CHAPTER 8 ENVIRONMENTAL STUDIES

8-1 Drilling Survey

Groundwater investigation was conducted in order to clarify concerns on the behavior of the groundwater, permeability and water quality in and around area of Rakah and Hayl as Safil deposits. This study was conducted by drilling holes for water level recovery tests and water quality analysis.

8-1-1 Result of the drilling survey

(1) Drilling works

Drilling works were made at the 5 points presented in TableⅢ-8-1 and Fig.Ⅲ-8-1.

TableⅢ-8-1 Result of Drilling Survey

Drill Hole No.	Location	UTM Coordination (m)		Ground Level (m)	Depth (m)	Pumping test	Water sampling
		Northing	Easting				
MJOY-W1	Wadi Falaj Sudayriyin	2617235	451334	630	75.00	S.*1, C. *2, R. *3	1
MJOY-W2	Wadi Rakah	2617148	457335	660	75.00	S., C., R.	1
MJOY-W3	Wadi al Hayl al Ali	2616673	454867	640	75.00	S., C., R.	1
MJOY-W4	Wadi Rakah + Wadi al Hayl al Ali	2614358	454867	600	75.00	S., C., R.	1
MJOY-W5	Wadi Rakah	2610903	453964	565	75.00	S., C., R.	1

*1 : S.: Step Drawdown Test, *2 : C.: Constant Discharge Test, *3 : R.: Recovery Test

(2) Geological features

The profile across the boreholes is shown in Fig.Ⅲ-8-2.

All of the holes presented overburden of wadi sediments and terrace sediments from 13m to 22m in thickness. The terrace sediments reach 30m to 40m in thickness at terrace areas, but all the holes located in wadi showed less thickness in the sediments because of erosion.

Wadi sediments consist of unconsolidated sand and gravels with only several meters in thickness. Terrace sediments also consist mainly of sand and gravels and consolidated with calcarious matrix. The lowest part of terrace sediments is interbeded with sand layer in places.

Groundwater was found in the time of drilling works in the following three boreholes of

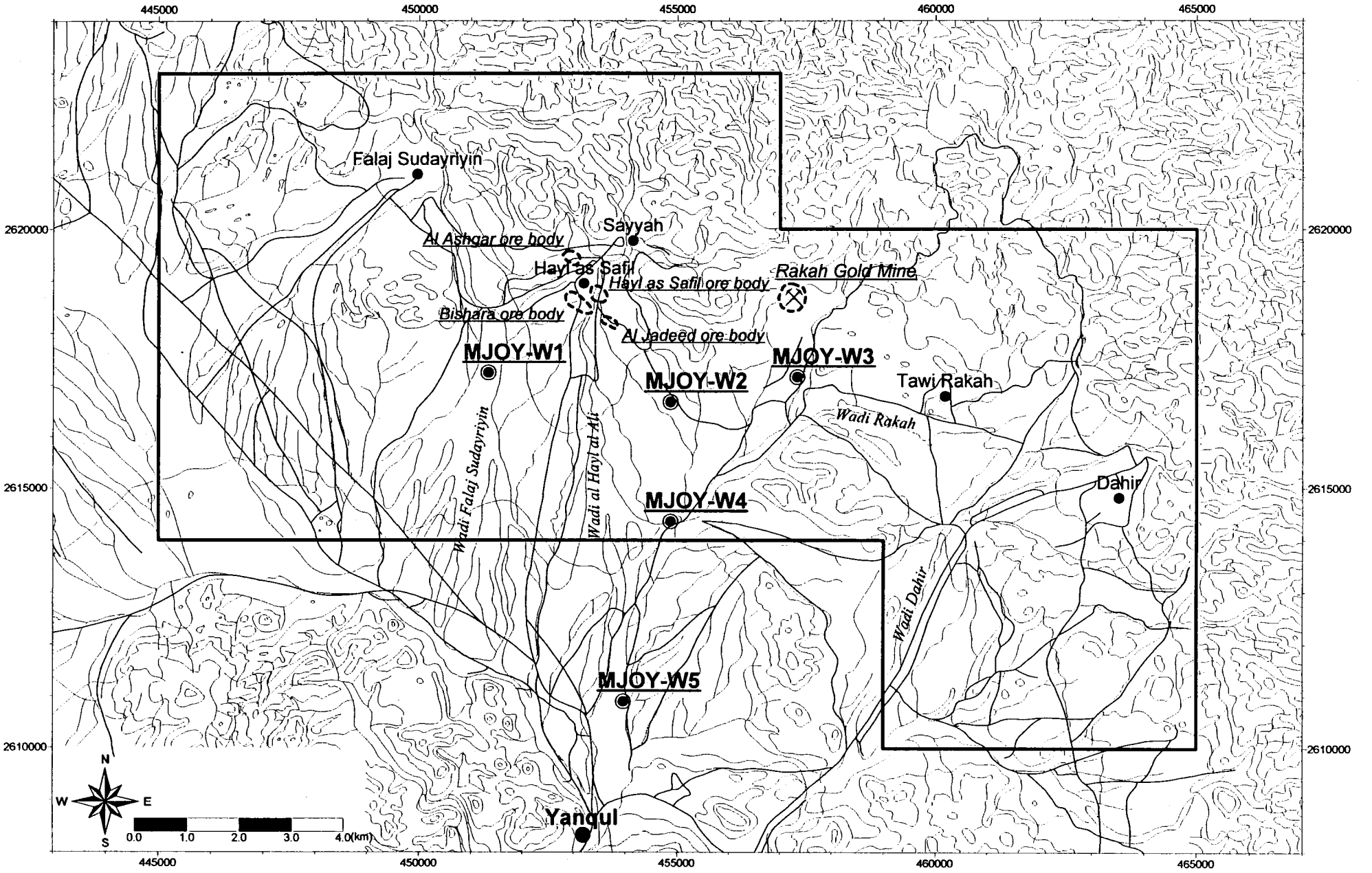


Fig.Ⅲ-8-1 Location of the drill holes

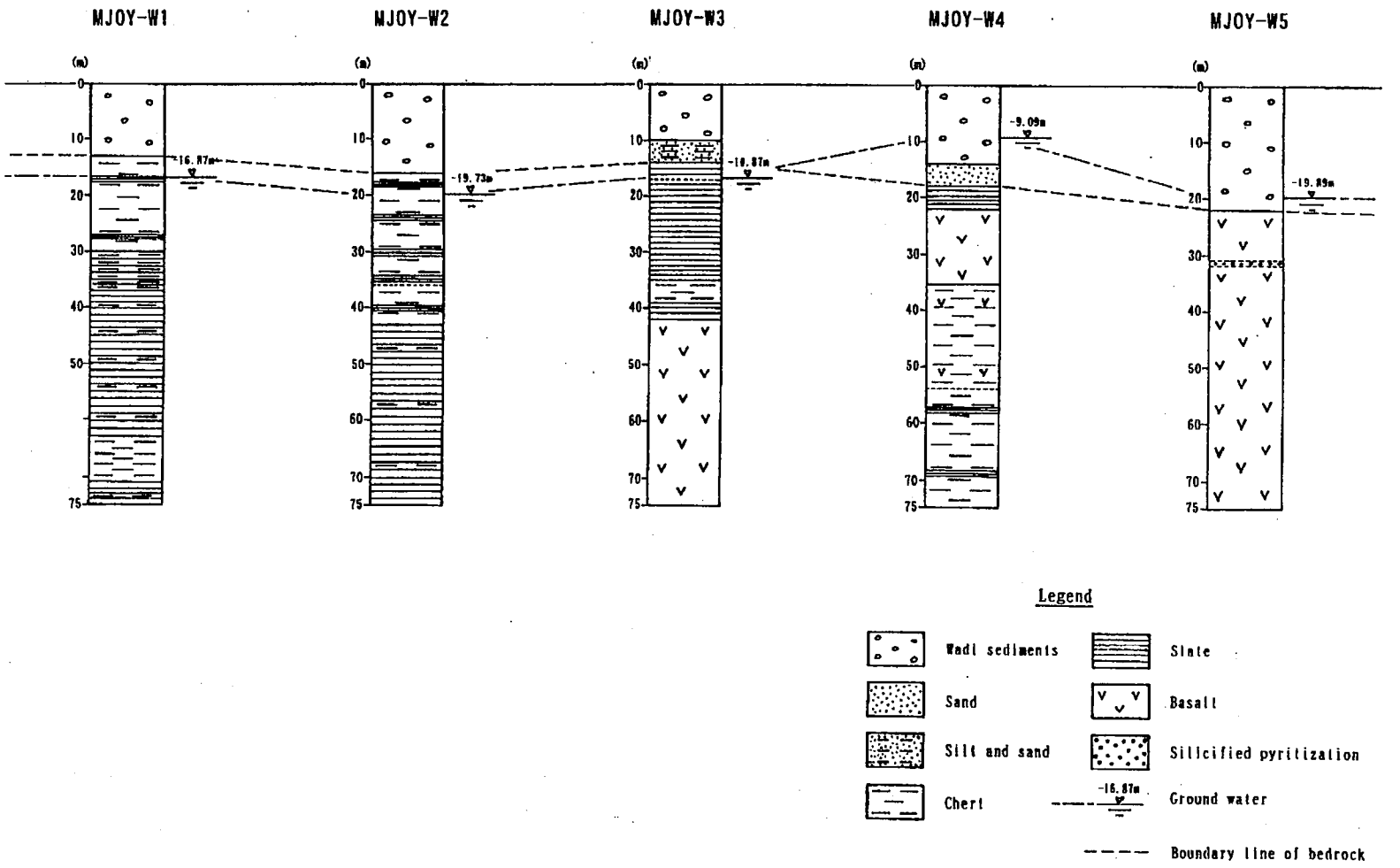


Fig. Ⅲ-8-2 Geological section of drill holes

MJOY-W3, MJOY-W4 and MJOY-W5. Since considerable amount of groundwater gushed out of the bore hole MJOY-W5 at a depth of 23m during drilling operations, it can be estimated that there exists confined groundwater. Only small amount of groundwater was found in the bore holes MJOY-W3 and MJOY-W4.

Groundwater levels in each borehole are presented in TableⅢ-8-2. The groundwater levels are distributed in a range from –9.09 to -19.89m. These levels presented identical levels to the basement rocks at the bore holes MJOY-W1, W2, W3 and W5, however, only that of MJOY-W4 was located within the gravel bed.

TableⅢ-8-2 Groundwater Level in the Drill Holes (2001/2/16) and Results of Pumping Tests

D.H. No.	Location	Groundwater level (m)	Pumping test	
			Pumping volume (L/s)	Permeability coefficient (cm/s)
MJOY-W1	Wadi Falaj Sudayriyin	-16.87	-	1.66 E-7
MJOY-W2	Wadi al Hayl al Ali	-19.73	-	3.23 E-6
MJOY-W3	Wadi Rakah	-16.87	0.4	1.47 E-6
MJOY-W4	Wadi Rakah	-9.09	1.5	2.92 E-5
MJOY-W5	Wadi Rakah	-19.89	5.0	4.55 E-5

8-1-2 Results of pumping tests

Results of pumping tests are shown in TableⅢ-8-2. The calculation of the permeability coefficients based on pumping test at each bore hole of this area indicated values distributed in a range between 4.55E-5 and 1.66E-7cm/s and with a tendency to present higher values in the lower downstream.

8-1-3 Results of water quality analysis

Groundwater taken from each drill hole was analyzed by measuring 15 parameters including pH, Electric conductivity, Total dissolved solids, Total alkalinity, Calcium Hardness, Magnesium hardness, Ca, Mg, Na, K, CO3, HCO3, Fe, SO4, Cl, NO2.

(1) Characteristics of water quality

Results of water quality analysis are presented in TableⅢ-8-3. pH values at 25°C are distributed between 7.6 and 7.76 of neutral range, and electric conductivity values ranged from 378 to 1,949 μ S/cm.

Total dissolved solids ranged in concentrations from 207 to 1,200 mg/L, and showed the highest value in MJOY-W3 which is located in downstream area of the Rakah deposit. The dissolved materials mainly consist of salt and gypsum.

Ca and Na showed the maximum value in MJOY-W3. Mg ranged in concentration from 10 to

36 mg/L, and showed the highest value in MJOY-W4 which is located downstream of Wadi Rakah. K ranged in concentration from 3.4 to 10 mg/L, and showed relatively high values at MJOY-W1 which is located in middle stream area of Wadi Falaj Sudayriyin.

Bicarbonate ions distributed in range of concentration between 96 and 257 mg/L showed the maximum value at MJOY-W4. Sulfate ions ranged in concentration between 11 to 415 mg/L with the highest values at MJOY-W3 which is located at the downstream part of the Rakah deposit. Nitrate ions are distributed in concentrations between 3.1 to 12.3 mg/L showing maximum values at MJOY-W1. Generally speaking, the ground water contains from 0.1 to about 1 mg/L of nitrate, however, all bore holes of this study showed relatively higher values.

TableⅢ-8-3 Analysis of Water Quality

Parameters	Unit	MJOY-W1	MJOY-W2	MJOY-W3	MJOY-W4	MJOY-W5
pH Value at 25℃		7.76	7.60	7.62	7.67	7.68
Electric conductivity at 25℃	μS/cm	816	378	1949	814	911
Total dissolved solids	mg/L	449	207	1200	460	504
(TDS)	mg/L	98	98	79	211	127
Tatal alkalinity as	mg/L	65	43	540	105	133
CaCO3	mg/L	49	70	41	148	95
Calcium hardness as	mg/L	114	113	581	253	228
CaCO3						
Magnesium hardness as						
CaCO3						
Total hardness						
Calcium (Ca)	mg/L	26	17	216	42	53
Magnesium (Mg)	mg/L	12	17	10	36	23
Sodium (Na)	mg/L	110	34	164	70	120
Potassium (K)	mg/L	10	3.4	4.8	6.6	6.1
Carbonate (CO3)	mg/L	1	1	1	1	1
Bi-Carbonate (HCO3)	mg/L	120	120	96	257	165
Sulphate (SO4)	mg/L	77	11	415	73	31
Chloride (Cl)	mg/L	125	23	305	82	174
Nitrate (NO2)	mg/L	12.3	3.1	6.6	10.5	8.4

(2) Classification of the water quality

The groundwater in the study area can be classified into three groups as follows (Fig.Ⅲ-8-3).

Group 1 : MJOY-W3

Group 2 : MJOY-W2, MJOY-W4

Group 3 : MJOY-W1, MJOY-W5

In the Group 1, represented by the ground water of MJOY-W3, indicates characteristics of high contents of calcium and sulfate ions (gypsum) and sodium and chlorine ions (salt).

The Group 2 which consists of the groundwater of MJOY-W2 and MJOY-W4, show relatively higher contents of bicarbonate ion. TDS in MJOY-W4 was little bit higher than that of MJOY-W1. To belong to same group can be substantiated topographically by the fact that the Wadi al Hayl ali and the Wadi Rakah join at near points of MJOY-W4. Characteristics of water quality of the Group 1 resemble to those of well water GW–1 and GW-2 in Ghuzayn area.

Group 3 consists of the groundwater of MJOY-W1 and MJOY-W5, showing higher contents of sodium and chlorine ions. Coincidence of water qualities of both drill holes can be indicated topographically by the fact that the Wadi Falaj Sudayriyin and the Wadi Rakah join at near points of MJOY-W5.

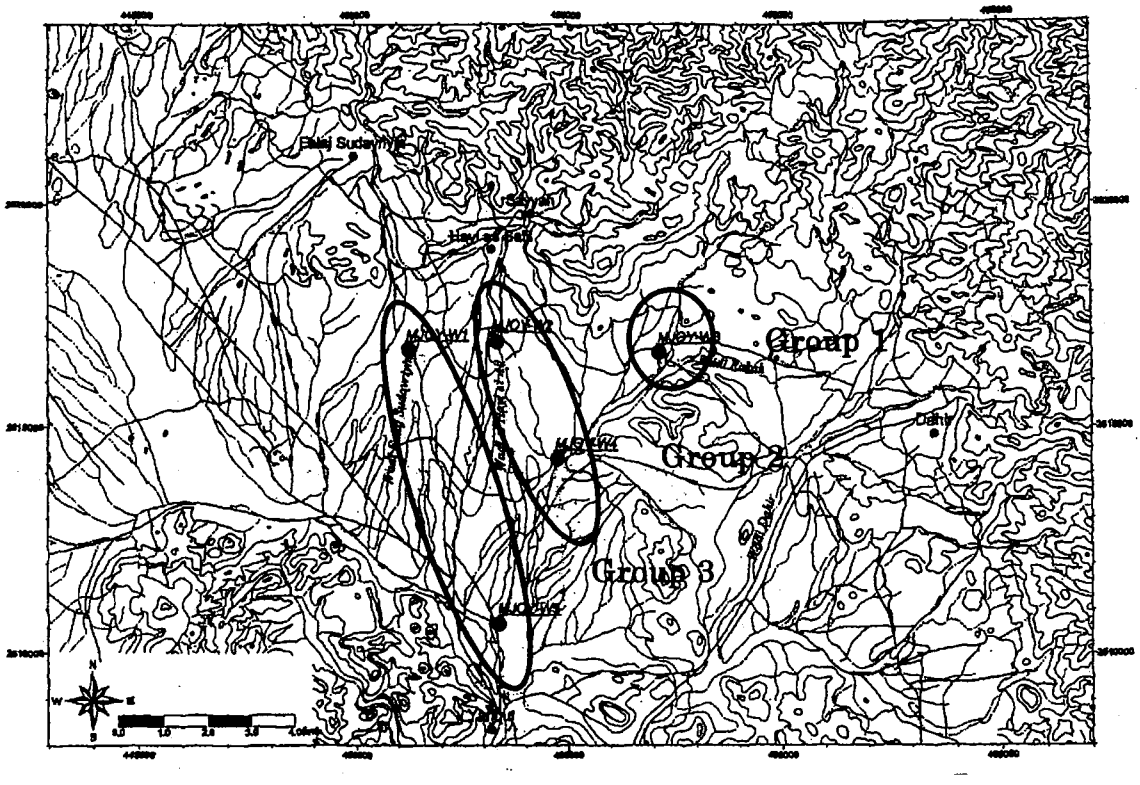


Fig.Ⅲ-8-3 Classification of Groundwater

(3) Water quality and quantity of the groundwater

It is presumed that the groundwater of Group 1 is detained in near area of MJOY-W3 and the Rakah deposit in the upstream of the Wadi Rakah and its quantity is poor. The groundwater in the Group 2 belongs to that of along the Wadi al Hayl ali and coincides with the groundwater in middle stream of the Wadi Rakah. Hence, quantity of the groundwater around MJOY-W4 flowed in from upstream area of the Wadi Rakah may be estimated to be very little.

The groundwater in the Group 3 belongs to that of along the Wadi Falaj Sudayriyin its water quality coincides with the groundwater in down stream of the Wadi Rakah. This fact may suggest that quantity of the Wadi Falaj Sudayriyin exceeds that along the Wadi al Hayl ali. Based on the fact that spring water volume at MJOY-W5 was 5 L/sec (18 m3/h) and confined, quantity of the groundwater here may be presumed to be relatively abundant.

8-2 Environmental Present Condition

The study area is located approximately 200 km west of Muscat, capital of Oman. The traffic between Muscat and Yanqul is well-maintained asphalt road through Nazwa and Ibri and approximately 370 km (4.5 hours driving). Access between Yanqul and the study area is 13 km and gravel road (20 minutes driving).

The study area is adjacent to Sayyah village on the north and Yanqul town, capital of the Yanqul prefecture, to the south.

8-2-1 Natural condition

(1) Land

The study area is located western foot to the hilly land of the Hajar Mountains extending northwest to southeast and various sizes of hills and terraces in the survey area are well developed.

Northern part of the area ranges in elevation from 800 to 1,000m of the low to middle relief of mountains extending east to west and shows steep topography. Hay as Safil deposits area is located in the wide spread terrace surface near the mountains, and Rakah deposit area is located at the foot part of the mountains.

The central and southern (Yanqul townsite) parts of the survey area, ranging in elevation from 580 to 650m, lies middle and low terraces and forms wide flat surface of 10km in direction of east to west, and 5 to 8 krn in the direction of north to south. The southern part of the survey area is hilly land scattering isolated hills and Wadi Yanqu l flows to the south. Townsite of Yanqul, ranging in elevation from 580 to 590m, is located on the low terrace surface.

Geology of the Hayl as Safil and Rakah deposits areas consist of basalts, belonging to the Lower extrusives I and II of the Samail volcanic rocks. The basalts are altered by green rock facies and are generally classified into soft to hard rocks. Central and southern (around Yanqul) parts of the survey area are occupied by the Hawasina sediments of Hawasinah Nappes, consisting of limestone, shale, chert, etc. and these rocks are classified into soft to hard rocks.

These rocks are widely covered by the Quaternary deposits consisting of terrace and wadi sediments ranging in thickness from 10 to 30m. The terrace sediments mainly consist of compact layers of sand and gravels containing fine to coarse grains of gravel and their matrix consist of sand and clay. The surface soil in the survey area is very poor.

(2) Water

Wadis in the survey area consist of two wadis, namely Wadi al Hayl al Ari in the Hayl as S'afil deposits area and Wadi Rakah in the Rakah deposit area. These wadis bclong to Wadi Dank river system.

Wadi al Hayl al Ari flows into Wadi Rakah and Wadi Dank. Wadi Dank changes her name to Wadi Yanqul and Wadi fida on her way. No surface watcr in these Wadis generally flows, but river-bed water along the lower part of Wadi Fida and Wadi Dank from Yanqul town site gushes and oasis, where numerous villagers live and perform agriculture, is formed along Wadi Fida and Wadi Dank. And villagers are using Falaj system for agriculture and living water, which is traditional irrigation system from ancient times.

The length until Yanqul and catchment area of Wadi Al Hayl Al Ari flowing in thc Hayl as Safil deposlts area is approximately 17 km and 29 krn, respectively (TableⅢ-8-4).

The land between Sayyah and Yanqul is flat and river water of the wadi is wholly river-bed water. The flat area, which consists of the terrace deposits like fan and wadi sediments, forms Quaternary water basin. The water basin is approximately 9 km long and more than 10 km wide, and the groundwater might be flowing out to the direction of Wadi Yanqul.

Wadi Rakah flowing in the Rakah deposit area is approximately 11 km and the wadi is supplying groundwater to the water basin together with Wadi al Hayl Al Ari. The catchment area of the expected Rakah mining area is 0.2 km2, being very small.

TableⅢ-8-4 River Condition of the Rakah Area

Name of wadi	Length (km)	Rver gradient (degree)	Catchment area (km 2)	Remarks
Wadi Al Hayl Al Ali	17	2.8	29	Hayl as Safil
Rakah	11	1.9	0.2	Rakah
Wadi Yanqul	-	<1	-	Yanqul

(3) Weather

The study area is arid weather of inland and precipitation of the year is less than 127 mm. The survey area has two seasons, namely summer from November to April and winter from Ma) to October. The concentrated heavy rain has very rare in winter. The average temperature, average evaporation and wind speed in the study area are 20 ~ 40℃, 2,100 mm, and 3 ~35 m/sec, respectively.

(4) Vegetation

The study area is mainly rock desert, so that the vegetation is very poor except oasis and along the wadis. Rare trees mostly consist of acacia group.

8-2-2 Social condition

(1) Population

The population of Yanqul and Sayyah village in 1991 are shown in TableⅢ-8-5. The population of Sayyah corresponds 4.2% to that of Yanqul.

TableⅢ-8-5 Populaton in the Rakah Area

Area	Population
Yanqul Wilayat	14,150
Sayyah	600

(2) Education

All of student in Sayyah village are going to school in Yanqul by school bus.

(3) Other public organization and facilities

Other organization consists of Municipality office, Royal Oman Police office, transmitting station and telephone office (wire and microwave). Although modern water supplying facility is not established yet, the falaj system as a traditional water supply and irrigation facility is used. But inhabitants in the townsite of Yanqul are getting living water by water wells. There are two disposal places for domestic wastes of Yanqul.

Football stadium, swimming pool, volleyball stadium and camel race stadium are established as a recreation facility.

(4) Cultural heritages

The cultural heritages in Yanqul consist of relatively small four ruins, namely Wadi Rakah, Hotein Mountain, Wadi Ruin, and Al Malahah. And ancient copper mining and smelting activities exist in the Rakah deposit area. No precious fauna in the survey area is registered, but Gazal (fox group) and rabbit group as a important fauna are mentioned.

(5) Traffic

Route No, 8 national road passes in Yanqul. This national road connects between Ad Dariz located about 25 km south and Sohar through Yanqul. The road between Ad Dariz and Yanqul and around Sohar is paved by asphalt, but mountain road crossing the Hajar Mountains is gravel road. Traffic facilities are mainly bus system connecting among main cities.

(6) Agriculture

Agricultural production mainly consists of fruits, including date, mango, lemon, orange, grape, etc., vegetables. and wool, but these production is relatively small. Main industry consists of gold mining and subordinate traditional woolen cloth.

(7) Disasters

Disasters in the study area consist of' flash flood after heavy rain, and falaj system, roads, cars etc. along Wadi Dank and Yanqul were damaged due to flash flood. In recent, concentrated heavy rain of 220 mm in Dank was recorded in March 1976. And the water level of Wadi al Hayl al Ari near Sayyah Village seems to be reached about 4 m after heavy rain in October 1997.

Other natural disasters in the study area are unknown,

(8) Pollution and existing monitoring data

In the study area, no pollution is known, but dust from roads is remarked. Dust caused from road is remarked.

The monitoring works of the groundwater are carried out around the active gold mine.

8-3 Environmental Legislation and Environmental (Evaluation) Standards

The environmental legislation in the Sultanate of Oman mainly consists of "Environmental law", "Law on the conservation of environmental and preservation of pollution", environmental standards, etc. According to the "Law on the conservation of environmental and preservation of pollution", the development project prescribed by the law is obligated to submit the environmental impact statement to the Ministry of Environment before development. The case of development project of copper mine is prescribed by the law and has to submit the environmental impact statement to the Ministry of Environment before development and to get an approval.

Standards of emission of Grit and Dust for scheduled works, Effluent standard of waste water, Water quality standard for drinking water, and Environmental standard for noise in the Sultanate of Oman are shown in TablesIII-8-6, III-8-7, III-8-8 and III-8-9, respectively.

Table Ⅲ-8-6 Standards of Emmition of Grid and Dust for Scheduled Works

No.	Items	Standard value (g/m3)
1	Grit and dust	0.050
2	Aggregates works particulates	0.050
3	Asbestos works (Total particulates)	0.050
4	Asphalt works (Bit mm en fume)	0.030
	(Total particulates)	0.050
5	Cement works (Particulates)	0.100
	(Hydrogen sulphide)	nil
6	Ceramic works (Particulates)	0.050
7	Copperbworks (Total particulates)	0.200
	(Copper compounds as copper)	0.100
	(Zinc compounds as copper)	0.100
	(Cadomium compounds as copper)	0.200
8	Incineration works (HCl)	0.200
	(HF)	0.100
	(NO2)	0.200
9	Lead works (Lead or its compounds)	0.030
	(Total particulates)	0.050
10	Lime works (Particulates from kiln)	0.100
11	Petroleum works (Particulates from	0.100
	CO from catalytic craclcers)	0.5% by volume
	(Subphur recovery units)	95% efficiency
	(Minimum H2SO4)	5% by volume
12	Power plants (Particulates from coal or oil firing)	0.100
13	Di-Isocyantes (Volatile Di-Isocyamates)	0.100
	(Particulates Di-Isocyanates)	0.001

Table Ⅲ-8-7 Effluent standard of Waste Water (mg/L)

Parameters	Area A	Area B		Parameters	Area A	Area B
BOD	15	20		Hg	0.001	0.001
COD	150	200		Mo	0.01	0.05
SS	15	30		Ni	0.1	0.1
TDS	1,500	2,000		N	5	50
EC	2,000	2,700		NO3	50	10
SAR	10	10		Oil & grease	0.5	0.5
pH	6-9	6-9		T-Phenols	0.01	0.002
Al	5	5		P	30	30
As	0.1	0.1		Se	0.02	0.02
Ba	1	2		Ag	0.01	0.01
Be	0.1	0.3		S04	400	400
B	0.5	1		S	0.1	0.1
Cd	0.01	0.01		V	0.1	0.1
Cl	650	650		Zn	5	5
Cr	0.05	0.05		Faecal oliform		
Co	0.05	0.05		bacteria		
Cu	0.5	1		(per 100mL)	200	200
CN	0.05	0.1		Viable nematode		
F	1	2		ova (per L)	<1	<1
Fe	1	5				
Pb	0.1	0.2				
Li	0.07	0.07				
Mg	150	150				
Mn	0.1	0.5				

Area A : Vegetables likely to be eaten raw. Fruit likely to be eaten raw and within 2 weeks of any irrigation. Public parks. Hotel Lawns Recreational areas. Areas with public access. Lakes with public contact. (except places which may be used for praying and hand washing.

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.

Table Ⅲ-8-8 Water Quality Standard for drinking water (mg/L)

Parameters	Maximum pemissible level
Pb	0.10
Se	0.01
As	0.05
Cd	0.01
CN	0.05
Hg	0.001

Table Ⅲ-8-9 Environmental Standard for Noise

	Noise value
Noise Pollution Control in Working Environment	<85 dB(A)

8-4 Forecasting and Evaluation of Environmental Impacts

Necessary environmental items for the environmental impact assessment with the mine development in the study area are discriminated by the matrix of the environmental factors and items as shown in Table Ⅲ-8-10.

Table Ⅲ-8-10 Matrix for Environmental Factors and Items

Stage	Construction					Operation						After mined out					Evaluation
Environmental factors / Environmental items	Foundation works	Transportation of materials	Installation of equipments	Road construction	Others	Mining works	Blasting	Transportation of ore, etc.	Mineral dressing	Discharge of water	Others	Water treatment	Reclamation	Replanting	Monitoring works	Others	Selected items
I. Living environment																	
1) Air quality	○	○	○	○	—	○	○	○	—	—	○	—	○	—	○	—	◎
2) Water quality	○	—	—	○	○	○	—	—	○	○	○	○	○	—	○	—	◎
3) Soil quality	—	—	—	—	—	○	—	—	○	○	—	—	○	○	○	—	◎
4) Noise/vibration	○	○	○	○	—	○	○	○	—	○	○	○	○	—	—	—	◎
5) Land subsidence	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6) Odor	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
II. Natural environment																	
7) Meteorology	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8) Land	○	—	—	○	○	○	—	—	—	—	—	—	○	○	—	—	◎
9) Water	—	—	—	—	○	○	—	○	○	○	○	○	○	—	○	—	◎
10) Soil	○	—	—	○	○	○	—	—	○	—	○	—	○	○	—	○	◎
11) Flora/Fauna	○	—	—	○	○	○	○	○	—	○	○	○	○	○	—	—	◎
12) Landscape	○	—	○	○	○	○	—	—	—	—	—	—	○	○	—	—	◎
III. Social environment																	
13) Waste	○	—	—	○	○	○	—	—	—	○	○	—	○	○	—	—	◎
14) Cultural heritage	○	—	—	○	—	○	—	—	—	○	—	—	—	—	—	—	◎
15) Communities	—	—	—	○	○	○	—	○	—	○	—	○	—	—	—	—	◎
16) Relocation	○	—	—	○	—	○	○	—	—	○	—	—	—	—	—	—	◎

The environmental factors mainly consist of excavation work of overburden, waste dump areas, mining work, ore dressing work, stock and transportation works of concentrate, tailing dump areas, waste water treatment, pumping and supply works of groundwater, mine office, accommodation, mine road, other associated facilities, etc.

Selected environmental items consist of 11 items, namely air, quality, water quality, noise/vibration, land water, flora/fauna, landscape, wastes, cultural heritages, communities, and relocation of havitants.

The results of preliminary forecasting and evaluation of environmental impacts are shown in Table Ⅲ-8-11.

Table Ⅲ-8-11 Results of Forecasting and Evaluation of Environmental Impacts

Items	Forecasting	Countermeasures	Evaluation
1.Air quality	Dust & Emission gas from mining pits, roads, waste dump areas, etc.	Watering	Few influences Detail investigation
2. Water quality	Seepages from mining pits, waste and tailing dump area, Concentrator, etc.	Water treatment plant, rubber sheet, culvert at dump area	Few influences Detail investigation
3.Soilquality	Scattering of waste &seepages of waste water	Rubber sheet, culvert, etc	Few influences Detail investigation
4.Noise& vibration	Noise/v. from mining pits, roads, concentrator, dump area, etc.	-	Few influences Detail investigation
5. Land	Altering of land by mining pits, roads, wadi diversion, dump area, etc	Retaining wall, stable standard slope	Few influences Detail investigation
6.Water	Wadi diversion, seepage from mining pits, etc	Water channel, cut off wall, culverts	Few influences
7. Soil	Limited area and thin layer of top soil	-	Few influences
8. Flora & fauna	Rare vegetation	-	Few influences
9. Landscape	Mining pits, dump area, etc.	-	Few influences
10.Waste	Disposing domestic waste	Inside of area	Few influences
11. Historical heritage	Ancient smelter and slags	Archaeological investigation	Waiting
12. Community	Sayyah village and Yanqul, 6 houses & farm, economic activity, etc.	Discuss with Sayyah village and Yanqul	Waiting
13. Relocation	Relocation for 6houses	Discuss with Sayyah village and Yanqul	Waiting

8-4-1 Air quality

(1) Forecasting

Main causes of air contamination from the mine development area consist of generation of dust and exhaust gas from heavy machines. The dust occurs due to blasting work, mining work by heavy machines, crushing work, waste and tailing dump areas, and transportation and dumping works of crude ore, waste, and tailings.

a. Dust

Although the dust mainly occurs from mining pits by blasting and transportation works, ore dressing

plant by crushing, and bare ground at the waste dump areas, the scattering area of dust is assumed to be limited relatively narrow area. Particularly, watering at the mining pits of Hayl as Safil and Al Asghar, adjoining Sayyah village, is planned. And waste and tailing dump areas is planned to cover promptly by graveland to compact after dumped.

Therefore, the generation of dust at the dump areas will be minimized. And vegetation work is impossible because of arid weather zone.

b. Exhaust gas from heavy machines

Using of heavy machines consists of the stage of mine construction and mining, transportation, dumping, and grading of dumped areas and pits mined out at the stage of mining operation. Maximum use of heavy machines might be at the time of operation of mine pits.

1) Forecasting area and points

Forecasting by simulation of SO2 andNO2, at the mining stage of Hayl as Safil and Bishara mining pits was examined. The forecasting points are Sayyah village and middle point between boundary of mine area and Yanqul.

2) Forecasting formula

Forecasting is calculated by the Plume-Puff method.

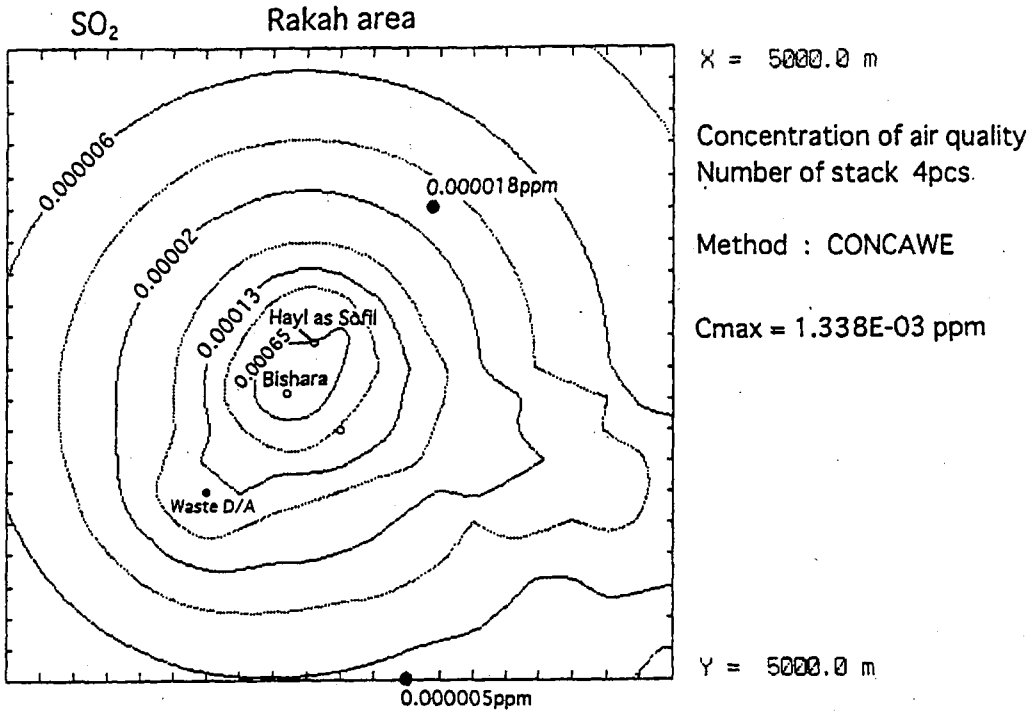
3) Forecasted results

Simulation result is shown in Fig.Ⅲ-8-4.

The simulated concentrations of SO2 and NO2 in Sayyah Village and middle point between boundary of mine area and Yanqul (P-1) at the mining stage are shown in TableⅢ-8-12.

TableⅢ-8-12 Simulation Result of Air Quality during Mine operation

Location	SO_2	NO_2
	ppm	ppm
Sayyah Village	0.000018	0.002
P-1	0.000005	0.00006



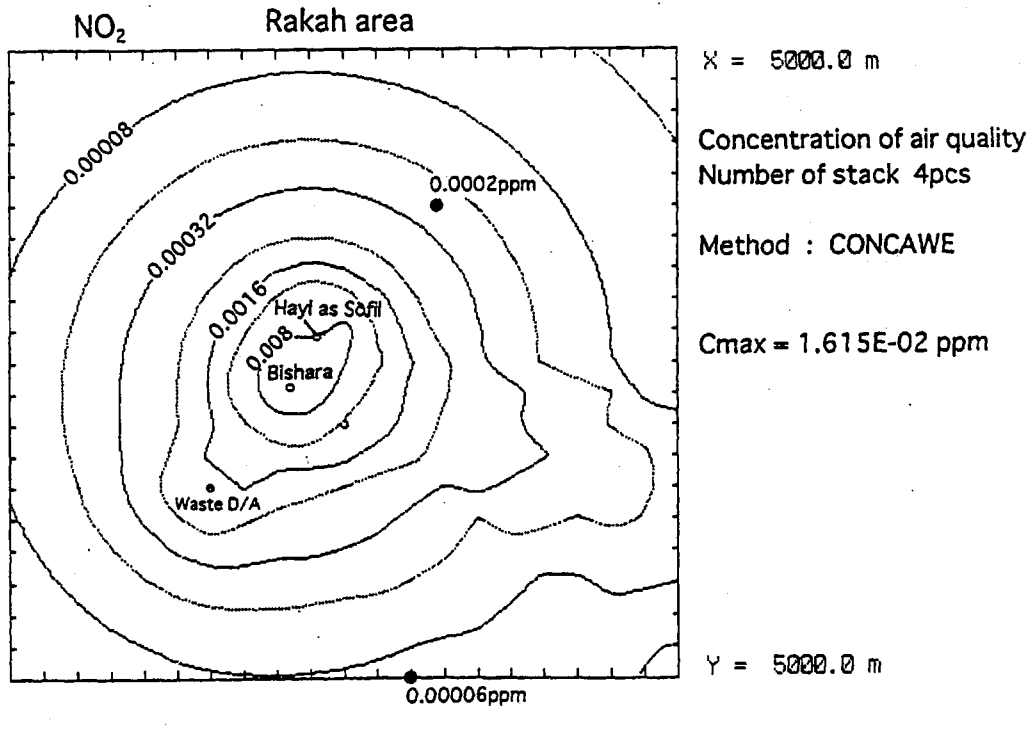


Fig. Ⅲ-8-4 Simulation result for air quality

(2) Evaluation

The generation of dust will be minimized by watering, so that the influence to the environment is thought to be few. The concentration of SO_2 andNO_2 in Sayyah village and middle point between boundary of mine area and Yanqul (P-1) due to the heavy machines is extremely low, so that the influence to the environment is thought to be very few.

8-4-2 Water quality

(1) Forecasting

Assumed sources of water contamination from the mine development area consist of seepage water from the mining pits and waste and tailing dump areas during operation and after mined out, All of' industrial water in the dressing plant during operation will be recycled, so that no water is discharged. And

suspended solid during the mine construction will be limited within the mine area because of very low precipitation, so that the influence to the environment is thought to be very few.

a. Mining pits

1) Operating stage

Seepage water from the mining pits during operation is divided into river-bed water of the quaternary deposits at the upper part of the pit wall and seep from basalts of mother rocks of deposits. The water quality is assumed to correspond to that of the river (wadi) water. The volume of seepage is calculated as below. The formula for the volume of seepage is shown in Formula - 1

$$Q = k \cdot i \cdot A \qquad \text{Formula - 1}$$

Q : Volume of seepage (m3/day)

K : Perrneability coefficicnt (m/day)

i : Hydraulic gradient

A : Cross sectional area (m2)

(Volumc of seepage from the pits)

Ministry of Water Resources (MWR) was carried out drilling survey around Yanqul and Hayl as Safil deposits area. Average permeability coefficient and gradient off groundwater table are shown in Table Ⅲ-8-13.

Table Ⅲ-8-13 Volume of Seepage through the Quaternary Deposits from each Mining Pit

Mining pit	K (m/day)	I	A (m^2)	Volume of seepage (m^3/day)
1. Hayl as Safil	2.79E-3	0.013	119,428	4.33
2. Al Asghar	2.79E-3	0.013	77,506	2.81
3. Bishara	2.79E-3	0.013	42,071	1.53
4. Rakah	1.27E-3	0.013	80,345	1.33
Total				10.00

Total forecasted volume of seepage from the pits is a little, calculated at 10 m3/day. But recent groundwater level is low, because recent precipitation volume is extremely low. In case of the year having much rainfall, the groundwater level will go up and the volume of seepage also will be increased (approximately 10s m3/day).

The seeped water will be used to watering for dust.

2) After mined out

After each pit mined out will be filled by mine water. The mine water could be acidic and contained heavy metals, namely Cu, Zn, Pb, Fe, Mn, etc.

b. Waste dump areas

Two waste dump areas, located in the Hayl as Safil and Rakah deposits areas are planned. Final area of the waste dump areas is calculated at 426,472 m2. The seepage volume caused from the waste dump areas is forecasted as below.

- Catchment area : 426,472 m^2
- Precipitation : 127 mm/year
- Evaporation rate : 114 mm/year (90 % to the precipitation value)
- Seeped volume : 5,544 m^3/year

Wastes consist of overburden and subordinate low grade ore, and disseminated sulphide containing in the wastes is oxidized by weathering and the environment. Therefore, a part of seeped water from the waste dump areas will be acidic and contain small amount of heavy metals. Although most of seeped water will be evaporated at the surface, a part of seeped water will be infiltrated into the ground.

c. Tailing dump area

The area of tailing dump area is calculated at 8,131,923 m^2. The moisture content of tailings is planned to be treated into 15 %. The seepage volume caused from the tailing dump area is forecasted as below.

- Catchment area : 140,865 m^2
- Tailing dump area : 282,738 m^2
- Precipitation : 127 mm/year
- Evaporation rate : 114 mm/year (90 % to the precipitation value)
- Seeped volume : 3,676 m^3/year

The seeped water from the tailing dump area will be acidic and contain much amount of heavy metals. But the contaminated seeped water will be protected infiltration into the ground, because using waterproofing sheet as a seepage control work.

(2) Evaluation

Total seepage volume from the pits will be small amount. After mined out, the pits will be filled by mine water. A part of seeped water from the waste dump areas will be infiltrated into the ground. The seeped water from the tailing dump area will be protected by waterproofing sheet as a seepage control work.

The seeped water from the pits and waste dump areas will be infiltrated into ground. Although the impact to the groundwater in the Yanqul groundwater basin by the seeped water is thought to be a few, it is necessary to observe the impact by the water monitoring.

8-4-3 Soil quality

(I) Forecasting

Main causes of soil contamination is generally said to be scattering of concentrate and wastes, etc. containing heavy metals and infiltration of contaminated groundwater into the surface soil. And the soil contamination by seepage water from the tailing dump area is controlled by waterproofing sheet covering on the floor of the dump area.

The dust from tailing dump area is controlled due to lining works made by coarse grained sand and gravel.

(2) Evaluation

The influence to the soil quality due to the scattering of concentrate and wastes and seepage water is thought to be relatively few. It is necessary to refer the monitoring result of waste dump area in the Sohar mine in order to understand the condition of soil quality.

8-4-4 Noise and vibration

(I) Forecasting

Main sources of noise in the development area consist of blasting in the mining pits, heavy machines, ore dressing plant and transportation of ore, etc. In general, the noise works decay by distance to the outside of development area.

The distance from Hayl as Safil deposits area to Sayyah village is 0,7 km. Noise level at Sayyah village during mine operation is calculated by Formula-5. But transitory noise such as blasting, dump truck for transportation, etc. is excepted. The power level of noise source of heavy machines is assumed to be 110 dB(A).

$$L = Lp - (20 \times \log 10\, r - 11) \qquad \text{Formula-2}$$

L : Noise level (dB(A))

Lp : Power level (dB(A))

r : Distance (m)

As a result of calculation, the noise level at Sayyah village is 58 dB(A), being less than genera environmental noise level. The vibration to Sayyah village is thought to be very small. Because soft ground is not distributed in and around the development area and the distance between noise sources and Sayyah Village is about 1 km. Therefore, the most of the vibration is decayed by distance and will be not felt.

(2) Evaluation

The influences of noise and vibration to the environment are thought to be few.

8-4-5 Land

(1) Forccasting

The banking and cutting works consist of open pits, waste and tailing dump areas, access roads, wadi diversion and cut-off dam. The slope of the embankments and cuts were designed using standard gradient for safety slope as shown in TableⅢ-8-14.

Table Ⅲ-8-14 Gradient Standard of Cut and Embankment

(1) Slope of cut

Lithology	High (m)	Gradient standard
Hard rock		1:O.3～1:O.8
Soft rock		1:0.5～1:1.2
Sand (compact)	<5m 5～10m	1:0.8～1:1.O 1:1.O～1:1.2
Clay with gravel (compact)	<5m 5～10m	1:1.0～1:1.2 1:1.2～1:1.5
Sand (loose)	<10m 10～15m	1:0.8～1:1.O 1:1.O～1:1.2
Clay with gravel	<10m 10～15m	1:1.0～1:1.2 1:1.2～1:1.5
Clay	5～15m	1:0.8～1:1.2

(2) Slope of embankment

Lithology	High (m)	Gradient standard
Rock fragments	10～20m	1:1.8～1:2.0
Sand	<10m <5m	1:1.5～1:1.8 1:1.8～1:2.0
Clay and sand	5～10m <5m	1:1.5～1:1.8 1:1.8～1:2.0
Clay and gravel	5～15m	1:1.8～1:2.0
Clay	<5m	1:1.8～1:2.0

(2) Evaluation

Slope of roads and dump areas planned based on the standard slope gradient arc thought to be stable. Unstable slopes in subsurface are necessary to make stable by slope protection. Surrounding of the pits mined out is necessary to make a fence.

8-4-6 Water

(1) Forecasting

a. Channel of wadi diversion

Wadi al Hayl al Ari is necessary to divert for the mining of Hayl as Safil deposit. The embankment and diversion channel of Wadi al Hayl al Ari are established from the distance of 600 m upper stream from the Hayl as Safil mining pit to the distance of 600 m lower stream from the mining

pit through between main gossan and small gossan. And mouth and exit of diversion channel is planned to be straight course for the protection of erosion.

The volume of discharge for the wadi diversion is 530 m3/sec corresponding to the estimated peak flow for a 50 years of return period, and the depth of channel has 1 m as a freeboard.

b. Seepage to mining pits

Total forecasted volume of seepage from the pits is a little, calculated at 10 m3/day. The seeped water will be used to watering for dust.

(2) Evaluation

Planned wadi diversion channel based on the estimated peak flow for 50 years of return period is thought to be enough section for discharge. And seepage water from the mining pits is assumed to be a little, so that the influence to the environment is thought to be few.

8-4-7 Fauna and flora

(I) Forecasting

No precious fauna and flora exist in the mine area.

(2) Evaluation

The influence to the fauna and flora by mine development is thought to be very few.

8-4-8 Landscape

(I) Forecasting

No precious landscape are existing in the mine area.

(2) Evaluation

The influence to the landscape by mine development is thought to be few.

8-4-9 Wastes

(I) Forecasting

Domestic waste is planned to incinerate and to dispose within the mine area.

(2) Evaluation

The influence to the environment landscape by mine development is thought to be few.

8-4-10 Cultural heritages

(1) Forecasting

As a cultural heritages in the Rakah area, the ancient copper mining and smelting remains as well as much slag scattered in the Rakah deposit area arc found. These ancicnt remains will be removed by

the mine development.

(2) Evaluation

As an ancient mining and smelting activities, which is symbol mark of OMCO are remained in Lasail mine It is necessary to conduct archaeological investigation before mine development

8-4-11 Community and retocation of habitants

(1) Forecasting

Communities in the Hail as Safil and Rakah deposits areas consist of Sayyah village and Yanqul. And several temporary houses are slightly scattered in the Rakah dcposit area. The population of Sayyah village is 600, and they are mainly conducting agriculture and s tock farming. Living and agricultural water is supplied by the falaj system from upper stream of wadi al Hayl al Ari. Small farming areas are located in the central part of Sayyah village and eastern part of the main gossan.

The relationship between Sayyah village and mine planned consist of access road to Yanqul and houses and farm located in the eastern part of the main gossan.

There are six houses and farms as about 7 ha in the eastern part of the main gossan. Houses should be relocated for safety. Farm is presently cultivated date, wheel, millet, etc, but south half of farm is closed. This farm is necessary to close by mine development. The closely relationship between Yanqul and mine planned consist of accommodation of mine worker, infrastructure, and economic activity accompanied with mining operation.

(2) Evaluation

Concerning the relationship between communities and mine planned, positive influence such as economic activities, etc. is evaluated, but it is thought that it is necessary to examine concerning relocation of inhabitants, closure of farm, safety. etc, and to sufficiently respect opinions of inhabitants and municipality, etc

8-5 Planning of environmental concentation countermeasures and evaluation

As results of examination of forecasting and evaluation based on the mine development plan including mine control plan, it is not necessary to add newly environmental conservation countermeasures. Therefore, the implementation of the primary mine control plan should be carried out.

However, the environmental items such as air quality, water quality, soil quality, noise and vibration, cultural heritages, etc,, that no enough data are obtained, and examination together with municipal organization are necessary to reexamine after base-line investigation and sufficiently discussion,

And concerning relocation of inhabitants, it is thought to be necessary to fully respect the opinions of inhabitants and municipal organization. The environmental conservation countermeasures, including the mine pollution control plan is shown in TableIII-8-15 and Fig.III-8-5.

Table Ⅲ-8-15 Environment Management Plan

Items	Environmental monitoring plan	Remarks
1.Air quality	Dust, NO_2, SO_2 at Sayyah, Rakah and Yanqul	3 points 4 times/year
2. Water quality	Water quality Volume of outflow	10 points 4 times/year
3.Soil quality	Soil at Sayyah and near Yanqul (downstreams)	4 points once /year
4.Noise& vibration	Noise& vibration level at Sayyah	1 pouints 4 times/year

8-6 Environmental monitoring plan

The environmental monitoring plan, consisting of the air quality, water quality, soil quality, noise and vibration is shown in Table Ⅲ-8-16 and Figure Ⅲ-8-5.

Table Ⅲ-8-16 Environmental Monitoring Plan

Items	Environmental management plan	Remarks
1.Air quality	Dust: Watering control of blasting	Monitoring
2. Water quality	Mining pits: Retaining wall and drainage, pumping Waste & tailing dump areas: Culvert for drainage Water treatment plant for seepages from pits etc.	Monitoring After mind out
3.Soil quality	Control of scattering of wastes, seeped water Water treatment plant for seepages from pits, etc	 After mind out
4.Noise& vibration	Mining pits: Control of blasting, cutting, transportation, compaction, etc.	Monitoring
5. Land	Control of slope of cut and embankment at mining pits, wadi diversion. Dump areas, plants, roads, etc. Fence for pits	 After mind out
6.Water	Control of wadi by wadi diversion Mining pits: Retaining wall and drainage system Pumping and water treatment	 After mind out
7. Landscape	Reclamation, smoothing at dump areas	
8. Waste	Disposing domestic wastes within the project area	
9. Historical heritage	Relocatlon the ancient smelting activity, If any	Archaeological investigation
10. Community	Discussion with communities, Sayyah and Yanqul	Discussion
11. Relocatlon	15 houses	Discussion

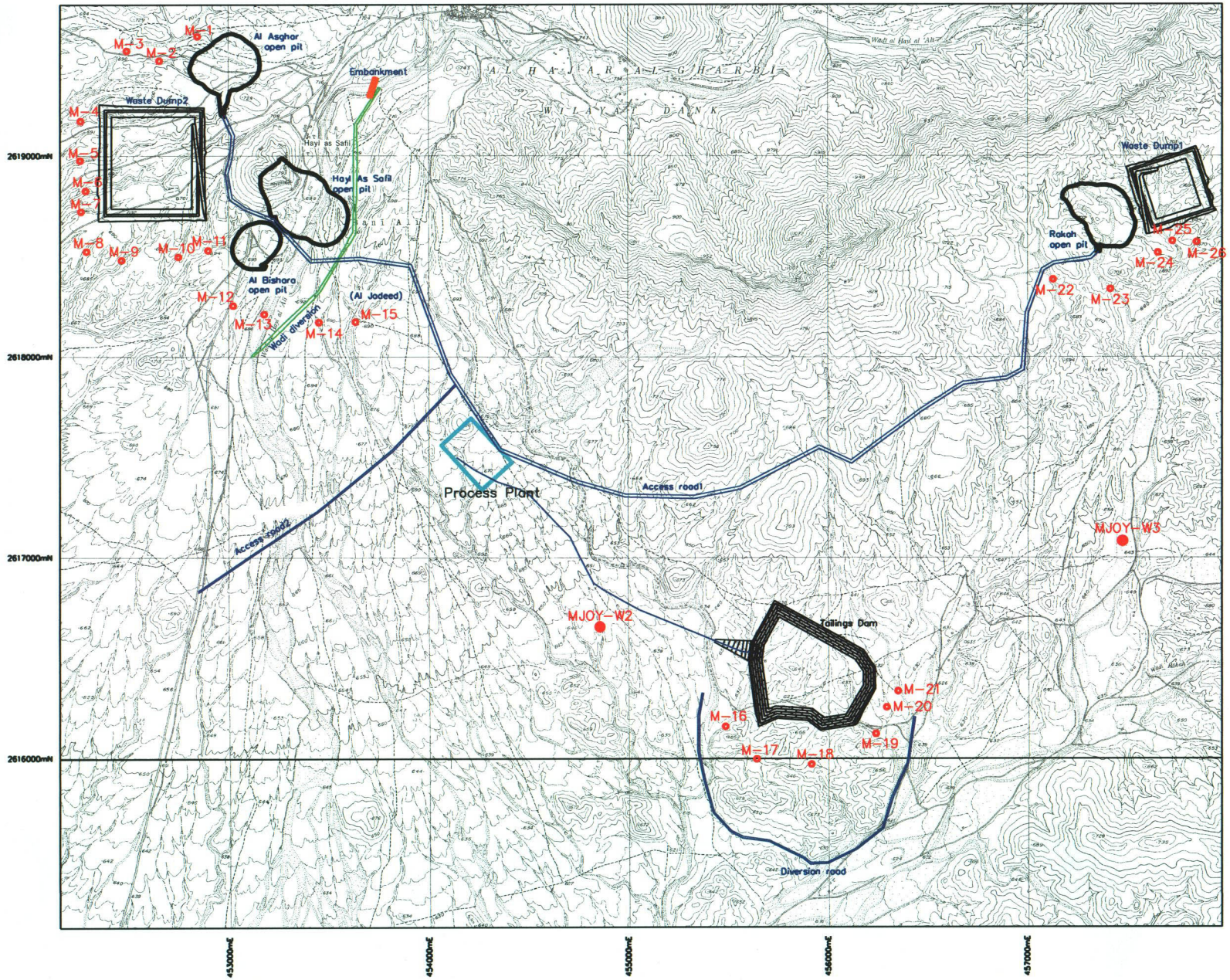


Fig. Ⅲ-8-5 Location of the drill holes for environmental monitoring