PART I GENERAL

CHAPTER 1 INTRODUCTION

1-1 Background of the Study

The mineral exploration, including geophysical and drilling surveys, in the Ghuzayn District of the South Batinah Coast Area was carried out as the copper exploration in the Oman Mountains by Prospection Ltd. in 1970's and small orebody near the gossan was found. After that, the mineral exploration as part of regional geological mapping and mineral exploration, consisting of geological, drilling and geophysical surveys, had been done by the Ministry of Petroleum and Minerals (MPM) and BRGM in 1980's, but promising results were not obtained.

The Metal Mining Agency of Japan (MMAJ) had been carried out the cooperative mineral exploration in the Central Batinah Coast Area since 1995, and consequently two orebodies of massive sulfide were newly discovered. After that, additional mineral exploration has been vigorously done in the South Batinah Coast including the Ghuzayn District.

Main orebodies in the Ghuzayn District are presently found three orebodies within about 2 kilometers west of the gossan zone. These orebodies are expected to the mine development in future.

1-2 Objectives of the Study

Objectives of the study in the Ghuzayn District conducted since 1997 as the Cooperative Mineral Exploration in the South Batinah Coast area, Sultanate of Oman, are to collect data conducing to the evaluation and to promote for a mine development in the district.

1-3 Location of the Study Area

Ghuzayn District, Kaburah Municipality (South Batinah Coast area), Sultanate of Oman (Figure 1).

1-4 Period of the Study

The period of the study is from January 26, 2000 to March 24, 2000, and the field investigation is 34 days from February 6, 2000 to March 10, 2000.

1-5 Content of the Study

The study consists of hydrological and ground water investigation and weather observation. The content of the study is shown in Table I-1-1.

The technical transfer to Omani counterpart should be conducted to collect data continually after the study team returns to Japan because the long term continuous data collection is indispensable for this study.

1-5-1 Hydrological Investigation

(1) Content of hydrological investigation

The hydrological investigation consists of five points including three points of surface current and two water wells. Measurement items of the hydrological investigation in each point consist of discharge (or groundwater level), pH, electric conductivity (EC) and water temperature.

It is necessary to establish an organization for the hydrological investigation in the study area in order to obtain periodically long-term data under seasonal changes. Therefore, the study team will arrange sufficient technical transfer to the counterpart concerning the hydrological investigation after the field investigation.

Table I-1-1 Content of the Study

<table>
<tr><th>Items</th><th colspan="2">Content</th><th>Remarks</th></tr>
<tr><td rowspan="4">1. Hydrological investigation</td><td rowspan="2">Hydrological measurement</td><td>River (3)</td><td>Discharge, pH, EC, water temperature</td></tr>
<tr><td>Well (2)</td><td>Ground water level, pH, EC, water temperature</td></tr>
<tr><td colspan="2">Water sampling</td><td>5 points</td></tr>
<tr><td colspan="2">Water quality analysis</td><td>9 components</td></tr>
<tr><td rowspan="5">2. Ground water investigation</td><td colspan="2">Drilling and bore well construction</td><td>5 wells</td></tr>
<tr><td colspan="2">Water quality measurement</td><td>Groundwater level, pH, Electric conductivity and water temperature</td></tr>
<tr><td colspan="2">Recovery test</td><td>5 wells</td></tr>
<tr><td colspan="2">Water sampling</td><td>5 wells</td></tr>
<tr><td colspan="2">Water quality analysis</td><td>9 components</td></tr>
<tr><td rowspan="2">3. Weather observation</td><td colspan="2">Installation of weather observation devices</td><td>In Ghuzayn village</td></tr>
<tr><td colspan="2">Data collection</td><td>Temperature, Humidity, Wind velocity and direction and Rain fall</td></tr>
</table>

(2) Water quality analysis

Five water samples taken for hydrological investigation are analyzed. Components of water quality analysis are shown in Table I-1-2.

Table I-1-2 Water Quality Analysis for Surface Water

No. of samples	Components of water quality analysis
5	Cu, Zn, Pb, Ni, Cr, Fe, Mn, Hg, SO_4 (9 components)

(4) Meteorological data collection

It is necessary to collect meteorological data for the past 10 years from the Meteorological Agency (or Ministry of Water Resources).

1-5-2 Ground water Investigation

(1) Content of Ground water investigation

For the study of groundwater behavior and permeability and ground water quality in the study area, five 50m-depth bore holes will be drilled and the water quality measurement, recovery test and water sampling for quality analysis will be conducted. The water quality measurement consists of ground water level, pH, electric conductivity (EC) and water temperature.

(2) Drilling and bore well construction

The location of bore wells is selected based on the result of the last study.

The none-core drilling, placement of casing pipe and screen for protection of bore wall and construction of well head cover are adopted for the long term monitoring.

(3) Recovery test

The recovery test of the ground water in the 5 bore wells is conducted.

(4) Water quality analysis

Five water samples are taken from the surface of ground water in each bore well for the chemical analysis on the same 9 components as the surface water shown in Table I-1-2.

1-5-3 Weather observation

(1) Content of weather observation

The weather data in the study area should be collected continually for making the weather condition of the study area clear.

(2) Installation of weather observation devices

The weather observation devices are installed in Ghuzayn village to collect continual weather data consists of temperature, humidity, wind velocity and direction and rain fall.

It is necessary to establish an organization for the weather data collection in the study area in order to prepare long-term weather data under seasonal changes. Therefore, the study team will arrange sufficient technical transfer to the counterpart concerning the weather observation after the device installation.

1-5-4 Establishment of organization for investigation and observation

It is necessary to establish an organization for continuing the study. Therefore, the study team will arrange sufficient technical transfer to the counterpart concerning the investigation and observation after the return of the study team.

1-6 Study Team

The study team consists of two persons including team leader and hydrological environment engineer as shown in Table I-1-3.

Table I-1-3 Participants for the Study

Inspection of the field work	
Tadashi Ito	MMAJ *1

*1 MMAJ : Metal Mining Agency of Japan

Japanese counterpart			Omani counterpart	
Toshio Koizumi	Team leader	OMRD *2	Salim Omer Ibrahim	MCI *3
Hiroshi Karashima	Hydrology/ Environment	OMRD	Khalid Al-Toobi	MCI

*2 OMRD : Overseas Mineral Resources Development Co., Ltd.

*3 MCI : Ministry of Commerce and Industry, Sultanate of Oman

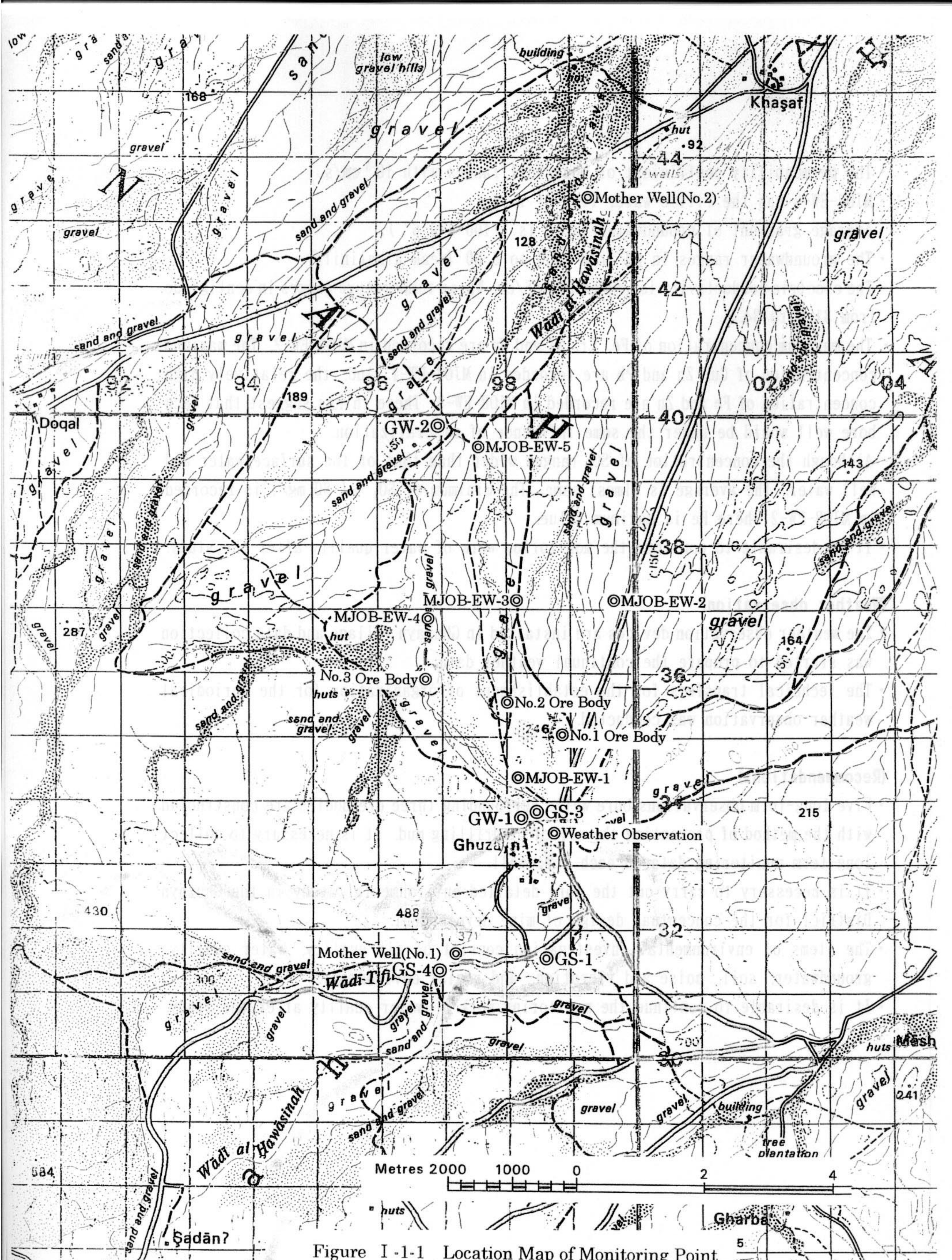

Figure Ⅰ-1-1 Location Map of Monitoring Point

- The permeability coefficient of bore well ranges with 10^{-5} cm/s.
- MJOB-EW-3 has the little water flow of 1 l/s.
- Average gradient of groundwater table is 1/100 (=0.6°).
- The groundwater ranges in pH from 8.00 to 8.60 (weak alkalinity).
- The electric conductivity is around 100 μS/cm. Water temperature ranges in centigrade from 31.5 to 34.8.
- The maximum concentration of Fe, Cr, Ni and Mn are recorded in MJOB-EW-2. The maximum concentration of Cu, Zn and Pb are recorded in MJOB-EW-1. And, the relatively high concentration of Fe and Zn are recorded in MJOB-EW-4. These things suggest that each bore well would be under the some influence of mineralization.
- Although the concentration of SO_4 ranges wider than that of the surface water and well water, the average is almost same. The minimum of SO_4 of 80 mg/l is recorded in MJOB-EW-2 where Fe is maximum value.
- It is desirable to continue the monitoring work of water quality after the study.

(Weather observation)

- The weather observation devices are installed in Ghuzayn village and data collection was started to prepare the continual weather data.
- The technical transfers for the establishment of organization for the periodical weather observation was conducted.

(Recommendations)

- Five long-term observations bore wells surrounding three ore bodies are constructed with the method of preventing the affect of drilling mud. It is necessary to collect long-term monitoring data on each bore well.
- It is necessary to carry out the more detailed environmental study in the Ghuzayn District for the conceptual design of mine development.
- The items of environmental investigation consist of air quality, water quality, groundwater, soil, noise and vibration, and social environment.
- It is desirable to continue the monitoring work of water quality after the study.

CHAPTER 2 GEOGRAPHY OF THE STUDY AREA

2-1 Location and Access

The Sultanate of Oman is approximately 300,000 km^2 in the Arabian Peninsular, lying at its southeast corner (Figure 1). The capital is Muscat, and the population of Oman is 2,018,000 in 1993.

The South Batinah Coast area is located in the northeastern flank of the Hajar Mountain range, over 2,500 m in elevation, running parallel to shoreline of the Gulf of Oman.

The Ghuzayn District belongs to the Kaburah Municipality of the north western part of the South Batinah Coast area, and has a latitude 23° 50′ N and a longitude 56° 59′ E.

The access road between Muscat and Ghuzayn District is approximately 170 km one paved by asphalt and it takes about 2 hours by vehicle.

2-2 Topography and Hydrological Condition

The Ghuzayn District is located on the boundary between hilly land, the northeastern flank of the Hajar Mountain Ranges, and flat area along the seashore. South half part of the district is hilly land ranging in elevation from 250 to 500 m, and north half part of the district is low terrace ranging in elevation from 175 to 200 m (Figure I-2-1).

Drainage system in the district belongs to that of the Wadi Al Hawasinah River Wadi Al Hawasinah River originates in the central part of the Hajar Mountain Ranges and bends its flow to the west at Ghuzayn Village.

Gully erosion is slightly found on the terrace, and all of small branches flow into the main stream of Wadi Al Hawasinah River (Figure I-2-2).

Surface water flows are found in several places in the Wadi Al Hawasinah River around Ghuzayn Village, and some spring water through Mother Well is taken through Falaj system to the village for irrigation.

2-3 Climate and Vegetation

The climate of the Ghuzayn District is arid-type, and average precipitation of the year in the Batinah Coast area is 120 mm (Sohar and Seeb Airport, 1980～1997). Average, maximum and minimum air temperature of the year (Sohar and Seeb Airport, 1980～1997) are 26.5℃, 50.0℃ and 5.7℃, respectively.

Summer (hot season) is between April and September, and winter is Between October and March and has a rare rainfall.

The vegetation in the Ghuzayn District is generally very rare except Ghuzayn Village, so-called oasis, and the district features the rock or gravel desert.

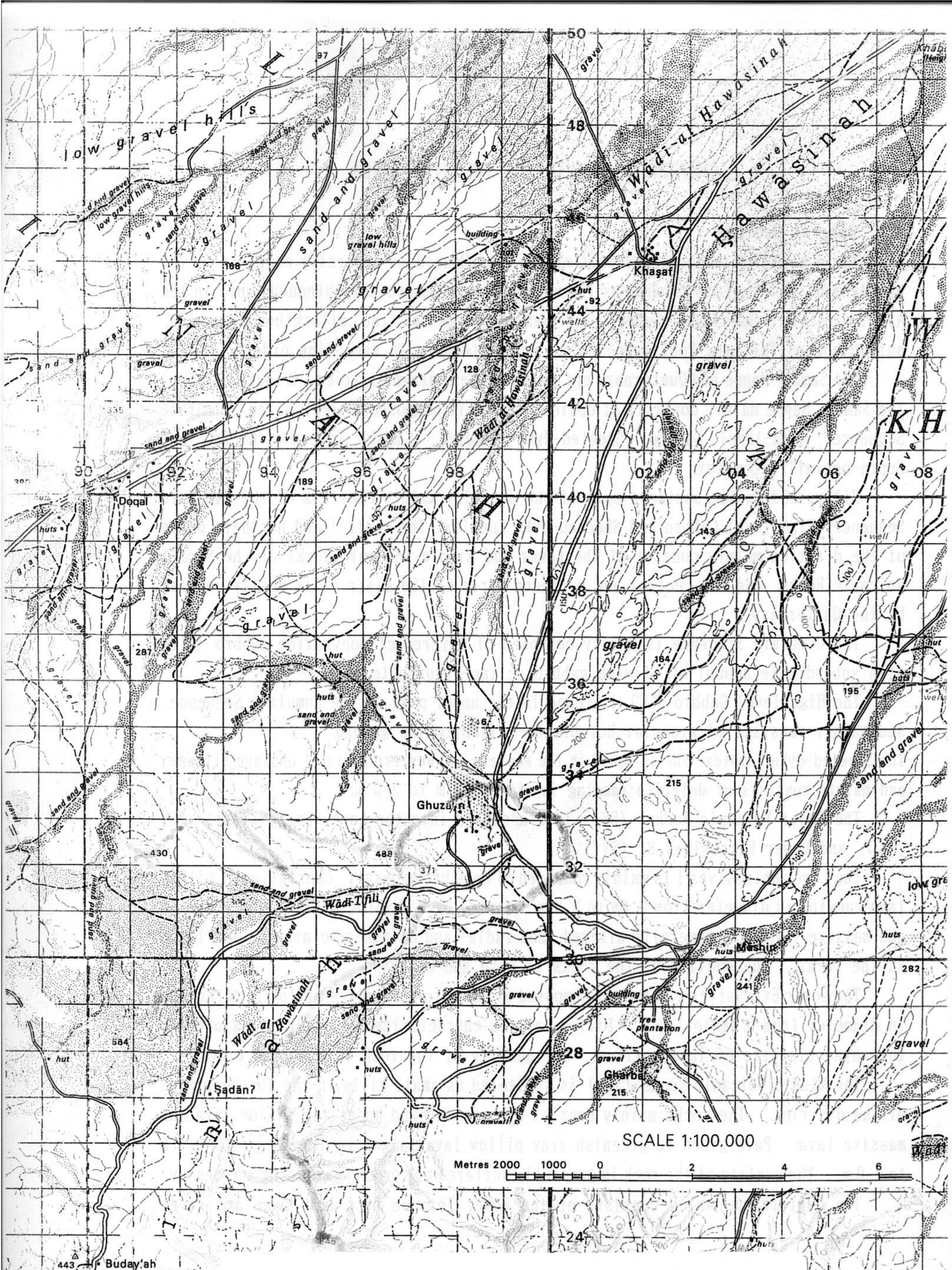

Figure Ⅰ-2-1 Topographic Map of the Ghuzayn District

CHAPTER 3 OUTLINE OF THE STUDY AREA

3-1 General Geology

The geology in the northern part of the Oman Mountains generally consists of the basement of the Pre-late Permian as the autochthonous to sub-autochthonous unit in the Arabian plate, Hawasinah Nappes and Samail Nappe as the allochthonous units, autochthonous Tertiary Post-Nappe Unit, and Quaternary in ascending order.

The Samail Nappe and Quaternary are found in the Ghuzayn District (Figure I-3-1). The Samail Nappe mainly consists of ophiolte which is composed of Tectonites, Cumulate Sequence, High-level Gabbro, Sheeted-dyke Complex, Samail Volcanic Rocks, and Supra-ophiolite Complex.

Hilly land in the southern part of the district mainly consists of the Cumulate Sequence, High-level Gabbro and Sheeted-dyke Complex. The central and northern parts of the district mainly consist of the Lower and Middle Volcanic Rocks of the Samail Volcanic Rocks, and the central and northern parts of the district is mostly covered by the Quaternary.

The Cumulate Sequence is mainly composed of layered clinopyroxine gabbro (ClG) with subordinate amount of olivine gabbro, clino-pyroxinite, etc.

The High-level Gabbro (GU') is found in the upper part of the Cumulate Sequence, and mainly consists of granular hornblende-clinopyroxine gabbro.
The Sheeted-dyke Complex (SD) is found in the eastern and western parts of Ghuzayn Village, and mainly consists of dolerite ranging in width 0.5 m to 3.0 m.

The Lower Volcanic Rocks (SV_1) is classified into the Lower Extrusives 1 (SV_{1-1}) and Lower Extrusives 2 (SV_{1-2}).

The Lower Extrusives 1 is mainly composed of dark brown basalt, consisting of pillow lava ranging in diameter from 0.8m to 2.0 m, massive lava, hyaloclastite, etc. Pillow and massive lavas are generally altered, and radial and columnar joints are developed in the rocks. The quality of the rocks is hard and cracky.

The Lower Extrusives 2 is mainly composed of dark brown basaltic pillow lava ranging in diameter from 0.1m to 1.0 m. Pillow lava is characterized by variole texture and thin hyaloclastite of inter pillow. The quality of the rock is hard and cracky.

The Middle Volcanic Rocks (SV_2) is scattered as small hills in the northern part of the district. The rocks mainly consist of basaltic and andesitic pillow lava and massive lava. Pale green to greenish gray pillow lava ranges in diameter from 0.5 m to 2.0 m. The quality of the rock is generally suffered by strong weathering and cracky.

The Quaternary, which consists of the Lower Terrace Deposits (Qgx) and River

Sediments, is widespread in the central and northern parts of the district.

The geological structure in the Ghuzayn District is characterized by nappe structure and homoclinic structure gently dipping to the northeast of the Samail Volcanic Rocks (SV). And WNW-ESE and NW-SE systems of high angled faults are recognized in the district.

3-2 Mineralization

At present, three orebodies including No. 1, No. 2 and No. 3 are discovered in the Ghuzayn District (Figure II-3-2) . Massive sulfide deposit in the district occurs in the Lower Volcanic Rocks of the Samail Volcanic Rocks. The deposit is inferred to be Cyprus-type copper deposits formed in the ancient ocean-floor, and same type of ore deposit is found in the Lasail, Bayda, Rakah, and Hayl as Safil deposits in the Oman Mountains. These deposits ranges in ore reserves from several hundred thousand to ten million tons.

The No. 1 Orebody, which is confirmed by drilling survey of MJOB-G3, G13 and G25, is located in the northern boundary of the gossan zone. The massive ore ranges in thickness of drilled core from 2.18 to 7.45 m, and the stock-work ore ranges in thickness from 25.90 to 94.60 m.

The No. 2 Orebody, which is confirmed by drilling survey of MJOB-G5, G14, G15, G16, G17, G18, G19, G20, G21, and G22, is located in the 800 m west of the gossan zone. The massive ore ranges in thickness of drilling core from 2.50 to 37.10 m, and the stock-work ore ranges in thickness of drilling core from 10.10 to 65.75 m. The ore reserve of No. 2 Orebody is approximately 5 million tons (Cu: 1.2%).

The No. 3 Orebody, which is confirmed by drilling survey of MJOB-G30, G31, G32, G33, G36 and G37, is located in the about 2 km west-northwest of the gossan zone. The massive ore ranges in thickness of drilling core from 0.90 to 91.40 m, and the thickness in drilling core of stock-work ore is 31.95 m. The orebody is inferred to be 130 m to 200m in width.

3-3 Environment

The environmental legislation in the Sultanate of Oman mainly consists of the environmental law and each environmental standards as shown Table II-3-1. According to the guideline of "Environmental Impact Assessment (draft stage)", the developing project is obligated to submit the environmental impact statement to the Ministry of Regional Municipalities and Environment before implementation. The development of copper mine is also involved in the legislation.

Effluent standard for wastewater in Oman is shown in Table II-3-2.

Table I-3-1 Laws and Regulations Related to the Environment

No.	Laws and regulations	Issued date
1	Environmental law	10/1982
2	Law on the conservation of environment and preservation of pollution	10/1982
3	Regulations for air pollution control from stationary sources	17/5/1986
4	Issuing regulation for noise pollution control in public environment	20/3/1993
5	Regulations for waste water re-use and discharge	13/6/1993
6	Regulations for the management of solid non-hazardous waste	2/2/1993
7	Regulation for the management of hazardous waste	2/2/1993

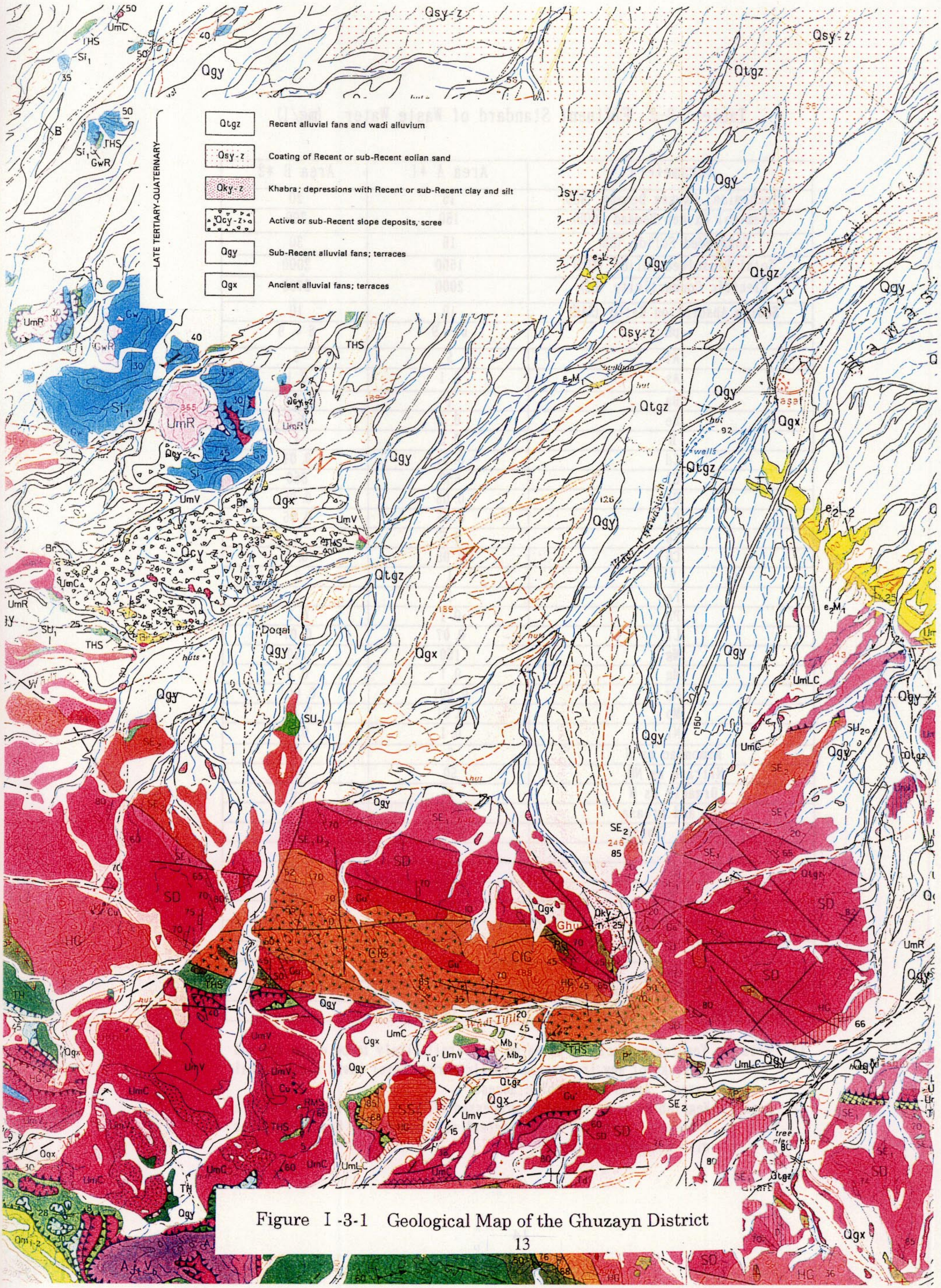

Figure Ⅰ-3-1 Geological Map of the Ghuzayn District

Table I-3-2 Effluent Standard of Waste Water (mg/l)

Parameters	Area A *1	Area B *2
Biochemical Oxygen Demand (BOD)	15	20
Chemical Oxygen Demand (COD)	150	200
Suspended Solids (SS)	15	30
Total Dissolved Solids (TDS)	1500	2000
Electric Conductivity (EC)	2000	2700
Sodium Absorption Ratio (SAR)	10	10
pH	6 - 9	6 - 9
Al	5	5
As	0. 1	0. 1
Ba	1	2
Be	0. 1	0. 3
B	0. 5	1
Cd	0. 01	0. 01
Cl	650	650
Cr	0. 05	0. 05
Co	0. 05	0. 05
Cu	0. 5	1
CN	0. 05	0. 1
F	1	2
Fe	1	5
Pb	0. 1	0. 2
Li	0. 07	0. 07
Mg	150	150
Mn	0. 1	0. 5
Hg	0. 001	0. 001
Mo	0. 01	0. 05
Ni	0. 1	0. 1
Ammoniac as N	5	10
Nitrate as NO_3	50	50
Organic as N	5	10
Oil and grease	0. 5	0. 5
Phenols (Total)	0. 01	0. 02
P	30	30
Se	0. 02	0. 02
Ag	0. 01	0. 01
SO_4	400	400
S	0. 1	0. 1
V	0. 1	0. 1
Zn	5	5
Fecal coliform bacteria (per 100 ml)	200	1000
Viable Nematode Ova (per litter)	<1	<1

*1 : Area A : Vegetable likely to be eaten raw. Fruit likely to be eaten raw and 2 weeks of any irrigation. Public parks, hotel lawns recreational area. Areas with public access.

*2 : Area B : Vegetables to be cooked or processed. Fruit if no irrigation within 2 weeks of cropping. Fodder cereal and seed crops. Pastures. Areas with no public access.

CHAPTER 4 SURVEY RESULTS

4-1 Hydrological Investigation

4-1-1 River Survey

Three sampling points of river water, including GS-1, GS-4 and GS-3, were selected. GS-1 is irrigation channel (Falaj system) located at about 2.5 km upper stream to Ghuzayn Village, GS-4 is located at about 4.0 km upper stream to Ghuzayn Village, and GS-3 is located in the lower stream to Ghuzayn Village.

There was no surface current water at the sampling point GS-2 where the water sample was taken in the last study, therefore, GS-4 is substituted for GS-2. The irrigation channel is called Falaj system, 50 to 80cm wide open and covered ditch made of concrete, through which the spring water from Mother Well in the mountain side is led to village by using gravitation.

Discharge of surface water by the flow speed meter was measured.

Table I-4-1 Measurement Result of Discharge and Water Quality

Sample No.	Water quality *1			Discharge (m^3/min)
	PH	EC (μS/cm)	Temp. (℃)	
GS-1	8.30	167.5	28.5	2.70
GS-4	8.60	121.2	29.1	0.30
GS-3	8.00	172.0	29.1	0.08

*1 : Electric Conductivity

The value of pH of water ranges from 8.00 to 8.60 (weak alkalinity).

The water balance in Ghuzayn village shows the approximately same volume of ground water as Falaj system exists somewhere.

4-1-2 Well Survey

The well water survey was carried out in two water wells, one is in Ghuzayn Village (GW-1) and the other is in the farm garden located at the meeting point of the small tributary which originates in this area and Wadi Al Hawasinah River, about 7 km north-northwest along Wadi Al Hawasinah River from Ghuzayn Village (GW-2).

Depth of groundwater table and water quality of well water are shown in Table I-4-2. The depth of groundwater table is almost same, and the water quality is assumed to be also similar.

Table I-4-2 Measurement Result of Water Level and Water Quality

Sample No.	Water quality			Groundwater level from surface (m)
	pH	EC *1 (μS/cm)	Temp. (℃)	
GW-1	8.30	177.8	25.6	-7.50
GW-2	7.96	112.6	32.0	-6.70

*1 : Electric Conductivity

4-1-3 Water Quality Analyses

Water quality analysis of surface water and well water was carried out. Characteristics of the water quality are shown as below.

- The groundwater ranges in pH from 8.10 to 8.29 (weak alkalinity).
- All concentration of Cu, Zn, Pb, Ni, Cr, Mn are <0.01 mg/l. All concentration of Hg is less than detection limit.
- The average concentration of Fe is 0.03 mg/l, maximum value is 0.07 mg/l in GW-1, and minimum value is <0.01 mg/l in GS-3. Those of GW-1 (Ghuzayn village) and GS-3 (river water) are relatively higher.
- The average concentration of SO_4 is 131 mg/l, maximum value is 145 mg/l, and minimum value is 114 mg/l.

4-2 Ground water survey

4-2-1 Selection of Bore Well Location

Bore well location was selected taking the ground water flow direction assumed in Ghuzayn district in the last study into consideration.

One bore well, MJOB-EW-1 is placed in the upper stream side for the whole ore bodies, No.1 to 3 ore bodies and three bore wells, MJOB-EW-2 to MJOB-EW-4 are placed in the down stream side for each ore body, No.1 to No.3, further more, MJOB-EW-5 is placed in the far down stream side for the whole ore bodies. In addition, for confirming the influence of Wadi Al Hawasinah River, MJOB-EW-3 and 5 are located on the flood plain of Wadi Al Hawasinah River.

4-2-2 Drilling of Bore Well

Drilling works were done by truck-mount rotary drilling machine. The topography in the study area is almost flat desert one covered with alluvium gravel, sand and clay, so the movement and setting of the machine and tools could be conducted smoothly. For the purpose of the protection of well wall and prevention of fall of the foreign substance, 8"PVC casing pipe and screen is placed, the annulus is filled with the washed round and semi-round gravel, the upper part of the well is reinforced with 133/8" M. S. conductor pipe and cement milk and the mouth of the well is covered with steal flange and framed by concrete plinth so that the well can be used for the long-term ground water observation.

The actual whole drilling work process from movement and setting of drilling machine, drilling and placement of casing pipe and screen to washing bore well by compressed air lift required net two days.

It took about two hours to finish the mouth of well after the recovery test (concrete enforcement, setting of concrete plinth and steal flange).

4-2-3 Recovery Test

After the compressed air lift washing of bore well, the recovery test was conducted. Small submergible pump and pipe line was installed from near the bottom of the bore well (about 48m depth) to the ground so that the ground water could be pumped out and the ground water level lowered.

The test result and the permeability coefficient of each bore well calculated are shown in Table I-4-3.

Table I-4-3 Permeability Coefficient

No.	Number of bore holes	t_1 (min)	t_2 (min)	h_1 (cm)	h_2 (cm)	L (cm)	R (cm)	r (cm)	Permeability Coefficient (cm/s)
1	MJOB-EW-1	10	100	2715	25	3500	10.25	15.56	7.04×10^{-5}
2	MJOB-EW-2	10	100	1617	27	2900	10.25	15.56	7.16×10^{-5}
3	MJOB-EW-3	1	10	682	408	2900	10.25	15.56	8.99×10^{-5}
4	MJOB-EW-4	10	100	2716	146	2900	10.25	15.56	5.11×10^{-5}
5	MJOB-EW-5	10	100	3254	1434	3500	10.25	15.56	1.23×10^{-5}

The permeability coefficients of the bore wells are ranked as 10^{-5}cm/s.

Judging from the cuttings taken by every one meter during drilling work, the geology consists of unconsolidated alluvium, consolidated or cemented diluvium, weathered basaltic rocks and basaltic rocks. The seepage point during drilling work was observed in the consolidated, cemented diluvium and top of weathered zone of the basaltic rocks.

Major aquifer in the district is assumed to be River Sediments, Lower Terrace Deposits, and cracky zone of basement (basalts).

The groundwater table is assumed to form a fan shape, whose pivot exists around MJOB-EW-1, slanting along the topography from south to north, with average gradient of 1/100 between about 4.6km, from 180m-SL to 130m-SL.

4-2-4 Water Quality Analysis

The result of water quality analysis is shown as below.

- The groundwater ranges in pH from 8.10 to 8.29 (weak alkalinity).
- Judging from that electric conductivity is 100μS/cm around and water temperature is higher than 30℃, relatively high, it is assumed that the ground water in the bore wells is supplied from the river current water and reserved in the alluvium bed.
- The Maximum concentration of Fe,. Cr, Ni and Mn are recorded in MJOB-EW-2. The Maximum concentration of Cu, Zn and Pb are recorded in MJOB-EW-1. And, the relatively high concentration of Fe and Zn are recorded in MJOB-EW-4. These things suggest that each bore well would be under the some influence of thin vein of mineralization.
- Although the concentration of SO_4 ranges wider than that of the surface water and well water, the average is almost same. The Minimum of SO_4 of 80 mg/l is recorded in MJOB-EW-2 where Fe is Maximum.
- The water quality and analysis result measured on the ground water sample taken in the bore wells with no affect of drilling mud are obtained.
- The continual long term monitoring is desirable to confirm the changes of ground water quality according to the undulation of the weather and ground water level etc.

4-3 Weather Observation

The weather observation devices are installed in the study area in order to collect continual long-term weather data in Ghuzayn district.

The technical transfers to the counterpart for establishment of organization for collecting long-term data was conducted.

4-3-1 Installations of Weather Observation Devices

Taking the collection of weather data representing Ghuzayn district and the convenience of installation and maintenance of devices into consideration, the devices are installed on the roof of private house on the left side bank of Wadi Al Hawashinah River

4-3-2 Collections of Weather Data

The continual weather data during the site survey was collected. The weather data was recorded by every o'clock concerning temperature, humidity, wind velocity and direction and rainfall. The weather data collected shows temperature and humidity undulates regularly and severely during day and night. The wind velocity and direction features windless during night and the northern wind blow in the highest temperature time zone. There was no rainfall at all during the site survey.

The climate of Ghuzayn district features the cyclic undulation, that is, the division into two parts, summer and winter; therefore, the long-term data collection at least during one year should be indispensable.

4-4 Establishment of Organization for Monitoring

The technical transfers to the counterpart for establishment of the organization for the periodical hydrological and weather monitoring in order to collect long-term data was conducted.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5－1 Conclusions

The conclusions of the study are as follows:

(Hydrological Investigation)

- Rivers in the Ghuzayn District belong to the drainage system of Wadi al Hawasinah River.
- Sampling points of water for the hydrological investigation consist of 5 points, 3 points of surface water survey (GS-1, GS-4 and GS-3) and 2 points of well survey (GW-1 and GW-2).
- Discharge of GS-1 (Falaj) is 2.70 m^3/min, GS-4 (upper stream) is 0.30 m^3/min, and GS-3 (lower stream) is 0.084 m^3/min.
- Water wells (GW-1 and GW-2) in the district are shallow well for irrigation. Depth of groundwater table is about -7.50, -6.70 m below GL, respectively.
- Approximately same volume of ground water as surface current water is assumed to exist near the Ghuzayn District by the water balance.
- Surface water of 2.70 m^3/min is taken from the mother well near Ghuzayn Village and supplied through Falaj system for irrigation.
- The surface water and well water range in pH from 8.00 to 8.60 (weak alkalinity).
- All concentration of Cu, Zn, Pb, Ni, Cr, Mn are <0.01 mg/l. All concentration of Hg are less than detection limit.
- The average concentration of Fe is 0.03 mg/l, Maximum is 0.07 mg/l in GW-1, Minimum is <0.01 mg/l in GS-3. Those of GW-1 (Ghuzayn village) and GS-3 (river water) are relatively higher.
- The average concentration of SO_4 is 131 mg/l, Maximum is 145 mg/l, and Minimum is 114 mg/l.
- The technical transfers for the establishment of organization for the periodical hydrological investigation was carried out.

(Water Investigation of Bore Wells)

- Five bore wells (one in the upstream and four in the down stream) are drilled by the method of preventing from the drilling mud affect, and casing and screen pipes are placed to protect the bore well wall for preparing the ground water observation.
- The recovery test, water sampling, water quality measurement and water quality analysis are conducted on each bore well.

- The permeability coefficient of bore well ranges with 10^{-5} cm/s.
- MJOB-EW-3 has the little water flow of 1 l/s.
- Average gradient of groundwater table is 1/100.
- The groundwater ranges in pH from 8.00 to 8.60 (weak alkalinity).
- The electric conductivity is around 100 μ S/cm. Water temperature ranges in centigrade from 31.5 to 34.8.
- The Maximum concentration of Fe, Cr, Ni and Mn are recorded in MJOB-EW-2. The Maximum concentration of Cu, Zn and Pb are recorded in MJOB-EW-1. And, the relatively high concentration of Fe and Zn are recorded in MJOB-EW-4. These things suggest that each bore well would be under the some influence of mineralization.
- Although the concentration of SO_4 ranges wider than that of the surface water and well water, the average is almost same. The Minimum of SO_4 of 80 mg/l is recorded in MJOB-EW-2 where Fe is Maximum.
- It is desirable to continue the monitoring work of water quality after the study.

(Weather observation)

- The weather observation devices are installed in Ghuzayn village and data collection was started to prepare the continual weather data.
- The technical transfers for the establishment of organization for the periodical weather observation was conducted.

5－2 Recommendations

The recommendation of the study is as follows:

- Five long-term observation bore wells surrounding three ore bodies are constructed with the method of preventing the affect of drilling mud. It is necessary to collect long-term monitoring data on each bore well.
- It is necessary to carry out the more detailed environmental study in the Ghuzayn District for the conceptual design of mine development.
- The items of environmental investigation consist of air quality, water quality, groundwater, soil, noise and vibration, and social environment.
- It is desirable to continue the monitoring work of water quality after the study.

PART II SURVEY RESULTS

CHAPTER 1 HYDROLOGICAL INVESTIGATION

1－1 Objectives

The objectives of the hydrological investigation in the Ghuzayn District are to collect data and information concerning river and water wells for clarifying the relation among surface water, groundwater, topography, geology, etc.

1－2 Investigation Area

Survey points for the hydrological investigation are five, including three points of the river survey and two points of well survey. Those survey points are shown in Figure I-1-1.

There was no water flow in GS-2 point, therefore, GS-4 (far upstream) is substituted for GS-2.

1－3 Investigation Method

1－3－1 River Survey

(1) Measurement of discharge

The measurement method of discharge conforms to Japan Industrial Standard (JIS), and the measurement method is shown in Table II-1-1.

Table II-1-1 Measurement Method of Discharge

Discharge (m^3/s)	Measurement method
$>$ 0.01	Vessels or flow meter
$\leq$ 0.01, $>$ 0.05	Triangle weir or flow meter
$\leq$ 0.05, $>$ 0.15	Square weir or flow meter
$\leq$ 0.15	Weir, flow meter or fluidic speed meter

(2) Measurement of water quality

Measurement items of water quality consist of pH, Electric Conductivity, and water temperature, which were measured at the sampling points.

(3) Water quality analysis

Three water samples taken from the surface current water were analyzed.

Chemical analysis consists of 9 components as shown in Table I-1-2.

All analysis method are the atomic absorption excluding the gravimetric method of SO_4.

1-3-2 Well Investigation

(1) Measurement of the ground water level

The ground water level in the wells was measured with the water-level indicator.

(2) Measurement of water quality

Measurement items of water quality consist of pH, Electric Conductivity, and Water Temperature.

(3) Water quality analysis

Two water samples taken in two wells were analyzed. Chemical analysis consists of 9 components as shown in Table I-1-2.

All analysis method are the atomic absorption excluding the gravimetric method of SO_4.

1－4 Survey Results

1－4－1 River Survey

(1) Hydrological condition

Drainage system of the Ghuzayn District belongs to that of the Wadi Al Hawasinah River (Figure I-2-1).

Wadi Al Hawasinah River originates in the central part of the Hajar Mountains, flows with meandering to the north in the hilly zone, bends its flow to the west at Ghuzayn Village, and is bifurcated to the northwest (main course) and north-northeast (branch). Flow channel of the river is obscured near Al Khaburah. It is assumed that from the mountain zone to Ghuzayn Village there are several surface and underflow repeatedly. There were two surface water currents at the sampling points only during the site study. The water, which sprang out and stored in the pit dug in the river gravel bed is pumped up to use for irrigation in Ghuzayn Village.

And the spring out water from Mother Well (about 15m deep) dug on the upstream river bed is taken to the irrigation canal called Falaj system and channeled to Ghuzayn Village by utilizing gravity. The irrigation canal in Ghuzayn Village is concrete-made ditch and approximately 3 km long and is repaired recently. Ghuzayn Village depends on this irrigation canal for almost all irrigation water.

Three sampling points for surface water are selected, including GS-1 (Falaj system) located at about 2.5 km upper stream to Ghuzayn Village, GS-4 (river surface water) located at about 4.0km upper stream to Ghuzayn Village, and GS-3 (river surface water) located at the northern part of Ghuzayn Village. There were no surface water current on the river bed without GS-4 and GS-3.

(2) Water quality

The measurement of discharge was conducted with the flow speed meter (Hiroi-type water current meter) on the condition of the appropriate rectangular flow section prepared as stably as possible. The calculation formula of discharge is shown in formula-1.

$$V = 0.132 \times N + 0.004$$

$$D = V \times A \times 60 \qquad \text{Formula-1}$$

V : Flow speed (m/s)

N : Number of rotation

A : Area of channel section (m^2)

D : Discharge (m^3/min)

Results of discharge and water quality measurement are shown in Table II-1-2.

Table II-1-2 Measurement Result of Discharge and Water Quality

Sample No.	Water quality			Discharge (m^3/min)
	pH	EC *1 (μS/cm)	Temp. (℃)	
GS-1	8.30	167.5	28.5	2.70
GS-4	8.60	121.2	29.1	0.30
GS-3	8.00	172.0	29.1	0.08

*1 : Electric Conductivity

Although the discharge of the upper stream surface current water GS-4 is very little (0.30 m^3/min), the large amount of water (2.70 m^3/min) spring out from Mother

Well is channeled for Falaj system. The surface current water turns to the underflow again at GS-4 sampling point and turns to surface current water at GS-3 sampling point in Ghuzayn Village. In Ghuzayn Village the water springs out in the pit dug on the river sediments is pumped up for irrigation. The discharge of surface current water at GS-3 is 0.08 m^3/min only.

The water quality is assumed to be almost similar. Judging from that pH is over 8.00 showing alkalinity, the water quality is assumed to be the hard water containing 100mg/l of Ca and Mg ions. Judging from that the water temperature in GS-1 (Falaj;28.5℃) is lower than those of GS-4, GS-3 (surface water;29.1℃), and electric conductivity in GS-1 (167.5 μS/cm) is higher than that of GS-4 (121.2 μS/cm), the water supplied to Falaj system from Mother Well originates in the deeper ground water. The water in GS-4, GS-3 originates in the underflow in the river bed sediments. The electric conductivity in GS-3 (172.0 μS/cm) is higher than that in GS-4 (121.2 μS/cm). The little amount of underflow in the river bed sediments from GS-4 to GS-3 causes the difference of electric conductivity between two points. The river bed near Ghuzayn Village consists of the cemented hard conglomerate on which sand and gravel sediment is deposited.

1-4-2 Well Survey

The well survey was conducted at two wells, including GW-1 and GW-2. GW-1 is located in Ghuzayn Village, and GW-2 is located at 7 km north-northwest of Ghuzayn Village and on the river bed at the meeting point of small branch originates in the alluvium terrace in the study area and Wadi Al Hawashinah (Figure II-1-1). There is no well in the study area without these two wells.

Water well (GW-1) is the only one well in Ghuzayn Village, which is used for irrigation for garden farming in the case of shortage of Falaj water. It is unconfined (manual excavated and concrete wall flamed), about 15 m in depth and 1.8 to 2.0 m in diameter, and the groundwater is mechanically pumped up.

Water well (GW-2) in the lower stream of Wadi Al Hawasinah River is used for irrigation for small garden farming (about 2 ha). It is unconfined (manual excavated and concrete wall flamed, and 0.54 to 1.2 m in diameter, and the groundwater is mechanically pumped up.

Groundwater level and water quality of the water wells are shown in Table II-1-3.

Table II-1-3 Measurement Result of Water Level and Water Quality

Sample No.	Water quality			Groundwater level from surface (m)
	pH	EC *1 (μS/cm)	Temp. (℃)	
GW-1	8.30	177.8	25.6	-7.50
GW-2	7.96	112.6	32.0	-6.70

*1 : Electric Conductivity

The groundwater table of the water wells are about 7m below GL, almost same depth. Judging from that pH is 8 around and similar to the surface water, the water in the two well originates in the hard water containing 100mg/l around of Ca and Mg ions similarly to the surface water.

However, in GW-1 the water temperature is higher (25.6℃) and the electric conductivity is higher (177.8μS/cm) than those in GW-2. The water in GW-1 is assumed to originate in the deeper ground water from the water quality. In GW-2, the electric conductivity is lower (112.6μS/cm) than that in GW-1 and the temperature is higher (32.0℃) than that in GW-1 and the atmosphere.

1-4-3 Water Quality Analysis

Results of water quality analysis of surface and well water are shown in Table II-1-4.

Table II-1-4 Analytical Result of Water in the Ghuzayn District

Items \ Sample No.		GW-1	GW-2	GS-1	GS-4	GS-3	Max.	Min.	Ave.
pH		8.30	7.96	8.30	8.60	8.00	8.60	7.96	8.23
EC	μS/cm	177.8	112.6	167.5	121.2	172.0	177.8	112.6	150.2
Cu	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pb	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ni	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe	mg/l	0.07	0.02	0.03	0.02	<0.01	0.07	<0.01	0.03
Mn	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hg	mg/l	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
SO_4	mg/l	135	114	120	140	145	145	114	131

Water ranges in pH from 8.00 to 8.60 (weak alkalinity). The similarity of electric conductivity could be classified as that in GW-1, GS-1 and GW-2, GS-4 are 170 μS/cm around, 110～120μS/cm, respectively.

The result of water quality analysis shows all concentration of Cu, Zn, Pb, Ni, Cr, Mn are <0.01 mg/l. All concentration of Hg are N.D.
The average concentration of Fe is 0.03 mg/l, maximum value is 0.07 mg/l in GW-1, minimum value is <0.01 mg/l in GS-3. Those of GW-1 (Ghuzayn village) and GS-3 (river water) are relatively higher.
The average concentration of SO_4 is 131 mg/l, Maximum is 145 mg/l, and Minimum is 114 mg/l.

It is desirable that the continual long-term monitoring should be conducted in the monitoring points-in addition to the existing points (three for the surface water and two for water well), five bore wells dug with no affect of drilling mud and the weather observation devices installed in the study during one year, because the weather undulates periodically.

CHAPTER 2 WATER INVESTIGATION OF BORE WELLS

2-1 Objectives

The objectives of the water investigation of bore wells in the Ghuzayn District is to collect data and information on the condition of groundwater through the measurement of water quality, chemical analysis and the recovery test in five bore wells dug with no affect of the drilling mud.

2-2 Selection of Bore Well Location

The bore well location is selected on the basis of the ground water flow direction in Ghuzayn district assumed in the last study. Five bore wells are distributed around the ore bodies as follows: one bore well, MJOB-EW-1, is in the whole ore bodies, one bore well is in the down stream of each ore body, MJOB-EW-2 to MJOB-EW-4, one bore well, MJOB-EW-5, is in the far down stream of bore bodies. Further more, the relation with the riverbed of the Wadi Al Hawashina River is considered. MJOB-EW-1 is located at about 800m upstream side of No. 1 ore body and on the right side bank of the Wadi Al Hawashina River, MJOB-EW-2 to MJOB-EW-4 are located at about 2km down stream side of No. 1 to No. 3 ore body, respectively. Because No. 3 ore body underlies the riverbed of the Wadi Al Hawashina River, MJOB-EW-4 is located on the flood plain of the left side bank of the river. MJOB-EW-5 is located in the about 2km down stream side of MJOB-EW-2 to MJOB-EW-4 and on the flood plain on the right bank side of the river, which is the meeting point of the river and the branch originates on the terrace in the study area. The depth of bore wells is decided to be 50m for penetrating the aquifer assumed in the last study, that is, the river bed sediment, low terrace sediment and cracked basement. (Figure I-3-2)

In deciding the bore well location, The bore well location should be decided in the presence of the officer of Ministry of Water Resources (MWR). The permission condition of new well construction of MWR is that the distance between the new well and the existing Mother Well is longer than 3km. The place of five bore wells meets this condition. The drilling work was started after obtaining the permission.

2-3 Investigation Method

2-3-1 Drilling of Bore Well

The air foam drilling method was adopted to construct the bore well with no affect of the drilling mud. The PVC casing pipe and screen was placed for protecting the bore wall and the enforcement of the mouth of bore well with the conductor pipe and cementing and steal flange to utilize the bore well as the long-term observation bore well.

The procedure of drilling and construction of bore well is summarized as follows:

① The rotary air foam non-core drilling is adopted.

② Drilled 171/2" bore hole by using tri-cone bit to a depth of 5m.
(Collected cuttings by every 1m)

③ Installed and cemented 133/8" M.S. Conductor casing.

④ Wait the hardening of cement

⑤ Drilled 121/4" bore hole by using tri-cone bit below base of conductor casing to a depth of 50m. (Collected cuttings by every 1m)

⑥ Installed 8"PVC casing, screen(slot size – 2mm, open area-20%) and bottom plug. (OD-225mm, ID-205mm)

⑦ Washed natural wadi gravel round to semi-round(size6-10mm) placed in the annulus between well casing and bore wall up to ground level.

⑧ Washed bore well by compressed air lifting.

⑨ Installed submergible test pump near to the bottom of the well.
(around 48m depth.)

⑩ Conducted the recovery test.

⑪ Measured the water quality and collected water sample for chemical analysis.

⑫ The well completed including construction of well head concrete plinth and bolted well cover flange.

2-3-2 Recovery Test

After the compressed air lift washing of bore well, the recovery test was conducted. Small submergible pump and pipe line was installed from near the bottom of the bore well (about 48m depth) to the ground so that the ground water could be pumped out and the ground water level lowered. The ground water level was measured until the natural ground level according to the measuring time for the recovery test shown in Table II-2-1.

The water sample was taken for chemical analysis and the water quality, that is, pH, electric conductivity and temperature, was measured.

Table II-2-1 Measurement Time for the Recovery Test

Measurement time (minute)	Interval (minute)
0 ～ 10	1
10 ～ 20	5
20 ～ 60	10
60 ～ 120	15
120 ～ 300	30
> 300	60

2-3-3 Water Quality Analysis

The water samples taken from the bore wells were analyzed. Chemical analysis consists of 9 components as shown in Table I-1-2.

All analysis methods are the atomic absorption excluding the gravimetric method of SO_4.

2-4 Survey Results

2-4-1 Drilling of Bore Well

(1) Drilling and Construction of Bore Well

The track mounted rotary drilling machine was adopted for the drilling work. The movement and setting of the machine could be conducted because of the almost flat topography.

The equipment for the drilling and construction of bore well are shown in Table II-2-2, Table II-2-3.

The materials for the drilling and construction of bore well are shown in Table II-2-4.

The bore wall should be protected and the foreign substance should be free from falling into the well so that the bore well should be used for the long-term groundwater observation.

The 8"PVC casing pipe and screen was placed in the bore well. The washed round and semi-round gravel was filled in the annulus. The upper part of and mouth of the well was reinforced with the 133/8" M. S. conductor pipe and cementing. The steal plait with flange and bolts covered the mouth of well.

The structure of bore wells are shown in Figure II-2-1～5.

The actual work process of the bore well drilling and construction is summarized as follows. The whole work from the movement and setting of machine and the washing of bore well by the compressed air lift took net two days.

① Movement and setting of machine ; 2 hours
② Drilling by 171/2" tri-cone bit (until 5m from GL) ; 1 hour
③ Placement of 133/8" conductor casing and cement milk; 1 hour
④ Waiting for cement hardening (Stand by until next morning)
⑤ Drilling by 121/4" tri-cone bit (from 5m to 50m) ; 3～5hours (according to formation quality)
⑥ Air foam circulation and recovery of rods; 1 hour
⑦ Placement of 8"PVC casing and screen; 1 hour
⑧ Filling of washed gravel; 1 hour
⑨ Placement of rod for air lift; 20 minutes
⑩ Washing of bore well; 5 hours
(3 hours on the same day of drilling and construction, 2 hours on the next day before movement)

And additionally, it took about 2 hours to construct the bore well mouth (concrete reinforcement, construction of concrete plinth and setting of the steal cover).

Table Ⅱ-2-2 List of Equipment for Drilling and Construction Bore Well

No.	Description	Qty	Remarks
I	DRILLING UNIT		
1	Top Head Drive Rig	1	Model-T4W Make INGERSOLLRAND, USA (Technical Data attached)
2	Compressor	1	Mounted on Rig Model HP 900 Make INGERSOLLRAND, USA
3	Foam Pump	1	Mounted on Rig
4	Drill Rod	7	41/2 ″φ, 25' long, 3-1/2 Reg. Thread
5	Drill Collar	1	65/8 ″φ, 25' long, 4-1/2 Reg. Thread
6	Drill Bit(1)	1	171/2 ″Tri-cone bit
7	Drill Bit(2)	1	121/4 ″Tri-cone bit
Ⅱ	RECOVERY TEST		
1	Crane	1	UNIC Hydraulic Winch for Test Pump Installation Capacity 4.5t, Height 8 m from GL Mounted on Bedford Truck 4×4 Drive
2	Test Pump	1	Electric Submersible Pump Make GRUNFOS, Model- SP8-10 Capacity 1L/sec Flow, 55m Head
3	Generator	1	55KVA Make LISTER, UK
Ⅲ	VEHICLES		
1	Water Tanker	1	Capacity 1500gal
2	Long Chassis Truck	1	9ton, for materials transportation
3	Double Cab P/Up	1	For Crew Transportation
Ⅳ	MISCELLANEOUS		
1	Portable Welding Set	1	Make LINCONE, Model 300 Amps
2	Mobile Telephone Set	1	Communication from Site

Table II-2-3 Bore Well Drilling Rig – Technical Data

No.	Description	Specification
1	Model As Per manufacturer's	Ingersoll Rand, T4W HP900 Deep Hole Package
2	Mast Rating / Max. Static Hook Load	31,750 kg
3	Draw Weight / Pull Back	31,750 kg
4	Pipe Racking Engine, Type / Capacity	Swing In/Out Carousel ; 45.6m
5	Power Pack Engine, Type / Capacity	GM 12V 71N ; 400 HP
6	Foam Injection Pump, Type / Capacity / Pressure	Triplex single acting : 95.0 L/min; 3791.7 kPa
7	Rotary table / Type	Top Head Drive ; Hydraulic
8	Max. Torque / rpm	7153 Nm/109 rpm
9	Table Opening	20"
10	Leveling Jack	Two at drilling end & One at front
11	Tank Volumes Fuel	1200 L
12	Working Clearance below crown	8.2 m
13	Compressor for Air/Foam drilling, Type/Output	Screw Type ; 2412.9kPa / 425Lps
14	Power Source	Direct drive from Diesel engine
15	Overall Weight t	22t
16	Overall Length m	10.7
17	Overall Width m	2.4m
18	Overall Height When Drilling m	11.1m
19	Overall Height When Traveling m	3.8m
20	Is Rig Carrier or Trailer or Skid Mounted	Carrier Mounted
21	Carrier Engine Type / Capacity	GM6L-71N; 230HP, 2100rpm
22	No. of Front Axles	One
23	No. of Front Driving Axles	None
24	No. of Rear Axles	Two
25	No. of Rear Driving Axles	Two
26	Transport speed on graded roads	50 km/hr

Table Ⅱ-2-4 List of Drilling and Well Construction Materials

No.	Description	Qty	Manufacturer	Remarks
1	Drilling Foam	550 L	Shell-United Kingdom	Drilling Chemicals (liquid) for consolidated Rock
2	Drilling Polymer		NL Baroid Industries, Inc. -USA	Drilling Chemicals (powder) for unconsolidated Sand and Gravel
	EZ Mud	75kg		
	Aquagel	250kg		
	Pac-R	25kg		
3	MS Conductor Pipe	30m		133/8"dia.
4	PVC Casing 8" dia.	93m	Cosmoplast Industrial Co., UAE	Pipe OD-225mm, ID-205mm
5	PVC Screen 8" dia.	157m	Cosmoplast Industrial Co., UAE	Pipe OD-225mm, ID-205mm Screen slot size-2mm Open area-20%
6	PVC End Cap	5 nos.	Cosmoplast Industrial Co., UAE	For Bottom of Casing
7	MS Well Flanged Cap	5 nos.	Fabricated at Lalbuksh workshop	Protector for Mouth of Casing
8	Pea Gravel	$16m^3$	Al-Turki Crusher, Oman	Natural wadi gravel round to semi-round 6-8mm size for Filling Annulus
9	Cement	700kg	Oman Cement Co. Oman	Fixing MS Conductor Pipe and Making Plinth
10	Fuel	9000L		
11	Lubricants	180L		

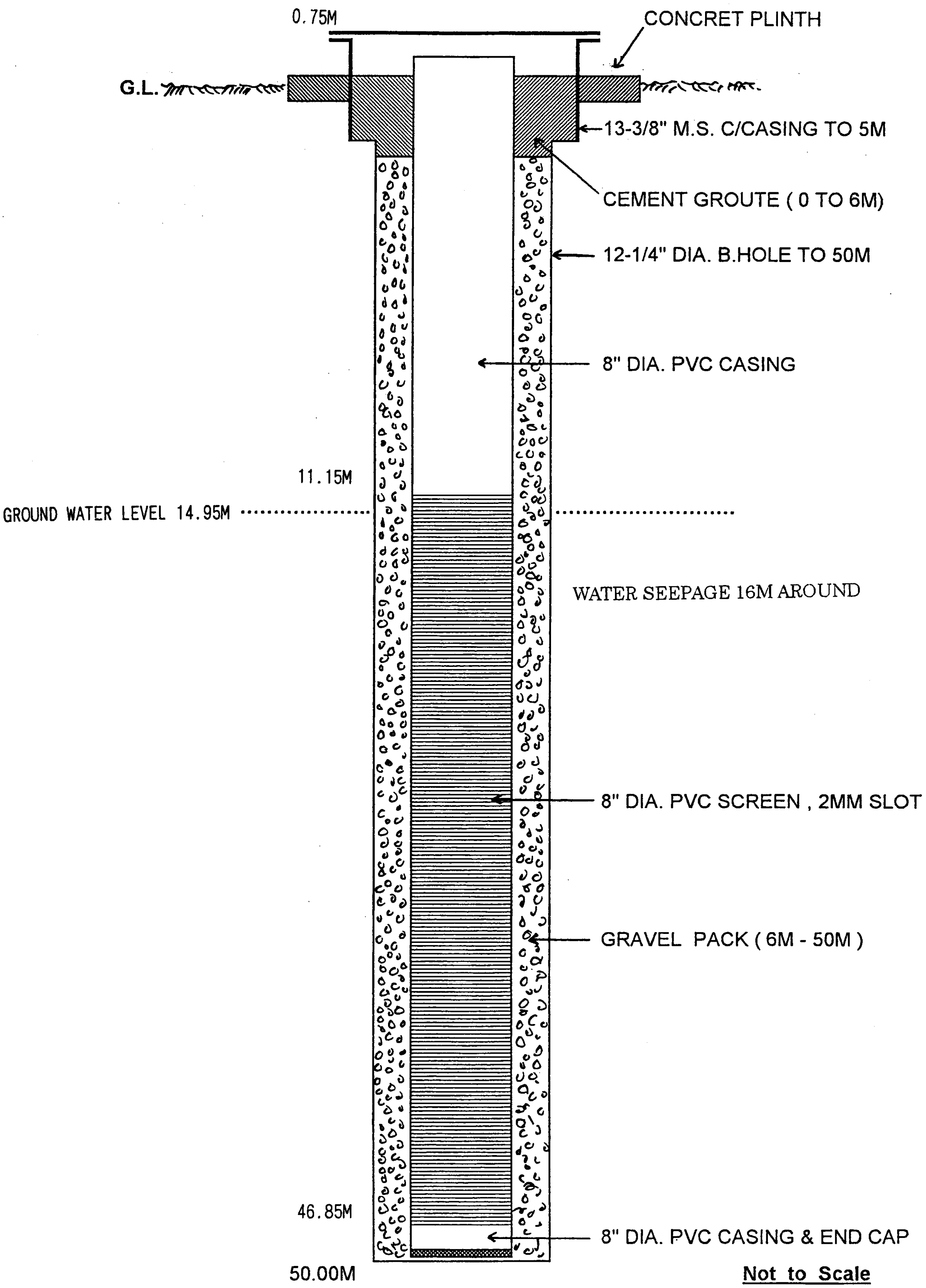

Figure II-2-1 Structure of Bore Well (MJOB-EW-1)

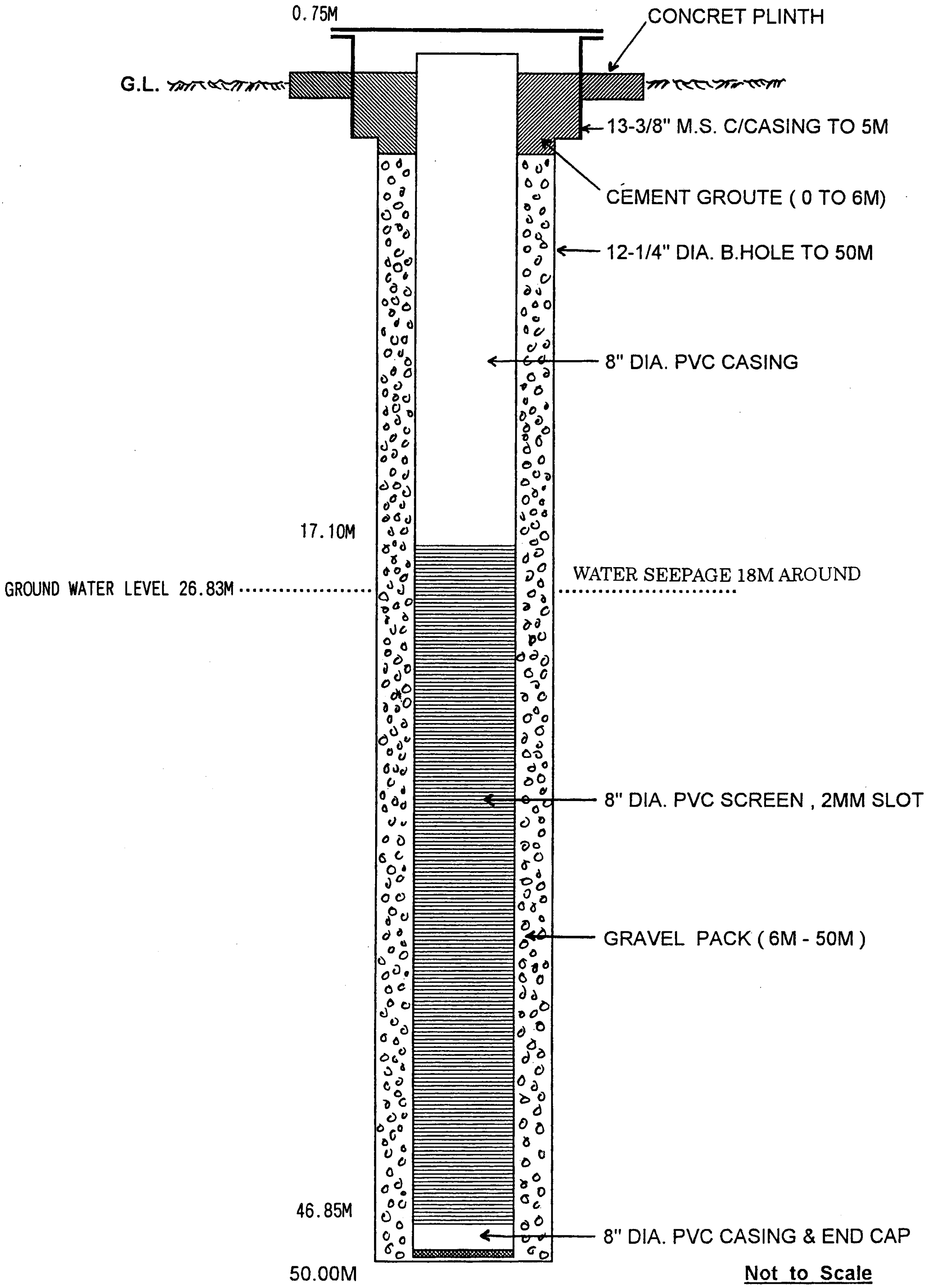

Figure II-2-2 Structure of Bore Well (MJOB-EW-2)

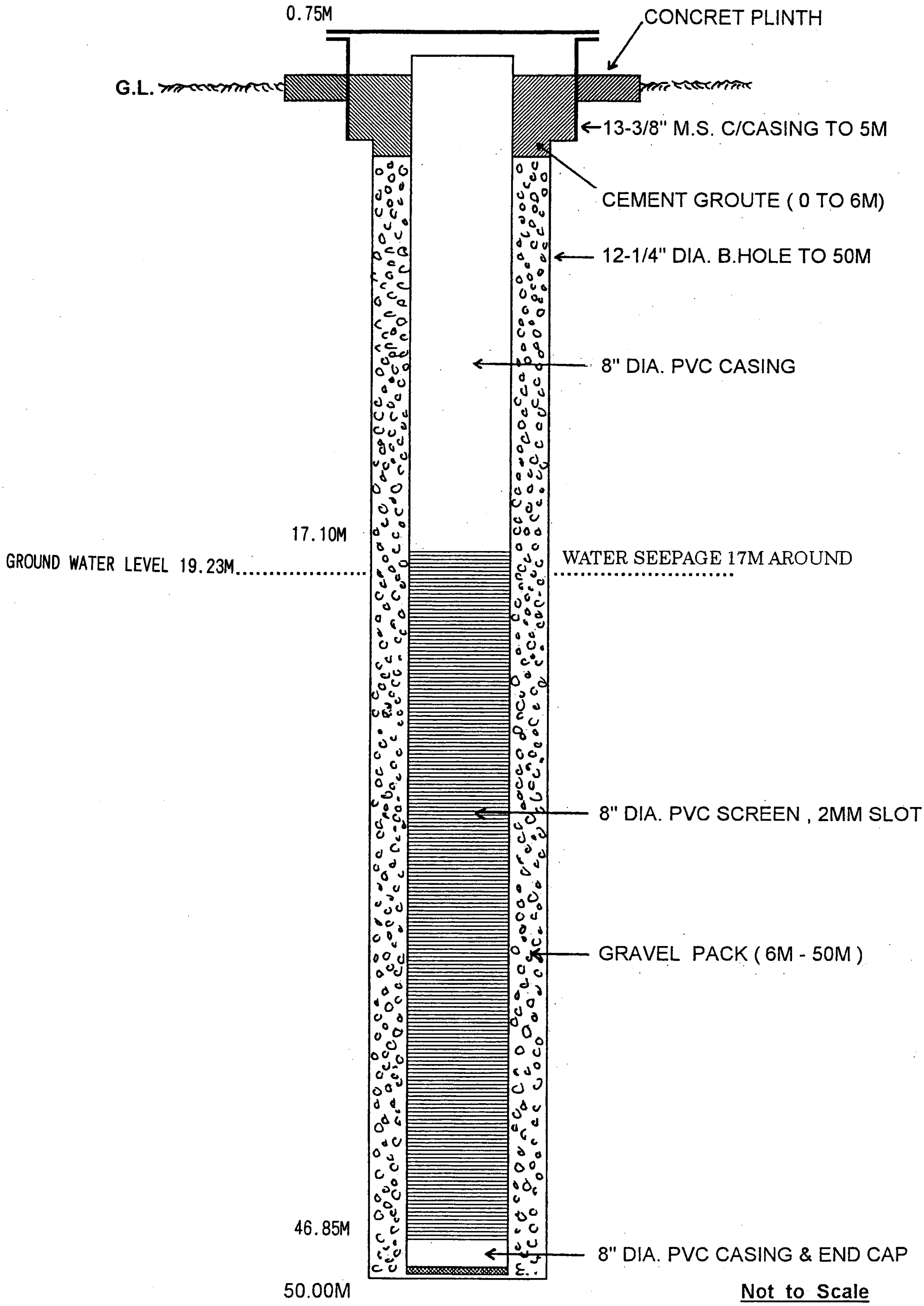

Figure II-2-3 Structure of Bore Well (MJOB-EW-3)

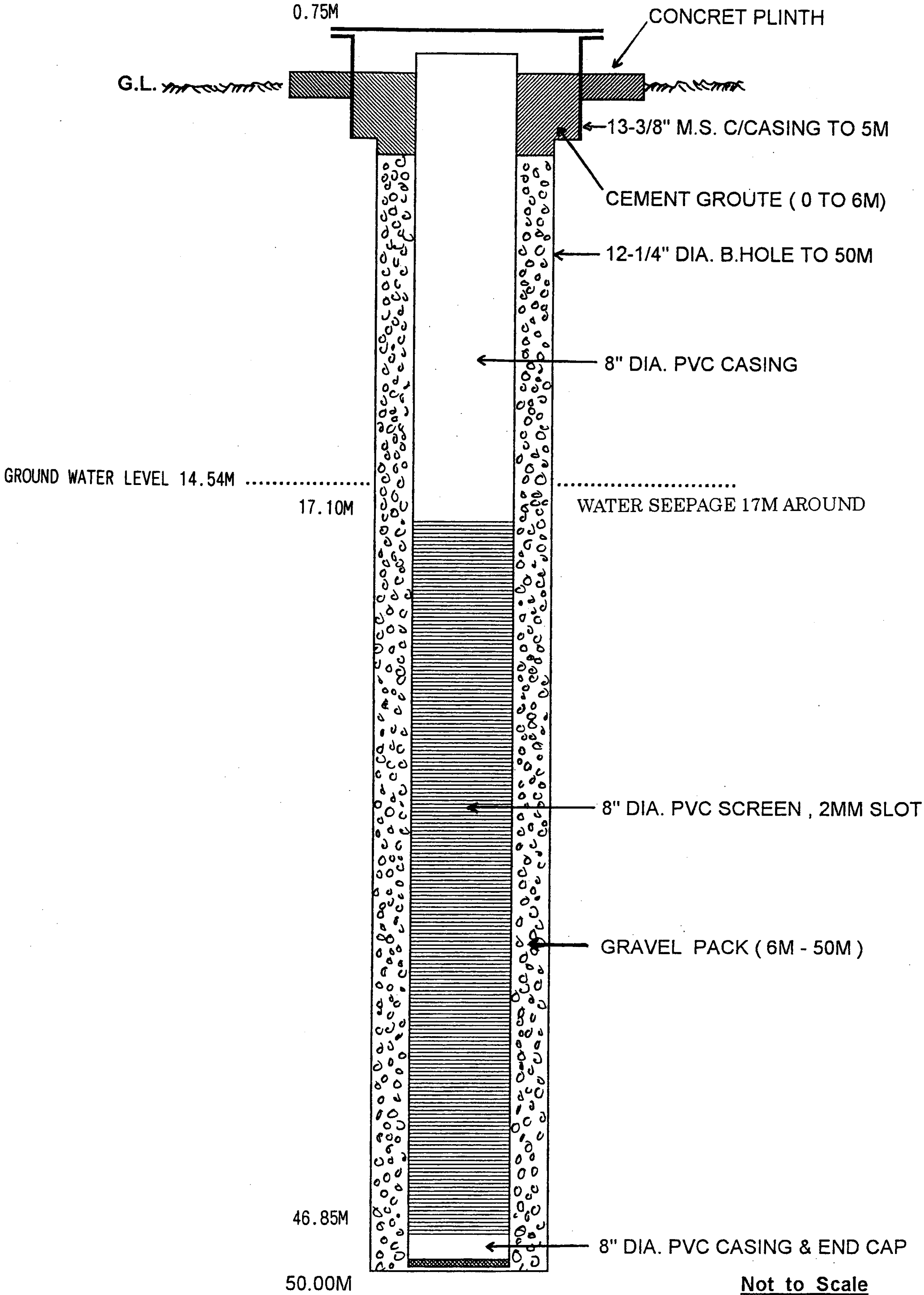

Figure II-2-4 Structure of Bore Well (MJOB-EW-4)

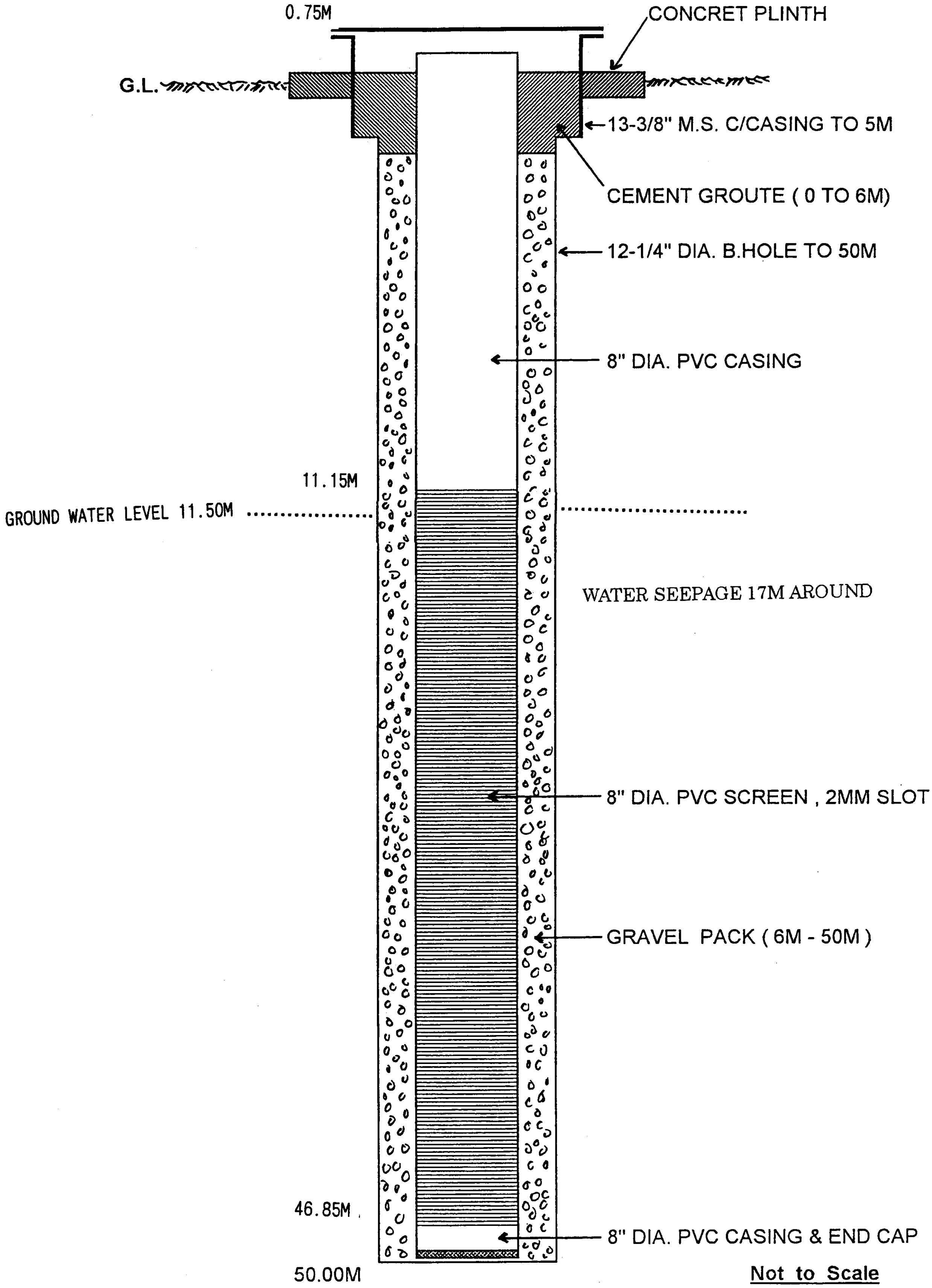

Figure II-2-5 Structure of Bore Well (MJOB-EW-5)

(2) Columnar Section of Bore Well

The conceptual columnar section of bore well was drawn on the basis of observation of the cuttings taken by every 1m during drilling. They are not always perfect because of based on the cuttings. The conceptual columnar sections are shown on Figure II-2-6~8.

Judging from the observation of the cuttings and the result of drilling works, geology of the bore well is assumed to be the top soil of alluvium, consolidated or cemented diluvium, argilized basalt and basalt, from the top to bottom. The lower part of the diluvium deposit is consolidated by carbonate minerals as calcrete.

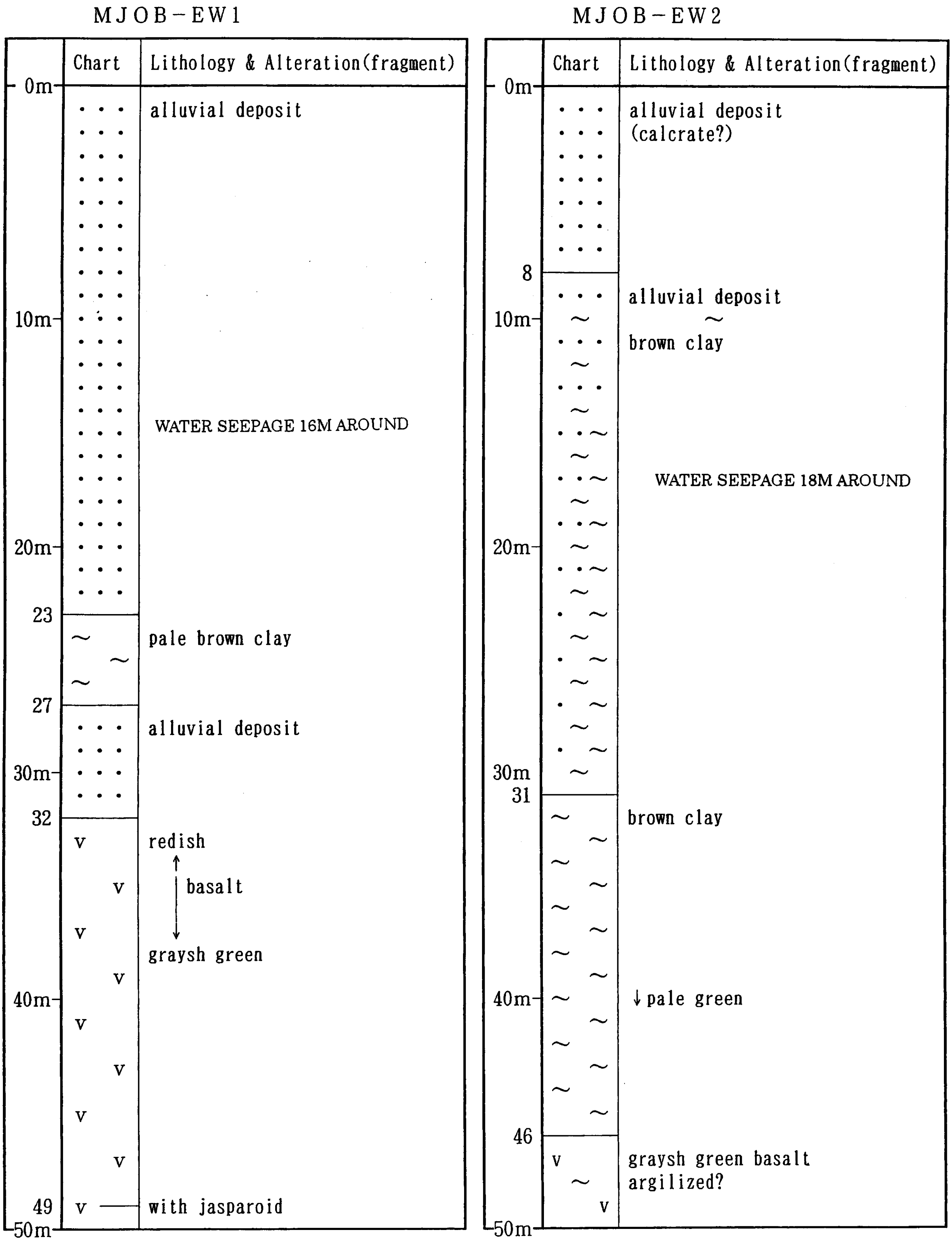

Figure II-2-6 Columnar Section of Bore Well (MJOB-EW-1,2)

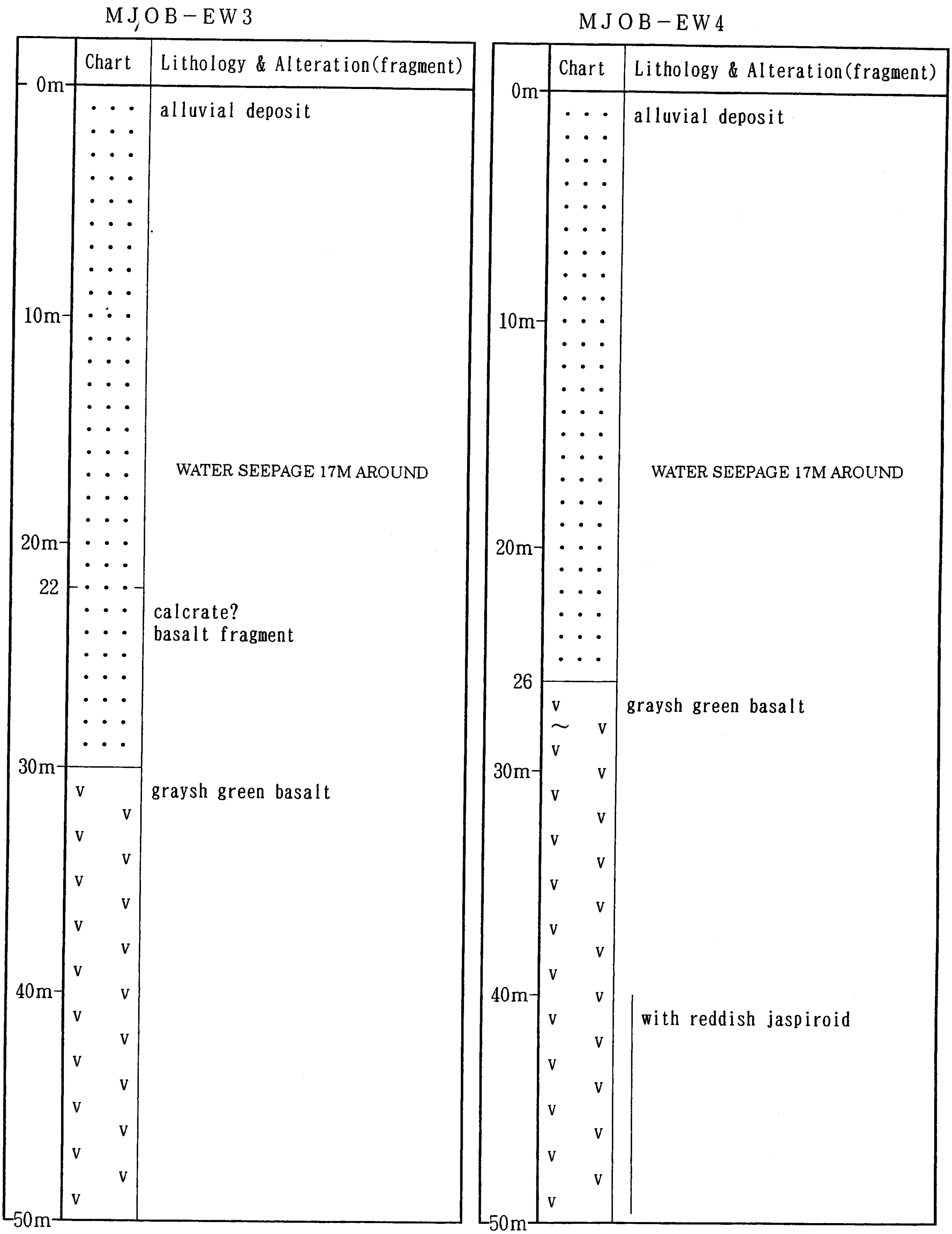

Figure II-2-7 Columnar Section of Bore Well (MJOB-EW-3,4)

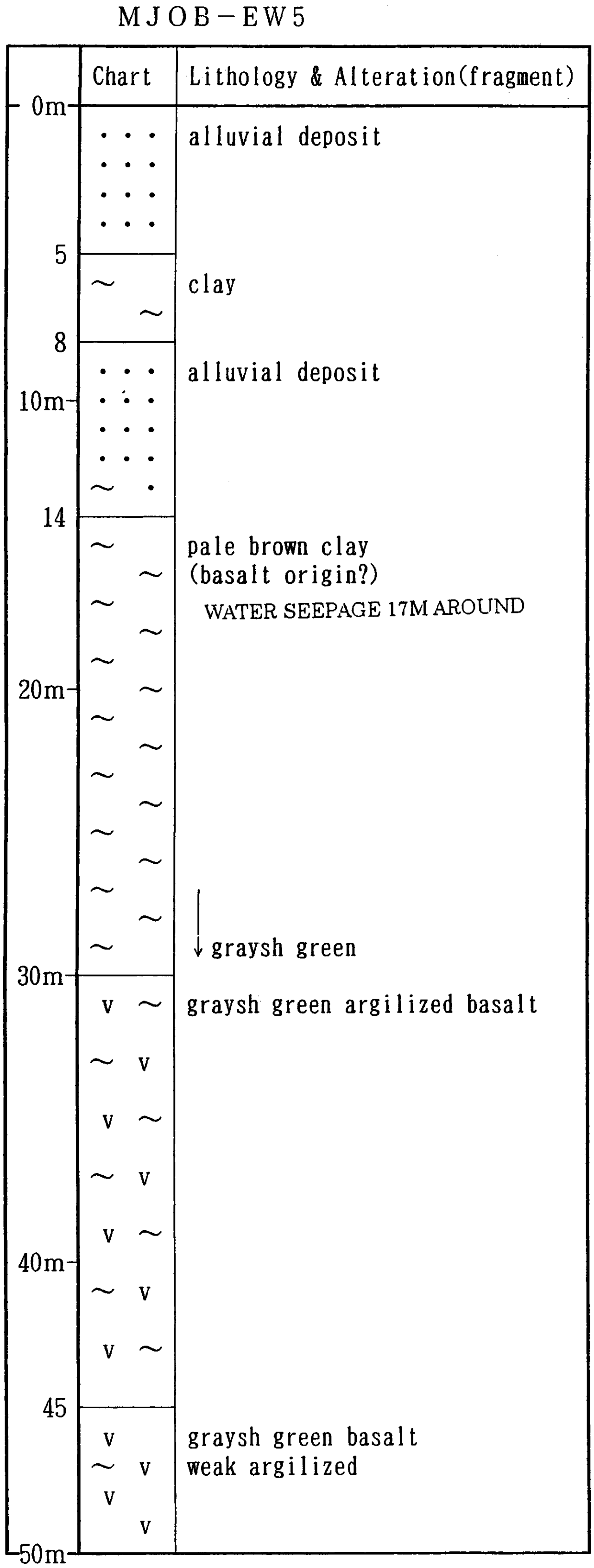

Figure II-2-8 Columnar Section of Bore Well (MJOB-EW-5)

2-4-2 Result of Recovery Test

(1) Recovery test

After the compressed air lift washing of bore well, the recovery test was conducted. Small submergible pump and pipe line was installed from near the bottom of the bore well (about 48m depth) to the ground so that the ground water could be pumped out and the ground water level lowered.

The test result and the permeability coefficient of each bore well calculated are shown in Table II-2-5 and the data sheets are attached at the end of this report.

During the process of pumping up the ground water in the bore well, very small amount of spring water in the bore well of MJOB-EW-3 was observed. Judging from the result of step pumping test, the yield of this well was assumed to be 1l/sec (60l/min) which could not support any use. In the other four wells any ground water to test was not observed.

(2) Calculation of permeability coefficient

The recovery test corresponds to the field permeability test by piezometer method. Therefore, the permeability coefficient is calculated by Formula - 2.

$$k = \frac{(2.3)^2 \cdot R_w^2}{2L\ (t_2 - t_1)} \cdot \log (L / r_w) \cdot \log (h_1 / h_2) \qquad \text{Formula - 2}$$

k	:	Permeability coefficient	(cm/s)
R_w	:	Radius of casing	(cm)
r_w	:	Radius of bore hole	(cm)
L	:	Length of aquifer	(cm)
t_1	:	Time-1 elapsed	(s)
t_2	:	Time-2 elapsed	(s)
h_1	:	Difference of water level at Time-1 elapsed	(cm)
h_2	:	Difference of water level at Time-2 elapsed	(cm)

The calculation result is shown in Table II-2-5.

Table II-2-5 Permeability Coefficient

No.	Number of bore holes	t_1 (min)	t_2 (min)	h_1 (cm)	h_2 (cm)	L (cm)	R (cm)	r (cm)	Permeability Coefficient (cm/s)
1	MJOB-EW-1	10	100	2715	25	3500	10.25	15.56	7.04×10^{-5}
2	MJOB-EW-2	10	100	1617	27	2900	10.25	15.56	7.16×10^{-5}
3	MJOB-EW-3	1	10	682	408	2900	10.25	15.56	8.99×10^{-5}
4	MJOB-EW-4	10	100	2716	146	2900	10.25	15.56	5.11×10^{-5}
5	MJOB-EW-5	10	100	3254	1434	3500	10.25	15.56	1.23×10^{-5}

The permeability coefficients of the bore wells are ranked as 10^{-5}cm/s class. MJOB-EW-3 is the only bore well where the 1l/sec of spring out water is observed. In MJOB-EW-5 which consists of clay and argilized basalt formation, the permeability coefficient of 1.23×10^{-5} cm/s shows the lowest one and the relatively low permeability in these five bore wells.

2-4-3 Water Quality Analysis

(1) Measurement of water quality

The water quality was measured on the ground water samples taken in bore wells. The water quality consisted of pH, electric conductivity, temperature and ground water level was measured.

The result of the water quality measurement is shown in Table II-2-6.

Table II-2-6 Measurement Result of Ground Water Quality

Sample No.	Water quality			Depth (-m)
	pH	EC*1 (μS/cm)	Temp. (℃)	
MJOB-EW-1	8.10	168.2	33.3	15.75
MJOB-EW-2	8.25	93.9	34.8	26.83
MJOB-EW-3	8.27	114.2	34.4	20.03
MJOB-EW-4	8.05	92.1	32.6	15.34
MJOB-EW-5	8.29	107.2	31.5	11.50

*1 : Electric Conductivitly

The value of pH of groundwater ranges from 8.05 to 8.29 (weak alkalinity).

The electric conductivity of all bore well expect to MJOB-EW-1 is 100μS/cm around and relatively low in the study area, similar to those of the river water and the GW-2 water well. It is not assumed that the groundwater is stored in the aquifer.

The water temperature is over 30℃ whose highest is 34.8℃ in MJOB-EW-3.

(2) Water quality analysis

The ground water samples were taken in the bore wells.

The result of water quality analysis is shown in Table II-2-7.

Table II-2-7 Analytical Result of Ground Water in Bore Wells

Items \ Sample No.		EW-1	EW-2	EW-3	EW-4	EW-5	Max.	Min.	Ave.
pH		8.10	8.25	8.27	8.05	8.29	8.29	8.05	8.19
EC	μS/cm	168.2	93.9	114.2	92.1	107.2	168.2	92.1	115.1
Cu	mg/l	0.02	0.02	<0.01	<0.01	<0.01	0.02	<0.01	0.01
Zn	mg/l	1.01	0.20	0.10	0.82	0.06	1.01	0.06	0.44
Pb	mg/l	0.03	0.03	<0.01	0.02	<0.01	0.03	<0.01	0.02
Ni	mg/l	0.04	0.10	0.01	0.03	<0.01	0.10	<0.01	0.04
Cr	mg/l	0.03	0.04	<0.01	0.01	<0.01	0.04	<0.01	0.02
Fe	mg/l	1.53	10.56	0.20	3.51	0.05	10.56	0.20	3.17
Mn	mg/l	0.09	0.10	0.04	0.04	0.05	0.10	0.04	0.06
Hg	mg/l	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
SO_4	mg/l	170	80	124	98	120	170	80	118

The concentration of Cu ranges from <0.01 to 0.02 mg/l. The average is 0.01 mg/l, maximum value is 0.02 mg/l in MJOB-EW-1, and -2, minimum value is <0.01 mg/l in MJOB-EW-3, -4 and 5. All the concentration of Cu is very low.

The concentration of Zn ranges from 0.06 to 1.01 mg/l. The average is 0.44 mg/l, maximum value is 1.01 mg/l in MJOB-EW-1, and minimum value is 0.06 mg/l in MJOB-EW-5. The concentration of Zn ranges relatively wide.

The concentration of Pb ranges from <0.01 to 0.03 mg/l. The average is 0.02 mg/l, maximum value is 0.03 mg/l in MJOB-EW-2, and minimum value is <0.01 mg/l in MJOB-EW-3 and 5. All the concentration of Pb is very low.

The concentration of Ni ranges from <0.01 to 0.10 mg/l. The average is 0.04 mg/l, maximum value is 0.01 mg/l in MJOB-EW-2, and minimum value is <0.01 mg/l in MJOB-EW-5.

The concentration of Cr ranges from <0.01 to 0.04 mg/l. The average is 0.02 mg/l, maximum value is 0. 04 mg/l in MJOB-EW-2, and minimum value is <0. 01 mg/l in MJOB-EW-3, 5. All the concentration of Cr is very low.

The concentration of Fe ranges from 0. 20 to 10. 56 mg/l. The average is 3. 17 mg/l, maximum value is 10. 56 mg/l in MJOB-EW-2, and minimum value is 0. 20 mg/l in MJOB-EW-3. The concentration of Fe ranges extremely wide.

The concentration of Mn ranges from 0. 04 to 0. 10 mg/l. The average is 0. 06 mg/l, maximum value is 0. 10 mg/l in MJOB-EW-2, minimum value is 0. 04 mg/l in MJOB-EW-3, 4. All the concentration of Cr is very low.

All concentration of Hg is less than minimum limit of determination.

The concentration of SO_4 ranges from 80 to 170 mg/l. The average is 118 mg/l, maximum value is 170 mg/l in MJOB-EW-1, and minimum value is 80 mg/l in MJOB-EW-2. Although the concentration of SO_4 ranges wider than that of the surface water and well water, the average is almost same. The maximum value of SO_4 of 80 mg/l is recorded in MJOB-EW-2 where Fe is maximum value.

The maximum concentration of Fe, Cr, Ni and Mn are recorded in MJOB-EW-2. The maximum concentration of Cu, Zn and Pb are recorded in MJOB-EW-1. And, the relatively high concentration of Fe and Zn are recorded in MJOB-EW-4. These things suggest that each bore well would be under the some influence of mineralization.

In this study, Five bore wells with no affect of the drilling mud were drilled and constructed, the relation between the ore bodies and the quality of the ground water was studied. Any water quality item shows no remarkable difference concerning the location with ore bodies. Because the ground water quality would be assumed to change according to the annual weather undulation, for example, rain fall and temperature, etc., the continual data collection would be desirable through the long-term monitoring on the existing points (surface current; 3 points, water wells; 2 points) and these bore wells.

CHAPTER 3 WEATHER OBSERVATION

3-1 Objectives

The weather data in the Ghuzayn district should be collected continually so that the weather condition could be grasped.

3-2 Location of Weather Observation

Taking the representative of the weather in the Ghuzayn district and the convenience of the installation of the devices and the continual data collection into consideration, the weather observation devices was installed on the roof of the private house in Ghuzayn Village on the left bank of the Wadi Al Hawashina River.

3-3 Method of Weather Observation

The continual weather observation will be conducted through the installation of the weather observation devices. The establishment of the organization of the counter part should be conducted carefully because the continual long-term weather data collection would be desirable. The observation items consist of temperature, humidity, rainfall and wind velocity and direction. The maintenance and check of devices and the exchange of the data memory IC card and read the data by personal computer should be conducted at least once a month regularly because the memory capacity of IC card recording the data is 1024. The solar panel system for the electric source was adopted so that the devices could be independent.

The components of the weather observation devices are shown in Table II-3-1.

3-4 Results of Weather Observation

The weather data collected during the site survey is attached at the end of this report. Although the period of the site survey was short one of about one month, the 12-day-long continual data was collected. In the study district, the annual weather is divided into two parts, that is, summer (from March to November, hot and humidity, the highest temperature in June) and winter(from December to February, the lowest temperature in January), in winter there would be some rain fall. (However, people in the district said that there has no rain since about two years ago.)

Table Ⅱ-3-1 Weather Observation Devices

No.	Device name	Quantity	Remarks
1	C680 model Weather Observation Data Logger	1	
2	Wind Direction Sensor	1	
3	Wind Direction Sensor Cable (20m)	1	
4	Wind Velocity Sensor	1	
5	Wind Velocity Sensor Cable (20m)	1	
6	Temperature and Humidity Sensor (with 20m Cable)	1	
	Temperature and Humidity Sensor Protector		
7	Rain Gauge	1	
8	Rain Gauge Cable (29m)	1	
9	Setting Pole	1	
10	Setting Bar for Wind Direction and Velocity Sensor		
11	Setting Tripod	1	
12	Battery (12V7. 2AH)	2	Spare 1
13	DC Power Cable	1	
14	Solar Cell Panel	1	
15	Over Charging Checking Circuit	1	
16	RAM Card	1	
17	DR30 Data Reader	1	
18	RS32C Cable for DR30	1	
19	Data Reading Soft	1	Windows

The continual weather data collection during at least longer than one year would be desirable.

(1) Temperature

The site survey period belongs to winter, the temperature is expected to be relatively low.

The collected weather data shows that as the daily maximum 27 to 28℃ is recorded at 2 to 4 o'clock in the afternoon ordinarily, in the hottest case over 30℃ is recorded and as the daily minimum 15 to 16℃ is recorded at 7 o'clock in the morning ordinarily, in the hottest case 20℃ is recorded. The weather undulates in temperature periodically with the cycle of several days as the daily severe temperature cyclic change is typical of the desert one.

(2) Humidity

It is said that in winter the temperature is relatively low and there is some height of rainfall, so it is relatively mild, but there was no rainfall during the site survey unusually.

The daily change of humidity is not so cyclic as the temperature one. The minimum humidity is recorded at 2 to 4 o'clock when the maximum temperature is recorded. In the case the maximum temperature is under 30℃, the minimum humidity is 30 to 40%, in the case the maximum temperature is over 30℃, the minimum humidity is even under 10%. These data shows the severe dry weather as typical in the desert. The maximum humidity is recorded from evening to the sunrise, ordinarily, at 6 to 7 o'clock when the minimum temperature is recorded. The wide range cyclic undulation of humidity from 10 to 90%, which is the typical in the desert as the temperature, is recorded.

(3) Rainfall

It is said that in winter the temperature is relatively low and there is some height of rainfall, so it is relatively mild, but there was no rainfall during the site survey unusually. No rainfall data has been recorded yet.

(4) Wind Velocity and Direction

The daily maximum wind velocity is recorded at 1 hour later since the maximum temperature is recorded. The maximum wind velocity of 2m/sec is recorded on the day when the maximum temperature is over 30℃. The maximum temperature is lower than 30℃, the maximum wind blows at the speed of 1 to 2 m/sec. During the time zone from 8 o'clock in the evening to 8 o'clock in the early morning, the calm or breeze is recorded.

The wind direction in the maximum wind velocity, 45% is northern northeast and 82% is from north to eastern northeast. The northern wind is predominating.

3-5 Establishment of Weather Observation

Because the continual long-term observation is indispensable for the weather observation, the technical transfer to the counter part to establish the organization for the weather observation was conducted carefully.

CHAPTER 4 Establishment of Organization for Monitoring

For the purpose of the establishment of the investigation and observation system for collecting the long-term data on the hydrological, the ground water and the weather observation, the technical transfer to the counterpart (Directorate General of Minerals) was conducted carefully.

The content of monitoring plan is shown in Table II-4-1.

Table II-4-1 Monitoring Plan in the Ghuzayn District

Items	Monitoring plan
1. Objectives	Understanding the hydrological and weather condition in the district
2. Duration and work schedule	Duration : At least one year Hydrological measurement : At least once on the fixed day in every month Weather observation : Observation devices operation
3. Monitoring points	(1) Surface water (Wadi Al Hawashina, etc.) : 3 points GS-1, GS-2 or GS-4 and GS-3 (2) Well water : 2 wells GW-1 and GW-2 (3) Bore wells : 5 wells MJOB-EW-1～5 (4) Weather observation : 1 point
4. Monitoring items (Chemical analysis etc.)	(1) Hydrological measurement : Discharge, water level, pH, EC and water temperature (2) Chemical analysis : 9 components Cu, Zn, Pb, Ni, Cr, Fe, Mn, Hg, SO_4 (3) Weather observation : Temperature, humidity, rainfall, wind velocity and direction

CHAPTER 5 CONSIDERATIONS

5－1 Hydrological Condition

5－1－1 Water Balance

(1) Wadi Al Hawasinah River

The Wadi Al Hawasinah River consists of the rainfall water, that is, does not originate in the melted water from the glacier in the high mountains nor the spring out water reserved in the stratum in the geological age. The drainage basin of the Wadi Al Hawasinah River could be divided into two parts in Ghuzayn District. The upper part is the drainage area of the basin of the Hajar Mountains, whose geology consists of the mountain body of the basement, the terrace in the basin and the alluvium on the Wadi Al Hawasinah River. In heavy rain from the upper area the large amount of rain water and sediments is supplied to the lower stream. On the alluvium along the river and at the spring out point oases are located. On the surface of the alluvium trees and shrubs grow according to the available water. On the mountain of the basement and the terrace plant is rare. The lower area is the alluvial fan formed with the large quantity of sediments carried and deposited by the river flow from the mountain to the plain, which is the typical plain along the seashore in the north east part in Oman. In the Wadi Al Hawasinah River flowing on the alluvium, the erosion and sedimentation is repeated, the width of the river is spread, water current turns into the underflow gradually, and is extirpated completely near the seashore. On the upper part of the plain, the rainfall water on the alluvium gathers in the lower points and erodes the alluvium and forms small tributaries, which join the Wadi Al Hawasinah River. Along the small tributaries trees and shrubs are distributed according to the available water. On the alluvium in the far lower area where the river width is spread and the large quantity of rainwater infiltrates in the heavy rain, the density of the plant turns into sick. At the lower point to the Qasf village on the Wadi Al Hawasinah River lower basin the dam is constructed.

The conceptual map of water balance in the Ghuzayn District is shown in Figure II-5-1. The input to the upper part to the Ghuzayn District is the rain fall only, and the output from the upper part to the Ghuzayn District consists of the evaporation (from the surface water and groundwater), surface current water, infiltration into underground and flow out, utilization for irrigation (including natural usage). The input to the lower part from the Ghuzayn District consists of the surface current water and ground water flow, rain fall, and the output from the lower part from the Ghuzayn District consists of the evaporation (from the surface water and ground water), surface current water, infiltration into underground, flow out, utilization for irrigation (including natural usage).

The data for the water balance is used hydrological and meteorological data obtained by the hydrological investigation.

Formula of water balance based on the conception is shown in Formula - 4.

$$R = E + S + U + G \qquad \text{Formula - 4}$$

$$E = Ev1 + Ev2$$

$$S = So1 - Si + Sgw$$

$$G = Go - Gi$$

R : Precipitation (m^3/year)
E : Volume of evapotranspiration (m^3/year)
S : Outflow of surface water (m^3/year)
U : Volume of water use (m^3/year)
G : Volume of infiltration (m^3/year)

Ev1 : Evapotranspiration from earth surface (m^3/year)
Ev2 : Evaporation from river, channel, etc. (m^3/year)
So1 : Outflow by rivers (m^3/year)
Si : Inflow of surface water (m^3/year)
Sgw : Inflow to rivers by groundwater (m^3/year)
Ds : Drainage (waste water) (m^3/year)
Go : Outflow of groundwater (m^3/year)
Gi : Inflow by groundwater (m^3/year)

Concerning the hydrological parameters as mentioned above, rain fall in the district is mean value of rain fall between Sohar and Seeb Airport, which is only one data available now, and the evaporation is assumed 80 % based on the result of the Follow-up Survey in the Rakah Area (MMAJ, 1997). But the volume of evaporation from rivers, inflow to rivers by groundwater and outflow of groundwater in the district are eccepted from the examination, because these data could not obtained.

Each value of hydrological parameters at Ghuzayn Village is shown as below.

R	=	37,985,750	(m^3/year)	: Rain fall : 104.5 mm/year	
E	=	30,388,600	(m^3/year)		
S	=	4,558,290	(m^3/year)		
		Si	:	0	(m^3/year)
		Sgw	:	-	(m^3/year)
		So2	:	0	(m^3/year)
U	=	1,419,120			(m^3/year)
		Ds	:	0	(m^3/year)
G	=	R - (E + S + U)			
	=	1,619,740	(m^3/year)		
		Go	:	0	(m^3/year)
		Gi	:	0	(m^3/year)

The additional volume of groundwater near Ghuzayn Village is calculated to be 1,619,740 m^3/year, which corresponds to about same as the discharge of irrigation channel (Falaj system). There is no rainfall this year, so the river water is quite limited. In the lower part from Ghuzayn Village no surface water exists.

Based on the calculation of water balance in the district, it is assumed that the volume of groundwater reserved near Ghuzayn Village, which is about same as the volume of Falaj water, is relatively small quantity. And the potential of groundwater around Ghuzayn Village also is assumed to be relatively small quantity, because water level of the Wadi Al Hawasinah River is quite unstable and wadi sediments around Ghuzayn Village are relatively small along the river.

(2) Ghuzayn Village

The water balance around Ghuzayn Village is shown in Figure II-3-2.

The inflow to Ghuzayn Village consists of the discharge in Falaj (GS-1) and pumping up water from the river underflow ((GS-4)-(GS-3)). (2.92 m^3/min)

The irrigation water in Ghuzayn Village is supplied through Falaj (GS-1;2.7 m^3/min), in shortage, it should be replenished by well water pumped up from GW-1. During the site survey, the pumping operation was not seen at all, so it is assumed that the present discharge water quantity is sufficient to the utilization in Ghuzayn Village. The drinking water is supplied with water track by the government.

At the lower point (GS-3), the surface current water becomes 0.08 m^3/min and turns into the underflow and is extirpated completely.

The only one water well (GW-1) is used in Ghuzayn Village.

All the drainage in Ghuzayn Village is treated by infiltration to the ground.

5-1-2 Groundwater

(1) Topography

The topographic map around the study area of bore wells in the district is shown in Figure I-2-1.

The river condition of the Wadi Al Hawasinah River from about 3.5 km upper stream from Ghuzayn Village to the village forms narrow and deep U-shaped valley. Especially, the width of river around Ghuzayn Village becomes narrow (about 100 m). And the river sediment is mined as the aggregates.

This year there is no rainfall, so the water level of the river near Ghuzayn Village largely changes by the year.

Wadi Al Hawasinah River, which bents flow to the west at Ghuzayn Village, is bifurcated to the northwest.

The study area is located at the mouth of the huge alluvium fan formed by Wadi Al Hawasinah River, and covered with wide and extensive alluvium terrace, which is eroded by the river. And on the other hand the rainfall water gathered on the alluvium terrace becomes the tributary and joins into the river. In the process of the flow down, the Wadi Al Hawasinah River grows wide, and penetrates into the riverbed sediments to supply the water to the aquifer in the plain along the seashore. At the foot of the alluvium fan of high population density area along the seashore, people utilize this ground water by pumping up through the well dug in the alluvium.

Wadi al Hawasinah River flows to the northeast and the drainage system shows parallel drainage pattern.

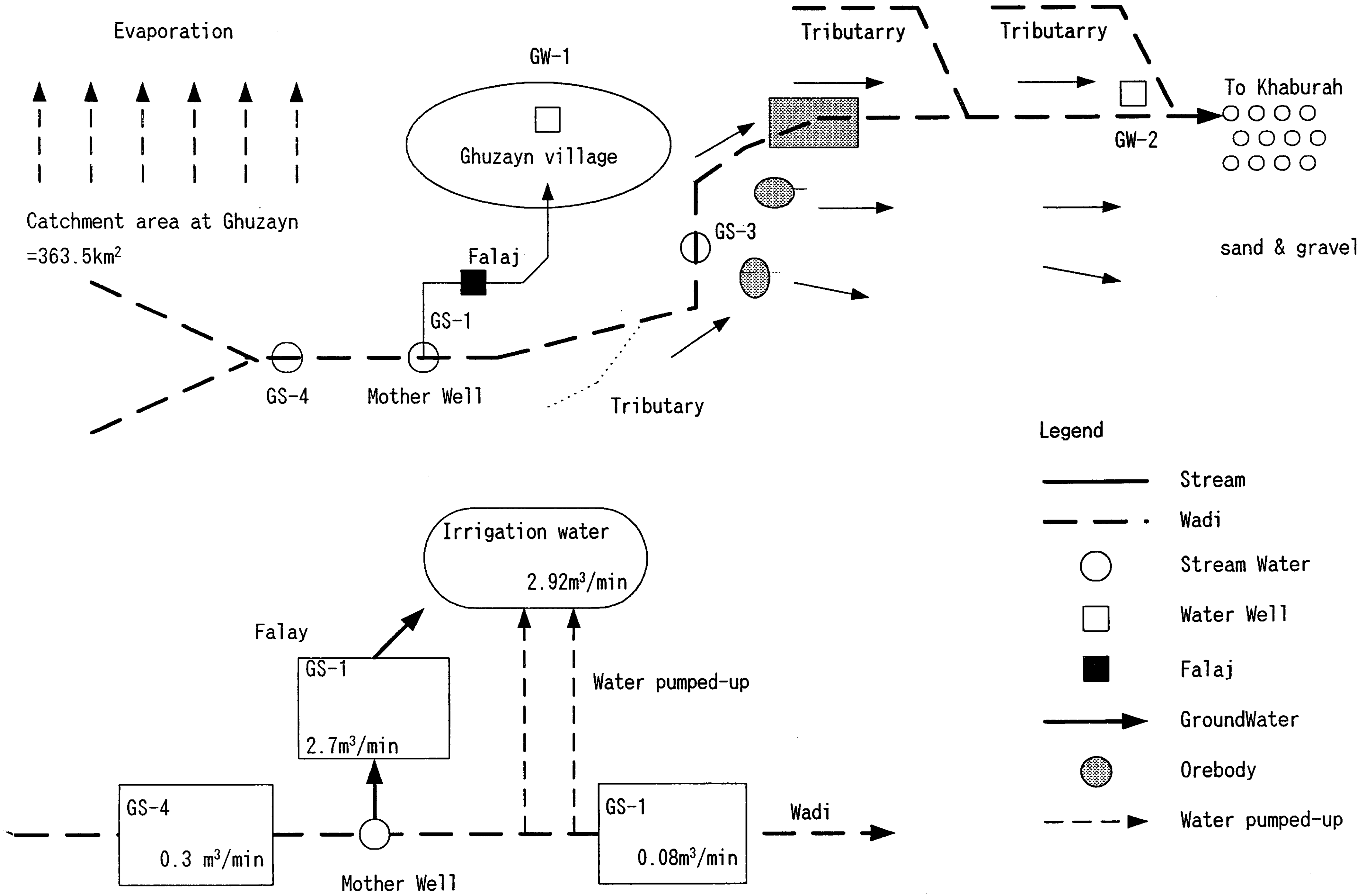

Figure II-5-1 Schematic Water Balance in the Ghuzayn District

(2) Geological features and aquifers

① Geological features

The columnar section of each bore well is shown in Figure II-2-6~8.

Judging from the observation of the cuttings and the result of drilling works, geology of the bore well is assumed to be the topsoil of alluvium, consolidated diluvium, weathered basalt, from the top to bottom. It is assumed that the consolidation of alluvium and the weathering of basalt have been accelerated by the up and down through the cementing and argilized zone of the river water and groundwater containing large amount of Ca and Mg.

② Aquifers

Through the drilling of large-diameter bore wells with no affect of the drilling mud, there was no large quantity of ground water grow. The water seepage during drilling was met in the consolidated or cemented alluvium or at the top of the clay zone. The only small quantity of ground water spring out was measured in the bore well of MJOB-EW-3, which could support the small family domestic use only.

Although the lower part of alluvium becomes calcrete layer filled by carbonate minerals, a part of calccrete layer seems to be remained permeability due to loose texture, fractures, etc. because the even small quantity of water seepage was met in drilling work.

The main aquifers of groundwater in the district are assumed to be composed of unconsolidated or cemented alluvium.

The basement consisting mainly of pillow lava is thought to be relatively good permeability due to the fractures developed by weathering and alteration, but its sphere is limited only upper part of the basement.

Incidentally, the water spring in the borehole during work at the No. 2 ore body was recorded, therefore it is assumed that there are limited aquifers in the basement and the confined groundwater is flowing.

(3) Water table

The location data of the monitoring point and water table of the bore well is shown in Table II-5-1. The ground water table around the bore wells in the district is shown in Figure II-5-2.

The groundwater table is assumed to form a fan shape, whose pivot exists around MJOB-EW-1, slanting along the topography from south to north, and the average gradient

Table Ⅱ-5-1 Location Data and Grand Water Level of Monitoring Point

No.	Monitoring point		Coordinates			G.W.L. (fromGL)	G.W.L. (from SL)	Basalt Level	G.L. (fromB.L)	Remarks
			Latitude	Longitude	Height					
1	Surface current	GS-1	2631506	498487	-					Ghuzayn village Falaj system
2		GS-2	2631506	498487	-					Waji Hawasina(No current)
3		GS-3	2633775	498723	-					Waji Hawasina(Near to primary school)
4		GS-4	2631486	496978	-					Waji Hawasina(New point(far upstream))
5	Water well	GW-1	2633576	498397	-					Ghuzayn village
6		GW-2	2639740	496983	-					Tributary alluvium
7	Observation well	MJOB-EW-1	2634374	498133	197	-14.95	182	165	+17	New drilled and constructed
8		MJOB-EW-2	2637163	499616	176	-26.83	149	130	+19	〃
9		MJOB-EW-3	2637210	498122	173	-19.23	154	143	+11	〃
10		MJOB-EW-4	2636810	496720	169	-14.54	154	143	+11	〃
11		MJOB-EW-5	2639539	497500	137	-11.5	126	107	+19	〃
12	Mather well	No.1	2631562	497186	-					Ghuzayn village Falaj system
13		No.2	2643332	499290	-					
14	Weather observation		2633531	498708	-					On the roof of private house

※ Height is measured by read on the topographic map.

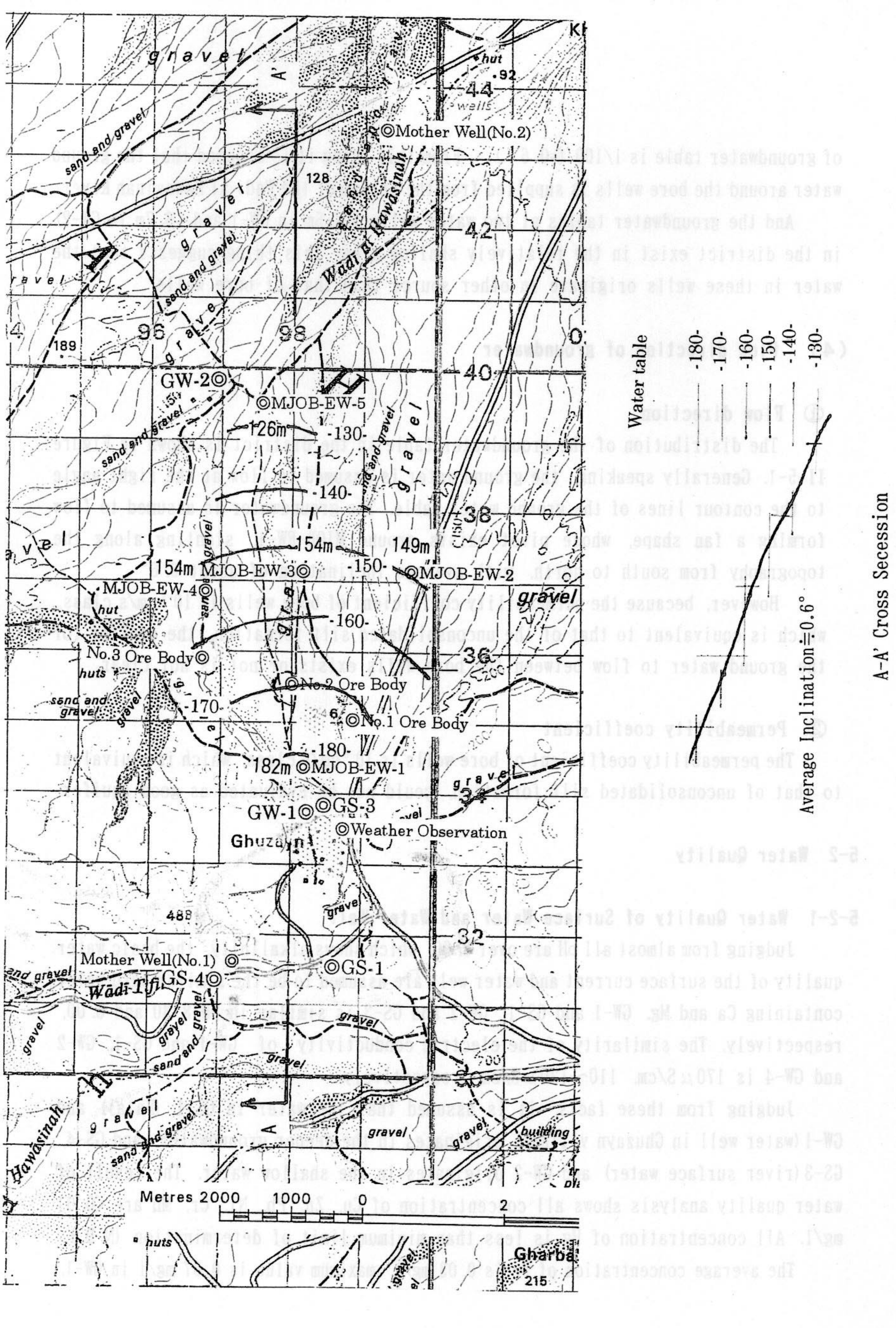

Figure II-5-2 Water Table in the survey area of groundwater table is 1/100 (=0.6°). From this thing it is assumed that the ground water around the bore wells is supplied from the stream of the Wadi al Hawasinah River.

And the groundwater tables at two water wells (-7.5m in GW-1 and –6.7m in GW-2) in the district exist in the relatively shallow area. This thing suggests that the water in these wells originate in other source than that of bore wells.

(4) Flow direction of groundwater

① Flow direction

The distribution of the groundwater table in the district is shown in Figure II-5-1. Generally speaking, the ground water is assumed to flow at the right angle to the contour lines of the ground water table. The groundwater is assumed to flow forming a fan shape, whose pivot exists around MJOB-EW-1, slanting along the topography from south to north, with average inclination of about 0.6°.

However, because the permeability coefficient of bore wells is 10^{-5} cm/s class, which is equivalent to that of the unconsolidated silt formation, the aquifer for the ground water to flow between the bore wells exists or not is not clear.

② Permeability coefficient

The permeability coefficient of bore wells is 10^{-5} cm/s class, which is equivalent to that of unconsolidated silt formation, could not be evaluated as good aquifer.

5-2 Water Quality

5-2-1 Water Quality of Surface Water and Water Well

Judging from almost all pH are over 8.00, which shows alkalinity, the basic water quality of the surface current and water well are assumed to be the similar hard water containing Ca and Mg. GW-1 and GS-1, GW-2 and GS-3 is similar in pH 8.30 and 8.00, respectively. The similarity of the electric conductivity of GW-1 and GS-1, GW-2 and GW-4 is 170 μS/cm, 110～120 μS/cm, respectively.

Judging from these facts, it is assumed that the water in GS-1 (Falaj) and GW-1 (water well in Ghuzayn village) originates in the deeper groundwater, and GS-4, GS-3 (river surface water) and GW-2 originates in the shallow water. The result of water quality analysis shows all concentration of Cu, Zn, Pb, Ni, Cr, Mn are <0.01 mg/l. All concentration of Hg is less than minimum limit of determination (N.D.).

The average concentration of Fe is 0.03 mg/l, maximum value is 0.07 mg/l in GW-1, and minimum value is <0.01 mg/l in GS-3. Those of GW-1 (Ghuzayn village) and GS-3 (river water) are relatively higher.

The average concentration of SO_4 is 131 mg/l, maximum value is 145 mg/l, and minimum value is 114 mg/l.

5-2-2 Water Quality of Groundwater in Bore Wells

Judging from pH is higher than 8.00 and alkalinity, it is assumed that the grand water in bore wells originates in the hard water containing Ca, Mg similar to the surface water and well water.

The electric conductivity of all bore well expect to MJOB-EW-1 is 100μS/cm around and relatively low in the study area, similar to those of the river water and the GW-2 water well. The low electric conductivity is assumed to show the amount of substance to solve in the water is relatively low. It is not assumed that the ground water is stored or flows along the long distance in the aquifer. The relatively high electric conductivity of MJOB-EW-1 might be assumed to be the affect of the suspended fine clay particle.

The water temperature is over 30℃ whose highest is 34.8℃ in MJOB-EW-3. This shows the relatively higher than that of other sampling point (Falaj (GS-1), surface water (GS-3, 4) and well water (GW-2)), and further more, higher than average of atmospheric temperature.

The concentration of Cu ranges from <0.01 to 0.02 mg/l. The average is 0.01 mg/l, maximum value is 0.02 mg/l in MJOB-EW-1, 2, and Minimum is <0.01 mg/l in MJOB-EW-3, 4, 5. All the concentration of Cu is very low.

The concentration of Zn ranges from 0.06 to 1.01 mg/l. The average is 0.44 mg/l, Maximum is 1.01 mg/l in MJOB-EW-1, and minimum value is 0.06 mg/l in MJOB-EW-5. The concentration of Zn ranges relatively wide.

The concentration of Pb ranges from <0.01 to 0.03 mg/l. The average is 0.02 mg/l, maximum value is 0.03 mg/l in MJOB-EW-2, and minimum value is <0.01 mg/l in MJOB-EW-3, 5. All the concentration of Pb is very low.

The concentration of Ni ranges from <0.01 to 0.10 mg/l. The average is 0.04 mg/l, maximum value is 0.01 mg/l in MJOB-EW-2, and minimum value is <0.01 mg/l in MJOB-EW-5.

The concentration of Cr ranges from <0.01 to 0.04 mg/l. The average is 0.02 mg/l, maximum value is 0.04 mg/l in MJOB-EW-2, and minimum value is <0.01 mg/l in MJOB-EW-3, 5. All the concentration of Cr is very low.

The concentration of Fe ranges from 0.20 to 10.56 mg/l. The average is 3.17 mg/l, maximum value is 10.56 mg/l in MJOB-EW-2, and minimum value is 0.20 mg/l in MJOB-EW-3.

The concentration of Fe ranges extremely wide.

The concentration of Mn ranges from 0.04 to 0.10 mg/l. The average is 0.06 mg/l, maximum value is 0.10 mg/l in MJOB-EW-2, and minimum value is 0.04 mg/l in MJOB-EW-3, 4. All the concentration of Cr is very low.

All concentration of Hg is less than minimum limit of determination.

The concentration of SO_4 ranges from 80 to 170 mg/l. The average is 118 mg/l, maximum value is 170 mg/l in MJOB-EW-1, and minimum value is 80 mg/l in MJOB-EW-2. Although the concentration of SO_4 ranges wider than that of the surface water and well water, the average is almost same. The Minimum of SO_4 of 80 mg/l is recorded in MJOB-EW-2, where Fe is maximum value.

The maximum concentration of Fe, Cr, Ni and Mn are recorded in MJOB-EW-2.

The maximum concentration of Cu, Zn and Pb are recorded in MJOB-EW-1. And, the relatively high concentration of Fe and Zn are recorded in MJOB-EW-4. These things suggest that each bore well would be under the some influence of thin vein of mineralization.

5-2-3 Water Quality around Orebodies

Comparing the water quality in the bore well with that of the surface and well, the farmer is higher than the latter.

The Maximum concentration of Cu, Zn and Pb are recorded in MJOB-EW-1. And, the relatively high concentration of Fe and Zn are recorded in MJOB- EW-4. These things suggest that each bore well would be under the some influence of thin vein of mineralization.

The water quality in the down stream of No. 2 orebody (MJOB-EW-3) and in the down stream of the whole orebodies (MJOB-EW-5) shows the almost same or slightly high concentration, so this water quality is assumed to be the representative of the influence of the ore body to the surrounding ground water.

In this study, five boreholes with no affect of the drilling mud were drilled and constructed. Because the ground water quality would be assumed to change according to the annual weather conditions, continual data collection would be desirable through the long-term monitoring on the existing points (surface current; 3 points, water wells; 2 points) and these bore wells.