FEASIBILITY REPORT

ON

WADI JIZZI AGRICULTURAL DEVELOPMENT PROJECT

IN

THE SULTANATE OF OMAN

(APPENDIX-I)

JANUARY 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

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APPENDIX I

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B. Surface Water

C. Ground Water

D. Geology

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A-4. Installation of Observation Gauges

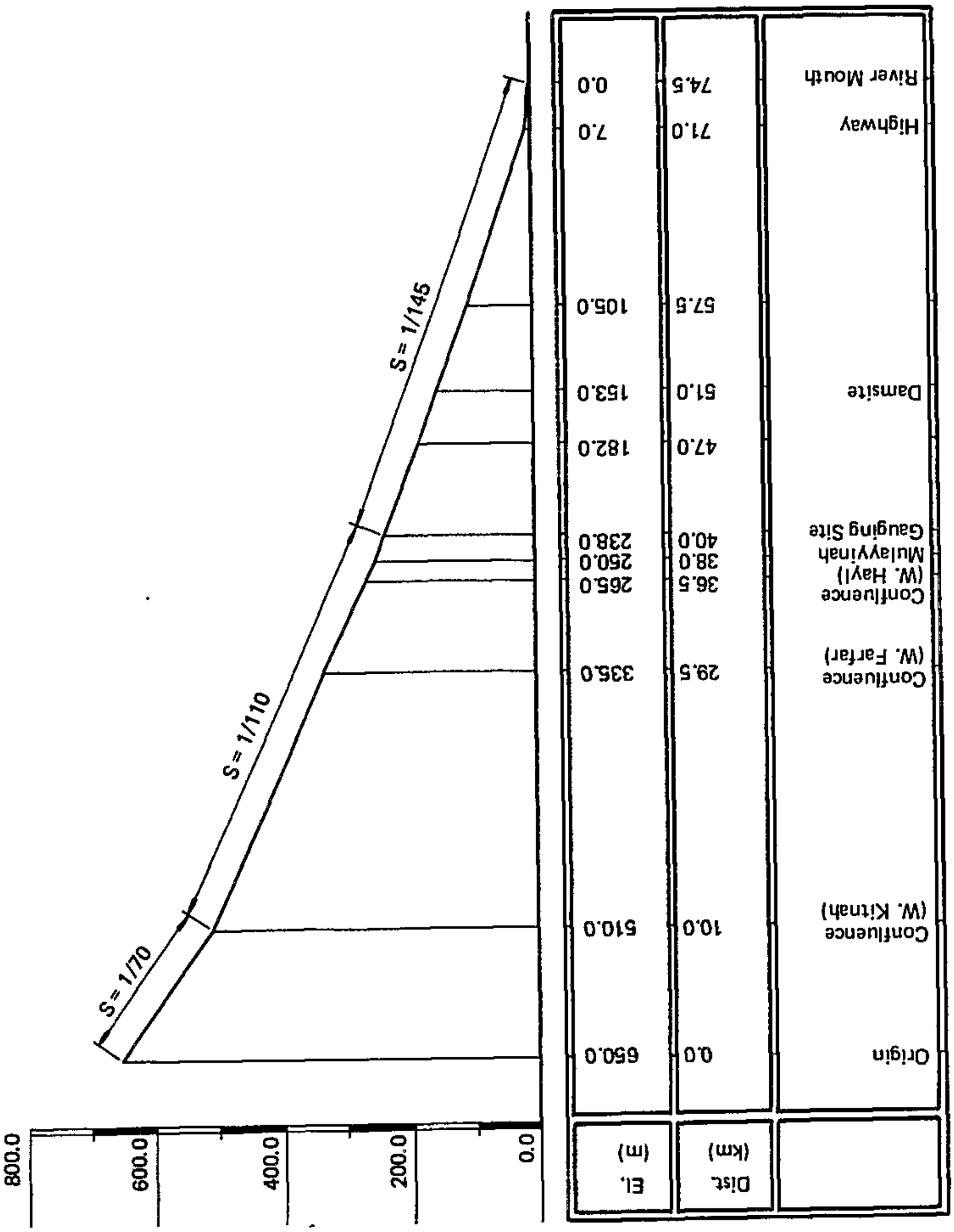


FIGURE A-1 PROFILE OF WADI JIZZI

Table A-1 Site of Rain Gauge Station

Name	U T M Grid Reference			Date of Installation			Altitude (m)
Daqiq	DB	424	2664	DEC.	23	1973	800*
Kitnah	DB	420	2669	DEC.	23	1973	655*
Hayl (Wadi Jizzi)	DB	422	2677	OCT.	24	1973	500
Hayl (Wadi Hayl)	DB	432	2688	DEC.	20	1973	430
Farfar	DB	435	2676	DEC.	22	1973	560
Sohar	DC	471	2793	DEC.	18	1973	15

* Barometric Measurement

Table A-2 Monthly Rainfall in Wadi Jizzi Basin

STATION DADIG

MONTHLY RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1974	3.9	41.8	7.5	3.3	0.0	3.3	11.5	16.1	0.0	0.0	0.0	0.0	87.4
1975	7.2	50.6	7.4	0.0	0.0	14.0	15.4	23.1	24.3	0.0	0.0	0.0	142.0
1976	31.8	148.3	234.8	89.3	0.0	18.3	37.2	25.0	12.0	0.0	6.7	28.4	630.8
1977	30.0	39.4	0.0	42.0	17.1	20.4	0.0	0.0	0.0	0.0	0.0	0.0	148.9
1978	0.0	60.5	16.2	0.0	0.0	0.0	61.7	0.0	22.0	0.0	0.0	0.0	160.4
1979	27.5	12.5	3.1	0.0	0.0	40.8	42.5	0.0	39.0	5.4	0.0	0.0	173.8
1980	40.0	18.0	15.0	0.0	0.0	0.0	40.4	1.4	0.0	0.0	0.0	0.0	114.8
1981	0.0	0.0	0.0	7.7	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.0
1982	0.0	115.4	7.4										

STATION KITNAH

MONTHLY RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1974	2.0	36.5	5.5	0.0	0.0	0.0	5.1	4.3	0.0	1.4	0.0	0.0	54.8
1975	4.7	50.8	0.0	0.0	6.1	4.0	0.0	3.4	5.5	0.0	0.0	0.0	74.5
1976	24.9	110.7	32.0	69.0	0.0	0.0	0.0	35.5	0.0	0.0	5.5	25.5	353.1
1977	25.0	25.3	6.0	0.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.3
1978	0.0	25.2	5.0	0.0	0.0	0.0	18.8	4.5	0.0	0.0	0.0	0.0	53.5
1979	34.1	0.0	0.0	0.0	3.8	5.2	14.7	0.0	0.0	0.0	0.0	27.5	85.3
1980	0.0	22.0	31.0	0.0	0.0	0.0	14.4	0.0	0.0	0.0	0.0	0.0	67.4
1981	11.0	0.0	8.6	22.3	24.1	18.3	0.0	0.0	0.0	0.0	0.0	0.0	84.3
1982	0.0	137.8	32.5										

STATION HAYL(J1771)

MONTHLY RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1974	3.0	34.1	6.2	6.8	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	51.2
1975	6.2	65.4	0.0	0.0	0.0	0.0	0.0	8.9	0.0	0.0	0.0	0.0	80.5
1976	27.6	155.0	137.0	0.0	0.0	0.0	0.0	8.9	0.0	0.0	0.0	0.0	328.5
1977	13.4	22.8	0.0	41.7	15.7	11.0	0.0	0.0	0.0	2.0	0.0	0.0	106.6
1978	0.0	31.2	4.3	0.5	0.0	2.0	22.5	30.5	0.0	0.0	0.0	0.0	91.0
1979	21.3	0.0	0.5	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.0	72.8
1980	0.0	33.5	31.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0
1981	2.5	0.0	0.0	0.0	21.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.8
1982	0.0	146.0	23.5										

STATION HAYL(HAYL)

MONTHLY RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1974	1.1	33.5	5.6	0.0	0.0	0.0	0.0	0.0	7.4	19.3	0.0	0.0	66.9
1975	10.1	49.5	0.0	0.0	0.0	0.0	0.0	12.3	0.0	0.0	0.0	0.0	71.0
1976	32.5	148.7	190.9	41.0	0.0	0.0	0.0	9.3	10.6	0.0	31.0	0.0	464.0
1977	31.4	15.7	0.0	25.0	46.5	32.5	0.0	0.0	0.0	5.1	17.7	0.0	173.9
1978	0.0	31.0	2.3	4.0	0.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	44.3
1979	17.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
1980	4.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.0	44.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.0	131.5	18.6										

STATION FARFAR

MONTHLY RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1974	4.6	50.4	5.3	2.0	0.0	0.0	0.0	6.4	0.0	13.9	0.0	0.0	82.6
1975	6.2	84.5	0.0	0.0	4.0	0.0	0.0	25.6	0.0	0.0	0.0	0.0	120.3
1976	20.1	126.0	97.0	85.0	0.0	0.0	3.0	62.0	0.0	0.0	12.0	1.0	406.1
1977	27.2	33.7	0.0	67.0	47.7	33.2	0.0	0.0	0.0	7.2	13.7	0.0	229.7
1978	0.0	54.5	3.0	6.0	0.0	5.0	12.0	73.0	0.0	0.0	0.0	0.0	153.5
1979	18.0	0.0	3.0	12.7	0.0	0.0	0.0	0.0	0.0	16.4	6.0	21.0	77.1
1980	4.0	18.8	34.0	0.0	5.0	0.0	17.0	0.0	0.0	0.0	0.0	8.0	86.8
1981	5.3	20.0	0.0	22.0	10.0	0.0	43.0	0.0	0.0	0.0	0.0	0.0	100.3
1982	0.0	125.0											

STATION KHAN

MONTHLY RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1982	0.0	34.0	28.5										

STATION SOHAR

MONTHLY RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1974	0.6	71.6	2.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	77.7
1975	2.6	44.5	0.0	0.0	0.0	0.0	0.0	6.2	0.0	0.0	0.0	0.0	53.3
1976	2.5	118.0	51.9	55.2	0.0	0.0	0.0	0.0	0.0	8.2	0.0	17.3	253.1
1977	68.1	26.3	2.6	38.7	10.9	0.0	0.0	0.0	0.0	0.0	17.6	0.2	164.4
1978	0.0	34.2	6.5	2.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.3	46.6
1979	21.4	0.0	1.5	2.3	0.0	0.0	0.0	0.0	0.0	36.6	0.7	58.4	120.9
1980	1.7	2.2	3.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	9.8
1981	4.8	0.0	1.5	16.2	12.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.1
1982	0.0	137.2	34.3										

Table A-3 Estimated Monthly Areal Rainfall

STATION AREAL RAINFALL AT D2 SITE

MONTHLY RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1974	2.9	39.7	5.8	2.3	0.0	0.3	2.0	4.0	2.1	9.6	0.0	0.0	68.6
1975	7.2	63.0	0.7	0.0	2.0	1.9	1.5	15.3	3.0	0.0	0.0	0.0	94.5
1976	26.8	138.4	142.5	53.6	0.0	1.7	4.4	29.5	4.1	0.0	13.5	6.3	420.8
1977	25.5	25.9	0.8	39.0	33.8	22.9	0.0	0.0	0.0	3.9	8.9	0.0	160.7
1978	0.0	39.9	4.6	3.0	0.0	1.9	16.4	30.0	2.1	0.0	0.0	0.0	97.8
1979	21.6	1.2	1.3	4.3	0.5	4.6	6.0	0.0	3.7	5.6	1.7	19.5	69.9
1980	6.1	20.5	21.8	0.0	1.5	0.0	10.7	0.1	0.0	0.0	0.0	9.9	70.5
1981	3.5	0.0	1.1	10.1	17.6	2.4	12.5	0.0	0.0	0.0	0.0	0.0	47.2

STATION AREAL RAINFALL AT RIVER MOUTH

MONTHLY RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1974	2.3	48.2	5.0	1.7	0.0	0.2	1.3	2.9	1.7	7.9	0.0	0.6	71.8
1975	6.1	59.0	0.4	0.0	1.5	1.2	0.9	13.5	1.9	0.0	0.0	0.0	84.5
1976	20.5	132.9	118.7	55.4	0.0	1.1	3.0	23.1	3.1	2.1	10.8	8.5	379.1
1977	36.8	26.0	1.2	40.1	29.5	18.2	0.0	0.0	0.0	3.2	11.9	0.1	166.8
1978	0.0	39.0	4.9	3.0	0.0	1.5	12.1	24.1	1.3	0.0	0.0	0.1	85.8
1979	21.1	0.8	1.4	4.1	0.3	2.9	3.8	0.0	2.3	13.9	1.7	28.6	80.9
1980	4.7	15.4	17.0	0.3	1.2	0.0	7.9	0.1	0.0	0.0	0.2	8.0	54.8
1981	3.8	0.0	1.1	12.4	16.3	1.5	10.7	0.0	0.0	0.0	0.0	0.0	45.8

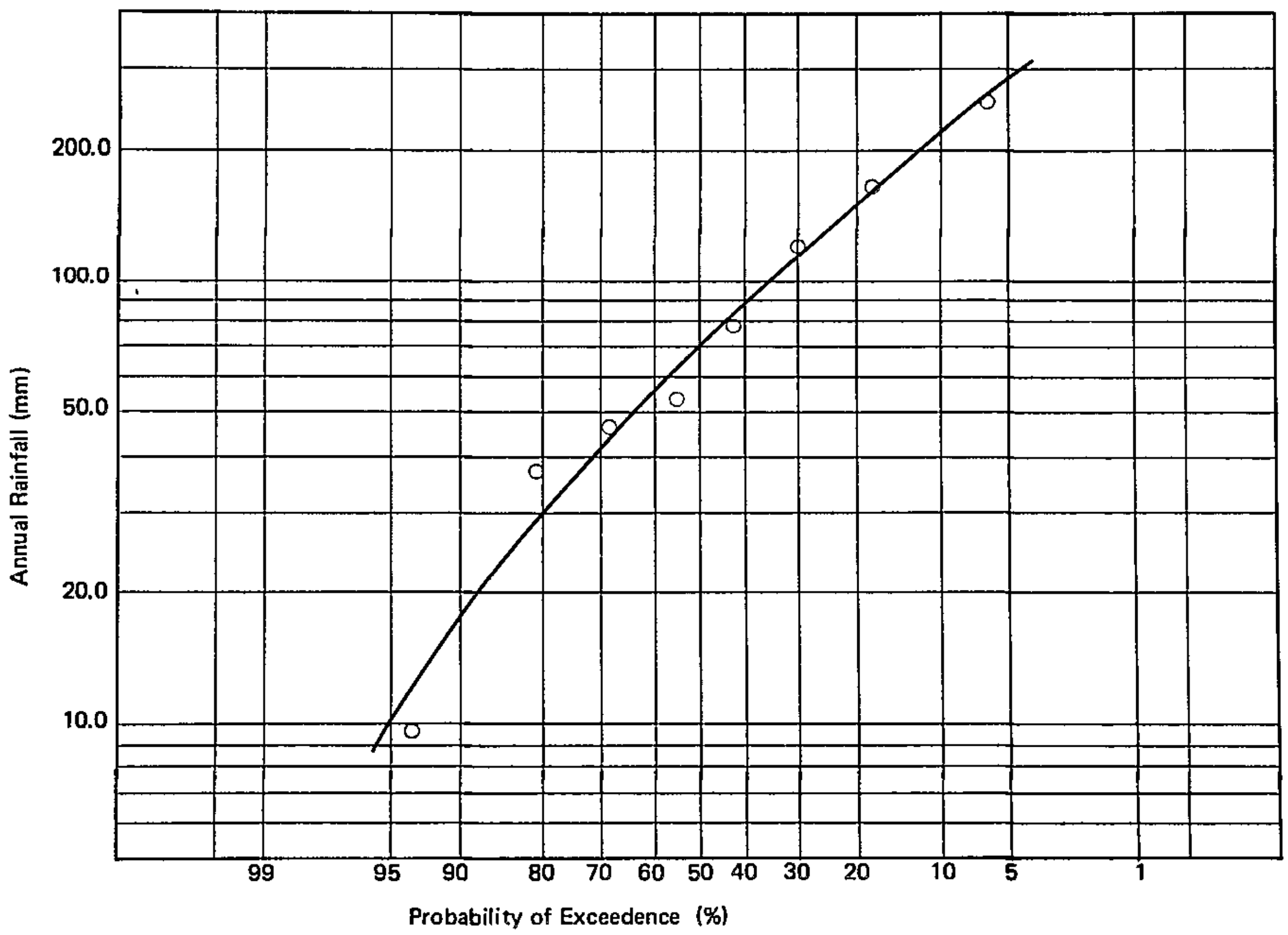


FIGURE A-2 FREQUENCY OF ANNUAL RAINFALL IN SOHAR

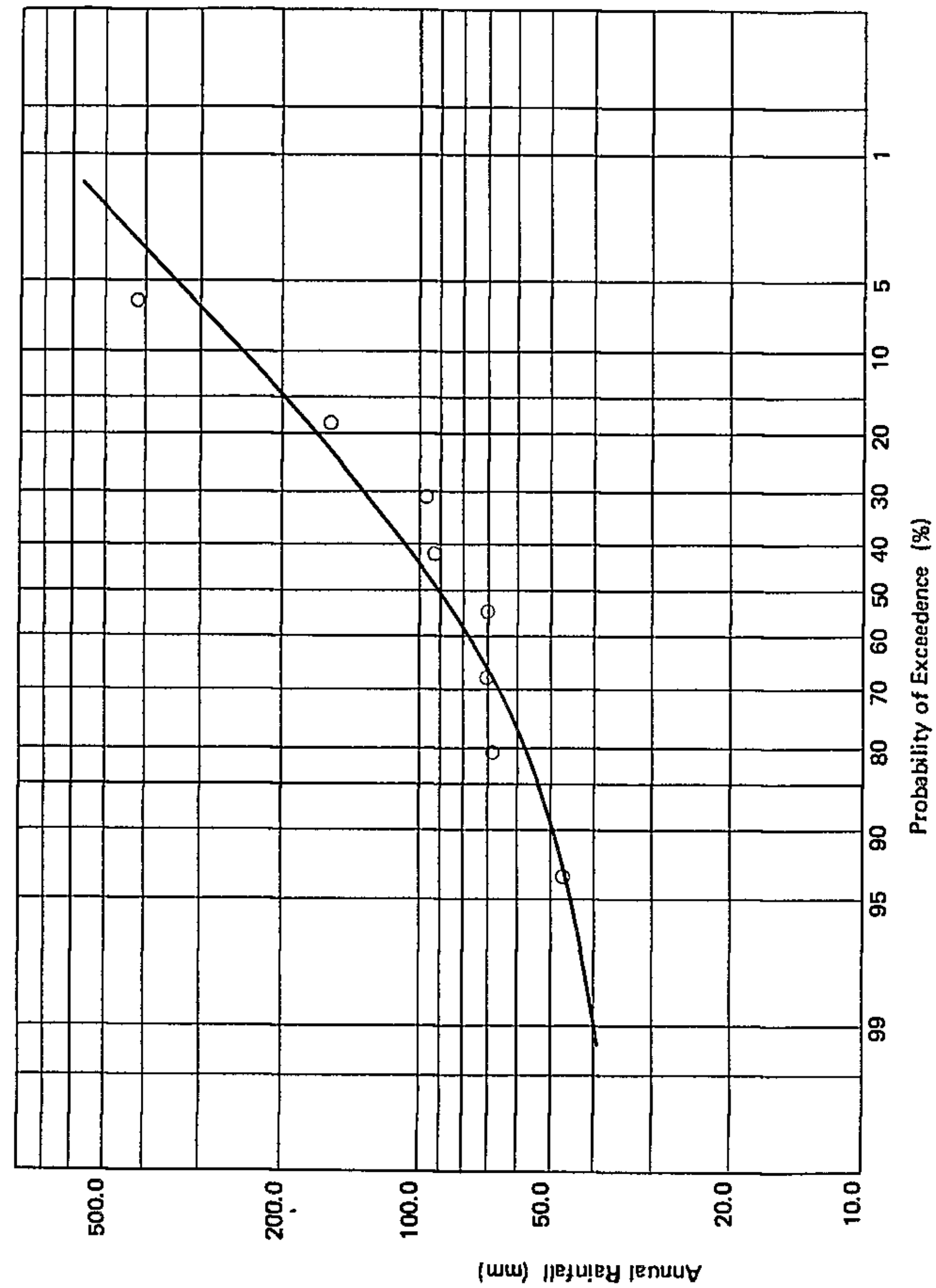


FIGURE A-3 FREQUENCY OF ANNUAL RAINFALL IN THE CATCHMENT

1974--1981

Y = 0.635 X + 2.841 (MM) R = 0.631
X = 0.627 Y + 3.002 (MM)

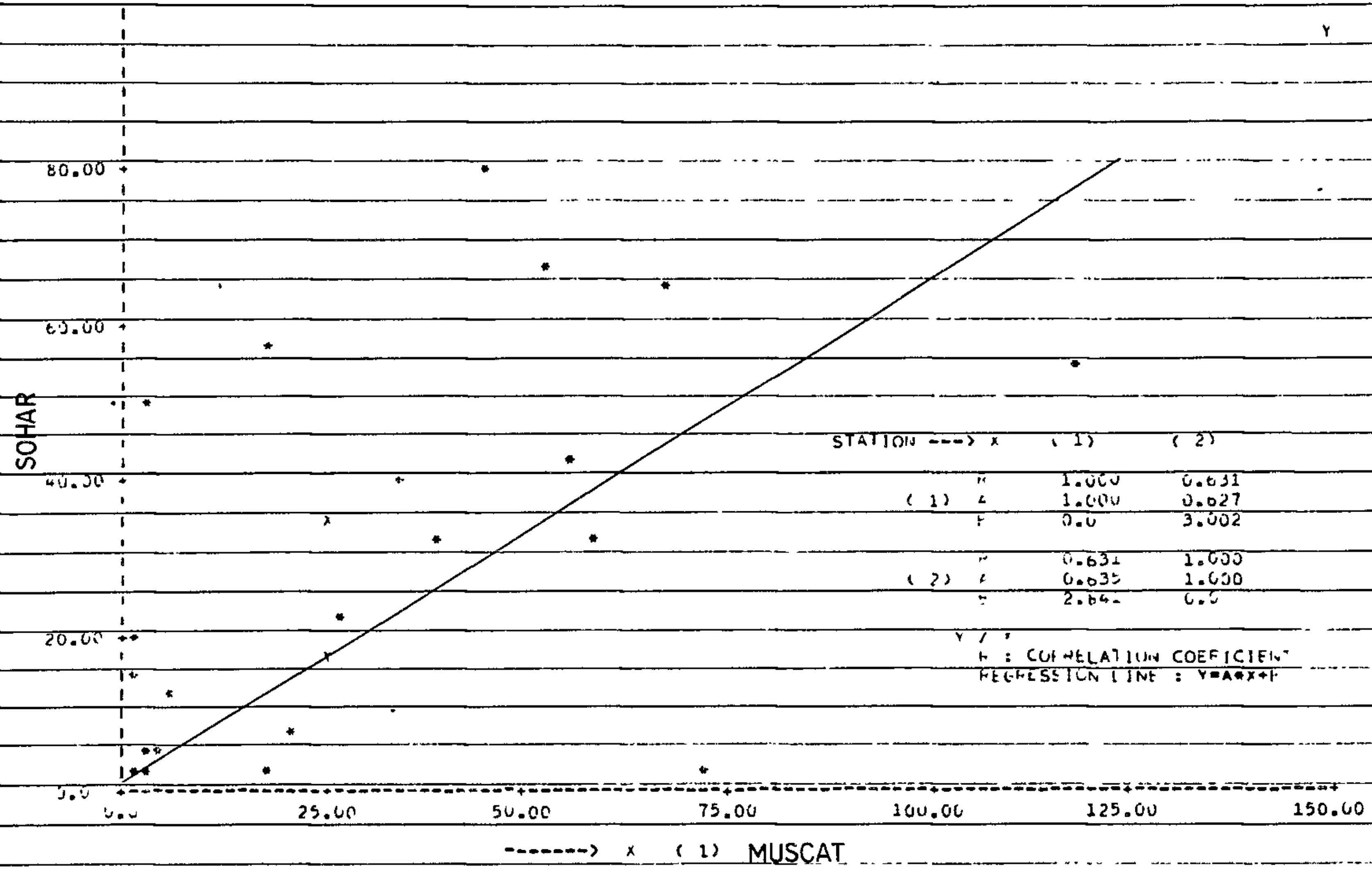


FIGURE A-4 CORRELATION OF MONTHLY RAINFALL BETWEEN SOHAR AND MUSCAT

Frequency Analyses of Seasonal Rainfall in Sohar

Seasonal rainfalls - winter (Nov. - April) and summer (May - Oct.) are shown as follows:

(Unit: mm)

Year	Winter	Summer
1974	49.3	0.0
1975	227.6	6.2
1976	153.0	8.2
1977	60.5	10.9
1978	25.5	3.6
1979	68.1	36.6
1980	25.3	0.0
1981	171.5	12.6
1982	-	0.0

A greater part of the annual rainfall falls during the winter. In summer season, no-rainfall appear with three year-frequency. A frequency curve is shown in Figure A-5.

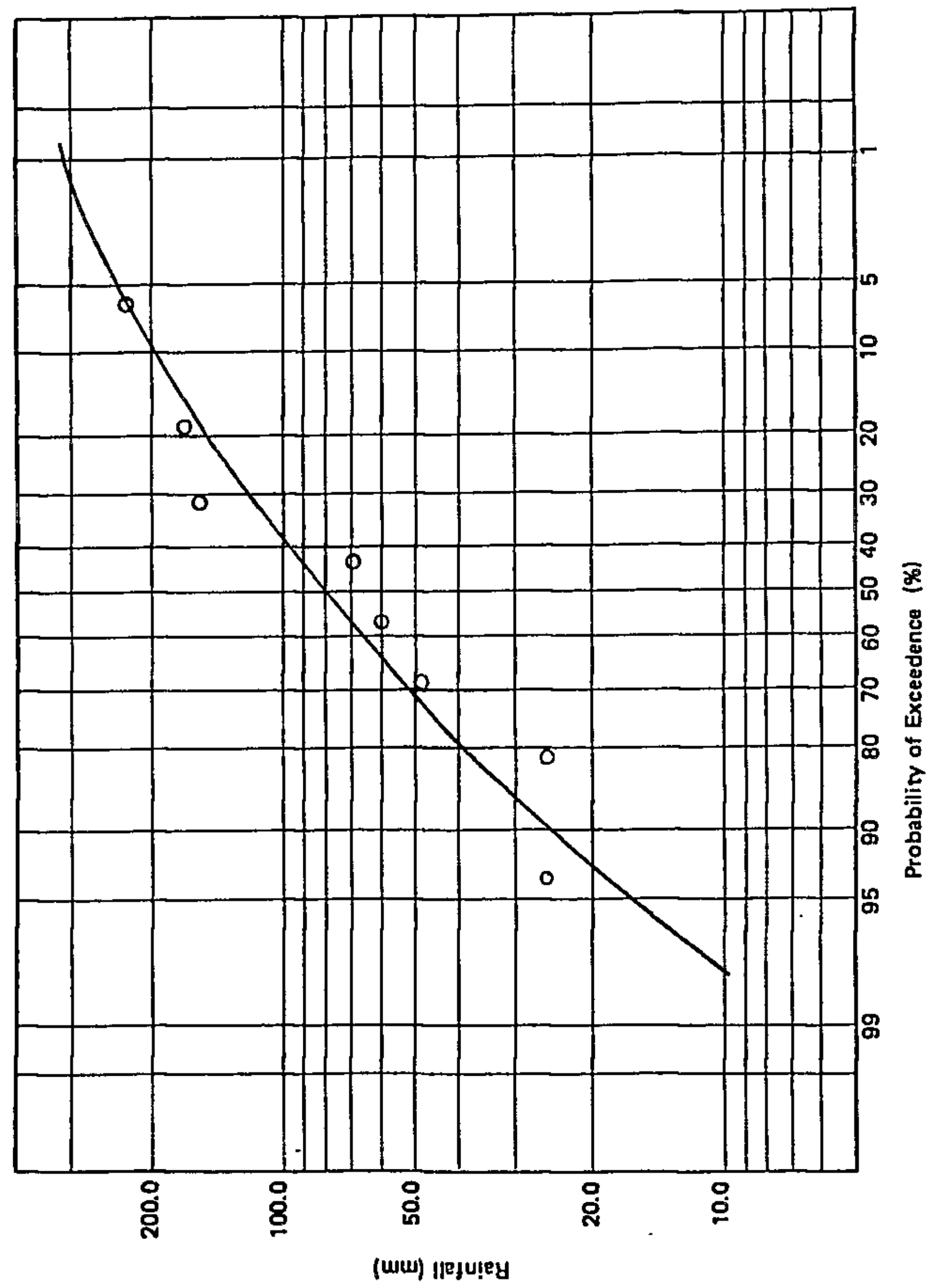


FIGURE A–5 FREQUENCY OF RAINFALL IN SOHAR DURING WINTER SEASON (NOV.–APR.)

Table A-4 Monthly Rainfall at Muscat

(Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Remarks
1893	-	39	*	*	*	*	*	*	*	*	1	13	*	British Emb.
1894	11	57	7	5	-	-	8	-	-	-	-	31	119	"
1895	106	16	65	-	-	-	-	-	-	-	18	-	205	"
1896	63	4	39	-	-	-	-	-	-	4	77	-	187	"
1897	13	16	1	-	-	-	-	-	-	-	-	-	30	"
1898	2	3	36	-	-	64	-	-	-	-	14	3	122	"
1899	-	7	40	-	-	-	-	-	-	-	-	1	48	"
1900	64	34	17	-	-	-	-	-	-	-	23	63	201	"
1901	-	12	28	-	-	-	-	-	-	-	-	13	53	"
1902	-	7	-	7	-	-	-	-	-	25	-	13	52	"
1903	10	-	-	11	-	1	-	-	-	-	1	3	26	"
1904	-	3	3	-	-	-	-	-	-	-	18	1	25	"
1905	31	46	56	-	-	-	-	-	-	-	5	2	140	"
1906	15	33	37	-	-	6	-	1	-	-	-	40	132	"
1907	6	79	-	22	-	-	-	-	-	-	5	4	116	"
1908	6	-	10	3	-	-	-	-	-	-	-	5	24	"
1909	115	-	-	-	-	-	-	-	-	-	-	54	169	"
1910	24	-	11	-	-	-	-	-	-	-	-	38	73	"
1911	67	3	7	-	-	-	-	-	-	-	18	6	101	"
1912	60	12	0	97	-	-	-	7	-	-	5	25	206	"
1913	-	99	22	-	-	-	-	-	-	-	-	14	135	"
1914	3	42	2	-	-	9	3	1	-	14	45	22	141	"
1915	7	1	3	32	-	-	-	-	-	-	-	7	50	"
1916	98	30	5	98	-	-	-	15	-	20	-	-	266	"
1917	60	19	-	2	-	-	-	-	-	-	-	24	105	"
1918	4	-	10	8	-	-	-	-	-	-	-	39	61	"
1919	22	22	20	-	4	-	-	-	-	-	-	-	68	"
1920	6	14	1	-	-	-	-	-	-	-	4	-	25	"
1921	4	-	-	-	-	-	-	-	-	-	25	15	44	"
1922	6	6	-	-	-	-	-	-	-	-	-	-	12	"
1923	7	8	-	36	-	-	-	-	-	-	20	39	110	"
1924	3	6	-	-	-	-	-	-	-	-	-	19	28	"
1925	7	2	5	-	-	-	-	-	-	44	1	-	59	"
1926	25	-	9	6	-	-	-	-	-	-	-	32	72	"
1927	-	17	-	10	-	-	4	-	-	-	10	9	50	"
1928	47	56	-	-	-	-	-	-	-	-	53	19	175	"
1929	8	3	-	-	-	-	-	-	-	-	34	116	161	"
1930	142	1	1	6	-	-	-	-	-	-	-	-	150	Ministry of Defence
1931							No record							
1932							"							
1933							"							
1934							"							
1935							"							
1936	143	6	28	-	-	-	-	-	-	-	12	-	189	British Emb.
1937	29	45	-	-	-	-	-	-	-	-	-	27	101	"
1938	-	-	-	-	-	-	-	-	-	10	-	20	30	"
1939	-	75	-	-	-	-	-	-	-	-	-	23	98	"
1940	21	-	10	-	-	-	-	-	-	-	-	55	86	"
1941	-	0.5	13.5	20	-	-	-	-	-	-	-	-	34	"
1942	4	29	-	-	-	-	-	-	-	-	-	8.5	41.5	
1943	87	*	*	*	*	*	*	*	*	*	*	*	*	
1944	*	*	*	*	*	*	*	*	*	*	*	166	*	
1945	1	-	-	-	-	*	*	*	*	*	*	*	*	
1946	-	*	*	-	-	-	-	-	-	-	-	14	*	
1947	-	2.5	14	-	-	-	-	*	*	*	*	*	*	
1948	29	44.5	25	2.5	-	-	*	*	*	*	*	*	*	
1949	*	*	*	*	*	*	*	*	*	*	*	*	*	
1950	16.5	4	1.5	1.5	2.5	-	0.5	*	*	*	*	*	*	
1951	-	-	62	-	-	-	-	-	-	1	-	6	69	
1952	52	-	-	1	-	-	-	-	-	-	-	16	69	
1953	2	27	-	-	5	-	-	-	-	-	-	15	49	
1954	11	10	1	2	-	-	-	-	-	-	-	1	25	
1955	97	7	70	-	-	-	-	-	-	-	-	14	188	

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Remarks
1956	12.2	13.2	-	0.5	-	-	37.1	-	-	-	-	171	234	
1957	109.0	-	-	62	9	-	-	-	-	-	9	36	225	
1958	53.0	-	-	-	2	-	5	-	-	-	-	16	76	
1959	10.9	-	21.8	2.5	-	-	-	-	-	-	68.6	12.7	115.5	
1960	13.7	-	-	18.3	36.8	-	-	-	-	-	24.1	16	108.9	
1961	2.3	-	2.3	12.2	14.5	-	0.5	-	-	-	1.8	1.0	34.6	
1962	19.8	-	-	6.9	-	-	72.1	-	-	-	-	20.3	119.1	
1963	-	2.3	-	24.9	94	-	-	-	-	-	8.4	11.4	141.0	
1964	11.4	-	10.4	-	-	-	-	-	-	-	-	5.1	26.9	
1965	22.6	-	-	83.1	-	-	-	-	-	-	2.0	-	107.7	
1966	-	88	1	7	-	-	-	-	-	-	-	-	96	P.D.O.
1967	-	-	0.6	7.9	6.2	-	1.9	0.1	-	-	-	5.9	22.6	"
1968	22.8	90.3	2.5	-	-	-	-	-	-	-	-	29.2	144.8	
1969	56.4	5.6	12.2	-	-	-	-	-	-	-	-	-	74.2	
1970	31.7	-	-	-	-	-	-	110	-	-	-	-	141.7	
1971	15.2	-	-	-	-	-	-	-	-	-	37.5	44.9	97.6	
1972	103.9	95.5	47.7	-	-	-	18.3	-	-	-	-	-	265.4	
1973	96.8	-	-	-	-	-	-	-	-	-	-	-	96.8	
1974	-	3.0	-	0.3	-	-	-	-	-	-	-	20.0	23.3	DAR SITE
1975	2.7	79.9	-	-	-	-	-	-	-	-	-	1.0	83.6	"
1976	51.0	56.0	66.3	43.3	-	-	10.0	-	-	-	-	2.0	228.6	"
1977	64.5	22.0	5.7	32.0	-	6.8	-	-	-	-	56.9	-	187.9	"
1978	12.4	39.4	13.4	1.0	-	-	-	-	-	-	0.6	-	66.8	"
1979	6.9	-	-	-	-	-	-	-	-	-	-	32.3	39.2	"
1980	0.8	2.6	0.3	-	-	-	-	-	-	-	-	-	3.7	"
1981	4.2	-	16.0	-	103	-	-	-	-	0.5	-	-	123.7	"

Source: Water Resources Department

Note: 1. - no rainfall
2. * no data

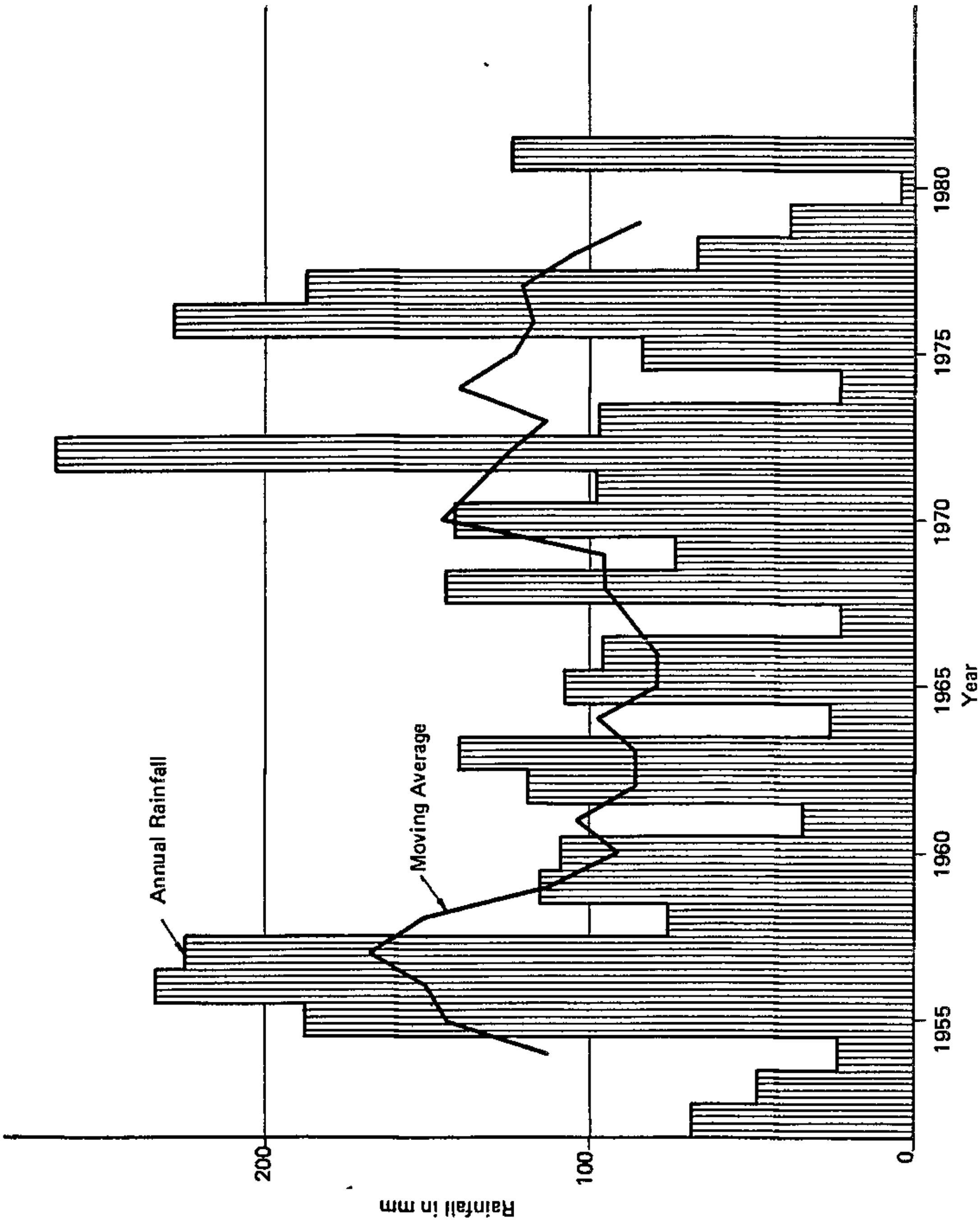


FIGURE A – 6 5 YEAR MOVING AVERAGE OF ANNUAL RAINFALL IN MUSCAT

Table A-5 Monthly Mean Temperature at Sohar

(Unit: °C)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
1973	-	-	-	-	-	-	-	-	-	22.8	20.6	17.7	-
1974	17.0	17.3	23.1	25.4	30.3	33.3	33.1	31.7	30.4	24.5	20.9	18.7	25.5
1975	17.3	18.3	21.4	25.4	31.5	33.2	31.2	31.1	23.2	26.3	22.1	19.2	25.0
1976	17.6	19.4	20.9	23.8	30.6	31.6	32.7	31.9	29.6	27.6	21.1	18.8	25.5
1977	17.6	18.0	22.2	25.2	30.4	31.6	31.7	*30.6	28.9*	26.1*	23.0*	21.0*	25.5
1978	18.4*	18.7*	20.5	26.7	29.4	31.8	32.6	31.3	28.5	25.2	23.4	19.8	25.5
1979	18.2	19.7	21.7	26.8	28.3	30.6	30.8	31.1	29.3	27.3	20.9	20.0	-
1980	18.0	19.9	22.3	28.3	31.5	32.3	33.2	30.9	29.4	-	-	-	-
Average	17.7	18.8	21.7	25.9	30.3	32.1	32.2	31.2	28.4	26.2	21.9	19.6	25.5

Source: Water Resources Department

Note: 1. figures indicate the average of 4 readings at 2:00, 8:00, 14:00 and 20:00 hrs.

2. *average of max. and min.

3. - no data.

Table A-6 Monthly Maximum (Mean and Absolute) Temperature at Sohar

(Unit: °C)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Mean Max. 1973	-	-	-	-	-	-	-	-	-	32.7	28.7	26.8	-
1974	24.4	23.9	30.0	33.1	38.1	40.4	41.2	37.1	36.4	33.8	29.6	25.6	32.8
1975	23.9	24.0	28.1	32.2	38.8	39.2	35.1	35.2	36.2	33.5	28.9	26.2	32.6
1976	24.3	23.2	25.8	30.2	36.0	38.4	37.0	37.4	35.8	33.8	28.4	25.5	31.3
1977	22.7	24.6	30.0	30.5	38.0	37.4	35.6	35.1	34.8	32.8	29.1	27.9	31.5
1978	25.3	24.5	28.9	33.9	37.2	38.4	37.9	36.0	34.1	34.0	30.7	27.0	32.3
1979	24.7	27.5	28.1	34.7	37.6	38.0	37.4	37.1	36.3	35.0	30.6	24.2	32.6
1980	24.4	25.4	28.7	37.1	39.6	38.8	38.9	36.2	35.5	-	-	-	-
Average	24.2	24.7	28.5	33.1	37.9	38.7	37.6	36.3	35.6	33.8	29.6	26.1	32.2
Abs. Max. 1973	-	-	-	-	-	-	-	-	-	35.1	34.2	29.0	-
1974	28.2	27.0	38.0	42.5	46.5	47.2	46.7	43.6	40.6	37.8	34.4	29.5	38.5
1975	28.6	28.9	33.5	36.4	41.5	47.3	39.0	39.5	39.9	39.5	33.8	29.7	36.4
1976	28.8	30.0	29.4	37.0	42.8	44.3	42.2	46.1	42.2	38.2	31.2	27.9	36.7
1977	25.5	28.5	36.5	40.7	43.0	43.5	40.0	42.8	42.4	35.6	34.1	31.8	36.3
1978	28.8	30.4	36.5	40.4	44.3	44.9	45.7	40.5	40.7	37.7	38.9	29.9	37.4
1979	27.5	33.7	34.5	39.9	45.3	45.0	45.7	42.0	41.9	40.4	33.0	30.6	38.3
1980	27.5	29.6	34.3	44.5	44.0	47.2	46.0	43.6	39.3	-	-	-	-
Average	27.8	29.7	31.8	40.2	43.9	45.6	43.7	42.6	41.0	37.9	34.2	29.8	37.4

Source: Water Resources Department

Note: - no data

Table A-7 Monthly Minimum (Mean and Absolute) Temperature at Sohar

(Unit: °C)

Year		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Mean Min.	1973	-	-	-	-	-	-	-	-	-	14.3	13.3	12.1	-
	1974	12.1	12.8	17.3	18.0	23.0	25.2	26.2	26.9	24.6	16.8	14.0	12.9	19.2
	1975	12.2	13.8	14.5	18.0	23.3	25.7	28.1	27.4	23.2	18.7	15.2	12.9	19.4
	1976	10.8	13.6	16.4	16.9	20.9	24.7	24.7	27.1	23.9	20.8	14.6	12.8	18.9
	1977	12.9	11.1	14.8	18.6	23.3	25.6	31.0	26.1	23.0	19.4	16.9	14.1	19.7
	1978	11.4	12.9	13.3	20.4	20.5	25.1	28.1	26.8	22.5	16.8	16.8	13.4	19.0
	1979	12.1	11.7	15.2	17.2	20.5	27.6	26.4	25.2	23.0	20.1	13.9	14.2	18.9
	1980	11.8	14.3	16.1	19.4	22.4	25.7	27.5	26.4	23.5	-	-	-	-
	Average	11.9	12.9	15.4	18.4	22.0	25.6	27.4	26.6	23.4	18.8	15.2	13.4	19.3
Abs. Min.	1973	-	-	-	-	-	-	-	-	-	12.6	5.4	8.2	-
	1974	8.4	9.0	13.4	12.5	18.7	20.6	21.6	23.9	22.0	10.2	10.3	9.3	15.0
	1975	8.7	8.3	9.3	10.7	19.2	22.6	25.0	22.8	19.1	11.4	11.0	10.0	14.8
	1976	7.3	8.7	11.0	12.8	15.0	22.1	21.7	23.8	19.9	17.9	7.9	7.5	14.6
	1977	6.7	7.2	9.5	13.6	20.1	21.5	21.2	23.2	16.3	17.8	11.0	10.8	14.9
	1978	6.5	9.4	9.0	11.8	16.2	20.2	23.3	23.0	19.5	13.4	11.0	10.7	14.5
	1979	7.4	8.3	10.1	13.7	15.9	24.7	23.4	21.4	16.9	17.5	6.4	10.8	14.7
	1980	8.5	8.0	9.4	14.2	17.3	21.0	23.0	21.5	20.3	-	-	-	-
	Average	7.6	8.4	10.2	12.8	17.5	21.8	22.7	22.8	19.1	14.4	9.0	9.6	14.7

Source: Water Resources Department

Note: - no data

Table A-8 Monthly Mean Humidity at Sohar

(Unit: %)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
1973	-	-	-	-	-	-	-	-	-	65.0	70.0	72.0	-
1974	74.0	75.0	70.0	69.0	58.0	59.0	66.0	79.0	76.0	67.0	73.0	75.0	70.1
1975	74.0	78.0	70.0	57.0	58.0	70.0	80.0	79.0	72.0	68.0	72.0	77.0	71.3
1976	73.0	78.0	79.0	-	53.0	74.0	77.0	78.0	79.0	78.0	70.0	78.0	-
1977	73.0	68.0	69.0	66.0	52.0	71.0	85.0	-	-	-	-	-	-
1978	-	-	77.0	75.0	67.0	71.0	77.0	85.0	83.0	76.0	77.0	80.0	-
1979	75.0	72.0	72.0	72.0	60.0	74.0	70.0	77.0	78.0	61.0	83.0	84.0	73.2
1980	77.0	79.0	77.0	65.0	58.0	79.0	71.0	74.0	75.0	-	-	-	-
Average	74.3	75.0	73.4	67.3	58.0	71.1	75.1	78.6	77.2	70.0	75.0	78.8	72.8

Source: Water Resources Department

Note: - no data

Table A-9 Monthly Maximum (Mean and Absolute) Humidity at Sohar

(Unit: %)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Mean Max. 1973	-	-	-	-	-	-	-	-	-	95.0	94.0	95.0	-
1974	94.0	94.0	94.0	98.0	86.0	91.0	95.0	98.0	97.0	97.0	99.0	96.0	94.9
1975	95.0	97.0	95.0	92.0	86.0	97.0	97.0	95.0	93.0	94.0	97.0	95.0	94.4
1976	95.0	85.0	93.0	94.0	92.0	98.0	96.0	98.0	99.0	100.0	98.0	100.0	95.7
1977	94.0	98.0	95.0	92.0	84.0	97.0	98.0	97.0	95.0	95.0	99.0	98.0	95.2
1978	97.0	96.0	92.0	87.0	87.0	96.0	97.0	100.0	100.0	100.0	99.0	100.0	95.9
1979	99.0	99.0	96.0	93.0	95.0	96.0	95.0	99.0	100.0	100.0	99.0	99.0	97.5
1980	99.0	99.0	99.0	98.0	94.0	99.0	97.0	100.0	100.0	-	-	-	-
Average	96.1	95.4	94.9	93.4	89.1	96.3	96.4	98.1	97.7	97.3	97.9	97.6	95.9
Abs. Max. 1973	-	-	-	-	-	-	-	-	-	97.0	100.0	100.0	-
1974	99.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9
1975	100.0	100.0	100.0	100.0	98.0	100.0	100.0	100.0	96.0	99.0	100.0	100.0	99.4
1976	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	100.0	100.0	97.0	95.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.3
1979	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1980	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	-	-	-	-
Average	99.9	100.0	99.6	99.3	99.7	100.0	100.0	100.0	99.4	99.4	100.0	100.0	99.8

Source: Water Resources Department

Note: - no data

Table A-10 Monthly Minimum (Mean and Absolute) Relative Humidity at Sohar

(Unit: %)

Year		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Mean Min.	1973	-	-	-	-	-	-	-	-	-	32.0	37.0	46.0	-
	1974	48.0	52.0	42.0	34.0	29.0	31.0	31.0	51.0	44.0	29.0	36.0	44.0	39.3
	1975	43.0	48.0	39.0	30.0	30.0	34.0	57.0	54.0	39.0	36.0	44.0	44.0	41.5
	1976	41.0	43.0	48.0	40.0	23.0	37.0	49.0	49.0	46.0	42.0	39.0	48.0	42.1
	1977	43.0	35.0	26.0	30.0	25.0	42.0	60.0	53.0	43.0	40.0	39.0	40.0	39.7
	1978	44.0	43.0	24.0	26.0	14.0	31.0	41.0	51.0	53.0	20.0	39.0	47.0	36.1
	1979	40.0	26.0	34.0	6.0	15.0	33.0	33.0	36.0	41.0	30.0	35.0	53.0	31.8
	1980	41.0	46.0	77.0	16.0	22.0	43.0	51.0	67.0	53.0	-	-	-	-
	Average	42.9	41.9	41.4	26.0	22.6	35.9	46.0	51.6	45.6	32.7	38.4	46.0	39.2
Abs. Min.	1973	-	-	-	-	-	-	-	-	-	20.0	17.0	32.0	-
	1974	28.0	24.0	17.0	21.0	12.0	9.0	11.0	16.0	25.0	15.0	14.0	21.0	17.8
	1975	27.0	21.0	17.0	17.0	16.0	9.0	35.0	13.0	13.0	19.0	18.0	23.0	19.0
	1976	22.0	22.0	21.0	13.0	10.0	13.0	17.0	18.0	15.0	17.0	17.0	24.0	17.4
	1977	23.0	14.0	12.0	11.0	9.0	15.0	30.0	17.0	16.0	18.0	23.0	24.0	17.7
	1978	17.0	13.0	7.0	2.0	2.0	2.0	5.0	5.0	25.0	4.0	23.0	22.0	10.6
	1979	7.0	9.0	4.0	2.0	1.0	2.0	8.0	2.0	9.0	2.0	10.0	27.0	6.9
	1980	18.0	15.0	49.0	0	2.0	3.0	7.0	3.0	8.0	-	-	-	-
	Average	20.3	16.9	18.1	9.4	7.4	7.6	16.1	10.6	15.9	13.6	17.4	24.7	14.8

Source: Water Resources Department

Note: - no data

Table A-11 Monthly Mean Wind Velocity at Sohar

(Unit: km/day)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
2 m height 1973	-	-	-	-	-	-	-	-	-	60.6	54.0	54.7	-
1974	69.5	75.5	60.6	85.6	87.3	93.4	81.6	92.5	79.9	57.6	48.3	42.8	72.9
1975	58.4	62.0	80.1	69.6	78.8	71.2	106.3	86.1	65.8	59.6	52.3	45.0	69.6
1976	46.5	60.8	61.8	57.3	57.7	62.0	71.7	84.5	80.8	55.4	46.0	40.5	60.4
1977	49.9	47.8	44.0	61.1*	79.1**	94.0	96.3	91.7	65.1	60.0	50.5	46.8	65.5
1978	56.7	61.7	68.7	78.6	76.5	75.2	92.1	87.1	81.6	61.8	60.5	46.3	70.6
1979	63.2	69.5	86.1	78.3	76.5	90.0	95.0	85.5	79.6	65.9	49.9	53.5	74.4
1980	54.1	55.2	73.5	74.2	79.3	65.9	87.9	94.0	76.4	-	-	-	-
Average	57.0	61.8	67.8	72.1	76.5	78.8	90.1	88.8	75.6	60.1	51.3	45.8	68.8
1/2 m height 1977	-	-	-	39.5	34.8	47.1	25.8	5.8	17.8	20.8	-	20.1	-
1978	26.2	-	37.8	41.0	-	27.8	38.0	26.5	33.5	31.2	31.7	24.7	-
1979	28.1	36.2	50.1	44.4	43.2	50.8	51.5	48.7	45.7	39.9	27.9	30.2	41.4
1980	28.1	33.0	34.6	39.9	41.9	43.4	49.5	52.1	-	-	-	-	-
Average	27.5	34.6	40.8	41.2	40.0	42.3	41.2	33.3	32.3	30.6	29.8	25.0	34.9

Source: Water Resources Department

Note: 1. * except 1.4 - 13.4

2.** except 21.5 - 29.5

Table A-12 Monthly Absolute Maximum Wind Velocity at Sohar

(Unit: km/day)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
2 m height 1973	-	-	-	-	-	-	-	-	-	68.4	91.1	106.0	-
1974	141.4	132.9	113.7	200.8	125.3	192.5	145.7	122.8	103.2	99.7	91.0	81.8	129.2
1975	222.0	184.0	195.8	160.7	158.9	104.9	145.3	139.8	104.2	84.5	96.4	61.6	138.2
1976	-	124.1	-	-	120.6	96.2	96.2	162.1	113.3	102.5	67.9	50.0	-
1977	91.8	73.9	59.8	81.5	188.0	238.2	124.0	188.0	89.8	72.2	68.0	73.2	112.4
1978	104.0	92.7	110.0	99.2	120.7	101.9	158.1	112.5	100.0	74.3	83.2	80.6	103.1
1979	94.8	105.7	131.9	113.9	111.7	142.7	153.2	106.7	114.1	79.9	74.1	87.6	109.7
1980	85.6	108.0	139.2	93.9	115.0	109.6	119.7	135.3	105.0	-	-	-	-
Average	123.3	117.3	125.1	125.0	134.3	140.9	134.6	138.2	104.2	83.1	81.7	77.3	115.4
1/2 m height 1977	-	-	-	76.8	54.3	156.2	54.8	21.4	35.0	29.7	-	32.4	-
1978	44.3	-	74.2	59.6	-	67.1	61.5	44.5	47.9	46.2	45.5	43.4	-
1979	38.6	58.3	86.4	65.9	56.1	89.9	84.1	59.3	73.2	52.7	48.4	50.5	63.6
1980	60.0	49.1	51.2	54.5	57.2	58.6	65.1	67.9	-	-	-	-	-
Average	47.6	53.7	70.6	64.2	55.9	93.0	66.4	48.3	52.0	42.9	47.0	42.1	57.0

Source: Water Resources Department

Note: - no data

Table A-13 Monthly Absolute Minimum Wind Velocity at Sohar

(Unit: km/day)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
2 m height 1973	-	-	-	-	-	-	-	-	-	50.5	36.0	39.9	-
1974	41.5	47.7	37.5	55.3	67.8	63.3	62.7	70.8	57.3	31.9	33.8	17.2	48.9
1975	36.4	19.7	51.6	12.3	53.4	48.2	57.8	53.4	38.0	39.3	36.4	32.6	39.9
1976	21.3	4.6	32.7	22.9	38.6	47.0	52.5	59.3	55.8	32.2	20.9	30.4	34.9
1977	24.5	23.5	24.2	40.9*	62.1**	59.3	73.5	46.4	37.5	52.0	36.6	30.8	42.6
1978	40.6	38.0	12.5	62.6	57.3	43.3	62.7	57.7	51.9	46.1	0.05	47.6	43.4
1979	41.8	42.4	69.7	56.6	56.3	53.0	41.3	52.6	60.9	51.3	34.5	13.8	47.9
1980	12.9	51.0	5.3	60.4	45.8	48.0	62.7	62.7	62.5	-	-	-	-
Average	31.3	32.4	33.4	44.4	54.5	51.7	59.0	57.6	52.0	43.3	28.3	30.3	43.2
1/2 m height 1977	-	-	-	11.3	22.2	28.1	5.9	0.3	0.4	11.0	-	7.3	-
1978	10.0	-	5.6	21.0	-	6.3	17.2	8.6	8.6	6.5	20.0	8.2	-
1979	13.9	18.8	36.6	29.1	33.1	25.7	35.5	27.0	31.2	29.9	13.2	11.8	25.5
1980	2.8	10.2	19.7	15.5	31.7	28.0	35.5	33.6	-	-	-	-	-
Average	8.9	14.5	20.6	19.2	29.0	22.0	23.5	17.4	13.4	15.8	16.6	9.1	17.5

Source: Water Resources Department

Note: - no data

Table A-14 Monthly Mean Evaporation at Sohra

(Unit: mm/day)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
1976	-	-	-	-	-	-	-	-	-	-	4.6	3.0	-
1977	3.1	4.0	5.3	6.6	9.2	8.1	7.1	6.9	6.4	5.3	3.8	3.2	5.78
1978	3.6	3.6	5.4	6.9	7.8	7.9	6.9	6.6	6.0	5.3	4.1	3.1	5.60
1979	3.3	4.3	5.4	8.1	8.2	8.5	8.3	7.1	6.9	5.1	3.4	2.8	5.95
1980	3.2	3.5	4.4	7.9	9.8	7.0	6.9	6.4	5.2	-	-	-	-
Ave.(mm/day)	3.3	3.9	5.1	7.4	8.8	7.9	7.3	6.8	6.1	5.2	3.7	3.0	5.72
(mm/mon.)	102.3	109.2	158.1	222.0	272.8	237.0	226.3	210.8	183.0	161.2	111.0	93.0	2,086.7

Source: Water Resources Department

Note: - no data

Table A-15 Monthly Maximum and Minimum Evaporation at Sohar

(Unit: mm/day)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Max. 1976	-	-	-	-	-	-	-	-	-	-	5.7	3.7	-
1977	5.7	5.5	9.6	9.4	13.6	13.1	12.2	10.9	12.8	12.2	5.2	5.2	9.6
1978	5.2	4.8	7.8	9.6	11.8	10.8	9.7	9.6	8.7	6.7	5.4	5.2	7.9
1979	4.7	6.4	10.4	13.4	9.7	11.1	10.5	8.3	9.6	6.5	3.9	4.7	8.3
1980	5.6	5.2	6.9	10.4	14.3	9.6	9.1	13.9	8.3	-	-	-	-
Average	5.3	5.5	8.7	10.7	12.4	11.2	10.4	10.7	9.9	8.5	5.1	4.7	8.6
Min. 1976	-	-	-	-	-	-	-	-	-	-	2.7	1.4	-
1977	0.5	1.9	3.1	0.2	5.3	5.2	4.4	4.3	4.2	3.7	2.0	1.7	3.0
1978	1.7	0.9	2.6	1.3	5.2	5.0	3.5	4.4	4.8	4.0	2.9	1.9	3.2
1979	2.4	3.1	3.4	4.2	7.0	6.5	7.0	5.7	4.7	2.2	2.5	0.5	4.1
1980	2.1	1.0	1.4	4.7	7.4	4.4	4.9	4.4	2.6	-	-	-	-
Average	1.7	1.7	2.6	2.6	6.2	5.3	5.0	4.7	4.1	3.3	2.5	1.4	3.4

Source: Water Resources Department

Note: - no data

Table A-16 Monthly Mean Sunshine Hours at Sohar

(Unit: hrs/day)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
1973	-	-	-	-	-	-	-	-	-	-	-	8.50	-
1974	7.00	7.50	7.40	9.20	10.10	10.60	9.90	9.00	9.30	9.40	9.30	7.70	8.90
1975	6.80	7.00	9.20	8.10	10.70	10.00	8.50	7.76	9.38	9.52	8.50	7.70	8.60
1976	7.31	6.67	6.75	8.80	10.75	10.78	9.33	8.77	9.58	8.77	8.29	7.01	8.60
1977	6.70	8.99	8.00	8.06	10.05	9.16	8.18	8.55	9.42	9.06	8.17	7.19	8.50
1978	7.75	7.40	9.10	8.33	10.12	9.00	7.76	8.60	9.00	8.93	7.91	7.50	8.50
1979	7.46	8.54	7.94	9.58	9.97	-	-	-	-	-	-	-	-
Average	7.17	7.68	8.07	8.68	10.28	9.91	8.73	8.54	9.34	9.14	8.43	7.60	8.63

Source: Water Resources Department

Note: - no data

Table A-17 Monthly Maximum and Minimum Sunshine Hours at Sohar

(Unit: hrs/day)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Max. 1973	-	-	-	-	-	-	-	-	-	-	-	9.10	-
1974	9.20	10.20	10.50	11.00	11.90	11.90	11.80	10.50	10.40	10.40	9.90	9.50	10.60
1975	9.50	10.10	10.80	12.00	12.05	11.19	11.33	10.58	10.97	10.35	9.50	8.77	10.60
1976	8.50	9.50	10.10	11.67	12.35	12.00	11.42	10.77	10.50	10.00	8.93	8.92	10.40
1977	9.15	10.35	10.33	10.58	11.42	11.25	10.47	10.40	10.40	10.25	14.63	8.40	10.60
1978	9.05	10.00	10.17	10.63	11.57	10.88	10.37	10.40	10.00	9.50	9.42	8.63	10.10
1979	8.68	9.25	10.42	10.88	11.42	-	-	-	-	-	-	-	-
Average	9.00	9.90	10.40	11.10	11.80	11.40	11.10	10.50	10.50	10.10	10.50	8.90	10.40
Min. 1973	-	-	-	-	-	-	-	-	-	-	-	7.20	-
1974	0.90	1.00	0.00	4.30	5.50	7.00	5.70	4.00	5.30	4.30	0.20	2.40	3.40
1975	0.00	0.00	2.40	0.20	5.53	8.55	6.08	0.40	6.30	8.03	6.50	1.50	3.80
1976	1.10	0.00	1.15	2.33	7.17	0.25	7.60	5.25	6.86	7.00	5.47	3.30	4.00
1977	1.42	1.65	0.13	0.00	6.75	2.75	0.85	2.03	5.85	1.83	2.77	1.17	2.30
1978	1.30	0.07	3.10	1.80	6.47	5.25	2.13	1.50	6.25	7.75	4.00	4.23	3.70
1979	4.68	5.08	0.50	3.53	5.28	-	-	-	-	-	-	-	-
Average	1.60	1.30	1.20	2.00	6.10	4.80	4.50	2.60	6.10	5.80	3.80	3.30	3.60

Source: Water Resources Department

Note: - no data

Table A-18 List of Water Level Recorder and Rainfall Recorder in the Basin

Gauge No.		Equipment No.	Date Installed	Name of Station	Note
Water Level Recorder	No.1	215888	Dec. 1981	Mulayyinah No.1	Three Month
"	No.2	215880	"	" 2	"
"	No.3	215884	"	Irish Bridge of Wadi Jizzi	"
"	No.4	215886	"	Mouth of Wadi Jizzi	"
Rainfall Recorder	No.1	207538	"	Daqiq	"
"	No.2	207536	"	Kitnah	"
"	No.3	207546	Jan. 1982	Hayl (Wadi Jizzi)	"
"	No.4	207547	"	Hayl (Wadi Hayl)	"
"	No.5	207548	Feb. 1982	Khan	"

Note: The location of these gauges are shown in Figure 3-2.
The meteorological data of the Sohar Royal Farm have not been collected.

APPENDIX B. SURFACE WATER

APPENDIX B. SURFACE WATER

Table B-1 Falaj Discharge in the Basin

Name of Village	Gross Area [1/] (ha)	Net Area [2/] (ha)	Falaj Discharge [3/] (ℓ/s)
1. Daqiq	14	9.1	7.28
2. Kitna	10	6.5	5.20
3. Hayl (W.Jizzi)	30	19.5	15.60
4. Wasit	24	15.6	12.48
5. Sahban	10	6.5	5.20
6. Farfar	5	3.2	2.56
7. Bani Hina	10	6.5	5.20
8. Hansi	5	3.2	2.56
9. Ghurfah	4	2.6	2.08
10. Ath Thuqbah	7	4.6	3.68
11. Ays	9	5.9	4.72
12. Jebba Gebba	2	1.3	1.04
13. Hayl (W.Hayl)	20	13.0	10.40
Total	150	97.5	78.00

1/; Topographical map (1:50,000)

2/; Gross area x 0.65

3/; Net area x 0.8 ℓ/sec

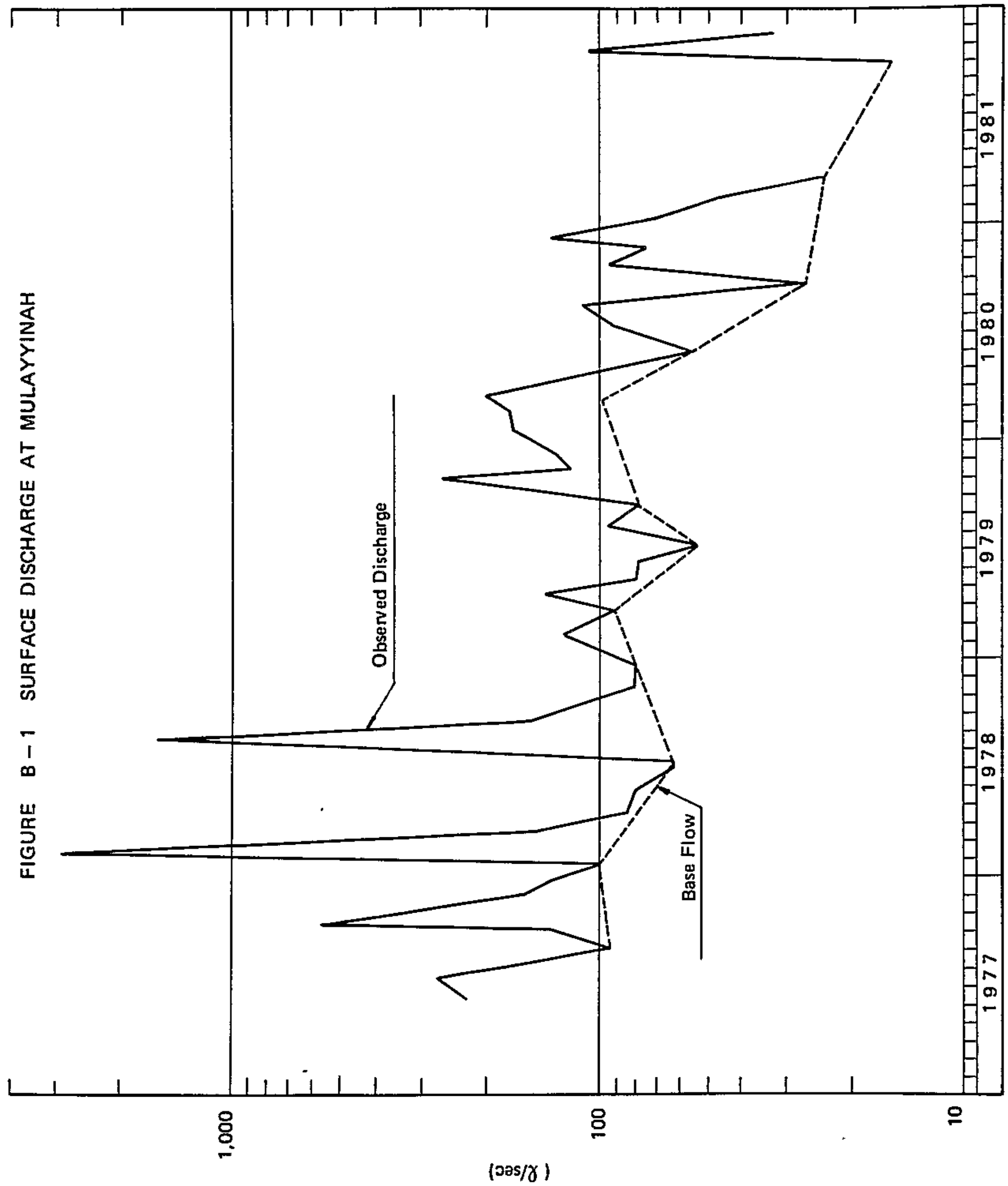


FIGURE B-1 SURFACE DISCHARGE AT MULAYYINAH

Table B-2 Base Flow Discharge at Mulayyinah (Unit: 1/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Mean
1977	*	*	*	*	*	*	*	*	95	96	98	99	*	(97)
1978	100	94	88	83	77	71	65	68	71	74	78	81	950	79
1979	84	87	90	81	73	64	55	68	80	83	87	90	942	79
1980	93	97	100	88	76	64	52	40	28	27	26	26	717	60
1981	25	24	23	22	21	20	18	17	16	*	*	*	*	(21)
Average														67.2 (0.101/sec/sq.km)

Note : * no available data

Table B-3 Observed Flood Volume at Mulayyinah (Catchment Area 654 sq.km)

Date	Flood Volume (cu.m '000)	Area Rainfall (mm)	Runoff Ratio (%)
15 Feb.'74	160	32.4	0.8
18 - 19 Feb.'74	140	7.0	3.1
2 Oct.'74	190	2.5	11.6
6 - 7 Oct.'74	910	6.0	23.2
11 Feb.'75	2,300	49.2	7.1
24 - 25 Jan.'79	160	15.4	1.6
2 Apr.'79	50	3.0	2.5
Average			7.1

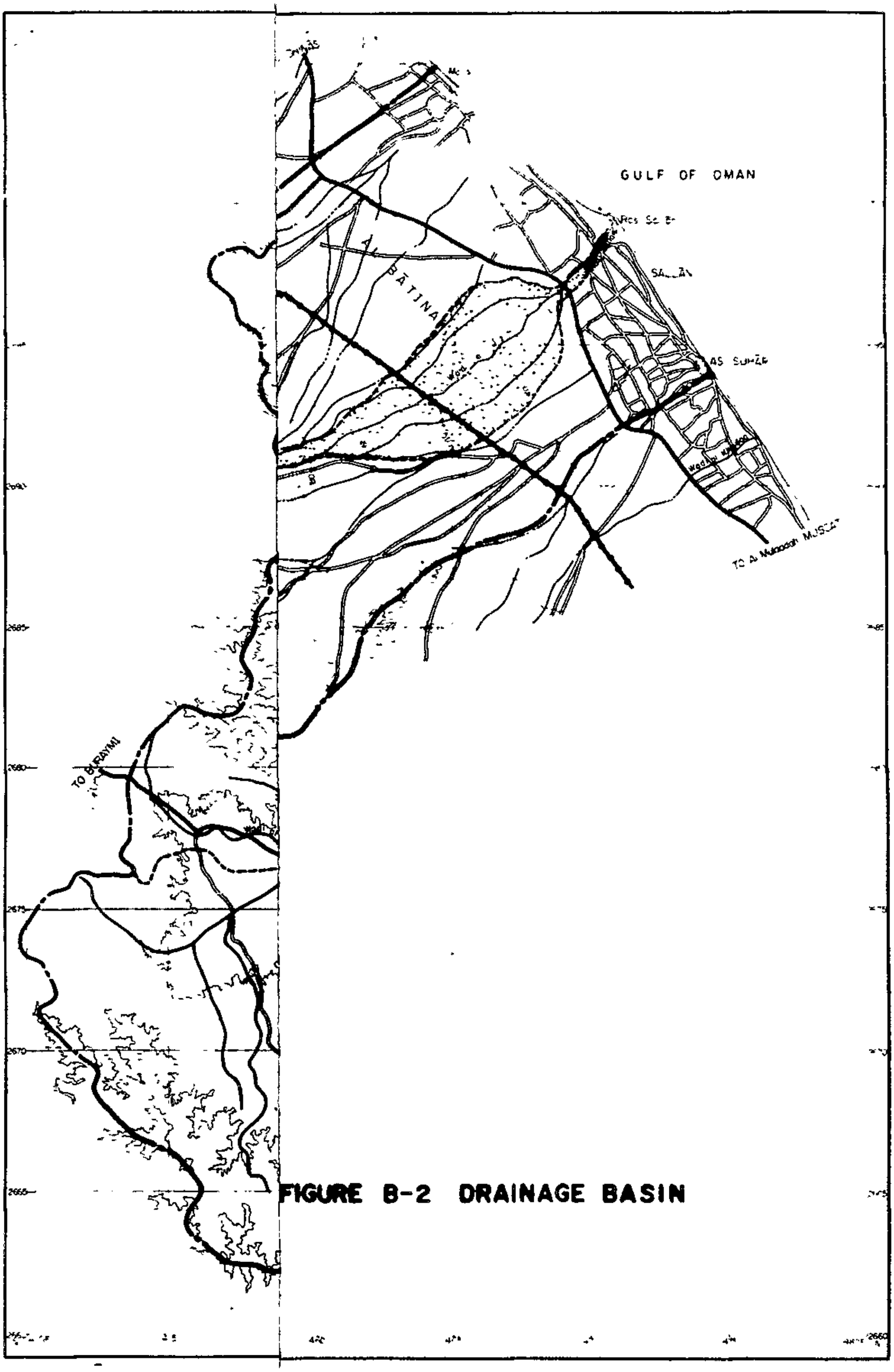


FIGURE B-2 DRAINAGE BASIN

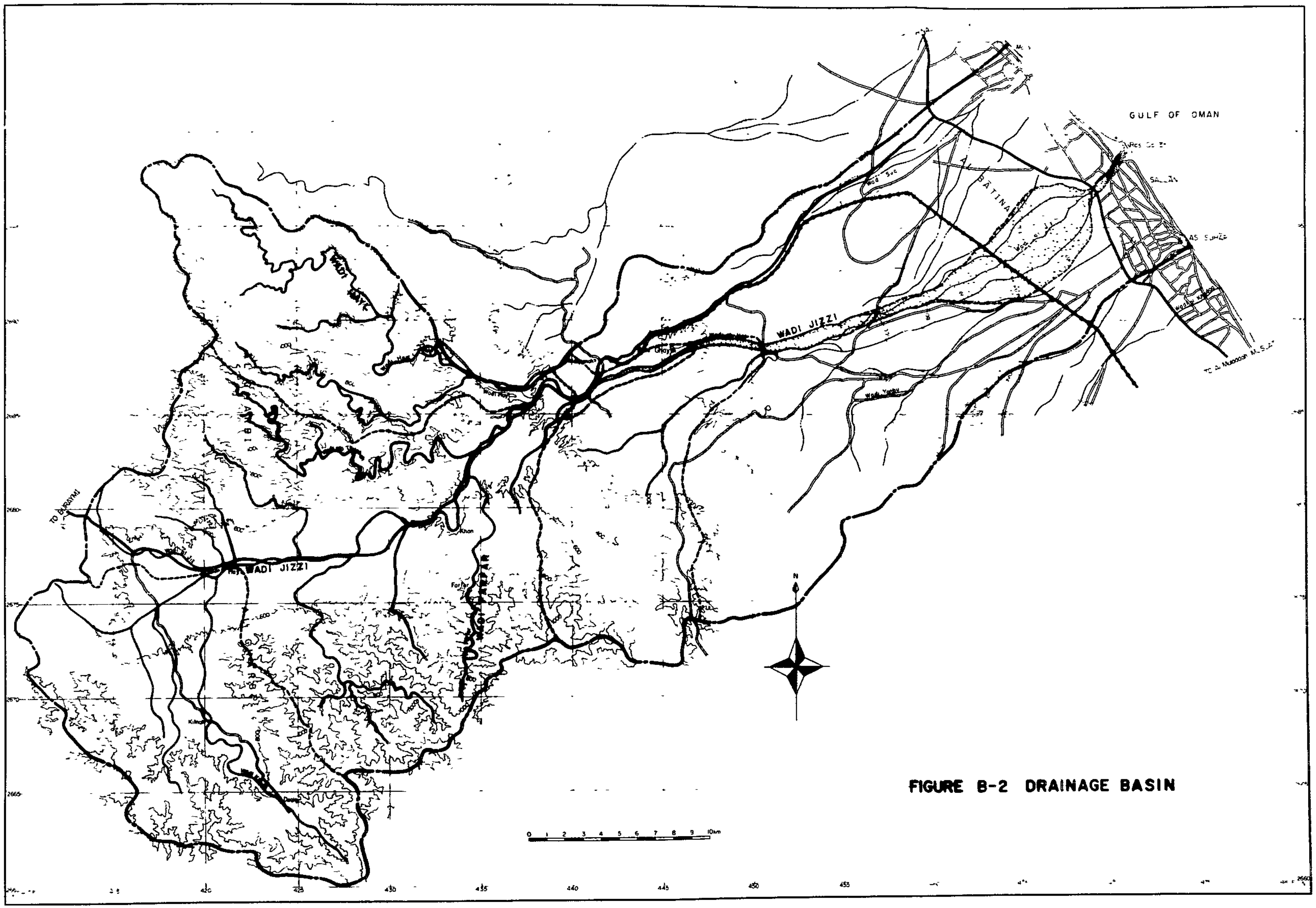


FIGURE B-2 DRAINAGE BASIN

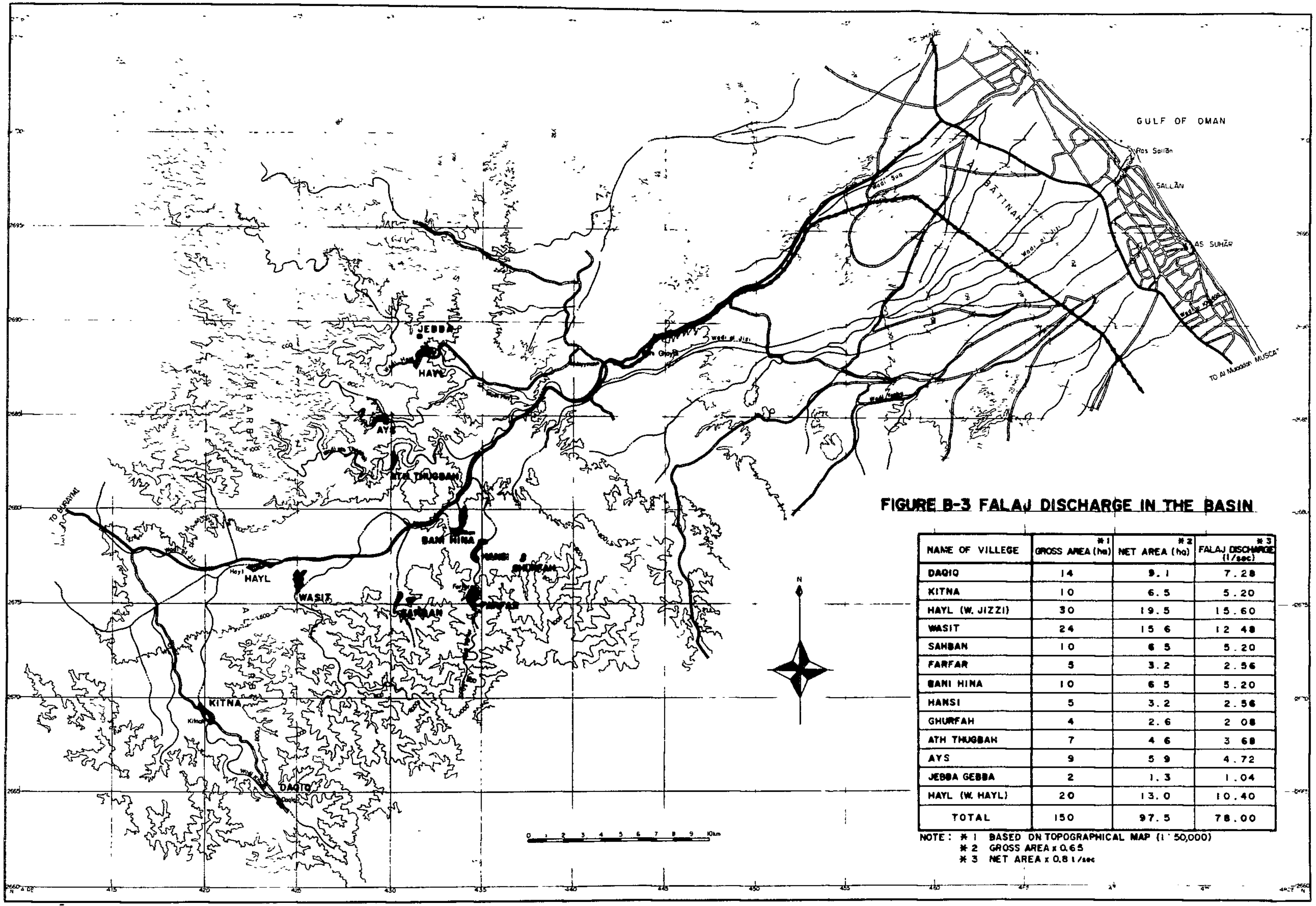


FIGURE B-3 FALAJ DISCHARGE IN THE BASIN

NAME OF VILLEGE	GROSS AREA (ha) *1	NET AREA (ha) *2	FALAJ DISCHARGE (l/sec) *3
DAQIQ	14	9.1	7.28
KITNA	10	6.5	5.20
HAYL (W. JIZZI)	30	19.5	15.60
WASIT	24	15 6	12 48
SAHBAN	10	6 5	5.20
FARFAR	5	3.2	2.56
BANI HINA	10	6 5	5.20
HANSI	5	3.2	2.56
GHURFAH	4	2.6	2 08
ATH THUGBAH	7	4 6	3 68
AYS	9	5 9	4.72
JEBBA GEBBA	2	1.3	1.04
HAYL (W. HAYL)	20	13.0	10.40
TOTAL	150	97.5	78.00

NOTE: *1 BASED ON TOPOGRAPHICAL MAP (1 : 50,000)
*2 GROSS AREA x 0.65
*3 NET AREA x 0.8 l/sec

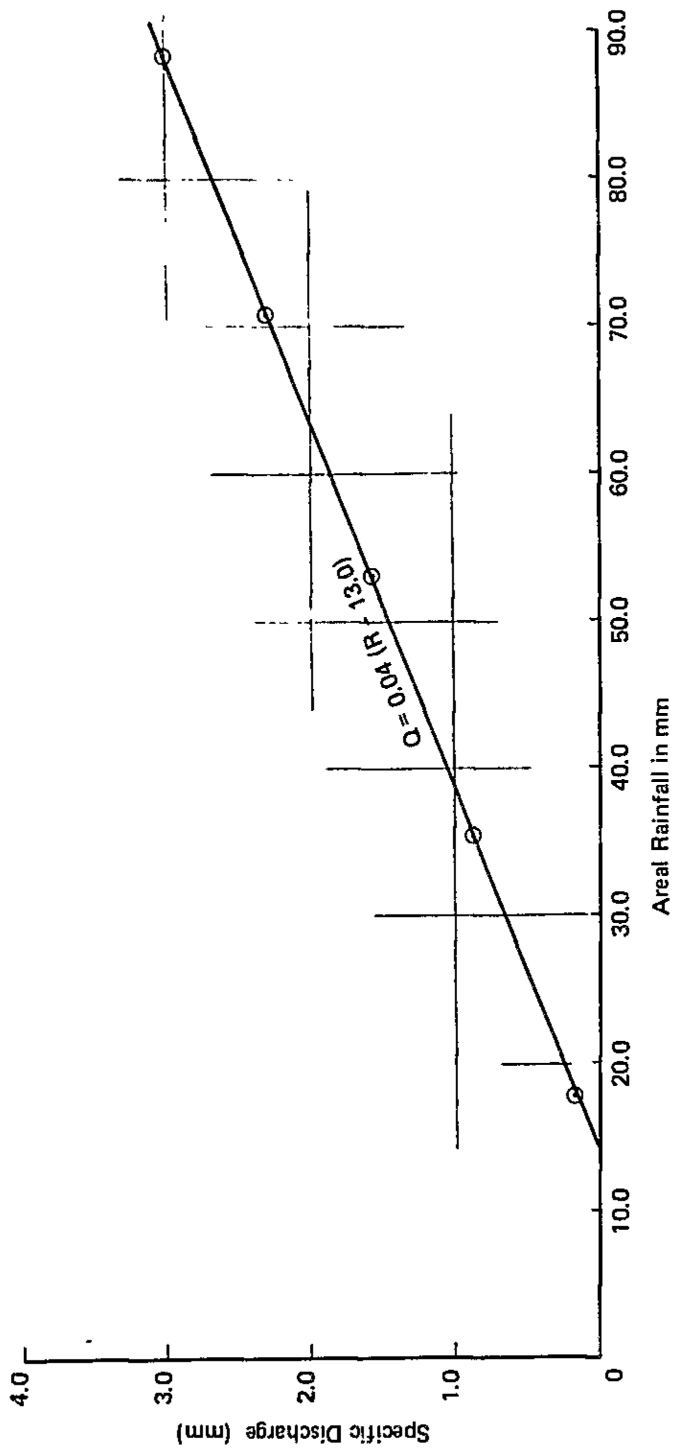


FIGURE B–4 RAINFALL-SPECIFIC DISCHARGE AT RIVER MOUTH

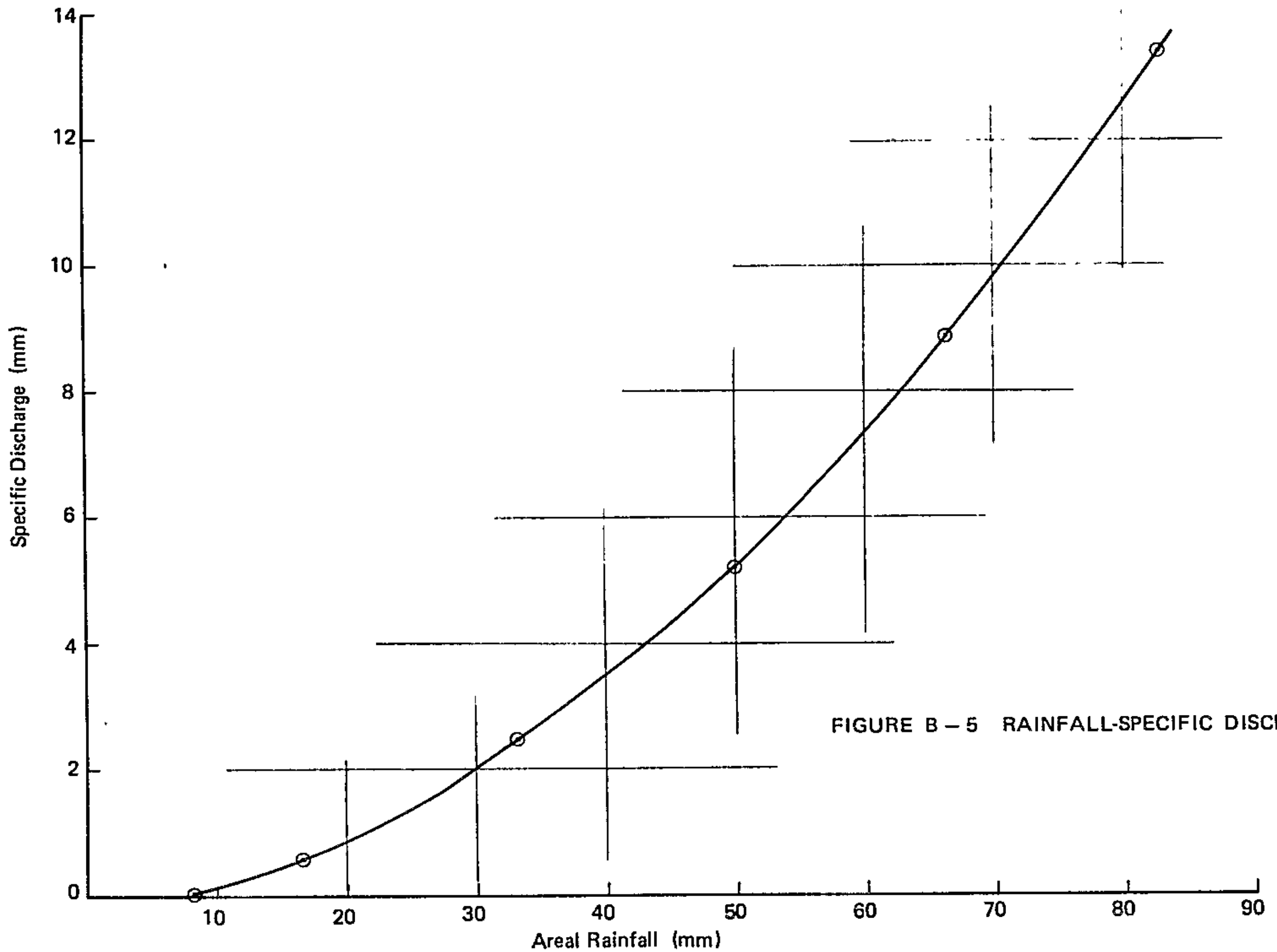


FIGURE B – 5 RAINFALL-SPECIFIC DISCHARGE AT DAMSITE

Runoff Analysis by the Multiple Regression Method

This method is applied to analyze the rainfall-runoff, in placing the catchment area as black box, by solving the response function of input-output by multiple regression analysis. Herein, the method developed by Shiraishi, Onishi and Ito of the Agricultural Engineering Research Station, Ministry of Agriculture, Forestry and Fisheries, Japan, was applied, although there is a variety of approaches available.

The method used herein is to explain the runoff by linear part of the rainfall and the non-linear second order terms on the part that cannot be given by the linear expression, and no higher terms than the third order shall be out of consideration. In particular, the runoff will be given in a statistical unit hydrograph when only the linear part is obtained.

1. Theory of Runoff Analysis by Multiple Regression Method

When the observation values of runoff (Q) and rainfall (R) are available, the runoff (Q) in general can be given as function of the rainfall (R).

$$Qi = f(Ri_1, Ri_2, Ri_3, \text{-------} Rin) \quad \text{-----------}(1)$$

Where, Ri_1 = Rainfall on the day when runoff takes place
Ri_2 = Rainfall one day before runoff takes place
Ri_3 = Rainfall two days before runoff takes place

If runoff can be given as the first order combination of rainfall, the equation (1) can be expressed as follows:

$$Qi = \beta_o + \beta_1 Ri_1 + \beta_o Ri_2 + \text{------} \beta n\ Rin + \varepsilon i \quad \text{---} \ (2)$$

Where, β_o, β_1 --- βn = Unknown parameters

εi = The residues that cannot be expressed by Ri_1 --Rin

The multiple regression analysis is to obtain the best available universal estimates of these known parameters, β_o, β_1--- βn, by the method of the least squares.

In order to obtain the b_o, b_1, --- bn as the estimates of β_o, β_1 --- βn, the quadratic sum of the residues,

$$E = \Sigma \{Qi - (b_o + b_1 Ri_1 + \text{------} bnRin)\}^2 \text{ --------} (3)$$

shall be minimized. In other words, the following equation can be obtained.

$$\left.\begin{aligned} \frac{\partial E}{\partial b_o} &= -2\Sigma \{Qi - (b_o + b_1 Ri_1 + \text{-------} bnRin)\} = 0 \\ \frac{\partial E}{\partial b_o} &= -2\Sigma Ri_1 \{Qi - (b_o + b_1 Ri_1 + \text{---}\ bnRin)\} = 0 \\ \frac{E}{b_o} &= -2\Sigma Rin \{Qi - (b_o + b_1 Ri_1 + \text{---}\ bnRin)\} = 0 \end{aligned}\right\} \text{--} \ (4)$$

These equations shall be arranged to obtain a first order simultaneous equation, so-called normal equation, with b_o, b_1, -- bn as unknowns.

$$\left.\begin{aligned} nb_o + (\Sigma Ri_1)b_1 + (\Sigma Ri_2)b_2 + \text{-----} + (\Sigma Rin)bn &= \Sigma Qi \\ (\Sigma Ri_1)b_o + (\Sigma Ri_1^2)b + (\Sigma Ri_1\ Ri_2)b_2 + \text{--} + (\Sigma Ri_1\ Rin)bn &= \Sigma Ri_1\ Qi \\ (\Sigma Ri_2)b_o + (\Sigma Ri_1 Ri_2)b_1 + (\Sigma Ri_2^2)b_2 + \text{--} + (\Sigma Ri2\ Rin)bn &= \Sigma Ri_2\ Qi \end{aligned}\right\} \ (5)$$

$$(\Sigma Rin)b_o + (\Sigma Ri_1 Rin)b_1 + (\Sigma Ri_2 Rin)b_2 + \cdots + (\Sigma Rin^2)bn = \Sigma Rin\ Qi$$

The second order term expressing the non-linear runoff shall be given by the following second order regression model so as to express the residue (e) between observation values and the linear estimated discharges.

$$ei = Qi - EQi$$

$$= \alpha_o + \sum_{j=i}^{i+n} \sum_{k=j}^{i+n} \alpha jk\ Rj\ Rk + \varepsilon i \quad \text{------------}(6)$$

In the same manner that was applied to the case of the linear part of runoff, the quadratic sum of the residues shall be minimized to determine α_o, αij. When the best available universal estimates are taken as a_o and aij, the quadratic sum of the residues which can be expressed by

$$E = \Sigma\{ei - (a_o + \sum_{j=i}^{i+n} \sum_{k=j}^{i+n} ajk\ Rj\ Rk)\}^2 \quad \text{----------}\ (7)$$

requires to establish the following equation for minimizing the value of the equation (7).

$$\left.\begin{aligned} \frac{\partial E}{\partial a_o} &= -2\Sigma\{ei - (a_o + \sum_{j=i}^{i+n} \sum_{k=j}^{i+n} ajk\ Rj\ Rk)\} = 0 \\ F \\ \frac{\partial E}{\partial aem} &= -2\Sigma Re\ Rm\ \{ei - (a_o + \sum_{j=i}^{i+n} \sum_{k=j}^{i+n} ajk\ Rj\ Rk)\} = 0 \end{aligned}\right] (8)$$

The above is a simultaneous equation with a_o and ajk as unknowns, and this is arranged to give the following equations.

$$na_o + \sum \sum_{j=i}^{i+n} \sum_{k=j}^{i+n} a_{jk} R_j R_k = \Sigma e_i$$

$$(\Sigma R_e R_m) a_o + \Sigma \{ R_e R_m \sum_{j=i}^{i+n} \sum_{k=j}^{i+n} a_{jk} R_j R_k \} = \Sigma R_e R_m e_i$$

Table B-4 Flood Flow Runoff at Mulayyinah (Catchment 654 Km^2)

(Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1974	-	2.35	-	-	-	-	-	-	-	-	-	-	2.35
1975	-	(0.35) (5.10) 5.45	-	-	-	-	-	0.20	-	-	-	-	5.65
1976	1.30	(3.35) (2.55) (8.60) 14.50	(1.05) (2.90) (9.85) 13.80	(4.00) (0.15) 4.15	-	-	-	(0.40) (0.20) 0.60	-	-	0.35	-	34.70
1977	0.75	1.10	-	3.30	2.55	(0.20) (0.15) 0.35	-	-	-	-	0.05	-	8.10
1978	-	2.90	-	-	-	-	-	0.35	-	-	-	-	3.25
1979	0.30	-	-	-	-	-	-	-	-	-	-	0.20	0.50
1980	-	0.20	0.90	-	-	-	-	-	-	-	-	-	1.10
1981	-	-	-	-	0.65	-	0.15	-	-	-	-	-	0.80
Mean													7.05

Table B-5 Runoff at the River-mouth (Catchment 1,283 Km^2)

(Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1974	-	1.140	-	-	-	-	-	-	-	-	-	-	1.140
1975	-	1.360	-	-	-	-	-	-	-	-	-	-	1.360
1976	0.232	4.272	3.356	1.236	-	-	-	-	-	-	-	-	9.096
1977	0.512	0.440	-	1.100	0.616	-	-	-	-	-	-	-	2.668
1978	-	0.908	-	-	-	-	-	-	-	-	-	-	0.908
1979	0.032	-	-	-	-	-	-	-	-	-	-	0.212	0.242
1980	-	-	0.108	-	-	-	-	-	-	-	-	-	0.108
1981	-	-	-	-	0.112	-	-	-	-	-	-	-	0.112
Mean													1.954

Table B-6 Daily Maximum and Three Days Consecutive Rainfall

Year	Daily Maximum		Three Days Maximum	
	(mm)	(Date)	(mm)	(Date)
1974	32.6	(Feb. 14)	32.6	(Feb. 14)
1975	23.2	(Feb. 10)	47.8	(Feb. 8,9,10)
1976	31.1	(Feb. 22)	70.3	(Mar. 24,25,26)
1977	18.8	(Feb. 25)	38.7	(Apr. 1,2,3)
1978	14.2	(Feb. 11)	36.2	(Feb. 9,10,11)
1979	12.7	(Jan. 24)	12.7	(Jan. 24)
1980	11.7	(Mar. 17)	20.3	(Mar. 16,17)
1981	15.8	(May 3)	16.9	(May 2,3,4)
1982	40.2	(Feb. 13)	83.3	(Feb. 12,13,14)

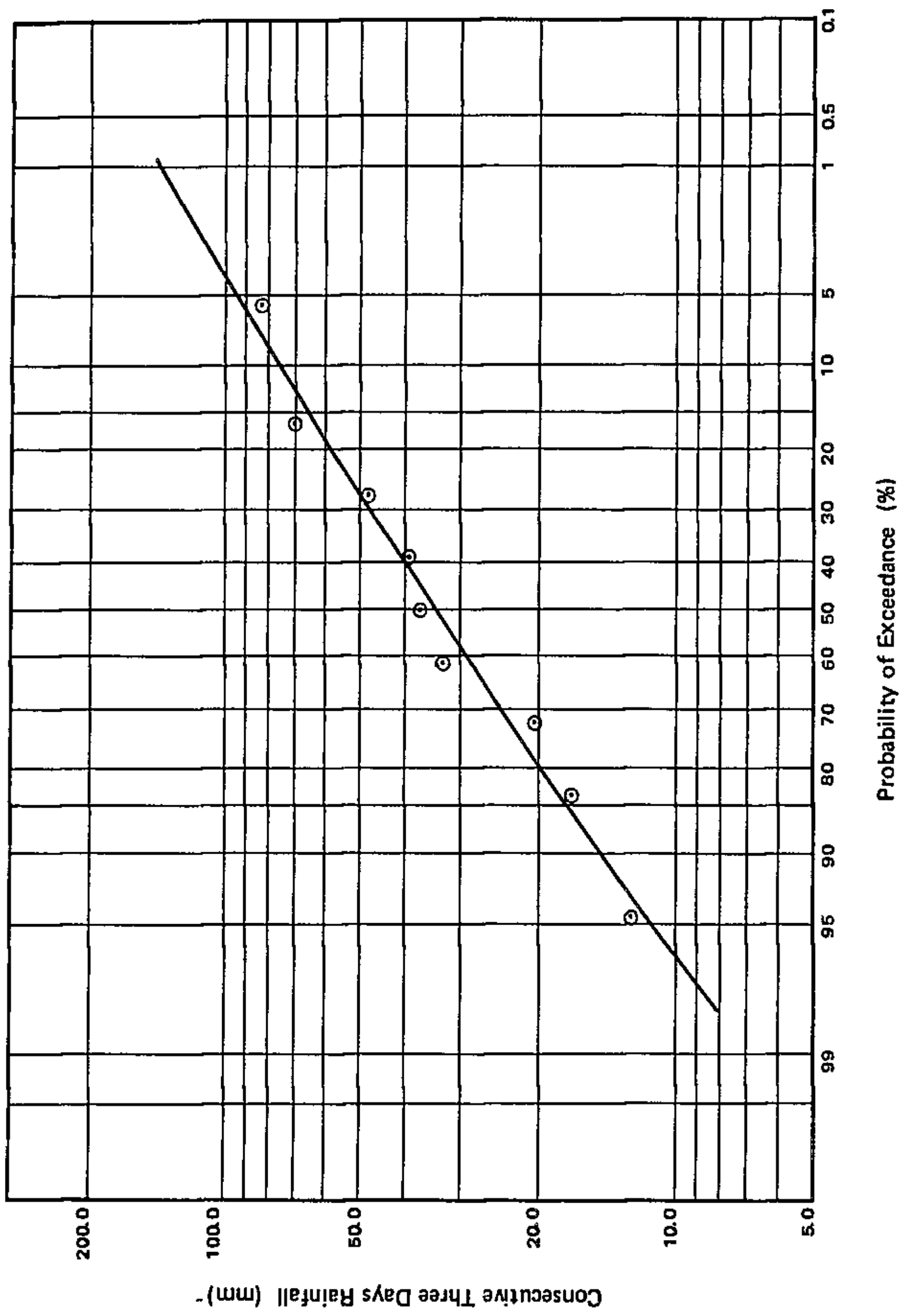


FIGURE B – 6 FREQUENCY OF CONSECUTIVE THREE DAYS RAINFALL

Peak Flood Estimate by Rational Formula

$$Q = \frac{1}{3.6} frA$$

where Q : Peak discharge (cu.m/sec)

f : Runoff coefficient

r : Rainfall intensity (mm/hr)

A : Catchment area (sq.km)

	D-2 Site
Runoff coefficient	0.5
Rainfall intensity	90.8/5.44=16.7 mm/hr
Catchment area	812 sq.km
Peak discharge	1,883.4 cu.m/sec
Design peak discharge	1,890 cu.m/sec

The estimated peak discharge of 1,890 cu.m/sec will be reasonable in due consideration of that the aforesaid peak discharge is equivalent to about three times as much as 654 cu.m/sec of the peak discharge at 1/100 probability which is estimated by the Channel Geometry method in the Water Resources Field Document, No.7, FAO.

On the other hand, the maximum possible flood discharge was estimated at 1,900 cu.m/sec for the catchment area of 1,600 sq.km in the Wadi Al Khawad Aquifer Recharge Project, and the specific discharge was found at 1.2 cu.m/sec/sq.km. The catchment area commanded at the proposed dam site for the Wadi Jizzi covers 812 sq.km and the specific discharge can be estimated at 2.3 cu.m/sec/sq.km which is deemed reasonable in comparison with that of the Wadi Al Khawad.

Probability of Daily Maximum Rainfall

Probability rainfall of 1/10,000 exceedance has been estimated by Gumbel method. The equation is given as follows.

$$P = 1 - e^{-e^{-b}} \quad \text{-----------------------(1)}$$

$$b = \frac{1}{0.7797\sigma}(X - \overline{X} + 0.45\sigma) \quad \text{--------(2)}$$

where P : Probability of exceedance

e : Base of natural logarithms

X : Magnitude with probability P

$\overline{X}$: Arithmetic average in the series

σ : Standard deviation

From the equation (1) and (2), the rainfall magnitude with recurrence interval of 10,000 year is calculated at 90.78 mm.

Lag Time

The lag time was calculated using the following formula.

$$Lg = C \left[\frac{0.186 L x Lca}{\sqrt{S}} \right]^X$$

where Lg : Lag time (Hour)

L : Length of the largest water course from the point of interest to the drainage divide.

Lca : Length of the water course from the point of interest to the intersection of a perpendicular from the centroide of the basin to the stream alignement

S : Slope in meters per kilometer of the length

C : Constant 1.2 was used

X : Constant 0.33 was used

From the topographic map with scale of 1/50,000, following values were obtained.

L = 65 Km

Lca = 33 Km

S = (1040 - 155)/65 = 13.6

Lg = 5.44 hours is calculated.

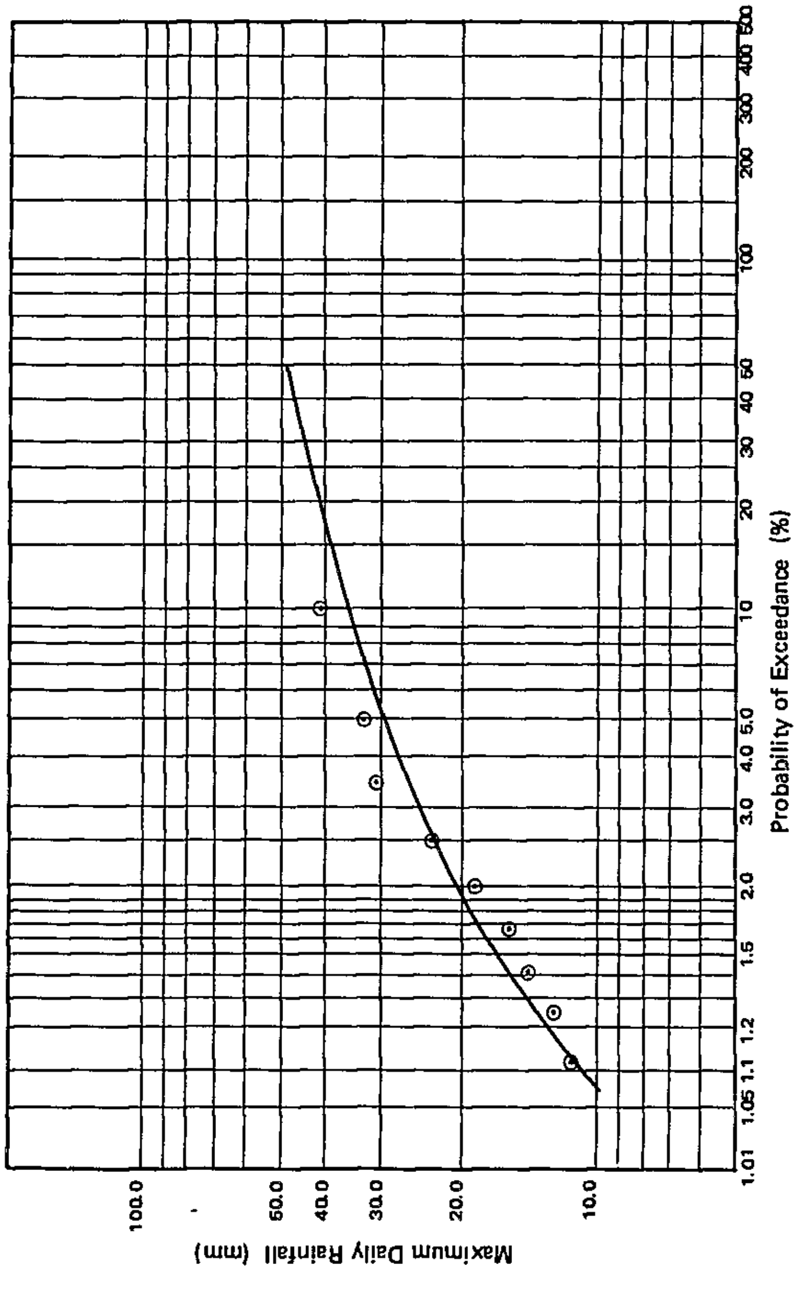


FIGURE B – 7 FREQUENCY OF MAXIMUM DAILY RAINFALL

Discharge Capacity from the Conduit

Dimensions of the Conduit are as follows.

Length (L) : 115 m

Diameter (D) : 1.4 m

Roughness coefficient (n): 0.015

Discharge capacity from the conduit is given in the following formula.

$$Q = \frac{\sqrt{2g} \ . \ A}{\sqrt{fv+fe+fr}} \ . \ \sqrt{H}$$

where fv : exit loss = 1.0

fe : entrance loss = 0.5

fr : friction loss

$124.5 \times n^2/D^{\frac{4}{3}} \times L = 2.057$

g : gravity acceleration = 9.8

A : flow area

$\pi \ . (\frac{D}{2})^2 = 1.539$

$$Q = 3.613 \sqrt{H}$$

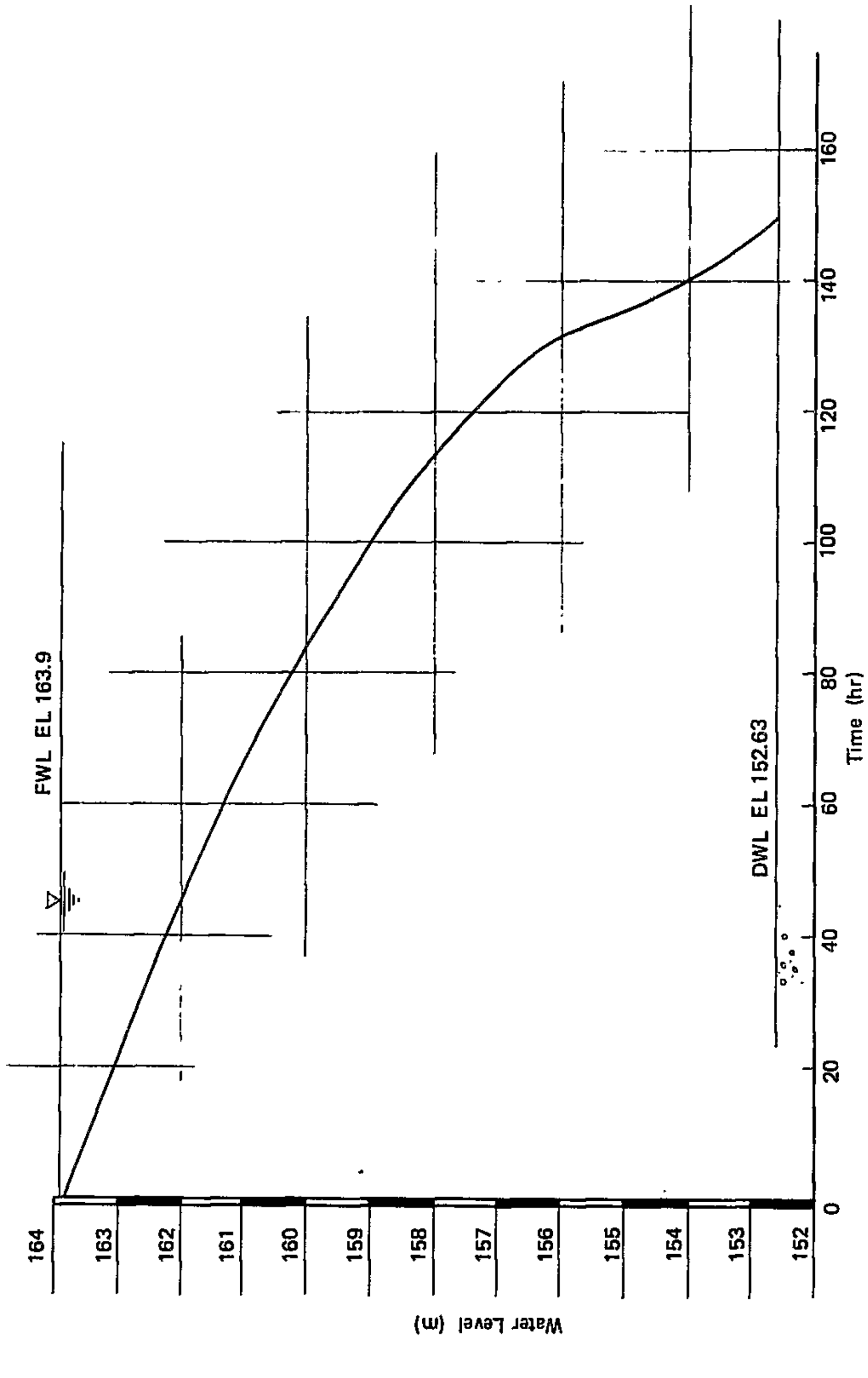


FIGURE B–8 RESERVOIR EMPTYING TIME IN WATER LEVEL

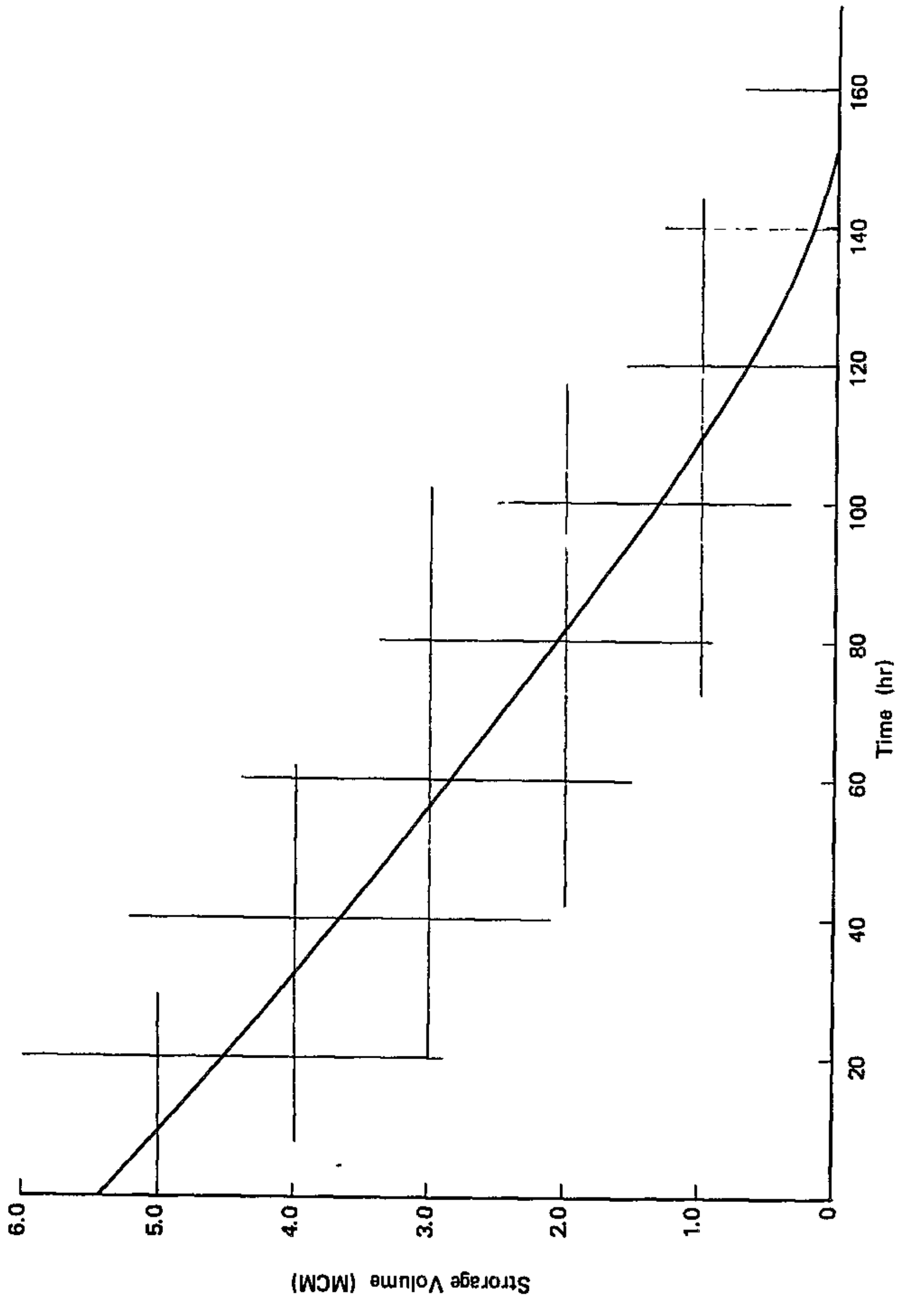


FIGURE B – 9 RESERVOIR EMPTYING TIME IN VOLUME

APPENDIX C. GROUNDWATER

APPENDIX C GROUNDWATER

1. Field Investigation

1.1 Drilling and Completion of Exploratory Wells

Six exploratory wells were drilled on the gravel plain of Wadi Jizzi basin to examine aquifer characteristics and groundwater potentials (see Figure C-1). Furthermore, in locating of wells, confirmation of hydrogeological structure, especially a form of groundwater basin was taken into consideration.

Following specifications were applied for drilling of the wells.

Rig type	:	D-40K (US made) and RD-1500 (India made)
Drilling method	:	Rotary method
Bit type	:	Three cutter rock bit
Bit size	:	375 mm
Casing material	:	Polyvinyl chloride (Durapipe)
Casing diameter	:	250 mm
Screen type	:	Perforate 3mm x 110mm
Opening rate	:	3.2%
Annula space	:	Gravel packing
Development	:	Air lift method with minimum 6 hrs

The results including geologic column with borehole loggings are show in Figure C-2 to C-7.

Impervious formations were found at depth of 34 and 45 mbgs in the wells of JA-4 and JA-5 respectively which were drilled on more than 40 mamsl of the plain. Impervious formations were not found in remaining wells. Sand and gravel at the wells of JA-1 and JA-2 are deposited at the recent age in spite of that sand and gravel in the other wells are considered to be of Pleistocene judging from the aquifer potential. Data summary for exploratory wells are shown in Table C-1.

FIGURE C-1 LOCATION MAP FOR GROUNDWATER SURVEY

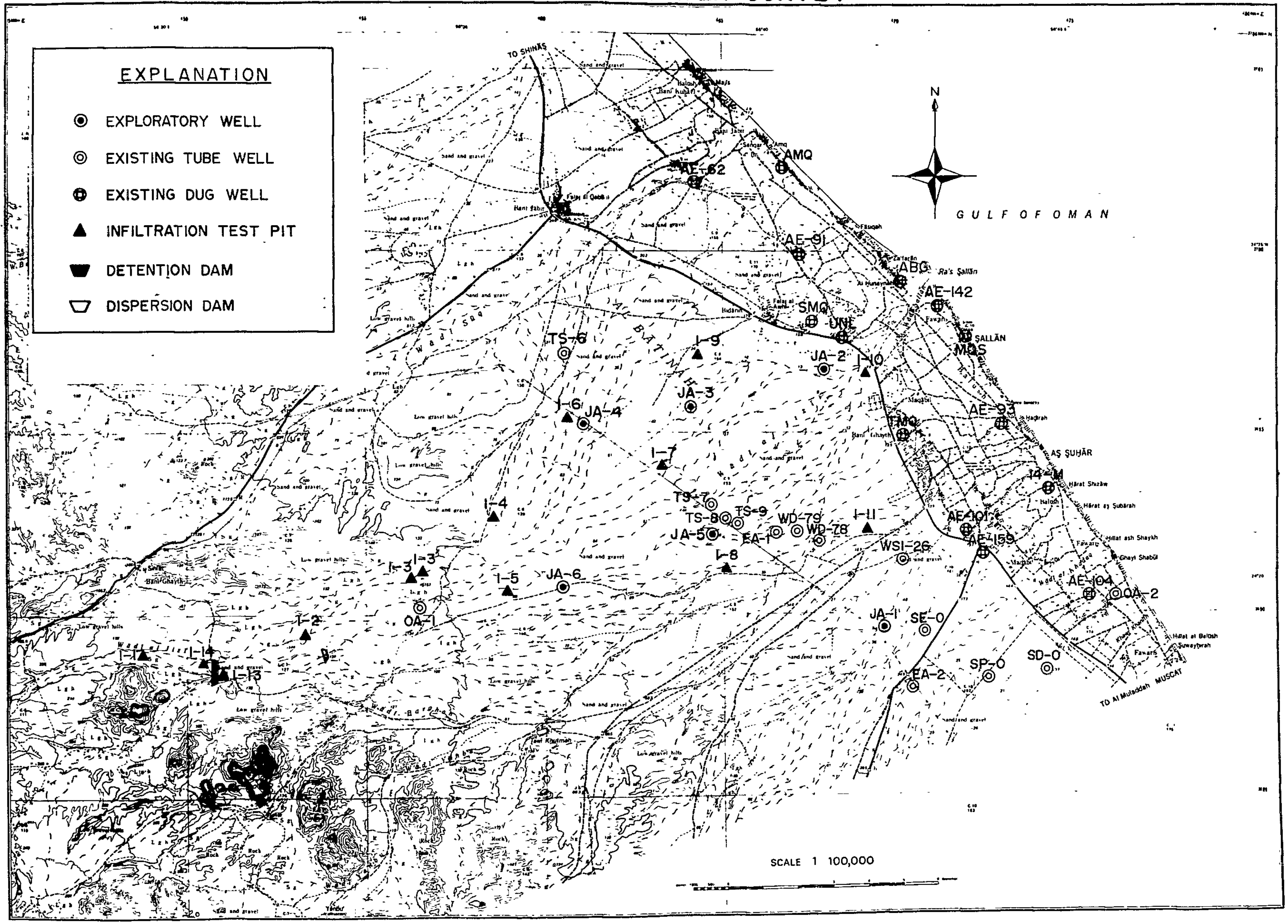


FIGURE C - 2 EXPLORATORY WELL LOG

Name of well	JA-1	Altitude of site	24.01 (mamsl)
Location, UTM	469550 2689580	Date of completion	Feb. 1982
Depth drilled	82.0 (m)	Borehole diameter	375 (mm)
Casing diameter	250 (mm)	Casing material	PV
Type of screen	slotted	Screen schedule	32.9 ~ 78.6 m
Static water level	20.9 (mbgs)	Yield	825.2 (lit/min)
Maximum drawdown	0.75 (m)	Specific Capacity	1,100 (lit/min/m)

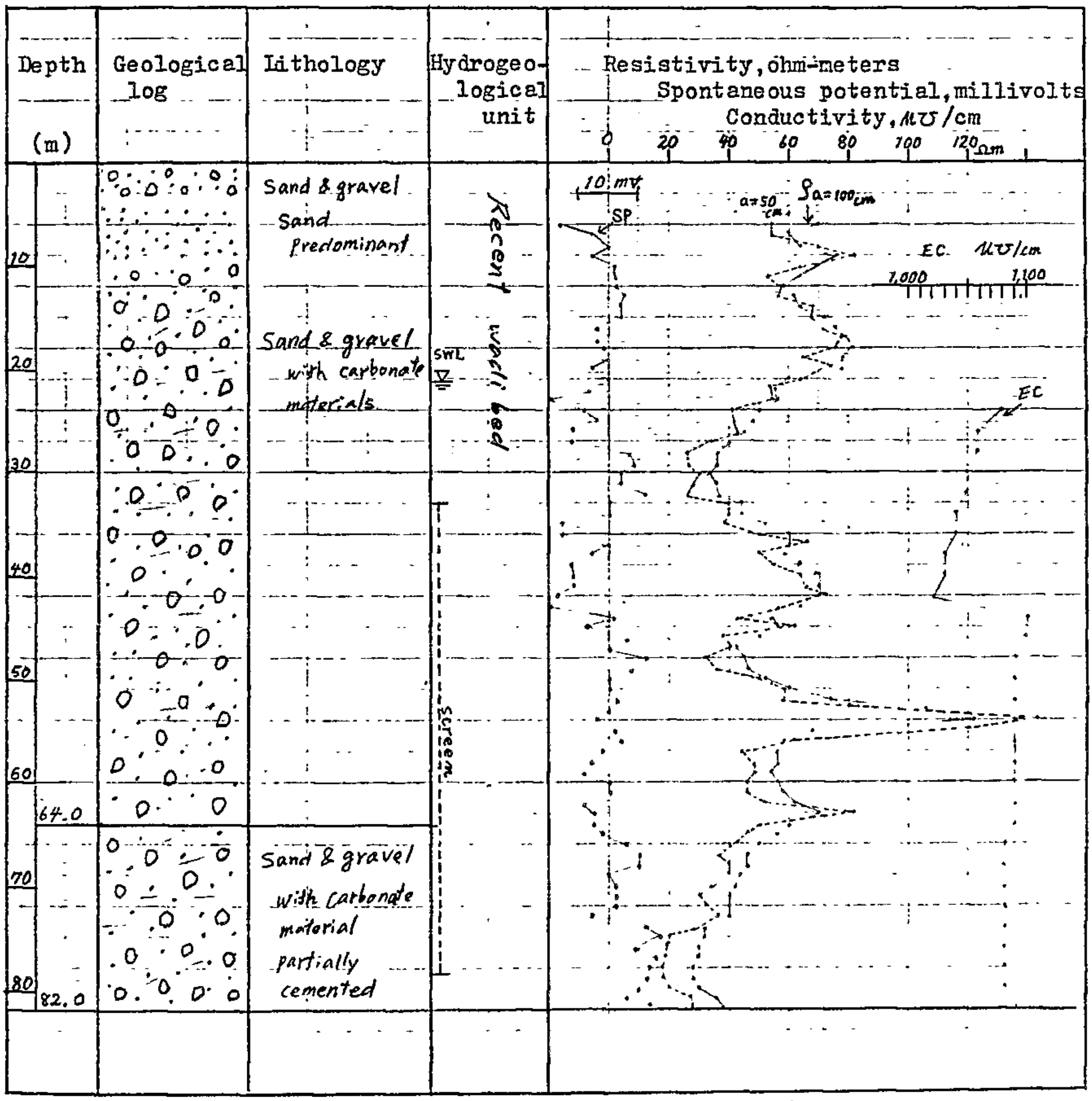


FIGURE C - 3

EXPLORATORY WELL LOG

Name of well	JA-2	Altitude of site	11 (mamsl)
Location, UTM	467850 2196740	Date of completion	Mar. 1982
Depth drilled	40.0 (m)	Borehole diameter	375 (mm)
Casing diameter	250 (mm)	Casing material	PV
Type of screen	slotted	Screen schedule	11.5 ~ 34.3 m
Static water level	7.08 (mbgs)	Yield	957.7 (lit/min)
Maximum drawdown	1.67 (m)	Specific Capacity	573.5 (lit/min/m)

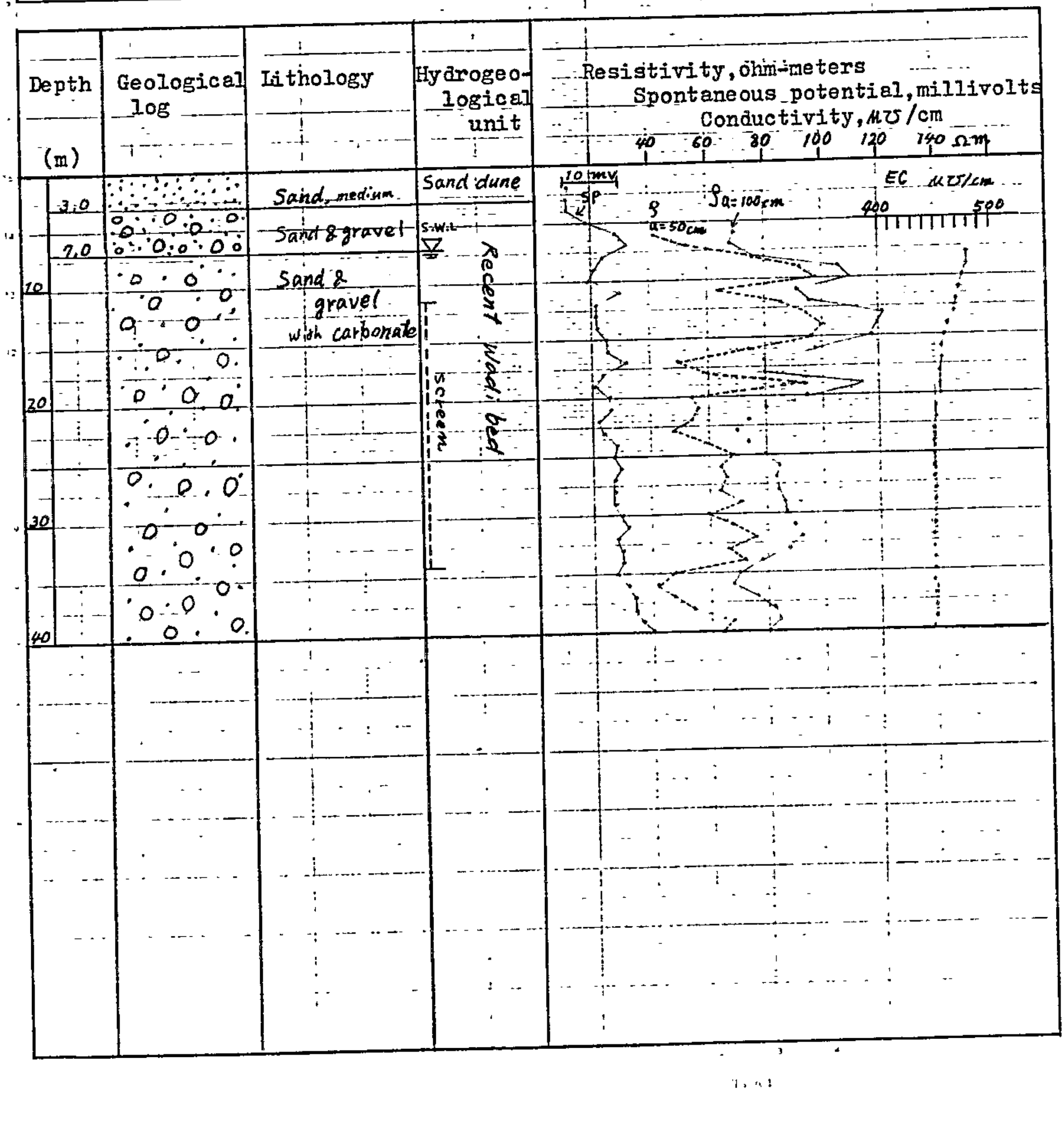


FIGURE C - 4 EXPLORATORY WELL LOG

Name of well	JA-3	Altitude of site	30 (mamsl)
Location, UTM	464050 2695700	Date of completion	Jan. 1982
Depth drilled	45.0 (m)	Borehole diameter	375 (mm)
Casing diameter	250 (mm)	Casing material	PV
Type of screen	Slotted	Screen schedule	22.0~39.1
Static water level	25.46 (mbgs)	Yield	252 (lit/min)
Maximum drawdown	7.37 (m)	Specific Capacity	34.2 (lit/min/m)

Depth (m)	Geological log	Lithology	Hydrogeological unit	Resistivity, ohm-meters / Spontaneous potential, millivolts / Conductivity, μS/cm
0 – 5.0		Sand & gravel with clay	Recent wadi beds	
5.0 – 8.0		Sand, coarse with gravel		
8.0 – 19.0		Sand & gravel		
19.0 – 45.0		Sand & gravel with carbonate partially cemented	SWL, screen; Terrace deposits	

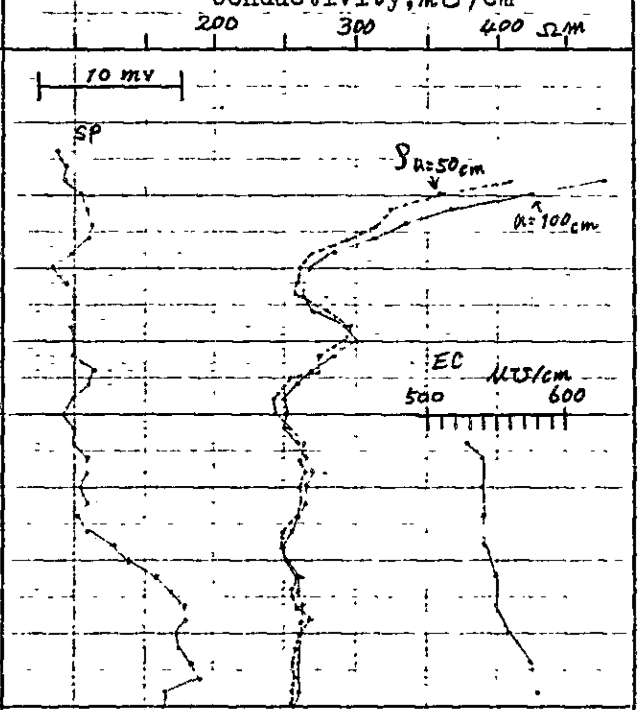


FIGURE C - 5

EXPLORATORY WELL LOG

Name of well	JA-4	Altitude of site	50 (mamsl)
Location, UTM	461080 2695200	Date of completion	Jan. 1982
Depth drilled	55.0 (m)	Borehole diameter	375 (mm)
Casing diameter	250 (mm)	Casing material	PV
Type of screen	Slotted	Screen schedule	10.0 ~ 32.8 m
Static water level	23.92 (mbgs)	Yield	480 (lit/min)
Maximum drawdown	2.12 (m)	Specific capacity	226.4 (lit/min/m)

Depth (m)	Geological log	Lithology	Hydrogeological unit
0 – 7.0		Sand & gravel	Recent sedi beds
7.0 – 34.0		Sand & gravel with Carbonate Partially cemented	Terrace deposits (SWL; Screen)
34.0 – 50.0		Mudstone weathered softened yellowish-brown	Tertiary impervious formation
50.0 – 55		Weathered mudstone very soft	

Resistivity, ohm-meters
Spontaneous potential, millivolts
Conductivity, μ℧/cm

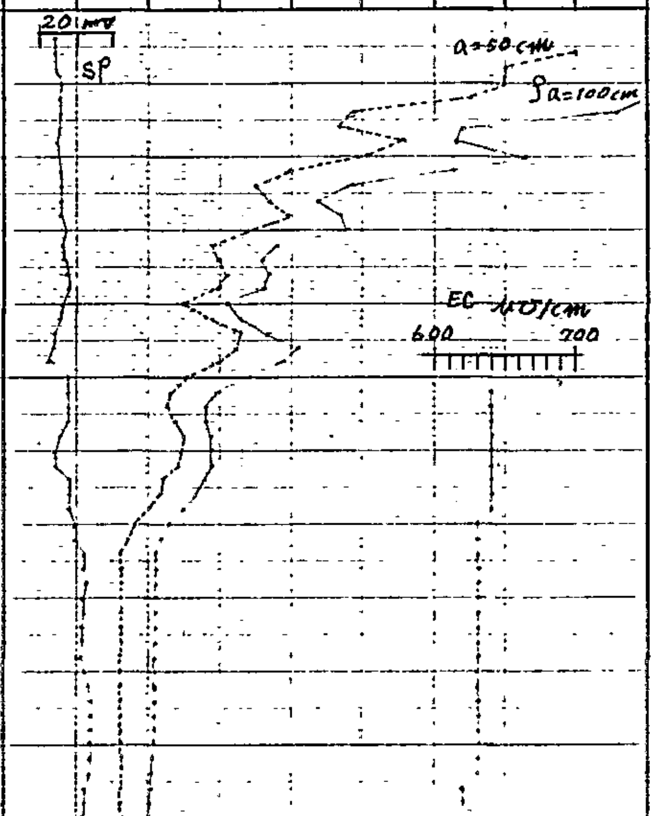


FIGURE C - 6 EXPLORATORY WELL LOG

Name of well	JA-5	Altitude of site	42 (mamsl)
Location, UTM	464660 2692200	Date of completion	Feb. 1982
Depth drilled	55.0 (m)	Borehole diameter	375 (mm)
Casing diameter	250 (mm)	Casing material	PV
Type of screen	Slotted	Screen schedule	32.1~54.9 m
Static water level	37.28 (mbgs)	Yield	78 (lit/min)
Maximum drawdown	2.28 (m)	Specific capacity	34.2 (lit/min/m)

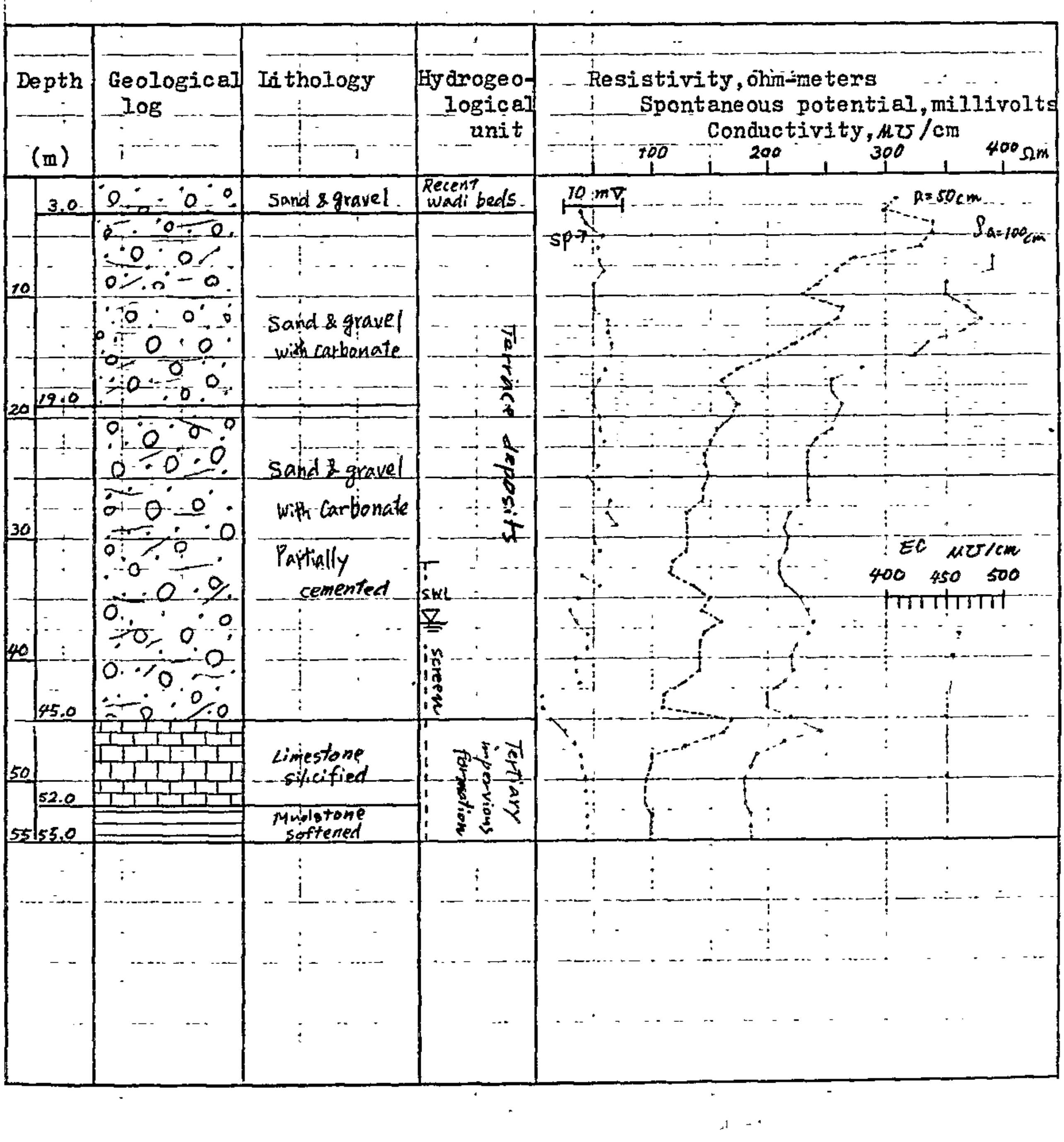


FIGURE C - 7

EXPLORATORY WELL LOG

Name of well	JA-6	Altitude of site	75 (mamsl)
Location, UTM	460450 2690750	Date of completion	Feb. 1982
Depth drilled	18.0 (m)	Borehole diameter	375 (mm)
Casing diameter	250 (mm)	Casing material	PV
Type of screen	slotted	Screen schedule	9.9 ~ 15.6 m
Static water level	16.13 (mbgs)	Yield	(lit/min)
Maximum drawdown	(m)		

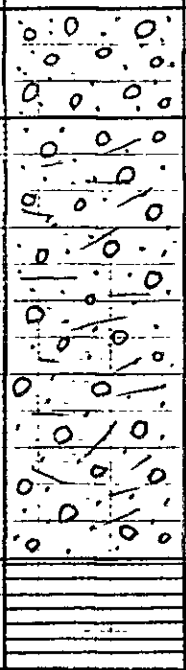
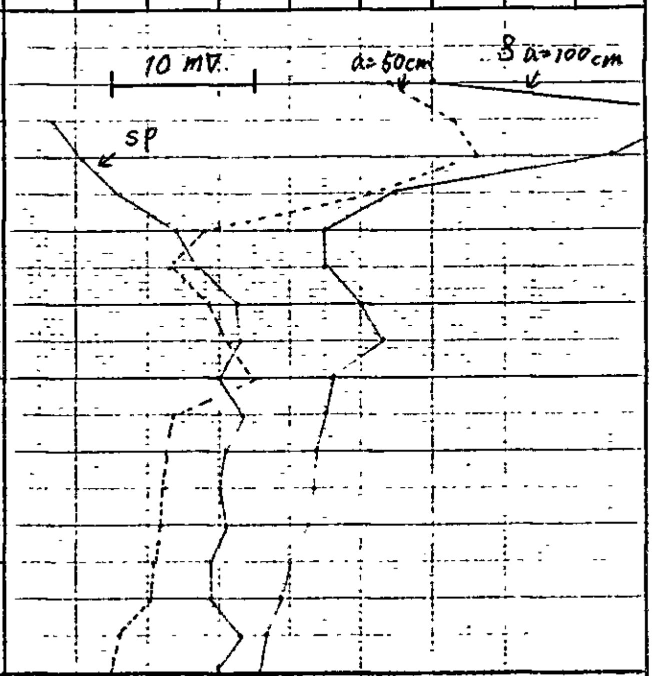
Depth (m)	Geological log	Lithology	Hydrogeological unit	Resistivity, ohm-meters / Spontaneous potential, millivolts / Conductivity, μƱ/cm
3.0		Sand & gravel	Recent Wadi beds	
5, 10, 15 / 15.0		Sand & gravel with Carbonate Partially cemented	Terrace deposited	
18 / 18.0		Mudstone softened	W.L. Tertiary Impervious formation	

Table C - 1

Data Summary of Exploratory Wells

Name of Well	Depth Drilled (m)	Diameter of Casing (mm)	Screen Schedule (m~m)	Altitude of Site (mamal)	Height to Top of Casing (mags)	Static Water Level (mbgs)	Tested Discharge (ℓ/sec)	Drawdown (m)	Specific Capacity (ℓ/sec/m)	Trans-missivity (m^2/day)
JA-1	82	250	32.9~78.6	24.04 1/	1.62	20.49	12.7	0.75	16.9	16,900
JA-2	40	250	11.5~34.3	11 2/	1.85	6.51	15.8	1.71	9.2	4,300
JA-3	45	250	22.0~39.1	30 2/	1.48	24.44	4.2	7.25	0.58	150
JA-4	55	250	10.0~32.8	50 2/	1.36	24.14	8.0	2.12	3.8	3,200
JA-5	55	250	32.1~54.9	42 2/	1.82	36.06	1.3	2.28	0.57	60
JA-6 3/	18	250	9.9~15.6	75 2/	1.16	-	-	-	-	-

1/ : Surveyed by optical method

2/ : Based on Contour lines of 1:50,000 topo-map

3/ : No available water because formation consists of cemented sand and gravel of pleistocene.
Automatic water level gauges are installed on JA-1,2,3,4 and 5.

1.2 Aquifer Tests

Two kinds of aquifer test; step-drawdown and constant discharge tests for each wells were conducted after completion of well development, however the test at JA-6 was not conducted because of no available groundwater.

Four steps increasing discharge with each three hours pumping and twenty four hours continuous pumping with constant discharge were conducted at each wells. Results of test are shown in Table, and relations between drawdown and pumping times are shown in Figure C-8 to C-20. Summarized aquifer and well characteristics are shown in Table C-2. Specific capacity for JA-1 and JA-2, which is one of quantitative indicator for well potentials are 1,100 and 570 lit/min/m respectively, however it shows less than 40 lit/min/m at JA-3 and JA-4 by reason of hydrogeological structure. Transmissivity for alluvial deposits and terrace deposits are calculated at 16,900 sqm/day at JA-1 and 60 at JA-5. As is shown in Figure C-21, relationship between specific capacity and transmissivity have good correlation. Storativity was not obtained by the tests because of no suitable observation wells around the wells.

1.3 Chemical Analysis of Well Samples

Water samples for chemical analysis taken at the end of constant discharge test were analysed at Rumais Agricultural Research Station. (Table C-3) Water quality of JA-2, 3, 4 and JA-5 which have 250 micro mho/cm at 25 C is considered excellent for irrigation use in contrast with 1,000 micro mho/cm at JA-1. Irrigation water containing conductivity of more than 1,000 micro mho/cm is required special attentions for the water managements.

In connection with limit of sodium at the water, SAR is calculated for each samples as indicates in the table. The values of SAR is calculated for each samples as indicated in the table. SAR values less than 10 can be considered as excellent category of irrigation water.

March 14, 1982

FIGURE C–8 JA–1, STEP DRAWDOWN TEST

S – t curve

Specific Capacity (lit/min/m)	Q_1	Q_2	Q_3	Q_4	Aver.
	1,125	1,136	1,124	1,270	1,164

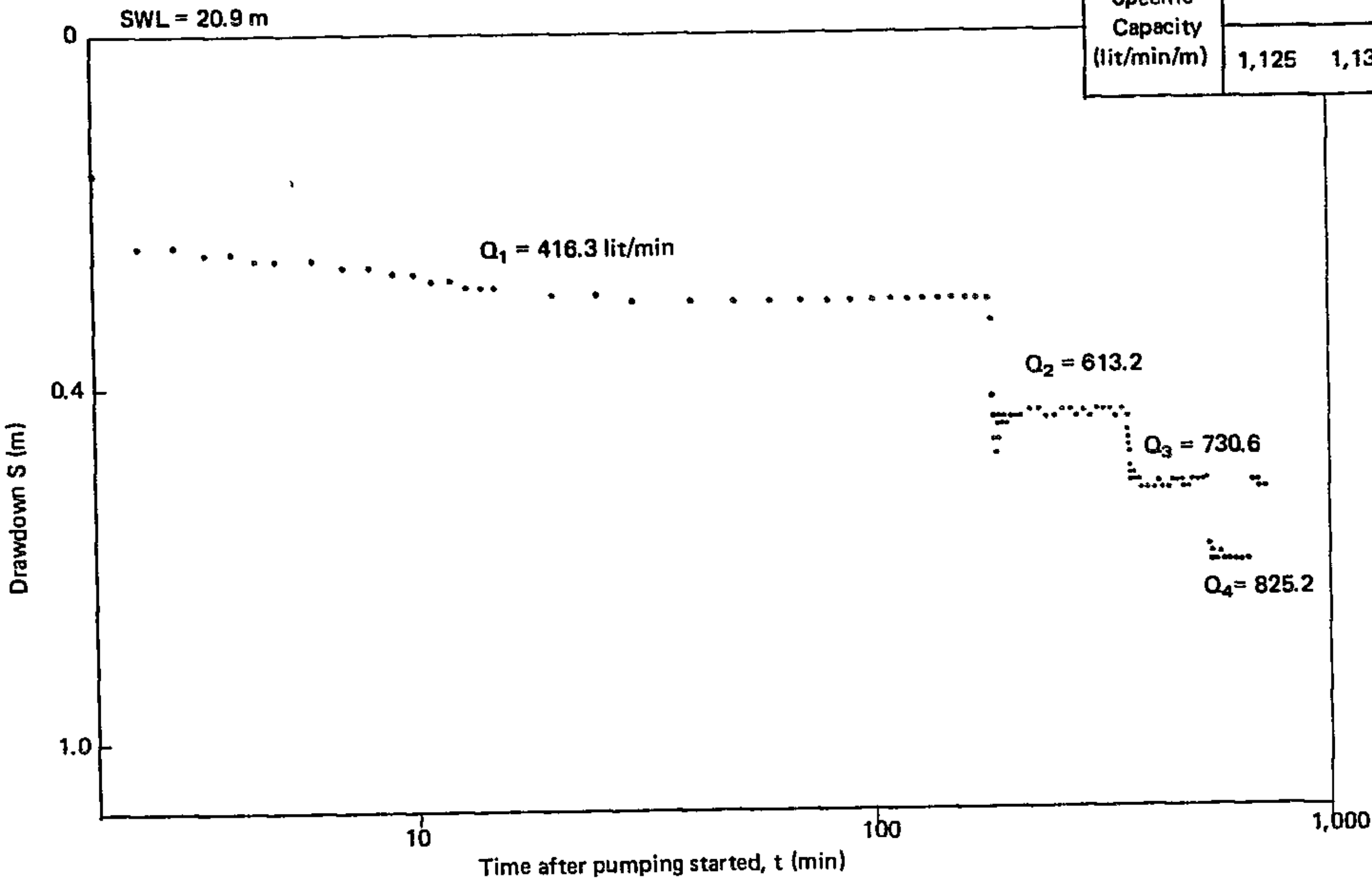


FIGURE C – 9 JA – 1, CONSTANT DISCHARGE TEST March 14, 1982

S – t curve

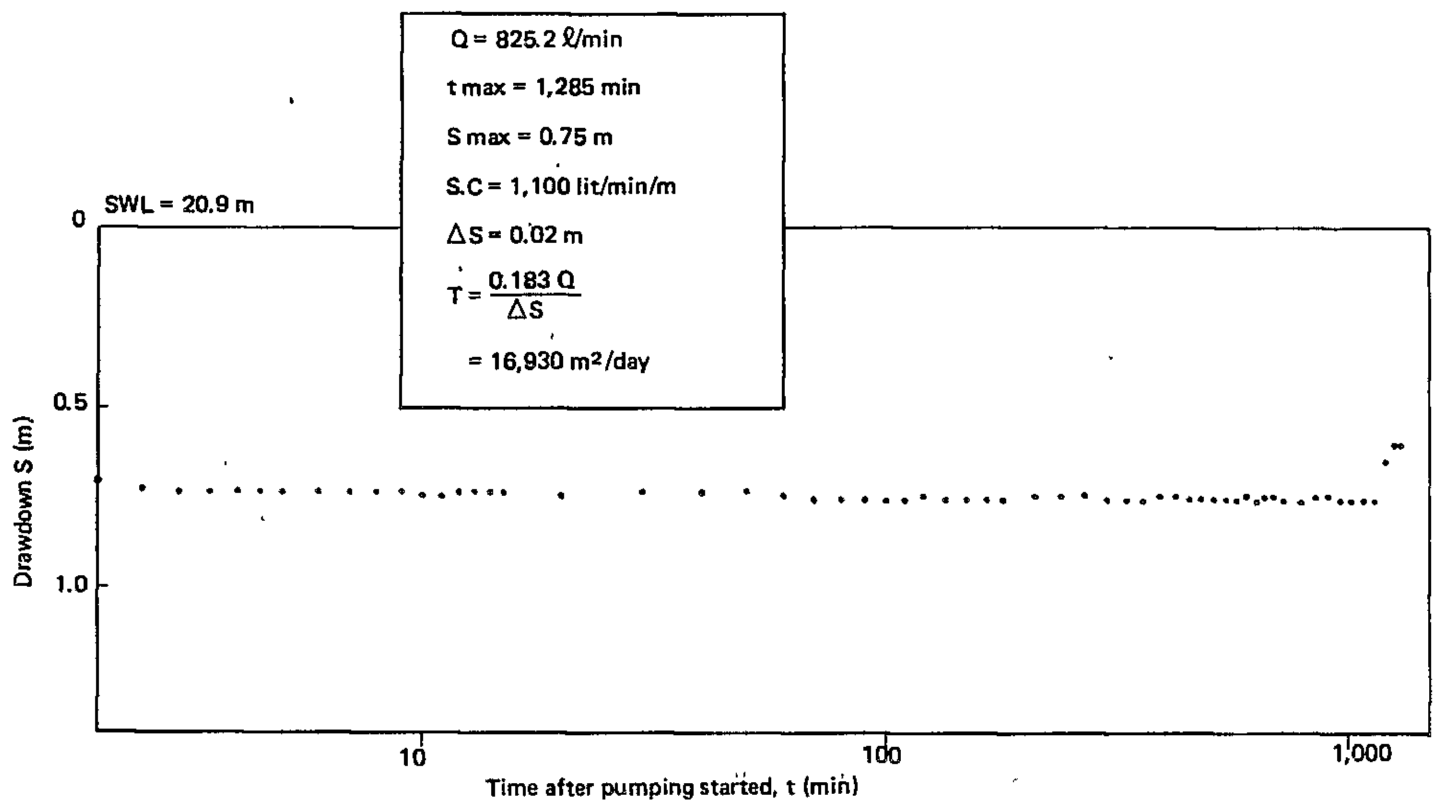


FIGURE C-10 JA-1, CONSTANT DISCHARGE TEST March 14, 1982

Sr – t/t' curve

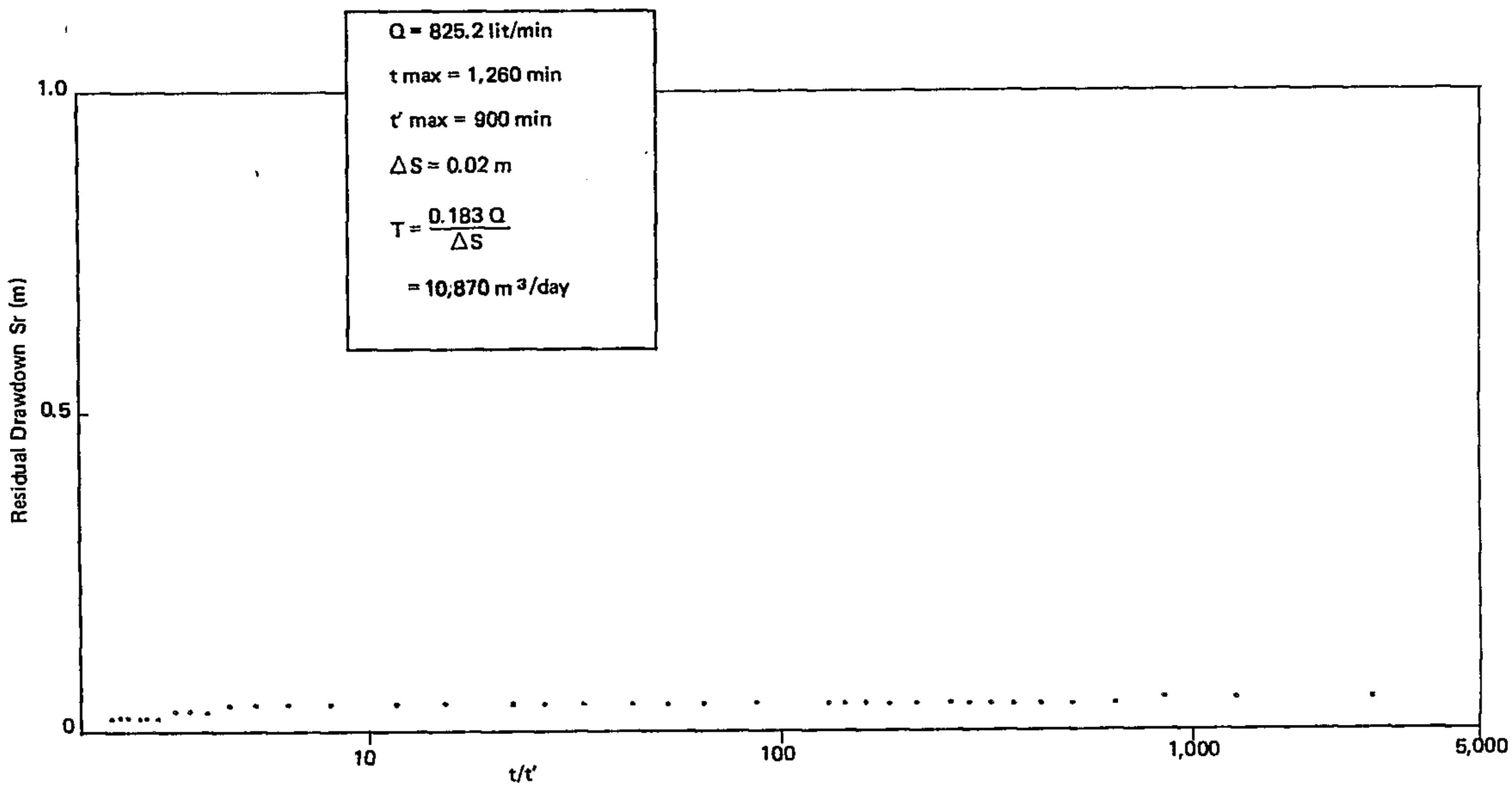


FIGURE C – 11, JA – 2, STEP-DRAWDOWN TEST

March 17, 1982

S – t curve

Specific capacity (lit/min/m)	Q_1	Q_2	Q_3	Aver.
	612.9	587.9	588.2	596

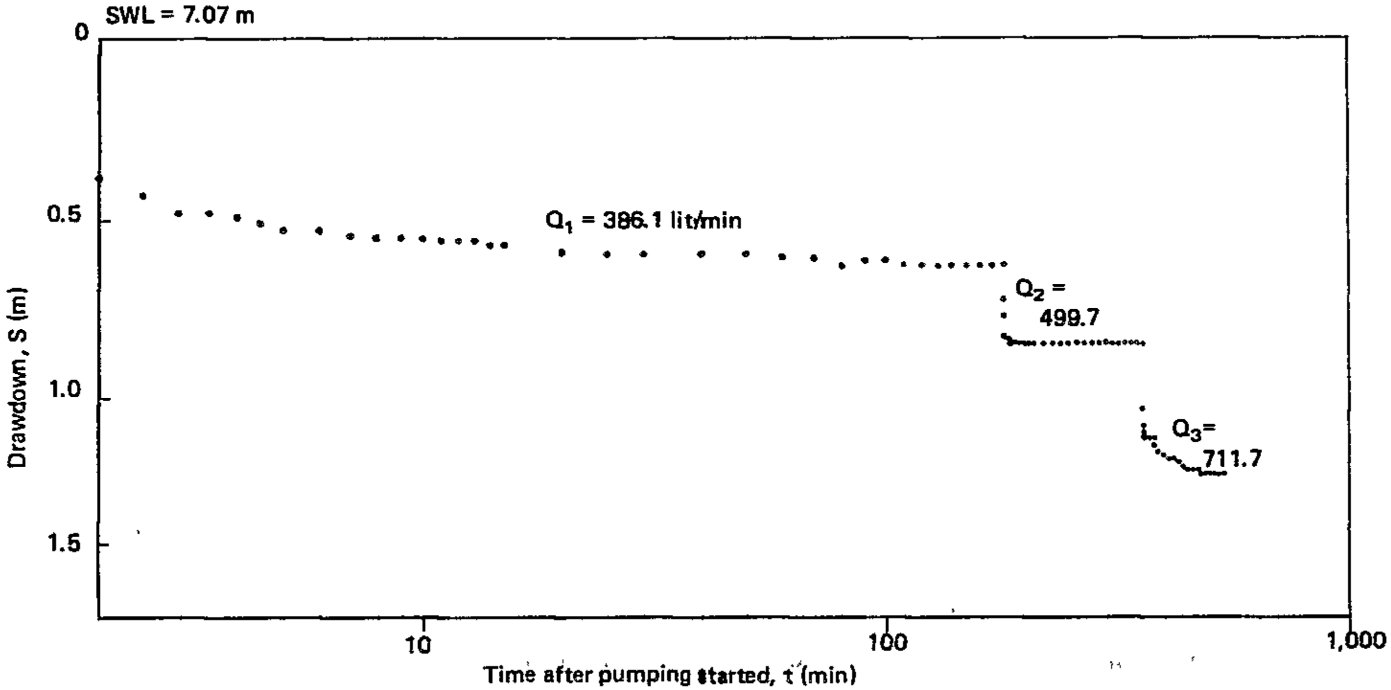


FIGURE C – 12. JA – 2, CONSTANT DISCHARGE TEST — March 18, 1982

S – t curve

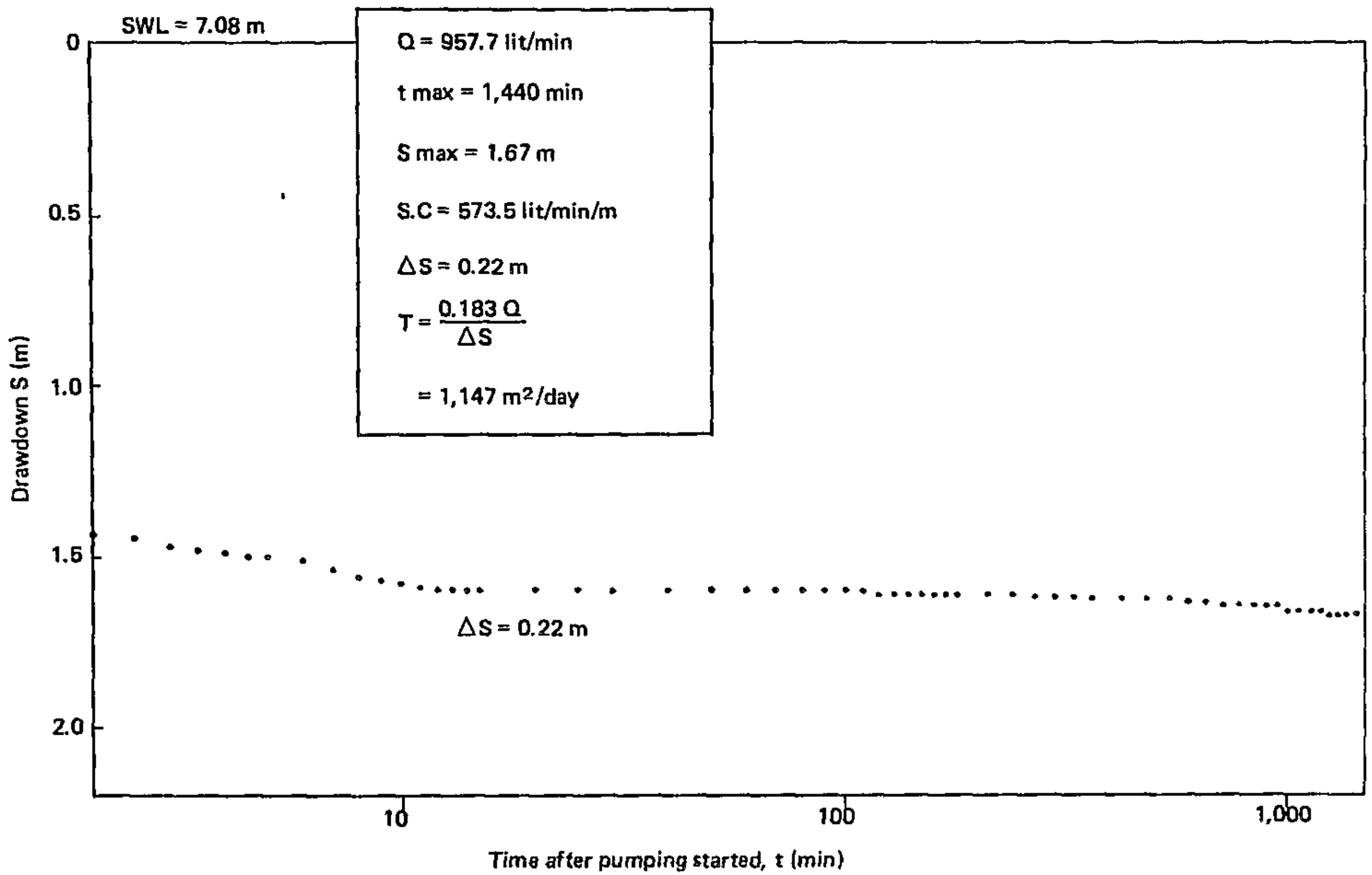


FIGURE C-13 JA-2, CONSTANT DISCHARGE TEST March 18, 1982

Sr – t/t' curve

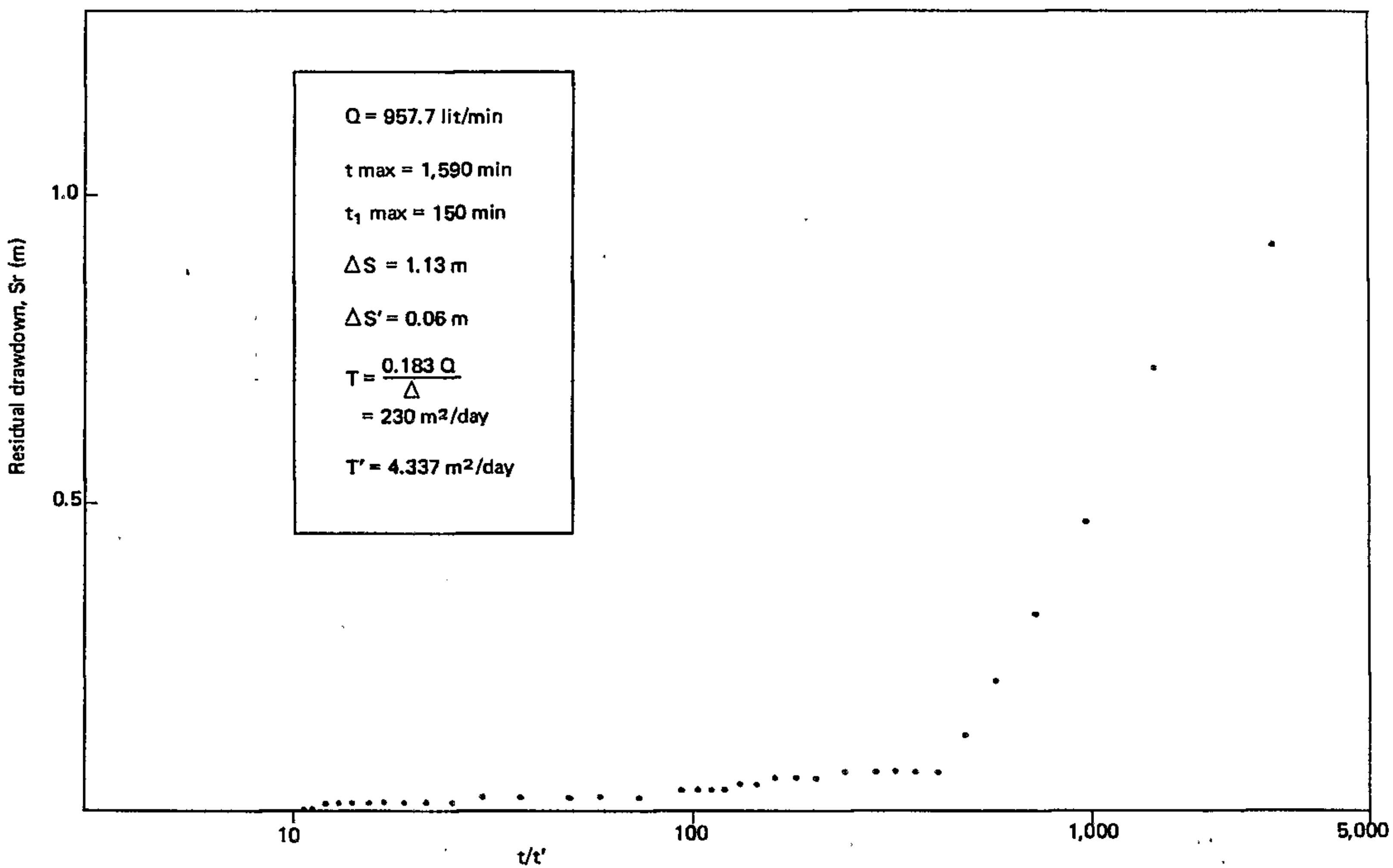
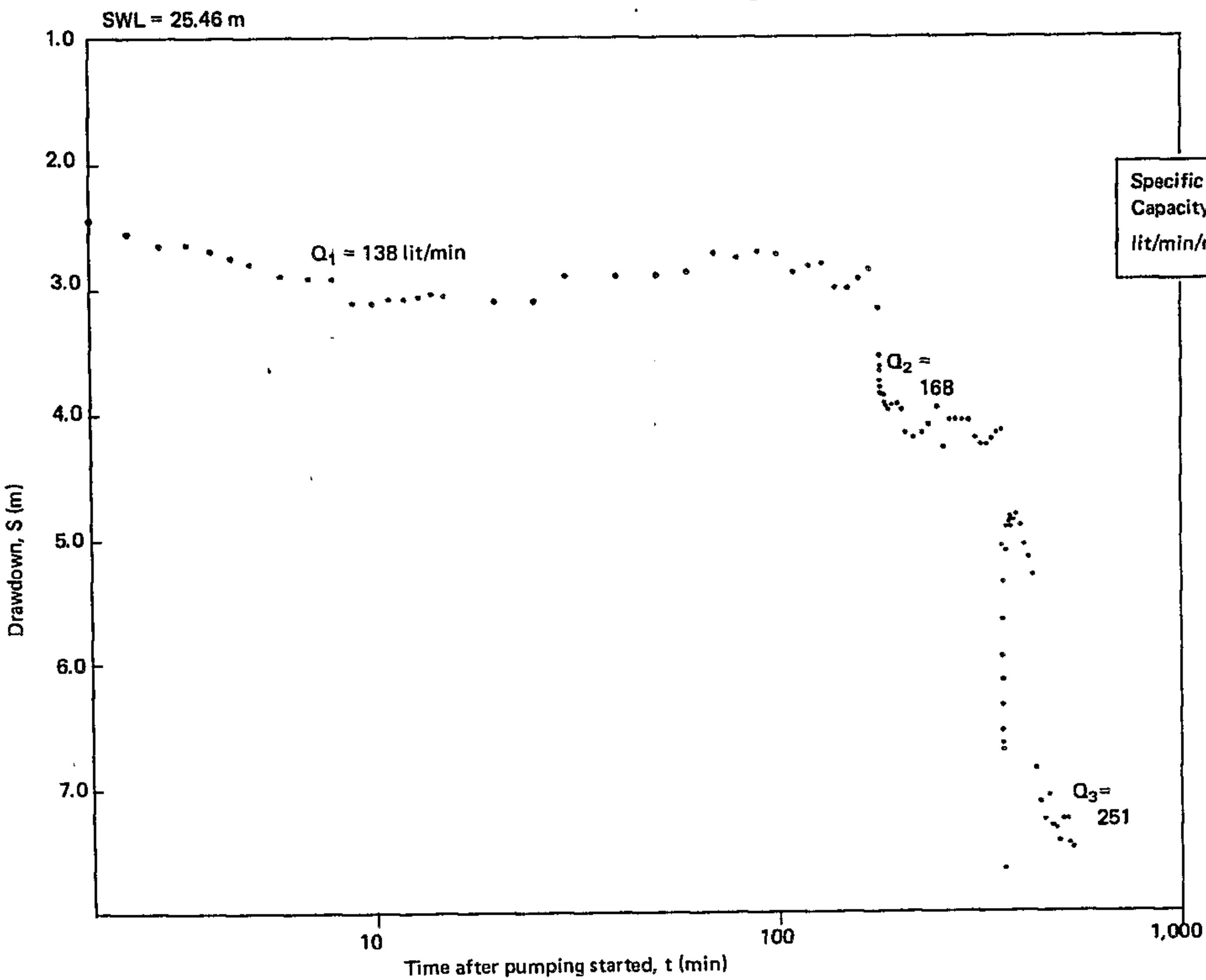


FIGURE C–14 JA–3, STEP-DRAWDOWN TEST

January 7, 1982

S – t curve



Specific Capacity lit/min/m	Q_1	Q_2	Q_3	Aver.
	44.2	39.6	33.7	39.2

FIGURE C–15 JA–3, CONSTANT DISCHARGE TEST January 8, 1982

S – t curve

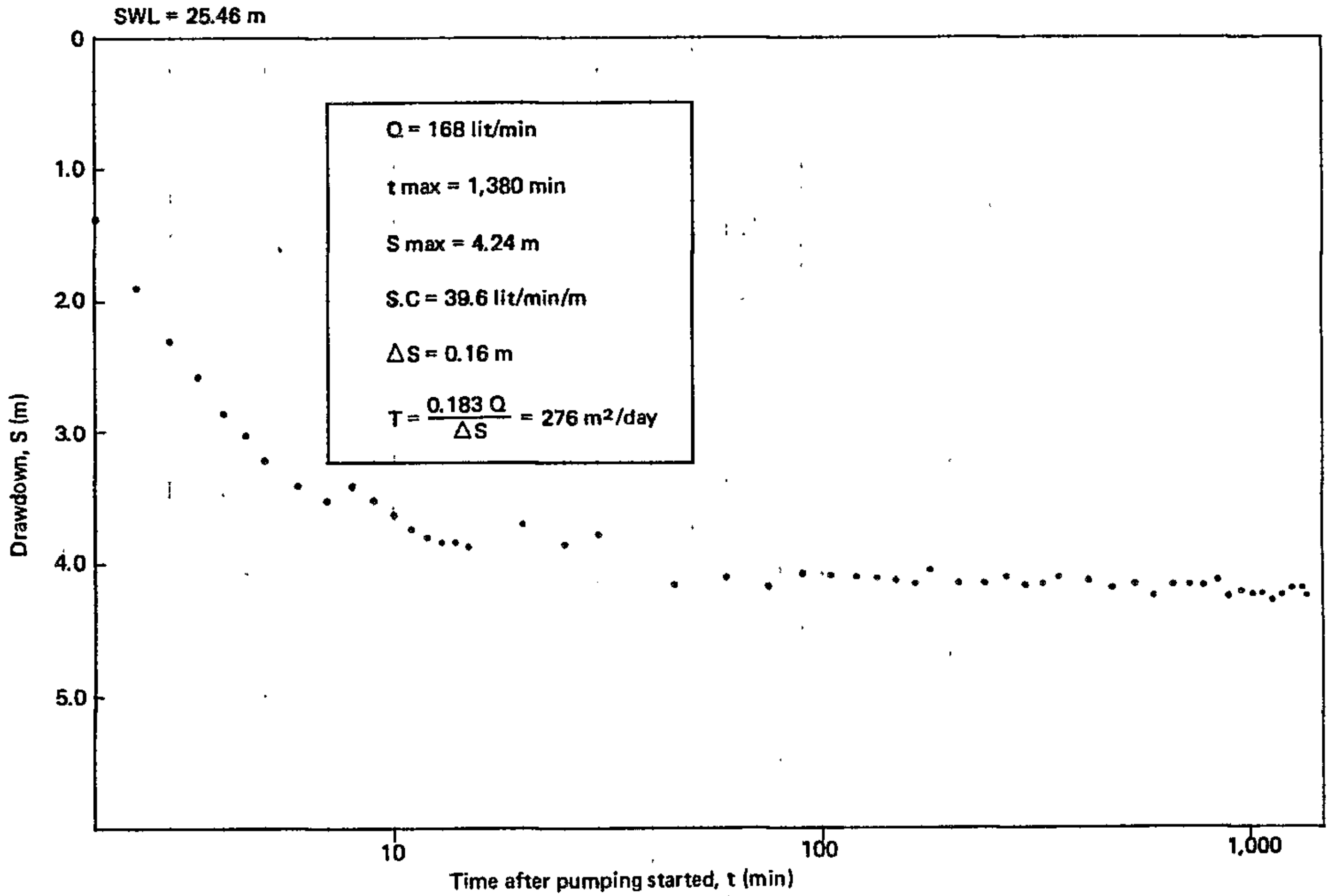


FIGURE C–16 JA–3, CONSTANT DISCHARGE TEST

Sr – t/t' curve

January 9, 1982

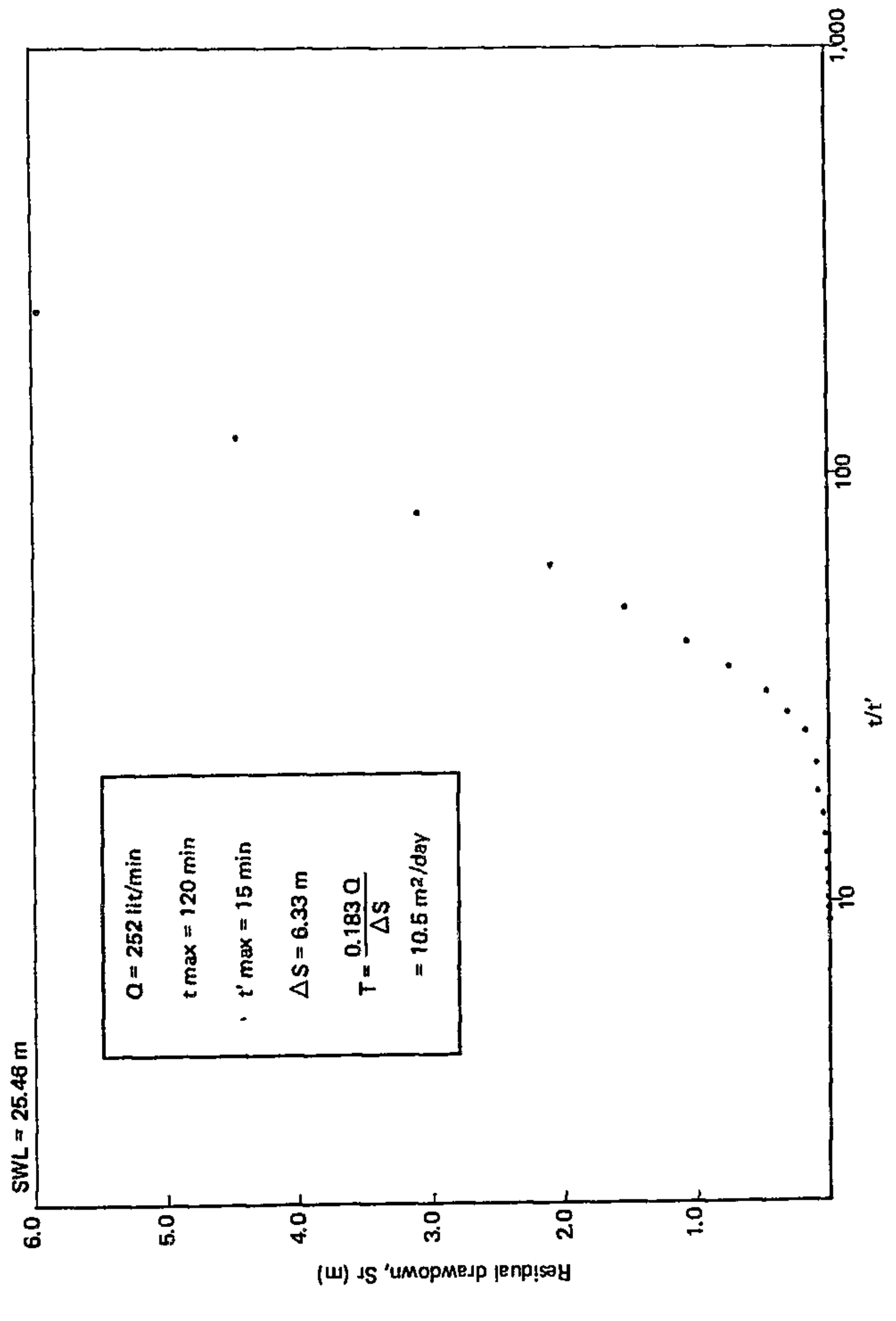


FIGURE C–17 JA–4, STEP-DRAWDOWN TEST

February 26, 1982

S – t curve

Specific Capacity (lit/min/m)	Q_1	Q_2	Q_3	Aver.
	261	293	232	262

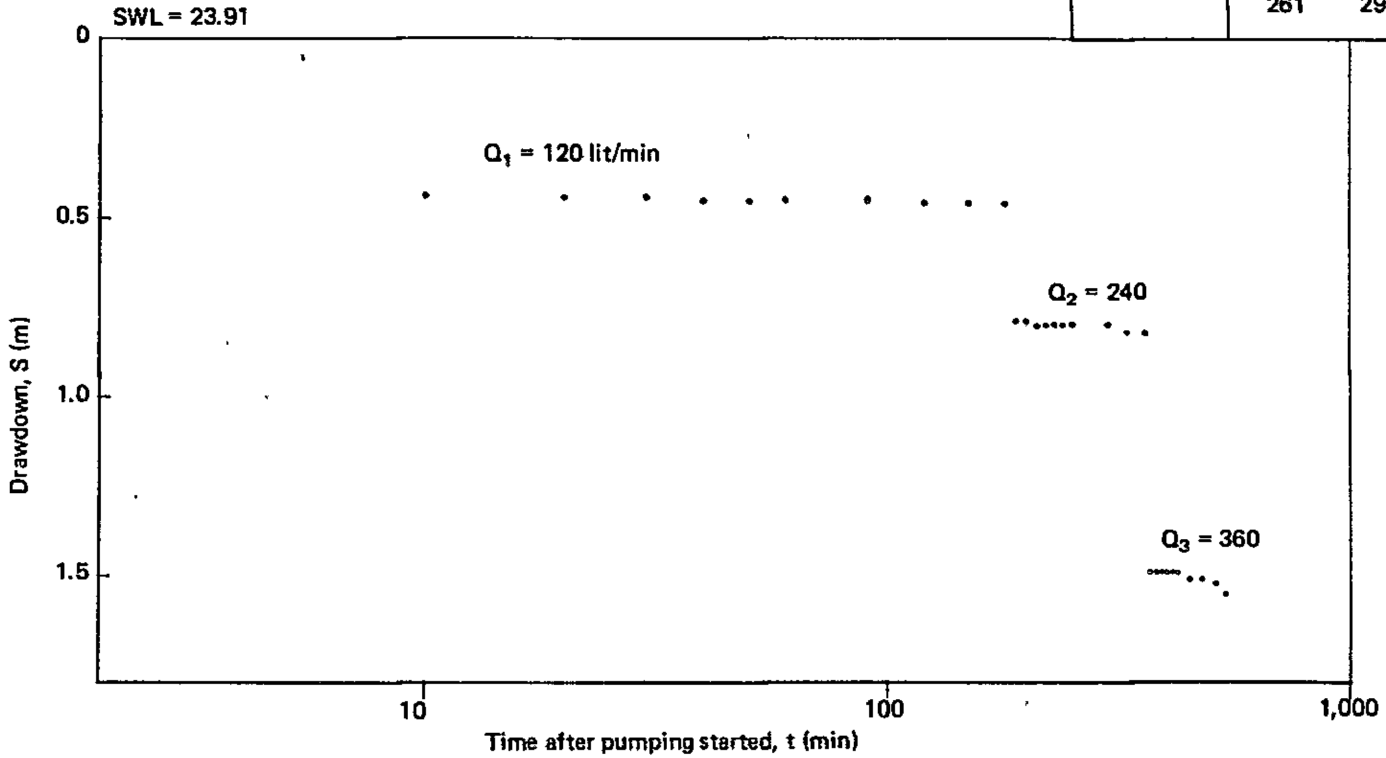


FIGURE C – 18 JA – 4, CONSTANT DISCHARGE TEST

S – t curve

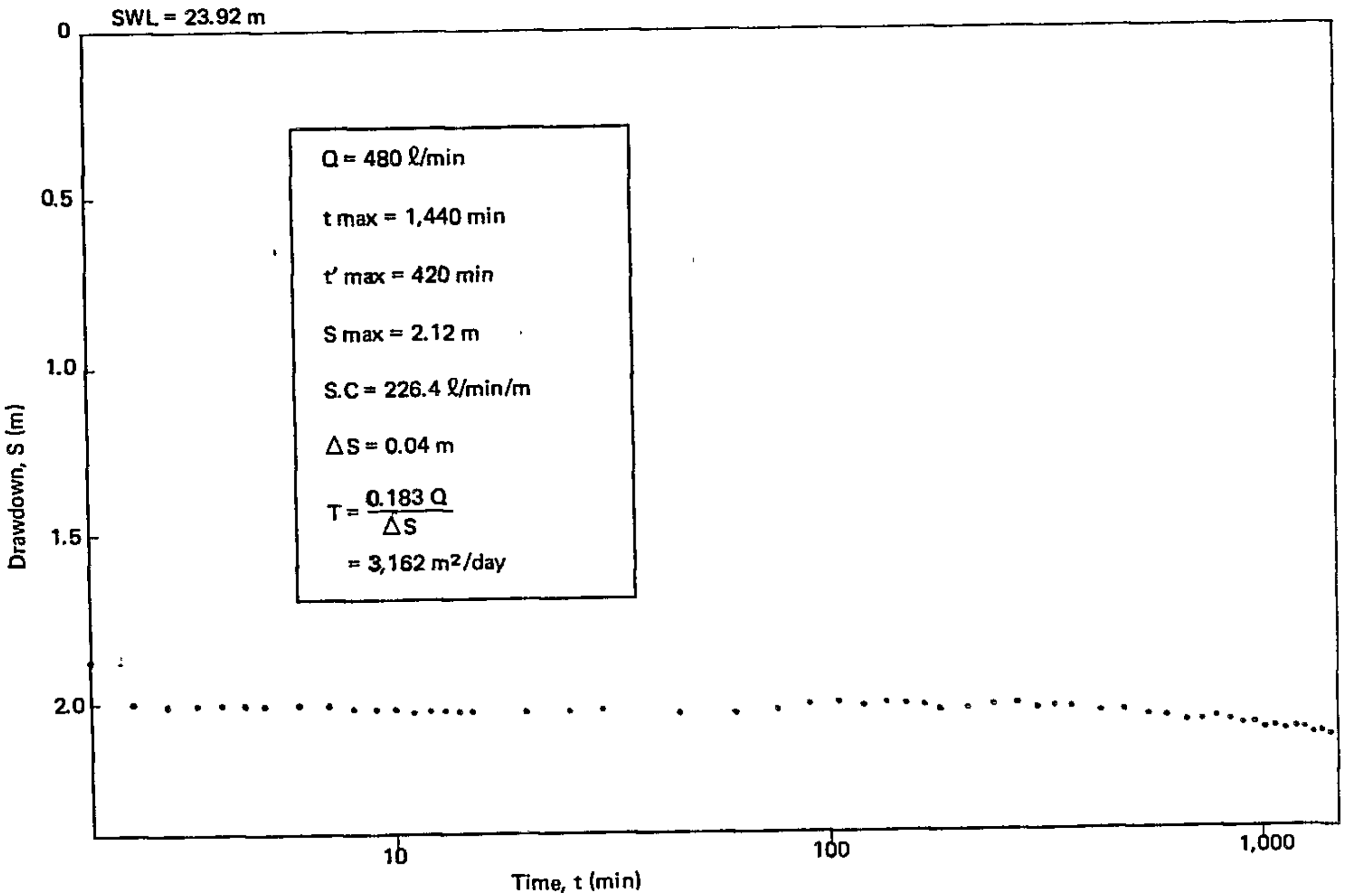


FIGURE C – 19 JA – 4, CONSTANT DISCHARGE TEST

Sr – t/t' curve

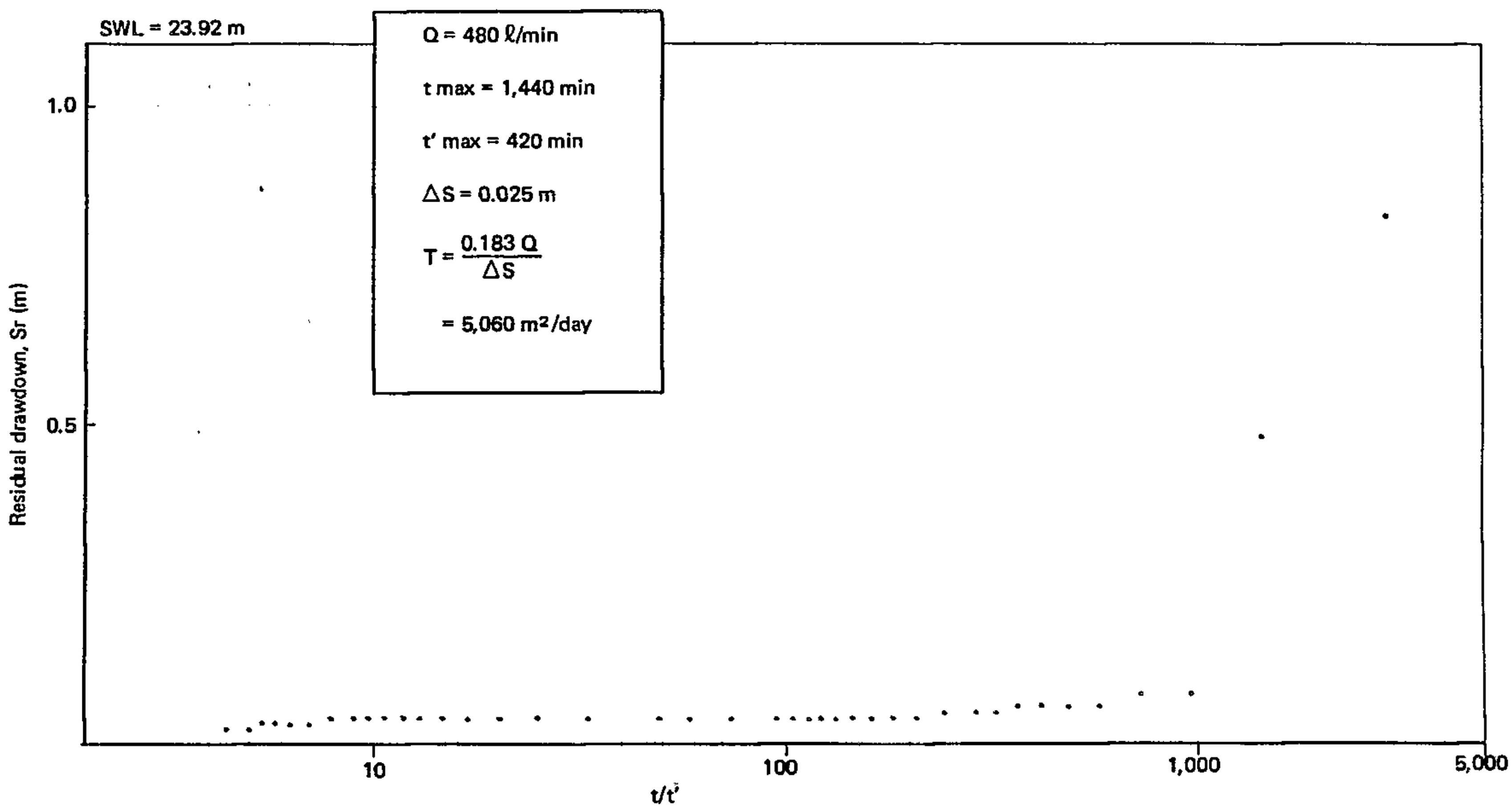


FIGURE C – 20 JA – 5, CONSTANT DISCHARGE TEST

March 10, 1982

S - t curve

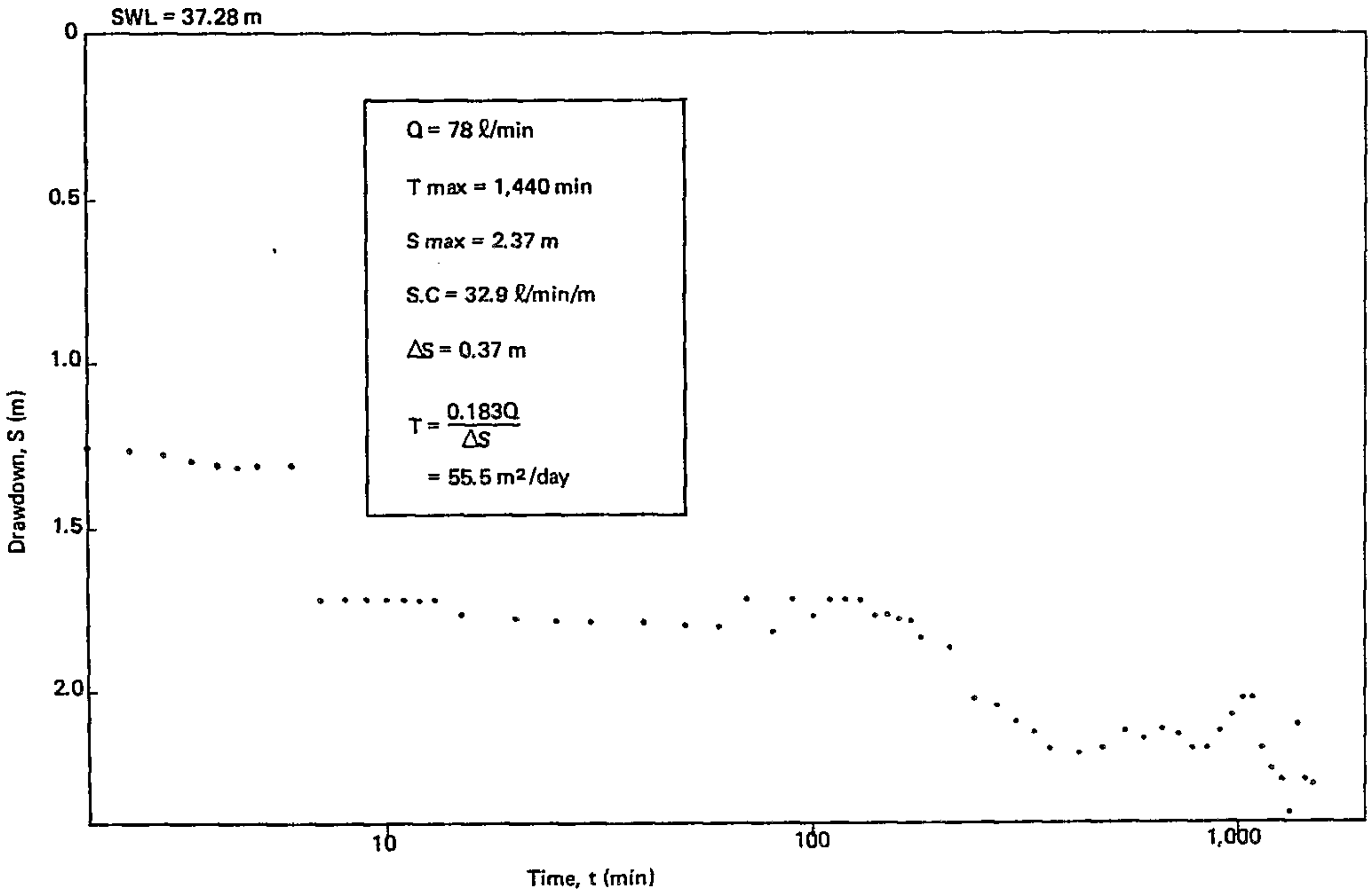


Table C - 2 Data Summary of Aquifer Tests

Well No.	S.W.L.	Step Drawdown Test									Constant Discharge Test					
		1st Step		2nd Step		3rd Step		4th Step								
		Q	S	Q	S	Q	S	Q	S	S.C	Q	S	S.C	T	B	C
	(m)	(ℓ/min)	(m)	(ℓ/min)	(m)	(ℓ/min)	(m)	(ℓ/min)	(m)	(ℓ/min/m)	(ℓ/min)	(m)	(ℓ/min/m)	(m^2/day)	(min/m^2)	(min^2/m^5)
JA-1	20.90	416	0.38	613	0.54	731	0.64	825	0.75	1,160	825	0.75	1,100	16,900	$8.2x10^{-4}$	$1.0x10^{-4}$
JA-2	7.08	386	0.63	500	0.85	712	1.21	-	-	600	958	1.67	574	4,340	$1.5x10^{-3}$	$3.0x10^{-4}$
JA-3	25.46	138	3.12	168	4.24	251	7.44	-	-	40	168	4.24	40	280	$1.3x10^{-2}$	$6.6x10^{-2}$
JA-4	23.92	120	0.46	240	0.82	360	1.55	-	-	260	480	2.12	226	3,160	$1.5x10^{-3}$	$4.5x10^{-3}$
JA-5	37.28	-	-	-	-	-	-	-	-	-	78	2.37	33	60	-	-

Remark:
Q : Discharge
S : Maximum Drawdown
S.C : Specific Capacity
T : Transmissivity
S.W.L : Water level before test
B : Aquifer loss constant
C : Well loss constant

FIGURE C–21 TRANSMISSIVITY-SPECIFIC CAPACITY RELATION

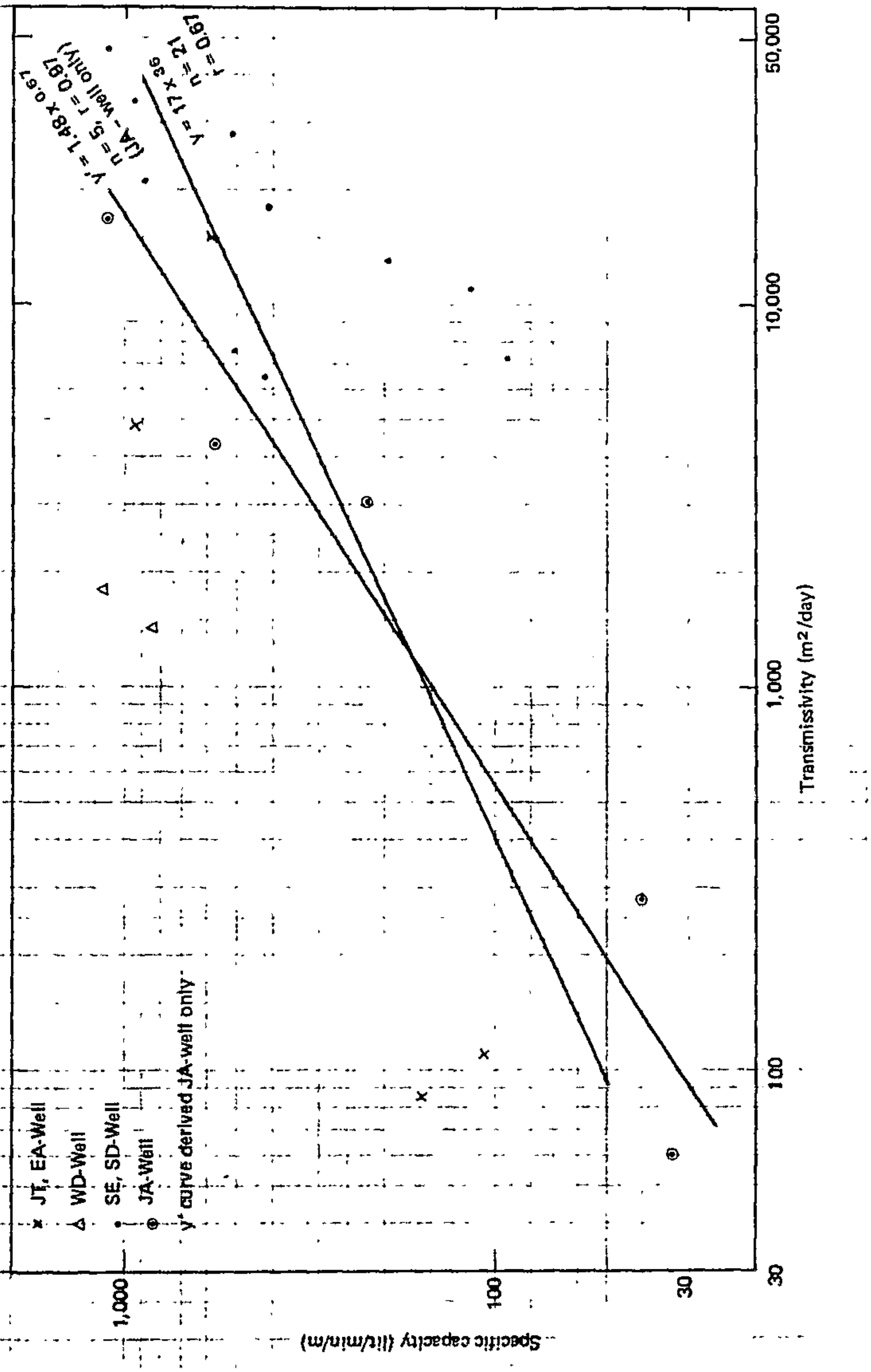


Table C - 3 Result of Chemical Analysis for Exploratory Wells

Sample No. Name of Well	Date, Analyzed	pH	EC (μmhos/cm at 25°C)	T.S.S (p.p.m)	Cations (me/L)					SAR	Anions (me/L)				
					Na^+	K^+	Ca^{++}	Mg^{++}	Total		$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$	Total
JA 1	24/3/1982	7.0	1,005.96	643.80	4.350	0.113	1.10	4.10	9.66	2.70	0.6	2.80	4.25	1.66	9.31
JA 2	24/3/1982	7.4	367.04	234.91	1.174	0.061	trace	2.50	3.74	1.05	0.6	1.45	1.10	0.16	3.31
JA 3	21/1/1982	7.6	518.00	331.50	1.552	0.074	0.40	2.80	4.83	1.23	trace	2.30	1.80	0.66	4.76
JA 4	24/3/1982	7.7	489.38	313.20	1.304	0.066	0.20	3.45	5.02	0.97	0.6	2.30	1.30	0.42	4.62
JA 5	24/3/1982	7.45	413.26	264.49	1.304	0.074	0.20	2.90	4.48	1.05	0.4	1.85	1.25	0.42	3.92

Note: Analyzed by Rumais Agricultural Research Station.

1.4 Infiltration Tests

Infiltration tests are conducted on the Wadi Jizzi basin to get basic data of recharge rate. Location of the tests is shown in Figure C-1, the location map of hydrogeology.

Iron cylinder with 30 cm in diameter and 40 cm in height, is plunged into the ground to a depth of about 20 cm and hook gauge is applied for measuring water levels. Dike was made around the cylinder to prevent lateral seepage from the cylinder. Within the dike water level was kept at the same level as inside the cylinder.

The results are listed in Annex Tables. The value of infiltration rate in 14 tests range from 0.3 to 12.0 mm/min and it lead to 3.0 mm/min in an average for recent river beds.

1.5 Measurements of Groundwater Level

Groundwater level measurements have been conducted by the WRD of MAF, Sultanate of Oman since 1973, not only on the Wadi Jizzi basin but also on the Batinah coast. Observed intervals had been once a month at initial year but it was reduced to twice or thrice a year because of shorthandedness in recent years.

Observation network on the coastal plain of the Wadi Jizzi basin was constructed for the Project at the end of December, 1981, and observation of water levels at the newly assigned wells have been continued to the end of March, 1982. Location and inventory of observation wells are shown in Figure C-1 and Table C-5 respectively.

Observed water levels including records from automatic level recorder at the wells of JA-3 and JA-4 are shown in Annex Table. Water table rising caused by the flood dated February 14, 1982 is shown in Table C-6. As is shown in table, average rising of water tables at wells locating on lower area of less than 12 mamsl on the coastal plain shows at 0.66 m which estimate to 33 mm of net water

Table C - 4 Data Summary of Infiltration Tests

Site No.	Site Altitude (mamsl)	Topographic Condition	Rate of infiltration (mm/min)	Remarks
1	190	Wadi bed	3.5	n = 13
				$\bar{x}$ = 3.2 mm/min
2	130	Wadi bed	3.5	
3	115	Wadi bed	4.0	
3'	103	Wadi bed	12.0	
4	80	Old wadi bed	2.0	
5	90	Wadi bed	2.0	
6	50	Old wadi bed	6.0	
7	40	Alluvial ter.	2.0	
8	40	Wadi bed	2.0	
9	25	Alluvial ter.	3.0	
10	8	Wadi bed	0.3	
11	18	Wadi bed	2.0	
12	2	Wadi bed	4.5	
13	155	Dam site Wadi bed	4.0	
14	155	Dam site Wadi bed	3.0	

Table C - 5 Inventory of Water Level Measurement Wells

Well No.	Location U TM Grid	Depth (m)	Diameter (mm)	Height to W.L.Measuring Point (mags)	Elevation of Well Site (mamsl)
JA-1	469550 2689580	82.0	250	1.597	24.04[1/]
JA-2	467850 2696740	40.0	250	1.85	11.00[3/]
JA-3	464050 2695700	45.0	250	1.48	30.00[3/]
JA-4	461080 2695200	55.0	250	1.36	50.00[3/]
JA-5	464660 2692200	55.0	250	1.82	42.00[3/]
JA-6	460450 2690750	18.0	250	1.16	
OA-1	456400 2690100	23.0 (150)	100	1.13	110.00[3/]
OA-2	476000 2690800	(105)	100	1.17	6.411[1/]
EA-1	466500 2693000	77.20 (200)	240	1.20	30.00[3/]
EA-2	470800 2687500	38.11 (130)	240	0.85	27.43[1/]
WSI-26	469100 2692800	58.40 (60)	360	0.10	13.68[2/]
SP-0	472500 2688150		200	0.24	21.00[3/]
AE-49	448400 2686300	12.62	1,450	0	156.00[2/]
AE-62		10.70	800	0.25	9.96[2/]
AE-91		9.20	800	0.15	10.53[2/]
AE-93		9.30	1,400	0.10	2.76[2/]
AE-101		11.10	800	0.10	12.68[1/]
AE-142		3.70	800	0.40	2.98[1/]
AE-159		11.81	800	0.10	13.59[1/]
AMQ		10.75	800	0.40	6.00[3/]
UNL		9.15	800	0.20	10.11[1/]
ABG		7.80	1,300	0.20	4.00[3/]
MQS		3.93	800	0.30	4.00[3/]
14/M		5.00	800	0	3.00[3/]
SMQ		11.60	800	0.50	13.06[1/]
TMQ		9.35	850	0.09	10.49[1/]

Note : 1/; Surveyed by JICA
2/; Surveyed by ILACO
3/; Based on contour lines of 1:50,000 map

Table C - 6 Rate of Water Table Increasement at the Flood, Feb. 14, 1982

Name of Well	Attitude of Well Site (mamsl)	Distance to Sea (km)	Water Table at Feb.14/End Mar. Date	Mamsl	Date	Mamsl	Differences m	Rate m/day
AE-49	156.00	22.0	2-16	145.79	3-21	152.38	6.59	0.20
AE-62	9.96	2.5	2-14	0.32	3- 1	1.76	1.44	0.10
AE-91	10.53	1.8	2-14	1.29	3-22	2.50	1.21	0.03
AE-93	2.76	0.7	2-14	0.96	3- 1	0.96	0	0
AE-101	12.68	3.2	2-14	1.98	3- 1	3.18	1.20	0.04
AE-142	2.98	0.5	2-14	0.38	3-20	0.98	0.60	0.02
AE-159	13.59	3.1	2-14	2.08	3-20	2.57	0.49	0.01
OA-1	110.00	17.5	2-17	97.28	3- 2	101.25	3.97	0.31
OA-2	6.41	0.7	2-14	1.08	3-20	1.36	0.28	0.01
JA-1	24.04	6.6	3- 2	3.40	3-22	3.51	0.11	0.01
JA-2	11.00	4.1	2-21	4.03	3-15	4.545	0.52	0.02
JA-3	30.00	7.0	2-14	5.16	3-24	5.56	0.39	0.01
JA-4	50.00	9.5	2-14	26.05	2-21	26.17	0.12	0.02
JA-5	42.00	9.3	2-14	4.37	3-21	5.85	1.48	0.04
AMQ	6.00	0.3	2-14	9.59	3- 1	9.40	0.19	0.01
ABG	4.00	0.7	2-14	3.26	3- 1	2.68	0.58	0.04
14-M	3.00	0.6	2-14	5.74	3-22	2.38	3.36	0.01
MQS	4.00	0.2	2-14	3.61	3-22	3.52	0.09	0.003
SP-0	21.00	5.0	2-14	18.90	3-15	18.57	0.33	0.01
TMQ	10.49	3.1	2-14	1.87	3-20	2.78	0.91	0.03
UML	10.11	3.0	2-14	2.40	3-20	3.12	0.72	0.03
WSI-26	13.68	5.2	2-14	1.85	3- 1	2.42	0.57	0.04
EA-1	30.00	7.7	2-14	5.12	3-22	6.375	1.26	0.03
EA-2	27.43	6.9	2-14	2.58	3-15	5.50	2.92	0.10

or 19% to the total amount of 170 mm rainfall untill the end of March, 1982, if applied 0.05 storativity.

1.6 Conductivity Loggings

Electric conductivity loggings at the existing wells were conducted for detection of sea water intrusion into the aquifer.

Loggings are conducted twice, at drought period, January, 1982 and wet period, March, 1982 after the big flood.

Tested data are listed in Annex Table and loggings of deep wells is shown in figures in comparison with results of previous logging conducted by ILACO. EC logging at JA-wells are drawn in the exploratory well logs. In general, EC loggings at west of the highway could not detect salt water of more than 700 micro mho/cm even at the depth of 60 mbgs except logging at JA-1 where EC was detected 1,000 micro mho/cm at surface layer of water.

Chemical analyses show that those items as the content of salinity and ionic composition fall within criteria of irrigation uses except JA-1.

FIGURE C–22 EC-LOGGING AT WSI-26

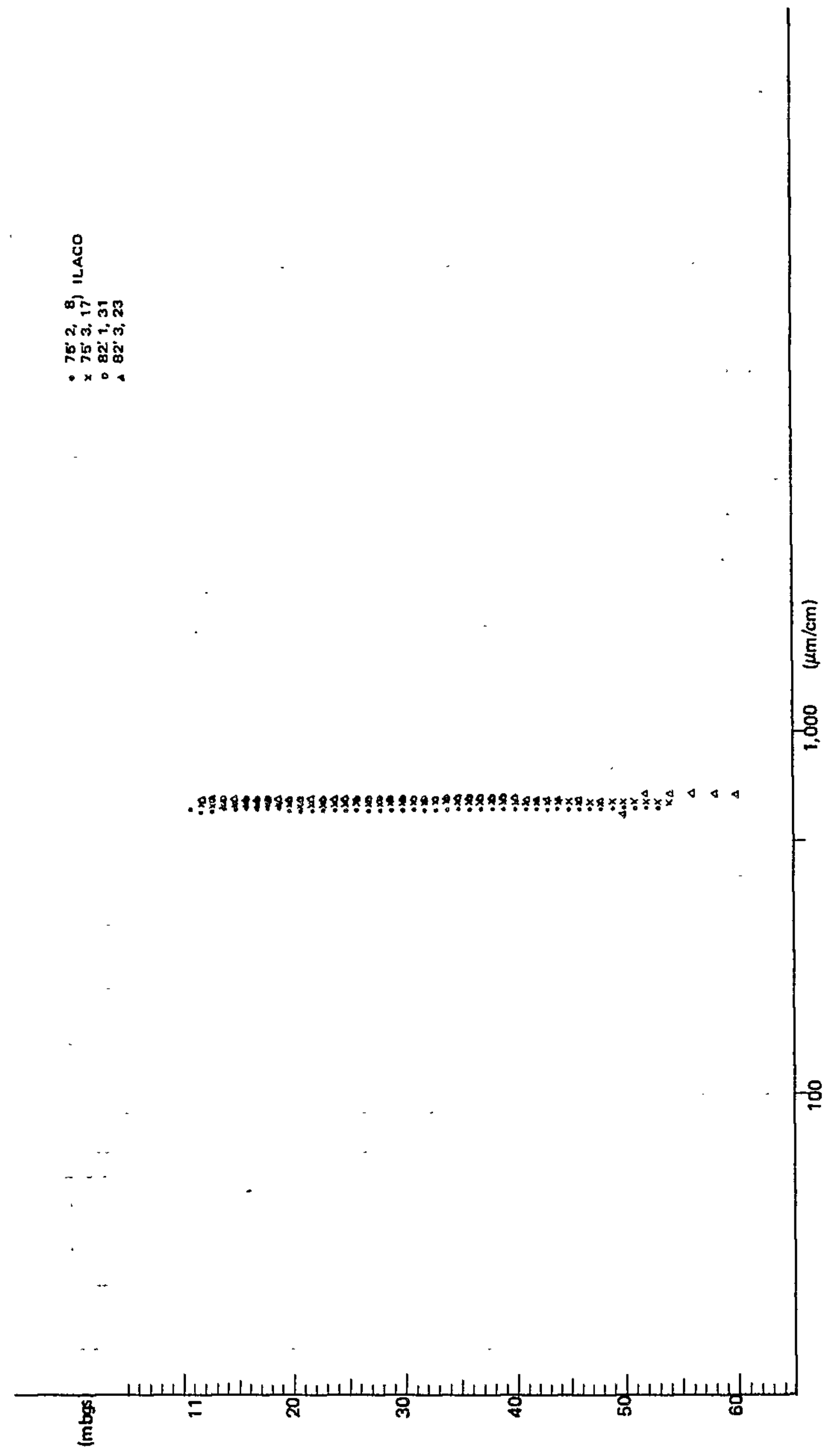
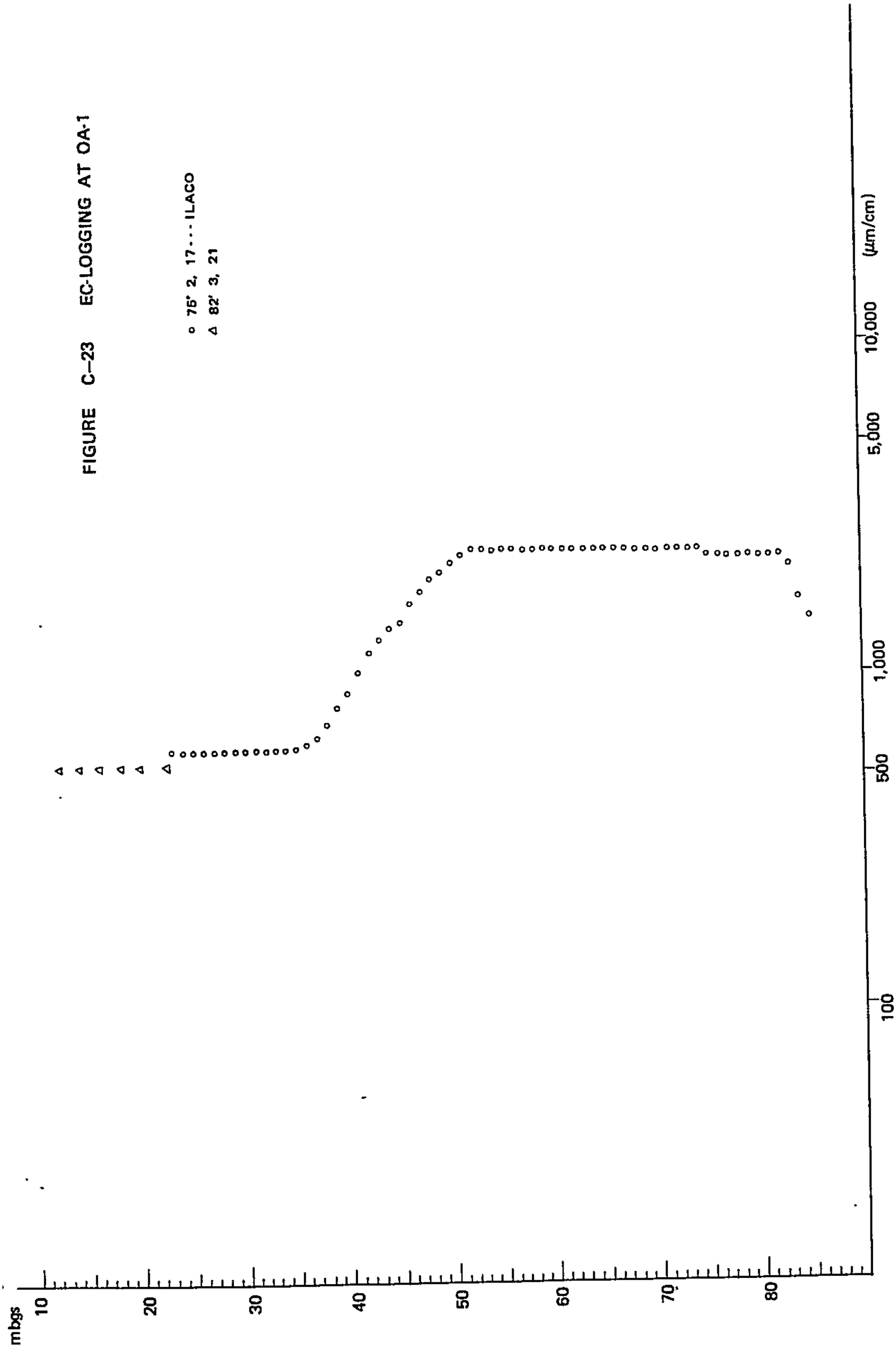


FIGURE C–23 EC-LOGGING AT OA-1



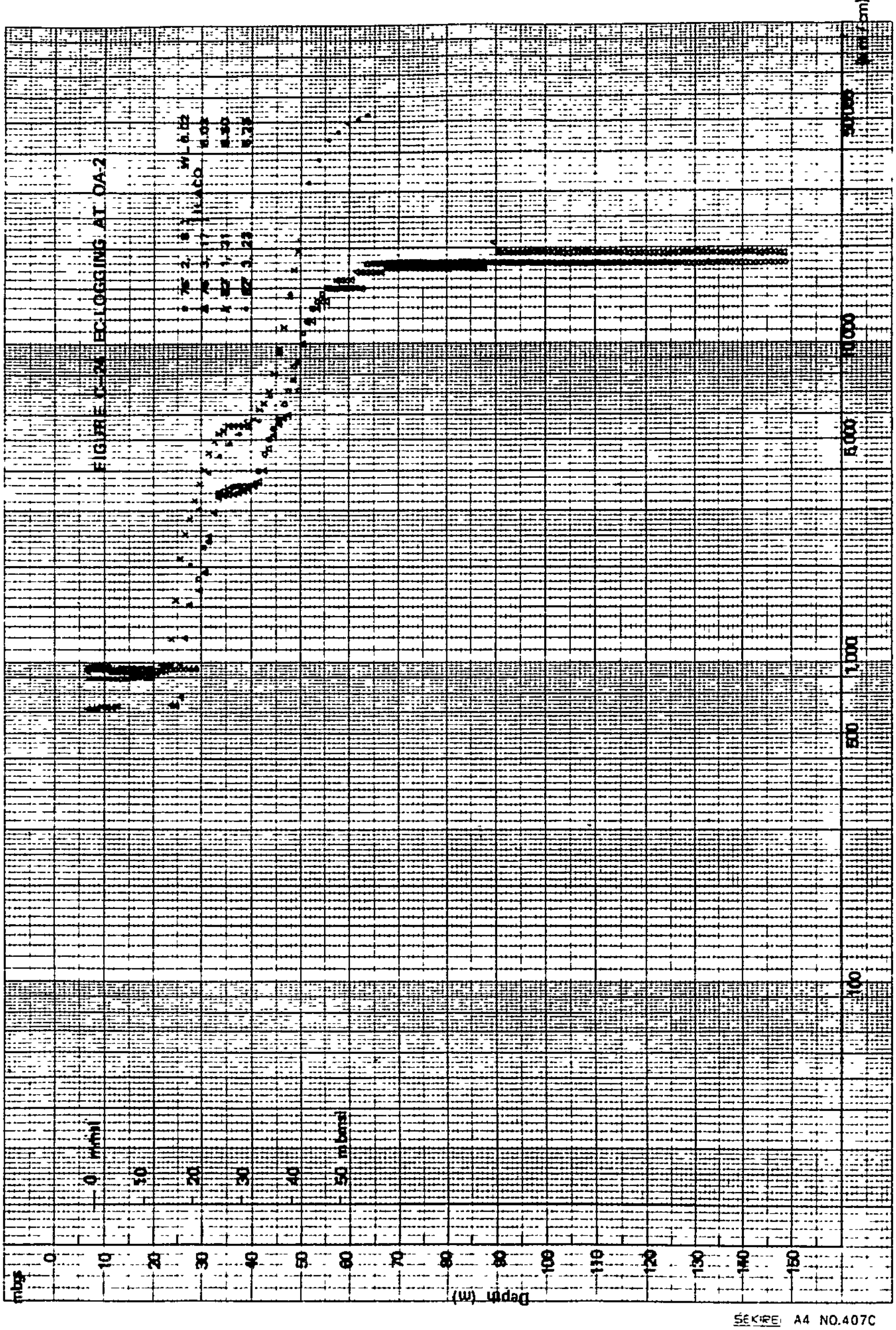


FIGURE C-24 EC LOGGING AT OA-2

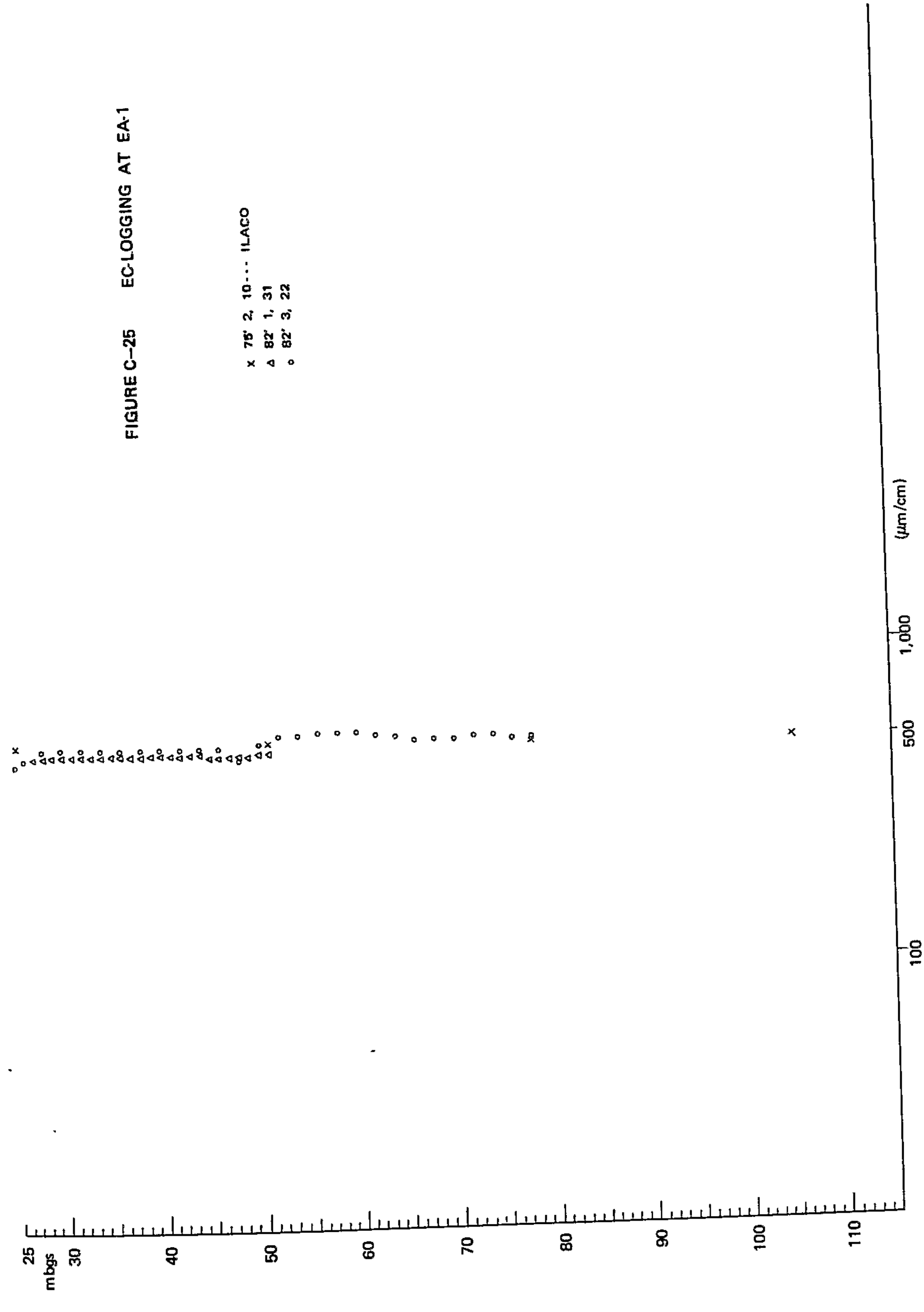


FIGURE C–25 EC-LOGGING AT EA-1

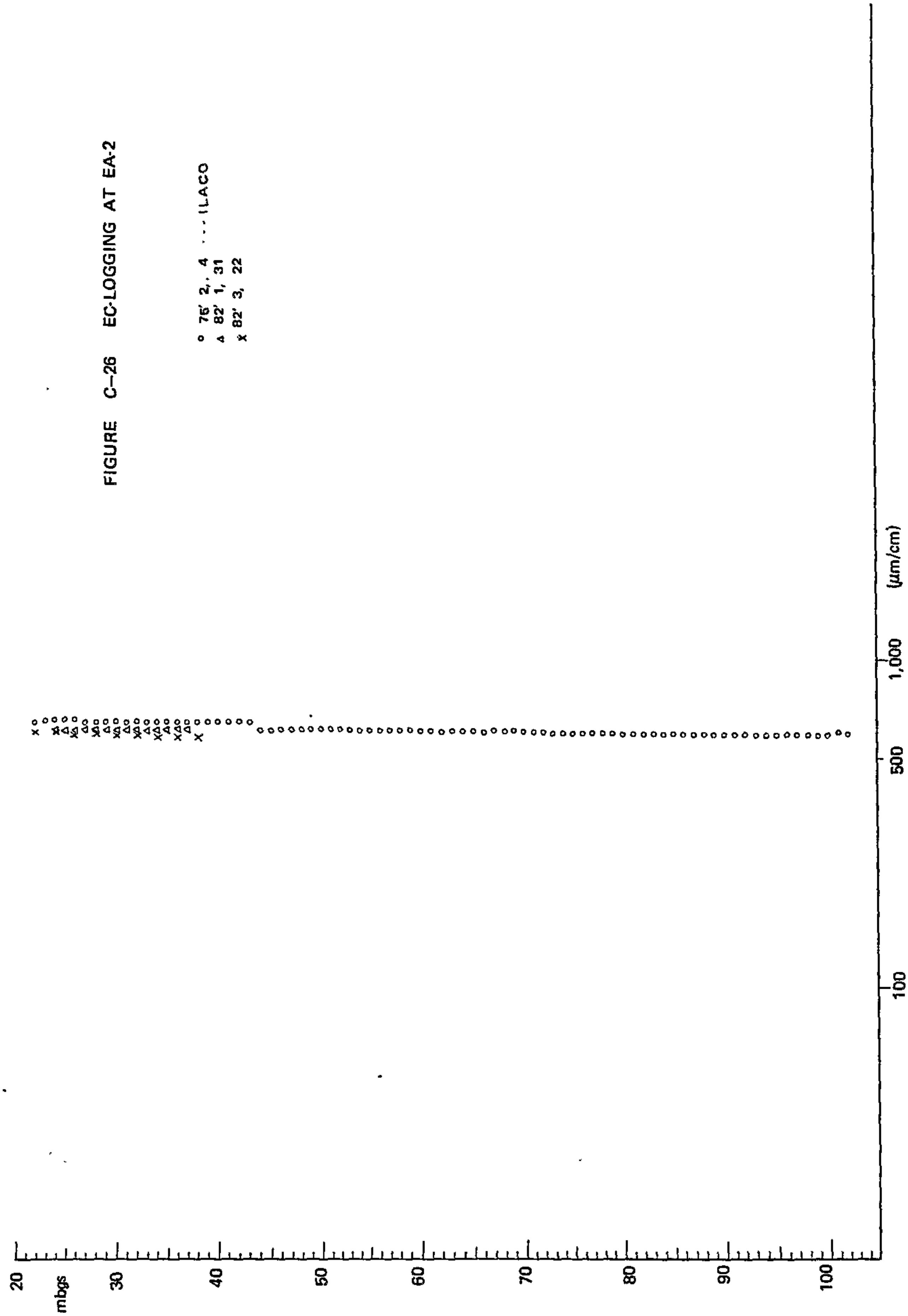


FIGURE C-26 EC-LOGGING AT EA-2

2. Hydrogeology

2.1 Hydrogeological Units

The Project area consists of following three hydrogeological units; the impervious formations, the terrace deposits, and the alluvial deposits.

a) The Impervious Formations

The impervious formations consist of Hawsasinah group, Basic volcanic rocks, and the tertiary sedimentary formations forming main central ranges and their flanks.

Hawsasinha Group consists of silicified limestone, mudstone and chert with well stratified beds of several ten centimeters. Basic volcanic rocks are composed almost entirely of Oman Ophiolite forming main central ranges in a middle stream of Wadi Jizzi. The tertiary sedimentary formations consists of mudstone and limestone forming besement of the terrace deposits and low hill in the west edges of gravel plain. The formations were found by the exploratory well drillings beneath the gravel plain at depth of 40 to 50 mbgs with weak consolidated condition. Depth to the tertiary formations which was confirmed by drillings are 34 mbgs (16 mamsl) at well site of JA-4 and 44 mbgs (6 mbmsl) at well site of TS-8, along the gas pipe line. Precise geologic informations in the coastal plain are still few. Clay layers with 100 m in thickness is correlative with tertiary mudstone starting depth of 118.7 mbgs which was confirmed by the bore hole of Sohal Expansion Farm.

The evidence that depth to basement of Alluvial deposits is revealed at 100 mbmsl is consistent with the opinion that regression along Gulf Bay at Wurm glacial age is estimated more than 100 m (H. Felber 1978)[1/].

1/ H. Felber, H. Hötzl, V. Maurin, H. Moser, W. Rauert, J.G. Zötl "Quaternary Period in Saudi Arabia" Springer-Verlag, 1978

b) Terrace Deposits

The Terrace deposits have a large exposure in a middle stream of the Wadi Jizzi and the west edge of the gravel plain but their distribution are restricted in an upper stream of the Wadi. The deposits are divided into four kinds of sediments based on height of their platform. Three of them are distributed in the Wadi Jizzi basin and the lowest one is distributed in a mouth of catchment of the Wadi Bani Umar forming alluvial fan.

The deposits are composed of partially cemented sand and gravel of fluvial origin with various size of grains of basic volcanic and sedimentary rocks.

The deposits seem aquifuge, however occasionally their uncemented thin layers of sand and granule among the deposits take a function of aquifers, therefore they act a part of aquifer in terms of hydrogeology. Thickness of each deposits and estimated height of their platform at the mouth of river compared with recent sea level are shown in following table.

Name of Terrace	Height of the mouth (mamsl)	Thickness (m)
Terrace dep. I	110	5 +-
Terrace dep. II	60	15 +-
Terrace dep. III	40	35 +-

The Terrace deposits III, lowerest one with 5 m height to the recent wadi course in the gravel plain is exposed in the right bank of the Wadi, whereas the left bank was eroded and filled by the recent wadi deposits. The distribution is restricted to the area in the edge of gravel plain, where altitude is more than 40 mamsl.

c) Alluvial Deposits

The Alluvial deposits are exposed in limited area along the wadi course in the catchment however, they have a large exposure in the coastal plain. The deposits consist of sand and gravel with partially cemented beds of alluvial origin. Thickness of the deposits range from few meters at the river beds in the catchment to 10 m in the mouth of catchment and finally it comes more than 80 m in thickness in coastal plain where the deposits are achieving the excellent unconfined aquifer.

2.2 Aquifer Characteristics

The main aquifers in the Project are restricted to the terrace deposits and alluvial deposits. Aquifer characteristics in the coastal plain, especially alluvial aquifers beneath the gravel plain have been obtained by the aquifer tests since 1973, however their characteristics in the terrace deposits weren't obtained except few data. Summarized well data including existing wells is shown in Table C-7. As is shown in table, specific capacity and transmissivity of the alluvial aquifers in the east edge of gravel plain are ranging from 30 to 60 cu.m/hr/m and from 4,000 to 50,000 sq/day respectively. Storativity which was obtained aquifer tests at production well No.1 of Sohar Expansion Farm is calculated 0.05 in an average showing reasonable value for alluvial unconfined aquifer.

2.3 Hydrogeological Structure

The groundwater basin comprising the terrace deposits and alluvial deposits coincides with depth of the impervious formations beneath the gravel plain.

The groundwater basin is enclosed by the Impervious formations at the north and west edges with depth of less than 80 m and it thickens to the east up to more than 100 m at the coast. The basin ends near Qabail and Majis where the Impervious formations crop out near the sea. Location of the south end of the basin is estimated at the

Table C - 7 Summary of Well Data at Wadi Jizzi Basin

Well No.	Location UTM	Altitude of Site (mamsl)	Depth (m)	Casing Dia. (mm)	Screen Type	Screen Depth (m - m)	S.W.L (mbgs)	Tested Yield (m^3/hrs)	Draw-Down (m)	Specific Capacity (m^3/hr/m)	T (m^2/day)	S	Well Efficiency (%/m^3/d)
JA-1	4696,26896	24.04	82	250	Slot	33-79	20.5	45.7	0.75	60.9	16,900	-	86/2,000
JA-2	4679,26967	11.00	40	250	Slot	12-34	6.5	56.9	1.71	33.1	4,300	-	77/2,000
JA-3	4641,26957	30.00	45	250	Slot	22-39	24.4	15.1	7.25	2.1	150	-	-
JA-4	4611,26952	50.00	55	250	Slot	10-33	24.1	28.8	2.12	13.7	3,200	-	-
JA-5	4647,26922	42.00	55	250	Slot	32-55	36.1	4.7	2.28	2.1	60	-	-
WST-26	4691,26928	13.68	60	370	Slot	42-55	12.0	49.0	0.45	108.9	-	-	-
JT-64	4746,26888	-	35	240	Slot	23-34	11.8	28.5	3.00	9.5	85	-	-
JT-65	4741,26889	-	35	240	Slot	24-35	13.1	28.5	4.40	6.5	110	-	-
WD-78	4672,26928	25.63	73	200	Slot	33-69	20.0	79.1	1.16	68.2	1,800	-	-
WD-79	4670,26929	27.17	70	255	Johnson	24-60	21.1	82.6	1.64	50.4	1,440	-	-
SE-1	4708,26898	20.00	56	273	Johnson	44-56	15.6	220.0	3.28	67.1	47,000	0.05	72/4,000
SE-2	4704,26904	18.60	50	273	Johnson	41-50	14.3	215.0	8.56	25.1	18,700	-	75/4,000
SE-3	4715,26900	18.40	55	273	Johnson	43-46 49-55	14.4	217.0	3.84	56.5	34,000	-	75/4,000
SE-4	4712,26959	17.50	56	273	Johnson	47-56	13.6	215.0	7.06	30.5	28,000	-	82/4,000
SD-5	4743,26887	15.70	35	244	Slot	23-35	12.3	82.8	11.54	7.2	11,000	-	57/2,000
SD-6	4749,26885	14.40	35	244	Slot	23-34	11.1	91.4	7.75	11.8	13,000	-	74/2,000
SD-7	4742,26881	17.20	44	273	Slot	30-44	13.2	93.7	3.70	25.3	6,400	-	63/2,000
SD-8	4745,26879	17.10	36	273	Johonson	27-36	13.1	68.5	11.97	5.7	7,200	-	63/2,000
SD-9	4748,26877	16.80	44	273	Slot	30-44	12.4	95.3	3.15	30.3	7,500	-	78/2,000
SD-10	4745,26879	17.10	55	324	Johonson	46-55		215.0	4.08	52.7	21,000	-	90/4,000
EA-1	4665,26930	30.00	200	240	Slot	50-75	23.46	31.5	0.89	35.4	15,050	-	
EA-2	4708,26875	27.40	130	240	Slot	42-104	21.15	31.5	0.56	56.3	4,800	-	

Remarks :
JA-Well: Tested by JICA
WSI-Well: Tested by ILACO
JT-Well: Tested by Gibbs
SD, SE-Well: Tested by IRI
EA-Well: Tested by ILACO
WD-Well: Tested by Macdonald

south of Wadi Ahin where the Impervious formations are croped out near the sea. An entire area of the groundwater basin mainly developing in the downstream of Wadi Jizzi extends about 20 km in length along the coast with 8 km width. Furthermore, depth of it is estimated 50 to 60 m at the west edge of the basin and it deepens to the sea up to more than 100 m. Depth of the basin, especially at the west edge is verified by the exploratory drilling at JA-5 and 6, the production well for Mining Co., TS-6, 7, 8 and 9, and geo-electric survey at lines ES-1 and ES-V4.

The groundwater basin in the west edge of the gravel plain is composed aquifers of the terrace deposits with depth ranging 40 m in maximum to less than 20 m at an outlet of catchment and it extends to the wadi beds in the catchment decreasing thickness of aquifer.

The impervious formations which underlay the minor groundwater basin forms one or two steps of platform caused by Pre-Wurm glacial regressions. Schematic hydrogeologic profile along the Wadi Jizzi is shown in Figure C-27. The figure is drawn based on data of the drillings which was carried out in the survey and the pervious studies.

The lithological logs for existing drillings around the coastal plain for Wadi Jizzi basin are also drawn in Figure C-28. As is shown in figure, extraordinary thickness of silt and clay are overlain by the wadi alluvial of sand and gravel at the depth of eighty (80) meters below mean sea level in the coastal drillings, OA-2, SE-0, SP-0 and SP-2.

The deposits of silt and clay which play a part of the aquiclude can be correlated with the Tertiary. Extraordinary thickness of silt and clay is incompatible with the commonly expressed concept of the fluvial origin.

FIGURE C–27 HYDROGEOLOGICAL PROFILE ON THE WADI JIZZI COASTAL PLAIN

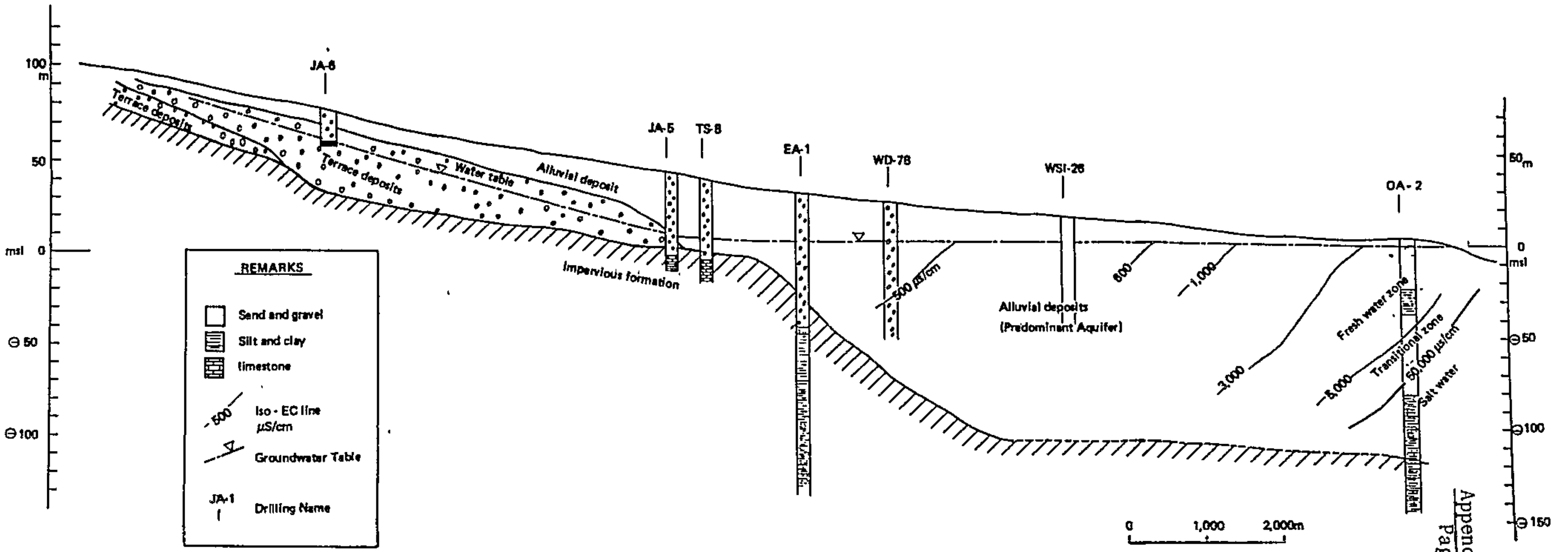
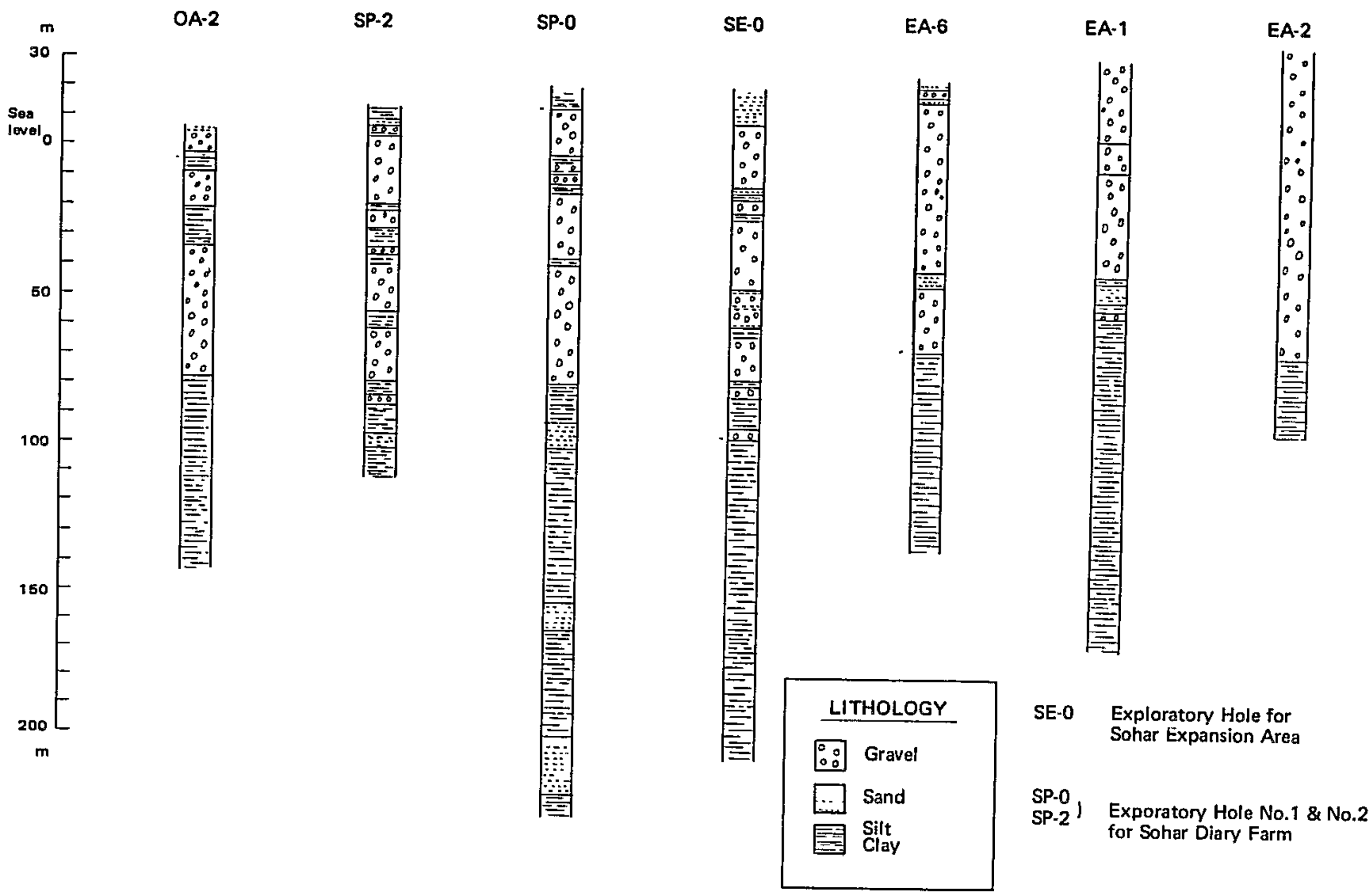


FIGURE C－28 LITHOLOGY OF DRILLING ON THE COASTAL PLAIN



3. Groundwater Hydrology

3.1 Occurence and Movement of Groundwater

Groundwater in the Project area is basically recharged by rainfall. Recharge take place in various manners from place to place. In the catchment, groundwater flows in wadi beds as an under flow with same hydraulic gradient as a gradient of river courses. Under flow turns to surface flow where basement rocks upheave to river bed.

Groundwater in the minor basin at the west edge of the gravel plain flows following comparatively steep under flow courses in contrast with the main groundwater basin in the coastal plain where it flows with moderate gradient. Under flow take a course where sediments deposited recently along eroded river beds during glacial age regression.

Hydraulic gradient at the west edge of gravel plain which calculated by water levels of OA-1 and JA-5 at drought month is about 1:100.

Groundwater in the major basin in the coastal plain is stored with comparatively moderate flow having 1:2000 of hydraulic gradient. Quantity of groundwater flow is estimated at several times of under flow because of large scale of flowing section.

Iso-depth contour lines to the Impervious formations and groundwater table contour lines on the coastal plain are drawn in the hydrogeological map in Figure C-29 and C-30. As is seen from the figure, groundwater flows at the coastal plain are summarized as follows:

Groundwater flow in drought month (the end of December, 1981)

° Groundwater with 5 mamsl water table at the west end of the basin flows to the coast having 1:2000 hydraulic gradient.

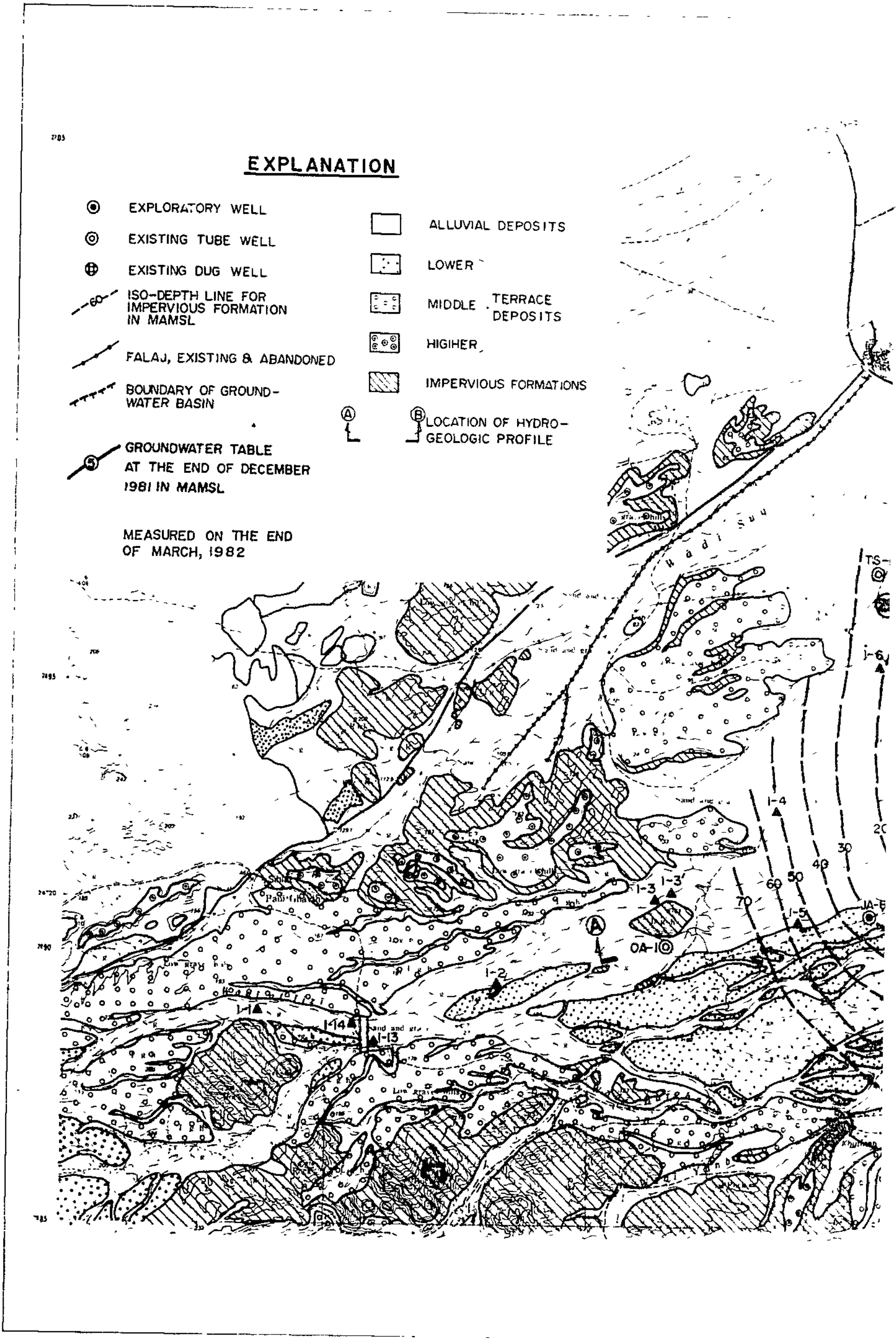
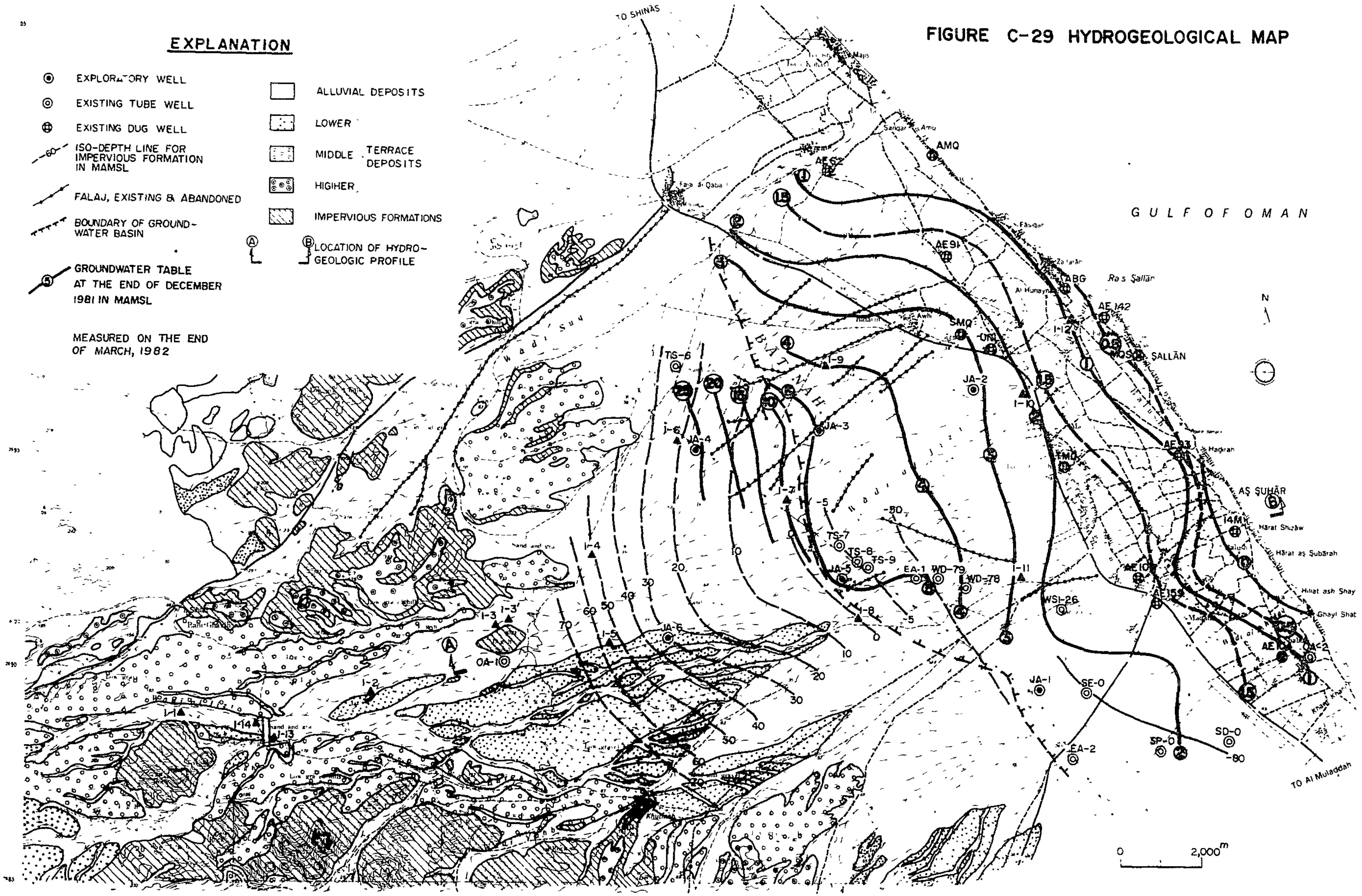

EXPLANATION
EXPLORATORY WELL
EXISTING TUBE WELL
EXISTING DUG WELL
ISO-DEPTH LINE FOR IMPERVIOUS FORMATION IN MAMSL
FALAJ, EXISTING & ABANDONED
BOUNDARY OF GROUND-WATER BASIN
GROUNDWATER TABLE AT THE END OF DECEMBER 1981 IN MAMSL
MEASURED ON THE END OF MARCH, 1982
ALLUVIAL DEPOSITS
LOWER
MIDDLE
HIGIHER
TERRACE DEPOSITS
IMPERVIOUS FORMATIONS
LOCATION OF HYDRO-GEOLOGIC PROFILE
Wadi Suq
I-1
I-2
I-3
I-3'
I-4
I-5
I-6
I-13
I-14
OA-1
JA-6
TS-
70
60
50
40
30
20

FIGURE C-29 HYDROGEOLOGICAL MAP



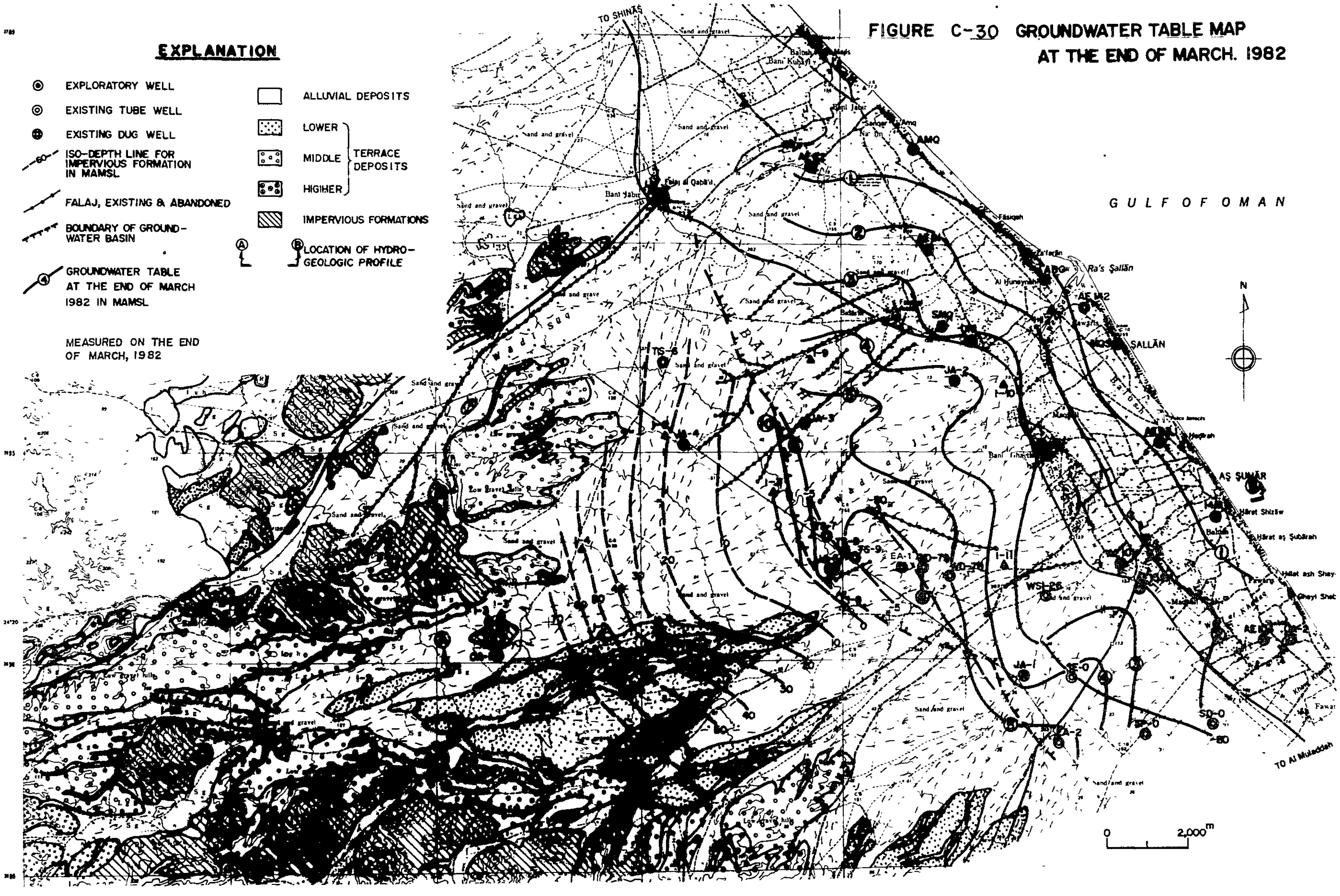


FIGURE C-30 GROUNDWATER TABLE MAP AT THE END OF MARCH. 1982

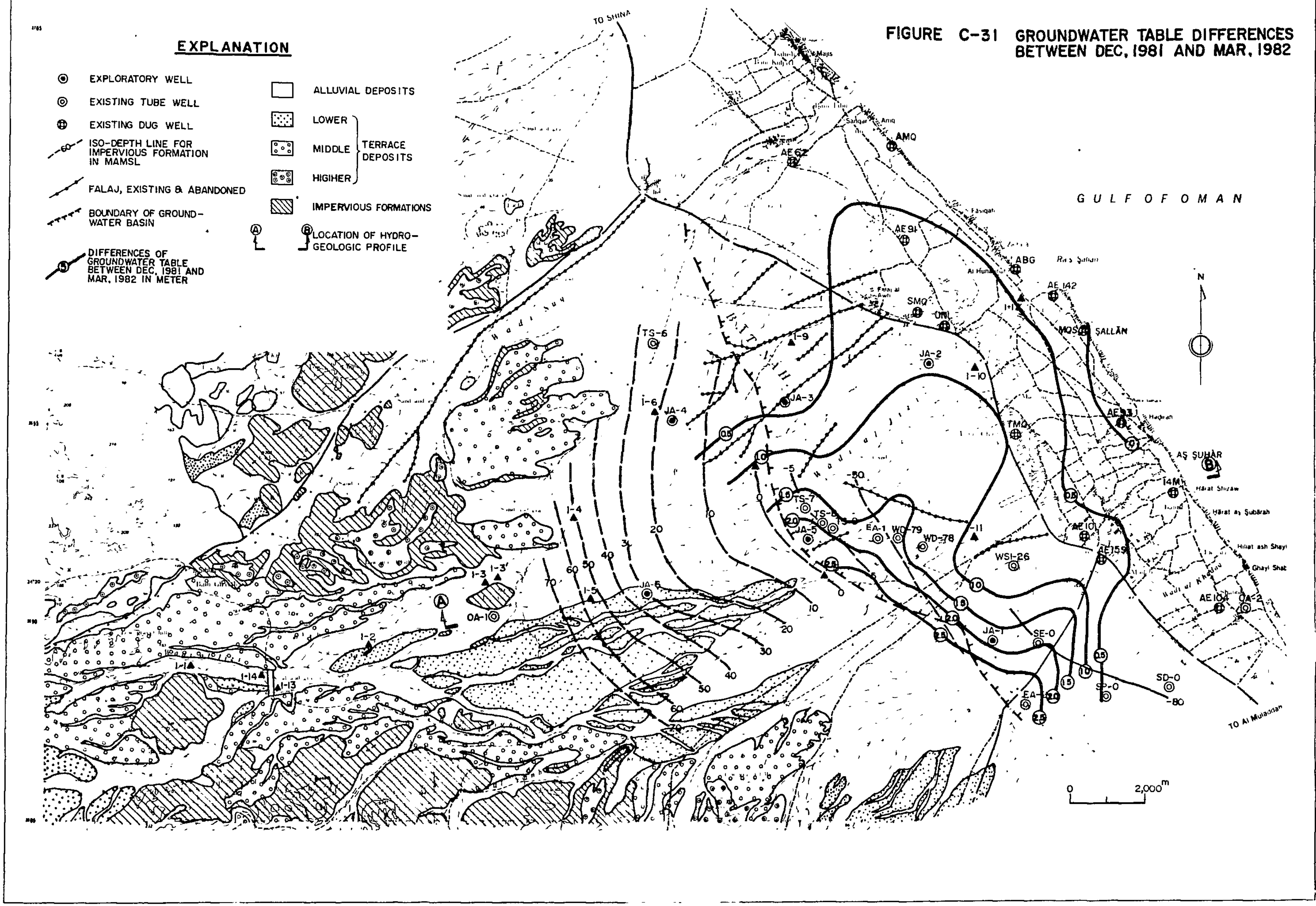


FIGURE C-31 GROUNDWATER TABLE DIFFERENCES BETWEEN DEC, 1981 AND MAR, 1982
EXPLANATION
EXPLORATORY WELL
EXISTING TUBE WELL
EXISTING DUG WELL
ISO-DEPTH LINE FOR IMPERVIOUS FORMATION IN MAMSL
FALAJ, EXISTING & ABANDONED
BOUNDARY OF GROUND-WATER BASIN
DIFFERENCES OF GROUNDWATER TABLE BETWEEN DEC, 1981 AND MAR, 1982 IN METER
ALLUVIAL DEPOSITS
LOWER
MIDDLE
HIGIHER
TERRACE DEPOSITS
IMPERVIOUS FORMATIONS
LOCATION OF HYDRO-GEOLOGIC PROFILE
TO SHINA
GULF OF OMAN
AŞ ŞUHĀR
ŞALLĀN
TO Al Muladdah
N
0
2,000m

- ° Groundwater flow lines make almost right angle with a coastal line which extends from the mouth of Wadi Sallan to town of Sohar.

- ° Estimated northern end of the basin can be delineated by the line following JA-4, TS-6 and Majis.

- ° Zero mamsl groundwater contour line intrude to Amq and the south of Sohar city with 1 km width from the coast respectively.

- ° Groundwater table trench extending from Sohar city to WSI-26 and JA-1 are intensified in the wet month showing conspicuous boundary to the Wadi Hilti groundwater basin. Location of groundwater table trench is corresponding to the trench of Iso-EC lines.

Groundwater flow in wet month (March 20, 1982)

- ° General flow patterns of groundwater are same as flows at drought month except hydraulic gradient of 1:1500.

- ° Groundwater table at the west end of the basin is one meter higher than in drought month.

- ° Pumping at TS-wells of Copper Mining effects groundwater table depression to 6 km distance towards the coast.

- ° Groundwater table trench is formed along the wells of WSI-26 and JA-1, which is caused by differential flows raised by the Wadi Jizzi and Wadi Hilti groundwater flows.

3.2 Recharge and Runoff

The groundwater basin in the coastal plain is extending down-stream of the Wadi Jizzi and Wadi Hilti with 8 km width, 20 km length and more than 100 m depth. Northern part of the basin is formed by the Wadi Jizzi groundwater sub-basin which extend from Amq to the

Wadi Khadaq with 13 km length.

Estimated groundwater flow in the basin based on groundwater table contours and EC lines is summarized as follows:

° The main groundwater flow take course corresponding to the course of the Wadi Jizzi.

° A minor groundwater branch is flowing to the direction of Amq.

° The main flow is extending to the Wadi Khadaq where the Wadi Hilti groundwater flow is encountered.

Quantity of groundwater storage in the basin is estimated by following assumptions.

Storage for the basin = 8km x 20km x 80m x 0.05 (Storativity)
= 640 MCM

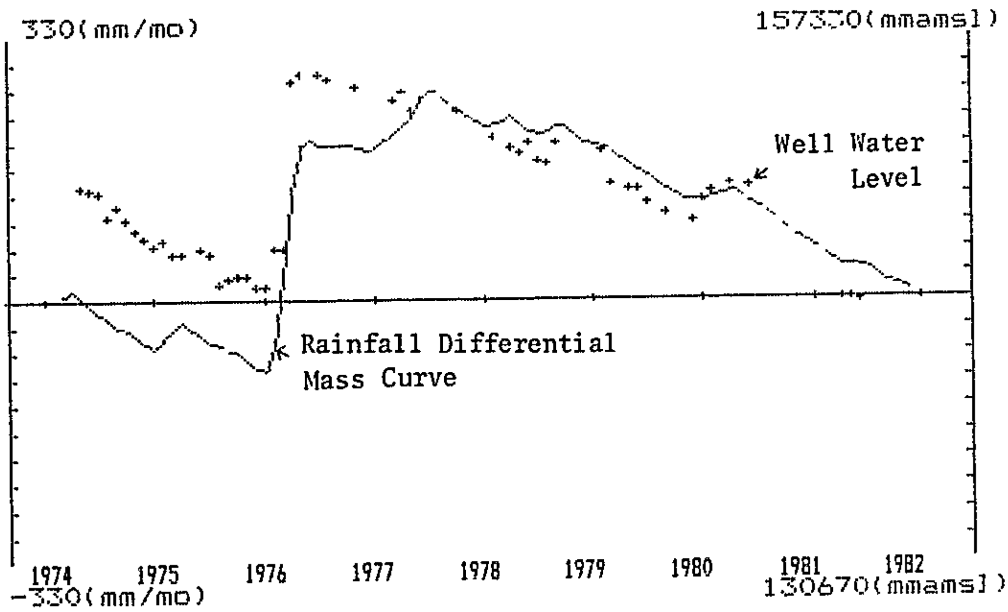
Storage for Wadi Jizzi sub-basin
= 8km x 13km x 80m x 0.05
= 416 MCM

Groundwater recharge is basically attained by rainfall. Relationship between rainfall and groundwater levels is plotted in Figure C-32 and C-33. Rainfall curves in figures are derived from cumulating three months moving average.

Source of groundwater at the gravel plain is depended upon groundwater inflow from the catchment. Groundwater inflow is composed of perennial under flow or base flow and inflow caused by flood. Surface water measurement by current-meter has been carried out since 1977 at Mulayyinah with a catchment of 654 sq.km. Observed base flow discharge is 67.2 lit/sec in an average, which corresponds to 0.10 lit/sec/sq.km. Single flood discharge ratio at Mulayyinah is varying depend on rainfall intensity.

FIGURE C - 32 RAINFALL-WELL WATER LEVELS RELATIONSHIP IN EA-49

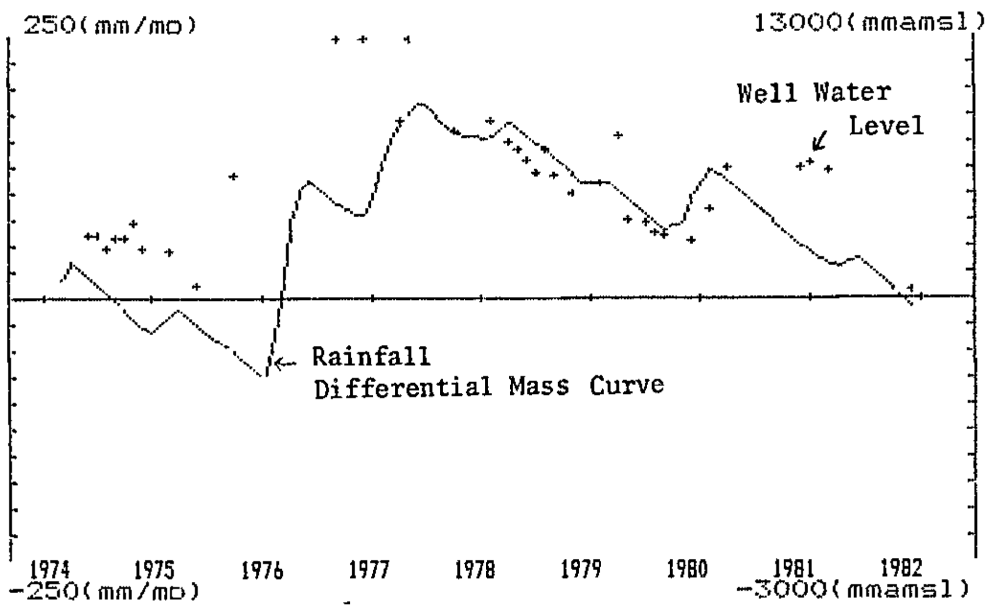
WELL NAME	EA-49
MOVING AVERAGE FOR RAIN IN MONTH	3
FULL SCALE FOR RAIN	330
SCALE AMPLITUDE FOR RAIN	0.3
FULL SCALE FOR WATER LEVEL	13330
SCALE AMPLITUDE FOR WATER LEVEL	.75E-02
WATER LEVEL mmamsl AT BASE LINE	144000
LOSS OF RAIN	0
INFILTRATION RATE	1
SELECT(SOHAR=1,E-SITE=2)	2
AVERAGE OF RAIN	10.7



Rainfall -

FIGURE C - 33 RAINFALL-WELL WATER LEVELS RELATIONSHIP IN EA-1

WELL NAME	EA-1
MOVING AVERAGE FOR RAIN IN MONTH	3
FULL SCALE FOR RAIN	250
SCALE AMPLITUDE FOR RAIN	0.4
FULL SCALE FOR WATER LEVEL	8000
SCALE AMPLITUDE FOR WATER LEVEL	0.0125
WATER LEVEL mmamsl AT BASE LINE	5000
LOSS OF RAIN	0
INFILTRATION RATE	1
SELECT(SOHAR=1.E-SITE=2)	1
AVERAGE OF RAIN	7.9



As mentioned in Appendix B, ratio ranges from 16% at 83 mm rainfall to 7.4% at 33.2 mm. Recharge rate of flood to the groundwater is analyzed based on the flood at February 14, 1982. (Table C-8) As is shown in table, rate of recharge is estimated 76% in an average though it varies according to rainfall intensity.

Water balance studies to determine the groundwater runoff is made on the coastal plain applying well hydrographs of EA-1, AE-104, AE-142 and DA-2.

Commanding areas for the wells of EA-1 and the rest wells are 56.6 an 317 sq.km respectively.

Applied groundwater balance equation is as follows:

$$P = (Ro - Ri) + E + (Go - Gi) \pm dH$$

Where;

P : Rainfall at plain
Ro : Surface outflow
Ri : Surface inflow
E : Evapotranspiration
Go : Groundwater outflow
Gi : Groundwater inflow
dH : Change groundwater storage

The values and ratios of parameters applied to the calculation of the water balance are explained as follows:

Rain (P) :

Observed rainfall at Sohar from 1974 to 1981.

Surface outflow (Ro) :

It is comprising flood runoff (FO) from the catchment and surface runoff (SG) caused by direct rainfall. A calculation of flood

Table C - 8 Calculation for Recharge Rate Based on Hydrological Analysis

Areal Rainfall at Mulayynah in mm (Pm)	83.0	66.4	49.8	33.2	16.0
Areal Rainfall at River mouth in mm (Ps)	88.4	70.7	53.0	35.4	17.7
Analized Discharge at Mulayynah in MCM (Dm)	8.777	5.789	3.394	1.615	0.392
Run-off Coefficient at Mulayynah in percent (C)	16.2	13.3	10.4	7.4	3.6
Expected Discharge at outlet to plain in MCM (DE = 893 km^2 x Pm x C)	12.007	7.886	4.625	2.194	0.514
Expected Discharge at River mouth in MCM (DS_1 = 1,283 x Ps x C)	18.374	12.064	7.072	3.361	0.818
Analized Actual Discharge at River mouth in MCM (DS_2)	3.85	2.94	2.04	1.13	0.23
Infiltration at plain in MCM $Rp = (Ds_1 - DE) - Ds_2$	2.517	1.238	0.407	0.037	0.074
Recharge from catchment in MCM $Ru = Ds_1 - Ds_2 - Rp$	12.017	7.886	4.625	2.194	0.514
Total Recharge at plain in MCM $Rt = Rp + Ru$	14.534	9.124	5.032	2.231	0.588
Recharge Rate in percent $Cr = Rt / Ds_1 \times 100$	79	76	71	66	72

runoff (RI) at the catchment is conducted based on the relationship curve of rainfall and specific discharge at dam site which was analyzed by the multiple regression method. (refer to Appendix B-1, Figure B-5) As a matter of convenience, the relationship curve can be separated into two straight lines. Formulas for calculation of flood runoff (RI) applying said straight lines are as follows:

$RI = (F - 29) \times 0.26 \times AR \qquad F \geq 50$

$RI = (F - 8) \times 0.19 \times AR \qquad F < 50$

$AR = A1/A2$

Where;

F : Sequential areal rainfall over 13 mm which probably bring flood.

A1: Area of catchment (893 sq.km)

A2: Commanding are of respective wells at the plain.

Well EA-1	(56.6 sq.km)
AE-104, 142 and OA-2	(317.0 sq.km)

Flood runoff into the plain (FO) can be obtained the subtraction recharge caused by flood (RF) from flood runoff at the catchment (RI).

$FO = RI - RF$

$RF = RI \times PR$

Where;

PR: Recharge ratio of flood at the plain. The ratio are estimated applying previous flood records. (see Table C-8) As is shown in table, average ratio is estimated 76% to flood runoff. It is applied to the calculation.

Surface runoff caused by direct rainfall at the plain (SG) is also applied by relationship of rainfall and specific discharge at river mouth which analyzed by multiple regression methods. (refer to Appendix B-1, Figure B-4)

Applied formula for calculation of surface runoff based on above relationship curve is as follows;

$$SG = (P - 13) \times 0.04$$

In the calculation for the coastal plain,

$$SG = (P - 13) \times 0.04/PR$$ can be applied.

Surface inflow (Ri) :

Surface inflow to the well EA-1 is equivalent to flood runoff (FO). And surface runoff (SG) caused by direct rainfall shall be added to (FO) for the coastal wells.

Groundwater outflow (Go) :

Groundwater outflow can be calculated by the balance equation. It is difficult to discriminate consumptive use and net groundwater runoff to the sea. Estimation for consumptive use of groundwater is attempted by applying analyzed essential groundwater runoff to the sea. In contrast with the coastal wells, groundwater outflow for the well EA-1 can be calculated by the equation:

$$Go = P - (Ro - Ri) + Gi - E \pm dH$$

Groundwater inflow (Gi) :

Baseflow runoff (RB) and recharged flood (RF) are counted into groundwater inflow (Gi) for the well of EA-1. Recharge caused by direct rain (RG) shall be added to RB and RF for the rest coastal wells. Following formulas and values are applied for calculation of baseflow runoff (RB) and recharge (RG).

$$RB = (ES \times R2) - RZ$$
$$R2 = AR \times DR$$

$$RG = (SG \times PR) - LO$$
$$LO = D \times EV$$

Where;

ES: Areal rainfall for the catchment calculated by observed rainfall records of Hayl Wadi Hayl, Kitnah, Hayl Wadi Jizzi, Daqiq and Farfar stations.

DR: Discharge ratio for baseflow at the catchment. The ratio is calculated by observed records of surface discharge at Mulayyinah where impervious rocks are exposed at the surface. Observed average specific baseflow discharge per annum is 6.9 mm in depth. The total potential baseflow discharge is estimated at 0.22 lit/sec/sq.km. (refer to Appendix B-1) Consequently, ratio of baseflow discharge to annual rainfall is applied 5.7% for the calculation.

RZ: Water use by the villages in the catchment. Water use is in the catchment is estimated 0.12 lit/sec/sq.km as equivalent as falaj discharge. (refer to 3.3.1 Surface Water) The ratio of water use at the catchment to annual rainfall is applied 2.0% for the calculation in consequence of the above estimation.

LO: Loss probably caused by soil detention. If rainfall (P) is smaller than calculated loss (LO), rainfall can be put into loss.

D : Sequential rain days among five stations.

EV: Potential evapotranspiration calculated by the modified Penman and modified Blaney-Cridle methods. (refer to Appendix G-2)

For the coastal wells, "Go" from the well EA-1 can be put into "Gi" for the coastal wells of AE-104, 142 and OA-2.

Evapotranspiration (E) :

Evapotranspiration comprises evaporation and loss. If rain is equal or smaller than loss rain (= 13 mm), rain is put into evaporation. If rain is exceeded loss rain, evaporation is calculated by following formula:

Evaporation = Rain(P)-(Surface runoff(SG)+Recharge(RG)+Loss(LO)

Change groundwater storage (dH) :

Change of storage can be calculated by change of groundwater table multiply storativity. Applied storativity 0.05 is analyzed by aquifer tests at Sohar Expansion Farm.

Calculated monthly water balance for each well is shown in Table C-9 to C-12.

Results summarized in an average of seven hydrological years from 1974 to 1981, are shown in Table C-13.

As is shown in the table, groundwater inflow to the gravel plain is calculated 17.6 MCM/annum comprising 6.7 MCM from baseflow and 10.9 MCM from flood. In comparison with groundwater inflow, groundwater outflow at the coastal plain is calculated 17.5 MCM including a part of consumptive use at the plain.

Groundwater recharge at the plain caused by direct rainfall does not counted by means of calculation.

Minimum essential groundwater runoff to the sea is estimated at 8.0 MCM/annum as is mentioned in the latter part. Calculated groundwater runoff must be shared to essential groundwater in proportion to water tables. Minimum runoff of 8.0 MCM can be shared to the sea because average water tables through calculated years is observed almost zero meter above mean sea level.

Consumptive use by crops in the project area is estimated at 21.1 MCM/annum. (refer to Appendix G-1) Calculated losses at the coastal plain comprising mostly soil detention, can be shared consumptive use with groundwater extraction as far as losses plays effective rainfall

Table C-9 Calculation for Water Balance, Well EA-1 (56.6 km^2)

(Unit : mm)

Year	Rain (P)	Surface inflow (Fo)	Ground water inflow Baseflow (Gib)	Ground water inflow Flood (Gif)	Recharge direct rain (Rg)	Evapo-transpiration (Et)	Surface outflow (Fo+Sg)	Change G.W storage (ds)	Ground water runoff (Go)
1974/75	49.3	29.6	75.0	93.5	0	47.6	31.3	-75	243.5
75/76	233.8	254.5	260.0	805.7	0	224.1	264.2	500	565.7
76/77	172.1	89.6	209.0	283.4	0.2	166.7	94.8	180	312.6
77/78	60.5	21.7	101.9	68.5	0	59.4	23.0	-490	660.2
78/79	29.1	7.3	72.5	23.0	0	28.7	7.7	-100	195.5
79/80	104.7	15.2	69.0	48.1	0	101.1	18.8	90	27.1
80/81	37.9	6.8	37.4	21.4	0.2	37.4	7.1	-70	129.0
Average	98.2	60.7	117.8	191.9	0	95.0	63.8	5	304.8

Table C-10 Calculation for Water Balance, Well AE-104 (317 km^2)

(Unit : mm)

Year	Rain (P)	Surface inflow (Fo)	Ground water inflow (Gi)	Recharge direct rain (Rg)	Evapotranspiration Total (Et)	Evapotranspiration Loss (Lo)	Surface outflow (Fo+Sg)	Change G.W. storage (ds)	Ground water runoff (Go)
1974/75	49.3	5.6	44.2	0	47.6	13.8	7.3	-7.5	51.7
75/76	233.8	47.2	101.5	0	224.1	129.4	56.9	25.5	76.0
76/77	172.1	16.9	56.4	0.2	166.7	68.6	22.1	-6.5	63.1
77/78	60.5	4.1	118.5	0	59.4	25.9	5.4	-3.0	121.3
78/79	29.1	1.4	35.5	0	28.7	3.0	1.8	-8.0	43.5
79/80	104.7	3.3	5.5	0	101.1	58.8	6.9	35.5	-30.0
80/81	37.9	1.3	23.7	0.2	37.4	12.6	1.6	-46.0	69.9
Average	98.2	11.4	55.0	0	95.0	44.6	14.6	-1.4	56.5

Table C-11 Calculation for Water Balance, Well AE-142 (317 km^2)

(Unit : mm)

Year	Rain (P)	Surface inflow (Fo)	Ground water inflow (Gi)	Recharge direct rain (Rg)	Evapotranspiration Total (Et)	Evapotranspiration Loss (Lo)	Surface outflow (Fo+Sg)	Change G.W. storage (ds)	Ground water runoff (Go)
1974/75	49.3	5.6	44.2	0	47.6	13.8	7.3	4.5	39.7
75/76	233.8	47.2	101.5	0	224.1	129.4	56.9	22.3	79.2
76/77	172.1	16.9	56.4	0.2	166.7	68.6	22.1	-5.5	62.1
77/78	60.5	4.1	118.5	0	59.4	25.9	5.4	-5.0	123.3
78/79	29.1	1.4	35.5	0	28.7	3.0	1.8	2.0	33.5
79/80	104.7	3.3	5.5	0	101.1	58.8	6.9	52.0	-46.5
80/81	37.9	1.3	23.7	0.2	37.4	12.6	1.6	-61.0	84.9
Average	98.2	11.4	55.0	0	95.0	44.6	14.6	+1.3	53.7

Table C-12 Calculation for Water Balance, Well OA-2 (317 km^2)

(Unit : mm)

Year	Rain (P)	Surface inflow (Fo)	Ground water inflow (Gi)	Recharge direct rain (Rg)	Evapotranspiration Total (Et)	Evapotranspiration Loss (Lo)	Surface outflow (Fo+Sg)	Change G.W. storage (ds)	Ground water runoff (Go)
1974/75	49.3	5.6	44.2	0	47.6	13.8	7.3	-3.0	47.2
75/76	233.8	47.2	101.5	0	224.1	129.4	56.9	-1.5	103.0
76/77	172.1	16.9	56.4	0.2	166.7	68.6	22.1	11.0	45.6
77/78	60.5	4.1	118.5	0	59.4	25.9	5.4	-9.5	127.8
78/79	29.1	1.4	35.5	0	28.7	3.0	1.8	22.0	13.5
79/80	104.7	3.3	5.5	0	101.1	58.8	6.9	-16.0	21.5
80/81	37.9	1.3	23.7	0.2	37.4	12.6	1.6	-6.5	30.4
Average	98.2	11.4	55.0	0	95.0	44.6	14.6	-0.5	55.6

Table C-13 Data Summary for Water Balance on Plain (1974-1981)

(Unit: MCM/ann.)

Name of Well	EA-1	AE-104	AE-142	DA-2	Average
Catchment					
Area (sq.km)		893			
Areal Rainfall (mm)		130			
Input		116			
Discharge					
Baseflow		9.2			
Flood		14.3			
Total		23.5			
Plain					
Area (sq.km)	56.6	317			
Rainfall (mm)		98			
Input	5.6	31.1			
Recharge					
Baseflow	6.7				
Flood	10.9				
Total	17.6	17.4	17.4	17.4	17.4
Surface Inflow					
Total	3.4	3.6	3.6	3.6	3.6
Surface Outflow					
Flood	3.4	3.6	3.6	3.6	3.6
Rain	0.2	1.0	1.0	1.0	1.0
Total	3.6	4.6	4.6	4.6	4.6
Evapotranspiration					
Evaporation		16.0	16.0	16.0	16.0
Losses		14.1	14.1	14.1	14.1
Total	5.4	30.1	30.1	30.1	30.1
Change Grounwater	+0.3	-0.5	+0.4	-0.2	-0.1
Groundwater Runoff	17.3	17.9	17.0	17.6	17.5
Consumptive Use					
Groundwater		10.4	8.6	9.8	9.6
Rain (Loss)	-	10.7	12.5	11.3	11.5
Total		21.1	21.1	21.1	21.1
Essential G.W. Flow		8.0	8.0	8.0	8.0
Coastal G.W. Balance		-0.5	+0.4	-0.2	-0.1

for the crops. Consequently required groundwater extraction for consumptive use is obtained the balance of calculated groundwater runoff (Go) and essential groundwater runoff plus change of groundwater storage.

Total surface runoff on the coastal plain is calculated at 4.6 MCM/annum, however most of it especially caused by direct rain would not join to the wadi courses in view of the topographic condition. Only the surface runoff which caused by flood at the catchment can be counted as the loss to the sea.

Consequently, the loss to the sea is estimated by 3.6 MCM/annum in contrast with 2.5 MCM analyzed by hydrological manners.

In reference to this calculation, results of previous studies of the water balance calculation on the Wadi Jizzi basin which have been conducted since 1978, are summarized in Table C-14.

3.3 Groundwater Balance at the Coastal Plain

a) Groundwater Balance

Groundwater balance at the plain can be estimated by the use of time series records of well water levels, and the results are shown schematically in Figure C-34. Changes of groundwater level at a certain period are resulted from difference of quantity between groundwater recharge and groundwater runoff. As is described previously average changes of groundwater levels at the coast from 1974 to 1981 are calculated 12 mm in defect and it is equivalent to 0.1 MCM in defect.

Groundwater defect at the coast seems small in comparison with total quantity of storage, however groundwater levels should be kept at least one meter above mean sea level to prevent sea water intrusion into the aquifers. Permissive drawdown at the coastal plain based on the concept of sea water intrusion, seems small because average water levels for the last eight years for wells of AE-104, AE-142 and OA-2 are 1.1, 1.1 and 1.5 mamsl respectively. (Figure C-35)

Table C-14 Data Summary Water Balance for Wadi Jizzi by Previous Studies

(Unit: MCM/ann.)

Item		FAO[1/] (1979)	Ministry of[2/] Communication (1978)	Ministry of[3/] Electricity & Water (1980)	JICA (1982)
1) Rainfall					
Annual Rainfall	(RF)(mm)	230	156	160	130
Area (sq.km)		650	770	770	893
Total Input	(IT)	150	120	123	116
2) Catchment					
Gross Yield	(YG)	28.4	42.8	24.8	23.5
Consumptive	(CC)	4.7	8.3	2.8	2.5
Net Runoff	(DN)	25.3	34.5	22.0	21.0
Ratio Runoff	(DN/IT)(%)	17	29	18	18
Net Flood Runoff	(DF)	17.8	24.5	13.5	14.3
Net Baseflow Runoff	(DB)	7.5	9.9	8.5	6.7
Ratio Flood	(DF/DN)(%)	70	71	61	68
Ratio Baseflow	(DB/DN)(%)	30	29	39	32
3) Groundwater Input					
Baseflow+Nonflood	(GB)	7.5	9.9	8.5	6.7
Recharge/Flood	(GF)	14.2	14.7	10.1	10.9
Recharge/Direct Rain	(GR)	0	0	0	0
Total Groundwater	(GT)	21.7	24.6	18.6	17.6
Ratio Recharge Flood	(GF/DF)(%)	80	60	75	76
Ratio Groundwater	(GT/IT)(%)	14	21	15	15
4) Coastal Water Balance					
Total Groundwater	(GT)	37.7[4/]	24.6	18.6	17.5
Consumptive Use	(CU)	34.1	22.1	9.6	9.6[5/]
Essential Flow	(GS)	4.0			8.0
Net Balance	(GB)	-0.4	+2.5	+9.0	-0.1
Flood Loss to Sea	(LF)	3.6	9.8	3.4	3.6
Ratio Loss	(LF/OF)(%)	20	40	15	17

Note: 1/ Water Resources of the Batinah.FAO Field Document No.10 1979.
2/ Water Supplies to Sohar, Water Resources Evaluation, Preliminary Report, 1978 Preece Cardew & Rider, Sir M. Macdonald & Partners, Rendel, Palmer & Tritton.
3/ Water Development Program, Town and Villages Vol.2 Hydrology, 1980 Preece Cardew & Rider, Sir M. Macdonald & Partners, Rendel, Palmer & Tritton.
4/ Including coastal Areas of Sug, Yanbu and Hilti.
5/ Total Consumptive is 21.1. 9.6 is only groundwater contribution to consumptive use.

FIGURE C - 34 SCHEMATIC FIGURE FOR WATER BALANCE AT COASTAL PLAIN

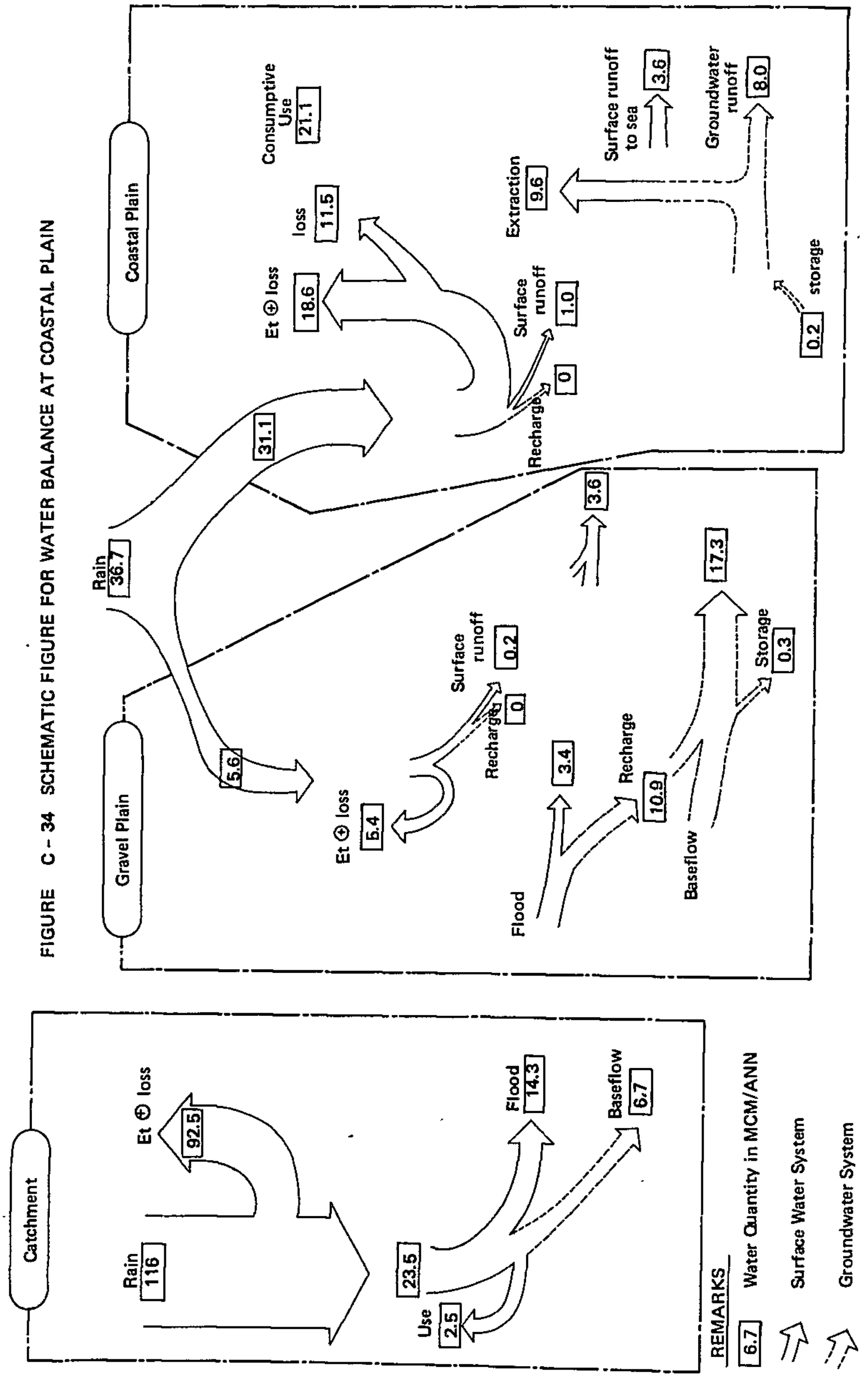
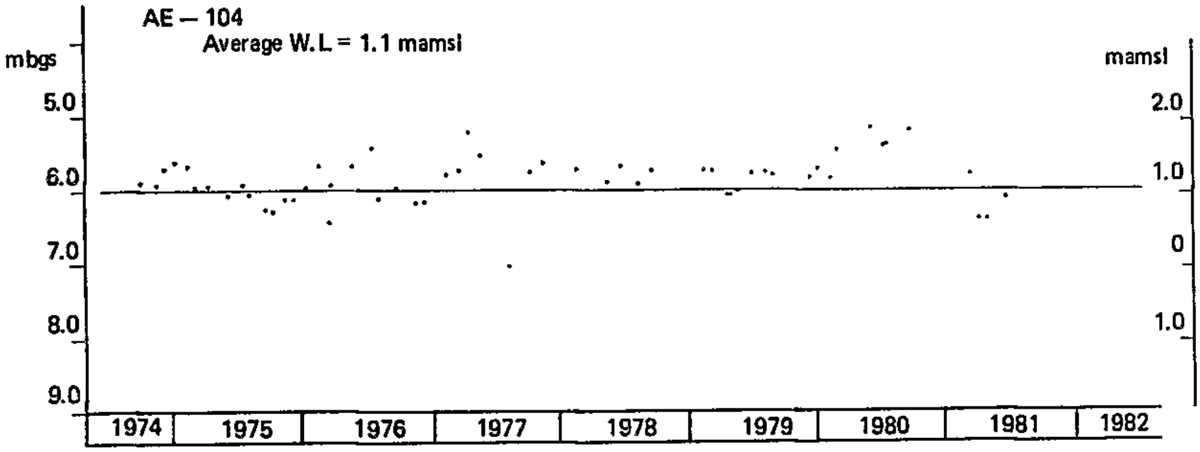
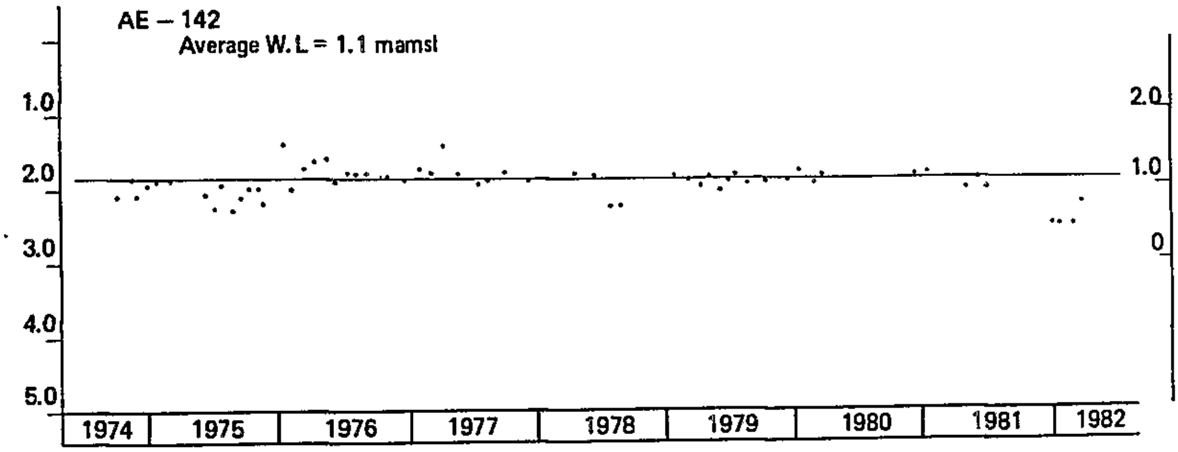
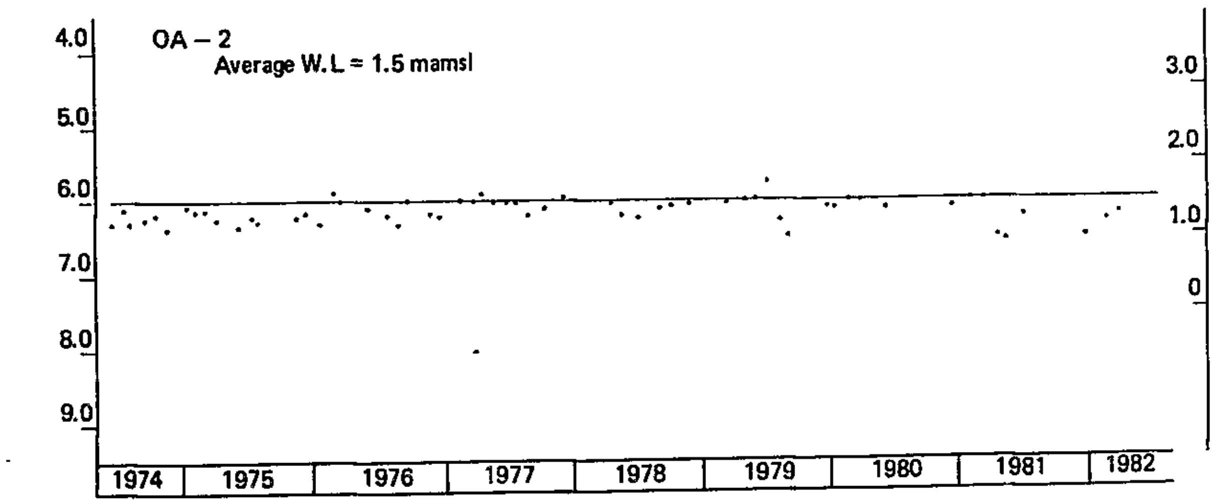


FIGURE C – 35 WELL WATER LEVELS AT COASTAL PLAIN







Minor defected change of groundwater level of 12 mm mentioned above should not assess underestimated.

Essential quantity of groundwater runoff to the sea should be assessed by means of hydrological ways. Following considerations are applied for estimation of it. Quantity of groundwater runoff when annual change of water levels shows zero mamsl is assumed minimum essential runoff, and quantity obtained by recession curve for coastal wells at dry month is also assumed minimum essential runoff. Estimated annual essential groundwater runoff by means of above manners are about 8.0 MCM in an average.

b) Sea Water Intrusion

Qualitative assessment of the coastal groundwater can be carried out by means of comparison of EC logging with of ILACO. (Figure C-22 to C-26)

As a results of the comparison with them, EC has not changed since 1974 at WSI-26, the west of national highway, representing almost stabilized conductivity with 600 - 700 micro mho/cm to the depth of 60 mbgs. EC logging at OA-2, which is located only 600 m far from the coast, detects interface between 900 micro mho/cm of surface layer and 5,500 of second layer at 24 mbgs (16 mbmsl), furthermore transgressional zone to the third layer of 50,000 micro mho/cm is detected at 42 mbgs (34 mbmsl). As is shown in Figure C-24, the former interface shifts to 5 m upwards compare with 1974, and third layer was detected 18,000 micro mho/cm instead of 50,000 at the same depth.

Depth to interface between fresh water (less than 1,000 EC) and brackish water shifts 5 m upwards during years from 1974 to 1982. It is estimated that groundwater level has been lowered about 13 cm since 1974, if Ghyben-Herzberg assumption is applied.

EC loggings at the wells of EA-1 and EA-2 on the gravel plain, which are located more than 7 km far from the coast shows almost stabilized conductivity up to 80 mbgs with 500 - 600 micro mho/cm. Change of EC with depth is summarized in Table C-15.

Ghyben-Herzberg assumption is expressed as follows:

$$Z \doteqdot 40\ h$$

Where densities of fresh and salt water are 1.000 and 1.025.

Z : Depth to interface between fresh and salt water from mean sea level

h : Height to fresh water table from mean sea level.

It can be assumed that shifting of interface was caused by lowering of groundwater table in accordance with above assumption, however water table at 1982 was 20 cm lower than 1974 in spite of 13 cm. So that increasement of EC is considered more serious than shifting of interface.

c) Groundwater Flow in View of Iso-EC Contour Lines

Distribution of EC at surface layer of groundwater along the Wadi Jizzi river courses and their idealized section are drawn in Figure C-36 and C-37.

Iso-EC map is drawn by based on the data at the end of March, 1982 after the big flood dated February 14, 1982.

As easily visualized from the figure, Iso-EC contour lines are consistent with groundwater table contour lines, and groundwater with 470 micro mho/cm/25 C at the upper stream of Wadi flows downwards solving saline materials. Also it is clear that areas where moderate EC increasement is consistent with areas where excellent groundwater potentials.

Table C - 15 Change of EC During 1974 - 1982 At OA-2

	Feb. 74		Mar. 82		Differences	
	Depth (mbmsl)	EC (µm/cm)	Depth (mbmsl)	EC (µm/cm)	Top of Layer (m)	EC (µm/cm)
1st Layer	- 21	880	- 16	900		+ 180
Transitional Layer	21 - 26	880 - 3,300	16 - 28	900 - 5,500	up + 6	
2nd Layer	26 - 34	3,500	28 - 34	5,500	up + 2	+ 2,000
Transitional Layer	34 - 55	3,500 - 17,000	34 - 55	5,500 - 32,000	down - 1	
3rd Layer	55 - 141+	18,000	55	50,000+	± 0	+ 32,000

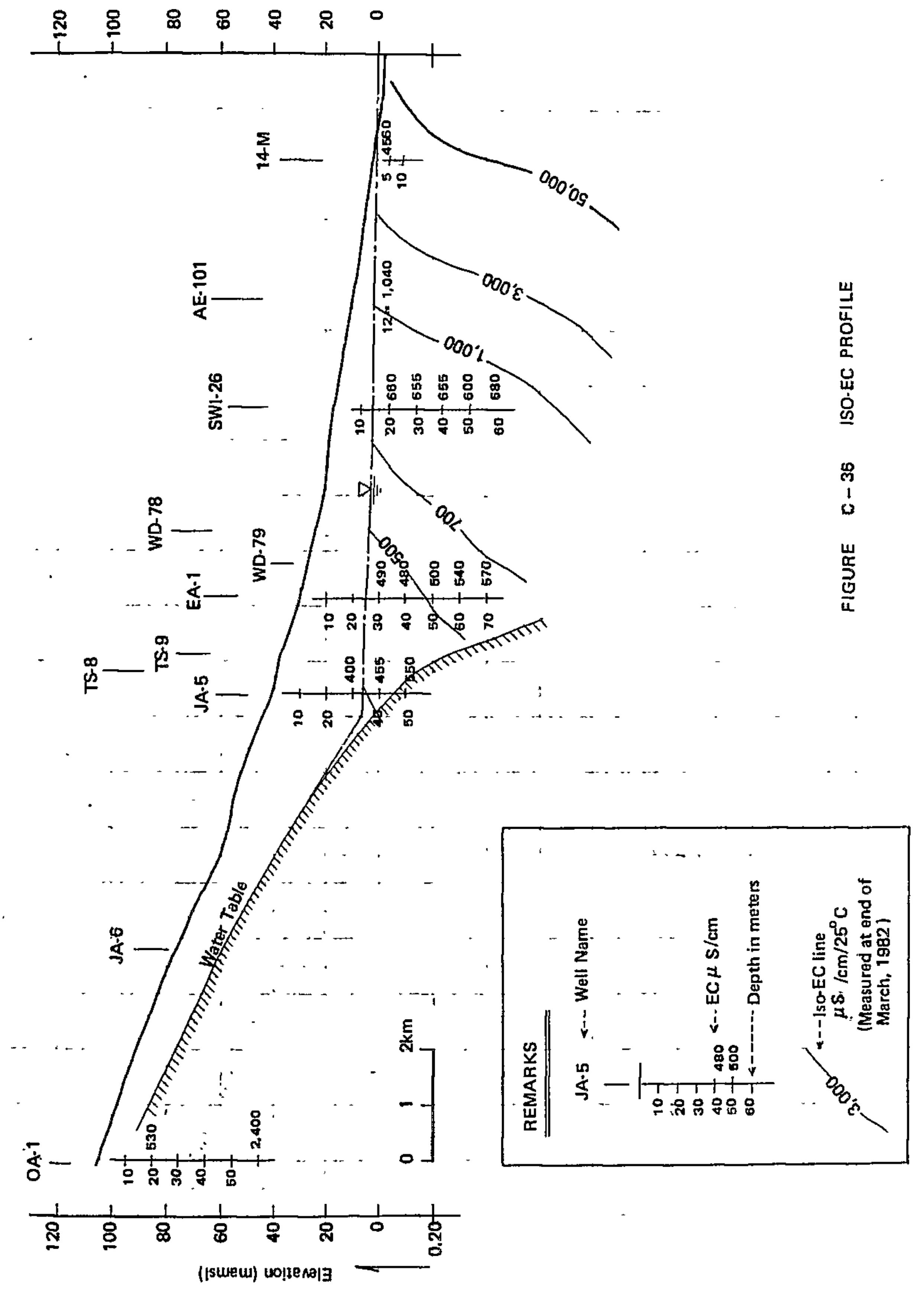


FIGURE C – 36 ISO-EC PROFILE

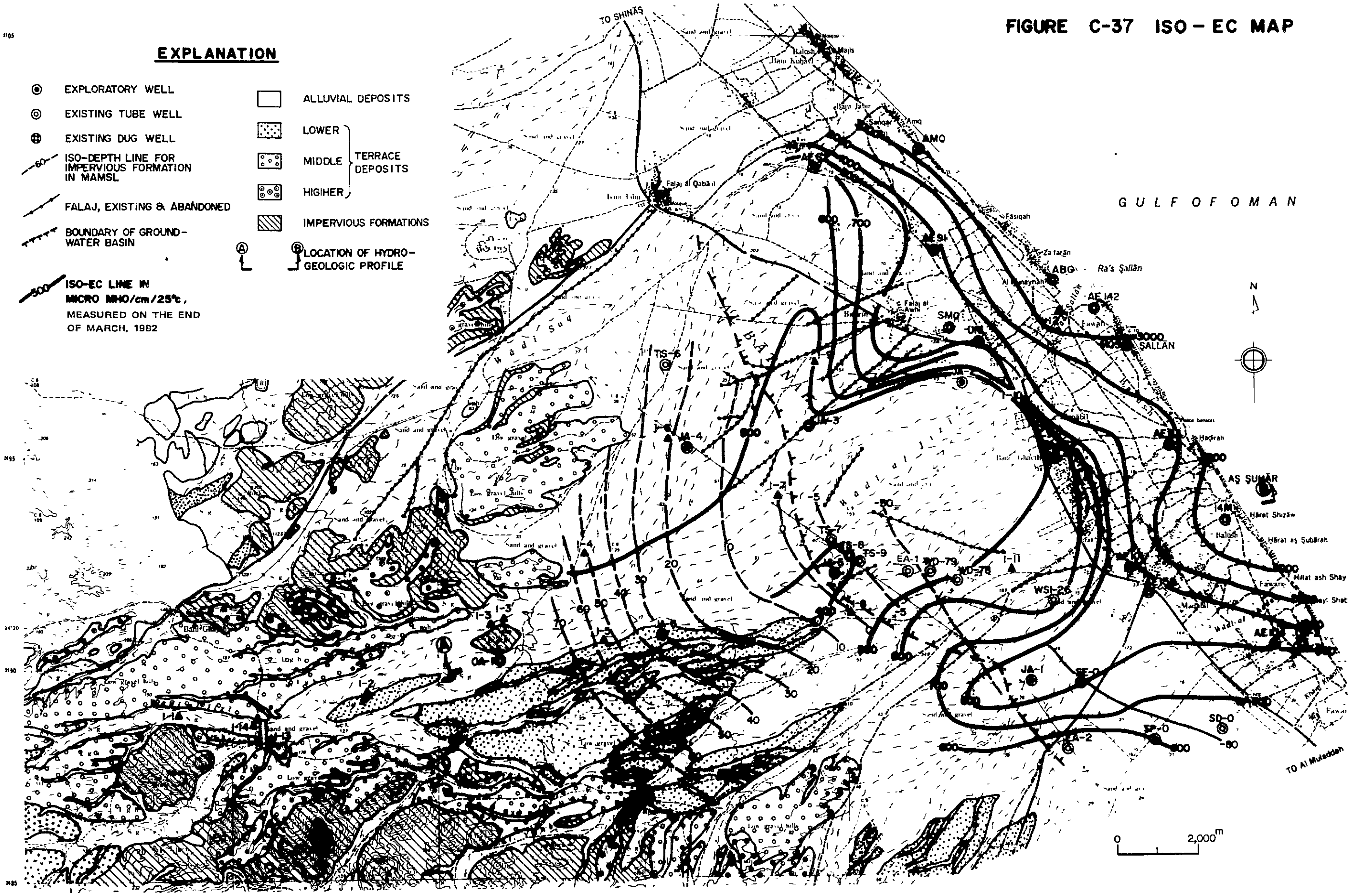


FIGURE C-37 ISO - EC MAP
EXPLANATION
EXPLORATORY WELL
EXISTING TUBE WELL
EXISTING DUG WELL
ISO-DEPTH LINE FOR IMPERVIOUS FORMATION IN MAMSL
FALAJ, EXISTING & ABANDONED
BOUNDARY OF GROUND-WATER BASIN
ISO-EC LINE IN MICRO MHO/cm/25°c, MEASURED ON THE END OF MARCH, 1982
ALLUVIAL DEPOSITS
LOWER
MIDDLE
HIGIHER
TERRACE DEPOSITS
IMPERVIOUS FORMATIONS
LOCATION OF HYDRO-GEOLOGIC PROFILE
GULF OF OMAN
TO SHINAS
TO Al Muladdah
SALLAN
AS SUMAR
AMQ
SMQ
Ra's Sallan
N
0
2,000m

3.4 Chemical Quality of Groundwater

Result of chemical analysis of groundwater for the basin are shown in Table C-3 and C-16.

Results are plotted on the key diagram of hydrochemistry. As is shown in Figure C-38, cations for all JA-Wells are plotted on Calcium-Sodium field, however plotted anions are spread to Chloride-Sulfate-Bicarbonate field for JA-1 and JA-3 and to Bicarbonate-Chloride-Sulfate field for JA-2, JA-4 and JA-5. In general, groundwater plotted on Chloride-Sulfate-Bicarbonate field have a hydrochemical signs of contamination with sea water or of fossil water. In case of JA-1, sign of contamination with sea water at the deeper part of aquifers may be considered.

Furthermore, chemical qualities of the production wells for Sohar Expansion Farm are also summarized as follows:

° Cation of No.2 plotted on Sodium-Calcium field, however the rest wells of it is on Calcium-Sodium field.

° Anion of whole wells plotted on Chloride-Sodium-Bicarbonate field, and

° Only the well of No.2 has a sign of contamination with sea water.

Table C - 16 Chemical Analysis for Production Wells at Sohal Expansion Farm

Well No. Date	EC μv/cm 125°C	Constituent in Mel. and Mg/1. Ca^{++}		Mg^{++}		Na^{++}		K^{+}		CO_3^{--}		HCO_3^{-}		SO_4^{--}		Cl^{-}	
		mel	mg/1	mel	mg/1	mel	mg/1	mel	mg/1	mel	mg/1	mel	mg/1	mel	mg/1	mel	mg/1
Production Well No.1 Mar.3, '78	731	1.15	23.0	3.55	43.1	3.06	70.4	0.06	2.34	-	-	3.80	231.8	1.51	72.5	2.50	88.8
	731	1.15	23.0	3.55	43.1	3.06	70.4	0.06	2.34	-	-	3.80	231.8	1.51	72.5	2.50	88.8
Production Well No.2 Feb.28, '78	925																
	1150	1,30	26.0	2.80	34.0	7.10	163.3	0.09	3.51	-	-	3.70	225.7	2.20	105.6	5.40	191.7
Production Well No.3 Mar.7, '78	472																
	685	0.95	19.0	3.45	41.9	2.78	63.9	0.06	2.34	-	-	3.10	189.1	1.10	52.8	2.80	99.4
Production Well No.4 Mar.23, '78	745	1.20	24.0	3.60	43.7	2.80	64.4	0.05	1.95	0.20	6.00	3.60	219.6	1.16	55.7	2.85	101.2
	736	1.20	24.0	3.55	43.1	2.80	64.4	0.05	1.95	0.40	12.00	3.40	207.4	1.16	55.7	2.85	101.2

(After IRI 1978)

Remarks : Well No.1, No.2 and No.3 are expected to be used for production wells in the project.

Source : IRI 1978

FIGURE C-38 — WATER ANALYSIS DIAGRAM FOR EXPLORATORY WELLS