REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE SOUTH BATINAH COAST AREA
SULTANATE OF OMAN
(ENVIRONMENTAL STUDY)

(PHASE II)

MARCH 1999

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

In response to the request of the Government of the Sultanate of Oman, the Japanese Government decided to conduct a Environmental Study for the Mineral Exploration Project in South Batinah Coast and entrusted the project to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

JICA and MMAJ sent to Oman a survey team headed by Mr. Toshio Koizumi from November 29, 1998 to December 23, 1998.

The team exchanged views with the officials concerned of the Government of Oman and conducted a field investigation in the Ghuzayn District. After the team returned to Japan, further studies were made and present report has been prepared. This report includes the survey result of environmental study.

We hope that this report will serve for the development of the mineral resources and contribute to the promotion of friendly relations between Japan and Oman.

We wish to express our deep appreciation to the officials concerned of the Government of Oman for their close cooperation extended to the team.

March 1999

Kimio Fujita
President
Japan International Cooperation Agency

Hiroaki Hiyama
President
Metal Mining Agency of Japan

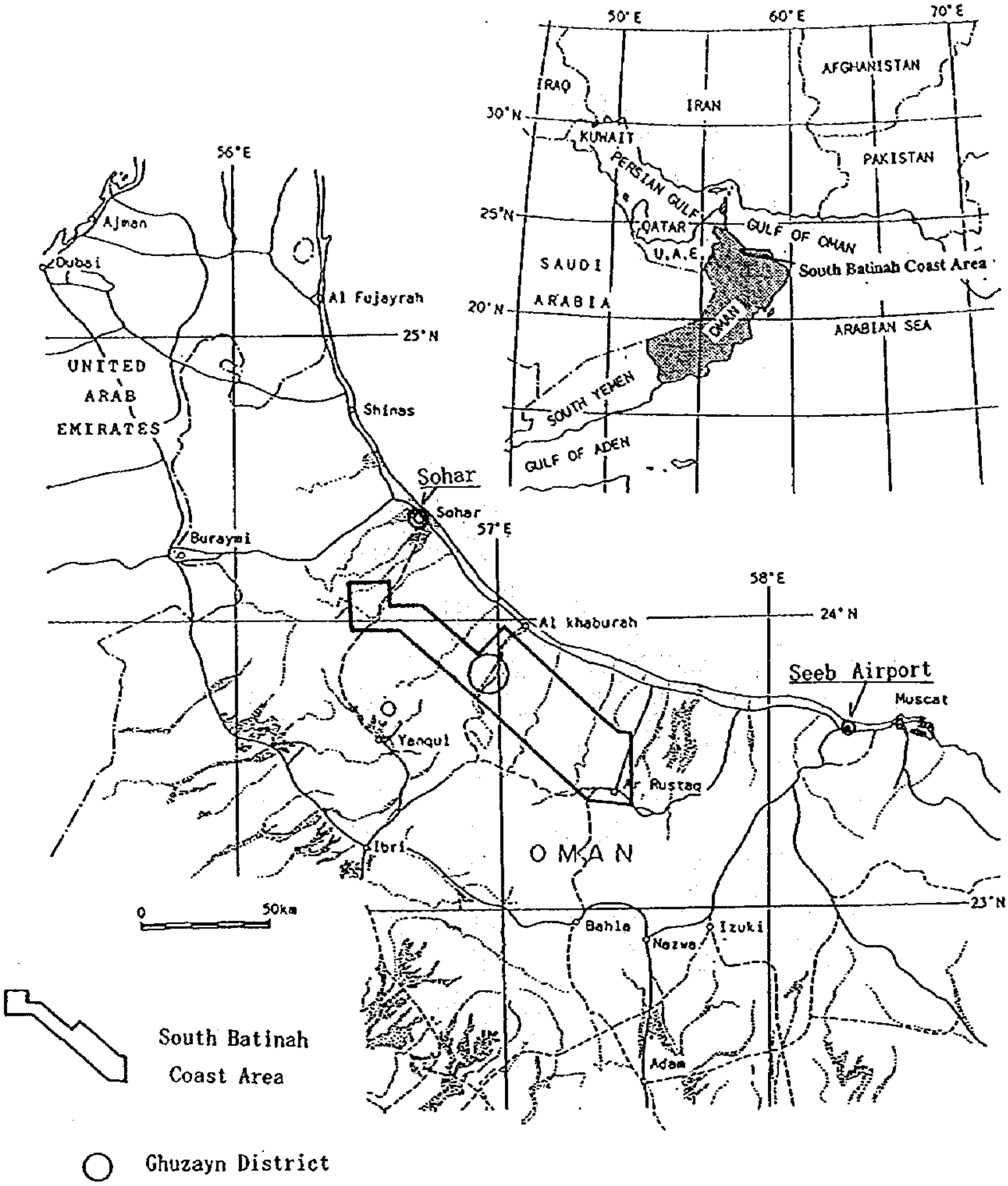

Figure 1 Location Map of the Ghuzayn District (1)

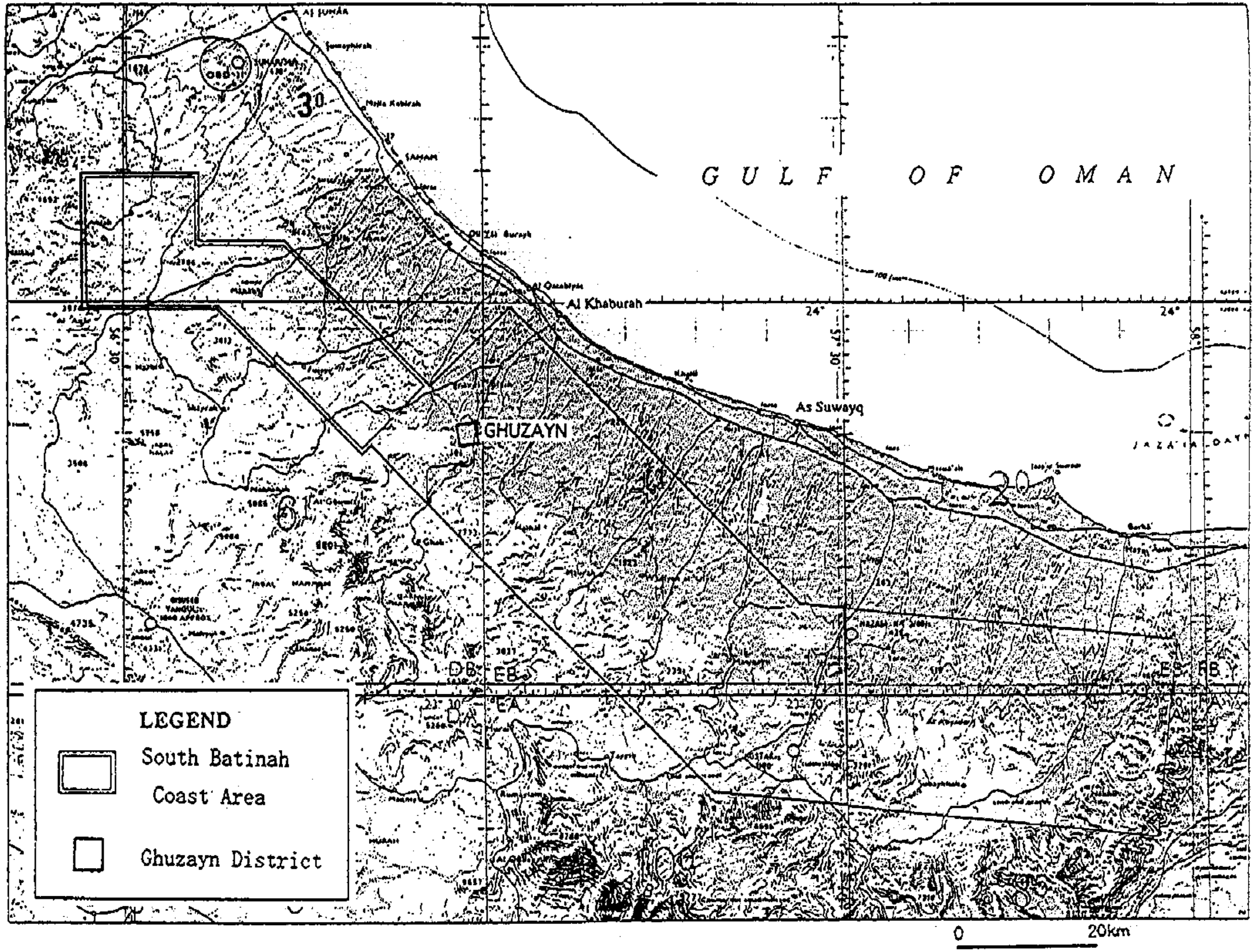

Figure 2 Location Map of the Ghuzayn District (2)

SUMMARY

Results of the "Cooperative Mineral Exploration in the South Batinah Coast Area, Sultanate of Oman (Environmental Study) (Phase II) are as follows:

(Hydrological Investigation)

- River in the Ghuzayn District belongs to the drainage system of Wadi al Hawasinah River.
- Sampling points of water for the hydrological investigation consist of 5 points, 3 points of river survey (GS-1, GS-2 and GS-3) and 2 points of well survey (GW-1 and GW-2).
- Discharge of GS-1 (Falaj) is 4.432 m^3/min, GS-2 (upper stream) is 1.119 m^3/min, and GS-3 (lower stream) is 1.213 m^3/min.
- Water wells (GW-1 and GW-2) in the district are shallow well for living and irrigation. Depth of groundwater table is about -7 m and water quality shows almost similar.
- Approximately two times of volume of surface water is assumed to supply to the groundwater by rain-fall in the Ghuzayn District. River water of 4.4 m^3/min is taken for the irrigation to Ghuzayn Village by Falaj system and water is used for living and agriculture.
- The water quality of river water and well water show almost similar, especially the well water of Ghuzayn Village (GW-1) is similar to that of Wadi al Hawasinah River at Ghuzayn Village (GS-3).
- River water and well water show that pH ranges from 7.63 to 8.46, electric conductivity ranges from 104.9 to 139.0 μS/cm.
- The concentration of heavy metals of river water and well water shows to be almost same group that Cu ranges in concentration from 0.03 to 0.04 mg/l, Fe ranges in concentration from 0.14 to 0.32 mg/l, and Mn ranges in concentration from <0.01 to 0.01 mg/l.
- The concentration of light metals of river water and well water shows to be almost same group that Ca ranges in concentration from 31.5 to 48.0 mg/l, K ranges in concentration from 3.34 to 4.65 mg/l, Mg ranges in concentration from 36.3 to 76.1 mg/l, and Na ranges in concentration from 107 to 129 mg/l.
- The concentration of anion of river water and well water shows to be almost same group that Cl ranges in concentration from 140 to 236 mg/l, NO_3 ranges in concentration from 0.83 to 4.69 mg/l, and SO_4 ranges in concentration from 31.5

to 48.0 mg/l.

- The technical transfers for the establishment of organization for the periodical hydrological investigation was carried out.

(Water Investigation of Bore Holes)

- 13 bore holes, including MJOB-G2, G4, G7, G8, G15, G16, G17, G19, G25, G26, G28, G32 and G36 were selected for the recovery test.
- The permeability coefficient in the district ranges from 10^{-4} to 10^{-7} cm/s, and that of MJOB-G36 is 10^{-4} cm/s and shows to be relatively good aquifer.
- River Sediments, which are found along the Wadi al Hawasinah River in the western part of the district, range in thickness from 6.90 to 15.10 m.
- The Lower Terrace Deposits, which widespread in the district, range in thickness from 7.30 to 28.97 m.
- Major aquifer in the district is assumed to be unconsolidated River Sediments, Lower Terrace Deposits, and cracky zone of basement (basalts).
- Groundwater table in the district forms very gentle slope (0.6°) from southeast (175 m in elevation) to northwest (155 m in elevation).
- The groundwater level around bore holes of MJOB-G5, G16, G22 and G28 is 176 m, which is about 5 to 10 m higher than that of other bore holes.
- The flow direction of groundwater in the district shows radial shape at the center of No. 2 Orebody.
- The drilling mud (EG-mud) is thought to be still remained in the bore holes, so that the drilling mud gives critical influence to the recovery test.
- The water quality of the bore hoes shows that pH ranges from 7.08 to 11.28. Groundwater of MJOB-G16, G17 and G25 shows alkali ranging from pH 9 to 11, because of the influence of cementing during drilling work.
- The Electric Conductivity ranges from 20.5 to >1999 μS/cm. Water temperature ranges from 28.7 to 35.3 ℃.
- The concentration of heavy metals shows that Cu ranges in concentration from 0.02 to 0.46 mg/l, Fe ranges in concentration from 0.93 to 32.90 mg/l, Mn ranges in concentration from 0.05 to 0.84 mg/l, Zn ranges in concentration from 0.02 to 7.00 mg/l.
- The difference between shallow groundwater and deep groundwater in the bore holes can not be recognized except Mn. Mn concentration of deep groundwater of MJOB-G8, G18, G22, G26, G32 and G36 is higher than that of surface groundwater.
- The drilling mud is thought to gives serious influence to the water quality of

the groundwater of the bore holes.

(Recommendations)

- It is necessary to settle bore holes in the upper and lower parts of the orebodies for monitoring of groundwater, because the existing bore holes are influenced by drilling mud.
- It is necessary to carry out the more detailed environmental study in the Ghuzayn District for the conceptional design of the 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 after the project.

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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 November 16, 1998 to February 26, 1999, and the field investigation is 25 days from November 29, 1998 to December 23, 1998.

1-5 Content of the Study

The study consists of hydrological investigation and water investigation of bore holes. The content of the study is shown in Table I-1-1.

1-5-1 Hydrological Investigation

(1) Content of hydrological investigation

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

Table I-1-1 Content of the Project

Items of the survey	Content of the survey	Remarks
1. Hydrological investigation - River water - Well water	Hydrological measurement	Discharge, pH, EC, water temperature
	Water sampling	5 sites
	Water quality analysis	25 components
2. Water investigation of bore holes	Hydrological measurement (37 holes)	Groundwater level, pH, electric conductivity and water temperature
	Recovery test	13 bore holes
	Water quality analysis	10 components

(2) Water quality analysis

Five water samples obtained by 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	BOD, COD, SS, TDS, Faecal Coliform, Total coliform, As, Ca, Cd, Cl, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, V, Zn, NO_3, SO_4, Total alkalinity (25 components)

(3) Establishment of Organization for hydrological investigation

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

(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 Water Investigation of Bore Holes

(1) Water investigation of bore holes

Drilling holes for the water investigation exist 33 holes in the Ghuzayn District. Items of hydrological measurement in each site consist of groundwater level in the holes, pH, electric conductivity (EC), and water temperature.

(2) Water quality analysis

Twenty water samples obtained by hydrological investigation are analyzed. Components of water quality analysis are shown in Table I-1-3.

Table I-1-3 Water Quality Analysis for Groundwater

Number of samples	Components of water quality analysis
5	Cu, Pb, Zn, Ni, Cr, As, Fe, Mn, Hg, SO_4 (10 components)

1-6 Study Team

The study team consists of two persons including team leader and hydrological environment as shown in Table I-1-4.

Table Ⅰ-1-4 Participants for the Study

Inspection of the field work	
Noboru Fujii	MMAJ *1

*1 MMAJ : Metal Mining Agency of Japan

Japanese counterpart			Omani counterpart	
Toshio Koizumi	Team leader	OMRD *2	Salim Omer Ibrahim	MCI *3
Mikio Kajima	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

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 paved road by asphalt of approximately 170 km and 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 the Wadi al Hawasinah River drainage system. Wadi al Hawasinah River is originated from the central part of the Hajar Mountain Ranges, bends flow to the west at Ghuzayn Village, and is bifurcated to the northwest (main stream) and north-northeast (branch).

Gully erosion is slightly found in the terrace, and all of small branch flows into the main stream of Wadi al Hawasinah River (Figure I-2-2).

Surface water is locally found in the Wadi al Hawasinah River around Ghuzayn Village, and a part of the surface water is taken by Falaj system for the village.

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

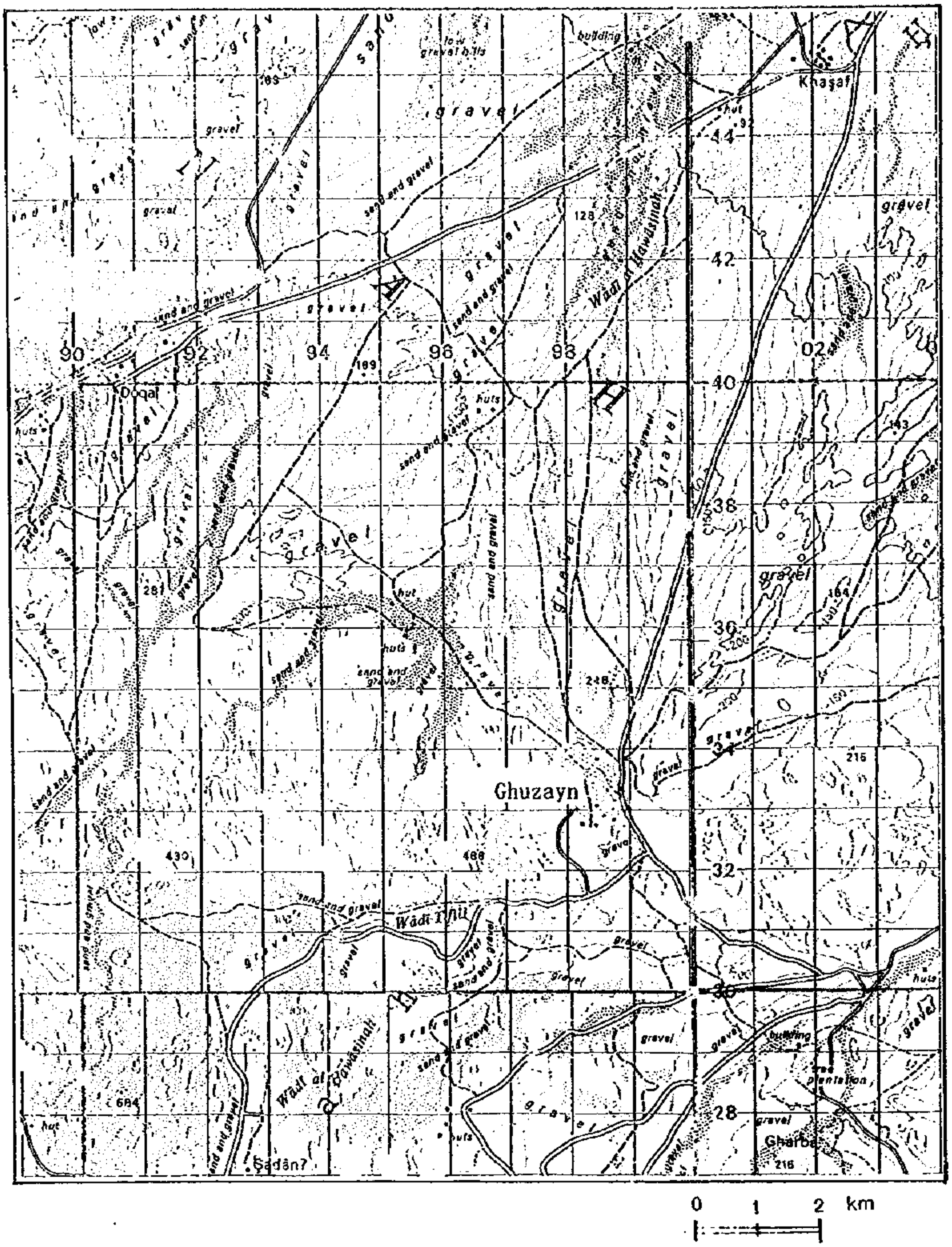


Figure I-2-1　Topographic Map of the Ghuzayn District

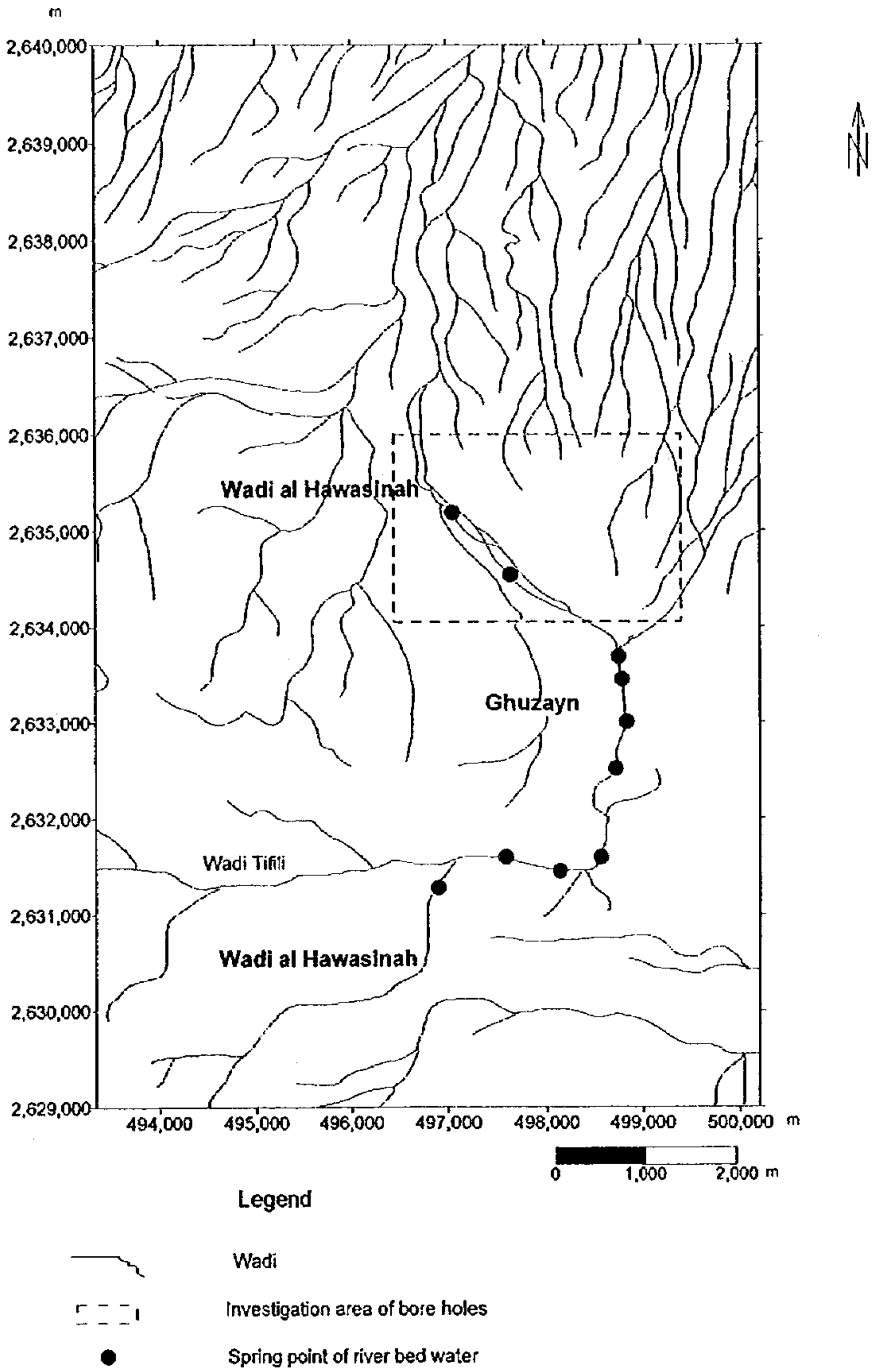


Figure I-2-2 River System in the Ghuzayn District

October and March and has a rare rainfall.

The vegetation in the Ghuzayn District is generally very rare except Ghuzayn Village, and the district shows a feature of the rock or gravel desert area.

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

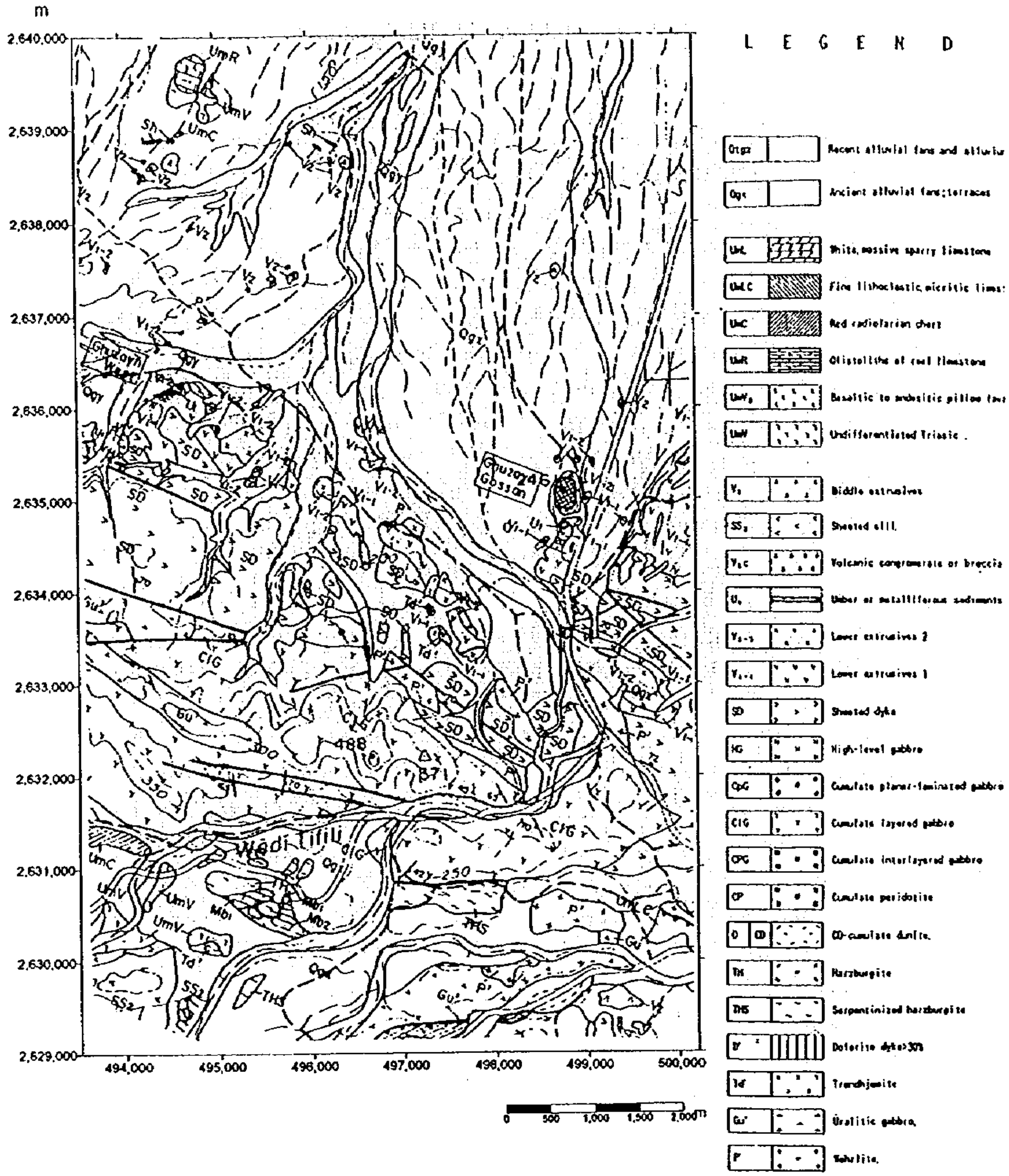


Figure I-3-1 Geologic Map of the Ghuzayn District weathering and cracky.

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.

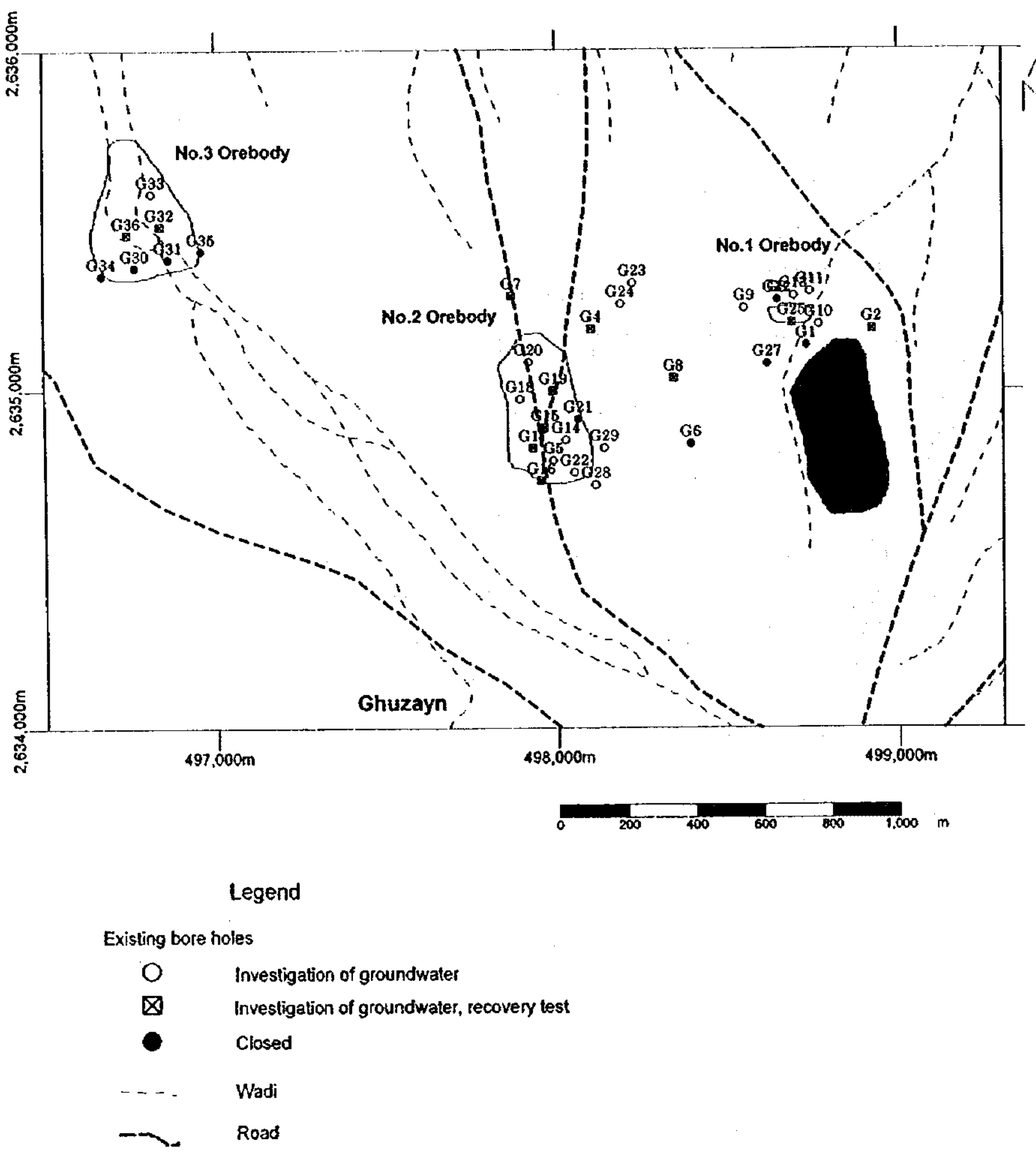
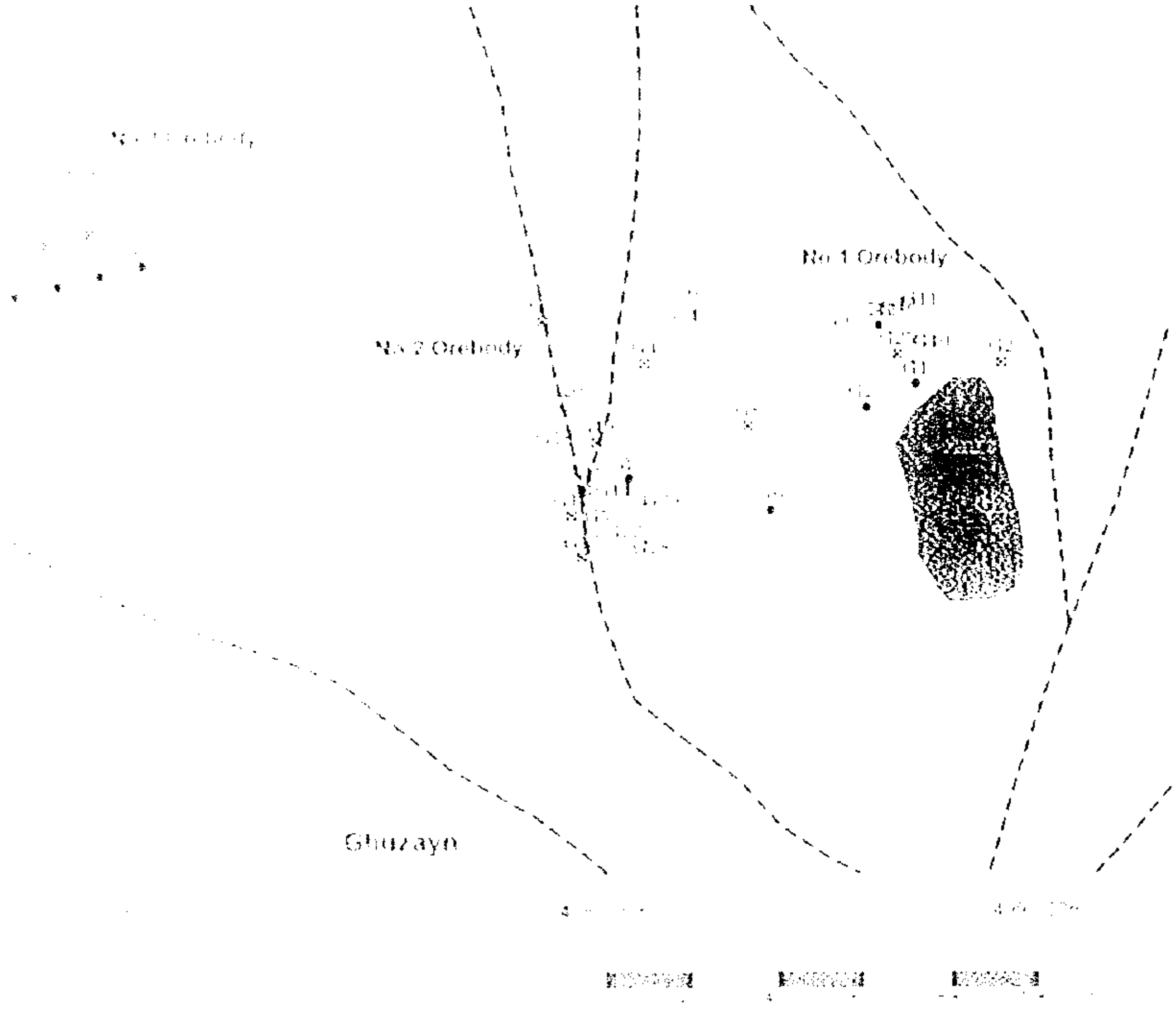


Figure I-3-2 Locality Map of Ore Deposits in the Survey Area


No 1 Orebody
No 2 Orebody
Ghuzayn

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 II-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

Table II-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-2 and GS-3, were selected. GS-1 is irrigation channel (Falaj system) located at 2.5 km upper stream of Ghuzayn Village, GS-2 is located at 2.5 km upper stream of Ghuzayn Village, and GS-3 is located in the lower stream of Ghuzayn Village.

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	8.36	109.5	27.1	4.432
GS-2	8.46	115.7	29.0	1.213
GS-3	7.87	133.3	28.6	1.119

*1 : Electric Conductivity

Approximately two times of volume of surface water is assumed to supply to the groundwater by rainfall in the Ghuzayn District. River water of 4.4 m^3/min is taken for the irrigation to Ghuzayn Village by Falaj system and the irrigated water is used for living and agriculture.

4－1－2 Well Survey

The well survey was carried out two water wells, including Ghuzayn Village (GW-1) and farm located in 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 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	7.67	148.8	28.6	-7.16
GW-2	7.63	108.1	32.1	-7.44

*1 : Electric Conductivity

4－1－3 Water Quality Analysis

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

- River water and well water show almost same feature on water quality, especially the well water of Ghuzayn Village (GW-1) and river water of Wadi al Hawasinah River at Ghuzayn Village (GS-3) show similar.
- River water and well water show that pH ranges from 7.63 to 8.46, Electric Conductivity ranges from 104.9 to 139.0 μS/cm, and BOD ranges from 1.0 to 3.0 mg/l.
- The concentration of heavy metals of river water and well water shows almost similar that Cu ranges in concentration from 0.03 to 0.04 mg/l, Fe ranges in concentration from 0.14 to 0.32 mg/l, and Mn ranges in concentration from <0.01 to 0.01 mg/l.
- The concentration of light metals of river water and well water shows to be almost similar that Ca ranges in concentration from 31.5 to 48.0 mg/l, K ranges in concentration from 3.34 to 4.65 mg/l, Mg ranges in concentration from 36.3 to 76.1 mg/l, and Na ranges r in concentration from 107 to 129 mg/l.
- The concentration of anion of river water and well water shows almost similar that Cl ranges in concentration from 140 to 236 mg/l, NO_3 ranges in concentration from 0.83 to 4.69 mg/l, and SO_4 ranges in concentration from 31.5 to 48.0 mg/l.

4－1－4 Establishment of Organization for Hydrological Investigation

The technical transfers for the establishment of organization for the periodical hydrological investigation in order to obtain long-term data to the counterpart was carried out.

4－1－5 Meteorological Data Collection

The meteorological data collection, including air temperature, precipitation, and wind direction and speed, in Sohar and Seeb Airport (Figure 1) during 18 years was carried.

4－2 Water Investigation of Bore Holes

4－2－1 Selection of Bore Holes for the Recovery Test

Thirteen bore holes, including MJOB-G2, G4, G7, G8, G15, G16, G17, G19, G25, G26, G28, G32 and G36 were selected for the recovery test. And the recovery test in selected bore holes was carried out.

4－2－2 Recovery Test

(1) Recovery test

The permeability coefficient of each bore hole obtained by the recovery test 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-G2	60	600	228	98	28266	7.57	7.57	1.30E-05
2	MJOB-G4	60	600	550	468	27695	7.57	7.57	2.53E-06
3	MJOB-G7	60	180	3	1	27842	7.57	7.57	7.72E-05
4	MJOB-G8	60	420	50	38	17874	7.57	7.57	9.47E-06
5	MJOB-G15	60	600	261	189	23304	7.57	7.57	5.89E-06
6	MJOB-G16	60	600	228	207	18355	7.57	7.57	2.17E-06
7	MJOB-G17	60	600	26	17	23531	7.57	7.57	7.69E-06
8	MJOB-G19	60	600	290	254	28201	7.57	7.57	2.05E-06
9	MJOB-G25	60	900	585	567	17351	8.89	8.66	6.43E-07
10	MJOB-G26	60	600	198	60	16518	7.57	7.57	2.94E-05
11	MJOB-G28	60	600	131	111	13078	7.57	7.57	5.00E-06
12	MJOB-G32	60	600	90	31	23572	7.57	7.57	1.93E-05
13	MJOB-G36	0	60	78	1	24144	7.57	7.57	6.94E-04

The permeability coefficient in the district ranges from 10^{-4} to 10^{-7} cm/s.

The permeability coefficient of MJOB-G36 is 10^{-4} cm/s and shows to be relatively good aquifer.

River Sediments (Qtgz), which are found along the Wadi al Hawasinah River in the western part of the district, range in thickness from 6.90 to 15.10 m.

The Lower Terrace Deposits (Qgx), which are widespread in the district, range in thickness from 7.30 to 28.97 m. Undulation in the surface of the basement (basalts) is recognized.

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

Groundwater table in the district forms very gentle slope (0.6°) from southeast (175 m in elevation) to northwest (155 m in elevation). The groundwater level around bore holes of MJOB-G5, G16, G22 and G28 is 176 m, which is about 5 to 10 m higher than that of other bore holes. The flow direction of groundwater in the district shows radial shape at the center of No. 2 Orebody.

The drilling mud (EG-mud) is thought to be still remained in the bore holes, so that the drilling mud gives critical influence to the recovery test.

4－2－3 Water Quality Analysis

The result of water quality analysis is shown as below.

- The water quality of the bore hoes shows that pH ranges from 7.08 to 11.28. Groundwater of MJOB-G16, G17 and G25 shows alkali ranging from pH 9 to 11, because of the influence of cementing during drilling work.
- Electric Conductivity ranges from 20.5 to >1999 μS/cm. Water temperature ranges from 28.7 to 35.3 ℃.
- The concentration of heavy metals shows that Cu ranges in concentration from 0.02 to 0.46 mg/l, Fe ranges in concentration from 0.93 to 32.90 mg/l, Mn ranges in concentration from 0.05 to 0.84 mg/l, Zn ranges in concentration from 0.02 to 7.00 mg/l.
- The difference between surface and deep groundwater in the bore holes is not recognized except Mn. Mn concentration of deep groundwater of MJOB-G8, G18, G22, G26, G32 and G36 is higher than that of surface groundwater.
- The drilling mud is thought to give silious influence to the water quality of the groundwater of the bore holes.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5－1 Conclusions

The conclusions of the study are as follows:

(Hydrological Investigation)

- River in the Ghuzayn District belongs to the drainage system of Wadi al Hawasinah River.
- Sampling points of water for the hydrological investigation consist of 5 points, 3 points of river survey (GS-1, GS-2 and GS-3) and 2 points of well survey (GW-1 and GW-2).
- Discharge of GS-1 (Falaj) is 4.432 m^3/min, GS-2 (upper stream) is 1.119 m^3/min, and GS-3 (lower stream) is 1.213 m^3/min.
- Water wells (GW-1 and GW-2) in the district are shallow well for living and irrigation. Depth of groundwater table is about -7 m and water quality shows almost similar.
- Approximately two times of volume of surface water is assumed to supply to the groundwater by rain-fall in the Ghuzayn District. River water of 4.4 m^3/min is taken for the irrigation to Ghuzayn Village by Falaj system and water is used for living and agriculture.
- The water quality of river water and well water show almost similar, especially the well water of Ghuzayn Village (GW-1) is similar to that of Wadi al Hawasinah River at Ghuzayn Village (GS-3).
- River water and well water show that pH ranges from 7.63 to 8.46, electric conductivity ranges from 104.9 to 139.0 μS/cm.
- The concentration of heavy metals of river water and well water shows to be almost same group that Cu ranges in concentration from 0.03 to 0.04 mg/l, Fe ranges in concentration from 0.14 to 0.32 mg/l, and Mn ranges in concentration from <0.01 to 0.01 mg/l.
- The concentration of light metals of river water and well water shows to be almost same group that Ca ranges in concentration from 31.5 to 48.0 mg/l, K ranges in concentration from 3.34 to 4.65 mg/l, Mg ranges in concentration from 36.3 to 76.1 mg/l, and Na ranges in concentration from 107 to 129 mg/l.
- The concentration of anion of river water and well water shows to be almost same group that Cl ranges in concentration from 140 to 236 mg/l, NO_3 ranges in concentration from 0.83 to 4.69 mg/l, and SO_4 ranges in concentration from 31.5

to 48.0 mg/l.

- The technical transfers for the establishment of organization for the periodical hydrological investigation was carried out.

(Water Investigation of Bore Holes)

- 13 bore holes, including MJOB-G2, G4, G7, G8, G15, G16, G17, G19, G25, G26, G28, G32 and G36 were selected for the recovery test.
- The permeability coefficient in the district ranges from 10^{-4} to 10^{-7} cm/s, and that of MJOB-G36 is 10^{-4} cm/s and shows to be relatively good aquifer.
- River Sediments, which are found along the Wadi al Hawasinah River in the western part of the district, range in thickness from 6.90 to 15.10 m.
- The Lower Terrace Deposits, which widespread in the district, range in thickness from 7.30 to 28.97 m.
- Major aquifer in the district is assumed to be unconsolidated River Sediments, Lower Terrace Deposits, and cracky zone of basement (basalts).
- Groundwater table in the district forms very gentle slope (0.6°) from southeast (175 m in elevation) to northwest (155 m in elevation).
- The groundwater level around bore holes of MJOB-G5, G16, G22 and G28 is 176 m, which is about 5 to 10 m higher than that of other bore holes.
- The flow direction of groundwater in the district shows radial shape at the center of No. 2 Orebody.
- The drilling mud (EG-mud) is thought to be still remained in the bore holes, so that the drilling mud gives critical influence to the recovery test.
- The water quality of the bore hoes shows that pH ranges from 7.08 to 11.28. Groundwater of MJOB-G16, G17 and G25 shows alkali ranging from pH 9 to 11, because of the influence of cementing during drilling work.
- The Electric Conductivity ranges from 20.5 to >1999 μS/cm. Water temperature ranges from 28.7 to 35.3 ℃.
- The concentration of heavy metals shows that Cu ranges in concentration from 0.02 to 0.46 mg/l, Fe ranges in concentration from 0.93 to 32.90 mg/l, Mn ranges in concentration from 0.05 to 0.84 mg/l, Zn ranges in concentration from 0.02 to 7.00 mg/l.
- The difference between shallow groundwater and deep groundwater in the bore holes can not be recognized except Mn. Mn concentration of deep groundwater of MJOB-G8, G18, G22, G26, G32 and G36 is higher than that of surface groundwater.
- The drilling mud is thought to gives serious influence to the water quality of the

groundwater of the bore holes.

5－2 Recommendations

The recommendations of the study are as follows:

- It is necessary to settle bore holes in the upper and lower parts of the orebodies for monitoring of groundwater, because the existing bore holes are influenced by drilling mud.
- It is necessary to carry out the more detailed environmental study in the Ghuzayn District for the conceptional design of the 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 after the project.

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 II-1-1.

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
≤ 0.01, > 0.05	Triangle weir or flow meter
≤ 0.05, > 0.15	Square weir or flow meter
≤ 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.

(3) Water quality analysis

Three water samples gotten by the river survey is analyzed. Chemical analysis consists of 25 components as shown in Table I-1-2.

1－3－2 Well Investigation

(1) Measurement of groundwater level

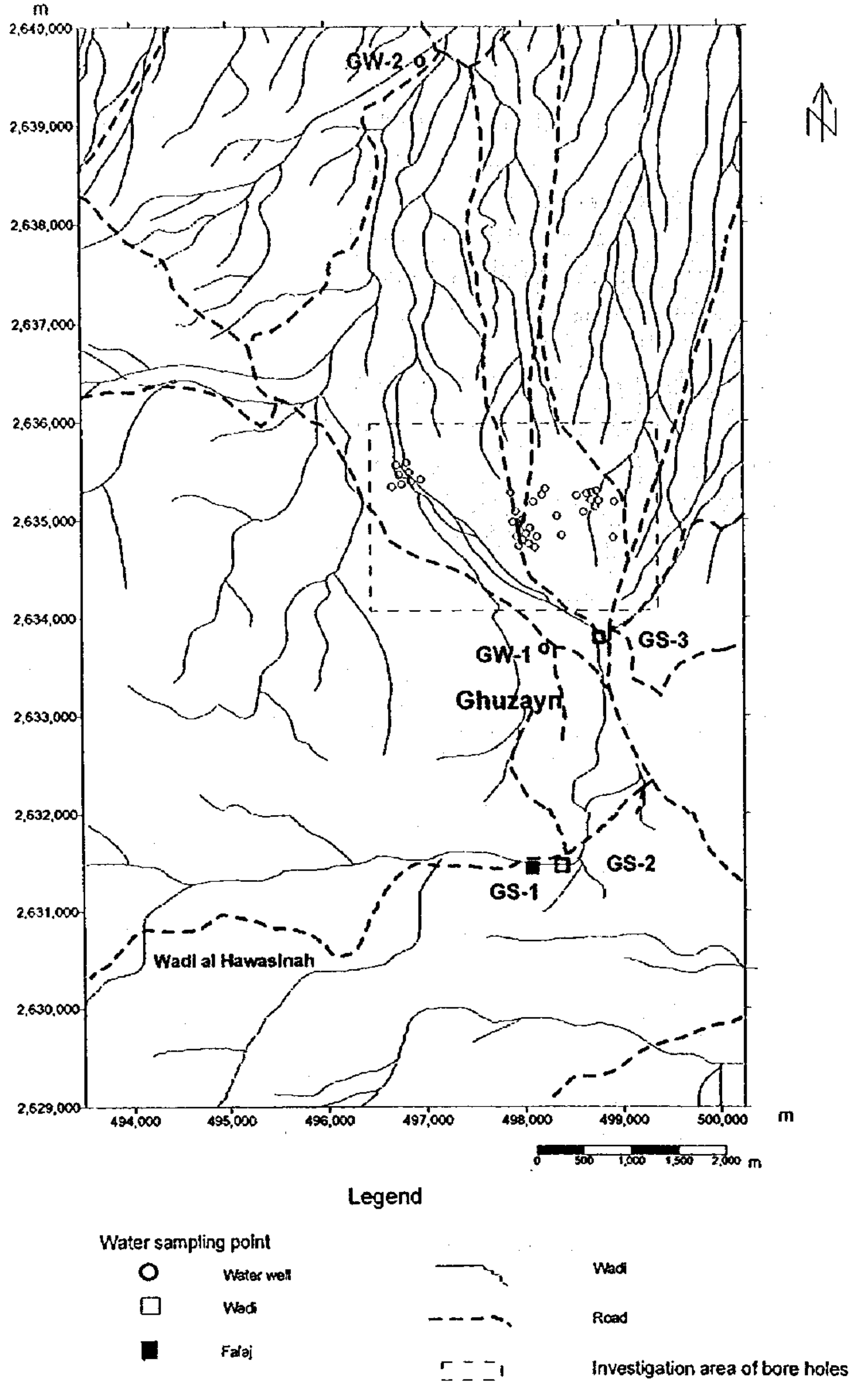


Figure II-1-1 Locality Map of the Hydrological Investigation

Water-level indicator measures groundwater level in the wells.

(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 gotten by the well survey is analyzed. Chemical analysis consists of 25 components as shown in Table I-1-2.

(4) Establishment of organization for hydrological investigation

Establishment of the organization for the periodical hydrological investigation in the Ghuzayn District is to obtain long-term data because of seasonal differences and to transfer techniques to the counterpart concerning the hydrological investigation.

(5) Meteorological data collection

Collection of the meteorological data during past 10 years is to analyze hydrological condition in the Ghuzayn District.

1－4 Survey Results

1－4－1 River Survey

(1) Hydrological condition

Drainage system of the Ghuzayn District belongs to the Wadi al Hawasinah River drainage system (Figure II-1-1).

Wadi al Hawasinah River is originated from 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 obscenities near Al Khaburah. Several points of surface water are around from hilly zone to Ghuzayn Village because river-bed water erupts at the shallow parts of basaltic basement. A part of surface water in Ghuzayn Village is pumped-up and irrigated.

And a part of surface and river-bed water is irrigated for living and agriculture by irrigation channel (Falaj system). The irrigation channel of

Ghuzayn Village is approximately 3 km in length and it is repaired recently.

Sampling points of river water are three, including GS-1 locating about 2.5 km upper stream from Ghuzayn Village, GS-2 locating about 2.5 km upper stream from Ghuzayn Village, and GS-3 locating at the north Ghuzayn Village.

(2) Water quality

The measurement of discharge was carried out by flow speed meter (Hiroi-type water current meter) after setting the appropriate channel section of river as stable 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)

Measurement results of discharge and water quality 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 ($\mu S/cm$)	Temp. (℃)	
GS-1	8.36	109.5	27.1	4.432
GS-2	8.46	115.7	29.0	1.213
GS-3	7.87	133.3	28.6	1.119

*1 : Electric Conductivity

Discharge of the irrigation channel (Falaj system) is approximately three times of discharge of the surface water. And the water quality of the irrigation channel is almost same to that of the surface water.

1-4-2 Well Survey

The well survey was carried out at two wells, including GW-1 and GW-2. GW-1 is located in Ghuzayn Village, and SW-2 is located in small village about 7 km north-northwest of Ghuzayn Village (Figure II-1-1).

Water well (GW-1) in Ghuzayn Village is used as irrigation for living and agriculture. It is unconfined (manual excavation) concrete well, about 30 m in depth and 1.8 to 2.0 m in diameter, and the groundwater is pumped up.

Water well (GW-2) in the lower stream of Wadi al Hawasinah River is used as irrigation for living and agriculture (about 2 ha). It is unconfined (manual excavation) concrete well, about 30 m in depth and 1.8 to 2.0 m in diameter, and the groundwater is pumped up.

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

Groundwater table of the water wells is almost same depth, and water quality is also similar.

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	7.67	148.8	28.6	-7.16
GW-2	7.63	108.1	32.1	-7.44

*1 : Electric Conductivity

1－4－3 Water Quality Analysis

Results of water quality analysis of river and well water are shown in Table II-1-4 and Figure II-1-2(1)～(5).

(Living environmental items)

- River water and well water show to be similar.
- pH ranges from 7.63 to 8.46, and electric conductivity (EC) ranges from 104.9 to 139.0 μS/cm.
- Biochemical Oxygen Demand (BOD) ranges in concentration from 1.0 to 3.0 mg/l. BOD of the river water of irrigation channel (GS-1) and well water in Ghuzayn Village (GW-1) is 3.0 mg/l and higher concentration than that of river water of Wadi al Hawasinah River (GS-2).
- Chemical Oxygen Demand (COD) ranges in concentration from 3.92 to 27.4 mg/l. COD of the well water in the lower stream of Wadi al Hawasinah River (GW-2) is 3.92 mg/l and the lowest concentration in the Ghuzayn District.

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

Items	Sample No.	GW-1	GW-2	GS-1	GS-2	GS-3	Maximum	Minimum	Average
pH		7.84	7.63	8.36	8.46	7.87	8.46	7.63	8.03
EC	μS/cm	136.3	104.9	117.5	115.8	139.0	139.0	104.9	122.7
BOD	mg/l	3.0	1.0	3.0	2.0	1.0	3.0	1.0	2.0
COD	mg/l	24.0	3.92	23.5	23.0	27.4	27.4	3.92	20.4
SS	mg/l	4.5	2.0	2.5	2.5	4.0	4.5	2.0	3.1
TDS	mg/l	830	575	635	610	795	830	575	689
Faecal coliform	No./100ml	<1	<1	4	<1	30	30	<1	17
Total coliform	No.	>1000	>1000	>1000	>1000	>1000	>1000	>1000	>1000
As	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ca	mg/l	48.0	37.8	32.3	31.5	43.3	48.0	31.5	38.6
Cd	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cl	mg/l	236	140	216	212	226	236	140	206
Cr	mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cu	mg/l	0.04	0.04	0.03	0.03	0.04	0.04	0.03	0.04
Fe	mg/l	0.15	0.20	0.14	0.14	0.32	0.32	0.14	0.19
Hg	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K	mg/l	4.25	3.34	4.35	4.25	4.65	4.65	3.34	4.17
Mg	mg/l	64.0	36.3	45.4	48.8	76.1	76.1	36.3	54.1
Mn	mg/l	0.01	0.01	0.02	<0.01	0.02	0.01	<0.01	0.01
Na	mg/l	129	111	107	107	113	129	107	113
Ni	mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Pb	mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
V	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Zn	mg/l	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	0.01
NO_3	mg/l	0.83	4.69	1.02	2.28	2.96	4.69	0.83	2.36
SO_4	mg/l	140	120	140	140	140	140	120	140
Total alkaline	mg/l	236	222	142	132	250	250	132	196

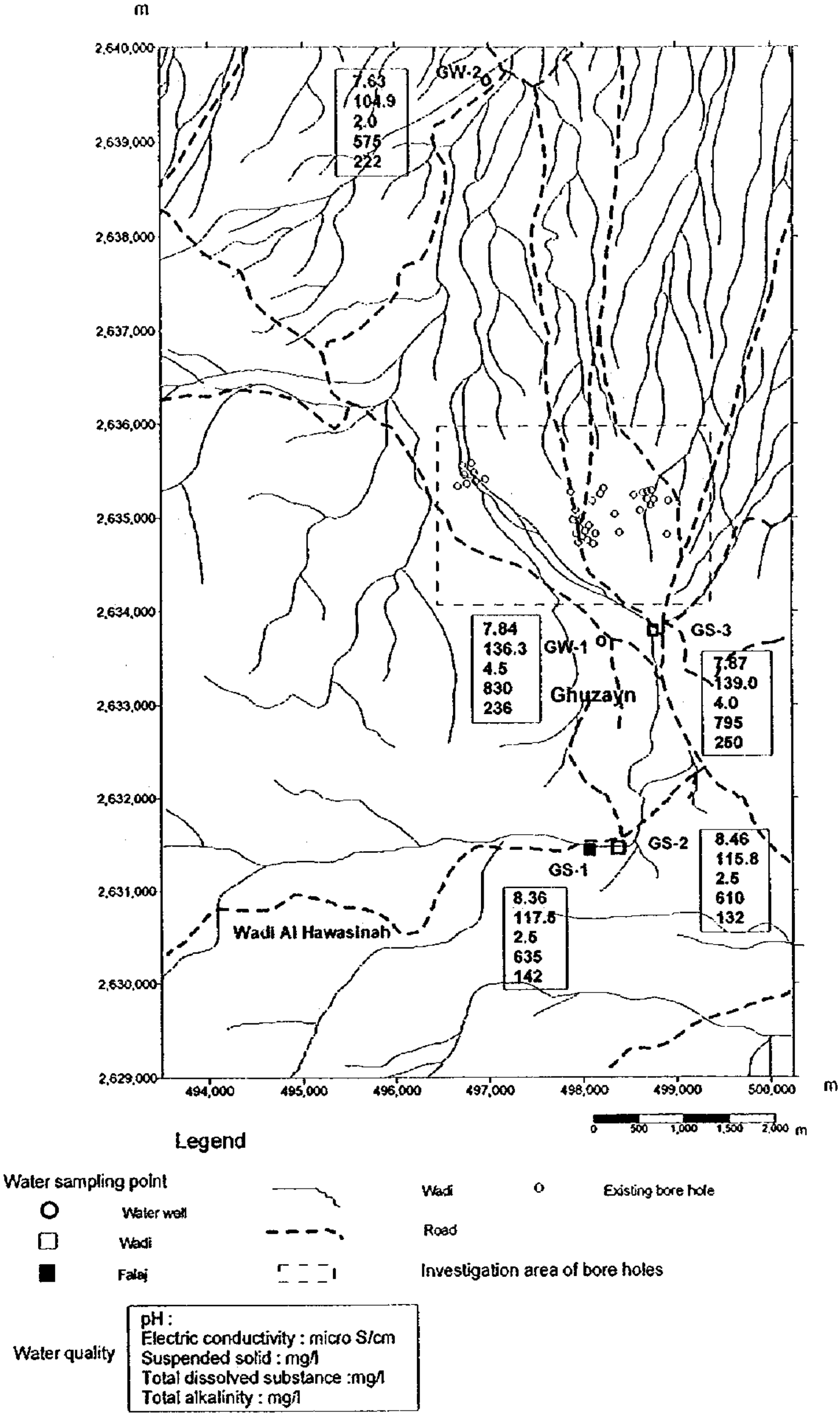
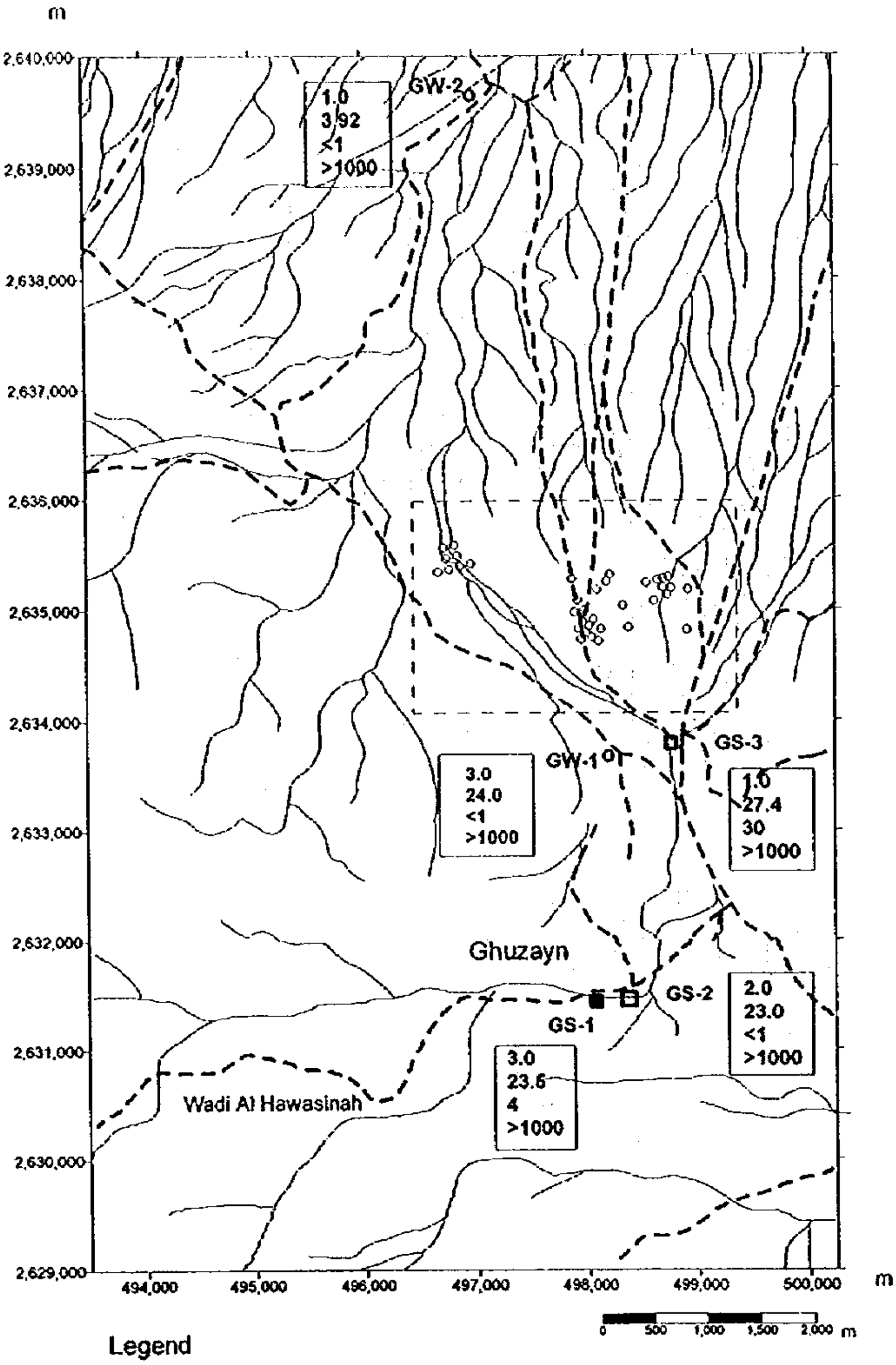


Figure II-1-2 Analytical result of River and Well Water (1)



Legend

Water sampling point

O Water well	Wadi		Existing bore hole
□ Wadi	Road		
■ Falaj	Investigation area of bore holes		

Water quality:
Biological oxigen demand : mg/l
Chemical oxigen demand : mg/l
Faecal coliform : No./100ml
Total coliform :No.

Figure II-1-2 (2)

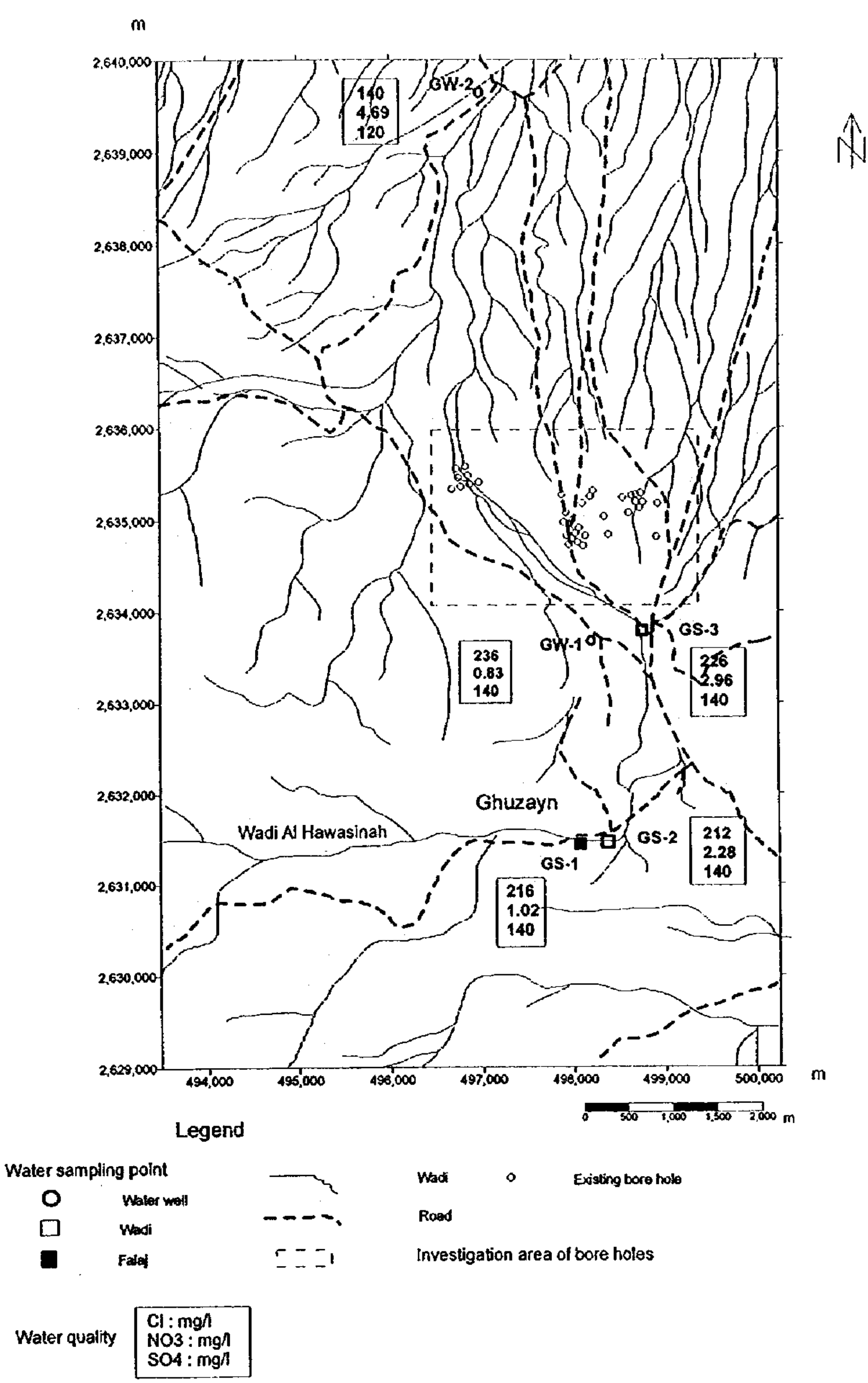


Figure II-1-2 (3)

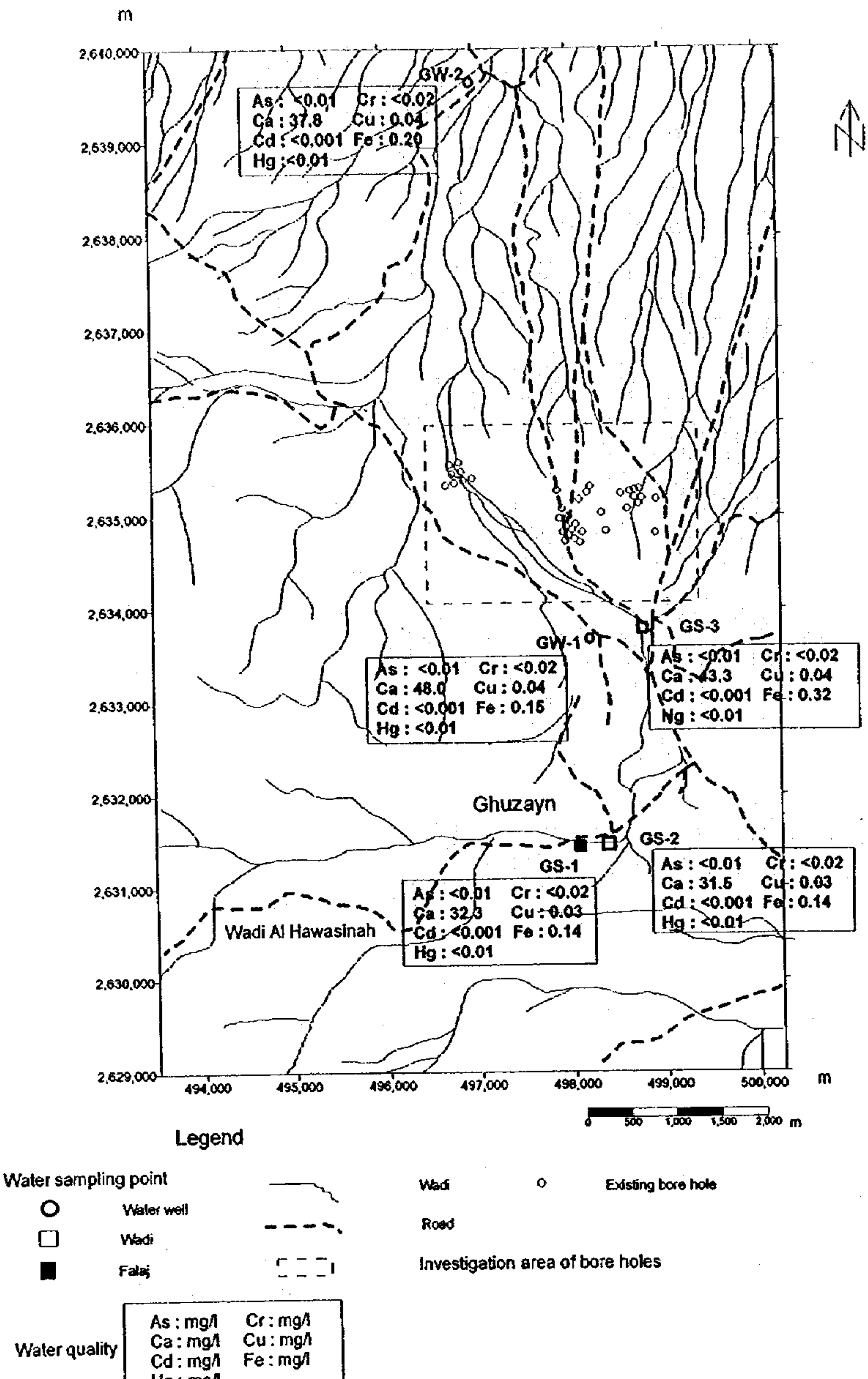


Figure II-1-2 (4)

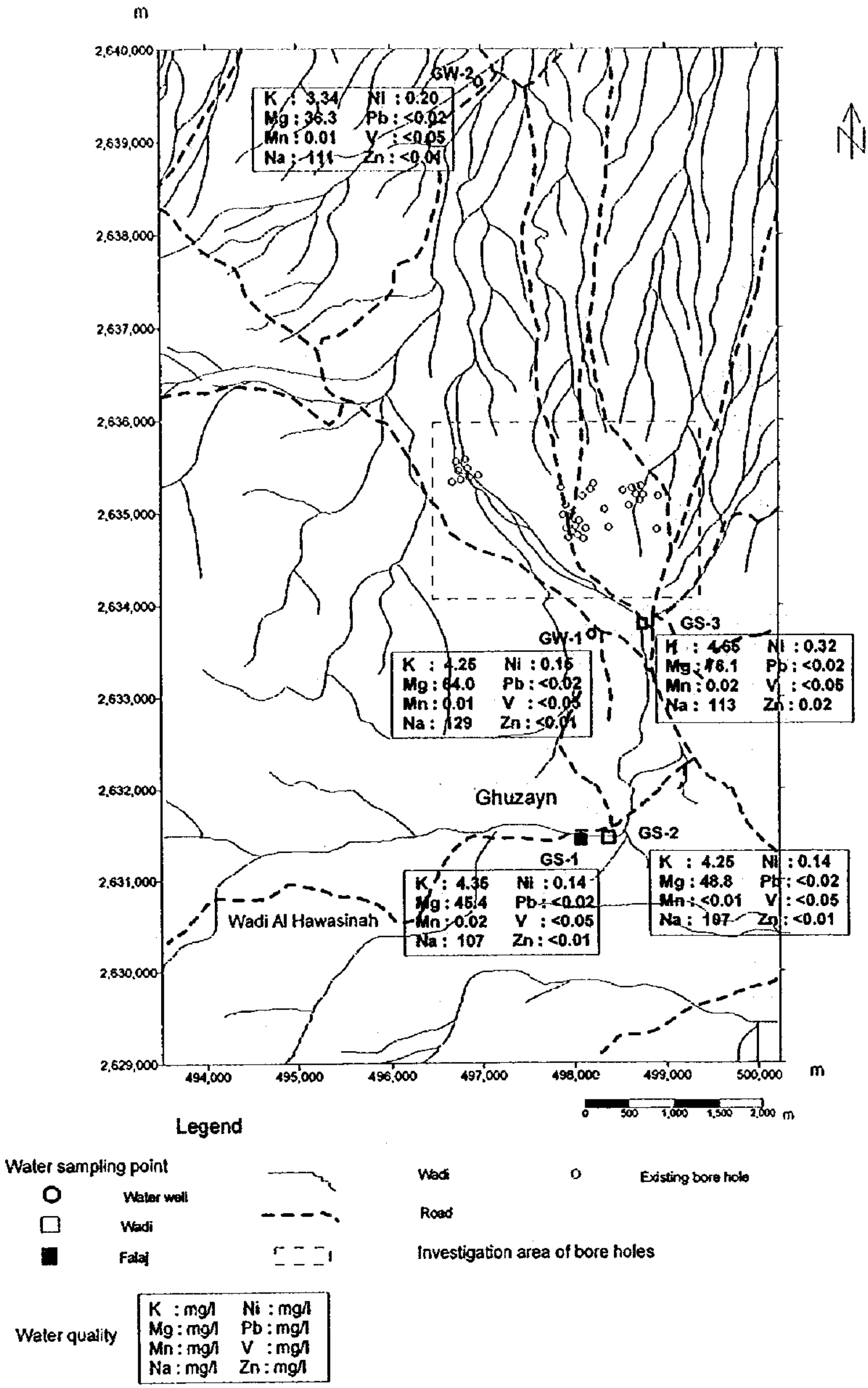


Figure II-1-2 (5)

- Suspended solid (SS) ranges in concentration from 2.0 to 4.5 mg/l.
- Total Dissoluble solid (SS) ranges in concentration from 575 to 830 mg/l.

(Heavy metals)

- The concentration of heavy metals of river water and well water shows to be almost similar.
- Cu ranges in concentration from 0.03 to 0.04 mg/l.
- Fe ranges in concentration from 0.14 to 0.32 mg/l.
- Mn ranges in concentration from <0.01 to 0.01 mg/l.
- The concentration of As, Cd, Co, Hg, Ni, V and Zn is less than minimum limit of determination.

(Light metals)

- The concentration of light metals of river water and well water shows to be almost similar.
- Ca ranges in concentration from 31.5 to 48.0 mg/l.
- K ranges in concentration from 3.34 to 4.65 mg/l.
- Mg ranges in concentration from 36.3 to 76.1 mg/l.
- Na ranges in concentration from 107 to 129 mg/l.

(Anion)

- The concentration of anion of river water and well water shows to be almost similar.
- Cl ranges in concentration from 140 to 236 mg/l.
- NO_3 ranges in concentration from 0.83 to 4.69 mg/l.
- SO_4 ranges in concentration from 31.5 to 48.0 mg/l.

1－4－4 Establishment of Organization for Hydrological Investigation

The organization for the periodical hydrological investigation in the Ghuzayn District was established and transferred techniques to the counterpart.

The content of monitoring investigation is shown in Table II-1-5.

Table II-1-5 Monitoring Plan in the Ghuzayn District

Items	Monitoring plan
1. Objectives	Understanding the hydrological condition in the district
2. Duration and work schedule	Once of water investigation in a month within one year (January to December, 1999)
3. Monitoring points	(1) Surface water (wadi al Hawasinah): 3 points : GS-1, GS-2 and GS-3 (2) Well water : 2 wells GW-1 and GW-2 (3) Bore holes : 2 holes MJOB-G7 and MJOB-G28 Total : 7 points
4. Chemical analysis	(1)Measurement : pH, EC and water temperature (2)Chemical analysis : 10 components As, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn, SO4

1－4－5 Meteorological data collection

The meteorological data including air temperature, rain-fall, and wind direction and speed at Sohar and Seeb Airport during past 18 years were collected. The location of Sohar and Seeb Airport is shown in Figure 1.

The meteorological data are shown in appendix.

(1) Air temperature

Air temperature including mean, minimum and maximum air temperature at Sohar and Seeb Airport are shown in Figure II-1-3 and Figure II-1-4, respectively.

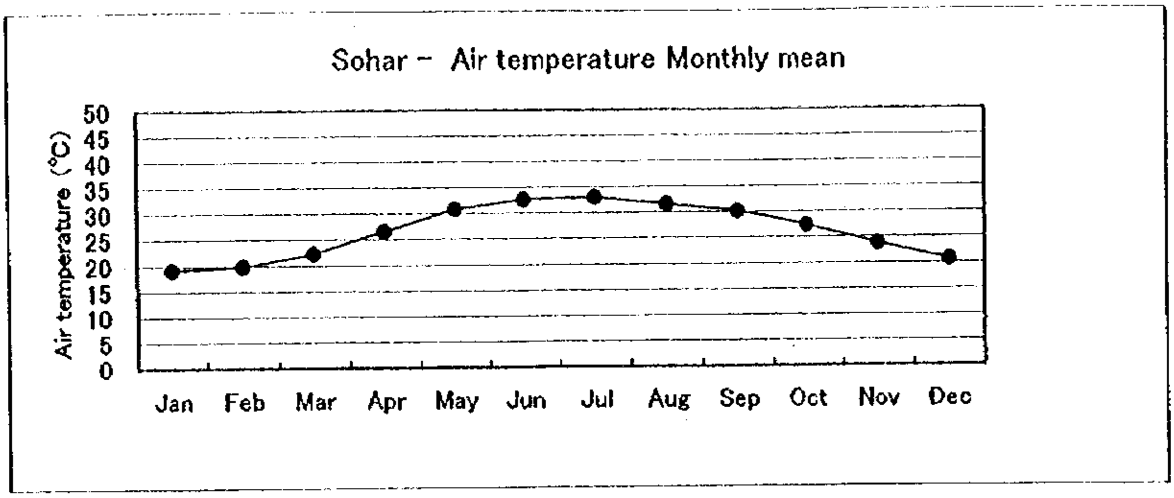
The highest and lowest mean air temperature at Sohar is 35.2℃ in June and 21.2℃ in January, respectively.

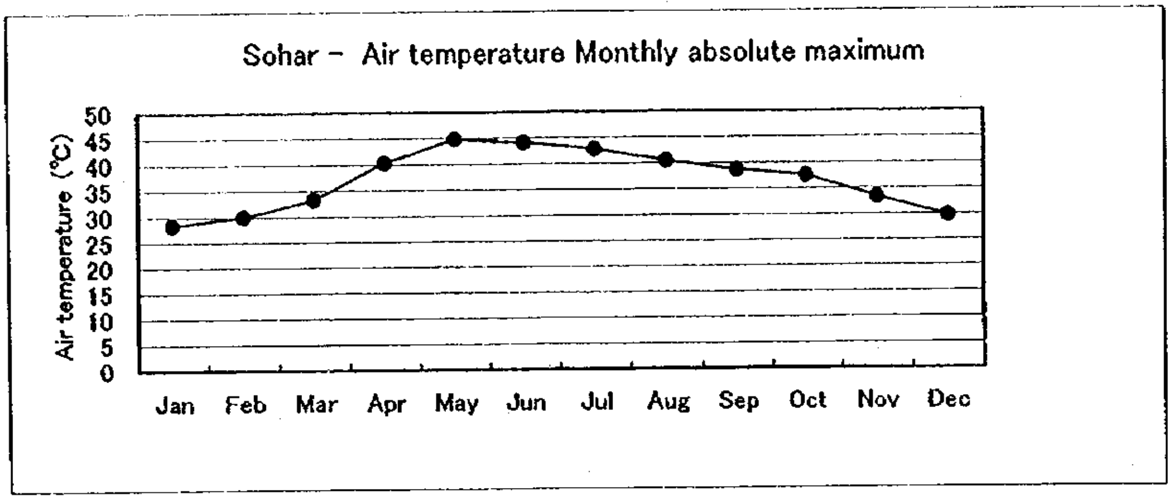
(2) Rain-fall

Precipitation at Sohar and Seeb Airport are shown in Figure II-1-5.

The year precipitation at Sohar ranges trace to 306.1 mm. It was not rain-fall in 1985. Average year precipitation is 126.2 mm, and the largest monthly average precipitation is 39.4 mm in February.

The year precipitation at Seeb Airport ranges 1.3 to 237.1 mm. Average year precipitation is 88.7 mm, and the largest monthly average precipitation





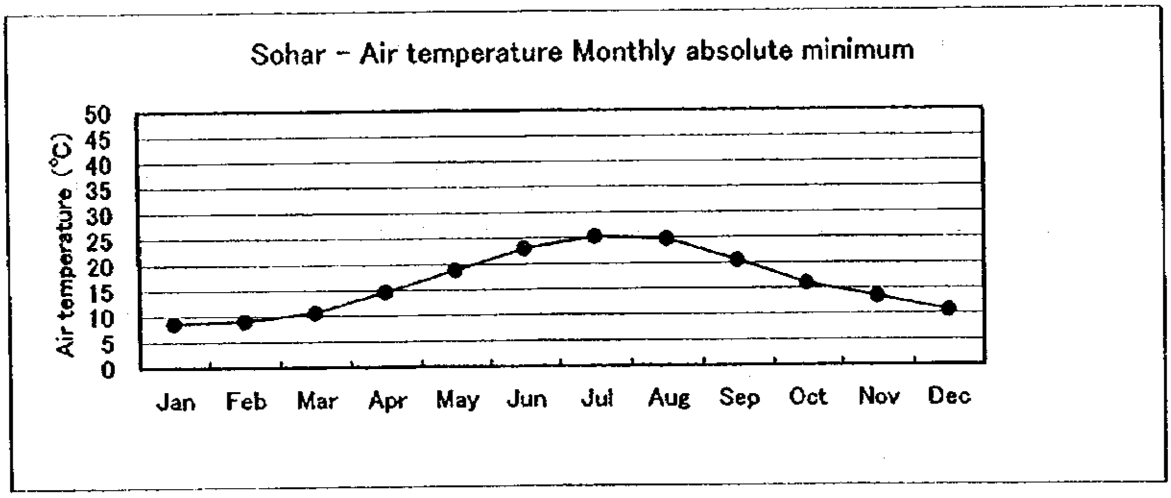
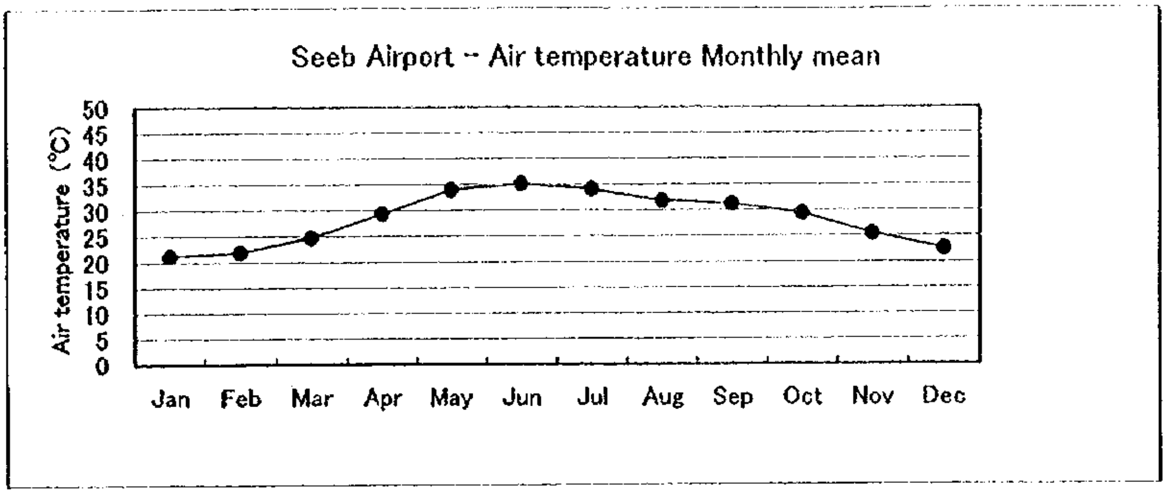
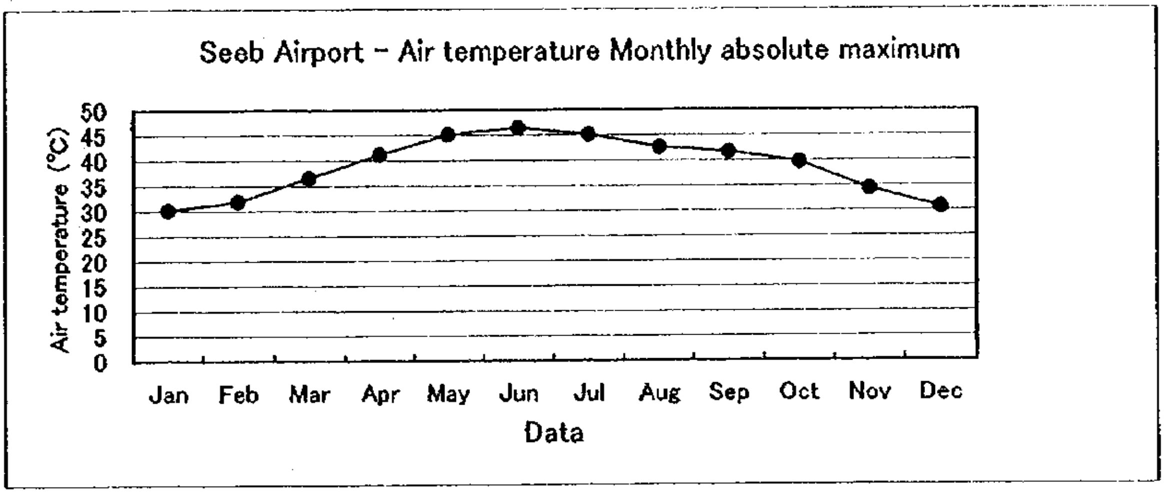


Figure II-1-3 Air Temperature in Sohar





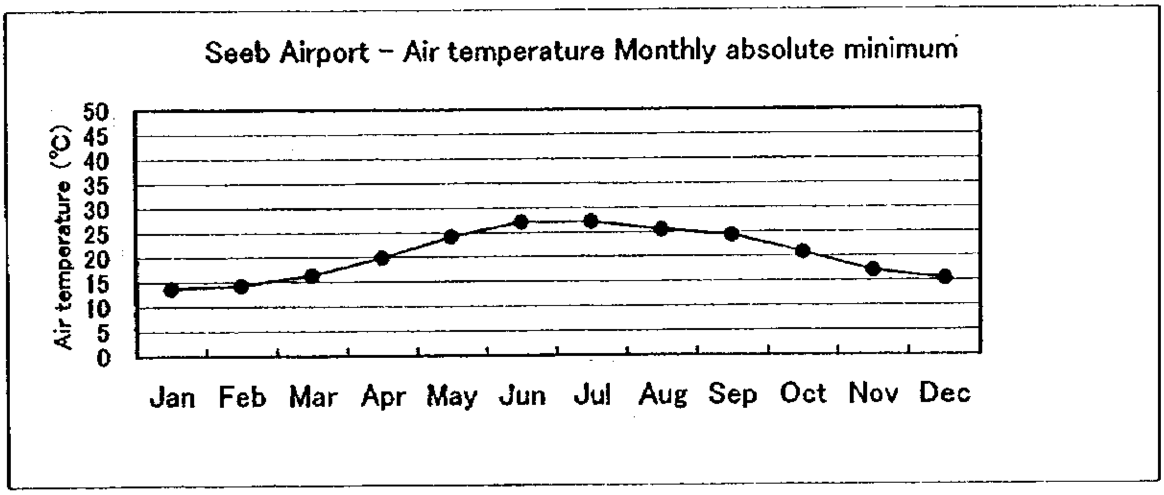
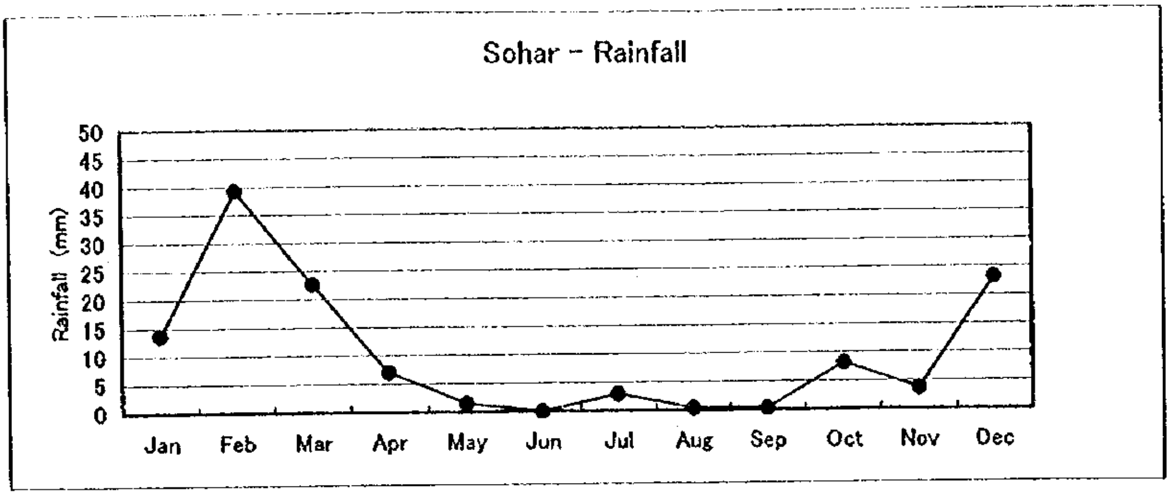


Figure II-1-4 Air Temperature in Seeb Airport



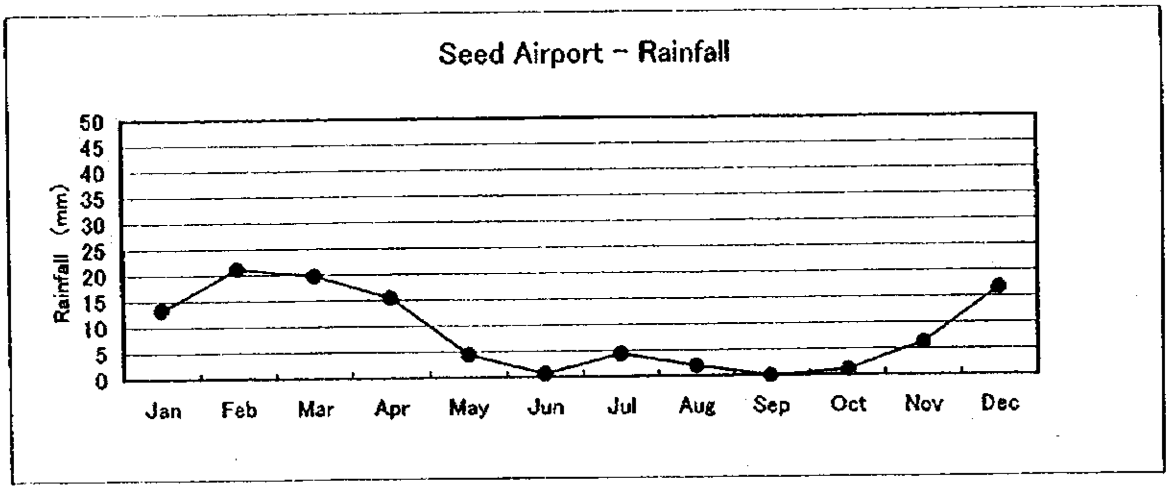


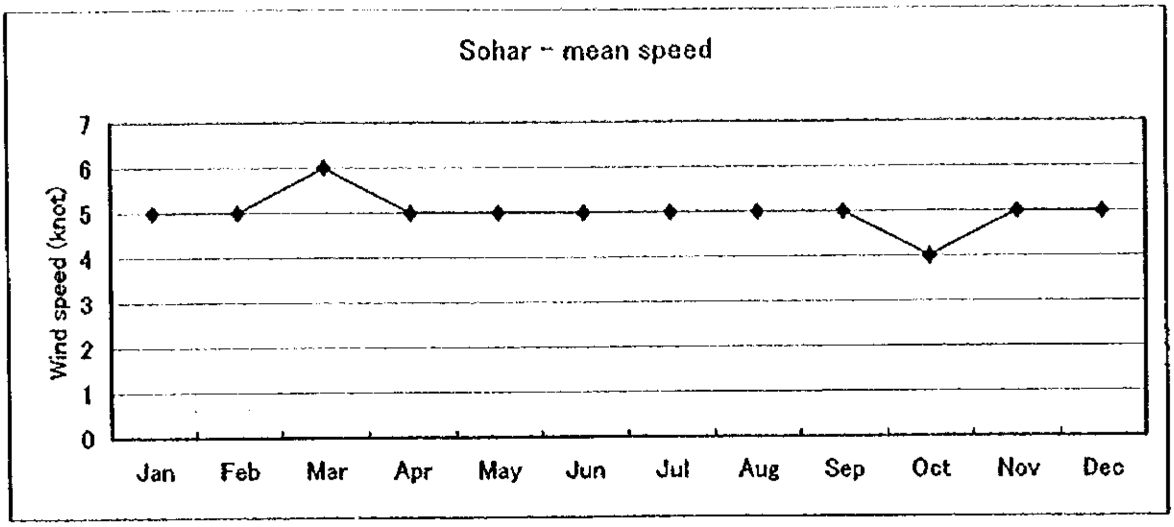
Figure II-1-5 Rain-fall in Sohar and Seeb Airport is 21.2 mm in February.

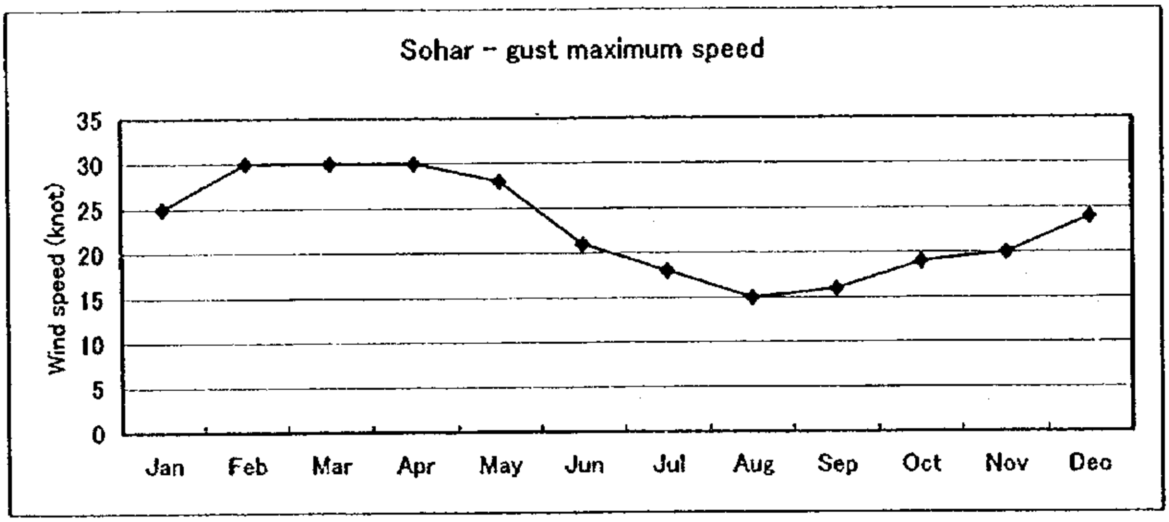
(3) Wind direction and speed

Wind direction and speed at Sohar and Seeb Airport are shown in Figure II-1-6 and Figure II-1-7.

The prevailing wind at Sohar is west to southwest wind, and wind speed in the year ranging from 4 to 6 knot/h is relatively stable.

The prevailing wind at Seeb Airport is northeast to east and south to south-southeast wind, and wind speed in the year ranging from 5 to 6 knot/h is relatively stable.





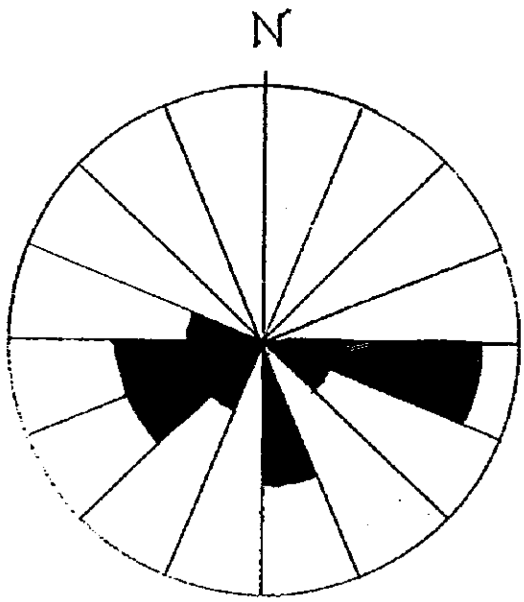
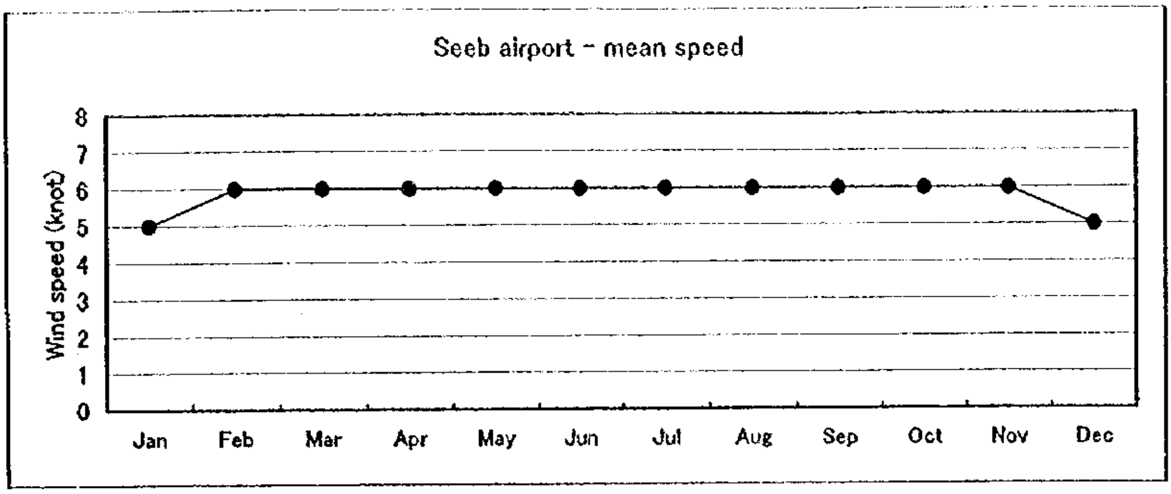
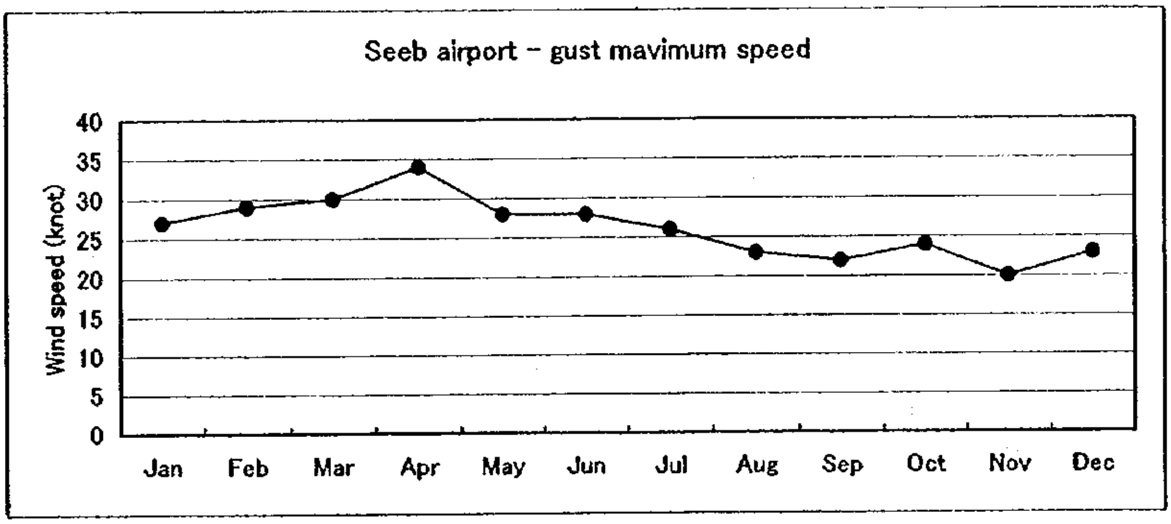


Figure II-1-6 Surface Wind Direction and Wind Speed in Sohar





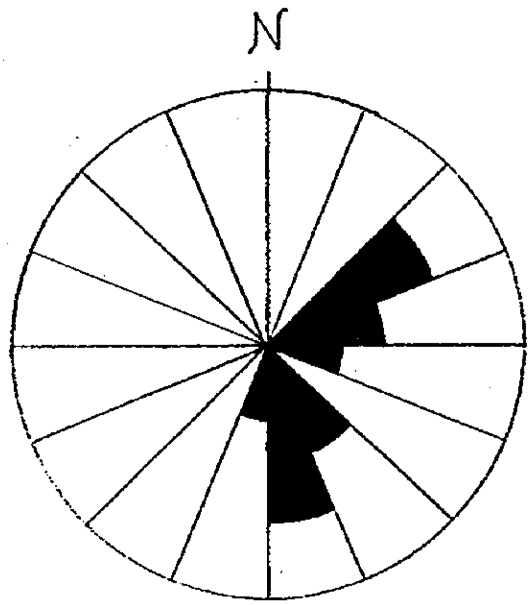


Figure II-1-7 Surface Wind Direction and Wind Speed in Seeb Airport

CHAPTER 2 WATER INVESTIGATION OF BORE HOLES

2－1 Objectives

The objectives of the water investigation of bore holes in the Ghuzayn District is to collect data and information concerning the condition of groundwater due to the recovery test of existing bore holes drilled in 1997 and 1998.

2－2 Investigation Area

The investigation area is within the existing bore holes in the Ghuzayn District, and the number of existing bore holes drilled since 1997 is 33 (Figure I-3-2).

2－3 Investigation Method

2－3－1 Selection of Bore Holes for the Recovery Test

It is necessary to select appropriate bore holes for the recovery test from existing bore holes and to measure groundwater level and water quality of groundwater including pH, Electric Conductivity and Water Temperature in the holes during selection.

2－3－2 Recovery Test

The recovery test of selected bore holes is to measure the recovering groundwater level until natural water level after drawn up groundwater by bailer.

Measurement time for the recovery test is shown in Table II-2-1.

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

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

2－3－3 Water Quality Analysis

Two kinds of water samples in the bore holes, shown as below, are collected before the recovery test.

- Deep groundwater samples in and around the orebody
- Surface groundwater samples

The number of the groundwater samples for water quality analysis is 33. The components of water quality are 10 items as shown in Table I-1-3.

2－4 Survey Results

2－4－1 Selection of Bore Holes for the Recovery Test

The condition of existing bore holes, total 37 holes including 17 holes drilled in 1996, 16 holes drilled in 1997 and 4 holes in 1998 (Table II-2-2) , was checked. The condition of existing bore holes is shown in Table II-2-3.

As a result of the hole investigation, 17 holes could not carry out further investigation due to inner collapse, etc. in the hole. And most of groundwater in the holes shows cloudy, glutinous, etc., because of the influence by the remains of drilling mud (EG-mud) used during drilling work. Especially, 7 bore holes, including MJOB-G17, G18, G19, G20, G23, G24 and G33 are strongly suffered by the drilling mud, so that these holes are assumed to get strict influence to the water quality and recovery test.

Consequently, 13 holes including MJOB-G2, G4, G7, G8, G15, G16, G17, G19, G25, G26, G28, G32 and G36 are selected as bore holes for the recovery test.

2－4－2 Result of Recovery Test

(1) Recovery test

Groundwater in selected bore holes (13 holes) was confirmed to be reached natural or stable water level after drawn groundwater in the holes by bailer.

Incidentally, most of groundwater in the holes changes to cloudy and glutinous water in deeper part of the hole, although the surface of groundwater shows relatively clean.

Result of the recovery test is shown in Table II-2-4 (1)～(3) and Figure II-2-4 (1)～(5).

Table II-2-2 Existing Bore Holes in the Survey Area

Bore holes	Coodination		Ground level	Length	Inclination	Bearing	Drilled
(No.)	N (km)	E (km)	(m)	(m)	(deg.)		year
MJOB-G1	2635.130	498.729	187.40	186.50	-70	S25E	1996
MJOB-G2	2635.179	498.923	189.25	305.40	-90		1996
MJOB-G3	2635.264	498.644	190.00	300.40	-70	S25E	1996
MJOB-G4	2635.179	498.099	188.15	300.50	-90		1996
MJOB-G5	2634.791	497.989	191.80	300.20	-90		1996
MJOB-G6	2634.840	498.389	192.40	300.30	-90		1996
MJOB-G7	2635.276	497.868	187.40	300.15	-90		1996
MJOB-G8	2635.034	498.341	192.10	200.25	-90		1996
MJOB-G9	2635.240	498.547	191.20	200.20	-90		1996
MJOB-G10	2635.191	498.766	187.90	200.10	-90		1996
MJOB-G11	2635.288	498.741	186.10	200.20	-90		1996
MJOB-G12	2635.264	498.644	190.00	200.30	-90		1996
MJOB-G13	2635.276	498.693	186.80	200.10	-90		1996
MJOB-G14	2634.852	498.026	191.45	250.10	-90		1996
MJOB-G15	2634.888	497.965	191.10	250.15	-90		1996
MJOB-G16	2634.731	497.953	192.90	201.85	-90		1996
MJOB-G17	2634.828	497.929	191.20	250.25	-90		1996
MJOB-G18	2634.973	497.892	189.70	300.25	-90		1997
MJOB-G19	2634.997	497.989	190.25	300.40	-90		1997
MJOB-G20	2635.082	497.917	189.15	300.45	-90		1997
MJOB-G21	2634.913	498.062	190.80	250.25	-90		1997
MJOB-G22	2634.755	498.050	193.20	200.60	-90		1997
MJOB-G23	2635.313	498.220	188.40	350.10	-90		1997
MJOB-G24	2635.252	498.184	187.85	350.25	-90		1997
MJOB-G25	2635.197	498.687	186.10	200.10	-90		1997
MJOB-G26	2634.815	498.911	198.70	200.15	-90		1997
MJOB-G27	2635.076	498.814	189.20	201.05	-90		1997
MJOB-G28	2634.718	498.111	194.40	150.20	-90		1997
MJOB-G29	2634.828	498.135	192.20	200.15	-90		1997
MJOB-G30	2635.362	496.765	169.10	250.20	-90		1997
MJOB-G31	2635.386	496.862	169.20	235.45	-90		1997
MJOB-G32	2635.483	496.838	169.00	250.50	-90		1997
MJOB-G33	2635.580	496.813	168.80	300.00	-90		1997
MJOB-G34	2635.338	496.668	179.10	250.40	-90		1998
MJOB-G35	2635.410	496.959	170.50	200.10	-90		1998
MJOB-G36	2635.459	496.741	169.20	251.00	-90		1998
MJOB-G37	2635.556	496.716	168.20	270.15	-90		1998

TableII-2-3 Selected Bore for Hydrological Investigation in the Survey Area

Bore holes No.	Ground level (m)	Depth of groundwater (m)	Groundwater level (m)	Recovery test	Remarks
MJOB-G1	187.40	-	-	-	Inclined bore hole
MJOB-G2	189.25	-20.24	169.01	done	
MJOB-G3	190.00	-	-	-	Inclined bore hole
MJOB-G4	188.15	-17.88	170.27	done	
MJOB-G5	191.80	-15.11	176.69	-	
MJOB-G6	192.40	-	-	-	Closed by collapse at -1.55m deep
MJOB-G7	187.40	-21.63	165.77	done	
MJOB-G8	192.10	-20.94	171.16	done	
MJOB-G9	191.20	-22.86	168.34	-	
MJOB-G10	187.90	-18.04	169.86	-	
MJOB-G11	186.10	-19.97	166.13	-	
MJOB-G12	190.00	-23.96	166.04	-	
MJOB-G13	186.80	-20.03	166.77	-	
MJOB-G14	191.45	-16.00	175.45	-	
MJOB-G15	191.10	-14.39	176.71	done	
MJOB-G16	192.90	-16.00	176.90	done	
MJOB-G17	191.20	-14.62	176.58	done	
MJOB-G18	189.70	-14.83	174.87	-	Too small diameter of strainer
MJOB-G19	190.25	-15.41	174.84	done	
MJOB-G20	189.15	-15.26	173.89	-	Too small diameter of strainer
MJOB-G21	190.80	-	-	-	Closed by collapse (?) at -11.0m deep
MJOB-G22	193.20	-15.75	177.45	-	Too small diameter of strainer
MJOB-G23	188.40	-18.30	170.10	-	Drilling mud remained
MJOB-G24	187.85	-19.10	168.75	-	Drilling mud remained
MJOB-G25	186.10	-20.51	165.59	done	
MJOB-G26	198.70	-32.67	166.03	done	
MJOB-G27	189.20	-	-	-	Closed by collapse (?) at -4.50m deep
MJOB-G28	194.40	-18	176.40	done	
MJOB-G29	192.20	-	-	-	Closed by collapse
MJOB-G30	169.10	-	-	-	Filled by sand (?) at -4.30m deep
MJOB-G31	169.20	-	-	-	Filled by sand (?) at -3.10m deep
MJOB-G32	169.00	-13.65	155.35	done	
MJOB-G33	168.80	-12.39	156.41	-	Drilling mud remained
MJOB-G34	179.10	-	-	-	Closed by collapse (?) at -5.46m deep
MJOB-G35	170.50	-	-	-	Filled by sand (?) at -4.35m deep
MJOB-G36	169.20	-9.40	159.80	done	
MJOB-G37	168.20	-	-	-	Filled by sand (?) at -6.00m deep

Table II-2-4 Result of Recovery Test in the Survey Area (1)

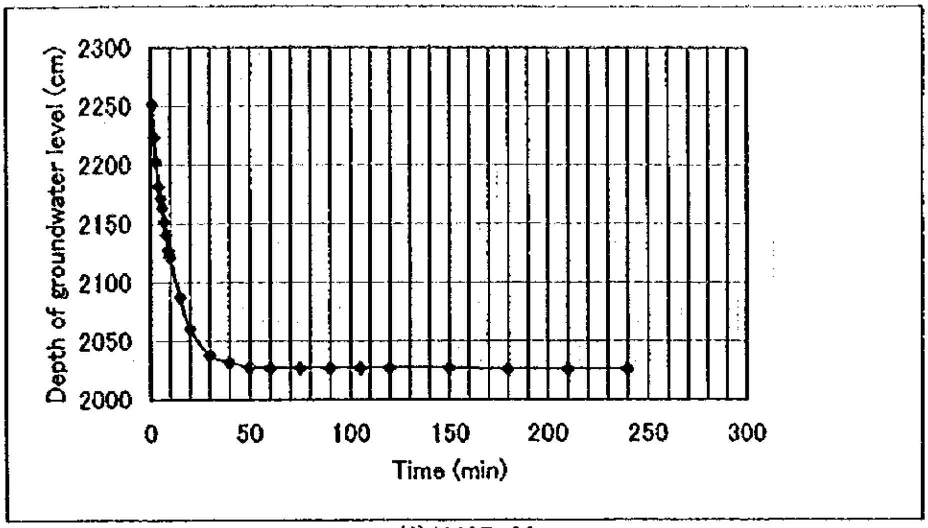
MJOB-Q2		MJOB-G4		MJOB-G7		MJOB-Q8		MJOB-Q15	
Time (min)	Water level (m)	Time (min)	Water level (m)	Time (min)	Water level (m)	Time (min)	Water level (m)	Time (min)	Water level (m)
1	22.52	1	23.35	1	21.71	1	21.46	1	16.96
2	22.24	2	23.15	2	21.71	2	21.41	2	16.93
3	22.03	3	22.85	3	21.69	3	21.39	3	16.84
4	21.82	4	22.80	4	21.69	4	21.37	4	16.78
5	21.72	5	22.73	5	21.69	5	21.35	5	16.67
6	21.64	6	22.69	6	21.69	6	21.34	6	16.59
7	21.52	7	22.64	7	21.69	7	21.34	7	16.49
8	21.41	8	22.60	8	21.69	8	21.33	8	16.39
9	21.28	9	22.57	9	21.69	9	21.33	9	16.33
10	21.22	10	22.53	10	21.69	10	21.325	10	16.24
15	20.88	15	22.42	15	21.69	15	21.325	15	15.91
20	20.61	20	22.33	20	21.69	20	21.325	20	15.58
30	20.38	30	21.90	30	21.69	30	21.325	30	15.20
40	20.32	40	21.60	40	21.69	40	21.32	40	14.90
50	20.28	50	21.33	50	21.68	50	21.32	50	14.69
60	20.27	60	21.07	60	21.68	60	21.32	60	14.56
75	20.27	75	20.76	75	21.68	75	21.32	75	14.47
90	20.27	90	20.54	90	21.68	90	21.32	90	14.37
105	20.27	105	20.32	105	21.68	105	21.32	105	14.34
120	20.27	120	20.15	120	21.68	120	21.32	120	14.32
150	20.27	150	19.85	150	-	150	21.32	150	14.30
180	20.26	180	19.75	180	-	180	21.32	180	14.29
210	20.26	210	19.65	210	-	210	21.31	210	14.285
240	20.26	240	19.56	240	-	240	21.31	240	14.27
270	-	270	19.50	270	-	270	21.31	270	14.27
300	-	300	19.47	300	-	300	21.31	300	14.27
360	-	360	19.385	360	-	360	21.31	360	14.27
420	-	420	19.30	420	-	420	-	420	-
480	-	480	19.21	480	-	480	-	480	-
540	-	540	-	540	-	540	-	540	-
600	-	600	-	600	-	600	-	600	-
660	-	660	-	660	-	660	-	660	-
720	-	720	-	720	-	720	-	720	-
960	-	960	-	960	-	960	-	960	-
1,020	-	1,020	-	1,020	-	1,020	-	1,020	-
1,080	-	1,080	-	1,080	-	1,080	-	1,080	-
1,320	-	1,320	-	1,320	-	1,320	-	1,320	-
1,380	-	1,380	-	1,380	-	1,380	-	1,380	-
1,440	-	1,440	-	1,440	-	1,440	-	1,440	-
2,850	20.27	1,500	18.66						

Table II-2-4 (2)

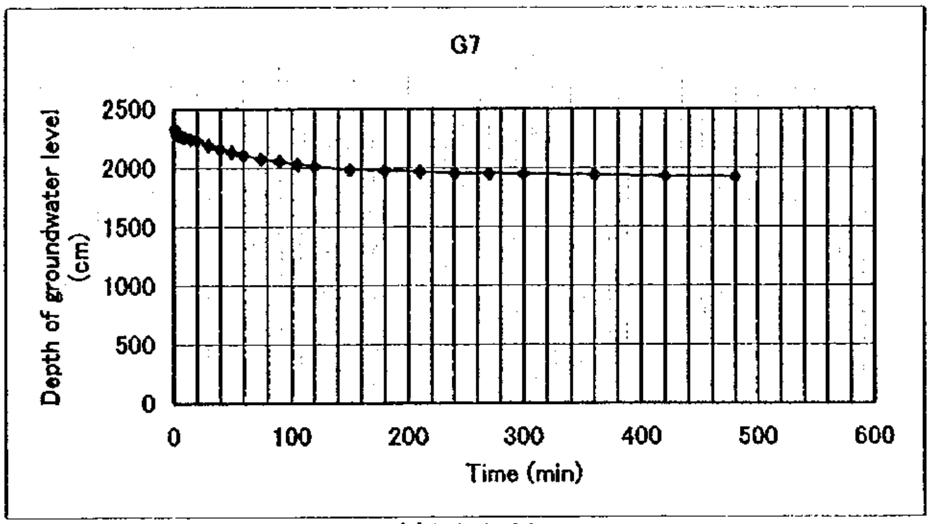
MJOB-G16		MJOB-G17		MJOB-G19		MJOB-G25		MJOB-G26	
Time (min)	Water level (m)	Time (min)	Water level (m)	Time (min)	Water level (m)	Time (min)	Water level (m)	Time (min)	Water level (m)
1	18.27	1	14.92	1	18.37	1	26.55	1	34.67
2	18.24	2	14.90	2	18.33	2	26.53	2	34.45
3	18.22	3	14.88	3	18.30	3	26.51	3	34.18
4	18.20	4	14.875	4	18.28	4	26.49	4	34.01
5	18.18	5	14.87	5	18.24	5	26.47	5	33.97
6	18.175	6	14.855	6	18.19	6	26.45	6	33.66
7	18.15	7	14.85	7	18.13	7	26.44	7	33.56
8	18.12	8	14.85	8	18.08	8	26.43	8	33.46
9	18.08	9	14.84	9	18.04	9	26.42	9	33.37
10	18.06	10	14.83	10	18.01	10	26.40	10	33.29
15	17.95	15	14.81	15	17.76	15	26.37	15	33.17
20	17.87	20	14.80	20	17.53	20	26.34	20	33.03
30	17.70	30	14.75	30	17.21	30	26.32	30	32.92
40	17.58	40	14.74	40	16.91	40	26.29	40	32.87
50	17.46	50	14.72	50	16.64	50	26.25	50	32.85
60	17.38	60	14.70	60	16.46	60	26.21	60	32.83
75	17.26	75	14.69	75	16.19	75	26.15	75	32.82
90	17.16	90	14.69	90	16.07	90	26.09	90	32.81
105	17.07	105	14.68	105	15.95	105	26.05	105	32.80
120	17.02	120	14.68	120	15.81	120	26.00	120	32.795
150	16.92	150	14.67	150	15.68	150	25.89	150	32.78
180	16.83	180	14.66	180	15.53	180	25.79	180	32.77
210	16.77	210	14.65	210	15.50	210	-	210	32.76
240	16.72	240	14.65	240	15.47	240	-	240	32.76
270	16.69	270	14.65	270	15.46	270	-	270	32.76
300	16.66	300	14.65	300	15.45	300	-	300	32.76
360	16.65	360	14.65	360	15.45	360	-	360	-
420	-	420	-	420	15.45	420	-	420	-
480	-	480	-	480	15.45	480	-	480	-
540	-	540	-	540	-	540	-	540	-
600	-	600	-	600	-	600	-	600	-
660	-	660	-	660	-	660	-	660	-
720	-	720	-	720	-	720	-	720	-
960	-	960	-	960	-	960	-	960	-
1,020	-	1,020	-	1,020	-	1,020	-	1,020	-
1,080	-	1,080	-	1,080	-	1,080	-	1,080	-
1,320	-	1,320	-	1,320	-	1,320	-	1,320	-
1,380	-	1,380	14.80	1,380	-	1,380	-	1,380	-
1,440	-	1,440	-	1,440	15.45	1,440	-	1,440	-
2,620	16.23					2,730	20.82	2,990	32.70

Table II-2-4 (3)

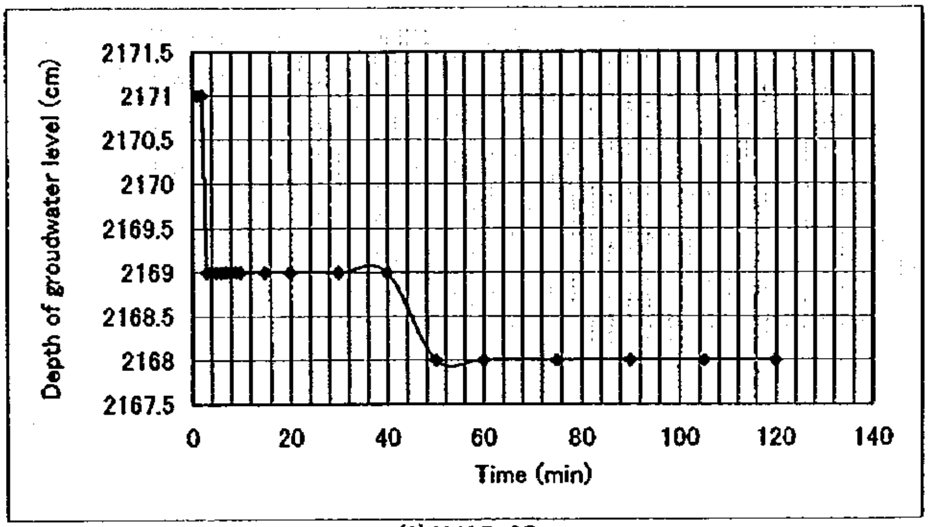
MJOB-G28		MJOB-G32		MJOB-G36	
Time (min)	Water level (m)	Time (min)	Water level (m)	Time (min)	Water level (m)
1	19.37	1	-	1	9.77
2	19.345	2	-	2	9.57
3	19.30	3	14.48	3	9.57
4	19.28	4	14.41	4	9.57
5	19.26	5	14.34	5	-
6	19.24	6	14.27	6	-
7	19.22	7	14.22	7	-
8	19.20	8	14.16	8	-
9	19.185	9	14.12	9	-
10	19.17	10	14.07	10	-
15	19.09	15	13.97	15	-
20	19.025	20	13.90	20	-
30	18.92	30	13.84	30	-
40	18.83	40	13.82	40	-
50	18.75	50	13.81	50	-
60	18.70	60	13.81	60	-
75	18.62	75	13.805	75	-
90	18.57	90	13.80	90	-
105	18.51	105	13.80	105	-
120	18.48	120	13.79	120	-
150	18.41	150	13.78	150	-
180	18.37	180	13.78	180	-
210	18.34	210	13.78	210	-
240	18.305	240	13.78	240	-
270	18.27	270	-	270	-
300	18.25	300	-	300	-
360	18.23	360	-	360	-
420	18.21	420	-	420	-
480	18.20	480	-	480	-
540	-	540	-	540	-
600	-	600	-	600	-
660	-	660	-	660	-
720	-	720	-	720	-
960	-	960	-	960	-
1,020	-	1,020	-	1,020	-
1,080	-	1,080	-	1,080	-
1,320	-	1,320	-	1,320	-
1,380	18.11	1,380	-	1,380	-
1,440	-	1,440	-	1,440	-



(1) MJOB-G2

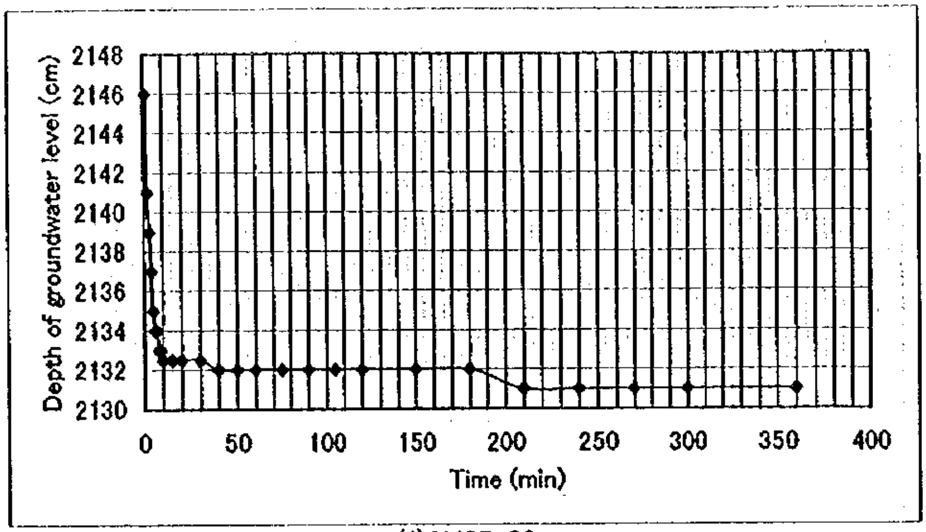


(2) MJOB-G4

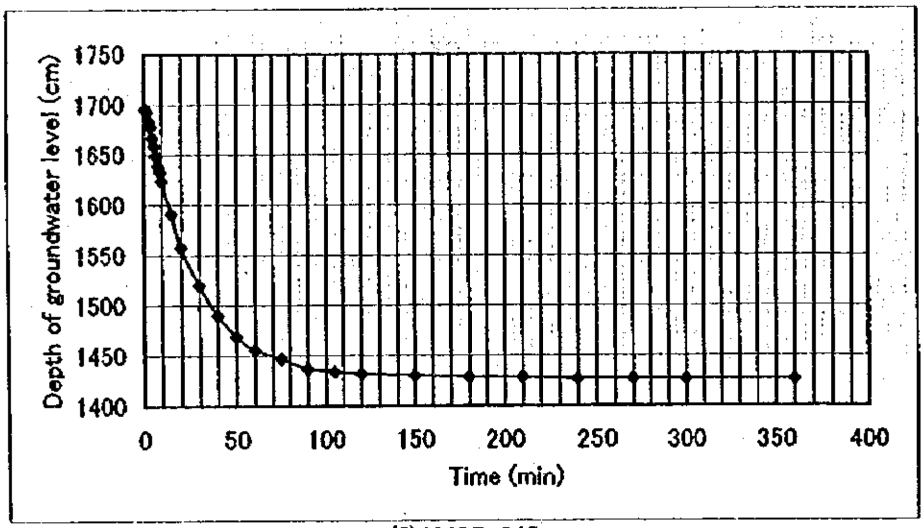


(3) MJOB-G7

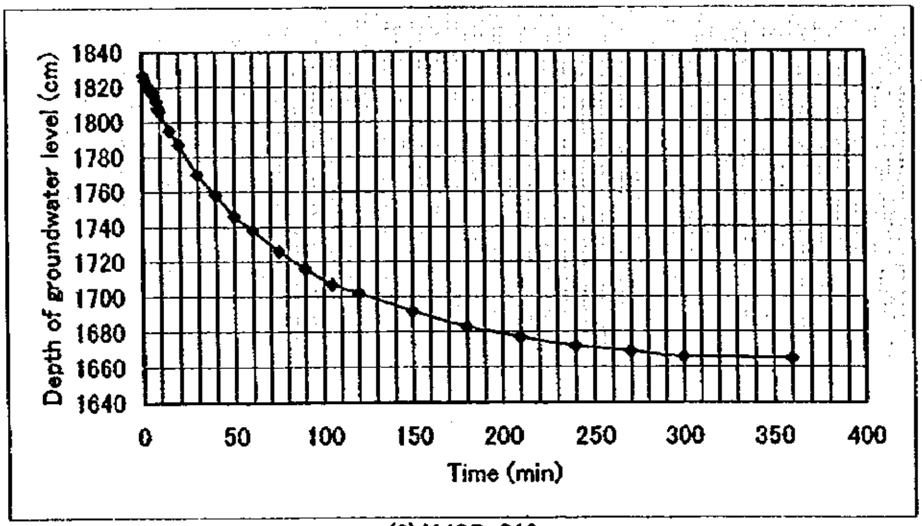
Figure II-2-1 Result of Recovery Test in the Ghuzayn District (1)



(4) MJOB-G8

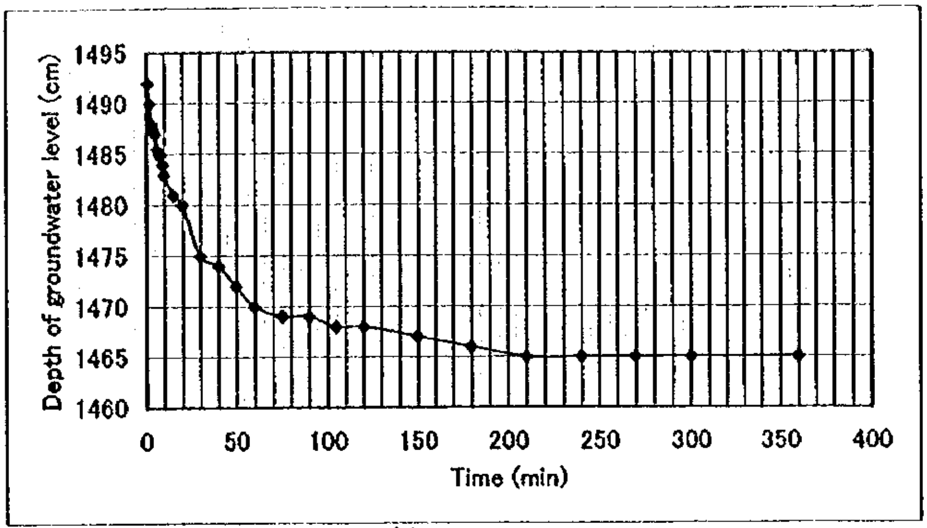


(5) MJOB-G15

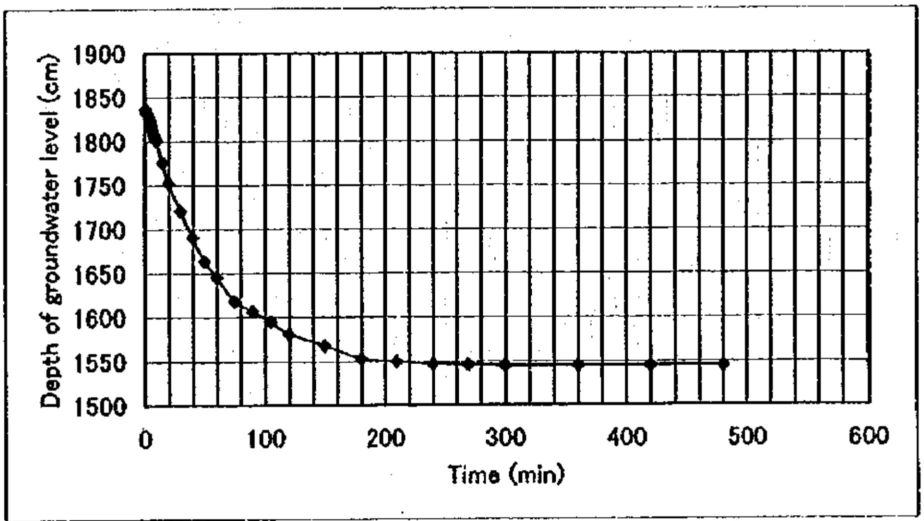


(6) MJOB-G16

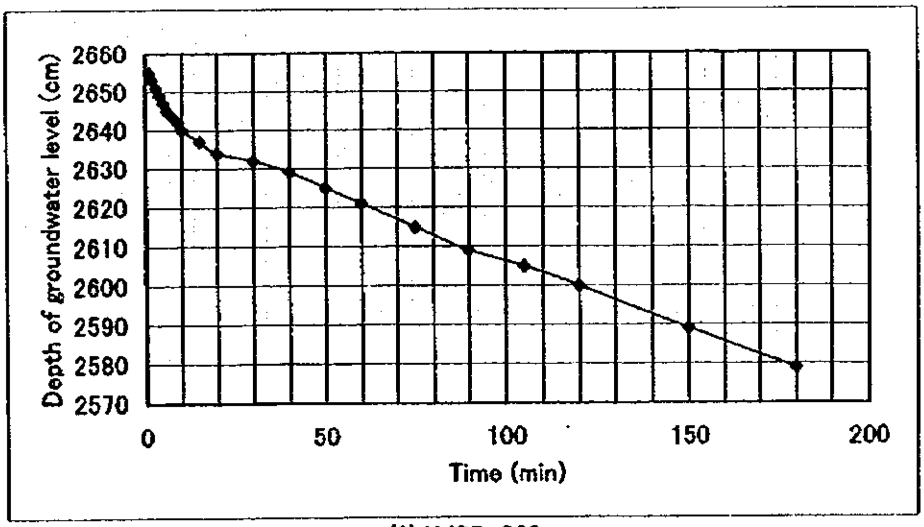
Figure II-2-1 (2)



(7) MJOB-G17

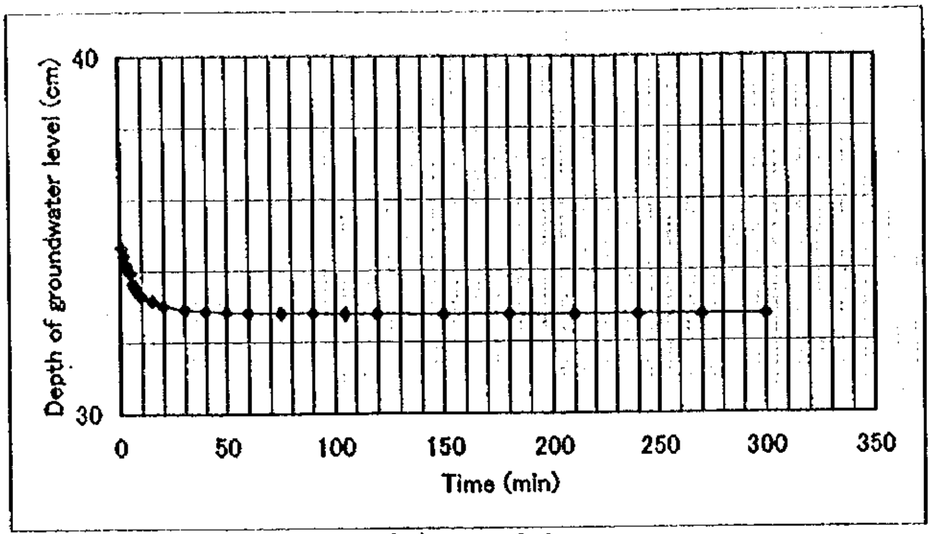


(8) MJOB-G19

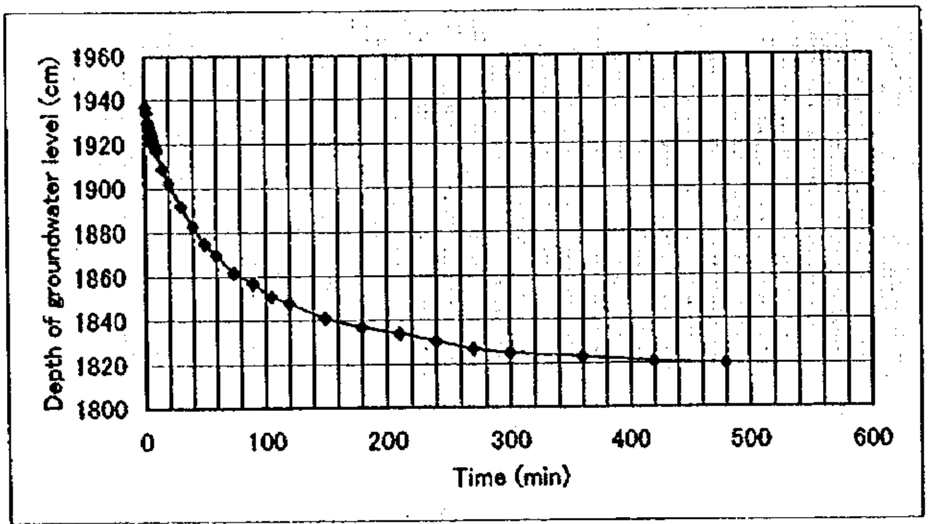


(9) MJOB-G25

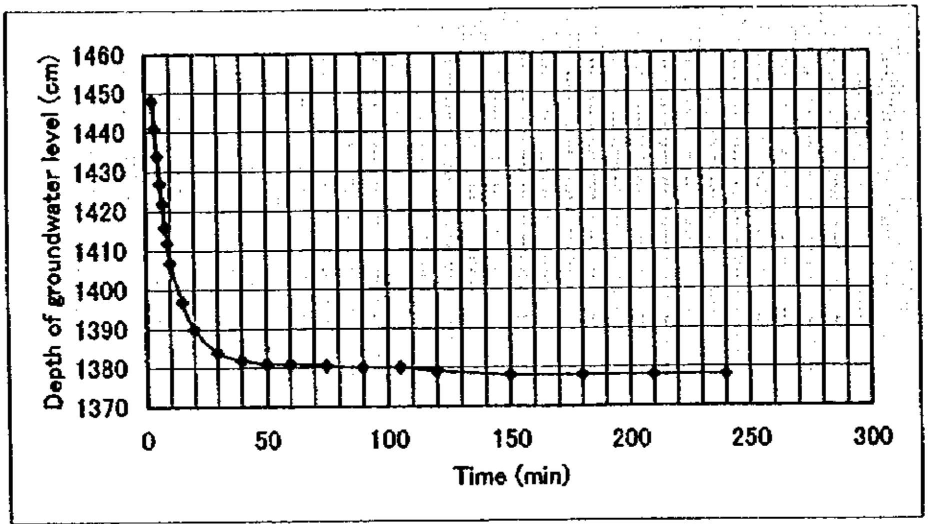
Figure II-2-1 (3)



(10) MJOB-G26

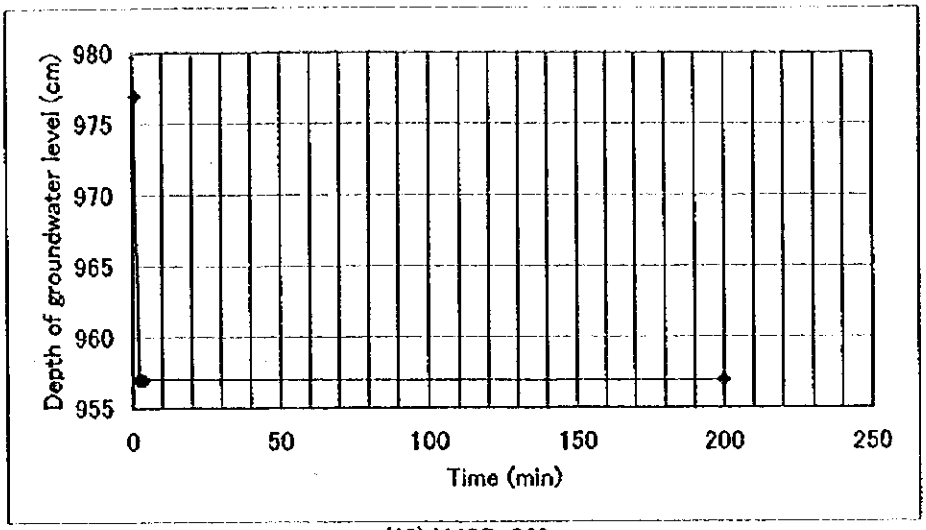


(11) MJOB-G28



(12) MJOB-G32

Figure II-2-1 (4)



(13) MJOB-G36

Figure II-2-1 (5)

(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)
$t1$	:	Time-1 elapsed	(s)
$t2$	:	Time-2 elapsed	(s)
$h1$	:	Difference of water level at Time-1 elapsed	(cm)
$h2$	:	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-G2	60	600	228	98	28266	7.57	7.57	1.30E-05
2	MJOB-G4	60	600	550	468	27695	7.57	7.57	2.53E-06
3	MJOB-G7	60	180	3	1	27842	7.57	7.57	7.72E-05
4	MJOB-G8	60	420	50	38	17874	7.57	7.57	9.47E-06
5	MJOB-G15	60	600	261	189	23304	7.57	7.57	5.89E-06
6	MJOB-G16	60	600	228	207	18355	7.57	7.57	2.17E-06
7	MJOB-G17	60	600	26	17	23531	7.57	7.57	7.69E-06
8	MJOB-G19	60	600	290	254	28201	7.57	7.57	2.05E-06
9	MJOB-G25	60	900	585	567	17351	8.89	8.66	6.43E-07
10	MJOB-G26	60	600	198	60	16518	7.57	7.57	2.94E-05
11	MJOB-G28	60	600	131	111	13078	7.57	7.57	5.00E-06
12	MJOB-G32	60	600	90	31	23572	7.57	7.57	1.93E-05
13	MJOB-G36	0	60	78	1	24144	7.57	7.57	6.94E-04

The permeability coefficient in the district ranges from 10^{-4} to 10^{-6} cm/s. The permeability coefficient of MJOB-G36 is 10^{-4}cm/s and relatively good.

2－4－3 Water Quality Analysis

(1) Measurement of water quality

The bore holes being possible to take samples of surface and deep groundwater in the holes are 23 and 10 holes, respectively. These water samples were measured pH, Electric Conductivity and water temperature.

Although the sampling depth of deep groundwater was planned to be inside of the orebody, bore holes of MJOB-G5, G16, G25 and G26 could not reached to the sphere of orebody because of collapse of the bore hole.

The measurement result of water quality is shown in Table II-2-5.

The water quality of groundwater in the bore hoes shows that pH ranges from 7.08 to 11.28. Groundwater of MJOB-G16, G17 and G25 shows alkali and ranges from pH 9 to 11, because of the influence of cementing during drilling work.

Electric conductivity ranges from 20.5 to >1999 μS/cm, and groundwater of MJOB-G8, G12, G32, and G36 shows more than 1000 μS/cm, because of the influence of drilling mud during drilling work.

Water temperature ranges from 28.7 to 35.3 ℃. The highest water temperature in the holes is 35.3 ℃ of MJOB-G14.

(2) Water quality analysis

The result of water quality analysis of the groundwater in the holes is shown in Table II-2-6.

The concentration of As is less than minimum limit of determination.

The concentration of Cr ranges from <0.02 to 0.13 mg/l. The groundwater of MJOB-G15, G16, G17 and G22 shows relatively high concentration of Cr.

The concentration of Cu ranges from 0.02 to 0.46 mg/l. The groundwater of MJOB-G22 shows relatively high concentration of Cu (0.45～0.46 mg/l).

The concentration of Fe ranges from 0.93 to 32.90 mg/l. The surface and deep groundwater of MJOB-G8, G13, G18, G22 and G36 shows relatively high concentration of Fe (13.60～32.90 mg/l). And it is not recognized to be clear difference between surface and deep groundwater.

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

The concentration of Mn ranges from 0.05 to 0.84 mg/l. The deep

Table II-2-6 Analytical Result of the Groundwater in the Survey Area

No.	Bore holes	Sample No. \ Items	pH	EC	Temp.	As	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	SO₄
				μS/cm	℃	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	MJO-G2	GD-21	7.28	174.2	33.2	<0.01	<0.02	0.02	1.49	<0.01	0.12	<0.02	<0.02	0.03	310
2	MJO-G4	GD-41	8.08	76.1	33.4	<0.01	0.02	0.02	8.11	<0.01	0.10	<0.02	<0.02	1.18	110
3	MJO-G5	GD-51	7.59	147.2	33.3	<0.01	0.02	0.17	11.43	<0.01	0.07	<0.02	0.12	0.93	240
4		GD-52	7.80	155.3	34.9	<0.01	<0.02	0.08	6.27	<0.01	0.18	<0.02	<0.02	0.08	220
5	MJO-G7	GD-71	7.81	140.1	32.5	<0.01	0.05	0.02	13.57	<0.01	0.14	0.02	<0.02	0.99	190
6	MJO-G8	GD-81	8.14	1,049	33.3	<0.01	0.05	0.04	20.76	<0.01	0.41	<0.02	<0.02	3.65	790
7		GD-82	8.65	1,122	33.4	<0.01	<0.02	0.04	2.31	<0.01	0.16	<0.02	<0.02	0.05	810
8	MJO-G9	GD-91	7.88	115.4	33.6	<0.01	<0.02	0.02	1.55	<0.01	0.05	0.02	<0.02	0.97	150
9	MJO-G10	GD-101	7.47	164.5	33.3	<0.01	<0.02	0.02	0.93	<0.01	0.06	<0.02	<0.02	0.02	280
10	MJO-G11	GD-111	7.67	82.6	33.5	<0.01	<0.02	0.03	3.24	<0.01	0.21	<0.02	<0.02	0.49	150
11	MJO-G12	GD-121	8.03	215.0	32.6	<0.01	<0.02	0.02	2.45	<0.01	0.10	<0.02	<0.02	0.93	620
12	MJO-G13	GD-131	7.92	172.6	33.5	<0.01	0.09	0.02	32.90	<0.01	0.23	<0.02	<0.02	7.00	340
13	MJO-G14	GD-141	7.88	198.7	33.7	<0.01	<0.02	0.05	2.82	<0.01	0.15	<0.02	<0.02	0.19	290
14		GD-142	8.08	289.0	35.3	<0.01	<0.02	0.04	1.09	<0.01	0.21	<0.02	<0.02	0.05	250
15	MJO-G15	GD-151	8.33	138.9	33.6	<0.01	0.13	0.04	6.85	<0.01	0.09	0.05	<0.02	1.40	240
16		GD-152	7.74	146.5	34.4	<0.01	<0.02	0.05	2.02	<0.01	0.17	<0.02	<0.02	0.04	190
17	MJO-G16	GD-161	9.62	92.4	33.6	<0.01	0.07	0.04	3.94	<0.01	0.09	0.05	<0.02	0.07	150
18		GD-162	11.28	180.5	33.7	<0.01	0.07	0.05	4.28	<0.01	0.13	<0.02	<0.02	0.06	140
19	MJO-G17	GD-171	9.85	120.6	33.0	<0.01	0.09	0.03	2.72	<0.01	0.09	<0.02	<0.02	4.90	220
20	MJO-G18	GD-181	7.99	156.2	32.9	<0.01	0.07	0.09	17.11	<0.01	0.40	0.15	0.21	0.08	200
21	MJO-G19	GD-191	7.88	129.6	33.1	<0.01	<0.02	0.03	3.37	<0.01	0.16	<0.02	<0.02	0.33	170
22	MJO-G20	GD-201	8.24	136.0	32.8	<0.01	0.04	0.05	6.21	<0.01	0.18	0.06	0.20	0.02	190
23	MJO-G22	GD-221	8.12	144.4	30.3	<0.01	0.07	0.46	15.17	<0.01	0.34	0.10	0.35	0.22	230
24		GD-222	8.13	142.8	34.4	<0.01	0.07	0.45	17.40	<0.01	0.53	0.09	0.62	0.22	210
25	MJO-G25	GD-251	10.49	100.1	33.5	<0.01	0.05	0.07	8.75	<0.01	0.10	0.06	<0.02	0.68	130
26		GD-252	8.99	246.0	32.0	<0.01	<0.02	0.04	1.21	<0.01	0.14	<0.02	<0.02	0.09	420
27	MJO-G26	GD-261	7.51	389.0	33.4	<0.01	<0.02	0.05	4.37	<0.01	0.25	<0.02	<0.02	1.62	1110
28		GD-262	7.51	432.0	32.7	<0.01	<0.02	0.05	6.58	<0.01	0.84	<0.02	<0.02	1.26	1230
29	MJO-G28	GD-281	8.05	20.5	33.1	<0.01	<0.02	0.05	1.40	<0.01	0.23	<0.02	<0.02	0.14	650
30	MJO-G32	GD-321	7.08	145.5	28.7	<0.01	<0.02	0.08	2.20	<0.01	0.17	<0.02	<0.02	0.06	130
31		GD-322	7.66	>1999	32.4	<0.01	<0.02	0.12	4.81	<0.01	0.32	<0.02	0.08	0.08	180
32	MJO-G36	GD-361	8.02	128.4	31.3	<0.01	<0.02	0.05	13.60	<0.01	0.20	<0.02	<0.02	0.05	150
33		GD-362	7.34	1,593	31.0	<0.01	<0.02	0.08	4.93	<0.01	0.51	<0.02	0.20	0.07	160
34		GW-1	7.67	148.8	28.6	<0.01	<0.02	0.04	0.15	<0.01	0.01	<0.02	<0.02	<0.01	140
35		GW-2	7.63	108.1	32.1	<0.01	<0.02	0.04	0.20	<0.01	0.01	<0.02	<0.02	<0.01	120
36		GS-1	8.36	109.5	27.1	<0.01	<0.02	0.03	0.14	<0.01	0.02	<0.02	<0.02	<0.01	140
37		GS-2	8.46	115.7	29.0	<0.01	<0.02	0.03	0.14	<0.01	<0.01	<0.02	<0.02	<0.01	140
38		GS-3	7.87	133.3	28.6	<0.01	<0.02	0.04	0.32	<0.01	0.02	<0.02	<0.02	0.02	140
	Maximum		11.28	>1999	35.3	<0.01	0.13	0.46	32.90	<0.01	0.84	0.15	0.62	7.00	1230
	Minimum		7.08	20.5	27.1	<0.01	<0.02	0.02	0.14	<0.01	<0.01	<0.02	<0.02	<0.01	110
	Average		8.16	247.6	32.5	<0.01	0.06	0.07	6.23	<0.01	0.19	0.07	0.25	0.82	303

groundwater of MJOB-G8, G18, G22, G26, G32 and G36 shows high concentration of Mn (0.32~0.84 mg/l). The concentration of Mn of deep groundwater indicates higher than that of surface groundwater.

The concentration of Ni ranges from 0.02 to 0.62 mg/l. The groundwater of MJOB-G18 and G22 shows relatively high concentration of Ni.

The concentration of Pb ranges from <0.02 to 0.15 mg/l. The groundwater of MJOB-G18, G20 and G22 shows relatively high concentration of Pb.

The concentration of Zn ranges from 0.02 to 7.00 mg/l. The groundwater of MJOB-G8, G13 and G17 shows high concentration of Zn (3.65~7.00 mg/l).

The concentration of SO_4 ranges from 110 to 1230 mg/l. The deep groundwater of MJOB-G8, G12 and G26 shows high concentration of SO_4.