda ridge and Kontane-Inseno-Kela plain.

Drilling

Because of the soft unconsolidated deposit at this locality the well was drilled using mud circulation system. The total depth of the well below ground surface is 64m. After completion of drilling 6 inches PVC casing and screens installed up to 86 m. There was no major drilling problem.

Well Construction

ND 6 inches PVC casing and screen has been installed down to 64 m depth. The screen casing has been installed between 23.40 - 26.25, 37.95 - 43.65, and 55.35 - 63.9. The remaining part is blind casing.

Formation Penetrated

The geological formations penetrated are mainly sand, silt and clay. Mostly sample was not recovered according to the drillers report. It seems that these areas are probably fine silt deposits. Ignimbrite has been drilled 16 m to 20 m, which could be a block of ignimbrite. Below the ignimbrite mainly clay and silt are reported. It seems that the one reported as silt or clay could be sediments deposited or highly weathered rocks in the fault zone; since the site is situated at the main fault zone separating Tora-Koshe-Dugda ridge from Kontane-Inseno-Kela plain.

The electrical logging result of the borehole shows relatively higher resistivity layer between 12 m and 22 m depth. Probably this belongs to the weathered ignimbrite/coarse sand layer. Below 22 m depth the formation has low resistivity, which is quite uniform up to the bottom of the well. The SP log indicates below 10 m depth the formation is more of sandy deposit. The electrical log indicates the depth to groundwater level at about 11m.

The gamma log is quite uniform and indicates occurrence of uniformly distributed clay content in the formation penetrated.

The temperature log indicates the temperature of the water doesn't show increase or decrease with depth.

The calliper log shows that the diameter of the well is quite uniform with some irregularities between 18m to 20 m, 30 m to 32 m and 54 m to 56 m.

For details see the Appendix .

2.4 BZDP/TW 4 KONTANE-INSENO-KELA PLAIN

Location

This test well is situated at Kuno Kertafa Village west of Inseno town.

- Geographic coordinates UTM; 440020 E, 888300 N
- Altitude 1854 m.a.s.l

Purpose

Many of the wells on the plain are shallow, and mostly the property of the shallow aquifer is partially known. The condition in the deeper part is not well understood. Therefore, the main purpose of this test well is to test the deeper aquifer in Kontane-Inseno-Kela plain.

Drilling

The total depth of the well below ground surface is 168 m. After completion of drilling 6 inches steel casing and screens installed up to 183 m. Due to collapse the casing could not be installed down to 168 m. The well was drilled using DTH method. Drilling problem encountered is caving of the formation. Due to heavy collapse casing was installed using method of simultaneous casing installation along with cleaning of the collapsed material through the casing using smaller diameter bit.

Well Construction

ND 6 inches mild steel casing and screen has been installed down to 163 m depth. 54 m screen casing has been installed between 60-66, 72-78, 84-90, 96-102, 108-114, 120-126, 132-138, 144-150, and 156 -162. The remaining part is plain casing.

Formation Penetrated

The formation is mainly loose pyroclastic deposits mainly fall deposits and reworked water lain pyroclastics. The pyroclastic deposits are composed of pumice, ash, and tuff with pumice and lithic materials.

The aquifer is unconfined and major aquifer occurs below 58 m depth. The aquifer is continuous and the drilling did not penetrate fully the aquifer.

Because of heavy collapse electrical logging was not performed.

2.5 BZDP/TW5 TORA-KOSHE-DUGDA RIDGE

Location

This test well is located at Koshe town, which is situated in the Tora-Koshe-Dugda ridge.

- Geographic coordinates UTM; 448646 E, 885794 N
- Altitude 1864 m.a.s.l

Purpose

The existing data indicates that the aquifer in Tora-Koshe-Dugda ridge has deeper water level as compared to the Kontane-Inseno-Kela plain. This difference requires appropriate explanation. Therefore, the purpose of the drilling at Koshe is to understand the aquifer behavior with respect to the aquifer at Kontane-Inseno-Kela plain and to understand the water level differences between the two aquifers.

Drilling

The total depth of the well below ground surface is 244 m. After completion of drilling 6 inches steel casing and screens installed up to 242 m. Due to some collapse the casing could not be installed down to 244 m. The well was drilled using DTH system. Drilling problem encountered due to circulation loss between 154 m and 196 m. No sample has been recovered from this depth.

Well Construction

ND 6 inches mild steel casing and screen has been installed down to 242 m depth. 42 m screen casing has been installed between 194 and 236 m. The remaining part is plain casing.

Formation Penetrated

The formation is mainly consolidated pyroclastic deposits such as alternating layers of tuff and ignimbrite with layers of ash and weathered tuff/ash. Tuff and ignimbrite deposits are mainly pumaceous and with lithic materials. The lithic materials are mainly derived from basaltic country rocks and some acidic rocks. In some layers the lithic grains are so dominant and in some of existing borehole logs it was described as basaltic layer. Because during drilling the pyroclastic materials get easily crushed and washed away with the drilling fluid and the hard lithic material is recovered. This led to mistakes in logging.

The electrical logging indicates open cavity between 154 m and 159 m depth. This could be the main reason for loss of circulation. The aquifer is encountered below 194 m and main aquifer below 226 m. The drilling did not penetrate fully the aquifer. The electrical logging indicates that the water level in the well is around 132 m depth.

The temperature logging indicates the water temperature increases gradually from about 30 ^{o}C to about 38 ^{o}C.

Gamma logging shows that the aquifer zone (Below 194 m) has relatively low counts indicating less clay content. The formation up to 194 m has higher clay content.

2.6 BZDP/TW6 GADEMOTTA CALDERA / ZIWAY PLAIN

Location

This test well is located at Shisho Tora village west of Adami Tulu village in the Gademotta Caldera.

- Geographic coordinates UTM; 463216 E, 867376 N
- Altitude 1675 m.a.s.l

Purpose

This part of the study area is characterized by a caldera, which is filled with lacustrine sediment filled. The area from the west is bounded by the caldera rim and in the other directions the caldera is down faulted and covered by lacustrine deposit. The aquifer in this area has limited recharge sources. Therefore, the purpose of this drilling is to study the aquifer condition within the Gademotta caldera.

Drilling

The total depth of the well below ground surface is 128 m. After completion of drilling 6 inches PVC casing and screens installed up to 126 m. Due to some collapse the casing could not be installed down to 128 m. The well was drilled using DTH system up to 100m. Drilling problem encountered due to circulation loss between 74 m and 100 m. No sample has been recovered from this depth. Therefore, the drilling changed to mud circulation and additional 28 m was drilled. The aquifer occurs below 100m depths.

Well Construction

ND 6 inches PVC casing and screen has been installed down to 126 m depth. 21.15 m screen casing has been installed between 100 and 121.15m m. The remaining part is plain casing.

Formation Penetrated

The formation up to 57 m is mainly sediment alternating between clay, silt, sand and gravel. Between 57 m and 74 m weathered trachyte/ignimbrite is encountered. Below 74 m sample could not be recovered due to loss of circulation.

The electrical logging indicates relatively uniform geology. The electrical log indicates the water level I around 74 m depth below ground. Below 94 m depth the resistivity value gradually declines and the SP log gradually increases. This indicates the water-bearing zone occurs below 94 m depth. Although there is circulation loss the electrical log mainly the SP log shows that the formation below 94 m has sandy property.

The Gama log indicates in the area of no sample recovery (74m to 128m) the formation is uniform with low clay content.

The temperature logging indicates the water temperature increases gradually from about 31 ^{o}C to about 35 ^{o}C.

The calliper log shows that the well has uniform diameter except between 64 m and 95 m depth where the diameter has irregular shape.

3 AQUIFER TESTING

3.1 TESTING METHODS

Testing was conducted using pumps. The testing methods used are;

- Step draw down test
- Constant rate pumping test and,
- Recovery tests

Continuous step draw down tests were used in the wells where this test is conducted. No recovery was measured at the end of each step. The pumping rate is progressively increased for each step while continuing pumping. Recovery was measured at the end the last step test.

After full recovery of the water level from the step test, the constant rate test commenced and continued until the water level is stabilized or continued until end of 24 hours.

After the shutting off the pump recovery test continued until full or 95% recovery of the water level.

3.2 KACHA BER TEST WELL (BZDP/TW1)

3.2.1 Test Pumping

After the well has been developed it has been test pumped. Step drawdown test was conducted for a total of 3 hours and consisted of three steps, where each steps lasted for 1 hour. The well was pumped successively at 1, 1.5, and 2 l/s. The total draw down of the step-wise test was 9.8 m, 55.1 m, and 64 m respectively.

24 hours constant rate test was carried out at the same pumping position at discharge rate of 1.5 lt./sec, the water level at the beginning of the test was at 18 m. During the pumping period the water level did not stabilize and reached 83 m with drawdown of 65 m. The recovery of the well was fast and 100 % recovered within 110 minutes.

3.2.2 Test Pumping Result

The time-drawdown curve shows that the decline in water level was fast and did nit stabilize. The time-drawdown plot has two segments with similar gentle slope. The first segment covers the first 30-minute and the second segment covers the remaining 1410 minutes. No barrier boundary effect is shown on the test-pumping curve.

The transmisivity of the aquifer has been calculated from the time-drawdown and recovery data of the constant and step test. The value calculated from the time drawdown of the constant test is 1.02 m^2/day. Summary of the test result is shown in the following table.

Table 1: Summary of test pumping result

BZDP/TW1	
Ground level (m.a.s.l)	2179
Drilled Depth (m)	123.8
Bottom of Casing (m)	120
Casing Diameter and type	6” PVC
Screen Location (m) below ground surface	
Water level below reference point at the beginning of constant discharge test	18 m
Pumping rate (m3/day)	129.6(1.5 l/s)
Pumping test length	24 hours
Stabilized pumping water level (m)	
Drawdown (m)	64.91 m
Specific Capacity (M3/day/m)	1.56
Transmisivity from time drawdown plot (m^2/d)	1.
TDS (mg/l)	
Fluoride (mg/l)	

This transmissivity value characterizes an aquifer with very low potential.

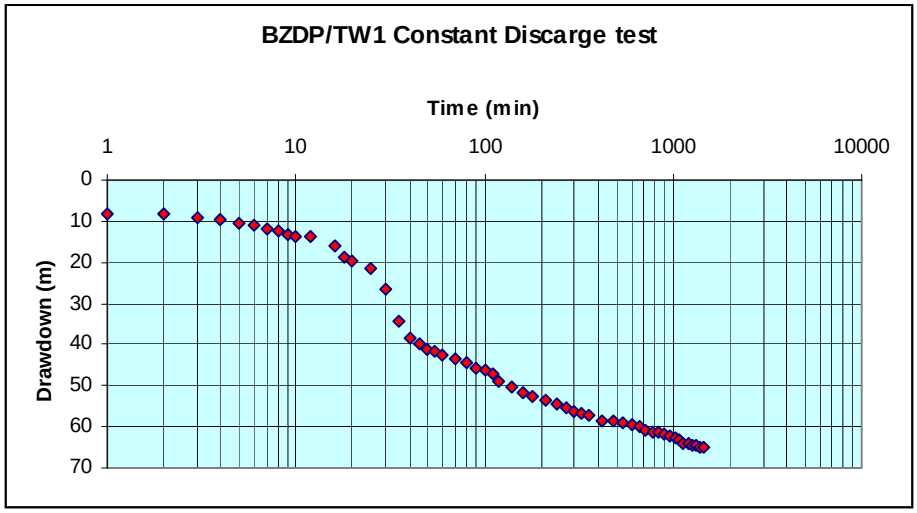


Figure 2. BZDP/TW1 Time Drawdown plot

The step drawdown test result shows that the drawdown in the well is mainly related to well loss.

Table 2: Result of Step Drawdown test

Steps	Sw (m)	Qn (m3/d)	Sw/Qn (d/m2)	B (d/m2)	C (d2/m5)	B*Qn (m)	CQn^2 (m)	Swn (m)
1	9.85	86.4	0.114005	0	0.0028	0.00	20.90	20.90
2	56.8	129.6	0.438272			0.00	47.03	47.03
3	83	172.8	0.480324			0.00	83.61	83.61

Figure 3. BZDP/TW1 Plot of Specific capacity Vs discharge

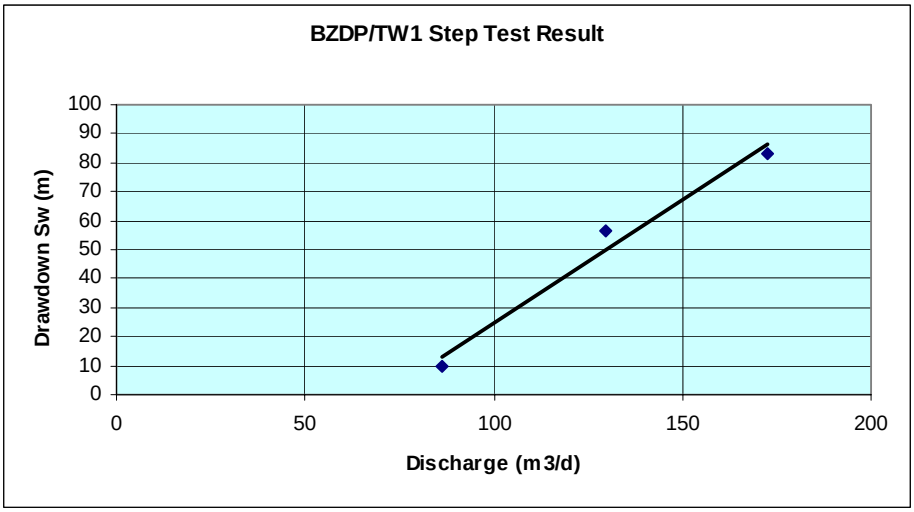


Figure 4. BZDP/TW1 Plot of Drawdown Vs discharge

3.3 SEMEN SHERSHERA TEST WELL (BZDP/TW2)

3.3.1 Test Pumping

After the well has been developed it was test pumped. Step drawdown test was conducted for a total of 3 hours and consisted of three steps, where each steps lasted for 1 hour. The well was pumped successively at 2, 3, and 4 l/s. The total draw down of the step-wise test was 3.85 m, 6.45 m, and 18.15 m respectively.

28 hours constant rate test was carried out at the same pumping position at discharge rate of 4 lt./sec, The water level at the beginning of the test was at 48.55 m. During the pumping period the water level stabilized around 1000 minute at 70.2 m below ground with a drawdown of 21.6 m. The recovery of the well was fast and 97 % recovered within 60 minutes.

3.3.2 Test Pumping Result

The transmisivity of the aquifer has been calculated from the time-drawdown data. The value calculated from the time drawdown of the constant test is 11.2 m^2/days. Semi-Logarithmic plot of time drawdown indicates that the aquifer is semi-confined type. Summary of the test result is shown in the following table.

Table 3: BZDP/TW2 Summary of test pumping result

BZDP/TW2	
Ground level (m.a.s.l)	1981
Drilled Depth (m)	86
Bottom of Casing (m)	86
Casing Diameter and type	6" PVC
Screen Location (m) below ground surface	50 - 56, 61-73, 77-83
Water level below reference point	48.55 m
Pumping rate (m3/day)	345.6 (4 l/s)
Pumping test length	28 hours
Stabilized pumping water level (m)	84.65 m
Drawdown (m)	21.6 m
Specific Capacity (M3/day/m)	16.06
Transmisivity from time drawdown plot (m^2/d)	11.2
TDS (mg/l)	238
Fluoride (mg/l)	0.32

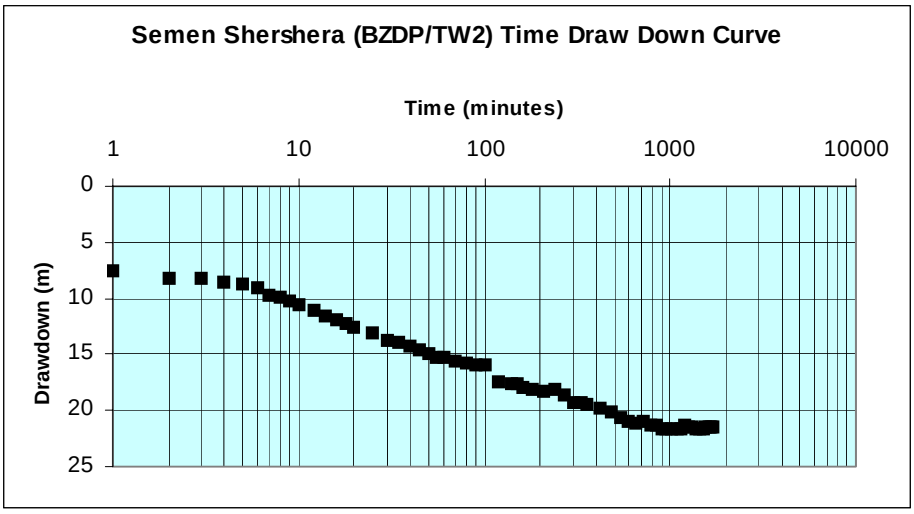


Figure 5. BZDP/TW2 Plot of Time Drawdown curve

The step drawdown test result shows that the drawdown in the well is mainly related to well loss. The optimum production-pumping rate from this borehole should not exceed 3.2 l/s.

Table 4: BZDP/TW2 Result of step drawdown test

Steps	Sw (m)	Qn (m3/d)	Sw/Qn (d/m2)	B (d/m2)	C (d2/m5)	B*Qn (m)	CQn^2 (m)	Swn (m)
1	3.85	172.8	0.02228	0	0.000133	0.00	3.97	3.97
2	6.45	259.2	0.024884			0.00	8.94	8.94
3	18.15	345.6	0.052517			0.00	15.89	15.89

Figure 6. BZDP/TW2 Plot of Drawdown vs discharge

Figure 7. BZDP/TW2 Plot of specific capacity vs discharge

3.4 WEJA KEBELE TEST WELL (BZDP/TW3)

3.4.1 Test Pumping

Because of very low drawdown step test was not conducted. 24 hours constant rate test was carried out at the same pumping position at discharge rate of 8.5 lt./sec, The water level at the beginning of the test was at 9.55 m. During the pumping period the water level stabilized around 1260 minute at 11.4 m below ground with a drawdown of 3.82 m. The recovery of the well was slaw and 88 % recovered within 1640 minutes.

3.4.1.1 Test Pumping Result

The transmisivity of the aquifer has been calculated from the time-drawdown data. The value calculated from the time drawdown of the constant test is 232 m^2/days. Summary of the test result is shown in the following table.

Table 5: BZDP/TW3 Summary of test pumping Result

BZDP/TW3	
Ground level (m.a.s.l)	1798 m
Drilled Depth (m)	64
Bottom Depth of casing (m)	64
Casing Diameter and type	6” PVC
Screen Location (m) below ground surface	23- 26, 38-41, 55-64
Water level below reference point	9.55 m
Pumping rate (m3/day)	731 (8.5 l/s)
Pumping test length	24 hours
Stabilized pumping water level (m)	11.4 m
Drawdown (m)	3.82 m
Specific Capacity (M3/day/m)	193.26
Transmisivity from time drawdown plot (m^2/d)	232
TDS (mg/l)	398
Fluoride (mg/l)	1.62

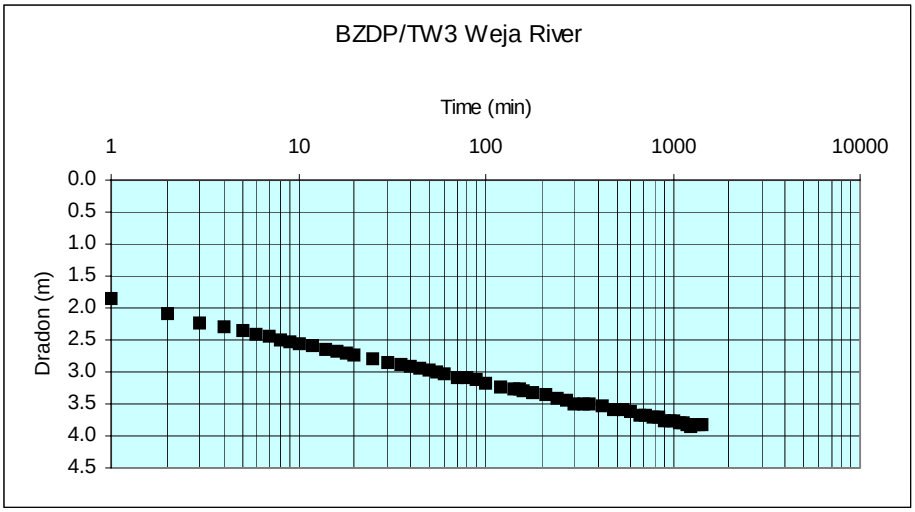


Figure 8. BZDP/TW3 Plot of Time Drawdown curve

3.5 KUNO KERTAFA TEST WELL (BZDP/TW4)

3.5.1 Test Pumping

After the well has been developed it was test pumped. Because of low drawdown Step drawdown test was not conducted

8 hours constant rate test was carried out at the same pumping position at discharge rate of 6 lt./sec, The water level at the beginning of the test was at 11.44 m. During the pumping period the water level stabilized around 12.54 m below ground with a drawdown of 1.1 m.

3.5.2 Test Pumping Result

The transmisivity of the aquifer has been calculated from the time-drawdown data. The value calculated from the time drawdown of the constant test is 505 m^2/day. Summary of the test result is shown in the following table.

Table 6: BZDP/TW4 Summary of test pumping Result

BZDP/TW4	
Ground level (m.a.s.l)	1854 m
Drilled Depth	168 m
Bottom Depth of Casing	163 m
Casing Diameter and type	6" steel
Screen Location (m) below ground surface	55-61, 67-73, 79-85, 91-97, 103-109, 115 - 121, 127-133, 139 -145, 151-157
Water level below reference point (m)	11.44 m
Pumping rate (m3/day)	518.4 (6 l/s)
Pumping test length	8 hours
Stabilized pumping water level (m)	12.54 m
Drawdown (m)	1.1 m
Specific Capacity (M3/day/m)	471
Transmisivity from time drawdown plot (m^2/d)	505
TDS (mg/l)	261
Fluoride (mg/l)	1.3

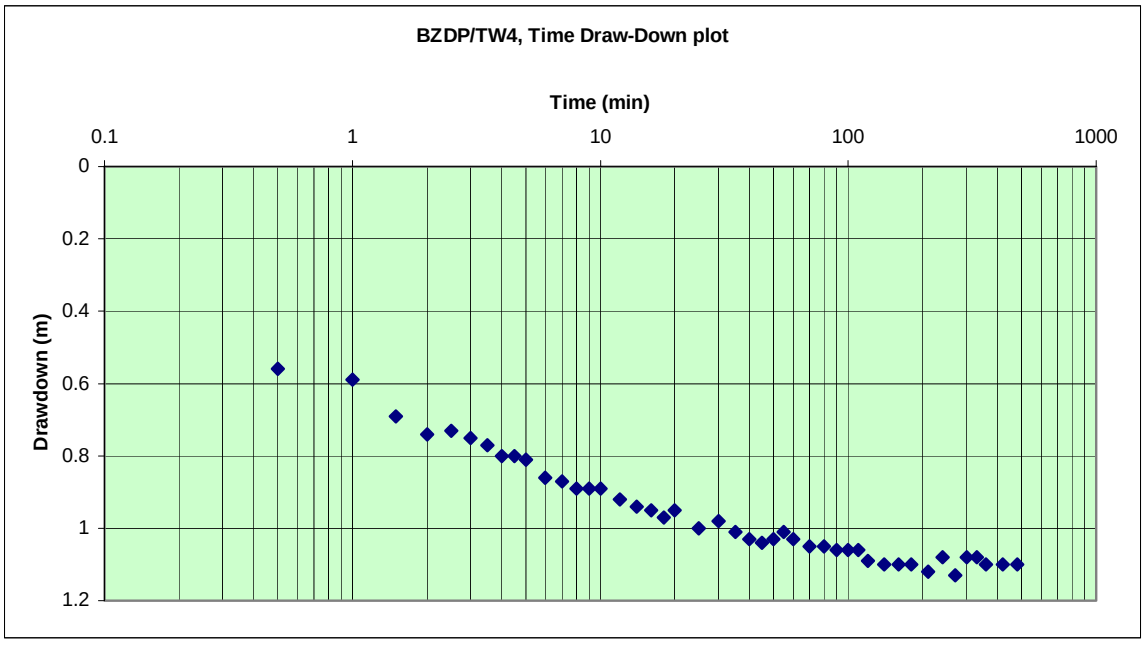


Figure 9. BZDP/TW4 Plot of Time Drawdown curve

3.6 KOSHE TEST WELL (BZDP/TW5)

This well was test pumped; however, the water level measured in the observation pipe does not represent the actual water level in the well as a result of plugging of the screens of the observation pipe. Therefore, the data is not used to analyse the aquifer parameter from this well.

Table 7: BZDP/TW5 Summary of test pumping Result

BZDP/TW5 (Koshe)	
Location	UTM; 448646 E, 885794N
Ground altitude (m.a.m.s.l)	1864
Drilled Depth (m)	244
Depth of Bottom of the casing (m)	242
Casing Diameter and type	6” steel
Screen Location (m) below ground surface	194 - 236m
Water level (m) below reference point at the beginning of constant discharge test	132
Water Level Altitude (m a.s.l)	1732
Pumping rate (m3/day)	259.2 (3l/s)
Pumping test length	24hours
Stabilized pumping water level (m)	
Drawdown (m)	
Specific Capacity (M3/day/m)	
Transmissivity from time drawdown plot (m^2/d)	
TDS (mg/l)	528
Fluoride (mg/l)	5

3.7 SHISHO TORA TEST WELL (BZDP/TW6)

3.7.1 Test Pumping

After the well has been developed it was test pumped. Because of low drawdown Step drawdown test was not conducted

24 hours constant rate test was carried out at the same pumping position at discharge rate of 4.4 lt./sec. The water level at the beginning of the test was at 76.55 m. During the pumping period the water level stabilized around 78.07 m below ground with a drawdown of 1.52 m.

3.7.2 Test Pumping Result

The transmisivity of the aquifer has been calculated from the time-drawdown data. The value calculated from the time drawdown of the constant test is 467 m^2/day. Summary of the test result is shown in the following table.

Table 8: BZDP/TW6 Summary of test pumping Result

BZDP/TW6	
Ground level (m.a.s.l)	1675
Drilled Depth	128 m
Bottom Depth of Casing	126 m
Casing Diameter and type	6” PVC
Screen Location (m) below ground surface	100 – 121.15
Water level below reference point (m)	76.55
Pumping rate (m3/day)	382.75 (4.43 l/s)
Pumping test length	24 hours
Stabilized pumping water level (m)	78.07
Drawdown (m)	1.52 m
Specific Capacity (M3/day/m)	471
Transmisivity from time drawdown plot (m^2/d)	467
TDS (mg/l)	734
Fluoride (mg/l)	5

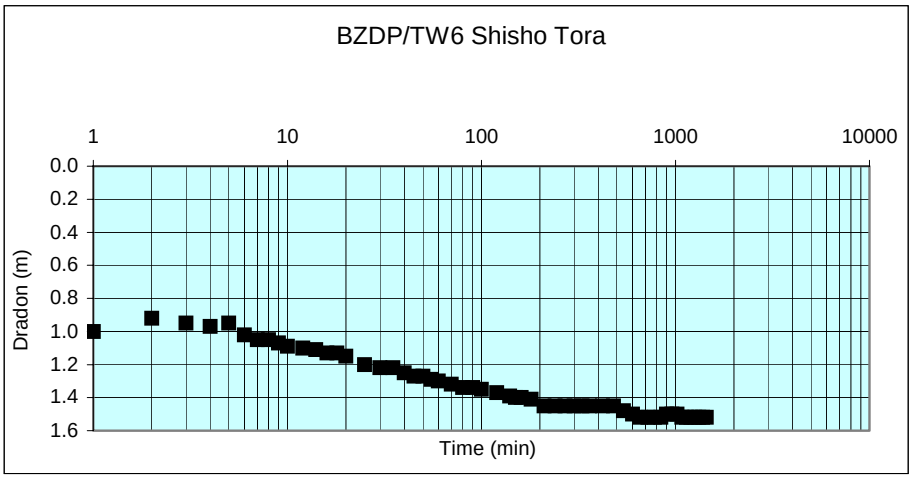


Figure 10. BZDP/TW6 Plot of Time Drawdown curve

4 WATER QUALITY

The test wells water quality shows concentrations of dissolved components are generally low close to the escarpment areas and increases towards Ziway plain. The main chemical components that show increasing trend are TDS, Sodium, Fluoride, alkalinity and Bicarbonate.

The fluoride concentration in the test wells ranges from 0.02 to 5 mg/l. Three samples (BZDP/TW3, BZDP/TW5, and BZDP/TW6) exceed the World Health Organization drinking water quality guidelines and two samples (BZDP/TW5, and BZDP/TW6) exhibited values above Ethiopian Drinking Water Quality Guidelines. The fluoride guideline values for World Health Organization and Ethiopian drinking water quality guidelines are 1.5 and 3.0 mg/l respectively. It has to be noted that fluoride concentrations above 1.5-mg/l causes dental fluorosis and above 3.0 mg/l can cause skeletal fluorosis. Fluoride values over 3 mg/l occur in the Ziway Plain and Tora-Koshe-Dugda ridge.

The sodium concentration in the test wells ranges from 7.7 mg/l to 246 mg/l. Two samples (BZDP/TW5 and BZDP/TW6) exceed the World Health Organization drinking water quality guidelines and one sample (BZDP/TW6) exhibited values above Ethiopian Drinking Water Quality Guidelines. The fluoride guideline values for World Health Organization and Ethiopian drinking water quality guidelines are 200 and 350 mg/l respectively.

Although the TDS, alkalinity and bicarbonate show an increasing trend, the values are within the WHO and Ethiopian Drinking Water Quality guidelines.

The other chemical constituents have lower concentration and are within the drinking water guideline values.

The following table provides summary of the chemical constituents that have an increasing trend towards the rift valley plain. For details refer the appendix.

Table 9: Summary of chemical constituents having an increasing trend from the base of the escarpment towards the rift plain

Test well	Location Name	UTME	UTMN	TDS (mg/l)	Sodium (mg/l)	Fluoride (mg/l)	Alkalinity as CaCO3 (mg/l)	Bicarbonate (mg/l	Remark
BZDP/TW1	Kacha Ber	424544	894351	152.00	7.40	0.02		128.8	Butajira Crescent
BZDP/TW2	Semen Shershera	436926	899128	238.00	25.00	0.32	194.70	237.50	Area of Cinder Cones and Basalt Flows
BZDP/TW4	Kuno Kertafa	440020	888300	261.00	107.50	1.30	254.00	202.00	Kuntane-Inseno-Kela Plain
BZDP/TW3	Weja Kebele	446999	886227	468.00	90.00	1.76	336.40	410.43	Kuntane-Inseno-Kela Plain
BZDP/TW5	Koshe Town	448646	885794	528.00	202.2	5.00	450.00	413.00	Tora-Koshe Dugda Ridge
BZDP/TW6	Shisho Tora	463216	867376	734.00	246.00	5.10	545.75	646.3	Gademotta Caldera / Ziway Plain

5 SUMMARY OF THE TEST DRILLING RESULTS

The test wells drilled have provided additional knowledge of the subsurface geology and the hydrogeology of the study area.

5.1 BUTAJIRA PEDIMENT/CRESCENT

The test drilling result close to the escarpment indicated thick unsorted to poorly sorted sediment derived from the escarpment. The alternating gravel and clay deposit has also indicated changes in sedimentation condition or successive faulting conditions.

The sediment deposit changes from poorly sorted deposit to relatively better sorting towards Butajira town or to the southern end of the area. This is shown by the river deposits close to Butajira town and the test drilling results of Butajira Town water supply.

The aquifer is found to be very poor with very low transmissivity. It doesn't have a potential to supply big pumping conditions. However, it can support low pumping condition for household or smaller community demand.

The water level monitoring conducted at this well indicates fast decline in the water level during 2 months period since it's drilling the water level dropped by 3.8 m from 17.6 m t 20.98 m.

In this area the aquifer improves toward its southern end or close to Butajira area, where well-sorted gravel and sand deposits are available. This is indicated from the data of test boreholes, which were drilled for Butajira Town.

The aquifer is in general unconfined at the top part with some semi-confined layers at depth.

The potential of underlying volcanic aquifer is not tested as the test-drilling borehole and other wells in the area have not progressed in the volcanic layers.

The water has low concentration in dissolved chemicals and is fit for drinking water.

5.2 SCORIA CONES AND BASALTIC LAVA FLOW REGION

This is the area, which has relatively high relief and separates Butajira pediment/crescent from Kontane-Inseno-Kela plain.

This area is characterised by cinder cones, lava flow and some sedimentation between lava flow layers.

The basaltic deposits sometimes rest on underlying acidic rocks such as ignimbrite or rhyolite and at some places on river sediment deposits. At some places river deposits are found inter-layered between lava flows or scoria deposits.

The test well drilled at Semen Shereshera indicated vesicular and scoria deposits underlain by ignimbrite.

In places such as Shershera Ele, Dirama shershera, Shershera Jole river sediment deposits mainly gavel deposits are encountered.

At place in Butajira Town the Borehole of Girar bet Ledekuman, indicated inter-layered gravel deposits within the basaltic lava flows.

Therefore, this region is characterised by basaltic lava flows or scoria/cinder deposits overlaying acidic volcanic rocks or at paces alluvial sediments. This indicates that the basaltic deposits are very young deposits.

The aquifer is found to have variable potential depending up on the amount of scoria deposits. In general it is relatively poor with low transmissivity. The aquifer is in general unconfined at the top part with some semi-confined layers at depth.

The water has low concentration in dissolved chemicals and is fit for drinking water.

5.3 KONTANE-INSENO-KELA PLAIN

The test drilling result in this plain indicated that the major geology comprising this plain is pyroclastic fall deposits and reworked water lain pyroclstics with little or absent lacustrine deposits. These deposits are unconsolidated with high intergranular (effective) porosity and permeability. Their thickness is over 168 m (which is the depth of the test well). This has also been indicated by the geophysical survey conducted in the area. The lacustrine deposit is only available at the surface, indicating that it is more recent phenomenon.

At its western extreme where there are hot springs and lakes and swamps lacustrine deposits as well as calcrete deposited by hot springs is observed.

The aquifer in this plain has high potential to support big pumping schemes. The aquifer is thick with thickness over about 200 m. The aquifer is unconfined.

In the eastern part close to Koshe ridge, the aquifer becomes more sandy and silty. As observed from the test drilling result of 64 m depth at Weja Kebele, this aquifer has shallow groundwater with a potential to support pumping rates of over 10 l/s. The static water level close to this ridge is about 1788 m.

The water has low concentration in dissolved chemicals and is fit for drinking water. However, it has relatively higher concentration in TDS, Fluoride, Sodium, alkalinity and bicarbonate as compared to the above areas.

5.4 TORA-KOSHE-DUGDA RIDGE

The test drilling and other existing data indicated that this ridge is mainly made up of tuff deposit with layers of ash. The tuff is composed of mainly pumice and lithic grains mainly derived from basaltic materials.

The aquifer is found at deeper depth deeper than 190 m. The aquifer is confined aquifer; the water level rises above the water strike zone to 132 m. The static water level at this well is at about 1732 m, which is deep as compared to the level in Weja Kebele test borehole. This difference in level is can be explained with regards to the shallow aquifer at Inseno plain. In Koshe area there is no shallow aquifer and is mainly deep aquifer.

The water has high concentration of Fluoride and sodium and is not fit for drinking water unless some treatment or dilution is implemented.

5.5 GADEMOTTA CALDERA / ZIWAY PLAIN

The test drilling in the Gademotta caldera indicated lacustrine deposit underlain by acidic rock deposit, which is probably part of the caldera formation. The aquifer is unconfined aquifer. The aquifer has high potential to yield large quantity of water to a well.

The water has high concentration of Fluoride and sodium and is not fit for drinking water unless some treatment or dilution is implemented.

6 CONCLUSION

The test drilling results have shown the occurrence of different aquifers with varying potential. Good potential aquifers occur at Kuntane-Inseno plain, Koshe ridge and Zeway plain. The available aquifers are mainly unconfined except the aquifer at Koshe ridge.

The alluvial and talus deposits of Butajira crescent has limited potential as a result of the unsorted sediment dominated with clay and highly variable sedimentation condition varying from alluvial to talus deposits. The potential of the underlying volcanic aquifers is not tested, as the drilling did not progress in this formation.

The major aquifers are the lacustrine and the pyroclastic deposits. The pyroclastic deposits are dominated with fall deposits of mainly pumice and reworked river pyroclastic deposits. These deposits are unconsolidated with high intergranular porosity and permeability.

The thickness of the aquifers is generally over 100 m. The groundwater levels vary from shallow from about 10 m below ground level to over 100 m. The availability of such thick aquifers in the area is a good development opportunity for the area.

Therefore, based on available recharge potential of the area different development conditions can be planned in accordance to the potential, quality and distribution of the groundwater.

Therefore, it is recommended to consider groundwater as one major resource in the study area for development purpose.

With regards to the water quality, Koshe ridge and Ziway plain have shown high concentration in fluoride and sodium above the guidelines for drinking water. While considering development of groundwater, the purpose of development and the suitability of the water quality for the intended development has to be considered.

APPENDICES

RESULTS OF WELL LOGS

WELL LOG

Well No.	Location	Coordination		Altitude	Town	Wareda	State	Cuntry
BZDP/TW1	*Kacha Ber*	*424544 E*	*894351N*	*2179mamsl*		*Meskan*	*SNNPR*	

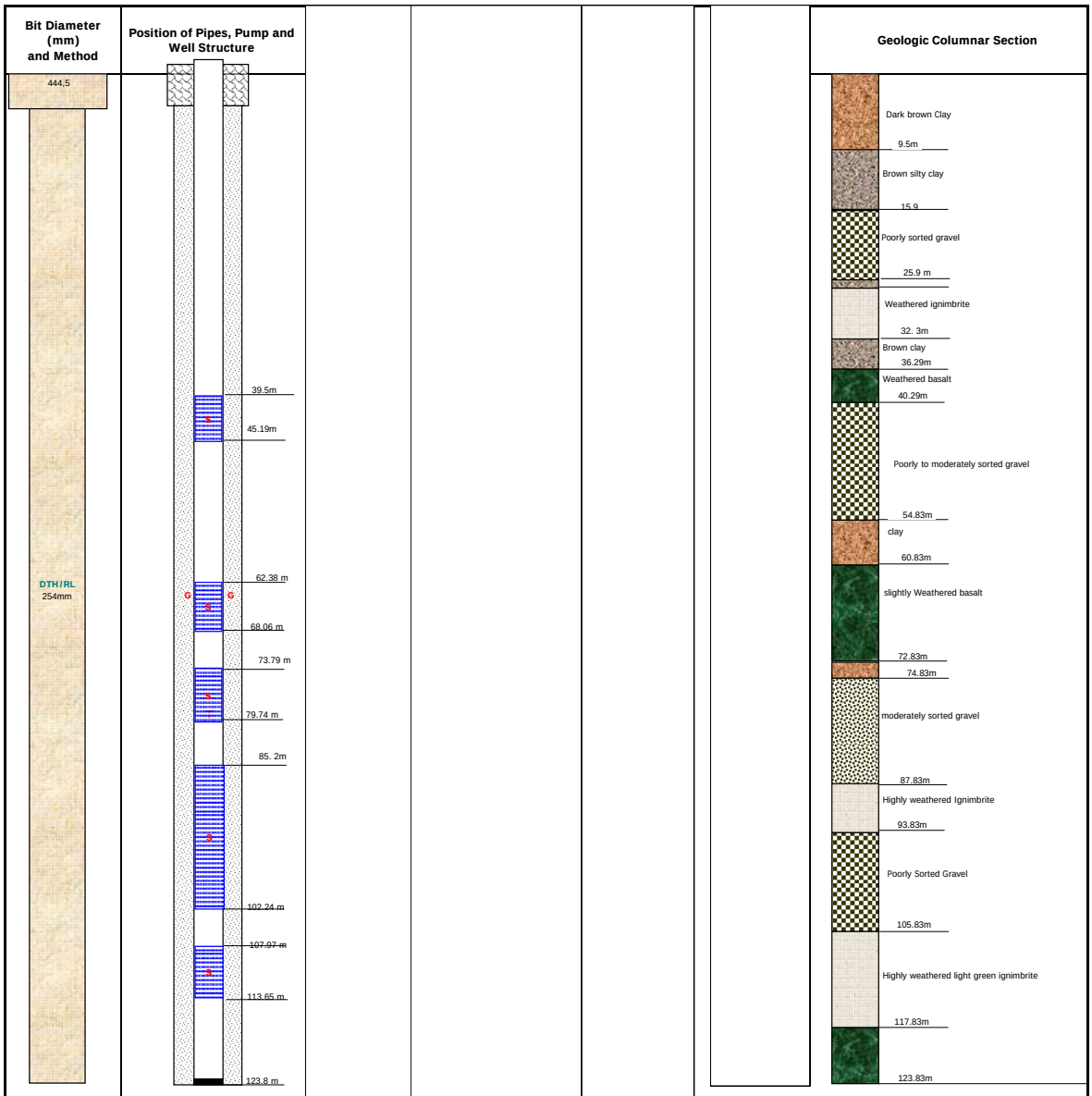
Date: from to	Drilling :	Equipment Type	Method	Flow	Depth	Depth	Depth	Final Depth
		ROTARY	*Rotation*	*Mud/DTH*				*123.8mm*

Casing type :	Type	Inside Dia.	Outside Dia.	Joint Type	Installation Position of pipe:				Total Length
(pvc)	*STPG 6" x 5.5m*	*151.0mm*	*165.2mm*	*Screw*	*+0,5-39.5;*	*145.19-62.38;*	*68.06.5-73.79;*	*79.74 -85.2;*	*102.4-107.97; 113.65-120*

Screen Pipe :	Material	Diameter	Silit Size	Open Rate	Joint Type	Installation Position of pipe:				Total Length
	SUS304	*150.0mm*	*1.0mm*	*20%*	*Screw*	*39.5 - 45.19;*	*62.38- 68.06;*	*73.79-79.74;*	*85,2-102.4, 107.97-113.65*	*42.0m*

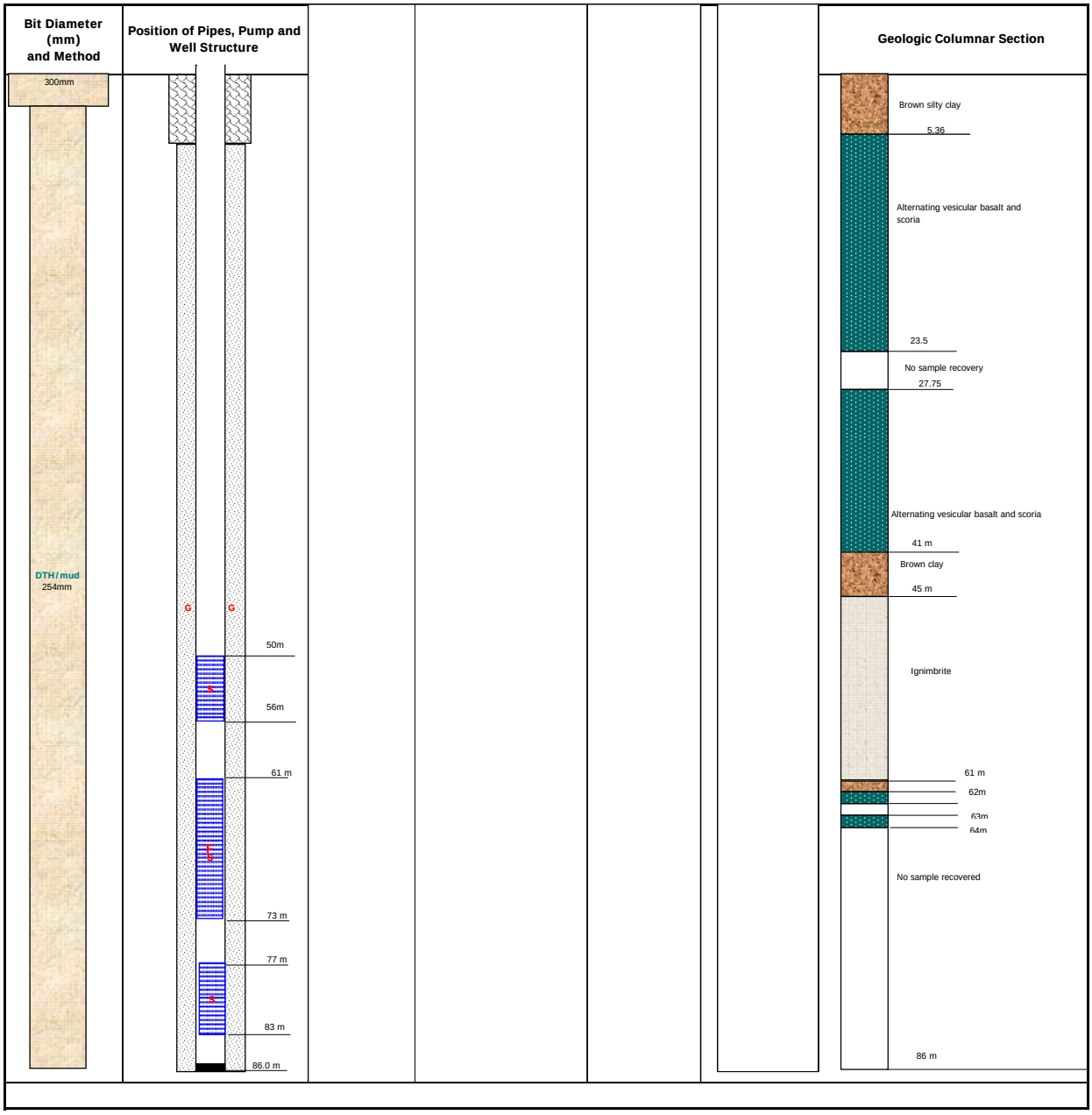
Gravel Pakking	Gravel Size	Location	Volume	Divelopment :	Static Water Level	Method	Duration	Descharge
	ø 2-6mm				*GL -18.0m*			

Submergible pump :	Installation Date :	Position :



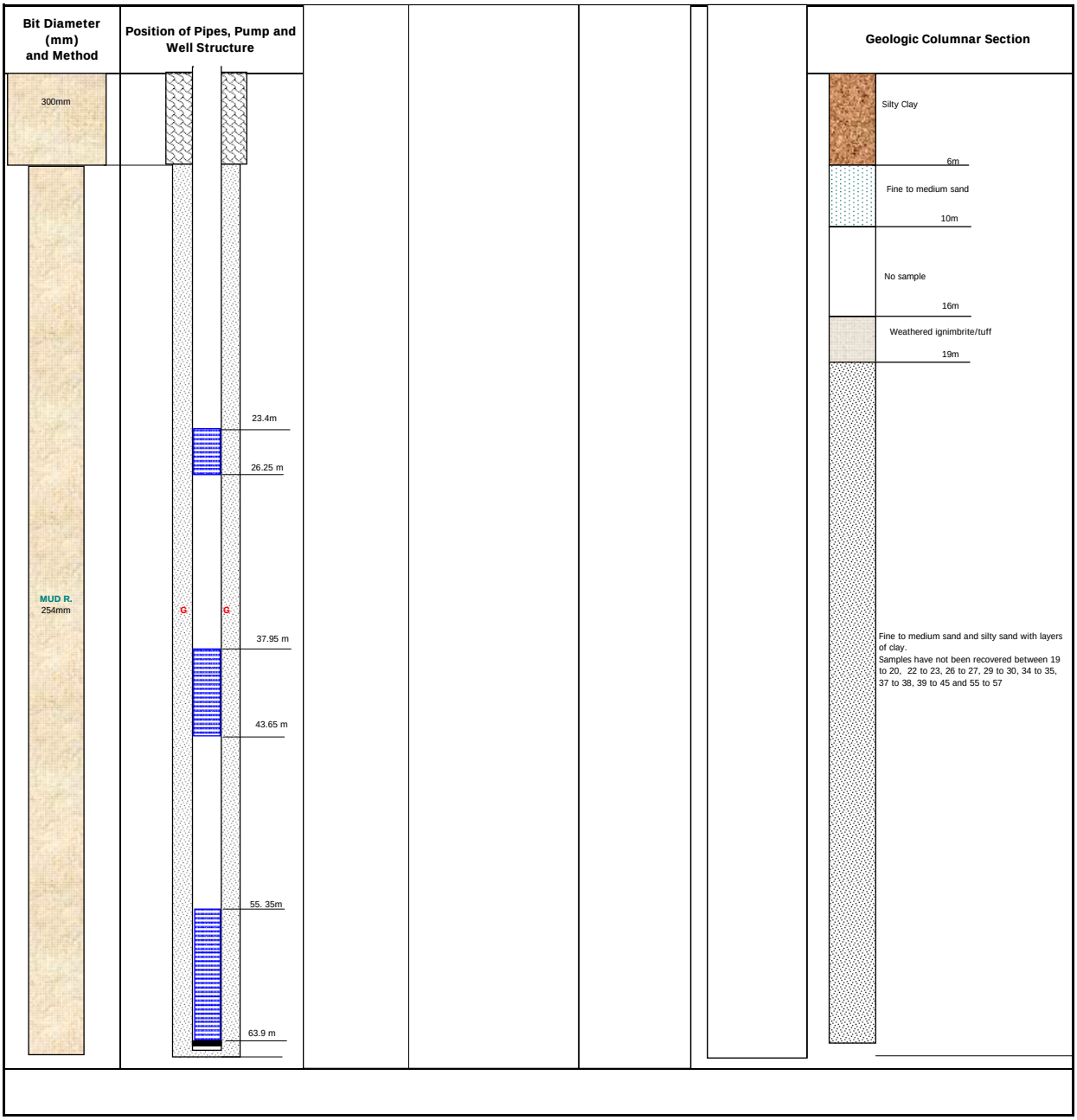
WELL LOG

Well No.	Location		Coordination		Altitude	Town	Wareda	State	Cuntry
BZDP/TW2	*Semen Shershera*		*436926 E,*	*899128N*	*1981mamsl*		*Meskan*	*SNNPR*	
Date: from to	**Drilling :**		Equipment Type	Method	Flow	Depth	Depth	Depth	Final Deth (m)
				Rotation	*DTH/Mud*				*86*
Casing type :	Tipe	Inside Dia.	Outside Dia.	Joint Type	Position of blind casing:				Total Length
(pvc)	*STPG 6" x 5.5m*	*151.0mm*	*165.2mm*	*Screw*	*+0,5-50;*	*56-61*	*73-77*	*83 - 86*	
Screen Pipe :	Material	Diameter	Silit Size	Open Rate	Joint Type	Position of screen			Total Length
	SUS304	*150.0mm*	*1.0mm*	*20%*	*Screw*	*50 - 56,*	*61-73,*	*77-83*	*24.0m*
Gravel Pakking	Origen	Gravel Size	Location	Volume	**Divelopment :**	Static Water Level	Method	Duration	Descharge
		ø 2-6mm				*GL -48.6m*			
Submergible pump :		Installation Date :		Position :					



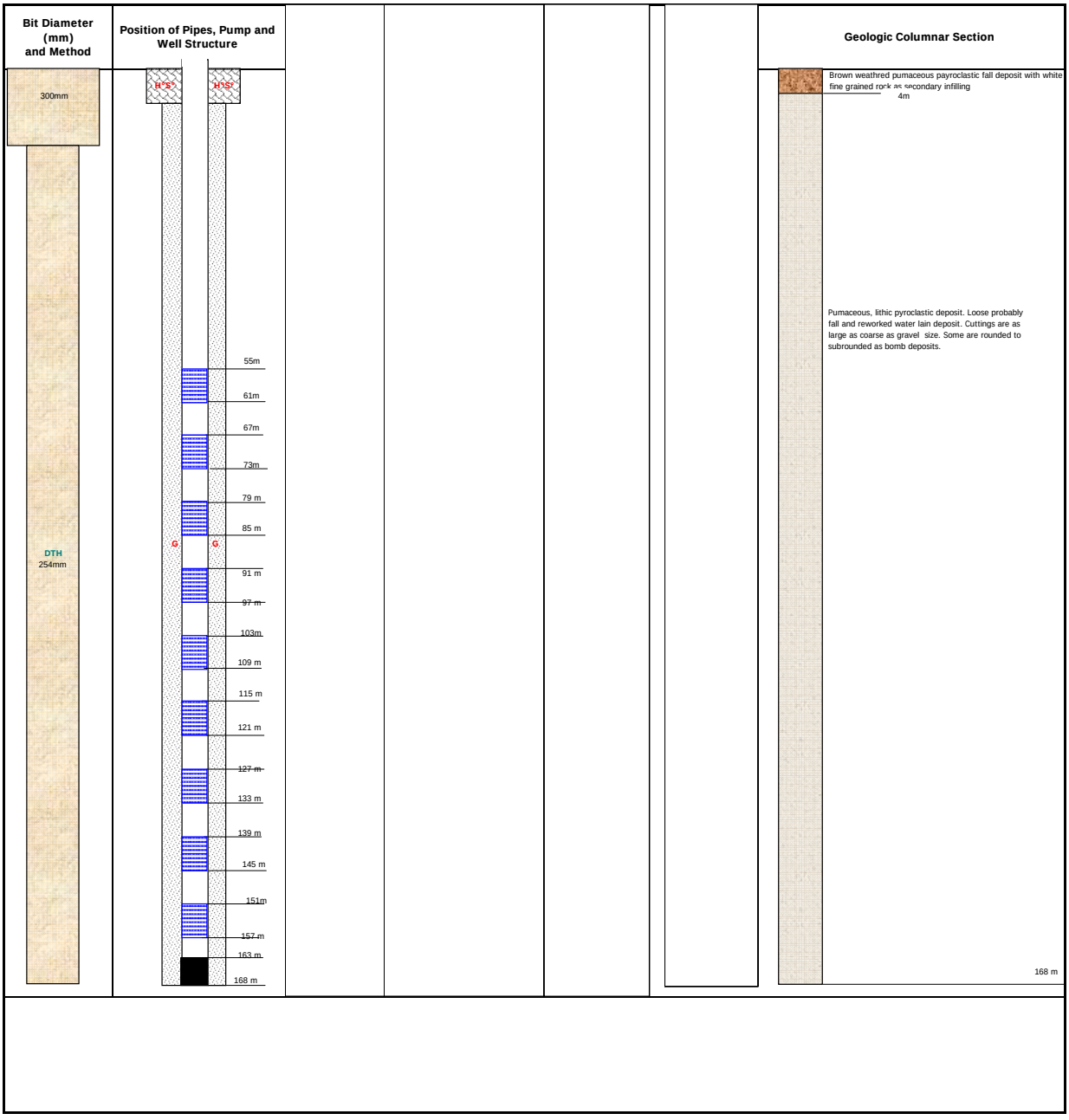
WELL LOG

Well No.	Location		Coordination		Altitude	Town	Wareda	State	Cuntry
BZDP/TW3	*Weja River/Koshe*		*446999 E,*	*886227 N*	*1798 mamsl*	*Koshe*	*Mareko*	*SNNPR*	
Date: from to	**Drilling :**	Equipment Type	Method		Flow	Depth	Depth	Depth	Final Depth
			Rotation		*Mud*				*64*
Casing :	Tipe	Inside Dia.	Outside Dia.	Joint Type	Installation depth:				Total Length
PVC	*6" x 5.5m*	*151.0mm*	*165.2mm*	*Screw*	*+0,5-23.4;*	*26.5 - 37.95*	*43.65 - 55.35;*		*46.9m*
Screen Pipe :	Material	Diameter	Silit Size	Open Rate	Joint Type	Installation depth:			Total Length
	PVC	*150.0mm*	*2.0mm*	*20%*	*Screw*	*23.40 - 26.25,*	*37.95 - 43.65,*	*55.35 - 64*	*17.1m*
Gravel Pakking	Origen	Gravel Size	Location	Volume	**Divelopment :**	Static Water Level	Method	Duration	Descharge
		ø 2-6mm				*GL -9.6m*			
Submergible pump :		Installation Date :		Position :					



WELL LOG

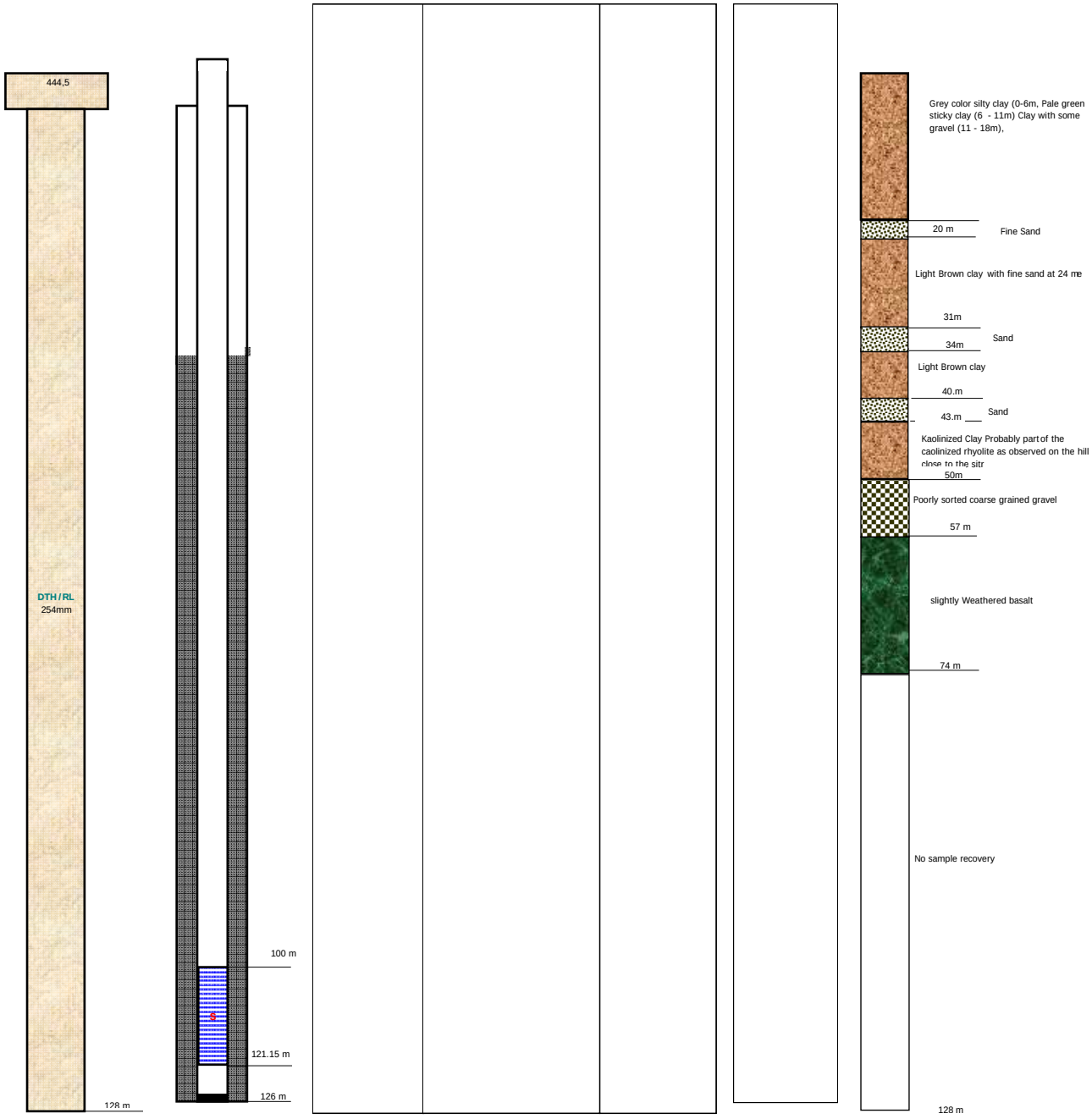
Well No.	Location		Coordination		Altitude	Town	Wareda	State	Cuntry
BZDP/TW4	*Kuno Kertafa/Samano Buraya*		*440020 E*	*888300 N*	*1854mamsl*		*Mareko*	*SNNPR*	
Date: from to		**Drilling :**	Equipment Type	Method	Flow	Depth	Depth	Depth	Final Depth
				Rotation	*DTH*	*mouth : 3.2m*	*depth.: 92.0m*	*Tub.: 130.0m*	*168*
Casing Type :	Type	Inside Dia.	Outside Dia.	Joint Type	Installation depth:				Total Length
Steel	*6" x 6*	*151.0mm*	*165.2mm*	*Screw+welding*	*+0,5-55;*	*61 - 67, 73-79;*	*85-91, 97-103;*	*109-115, 121-127;*	*133- 139, 145-151, 157-163*	*109.0m*
Screen Pipe :	Material	Diameter	Silot Size	Open Rate	Joint Type	Installation depth:				Total Length
Steel		*150.0mm*	*2.0mm*	*10%*	*Screw+welding*	*55-61, 67-73,*	*79-85, 91-97,*	*103-109, 115 -121,*	*127-133, 139 -145, 151-157*	*54.0m*
Gravel Pakking	Origin	Gravel Size	Location	Volume	**Divelopment :**	Static Water Level	Method	Duration	Descharge	
		ø 2-6mm				*GL -11.2m*				
Submergible pump :	Installation Date :									



WELL LOG

Well No.	Location		Coordination		Altitude	Town	Wareda	State	Cuntry
BZDP/TW5	*Semen Koshe*		*448646 E*	*885794 N*	*1864 mamsl*	*Koshe*	*Mareko*	*SNNPR*	
Date: from to		**Drilling :**	Equipment Type	Method	Flow	Diameter	Depth	Depth	Final Depth
02-05-06	*02-12-06*			*Rotation*	*Air*	*300 mm (0 -12m) 254 mm (12 - 244m)*			*244 m*
Pipe of Steel :	Tipe	Inside Dia.	Outside Dia.	Joint Type	Instration Position of pipe:				Total Length
	6" x 6m	*152.4mm*	*159.4mm*	*Screw*	*+0,5-196*	*238,- 242;*			*200.0m*
Screen Pipe :	Material	Diameter	Silit Size	Open Rate	Joint Type	Instration Position of pipe:			Total Length
		152.0mm	*2.0mm*	*10%*	*Screw*	*196 - 238*			*42.0m*
Gravel Pakking		Gravel Size	Location	Volume	**Divelopment :**	Static Water Level	Method	Duration	Descharge
		ø 2-6mm				*GL -132.0m*			
Submergible pump :									

Bit Diameter (mm) and Method	Position of Pipes, Pump and Well Structure			Geologic Columnar Section
300mm DTH 254	G G 196 m 238 m 242 m			Dark brown clay soil Pumacous lithic tuss with reworked pyroclastic deposits and weathered zones Circulation loss no sample recovery 196 m Pumaceous lithic tuff 234 m Ignimbrite 244 m


444,5
DTH / RL
254mm
128 m
100 m
121.15 m
126 m
Grey color silty clay (0-6m, Pale green sticky clay (6 - 11m) Clay with some gravel (11 - 18m),
20 m
Fine Sand
Light Brown clay with fine sand at 24 me
31m
34m
Sand
Light Brown clay
40.m
43.m
Sand
Kaolinized Clay Probably part of the caolinized rhyolite as observed on the hill close to the sitr
50m
Poorly sorted coarse grained gravel
57 m
slightly Weathered basalt
74 m
No sample recovery
128 m

TEST PUMPING DATA

AG Consult
P.O.Box 4661
Addis Ababa, Ethiopia

Constant discharge test

Date 25-07-06 Annexes, Page
Project: BZDP
Evaluated by:EWTC

Test well:- BZDP/TW6
Test conducted on: 25-07-06
Location:- UTM; 463216 E, 867376 N Shisho Tora
Discharge 4.43 l/s
Static water level: 76.550m below datum

	Pumping test duration (min)	Water level (m)	Drawdown (m)	
1				
2	1.00	11.400	1.850	
3	2.00	11.650	2.100	
4	3.00	11.780	2.230	
5	4.00	11.850	2.300	
6	5.00	11.910	2.360	
7	6.00	11.960	2.410	
8	7.00	12.000	2.450	
9	8.00	12.050	2.500	
10	9.00	12.070	2.520	
11	10.00	12.100	2.550	
12	12.00	12.150	2.600	
13	14.00	12.200	2.650	
14	16.00	12.230	2.680	
15	18.00	12.250	2.700	
16	20.00	12.280	2.730	
17	25.00	12.340	2.790	
18	30.00	12.390	2.840	
19	35.00	12.430	2.880	
20	40.00	12.450	2.900	
21	45.00	12.500	2.950	
22	50.00	12.530	2.980	
23	55.00	12.550	3.000	
24	60.00	12.580	3.030	
25	70.00	12.630	3.080	
26	80.00	12.650	3.100	
27	90.00	12.680	3.130	
28	100.00	12.720	3.170	
29	120.00	12.780	3.230	
30	140.00	12.800	3.250	
31	150.00	12.820	3.270	
32	160.00	12.850	3.300	
33	180.00	12.870	3.320	
34	210.00	12.910	3.360	
35	240.00	12.950	3.400	
36	270.00	13.000	3.450	
37	300.00	13.050	3.500	
38	330.00	13.050	3.500	
39	360.00	13.040	3.490	
40	420.00	13.080	3.530	
41	480.00	13.130	3.580	
42	540.00	13.150	3.600	
43	600.00	13.170	3.620	
44	660.00	13.220	3.670	
45	720.00	13.220	3.670	
46	780.00	13.250	3.700	
47	840.00	13.270	3.720	
48	900.00	13.300	3.750	
49	960.00	13.310	3.760	
50	1020.00	13.300	3.750	
51	1080.00	13.350	3.800	
52	1140.00	13.340	3.790	
53	1200.00	13.370	3.820	
54	1260.00	13.400	3.850	
55	1320.00	13.360	3.810	
56	1380.00	13.380	3.830	
57	1440.00	13.380	3.830	

WATER QUALITY DATA