Figure B-4 H-A Curve for Mereb3

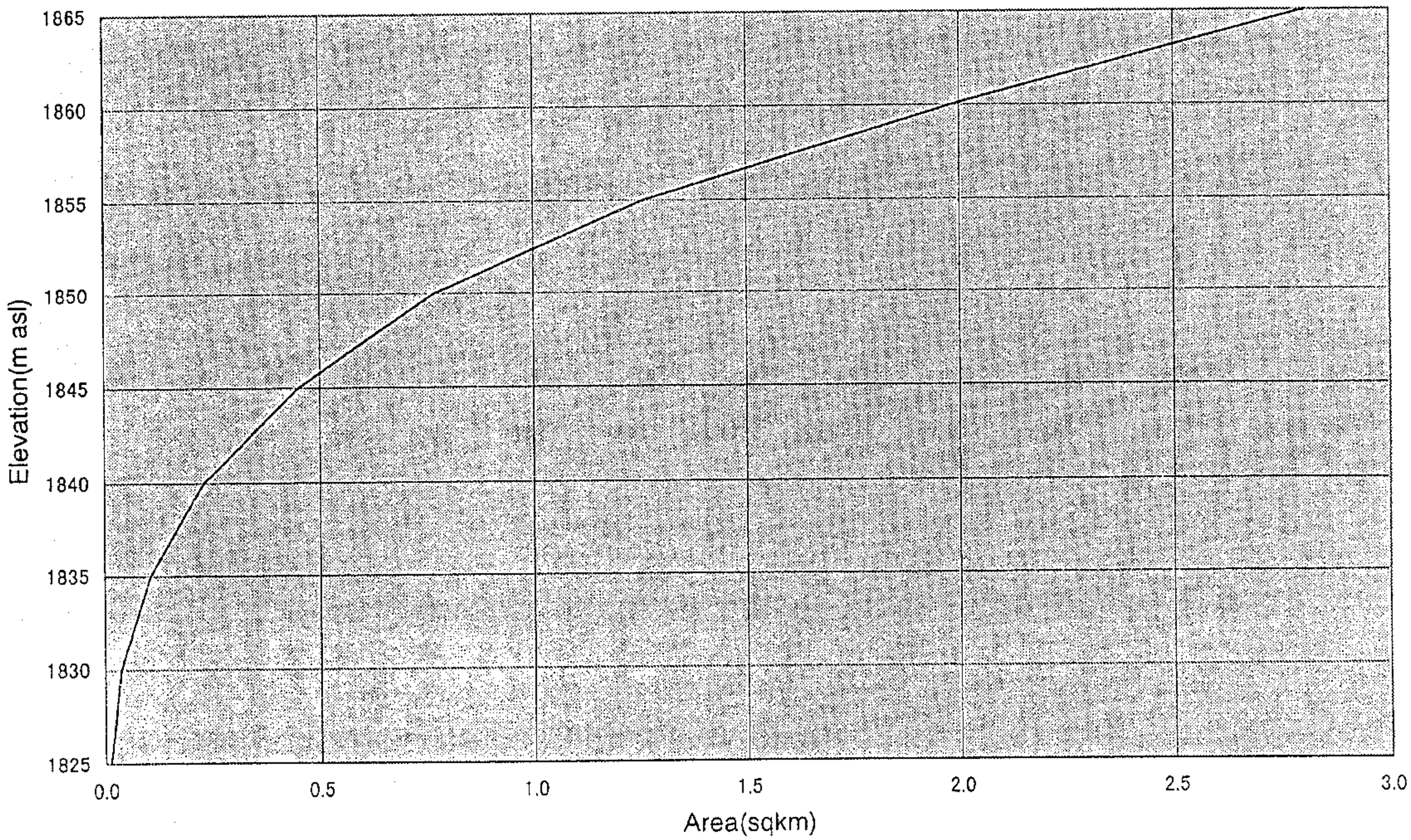


Figure B-5 H-V Curve for Mereb3

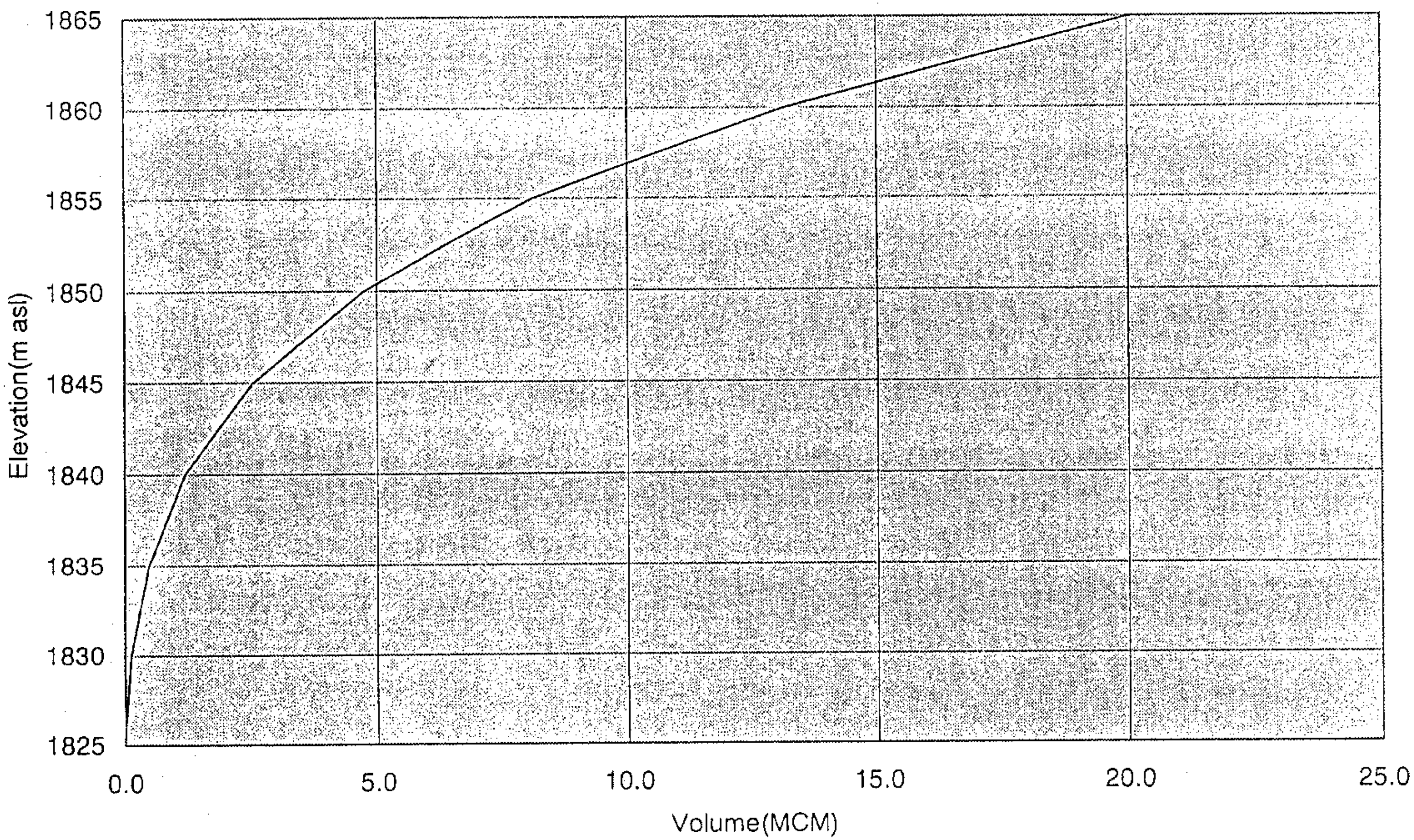


Figure B-6 H-A Curve for Mereb5

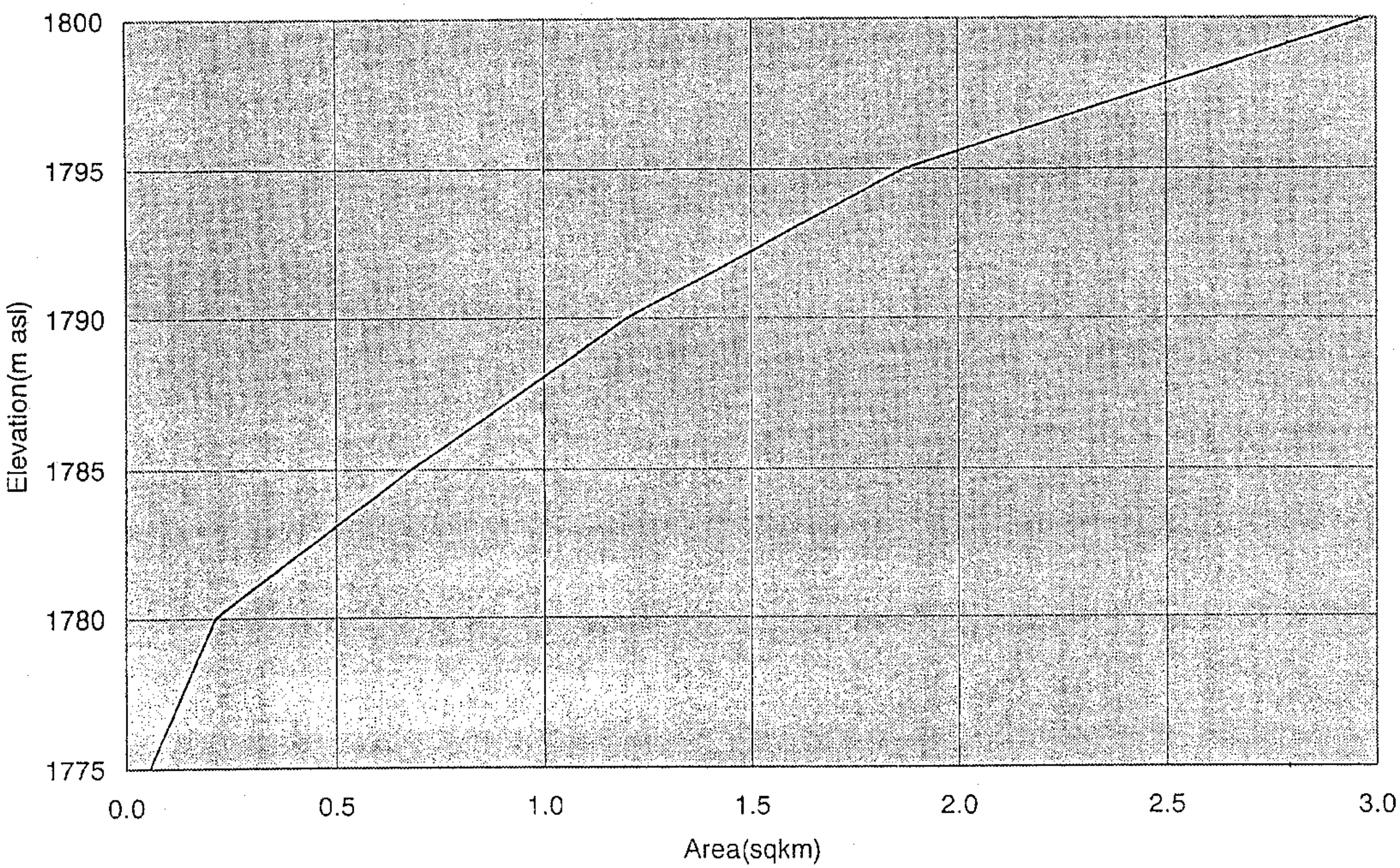


Table B-4 Calculation of Dam Parameters

(1) Reservoir Parametrs

In this connection, land-mark survey during the phase-l field investigation was carried out and topographical map with 5m contour was prepared. Using this map, H-V and H-A curves for both dams were constructed. The reservoir parameters are tabulated below.

Mereb 3			Mereb 5		
EL (m asl)	Area (sqkm)	Volume (MCM)	EL (m asl)	Area (sqkm)	Volume (MCM)
1825	0.013	0.000	1775	0.056	0.000
1830	0.037	0.125	1780	0.212	0.670
1835	0.106	0.483	1785	0.680	2.900
1840	0.230	1.198	1790	1.200	7.600
1845	0.451	2.543	1795	1.870	15.275
1850	0.768	4.750	1800	2.980	27.400
1855	1.258	8.113			
1860	1.980	13.160			
1865	2.804	20.055			

(2) Dam Height

Dam height will be selected using the following equation.

$$\text{Dam height} = HWL + H_d + F_b$$

where, HWL is high water level (m)

H_d is water depth in the spill-way (m)

F_b is free board (m)

(3) Spill-way

In deciding Spill-way size, maximum specific yield is calculated using Creager equation as follows.

$$q = CA^{(A^{-0.05}-1)}$$

where, q is maximum specific yield(m^3/sec/km^2)

A is catchment area(km^2)

C is a coefficient depending on regional characteristics

Considering C = 15, q may be calculated as 2.8755 m^3/sec/km^2

Now, Design flood discharge (Q) may be computed as

$$Q = q * A = 2.8755*492 = 1,415 = 1,450 \text{ m}^3\text{/sec(rounded)}$$

Cont.

Next, calculation for various flow depths in Spill-way (H_d) with corresponding widths is performed using the following equation.

$$Q = CLH_d^{3/2}$$

where, H_d is flow depth in the Spill-way (m)

Q is design flood discharge (m^3/sec)

C is coefficient (2.1)

L is width of Spill-way (m)

Calculated depths with corresponding widths are as follows.

Flow depth(m)	Width(m)
1.0	690
2.0	245
2.5	175
3.0	133
3.5	106
4.0	87
5.0	62

From the amount of design flood discharge, flow depth(Hd) is selected as 3.5m with corresponding length(L) as 106m. It is noteworthy to mention that, from the topographical conditions, the location of the Spill-way should be on the right bank and a overflow type(without gate) structure is recommended.

(4) Sediment and Effective Capacity

Assuming river bed width as 8m, flow depth as 2m and velocity as 2m/sec, inflow rate may be calculated as 32m3/sec. Using Bed Material Load Graph prepared by the Sector Study, calculation of sediment may be done as follows.

$$q_s = 1606.4*Q^{0.5618}$$

$$= 11300 mg/l = 11.3 kg/m^3$$

Now, total volume may be found by multiplying inflow volume i.e. 25.0MCM and gives 282,500 tons/year. Dividing this value by density(1.8ton/m^3) gives 156,944 m^3/year, say 157,000 m^3/year.

Considering dam life as 50 years, effective capacity may be calculated as follows.

Total amount of Sediment = 157,000*50 = 78,850,000m^3 = 8.0MCM(rounded)

Therefore, effective capacity = 25.0MCM − 8.0MCM = 17.0MCM. However, actual available amount for use has to be calculated subtracting the losses such as evaporation, percolation etc.

Cont.

(5) Low Water Level(LWL) and Flood Water Level(FWL)

From the H-V curve, for 8MCM of sediment, the elevation will be 1790.33m asl, which is the Low Water Level(LWL)

The Flood Water Level(FWL) may be computed as follows.

$$FWL = HWL + H_d = 1799m\ asl + 3.5\ m = 1802.50m\ asl$$

(6) Crest Elevation and Width

The dam crest elevation may be calculated as follows.

$$HWL + H_d + F_b = 1799m\ asl + 3.5m + 1.5m = 1804m\ asl$$

From the above dimensions, the total dam height would be

Crest level elevation − El at the foundation excavation i.e 1804m asl − 1770m asl = 34.0m

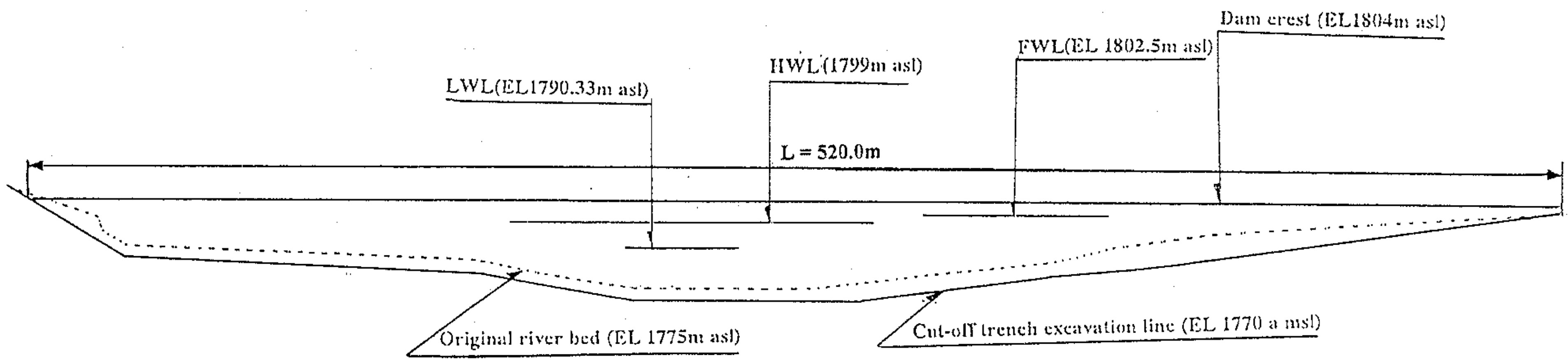
The Crest width is determined according to the formula recommended by International Association for Large Dams, which is as follows.

$$\text{Crest width(B)} = 3.6H^{1/3} - 3.0 = 3.6*34.0^{1/3} - 3.0 = 8.66m = 9.0m\text{(rounded)}$$

(7) Salient Features

i)	Name	: Mereb 5
ii)	Dam Type	: Rock-fill
iii)	Purpose	: Multi-purpose
iv)	Catchment Area	: 492.0 sqkm
v)	Reservoir Capacity	: 25.0 MCM
vi)	Surface Area	: 2.8 km^2
vii)	Effective Storage	: 17.0 MCM
viii)	Dead Storage	: 8.0 MCM
ix)	Low Water Level(LWL)	: 1790.33m asl
x)	High Water Level(HWL)	: 1799.0m asl
xi)	Flood Water Level(FWL)	: 1802.5m asl
xii)	Free Board	: 1.50m
xiii)	Dam Crest Level	: 1804.0m asl
xiv)	Crest Width	: 9.0m
xv)	Crest Length	: 520.0m
xvi)	Basement Width	: 135.0m
xvii)	Spill-way Length	: 106.0m
xviii)	Embankment Volume	: 665,000m^3
xix)	Approximate Cost	: Embankment Vol./Unit cost = 21.0million (32.0 US$ per cubic meter)

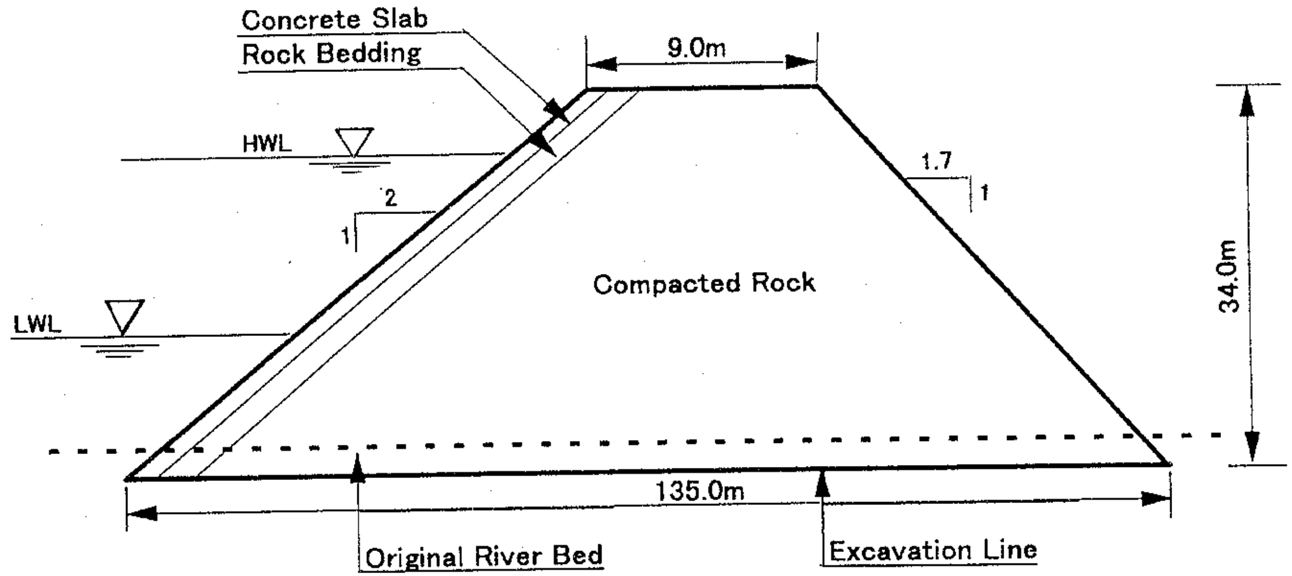
Figure B-7 Longitudinal Section Along Mereb5 Dam Axis



Longitudinal Section Along Dam Axis

Scale: 1 : 2000

Figure B-8 Cross-section of Mereb5 Dam



APPENDIX C

HYDROGEOLOGY

CHAPTER 3 THE DEBUB REGION

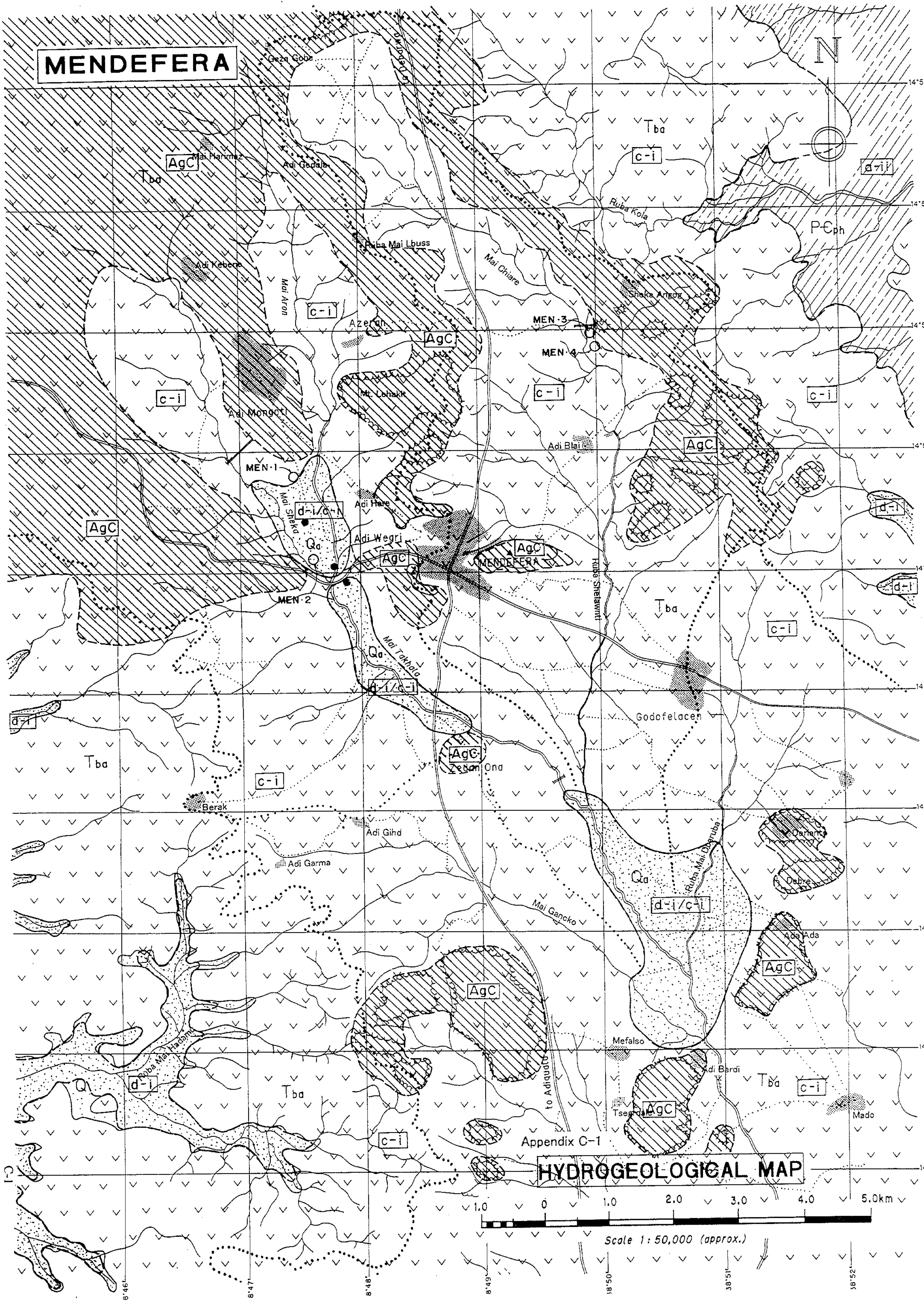
3.1 Natural Conditions

CHAPTER 4 CURRENT SITUATION (Mendefera)

4.1 Natural Conditions

CHAPTER 7 PROJECT FEASIBILITY STUDY

7.1 Groundwater Development Plan


MENDEFERA
HYDROGEOLOGICAL MAP
Appendix C-1
Scale 1: 50,000 (approx.)
1.0
0
1.0
2.0
3.0
4.0
5.0km
N
14°57'
14°56'
14°55'
14°54'
14°53'
14°52'
14°51'
14°50'
14°49'
14°48'
8°46'
8°47'
8°48'
8°49'
38°50'
38°51'
38°52'
Tba
AgC
c-i
d-i
d-i/c-i
Qa
P-Єph
MEN-1
MEN-2
MEN-3
MEN-4
Geza Gobe
Mai Harimaz
Adi Gadala
Adi Kebere
Ruba Mai Lbuss
Mai Aron
Azeran
Adi Mongoti
Mt. Lohakit
Adi Hare
Mai Sheka
Adi Wegri
MENDEFERA
Ruba Kola
Mai Chiare
Shaka Angog
Adi Blai
Ruba Shelawnti
Godofelacen
Mai Takhala
Zedan Ona
Berak
Adi Gihd
Adi Garma
Ruba Mai Dbaruba
Darfant
Debre
Mai Gancko
Ada Ada
Mefalso
Adi Bardi
Tseada
Mado
Ruba Mai Hadam
to Adiquala
to Debarwa

C-2 Legend on HYDROGEOLOGICAL MASP

Geological Legend

Qa/Qc	: Alluvial deposits	Quaternary
L	: Laterite covers	Quaternary
Tb	: Basaltic volcanics	Tertiary
Tt	: Trachytic volcanics	Tertiary
Ms	: Adigrat Sandstone	Mesozoic
Ps	: Sandstone	Paleozoic
Ch	: Chart	Paleozoic
Gt	: Granite	Precambrian
Gt	: Granite (marginal phase)	Precambrian
PCs	: Schist, Gneiss	Precambrian
PCp	: Phyllite, Slate	Precambrian
PCv	: Metavolcanic	Precambrian
PCd	: Dolomite	Precambrian
Ai	: Alkaline Intrusives	Tertiary
Hf	: 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.

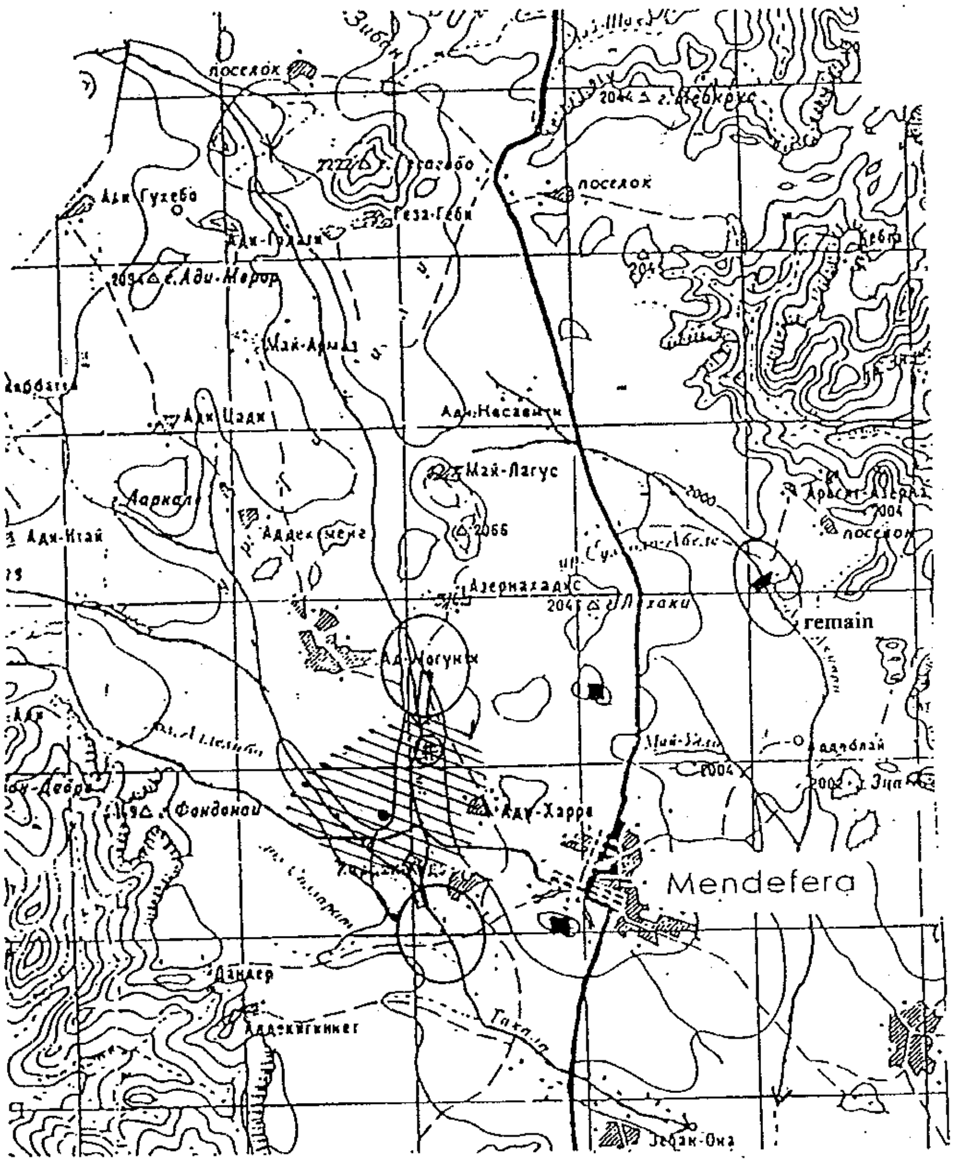
Table C-3.2 Geophysical Prospecting Works (The final)

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

MENDEFARA



No scale

 : original survey area

 : modifies survey area

C-3.3. Summarized Results of Geophysical Prospecting Works

The survey site is very flat plain covered by thin alluvial deposits, and the both sides (west and east) are bounded by gentle hills. These hills are consisted of rather fresh and hard basalt showing more than 1,000 ohm-m, however, the alluvial plain is underlain by weathered or fissured basalt showing several 10s to 150 ohm-m. The depth of weathered rock zone varies irregularly, from only 2,3m to nearly 80m. As a tendency, it is deep along the current streams route, but in between them there is a mound of fresh rock. Near the village of Adi Mongoti, it means the northern end of the survey area, bedrock is exposed out again. Further, the report of Department of Mines pointed out a fault passing through the upstream side of the Power Station.

Those situation suggest the major part of survey area forms an individual groundwater basin in between the two streams, separated from the wide Mai Takhala basin, further downstream of the survey area, by low hills and the fault. And two of the drilling points were proposed inside of the groundwater basin, just avoiding the fresh rock mound in the center of basin.

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 Downstream of Kilowlie Dam	2 x 80m	2 x 30m	1 2
Dekemhare	East of old run-way	2 x 80m		2
Segeneiti	Valley at 3.5km SE Near the Municipality Valley at 4.5km W	1 x 60m 1 x 60m 1 x 60m		1
Adi Keyih	Upstream of eastern valley Valley at 4.0km NW	1 x 60m 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

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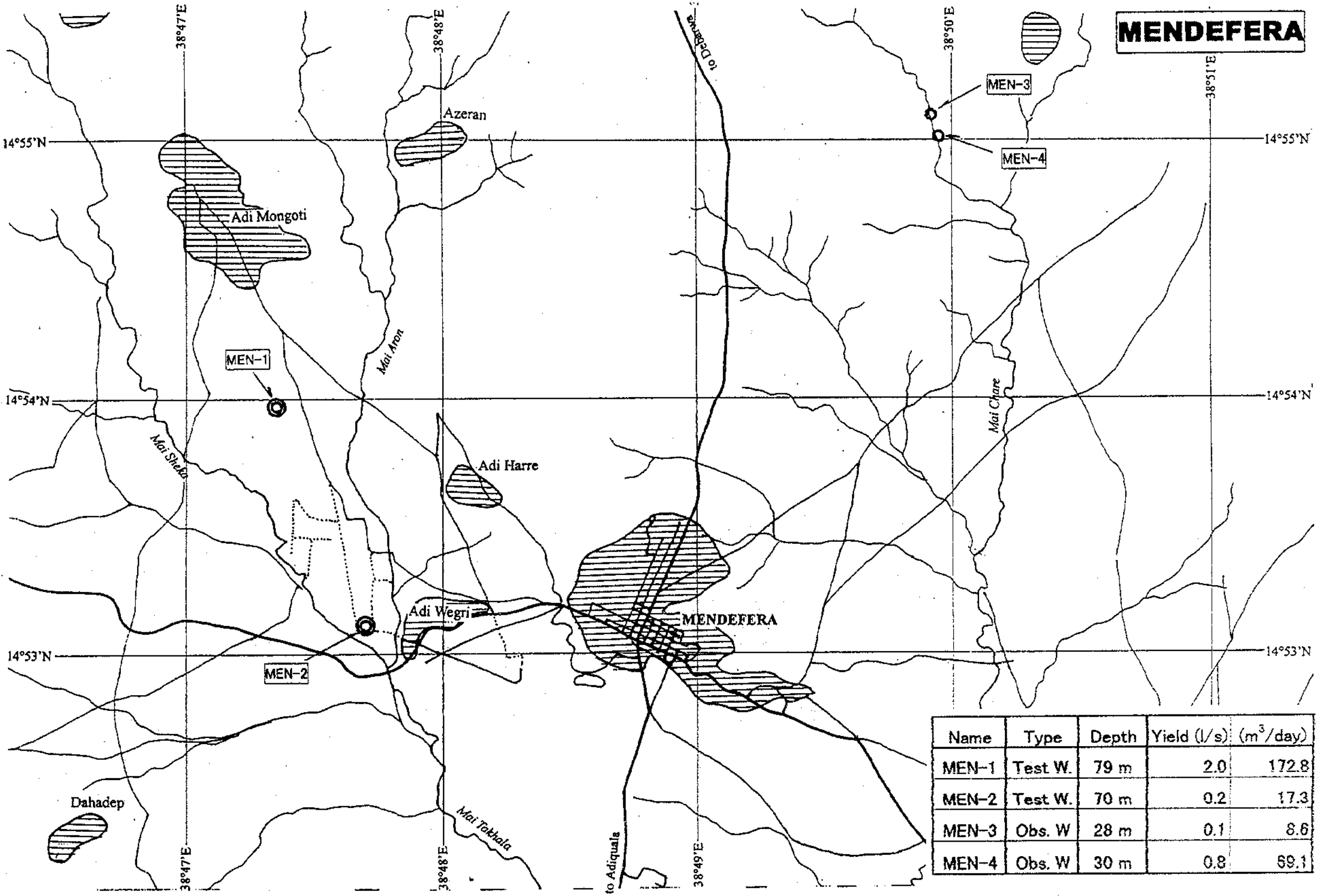


Name	Type	Depth	Yield (l/s)	(m^3/day)
MEN-1	Test W.	79 m	2.0	172.8
MEN-2	Test W.	70 m	0.2	17.3
MEN-3	Obs. W	28 m	0.1	8.6
MEN-4	Obs. W	30 m	0.8	69.1

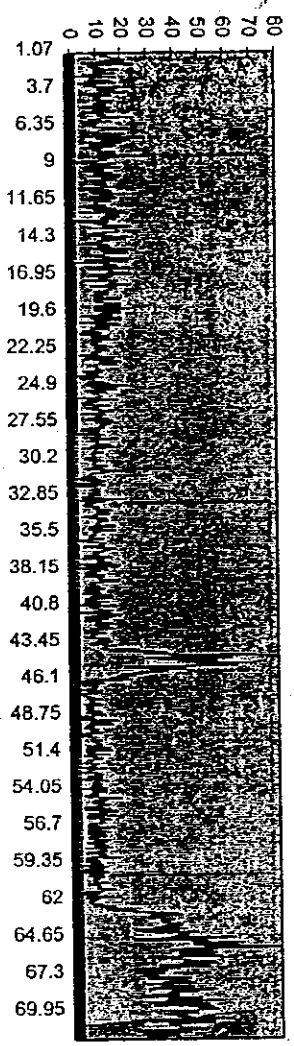
C-4.3 Lithological Logs

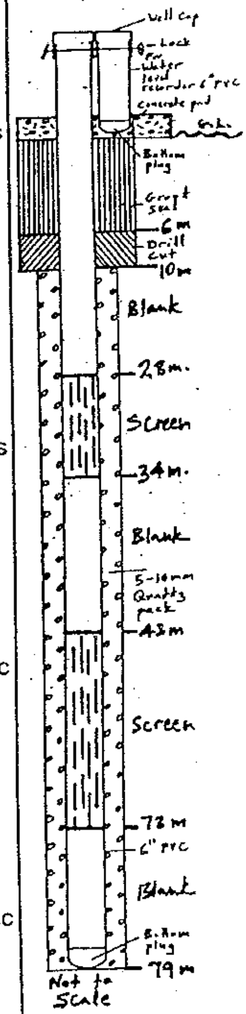
MEN-1

GEDECC BOREHOLE DRILLING DATA:

Project:JICA	Village/Town:Mendefera	File No.:D - 025
Drilling started:December 23, 1997	Zone:South	BH No.: MEN-1
Rig type:Schramm	Casing:Temporary 12" PVC	Latitude:38° 47"25' E
Depth drilled: 79 meters	From 0 T0 12 m.	Longtude:14° 53" 50' N
Drilling completed:December 30, 1997	Casing: Permanent 6" PVC	Elevation:
Filter slots: 2.00 mm.	From 0 to 79 m.	SWL:13.5 meters
Gravel type, size: Quartz, 10 mm.	Volume:2.5 cubic meters	Drill bit size:0-12m. 15" & 12-79m. 10" bit

Geology: Depth (m)	Section:	Description:	Geophysical borehole logging: N.Gamma (M/Min) SP (mv)	Drilling speed: (m/hr)	Water struck: (L/sec)	Casing and Screen:
0		Slightly weathered basalt, with soil in it. Course gravel to cobble size. Brown to black		.6m/hr	1/2 L/s	
		Fresh, subangular, gravel size basaltic fragments, dark to bluish color				
-10				1.2m/hr		
-20				3m/hr	2.5 L/s	
-30		Slightly to moderately weathered basalt, porous with zeolitic fill. Dark to bluish color				
		Powder like basalt, fine to medium grained, dark to blue color			2L/sec	
-40		weathered basalt, powder like				
-50		Intensely weathered basalt, brown colored		2.8m/hr		
		Weathered basalt, powder like, dark to bluish color			8L/sec	
-60				1.5m/hr		
		Intensely weathered basalt, powder like, dark to blue				
-70		Slightly weatherd basalt,				
		Fresh, massive, basalt.				





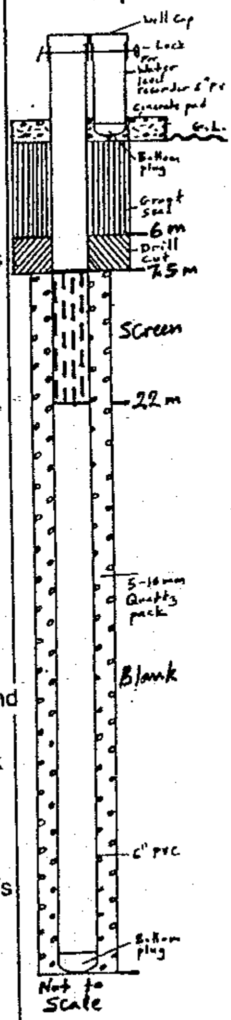
Prepared by:Amanuel G. Woldu Date:Dec. 31, 1997

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:

oject:JICA	Village/Town:Mendefera	File No.:D - 025
illing started:December 5, 1997	Zone:South	BH No.: MEN-2
g type:Schramm	Casing:Temporary 12" PVC	Latitude:38° 47"37' E
epth drilled: 70 meters	From 0 T0 7.5 m.	Longtude:14° 53" 80' N
illing completed:December 10, 1997	Casing: Permanent 6" PVC	Elevation:
lter slots: 2.00 mm.	From 0 to 70 m.	SWL:13.5 meters
avel type, size: Quartz, 10 mm.	Volume:3 cubic meters	Drill bit size:0-7.5m. 15" & 7.5-70m. 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:
		Surface material, clayey, fine grained, sticky, dark colored		.8m/hr	First water struck at 16m	
		Sandy gravel, alluvial origin				
10		Fresh basalt, massive, fine gra.		2.5m/hr	0.1 L/s	
		Weathered basalt				
20		Moderatly weathered basalt		3m/hr		
30		Fresh basalt, massive, fine grained, dark to blue color				
		Strongly weathered tuff like, sticky character like clay, brown color.		3.4m/hr		
40		Angular, course gravel size, weathered basalt			Second water struck at 62 m	
		Moderatly weatherd basalt				
50		Fine grained, powder like, very hard basalt, dark to blue color			0.1 L/s	
60				2.6m/hr		
70						



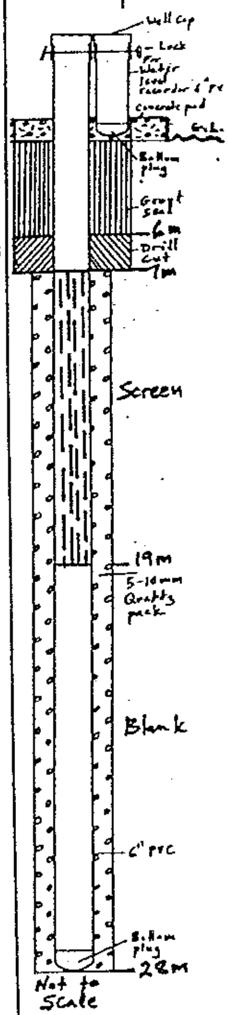
Prepared by:Amanuel G. Woldu | Date:Dec. 11, 1997

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:Mendefera	File No.:D - 025
Drilling started:December 14, 1997	Zone:South	BH No.: MEN-3
Rig type:Schramm	Casing:Temporary 12" PVC	Latitude:38° 50"00' E
Depth drilled: 28 meters	From 0 T0 9 m.	Longtude:14° 54" 58' N
Drilling completed:December 16, 1997	Casing: Permanent 6" PVC	Elevation:
Filter slots: 2.00 mm.	From 0 to 28 m.	SWL:2.4 meters
Gravel type, size: Quartz, 10 mm.	Volume:2 cubic meters	Drill bit size:0-9m. 15" & 9-28m. 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		Top soil, sticky character, clay to silt, volcanic ash origin		1.9m/hr		
		Fresh basalt, massive, course gravel size, dark to bluish color				
-10					0.5 L/s	
		Weathered basalt, course gravel		1.9m/hr		
		Angular, course basalt				
-20		Rounded, course basalt				
		Angular, course basalt				
-30						
-40						
-50						
-60						
-70						



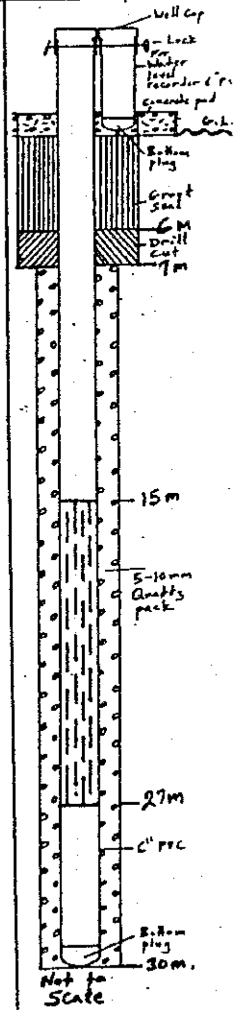
Prepared by:Amanuel G. Woldu　Date:Dec. 17, 1997

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:Mendefera	File No.:D - 025
Drilling started:December 20, 1997	Zone:South	BH No.: MEN-4
Rig type:Schramm	Casing:Temporary 12" PVC	Latitude:38° 50"30' E
Depth drilled: 30 meters	From 0 T0 12 m.	Longtude:14° 54" 51' N
Drilling completed:December 21, 1997	Casing: Permanent 6" PVC	Elevation:
Filter slots: 2.00 mm.	From 0 to 30 m.	SWL:1.8 meters
Gravel type, size: Quartz, 10 mm.	Volume:2 cubic meters	Drill bit size:0-12m. 15" & 12-30m. 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		Sticky top soil, clayey nature volcanic ash origin, dark-brown			1L/sec	
		Basaltic fragments and silt, alluvial origin, red to brown		3.6m/hr		
-10		Weathered basaltic fragments, course gravel size, red colored				
				3.6m/hr		
-20		Moderately weathered, rounded basaltic fragments, gravelly size				
		Rounded to angular matrix of fresh basalt, course gravel size dark to bluish color		2.6m/hr		
-30						
-40						
-50						
-60						
-70						



Prepared by:Amanuel G. Woldu Date:Dec. 22, 1997

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.

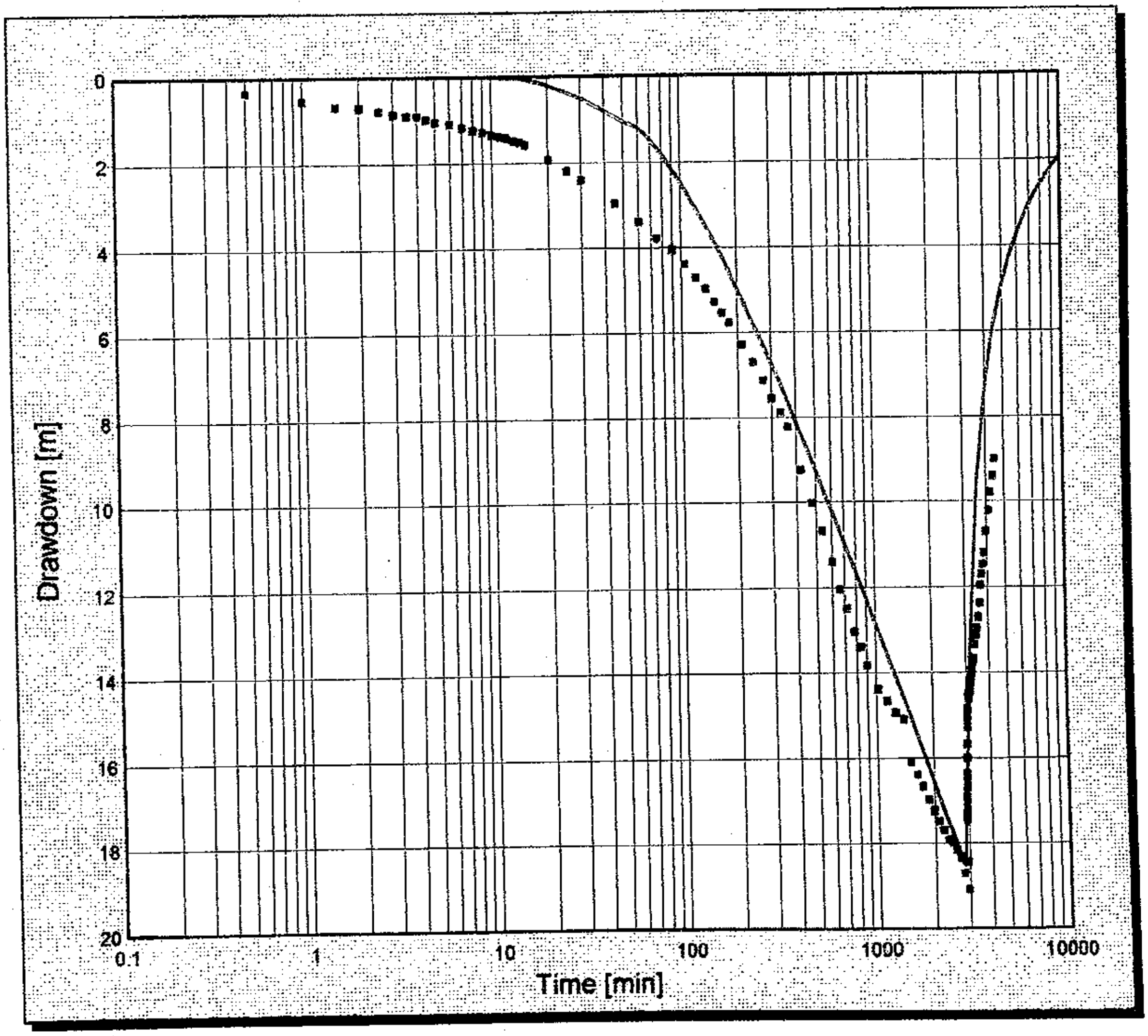
C-4.4 Result of Pumping Test

Pumping Test

Well Ident	Description		
Men-1			
Obs. Well Distance [m]	Average Pump. Rate [m3/day]	Duration [min]	Initial Sat. Thickness [m]
0.08	175.3900	4440.000	

Results

Transmissivity [m2/day]	Storage Coefficient	Leakance [1/day]	Estimation Error [m]
2.537744			1.61
Fit Method			Theis Method



Appendix C-5 Water Quality

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 = kEÇ, 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 CaCO3, causes scale deposition in pipelines and scum formation in boilers. Soft Waters, less than 75 mg/l as CaCO3 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-2 Water Quality In Mendefera

I.Physical Quality

Date Sampled 30/09/97

Date Analysed 01/10/97

Well	Description	EC	pH	Temp	Odor	Taste	Turb.	Color
Ident		us/cm		°c			TU	
MN-01	Dam, Kilowlie	152	7.5	23.0	agreeable	disagree	150	muddy
MN-02	HDW, Kilowlie, not concrete	577	6.9	27.9	agreeable	agreeable	<5	clear
MN-03	Underground reservoir, Kilowlie	403	7.2	23.0	agreeable	agreeable	<5	clear
MN-04	Main Reservoir, 500 cum	377	7.2	28.1	agreeable	agreeable	<5	clear
MN-05	Public tap	560	7.2	22.5	agreeable	agreeable	<5	clear
MN-06	BH, Sub.Pump, Adimongoti	1091	7.1	25.6	agreeable	agreeable	<5	clear
MN-07	Underground Reservoir at Konel	977	7.2	25.5	agreeable	agreeable	<5	clear
MN-08	Reservoir at Forto	1044	7.1	23.0	agreeable	agreeable	<5	clear
MN-09	Consumer's Tap	458	7.3	26.7	agreeable	agreeable	<5	clear
MN-10	HDW, Private, Alimuth	622	7.0	24.2	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	
4	0	Safe
0	28	contaminated
8	0	Safe
2	26	contaminated
2	20	contaminated
0	0	Safe
5	0	Safe
2	0	Safe
0	many	contaminated
5	0	Safe

III.Chemical Quality

Date Sampled 01/10/97

Date Analysed 14/10/97

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
MN-01	Dam, Kilowlie	17	1	9	3.0	0.41	0.0	73	0	6	0.0	0.77	0.04	0.01	2.7
MN-02	HDW, Kilowlie, not concrete	72	5	39	2.2	0.01	0.0	305	0	14	30.1	0.45	0.05	0.27	11.2
MN-03	Underground reservoir, Kilowlie	46	10	21	2.2	0.09	0.0	200	0	12	6.2	0.35	0.02	0.00	8.7
MN-04	Main Reservoir, 500 cum	43	11	22	1.8	0.02	0.1	212	1	12	1.4	0.05	0.02	0.25	8.6
MN-05	Public tap	58	17	28	2.2	0.03	0.1	256	1	40	6.2	0.10	0.01	0.26	12.0
MN-06	BH, Sub.Pump, Adimongoti	105	21	78	10.1	0.01	0.0	464	80	26	11.5	0.51	0.03	0.10	19.6
MN-07	Underground Reservoir at Konel	90	14	55	5.7	0.21	0.0	393	53	30	42.5	0.43	0.01	0.21	13.0
MN-08	Reservoir at Forto	95	33	64	2.2	0.01	0.0	405	80	40	20.8	0.54	0.01	0.22	20.9
MN-09	Consumer's Tap	104	21	68	2.6	0.01	0.0	437	95	56	18.2	0.71	0.07	0.24	19.3
MN-10	HDW, Private, Alimuth	65	12	40	1.8	0.00	0.1	290	15	20	19.5	0.16	0.04	0.27	11.8

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

* Note: HDW = Hand dug well

BH = Borehole

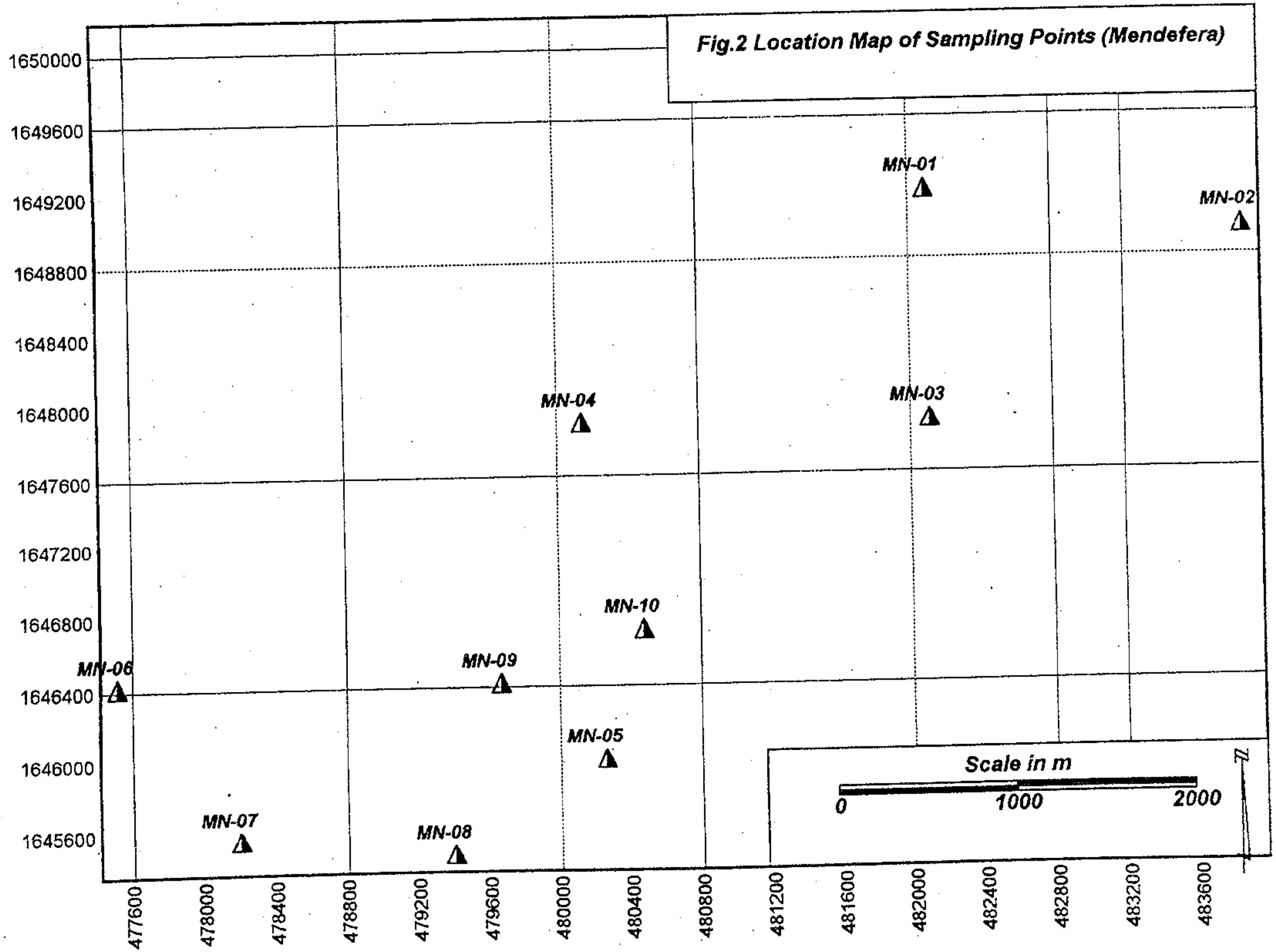


Fig.2 Location Map of Sampling Points (Mendefera)

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

II. Bacteriological Quality

T.C.B = Total Coliform Bacteria

F.C.B = Faecal Coliform Bacteria

Well Idnt	Sub-Zoba	EC	pH	Temp	Odor	Taste	Turb	Color	T.C.B	F.C.B	Remarks
		us/cm		°c			NTU		count/100ml,35°c	count/100ml,44.5°c	
MEN-01	Mendefera	468	8.66	22.1	agreeable	agreeable	0	clear	0	0	safe
DUB-01	Dubarwa	762	7.46	22.2	agreeable	agreeable	0	clear	0	0	safe
SEG-01	Segeneyti	832	6.95	24.0	agreeable	agreeable	0	clear	0	0	safe
SEG-03	Segeneyti	791	6.74	22.5	agreeable	agreeable	0	clear	0	0	safe
ADK-01	Adi-Keyih	1051	6.85	21.4	agreeable	agreeable	5	muddy	0	0	safe
ADK-02	Adi-Keyih	948	6.77	20.7	agreeable	agreeable	0	clear	0	0	safe
SEN-01	Senafe	734	6.68	21.5	agreeable	agreeable	0	clear	many	30	contaminated
DEK-01	Dekemhare	1247	7.10	22.7	agreeable	agreeable	0	clear	0	0	safe
DEK-02	Dekemhare	1184	6.91	22.6	agreeable	agreeable	0	clear	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

Appendix C-6 Groundwater Monitoring Data

Groundwater monitoring data

MENDEFERA(NO.2) at 6:00 a.m.

Date	Reading	from G.L
(16:08)3/7	8m48.8	-8.488
1998/3/8	8m48.8	-8.488
1998/3/9	8m49.1	-8.491
1998/3/10	8m49.3	-8.493
1998/3/11	8m49.9	-8.499
1998/3/12	8m50.0	-8.500
1998/3/13	8m49.9	-8.499
1998/3/14	8m49.8	-8.498
1998/3/15	8m49.5	-8.495
1998/3/16	8m49.0	-8.490
1998/3/17	8m48.6	-8.486
1998/3/18	8m47.9	-8.479
1998/3/19	8m47.6	-8.476
1998/3/20	8m47.2	-8.472
1998/3/21	8m46.8	-8.468
1998/3/22	8m46.1	-8.461
1998/3/23	8m45.8	-8.458
1998/3/24	8m45.4	-8.454
1998/3/25	8m45.1	-8.451
1998/3/26	8m44.9	-8.449
1998/3/27	8m44.4	-8.444
1998/3/28	8m44.0	-8.440
1998/3/29	8m43.8	-8.438
1998/3/30	8m42.9	-8.429
1998/3/31	8m42.5	-8.425
1998/4/1	8m42.0	-8.420
1998/4/2	8m42.0	-8.420
1998/4/3	8m42.0	-8.420
1998/4/4	8m42.0	-8.420
1998/4/5	8m42.0	-8.420
1998/4/6	8m39.8	-8.398
1998/4/7	8m39.6	-8.396
1998/4/8	8m39.2	-8.392
1998/4/9	8m38.9	-8.389
1998/4/10	8m38.8	-8.388
1998/4/11	8m38.0	-8.380
1998/4/12	8m37.9	-8.379
1998/4/13	8m37.3	-8.373
1998/4/14	8m37.0	-8.370
1998/4/15	8m36.8	-8.368
1998/4/16	8m36.0	-8.360
1998/4/17	8m35.7	-8.357
1998/4/18	8m35.4	-8.354
1998/4/19	8m35.5	-8.355
1998/4/20	8m34.7	-8.347
1998/4/21	8m34.2	-8.342
1998/4/22	8m33.7	-8.337
1998/4/23	8m33.3	-8.333
1998/4/24	8m33.0	-8.330
1998/4/25	8m32.8	-8.328
1998/4/26	8m32.2	-8.322
1998/4/27	8m31.9	-8.319
1998/4/28	8m31.3	-8.313
1998/4/29	8m31.0	-8.310
1998/4/30	8m30.6	-8.306
1998/5/1	8m30.3	-8.303
1998/5/2	8m30.0	-8.300
1998/5/3	8m29.9	-8.299
1998/5/4	8m29.2	-8.292
1998/5/5	8m29.0	-8.290
1998/5/6	8m28.6	-8.286
1998/5/7	8m28.2	-8.282
1998/5/8	8m28.1	-8.281
1998/5/9	8m27.9	-8.279
1998/5/10	8m26.9	-8.269
1998/5/11	8m26.8	-8.268

MENDEFER(NO.3) at 6:00 a.m.

Date	Reading	from G.L
(10:23)3/7	2m65.0	-2.650
1998/3/8	2m63.2	-2.632
1998/3/9	2m62.0	-2.620
1998/3/10	2m62.2	-2.622
1998/3/11	2m62.7	-2.627
1998/3/12	2m62.1	-2.261
1998/3/13	2m61.5	-2.615
1998/3/14	2m61.2	-2.612
1998/3/15	2m60.0	-2.600
1998/3/16	2m62.2	-2.622
1998/3/17	2m63.2	-2.632
1998/3/18	2m62.1	-2.621
1998/3/19	2m61.0	-2.610
1998/3/20	2m60.0	-2.600
1998/3/21	2m60.4	-2.604
1998/3/22	2m60.0	-2.600
1998/3/23	2m58.6	-2.586
1998/3/24	2m59.2	-2.592
1998/3/25	2m60.1	-2.601
1998/3/26	2m60.4	-2.604
1998/3/27	2m59.2	-2.592
1998/3/28	2m62.2	-2.622
1998/3/29	2m64.5	-2.645
1998/3/30	2m65.3	-2.653
1998/3/31	2m67.9	-2.679
1998/4/1	2m69.2	-2.692
1998/4/2	2m70.7	-2.707
1998/4/3	2m71.2	-2.712
1998/4/4	2m71.8	-2.718
1998/4/5	2m71.0	-2.710
1998/4/6	2m69.6	-2.696
1998/4/7	2m70.7	-2.707
1998/4/8	2m71.3	-2.713
1998/4/9	2m71.6	-2.716
1998/4/10	2m71.6	-2.716
1998/4/11	2m71.2	-2.712
1998/4/12	2m71.0	-2.710
1998/4/13	2m69.8	-2.698
1998/4/14	2m70.5	-2.705
1998/4/15	2m71.1	-2.711
1998/4/16	2m71.1	-2.711
1998/4/17	2m71.3	-2.713
1998/4/18	2m69.1	-2.691
1998/4/19	2m67.5	-2.675
1998/4/20	2m66.1	-2.661
1998/4/21	2m68.7	-2.687
1998/4/22	2m69.1	-2.691
1998/4/23	2m69.2	-2.692
1998/4/24	2m69.0	-2.690
1998/4/25	2m69.2	-2.692
1998/4/26	2m66.6	-2.666
1998/4/27	2m66.9	-2.669
1998/4/28	2m68.6	-2.686
1998/4/29	2m70.0	-2.700
1998/4/30	2m69.6	-2.696
1998/5/1	2m69.6	-2.696
1998/5/2	2m72.6	-2.726
1998/5/3	2m72.1	-2.721
1998/5/4	2m93.4	-2.934
1998/5/5	3m16.9	-2.169
1998/5/6	3m16.9	-2.169
1998/5/7	3m16.9	-2.169
1998/5/8	3m17.0	-3.170
1998/5/9	3m17.0	-3.170
1998/5/10	3m17.0	-3.170
1998/5/11	3m17.0	-3.170

MENDEFERA(NO.4) at 6:00 a.m.

Date	Reading	from G.L
(14:30)3/7	2m78.0	-2.780
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1998/3/9	2m80.2	-2.802
1998/3/10	2m81.0	-2.810
1998/3/11	2m82.0	-2.820
1998/3/12	2m83.0	-2.830
1998/3/13	2m84.0	-2.840
1998/3/14	2m84.8	-2.848
1998/3/15	2m85.1	-2.851
1998/3/16	2m79.0	-2.790
1998/3/17	2m79.0	-2.790
1998/3/18	2m79.0	-2.790
1998/3/19	2m79.1	-2.791
1998/3/20	2m79.1	-2.791
1998/3/21	2m80.0	-2.800
1998/3/22	2m80.0	-2.800
1998/3/23	2m80.0	-2.800
1998/3/24	2m80.0	-2.800
1998/3/25	2m80.1	-2.801
1998/3/26	2m80.1	-2.801
1998/3/27	2m80.1	-2.801
1998/3/28	2m80.2	-2.802
1998/3/29	2m80.2	-2.802
1998/3/30	2m80.2	-2.802
1998/3/31	2m80.3	-2.803
1998/4/1	2m80.3	-2.803
1998/4/2	2m80.3	-2.803
1998/4/3	2m80.3	-2.803
1998/4/4	2m80.3	-2.803
1998/4/5	2m80.4	-2.804
1998/4/6	2m80.4	-2.804
1998/4/7	2m99.0	-2.990
1998/4/8	2m98.9	-2.989
1998/4/9	2m98.9	-2.989
1998/4/10	2m98.9	-2.989
1998/4/11	2m98.9	-2.989
1998/4/12	2m98.9	-2.989
1998/4/13	2m99.0	-2.990
1998/4/14	2m99.0	-2.990
1998/4/15	2m99.0	-2.990
1998/4/16	2m99.0	-2.990
1998/4/17	2m99.0	-2.990
1998/4/18	2m99.0	-2.990
1998/4/19	2m99.0	-2.990
1998/4/20	2m99.0	-2.990
1998/4/21	2m99.0	-2.990
1998/4/22	2m99.0	-2.990
1998/4/23	2m99.0	-2.990
1998/4/24	2m99.0	-2.990
1998/4/25	2m99.8	-2.998
1998/4/26	2m99.8	-2.998
1998/4/27	2m99.8	-2.998
1998/4/28	2m99.9	-2.999
1998/4/29	3m00.0	-3.000
1998/4/30	3m00.0	-3.000
1998/5/1	3m00.0	-3.000
1998/5/2	3m00.0	-3.000
1998/5/3	3m00.0	-3.000
1998/5/4	3m00.0	-3.000
1998/5/5	3m00.0	-3.000
1998/5/6	2m94.2	-2.942
1998/5/7	2m98.0	-2.980
1998/5/8	2m98.0	-2.980
1998/5/9	2m98.0	-2.980
1998/5/10	2m98.0	-2.980
1998/5/11	2m98.0	-2.980

1998/5/12	8m26.3	-8.263	1998/5/12	3m17.2	-3.172	1998/5/12	2m98.0	-2.980
1998/5/13	8m26.0	-8.260	1998/5/13	3m17.2	-3.172	1998/5/13	3m00.1	-3.001
1998/5/14	8m25.6	-8.256	1998/5/14	3m17.2	-3.172	1998/5/14	3m00.1	-3.001
1998/5/15	8m25.4	-8.254	1998/5/15	3m17.2	-3.172	1998/5/15	3m00.1	-3.001
1998/5/16	8m25.0	-8.250	1998/5/16	3m30.3	-3.303	1998/5/16	3m68.9	-3.689
1998/5/17	8m24.7	-8.247	1998/5/17	3m31.3	-3.313	1998/5/17	3m69.0	-3.690
1998/5/18	8m24.2	-8.242	1998/5/18	3m33.0	-3.330	1998/5/18	3m70.8	-3.708
1998/5/19	8m23.9	-8.239	1998/5/19	3m35.7	-3.357	1998/5/19	3m70.8	-3.708
1998/5/20	8m23.5	-8.235	1998/5/20	3m30.2	-3.302	1998/5/20	3m73.7	-3.737
1998/5/21	8m23.0	-8.230	1998/5/21	3m37.5	-3.375	1998/5/21	3m73.0	-3.730
1998/5/22	8m22.7	-8.227	1998/5/22	3m38.7	-3.387	1998/5/22	3m73.0	-3.730
1998/5/23	8m22.3	-8.223	1998/5/23	3m40.8	-3.408	1998/5/23		
1998/5/24	8m22.0	-8.220	1998/5/24	3m40.8	-3.408	1998/5/24		
1998/5/25	8m21.8	-8.218	1998/5/25	3m39.0	-3.390	1998/5/25		
1998/5/26	8m21.5	-8.215	1998/5/26	3m38.4	-3.384	1998/5/26		
1998/5/27	8m21.0	-8.210	1998/5/27	3m38.4	-3.384	1998/5/27	2m76.8	-2.768
1998/5/28	8m20.8	-8.208	1998/5/28	3m38.0	-3.380	1998/5/28	2m76.0	-2.760
1998/5/29	8m20.2	-8.202	1998/5/29	3m37.9	-3.379	1998/5/29	2m75.6	-2.756
1998/5/30	8m20.0	-8.200	1998/5/30	3m37.7	-3.377	1998/5/30	2m75.1	-2.751
1998/5/31	8m19.8	-8.198	1998/5/31	3m37.0	-3.370	1998/5/31	2m74.6	-2.746
1998/6/1	8m19.3	-8.193	1998/6/1	3m36.9	-3.369	1998/6/1	2m74.2	-2.742
1998/6/2	8m19.1	-8.191	1998/6/2	3m36.5	-3.365	1998/6/2	2m74.5	-2.745
1998/6/3	8m19.0	-8.190	1998/6/3	3m36.7	-3.367	1998/6/3	2m74.8	-2.748
1998/6/4	8m18.8	-8.188	1998/6/4	3m36.3	-3.363	1998/6/4	2m75.0	-2.750
1998/6/5	8m18.3	-8.183	1998/6/5	3m36.4	-3.364	1998/6/5	2m75.0	-2.750
1998/6/6	8m18.0	-8.180	1998/6/6	3m36.4	-3..364	1998/6/6	2m74.9	-2.749
1998/6/7	8m17.5	-8.175	1998/6/7	3m36.4	-3.364	1998/6/7	2m74.8	-2.748
1998/6/8	8m17.1	-8.171	1998/6/8	3m34.0	-3.340	1998/6/8	2m74.7	-2.747
1998/6/9	8m16.9	-8.169	1998/6/9	3m32.7	-3.327	1998/6/9	2m74.1	-2.741
1998/6/10	8m16.4	-8.164	1998/6/10	3m31.3	-3.313	1998/6/10	2m73.9	-2.739
1998/6/11	8m16.1	-8.161	1998/6/11	3m30.2	-3.302	1998/6/11	2m74.0	-2.740
(10:40)6/11	8m16.0	-8.160	(11:15)6/11	3m30.0	-3.300	(11:30)6/11	2m73.2	-2.732

Appendix C-7 Well Inventory Study

C-7.1 Well Inventory

Table -.-.2 Well Inventory 2 MENDEFERA

<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	Downstream of Kilowlie dam	1970	14	54	53	38	49	54	Public W/S Mendefera	1994	5.1	9.05	5		634	7.00	Motor (YANIMAL)	Functional		
DW-2	Downstream of Kilowlie dam	1970	14	54	54	38	49	56	Public W/S Mendefera	Italian period	5.1	8	4.8		542	7.25	Motor(LAM BHRDINI)	Functional		
DW-3	Downstream of Mai Aron dam	2050	14	55	56	38	47	29	Public W/S Mendefera	1997	1.6	5	0		584	7.35	Motor(LAM BHRDINI)	Not yet installed	Public W/S in dry season only	
BH-4	Adi Mongoti	2000	14	53	30	38	47	29	Public W/S Mendefera	Ethiopian period	60	0.2032			1085	7.14	Submersible (LESTER)	Functional		
BH-5	Near electric power station	1995	14	53	5	38	47	47	Public W/S Mendefera	Ethiopian period	30				972	7.59	Submersible (LESTER)	Functional		
BH-6	Mai Takhala	1985	14	52	47	38	47	49	Capped	1997	62						Capped	Capped		
BH-7	Mai Takhala	1990	14	52	55	38	47	53	Out of use	Italian period	60	0.15	6.67				Out of use	Out of use		
BH-8	Mai Takhala	1994	14	53	0	38	47	56	Domestic	1993		0.15			638	9.23	Hand (India Mark II)	Functional		
BH-9	Near stadium	2000	14	52	22	38	48	46	Capped	1996	60	0.1905					Capped	Capped		
BH-10	Ziban Una	1920	14	50	52	38	50	1	Capped	1997	72[1)]						Capped	Capped		
BH-11	Downstream of Kilowlie dam	1969	14	54	48	38	50	2	Capped	1996	65						Out of use	Out of use		
BH-12	Adi Mongoti	2003	14	53	51	38	47	6	Cleaning	Ethiopian period	60	0.2032								
BH-13	Adi Wegri	1995	14	53	1	38	47	51	Capped	1996	68	0.2032								

Date surveyed : mainly 10 Oct., 1997

1) : Drilling data of the Sector Study

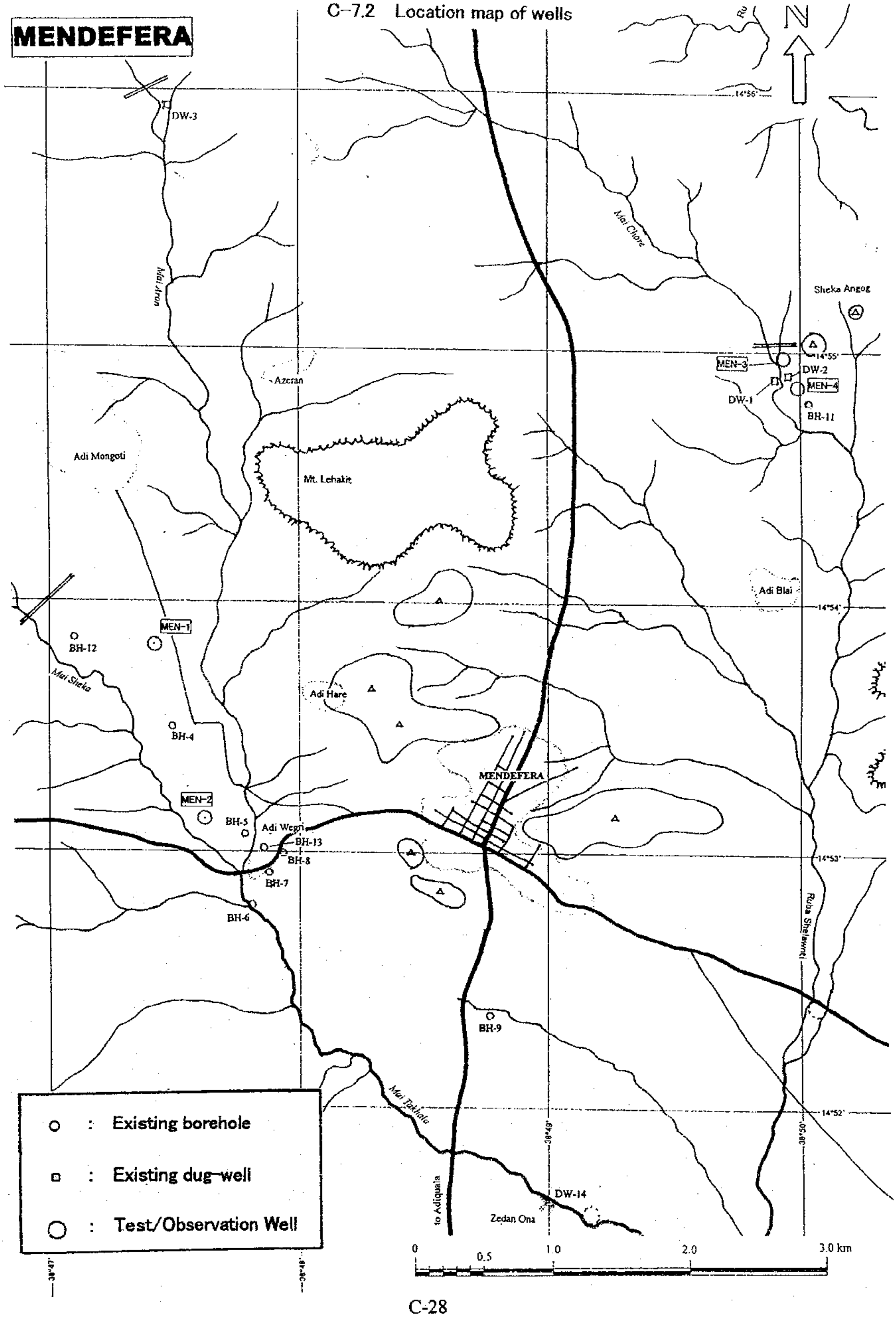
Well ident. : BH:Borehole, DW:Dug well, R:Reservoir

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



Appendix C-8 Technical Specification of Production Well

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