APPENDIX C

HYDROGEOLOGY

CHAPTER 3 THE DEBUB REGION

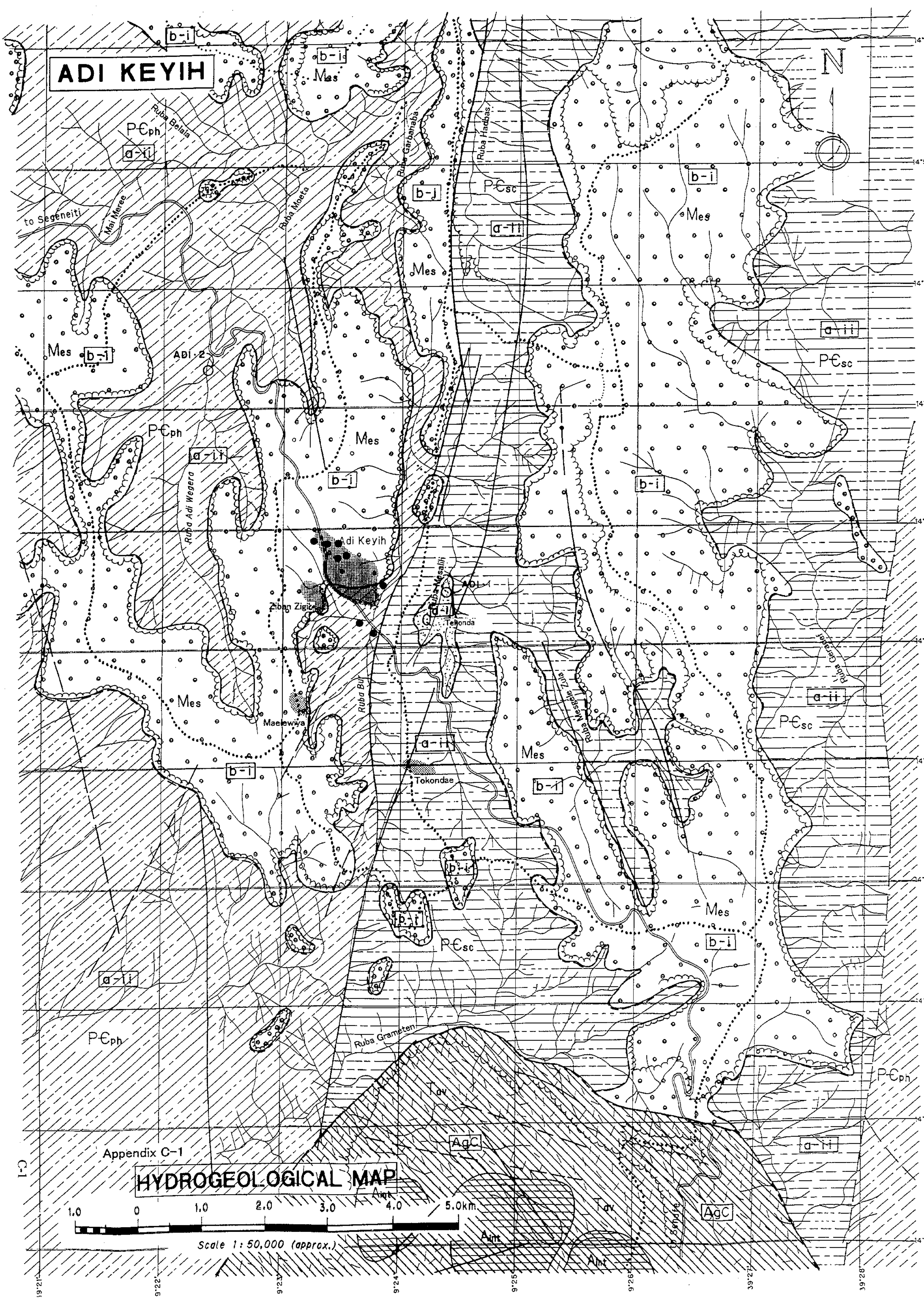
3.1 Natural Conditions

CHAPTER 4 CURRENT SITUATION (Adi Keyih)

4.1 Natural Conditions

CHAPTER 7 PROJECT FEASIBILITY STUDY

7.1 Groundwater Development Plan


ADI KEYIH
N
Ruba Belala
Ruba Moeta
Ruba Garbanaba
Ruba Hadbas
Mai Meree
to Segeneiti
ADI-2
ADI-1
Adi Keyih
Ziban Zigib
Maelewiya
Tekonda
Tokondae
Ruba Adi Wegera
Ruba Bur
Ruba Mesalili
Ruba Mesgele Zula
Ruba Geralet
Ruba Grameten
Ruba Sorote
Mes
P€ph
P€sc
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AgC
Aint
a-ii
b-i
14°55'
14°54'
14°53'
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14°51'
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14°49'
14°48'
14°47'
14°46'
14°45'
39°21'
39°22'
39°23'
39°24'
39°25'
39°26'
39°27'
39°28'
Appendix C-1
HYDROGEOLOGICAL MAP
1.0 0 1.0 2.0 3.0 4.0 5.0km
Scale 1:50,000 (approx.)
C-1

C-2 Legend on HYDROGEOLOGICAL MASP

Geological Legend

: Alluvial deposits	Quaternary
: Laterite covers	Quaternary
: Basaltic volcanics	Tertiary
: Trachytic volcanics	Tertiary
: Adigrat Sandstone	Mesozoic
: Sandstone	Paleozoic
: Chart	Paleozoic
: Granite	Precambrian
: Granite (marginal phase)	Precambrian
: Schist, Gneiss	Precambrian
: Phyllite, Slate	Precambrian
: Metavolcanic	Precambrian
: Dolomite	Precambrian
: Alkaline Intrusives	Tertiary
: Hornfels	Precambrian

Hydrogeological Legend

(a) Fissured aquifer of Basements

- a-i : Granite
- a-ii : Metamorphics
- a-iii : Meta-volcanics

(b) Fissured aquifer of Sedimentary rocks

- b-i : Adigrat Sandstone
- b-ii : Paleozoic sandstone

(c) Fissured aquifer of volcanics

- c-i : Basaltic volcanics

(d) Intergranular aquifer of Sediments

- d-i : Alluvial deposits
- d-ii : Colluvial deposits.

Aquitard and Aquiclude

- AqC : Trachytics, Alkaline intrusives, Hornfels, Chart, and a part of basaltic volcanics.

● : Existing borehole

○ : Test/Observation Well

: Basin boundary

Appendix C-3 Geophysical Prospecting Works

C-3.1. Works Volume

(1) Methodology and Equipment

In this Study, three kinds of geophysical prospecting were introduced; those were Very Low Frequency Electromagnetic wave sounding (VLF-EM), Horizontal electric Sounding (HS) and Vertical Electric Sounding (VES).

Equipment used in this work were as follows:

- for VES and HS — SYSCAL R-2 (Team)
  Terrameter SAS 300B (Dept. of Mines)
- for VLF — ABEM WADI

(2) Works volume

Table C-3.1 Geophysical Prospecting Works (Original plan)

Township	Site	VLF	HS	VES
Debarwa	Near Adi Logo The Mereb	-	2 (2)	8 (5)
Mendefera	Upstream of power plant Downstream of power plant	- -	- -	15 10
Dekemhare	East of old run-way	8	-	30
Segeneiti	Valley at 3.5km SE Near the Municipality Valley at 4.5km W	4 4 -	1 1 2	4 4 -
Adi Keyih	Downstream of eastern valley Upstream of eastern valley Valley at 4.0km NW	4 4 -	2 2 2	6 6 -
Senafe	Afoma area Small valley at SE	- 4	2 2	7 -
Total		28 lines	16 lines (2 lines)	90 points (5 lines)

Note: ( ) means small-scale survey.

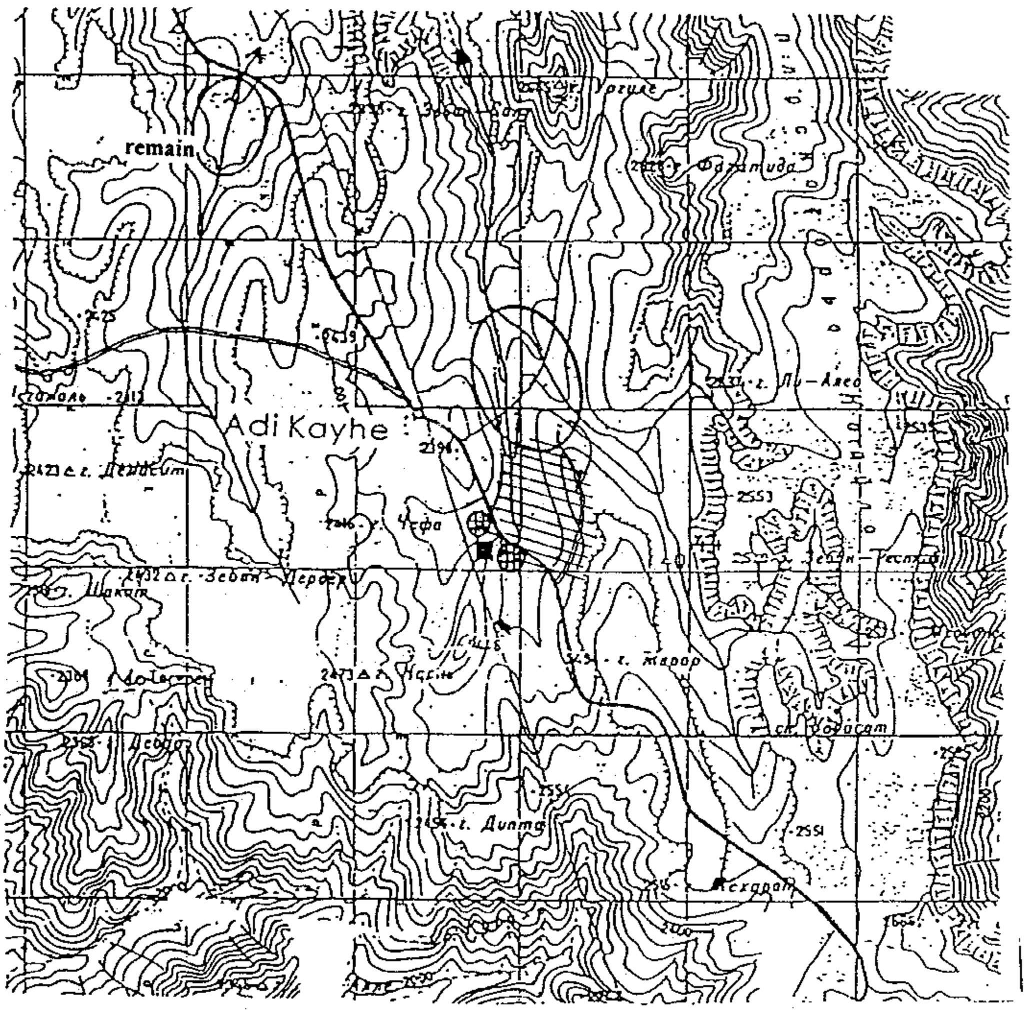
Table C-3.2 Geophysical Prospecting Works (The final)

Township	Site	VLF	HS	VES	Remark
Debarwa	Near Adi Logo The Mereb	-	2 (4)	9 (5)	Shift the site
Mendefera	Near the power plant	-	-	28	Unified
Dekemhare	East of old run-way	10	-	29	No change
Segeneiti	Valley at 3.5km SE Near the Municipality Valley at 4.5km W	4 3 5	2 1 2	- 6 8+(2)	Shift the sites
Adi Keyih	Upstream of eastern valley Valley beneath the town Valley at 4.0km NW	- 3 6	4 - 2	6 - 13	Shift the sites
Senafe	Afoma area Small valley at SE	- 6	3 2	8+(8) -	No change
Total		37 lines	18 lines (4 lines)	107 points (15 points)	

Note: ( ) means small-scale survey.

C-3.2. Location Map of Geophysical Works

ADI KEYIH



No scale

 : **original survey area**

 : **modifies survey area**

C-3.3. Summarized Results of Geophysical Prospecting Works

(1) Ruba Bur valley

VLF sounding were conducted and they detected out some structural lines along the valley. However, the valley was too narrow to conduct other prospecting works and a borehole was existed already in the valley. Thus, neither other sounding nor drilling was recommended here.

(2) Mai Adi Wegera valley

The valley forms a small alluvial plain at downstream area than the broken dam. VLF and HS sounding detected a major structure line along the valley at slightly eastern side, and some minor abnormalities. Then, VES detected another strong structure crossing with the major structure line obliquely, at just upstream side of the Highway. Upstream side of this sub-fault has very deep weathered rock zone of nearly 100m, while the downstream side has less than 50m of weathered zone, it means the fault has made a step structure here. Groundwater flows down through the valley must be obstructed by this underground structure much or less. Thus, one drilling was settled at just upstream side of the fault.

(3) Tekonda valley

The valley is characterized by fairly wide flat plain covered by deep green and used as pastureland. Beneath the ground surface should be river deposits with 15 to 20m in depth, showing 15 to 50 ohm-m. Below the deposits, a quite deep extremely low resistivity zone showing 1.2 to 2.0 ohm-m of apparent resistivity continues to the depth of around 100m. Further below the layer is a normal weathered rock showing 100 ohm-m. Non of normal geological unit shows such extremely low apparent resistivity as lower than 2.0 ohm-m, excepting seawater or any special mineralization phenomenon. Mostly from a geological and mineralogical interest, one drilling was allocated in this valley.

Appendix C-4 Test/Observation Well Drilling Works

C-4.1. Work volume

(1) Type of Wells

In this Study, two types of well are set; "Test Wells" and "Observation Wells". The main purpose of the Test Well is to know its exact hydrogeological condition and to evaluate the aquifer potential of the site. The purpose of the Observation Well is to estimate the recharging function of an existing dam to the groundwater system downstream. Two dams, namely Kilowlie Dam in Mendefera and Afoma Dam in Senafe, were selected for this study.

(2) Work volume

Table C.4.1 shows the final drilling plan. Those sites and the number of wells in each town were fixed but the depth of each drilling should be revised in accordance with the hydrogeological situation of the site.

Table C.4.1 Test/Observation Well Drilling Plan

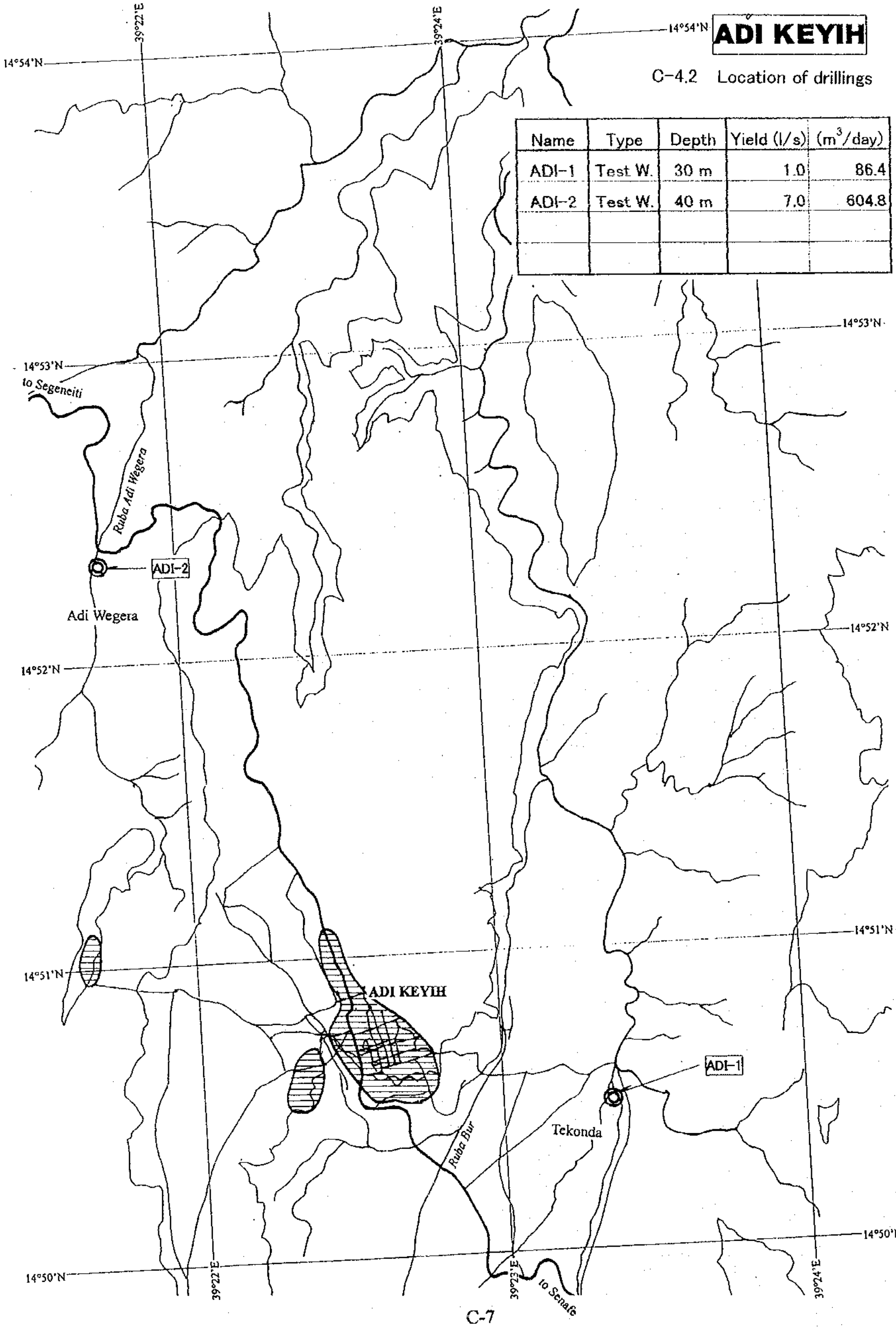
Township	Site	Test Well	Obs.Well	Recorder*
Debarwa	West of the town	1 x 80m		1
Mendefera	Near the power plant	2 x 80m		1
	Downstream of Kilowlie Dam		2 x 30m	2
Dekemhare	East of old run-way	2 x 80m		2
Segeneiti	Valley at 3.5km SE	1 x 60m		1
	Near the Municipality	1 x 60m		
	Valley at 4.5km W	1 x 60m		
Adi Keyih	Upstream of eastern valley	1 x 60m		
	Valley at 4.0km NW	1 x 60m		1
Senafe	Afoma Dam downstream		1 x 60m	1
Total		10 wells (700m)	3 wells (120m)	9 wells

● : Automatic water level recorder installatio

ADI KEYIH

C-4.2 Location of drillings

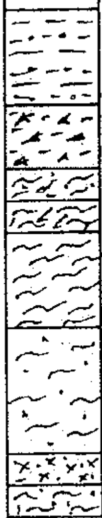
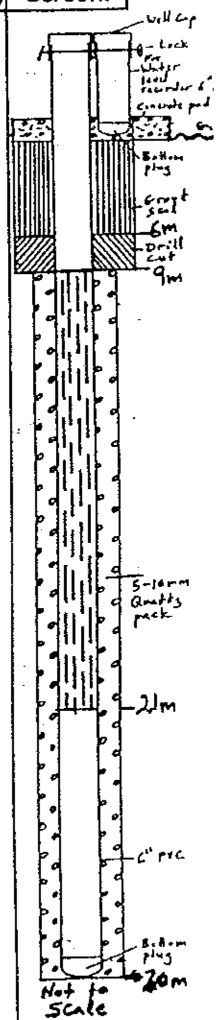
Name	Type	Depth	Yield (l/s)	(m^3/day)
ADI-1	Test W.	30 m	1.0	86.4
ADI-2	Test W.	40 m	7.0	604.8



ADI-1

GEDECC BOREHOLE DRILLING DATA:

Project:JICA	Village/Town:Adi keyih	File No.:D - 025
Drilling started:January 16, 1998	Zone:South	BH No.:ADI-1
Rig type:Atlas copco RSO	Casing:Temporary 12" Steel	Latitude:39° 23"28' E
Depth drilled: 30 meters	From 0 T0 11 m.	Longtude:14° 50" 26' N
Drilling completed:January 21, 1998	Casing: Permanent 6" PVC	Elevation:
Filter slots: 2.00 mm.	From 0 to 30 m.	SWL:3.2 meters
Gravel type, size: Quartz, 10 mm.	Volume:1.5 cubic meters	Drill bit size:0-11m. 121/2" & 11-30m. 10" bit

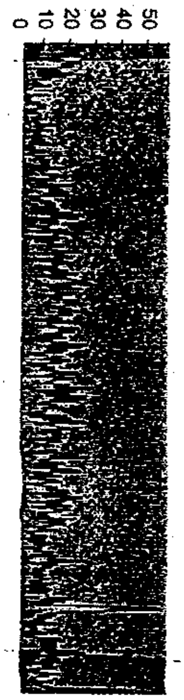
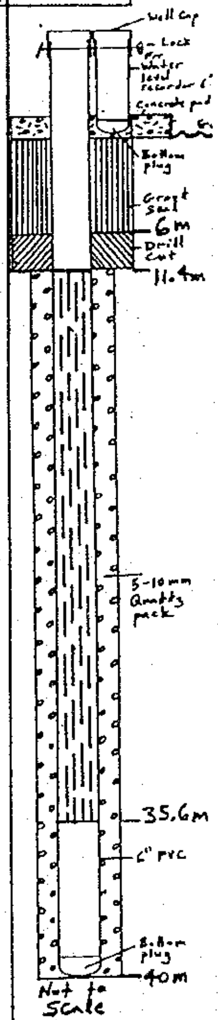
Geology: Depth (m)	Section:	Description:	Geophysical borehole logging: N.Gamma (M/Min) S&L	Drilling speed: (m/hr)	Water struck: (L/sec)	Casing and Screen:
0		Top soil, clayey nature, fine to medium grained, brown color				
		Angular schisted rock, fine to course gravel size		2.5m/hr		
-10		contact rock, schisted-graphite				
		Foliated graphite schist				
		Sticky, powdered graphite schist				
-20		Same composition as above but more sticker		4.2m/hr		
		A thick vein (Aplitic) intercepted				
-30		Foliated graphite schist, dark colored				
-40						
-50						
-60						
-70						

Prepared by:Amanuel G. Woldu Date:January 22, 1998

Note: These logs were taken by Hydrogeologist of GEDECC. Descriptions on lithology and depth of layer are slightly different with the one taken by Drilling Supervisor of the Team which are explained in the main text.

GEDECC BOREHOLE DRILLING DATA:

Project:JICA	Village/Town:Adi keyih	File No.:D - 025
Drilling started:January 9, 1998	Zone:South	BH No.:ADI-2
Rig type:Atlas copco RSO	Casing:Temporary 12" Steel	Latitude:39° 21"24' E
Depth drilled: 40 meters	From 0 T0 7.5 m.	Longtude:14° 52" 22' N
Drilling completed:January 15, 1998	Casing: Permanent 6" PVC	Elevation:
Filter slots: 2.00 mm.	From 0 to 40 m.	SWL:2.05 meters
Gravel type, size: Quartz, 10 mm.	Volume:2.5 cubic meters	Drill bit size:0-11m. 121/2" & 11-30m. 10" bit

Geology: Depth (m)	Section:	Description:	Geophysical borehole logging: N.Gamma (M/Min)	Drilling speed: (m/hr)	Water struck: (L/sec)	Casing and Screen:
0		Surface soil, course grained brown colored		3.6m/hr		
-10		Fresh, granular basement rock				
		Quartz vein fragments in schist		3m/hr		
-20		Weathered schist, course gravel size, bluish in color				
-30		Quartz vein in schist				
		Weathered schist				
		Quartz vein in schist				
-40		Weathered schist				
-50						
-60						
-70						

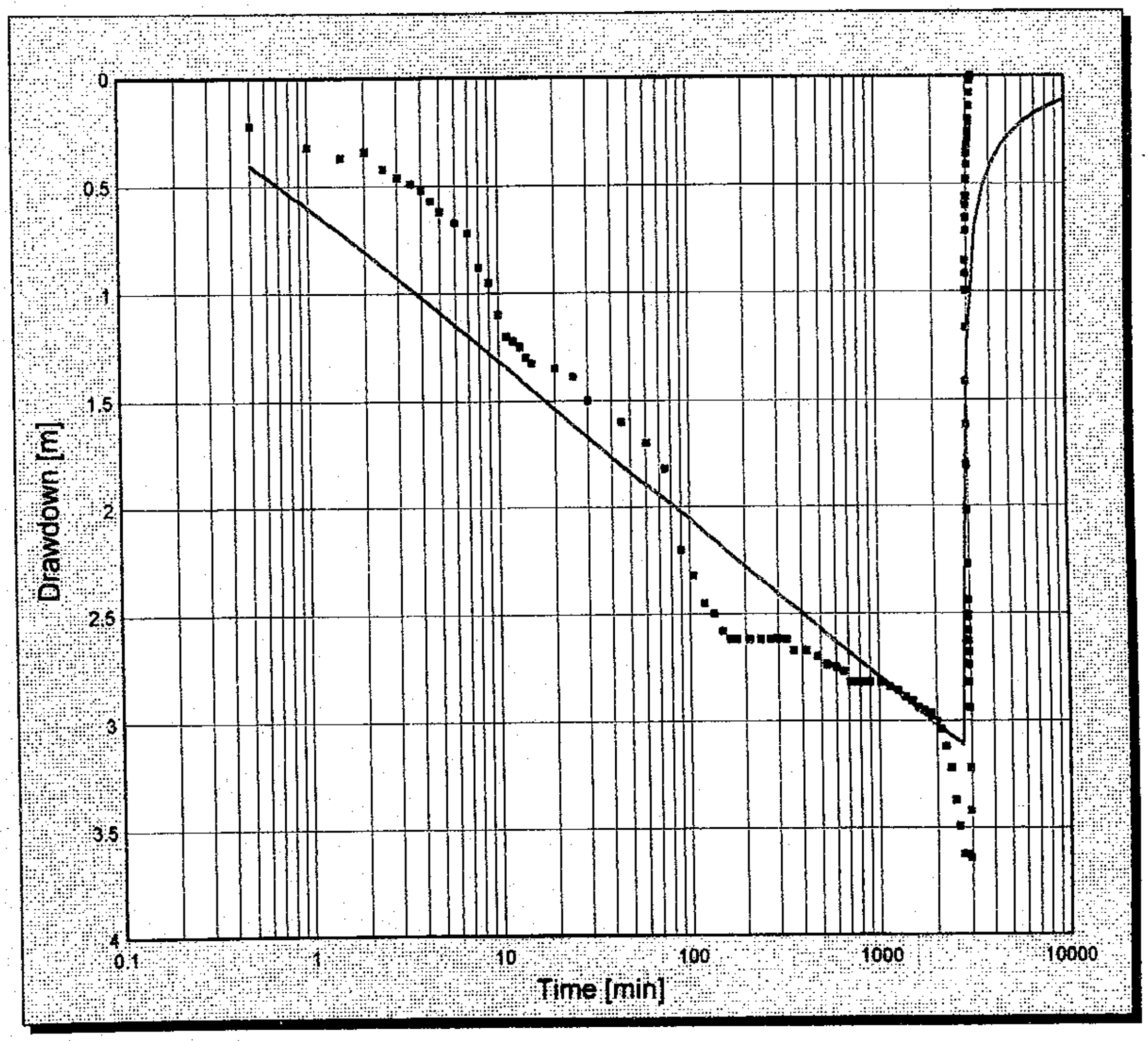
Prepared by:Amanuel G. Woldu Date:January 16, 1998

Note: These logs were taken by Hydrogeologist of GEDECC. Descriptions on lithology and depth of layer are slightly different with the one taken by Drilling Supervisor of the Team which are explained in the main text.

C-4.4 Result of Pumping Test

Pumping Test			
Well Ident Adi-1	Description		
Obs. Well Distance [m] 0.08	Average Pump. Rate [m3/day] 105.4197	Duration [min] 3210.000	Initial Sat. Thickness [m]

			Results
Transmissivity [m2/day] 26.88431	Storage Coefficient	Leakance [1/day]	Estimation Error [m] 0.44
Fit Method			Theis Method

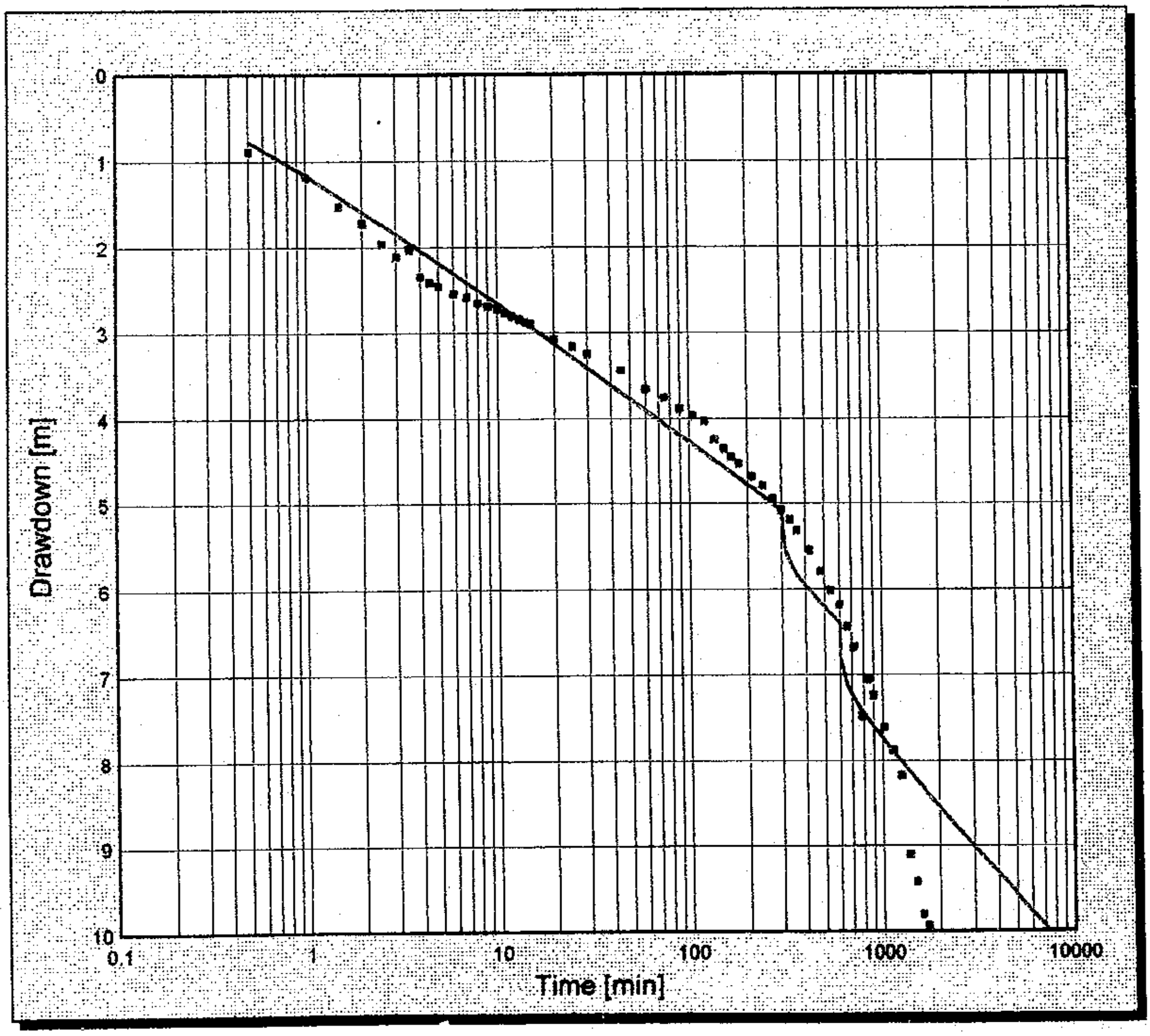


Pumping Test

Well Ident	Description		
Adi-2			
Obs. Well Distance [m]	**Average Pump. Rate [m3/day]**	**Duration [min]**	**Initial Sat. Thickness [m]**
0.08	733.0654	1740.000	40.00

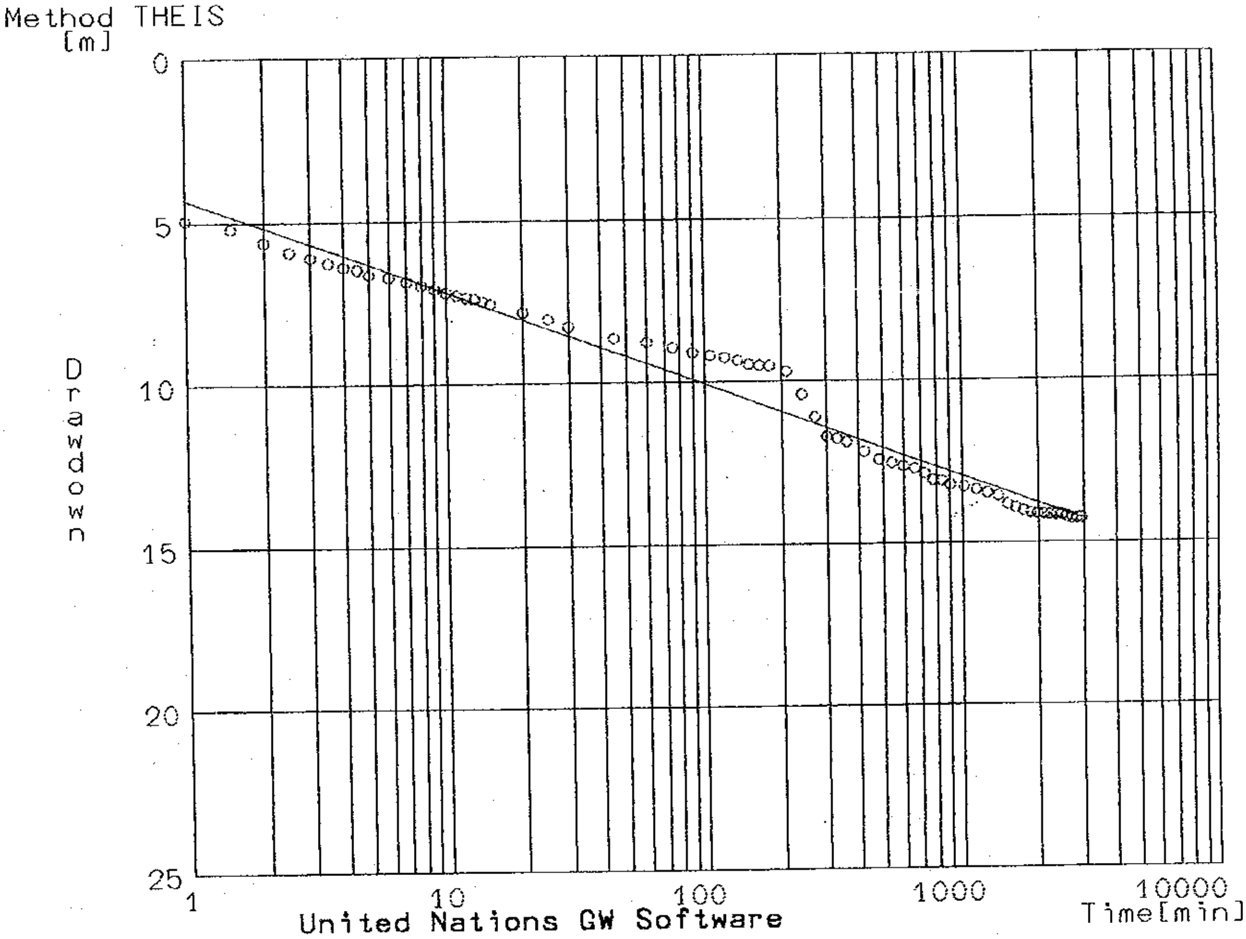
Results

Transmissivity [m2/day]	Storage Coefficient	Leakance [1/day]	Estimation Error [m]
77.15064			0.35
Fit Method			Theis Method



Project : Eritrea
Organization : WRD/JICA
Existing capped well
Test : BH5con

Constant Pumping Rate = 89.0 [m3/day]
Distance from Pumping Well = 0.10 [m]
Type of Aquifer = UNCONFINED
Initial Saturated Thickness = 40.00 [m]
Type of Input Data = DRAWDOWN
Well Type = STANDARD



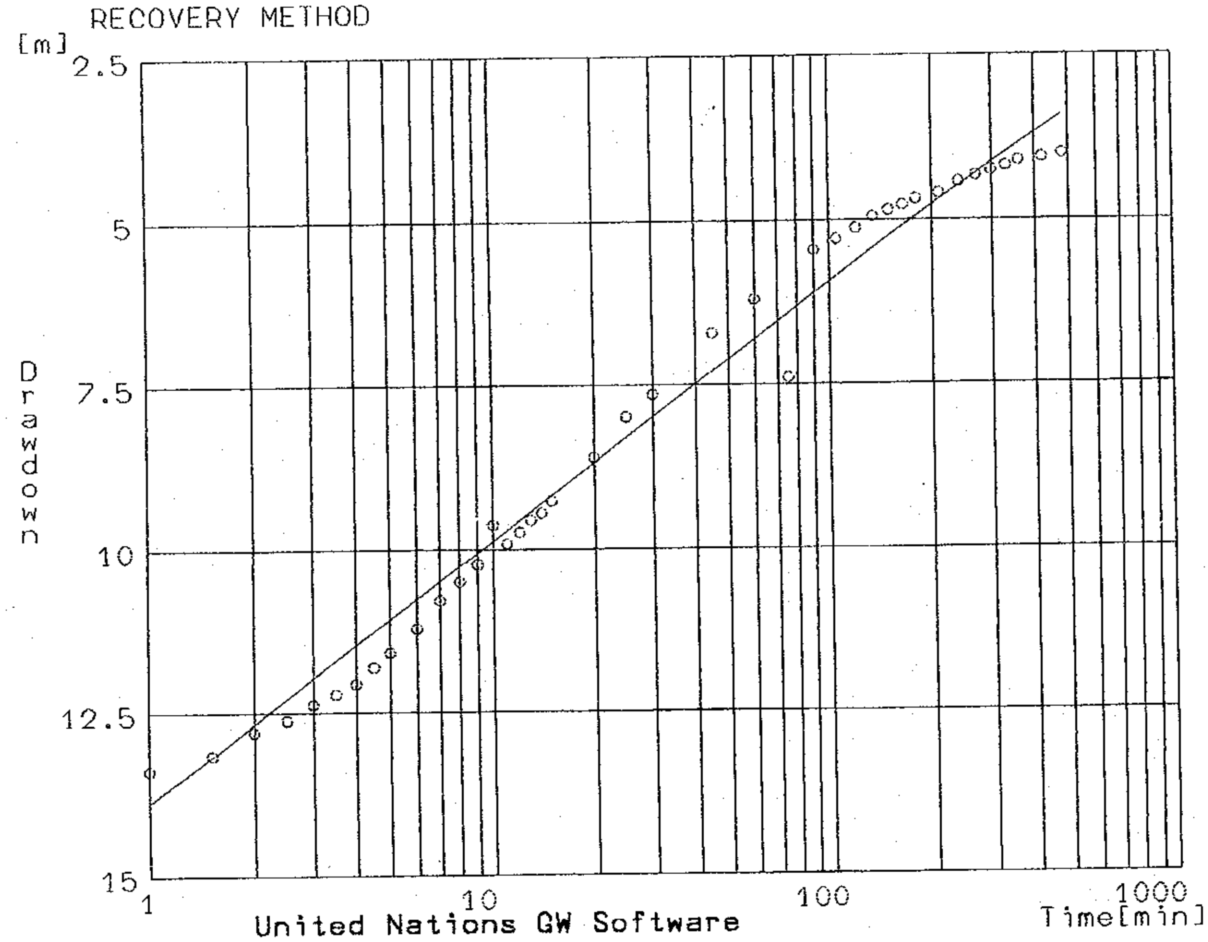
Transmissivity = 6. [m2/day]

Standard Deviation = 0.5025 [m]

Number of Points = 65 of 65

Project : Eritrea
Organization : WRD/JICA
Existing capped well
Test : BH5rec

Constant Pumping Rate = 89.0 [m3/day]
Distance from Pumping Well = 0.10 [m]
Type of Aquifer = UNCONFINED
Initial Saturated Thickness = 40.00 [m]
Type of Input Data = DRAWDOWN
Well Type = STANDARD



Transmissivity = 4. [m2/day]

Standard Deviation = 0.4600 [m]

A0 = 0.431728E+01

A1 = 0.287317E+01

Number of Points = 41 of 41

C-5.1 Water qualities of Current water supply system

Report

On

WATER QUALITY ANALYSIS

For

SEVEN TOWNS IN DEBUB REGION

Fikremariam Kahsai
Department of water resources
Asmara, Eritrea
Oct.24,1997

Introduction

As per request of Japan international co-operation agency (JICA) study team, the laboratory of WRD has conducted water quality analysis for seven target towns in the southern region of the country. These towns are, Debarwa, Mendefera, Adi-Quala, Dekemhare, Segeneiti, Adi-Keyih, and Senafe. The study encompasses chemical, bacteriological and physical assessment of water samples. To accomplish the task, ten sampling points were chosen from each town.

Water source intended for drinking should fulfil requirements which are essential for the well being of the consumer. It should be safe, as well aesthetically acceptable. The basic aspect of water quality which should be examined are:

1. Chemical quality: Chemically, water for public supply should hold optimum concentration of ions and trace metals.
2. Bacteriological quality: It should be free from pathogenic micro-organisms.
3. Physical quality: Aesthetically it should be acceptable to consumers. Meaning, its taste should be palatable, its color and odor acceptable.

The bacteriological and physical examination of water points was carried out in the field, and the technique used for the enumeration of coliforms was membrane filtration. Concerning chemical analysis, water samples were brought to the WRD water laboratory in Asmara and analysed

The analytical results and location of of the sampling points (in UTM coordinates) are annexed within this report.

Evaluation of analytical data

Water for public water supply should be free from any pathogens, chemically safe for human consumption and aesthetically acceptable.

To meet the intended purpose some countries set their own drinking water standards which comply with their own specific conditions. Most countries in the world follow WHO guidelines. Inspite of this, there are no measure differences between standards of some developed countries and that of WHO.
For practical purposes of this report, all references and evaluations of analytical data are given on WHO guidelines.

1. Physio-Chemical characteristics:

A. Electrical conductivity (EC)

EC is a measure of the ability of salts in solution to carry an electric current. The EC value rises with the rise in the degree of mineralisation or salinity.

Potable water should consist optimum concentration of dissolved substances, to serve as feasible source. Consideration of EC value as water quality is mainly due to its effect on taste. WHO has not set a standard for EC value, but the guideline value for TDS(total dissolved solids) which is directly related to EC (TDS = kEC, Where k ranges 0.55 to 0.7 for natural waters) is 1000ppm.

Among the seventy samples analysed from the seven towns, a borehole in Adiquala (AD-06), a well in (SG-09), borehole and a well in Dekemhare (DK-04), (DK-10), have electrical conductivity value greater than 1200 μs/cm to impart disagreeable taste.

B. pH Value

The pH value which is a measure of the concentration of the hydrogen ion is used as indicator of either acidic or basic pollution. The pH value of all the waters in the towns lie within the range of 6.5-8.5 units, which is a recommended limit for drinking.

C. Turbidity

Clarity is an important water quality parameter of water supply. Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. If the turbidity exceeds 5NTU, then it is clearly visible in a glass of water and usually rejected by consumer on aesthetic grounds.

Turbidity higher than the recommended value was registered in Segeneyti, Kilowlie(Mendefera),Sememo(Adiquala), and Adi-Keyih dams. This is mainly caused by silt and clay materials transported with the flowing water during raining.

The other sources which are mainly ground water, have value less than 5NTU which meets the standard of WHO.

D. Total Hardness

Total hardness is the sum of calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per litre. The hardness or softness of water varies from place to place and reflects the nature of the geology of the area with which the water has been in contact. In general, surface waters are softer than ground waters. Hard waters are associated with chalk and limestone catchment areas, whereas soft waters are associated with impermeable rocks such as grinite.

Very hard water, greater than 350 mg/l as $CaCO_3$, causes scale deposition in pipelines and scum formation in boilers. Soft Waters, less than 75 mg/l as $CaCO_3$ causes leaching of metals and corrosion.

The dams in Adi-Keyih(AK-09), Adi-Quala(AD-01), and Mendefera (Kilowlie)(MN-01) has 62, 54, and 48 mg/l total hardness as Calcium Carbonate, hence classified as soft water. Whereas, nine sampling points which are coded as SN-02, SN-08, AD-06, MN-06, MN-08, DB-06, SG-09, DK-04 and DK-10 has registered hardness value ranging 350 to 743 mg/l as Calcium Carbonate. Therefore, classified as very hard waters.

E. Nitrogenous Compounds

The chemical compounds nitrate, nitrite, and ammonia play a major role in evaluation of water quality. Three of them are interconnected by nitrogen cycle, hence one is a precursor of the other. oxidation of ammonia gives rise to nitrite and further to nitrate. The main concern of nitrate presence in excess is that it is linked to a condition known as blue baby syndrome or infant methaemoglobinemia. Due to its toxicity effect on human body, an upper limit value of 45mg/l has been set.

As the analytical results show, boreholes in Adi-Keyih (AK-10), Adi-Quala (AD-06), and Dubarwa (DB-05), a borehole(DK-04) and a well (DK-10) in Dekemhare, registered 45.2, 89.5, 64.2, 97.4, and 51.8 mg/l nitrate respectively.

Besides, in Senafe at consumer's tap (SN-06), the levels of nitrite was 5.16mg/l . This is exceedingly high in relation to WHO guideline value, which is 3mg/l as nitrite. This could be due to old pipeline system which permits intrusion of contaminants.

The possible source of nitrate contamination is organic matter broken down by bacteria in the soil.

F. Chloride

Chloride is widely distributed in nature in the form of varied salts. Its presence in natural waters can be attributed to dissolution of salt deposits, sewage discharges and sea water intrusion in coastal areas.

The taste threshold for chloride in drinking water is dependent upon the associated cation, but is usually within the range 200-300mg/l. WHO recommends a guideline value of 250mg/l .

Among the seventy samples analysed, with the exception of a bore hole in Dekemhare (DK-04) which was found 260mg/l, all were found to contain less than 250mg/l, hence in the desired limit.

G. Sulphate

High sulphate concentrations in water may contribute to the corrosion of metals in the distribution system. Due to the cathartic effect of sulphate, a guideline value of 400mg/l is set.

The sulphate content of all the analysed samples is far less than the recommended guideline value, therefore there will not be any sulphate related problem with the water supplies.

H. Sodium

The recommended guideline value is 200mg/l which is based on taste thresholds. With the exception of a borehole in Dekemhare (DK-04) which is found to be 215mg/l, all the analysed samples showed a sodium level in the range of acceptable quantity.

I. Iron and Manganese

Both chemical elements are related with staining of laundry and sanitary ware. For this reason a guideline value of 0.3mg/l and 0.1mg/l is set for iron and manganese respectively. For health related reasons a 0.5mg/l guideline value is set for manganese.
Among the analysed samples, a borehole in Senafe (SN-10), a dam in Mendefera (MN-01), and a well in Segeneyti (SG-07) were found to contain 0.39mg/l, 0.41mg/l and 0.61mg/l of iron. The rest samples are free from iron which can cause staining.
Furthermore, four water sources are found to consist 0.2mg/l of manganese. These are, a spring and a hand dug well in Dubarwa (DB-09, DB-10), a well in Segeneyti (SG-07) and a borehole in Dekemhare (DK-05). The rest are found to be free from manganese induced staining problems.

J. Fluoride

Fluoride levels in excess of 1.5mg/l lead to an increase in the occurrence and severity of dental fluorosis (teeth become mottled and brittle). Normally, 1 to 2mg/l fluoride is mentained in public drinking water supplies for the prevention of dental carries in children. All the analysed samples of water showed that the sources contain optimum concentration of fluoride.

K. Copper

As Debarwa was a copper mining site, analysis of water points for copper was done to evaluate the water chemistry of the town.
The guidelines value for copper for health related considerations is 2mg/l.
All the samples analysed contain copper in the limits of the recommended value.

Conclusion Concerning Pysio-Chemical Characteristics

Generally the physio-chemical characteristics of water sources in the seven towns is evaluated as good . The few exceptions being a borehole in Adiquala (AD-06), a well in Segeneyti (SG-09), borehole and a well in Dekemhare (DK-04), (DK-10), which have electrical conductivity value greater than 1200 μs/cm to impart disagreeable taste.

In addition, boreholes in Adi-Keyih (AK-10), Adi-Quala (AD-06), and Dubarwa (DB-05), a borehole(DK-04) and a well (DK-10) in Dekemhare, were found to contain 45.2, 89.5, 64.2, 97.4, and 51.8 mg/l nitrate respectively, which could be potentially health hazard to consumers.

2. Bacteriological Characteristics

The basic requirement for any water source to be considered as an acceptable source for drinking is that it should be freed from bacteria, virus and protozoan.

In evaluation of bacteriological safety of water, routinely testes are done to identify for organisms indicators of pollution. The coliform group of bacteria which are found in sewage, animal and human excrement are the accepted indicators of pathogenic micro-organisms.

WHO standard recommends drinking water must not contain faecal coliform bacteria. Otherwise, it is unsafe for human consumption.

Out of seventy samples analysed from the seven towns, 29 were found to be contaminated with bacteria which are faecal in origin. This shows that the sanitary conditions of the water sources and reservoirs is not well mentained. The most probable source of contamination is human and animal waste which adds up to dams, ground water sources and pipeline systems with run off, percolation and infiltration respectively.

Total coliform bacteria should not occur repeatedly in water samples in regular water quality monitoring programme. Thier presence in a single analysis, as in the case of this study, does not necessarly imply the water sources are unsafe.

Conclusion Concerning Bacteriological Characteristics

As twenty nine of the seventy sampling points were found to be bacteriologically contaminated, it can be concluded that some of the people in these towns is getting unsafe water. However, it is noteworthy to mention that high rate of contamination may be due to unusual rainfall in the area before sampling which may helped to carry/percolate human and animal waste to the sources.

To improve the situation:

- The sanitary condition of the surroundings of the water points should be improved.
- Open wells should be covered with slab and a pump installed.
- Supplies from surface water should be treated before distribution.
- Regular water quality monitoring programme should be introduced.
- Public awareness on hygiene and sanitation should be increased.

Table-6 Water Quality In Adi-Keyih

I. Physical Quality

Date Sampled 27/10/97

Date Analysed 28/10/97

Well	Description	EC	pH	Temp	Odor	Taste	Turb.	Color
Ident		us/cm		°c			NTU	
AK-01	BH in town,with pump	389	6.5	18.7	agreeable	agreeable	<5	clear
AK-02	Reservoir,100cu.m	225	7.2	22.3	agreeable	agreeable	<5	clear
AK-03	Public Tap in Town	367	6.2	20.4	agreeable	agreeable	<5	clear
AK-04	Consumer's Tap	379	7.0	18.3	agreeable	agreeable	<5	clear
AK-05	Consumer's Tap	444	7.2	18.8	agreeable	agreeable	<5	clear
AK-06	BH Near Reservoir	639	6.5	26.4	agreeable	agreeable	<5	clear
AK-07	Reservoir 360 cu.m	449	7.3	20.1	agreeable	agreeable	<5	clear
AK-08	Shallow Well	437	6.9	24.1	agreeable	agreeable	<5	clear
AK-09	Dam	103	7.5	22.9	agreeable	disagree	32	muddy
AK-10	BH, Sec School	484	5.8	19.8	agreeable	agreeable	<5	clear

II. Bacteriological Quality

T.C.B = Total Coliform Bacteria

F.C.B = Faecal Coliform Bacteria

T.C.B	F.C.B	Remarks
count/100ml,35°c	count/100ml,44.5°c	
0	0	Safe
0	0	Safe
0	0	Safe
140	89	contaminated
many	many	contaminated
0	0	Safe
many	many	contaminated
many	many	contaminated
many	many	contaminated
many	many	contaminated

III. Chemical Quality

Date Sampled 27/10/97

Date Analysed 07/11/97

Well	Description	Ca	Mg	Na	K	Fe	Mn	HCO3	SO4	Cl	NO3	N-NH3	NO2	F	Hard.
Ident		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	*G.d.h
AK-01	BH in town,with pump	54	17	15	1.3	0.06	0.1	185	13	16	18.2	0.28	0.99	0.24	11.4
AK-02	Reservoir,100cu.m	59	19	24	1.3	0.01	0.0	215	27	16	9.7	0.03	0.00	0.39	12.7
AK-03	Public Tap in Town	64	8	15	1.3	0.02	0.0	176	9	28	17.3	0.03	0.01	0.11	10.7
AK-04	Consumer's Tap	43	21	14	1.3	0.02	0.0	171	3	28	17.3	0.00	0.06	0.18	10.9
AK-05	Consumer's Tap	62	17	26	1.3	0.02	0.1	264	34	12	5.8	0.04	0.00	0.49	12.5
AK-06	BH Near Reservoir	55	20	40	1.4	0.10	0.1	195	26	52	4.0	0.24	0.01	0.63	12.3
AK-07	Reservoir 360 cu.m	56	23	27	1.3	0.01	0.0	259	31	16	6.2	0.11	0.01	0.48	13.2
AK-08	Shallow Well	59	19	30	3.1	0.01	0.0	254	35	16	5.3	0.20	0.01	0.37	12.7
AK-09	Dam	10	9	3	2.6	0.05	0.1	63	0	8	3.5	0.12	0.01	0.12	3.5
AK-10	BH, Sec School	46	27	14	2.6	0.00	0.0	93	13	72	45.2	0.09	0.70	0.05	12.7

*G.d.h = German degree of hardness, 1G.d.h = 17.9mg/l hardness as CaCo3

* Note: HDW = Hand dug well
BH = Borehole

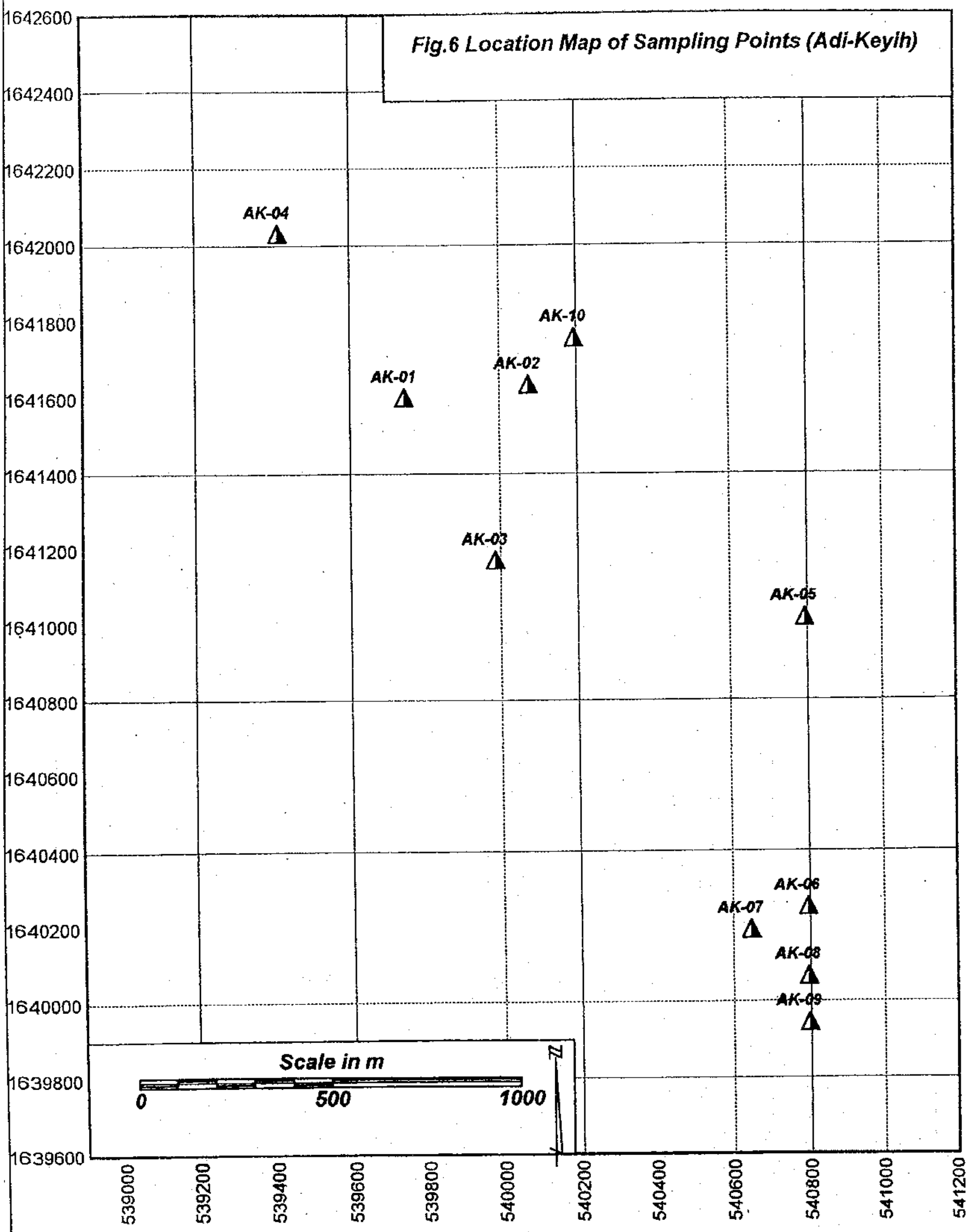


Fig.6 Location Map of Sampling Points (Adi-Keyih)
AK-04
AK-10
AK-01
AK-02
AK-03
AK-05
AK-06
AK-07
AK-08
AK-09
Scale in m
0
500
1000
1642600
1642400
1642200
1642000
1641800
1641600
1641400
1641200
1641000
1640800
1640600
1640400
1640200
1640000
1639800
1639600
539000
539200
539400
539600
539800
540000
540200
540400
540600
540800
541000
541200

Report

on

WATER QUALITY ANALYSIS

JICA TESTING BOREHOLES IN DEBUB REGION

Fikremariam Kahsai
Water Resources Department
Asmara, Eritrea
Feb. 19, 1998

Water Quality Evaluation of testing boreholes drilled in Debub region of JICA project

1. Mendefera :

Borehole No1 of Adimongoti is of acceptable with respect to chemical and bacteriological quality. Though manganese is present in significant concentration, it has not exceeded the WHO guidelines to cause any staining problems and, as the water is very soft it will be corrosive to pipelines. Besides, the pH is high (8.66) to make the water tastes alkaline.

2. Dubarwa :

This borehole has chemically and bacteriologically acceptable water quality although slightly hard due to calciumbicarbonate.

3. Segeneyti (SEG-01):

The water quality of this borehole is bacteriologically safe and based on the amount of total dissolved solids it is chemically acceptable for drinking. But, the concentration of manganese which is 0.4mg/l exceeds the WHO guidelines of 0.1 mg/l, therefore it will cause staining problem. The amount of ammonia though in the limits of WHO guidelines is considerable to show that there is domestic organic contamination. Furthermore it is slightly hard water which will consume considerable amount of soap for lathering.

4. Segeneyti (SEG-03) :

The source is bacteriologically safe for domestic water supply. Chemically the water quality is fairly good. The electrical conductivity value indicates that the dissolved solids are within the limits of WHO guidelines. Hence good quality with respect to dissolved solids. But, the source is slightly hard water and with manganese concentration exceeding the WHO guideline value to cause staining problem.

5. Adikeyih/ Tekondae (ADK-01):

The source is bacteriologically acceptable for drinking. The amount of dissolved solids indicated by the electrical conductivity value is considerable though in the limits of WHO guidelines.

The amount of ammonia is high showing sewage or organic pollution. Furthermore, the concentration of manganese is higher than WHO guideline value. The degree of clarity of the water is not satisfactory which is measured 5 NTU. Besides, it is very hard water due to calciumbicarbonate.

The source can be used as source of water supply only if no better alternative source is available.

6. Adi-Keyih/ Adiwegera (ADK-02):

The source is bacteriologically acceptable for drinking. Chemically the water quality is fairly good . The dissolved minerals is considerable though in the range of WHO guidelines and the concentration of manganese is high to cause staining in laundry and utensils. The amount of calcium is high to make the source hard water. The amount of ammonia though not exceeding WHO guidelines it indicates occurrence of organic contamination.

7. Senafe (SEN-02):

The borehole is found to contain bacteria indicators of faecal pollution. Therefore the source is bacteriologically unsafe for human consumption. Chemically, the source has good composition except for manganese (0.3mg/l) which is exceeding the WHO guidelines of 0.1mg/l for reasons of aesthetic.

8. Dekemhare : DEK-01 and DEK-02

These sources are found to be free from bacteriological contamination. Therefore bacteriologically safe for drinking. Chemically, though safe from health point of view, there are high concentration of calcium and magnesium to make the sources very hard water.

Table 1. Water Quality of JICA testing wells in Zoba Debub

I. Physical Quality

Date Sampled 05.01.98 - 30.01.98

Date Analysed 13.01.98 - 06.02.98

Well Idnt	Sub-Zoba	EC	pH	Temp	Odor	Taste	Turb	Color
		us/cm		°c			NTU	
MEN-01	Mendefera	468	8.66	22.1	agreeable	agreeable	0	clear
DUB-01	Dubarwa	762	7.46	22.2	agreeable	agreeable	0	clear
SEG-01	Segeneyti	832	6.95	24.0	agreeable	agreeable	0	clear
SEG-03	Segeneyti	791	6.74	22.5	agreeable	agreeable	0	clear
ADK-01	Adi-Keyih	1051	6.85	21.4	agreeable	agreeable	5	muddy
ADK-02	Adi-Keyih	948	6.77	20.7	agreeable	agreeable	0	clear
SEN-01	Senafe	734	6.68	21.5	agreeable	agreeable	0	clear
DEK-01	Dekemhare	1247	7.10	22.7	agreeable	agreeable	0	clear
DEK-02	Dekemhare	1184	6.91	22.6	agreeable	agreeable	0	clear

II. Bacteriological Quality

T.C.B = Total Coliform Bacteria

F.C.B = Faecal Coliform Bacteria

T.C.B	F.C.B	Remarks
count/100ml,35°c	count/100ml,44.5°c	
0	0	safe
0	0	safe
0	0	safe
0	0	safe
0	0	safe
0	0	safe
many	30	contaminated
0	0	safe
0	0	safe

III. Chemical Quality

Date Sampled 05.01.98 - 12.02.98

Date Analysed 13.01.98 - 18.02.98

Well Idnt	Sub-Zoba	Ca	Mg	Na	K	Fe	Mn	HCO3	SO4	Cl	NO3	N-NH3	NO2	F	Hardness
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	*G.d.h
MEN-01	Mendefera	2.9	0.7	92.4	0.7	0.02	0.1	122.0	34.0	60.0	4.9	0.01	0.004	0.26	0.56
DUB-01	Dubarwa	86.0	32.8	30.8	0.5	0.04	0.0	427.0	32.0	30.0	10.6	0.02	0.340	0.18	19.55
SEG-01	Segeneyti	96.0	37.7	42.9	7.6	0.05	0.4	420.9	68.0	45.0	1.3	0.54	0.000	1.22	22.06
SEG-03	Segeneyti	102.0	32.8	35.2	0.6	0.07	0.4	555.1	34.0	40.0	7.1	0.26	0.049	0.42	19.83
ADK-01	Adi-Keyih	124.0	47.4	51.2	0.6	0.02	0.2	542.9	135.0	32.5	2.7	1.11	0.009	0.62	28.21
ADK-02	Adi-Keyih	110.0	30.4	56.1	0.4	0.02	0.4	488.0	75.0	50.0	1.8	0.60	0.007	0.38	22.35
SEN-01	Senafe	82.0	7.3	40.7	4.5	0.03	0.3	268.4	39.0	30.0	2.7	0.40	0.013	1.05	13.13
DEK-01	Dekemhare	141.2	27.2	75.0	0.9	0.09	0.1	402.6	70.0	155.0	6.2	0.52	0.007	0.52	25.98
DEK-02	Dekemhare	120.0	24.3	98.0	1.2	0.02	0.1	323.3	75.0	170.0	36.3	0.34	0.290	0.44	22.35

*G.d.h = German degree of hardness, 1G.d.h = 17.9 mg/lhardness as CaCO3

Tel. 116265	**Department Of Water Resources**		P.O.BOX 1488
Date-Sampled 07.03.98	**Water Lab Report**		Date-Analysed 17.03.98
Well Ident Existing capped well	Description	Borehole, JICA rehabilitated	Lab-No 808
BH5 Adikeyih		Village Adikeyhih	

Cations	***Ca***	***Mg***	***Na***	***K***	***Fe***	***Mn***
EPM	4.1916	2.3987	2.9145	0.05114	0.0032	
PPM	84.00	29.16	67.00	2.00	0.06	0.60

Anions	***HCO3***	***CO3***	***SO4***	***Cl***	***NO3***	***F***
EPM	6.59861	0.0000	1.66560	1.26945	0.03565	
PPM	402.60	0.00	80.00	45.00	2.21	0.59

Calculated Data

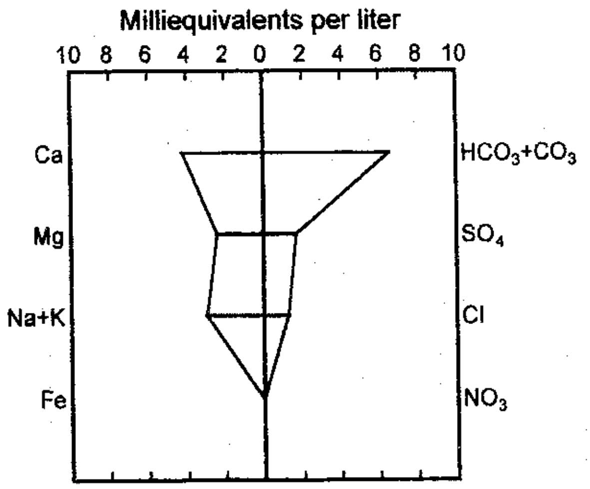
SAR	Cations	Anions	BalErr
1.6056		9.6	0.10

NO2(tot) 0.003	B(tot)	N-NH3 1.75	H2S	CO2
M-Alk 330.0	P-Alk 0.0	EC 483.00	pH 8.66	TDS
Hardness 335.0	Temp°c	Odor	Color	Turbidity

Heavy Metals (ppm)

Cu	Zn	Pb	Hg	Cr

STIFF Diagram



Water Type	**Calcium Bicarbonate**

Analyst Kidane Araya

C-6 Groundwater Monitoring Data

Adi Keyih at 6:00

Date	Reading	G.L.
1998/6/17	2.060	-1.560
1998/6/18	2.060	-1.560
1998/6/19	2.051	-1.551
1998/6/20	2.040	-1.540
1998/6/21	2.030	-1.530
1998/6/22	2.020	-1.520
1998/6/23	2.010	-1.510
1998/6/24	1.995	-1.495
1998/6/25	1.980	-1.480
1998/6/26	1.980	-1.480
1998/6/27	1.970	-1.470
1998/6/28	1.960	-1.460
1998/6/29	1.950	-1.450
1998/6/30	1.940	-1.440
1998/7/1	1.935	-1.435
1998/7/2	1.930	-1.430
1998/7/3	1.925	-1.425
1998/7/4	1.920	-1.420
1998/7/5	1.930	-1.430
1998/7/6	1.940	-1.440
1998/7/7	1.950	-1.450
1998/7/8	1.970	-1.470
1998/7/9	1.980	-1.480
1998/7/10	1.980	-1.480
1998/7/11	2.380	-1.880
1998/7/12	2.070	-1.570
1998/7/13	2.110	-1.610
1998/7/14	2.200	-1.700
1998/7/15	2.270	-1.770
1998/7/16	2.315	-1.815
1998/7/17	2.340	-1.840
1998/7/18	2.360	-1.860
1998/7/19	2.370	-1.870
1998/7/20	2.375	-1.875
1998/7/21	2.370	-1.870
1998/7/22	2.370	-1.870
1998/7/23	1.730	-1.230
1998/7/24	1.760	-1.260
1998/7/25	1.855	-1.355
1998/7/26	1.940	-1.440
1998/7/27	1.960	-1.460
1998/7/28	1.770	-1.270
1998/7/29	1.750	-1.250
1998/7/30	1.745	-1.245
1998/7/31	1.735	-1.235
1998/8/1	1.710	-1.210
1998/8/2	1.710	-1.210
1998/8/3	1.695	-1.195
1998/8/4	1.690	-1.190
1998/8/5	1.690	-1.190
1998/8/6	1.680	-1.180
1998/8/7	1.670	-1.170
1998/8/8	1.670	-1.170
1998/8/9	1.650	-1.150
1998/8/10	1.640	-1.140
1998/8/11	1.630	-1.130
1998/8/12	1.620	-1.120
1998/8/13	1.620	-1.120
1998/8/14	1.610	-1.110
1998/8/15	1.570	-1.070
1998/8/16	1.430	-0.930
1998/8/17	1.450	-0.950
1998/8/18	1.940	-1.440
1998/8/19	2.100	-1.600
1998/8/20	2.050	-1.550
1998/8/21	2.200	-1.700
1998/8/22	2.155	-1.655
1998/8/23	2.075	-1.575

Appendix C-7 Well Inventory Study

C-7.1 Well Inventory

Table -.-.6 Well Inventory 6 ADI KEYIH

<Well Ident>	<Location>	<Altitute> (m)	<Latitude> deg	min	sec	<Longi.> deg	min	sec	<Wateruse>	<Constr. year>	<Depth> (m)	<Diameter> (m)	<Water level(m)>	<Yield> (l/min)	EC (micro S/cm)	<pH>	<Pump system>	<Pump status>	<Remarks>	<Well ident. of WRD>
DW-1	Ruba Bur	2278	14	50	5	39	22	42	Out of use	1935	5.9	6 x 6	2.2		327	7.10	Out of use	Out of use		AK012W01
DW-2	Ruba Bur	2280	14	50	1	39	22	46	Public W/S Adi Keyih	1935	7.5	5.8 x 5	3.8	Not yet tested	485	7.06	Motor (8 *l/sec*)	Functional	8 hrs/day (4 hrs/day in dry season)	AK004W04
BH-3	Ruba Bur	2280	14	50	10	39	22	46	Public W/S Adi Keyih	1986	55.0	0.127	3.55	Not yet tested			Submersible	Not functional	Pump burnst	AK004B03
BH-4	Ruba Bur	2281	14	50	12	39	22	40	Public W/S Adi Keyih	1986	65.0	0.1524		Not yet tested			Motor (2 *l/sec*)	Functional		AK004B02
BH-5	Ruba Bur	2275	14	50	27	39	22	50	Capped	1991	52.0	0.1524	6.5	168			Capped	Capped		
BH-7	Adi Keyih	2358	14	50	52	39	22	12	Public W/S Adi Keyih	1989	70.0	0.1524		240	418	6.65	Submersible	Functional		
R-8	Adi Keyih	2373	14	50	58	39	22	27	Reservoir of public W/S, Adi Keyih						418	6.65				
BH-9	Adi Keyih hospital	2370	14	50	51	39	22	27	Domestic	1992	61.0	0.1524		24	853	6.28	Hand (KARDIA)	Functional		AK004B07
BH-10	Adi Keyih secondary school	2373	14	50	51	39	22	22	Domestic	1991	45.0	0.1524	24.0		557	6.18	Hand (KARDIA)	Functional		AK004B06
BH-11	Catholic church	2368	14	50	44	39	22	28	Domestic	1989		0.1524		34.2	1052	6.78	Hand (India Mark II)	Functional		AK004B08
BH-12	Catholic church	2367	14	50	45	39	22	32	Domestic	1989	70.0			30	1152	7.09	Hand (India Mark II)	Functional		AK004B09

Date surveyed : mainly 21 Oct., 1997

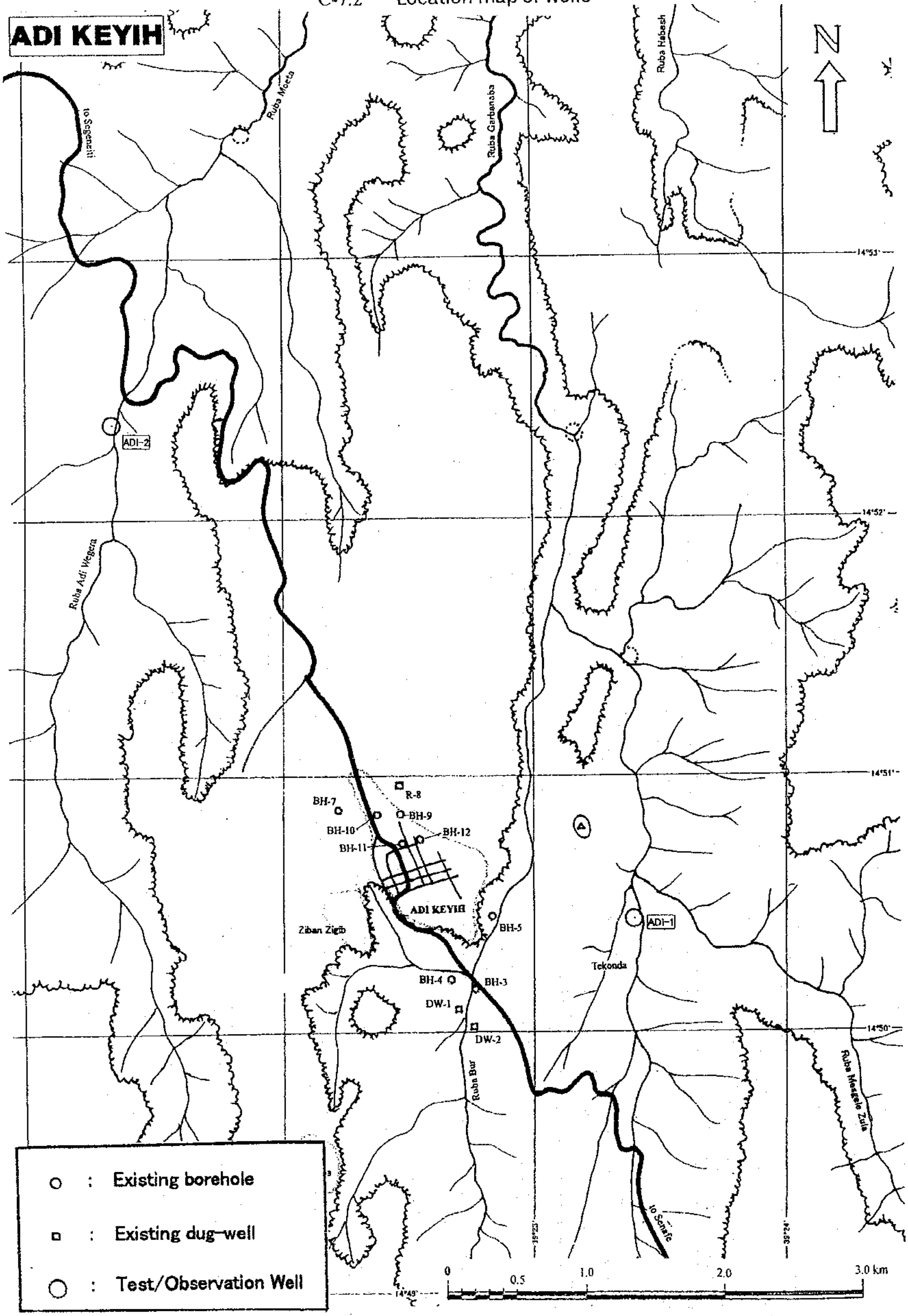
Well ident. : BH:Borehole, DW:Dug well, R:Reservoir

Bracket of construction year : year of repair

Bracket of Wpt. Diameter : inside diameter

Bracket of pump system : pump type and capacity

C-7.2 Location map of wells



1. SCOPE OF WORKS

1.1. OBJECTIVES OF WORKS

The objectives of works are to establish production well(s) for one of the water sources of _____ town. The detail of specifications will be mutually adjusted between the Engineer and the Contractor during the course of work.

1.2. CONTENTS OF WORKS

The content of works under this Contract consists of as below:

(1) Mobilization and Demobilization to/from the survey area, inclusive of moving from the Site to Site, and Site preparation.

(2) Production Well Drilling;
Drilling works, inclusive of a drilling, borehole logging, casing installation, gravel-packing, grout-sealing, development, head works, etc.

(3) Pumping Test, composed of Preliminary, Step-drawdown, Constant discharge, and Recovery tests, inclusive of water sampling and water quality analysis.

(4) Reporting, inclusive of daily drilling records, borehole and lithological logs, pumping test records, photographs, sketches, and so forth.

1.3. MEASUREMENT AND PAYMENT

The measurement and payment for the works carried out by the Contractor shall be made in accordance with the quantity actually worked out by the Contractor and confirmed by the Engineer's (Consultant's supervisor) measurement; and the unit or lump sum price specified in the Bill of Quantities, APPENDIX-__ of the Contract.

The unit or lump sum price specified in the Bill of Quantities shall be deemed to involve every costs necessary for the appropriate item of work inclusive of personnel, machinery amortization, consumable and permanently installed materials, overhead, profit, tax, duties and so forth. No extra payment shall be made for the lump sum price in case the quantities of works specified in the Bill of Quantities may be increased or decreased.

2. LOCATION OF WORKS

The works under this Contract are to be carried out in and around the six (6) towns as shown in the Figure-A "Location Map of the Drilling Works" attached.

The exact well drilling sites are to be indicated in-situ to the Contractor by the Engineer prior to the mobilization of drilling equipment.

3. EQUIPMENT, TOOLS, DEVICES AND MATERIALS TO BE EMPLOYED

3.1. GENERAL

The equipment, sampler, tools, measuring devices, and materials to be employed to the works under this Contract shall be provided by the Contractor, excepting water sampler for water quality analysis, and water quality meters for in-situ water quality test which are to be provided by the Study Team.

The Contractor shall submit, prior to the mobilization to the area, a list of equipment, samplers, and major tools, describing the model, type, capacity, specification, quantities to the Engineer for his approval.

3.2. SCREEN AND BLANC CASING

Blank casing pipes for the wells shall be made of PVC with inner-diameter of 6 inches. Screen pipes to be installed in the wells shall also be made of PVC with 6 inches diameter and of open ratio of more than ten percent (10%).

3.3. CENTRALIZER AND BOTTOM PLUG

Centralizer and bottom plug shall be of the same material and diameter of above mentioned pipes.

4. WORKS

4.1. MOBILIZATION AND DEMOBILIZATION

The Contractor shall mobilize and demobilize the personnel, equipment, tools, devices, and materials necessary for the works under this Contract to/from the work area under the Project from/to the Contractor's base within Eritrea.

The Contractor shall prepare the drilling sites to suite for the erection of equipment, working space, and others.

Further, the Contractor shall make moving the drilling equipment and others from a site to another site.

4.2. DRILLING OF WELLS

4.2.1. DRILLING

(1) Drilling Site

The exact site of well to be drilled is indicated in-situ to the Contractor by the Engineer prior to the mobilization to the area.

Upon the Engineer's indication, the Contractor shall mark out the point by means of wooden or stone stake with the Well Number.

(2) Type of Well

The standard type of well is shown as the Figure-__ "Standard Well Structure", and explained as follows:

The well shall consist of blank casing, slotted screen, and bottom plug of PVC pipes in 150 mm (6 inches) diameter.

The drilling diameters, the bit size, shall be good enough for the casing and gravel-packing, and be not less than 240 mm (9-5/8 inches) except surface casing portion which required to drill by 317 mm (12-1/2 inches) or more larger size bit.

The depth of the well shall be just covering the aquifer portion and as instructed by the Engineer.

(3) Quantities of Drilling Works

The work quantities in the initial plan are as shown in the Table-__ "Summary of the Works" and Table-__ "Drilling Site and Plan" attached. The depth of each well and the total quantities are to be modified on the course of works in accordance with the Engineer's instruction.

The unit and lump sum prices in the related items of the Bill of Quantities (APPENDIX-__ of the Contract) shall never be revised even if the said modification may take place.

(4) Drilling Works

The drilling of well shall be carried out by fluid-circulating direct rotary and/or the down-the-hole method or other method approved by the Engineer. The circulating fluid shall be as thin as possible except under an artesian condition.

The surface casing pipe at the top six (6) meter portion of all wells shall be installed to control sloughing and to ensure good condition to make the grout-sealing.

(5) Sampling

The drill-cut sampling about a half (0.5) kg in weight shall be collected at an interval of every one (1) meter and every change of formation encountered. The sample collected shall be put into a plastic bag together with a tag marked the Well Number and the depth collected.

The sample corrected shall be submitted to the Engineer for his inspection for casing program immediately after the completion of well drilling.

(6) Daily Drilling Record

The Contractor shall provide the daily drilling record in a form approved by the Engineer describing water level before and after the daily drilling work, drilling rate, characteristics of drill-cut, loss or increase of drilling fluid, and so forth. The record shall be submitted to the Engineer upon the completion of drilling of any well.

4.2.2. BOREHOLE LOGGING

Immediately after the completion of well drilling to the designated depth, the Contractor shall make borehole logging.

The logging items shall be of 1) resistivity (long and short) and 2) Spontaneous Potential (SP). The borehole log thus measured shall be submitted to the Engineer, immediately after completion of the logging, for his examination and formulation of the casing program.

4.2.3. INSTALLATION OF CASING AND SCREEN PIPES

On the basis of the results obtained from lithological and borehole logs, and so forth, the casing program shall be finally decided by the Engineer. In accordance with the Engineer's instruction on casing program, the Contractor shall install, in the center of the borehole, bottom plug, screen and blank casing pipes into the drilled hole. The centralizer shall be attached to the said pipes at every twelve (12) meters interval from the bottom or as instructed by the Engineer.

4.2.4. GRAVEL-PCKING AND GROUT-SEALING

(1) Gravel-packing

Immediately after the casing installation is over, gravel-packing shall be carried out into the annular space between the pipes installed and the hole.

The packing gravel shall be composed of siliceous materials and selected gradation, approved by the Engineer prior to the installation work.

The most care shall be paid dropping gravel at equal rate and shaking the pipes to avoid sticking and bridging of gravel at the annular apace and/or the centralizer.

Upon the Engineer's instruction, drill-cut or impervious materials may be packed at the blank casing portion.

(2) Grout-sealing

The Contractor shall seal by means of cement or mortar grouting the annular space between the hole and casing pipes at the upper-most six (6) meters portion of the borehole.

4.2.5. DEVELOPMENT

Immediately after the gravel-packing is over, the borehole shall be developed by means of jetting, surging by water or air, and water lifting by air or other appropriate manners. Borehole development shall be lasted when the lifted water is judged to be free from mud, sand, and other suspensions, and otherwise instructed by the Engineer, but for at least 24 hours.

4.2.6. PUMPING TEST

(1) Equipment and devices

The Contractor shall provide a proper pump and its attachment to be utilized for the pumping test. The type, name, capacity, and its specification shall be noticed to the Engineer for his approval prior to carry it to the site.

For measurement of discharge, the Contractor shall provide a calibrated wear, orifice or venture meter and/or accurate associated piezometer.

Water level in the well shall be measured by electric detective devices.

The pumped water shall be led and released at the position enough far from the teat well, not to disturb the test by re-infiltration, by proper conduit or through other suitable means.

(2) Preliminary Test

After setting of all equipment and devices, the pumping equipment shall be calibrated at various pumping rates in order to ensure that all the equipment are properly functioning and to select the pumping rate for the subsequent step-drawdown test, the drawdown and yield shall be presumed through the test.

The pumping rate shall be modified according to the drawdown at the pumping well, and the preliminary pumping shall be continued at least four (4) hours.

The static water level of both pumping and observatory well (if exist) shall be measured carefully before any pumping, and the tests described below shall be started after the water level recovered to the original water level.

(3) Step-drawdown Test

The borehole shall be pumped continuously at least three (3) increasing and two (2) decreasing discharge rates, maintaining each rate at a water level to be stable, but at least more than 180 minutes.

The pumping rate of each step shall be instructed by the Engineer based on the result of preliminary test.

For each pumping discharge, the water level at the borehole shall be measured and recorded in the manner shown below;

Period	*Interval of recording*
0 – 5 min.	30 sec.
5 – 15 min.	1 min.
15 – 30 min.	5 min.
30 – 90 min.	10 min.
after 360 min.	30 min.

(4) Constant Discharge Test and Recovery Test

Pumping shall be continued at least 48 hours without any interruption. The constant discharge rate shall be instructed by the Engineer.

Water level of the borehole shall be measured and recorded during full pumping and recovery period. The measurement of recovery can be stopped when the recovery attains to the static water level.

The water level shall be measured and recorded as following time interval;

Period	*Interval of recording*
0 – 5 min.	30 sec.
5 – 15 min.	1 min.
15 – 30 min.	5 min.
30 – 180 min.	15 min.
180 – 360 min.	30 min.
360 – 900 min.	60 min.
after 900 min.	120 min.

(5) Test Record

The Contractor shall submit the pumping test records, in a proper forms of hard-printed and floppy-disk-base approved by the Engineer, within three (3) days after the completion of any pumping test to the Engineer.

(6) In-situ Water Quality Analysis

The Contractor shall make a series of in-situ water quality test of water temperature, pH, EC, and so forth, and take water sample for laboratory water quality analysis, during the constant discharge test.

(7) Laboratory Water Quality Analysis

The Contractor shall send water samples to the laboratory of WRD, immediately after the sampling. The items to be analyzed are as follows, and the cost on the analysis shall be born by the Contractor.

Cations: Ca, Mg, Na, K, Fe

Anions: HCO_3; CO_3, SO_4, Cl, NO_3

Others: Mn, NO_2, PO_4, F, B, SiO_2, N-NH_3

Physical Properties: TDS, Hardness, Conductivity, pH

Bacteriologic properties: Total coliform bacteria, Faecal coliform bacteria

4.2.7. HEADWORK

Upon the completion of all the works specified above, the Contractor shall place the concrete pad and well-cap to the wells as the following manners;

(1) Concrete Pad

The dimension of concrete pad for the well shall be 1.00 m of wide, 1.00 m of long, both centered by the drilled well, and 0.50 m of deep, or otherwise instructed by the Engineer. The concrete mix of the Portland cement, fine and coarse aggregates, by volume ratio, shall be of 1:2:4 or as instructed by the Engineer.

(2) Well-cap

All the wells completed shall be covered by cap. The design, dimension, size and type of cap shall be approved by the Engineer prior to actual providing.

(3) Installation of Automatic water-level recorder

The Contractor shall install total ____ of automatic water-level recorders provided by WRD into ___ monitoring wells existing or drilled under this Contract. Details on hook, wire, method to set, etc., shall be proposed by the Contractor for Engineer's approval prior to the installation work.

4.2.8. SITE CLEARANCE

On the completion of all the works in the field, the Contractor shall remove all equipment and materials concerned, clean up the site as almost same as original states before the commencement of the works.

4.2.9. REPORTING

The Contractor shall provide the following reports and records, and on all occasions submit them to the Engineer;

(1) Daily Reports

- Daily drilling record
- Daily work record

(2) Results

- Drilling logs
- Lithological logs
- Borehole logs
- Pumping tests

(3) Color photograph (or sketch by the instruction)

- Typical work operation
- Site views
- Equipment, measuring devices and materials
- Other related to the execution of the works and indicated by the Engineer.

Appendix C-9 Standard Design of Production Well