CHAPTER VIII
GENERAL DESIGN CONSIDERATIONS & DESIGN CRITERIA

CHAPTER VIII

GENERAL DESIGN CONSIDERATIONS & DESIGN CRITERIA

8-1 Design Period

In order to make the necessary review of the rural water supply planning in 10 to 15 years from now, the design period was recommended to be 15 years as described in section 7-4-4.

This design period has the advantage to allow the present planning to adapt to the economic conditions 15 years from now which will be different from the present situation. At that time most of the machinery under the project will require rehabilitation and/or replacement due to its age.

8-2 Design Capacity of Water Supply

The water supply under the project requires a relatively high investment cost due to the scarcity of water and the location of the service areas which are higher up on the mountains than the water sources located at lower altitudes.

In addition, the size of the population to be served by the project differs from place to place and ranges from 380 to 15,000. Since the yield of a single borehole is limited due to the hydrogeological conditions in the site, multiple boreholes are required at some sites to meet the demand based on the design criteria proposed by the Ministry. Multiple boreholes will cause increases in the price of water. For this reason, further consideration is necessary to reduce the cost for the water source at some sites in order to have an equitable water supply based on the cost-effectiveness concept. (See Section 7-4-4)

At the sites where the yield of a single borehole is sufficient to meet the demand at service level A during the design period, the design capacity was determined to attain the maximum use of the investment for the water source, since the "sufficiency" of water source was determined in terms of relatively small demand rather than by an abundance of water. This design capacity was adopted for the following sites:

Elman & 4 Other Villages	(HA-2)
Hufash	(A-2)
Al-Rajam	(A-3)
Al-Khabet	(A-4)
Bany Shaker & Bait Abo Saba'a	(S-1)
Bait Abo Hashem	(S-2)
Al-Sheab Al-Aswad	(S-3)
Bany Farhan & Bany Saria'a	(S-4)
Ghulayfagah	(H-1)
Al-Mounirah	(H-3)
Al-Mashjab	(T-1)
Al-Manara & Al-Dukum	(T-2)
Al-Maydan, Al-Jubail Sheiba Hamud	(T-3)
Hadad, Qahfa	(T-4A)
Shohat, Al-Kadash	(T-5)
Yahkhtol	(T-8)
Makbana	(T-9)

On the other hand, the yield of a single borehole is not sufficient to meet the demand at service level A during the design period for the following sites:

Al-Madan & 8 Villages	(HA-1)
Shihara	(HA-3A)
Thari	(HA-3B)
Harad	(HA-4)
Al-Mahweet City	(A-1)
Al-Dahi	(H-2)
Bab-Al-Mandab	(T-7)

For these sites, it is proposed that the design capacity covers at least service level C demand (the minimum requirement for the human health) at the end of the planning period. The gap between the design capacity of the improved water supply and the total demand will be met by other water sources (proposed in the Technical Report, Hydrogeology and see section 5-4) which will be incorporated with the existing water sources.

Accordingly, the design capacity of the rural water supply at each site is summarized in Table 9-1 as shown in Fig. 7-5.

Therefore, the design capacity of the rural water supply in the project was determined in two ways: either by the future demand or by the capacity of water source. This design capacity represents the basic design capacity for each survey site.

8-3 Daily Consumption

The water consumption pattern observed at present in the sites during the field survey is summarized as shown in Fig. 8-1. Although there will be increases in the daily water consumption in future, the water use pattern will remain the same as shown in Figure 8-1 unless some substantial changes occur in the life style of the inhabitants. The daily peaks in the water use pattern are described below.

The first peak of water use in the morning indicates the water used for the morning prayer and the next peak is for the preparation of breakfast. The highest peak is observed at lunch time followed by intensive water use for washing in the early afternoon. The last peak of the daily water use represents the water consumption for supper.

According to the water consumption pattern, the daily activity of the people in the sites was estimated to last for 14 hours including intensive water use for a total duration of 10 hours. Based on those figures, the daily maximum demand and the hourly maximum demand were estimated as shown in Fig. 8-2. In the figure, the hourly maximum was estimated at 1.5 times the average hourly demand which is almost 1.4 times the daily average demand. The volume of daily per capita consumption varies from 20 to 40 L/cap/day based on the total demand or the availability of water.

As shown in Fig. 8-2, the maximum operating hours of machinery was determined as 19 hours and the average number of hours of service was estimated at 10 hours.
Consequently, the following design capacities were used for the design of the substantial water supply units.

$$\text{Average hourly capacity} \quad (Qhr) = \frac{\text{Basic Design Capacity } (Qo)}{10}$$

$$\text{Hourly maximum capacity} \quad (Qp) = 1.5 \times Qhr.$$

Fig. 8-1 Daily Water Consumption Pattern

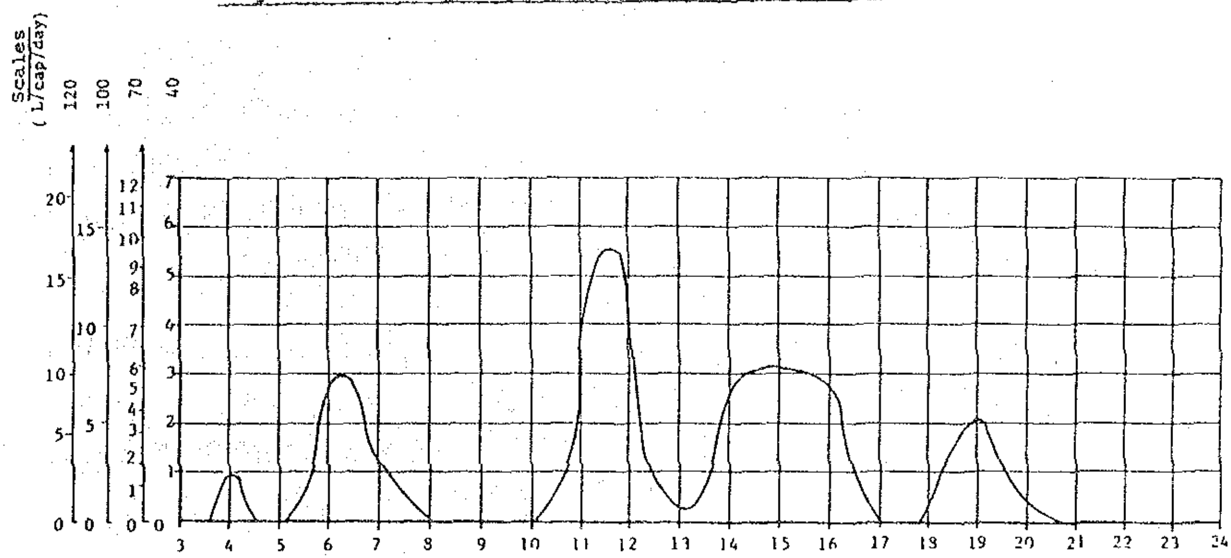
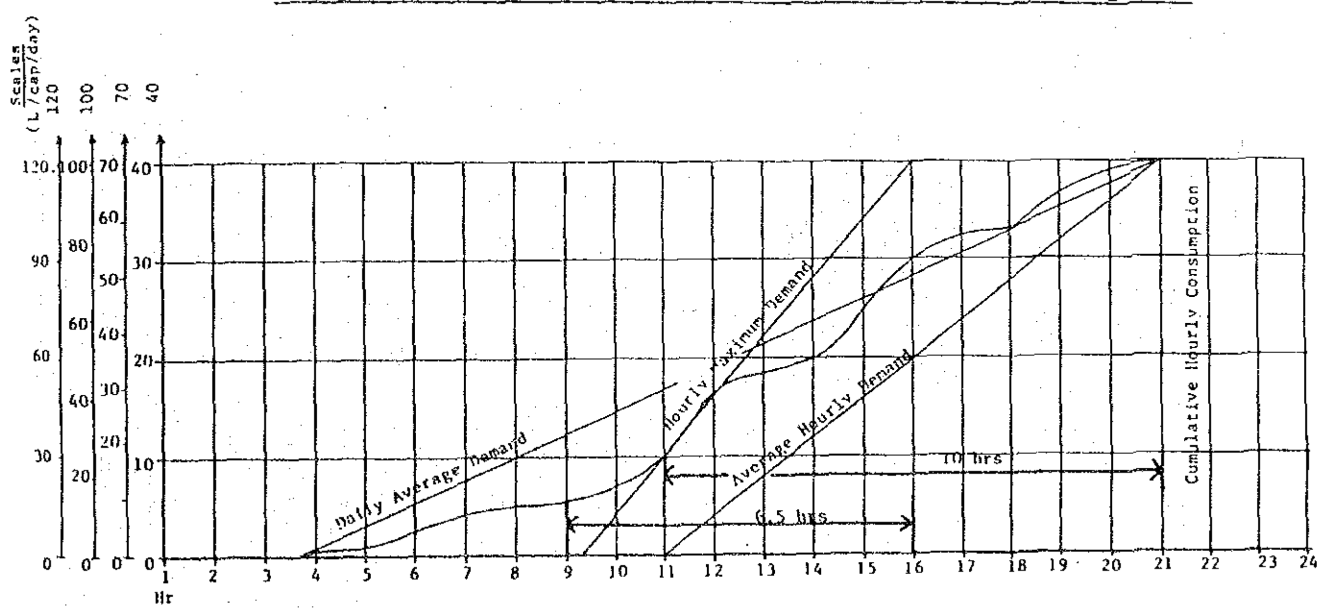


Fig. 8-2 Cumulative Curve of the Daily Water Consumption



8-4 Design Criteria for Distribution Tank and Service Tank

8-4-1 Determination of Construction Material for Water Tanks

Although masonry works have been highly developed in the Republic, construction work using concrete appears to be at a rather low standard since it was deserved in the field survey that some of the concrete-made water tanks were suffering from leaks with cracks in many places.

However, since the construction cost of concrete water tanks is much smaller than that of the other types of water tanks, the concrete water tanks are proposed for the ground and semi-elevated tanks in the coastal area.

For this purpose special consideration is required to protect the reinforcement steel bars in the concrete structure against rust due to high saline environment.

The methods to protect reinforcement steel bars in the concrete structure are classified into two categories:

1. To protect steel bars by an additional concrete cover thickness,
2. To protect steel bars with the chemicals mixed into the concrete.

Under the project, it is recommended to take the second method applying the corrosion inhibitors into the concrete.

On the other hand, for the water tanks to be installed in the mountainous areas, prefabricated steel tanks are proposed because of workability in the construction and the minimum requirement for material transportation.

Types of water tanks proposed for each survey site are summarized in the General Layout Plan of Water Supply System in the attached drawings.

In addition, as shown in the attached drawings, it is proposed to utilize the favourable topographic conditions for the location of water tanks so as to minimize the number of the elevated water tanks in the mountainous area.

Accordingly, the majority of water tanks are ground tanks and the semi-elevated tanks resting on concrete supports. The elevated tanks are proposed only at coastal area.

8-4-2 Design Capacity of Water Tanks

The design capacity of water tanks was determined by the daily water demand and the demand for other purposes in addition to the usual domestic demand. These other purposes are listed as follows:

Public Purposes	:	20% of The Basic Design Capacity
Hydrant Purposes	:	25% of The Basic Design Capacity
Emergency Purposes	:	2.5 L/cap/day

Since the basic design capacity was determined either by the future demand or by the limited volume of water source at each site, the magnitude of the basic design capacity differs from place to place. In addition, the occurrence of hydrant (fire fighting) requirements will be sporatic.

Accordingly, the larger volume of either public or hydrant was added to the design capacity of water tanks as Qr.

The rural water supply facilities are subject to various kinds of accidents. For this reason, consideration was made for emergency need which would arise accidentally.

In the Republic, repair work for water supply facilities took on average of 7-9 days in rural areas according to past experience. Assuming that the daily basic water requirement for an adult single person is 2.5 liters, the amount to meet this demand for nine days in case of emergency will be necessary.

Since the total population consists of a large proportion of women and children, the design capacity for emergency purposes was determined as 70% of the above volume: i.e.,

$$Qe \simeq 2.5 \text{ L/cap/day} \times \text{Total Population} \times 0.7$$

Although the provision of the above listed three items of water is necessary for the determination of the design capacity of water tanks, the magnitude of required water volume is rather large when compared with the design capacity of the water tanks for domestic purposes.

Therefore, only the largest of these three volumes of water was included in the actual design capacity.

8-4-3 Type of Water Tanks

The water tanks of the rural water supply under the project were classified into four types:

1. Service Tank

   The major function of this tank is to store necessary volume of domestic water and to distribute the water through public taps.

   The design capacity of the service tank is equivalent to the total of the hourly maximum demand for three hours (Qp x 3) plus the larger of two additional volumes (either Qr or Qe). The exact location of service tanks will be determined in the detailed design incorporated in the future development plan of the village.

2. Distribution Tank

The major function of this tank is to distribute the water to the service tanks. Since this tank serves the function of branch pipes, no large design capacity is required. The design capacity of this type of tank was determined as the hourly maximum demand for one hour. (Qp)

3. Booster Pump Station Tank

This tank is installed at the booster pump station and its fundamental function is to join pipes. The minimum design capacity should be sufficiently large to prevent air flowing into the pipes.

The design capacity of the tank was determined as the average hourly demand for 30 minutes. (Qhr x 0.5)

4. Booster Pump Station Tank with Service Taps

This tank is installed at the booster pump station where water is required through service taps connected to the booster pump station tank. The design capacity was determined as the hourly maximum demand for three hours (Qp x 3) plus the demand for one hour of the design capacity of the pump. (Qhr)

A water level indicator should be provided for all types of tanks.

8-4-4 Design Criteria of Pipelines

Most of the survey sites are located either on the rocky mountain slopes or on the coastal plain on predominantly highly saline soils.

Accordingly, it is recommended that in the rocky mountainous areas pipelines be placed on the surface of the ground because of the high cost for excavation of the rocky terrain.

This plan has advantages in terms of easy identification of leakage and easy repair. For this reason, galvanized steel pipes are recommended with the necessary anchors for pipelines in the mountainous areas. In addition, expansion loops should be placed at 250 m intervals to prevent accidents caused by significantly different variations of the ground surface temperature.

On the other hand, in the coastal areas it is recommended that asbestos cement pipes be used for pipelines to prevent troubles caused by highly saline environment. This plan has economic advantages for the rural water supply because the cost of asbestos cement pipes is less than galvanized steel pipes even including the earth work necessary for asbestos cement pipe placement. For this purpose, first grade asbestos cement pipes, which are durable to the water pressure of 28 kg/cm^2, are recommended.

However, asbestos cement pipes requires earth work and at least 0.6 m earth cover is necessary for general purposes 1.2 m of earth covering where the pipe crosses under roads.

Galvanized fittings should be used for different size pipes and asbestos cement collars are available for the joints of the same size pipes.

Based on Fig. 6-3, the selection of the optimal size of pipe for required capacity of water was determined as shown below:

Optimal Pipe Size	Required Water Capacity
ø 1'	15 - 75 L/min
ø 2'	75 - 217 L/min
ø 3'	217 - 583 L/min
ø 4'	583 - 1,250 L/min
ø 6'	1,250 - 1,783 L/min

8-4-5 Design Criteria of Pumping Facilities

Electric submersible pumps driven by water-cooled diesel engines are recommended for the water sources. Pumping housing should be provided and the foundation of the diesel engine should be independent from the floor slab of the pump house.

In case the well is located inside the pump house, openings with covers should be provided for repair purposes; however, there is no necessity to arrange a hoist crane for repair purposes since the machinery is relatively light. Where the service area is located either at a higher elevation from the level of water source or at a remote place, booster pump stations should be provided. The operation of pump and engine at the water source and the booster pump station should be controlled by an automatic electric system. The automatic system should be controlled by electro-magnetic valves and ball taps. For the protection of this system, pipes should be provided for the electric cables.

Considering circumstances of a control panel, specifications of relays should be "tropical specifications" and the structure of the control panel should be resistant to moisture and dust. To ease identification of troubles, the control panel should be provided with an alarm or trouble indicator.
For the security of the electrical system from strangers, the control panel should have a lock system.

8-4-6 Design Criteria of Service Facilities

Service facilities consist of the public taps, the cattle troughs and the sewer basin. The public taps are to be installed at the rate of one tap for every 200 people. The minimum number of taps at a single service point was determined as four units.

The length of cattle trough was determined as one meter for every 200 head. The minimum length of the cattle trough is proposed to be 4 m.

The sewer basin is to be located more than 50 m from the taps. The size of surface area was determined by the number of taps at the rate of 1 m^2 for each tap. The minimum size of surface area should be 4 m^2. The surface level of the sewer basin was designed to be 1.5 m lower than the ground surface with gravel and sand layers 15 cm thick.

At some sites under the project, especially in Hajja and Al Mahweet Governorates, the relative height between the service area and the water source is considerably high.

Accordingly, different types of booster pump stations are required and the construction cost of these booster pump stations shows high cost impact for the water supply schemes of these sites.

In order to minimize the investment cost of the booster pump stations, cost analysis is made for different types of pumping methods.

For this purpose assumptions are made that three types of booster pump are used to lift up water for 500 m and each cost component is estimated in different design capacities as shown in Table 8-1 and Figs. 8-3 to 8-5.

As shown in the figures, the largest cost component of the booster pump station is that of the generator; the high pressure pump requires the largest investment cost.

The comparison of the total construction cost of different types of booster pump stations is made as shown in Fig. 8-6. This figure clearly shows that the low pressure, 100 m head, pump station is the most economical for the design capacity more than 0.55 m^3/min. In the range of small design capacity, however, a 2-stage system with 250 m head pumps requires the minimum investment cost.

The required design capacities for these survey sites range from 100 to 460 m^3/day which is equivalent to the range from 0.1 to 0.4 m^3/min assuming maximum 19 hrs operation. Therefore, it is concluded that the combination of 100 m and 250 m head pumps is the most economical design for the booster pump stations for these survey sites.

As shown in Figs. 8-3 to 8-5 the cost component of the generator has the highest impact to the total construction cost of booster pump stations. Therefore, the comparison of cost for generators was made in two cases; the independent control of generators and the centralized control of generators.

The investment costs of generators in different capacities are shown in Fig. 8-7 which indicates that when the total capacity is larger than a few hundred kVA, the centralized control system is cheaper than the individual control; however, the centralized control is more expensive when small numbers of stations are required with a small total capacity. In case of the extremely small total capacity requirement, the centralized control is most economical.

In Fig. 8-8, the required capacity and its cost of generators are compared in all sites which require high lift up of water to the service area. It is indicated in the figure that at the majority of these sites, the individual control system is more economical than the centralized system except at the sites Al Mahweet City (A-1) and Hufash (A-2). Therefore, considering the necessary additional cost of the electric cables for centralized operation system, the provision of electric power at each individual booseter pump station is recommended.

8-4-6 Design Criteria of Service Facilities

In the rocky area, pipelines should be laid on the ground surface due to the difficulty of excavation. An expansion joint should be used against the variation of temperature. In the case of using of high pressure pipes, workability of pipe bending will be very hard because of the thick thickness of the pipe wall. Accordingly, it is recommended to construct a multi-booster pump station to reduce the water pressure.

Table 8-1

Construction Cost of Booster Pump Station

(Length of Pipe 1,000M)
(Actual Head 500M)

Pump	Capacity (m^3/min.)	Cost of the Construction Work (Y.R.)			
		Pump	Generator	Pipe	Total
	0.2	238,000	106,000	400,000	744,000
500m x 1 set	0.4	308,000	520,000	500,000	1,328,000
	0.6	380,000	660,000	620,000	1,660,000
	1.5	600,000	1,200,000	700,000	2,500,000
	0.2	136,000	136,000	86,000	358,000
250m x 2 sets	0.4	154,000	198,000	100,000	452,000
	0.6	214,000	308,000	132,000	654,000
	1.5	480,000	1,320,000	700,000	2,500,000
	0.2	146,000	186,000	86,000	418,000
100m x 5 sets	0.4	180,000	246,000	100,000	526,000
	0.6	198,000	300,000	132,000	630,000
	1.5	270,000	530,000	160,000	960,000

Fig. 8-3 INVESTMENT COST OF BOOSTER PUMP STATION (5-Stage)

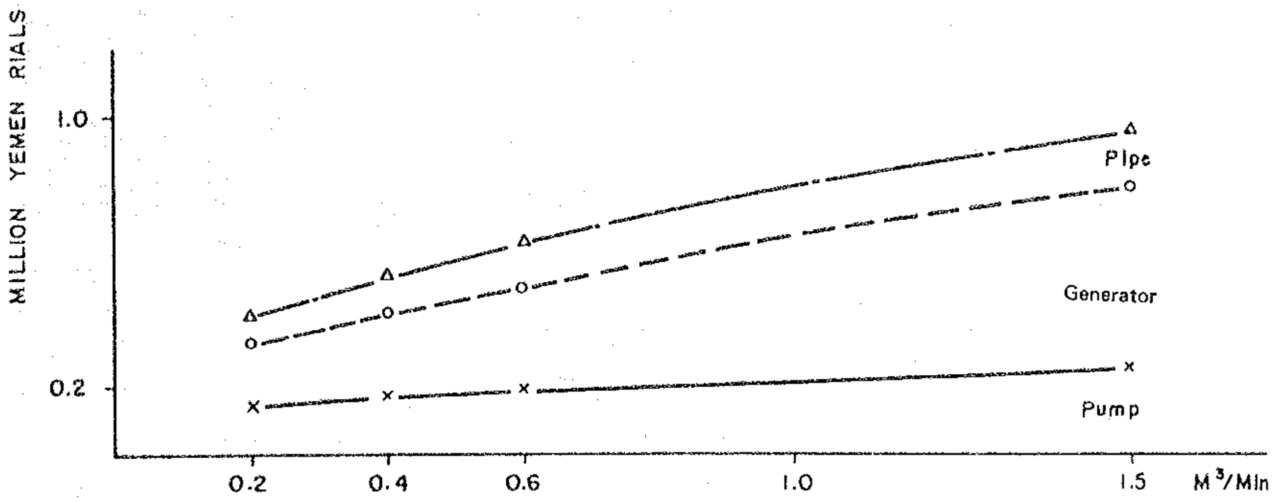


Fig. 8-4 INVESTMENT COST OF BOOSTER PUMP STATION (2-Stage)

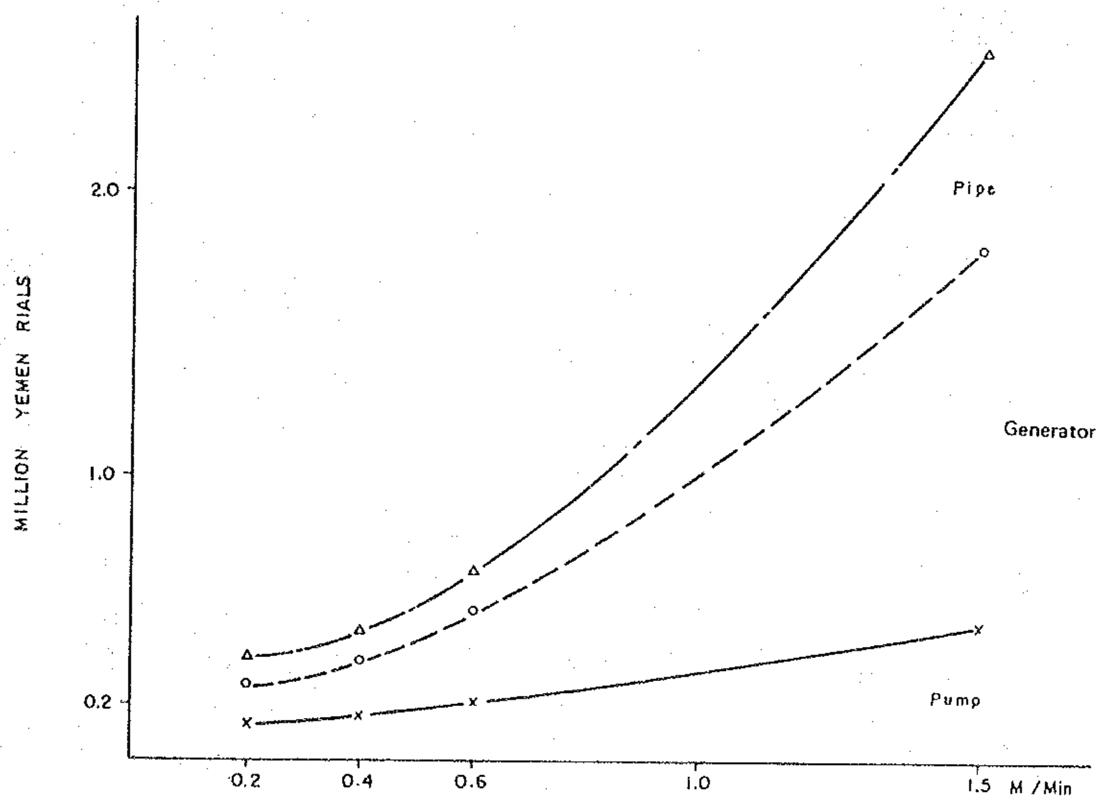
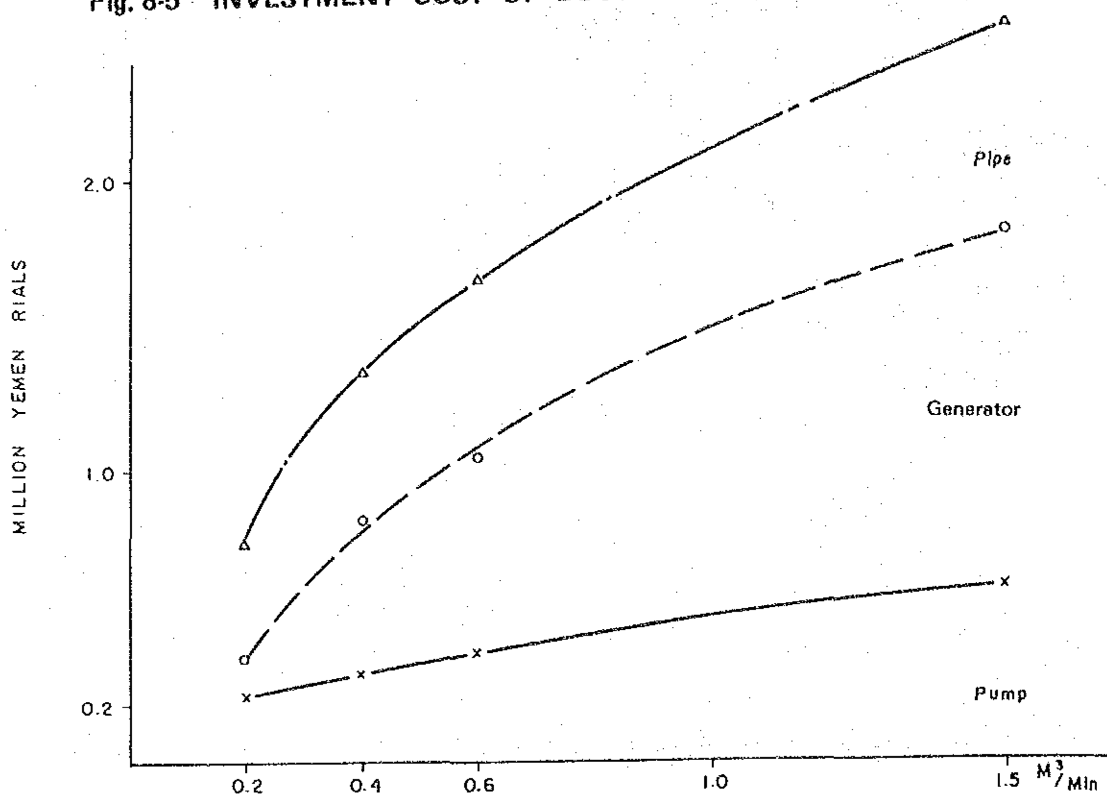


Fig. 8-5 INVESTMENT COST OF BOOSTER PUMP STATION (1-Stage)



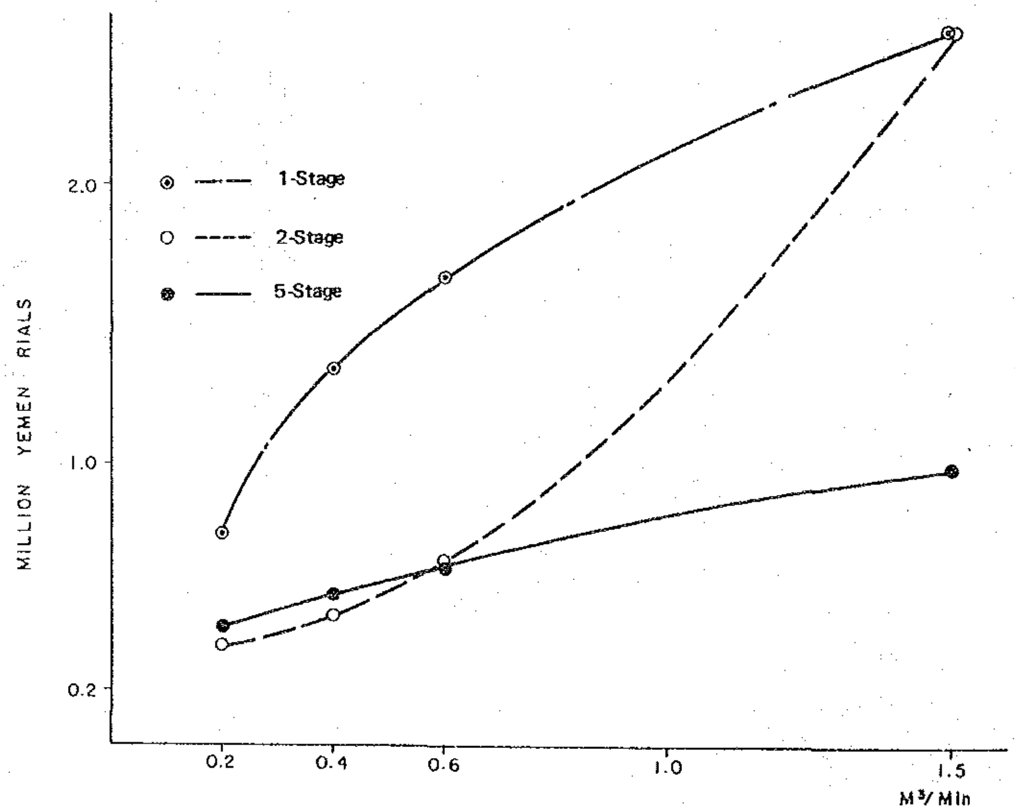


Fig. 8-7 INVESTMENT COST OF GENERATORS

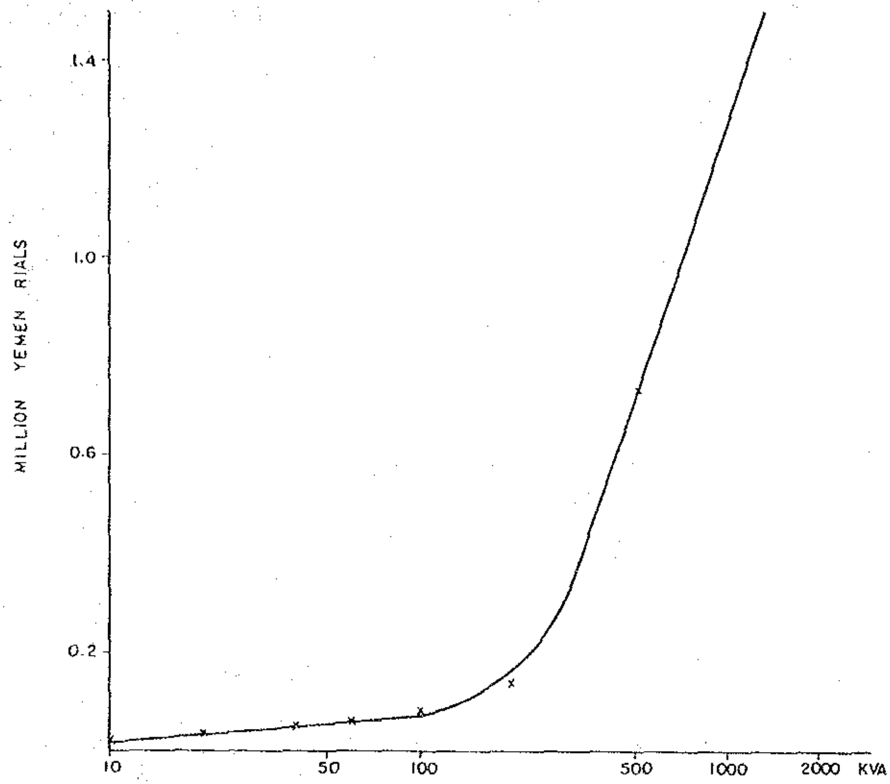
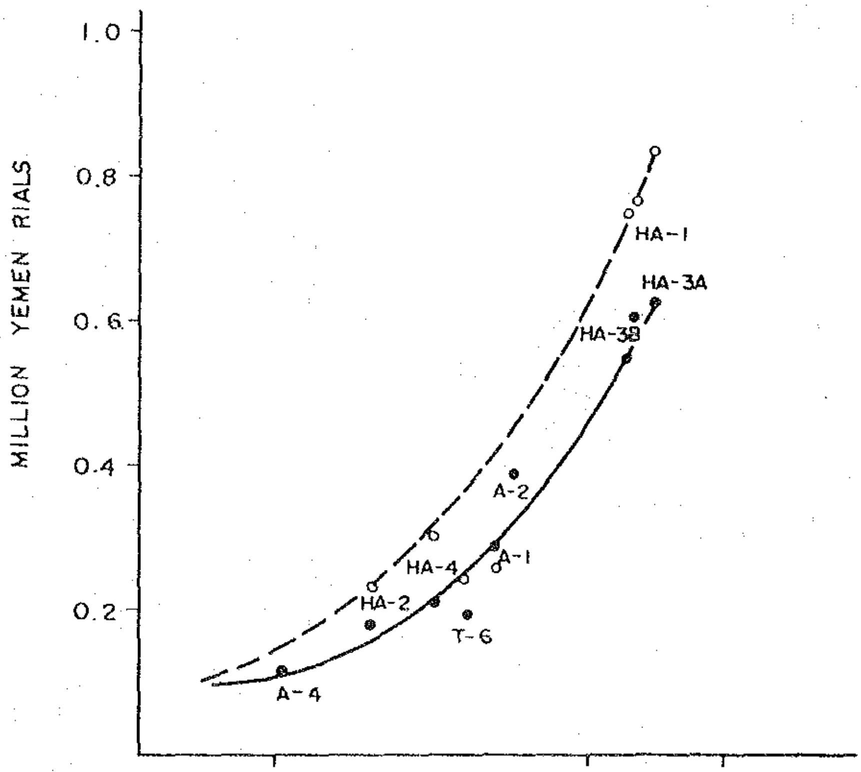


Fig. 8-8 COMPARISON OF GENERATOR SYSTEMS



CHAPTER IX
PROPOSED WATER SUPPLY SYSTEM FOR THE SURVEY SITE & BASIC DESIGN

CHAPTER IX

PROPOSED WATER SUPPLY SYSTEM FOR THE SURVEY SITE & BASIC DESIGN

9-1 Introduction

In order to provide the solution for the accute shortage of the domestic water at all survey sites, the basic design was proposed for each survey site based on the cost effectiveness concept.

However, no basic design was proposed for the site T-4B and T-6 in Taiz Governorate since no Promising water source was found in the vicinity of each site at this stage of the study. (see Section 7-4-1) It is urgently recommended to undertake the water master plan for the coordinated solution to combine resources on a regional level instead of allocating a smaller amount of resources for each individual village.

The sub-surface reservoir was proposed for the site Shohat/ Al Kadash (T-5) where the preferable topography and the groundwater source were available for this purpose.

In the attached drawings, an approximate location of the water source, pumping station, distribution tanks were indicated at each survey site, however, the exact location of facilities are to be determined in the detailed design stage based on the result of detailed topographic survey. Also, the final design of the service facility (service tank, public taps and cattle troughs) should be determined at the detailed design stage incorporated in the future plan of each site.

An approximate construction cost of each proposed water supply system was estimated. For this purpose, the cost of material and other items were obtained from the Unit Rates for Estimating the Cost of Projects and the Builders Price Book Volume 1 published by the M.P.W. in 1979.

However, the cost for the booster pumps and the submercible pumps were not listed in the above documents in a sufficient range of the design capacity. Therefore, an estimated cost at F.O.B. Tokyo in April, 1979 was adopted for these items. These costs are subject to increase due to transportation and inflation.

Since the major type of water source is the groundwater, the drilling cost is an important item for cost estimate. The unit cost of drilling, material and pumping test were estimated as shown in the section 6-3-2 based on the assumption that the drilling machinery and material are available at Sana'a.

9-2 General Conditions of The Sites in Relation to The Construction of Rural Water Supply

Since the survey sites distribute over the country in a various locations the general conditions of each site varies from place to place. The important aspects for the implementation of the rural water supply schemes are the availability of satisfactory water sources, the topographic conditions in the area between the water source and the service area, and the accessibility to the site.

In this respect, the necessary general consideration for the implementation of each rural water supply scheme is given in the following paragraphs of this section.

9-2-1 Al-Madan and 8 Villages : Site No. HA-1

This site is located in a steep mountainous area in the Hajja Governorate. The service area is situated on the top of mountains and the steep upper slopes which cover almost 10 Km2. As the only available water source in this site is found on the floor of wadis far below the service area, multiple booster pump stations are required. For this purpose, further detailed survey will be necessary to determine the final location and the type of construction of pipelines and booster pump stations.

In addition, extension of road width is necessary for about 300 m on the way from the village to the proposed water source in Wadi Gaaman.

9-2-2 Elman and 4 villages : Site No. HA-2

The service area of this site is also located on the mountain slopes in the head water area of Wadi Nahar and separated by cliffs of 250 m from the land below.

The relative height between the service area and the water source on the wadi floor is about 600 m. Multiple booster pump stations are required. For this purpose detailed survey will be necessary to determine the final location and the type of structure of pipelines and booster pump stations.

In addition, road construction is necessary for about 3 Km to the proposed water source on one of the tributaries of Wadi Nahar.

9-2-3 Sihara : Site No. HA-3A

The service area of this site covers a wide area of about 18 Km^2 ranging from the mountain top (2,500 m A.S.L.) to the foot hills at an altitude of 1,300 m A.S.L. The center of the village is located on the top of mountain above an altitude of 2,300 m A.S.L.

The mountains are deeply dissected by valleys such that steep cliffs are a prevalent topographic feature. A narrow and steep rocky road is the only access to the center of the village.

Taking the hydrogeological conditions and the accessibility of the water source into consideration, it is proposed to drill a borehole on the floor of wadi at an altitude around 1,200 m A.S.L. A detailed topographical survey will be necessary to determine the exact location of water supply facilities.

9-2-4 Thari : Site No. HA-3B

The topographic conditions of the service area of this site are similar to HA-3A, Shihara and the majority of the population is also concentrated on the top of mountain; however, the service area extends over a 26 Km^2 area.

The pontential water sources for this site are available at Wadi Nahar to the west of the site and Wadi Swuar to the east; however, the gradient of the wadi bed is rather steep above an altitude of 1,500 m A.S.L. in the both wadis. Considering the topographic conditions, the water source for this site was proposed at the floor of Wadi Nahar at an altitude of 1,400 m A.S.L.
As with site HA-3A, the accessibility to the service area, the water source and construction sites of booster pump stations are very poor due to steep and rocky topography.

9-2-5 Harad : Site No. HA-4

This survey site consists of two villages new and old Harads located on the Tihama Coastal Plain at an altitude of 100 m A.S.L. The distance between the new and the old Harads is about 1.5 Km and Wadi Harad flows to the west in-between the two Harads. Since the rapid growth of this site is expected as a transportation terminal at the country's border domestic water is urgently required.

Three boreholes are proposed for the water sources of this site. A topographic survey is necessary for the preparation of the detailed design. No difficulty in accessibility was observed; however, construction should be undertaken during the dry season.

9-2-6 Al-Mahweet City : Site No. A-1

This site is located on the top of mountain on the upper slopes at altitudes between 2,000 and 2,100 m A.S.L. The major topographic feature in the area is steep rocky mountain slopes.

Since this site is the center of the Al-Mahweet Governorate, the provision of safe and sufficient domestic supply is urgently required.

For this purpose, the Ministry proposed a design for the improvement of the water supply system. However, the proposed water source is a small spring at Sael Al Eyown far below the City and sufficient back up data of the spring yield is not available.

Since the water source is located on the bottom of the Sael Al Eyown river where floods occurs several times a year and the relative height between the spring and the service area is almost 500 m, an alternative source, deep groundwater, was proposed. (See the Technical Report Hydrogeology)
At present no access is available to the proposed water source from the city and a topographic survey should be undertaken for the final determination of the location of pipelines and booster pump stations in the detailed design stage.

In addition, Sael Al Eyown spring which is proposed by MPW is also studied in this report.

9-2-7 Hufash : Site No. A-2

The service area of this site extends over a wide area and the center of the village is located on the top of mountain at an altitude of 2,100 m A.S.L. The mountain is deeply incised by valleys, and cliffs and steep slopes predominate in the area.

Several springs presently serve as domestic water sources. However, their utilization for future permanent water source planning is not recommendable since the location of spring is just below the mountain summit and the recharge area of the spring water appears to be very limited.
Accordingly, a borehole is proposed for the water source of this site in the fracture zone of the fault along Wadi Sheahe around Madeh.

At present, accessibility to the water source, the construction site of pipelines and booster pump stations and the service area are very poor.

9-2-8 Al-Rajam : Site No. A-3

The service area of this site occupies a rather limited extension of area located on the corner of the basin-like topography at an altitude of 2,000 m A.S.L. Based on the result of the field survey, it was found the ground water was an only available permanent water source of the rural water supply. The location of a borehole is proposed at the area where two faults cross to the west of the center of the village.

Since the general topography around the site is moderately level, no difficulties are expected for the construction of the borehole and the other facilities. However accessibility to the site is very poor.

9-2-9 Al-Khabet : Site No. A-4

The service area of this site extends over a wide area ranging from the bottom floor of the wadi to the summit of the mountain. The center of the village is located on moderately level mountain slopes at an altitude of 1,200 m A.S.L.

Two wadis are located nearby the site; however, due to periodical floods and only a seasonal flow of water, the surface water in these wadis were not considered as the permanent source for domestic water of the site. A borehole is proposed for the water source of this site along Wadi.

Accessibility to the site and the water source is satisfactory; however, it is not easy to approach the construction site of the pipelines and booster pumps.

9-2-10 Bany Shaker and Bait Abo Saba'a : Site No. S-1

The service area of this site is located along a small valley surrounded by high mountains. The altitude of the mountain tops reaches 2,300 m A.S.L.

At present, accessibility from the main road to the site for about 2 Km is very poor but road improvement is being undertaken now. However, accessibility to the construction site of pipelines and booster pump stations will still be very poor.

A borehole is proposed for the source of rural water supply; however, a feasibility study for the construction of the reservoir and for the horizontal boring are proposed for the future water source.

9-2-11 Bait Abo Hashem : Site No. S-2

The service area of this site is located on undulating ground surface on a large scale plateau at an altitude of 2,200 m A.S.L. The fringe of the plateau area is deeply incised by valleys flowing into the Wadi about 50 m below the plateau.

A borehole is proposed for the permanent source of domestic water of this site.
Accessibility to the site is satisfactory however, the access to the construction site of pipelines and the water source requires improvement.

9-2-12 Al-Sheab and Al-Aswad : Site No. S-3

The service area of this site is located on the terrace of a mountain. The lower slope from the site is deeply incised by valleys.

During the field survey, the drilling site was located by the survey team and the result was successful.
However, accessibility to the construction site of pipelines should be improved for the implementation of the scheme.

9-2-13 Bany Farhan and Bany Saria'a : Site No. S-4

The topographical setup of this site is similar to the site S-3 and a borehole along the wadi was proposed for the source of domestic water in this site.

Accessibility to the site is satisfactory except for a few hundred meters in the village however, the approach to the construction site of pipelines is poor. No alternative water source is expected at present stage in this site.

9-2-14 Ghulayfagah : Site No. H-1

This site is located on the coastal plain along the Red Sea at a few kilometers from the shore line. The groundwater surface is available in the vicinity of the village.
Accessibility to the site is satisfactory.

9-2-15 Al Dahi : Site No. H-2

This site is also located on the coastal plain. At present partly private service connections of water supply were observed. There is the design of water supply for improvement of the existing system.

Accordingly it was requested that the provision of water source and the storage tank by the local authority. For this purpose, a borehole was proposed in the vicinity of the village.

9-2-16 Al-Mounirah : Site No. H-3

This is the water source for the villages Ebn Abbas and Al Harunia located 16 Km and 22 Km away from the water source. Since only available water source (groundwater) at the service area of the two villages is contiminated by high salinity, the water source was sought at this site about 15 Km inland from the sea shore. No difficulty was observed in accessibility to the service areas and the water source.

9-2-17 Al-Mashajab : Site No. T-1

The site is located at the opening of the Wadi Mashjab from the mountainous area to the open flat land. The service area is located on the lower mountain slope at an altitude of 1,200 m A.S.L.

The proposed water source is a borehole drilled in the wadi floor.

Accessibility to the service area and the water source is satisfactory however, the approach to the construction site of pipelines is difficult at present.

9-2-18 Al-Manara & Al-Dukum : Site No. T-2

This site is located in a matured stage of geomorphology developed on precambrian rocks. Predominating topography is a deep "V" shaped valleys surrounding the site. General setup of this site is similar to the site Al Mashajab (T-1) and a borehole was proposed for a source of domestic water of this site.
Accessibility to the water source and the service area is satisfactory however, the approach to the construction site of pipelines is observed rather difficult at present.

9-2-19 Al-Maydan, Al-Jubail and Sheibd Hamud : Site No. T-3

The service area of this site consists of three villages located on a slightly hilly terrain at an altitude of 1,500 m A.S.L.
Each village distributes within a few kilometers apart from each others. Trees are observed along the small wadis flowing among low hills.

A borehole was proposed for the water source of this site on the flat terrain in-between Al-Maydan and Al-Jubail. For the implementation of the scheme, the improvement of the existing road will be necessary at a few places and accessibility to the construction site of pipelines is to be constructed.

9-2-20 Kadad and Qahfa : Site No. T-4A

The service area of this site is located along the Torba Road about 5 Km from Taiz Town, accordingly there is no difficulty in accessibility. A borehole was proposed for the water source of this site under the project however, the feasibility study for the construction of a reservoir along the valley in the south of Qahfa for the increasing demand of the future water supply.

9-2-21 Shohat and Al-Kadash : Site No. T-5

The service area of this site is located on a relatively flat terrain at an altitude of 1,600 m. Since this site is one of the problematic sites together with T-4B and T-6 and it is proposed to undertake a feasibility study to solve the regional problem for water source.

However, at this site the subsurface reservoir was proposed for the water source based on the result of field survey.

Assuming the 20% of effective porocity and 10 m of the maximum thickness of aquifer, it is estimated that some 100,000 m^3 net storage capacity will be obtained for the source of the rural water supply for this site.

Further detailed geophysical survey will be necessary for the implementation of the scheme.
In addition, the improvement of the existing road to the site is necessary for about 300 m.

9-2-22 Bab-Al-Mandab : Site No. T-7

The service area is located in the coastal area of the mouth of Red Sea where the ground water is highly saline with high conductivity. According to these conditions, drinking water is supplied by a desalination plant.

Considering the high price of water, an alternative water source is required in spite of its being faraway.
Therefore, a deep well is proposed 30 Km to north, far from the village.

9-2-23 Yahkhtol : Site No. T-8

The service area is located in the coastal plain where the ground water is contaminated by high salinity. Accordingly the water source was located 16 Km from the village.

A borehole was proposed for the water source of this site.
No difficulties in accessibility is observed.

9-2-24 Makbana : Site No. T-9

The service area of this site extends over a wide range on the slopes of low mountains in the area and the center of the village is located on the highest top of the mountains.

There is a large wadi to the south of the site. Many shallow dug wells are well utilized for irrigation on the wadi floor. However, it was observed that the water level in the wells significantly fluctuate by seasons.

Therefore, a borehole was proposed for the water source of the site along the fracture zone in the wadi.

9-3 Future Demand of Rural Water Supply and Design Capacity

Future demand of the rural water supply at each survey site is estimated according to the design criteria proposed by the Ministry for the analysis of the price of water based on the cost-effectiveness concept. (see Table 7-3)

However, Fig. 7-6 indicates that the cost for the water source has significant impact to the unit price of water under the project due to the rather dry climatic conditions which also is reflected in the given condition of the human geography at the survey sites. Accordingly, in order to maintain an equitable allocation of the safe domestic water among all of the survey sites, consideration was given to minimize the unit cost impact of water source to maintain human health. Based on the above analysis the design capacity of the rural water supply at each survey site was determined as shown in Table 9-1.

9-4 Proposed Water Source

As discussed in Chapter IV, the objective of this project is to provide for the solution to the accute shortage of safe domestic water at the survey sites.

For this purpose, the determination of the type of water source proposed for each survey site was made based on conditions as shown below:

1. The major objective of this project is to provide the safe and sufficient domestic water for immediate use.

2. Since immediate decisions were required and back-up data was insufficient, potential water sources like springs, surface water for reservoir, shallow wells in the wadi floor were discarded from consideration. All these potential water sources are subject to seasonal fluctuation of the available volume of water.

Under the circumstances, deep groundwater sources were proposed for most of the sites to ensure the provision of stable and safe water sources as shown in Table 7-4.

9-5 Proposed Basic Design of The Rural Water Supply

Taking the results of the above analysis into consideration, the basic design of the rural water supply for each survey site was proposed as shown in Table 1 - 4 in the Drawing List. The location and general layout is shown in the drawings (See Drawings B Location and C General Layout).

Summary of the basic design for each survey site and the comparison of the present state of rural water supply with the proposed design are summarized in Table 9-2.

9-6 Estimated Construction Cost

Estimated construction cost at each survey site is summarized in Tables 9-3 (Y.R.) and 9-4 (Yen). The total construction cost including service facilities of rural water supply ranges from YR 0.6 million to YR 11.5 million depending on the specific conditions at each survey site.

However, the per capita investment cost of rural water supply falls in the range between 173 and 2,954 YR/cap. The per capita investment cost at 50% of the total number of the survey sites is estimated at less than 1,000 YR/cap. At the other 35% of the total number of survey sites, the per capita investment cost is estimated at between 1,000 and 2,000 YR/cap. The per capita investment cost exceeds 2,000 YR/cap at two sites, Bany Shaker/Bait Abo Saba'a and Bait Abo Hashem at Sana'a Governorate. However, as the design capacity of these two sites is rather small, the construction costs of the two sites requires only 3.9% of the total construction cost of the project.

Almost 65% of the total construction cost estimated (YR 79.6 million) will be utilized at these sites which require the per capita investment cost less than 1,000 YR/cap.

In conclusion, the average investment cost of the rural water supply under the project is estimated at 594 YR/cap and the total investment cost at YR 90.7 million.

However the total construction cost is not included consultancy cost (10% of total construction cost) and contingency (10% of total construction cost).

TABLE 9-1

PROPOSED DESIGN CAPACITY

SURVEY SITES		FUTURE DEMAND BASED ON THE MPW DESIGN CRITERIA (m^3/day)	DESIGN CAPACITY (m^3/day)	SERVICE LEVEL
HA-1	Al-Madan & 8 Villages	665	460	C
HA-2	Elman & 4 Villages	900	100	A
HA-3	Sihara	882	460	C
HA-3B	Thari	1,075	460	C
HA-4	Harad	1,205	1,508	A
A-1	Al-Mahweet City	831	460	C
A-2	Hufash	93	93	A
A-3	Al-Rajam	52	52	A
A-4	Al-Khabet	95	95	A
S-1	Bany Shaker & Bait Abo Saba'a	37	37	A
S-2	Bait Abo Hashem	36	36	A
S-3	Al-Sheab, Al-Aswad	207	207	A
S-4	Bany Farhan & Bany Saria'a	49	49	A
H-1	Ghulayfagah	34	34	A
H-2	Al-Dahi	2,124	1,580	A
H-3	Al-Mounirah	172	172	A
T-1	Al-Mashjab	105	105	A
T-2	Al-Manar & Al-Bukum	89	89	A
T-3	Al-Maydan, Al-Jubail Sheiba Hamud	82	82	A
T-4A	Hada, Qahfa	128	128	A
T-5	Shohat, Al-Kadash	150	150	A
T-7	Bab-Al-Mandab	1,078	1,078	A
T-8	Yahkhtol	338	338	A
T-9	Makbana	602	550	A

Table 9-2

Summary of Basic Design For Rural Water Supply

Table 9 - 2

Site No.	Survey Site	Distance From Sana'a	Condition of Access Road	Actual Condition of Water Supply: No. of Population	No. of Livestock	Water Consumption l/c/day	Water Source (Distance to it)	Planned Water Supply: Number of Population	Number of Livestock	Design Capacity	Planned Water Source (Distance to it)	Planning of Construction: Number of Well Depth of Well	Size of Submerge Pump	Tank of Water Source	Actual Head (m) Length of Pipe (Km)	Distribution Tank
HA-1	AL-MADAN & 8 VILLAGES	177 Km	Improvement Req.	7,500	3,680	14.3	Spring/S.Well (2 Km)	11,685	5,734	20 l/c/day	D. Well (0.5-1.0 Km)	2 - 300 m	30 KW	15 ton	1190 m 9.3 Km	600 ton
HA-2	ELMAN & 4 OTHER VILLAGES	174	Improvement Req.	1,500	1,470	10.0	Spring/S.Well (2 Km)	2,173	2,129	40 "	D. Well (0.5-1.0 Km)	300 m	30 KW	10 "	450 m 3.1 Km	120 "
HA-3-A	SIHARA	172	Good	4,500	8,830	11.4	Cistern (1 Km)	10,785	21,162	20 "	D. Well (0.5-1.0 Km)	2 - 300 m	30 KW	15 "	1200 m 11.0 Km	420 "
HA-3-B	THARI	180	Improvement Req.	15,000	15,000	6.0	Cistern/Spring(10-15 Km)	23,370	23,370	20 "	D. Well (0.5-1.0 Km)	2 - 200 m	19 KW	15 "	1000 m 8.0 Km	324 "
HA-4	HARAD	377	Good	7,000	6,620	21.4	S.Well (1-2 Km)	16,776	15,865	40 "	D. Well (0.5-1.0 Km)	3 - 120 m	26 KW x 2.30 KW	Old 396 New 864	10 m 0.8 Km	Old 156 New 156
A-1	AL-MAHWEET CITY	173	Improvement Req.	5,400	6,320	40.0	Spring/Cistern (2 Km)	7,790	9,847	40 l/c/day	D. Well (0.5-1.0 Km)	2 - 200 m	19 KW	15 ton	470 m 7.7 Km	672 ton
A-2	HUFASH	160	Construction Req.	1,500	630	25.0	Cistern/Spring(1-2 Km)	2,173	912	40 "	D. Well (0.5-1.0 Km)	200 m	19 KW	10 "	1100 m 14.1 Km	120 "
A-3	AL-RAJAM	198	Construction Req.	800	630	25.0	Spring/Cistern (1-2 Km)	1,159	912	40 "	D. Well (0.5-1.0 Km)	300 m	30 KW	5 "	20 m 3.5 Km	60 "
A-4	AL-KHABET	163	Good	1,500	880	31.0	Spring/Surface Water (1 Km)	2,172	1,275	40 "	D. Well (0.5-1.0 Km)	200 m	11 KW	10 "	380 m 6.1 Km	120 "
S-1	BANY SHAKER & BAIT ABO SABA'A	56	Construction Req.	500	860	3.8	Spring (2-5 Km)	724	1,246	40 l/c/day	D. Well (0.5-1.0 Km)	200 m	19 KW	5 ton	50 m 0.8 Km	40 ton
S-2	BAIT ABO HASHEM	57	Good	380	1,600	11.3	S.Well (6 Km)	550	2,317	40 "	D. Well (0.5-1.0 Km)	200 m	19 KW	10 "	30 m 1.2 Km	40 "
S-3	AL-SHEAB & AL-ASWAD	68	Good	2,000	8,800	23.8	Cistern/Spring/S.Well (15 Km)	3,116	13,710	40 "	D. Well (0.5-1.0 Km)	100 m	19 KW	40 "	50 m 1.3 Km	240 "
S-4	BANY FARHAN & BANY SERIA'A	77	Good	650	1,300	16.0	Spring(6-10 Km)	941	1,883	40 "	D. Well (0.5-1.0 Km)	100 m	19 KW	40 "	20 m 0.3 Km	-
H-1	GHULAYFAGAH	261	Improvement Req.	500	510	26.0	S.Well (1 Km)	724	739	40 l/c/day	D. Well (0.5-1.0 Km)	30 m	3.7 KW	30 ton	10 m 0.0 Km	10 ton
H-2	Al-DAHI	266	Good	7,000	7,710	41.6	D.Well (1 Km)	16,776	18,477	40 "	D. Well (0.5-1.0 Km)	2 - 80 m	19 KW	984 "	10 m 0.7 Km	156 "
H-3	AL-MOUNIRAH	293	Good	1,700	640	13.3	D.Well (1 Km)	4,075	1,534	40 "	D. Well (0.5-1.0 Km)	60 m	19 KW	60 "	50 m 25.1 Km	225 "
T-1	AL-MASHJAB	295	Good	800	6,670	16.7	S.Well (2 Km)	1,159	9,660	40 l/c/day	D. Well (0.5-1.0 Km)	110 m	19 KW	75 ton	55 m 0.7 Km	-
T-2	AL-MANARA & AL-DUKUM	297	Good	600	6,240	15.0	S.Well/Spring(2-4 Km)	869	9,037	40 "	D. Well (0.5-1.0 Km)	110 m	30 KW	40 "	50 m 3.6 Km	40 ton
T-3	AL-MAYDAN AL-JUBAIL SHEIBD HAMUD	284	Improvement Req.	1,000	2,740	15.0	Spring/S.Well(3-10 Km)	1,448	3,968	40 "	D. Well (0.5-1.0 Km)	200 m	26 KW	15 "	30 m 3.0 Km	80 "
T-4-A	HADAD, QAHFA	310	Good	1,800	2,740	30.0	Spring (2-3 Km)	2,607	3,968	[illegible] "	D. Well (0.5-1.0 Km)	180 m	19 KW	30 "	61 m 1.3 Km	135 "
T-4-B	AL-KUDAH, AL-HAGL	330	Good	2,500	3,430	45.0	D.Well/S.Well(2 Km)	3,621	4,968	20 "	D. Well (0.5-1.0 Km)	250 m	19 KW	15 "	40 m 1.1 Km	120 "
T-5	SHOHAT, AL-KADASH	334	Construction Req.	2,000	3,740	40.0	S.Well (5-10 Km)	2,897	5,417	40 "	U.G. Reservoir / S.Well (0.5-1.0 Km)	10 m	7.5 KW	10 "	200 m 1.6 Km	135 "
T-6	AL-ZAKIRA	340	Construction Req.	4,000	8,220	10.0	Cistern/Spring (3 Km)	6,232	12,807	20 "	D. Well (0.5-1.0 Km)	250 m	30 KW	90 "	455 m 1.3 Km	235 "
T-7	BAB-AL-MANDAB	396	Good	5,000	410	43.0	Seawater Desalination Plant/S.Well (15 Km)	11,983	983	40 "	D. Well (0.5-1.0 Km)	85 m	11 KW x 2, 75 KW	903 "	80 m 52.5 Km	406 "
T-8	YAHKHTOL	366	Good	2,500	6,850	8.0	S.Well (15 Km)	5,991	16,416	40 "	D. Well (0.5-1.0 Km)	100 m	26 KW	210 "	80 m 16.5 Km	60 "
T-9	MAKBANA	321	Good	7,000	2,740	33.3	S.Well (2 Km)	10,906	4,269	40 "	D. Well (0.5-1.0 Km)	300 m	30 KW	156 "	100 m 0.6 Km	360 "

N.B. D. Well = Deep Well
S. Well = Shallow Well

* Classified Availability of Groundwater (See Section 5-4-2)

Table 9-3 Construction Cost Summary (Y.R.) *

(Unit : Yemen Rials)

Site No.	W. Source	Pump, etc.	W. S. Tank	Booster P. Pipeline etc.	Distribution Tank, etc.	Total
HA-1	3,036,000	600,000	48,000	3,273,000	1,505,000	8,462,000
HA-2	1,518,000	197,000	42,000	689,000	340,000	2,786,000
HA-3-A	3,014,000	600,000	48,000	3,679,000	893,000	8,234,000
HA-3-B	2,058,000	600,000	48,000	2,967,000	1,618,000	7,291,000
HA-4	1,603,200	1,188,000	1,390,000	430,000	800,000	5,411,200
A-1	1,857,000 (40,000)	600,000 (315,000)	48,000 (109,000)	1,927,000 (1,678,000)	1,618,000 (272,000)	6,050,000 (2,414,000)
A-2	1,018,000	197,000	42,000	3,047,000	340,000	4,644,000
A-3	1,527,000	197,000	34,000	327,000	178,000	2,263,000
A-4	1,017,000	197,000	42,000	865,000	800,000	2,921,000
S-1	1,007,000	187,000	34,000	183,000	127,000	1,538,000
S-2	1,015,000	187,000	42,000	254,000	127,000	1,625,000
S-3	569,000	126,000	127,000	95,000	620,000	1,537,000
S-4	580,000	126,000	127,000	27,000	-	860,000
H-1	264,000	126,000	108,000	108,000	48,000	654,000
H-2	819,000	526,000	972,000	240,000	360,000	2,917,000
H-3	356,000	126,000	168,000	2,766,000	415,000	3,831,000
T-1	514,000	126,000	197,000	77,000	-	914,000
T-2	523,000	126,000	127,000	393,000	127,000	1,296,000
T-3	1,040,000	186,000	48,000	630,000	310,000	2,214,000
T-4-A	965,000	126,000	109,000	241,000	340,000	1,781,000
T-4-B	-	-	-	-	-	-
T-5	4,346,000	282,000	42,000	335,000	340,000	5,345,000
T-6	-	-	-	-	-	-
T-7	1,796,800	418,000	1,640,000	7,109,000	534,000	11,497,800
T-8	496,000	146,000	367,000	2,136,000	178,000	3,323,000
T-9	1,467,000	315,000	415,000	243,000	893,000	3,333,000
Total	32,406,000	7,505,000	6,265,000	32,041,000	12,511,000	90,728,000

* The construction cost does not include consultancy cost and contengency.

Table 9-4 Construction Cost Summary (Yen)**

(Unit : 000's Yen)

Site No.	W. Source (A)*	Pump, etc. (B)*	W. S. Tank (C)*	Booster P. Pipeline etc. (D)*	Distribution Tank, etc. (E)*	Total (F)*
HA-1	151,800	30,000	2,400	163,650	75,250	423,100
HA-2	75,900	9,850	2,100	34,450	17,000	139,300
HA-3-A	150,700	30,000	2,400	183,950	44,650	411,700
HA-3-B	102,900	30,000	2,400	148,350	80,900	364,550
HA-4	80,160	59,400	69,500	21,500	40,000	270,560
A-1	92,850 (2,000)	30,000 (15,750)	2,400 (5,450)	96,350 (83,900)	80,900 (13,630)	302,500 (120,730)
A-2	50,900	9,850	2,100	152,350	17,000	232,200
A-3	76,350	9,850	1,700	16,350	8,900	113,150
A-4	50,850	9,850	2,100	43,250	40,000	146,050
S-1	50,350	9,350	1,700	9,150	6,350	76,900
S-2	50,750	9,350	2,100	12,700	6,350	81,250
S-3	28,450	6,300	6,350	4,750	31,000	76,850
S-4	29,000	6,300	6,350	1,350	–	43,000
H-1	13,200	6,300	5,400	5,400	2,400	32,700
H-2	40,950	26,300	48,600	12,000	18,000	145,850
H-3	17,800	6,300	8,400	138,300	20,750	191,550
T-1	25,700	6,300	9,850	3,850	–	45,700
T-2	26,150	6,300	6,350	19,650	6,350	64,800
T-3	52,000	9,300	2,400	31,500	15,500	110,700
T-4-A	48,250	6,300	5,450	12,050	17,000	89,050
T-4-B	–	–	–	–	–	–
T-5	217,300	14,100	2,100	16,750	17,000	267,250
T-6	–	–	–	–	–	–
T-7	89,840	20,900	82,000	355,450	26,700	574,890
T-8	24,800	7,300	18,350	106,800	8,900	166,150
T-9	73,350	15,750	20,750	12,150	44,650	166,650
Total	1,620,300	375,250	313,250	1,602,050	625,550	4,536,400

* Further breakdown is shown in Appendix 4.

** The construction cost does not include consultancy cost and contingency.

9-7 Recommendations

The hydrometeorology of the country is as follows: Rainfall is sporadic and occurs in torrential showers and river discharge occuring immediately after the rain has an extremely steep hydrograph recession curve due to the high intensity of shower and steep rocky topographic conditions.

Accordingly, there are difficulties in assessing the volume of available natural surface water sources due to the above conditions and lack of data. Therefore, it is urgently recommended to improve and establish hydrometeorological observation and an analysis network.

The network will consist of observation stations, analysis and utilization centers. It is also recommended to create and train the necessary staff and members for this newly organized network.

Generally, the collection of hydrometerological data suffers from the lack of observation stations on the upper slopes of mountains. However, the Republic has an advantage in this respect since villages are located either on the top or upper slopes of mountains, so that establishment of observation stations is not so difficult.

Necessary data to be collected are: daily rainfall, river and spring discharge, water levels at existing boreholes and shallow dug wells, and general meteorology.

A study to assess the available surface water resources should be urgently undertaken on seasonal basis. For this purpose, the concept of catchment-wise water balance should be adopted including the study of the behavior of groundwater.

CHAPTER X

EVALUATION OF THE RURAL WATER SUPPLY PROJECT

CHAPTER X

EVALUATION OF THE RURAL WATER SUPPLY PROJECT PART II

Since the end of the civil war in mid-1970, economic activity in the Republic has expanded vigorously. More recently, especially since the quadrupling of international oil prices at the beginning of 1974, there has been an unprecedented increase in personal cash incomes based mainly on remittance by Yemenis who go to work in Saudi Arabia and the Gulf States. Largely as a result of these cash inflows, the Republic's per capita GNP has more than doubled in real terms since 1969/70 reaching a level of about $390 in 1967/77.

Although private cash incomes have risen sharply in recent years and most families can now afford substantially high levels of consumption, the supply of social services, especially domestic water supply, has not kept pace with the growth in per capita incomes. The need for the basic requirements of the population is greatest in the rural areas since most rural inhabitants still live under sub-standard conditions, frequently isolated from the rest of the country.

As shown in Appendix III-3, only 4.7% of the rural population had easy access to village water supplies in 1974, and taking the design capacity of on-going projects into consideration, by 1981, still only 14% of rural population will be served by rural water supply.

The survey sites under the project distribute over various parts of the Republic and most of them have been regarded as problematic areas for obtaining a safe and sufficient water supply for domestic purposes.

At present, the most common types of water sources at survey sites are cisterns springs and shallow dug wells. Since the yield of these sources is limited and experience great seasonally fluctuation, several different types of water sources are used wherever the water is available. The available volume of water for domestic purposes in the vicinity of each survey site limits the consumption of domestic water to the minimum level in many cases.

The per capita daily consumption of the domestic water in the survey sites ranges from the extremely small magnitude of 4 L/cap/day to 40 L/cap/day.

The per capita daily consumption of domestic water was estimated as less than 20 L/cap/day at 13 survey sites (50% of the total number of the survey sites). Only at 5 sites (20% of the total number of survey sites) the per capita daily consumption is estimated at 40 L/cap/day which is the same rate of consumption as the design criteria recently proposed by the Ministry. (See Table 5-3)

In addition, in many dry areas, the available water source consists of only open cisterns and/or shallow dug wells which are constantly subject to contamination due to the inflow of organic pollutants as well as the rapid growth of algae.
At present 20% of the total consumption of domestic water at all sites is served from clean and safe water sources. (See Fig. 5-4)

Therefore, what clean and safe water is available has a high market price at present. At 9 of the survey sites (35% of the total number of survey sites), people are paying for clean and safe domestic water transported from remote water points. The water price ranges from 8 YR/m^3 to 300 YR/m^3 including transportation cost for 20 Km. The most common price was observed to be in the range of 50-60 RY/m^3 which is equivalent to almost 20,000 YR/m^3/year or 2.2 YR/cap/day assuming a daily consumption rate of 40 liters per capita.

In order to provide a solution to this acute shortage of domestic water, a basic design was proposed for each survey site based on the cost-effectiveness concept. (See Chapters VI and IX)
For the preparation of the basic design, consideration was given to minimize the impact of water source cost to the unit price of water. Accordingly the design capacity was determined mainly based on the availability of water sources.

As a result, a design capacity was adopted for 21 of the sites to meet the future demand after 15 years from now based on the proposed design criteria by the Ministry. (40 L/cap/day)
For the other sites, the design capacity was adopted to meet the water demand even after 20 years which is necessary to promote human health.

At present, the price of safe domestic water ranges from 8 YR/m^3 to 300 YR/m^3 which is equivalent to the range from 0.32 YR/cap/day to 12 YR/cap/day assuming the per capita daily consumption of 40 L/cap/day.

On the other hand the price of water to be supplied by the proposed basic design falls between 0.03 YR/cap/day and 0.87 YR/cap/day which will obviously alleviate the present weight of domestic water cost on the household economy.
In addition, the effect of the project to human health will be considerable since all of the basic designs provide safe water from an improved rural water supply system.

While the Rural Water Supply Project Part II will serve about 84,000 people at the beginning of the project. The total design capacity of the project will serve a total population of 153,000 people.

In the year 1981, 14% of rural population (720,000 people) will be served by rural water supply taking the design capacity of on-going projects into consideration.

Therefore, the contribution of this project to the total rural population served by safe domestic water is estimated at more than 10% in 1981.

In conclusion, the increased benefits of water supply to the project sites is substantial as summarized below.

	Current Condition	Improved by The Project
Water Source	20% is stable and safe	100% of water which has direct influence on human health will be provided on a stable and safe basis.
Daily Consumption	4-40 L/cap/day	20-40 L/cap/day
Price of Water	0.32-12 YR/cap/day	0.03-0.87YR/cap/day
Distance to the Safe Water	1 - 20 Km	0.5 - 1.0 Km

APPENDIX

APPENDIX III-1

LDA Achievements until FY 78[1]

				Up to FY 76	FY 77-78
1.	Roads	a)	km	5567	6520
		b)	costs: YR min	134	389
2.	Water[2]	a)	Projects	881	643
		b)	costs: YR min	13	25
3.	Schools	a)	Projects[3]	1667	347
		b)	costs: YR min	35	65
4.	Health	a)	Projects	46	30
		b)	costs: YR min	2	4
5.	Other	a)	Costs	6	25
	TOTAL COST:			190	508

Gov. Dev. Expenditures (YR min) of which	1741
government budget share	873
External sources	868
Customs Duties	1625

1/: Official figures given by CYDA to foreign aid agencies in 1979 for the period after the official establishment of LDAs in 1973.

2/: The Five Year Plan, 1976/77 - 1980/81, (p. 2) puts the number of water projects at 852 and costing not less than YR 11 million.

3/: This designation most likely refers to the number of classrooms as the Five-Year Plan cites the number of classrooms and schools as more than 1596 and 580, respectively.

APPENDIX III-2

NUMBER OF SETTLEMENTS BY SIZE AND GOVERNORATE 1975

Governorate	Settlement Size (Number of Inhabitants) 750-1000	1000-2000	2000-5000	5000-10,000	10,000-25,000	25,000-100,000	100,000 +	Sub-total over 2000 inhab.	Total over 750 inhab.
Sana'a	49	19	8	-	-	-	1	9	77
Sa'adah	4	7	1	-	-	-	-	1	12
Hajjah	30	24	5	1	-	-	-	6	60
Marib	1	-	1	-	-	-	-	1	2
Mahweet	4	4	2	-	-	-	-	2	10
Hydaydah	51	37	18	7	2	1	-	28	116
Dhamar	23	10	1	-	1	-	-	2	35
Ibb	49	36	3	3	1	-	-	7	92
Taiz	115*	91	13*	-	-	1	-	14	220
Beidha	20	8	3	2	-	-	-	5	33
TOTAL:	346	236	54	13	4	2	1	75	656

*Note : includes many hamlets per settlement
Source : Compiled by Berger-Kampsax from 1975 Population Census

APPENDIX III-3

WATER SUPPLY AND SEWAGE DISPOSAL[a]

	Population served in 1975		Population served in mid 1981	
	Population	Coverage	Population[d]	Coverage
Water supply[b]				
Urban	222,000[c]	42.4	438,600	52.0
Rural	220,000[c]	4.7	720,000	14.0
TOTAL	442,000[c]	8.4	1,158,600	19.2
Sewage disposal				
Urban	negligible	-	370,000	43.8
Rural	negligible	-	negligible	-
TOTAL	negligible	-	370,000	6.1

a: All figures are rough estimates.

b: Water supply may include house connection or systems by which water is easily accessible to the population.

c: Present water supply is not considered safe.

d: (i) Projected population within the country for mid 1981: 6,037,618
Projected percentage of rural population: 86%

(ii) Projections based on on-going and planned programmes

APPENDIX V-1

SELECTED SURVEY SITES

GOVERNORATE	DISTRICT	NUMBER	SURVEY SITE
HAJJA	Al-Ahnoom	1	Al-Madan & Eight Villages
	Al-Ahnoom	2	Elman & Four Other Villages
	Shehara	3	Shihara & Thari
	Harad	4	Harad
AL-MAHWEET	Al-Mahweet	1	Al-Mahweet City
	Al-Mahweet	2	Hufash
	Al-Mahweet	3	Al-Rajam
	Al-Mahweet	4	Al-Khabet
SANA'A	Sehman	1	Bany Shaker & Bait Abo Saba'a
	Sehman	2	Bait Abo Hashem
	Banishadad	3	Al-Sheab Al-Aswad
	Banishadad	4	Bany Farhan & Bany Saria'a
HODEIDAH	Dlifum	1	Ghulayfagah
	Zahrah	2	Al-Dahi
	Zahrah	3	Al-Mounirah
TAIZ	Al-Sely	1	Al-Mashjab
	Al-Sely	2	Al-Manara & Al-Dukum
	Kadier	3	Al-Maydan, Al-Jubail Sheiba Hamud
	Al-Torba	4	Hada, Qahfa Al-Kudha, Al-Hagl
	Al-Torba	5	Shohat, Al-Kadash
	Al-Torba	6	Al-Zakira
	Bab-Al-Mandab	7	Bab-Al-Mandab
	Moka	8	Yahkhtol
	Makbana	9	Makbana
TOTAL			
5	14		24

APPENDIX 1

TERMS OF REFERENCE

1. MINUTES OF DISCUSSION

The Preliminary Survey Team for the Rural Water Supply Project Part II dispatched by the Government of Japan stayed in the Yemen Arab Republic from November 30, 1978 to December 15, 1978. Concerning the Project, the Team examined on the necessary matters and consulted with relevant authorities of the Government of Yemen Arab Republic.

The Preliminary Survey Team had a final joint meeting with representatives of Central Planning Organization and Ministry of Public Works on December 13, 1978 in the Central Planning Organization office and discussed on the draft of Scope of Work of Feasibility Study of Rural Water Supply Project Part II, prepared by the Japanese Team.

Both sides agreed on the matters stated in the Scope of Work attached herewith.

December 14, 1978

Sana'a, Y.A.R.

ALI ABDUL RAHMAN AL-BAHR	GAMAL M. ABDU	SHIZUO SHINDOU
Deputy Chairman	Deputy Minister	Leader
Central Planning Organization	Ministry of Public Works	Japanese Preliminary Survey Team.

2. SCOPE OF WORK

ON

FEASIBILITY STUDY OF RURAL WATER SUPPLY PROJECT PART II

I. INTRODUCTION

In response to the request made by the Government of the Yemen Arab Republic (YAR), the Japan International Cooperation Agency (JICA), an official agency responsible for the implementation of technical cooperation programme of the Government of Japan, will carry out the study of the Rural Water Supply Project Part II in close cooperation with the Government of the Yemen Arab Republic and authorities concerned.

II. OBJECTIVES OF THE STUDY

The objectives of the Study are to conduct survey and study in order to assure water supply for residents in the fourteen (14) rural areas. Prior to the implementation of the plan, it is considered highly important to make the feasibility study, for the purpose of furnishing the project with a firm basis in technical and economical aspects and also in environmental assessment.

III. PROJECT AREAS

The study areas are as follows:

	District	Governate
1.	Al-Ahnoom	Hajja
2.	Shehara	"
3.	Haradh	"
4.	Al-Mahweet	Al-Mahweet
5.	Al-Taweela	"
6.	Al-Sehman (Kholan)	Sana'a
7.	Banishadad (Kholan)	"
8.	Al-Selo	Taizz
9.	Kulaifah	Hudeidah
10.	Khadier Al-Bourahie	Taizz

11.	Al-Zorikatayn	Taizz
12.	Al-Zakkayra	"
13.	Makbana	"
14.	Bayt Al-Ashwal	Ibb

IV. SCOPE OF WORK

The scope of work are as follows:

1. Water Resources Survey

Survey and evaluation of available water resources such as groundwater, stream, spring and stored water and optimum method of their development to meet various conditions of individual areas. The first priority should be given to the underground water resources and their improvement.

(a) Meteorological and hydrological survey
(b) Physical geographical survey
(c) Geological survey
(d) Geophysical survey
(e) Others

2. Human Geographical Survey

Studies and evaluation of present and future population and water demands.

(a) Population
(b) Tradition of water usage
(c) Water demands
(d) Water cost
(e) Land use
(f) Income of population
(g) Others

3. Survey of Water Supply and Conservation System

Examination of existing water system and a rough study for layout of water supply facilities including pipeline and reservoir.

(a) Water facilities
(b) Water quality and quantity

(c) Assessment for water supply facilities

(d) Others

4. Programming of Project Implementation

Preparation of outline of preliminary design on recommended scheme.
Preparation of cost estimate for engineering, construction, operation and maintenance of the project recommended for implementation. Preparation of financing programme for proposed work.

5. Transfer of Knowledge

During the execution of the study, transfer of technical knowledge to the Government staff of the Yemen Arab Republic concerned.

V. REPORTS

1. Inception Report

The JICA will prepare and submit to the Government of the YAR 20 copies of Inception Report (in English) within 15 days after the commencement of the survey.

2. Progress Report

The JICA will prepare and submit to the Government of the YAR 20 copies of Progress Report (in English) after the field survey.

3. Draft Report

The JICA will prepare and submit to the Government of the YAR 20 copies of Draft Report (in English) within 10 months after the commencement of the survey.
The Government of the YAR will provide the JICA with its comments within 30 days after the receipt of the Draft Report.

4. Report

The JICA will prepare and submit to the Government of the YAR 30 copies of Report (in English) within 60 days after the receipt of the comments on the Draft Report.

VI. UNDERTAKINGS OF THE GOVERNMENT OF THE YAR

To secure the smooth performance of the study, the Government of the YAR will agree:

(a) to provide the study team with and to assist them to get data and information available for the study.

(b) to exempt all equipments and materials from taxes and custom duties including personal effects.

(c) to assure security of team during their services in Yemen.

(d) to assign the necessary number of counterpart personnel to co-operate and assist the team, as well as to be trained during the implementation of the project.

(e) to provide and arrange the study team with suitable office and accomodation.

(f) to assist the team in hiring 4-wheel-drive vehicles.

(g) to make necessary arrangements for the study team bring the data and materials concerning the study into Japan.

APPENDIX 2

WATER QUALITY

APPENDIX 2

GENERAL REVIEW OF WATER QUALITY

Introduction

Concerning the existing water sources within the survey site, i.e. mainly shallow wells, and subordinately deep wells, springs, surface flow etc., it was difficult to obtain data about ordinary water quality. Therefore, at each site samples were obtained and several analytical tests were applied as well as some field tests. The results are compiled in a table attached to this report, with the descriptions of each site or area.

Usually, such tests for a city water supply should be performed periodically. The analytical results, which were obtained therefore on just one single occasion at a restructed number of places, cannot be considered to be representative. There are still many unknown aspects with respect to seasonal trends and differences between the dry and wet seasons in water quality.
Consequently, the discussion in this report can only present some general ideas.

1. The Characteristic Water Qualities for Each Site and Area

1-1 Inland Mountain Region

Hajja area: There are many springs in Al-Madan and Al-Man. The total dissolved solid, electric conductivity and chlorinity of the spring waters are at a low level, and their total hardness is at the medium level (200-300 mg/ℓ).
Spring and wadi waters in Thari and places adjacent thereto are at a higher level of electric conductivity, exceeding 1,000 μʊ/cm, with a somewhat high total hardness i.e. around 300 mg/ℓ.

Taizz area: Springs and shallow wells at Al-Sulu and Torba produce waters of 800-1,000 μʊ/cm electric conductivity and not more than 100 mg/ℓ in chlorinity. Shallow well waters at Kadier Al-Borehee, Al-Maydan, Al-Jubail and Sheb Hamud however, have slightly higher values in electric conductivity (1,700-1,900 μʊ/cm), total hardness (270-400 mg/ℓ) and chlorinity (150-220 mg/ℓ).

At the central part of Makbana (at the head of a wadi near the pass) wadi water showed a high value in electric conductivity (2,000 μʊ/cm), total hardness ($>$600 mg/ℓ) and chlorinity ($>$400 mg/ℓ).

1-2 Tihama area (See the table attached)

In the present survey we covered widely in the Tihama area: Harad of Hajja province in the north, Al-Munirah and Al-Dahi of the northern Hodeidah province in the middle, Yahkhtol of Taizz province and Al-Ghulayfagah in the south and Bab Al-Mandad in the southern most.

Referring to electric conductivity, total hardness and chlorinity, waters in this area generally contain a good deal of dissolved salts. The ranges of values are 1,300-1,500 μʊ/cm for electric conductivity, 100-1,000 mg/ℓ for chlorinity (except for Harad; 65-81 mg/ℓ) and 100-1,000 mg/ℓ in total hardness.
No systematic change was identified in total hardness in connection with geographic distribution. The high groundwater salinity could not be explained by assuming that sea water intrusion might have caused it. Instead, in some cases in the Tihama sand dune area, high evapotranspiration, caused by strong solar radiation, might cause an increase in the salinity of the groundwater. In order to elaborate or the correlations between electric conductivity, chlorinity and total hardness of well water we prepared graphic plots (See the attached figure). In this figure, electric conductivity

is plotted as the abscissa, and chlorinity, total hardness and Mg hardness/Ca hardness ratio are the ordinate. The resulting figure does not provide any clearly defined distributions of the plotted data, instead ratties large scattering of data, which indicates mixing among various kind waters. In some wells near the coast, like Al-Gaha and Ghulayfagah, low values in electric conductivity were found in the water and salinity and total hardness, were found to be contrary to our previous understanding. This suggests that the local geological structure is blocking sea water intrusion at some localities. Shallow wells, on the other hand, in Al-Munyrah and Yahkhtol produce highly saline waters (about 5,000 μʊ/cm in electric conductivity and more than 1,000 mg/ℓ in chlorinity).
Shallow wells in Al-Munyrah may be underlain by a rock salt formation as in some coastal places, or dug into the sandy soil with salt which accumulates perennially. The total hardness is 600 mg/ℓ at the Al-Munyrah site and 1,000 mg/ℓ in Bir Okrepas in Yahkhol. With regard to nitrate nitrogen contents, the shallow wells in Al-Munyrah indicated very high values, i.e. 150 mg/ℓ. This tendency remains valid even in the deep well waters at the same location, i.e. 38 mg/ℓ, which is still rare compared to other deep well waters, except for some in Saada. In the Tihama area nitrate nitrogen contents in well waters range between 5-10 mg/ℓ, (for referrence; 4-8 mg/ℓ indicated in the mountain area). Other high nitrate nitrogen contents were measured in Marawiya east of Hodeidah (27 mg/ℓ) and in Makbana (T-9) (38.5 mg/ℓ). These might be due to the fertilizers in agricultural field, however, detailed reasons are still not clearly defined.

1-3 Stored Rainwater in Cistern

There are many different types of cisterns throughout the country. They are built with special care for the topographical conditions, e.g. cisterns built in a dug-out with low embankment and plastered surface in a flat place; cisterns built behind rock-work dam in valley or on slope and cisterns of the swimming pool type at the center of residential areas. Their storage is not only replenished by their surface rain catchment but also by collecting water from the surrounding areas. Water storage is often plluted by things which are dumped around the houses and animal excrement on the road, field and grassland. Stored water may still remain some months after the rainy season, however, the surface of the water is usually covered by aquatic plants and weeds, and various insects, micro organs and green algae which grow in the water. These can be regarded as additional deteriorating factors to the water quality besides chemical ones. The condition varies from one cistern to another, however, the chemical quality, e.g. alkalinity, chlorinity and total hardness, generally remains at a low levels just after the rainy season. Same tendency occurs in the values of electric conductivity, i.e. 100-300 μυ/cm during same period. As time advances and the local flora flourish, pH values increase during the day time and KMnO4 consumptions also increases gradually, indicating an increasing amount of dissolved organic materials. Although electric conductivities do not increase sharply, they may be influenced by the salt enrichment caused by evaporation, with an accompanying increase in hardness. During the present survey period, 2-3 months after the rainy season, most of the cistern waters showed values 200-500 μυ/cm of electric conductivity, slightly higher values in pH, i.e. 8-9, except for cisterns which have been almost completely consumed with a losser amount of residual water (See the table attached). We were informed by the local people that very little rain occurred last September.

We were impressed with some underground cisterns, or cisterns under housing, because of their better water quality, i.e. without green algae, and crystal clean except for some micro-organisms and insects (e.g. mosquito larvae and water beetles).

Cisterns with roofing are worth considering for use in order to prevent them from being polluted from the out-side. It will also be necessary to design a storm water drainage ditch collection system without any accumulation of dirt or debris along its length.

2. Bacteological Test Results

For the sake of hygienic examination of well waters we introduced the Coli-Count and Total Bacteria Count Sampler, developed and manufactured by the Millipore Corporation (U.S.A.) to the survey investigation.

In ordinary cases it can be presumed that the polluted levels are qualitatively evaluated by observing the appearance of the well and its environment. However, based on the present examinations, we obtained an unexpected high general bacteria count and less general faecal coli-form bacteria count in total Coli count even at cistern locations which had been replenished with rain water. Consequently we often encountered so called "innumerable" or "more than hundreds of colonies" levels, however, this may come from an inadequate diluting ratio in some cases. The results are based on the colony pictures taken after a one day incubation period.

Coli-form bacterias, presumably originated from some kind of faecal bacteria (identifiable after a higher grade examination), were detected in spring water in Wahab on the way to Hajja to the west of Amran, Taizz (T-6), cistern and spring near Mosque of Zakira and on the top of the hill respectively, waters from attached tank to Bir Umari well in Bab el-Mandab and at the Bir Kadash well T-5.

Most of the ordinary bacteria count (by white sampler method) exceeded several hundreds. By this method only the number of colonies are counted, so that the specie of each bacteria must be identified in some proper way. At the same time it is necessary to initiate a project to establish how to protect urban and suburban shallow wells from biological pollution.

If disinfection could be done for each well, additional hygienic safety and higher standards of water quality could be achieved.

	No.	Site	(Water source)	Elec.C. (25°C)	pH	T-Alk	Cl'	T-H	CaH	Mg/Ca	NO3-N	NH3-N	Biol. Test	KMnO4 Cons.	T-Fe	T-P	SO4	Na+K
HAJJA		Gafla	S.W.	730	7.7	306	42	174	85	1.05	4.3	0.4						
	HA-1	Al Madan	S.W. in Wadi	1040 550(18°C)	7.5	254	167	304	234	0.30	3.3	0.27			0			
		"	Spring, lower	645 530(20°C)	8.1													
		"	Spring, upper	590	8.1	180	74	214	156	0.37	3.3	0.09		7.7		0.007	56	
		"	Al Maa'ian spring	700	7.9	214	80	242	163	0.48	2.6	0.12		7.4				
		"	Bir Zugga in West Wadi	970	7.3	274	133	296	170	0.74	4.7	0.22		7.4	0	0.020	83	
	HA-2	Al Man	lower spring	735	7.0	204	91	249	182	0.37	0.8	0.55						
			upper spring	760	6.9	-	-	-	-		-			6.3				
	HA-3	Sihara	Cist. near Bab Al Nadar	250	7.6	-	-	-	-		-							
		"	Res. under Mosk	505	7.5	154	104	138	120	0.15	5.0	0.16	C-0 B4000	10.3				
		"	Cist. of East	400	7.1	-	-	-	-		-							
		Al Nagid	Spring	1230	7.3	-	-	-	-		-							
	HA-3B	Thari	Cist. Shaker	480	8.7	100	66	79	55	0.44	0.6	1.7	C-0 B 90	30.8		0.071	-	
		"	Shdeiny spring	1000	8.1	224	157	305	154	0.98	0.4	0.17						
		"	West(higher) Cist.	1600	8.9	-	-	-	-	-	-	-						
		"	Wadi Nahar spring	1107	7.6	-	-	-	-	-	-	-						
		"	Wadi (down)	1200	7.5	-	-	-	-	-	-	-						
		"	Wadi Sawaru	810	7.5	218	53	332	198	0.68	2.7	0.1		7.7	0	0.029	194	
	HA-4	Harad	New Harad, S.W.# 1	820	7.5	192	81	246	137	0.80	8.5	-	F 4 B 70			0.005		
AL-MAHWEET	A-1	Al Mahweet	Higher cist.	210	9.4	-	-	-	-	-	-	-	C-0 B 200					
		"	City Spring (Sayl Al Eyown)	620	7.6	218	50	257	146	0.76	2.0	0.07		5.2	0		49	
		"	near Kard Spring	500	7.8	168	-	-	-	-	2.9	-						

- CONT'D -

	No.	Site	(Water source)	Elec.C. (25°C)	pH	T-Alk	Cl'	T-H	CaH	Mg/Ca	NO3 -N	NH3 -N	Biol. Test	KMnO4 Cons.	T-Fe	T-P	SO4	Na+ K
AL-MAHWEET	A-1	Al Mahweet	City Center, under Mosk	420	7.9	111	69	165	103	0.60	7.0	0.25	C-0 B 350	5.9				
		"	West River, Sela Ayown	770	8.1	201	88	272	147	0.85	-	-				0.020		
	A-2	Al Rajam	Halawan Spring	360	7.8	141	26	147	98	0.50	0.4	0.28		6.6				
	A-3	Al Khabet	Pond in Wadi Mosanaba	720	6.9	274	62	302	194	0.56	0.6	0.14			0	0.049		
		"	Wadi Mosanaba # 1	770	7.8	-	-	-	-	-	-	-	C-0 B 350					
		"	Wadi Mosanaba # 2	720	6.9	-	-	-	-	-	-	-						
	A-4	Hufash	Salabat Amed Spring # 1	600	8.1	205	48	220	144	0.53	1.1	0.19		5.7	0		31	
SANA'A	S-1	Bany Shaker & Bait Abo Saba'a																
	S-2	Bait Abo Hashem		308	7.1	74	-	-	-	-	<0.1	<0.05	C 70 B 820	15				
	S-3	Al-Sheb Al-Aswad	Cistern	155	7.3	49	-	-	-	-	<0.1	0.6	C 410 B 650	16				
		"	Well of neighboring Vill.	734	7.3	27	17	-	-	-	1.0	<0.05	C 410 B1030	-				
	S-4	Bany Farhan & Bany Saria'a																
HODEIDAH	H-1	Ghulayfigah	Shallow Well # 1	1850	8.3	320	481	111	34	2.3	3.3		F - 0 B 340			0.072	114	707/ 11
		"	Shallow Well (west) # 2	1850	7.8	-	-	-	-		-							
	H-2	Al Dahi	Deep Well (65 m)	1175	7.7	275	157	336	86	2.9	13	0.1		22.4	0	0.007	184	283/ 2
		Al Torba	Shallow Well (on the road)	2520	7.9	171	507	208	83	1.5	16	0.2						
		Marawiyah	Deep Well (60 m)	2630	7.3	112	628	754	286	1.64	27	0.1		5.2	0	0.002		
		Al Quttay,	Canada Dry Co. 50m Well	1390	7.6	275	189	254	93	1.73	6.4	0.1						
		Well # 1 on the road from Hodeidah to Taiz		3475	7.8	-	-	-	-	-	-						136	217/ 4.5
		Well # 2 on the road from (Al Mousea) to Ghulayfiga		1300	7.3	255	223	361	99	2.65	8.7							

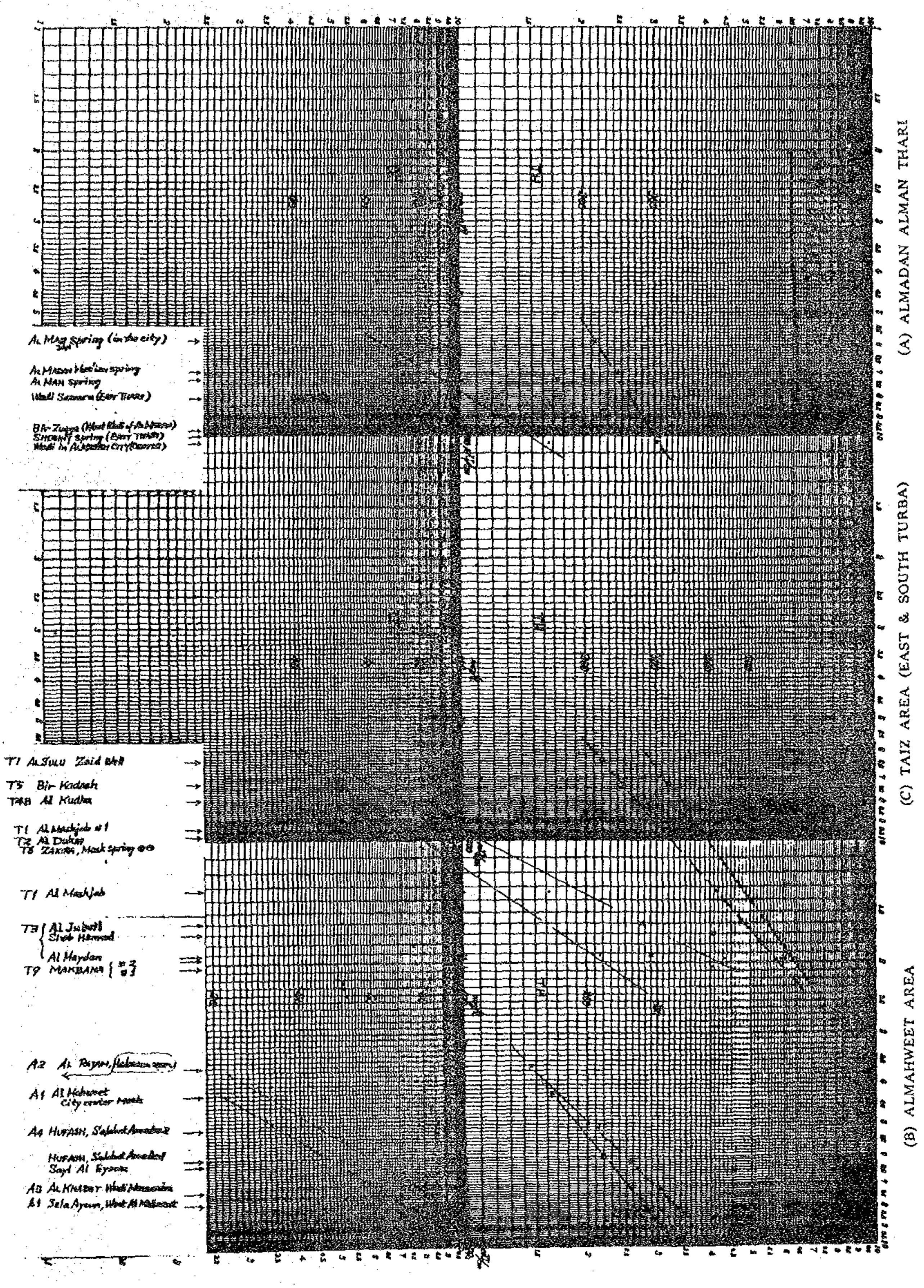
– CONT'D –

	No.	Site	(Water source)	Elec.C. (25°C)	pH	T-Alk	Cl'	T-H	CaH	Mg/Ca	NO3 -N	NH3 -N	Biol. Test	KMn04 Cons.	T-Fe	T-P	SO4	NA+ K
HODEIDAH	H-2	Shallow Well # 3 on the road from Fusainiya to Ghulayfiga		1245	7.4	-	-	-	-	-	-							
		Shallow Well # 4 on the road (Al Kaba)		1390	7.7	-	-	-	-	-	-						273	543/ 4.5
		Shallow Well # 5 on the road (Al Gaha)		2185	7.5	195	579	341	161	1.1	5.6							
		Shallow Well # 6 on the road		1470	7.7	-	-	-	-		-							
	H-3	Al Munirah	Deep Well (60 m)	3040	7.6	171	610	355	81	3.4	38	0.14		5.4				
		"	Shallow Well # 2	5000	7.7	231	1041	592	191	2.1	150	0.1		7.7				
TAIZZ	T-1	Al-Mashjab	Dug well # 1	940	7.5	316	74	315	200	0.58	0.65			15.8				
		"	Dug well # 2	1330	6.9	406	163	414	268	0.54	1.4							
		"	Zaid well	640	7.1	208	44	220	108	1.04	4.5			15.5				
	T-2	Al-Manara & Al Dukum	Spring	980	8.5	340	79	370	204	0.81	0.5			22.1				
	T-3	Al-Maydan	Shallow Wells	1910	7.7	556	2.7	290	50	4.8	6.2	0.05	C-0 B M	18.0	0	0.071		
		Al-Jubeil	"	1600	8.2	464	161	274	83	2.3	12	0.1		23.7				
		Sheb Hamud	"	1700	7.7	566	147	406	91	3.5	-		C-0 B M					
	T-4A	Hedad & Gahfa																
	T-4B	Al Kudha & Al Hagl	Shallow Wells	800	8.2	288	81	340	204	0.67	3.2	0		14.2				
	T-5	Shohat & Kadash	Bir Kadash	730	7.2	298	56	320	169	0.89	0.5	0	C 40 B200+		0	0.002		
	T-6	Zakira	Spring near Mosk	980	7.0	428	71	410	135	2.04	0.3	0.2	C 17 B400	14.5				
		"	Cistern rain water	134	9.5	46	8	46	30	0.53	0.2	0.1	C 2 B 60					
	T-7	Bab Al Mandab	Bir Umari	1400	7.4	174	590	270	179	0.51	4.2		F100 B200	17.8	0	0.021	234	463/ 4
		"	Bir Al Musalas	1700	7.5	184	456	194	133	0.46	6.9						168	463/ 2
		"	Desalination Plant, water	380	8.7	20	128	135	121	0.12	-							

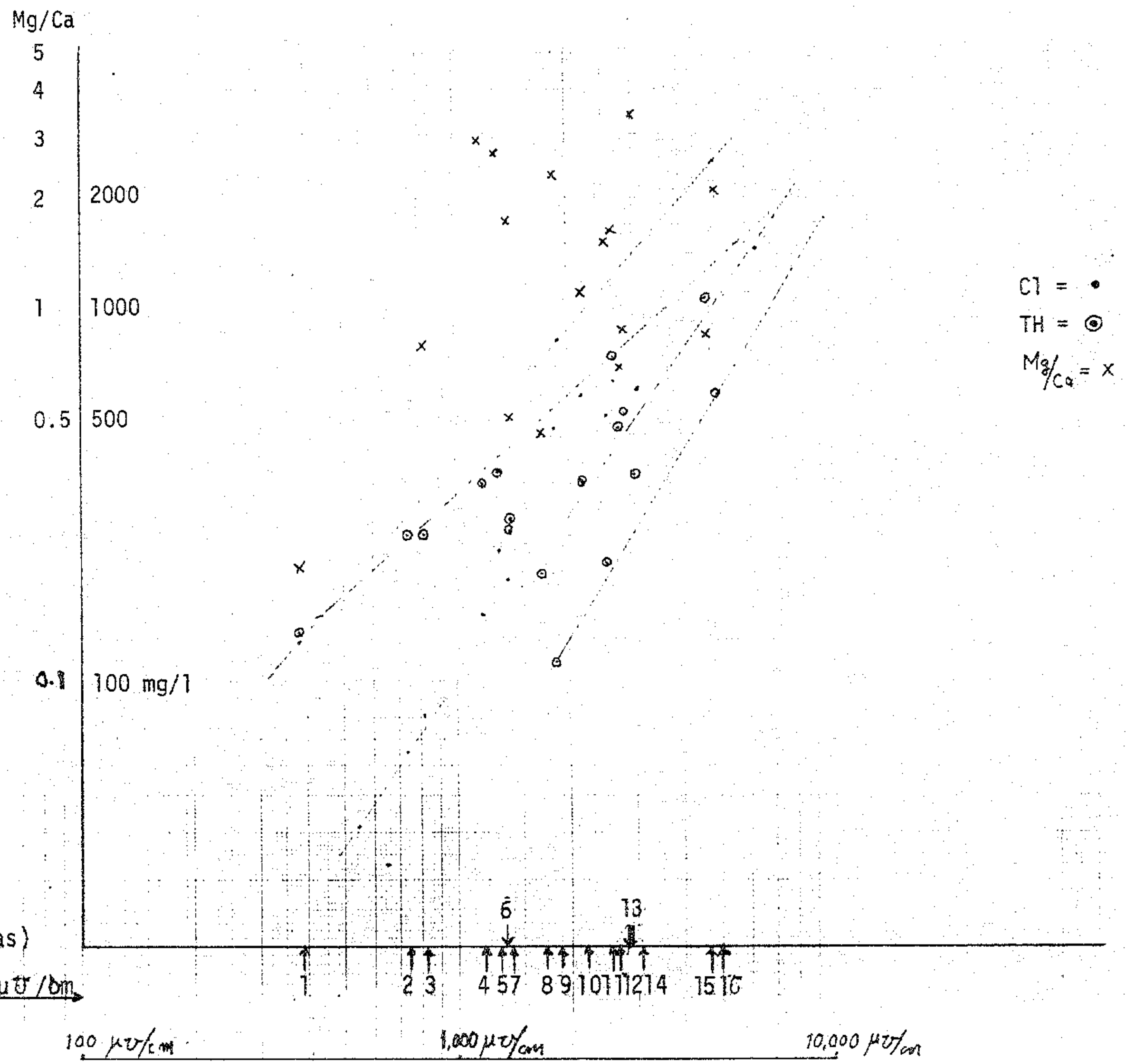
-CONT'D -

	No.	Site	(Water Source)	Elec.C. (25°C)	pH	T-Alk	Cl'	T-H	CaH	Mg/Ca	NO3-N	NH3-N	Biol. Test	KMnO4 Cons.	T-Fe	T-P	SO4	NA+K
TAIZZ	T-8	Yahkhtol	Shallow Wells Bir Ok Bir Okrepas	4710	7.4	130	1114	1074	579	0.85	5.0				0			
		"	Bakalia # 1	2750	7.3	238	524	476	280	0.7	5.8					0.030	783	952/ 12.1
		"	Bakalia (New) # 2	2830	7.5	240	539	517	273	0.89	6.6							
	T-9	Makbana	Shallow Wells Lower (# 1)	2050	7.0	300	407	657	512	0.28	38.5							
		"	Shallow Wells town (# 2)	1950	7.1	324	432	603	482	0.25	10				0			

KADASH C40 (light green)



(A) ALMADAN ALMAN THARI
(C) TAIZ AREA (EAST & SOUTH TURBA)
(B) ALMAHWEET AREA
Wadi Samara (East Turba)
T1 Al Sulu Zaid Well
T5 Bir Kadash
T1 Al Mashjab #1
T2 Al Duhan
T1 Al Mashjab
T3 Al Jubail
Al Maydan
T9 MAKBANA #2 #3
A1 Al Mahweet City center
Sayl Al Eyoon



Site Name

1. Bab-Al-Mandab
   Desalination Water
2. Old Harad
3. New Harad
4. Dahi
5. Musea
6. Quttay
7. Umari
8. Musalas
9. Ghulayfagah
10. Gaha
11. Turba
12. Marawiya
13. Baklia -1
    Baklia -2
14. Munyrah Deep
15. Yahkhtol (Bir Okrepas)
16. Munyrah S.W.

APPENDIX 3

CRITERIA OF DESIGN CAPACITY OF RURAL WATER SUPPLY

DESIGN CRITERIA FOR BASIC DESIGN OF RURAL WATER SUPPLY

1. Water Source

Factor	Symbol	Unit
Approximate Safe Yield of Borehole ...	Qw ,	ton/day
Daily Maximum Yield of Borehole with 19 hrs Operation	Qmw ,	ton/day
Maximum Pumping Rate	Qm ,	L/min

It is designed that the maximum running hours of well pump is 19 hours per day. Therefore Qmw is calculated from Qw.

$Qmw = Qw \div 24 \text{ hrs} \times 19 \text{ hrs}$

Qm is calculated from Qw

$Qm = Qw \div 24 \text{ hrs/d} \div 60 \text{ min} \times 1000 \text{ L/min}$

Qw (t/d)	Qmw (t/d)	Qm (L/min)
1,000.0	790.0	690.0
700.0	550.0	480.0
500.0	400.0	340.0
400.0	310.0	270.0
300.0	230.0	200.0
200.0	150.0	130.0
100.0	80.0	70.0

2. Water Demand

Factor	Symbol	Unit
Number of Population	P ,	capita
Number of Livestock	L ,	head
Growth Rate	R1 ,	%
Water Demand of Human	qc ,	L/cap/day
Water Demand of Livestock	*qh ,	L/head/day
Total Water Demand of Human	Qc ,	L/day
Drinking Water Demand of Human	Qc' ,	L/day
Total Water Demand of Livestock ...	Qh ,	L/day
Design Capacity of Water Supply ...	Qd ,	L/day
Multipurpose Rate .... (including leakage of water)	R2 ,	20%
Fire Fighting Purpose	R2 ,	25%
Quantity of Multipurpose	Qr ,	ton
Quantity of Fire Fighting Purpose ..	Qr ,	ton
Emergency Purpose	**qe ,	L/cap/day
Total Emergency Purpose	Qe ,	ton

* qh = 6.0 L/head/day
** qe = 2.5 L/cap/day

$P = (1 + R1)^N \times Pp$ Pp : Number of present population

$L = (1 + R1)^N \times Lp$ Lp : Number of present livestock

$Qc = P \times qc \div 1000$ N : Design Period in years

$Qc' = Qc \times 0.5$

$Qh = L \times qh \div 1000$

Qd : Type - A : $Qd = Qc + Qh$

Type - B : $Qd = Qc$

Type - C : $Qd = Qc'$

$Qr = Qd \times R2 \div 100$

$Qe = P \times qe \times 9 \text{ days} \times 0.7$

3. Tank - 1.

Factor	Symbol	Unit
Daily Design Capacity	qo ,	m^3/day
Average Hourly Design Capacity	Qhr ,	m^3/hr
Hourly Peak Load	Qp ,	m^3/hr
Storage Capacity	Qt ,	m^3

qo = Qmw or Qd

Qhr = qo ÷ 10 hours

Qp = Qhr x 1.5 hours

Qt = (Qp x 3 hours) + A

If Qr   Qe, A = Qr,   If Qr   Qe, A = Qe.

4. <u>Tank - 2.</u>

Type of tanks is as follows:

Firstly, the tanks can be set up in three different ways.

1 - 1 : Ground Tank .... (G.T)

1 - 2 : Semielevated Tank .... (SE.T)

1 - 3 : Elevated Tank .... (E.T)

Secondly, the tanks can be used in four different ways.

2 - 1 : Service Tank .... (S.T)

2 - 2 : Distributing Tank .... (D.T)

2 - 3 : Booster Station Tank .... (B.T)

2 - 4 : Service & Booster Station Tank .... (SB.T)

Combination:

	G.T	SE.T	E.T
S.T.	A	B	C
D.T	D	-	-
B.T	E	-	-
SB.T	F	G	-

Factor	Symbol		Unit
Design Capacity of Service Tank ...	Vs	,	m^3
Design Capacity of Distributing Tank	Vd	,	m^3
Design Capacity of Booster Station Tank	Vb	,	m^3
Design Capacity of Service & Booster Station Tank	Vsb	,	m^3
Number of Service Tanks	Ns	,	each
Number of Distributing Tanks	Nd	,	each
Number of Booster Station Tanks ...	Nb	,	each

Factor	Symbol	Unit
Emergency Capacity of Service Tanks	Ve ,	m^3

$Vs = Qt \div Ns$

$Vd = Qp \times 1$ hour

$Vb = Qhr \times 0.5$ hour

$Vsb = Vs + (Qhr \times 1$ hour$)$

$Ve = Qe \div Ns$

If it is necessary to set up an elevated tank, capacity of Vh is ... $Vh = (Vs - Ve) \div 3$.
Accordingly the capacity of the ground tank (Vg) is determined as $Vg = Vs - Vh$.

Number	Survey Site		
HA - 1	Al Madan & 8 Villages	[ ] U .. Urban [X] S .. Semiurban [X] R .. Rural	

Number of Population ... (S) 3,500, (R) 4,000, capita ... P

Number of Livestock .... 3,680, head L

Growth Rate .... 3.0 , % R1

Water Demand of Human ... (S) 70 (R) 40, L/c/d .... qc

Water Demand of Livestock .... 6.0, L/h/d .... qh

[X] Multipurpose Rate .... 20.0, % R2

[ ] Fire Fighting Use Rate .... 25.0, %

Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		S3,500 R4,000	4,057 4,637	4,704 5,376	5,453 6,232	6,321 7,224
L		3,680	4,267	4,946	5,734	6,647
Qc		S245.0 R160.0	284.0 185.5	329.3 215.0	381.7 249.3	442.5 289.0
Qh		22.1	25.6	29.7	34.4	39.9
Qc' : Qc x 0.5		S122.5 R 80.0	142.0 92.8	164.5 107.5	190.9 124.7	221.3 144.5
Qd	Type - A Qc + Qh	427.1	495.1	574.0	665.4	771.4
	Type - B Qc	405.0	469.5	544.3	631.0	731.5
	Type - C Qc'	202.5	234.8	272.0	315.6	365.8
Qr	Type - A	85.4	99.0	114.8	133.1	154.3
	Type - B	81.0	93.9	108.9	126.2	146.3
	Type - C	40.5	47.0	54.4	63.1	73.2
Qe		118.1	136.9	158.8	184.0	213.3

Approximate Safe Yield of Borehole (Qw) .... 300 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 230 m^3/day

Maximum Pumping Rate (Qm) .... 200 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 2 ea = 460 m^3/day

Design Capacity: 460
Type (C) - (4) determinated by [ ] Water Demand. [X] Capacity of Water Source.

Number	Survey Site		
HA - 2	ElMan & 4 Other Villages	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural	

Number of Population .... 1,500, capita ... P

Number of Livestock .... 1,470, head L

Growth Rate .... 2.5, % R1

Water Demand of Human ... 40 , L/c/d .... qc

Water Demand of Livestock .... 6.0, L/h/d .... qh

[X] Multipurpose Rate .... 20.0, % R2

[ ] Fire Fighting Use Rate .... 25.0, %

Emergency Purpose .... 2.5, L/c/d .... qe

		1 Present	2 5 years	3 10 years	4 15 years	5 20 years
P		1,500	1,697	1,920	2,173	2,458
L		1,470	1,663	1,882	2,129	2,409
Qc		60.0	67.9	76.8	86.9	98.3
Qh		8.8	10.0	11.3	12.8	14.5
Qc' : Qc x 0.5		30.0	34.0	38.4	43.5	49.2
Qd	Type - A Qc + Qh	68.8	77.9	88.1	99.7	112.8
	Type - B Qc	60.0	67.9	76.8	86.9	98.3
	Type - C Qc'	30.0	34.0	38.4	43.5	49.2
Qr	Type - A	13.8	15.6	17.6	19.9	22.6
	Type - B	12.0	13.6	15.4	17.4	20.0
	Type - C	6.0	6.8	7.7	8.7	9.8
Qe		23.6	26.7	30.2	34.2	38.7

Approximate Safe Yield of Borehole (Qw) .... 300 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 230 m^3/day

Maximum Pumping Rate (Qm) .... 200 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 230 m^3/day

Design Capacity: 100
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site		
HA - 3A	Sihara	[ ] U .. Urban [X] S .. Semiurban [ ] R .. Rural	

Number of Population .... 4,500, capita ... P
Number of Livestock .... 8,830, head L
Growth Rate .... 5.0, % R1
Water Demand of Human .... 70.0, L/c/d .... qc
Water Demand of Livestock .... 6.0, L/h/d .... qh
[X] Multipurpose Rate .... 20.0, % R2
[ ] Fire Fighting Use Rate .... 25.0, %
Emergency Purpose .... 2.5, L/c/d .... qe

		1 Present	2 5 years	3 10 years	4 15 years	5 20 years
P		4,500	6,022	8,059	10,785	14,432
L		8,830	11,817	15,813	21,162	28,319
Qc		315.0	421.5	564.1	755.0	1010.2
Qh		53.0	70.9	94.9	127.0	169.9
Qc' : Qc x 0.5		157.5	210.8	282.1	377.5	505.1
Qd	Type - A Qc + Qh	368.0	492.4	659.0	882.0	1180.1
	Type - B Qc	315.0	421.5	564.1	755.0	1010.2
	Type - C Qc'	157.5	210.8	282.1	377.5	505.1
Qr	Type - A	73.6	98.5	131.8	176.4	236.0
	Type - B	63.0	84.3	112.8	151.0	202.0
	Type - C	31.5	42.2	56.4	75.5	101.0
Qe		70.9	94.8	126.9	169.9	227.3

Approximate Safe Yield of Borehole (Qw) .... 300 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 230 m^3/day

Maximum Pumping Rate (Qm) .... 200 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 2 ea = 460 m^3/day

Design Capacity: 460
Type (C) - (4) determinated by [ ] Water Demand.
[X] Capacity of Water Source.

Number	Survey Site	
HA - 3B	Thari	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural

Number of Population .... 15,000 , capita ... P

Number of Livestock .... 15,000 , head L

Growth Rate .... 3.0 , % R1

Water Demand of Human .... 40.0 , L/c/d .... qc

Water Demand of Livestock .... 6.0 , L/h/d .... qh

[X] Multipurpose Rate .... 20.0 , % R2

[ ] Fire Fighting Use Rate .... 25.0 , %

Emergency Purpose .... 2.5 , L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		15,000	17,389	20,159	23,370	27,092
L		15,000	17,389	20,159	23,370	27,092
Qc		600.0	695.9	806.4	934.8	1083.7
Qh		90.0	104.3	121.0	140.2	162.6
Qc' : Qc x 0.5		300	347.8	403.2	467.4	541.9
Qd	Type - A Qc + Qh	690.0	799.9	927.4	1075.0	1246.3
	Type - B Qc	600.0	695.6	806.4	934.8	1083.7
	Type - C Qc'	300.0	347.8	403.2	467.4	541.9
Qr	Type - A	138.0	160.0	185.5	215.0	249.3
	Type - B	120.0	139.1	161.3	187.0	216.7
	Type - C	60.0	70.0	80.6	93.5	108.4
Qe		236.3	273.9	317.5	368.1	426.7

Approximate Safe Yield of Borehole (Qw) .... 300 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 230 m^3/day

Maximum Pumping Rate (Qm) .... 200 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 2 ea = 460 m^3/day

Design Capacity: 460

Type (C) - (4) determinated by [ ] Water Demand.
[X] Capacity of Water Source.

Number	Survey Site	
HA - 4	Harad	[X] U .. Urban [X] S .. Semiurban [ ] R .. Rural

Number of Population ... (U) 4,000, (S) 3,000, capita ... P
Number of Livestock .... (U) 3,780, (S) 2,840, head L
Growth Rate .... 6.0, % R1
Water Demand of Human ... (U) 120 , (S) 80, L/c/d .... qc
Water Demand of Livestock .... 6.0, L/h/d .... qh
[ ] Multipurpose Rate .... 20.0, %
[X] Fire Fighting Use Rate .... 25.0, % R2
Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		U4,000 S3,000	6,691 4,015	7,163 5,373	9,586 7,190	12,829 9,621
L		U3,780 S2,840	5,059 3,800	6,769 5,086	9,059 6,806	12,123 9,108
Qc		U480.0 S240.0	802.9 321.2	859.6 429.8	1150.3 575.2	1539.5 769.6
Qh		U 22.7 S 17.0	30.4 22.8	40.6 30.5	54.4 40.8	72.7 54.6
Qc' : Qc x 0.5		U240.0 S120.0	401.5 160.6	429.8 214.9	575.2 287.6	770.0 384.8
Qd	Type - A Qc + Qh	U502.7 S257.0	833.3 344.0	900.2 460.3	1204.7 616.0	1612.2 824.2
	Type - B Qc	U480.0 S240.0	802.9 321.2	859.6 429.8	1150.3 575.2	1539.5 769.6
	Type - C Qc'	U240.0 S120.0	401.5 160.6	429.8 214.9	575.2 287.6	770.0 384.8
Qr	Type - A	U125.7 S 64.3	208.3 86.0	225.1 115.1	301.2 154.0	403.1 206.1
	Type - B	U120.0 S 60.0	200.7 80.3	214.9 107.5	287.6 143.8	384.9 192.4
	Type - C	U 60.0 S 30.0	100.4 40.2	107.5 53.7	143.8 71.9	192.5 96.2
Qe		U 63.0 S 47.3	105.4 63.2	112.8 84.6	151.0 113.2	202.1 151.5

Approximate Safe Yield of Borehole (Qw) ....1,000 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 790 m^3/day

Maximum Pumping Rate (Qm) .... 690 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 3 ea =2,370 m^3/day

Design Capacity: 1,580
Type (A) - (4) determinated by [ ] Water Demand.
[X] Capacity of Water Source.

Number	Survey Site	
A - 1	Al Mahweet City	[ ] U .. Urban [X] S .. Semiurban [ ] R .. Rural

Number of Population .... 5,000, capita ... P

Number of Livestock .... 6,320, head L

Growth Rate .... 3.0, % R1

Water Demand of Human .... 100.0, L/c/d .... qc

Water Demand of Livestock .... 6.2, L/h/d .... qh

[X] Multipurpose Rate .... 20.0, % R2

[ ] Fire Fighting Use Rate .... 25.0, %

Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		5,000	5,794	6,720	7,790	9,031
L		6,320	7,327	8,494	9,847	11,415
Qc		500.0	579.4	672.0	779.0	903.1
Qh		37.9	44.0	51.0	59.1	60.5
Qc' : Qc x 0.5		250.0	289.7	336.0	389.5	451.6
Qd	Type - A Qc + Qh	537.9	623.4	723.0	838.1	971.6
	Type - B Qc	500.0	579.4	672.0	779.0	903.1
	Type - C Qc'	250.0	289.7	336.0	389.5	451.6
Qr	Type - A	107.6	124.7	144.6	167.6	194.3
	Type - B	100.0	115.9	134.4	155.8	180.6
	Type - C	50.0	57.9	67.2	77.9	90.3
Qe		78.8	91.3	105.8	122.7	142.2

Approximate Safe Yield of Borehole (Qw) .... 300 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 230 m^3/day

Maximum Pumping Rate (Qm) .... 200 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 2 ea = 460 m^3/day

Design Capacity: 460
Type (C) - (4) determinated by [ ] Water Demand.
[X] Capacity of Water Source.

Number	Survey Site		
A - 2	Hufash	[ ]	U .. Urban
		[ ]	S .. Semiurban
		[X]	R .. Rural

Number of Population .... 1,500, capita ... P

Number of Livestock .... 630, head L

Growth Rate .... 2.5, % R1

Water Demand of Human .... 40.0, L/c/d .... qc

Water Demand of Livestock .... 6.0, L/h/d .... qh

[X] Multipurpose Rate .... 20.0, % R2

[ ] Fire Fighting Use Rate .... 25.0, %

Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		1,500	1,697	1,920	2,173	2,458
L		630	713	807	912	1,032
Qc		60.0	67.9	76.8	86.9	98.3
Qh		3.8	4.3	4.8	5.5	6.2
Qc' : Qc x 0.5		30.0	34.0	38.4	43.5	49.2
Qd	Type - A Qc + Qh	63.8	72.2	81.6	92.4	104.5
	Type - B Qc	60.0	67.9	76.8	86.9	98.3
	Type - C Qc'	30.0	34.0	38.4	43.5	49.2
Qr	Type - A	12.8	14.4	16.3	18.5	20.9
	Type - B	12.0	13.6	15.4	17.4	19.7
	Type - C	6.0	6.8	7.7	8.7	9.8
Qe		23.6	26.7	30.2	34.2	38.7

Approximate Safe Yield of Borehole (Qw) .... 300 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 230 m^3/day

Maximum Pumping Rate (Qm) .... 200 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 230 m^3/day

Design Capacity: 93
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site		
A - 3	Al Rajam	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural	

Number of Population .... 800, capita ... P

Number of Livestock .... 630, head L

Growth Rate .... 2.5, % R1

Water Demand of Human .... 40.0, L/c/d .... qc

Water Demand of Livestock .... 6.0, L/h/d .... qh

[X] Multipurpose Rate .... 20.0, % R2

[ ] Fire Fighting Use Rate .... 25.0, %

Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
	P	800	905	1,024	1,159	1,311
	L	630	713	806	912	1,032
	Qc	32.0	36.2	41.0	46.4	52.4
	Qh	3.8	4.3	4.8	5.5	6.2
Qc' : Qc x 0.5		16.0	18.1	20.5	23.2	26.2
Qd	Type - A Qc + Qh	35.8	40.5	45.8	51.9	58.6
	Type - B Qc	32.0	36.2	41.0	46.4	52.4
	Type - C Qc'	16.0	18.1	20.5	23.2	26.2
Qr	Type - A	7.2	8.1	9.2	10.4	11.7
	Type - B	6.4	7.2	8.2	9.3	10.5
	Type - C	3.2	3.6	4.1	4.6	5.2
	Qe	12.6	14.3	16.1	18.3	20.6

Approximate Safe Yield of Borehole (Qw) .... 200 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 150 m^3/day

Maximum Pumping Rate (Qm) .... 130 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 150 m^3/day

Design Capacity: 52
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site	
A - 4	Al Khabet	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural

Number of Population .... 1,500, capita ... P

Number of Livestock .... 880, head L

Growth Rate .... 2.5, % R1

Water Demand of Human .... 40.0, L/c/d .... qc

Water Demand of Livestock .... 6.0, L/h/d .... qh

[X] Multipurpose Rate .... 20.0, % R2

[ ] Fire Fighting Use Rate .... 25.0, %

Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		1,500	1,697	1,920	2,172	2,458
L		880	996	1,126	1,275	1,442
Qc		60.0	67.9	76.8	86.9	98.3
Qh		5.3	6.0	6.8	7.7	8.7
Qc' : Qc x 0.5		30.0	34.0	38.4	43.5	49.2
Qd	Type - A Qc + Qh	65.3	73.9	83.6	94.6	107.0
	Type - B Qc	60.0	67.9	76.8	86.9	98.3
	Type - C Qc'	30.0	34.0	38.4	43.5	49.2
Qr	Type - A	13.1	14.8	16.7	18.9	21.4
	Type - B	12.0	13.6	15.4	17.4	19.7
	Type - C	6.0	6.8	7.7	8.7	9.8
Qe		23.6	26.7	30.2	34.2	38.7

Approximate Safe Yield of Borehole (Qw) .... 200 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 150 m^3/day

Maximum Pumping Rate (Qm) .... 130 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 200 m^3/day

Design Capacity: 95
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site		
S - 1	Bany Shaker & Bait Abo Sara'a	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural	

	BANY SHAKER	BAIT ABO SARA'A		
Number of Population	300,	200,	capita ...	P
Number of Livestock		860,	head	L
Growth Rate		2.5,	%	R1
Water Demand of Human		40.0,	L/c/d	qc
Water Demand of Livestock		6.0,	L/h/d	qh
[X] Multipurpose Rate		20.0,	%	R2
[ ] Fire Fighting Use Rate		25.0,	%	
Emergency Purpose		2.5,	L/c/d	qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		500	566	640	724	819
L		860	973	1,101	1,246	1,409
Qc		20.0	22.6	25.6	29.0	32.8
Qh		5.2	5.8	6.6	7.5	8.5
Qc' : Qc x 0.5		10.0	11.3	12.8	14.5	16.4
Qd	Type - A Qc + Qh	25.2	28.4	32.2	36.5	41.3
	Type - B Qc	20.0	22.6	25.6	29.0	32.8
	Type - C Qc'	10.0	11.3	12.8	14.5	16.4
Qr	Type - A	5.0	5.7	6.4	7.3	8.3
	Type - B	4.0	4.5	5.1	5.8	6.6
	Type - C	2.0	2.3	2.6	2.9	3.3
Qe		7.9	8.9	10.1	11.4	12.9

Approximate Safe Yield of Borehole (Qw) .... 200 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 150 m^3/day

Maximum Pumping Rate (Qm) .... 130 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 150 m^3/day

Design Capacity: 37
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site		
S - 2	Bait Abo Hashem	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural	

Number of Population .... 380, capita ... P

Number of Livestock .... 1,600, head L

Growth Rate .... 2.5, % R1

Water Demand of Human .... 40.0, L/c/d .... qc

Water Demand of Livestock .... 6.0, L/h/d .... qh

[X] Multipurpose Rate .... 20.0, % R2

[ ] Fire Fighting Use Rate .... 25.0, %

Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		380	430	486	550	623
L		1,600	1,810	2,048	2,317	2,622
Qc		15.2	17.2	19.4	22.0	24.9
Qh		9.6	10.9	12.3	13.9	15.7
Qc' : Qc x 0.5		7.6	8.6	9.7	11.0	12.5
Qd	Type - A Qc + Qh	24.8	28.1	31.7	35.9	40.6
	Type - B Qc	15.2	17.2	19.4	22.0	24.9
	Type - C Qc'	7.6	8.6	9.7	11.0	12.5
Qr	Type - A	5.0	5.6	6.3	7.2	8.1
	Type - B	3.0	3.4	3.9	4.4	5.0
	Type - C	1.5	1.7	1.9	2.2	2.5
Qe		6.0	6.8	7.7	8.7	9.8

Approximate Safe Yield of Borehole (Qw) .... 200 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 150 m^3/day

Maximum Pumping Rate (Qm) .... 130 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 200 m^3/day

Design Capacity: 36
Type (A) - (4) determinated by [X] Water Demand. [ ] Capacity of Water Source.

Number	Survey Site	
S - 3	Al Sheab, Al Aswad	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural

Number of Population .... 2,000, capita ... P

Number of Livestock .... 8,800, head L

Growth Rate .... 3.0, % R1

Water Demand of Human .... 40.0, L/c/d .... qc

Water Demand of Livestock .... 6.0, L/h/d .... qh

[X] Multipurpose Rate .... 20.0, % R2

[ ] Fire Fighting Use Rate .... 25.0, %

Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		2,000	2,319	2,688	3,116	3,612
L		8,800	10,202	11,826	13,710	15,894
Qc		80.0	92.8	107.5	124.6	144.5
Qh		52.8	61.2	71.0	82.3	95.4
Qc' : Qc x 0.5		40.0	46.4	53.8	62.3	72.3
Qd	Type - A Qc + Qh	132.8	154.0	178.5	206.9	239.9
	Type - B Qc	80.0	92.8	107.5	124.6	144.5
	Type - C Qc'	40.0	46.4	53.8	62.3	72.3
Qr	Type - A	26.6	30.8	35.7	41.4	48.0
	Type - B	16.0	18.6	21.5	24.9	28.9
	Type - C	8.0	9.3	10.8	12.5	14.5
Qe		31.5	36.5	42.3	49.1	56.9

Approximate Safe Yield of Borehole (Qw) .... 300 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 230 m^3/day

Maximum Pumping Rate (Qm) .... 200 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 230 m^3/day

Design Capacity: 207
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site		
S - 4	Bany Farhan & Bany Saria'a	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural	

Number of Population	650,	capita ...	P
Number of Livestock	1,300	head	L
Growth Rate	2.5	%	R1
Water Demand of Human	40.0,	L/c/d	qc
Water Demand of Livestock	6.0,	L/h/d	qh
[X] Multipurpose Rate	20.0,	%	R2
[ ] Fire Fighting Use Rate	25.0,	%	
Emergency Purpose	2.5,	L/c/d	qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		650	735	832	941	1,065
L		1,300	1,471	1,664	1,883	2,130
Qc		26.0	29.4	33.3	37.6	42.6
Qh		7.8	8.8	10.0	11.3	12.8
Qc' : Qc x 0.5		13.0	14.7	16.7	18.8	21.3
Qd	Type - A Qc + Qh	33.8	38.2	43.3	48.9	55.4
	Type - B Qc	26.0	29.4	33.3	37.6	42.6
	Type - C Qc'	13.0	14.7	16.7	18.8	21.3
Qr	Type - A	6.8	7.6	8.7	9.8	11.1
	Type - B	5.2	5.9	6.7	7.5	8.5
	Type - C	2.6	2.9	3.3	3.8	4.3
Qe		10.2	11.6	13.1	14.8	16.8

Approximate Safe Yield of Borehole (Qw) .... 300 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 230 m^3/day

Maximum Pumping Rate (Qm) .... 200 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 230 m^3/day

Design Capacity: 49
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site		
H - 1	Ghulayfagah	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural	

Number of Population .... 500, capita ... P

Number of Livestock .... 510, head L

Growth Rate .... 2.5, % R1

Water Demand of Human .... 40.0, L/c/d .... qc

Water Demand of Livestock .... 6.0, L/h/d .... qh

[ ] Multipurpose Rate .... 20.0, %

[X] Fire Fighting Use Rate .... 25.0, % R2

Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		500	566	640	724	819
L		510	577	653	739	836
Qc		20.0	22.6	25.6	29.0	32.8
Qh		3.0	3.5	3.9	4.4	5.0
Qc' : Qc x 0.5		10.0	11.3	12.8	14.5	16.4
Qd	Type - A Qc + Qh	23.0	26.1	29.5	33.4	37.8
	Type - B Qc	20.0	22.6	25.6	29.0	32.8
	Type - C Qc'	10.0	11.3	12.8	14.5	16.4
Qr	Type - A	5.8	6.5	7.4	8.4	9.5
	Type - B	5.0	5.7	6.4	7.3	8.2
	Type - C	2.5	2.8	3.2	3.6	4.1
Qe		7.9	8.9	10.1	11.4	12.9

Approximate Safe Yield of Borehole (Qw) .... 100 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 80 m^3/day

Maximum Pumping Rate (Qm) .... 70 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 80 m^3/day

Design Capacity: 34
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site	
H - 2	Al Dahi	[X] U .. Urban [ ] S .. Semiurban [ ] R .. Rural

Number of Population .... 7,000 capita ... P

Number of Livestock .... 7,710 head L

Growth Rate .... 6.0 % R1

Water Demand of Human .... 120.0 L/c/d .... qc

Water Demand of Livestock .... 6.0 L/h/d .... qh

[ ] Multipurpose Rate .... 20.0 %

[X] Fire Fighting Use Rate .... 25.0 % R2

Emergency Purpose .... 2.5 L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		7,000	9,368	12,536	16,776	22,450
L		7,710	10,318	13,807	18,477	24,727
Qc		840.0	1,124.2	1,504.3	2,013.1	2,694.0
Qh		46.3	61.9	82.8	110.9	148.4
Qc' : Qc x 0.5		420.0	562.1	752.2	1,006.6	1,347.0
Qd	Type - A Qc + Qh	886.3	1,186.1	1,587.1	2,124.0	2,842.4
	Type - B Qc	840.0	1,124.2	1,504.3	2,013.1	2,694.0
	Type - C Qc'	420.0	562.1	752.2	1,006.6	1,347.0
Qr	Type - A	221.6	296.5	396.8	531.0	710.6
	Type - B	210.0	281.1	376.1	503.3	673.5
	Type - C	105.0	140.5	188.1	251.7	336.8
Qe		110.3	147.5	197.4	264.2	353.6

Approximate Safe Yield of Borehole (Qw) .... 1,000 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 790 m^3/day

Maximum Pumping Rate (Qm) .... 690 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 2 ea =1,580 m^3/day

Design Capacity: 1,580
Type (A) - (3) determinated by [ ] Water Demand.
[X] Capacity of Water Source.

Number	Survey Site	
H - 3	Al Mounirah	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural

	ABBAS	HARUNIA		
Number of Population	700,	1,000,	capita ...	P
Number of Livestock	265,	375,	head	L
Growth Rate		6.0,	%	R1
Water Demand of Human		40.0,	L/c/d	qc
Water Demand of Livestock		6.0,	L/h/d	qh
[ ] Multipurpose Rate		20.0,	%	
[X] Fire Fighting Use Rate		25.0,	%	R2
Emergency Purpose		2.5,	L/c/d	qe

			1	2	3	4	5
			Present	5 years	10 years	15 years	20 years
P		A	700	937	1,254	1,678	2,245
		H	1,000	1,338	1,791	2,397	3,207
L		A	265	355	475	635	850
		H	375	502	672	899	1,203
Qc		A	28.0	37.5	50.2	67.1	89.8
		H	40.0	53.5	71.6	95.9	128.3
Qh		A	1.6	2.1	2.9	3.8	5.1
		H	2.3	3.0	4.0	5.4	7.2
Qc' : Qc x 0.5		A	14.0	18.8	25.1	33.6	44.9
		H	20.0	26.8	35.8	48.0	64.2
Qd	Type - A Qc + Qh	A	29.6	39.6	53.1	70.9	94.9
		H	42.3	56.5	75.6	101.3	135.5
	Type - B Qc	A	28.0	37.5	50.2	67.1	89.8
		H	40.0	53.5	71.6	95.9	128.3
	Type - C Qc'	A	14.0	18.8	25.1	33.6	44.9
		H	20.0	26.8	35.8	48.0	64.2
Qr	Type - A	A	7.4	9.9	13.3	17.7	23.7
		H	10.5	14.1	18.9	25.3	33.9
	Type - B	A	7.0	9.4	12.6	16.8	22.5
		H	10.0	13.4	17.9	24.0	32.1
	Type - C	A	3.5	4.7	6.3	8.4	11.2
		H	5.0	6.7	9.0	12.0	16.1
Qe		A	11.0	14.8	19.8	26.4	35.4
		H	15.8	21.1	28.2	37.8	50.5

Approximate Safe Yield of Borehole (Qw) .... 500 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 400 m^3/day

Maximum Pumping Rate (Qm) .... 340 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 400 m^3/day

Design Capacity: 172
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site	
T - 1	Al Mashjab	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural

Number of Population .... 800 , capita ... P

Number of Livestock .... 6,670 , head L

Growth Rate .... 2.5 , % R1

Water Demand of Human .... 40.0 , L/c/d .... qc

Water Demand of Livestock .... 6.0 , L/h/d .... qh

[X] Multipurpose Rate .... 20.0 , % R2

[ ] Fire Fighting Use Rate .... 25.0 , %

Emergency Purpose .... 2.5 , L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		800	905	1,024	1,159	1,311
L		6,670	7,547	8,538	9,660	10,930
Qc		32.0	36.2	41.0	46.4	52.4
Qh		40.0	45.3	51.2	58.0	65.6
Qc' : Qc x 0.5		16.0	18.1	20.5	23.2	26.2
Qd	Type - A Qc + Qh	72.0	81.5	92.2	104.4	118.0
	Type - B Qc	32.0	36.2	41.0	46.4	52.4
	Type - C Qc'	16.0	18.1	20.5	23.2	26.2
Qr	Type - A	14.4	16.3	18.4	20.9	23.6
	Type - B	6.4	7.2	8.2	9.3	10.5
	Type - C	3.2	3.6	4.1	4.6	5.2
Qe		12.6	14.3	16.1	18.3	20.6

Approximate Safe Yield of Borehole (Qw) .... 400 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 310 m^3/day

Maximum Pumping Rate (Qm) .... 270 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 310 m^3/day

Design Capacity: 105
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site		
T - 2	Al Manara & Al Dukum	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural	

Number of Population .... 600, capita ... P

Number of Livestock .... 6,240, head L

Growth Rate .... 2.5, % R1

Water Demand of Human .... 40.0, L/c/d .... qc

Water Demand of Livestock .... 6.0, L/h/d .... qh

[X] Multipurpose Rate .... 20.0, % R2

[ ] Fire Fighting Use Rate .... 25.0, %

Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		600	679	768	869	983
L		6,240	7,060	7,988	9,037	10,123
Qc		24.0	27.2	30.7	34.8	39.3
Qh		37.4	42.4	47.9	54.2	60.7
Qc' : Qc x 0.5		12.0	13.6	15.4	17.4	19.7
Qd	Type - A Qc + Qh	61.4	69.6	78.6	89.0	100.0
	Type - B Qc	24.0	27.2	30.7	34.8	39.3
	Type - C Qc'	12.0	13.6	15.4	17.4	19.7
Qr	Type - A	12.3	13.9	15.7	17.8	20.0
	Type - B	4.8	5.4	6.1	7.0	7.9
	Type - C	2.4	2.7	3.1	3.5	3.9
Qe		9.5	10.7	12.1	12.7	15.5

Approximate Safe Yield of Borehole (Qw) .... 400 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 310 m^3/day

Maximum Pumping Rate (Qm) .... 270 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 310 m^3/day

Design Capacity: 89
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site	
T - 3	Al Maydan, Al Jubail	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural

Number of Population .... 1,000, capita ... P
Number of Livestock .... 2,740, head L
Growth Rate .... 2.5, % R1
Water Demand of Human .... 40.0, L/c/d .... qc
Water Demand of Livestock .... 6.0, L/h/d .... qh
[X] Multipurpose Rate .... 20.0, % R2
[ ] Fire Fighting Use Rate .... 25.0, %
Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		1,000	1,131	1,280	1,448	1,639
L		2,740	3,100	3,507	3,968	4,490
Qc		40.0	45.3	51.2	57.9	65.6
Qh		16.4	18.6	21.0	23.8	26.9
Qc' : Qc x 0.5		20.0	22.7	25.6	29.0	32.8
Qd	Type - A Qc + Qh	56.4	63.9	72.2	81.7	92.5
	Type - B Qc	40.0	45.3	51.2	57.9	65.6
	Type - C Qc'	20.0	22.7	25.6	29.0	32.8
Qr	Type - A	11.3	12.8	14.4	16.3	18.5
	Type - B	8.0	9.1	10.2	11.6	13.1
	Type - C	4.0	4.5	5.1	5.8	6.6
Qe		15.8	17.8	20.2	22.8	25.8

Approximate Safe Yield of Borehole (Qw) .... 700 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 550 m^3/day

Maximum Pumping Rate (Qm) .... 480 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 550 m^3/day

Design Capacity: 82
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site		
T - 4A	Hadad & Qahfa	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural	

	HADAD	QAHFA		
Number of Population ...	700 ,	1,100 ,	capita ...	P
Number of Livestock	1,100 ,	1,640 ,	head	L
Growth Rate		2.5 ,	%	R1
Water Demand of Human		40.0 ,	L/c/d	qc
Water Demand of Livestock		6.0 ,	L/h/d	qh
[X] Multipurpose Rate		20.0 ,	%	R2
[ ] Fire Fighting Use Rate		25.0 ,	%	
Emergency Purpose		2.5 ,	L/c/d	qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		H 700 G1,100	792 1,245	896 1,408	1,014 1,593	1,147 1,802
L		H1,100 G1,640	1,245 1,856	1,408 2,099	1,593 2,375	1,802 2,687
Qc		H 28.0 G 44.0	31.7 49.8	35.8 56.3	40.6 63.7	45.9 72.1
Qh		H 6.6 G 9.8	7.5 11.1	8.4 12.6	9.6 14.3	10.8 16.1
Qc' : Qc x 0.5		H 14.0 G 22.0	15.9 24.9	17.9 28.2	20.3 31.9	23.0 36.1
Qd	Type - A Qc + Qh	H 34.6 G 53.8	39.2 60.9	44.2 68.9	50.2 78.0	56.7 88.2
	Type - B Qc	H 28.0 G 44.0	31.7 49.8	35.8 56.3	40.6 63.7	45.9 72.1
	Type - C Qc'	H 14.0 G 22.0	15.9 24.9	17.9 28.2	20.3 31.9	23.0 36.1
Qr	Type - A	H 6.9 G 10.8	7.8 12.2	8.8 13.8	10.0 15.6	11.3 17.6
	Type - B	H 5.6 G 8.8	6.3 10.0	7.2 11.3	8.1 12.7	9.2 14.4
	Type - C	H 2.8 G 4.4	3.2 5.0	3.6 5.6	4.1 6.4	4.6 7.2
Qe		H 11.0 G 17.3	12.5 19.6	14.1 22.2	16.0 25.1	18.1 28.4

Approximate Safe Yield of Borehole (Qw) .... 500 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 400 m^3/day

Maximum Pumping Rate (Qm) .... 340 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 400 m^3/day

Design Capacity: 128
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site		
T-4B	Al Kudha & Al Hagl	[ ]	U .. Urban
		[X]	S .. Semiurban
		[ ]	R .. Rural

Number of Population	2,500,	capita ...	P
Number of Livestock	3,430,	head	L
Growth Rate	2.5,	%	R1
Water Demand of Human	40.0,	L/c/d	qc
Water Demand of Livestock	6.0,	L/h/d	qh
[X] Multipurpose Rate	20.0,	%	R2
[ ] Fire Fighting Use Rate	25.0,	%	
Emergency Purpose	2.5,	L/c/d	qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		2,500	2,829	3,200	3,621	4,097
L		3,430	3,881	4,391	4,968	5,620
Qc		100.6	113.2	128.0	144.8	163.9
Qh		20.6	23.3	26.3	29.8	33.7
Qc' : Qc x 0.5		50.0	56.6	64.0	72.4	82.0
Qd	Type - A Qc + Qh	120.6	136.5	154.3	174.6	197.6
	Type - B Qc	100.0	113.2	128.0	144.8	163.9
	Type - C Qc'	50.0	56.6	64.0	72.4	82.0
Qr	Type - A	24.1	27.3	30.9	34.9	39.5
	Type - B	20.0	22.6	25.6	29.0	32.8
	Type - C	10.0	11.3	12.8	14.5	16.4
Qe		39.4	44.6	50.4	57.0	64.5

Approximate Safe Yield of Borehole (Qw) .... 100 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 80 m^3/day

Maximum Pumping Rate (Qm) .... 70 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 80 m^3/day

Design Capacity:
Type (C) - (4) determinated by [ ] Water Demand.
[X] Capacity of Water Source.

Number	Survey Site
T - 5	Shohat & Al Kadash

[ ] U .. Urban
[ ] S .. Semiurban
[X] R .. Rural

Number of Population .... 2,000, capita ... P
Number of Livestock .... 3,740, head L
Growth Rate .... 2.5, % R1
Water Demand of Human .... 40.0, L/c/d .... qc
Water Demand of Livestock .... 6.0, L/h/d .... qh
[X] Multipurpose Rate .... 20.0, % R2
[ ] Fire Fighting Use Rate .... 25.0, %
Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		2,000	2,263	2,560	2,897	3,277
L		3,740	4,231	4,787	5,417	6,128
Qc		80.0	90.5	102.4	115.9	131.1
Qh		22.4	25.4	28.7	32.5	36.8
Qc' : Qc x 0.5		40.0	45.3	51.2	58.0	65.6
Qd	Type - A Qc + Qh	102.4	115.9	131.1	148.4	167.9
	Type - B Qc	80.0	90.5	102.4	115.9	131.1
	Type - C Qc'	40.0	45.3	51.2	58.0	65.6
Qr	Type - A	20.5	23.2	26.2	29.7	33.6
	Type - B	16.0	18.1	20.5	23.2	26.2
	Type - C	8.0	9.1	10.2	11.6	13.1
Qe		31.5	35.6	40.3	45.6	51.6

Approximate Safe Yield of Borehole (Qw) .... 200 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 150 m^3/day

Maximum Pumping Rate (Qm) .... 130 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 150 m^3/day

Design Capacity:
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site	
T - 6	Al Zakira	[ ] U .. Urban [X] S .. Semiurban [ ] R .. Rural

Number of Population .... 4,000 capita ... P

Number of Livestock .... 8,220 head L

Growth Rate .... 3.0 % R1

Water Demand of Human .... 70.0 L/c/d .... qc

Water Demand of Livestock .... 6.0 L/h/d .... qh

[X] Multipurpose Rate .... 20.0 % R2

[ ] Fire Fighting Use Rate .... 25.0 %

Emergency Purpose .... 2.5 L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		4,000	4,637	5,376	6,232	7,224
L		8,220	9,529	11,047	12,807	14,846
Qc		280.0	324.6	376.3	436.2	505.7
Qh		49.3	57.2	66.3	76.8	89.1
Qc' : Qc x 0.5		140.0	162.3	188.2	218.1	252.9
Qd	Type - A Qc + Qh	329.3	381.8	442.6	513.0	594.8
	Type - B Qc	280.0	324.6	376.3	436.2	505.7
	Type - C Qc'	140.0	162.3	188.2	218.1	252.9
Qr	Type - A	65.9	76.4	88.5	102.6	119.0
	Type - B	56.0	64.9	75.3	87.2	101.1
	Type - C	28.0	32.5	37.6	43.6	50.6
Qe		63.0	73.0	84.7	98.2	113.8

Approximate Safe Yield of Borehole (Qw) .... 100 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 80 m^3/day

Maximum Pumping Rate (Qm) .... 70 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 3 ea = 240 m^3/day

Design Capacity:
Type (C) - (3) determinated by [ ] Water Demand.
[X] Capacity of Water Source.

Number	Survey Site		
T - 7	Bab Al Mandab	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural	

Number of Population .... 5,000, capita ... P

Number of Livestock .... 410, head L

Growth Rate .... 6.0, % R1

Water Demand of Human .... 120.0, L/c/d .... qc

Water Demand of Livestock .... 6.0, L/h/d .... qh

[ ] Multipurpose Rate .... 20.0, %

[X] Fire Fighting Use Rate .... 25.0, % R2

Emergency Purpose .... 2.5, L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		5,000	6,691	8,954	11,983	16,036
L		410	549	734	983	1,315
Qc		600.0	802.9	1,074.5	1,438.0	1,924.3
Qh		2.5	3.3	4.4	5.9	7.9
Qc' : Qc x 0.5		300.0	401.5	537.3	719.0	962.2
Qd	Type - A Qc + Qh	602.5	806.2	1,078.9	1,443.9	1,932.2
	Type - B Qc	600.0	802.9	1,074.5	1,438.0	1,924.3
	Type - C Qc'	300.0	401.5	537.3	719.0	962.2
Qr	Type - A	150.6	201.6	269.7	361.0	483.1
	Type - B	150.0	200.7	268.6	359.5	481.1
	Type - C	75.0	100.4	134.3	179.8	240.6
Qe		78.8	105.4	141.0	188.7	252.6

Approximate Safe Yield of Borehole (Qw) .... 500 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 400 m^3/day

Maximum Pumping Rate (Qm) .... 340 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 3 ea =1,200 m^3/day

Design Capacity:
Type (A) - (3) determinated by [ ] Water Demand.
[X] Capacity of Water Source.

Number	Survey Site		
T - 8	Yahkhtol	[ ] U .. Urban [ ] S .. Semiurban [X] R .. Rural	

Number of Population .... 2,500 , capita ... P
Number of Livestock .... 6,850 , head L
Growth Rate .... 6.0 , % R1
Water Demand of Human .... 40.0 , L/c/d .... qc
Water Demand of Livestock .... 6.0 , L/h/d .... qh
[ ] Multipurpose Rate .... 20.0 , %
[X] Fire Fighting Use Rate .... 25.0 , % R2
Emergency Purpose .... 2.5 , L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		2,500	3,346	4,477	5,991	8,018
L		6,850	9,167	12,267	16,416	21,969
Qc		100.0	133.8	179.1	239.6	320.7
Qh		41.1	55.0	73.6	98.5	131.8
Qc' : Qc x 0.5		50.0	66.9	89.6	119.8	160.4
Qd	Type - A Qc + Qh	141.1	188.8	252.7	338.1	452.5
	Type - B Qc	100.0	133.8	179.1	239.6	320.7
	Type - C Qc'	50.0	66.9	89.6	119.8	160.8
Qr	Type - A	35.3	47.2	63.2	84.5	113.1
	Type - B	25.0	33.5	44.8	59.9	80.2
	Type - C	12.5	16.7	22.4	30.0	40.2
Qe		39.4	52.7	70.5	94.4	126.3

Approximate Safe Yield of Borehole (Qw) .... 1,000 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 790 m^3/day

Maximum Pumping Rate (Qm) .... 690 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 690 m^3/day

Design Capacity: 338
Type (A) - (4) determinated by [X] Water Demand.
[ ] Capacity of Water Source.

Number	Survey Site	
T - 9	Makbana	[ ] U .. Urban [X] S .. Semiurban [X] R .. Rural

Number of Population ... (S) 3,000 , (R) 4,000, capita ... P

Number of Livestock .... 2,740, head L

Growth Rate .... 3.0, % R1

Water Demand of Human ... (S) 70.0 , (R) 40.0, L/c/d .... qc

Water Demand of Livestock .... 6.0, L/h/d .... qh

[X] Multipurpose Rate .... 20.0 % R2

[ ] Fire Fighting Use Rate .... 25.0 %

Emergency Purpose .... 2.5 L/c/d .... qe

		1	2	3	4	5
		Present	5 years	10 years	15 years	20 years
P		S3,000 R4,000	3,478 4,637	4,032 5,376	4,674 6,232	5,418 7,224
L		2,740	3,176	3,682	4,269	4,929
Qc		S210.0 R160.0	243.5 185.5	282.2 215.0	327.2 249.3	379.3 289.0
Qh		16.4	19.0	22.1	25.6	29.6
Qc' : Qc x 0.5		S105.0 R 80.0	121.8 92.8	141.1 107.5	163.6 124.7	189.7 144.5
Qd	Type - A Qc + Qh	386.4	448.0	519.3	602.1	697.9
	Type - B Qc	370.0	429.0	497.2	576.5	668.3
	Type - C Qc'	185.0	246.0	248.6	288.3	334.2
Qr	Type - A	77.3	89.6	103.9	120.4	139.6
	Type - B	74.0	85.8	99.4	115.3	133.7
	Type - C	37.0	49.2	49.7	57.7	66.8
Qe		110.3	127.8	148.2	171.8	199.1

Approximate Safe Yield of Borehole (Qw) .... 700 m^3/day

Daily Maximum Yield of Borehole with
19 hrs Operation (Qmw) .... 550 m^3/day

Maximum Pumping Rate (Qm) .... 480 L/min

Total Yield of Borehole per Day (Qmw)
.... Qmw x 1 ea = 550 m^3/day

Design Capacity: 550
Type (A) - (4) determinated by [ ] Water Demand.
[X] Capacity of Water Source.

APPENDIX 4

COST ESTIMATE

Cost of Water Source - (1)

Number	Survey Site	Total Depth	Drilling Cost: Sand & Gravel ϕ=350 Q'ty	Rate	Amount	Sand & Gravel ϕ=300 Q'ty	Rate	Amount	Soft Rock ϕ=300 Q'ty	Rate	Amount	Medium to Hard Rock ϕ=300 Q'ty	Rate	Amount	Sub Total	Electric-Logging Q'ty	Rate	Amount
			m	¥/m	¥	m	¥/m	¥	m	¥/m	¥	m	¥/m	¥	¥	m	¥/m	¥
HA-1	AL-MADAN & VILLAGES	300	20	91,394	1,827,880		85,133		80	122,950	9,836,000	200	165,068	33,013,600	44,677,480	300	1,670	501,000
HA-2	ELMAN & 4 OTHER VILLAGES	300	20		1,827,880				80		9,836,000	200		33,013,600	44,677,480	300		501,000
HA-3A	SIHARA	300	20		1,827,880				80		9,836,000	200		33,013,600	44,677,480	300		501,000
HA-3B	THARI	300	20		1,827,880				80		9,836,000	100		16,506,800	28,170,680	200		334,000
HA-4	HARAD	120	10		913,940	90		7,661,970	20		2,459,000				11,034,910	120		200,400
A-1	AL-MAHWEET CITY	200	20		1,827,880				180		22,131,000				23,958,880	200		334,000
A-2	HUFASH	200	20		1,827,880				80		9,836,000	100		16,506,800	28,170,680	200		334,000
A-3	AL-RAJAM	300	20		1,827,880				80		9,836,000	200		33,013,600	44,677,480	300		501,000
A-4	AL-KHABET	200	20		1,827,880				80		9,836,000	100		16,506,800	28,170,680	200		334,000
S-1	BANY SHAKER & BAIT ABO	200	20		1,827,880				80		9,836,000	100		16,506,800	28,170,680	200		334,000
S-2	BAIT ABO HASHEM	200	10		913,940				90		11,065,500	100		16,506,800	28,486,240	200		334,000
S-3	AL-SHEAB & AL-ASEAD	100	10		913,940				40		4,918,000	50		8,253,400	14,085,340	100		167,000
S-4	BANY FARHAN & BANY SERIA'A	100	10		913,940				40		4,918,000	50		8,253,400	14,085,340	100		167,000
H-1	GHULAYFAGAH	30	10		913,940	20		1,702,660							2,616,600	30		50,100
H-2	AL-DAHI	80	10		913,940	70		5,959,310							6,873,250	80		133,600
H-3	AL-MOUNIRAH	60	10		913,940	50		4,256,650							5,170,590	60		100,200
T-1	AL-MASHJAB	110	10		913,940	80		6,810,640	20		2,459,000				10,183,580	110		183,700
T-2	AL-MANARA & AL-DUKUM	110	10		913,940	80		6,810,640	20		2,459,000				10,183,580	110		183,700
T-3	AL-MAYDAN AL-JUBAIL SHEIBD HAMUD	200	20		1,827,880				80		9,836,000	100		16,506,800	28,170,680	200		334,000
T-4A	HADAD, QAHFA	180	20		1,827,880				60		7,377,000	100		16,506,800	25,711,680	200		334,000
T-4B	AL-KUDAH, AL-HAGL																	
T-5	SHOHAT, AL-KADASH					15		1,276,995	5		614,750				1,891,745	20		33,400
T-6	AL-ZAKIRA																	
T-7	BAB-AL-MANDAB	85	20		1,827,880							65		10,729,300	12,557,300	85		141,950
T-8	YAHKHTOL	100	10		913,940	70		5,959,310	20		2,459,000				9,332,250	100		167,000
T-9	MAKBANA	300	20		1,827,880				140		17,213,000	140		23,109,520	42,150,400	300		501,000

Cost of Water Source - (2)

Number	Casing and Screen													Pumping Test		Temporary Work			
	Casing Insertion			Casing Pipe ø = 200			Screen ø=200			Gravel Pack									
	Q'ty	Rate	Amount	Q'ty	Rate	Amount	Q'ty	Rate	Amount	Q'ty	Rate	Amount	Sub-Total	Q'ty	Amount	Scaffolding	Bentonite	Assemblage and Disassemblage of Drilling Machine	Sub Total
	m	¥/m	¥	m	¥/m	¥	m	¥/m	¥	m^3	¥/m^3	¥	¥	set	¥	¥	¥	¥	¥
HA-1	300	4,640	1,392,000	237	7,500	1,777,500	63	85,000	5,355,000		50,000		8,524,500	1	2,188,248	229,600	417,000	791,920	1,438,520
HA-2	300		1,392,000	237		1,777,500	63		5,355,000				8,524,500	1	2,188,248	229,600	417,000	791,920	1,438,520
HA-3A	300		1,392,000	237		1,777,500	63		5,355,000				8,524,500	1	2,188,248	229,600	417,000	791,920	1,438,520
HA-3B	200		928,000	158		1,185,000	42		3,570,000				5,683,000	1	2,188,248	229,600	417,000	791,920	1,438,520
HA-4	120		556,800	197		727,500	23		1,955,000	2.5		125,000	3,364,300	1	2,188,248	229,600	417,000	791,920	1,438,520
A-1	200		928,000	158		1,185,000	42		3,570,000				5,683,000	1	2,188,248	229,600	417,000	791,920	1,438,520
A-2	200		928,000	158		1,185,000	42		3,570,000				5,683,000	1	2,188,248	229,600	417,000	791,920	1,438,520
A-3	300		1,392,000	237		1,777,500	63		5,355,000				8,524,500	1	2,188,248	229,600	417,000	791,920	1,438,520
A-4	200		928,000	158		1,185,000	42		3,570,000				5,683,000	1	2,188,248	229,600	417,000	791,920	1,430,520
S-1	200		928,000	158		1,185,000	42		3,570,000				5,683,000	1	2,188,248	229,600	417,000	791,920	1,438,520
S-2	200		928,000	158		1,185,000	42		3,570,000				5,683,000	1	2,188,248	229,600	417,000	791,920	1,438,520
S-3	100		464,000	80		600,000	20		1,700,000				2,764,000	1	2,188,248	229,600	417,000	791,920	1,438,520
S-4	100		464,000	80		600,000	20		1,700,000				2,764,000	1	2,188,248	229,600	417,000	791,920	1,438,520
H-1	30		139,200	20		150,000	10		850,000				1,139,200	1	2,188,248	229,600	417,000	791,920	1,438,520
H-2	80		371,200	60		450,000	20		1,700,000	3.2		160,000	2,681,200	1	2,188,248	229,600	417,000	791,920	1,438,520
H-3	60		278,400	40		300,000	20		1,700,000	3.0		150,000	2,428,400	1	2,188,248	229,600	417,000	791,920	1,438,520
T-1	110		510,400	89		667,500	21		1,785,000	4.5		225,000	3,187,900	1	2,188,248	229,600	417,000	791,920	1,438,520
T-2	110		510,400	89		667,500	21		1,785,000	4.5		225,000	3,187,900	1	2,188,248	229,600	417,000	791,920	1,438,520
T-3	200		928,000	158		1,185,000	42		3,570,000				5,683,000	1	2,188,248	229,600	417,000	791,920	1,438,520
T-4A	200		928,000	158		1,185,000	42		3,570,000				5,683,000	1	2,188,248	229,600	417,000	791,920	1,438,520
T-4B																			1,438,520
T-5	20		92,800	10		75,000	10		850,000	0.8		40,000	1,057,800	1	2,188,248	229,600	417,000	791,920	1,438,520
T-6																			
T-7	85		394,400	55		412,500	30		2,550,000				3,356,900	1	2,188,248	229,600	417,000	791,920	1,438,520
T-8	100		464,000	80		600,000	20		1,700,000	4		200,000	2,964,000	1	2,188,248	229,600	417,000	791,920	1,438,520
T-9	300		1,392,000	237		1,777,500	63		5,355,000				8,524,500	1	2,188,248	229,600	417,000	791,920	1,438,520

Cost of Water Wource - (3)

Number	Transportations		T.I.P.S		C. Crane		Sub Total	Net Construction Cost	Overhead Cost, etc.							Construction Cost	Management Cost		C. Cost Include Management Cost
	Transportations		T.I.P.S		C. Crane				Rent of Building		Trans-Laborer		Overhead Cost		Sub Total				
	N.D	Amount	N.D	Amount	H	Amount			%	Amount	%	Amount	%	Amount			%	Amount	
HA-1		1,800,000			16	480,000	2,280,000	59,609,748	0.9	536,487	0.5	298,048	8.0	4,768,779	5,603,314	65,213,062	12.5	8,151,632	73,364,694
HA-2		1,800,000			16	480,000	2,280,000	59,609,748	0.9	536,487	0.5	298,048	8.0	4,768,779	5,603,314	65,213,062	12.5	8,151,632	73,364,694
HA-3A		1,350,000			16	480,000	1,830,000	59,159,748	0.9	532,437	0.5	295,798	8.0	4,732,779	5,561,014	64,720,762	12.5	8,090,095	72,810,857
HA-3B		1,800,000			16	480,000	2,280,000	40,094,448	0.9	360,850	0.5	200,472	9.0	3,608,500	4,169,822	44,264,270	12.5	5,533,033	49,797,303
HA-4		1,800,000	1	187,500	16	480,000	2,467,500	20,693,878	0.9	186,244	0.5	103,468	9.0	1,862,449	2,152,161	22,846,039	12.5	2,855,754	25,701,793
A-1		1,800,000			16	480,000	2,280,000	35,882,648	0.9	322,943	0.5	179,413	9.0	3,229,438	3,731,794	39,614,442	13.0	5,149,877	44,764,319
A-2		1,350,000			16	480,000	1,830,000	39,644,448	0.9	356,800	0.5	198,222	9.0	3,568,000	4,123,022	43,767,470	12.5	5,470,933	49,238,403
A-3		2,250,000			16	480,000	2,730,000	60,059,748	0.9	539,637	0.5	299,798	8.0	4,796,779	5,636,214	65,595,962	12.5	8,199,495	73,795,457
A-4		1,350,000			16	480,000	1,830,000	39,644,448	0.9	356,800	0.5	198,222	9.0	3,568,000	4,123,022	43,767,470	12.5	5,470,933	49,238,403
S-1		900,000			16	480,000	1,380,000	39,194,448	0.9	352,750	0.5	195,972	9.0	3,527,500	4,076,222	43,270,670	12.5	5,408,833	48,679,503
S-2		900,000			16	480,000	1,380,000	39,510,008	0.9	355,590	0.5	197,550	9.0	3,555,900	4,109,040	43,619,048	12.5	5,452,381	49,071,429
S-3		900,000			16	480,000	1,380,000	22,023,108	1.2	264,277	0.5	110,115	9.0	1,982,079	2,356,471	24,379,579	13.0	3,169,345	27,548,924
S-4		1,350,000			16	480,000	1,830,000	22,473,108	1.2	269,677	0.5	112,365	9.0	2,022,579	2,404,621	24,877,729	13.0	3,234,104	28,111,833
H-1		2,250,000			16	480,000	2,730,000	10,162,668	1.2	121,952	0.8	81,301	10.5	1,067,080	1,270,333	11,433,001	13.0	1,486,290	12,919,291
H-2		1,800,000			16	480,000	2,280,000	15,594,818	1.2	187,137	0.8	124,758	10.5	1,637,455	1,949,350	17,544,168	13.0	2,280,741	19,824,909
H-3	2.0	1,800,000			16	480,000	2,280,000	13,605,958	1.2	163,271	0.8	108,847	10.5	1,428,625	1,700,743	15,306,701	13.0	1,989,871	17,296,572
T-1		1,800,000			16	480,000	2,280,000	19,461,948	1.2	233,543	0.8	155,695	10.5	2,043,504	2,432,742	21,894,690	13.0	2,846,309	24,740,999
T-2		1,800,000	1	375,000	16	480,000	2,655,000	19,836,948	1.2	238,043	0.8	158,695	10.5	2,082,879	2,479,617	22,316,565	13.0	2,901,153	25,217,718
T-3		2,250,000			16	480,000	2,730,000	40,544,448	0.9	364,900	0.5	202,722	9.0	3,649,000	4,216,622	44,761,070	12.5	5,595,133	50,356,203
T-4A		1,800,000			16	480,000	2,280,000	37,635,448	0.9	338,719	0.5	188,177	9.0	3,387,190	3,914,086	41,549,534	12.5	5,193,691	46,743,225
T-4B		2,250,000			16	480,000	2,730,000												
T-5		747,000	0.5	187,500	8	240,000	1,175,000	7,784,713	1.2	93,416	0.8	62,277	10.5	817,394	973,087	8,757,800	13.0	1,138,515	9,896,315
T-6																			
T-7	3.5	3,150,000			16	480,000	3,630,000	23,312,918	1.2	279,755	0.5	116,564	9.0	2,098,162	2,494,481	25,807,399	13.0	3,354,961	29,162,360
T-8		2,250,000			16	480,000	2,730,000	18,820,018	1.2	225,840	0.8	150,560	10.5	1,976,101	2,352,501	21,172,519	13.0	2,752,427	23,924,946
T-9		2,250,000			16	480,000	2,730,000	57,532,168	0.9	517,789	0.5	287,660	8.0	4,602,573	5,408,022	62,940,190	12.5	7,867,523	70,807,713

Cost of Water Source - (4)

(Unit: ¥ 1,000)

Number	Transportation Japan-Yemen				Total Construction Cost		Q'ty	(A)* Total Construction
	M^3	Freight	Domestic Transportation	Sub Total	Total Construction (¥)	Total Construction Yemen Rial		
HA-1	29.4	1,984,500	562,500 5	2,547,000	75,911,694	1,518,233	2	151,800
HA-2	29.4	1,984,500	562,500 5	2,547,000	75,911,694	1,518,233	1	75,900
HA-3A	29.4	1,984,500	562,500 5	2,547,000	75,357,857	1,507,157	2	150,700
HA-3B	19.6	1,323,000	337,500 3	1,660,500	51,457,803	1,029,156	2	102,900
HA-4	11.8	793,125	225,000 2	1,018,125	26,719,918	534,398	3	80,160
A-1	19.6	1,323,000	337,500 3	1,660,500	46,424,819 (2,000,000)	928,496 (40,000)	2 (1)	92,850 (2,000)
A-2	19.6	1,323,000	337,500 3	1,660,500	50,898,903	1,017,978	1	50,900
A-3	29.4	1,984,500	562,500 5	2,547,000	76,342,457	1,526,849	1	76,350
A-4	19.6	1,323,000	337,500 3	1,660,500	50,844,903	1,016,898	1	50,850
S-1	19.6	1,323,000	337,500 3	1,660,500	50,340,003	1,006,800	1	50,350
S-2	19.6	1,323,000	337,500 3	1,660,500	50,731,929	1,014,638	1	50,750
S-3	9.8	661,500	225,000 2	886,500	28,435,424	568,708	1	28,450
S-4	9.8	661,500	225,000 2	886,500	28,998,333	579,966	1	29,000
H-1	2.9	195,750	112,500 1	308,250	13,227,541	264,550	1	13,200
H-2	7.8	526,500	112,500 1	639,000	20,463,909	409,278	2	40,950
H-3	5.9	398,250	112,500 1	510,750	17,807,322	356,146	1	17,800
T-1	10.8	729,000	225,000 1	954,000	25,694,999	513,899	1	25,700
T-2	10.8	729,000	225,000 2	954,000	26,171,718	523,434	1	26,150
T-3	19.6	1,323,000	337,500 3	1,660,500	52,016,703	1,040,334	1	52,000
T-4A	17.6	1,188,000	337,500 3	1,525,500	48,268,725	965,374	1	48,250
T-4B								
T-5	1.45	97,875	56,250 0.5	154,125	10,050,440	201,008	1	217,300
T-6			2 wells Underground dam Total		20,100,880 197,215,850 217,316,730	402,017 3,944,317 4,346,334		
T-7	8.3	560,250	225,000 2	785,250	29,947,610	598,952	3	89,840
T-8	9.8	661,500	225,000 2	886,500	24,811,446	496,228	1	24,800
T-9	29.4	1,984,500	562,500 5	2,547,000	73,354,713	1,467,094	1	73,350

(A)* Refers to Table 9-2

Cost of PUMP, ETC.

(Unit: ¥ 1,000)

	MACHINE		PUMP HOUSE			OVER HEAD COST			FREIGHT			DOMESTIC TRANSPORTATION			TOTAL, ≑ (B)	
	MACHINE	INSTALLATION	Q'TY	RATE	AMOUNT	Q'TY	RATE	AMOUNT	Q'TY	RATE	AMOUNT	Q'TY	RATE	AMOUNT		
			m^3						m^3							
HA-1	20,400	1,020	48	100	4,800			2,622.0	14	67	938.0	2	112.5	225.0	30,005.0	30,000
HA-2	5,100	510	24	100	2,400			1,201.5	6.5	67	435.5	2	112.5	225.0	9,872.0	9,850
HA-3A	20,400	1,020	48	100	4,800			2,622.0	14	67	938.0	2	112.5	225.0	30,005.0	30,000
HA-3B	20,400	1,020	48	100	4,800			2,622.0	14	67	938.0	2	112.5	225.0	30,005.0	30,000
HA-4	43,600	1,530	72	100	7,200			5,233.0	21	67	1,407.0	4	112.5	450.0	59,420.0	59,400
A-1	20,400	1,020	48	100	4,800			2,622.0	14	67	938.0	2	112.5	225.0	30,005.0	30,000
	(9,274)	(1,020)	(72)	(100)	(4,200)			(830)	(3)	(67)	(201.0)	(2)	(112.5)	(225.0)	(15,750.0)	(15,750)
A-2	5,100	510	24	100	2,400			1,201.5	6.5	67	435.5	2	112.5	225.0	9,872.0	9,850
A-3	5,100	510	24	100	2,400			1,201.5	6.5	67	435.5	2	112.5	225.0	9,872.0	9,850
A-4	5,100	510	24	100	2,400			1,201.5	6.5	67	435.5	2	112.5	225.0	9,872.0	9,850
S-1	4,700	510	24	100	2,400			1,141.5	6	67	402.0	2	112.5	225.0	9,378.5	9,350
S-2	4,700	510	24	100	2,400			1,141.5	6	67	402.0	2	112.5	225.0	9,378.5	9,350
S-3	3,900	255	12	100	1,200			651.0	3	67	201.0	1	112.5	112.5	6,319.5	6,300
S-4	3,900	255	12	100	1,200			651.0	3	67	201.0	1	112.5	112.5	6,319.5	6,300
H-1	3,900	255	12	100	1,200			651.0	3	67	201.0	1	112.5	112.5	6,319.5	6,300
H-2	17,600	1,020	48	100	4,800			1,734.2	14	67	938.0	2	112.5	225.0	26,317.2	26,300
H-3	3,900	255	12	100	1,200			651.0	3	67	201.0	1	112.5		6,319.5	6,300
T-1	3,900	255	12	100	1,200			651.0	3	67	201.0	1	112.5	112.5	6,319.5	6,300
T-2	3,900	255	12	100	1,200			651.0	3	67	201.0	1	112.5	112.5	6,319.5	6,300
T-3	4,600	510	24	100	2,400			1,143.0	6.5	67	435.5	2	112.5		9,313.5	9,300
T-4A	3,900	255	12	100	1,200			651.0	3	67	201.0	1	112.5	112.5	6,319.5	6,300
T-4B	-	-														
T-5	6,290	510	48	100	4,800			1,740.0	8.5	67	569.5	2	112.5	225.0	14,134.5	14,100
T-6	-	-		-	-											
T-7	8,790	1,530	72	100	7,200			1,752.0	18	67	1,206.0	4	112.5	450.0	20,928.0	20,900
T-8	2,930	510	24	100	2,440			836.0	6	67	402.0	2	112.5	225.0	7,343.0	7,300
T-9	10,200	510	24	100	2,440			1,926.5	7	67	469.0	2	112.5	225.0	15,770.5	15,750

Cost of WATER SOURCE TANK

(Unit : ¥ 1,000)

	TANK & INSTALLATION			OVER HEAD COST			FREIGHT			DOMESTIC TRANSPORTATION			TOTAL	≑ (C)
	Q'TY	RATE	AMOUNT	Q'TY	RATE	AMOUNT	Q'TY	RATE	AMOUNT	Q'TY	RATE	AMOUNT		
HA-1			1,778.0			266.7	$4m^3$	67	268.0	1	112.5	112.5	2,425.2	2,400.0
HA-2			1,590.0			238.5	3	67	201.0	1	112.5	112.5	2,142.0	2,100.0
HA-3A			1,778.0			266.7	4	67	268.0	1	112.5	112.5	2,425.2	2,400.0
HA-3B			1,778.0			266.7	4	67	268.0	1	112.5	112.5	2,425.2	2,400.0
HA-4			55.810.0			8,371.5			-	-		5,581.0	69,762.5	69,500.0
A-1			1,778.0 (4,198.9)			266.7 (770.1)	4 (5.5)	67 (67)	268.0 (368.5)	1 (1)	112.5 (112.5)	112.5 (112.5)	2,425.2 (5,450)	2,400.0 (5,450)
A-2			1,590.0			238.5	3	67	201.0	1	112.5	112.5	2,142.0	2,100.0
A-3			1,270.0			190.5	2	67	134.0	1	112.5	112.5	1,707.0	1,700.0
A-4			1,590.0			238.5	3	67	201.0	1	112.5	112.5	2,142.0	2,100.0
S-1			1,270.0			190.5	2	67	134.0	1	112.5	112.5	1,707.0	1,700.0
S-2			1,590.0			238.5	3	67	201.0	1	112.5	112.5	2,142.0	2,100.0
S-3			5,134.0			770.1	5.5	67	368.5	1	112.5	112.5	6,385.1	6,350.0
S-4			5,194.0			770.1	5.5	67	368.5	1	112.5	112.5	6,385.1	6,350.0
H-1			4,350.0			652.5			-			435.0	5,437.5	5,400.0
H-2			38,880.0			5,832.0			-			3,888.0	48,600.0	48,600.0
H-3			6,750.0			1,012.5			-			675.0	8,437.5	8,400.0
T-1			8,016.0			1,202.4	8	67	536.0	1	112.5	112.5	9,866.9	9,850.0
T-2			5,134.0			770.1	5.5	67	368.5	1	112.5	112.5	6,385.1	6,350.0
T-3			1,778.0			266.7	4	67	268.0	1	112.5	112.5	2,425.2	2,400.0
T-4A			4,556.6			455.7	5	67	335.0	1	112.5	112.5	5,459.7	5,450.0
T-4B														
T-5			1,590.0			238.5	3	67	201.0	1	112.5	112.5	2,142.0	2,100.0
T-6														
T-7			65,600.0			9,840.0			-			6,560.0	82,000.0	82,000.0
T-8			14,700.0			2,205.0			-			1,470.0	18,375.0	18,350.0
T-9			17,096.0			2,564.4	13	67	871.0	2	112.5	225.0	20,756.4	20,750.0

Cost of BOOSTER FACILITY

(Unit : ¥ 1,000)

	PUMP	HOUSE	PIPE LINE	TANK	SUB TOTAL	OVER HEAD COST	TOTAL	÷ (D)
HA-1	40,400.0	20,000.0	43,475.0	44,932.0	148,830.0	14,880.7	163,687.7	163,650.0
HA-2	13,600.0	7,500.0	8,975.0	1,270.0	31,345.0	3,134.5	34,479.5	34,450.0
HA-3A	61,000.0	17,500.0	59,525.0	29,156.0	167,181.0	16,818.1	183,999.1	183,950.0
HA-3B	50,010.0	17,500.0	46,220.0	21,140.0	134,870.0	13,487.0	148,357.0	148,350.0
HA-4	8,420.0	7,500.0	3,680.0	-	19,600.0	1,960.0	21,560.0	21,500.0
A-1	24,980.0 (20,400.0)	10,000.0 (7,200.0)	48,420.0 (44.360.0)	4,228.0 (0)	87,628.0 (71,960.0)	8,762.8 (11,940.0)	96,390.8 (83,900.0)	96,350.0 (83,900.0)
A-2	39,740.0	17,500.0	70,500.0	10,800.0	138,540.0	13,854.0	152,394.0	152,350.0
A-3	-	-	14,875.0	-	14,875.0	1,487.5	16,362.5	16,350.0
A-4	6,620.0	5,000.0	25,925.0	1,800.0	39,345.0	3,934.0	43,279.5	43,250.0
S-1	2,430.0	2,500.0	3,400.0	-	8,330.0	830.0	9,160.0	9,150.0
S-2	4,860.0	2,500.0	4,220.0	-	11,580.0	1,158.0	12,738.0	12,700.0
S-3	-	-	4,340.0	-	4,340.0	434.0	4,774.0	4,750.0
S-4	-	-	1,250.0	-	1,250.0	125.0	1,375.0	1,350.0
H-1	2,430.0	2,500.0	-	-	4,930.0	493.0	5,423.0	5,400.0
H-2	5,200.0	2,500.0	3,220.0	-	10,920.0	1,092.0	12,012.0	12,000.0
H-3	11,550.0	2,500.0	111,680.0	-	125,730.0	12,573.0	138,303.0	138,300.0
T-1	-	-	3,500.0	-	3,500.0	350.0	3,850.0	3,850.0
T-2	-	-	17,885.0	-	17,885.0	1,788.5	19,673.5	19,650.0
T-3	6,350.0	2,500.0	19,800.0	-	28,650.0	2,865.0	31,515.0	31,500.0
T-4A	2,430.0	2,500.0	6,050.0	-	10,980.0	1,098.0	12,078.0	12,050.0
T-4B								
T-5	-	-	-	15,264.0	15,264.0	1,526.4	16,790.4	16,750.0
T-6								
T-7	43,360.0	10,000.0	269,800.0	-	323,160.0	32,316.0	355,476.0	355,450.0
T-8	8,820.0	2,500.0	85,800.0	-	97,120.0	9,712.0	106,832.0	106,800.0
T-9	4,590.0	2,500.0	3,960.0	-	11,050.0	1,105.0	12,155.0	12,150.0

Cost of DISTRIBUTION-TANK

(Unit : ¥ 1,000)

	TANK & INSTALLATION			OVER HEAD COST			FREIGHT			DOMESTIC TRANSPORTATION			TOTAL	≑ (E)
	Q'TY	RATE	AMOUNT	Q'TY	RATE	AMOUNT	Q'TY	RATE	AMOUNT	Q'TY	RATE	AMOUNT		
HA-1			65,130.0			5,210.4	$60m^3$	67.0	4,020.0	8	112.5	900.0	75,260.4	75,250.0
HA-2			14,496.0			1,449.6	13	67.0	871.0	2	112.5	225.0	17,041.6	17,000.0
HA-3A			38,192.0			3,055.4	43	67.0	2,881.0	5	112.5	562.5	44,690.9	44,650.0
HA-3B			70,198.0			5,615.8	63	67.0	4,221.0	8	112.5	900.0	80,934.8	80,900.0
HA-4			34,192.0			2,720.4	38	67.0	2,546.0	5	112.5	562.5	40,020.9	40,000.0
A-1			70,198.0 (7,131.0)			5,615.8 (3,055.5)	63 (43)	67.0 (67.0)	4,221.0 (2,881.0)	8 (5)	112.5 (112.5)	900.0 (562.5)	80,934.8 (13,630.0)	80,900.0 (13,630.0)
A-2			14,496.0			1,449.6	13	67.0	871.0	2	112.5	225.0	17,041.6	17,000.0
A-3			7,248.0			1,087.2	7	67.0	469.0	1	112.5	112.5	8,916.7	8,900.0
A-4			34,192.0			2,720.4	38	67.0	2,546.0	5	112.5	562.5	40,020.9	40,000.0
S-1			5,134.0			770.1	5.5	67.0	368.5	1	112.5	112.5	6,385.1	6,350.0
S-2			5,134.0			770.1	5.5	67.0	368.5	1	112.5	112.5	6,385.1	6,350.0
S-3			26,189.0			2,619.0	26	67.0	1,742.0	4	112.5	450.0	31,000.0	31,000.0
S-4			-			-		-	-		-	-	-	-
H-1			1,778.0			266.7	4	67.0	268.0	1	112.5	112.5	2,425.2	2,400.0
H-2			15,366.8			1,537.3	13	67.0	871.0	2	112.5	225.0	18,000.0	18,000.0
H-3			17,096.0			2,564.4	13	67.0	871.0	2	112.5	225.0	20,756.4	20,750.0
T-1			-			-			-			-	-	-
T-2			5,134.0			770.1	5.5	67.0	368.5	1	112.5	112.5	6,385.1	6,350.0
T-3			13,094.5			1,309.5	13	67.0	871.0	2	112.5	225.0	15,500.0	15,500.0
T-4A			14,496.0			1,449.6	13	67.0	871.0	2	112.5	225.0	17,041.6	17,000.0
T-4B			-			-			-			-	-	-
T-5			14,496.0			1,449.6	13	67.0	871.0	2	112.5	225.0	17,041.6	17,000.0
T-6			-			-			-			-	-	-
T-7			22,290.0			2,229.0	26	67.0	1,742.0	4	112.5	450.0	26,711.0	26,700.0
T-8			7,248.0			1,087.2	7	67.0	469.0	1	112.5	112.5	8,916.7	8,900.0
T-9			38,192.0			3,055.4	43	67.0	2,881.0	5	112.5	562.5	44,690.9	44,650.0

Cost Summary of the Construction Work

	¥ (1,000)				Y.R.			
	PUMP ETC.	W.S. TANK	B. FACILITY	D. TANK	PUMP ETC.	W.S. TANK	B. FACILITY	D. TANK
HA-1	30,000	2,400	163,650	75,250	600,000	48,000	3,273,000	1,505,000
HA-2	9,850	2,100	84,450	17,000	197,000	42,000	689,000	340,000
HA-3A	30,000	2,400	183,950	44,650	600,000	48,000	3,679,000	893,000
HA-3B	30,000	2,400	148,350	80,900	600,000	48,000	2,967,000	1,618,000
HA-4	59,400	69,500	21,500	40,000	1,188,000	1,390,000	430,000	800,000
A-1	30,000	2,400	96,350	80,900	600,000	48,000	1,927,000	1,618,000
	(15,750)	(5,450)	(83,900)	(13,630)	(315,000)	(109,000)	(1,678,000)	(272,000)
A-2	9,850	2,100	152,350	17,000	197,000	42,000	3,047,000	340,000
A-3	9,850	1,700	16,350	8,900	197,000	34,000	327,000	178,000
A-4	9,850	2,100	43,250	40,000	197,000	42,000	865,000	800,000
S-1	9,350	1,700	9,150	6,350	187,000	34,000	183,000	127,000
S-2	9,350	2,100	12,700	6,350	187,000	42,000	254,000	127,000
S-3	6,300	6,350	4,750	31,000	126,000	127,000	95,000	620,000
S-4	6,300	6,350	1,350	-	126,000	127,000	27,000	-
H-1	6,300	5,400	5,400	2,400	126,000	108,000	108,000	48,000
H-2	26,300	48,600	12,000	18,000	526,000	972,000	240,000	360,000
H-3	6,300	8,400	138,300	20,750	126,000	168,000	2,766,000	415,000
T-1	6,300	9,850	3,850	-	126,000	197,000	77,000	-
T-2	6,300	6,350	19,650	6,350	126,000	127,000	393,000	127,000
T-3	9,300	2,400	31,500	15,500	186,000	48,000	630,000	310,000
T-4A	6,300	5,450	12,050	17,000	126,000	109,000	241,000	340,000
T-4B	-	-	-	-	-	-	-	-
T-5	14,100	2,100	16,750	17,000	282,000	42,000	335,000	340,000
T-6	-	-	-	-	-	-	-	-
T-7	20,900	82,000	355,450	26,700	418,000	1,640,000	7,109,000	534,000
T-8	7,300	18,350	106,800	8,900	146,000	367,000	2,136,000	178,000
T-9	15,750	20,750	12,150	44,650	315,000	415,000	243,000	893,000

CONSTRUCTION COST ESTIMATION
(UNDERGROUND DAM)

(Y.R.)

ITEM	SPECIFICATION	UNIT	Q'TY	RATE	AMOUNT	NOTE
1. EARTH WORK						
(1) EXCAVATION	Common Soil	m^3	17,426 4	47.5	827,754.0	
(2) "	Middle Hard Rock	m^3	549 0	96.0	52,704.0	
2. CONCRETE WORK	1 : 3 : 6 Reinforcement 220 Kg	m^3	1,331 6	1,182.0	1,573,951.2	INCLUDE REINFORCEMENT, FORM
3. BACK-FILLING	Gravel	m^3	9,062 3	87.0	788,420.1	
SUB-TOTAL:					3,242,829.3	
4. OVERHEAD COST					243,212.2	7.5 %
5. MANAGEMENT COST					458,275.5	12 %
TOTAL :					3,944,317	

APPENDIX 5

APPLICATION OF SOLAR ENERGY FOR RURAL WATER SUPPLY

APPENDIX 5

APPLICATION OF SOLAR ENERGY FOR RURAL WATER SUPPLY

1. General Description of Solar Energy Utilization Methods

The solar energy utilization process is not yet applicable to commercial scale plant, it seems only in the pilot scale testing plant or quite small scale water collecting plant. In Table 1, existing desalination plants using the direct method of solar energy utilization are shown.

Table 1. Desalinization Plants, Direct Method

Country	Place	Construction	Cover
Chile	Quillagua	1968	Glass
Greece	Patmos	1967	"
	Kimolos	1968	"
	Nisyros	1969	"
	Fiskardo	1971	"
	Kionion	1971	"
	Megisti	1973	"
India	Awania	1978	"
Mexico	Natividad Is.	1969	"
Pakistan	Gwadar	1969	"
	"	1972	"
West Indian Is.	Petit St. Vincent	1967	Plastic
India	Gujarat	Under construction	
	Rajasthan	" "	

Basically, there are two types of method of solar energy utilization. These are, direct method and indirect method. (see Fig. 4)

Direct method

Under the principle of receiving solar radiation directly through the almost transparent roof, made of glass or plastics, sea water absorbs the solar heat in the evaporation house, the water is evaporated and again condensed behind the surface of the roof, and the condensed, distilled water flows down both side of solar house and collected as pure water. Basic structure of solar house is shown in Fig. 1. Several modifications of roof style of the solar house are shown Fig. 2.

Fig. 1

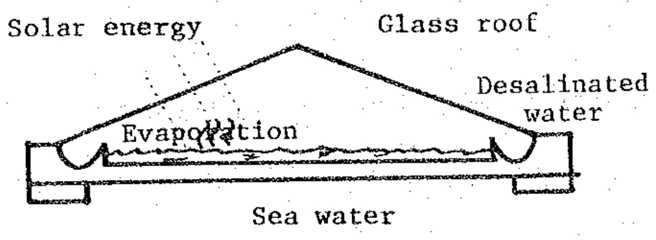
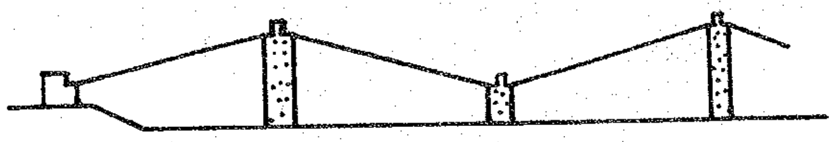
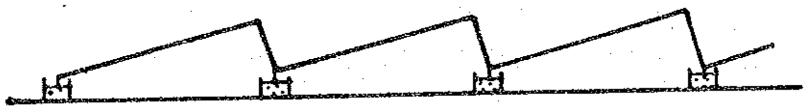


Fig. 2

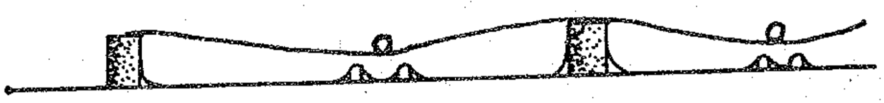


(a) Deep Bed Type(Basin)

(b) Cairo Type



(c) Greece Type



(d) Inverse V Type

Indirect method

In order to improve remarkably high efficiency of heat collection and utilization, the device of solar energy collection and the device of so-collected energy as heat are separated.

In the evaporation method, the energy used for evaporation of sea water can be recovered as the form of heat at the point of condensing the vapor, and can be utilized repeatedly. The indirect method have high efficiency of heat use about 22 times of that of direct method, practically the capacity per unit area shows about 10 times, 40 liter/m^2.

Indirect method facility is composed of solar energy collection device with some heat reservoir and desalination facility (evaporater) of sea water with some kind of heat exchangers separately. In Fig. 3 typical flow diagram of combination of each stage previously described is shown.

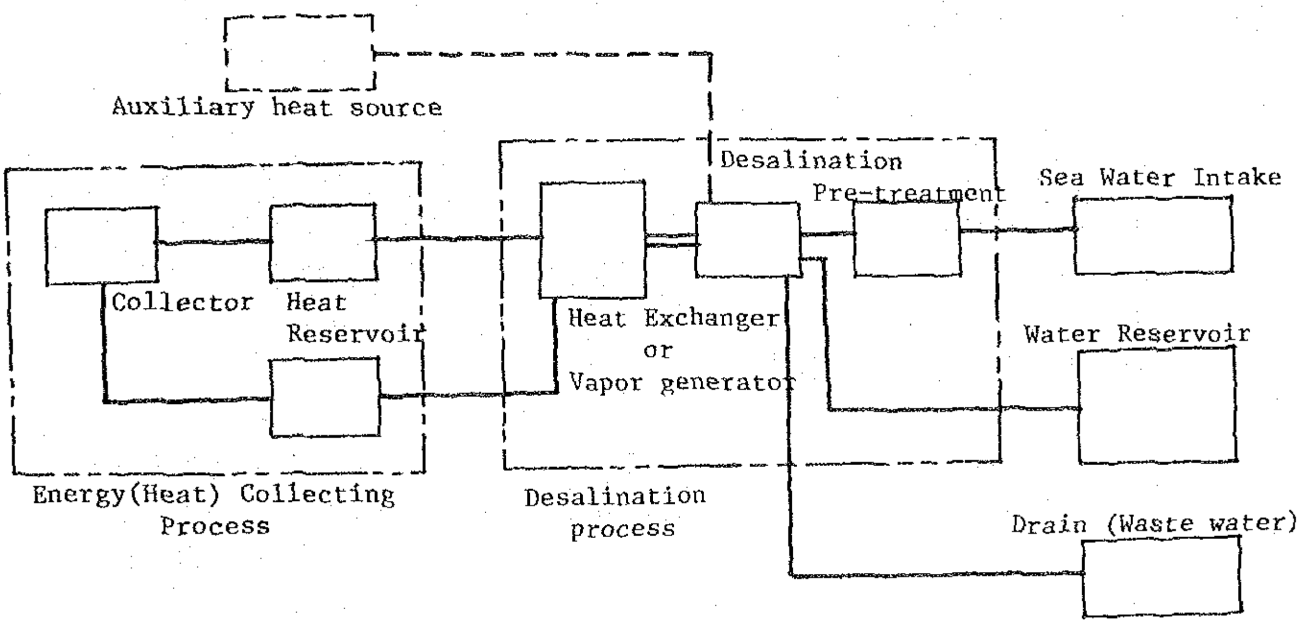
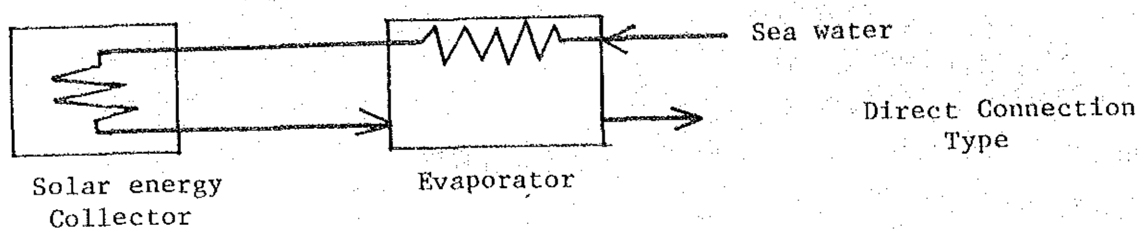


Fig. 3 Basic Flow Diagram of Indirect method of solar energy utilization



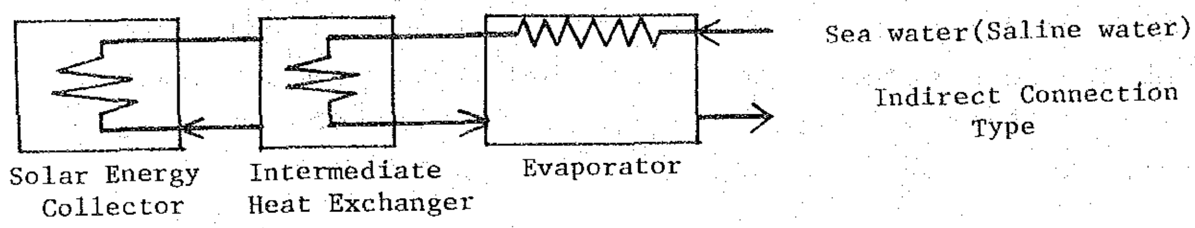


Fig. 4 Flow diagrams showing heat transfer method for evaporation method

2. Characteristic Features of Solar Energy Utilization Process for Sea Water Desalination System

1) Energy efficiency

The pure water production process from sea water means the process of separation of pure water from concentrated sea water, and naturally it is necessary to supply the energy from outside. According to the theory of thermodynamics, theoretical minimum energy consumption shall be 1 to 1.5 KWH or 860 to 1,290 Kcal/m^3 for producing 1 cubic meter of desalined water in the process in which the sea water having the temperature of 25 - 125°C can be concentrated to about twice. However, there are several desalination processes practically, it consumed about 50,000 to 100,000 Kcal/m^3 by evaporation method, 40,000 Kcal/m^3 by electro-dialysis and 20,000 Kcal/m^3 by reverse osmosis method. It can be changed to express the heat energy in terms of the consumption of oil having 10,000 Kcal/liter oil,

Multi-stage flash evaporation	7.5-7.9	l/m^3 prod.water
Multi-effect evaporater	4.9-9.0	"
Electro-dialysis	4.1	"
Reverse osmosis	2.0-2.1	"

Both processes of electro-dialysis and reverse osmosis consume the energy by the form of electricity, however, the consumption of energy is more economical than that of evaporation process expressed by the unit of oil consumption l-oil/m^3-water, converted by electricity generating efficiency of about 35%. Of course, these energy consumption is the most efficient case by the use of modernest, large scale plant. However, in the small scale plant, 10 to 200 m^3/day, the unit energy consumption may be larger, excess of about 50 to 100%, consume 3 to 20 l/m^3 product water.

In the solar energy utilization process, engineers are trying to utilize clean solar energy as infinite as possible, it seems quite desirable from the resources conservation and pollution prevention points of view.

2) Scale of Plant

It is said that the solar energy utilization plant seems to be lower energy density and quite changeable-fluctuate very much. In other words, the production of pure water depends largely on the energy (Kcal) per unit area (m^2) upon where the solar radiation shall be captured - absorbed (through the surface of the roof of solar house).

The efficiency of heat transfer seems to be 20 to 50%, and the production of water will be only about 1.2 to 2.9 l/m^2 in the area of solar energy density of 3,240 Kcal/m^2/day. The production depends largely on the energy density times numbers of effective days (sunshine) a year, several examples of field small plant of direct solar energy utilization plant are shown as follows:

	Kcal/m^2/day	(Btu/ft^2/day)	l/m^2day	air temp. °C, rainfall (mm/y)
Greece	3,000		3 to 3.5	
Kuwait	5,150	(1,900)		50mm/y, max.50°
India	5,000			200-250mm/y, 25-30°
Australia	5,068	(1,870)	1,180	
		(max. 6.0 l/m^2d. at 7,170 Kcal/m^2/d., average 3.5 l/m^2d)		

In rainy days usually, the rain water is collected and added to the product water.

JICA