No.7 AL-JABUB

Prospecting point (1)

Resistivity layer	Depth(m)	Resistivity value(Ω•m)	Geological Features	Formation Group
No.1	0 - 8	6 - 57	Wadi deposits composed of sand and gravel	Alluvium
No.2	12 - 64	70 - 110	Fractured zone (12-32m) Basalt (32-40m), Fractured zone (40-48m) Basalt (48-64m)	Yemen Volcanics
No.3	64 - 100	12	Fractured zone	
No.4	100 - 130	104	Hard basalt	
No.5	130 - 160	54	Fractured zone	
No.6	160 - 190	126	Hard basalt	
No.7	190 -	44	Fractured zone	

At this point the aquifer starts at a depth of 60m, and the depth of a new well is recommended to be 200m.

Prospecting point (2)

Resistivity layer	Depth(m)	Resistivity value(Ω•m)	Geological Features	Formation Group
No.1	0 - 6	100 - 4200	Wadi deposits composed of sand and gravel	Alluvium
No.2	6 - 11	124	Wadi deposits sand and gravel	Yemen Volcanics
No.3	11 - 40	9 -36	Clayey basalt by weathering	
No.4	40 - 150	42 - 120	alternating beds basalt and fractured zone Fractured zone: (52-64m)(80-96m)	
No.5	150	38	Fractured zone	

The aquifer is judged to lie at 50-96m and 140-180m in depth.
According to the analysis, hydrogeological conditions at the prospecting point of No.1 is better than No.2. Therefore, the drilling point of a new well is recommended to be near the prospecting point of No.1.

No.13 AL-THAIAH

Prospecting point (1)

Resistivity layer	Depth(m)	Resistivity value(Ω•m)	Geological Features	Formation Group
No.1	0 - 0.94	40	Fine sand	Eolian sand
No.2	0.9 - 4	600	Weathered granite gneiss	Pre-Cambrian granite gneiss
No.3	4 - 12	134	Weathered zone	
No.4	12 - 48	?(High)	Hard granite gneiss	
No.5	48 - 96	412	Fractured zone	
No.6	96 -	?(High)	Hard granite gneiss	

Prospecting point (2)

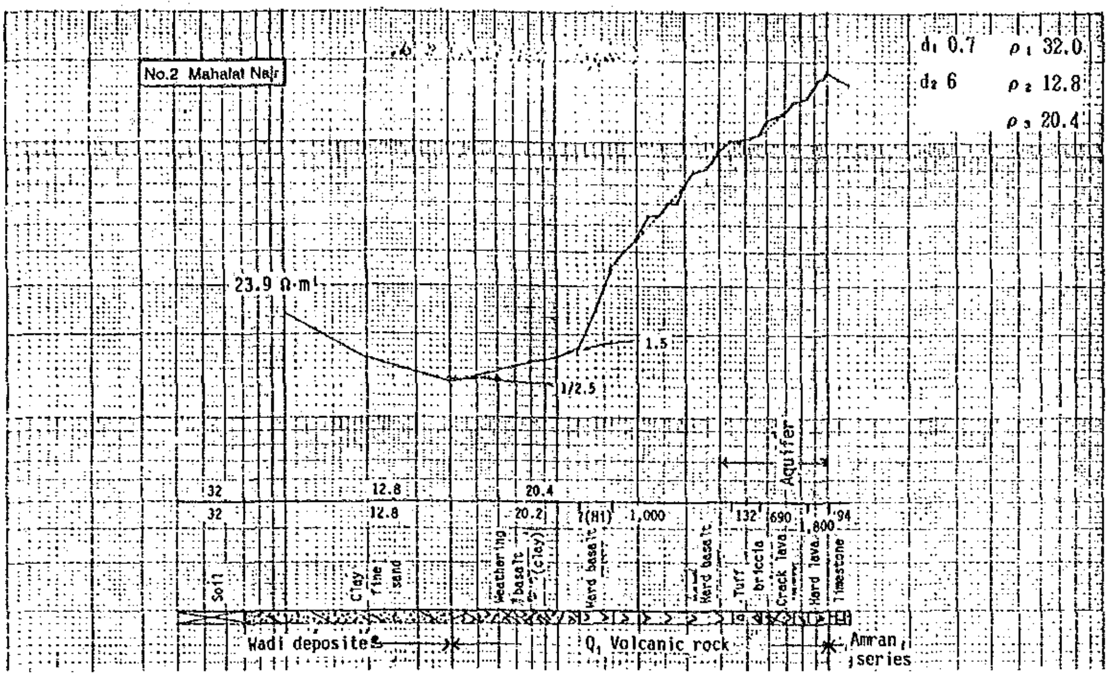
Resistivity layer	Depth(m)	Resistivity value(Ω•m)	Geological component	Formation
No.1	0 - 4	60	Fine sand	Eolian sand
No.2	4 - 30	?(High)	Hard granite gneiss	Pre-Cambrian granite gneiss
No.3	30 - 48	440	Slightly hard granite gneiss	
No.4	48 - 80	214	Hard granite gneiss	
No.5	80 -	380 - ?(High)	Fractured zone	

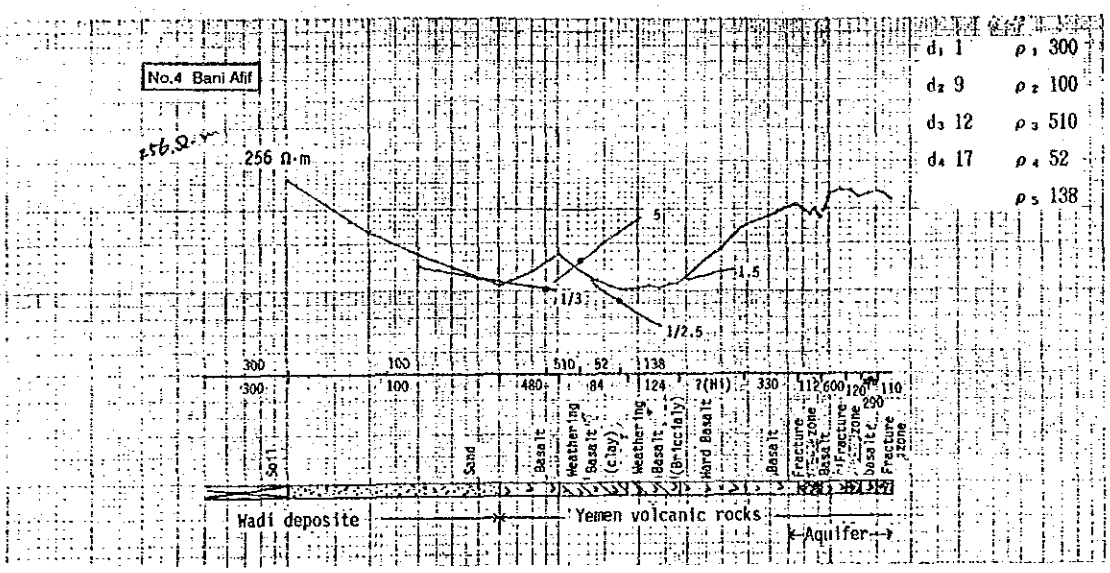
Cracked zones exist at both prospecting points of No.1 and No.2. However, according to the condition of the existing well (W-1), with its static water level standing at 210m and producing hot water with at a temperature over 50C°, this area is judged to be unsuitable for developing a new source for water supply facilities.

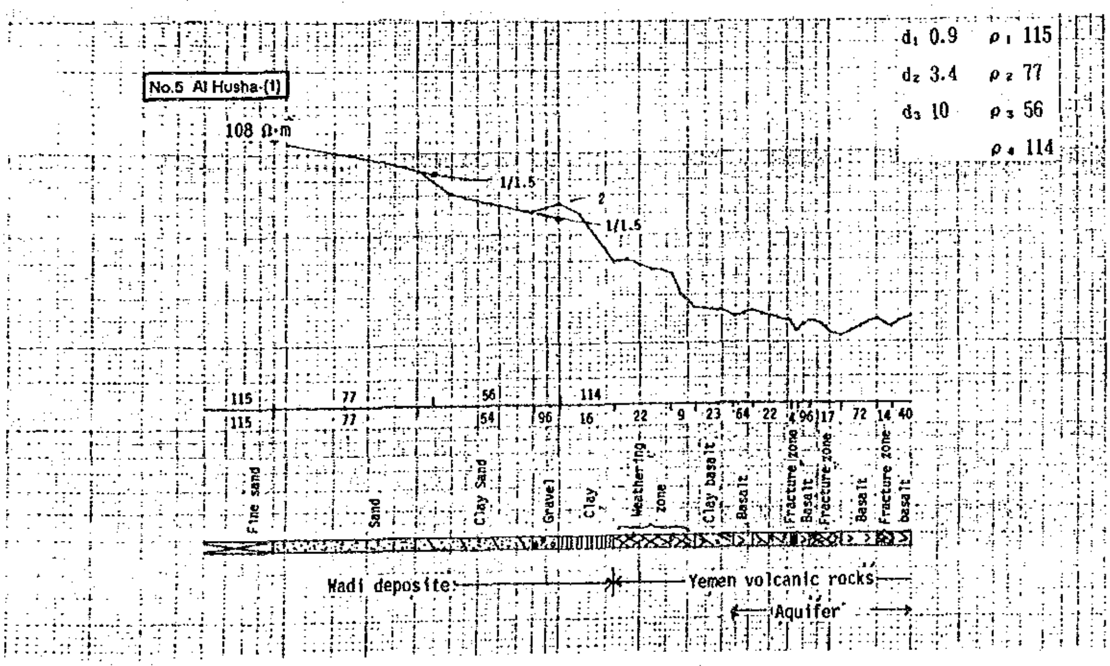
No.14 AL-MALLAHEETH

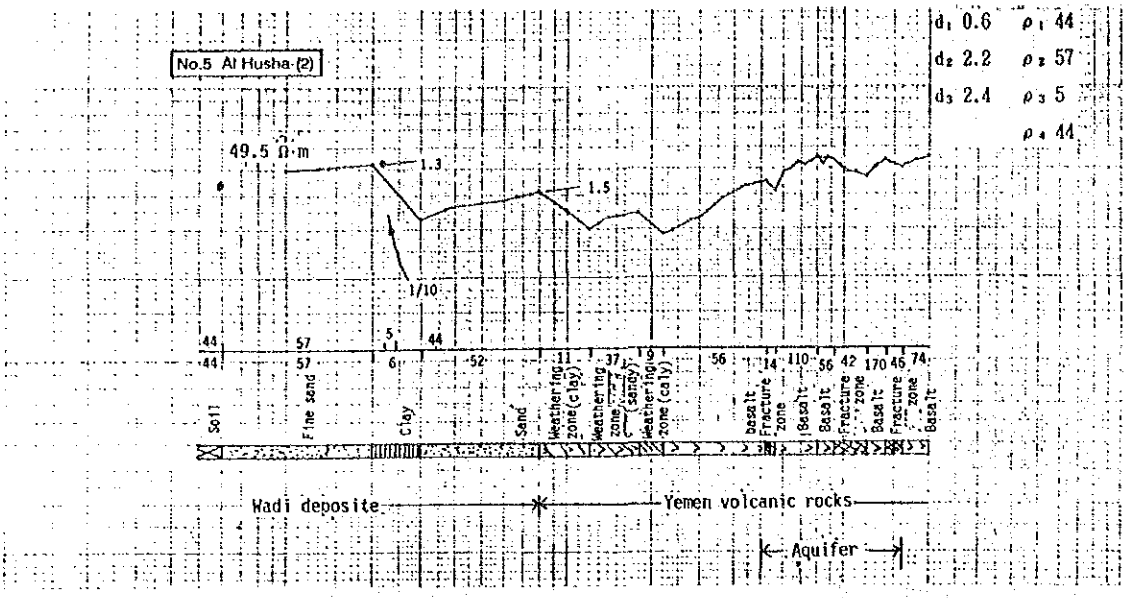
Resistivity layer	Depth(m)	Resistivity value(Ω•m)	Geological Features	Formation Group
No.1	0 - 4	27	Fine sand	Eolian sand
No.2	4 - 22	110	Slightly hard granite gneiss	Pre-Cambrian granite gneiss
No.3	22 - 64	36 - 46	Fractured zone: (22-28m,32-56m)	
No.4	64 - 110	360	Slightly hard, mica schist	
No.5	110 - 130	40	Fractured zone	
No.6	130 -	?(High)	Hard mica schist	

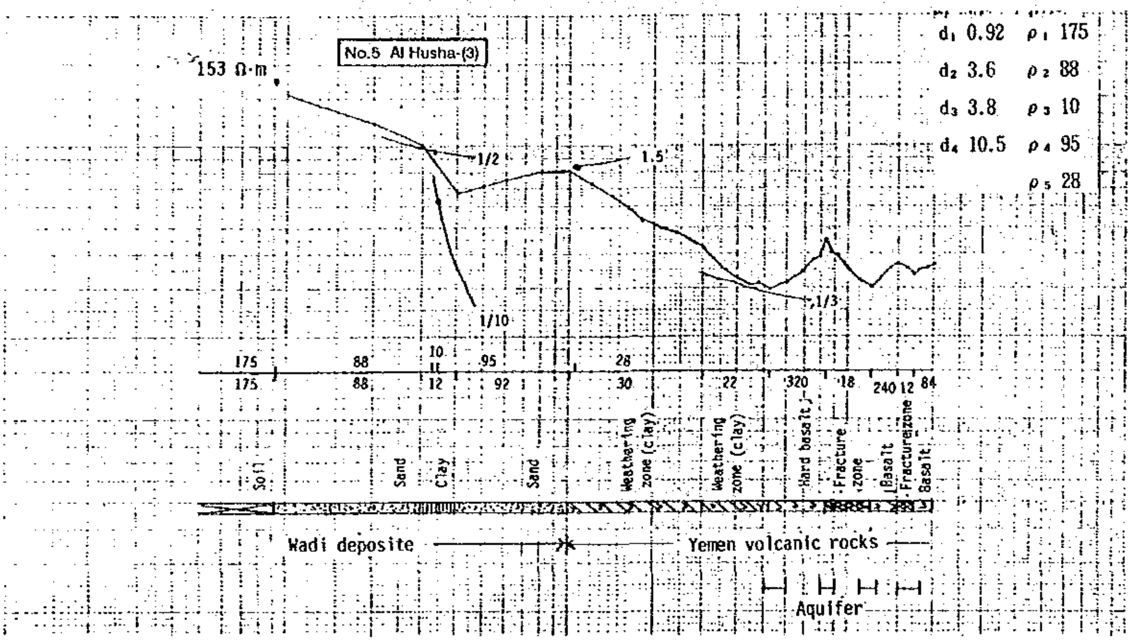
The aquifer is judged to lie from 40 to 130m in depth, and the depth of a new well is recommended to be 130m.

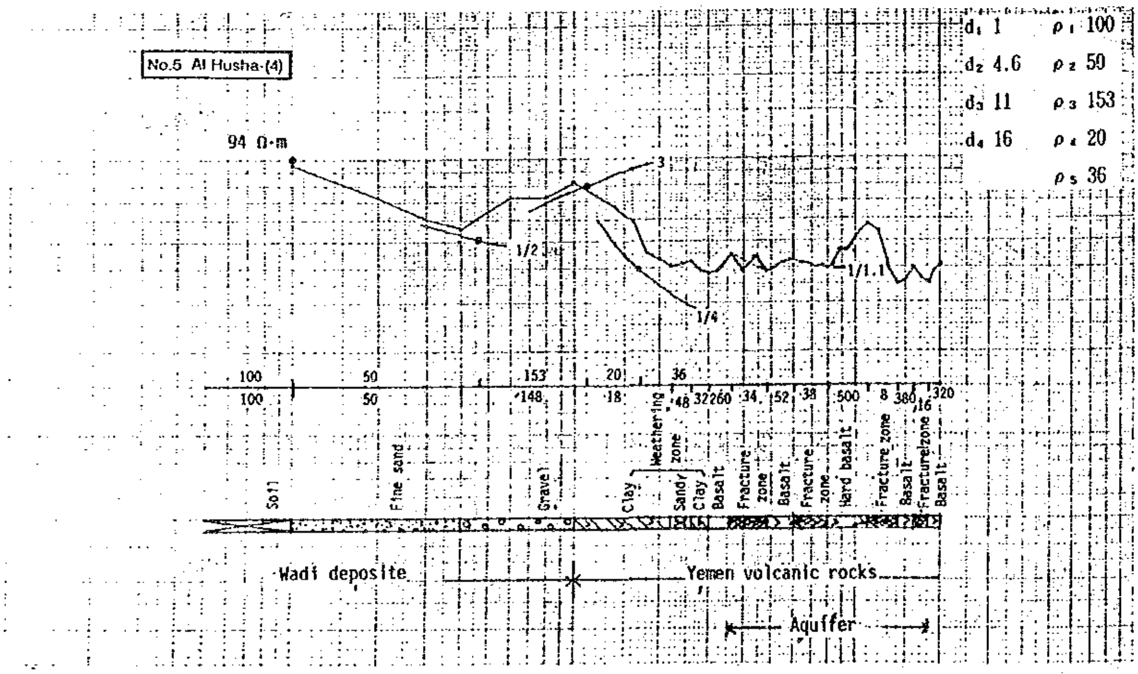

No.2 Mahalat Najr
d1 0.7 ρ1 32.0
d2 6 ρ2 12.8
ρ3 20.4
23.9 Ω·m
1.5
1/2.5
Aquifer
32 12.8 20.4
32 12.8 20.2 ?(H1) 1,000 132 690 1,800 94
Soil
Clay fine sand
Weathering basalt (clay)
Hard basalt
Hard basalt
Tuff breccia
Crack lava
Hard lava
Limestone
Wadi deposite
Q1 Volcanic rock
Amran series

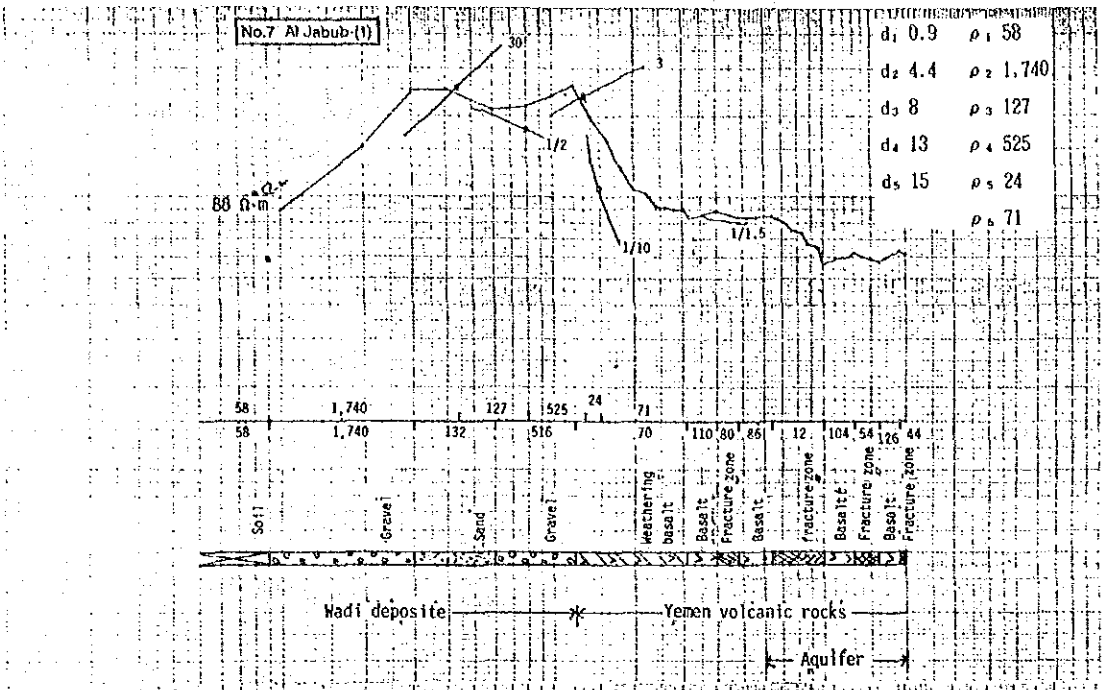

No.4 Bani Afif
d1 1 ρ1 300
d2 9 ρ2 100
d3 12 ρ3 510
d4 17 ρ4 52
ρ5 138
256 Ω·m
5
1.5
1/3
1/2.5
300 100 510, 52, 138
300 100 480 84 124 ?(H1) 330 112 600 120 290 110
Soil
Sand
Basalt
Weathering basalt (clay)
Weathering (Breccia)
Hard Basalt
Basalt
Fracture zone
Basalt
Fracture zone
basalt
Fracture zone
Wadi deposite
Yemen volcanic rocks
Aquifer

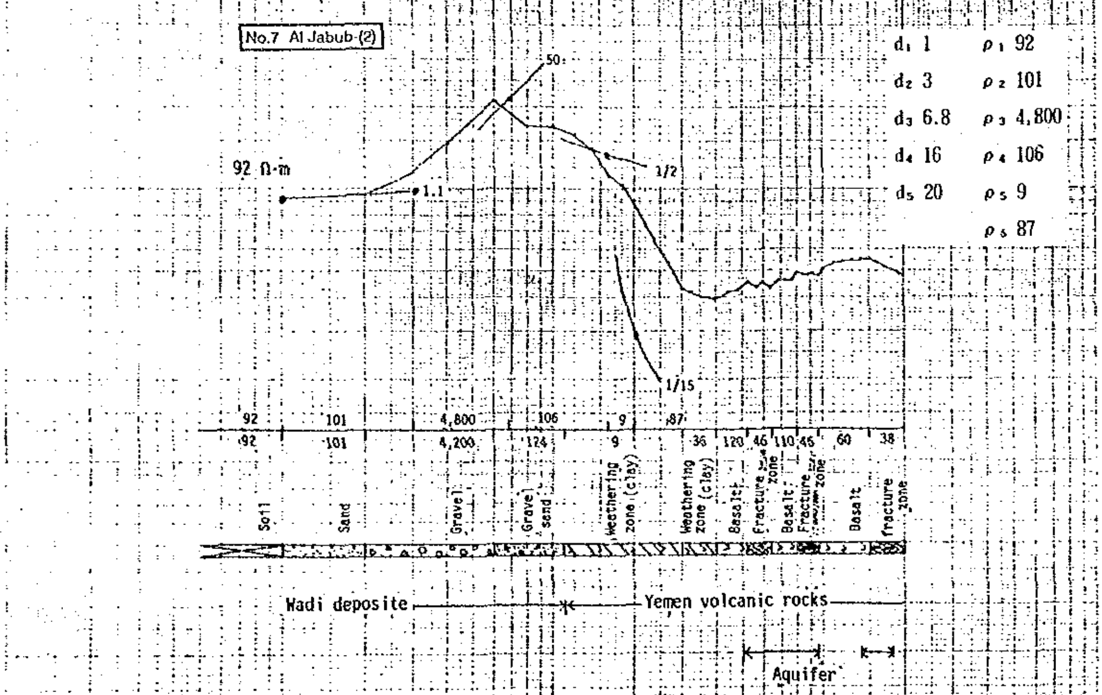

No.5 Al Husha-(1)
d1 0.9 ρ1 115
d2 3.4 ρ2 77
d3 10 ρ3 56
ρ4 114
108 Ω·m
1/1.5
2
1/1.5
115 77 56 114
115 77 54 96 16 22 9 23 64 22 4 96 17 72 14 40
Fine sand
Sand
Clay Sand
Gravel
Clay
Weathering zone
Clay basalt
Basalt
Fracture zone
Basalt
Fracture zone
Basalt
Fracture zone
basalt
Wadi deposite
Yemen volcanic rocks
Aquifer

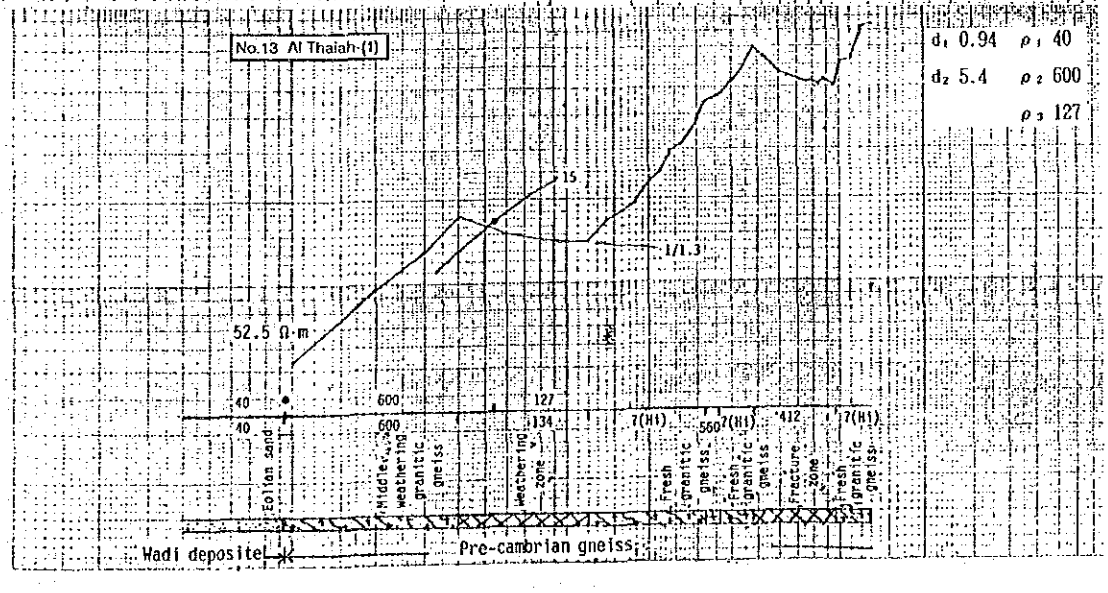

No.5 Al Husha-(2)
d₁ 0.6 ρ₁ 44
d₂ 2.2 ρ₂ 57
d₃ 2.4 ρ₃ 5
ρ₄ 44
49.5 Ω·m
1.3
1.5
1/10
Soil
Fine sand
Clay
Sand
Weathering zone(clay)
Basalt
Fracture zone
Wadi deposite
Yemen volcanic rocks
Aquifer

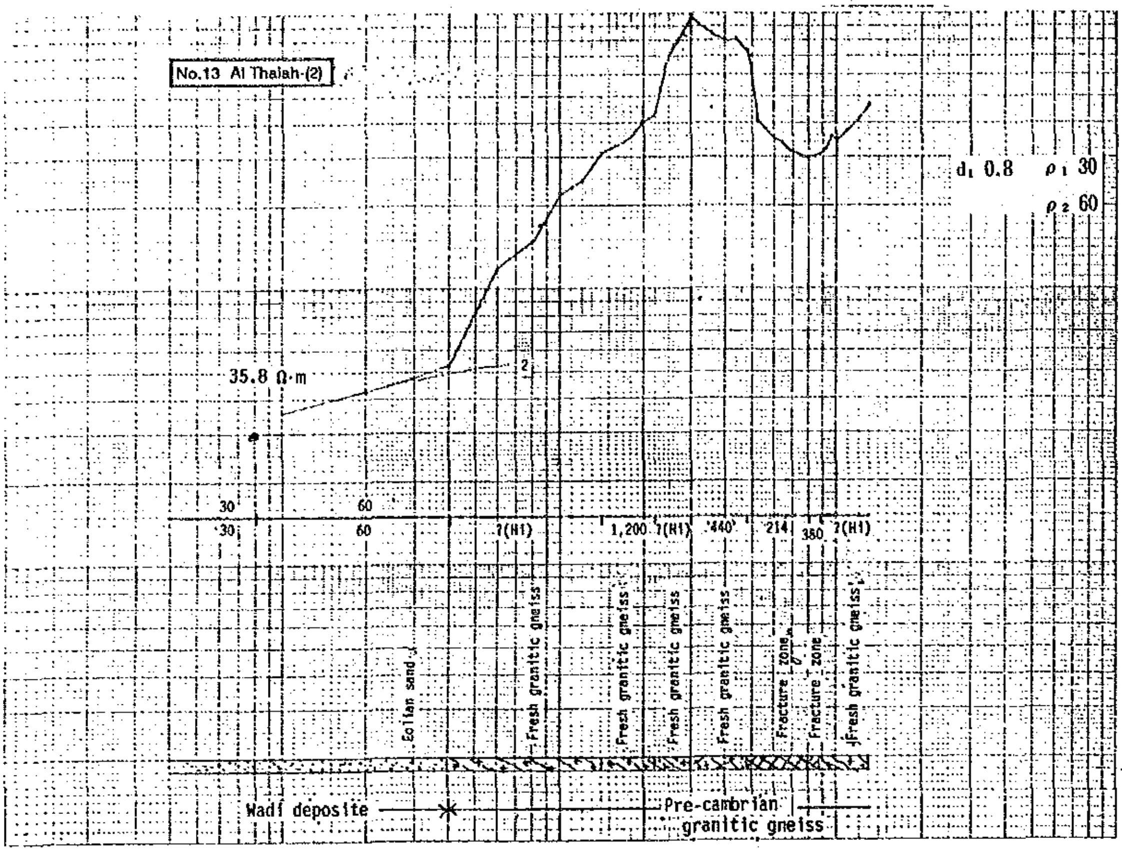

No.5 Al Husha-(3)
d₁ 0.92 ρ₁ 175
d₂ 3.6 ρ₂ 88
d₃ 3.8 ρ₃ 10
d₄ 10.5 ρ₄ 95
ρ₅ 28
153 Ω·m
1/2
1.5
1/10
1/3
Soil
Sand
Clay
Weathering zone (clay)
Hard basalt
Fracture zone
Basalt
Wadi deposite
Yemen volcanic rocks
Aquifer

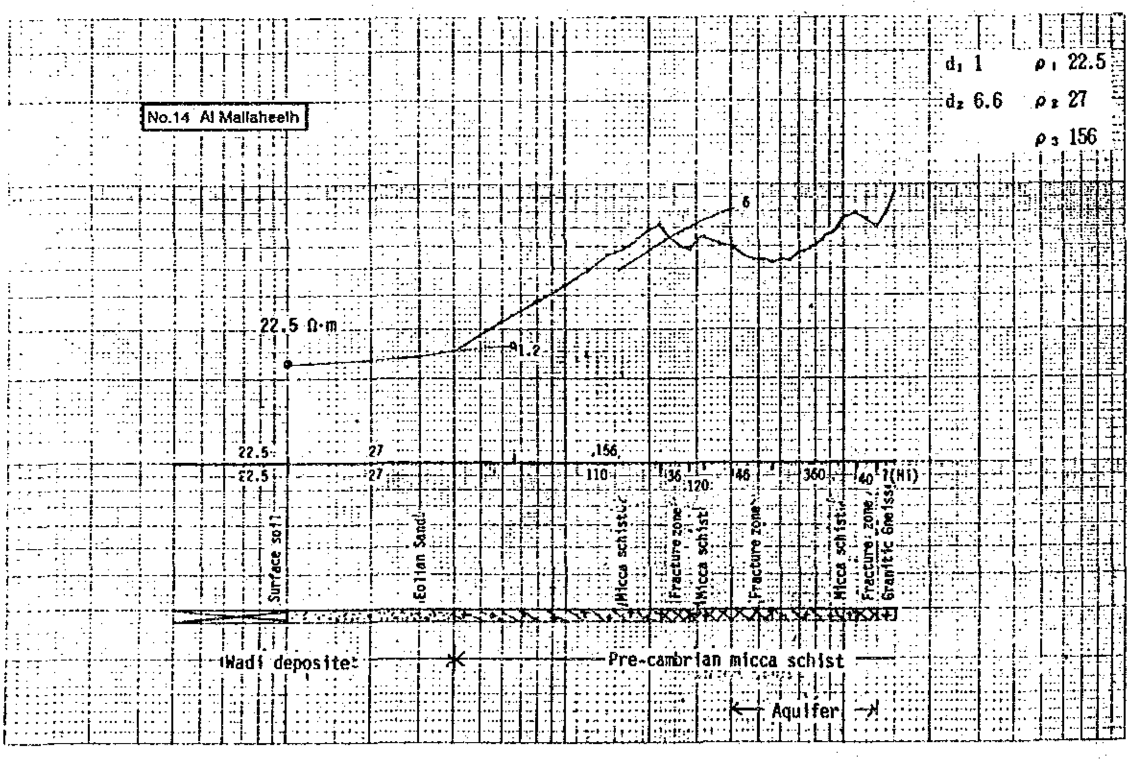

No.5 Al Husha-(4)
d₁ 1 ρ₁ 100
d₂ 4.6 ρ₂ 50
d₃ 11 ρ₃ 153
d₄ 16 ρ₄ 20
ρ₅ 36
94 Ω·m
3
1/2
1/4
1/1.1
Soil
Fine sand
Gravel
Clay
Weathering zone
Sandy
Basalt
Fracture zone
Hard basalt
Wadi deposite
Yemen volcanic rocks
Aquifer


No.7 Al Jabub-(1)
d1 0.9 ρ1 58
d2 4.4 ρ2 1,740
d3 8 ρ3 127
d4 13 ρ4 525
d5 15 ρ5 24
ρ6 71
88 Ω·m
30
3
1/2
1/10
1/1.5
58 1,740 127 525 24 71
58 1,740 132 516 70 110 80 86 12 104 54 126 44
Soil
Gravel
Sand
Gravel
Weathering basalt
Basalt
Fracture zone
Basalt
Fracture zone
Basalt
Fracture zone
Basalt
Fracture zone
Wadi deposite
Yemen volcanic rocks
Aquifer


No.7 Al Jabub-(2)
d1 1 ρ1 92
d2 3 ρ2 101
d3 6.8 ρ3 4,800
d4 16 ρ4 106
d5 20 ρ5 9
ρ6 87
92 Ω·m
50
1.1
1/2
1/15
92 101 4,800 106 9 87
92 101 4,200 124 9 36 120 46 110 46 60 38
Soil
Sand
Gravel
Gravel sand
Weathering zone (clay)
Weathering zone (clay)
Basalt
Fracture zone
Basalt
Fracture zone
Basalt
Fracture zone
Wadi deposite
Yemen volcanic rocks
Aquifer


No.13 Al Thaiah-(1)
d1 0.94 ρ1 40
d2 5.4 ρ2 600
ρ3 127
52.5 Ω·m
15
1/1.3
40 600 127
40 600 134 7(H1) 560 7(H1) 412 7(H1)
Eolian sand
Middle weathering granitic gneiss
Weathering zone
Fresh granitic gneiss
Fresh granitic gneiss
Fracture zone
Fresh granitic gneiss
Wadi deposite
Pre-cambrian gneiss


No.13 Al Thalah-(2)
d1 0.8 ρ1 30
ρ2 60
35.8 Ω·m
Eolian sand
Fresh granitic gneiss
Fracture zone
Wadi deposite
Pre-cambrian granitic gneiss


No.14 Al Mallaheeih
d1 1 ρ1 22.5
d2 6.6 ρ2 27
ρ3 156
22.5 Ω·m
Surface soil
Eolian Sand
Micca schist
Fracture zone
Granitic Gneiss
Wadi deposite
Pre-cambrian micca schist
Aquifer

APPENDIX III-c Hydrogeological Features of Canceled Sites

The field survey for the basic design study for the rural water supply project from April 23 to June 22, 1991 involved 14 sites in 7 governorates in the Republic of Yemen. As a result of this survey, it has been agreed between the representatives of the Yemen government and the study team that the three (3) sites out of these fourteen be canceled from the planning due to the discouraging hydrogeological conditions of the sites which are not likely to allow to secure stable water sources for the projects. The names of the canceled sites are as follows:

(1) Site No. 8: Majzal (Marib)
(2) Site No. 10: Ash Sharaqi (Hajjah)
(3) Site No. 13: Al Thaiah (Sa'dah)

The results of the survey and the hydrogeological maps for these sites are presented hereafter.

Site No.	Site Name	**MAJZAL**	Present Population	No. of Villages
8.	Governorate	Marib	Unknown	Unknown

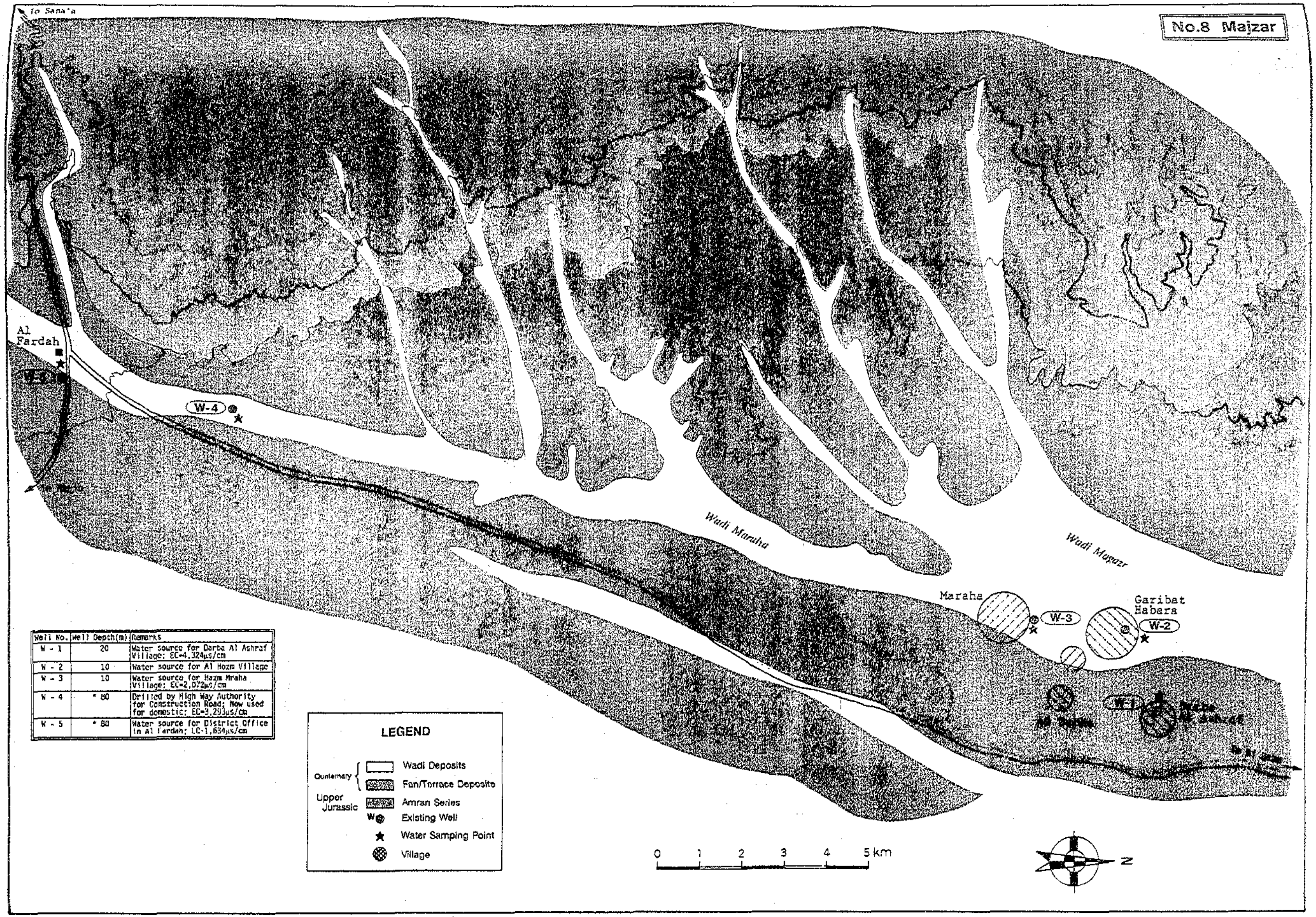
(1) Water Practice/Existing Sources

This site covers villages dispersed in a desert area just south of **Barraquish**, one of the representative remains of the **Maween** Kingdom in the **Majzal** district of the Marib governorate. The new highway linking the district center, **Al Fardah** to **Al Hazm**, the capital of the **Al Jawf** governorate, runs across this western edge of the Ar Rub Al Khari desert, made up of the Quaternary river terraces and eolian sand. The existing water sources in this area such as hand-dug wells and deep wells near Barraquish are all so saline that they are unfit for drinking. The water samples from hand-dug wells in the villages of **Darba Al Ashraf** and **Hazm Maraha** were analyzed, and the results, as presented in Table 3.5 in the text of this report, show the water has not only a high content of chloride ion but contains critical levels of hardness and fluoride. For this reason, inhabitants never use the water from their wells for drinking or cooking. They have no choice but to buy water for such a purpose.

The nearest sources available for them exist in Al Farda, the district center, about 30 km south of the area, where the deep well for the directorate of the district manager can produce potable water. Another deep well is located 4 km north of Al Farda. Installed by the Highway Authority during the construction of the highway, this well has now a vertical shaft pump which can supply the potable water to the nearby villages. However, these wells are 30 km away from the site, too distant to make a feasible project.

(2) Hydrogeological Features

Located in the western fringe of the Ar Rub Al Khari desert, this area consists of river terraces of the Quaternary sediments and a wadi-dissected plain mantled with alluvium and eolian sand. Outcrops of older formations cannot be recognized. However, the mountainous area rising west of the area is made up of the *Amran series* limestone. During the operation of drilling a well 250 m deep near Barraquish, the *Tawilah groups* sandstone overlying limestone was penetrated. Groundwater in this area entirely contains high salinity, but gets drinkable in such areas as Al Farda located near the mountains, where the existing wells are 80 to 100 deep, producing water of good quality. This situation indicates that groundwater still maintains low salt contents in areas of fans just down the mountains, which get concentrated in the river terrace or eolian sand zone through high evapotranspiration.



Well No.	Well Depth(m)	Remarks
W - 1	20	Water source for Darba Al Ashraf Village: EC=4,324µs/cm
W - 2	10	Water source for Al Hozm Village
W - 3	10	Water source for Hazm Mraha Village: EC=2,072µs/cm
W - 4	* 80	Drilled by High Way Authority for Construction Road; Now used for domestic: EC=3,293µs/cm
W - 5	* 80	Water source for District Office in Al Fardah: LC-1,634µs/cm

Site No.	Site Name	ASH SHARAQI	Present Population	No. of Villages
10.	Governorate	Hajjah	4,400	18

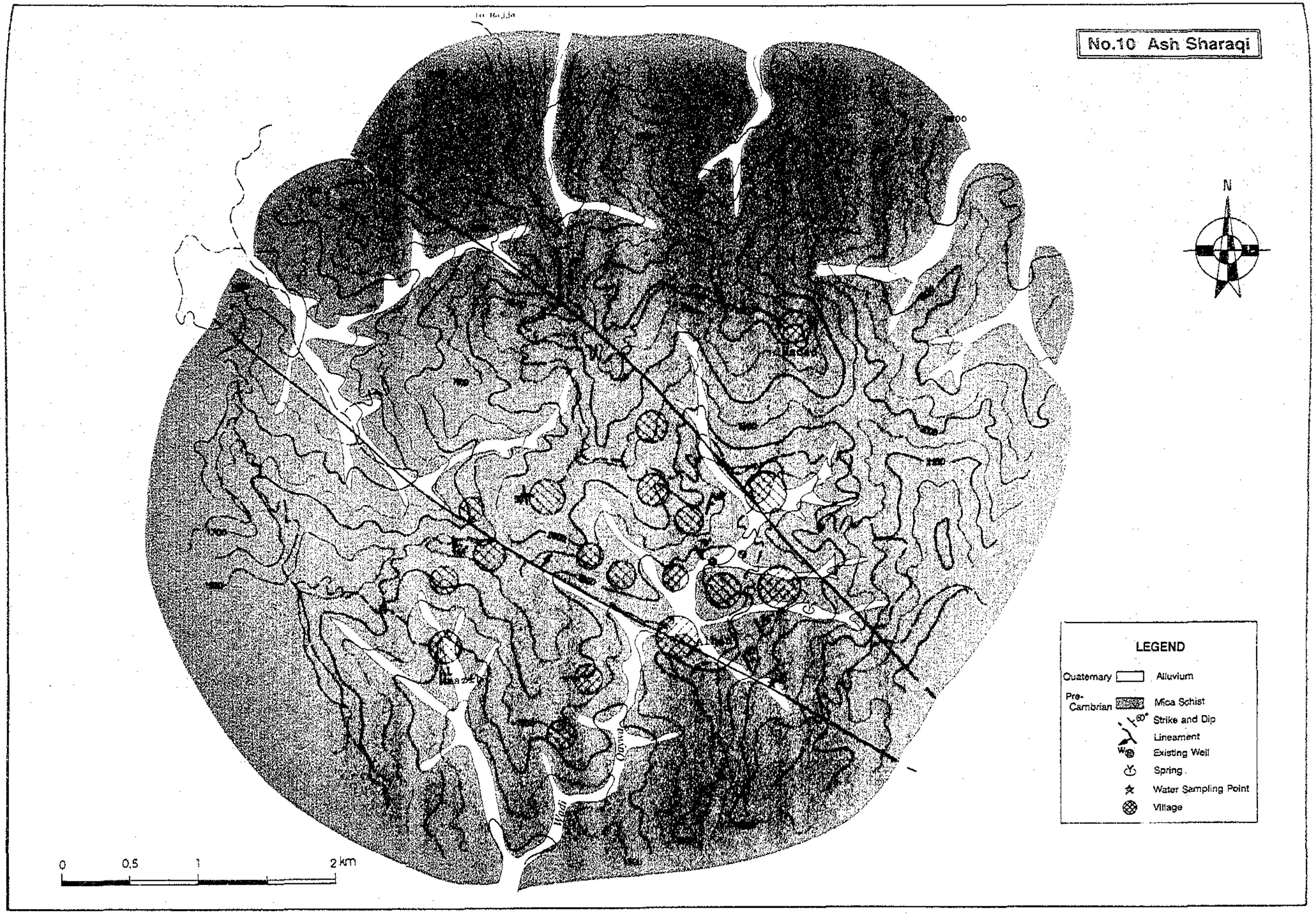
(1) Water Practice/Existing Sources

This site involves an entire area of the **Ash Sharaqi** sub-district about 10 km south of the capital of Hajjah. The mountains composing the site are in their prime, rising steeply with sharply angular ridges and V-shaped valleys. The settlements nestle on these sharp ridges, and the steep slopes of mountains are entirely the remarkable terraced fields. In this mountainous area, springs are only available water sources: one emerges from small cracks in the **Wadi Gail Masaib**, a tributary of the **Wadi Qaywal**; and the other, in the midstream of the **Wadi Shatreh** adjacent to the former wadi. The two springs have several sources respectively, and issue a combined volume of about 150 m^3/day, which are used not only for domestic water for the villages such as **Alhan** and **Shatreh** but for major irrigation water for fields in the wadi lowland.

The Wadi Qaywal, the main stream, has an alluvial belt 2 to 5 m thick, where there is one hand-dug used by nearby inhabitants. The depth of the well is 8 m, with the water table standing at about the same level of the river bed of the Wadi Qaywal. The alluvium is underlain by mica schist at 4 to 5 m below ground. Taking a southerly course west of the **Addar** village, this wadi forms a dry water fall about 3 m high made up of a pegmatite dike, just upstream of which the wadi underflow emerges on the surface, providing a spot for washing or just taking water, although the discharge is only about 20 to 30 m^3 in a day.

(2) Hydrogeological Features

The area of the site is made up of the Precambrian mica schist with frequent dikes of pegmatite and quartzite. Its schistocity bears the NS direction, with dips of 40° to 70° eastward, in places showing complex minute structures. The Wadi Qaywal running through the central part of the site is a strike valley dissected along the direction of schistocity. The belt of the alluvium along the wadi is 20 to 30 m wide, but is 1 to 2 m in thickness. Two lines of lineaments are seen in the area running in the EW direction, but have no fracture zones. Cracks bear the directions of either NS or EW. The small springs in the Wadi Gail Masaib and the Wadi Shatreh are issued through cracks in the NS direction. Since this area has neither lineaments nor fracture zones in the NS direction which can frequently provide courses of groundwater flow, it is judged to be difficult to develop a new stable source there.


No.10 Ash Sharaqi
N
LEGEND
Quaternary
Alluvium
Pre-Cambrian
Mica Schist
60°
Strike and Dip
Lineament
W
Existing Well
Spring
Water Sampling Point
Village
Wadi
0
0.5
1
2 km

Site No.	Site Name	AL THAIAH	Present Population	No. of Villages
13.	Governorate	Sa'dah	1,445	17

(1) Water Practice/Existing Sources

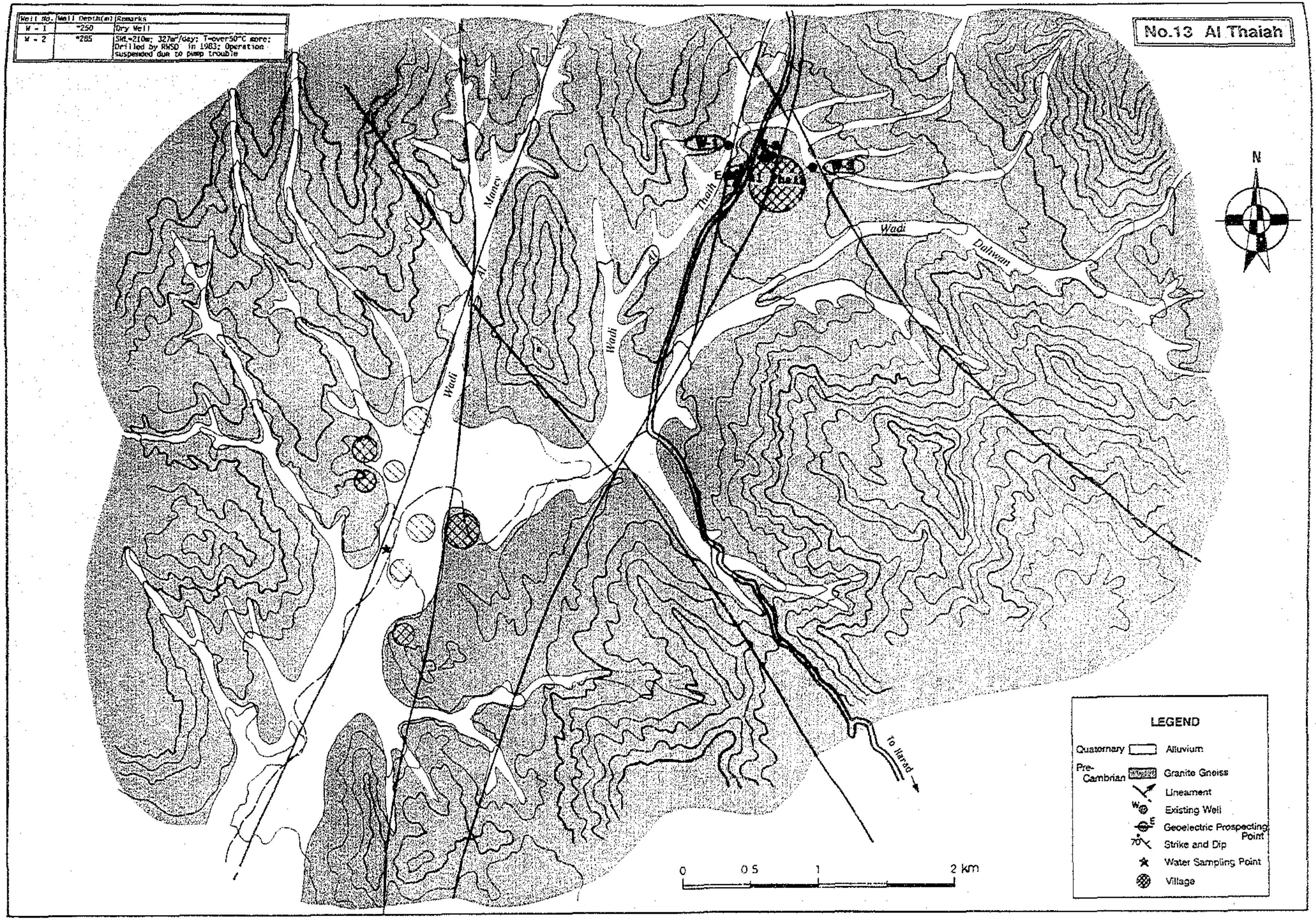
This site is about 20 km northwest of Al Mallaheeth (Site No. 14) along the highway under construction connecting Harad and Sa'dah. Its location is at the base of the Central Mountains Zone.

The area is made up of gently undulating hills along the **Wadi Al Thaiah** and the wadi lowland, composed of the Precambrian granite gneiss. The directions of schistocity are NW50° to EW with northward dips of 40° to 70° on the right bank of the wadi and NE30° to 40° with westward dips of 50° to 70° on its left bank, clearly indicating this wadi is a tectonic valley. Pegmatite or quartzite dikes are frequent, but their directions are not uniform.

The alluvium in the wadi mainly consists of arkosic sand of granite origin, in places having beds of gravel, with its surface mantled with eolian sand. Its thickness is 2 to 3 m. Several hand-dug wells were installed along the wadi by inhabitants. These wells are said to run dry during the dry season.

The site has a deep well drilled by the RWSD in 1983 in a northern hilly area along the new highway. It is 285 m deep, reportedly yielding 327 m^3/day of hot water over 50°C. The vertical shaft pump had a trouble during the test run, and had since been left untouched. The hot water yield suggests that the lineament along the Wadi Al Thaiah is an anomalous geothermal zone. The static water level in the existing well was an extraordinarily low 210 m. Taking such conditions into account, the site has little chance of finding a new suitable source.

Well No.	Well Depth(m)	Remarks
W - 1	*250	Dry Well
W - 2	*285	SWL=210m; 327m³/day; T=over50°C more; Drilled by RWSD in 1983; Operation suspended due to pump trouble



APPENDIX IV

WATER SUPPLY FACILITIES

APPENDIX IV - a

REPUBLIC OF YEMEN

Rural Water Supply Department

Design Criteria for Rural Water Supplies

1. Population Present

Population statistics issued by the Central Planning Organization (CPO) show figures which appear to be on the lower side. Databank on Yemen's population issued in 1975 by the Swiss Technical Cooperation Service shows also figures lower than the actual population. Information provided by the local villages gives figures that are often exaggerated.

To obtain reasonable estimates of present population, the following steps should be followed:

a. Obtain CPO figures: population, number of families and number of houses;

b. Obtain population estimate independently from more than one reliable source from the village;

c. Calculate population by;
   - multiplying number of families by 7
   - multiplying number of houses by 10;

d. Compare population estimates obtained from above a, b and c discarding doubtful figures, take the mean and then use it for design purposes;

e. Try and obtain from the village Sheikh population figure according to "FITRAH" (or religious taxes) which is probably the most accurate estimate although it usually indicates less figure than the actual population.

2. Population Figure

It is pratically impossible to use population projection techniques as there exist no statistics prior to 1975 the overall growth rate is about 2.9% per annum; 2.5% for rural population and 8.5% for urban population. The growth rate in some urban towns may reach 16% and great care must therefore be exercised in establishing, as far as possible, how fast does a village or town expand by examining its economical and social conditions affecting such growth. In some cases, an idea of growth tendencies can be had by obtaining information on building permits granted and population figures in the last few years.

The following table gives population projections for certain growth rates. Multiply present population by shown multiplier for the required design period.

Growth Rate %	Multiplier by 15 years	Multiplier by 20 years
2.5	1.41	1.60
3.0	1.51	1.75
3.5	1.62	1.92
4.0	1.75	2.11
4.5	1.85	2.31
5.0	1.98	2.53
5.5	2.12	2.77
6.0	2.26	3.03

However, it is suggested that the following projections used;

a. For rural areas: 2 x present population;

b. For semi-urban centers: use an annual growth rate of 6% - or 3 x present population;

c. For urban centers: investigate each case separately.

3. Water Demand

a. 45 lit/person/day - using public fountains only with no house connections, especially when the source is not sufficient;

b. 80 - 100 lit/person/day - for general house connections with some public fountains. Use low figuer for temperate climates and high figure for hot areas such as Taizz region;

c. Fire fighting demand - is not economically warranted for the rural areas.

4. Daily Operating hours

Ideally, the shorter the daily operating hours the better, in order to facilitate operation and maintenance of the mechanical equipment and to provide flexibility in the operation of the system by enabling the operator to incease operation hours, if the need arises without putting too much load on the pumping unit.

Twenty-four hour operation is not desirable, as this leaves no time for necessary maintenance and would reduce the life of the pumping unit significantly. However, a standby unit must be provided if 24-hour pumping is desired.

The following guidelines are proposed:

a. The design should aim at maximum daily operating hours of 8 - 20 hours at the end of the design period, if the source yield is adequate;

b. The daily operating hours should preferably not exceed 8 hours for human consumption if the same well is utilized to supply water for irrigation purpose;

c. If the yield of the available source is low, the daily operating hours at the end of the design period may have to be increased beyond 16 hours. In the case, the concerned authorities should be warned of the situation and advised to look for a supplementary source. The period after which 16 hours daily pumping will be necessary can be roughly calculated and noted.

5. Storage Tax (Storage Capacity)

a. For ground tanks storage capacity of the reservoir should be based on maximum daily demand at end of the design period. This is necessary in rural areas where repair of mechanical equipment may take a few days to be carried out. However, a maximum atorage capacity of 250 m^3 or more may be used in larger villages.

   If the designed storage capacity is more than 100 m^3, then it is preferable to split the storage volume in phases according to the demand and local conditions and the availability of the funds.

b. For elevated tanks: about 25% of maximum daily demand at end of design period.

c. Use the following standard sizes for ground tanks:
   24 - 36 - 48 - 75 - 90 - 120 - 180.

6. Water Distribution Networks

a. For small water distribution system with no fire hydrants, the minimum head at any point in the system should be 10 m for double-story houses.

b. For water distribution systems with fire hydrants, the minimum head should be 20 m.

c. In case the fire frighting vehicles are equipped with pumping unit then the pressure may be reduced.

7. Public Fountains

a. Standard units are 4 and 6 taps per unit.

b. The loading per tap should not exceed 200 persons.

c. Maximum walking distance to any public fountain should preferably not exceed 200 m.

8. Distribution Flow

The gravity flow in any pipe should be taken as 2 times the average daily flow. The average flow is the total demand divided by 24 hours (converted to liters per seconds or US gpm).

9. **Arrangement of Valves**

a. Immediately on the pump discharge line a non-return valve should be installed followed by sluice (or gate) valve.

b. Air-relief valves must be installed at high points on pipelines.

c. Drain valves (Sluice or gates) must be installed at low points in pipelines.

d. Working pressuer must be defined in the drawing.

10. **Water Marker**

In high pressure systems it is necessary to calculate the instantaneous rise in pressure at the pump upon closure of the non-return valve after stoppage of the pumping unit. This rise in the pressure should be added to the total manometric head and the summation constitutes the working pressure for the pipe.

11. **Duration of Prime Movers**

Engines must be derated for the altitude and maximum ambient temperature combined. Humidity has also an effect on the rating of electric motors.

12. **How to Specify Pumps**

Any pump must be specified by the following:

a. Discharge: (US gpm) or (lit/second)

b. Total manometric head - m

c. Internal size of well casing (if a deep well)

d. Installation depth (if a deep well). Consideration must be given in both horizontal and vertical pumps to the NPSH (Net Positive Suction Head) of the pumps in question.

e. Minimum rated output of prime mover which must be based on:
Temperature and altitude duration and the maximum S.N.P. of the pump at rated speed (not the SNP at the rated at the rated Q and E). An allowance should be added for flexibility of operation and other factors such as type of drive (belt).

f. Multiplier of the power needed is 1.2 - 1.4.

APPENDIX IV-b

Existing Facilities and Future Supply Planning in Al Husha and Al Usfyn

As a result of the field survey, the water supply schemes for the entire areas of two specially extensive sites, **Al Husha** and **Al Usfyn**, are studied herein for reference.

(1)

Name of Site	**AL HUSHA**	Governorate	Taizz
Population (1991)	Eastern Supply Zone - 5,000		
	Central Supply Zone - 5,000		
	Western Supply Zone - 3,000		

1) Existing Supply Facilities

This site has existing water supply facilities composed of the following ones:

a.	Hand-dug well as water source	x 1 No.
b.	Vertical shaft pump/pump house	x 1 No.
c.	Booster pump/pump house	x 1 No.
d.	Booster & distribution tank, 180 m	x 1 No.
e.	Pumping main, 3"	x Approx. 5,000 m
f.	Distribution tank, 200 m	x 1 No.

These facilities were constructed by the *Southern Highlands Development Authority* of the Ministry of Agriculture and Water Resources for the purpose of supplying drinking water to the Wester Supply Zone of the area as classified in the above table. In contrast to the existing deep wells drilled by the LCCD in the northern wadi basin, the hand-dug well for this system was installed in the southern basin near Suq Al Khamis, but has now run dry, leaving all facilities idle. The LCCD, therefore, was desirous to include them as part of the new system to be planned by the Japanese project.

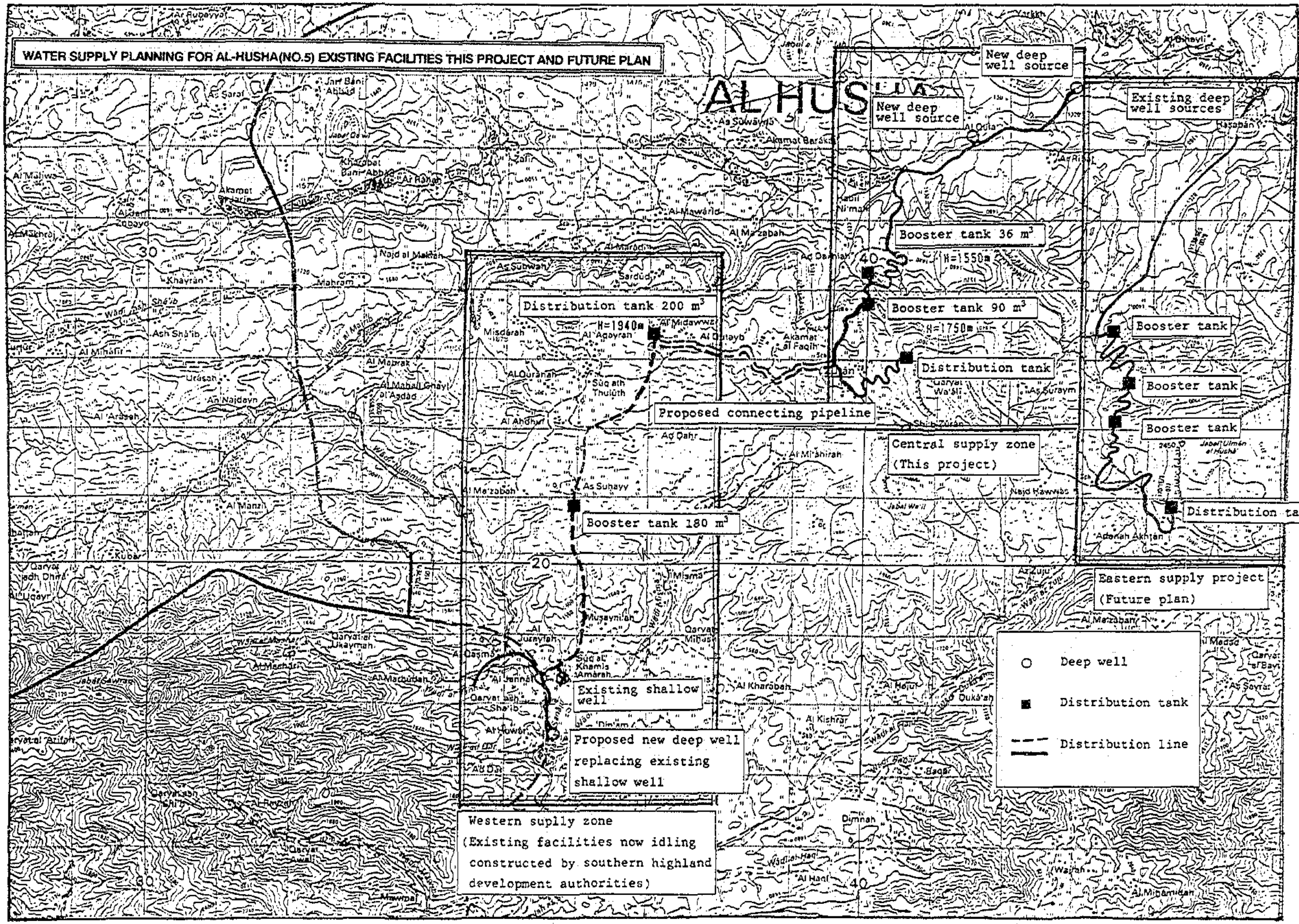
According to the survey this time, the hydrogeological conditions in the southern basin are judged to be more promising than those in the northern one. In case deep wells are newly drilled in the former basin to replace the dried-up water source, the idle facilities can effectively be utilized for the revival of the supply. This scheme was proposed to the RWSD as one of feasible plans for the area, and the RWSD responded with the idea that the scheme could be undertaken with its own fund.

In case these facilities could be revived, further utilization becomes possible: since the existing 200 m distribution tank is located close to the Central Supply Zone, the design for which is planned in this study, a further pipeline could be extended to a planned service tank in Zuran City to link the two systems for the Western and the Central Zones, so that water sources installed in the northern and southern basins can effectively be used for both systems. The outline of this scheme is illustrated in Fig. IV.b.-(1).

2) Relation to the Future Planning

The future use of existing facilities has been referred to in the foregoing section. As for the Eastern Supply Zone where the LCCD most earnestly desires the project to be urgently implemented, the planned system is composed of the existing two deep wells in the northern basin, transmission facilities including pumping main over 20 km in length and a final service tank installed on the top of Mt. Al Husha rising about 1,200 m from the basin, as shown in Fig. IV.b-(1). Part of a new road to reach Mt. Al Husha is now under construction, but the implementation of the project for this supply zone still has a great deal of difficulty due to its extraordinarily steep and rugged topographic condition. An alternative is the extension of the planned system for the Central Zone through another mid-mountain route. It is recommended, therefore, that a comprehensive supply scheme be further studied.

APPENDIX IV - b Existing Facilities and Future Planning in Two Existing Sites



(2)

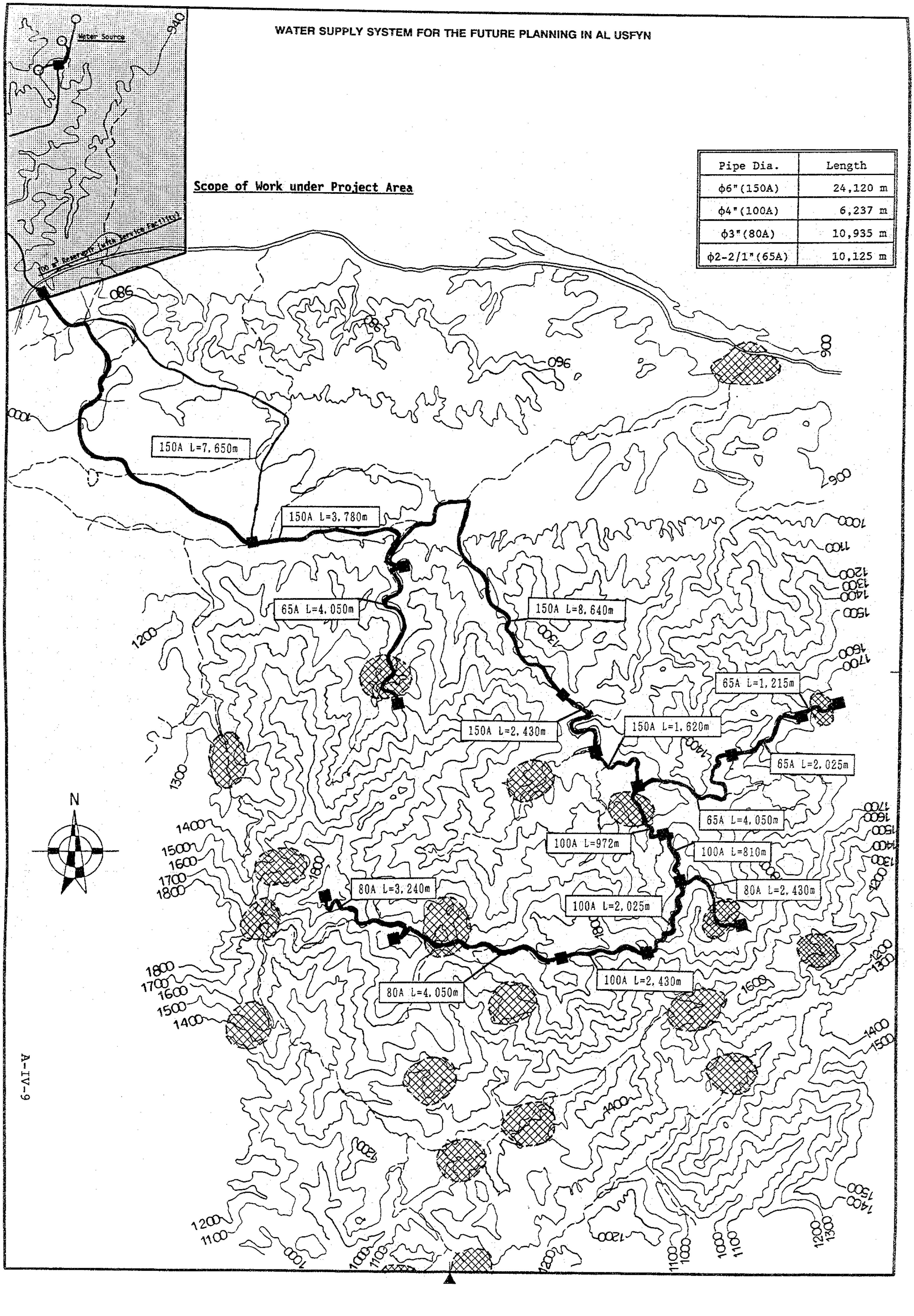
Name of Site	**AL USFYN**	Governorate	Taizz
Population	1991 - 28,500 (20 villages)		

The new facilities focusing on the development of water sources are planned to be installed for this site under the Project. However, a gigantic size of the site makes it extremely hard to extend piped water from these facilities to villages in the mountainous areas. A typical layout of necessary transmission facilities is shown in Fig. IV.b-(2) for reference. One method to realize the water supply scheme for this site is considered to implement the project step by step in place of completing all facilities in one stage, with the understanding and cooperation of the entire residents. In this view, the whole scale of the project is recommended to be reviewed again in detail.

WATER SUPPLY SYSTEM FOR THE FUTURE PLANNING IN AL USFYN

Scope of Work under Project Area

Pipe Dia.	Length
φ6"(150A)	24,120 m
φ4"(100A)	6,237 m
φ3"(80A)	10,935 m
φ2-2/1"(65A)	10,125 m

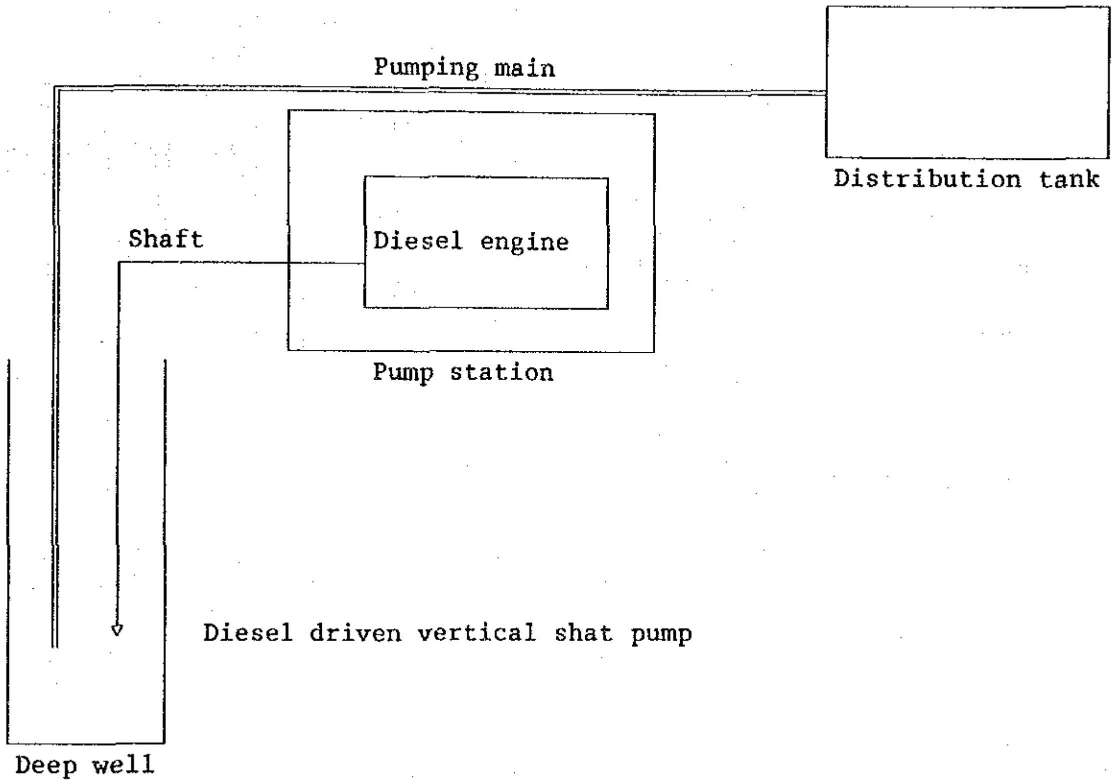


APPENDIX IV - c   Types of Deep Well Pumps

The selection of a type of deep well pump (diesel driven vertical shaft pump or submersible motor pump) has been made, based upon the conditions of planned facilities in the respected sites as follows:

(1) Diesel driven vertical shaft pump

The diesel driven vertical shaft pumpis installed where a head of the pump required in the system is less than 200m, as typically illustrated in the diagram below.

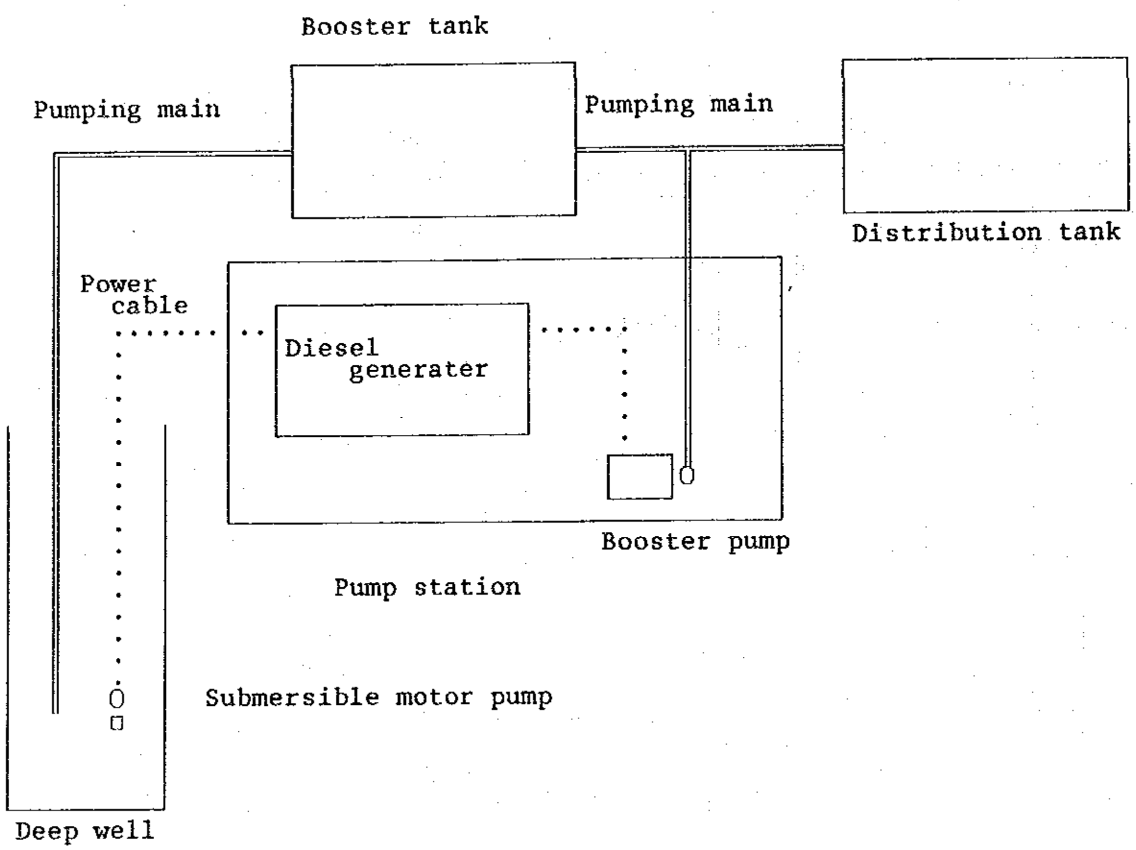


This system is employed in the following sites:

Priority	Site	Water source
1	AL-MALLAHEETH	Project wells × 2 Nos.
4	AL-USFYN	Project wells × 3 Nos.
11	MAHALAT-NAJR	Project well × 2 No.

(2) Submersible Motor Pump

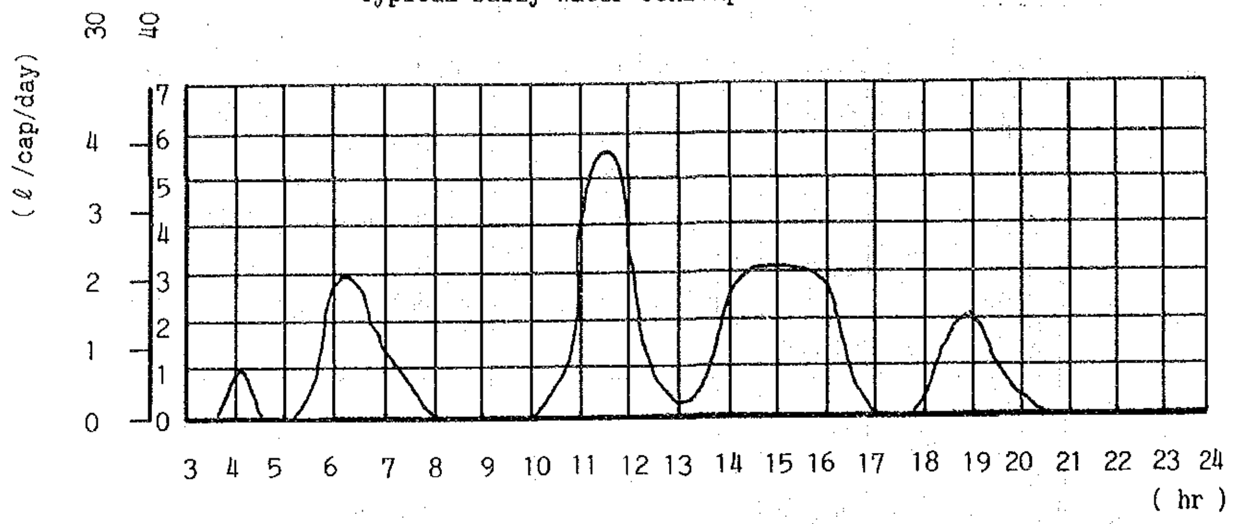
The submersible motor pump is employed where a head of the pump required in the system is over 200m. In case a booster pump is installed simultaneously in the intake pump station, the typ of deep well pump is fixed for submersible motor pump, even if the head is less than 200m, in order to drive both pumps with one power unit as shown in the diagram below.



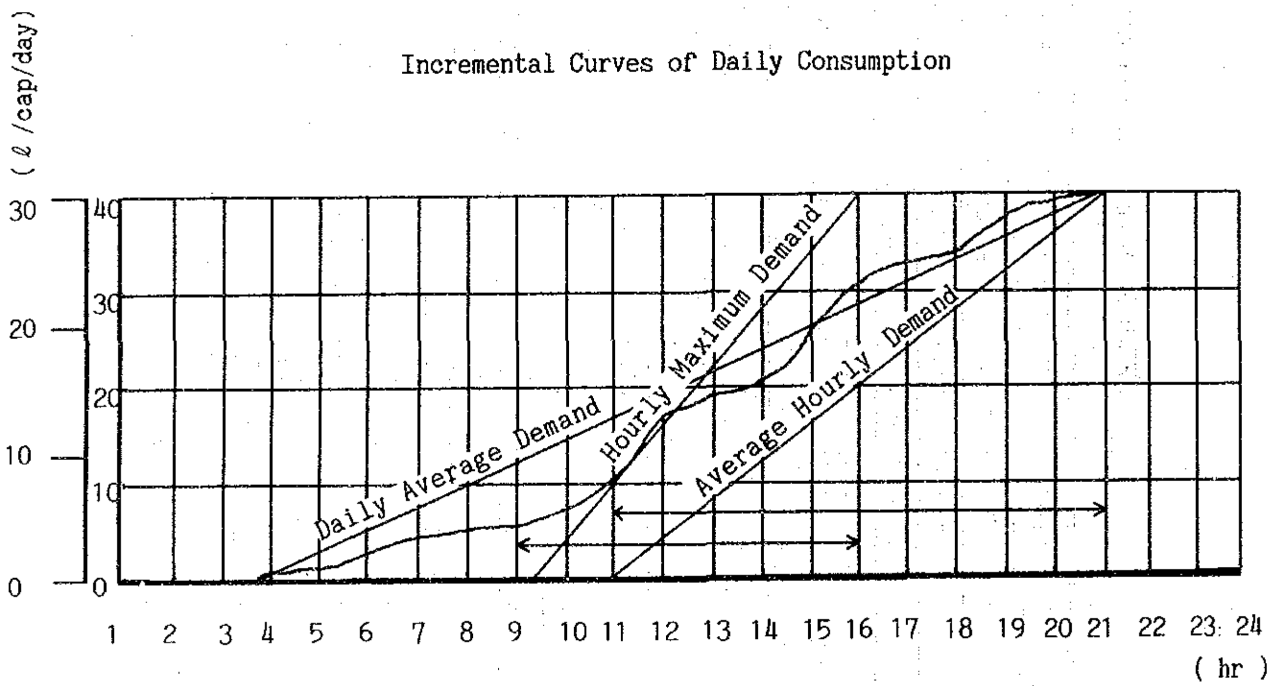
APPENDIX IV - d Considerations on Water Tank

No. Prty.	Site Name	Popula -tion	Type of Tank	Basic Storage Capacity (m^3/day)	Capacity for Booster Pump (m^3)	Emergency Storage Capacity (m^3)	Design Tank Capacity (m^3)	Nominar Tank Size (m^3)
1	Al Mallaheeth	4,670	Service	56.0	-	54.0	110.0	120.0
2	Iyal Qasim	2,188	Service	23.0	-	59.5	82.5	90.0
3	Khamis Bani Hajaj	2,188 1,313 4,377	Booster Booster Service	19.7 11.8 39.4	12.9 9.9 -	49.1 32.2 70.6	68.8 44.0 110.0	75.0 48.0 120.0
4	Al Usfyn	-	-	-	-	-	-	-
5	Al Husha (Zuran area)		Booster Service	31.5 73.5	12.0 -	51.0 91.5	82.5 165.0	90.0 180.0
6	Aflah Al Yaman		Service Booster Service	39.9 3.9 35.0	- 9.0 -	70.1 40.1 24.0	110.0 44.0 110.0	120.0 48.0 120.0
7	Al Ghudu	2,585	Service	23.3	-	45.5	68.8	75.0
8	Bait Al Sultan	3,939 1,313	Booster Service	35.5 11.8	3.0 -	74.5 32.2	110.0 44.0	120.0 48.0
9	Bani Afif		Booster Service Booster Service	23.5 9.1 16.3 47.0	8.1 - 9.0 -	59.0 23.9 52.5 63.0	82.5 33.0 68.8 110.0	90.0 36.0 75.0 120.0
10	Al Jabub	1,663 1,255	Service Service	13.5 10.2	- -	30.5 33.8	44.0 44.0	48.0 48.0
11	Mahalat Najr	1,167 1,751	Service Service	14.0 21.0	- -	30.0 47.8	44.0 68.8	48.0 75.0

Typical Daily Water Consumption Pattern in Villages



Incremental Curves of Daily Consumption



APPENDIX IV - e Operation and Maintenance Cost in The Project Area (1)

No. Prty.	Site Name	Drive Unit	Capacity	Daily Operating Hours	Hourly Fuel Consumption	Daily Fuel Consumption	Daily Fuel Cost	Daily Oil Cost	Daily Total (F/O)	Monthly Total (F/O)	Operators' Salaies	Maintenaunce Cost	Monthly Total OM cost
1	Al Mallaheeth	Engine	24.5 PS	8.9	4.1	36.5	146	15	161	4,830			
		Engine	24.5 PS	8.9	4.1	36.5	146	15	161	4,830			
					Total	73.0	292	30	322	9,660	5,500	1,516	16,676
2	Iyal Qasim	Generator	70 KVA	9.2	14.6	134.3	537	54	591	17,730			
					Total	134.3	537	54	591	17,730	5,500	2,323	25,553
3	Al Usfyn	Engine	40 PS	17.4	6.7	116.6	466	47	513	15,390			
		Engine	40 PS	17.4	6.7	116.6	466	47	513	15,390			
		Engine	40 PS	17.4	6.7	116.6	466	47	513	15,390			
		Generator	130 KVA	17.4	25.7	447.2	1.789	179	1,968	59,040			
					Total	797.0	3,188	319	3,507	105,210	19,000	12,427	136,631
4	Aflah Al Yaman	Generator	70 KVA	8.9	14.6	129.9	520	52	572	17,160			
		Generator	55 KVA	8.6	11.5	98.9	396	40	436	13,080			
					Total	228.8	916	92	1,008	30,240	11,000	4,124	45,364
5	Al Ghudu	Engine	35 PS	7.2	5.9	42.5	170	17	187	5,610			
					Total	42.5	170	17	187	5,610	4,000	961	10,571

APPENDIX IV - e Operation and Maintenance Cost in The Project Area (2)

No. Prty.	Site Name	Unit Water Cost			Monthly Operation and Maintenance Cost Borne by a household	Ration of Water Bill to Average Income/household	
		(a) Monthly Operation and Maintenance Cost (YR)	(b) Monthly Supply Rate (m^3)	(c) OM Cost per 1 m^3 (a) ÷ (b) (YR)	(d) (c) × 0.85 × 0.03 m^3 × 30 days	(e) Monthly Avearge income (YR)	Ratio (%) (d) ÷ (e)
1	Al Mallaheeth	16,676	4,203	4.0	* 41	2,500	1.6
2	Iyal Qasim	25,553	1,970	13.0	99	3,000	3.3
3	Al Usfyn	136,631	37,422	3.6	28	1,750	1.6
4	Aflah Al Yaman	45,364	5,910	7.7	* 79	3,330	2.4
5	Al Ghudu	10,571	2,327	4.5	34	3,330	1.0

* Average supply 0.04 m^3 /person/day2