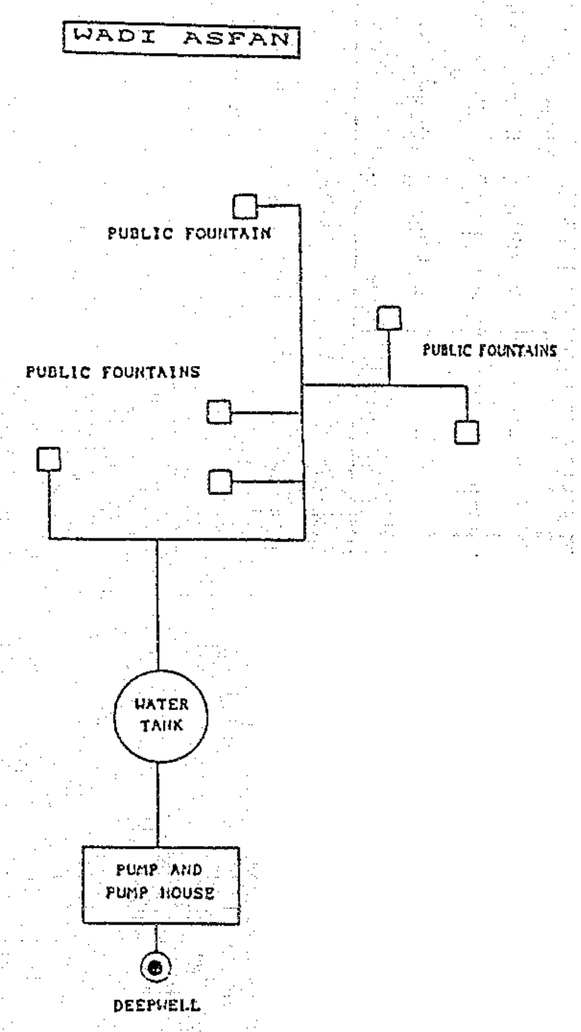
4.3.1 General Features of Planned Facilities

The general features of planned facilities and quantities of each facility are shown in Fig. 10 and Table 18, respectively.

Table 18 Amount of Design Facilities

Site	Design Population (prns.)	Design Served Demand (m^3/day)	Water Source Well (depth) x (number)	Pipeline	Water Tank	Public Fountain
Wadi Asian	990	39.6	200mx1	3,475m	$30m^3$x1	6 lots
Al Khashna	490	19.6	-	1,464m	$30m^3$x1	1 lot
Al Zakira	820	32.8	-	3,270m	$50m^3$x1	3 lots
Al Kheisen	1,170	46.8	-	5,077m	$20m^3$x1 $30m^3$x1	5 lots
Al Rajam	6,070	242.8	200mx2	14,178m	$50m^3$x1 $50m^3$x2	12 lots
Shihara	8,440	337.6	200mx1	14,871m	$150m^3$x1 $30m^3$x1 $50m^3$x4 $60m^3$x1	8 lots
Ad Dahi	9,030	634	-	7,200m	$100m^3$x1 $100m^3$x15(H)	10 lots
Harad	6,920	488	-	6,595m	x2 $100m^3$x15(H) x2	6 lots

Fig 10 Outline of Water Supply System (1/4)



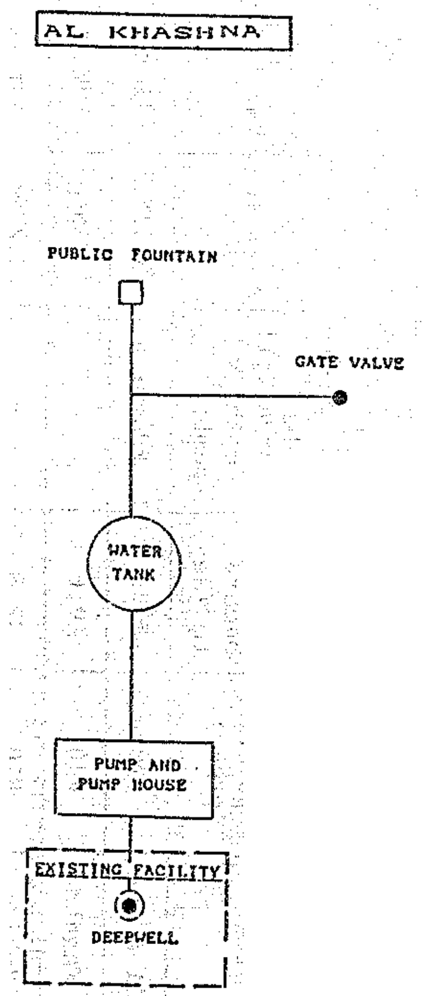
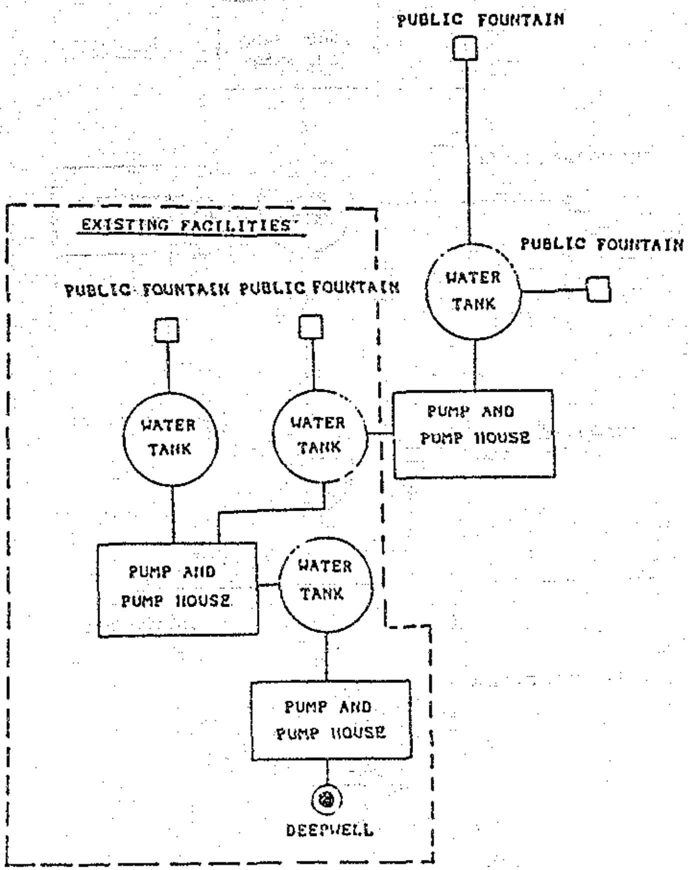


Fig 10 Outline of Water Supply System (2/4)

AL ZAKIRA



AL KHEISEN

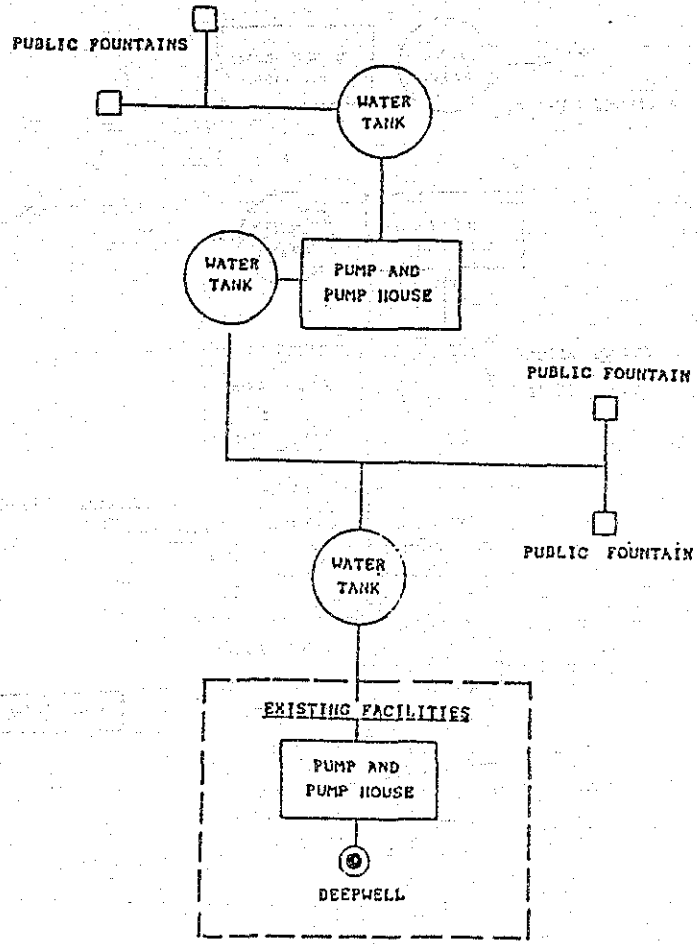


Fig 10 Outline of Water Supply System (3/4)

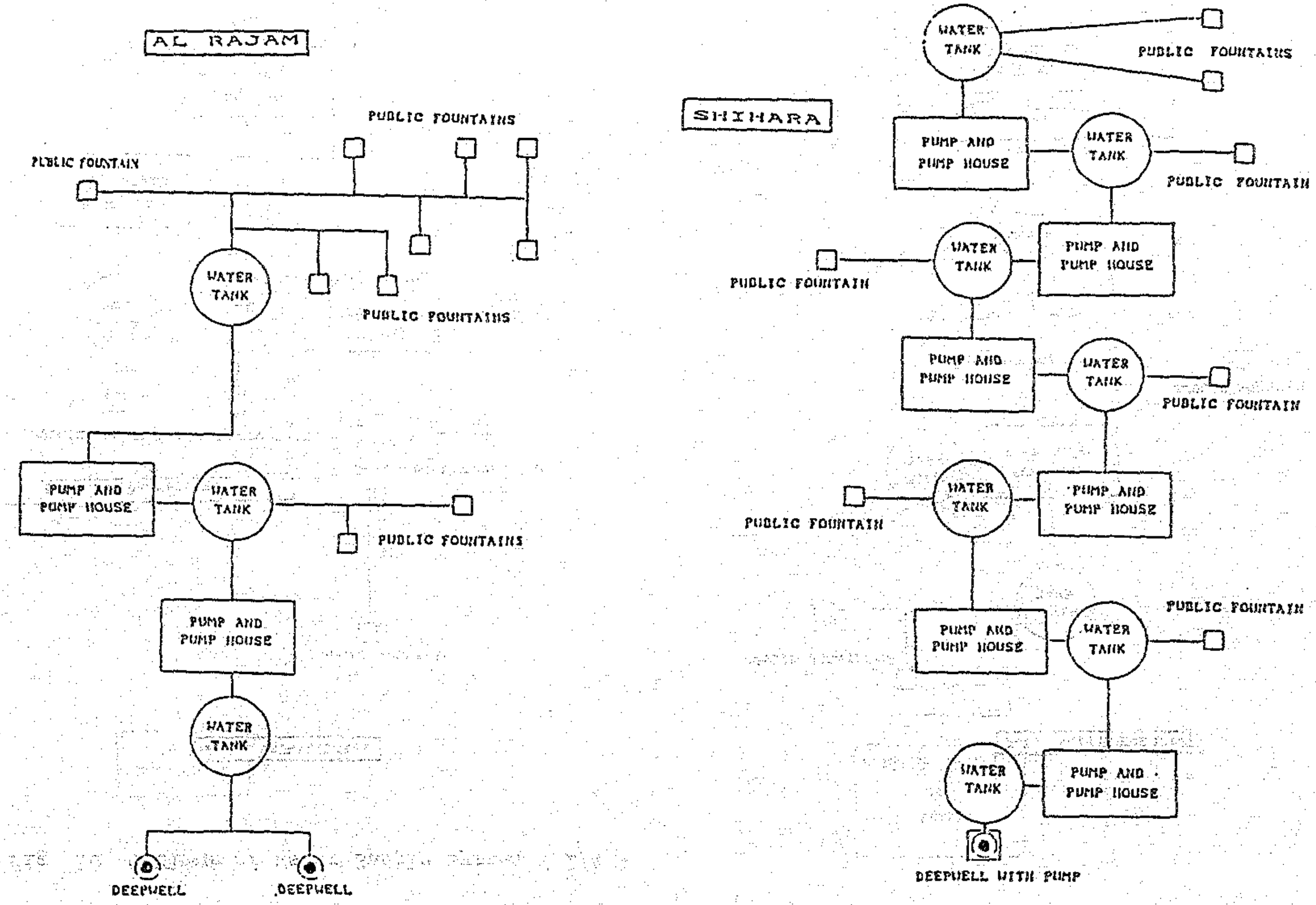
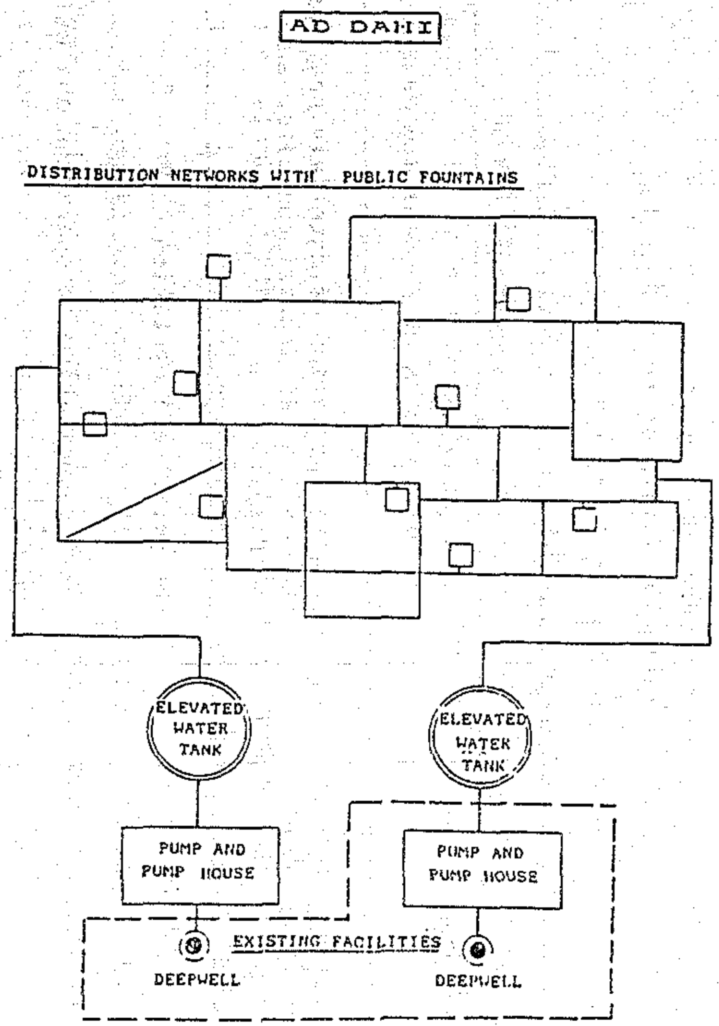
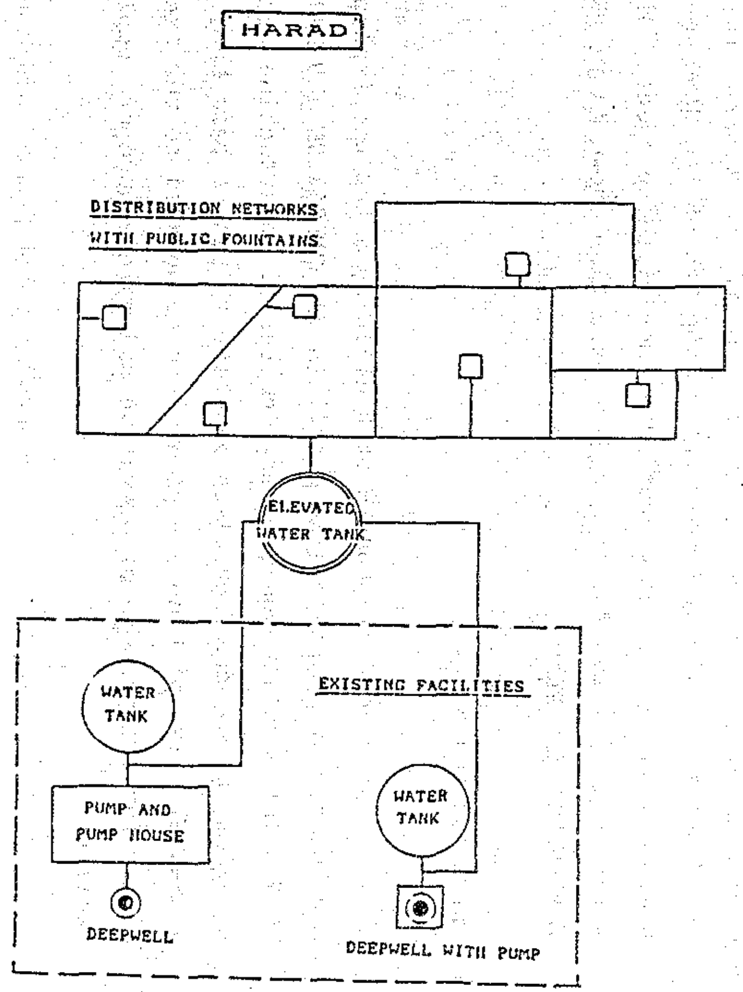


Fig 10 Outline of Water Supply System (4/4)





4.3.2 Executing Agency

The Rural Water Supply Department of the MPW of the Government of YAR plays a leading role as executing agency of the project. The whole set-up organization for the project execution shown in VI PROJECT IMPLEMENTATION PLAN.

4.3.3 Operation and Maintenance

The operation and maintenance of facilities after the implementation of the Project are mentioned in detail in VII OPERATION AND MAINTENANCE PLAN. This project needs a large number of construction equipment and vehicles, among which carriers on steep slopes, a back hoe, a truck and a 4-wheel drive pick up are planned to be donated to the executing agency for the purpose of operation and maintenance of completed facilities.

4.3.4 Supply of Equipment

Equipment to be supplied is listed in the following table and its specifications are summarized in Appendix A-5-X.

Table 19 Equipment to be Supplied

Type	Unit	Description
Back Hoe	1	- for excavation. - for piping works at Ad Dahi and Harad.
Materials Carrier for Steep Slope	2	- for transportation of materials and equipmen on steep slopes in mountainous sites such as Shihara and Harad.
Pick Up	1	- for patrol and operation.
8 m^3 Truck	1	- for transportation of operation and maintenance materials.

In order to complete the water supply facilities mentioned in 4.3.1 General Features of Planned Facilities, the following construction materials are necessary.

- Pipe (galvanized steel, carbon steel)
- Valves, Joints, and fittings and other attachments
- Submersible Motor Pumps for groundwater intake
- Turbine Pumps as booster pumps
- Generators (power unit)
- Diesel Engines (power unit)
- Steel Panel Tanks and Steel Materials with anti-corrosive coating
- Taps
- Electric facilities (electric poles, transformers, control panels, etc.)
- Drilling Materials (casing, strainer, etc.)

4.4 Examination of Basic Design Concept

4.4.1 Basic Design Concept

The characteristics and design policy featuring this project are summarized from the viewpoint of water supply planning as follows:

1) This project is planned for the Japan's fourth grant aid for rural water supply development in the Yemen Arab Republic, following the previous ones implemented from 1981 to 1982, all of which are based upon the study by Japan International Cooperation Agency (JICA) in 1979-80.

2) Most of the country is hilly and mountainous except for the plain area along the Red Sea, where the altitude varies from 2,000 to 3,000 m m.s.l. Water supply planning for villages scattered in these complex terrains must overcome varied difficulties on technological and financial matters. In view of the types of the communities and surrounding topographic conditions, the eight sites in the project are classified into three groups as follows:

Group A: Small to middle class villages in mountanous areas

Population : 500 - 1,000 persons

Number of villages in the community : 1 - 6 nos.
(Scattered over the mountain sides, these villages form an administrative unit under the control of the village chief called sheikh of the main village.)

Water supply scheme: Typical rural water supply system

Number of classified sites : 4 nos.

Group B: Village complees in mountanous areas

Population : 6,000 - 9,000 persons

Number of villages in the community : 12 - 20 nos.
(The types of villages composing this group of sites and their environment are nearly the same as those of Group A. This group is, as it were, a complex comprised of multiple villages like those in Group A, forming one administrative unit as a whole. this unit extends more than 10 km^2 of this area.)

Water supply scheme: Extended rural water supply system

Number of
classified sites : 2 sites

Group C: Semi-urban cities in the plain area

Semi-urbanized with a population of less than 10,000, these cities play a role of the terminal for the surrounding districts.

Water supply scheme: Small-sized urban-type supply system with pipeline network inside the city.

3) Water supply planning for rural areas in recent years tends to reflect the demand of inhabitants for the construction of piped water system even in remote mountanous areas. The earlier projects such as Japanese loan project and the first grant aid project started with a design policy of point-source supply systems. In the course of the execution of the loan project, however, this policy was revised into an upgraded one so as to even make house connections possible in the future at each village by means of relocating the initial design of the service tank to a higher land. Under such circumstances the office of Rural Water Supply Department is now employing a policy to implement its projects with the extension of distribution mains to the respective villages composing the site, each line with one public faucet at its end. This project will follow this line. Considering the characteristics of the project under Japan's grant aid program, however, the implementation of notably large-sized project has a number of limiting factors in respect of construction period, etc. Therefore, the most appropriate design in line with Japan's grant aid system will be planned for each of the eight project sites, based upon the results of the site survey.

4) In terms of design criteria, the one prepared by the Rural Water Supply Department is basically relied upon, with a reference to Japanese Standards for Rural (Small-Sized) Water Supply since these criteria can practically be based upon for the formulation of project design.

4.4.2 Relation to Projects Implemented

The rural water supply projects with the assistance of the Government of Japan preceeding this term of planning includes the one with a loan for 42 sites across the country which commenced in 1978 after the Exchange of Notes in 1977, and the three others with grant aid which were implemented at 9 sites for three consecutive periods, based upon the social development study (feasibility study) by JICA in 1979-80.

The loan project funded by the OECF, Japan, underwent the alterations of design at the respective stages of surveying, designing and implementing. Initially the basic supply planning was intended for the point-source type systems, but at the final stage was upgraded into improved service systems (Refer to Fig. 11).

a) Point-source Water Supply System

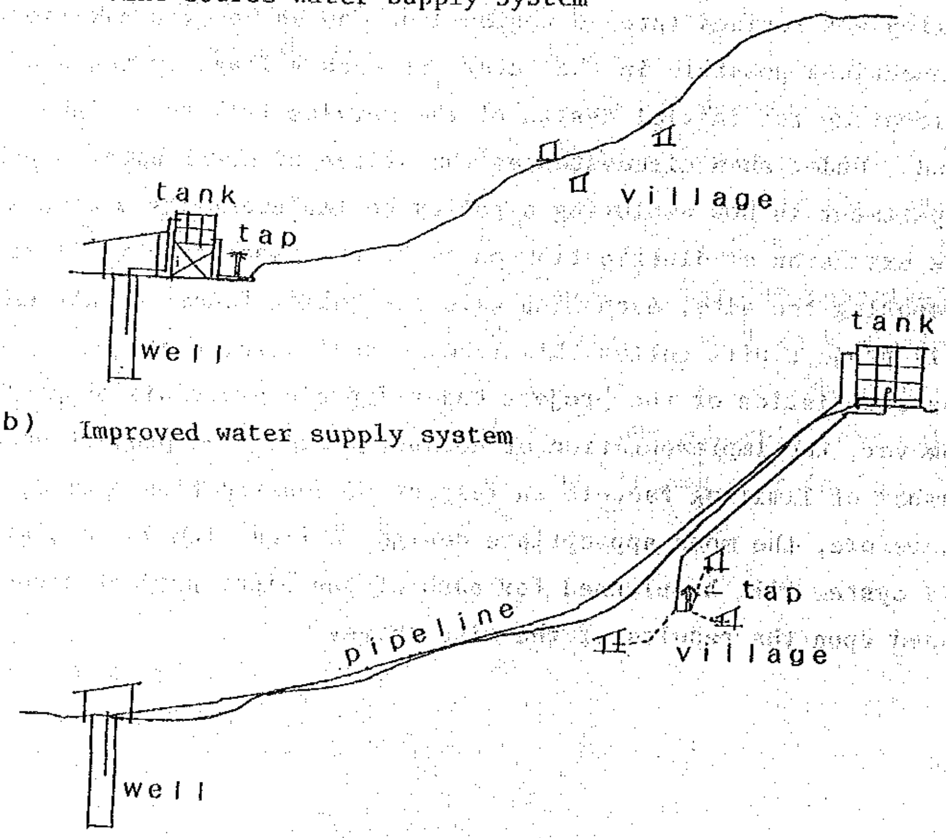


Fig. 11 Diagram of Water Supply System

a. Point-source system (in which facilities are constructed at or near the water well in the lowland of wadi)

b. Improved water system (aimed at completing house connections at the final stage)

Growing demand among inhabitants for service connections to their dwellings moved the Rural Water Supply Department to make such alterations, as the social circumstances were getting stable, with living standards gradually improved even in rural areas. As a result, a greater part of the loan project sites where improved supply facilities were constructed have now completed house connections mainly through the efforts of local offices of Local Development Associations (LDA's). These offices are now managing charged water systems in the respective communities.

The earlier design for the preceeding three grant aid projects was based upon the point-source type systems as well. One of the examples is Harad city where this earlier type of system was completed under the first grant aid project in 1981-1982. It used to be a medium-sized community situated in the desert of the coastal plain, but with the completion of the highway through the area it has grown into a semi-urbanized city, where the installation of urban supply system is now an urgent demand among citizens. Such a situation has led to the request for replanning of the supply system for this site.

The second and third grant aid projects made efforts as much as possible in planning to reflect this trend of transition from the point source system to the improved one, selecting the locations of service tanks to higher places to make the future house connections possible. In addition, distribution lines and public faucets were provided to small to medium-sized village in an appropriate range of the project scope. However, the range of construction of distribution lines were limited, particularly at large-sized communities like Al Rajam where

Table 20 Comparison of Water Supply Plans

No.	Parameter	OECF Loan Project	Study by JICA (1979/1980)	This Project	Remarks for This Project
1.	Design population	Mainly based upon the survey at the respective sites with reference to 1975 census by sampling by CPO Growth rate; Rural : 3% Urban : 6%	Based on the survey at the respective sites and 1981 census by CYDA Growth rate; Large Community : 6% Medium C.: 3% Small C.: 2.5%	Estimated with reference to 1982 and 1986 census by CPO Growth rate; Mountaneous area: 1.7% Plain area : 2.9%	Depends upon a census prompt 1986 by CPO*with consideration to population trend of 1982 to 1986 *"Population Report"
2.	Target Year	15-20 years hence	15 years hence	20 years (partly 10 years) hence	Adopts RWSD's criteria, taking into account RWSD's request to make capacities of facilities as large as possible
3.	Per capita consumption	Rural: 45 ℓ/d/c Urban: 70 ℓ/d/c (including supply for livestock)	Rural: 40 ℓ/d/c Semi-urban : 70 ℓ/d/c (Supply for livestock added separately)	Same as Criteria of JICA study (Supply for livestock not included)	Adopts JICA study criteria taking the survey results into account
4.	Design supply rate	Daily average supply=(Per capita consumption) x (Projected population in design target year) Daily maximum = (Daily average) x 1.5	Daily average: Same as OECF loan project Hourly maximum =(Daily average) /10 hrs x 1.5	Daily average: Same as OECF loan project Daily maximum : same as OECF loan project	Conforms to criteria of Japan's Rural Water Supply Standards
5.	Service hour	not specifically determined	10 hrs	24 hrs	Due to present water consumption pattern in general

(continue)

(continued)

No.	Parameter	OECF Loan Project	Study by JICA (1979/1980)	This Project	Remarks for This Project
6.	Water source and intake pump	Deepwell (Submersible motor pump: SP) Shallow well (Borehole pump : BP)	Deepwell (Submersible motor pump)	Same as OECF loan project: Basically, SP: for pumping head higher than 200m BP: for pumping head less than 200m	Adopts RWSD's practice
7.	Distribution tank	Type: Steel panel tank Storage volume: 12 hrs of daily average	Type: Same as OECF loan project Vol: (Hourly max x 3 hr) + (Emergency storage)	Type: Same as OECF loan project Vol: (Daily max) or (Storage hour rate by population of daily max)	According to requests from RWSD and inhabitants, the basic policy aimed to make the volume as large as possible, employing RWSD's criteria as well as Japan's Rural Water Supply Standards
8.	Pipeline	Type: Galvanized steel pipes for water service (SGP) Diameter: Calculated by Hazen-Williams Formula	Type: SGP and carbon steel pipes for pressure service (STPG) Diameter: Same as OECF loan project	Type: SGP and STPG Diameter: Same as OECF loan project	
9.	Supply system	Initially point-source type system, later upgraded to improved water system, service tank to a higher location in the village. Planned to serve by public fountain.	Basically point-source type system with public fountain as service facilities. During implementation a part of projects were upgraded to improved systems.	Basically improved water system. In urban area distribution network is planned.	Improved system is employed as a standard type of construction in the country. In addition, urban type of system is planned in congested community in plain area.

the three projects for Blocks A, B and C were completed under the second and the third grant aid projects, with their supply systems mainly composed of lengthy transportation pipelines to the main service tanks at the top of the mountains, since the initial design policy did not include the extension of distribution lines from the tanks. The present situation at these sites is that although the local LDA's office is now negotiating with the Rural Water Supply Department for the installation of distribution lines, it still seems to take a long time before launching into the implementation due to a great deal of technical and financial difficulties. With such a background, the Department has requested for this project to establish a practical plan for distribution not only at small- to medium-sized villages but at large-sized village complexes like the remaining Block Al Rajam, Block D.

The present practice in the construction of rural water supply projects by the Department is to complete the facilities with extended distribution lines with public faucets to villages located down the main tank. Service connections from these lines are the responsibility of the beneficiaries. This project will also follow this line in planning, but at the specially broad area of Shihara, the size of distribution/service facilities will have to be limited to avoid excessive investment.

4.4.3 Comparison of Water Supply Plans

The comparison of design criteria for water supply planning among loan projects, the previous study by JICA and this project is presented in Table 20.

4.4.4 Examination of Water Sources

1) General

One of the main reasons the extension of water supply systems has been delayed in rural areas of the country lies in the fact that the development of groundwater is still highly difficult in a larger part of the country. In Tihama plain along the Red Sea developed alluvial layers where groundwater has a high chloride content, particularly in the area near the coastline. For this reason, water supply for the coastal cities like al Hudeidah, prime port of the country, depends upon the deep wells situated near the mountainsides some 10 km far from the coast. Further towards inland of Tihama plain, the better the water quality becomes. The two sites in this project, Ad Dahi and Harad situated in the coastal plain, have existing deep wells, which are to be used for this project. Groundwater in these wells are fresh, classified as inland type. These sources are judged to be sound both in water quantity and quality and can safely be used as water sources for the project.

The remaining two thirds of the country is occupied with mountains and highlands at an average altitude of 2000 m MSL. In this area, groundwater is mainly fissure water transported through faults running along and/or across the lowland of wadi (dried valley) or through interconnected cracks of rocks. Inhabitants commonly have their dwellings made of stone on the mountain ridges where the wadi or lowland is viewed. For their daily use of water, they used to depend merely upon cisterns installed in or near their dwellings collecting surface water, hand dug wells in the lowland and/or natural springs on the mountainsides. In recent years deep well drilling has become popular in this area as well, but the development of groundwater in the mountainous area still entails some difficulty due to complicated geological conditions through which it is transported. The Rural Water Supply Department admits that drilling in this area is not always successful. The rate of success in drilling by this office is estimated to reach about 70% these years. The method of testing the yield is recommended to be improved together with the employment of units suitable for test pumping. This measure will increase the accuracy of reliable yield of groundwater developed.

Of the six sites in this project scattered across the mountainous areas, three sites have existing deep wells drilled by the Department. These wells are planned to be used as water sources for the project. Quantities and qualities have been confirmed by the field survey to meet the requirements of the project.

The other 3 sites in this area need drilling for the construction of new water sources for the project. During the field survey for this study, feasibility of groundwater resources development was examined by means of hydrogeological study and geoelectrical prospecting. The results are described in the next section with details in Appendix in respect of the results of survey analysis and the method of groundwater resource development. This study has proven that each site is prospective in developing new sources. The specifications for the deep wells to be drilled will be referred to in Section 5.1.3 "Study on New Water Sources".

2) Study on Feasible Yield

The feasible yield for the development of groundwater at each site is examined through two approaches of hydrological and hydrogeological analyses. Details are presented in the Appendix, and the results are shown in the table below together with data of design pumping rates in the project.

Table 21. Water Source and its Feasible Yield

Name of Site	Water Source	Aquifer	Pumping Rate	Feasible Yield per Well
1. Wadi Asfan	New deepwell (200 m)	Volcanic rock	150 lit/min 39.6 m3/day	416.9 m3/day
2. Al Khashna	Existing deep well (150 m)	Volcanic rock	150 lit/min 19.6 m3/day	48.9 m3/day
3. Al Zakira	Existing deep well (180 m)	Sandstone	300 lit/min 32.8 m3/day	93.7 m3/day
4. Al Khesen	Existing deep well (315 m)	Limestone	190 lit/min 46.8 m3/day	301.6 m3/day
5. Al Rajam	New deepwell (200 m x 2)	Sandstone	280 x 2 lit/min 242.8 x 2 m3/day	150.8 m3/day
6. Shihara	New deepwell (200 m)	Alluvium/ Volcanic rock	450 lit/min 337.6 m3/day	2,372.0 m3/day
7. Addahi	Existing deepwells (200 m x 2)	Alluvium	600 x 2 lit/min 634 x 2 m3/day	658.7 m3/day
8. Harad	Existing 2 deepwells (80m/50m)	Alluvium	400 lit/min 488 m3/day	1,296 m3/day

Since the above list shows that the feasible yields are all estimated to be larger than design demands except the one at Al Rajam, no question will be raised concerning the water sources. For the site of Al Rajam, a plan to install two wells can satisfy the design demand. It is noted the analysis for three sites where new water sources are required depends upon data available in the surrounding areas. The following table shows the details of existing deep wells planned to be used as the project sources in the six sites.

Table 22. Existing Water Source

Name of Site	Well Depth (m)	Diameter (mm)	Static Waterlevel -GL(m)	Existing Pumping Facilities and their types	Name of Executing Project
Al Khashna	150	200	85	nil	Drilling Project by MPW
Al Zakira	180	250	5.4	Existing, G&SP	Second Japan's Grant Aid Project
Al Kheisen	315	250	100	Existing, E&BP	Drilling Project by MPW
Ad Dahi	60	250	28	Existing, E&BP	Project of Local Development Associations
- do -	80	200	45	nil	Drilling Project by MPW
Harad	50	250	19	Existing, E&BP	Project of Local Development Associations
- do -	81.4	350	15.7	Existing, E& BP	First Japan's Grant Aid Project

Note: G & SP: Generator and submersible pump

E & BP: Engine and borehole pump

4.4.5 Target Year of the Project

The target year of the project is determined taking diverse factors into account such as the durability of structures, possibility of facilities expansion, prospect for the development of communities and others. The design criteria concerning this project designates the target as shown in the following table.

Table 23 Target Year of Water Supply Project

RWSD, MPW Y A R	20 Years (allows to extend completion into several phases in case project scale is large)
Design Criteria for Rural Water Supply JAPAN	10 Years starting at the time of planning
Survey Report JICA, 1980	15 Years (requires to review the situation on the midway)

The useful life of main facilities such as deep wells and service tanks is as long as 15 years. With proper maintenance, their useful lives can be prolonged to more than 20 years. On the other hand equipment such as pumps, diesel engines and generators have rather a short life of 4 - 6 years according to Japanese standards, requiring repairs and replacements in case of shutdown. Despite these differing lives of system components, the target year in this aspect is judged to be based upon those of main structures such as wells and tanks, namely 15 to 20 years.

Another approach to the study of design period is to take into account the possibility of future expansion of the supply system and the trend in the development of the community. Since the project sites are varied in the conditions of their environments, communities, population trend and others, they are divided into two groups with similar conditions for the consideration of the target period for planning; mountanous and plain area sites.

1) Groups A and B: Mountanous sites including small to middle villages and large-sized village complexes - 6 sites (Wadi Asfan, Al Khashna, Al Zakira, Al Kheisen, Al Rajam and Shihara)

In these mountanous communities Yemeni traditions have been well preserved, with their dwellings nestled on the mountainsides and inhabitants' conventional life style little altered. Conditions to develop agriculture as basic industry of inhabitants is harsh in these areas in every aspect of land and climate. Since the communities under such circumstances are not likely to undergo drastic change any time in the near future, the necessity of altering the constructed systems with additional facilities can little be forecasted. In view of this fact, longer design period of 20 years can be applied to the planning for these project sites.

2) Group C: Plain-area semi-urbanized communities - 2 sites (Ad Dahi and Harad)

Located near the northern border with Saudi Arabia, Harad city has seen a conspicuous development of the urbanized areas, with shops and residences sprawlingly expanding along the highway recently opened. A similar trend is noted in Ad Dahi. However, since there is no city planning existing for both communities, a question will be raised to forecast the future development with any accuracy. The most appropriate target for these communities, therefore, is 10 years on condition that the whole system should be reviewed and replanned around the end of this period. However, a design period of 20 years should be applied to such facilities as buried network of pipeline, which need much difficulty in enlarging.

The design period for the project planning is concluded as follows:

Mountanous sites: All the facilities - 20 years after (the year 2007)

Plain area sites : Pipelines, equipment - 20 years after (the year 2007)

Others - 10 years after (the year 1997)

4.4.6 Planned Water Supply Sites

The design supply area in the respective sites covers the whole of the administrative unit governed under the name of the project sites, based upon the results of the field survey. Most of the sites are comprised of a multiple number of villages, and the table below indicates the number of such villages composing each project site.

Table 24. Number of Villages Composing a Supply Area

Name of Sites	Number of Villages
1. Wadi Asfan	6
2. Al Khashna	1
3. Al Zakira (Qore Area)	3
4. Al Kheisen	5
5. Al Rajam (Block D)	13
6. Shihara	22
7. Ad Dahi	Urban community in the plain area
8. Harad	Urban community in the plain area

In these village complexs, the borders between neighbors have been fixed under the strict land-ownership kept over from olden times. A greater part of the mountanous communities in the country take a similar form of village complex. Moreover, since these villages are scattered in all directions across highly undulating terrain of mountaneous areas, efficient and effective water supply planning is always difficult to attain.

As a basic policy, this project aims to extend distribution lines to each of villages composing a site with one unit of public faucet at the ends. However, at the site of Shihara where a large number of villages are involved in a broad territory, the construction of complete service system is expected to amount to an excessive investment. To achieve an effective investment, distribution/service facilities are planned to be located mainly along the lengthy transportation line with reservoirs on the way having a storage facility for future connections to remote villages.

4.4.7 Design Population

The design population for the project is calculated, based upon the present population surveyed at each site, the growth rate described in Chapter 3, and the design period of project analyzed in Section 4.4.5. The list of the projected populations for the respective sites with details for villages composing the sites are attached in the Appendix, and the summary is presented in the table below.

Table 25. Design Populations

Name of Site	Design Population (persons)	Target Year
1. Wadi Asfan	990	2007
2. Al Khashna	490	2007
3. Al Zakir	820	2007
4. Al Kheisen	1,170	2007
5. Al Rajam	6,070	2007
6. Shihara	8,440	2007
7. Ad Dahi	6,779 (9,030)	1997 (2007)
8. Harad	5,198 (6,920)	1997 (2007)

4.4.8 Unit Consumption for Planning

Per capita demand or unit consumption is intended solely for domestic use. Other various uses such as car washing are not included in the supply. Although upgraded life style is nowadays growing among people, actual water consumption in rural areas is recognized to have little difference from the one observed during the previous study by JICA in 1979. Suspension of domestic water supply, however, has conspicuously decreased even in remote mountainous areas, since water selling transported in a tank of one or two m^3 on a small truck is actively carried out. According to the interviews during the field survey, daily consumption was 15 to 25 l/day/capita (l/d/c) in the mountainous areas and 20 to 40 l/c/d in the plain areas.

Upon completion of the project, each village is given a public fountain within its premise, and in the future may have service connections completed by the hand of local LDA's. This will inevitably lead to increase in consumption, but without any sewage systems at present particularly in the mountainous areas, they will have to control rapid change in consumption patterns. It is judged, therefore, that the unit consumption for the project should be near the range of the standard one adopted by the local authorities, including the following:

Table 26. Criteria for Unit Consumption

Design criteria Rural Water Supply Dept	Final Report of JICA Study (1980)
(1)Rural areas supplied with public faucets: 45 lit/day/capita (2)Areas with house connections: 80 - 120 lit/day/capita (Lower rates for mountainous communities,and high rate for coastal plain communities)	(1) Rural areas in general: 40 lit/day/capita (2) Semi-urban cities 70 lit/day/capita

Of the two criteria above, this project is planned to follow the criteria with lower rates determined by the previous JICA study, since the facilities constructed under the project have extra capacities for the time being owing to longer design period. The review of planning, however, is recommended at a time when house connections become a general trend at project sites in the mountainous areas. Therefore, unit consumption for this project are determined as follows:

Group A, B	Mountainous communities :	40 l/day/capita
Group C	Plain area semi-urban communities:	70 l/day/capita

4.4.9 Design Demand

1) Daily Peak Demand

The design criteria of the Rural Water Supply Department has no clear definition of the daily peak demand, which is applied to the design of facilities such as distribution tanks and others. In this country, supply facilities should be designed to have sufficiently large capacities, since repairs in case of their shutdowns frequently take a long time due to lack of proper maintenance system, leaving inhabitants waterless. Taking such conditions into account, daily peak demand in this project is determined to use the criteria of Japan's Rural Water Supply Standard as follows:

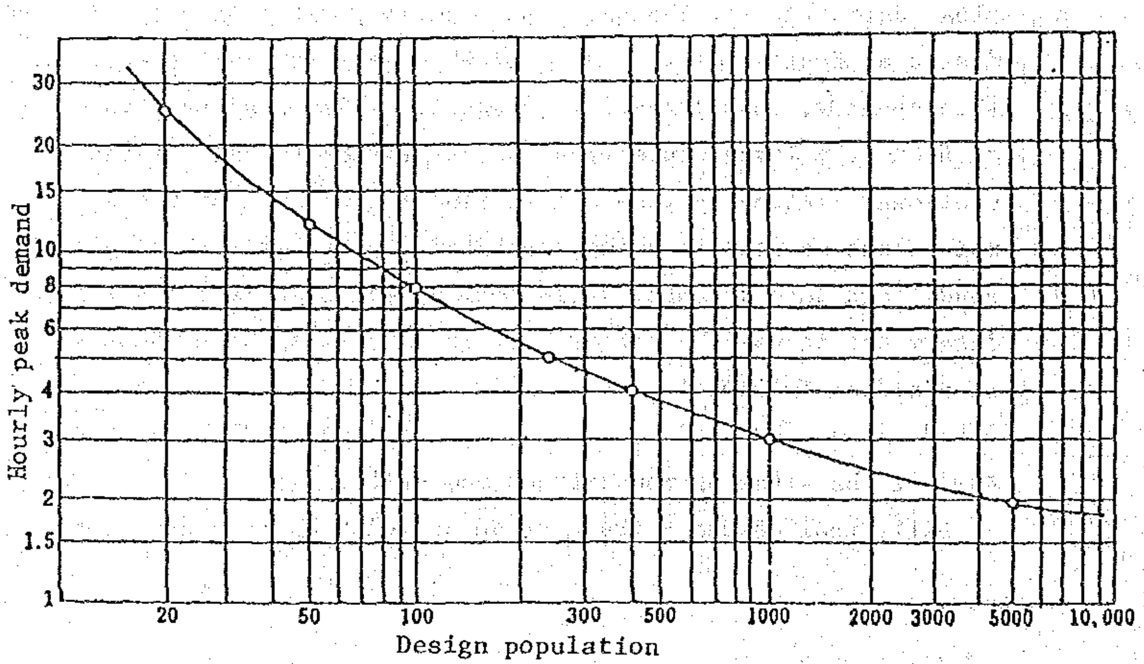
For all the sites of mountainous and plain areas:

Daily peak demand = (Population served x Unit consumption) x 1.5

2) Hourly Peak Demand

This rate is used for the design of distribution lines in this project. Upon completion of this project and in the future when house connections are completed with self-supporting efforts of the villages, the water consumption pattern there is expected to look like that of Japanese practice, though the consumption rates may still largely differ. In this view, the criteria of Japan's rural water standard, which reflects the relationships between distribution and service facilities based upon water consumption pattern in general, is proposed to be applied. The following graph shows the relation of daily peak demand to hourly one by populations, upon which designing of facilities for this project is planned to be based.

Fig. 12 Design Population Versus Hourly Peak Ratio
(Hourly Peak Demand/Daily Peak Demand)



3) Public Consumption Rate

As the Rural Water Supply Department does not have a standard for public consumption rates, service rate calculations will be based upon actual water consumption trends as described below.

a. School

Since children of the village gather here, the demand is not so high as to have influence on the total design demand. Therefore, this will not be considered in the design.

The actual consumption rate in the mountainous areas is about 1-2 liter/capita/day which is mainly used as cleaning water in toil etc. After completion of water supply facilities, the rate is forecasted to increase to about 5 liter/capita/day, but will not influence the total demand.

In contrast, the schools at Ad Dahi and Harad in the plain areas have flush toilets with infiltration pits and according to interviews, they consume about 15 liter/capita/day. The elementary and junior high schools of the 2 sites are dispersed inside the city and so these demands must be considered in determining pipe diameters for service allocations.

b. Hospital

There is a hospital, one each, at Shihara's main village (15 beds), Ad Dahi (5 beds) and Harad (10 beds). The water consumption rate in hospitals, including those for attendants, of 200 liter/capita/day, which is normally used by the Department, need to be considered in the design rate. However, due to the small scale of facilities, this amount will not have impact on the total demand.

c. Sotre

According to field surveys, the consumption rates of restaurants in the plain areas are conspicuously high. This is judged to result from water used for washing hands before and after eating by the customers in addition to that for preparing food. Generally these stores are dispersed in the served area so that special attention is not needed in considering the total demand.

d. Mosque

At mosques, the average consumption rate is less than 1 liter per person per call and a tank of several m^3 is located at the cleaning area. Therefore, the influence on the total demand is small enough to neglect consideration in the design.

4) Design Total Demand

The design total daily demand is determined by design population, unit consumption, design period and public consumption rate, based upon the following formula:

a. Mountainous communities - 6 sites

(Unit consumption = 40 liter/d/c) x (Design population in the year 2007) + (Nos. of beds at hospital x 200 liter)

b. Plain area communites - 2 sites

(Unit consumption = 70 liter/d/c) x (Design population in the year 2007 for pipelines, etc.) + (Nos. of beds at hospital x 200 liter)

4.4.10 Service Hours

Without electricity until very recently, daily life of rural inhabitants in YAR used to begin with praying at 4 o'clock in the morning and end with a family gathering for a short while under gas lamp after darkness falls. Most of water consumption, therefore, used to be seen from 4 o'clock in the morning to 7 o'clock in the evening. However, introduction of diesel generators and TV sets into rural areas in recent years have completely altered their life style during night time, leading to gradual increase of water consumption due to prolonged activities. The cut-out time of electricity differs with villages, but usually is 11 o'clock at night when TV airing finishes. Present water consumption pattern, therefore, is depicted as follows:

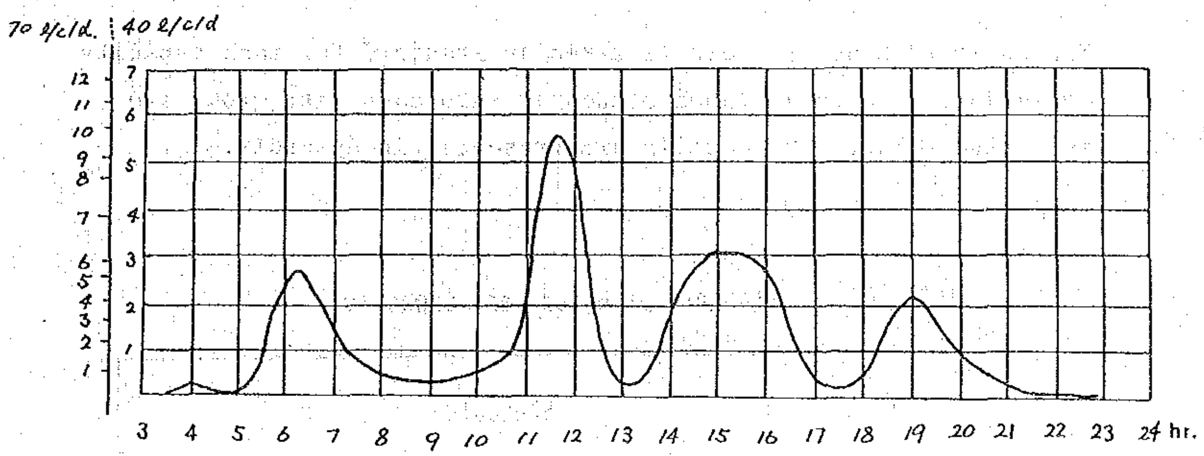


Fig. 13 Daily Water Consumption Pattern

As shown in the above, consumption continues through day and night with several peaks except during mid-night hours. In this project, therefore, 24-hour service is considered. Continuous supply at present has been made possible by a storage in one to two m^3 tank of zinc-coated steel sheet, which most of households own nowadays in these areas.

4.4.11 Design Capacity of Water Tanks

In general, a larger tank capacity is preferred in this country. The Rural Water Supply Department has set the standard of a minimum capacity of 50 m^3 for small villages. This has resulted from the fact that, since after-care service is not properly carried out, the storage of emergency water as much as possible for use during equipment breakdowns has been necessary. This project will also select tank capacities somewhat larger within a reasonable limit and with consideration on local site conditions.

The daily peak demand rate is taken as standard for tank capacity selection. The established standards into each site group are indicated below. The details are presented in Appendix.

Table 27 Standard of Water Tank Capacity

Site	Standard
Group A	Daily Max. Water Supply Volume
Group B	Strage hour rate volume at 2007 Japan's Rural Water Supply Standard
Group C	Strage hour rate volume at 1997 Japan's Rural Water Supply Standard

4.4.12 Service Pressure

According to RWSD's Design Criteria, the minimum water head at public fountain and the munimum dynamic water pressure at distribution pipeline are defined 5 meters and 10 meters, respectively.

Considering the further extention of service pipeline which will be proveided by residents after the completion of the project.
A paticular attention shall be paid to the minimum dynamic water pressure at distributio pipelines in order to keep the minimum water service pressure at funtains by selecting the proper pipe diameters.

4.5 Water Supply System

The present rural water supply of this country consists of groundwater intake from wells constructed in the lowlands, transportation through a pipeline to a service tank on an elevated land, and distribution to villages scattered on mountainsides. The Rural Water Supply Department refers to this as the "Improved Water Supply System" to differentiate it from the former point-source system.

This project will adopt the improved system which has a basic flow as depicted below.

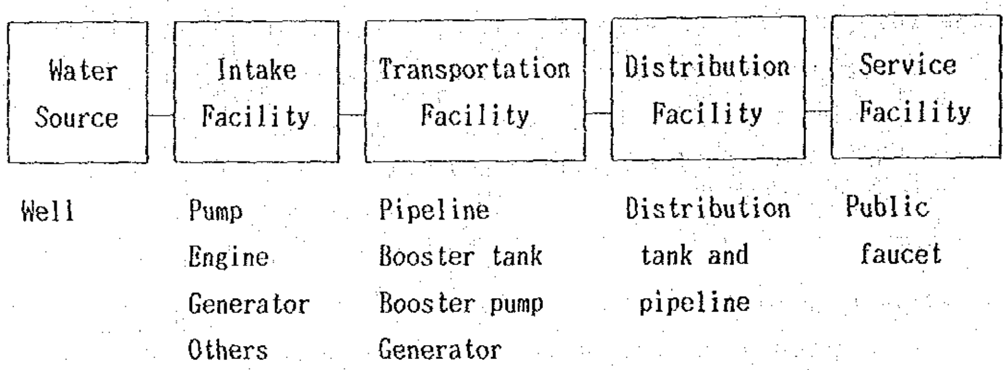


Fig. 14 Basic Flow of Improved Water Supply System

The water sources for all 8 project sites are deep wells. The service facilities are basically public faucets only, and service lines and house connections are made through self-support activities by the villagers themselves.

Water supply undertakings of YAR do not include disinfection except for parts of the capital city of Sana'a. The reason for this is that the water sources are deep groundwater of good quality, and that imported disinfectants are difficult to procure. Furthermore, disinfection facilities carry technical and operation/maintenance-wise problems which are presently difficult to manage by YAR-standards and therefore have potential for facilities shutdown. Moreover, the results of water quality analyses on the project water sources reveal that they do not possess any great problems as drinking water, as was explained previously. Therefore, disinfection facilities will not be installed for this project. However, conservation of raw water and preventive measures against water contamination will be sufficiently considered.

As reference, the disinfection system suitable for facilities of this project is described in the Appendix.

However, in accordance with the increase in water consumption, adopting this system in the future should be taken into account.

The supply systems in this project vary with the conditions of the respective sites, ranging from those using in part existing facilities to those that require completely new ones. Moreover, scale differences and variations of systems arise out of factors such as topographic conditions, village types, served population, etc. This is explained in more detail in a separate section.

4.6 Relation and Evaluation of Existing Facilities

The Rural Water Supply Department is promoting the expanded version of the former point-source water supply system or the improved water supply system. Moreover, requests from the villagers to the Department are mostly for the improved system. Also in this project, expansion will be designed based upon the water source wells already existant at 5 of the project sites. These expansion works are summarized below.

a. Al Khashna : An improved system will be constructed based upon the well of the Department. This site was formerly a candidate for the Japanese grant aid project.

b. Al Zakira : The water supply works were completed in the 2nd Japanese grant project, but extension of distribution/service facilities to the remote villages in this site will be made.

c. Al Kheisen : The existing point-source system of the Department will be upgraded into the improved system.

d. Ad Dahi : The deteriorated, small-scale existing system will be renewed to encompass the whole city with an improved system.

e. Harad : A point-source system was completed at this site in the 1st Japanese grant project. To meet the rapid urban development since that time, the existing system will be expanded into an improved system.

The relationship between the present basic design and the existing facilities is conceptualized in the following figure.

4.7 Relation with Future Plans

Possible future plans include further extension of distribution main for the completion of system in the whole supply area and also installation of service connections for household supply. Furthermore, management of charged water service systems will become an important point for consideration.

1) Future Expansion Project

After completion of this project, only Shihara will require further expansion of transportation/distribution lines to remote villages in the service area. If expansion is to be carried out in the form of public faucets construction in each village, installation of over 15 km of additional pipes and construction of more than 5 booster stations will be required. This expansion works is scheduled as the 2nd phase works and is differentiated from the 1st phase works under this project which plans to pump water up to the summit as main works.

4.8 Characteristic Features of Basic Design

Major points in the basic design for this project are summarized as follows:

1) In the basic design for the project, special attention has been paid to selection of pertinent locations of service tanks and layout of distribution mains in order to achieve uniform water distribution thereafter to each village within the service areas. However, since Shihara site needs facilities in larger scale simply for water transportation system extending from the source to the summit, and furthermore its broad service area having 22 villages over mountainsides requires an extensive distribution system, the entire system is feared to become oversized. This project, therefore, aims to complete a main water transportation system only, as the first phase, together with a minimal range of distribution/service facilities. For the future plan, however, the service tanks to be installed along the transportation line under this project is designed to have storage capacities even for remote villages so as to make future connections for distribution to these villages possible.

2) At the two semi-urban communities in the coastal plain, distribution network is planned as an optimum service system.

3) At the mountainous village complexes of Shihara and Al Rajam, central electric control system is planned for a part of pumping facilities. The rural electrification is now expanding all over the country and the Rural Water Supply Department has completed large-scale facilities controlled by electricity at a mountainous city of Manakhah in Sana'a Governorate. Compared to Manakhah city, urbanization of Shihara and Al Rajam remains yet to be seen, and the application of central control system is limited to the most effective minimum in their entire operation systems. For the locally-completed large scale facilities like Manakhah project, reference shall be made to the Appendix.

V. BASIC DESIGN

V. BASIC DESIGN

5.1 Water Source Facilities

5.1.1 Pumping Rate

Though precipitation is low and groundwater is scarce in general in this country, the practice is to intake water to its fullest from wells. Therefore, the realization of using an economic pumping rate (safe yield) is far from possible. In particular, well drilling has become relatively easy in every part of the country and within the limited wadi area in the premise of the village, not only a well for domestic use but also for irrigation are being drilled, which implies that groundwater conservation is a significant problem to be considered. Since legislation on groundwater conservation is not yet existant in this country, some areas are believed to be haphazardously overpumping. The potential development rate for this project is studied from hydrologic and hydrogeologic methods, while the design pumping rate is recommended to be about 70% of the maximum rate in accordance with the Japan's Standards for Water Supply.

The daily peak demand is used as the daily design pumping rate for each project site, and 1.5 times the daily average demand is taken as the standard. The pumping rate per minute is based upon the safe yield to determine the pump capacity and using well data of each site as reference, the pumping rate is established as indicated below.

Table 28 Pumping Rate

Site Name	Design Pumping Rate (ℓ/min)
Wadi Asfan	150
Al Khashna	150
Al Zakira	300
Al Kheisen	190
Al Rajam	280
Shihara	450
Ad Dahi	600 each
Harad	400 each

5.1.2 Number of Wells

In accordance with the estimated potential yields from a well and the design demands at the respective sites as described in Section 4.4.4, the numbers of water wells required for the project are listed below:

Wadi Asfan	1 No
Al Khashna	(1 No)
Al Zakira	(1 No)
Al Kheisen	(1 No)
Al Rajam	2 Nos
Shihara	1 No
Ad Dahi	(2 Nos)
Harad	(2 Nos)

Note: Numbers in parentheses are those existing.

5.1.3 Study on New Wells

1) Location of Well

The three sites needs new well drilling for the project, and the locations of these wells are determined at the most prospective points selected among the geoelectric survey stations in the field survey. These locations at the respective sites are as follows:

* Wadi Asfan — E-3 Station, west of the village

* Al Rajam — E-1 and E-4 stations located in the southern part of the wadi lowland

* Shihara — E-2 station in the Wadi Woar

(For the details, refer to Appendix A-2-h.)

2) Well Screen

The length of well screens (or strainers) required for the new wells is determined, based upon both the conditions of aquifers to be penetrated and the structure of wells, as follows:

Where the aquifer is saturated with groundwater, constituent particles tends to move and flow into the well through the screen openings during pumping. To restrain this, the critical inflow velocity is considered. The relationships between the pumping rate (Q), opening area of screens (A) and inflow velocity (V) are expressed by the following formula:

$$Q = AV \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The total opening area of screens installed (A) is calculated as follows:

$$A = 2\pi r l \times \alpha \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where

r = radius of well screen
l = total length of screen
α = unit opening area of well screen

Therefore, screen length is calculated as follows:

$$l = A/2\pi r\alpha \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)'$$

The critical velocities against varied sizes of soil particles of aquifer are shown in the following table:

Table 29 Critical Velocities

Soil classification	Particle size	Critical velocity mm/sec
Silt	0.01 - 0.05	2.8 >
Very fine sand	0.05 - 0.1	2.8 - 9.6
Fine sand	0.1 - 0.25	9.6 - 27
Medium sand	0.25 - 0.5	27 - 52
Coarse sand	0.5 - 1.0	52 - 97

In this project, since aquifers to be penetrated by screens are interbedded volcanic materials, the calculation of necessary screen length, based upon the above formulae, depends upon the critical velocity against very fine sand listed in Table 29. Taking the well for the site of Al Rajam, the calculation of screen length is shown as follows. (Note: Screens employed in the project wells are perforated pipe-base screens and wire-wound screens with larger unit opening areas to increase inflow efficiency. Detailed structure is shown in the attached drawing.)

In case of the Al Rajam well, parameters for the calculation are presented as follows:

Q : Pumping rate (280 l/min)
r : Radius of screens (100 mm)
α : Unit opening area of screen (15%)
l : Screen length (m)
V : Critical inflow velocity (2.8 mm/sec = 0.168 m/min - lower limit of very fine sand in Table 20)

The calculation of screen length is:

$$l = Q/2\pi r\alpha V = 0.28/2 \times 3.14 \times 0.1 \times 0.15 \times 0.168 = 18\ (m)$$

According to the above calculation, the required screen length is more than 18 m to avoid inflow of particles of sizes of very fine and larger sand.

On the other hand, screen length should be sufficiently long through the aquifers to tap, or inflow lines will be distorted, resulting in larger well loss. Recommended penetration ratio of screens is 80 to 90% of the total thickness of aquifer. According to the geoelectrical survey for the project, the aquifer thicknesses at the drilling sites range from 60 to 100 m, of which portions rich in cracks for groundwater flow are estimated to be about 1/2 of total thickness. Therefore, at least screens of 30 m in length is recommended from the viewpoint of well structure.

The above study proposes two plans concerning the screen length: one is 18 m, based upon critical inflow velocity; the other 30 m at minimum in view of penetration ratio through the aquifer. In this project, the longer length is preferred, since it is more effective for properly maintaining wells.

3) Study on Well Structure

a. Wadi Asfan

The hydrogeological conditions at this site are that unconfined groundwater (free and not pressurized) and/or semi-confined one are expected in the upper subsurface portion consisting of alluvium of 20 m and underlying weathered tuffaceous andesite of 50 m in thickness. Confined aquifer of fissure-water type is likely to occur in the lower tuffaceous andesite formation.

Aquifers are developed down to the depth of 200 m. Accordingly drilling depth is determined to be basically 200 m. Through unconfined aquifer to the depth of 70 m, a larger diameter of 500 mm (20") is desired, while for confined one from 71 to 200 m, a size of 200 mm (8") is suitable. Screen shall be 30 m in total, of which 12 m (2 pcs of 6 m standard length) are 500 mm in size through unconfined aquifer, and 18 m (3 pcs) are 200 mm for confined one. The uppermost portion of annular space between casing and the borehole must be cemented to prevent contamination from the ground surface. In addition, gravel packing to the depth of 70 m is necessary for protection of collapsing in unconfined aquifers.

b. Al Rajam

At this site deep groundwater of confined nature is the sole source to be expected in lower quartzite sandstone. According to the results of geoelectrical survey, the aquifers are judged to be interbedded down to a depth of 200 m. Drilling depth, therefore, is determined to be 200 m. Since the most promising aquifers are expected in locations deeper than 100 m, the size of planned well is 200 mm (8") from top to bottom, including 30 m long well screens. Cementation of upper portion must tightly be carried out for safeguarding against contamination.

c. Shihara

Unconfined aquifer of silty soil and soil/gravel reach a depth of 74 m, where free and semi-confined groundwater occurs. Judging from the pumping test at existing had-dug wells nearby during the field survey, potential of these aquifers is not high. Sandsone follows the alluvium with its upper portion from 74 m to 100 m in depth consolidated and less cracked, while the lower portion to the depth of 200 m is rich in cracks possibly forming a good confined aquifer. Drilling depth, therefore, is determined to be 200 m. The upper portion of the well to a depth of 30 m should be as large as 500 mm (20") in size for the development of shallow groundwater, followed by 200 mm (8") down to the bottom to tap fissure water. A portion of the well in larger size shall have screens of 12 m in length wrapped with gravel pack. The lower portion is designed to include 200 mm screens, 18 m long. Cementation of the uppermost portion of the well is necessary to prevent contamination.

The typical structure of wells at the three sites above-described are shown in Fig. 15 at next page.

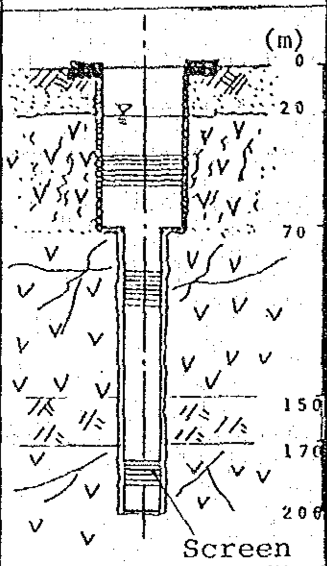
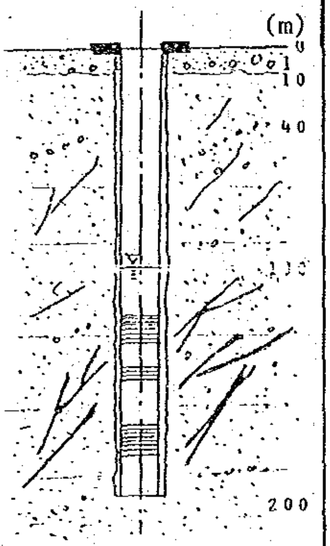
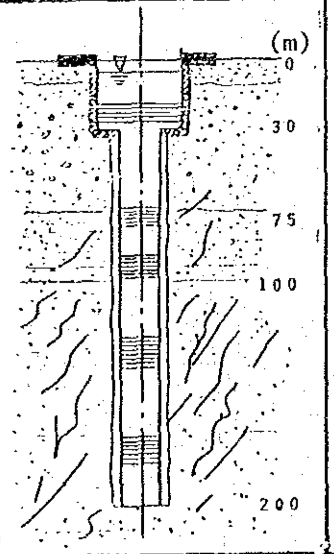
SITE NAME	WELL DESIGN	DESCRIPTION
(1) WADI ASFAN		1. Total Depth : @ 200 m x 1 well 2. Well Diameter : ϕ 500 mm (0 - 70 m) ϕ 200 mm (70 - 200 m) 3. Screen : ϕ 500 mm (12m) ϕ 200 mm (18 m) 4. Casing Pipe : ϕ 500 mm (58 m) ϕ 200 mm (112 m) 5. Discharge Rate : 150 lit/min 6. Static Water Level : 20 m 7. Gravel Pack * Well Logging * Pumping Test
(2) AL RAJAM (Block-D)		1. Total Depth : @ 200 m x 2 wells 2. Well Diameter : ϕ 200 mm (0 - 200 m) 3. Screen : ϕ 200 mm (30 m) 4. Casing Pipe : ϕ 200 mm (170 m) 5. Conductor Pipe : 300 mm (1.20 m - Cementing) 6. Discharge Rate : 280 lit/min 7. Static Water Level : 110 - 120 m * Well Logging * Pumping Test
(3) SHI- HARA		1. Total Depth : @ 200 m x 1 well 2. Well Diameter : ϕ 500 mm (0 - 30 m) ϕ 200 mm (30 - 200 m) 3. Screen : ϕ 500 mm (12m) ϕ 200 mm (18 m) 4. Casing Pipe : ϕ 500 (18m) ϕ 200 (152m) 5. Discharge Rate : 450 lit/min 6. Static Water Level ; 3 m 7. Gravel Pack * Well Logging * Pumping Test

Fig. 15 Proposed Well Structure

5.2 Intake Facilities

5.2.1 Pumping Facilities

Pumping facilities at deep wells are diesel-generator driven submersible motor pumps or diesel-engine driven borehole pumps. The latter has particularly been popular in this country, because of its convenient handling, only movable parts in water being pump impellers. However, the borehole pump is not fitted to higher lifting due to its structure, and is replaced by a submersible motor pump. For this reason, Japan's previous projects mainly employed a submersible motor pump. The present practice by the Rural Water Supply Department chooses the borehole type for a required head under 200 m, and the submersible motor type above 200 m. This project plans to conform to this classification, since it includes the wells less than 100 m in depth. Design pumping rate is based upon the following principle:

Design pumping rate = Safe yield (ℓ/min)

Pumping duration = Daily peak demand/Safe yield < 20 hours

5.2.2 Pumping Duration

As described in detail later in Chapter 7, the completed facilities are to be operated and maintained by local communities' management, and the costs thereof are borne by villagers. In this view, pumping duration should be kept to a minimum so that their burden can be reduced as much as possible. The Rural Water Supply Department also recommends to limit it to the shortest period possible within 20 hours/day at maximum. Taking this situation into account, the pumping duration in this project is planned not to exceed 20 hours a day. Planned pumping hours at the respective sites are listed in the following table:

Table 30 Planned Pumping Duration

Project Site	Pumping Hours (hr/day)
Wadi Asfan	6.6
Al Khashna	3.3
Al Zakira	3.3
(for facilities to be installed under this project only)	
Al Kheisen	6.2
Al Rajam	10.9 (x 2 wells)
Shihara	18.8
Ad Dahi	13.2
Harad	15.3

5.3 Booster Pumping Facilities

5.3.1 Booster Pumps

At the project sites where the service areas are far and wide, one or multiple intermediate booster stations are necessary to transport water from the water sources in the lowland to the main distribution tanks at the highest locations. In this project, a small size of such facilities are designed for the sites of Al Zakira and Al Kheisen, and a larger one for Al Rajam and Shihara. For lifting water high, regardless of its rates, a type of pumps selected is of multi-stage turbine pump. For small facilities where booster pump rates are low, a pump directly connected to a diesel engine is employed, since it saves a space for installation and handling is simple and easy. On the other hand, for large systems at Shihara and Al Rajam, a basic concept is to follow the one employed in the previous grant aid projects in which the multi-stage pumps with a lifting capacity of 200 to 250 m were used, since pumps with specially higher head could not safely be employed in these rural areas for operation and maintenance. Since these pumps require larger power units of 30 to 45 kw in output at higher revolutions of 2900 per minute, driving with electric motors directly coupled to pumps and powered by diesel generators are preferred to direct driving by diesel engines.

5.3.2 Control System of Pumping Facilities

For the large facilities in this project, Shihara is planned to have six booster stations, and Al Rajam, two. The most appropriate method to control the operation of such a series of facilities is to provide a central control system at one power and control station. However, located amid rugged mountains, both sites are in the worst conditions for the installation of power-transmitting and transforming facilities. In addition, maintenance practice in this country remains at a not high level as yet. In this view, the individual operation and control system with a generator installed at each station is basically preferred at both sites. However, parts of these facilities are planned to be provided with a minimum range of this central control system, with details described later in Section 5.7.

5.4 Pipelines

5.4.1 Type of Pipelines

The pipelines for this project are classified as shown below.

a. Transportation pipeline: Pipeline to transport well water by the use of a deepwell pump to the booster tank and to deliver this water to the service tank using a vertical, multi-stage turbine pump.

b. Distribution pipeline : Pipeline to distribute water from the service tank to each village by gravity.

5.4.2 Kind of Pipes

Since rock formations are cropped out in mountainous areas, underground-burying pipes is impossible. Therefore, most of the lines are laid exposed on the ground. As a result, the pipes must be anti-corrosive, high head resistant and durable. For this project, to meet these requirements, galvanized steel pipes (JIS G-3442 Galvanized Steel Pipes for Water Supply) are selected. Meanwhile, since the transportation pipes for Shihara and Al Rajam must be able to withstand a maximum head of over 20 kg/cm^2 (over 40 kg/cm^2 in some parts), those equivalent to carbon steel pipes for pressure service (JIS G-3454 Schedule 40) must be used.

On the other hand, the distribution network at sites in the plain area will be buried. For standardization, galvanized steel pipes will be adopted.

5.4.3 Diameter of Pipes

Basically, the transportation pipe diameters are determined from economic flow velocities. However, concening the lengthy transportation pipelines with high pressures required for Shihara and Al Rajam, the diameter is determined with consideration on preventing water hammer and taking a flow velocity lower than the optimum velocity. The details are given in Appendix.

The diameters of distribution lines are chosen by taking into account the village layout of the served area to distribute water by gravity from the service tank to each village, and with consideration on minimizing the cost. Pipe diameter is calculated by considering the economic velocity through the pipe to meet the hourly peak supply and based upon the effective pressure of over 5 m at the supply end (public faucet).

The formulae used to calculate the pipe diameter are as follows.

For diameter $\leq$ 50 mm, empirical formula of Tokyo Metropolitan Government
For diameter $>$ 50 mm, Hazen-Williams equation

5.4.4 Additional Facilities of Pipelines

Various valves are the main appurtenances for pipes. The main valves and functional purposes are listed below, and these are to be installed at required locations by taking into consideration the topography, pipe layout and water pressure.

Table 31 Valves and Their Purpose

Type	Purpose
Gate valve	For operation/maintenance and flow rate adjustment
Check valve	To prevent water hammer and backflow
Drain valve	For mud drain
Air-release valve	To release air mixed in pipe

The details of valve selection are described in Appendix.

5.5 Water Tanks

5.5.1 Material of Water Tanks

Until the present, concrete tanks, stone-piled tanks and the like were made in YAR. However, for the implementation of Japanese aid projects, special anti-corrosive coated, steel panel tanks were widely used. Since these panel tanks are prefabricated, they are superior in transportability and constructability, and also preserve the surrounding scenery. As a result, these are appraised by the Rural Water Supply Department. In consequence, steel panel tanks will also be used in this project.

5.5.2 Capacity of Water Tanks

Capacity of water tank in each site is designed as follws;

Table 32 Capacity of Water Tank

Site	Kind of Tank	Capacity
Wadi Asfan	Distribution tank	50m³
Al Khashna	- do -	50m³
Al Zakira	- do -	50m³
Al Kheisen	1st Distribution tank	50m³
	2nd Distribution Tank	30m³
	Booster tank	20m³
Al Rajam	Booster tank	50m³
	Booster tank	50m³
	Distribution tank	150m³
Shihara	Booster tank	50m³
	1st Booster Tank	60m³
	2nd Booster Tank	50m³
	3rd Booster Tank	50m³
	4th Booster Tank	50m³
	5th Booster Tank	50m³
	6th Booster Tank	30m³
	Distribution Tank	100m³
Ad Dahi	Elevation Tank	200m³ (100m³× 2)
Harad	- do -	200m³ (100m³+ Ground tank)

5.6 Public Fountains

As service facilities, a public fountain will be constructed at the terminal point of distribution branch from the trunk main. Taking the precedent works of the Rural Water Supply Department as reference, public fountains having 2-taps, 4-tap and 6-taps will be selected. Further, the number of taps will be determined by using the standard of the Rural Water Supply Department of one tap/200 persons.

The design head of public faucets will be established as over 5 m at taps against peak flow, as far as possible. The supply rate within the service area will be determined with consideration of the population distribution. The calculated results for each site are described in Appendix.

5.7 Details of Facilities at the Respective Sites

Based upon the policies for water supply planning of this project described in the foregoing sections, major factors for the supply scheme and details of facilities at the respective sites are listed below.

5.7.1 Wadi Asfan

Location: Sanaa, Khowlan

Site elevation: Water source 2,276 m MSL, Service Tank 2,395 m MSL

No. of villages in site: 6 Villages

Projected population: 695 (year 1986) 990 (2007)

Planned Demand in Design Period: Average per day per capita: 40 ℓ/d/c

Total daily demand: 39.6 m^3/d

Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Water source	Deep well	■	Drilling depth: 200 m Casing size x depth: 20" x 0-70 m 8" x 71-200 m	1 No.	
Intake facilities	Deep well pump	■	Submersible Motor pump 150 1/m x 212m x 11 kW	1 No.	
	Power unit	■	Diesel generator 30 kVA, 400 V	1 No.	
	Deep well pump station	■			
Water transportation facilities	Transportation line	■	50 mm	305 m	
Distribution facilities	Distribution tank	■	50 m^3 ground tank	1 No.	
	Distribution line	■	80 mm 50 mm 40 mm	440 m 1835 m 895 m	
Service facilities	Public fountain	■	4-tap type 2-tap type	1 No. 7 No.	

5.7.2 Al Khashna

Location: Dhamar, Anse

Site elevation: Water source 2,380 m MSL, Service Tank 2,450 m MSL

No. of villages in site: 1 Village

Projected population: 350 (year 1986) 490 (2007)

Planned Demand in Design Period: Average per day per capita: 40 ℓ/d/c
Total daily demand: 19.6 m^3/d

Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Water source	Deep well	□	8" x 150 m	1 No.	
Intake facilities	Deep well pump	■	Submersible Motor pump 150 l/m x 230m x 11 kW	1 No.	
	Power unit	■	Diesel generator 400 V, 30 kVA	1 No.	
	Deep well pump station	■		1 No.	
Water transportation facilities	Transportation line	■	65 m/m	650 m	
Distribution facilities	Distribution tank	■	30 m^3 Ground tank	1 No.	
	Distribution line	■	50 m/m 40 m/m 32 m/m	50 m 414 m 350 m	
Service facilities	Public fountain	■	6-tap type	1 No.	

1) The new deep well as water source for this site shall have a structure to tap both shallow and deep aquifers.
For the details, refer to the drawing attached.

5.7.3 Al Zakira

Location: Taizz, Hozaria

Site elevation: Water source 1,450 m MSL, Water Tank 1,770 m MSL

No. of villages in site: Whole area consisting of 6 villages, among which 3 villages are to be supplied under this project

Projected population: Whole area - 2,700 of which 2,200 are being served by existing system
This project - year 1986: 576, year 2007: 820

Planned demand for this project: Average per day per capita: 40 ℓ/d/c
Total daily demand: 32.8 m^3/d

Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Water source	Deep well	□	8" x 180 m		
Intake facilities	Deep well pump	□	Submersible Motor pump 250 l/m x 245m x 18,5kW	1 No.	
	Power unit	□	Diesel generator 60 kVA, 400 V	1 No.	
	Deep well pump station	□		1 No.	
Water transportation facilities	Booster pump	□	Multi-stage turbine pump directly coupled to Motor 300 l/m x 270m x 22 kW	1 No.	
			Engine-connected multi-stage turbine pump 100 l/m x 100m x 15 ps	1 No.	
	Generator	□	60 kVA	1 No.	
	Booster pump station	□		1 No.	
	Distribution/ service line	□	80 m/m High pressure pipe Sch 40 50 m/m, JIS 10 kg/cm^2	2,250m 1,350m	

(continued)

Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Distribution Service facilities	Distribution tank	□	24 m^3 ground tank 50 m^3 ground tank 100 m^3 ground tank	1 No. 1 No. 1 No.	
	Public fountain	□	6-tap type	3 No.	
Water transportation facilities	Booster pump	■	Engine-connected Multi-stage turbine pump 120 1 /m x 76 m	1 No.	
	Power unit	■	Water-cooled engine 10 pc	1 No.	
	Booster pump station	■		1 No.	
	Transportation line	■	50 m/m	1,460m	
Distribution facilities	Distribution tank	■	50 m^3 ground tank	1 No.	
	Distribution line	■	50 m/m 40 m/m	1,550m 260m	
Service facilities	Public fountain	■	2-tap type 4-tap type	2 No. 1 No.	

1) The existing facilities in the above list were all constructed under the previous project with Japan's 2nd grant aid, with their supply area covering Al Kadra area (main village and other villages in the wadi).

2) The existing system terminated with 100 m^3 distribution tank at the main village. This project aims to expand it to a farther mountainous area, named Qore. The water source for the new project is planned to use the existing deep well, which is judged to have an adequate production to supply to additional villages. The detailed analysis of its capacity is described in the following paragraph.

3) Relation between new and existing systems
This project is planned to expand the existing system to new areas in the whole project site of Al Zakira. Population and demand for the whole area is listed below.

(Unit: persons)

Area	1986	1997	2002	2007	
Al Kadra	1,300	1,338	1,674	1,821	Second Grant Aid Project
Wadi villages	900	1,065	1,159	1,261	
Qore	576	684	744	820	
Total	2,776	3,087	3,577	3,902	

Site Name	Daily Average Demand in 2007	Daily Peak Demand in 2007
Al Kadra	73 m^3	110 m^3
Wadi villages	50 m^3	75 m^3
Qore	33 m^3	50 m^3
Total	156 m^3	235 m^3

Capacity of each facility in the existing system is evaluated as follows: according to this analysis, it is concluded the enhancement of capacities of existing facilities is not necessary.

a. Existing deep well: Planned pumping rate is 250 lit/min. Since the total demand in the year 2007 including the newly-served areas is 235 m^3/day, the production well can cover this demand in 15.7 hours pumping.

b. Distribution tank: The new supply system is to be connected to the existing 100 m^3 tank at Al Kadra village. Since the daily peak demand at this area in the year 2007 (after 20 years) is 110 m^3, the existing tank is slightly small in volume, but is large enough for demand in 15 years, even based upon daily peak storage standards. Accordingly it is judged the enhancement of the volume of the existing tank is not necessary for the present.

Through the above mentioned analysis, the water supply scheme for the whole area of Al Zakira is evaluated to be consistent in design criteria, sizes of various facilities, etc. throughout the previous phase and this one.

5.7.4 Al Kheisen

Location: Sana'a, Khamer

Site elevation: Water source 2,200 m MSL, Water Tank 2,260 m MSL

No. of villages in site: 5 Villages

Projected population: 824 (year 1986), 1,170 (2007)

Planned Demand in Design Period: Average per day per capita: 40 ℓ/d/c
Total daily demand: 46.8 m^3/d

Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Water source	Deep well	□	Total depth: 250 m	1 No.	Installed by RWSD
Intake facilities	Deep well pump	□	Borehole pump 190 ℓ/m x 300 m	1 No.	Already in service
	Power unit	□	Deyal Engine	1 No.	
	Well pump station	□		1 No.	
Water transportation facilities	Booster pump	■	Engine-connected multi-storage turbine pump 100 ℓ/m x 130 m	1 No.	
	Power unit	■	Water cooled engine 12 ps	1 No.	
	Transportation line	■	65 m/m 50 m/m	200 m 700 m	
Distribution facilities	Distribution tank	■	50 m^3 ground tank 30 m^3 ground tank 20 m^3 ground tank	1 No. 1 No. 1 No.	
	Distribution line	■	80 m/m 65 m/m 50 m/m 40 m/m	1,437m 2,140m 250m 350m	
Service facilities	Public fountain	■	2-tap type 4-tap type 6-tap type	3 No. 1 No. 1 No.	

1) At this site, two distribution tanks are to be installed on the tops of the mountains, dividing the site into two areas of east and west. A booster pump station at the base of the western mountain connect the two areas.

5.7.5 Al Rajam (Block D)

Location: Al Mahweet, Al Rajam

Site elevation: Water source 1,975 m MSL, Main Tank 2,390 m MSL

No. of villages in site: 13 Villages

Projected population: 4,055 (year 1986), 6,070 (2007)

Planned Demand in Design Period: Average per day per capita: 40 ℓ/d/c
Total daily demand: 242.8 m^3/d

Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Water source	Deep well	■	8" x 200 m	2 No.	
Intake facilities	Deep well pump	■	280 ℓ /mx215mx18.5kW (Refer to Electric facilities for power unit)	2 No.	
	Well pump station	■	Steel prefabricated unit	2 No.	Under-ground buried type
Water transpor-tation/ Distribu-tion facilities	Booster tank	■	50 m^3 ground tank	1 No.	For No.1 booster pump station
	Booster/ distribu-tion tank	■	50 m^3 ground tank	1 No.	For No.2 booster pump station
	Distri-bution tank	■	150 m^3 ground tank	1 No.	
	Booster pump	■	No.1 Booster pump, multi-stage turbine pump directly coupled to motor 560 l/m x 219 m x 37 kW No.2 Booster pump, 460 l/m x 283 m x 45 kW	1 No. 1 No.	

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Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
	Booster pump station	■		2 No.	
	Transpor-tation line	■	80 m/m 100 m/m high pressure pipe sch 40	970 m 3,530m	
	Distri-bution line	■	100 m/m JIS 10 kg/cm^2 80 m/m JIS 10 kg/cm^2 65 m/m JIS 10 kg/cm^2 50 m/m JIS 10 kg/cm^2 40 m/m JIS 10 kg/cm^2	835m 1,253m 2,445m 2,945m 2,200m	
Service facilities	Public fountain	■	2-tap type 4-tap type 6-tap type	1 No. 3 No. 8 No.	
Electric facilities	Generator	■	Water-cooled diesel generator 200 kVA, 400V	1 No.	For 2 units of pumps and No.1 Booster pump
			Water-cooled diesel general 175 kVA, 400 V	1 No.	For No.2 Booster pump
	Transformer	■	6 kV/380 V 30 kVA	2 No.	For Deep well pump 2 units
	Control panel	■	Central control panel for two deep well pumps and No.1 booster pump	1 No.	
			Control panel on site for deep well pump	2 No.	
			Control panel for No.2 booster pump	1 No.	
	Power trans-mitting facilities	■	Electric pole 150 m/m x 10 m high	17 No.	
			Power cable 6 kV, CVT 8 x 3c	1,034m	
			Control cable 2 x 7c	1,076m	

1) This site features long distribution pipelines reaching the 13 villages scattered over the mountainous side. One trunk line extends from the 2nd booster station reservoir to three villages, and the other from the main distribution reservoir on top of the mountain to ten villages. The water supply system is also large-scaled, involving two booster stations. Because of high pressure required for transportation from the lower basin of the wadi where the deep wells are to be installed to the main distribution tank on the mountain top, heavy duty high pressure piping materials must be used for transportation system.

2) In the lowland of the wadi are constructed two deep wells and No. 1 booster station. In order to operate and maintain these three facilities efficiently and effectively, an integrated operating and controlling system is planned for this part of the supply system.

One unit of large low voltage generator is to be installed in No. 1 booster station to run the two deep well pumps and one booster pump. Power generated by this unit is stepped up to 6 kV at the central control panel at the booster station, transmitted through overhead lines to the respective deep well station, stepped down to 380 V at the transformers installed on the electric pole, and finally connected to the respective panels at the deep well stations.

3) The supply system planned for this site is large-sized and extensive in scale. For the implementation under the Japan's grant aid system, it is appropriate to divide the whole work into two phases. The first phase is planned to construct two deep wells with a reservoir, and the second to complete major transportation and distribution system.

5.7.6 Shihara

Location: Hajja, Shihara

Site elevation: Water source 1,800 m MSL, Service Tank 2,600 m MSL

No. of villages in site: 22 Villages

Projected population: 5,972 (year 1986), 8,440 (2007)

Planned Demand in Design Period: Average per day per capita: 40 ℓ/d/c
Total daily demand: 337.6 m^3/d

Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Water source	Deep well	■	Drilling depth: 200 m Casing 20" x 0-30 m Casing 8" x 31-200 m	1 No.	
Intake facilities	Deep well pump	■	Submersible motor pump 450 ℓ/mx184mx360kW	1 No.	
	Power unit	■	Water cooled diesel engine 175 kVA, 400 V		Combined use No.1 booster pump
	Deep well pump station	■		1 No.	
Water conduit facilities	Conduit line	■	80 m/m	20 m	
Transportation/ Distribution facilities	Booster pump	■	Multi-stage turbine pump directly coupled to motor No.1 Booster pump 440 l/m x89m x 15 kW No.2 Booster pump 385 l/m x225m x 45 kW No.3 Booster pump 370 l/m x352m x 45 kW No.4 Booster pump 285 l/m x165m x 22 kW No.5 Booster pump 215 l/m x295m x 30 kW No.6 Booster pump 215 l/m x299m x 30 kW	 1 No. 1 No. 1 No. 1 No. 1 No. 1 No.	

(continue)

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Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Service facilities	Public fountain	■	2-tap type 4-tap type 6-tap type	1 No. 1 No. 6 No.	
Electric facilities	Control panel	■	Control panel Central control panel	1 No.	For No.5 and No.6 booster pumps
			15 kW, 30 kW 400 V	1 No.	For In-take and booster pump
			22 kW, 30 kW 400 V	1 No.	No.4 booster pump
			30 kW, 30 kW 400 V	2 No.	No.2 No.6 booster pump
			45 kW, 30 kW 400 V	1 No.	No.3 booster pump
	Transformer	■	50 kVA, 6 kV/380 V	1 No.	No.5 and No.6 booster Central Control
	Trans-mission facilities	■	Electric pole 150 m/m x 10 m high Power cable 6 kV, CVT 8 x 3c Control cable CVV-SS 2 x 7c	 24 No. 1,100m 1,100m	
Trans-portation/ Distribu-tion facilities	Power unit	■	Water cooled diesel engine generator 400 V, 70 kVA	1 No.	For No.4 booster pump
			400 V, 100 kVA	1 No.	For No.2 booster pump
			400 V, 175 kVA	1 No.	For No.3 booster pump
			400 V, 200 kVA	1 No.	For No.5 & 6 booster pump

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Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
	Booster/ Distribu- tion tank	■	30 m^3 ground tank	1 No.	No.6 booster pump station
			50 m^3 ground tank	4 No.	No.1, No.3, No.4, No.5 booster pump station
			60 m^3 ground tank	1 No.	No.2 booster pump station
			100 m^3 ground tank	1 No.	Service tank at Shihara
	Trans- portation line	■	High pressure pipe Sch 40, 100 m/m	8,880m	
			Galvanized steel pipe 150 m/m	4,100m	From No.1 to No.2 booster pump stations
			80 m/m	20 m	
	Distri- bution line	■	Galvanized steel pipe 80 m/m 50 m/m	 1,200m 600m	
	Booster pump station	■		5 No.	

1) At this site, the elevation from the water source in the wadi lowland to the main distribution tank at the top of Shihara mountain is approximately 1,300 m and distance between them reach about 13 km. The water transportation system at this site, therefore, becomes conspicuously large in scale.

2) The transportation pipeline is designed to be installed mostly along the existing mountaneous road leading to Shihara at the top of the mountain except a section form No. 5 booster station via No. 6 to the main distribution tank at the summit, where the pipeline is installed along the old mountaneous path (driving is not possible) to cut the pipeline length. Climbing precipitous slopes, the access along this section is extremely bad. No. 6 station to be constructed on the way, therefore, is planned to be operated by remote controlling with a power unit and a panel installed at No. 5 station. A similar control system employed at Al Rajam for power transmitting and transforming will be applied to this site as well.

3) Distribution and service facilities include those respectively from the reservoirs at the booster stations to nearby villages along the transportation line as well as the ones for the public square and several establishments at the summit of Shihara mountain. The reservoir tanks will have taps for future expansion of distribution lines to remote villages.

5.7.7 Ad Dahi

Location: Hudeydah, Ad Dahi

Site elevation: 70 m MSL

Type of community: Semi-urban city

Projected population: 5,093 (year 1986), 6,779 (1997), 9,030 (2007)

Planned Demand in Design Period: Average per day per capita: 70 ℓ/d/c
Total daily demand in 2007: 476 m^3/d

Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Water source	Deep well	□	No.1 deep well 8" x 60 m No.2 deep well 8" x 80 m	1 No. 1 No.	Item in service Existing water source net in use
Intake facilities	Deep well pump	■	Engine connected Borehole pump 90 m^3/n x 64 m Engine output 23 ps/ 1000 rpm Engine connected Borehole pump 600 ℓ/m x 80 m Engine output 20 HP	1 No. 1 No.	to re-place the existing pump at No. 1 well For No.2 well
	Deep well pump station	■	No.1 pump station No.2 pump station	1 No. 1 No.	To re-place existing house
Water transpor-tation	Trans-portation line	■	100 m/m	80 m	From wells to tanks
Distribu-tion facilities	Elevated tank	■	100 m^3 x 15 m high	2 No.	

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Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Distri-bution facilities	Distri-bution line	■	150 m/m 100 m/m 80 m/m 50 m/m 40 m/m	70m 150m 6,200m 600m 100m	
Service facilities	Public fountain	■	2-tap type 6-tap type	8 No. 2 No.	

1) A part of the city has been served with worn-out existing system. Under this project, a new distribution network covering the whole area of the city is planned. Two units of new elevated tanks are to be erected for supply.

2) Service lines will be extended to various public establishments inside the city with the ends of new lines closed with a gate valve so as to be ready for connection to existing reservoirs they already own.

5.7.8 Harad

Location: Hajja, Harad

Site elevation: 90 m MSL

Type of community: Semi-urban city

Projected population: 3,905 (year 1986), 5,198 (1997), 6,920 (2007)

Planned Demand in Design Period: Average per day per capita: 70 ℓ/d/c
Total daily demand in 2007: 367 m^3/d

Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Water source	Deep well	□	No.1 Well 50 m	1 No.	in operation
			No.2 Well 8" x 100 m	1 No.	in operation
Intake facilities	Deep well pump	■	No.1 Well Engine-connected borehole pump 400 ℓ/m x 70 m Engine output 13 ps	1 No.	to replace the existing pump at No. 1 well
		□	No.2 Well Submersible Motor pump 400 l/m x 50 m x 7.5 kW	1 No.	
		□	Diesel generator for pump 45 kVA, 400 V		
	Deep well pump station	■	No.1 pump station	1 No.	
		□	No.2 pump station	1 No.	
Transportation facilities	Booster pump	■	For No.2 Well Centrifugal pump directly coupled with motor 400 l/m x 35 m x 5.5 kW	1 No.	To be installed in existing No.2 station and connected to the existing generator
	Transportation line	■	100 m/m	660 m	

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Category	Facilities	New ■ Exist □	Specifications	Q'ty	Note
Distribution facilities	Elevated tank	■	100 m^3 x 15 m high	1 No.	
	Booster tank	□	100 m^3 ground tank	1 No.	No. 1 Well
		□	200 m^3 ground tank	1 No.	No. 2 Well
	Distribution line	■	100 m/m 50 m/m 40 m/m	5,035m 600m 300m	
Service facilities	Public fountain	□ ■ ■	6-tap type 2-tap type 6-tap type	2 No. 3 No. 3 No.	Beside existing booster tank

1) The existing facilities were constructed under the previous Japan's grant aid, 1st phase, except those of the existing shallow well. Under this project a part of these facilities will be incorporated into the new system.

2) For this site, distribution network is designed, together with public fountains at various locations inside the city. Service lines will be extended to major public establishments so as to be ready for connections.

5.8 Project Cost

The Government of YAR and Local Development Association will prepare to construct the project for the expenses of land acquisition and compensation, arrangement of access road, counterparts, and operation and maintenance.

Based on the basic design, the local portion of the project is estimated 12 million Yemen Riyal. Considering the construction plan the project is divided into three phases.

The breakdown of expenses to be prepared by the Government of YAR and Local Development Association are tabulated as below.

Table 33 Local Portion of the Construction

Item	Unit	Amount: 10^4 YR	(10^4 Yen)
Land Acquisition/compensation	1200 m^2	120	(1600)
Access Road	28200 m^2	280	(3800)
Expenses of counterparts	122 M/M	610	(8200)
Operation & Maintenance (Training of operator)	19 persons	60	(810)
Contingency	10%	107	(1400)
Total		1200	(16000)