CHAPTER 3 WELL HYDROGRAPH

Since 1976 DGWRI of MAF has been conducting groundwater level monitoring through the bore holes of approximately 60 in the Batihah Coast. The data have been filed both for monthly mannual measurements and automatic recordings.

In addition to these data, the present project has contributed its own observation of 1984. These data have been compiled and presented as 9-year hydrographs.

When these hydrographs are reviewed, one can recognize relatively long periods of apparent unreliable measurements.

The quality of measurement has been improved considerably in later part of the hydrographs, i.e. 1983 and 1984, due to the guidance of the present project team.

Unfortunately well hydrographs in the northern project area are not available. However, one can notice two particular tendencies in the fluctuation of groundwater level. In the mid-plain groundwater level changes with large amplitudes which sometimes exceed 10m in a period of three to six month. The crest of the variation seems to appear once in seven to ten years. In the coastal strip groundwater fluctuation is quite smalll and majority of the coastal wells shows steady decrease of the water level.

Supporting Report C

Fig. C-3-1

OBSERVATION WELL HYDROGRAPH

(1976 - 1984)

1. Basin 1 ---------- Wadi Ahin
2. Basin 2 ---- Wadi Bani Ghafir
3. Basin 3 ------- Wadi Al-Fara'
4. Basin 4 ---- Wadi Bani Kharus
5. Basin 5 ----- Wadi Al-Ma'awil

1. Basin 1 ---------- Wadi Ahin

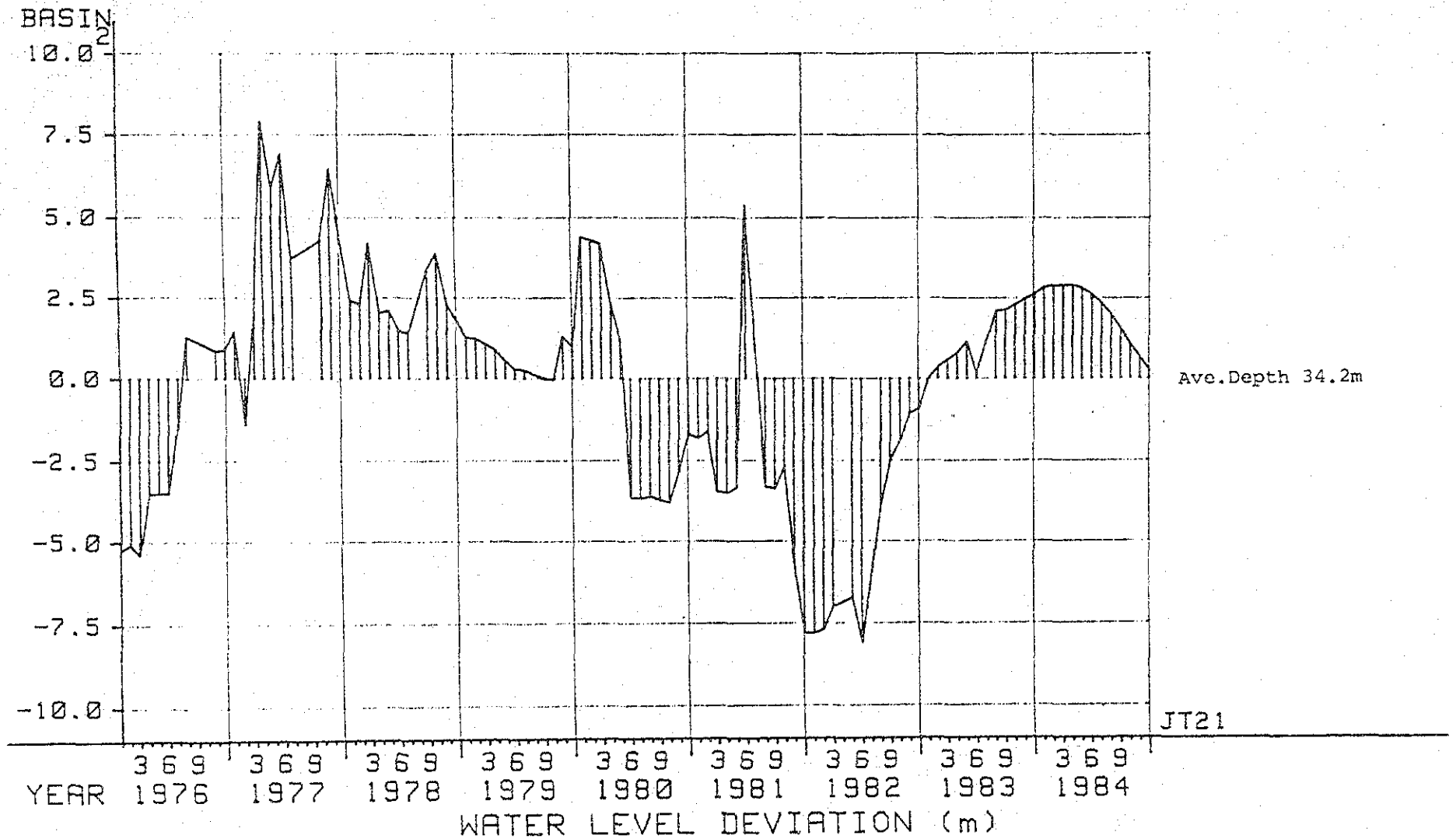
Well Hydrograph Not Available.

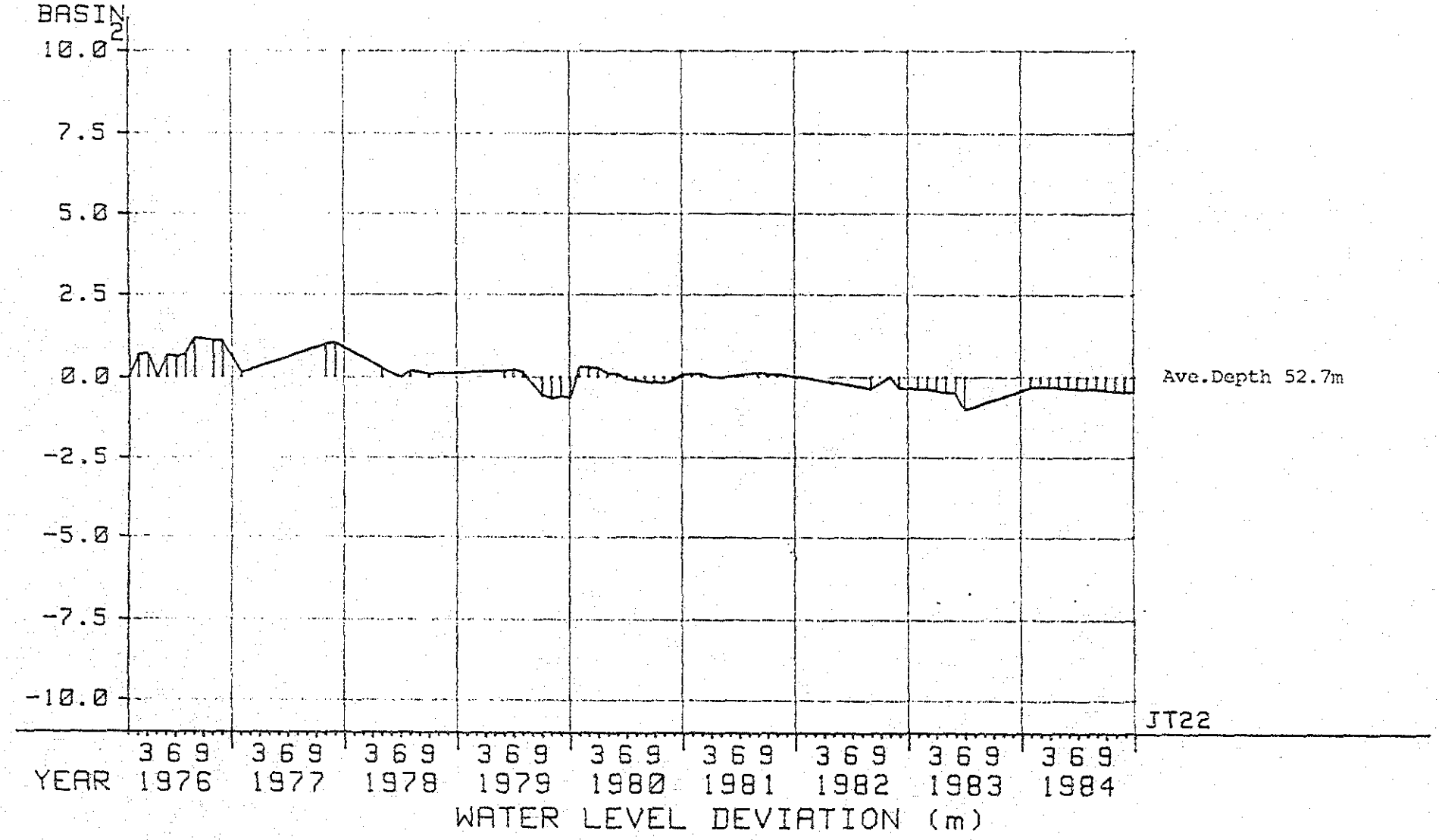
2. Basin 2 ---- Wadi Bani Ghafir

Well Hydrograph of: JT21

JT22

ADG26


BASIN 2
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 34.2m
JT21
3 6 9
YEAR 1976
3 6 9
1977
3 6 9
1978
3 6 9
1979
3 6 9
1980
3 6 9
1981
3 6 9
1982
3 6 9
1983
3 6 9
1984
WATER LEVEL DEVIATION (m)


BASIN 2
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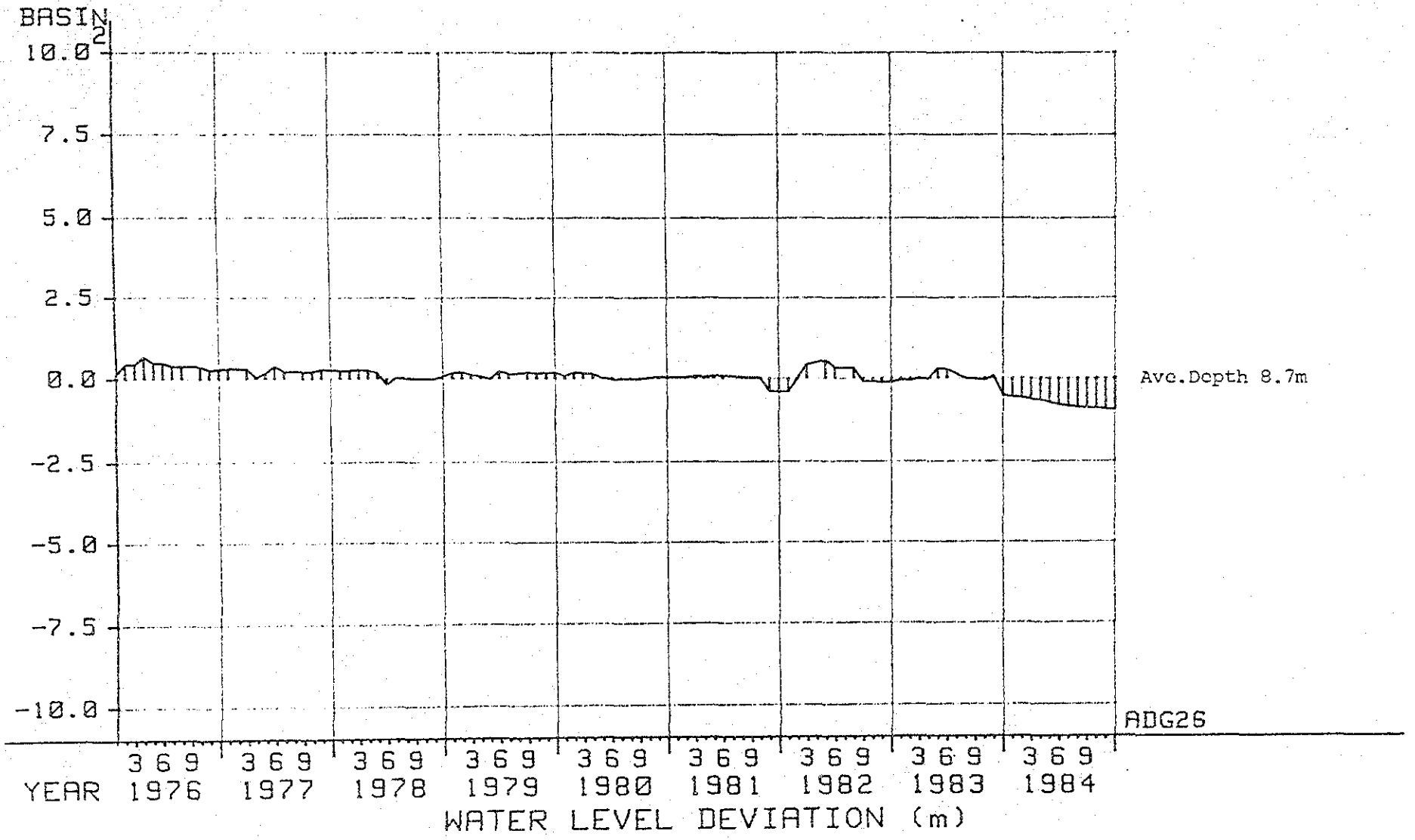
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 52.7m
JT22
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 2
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Avc.Depth 8.7m
ADG26
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)

3. Basin 3 -------- Wadi Al-Fara'

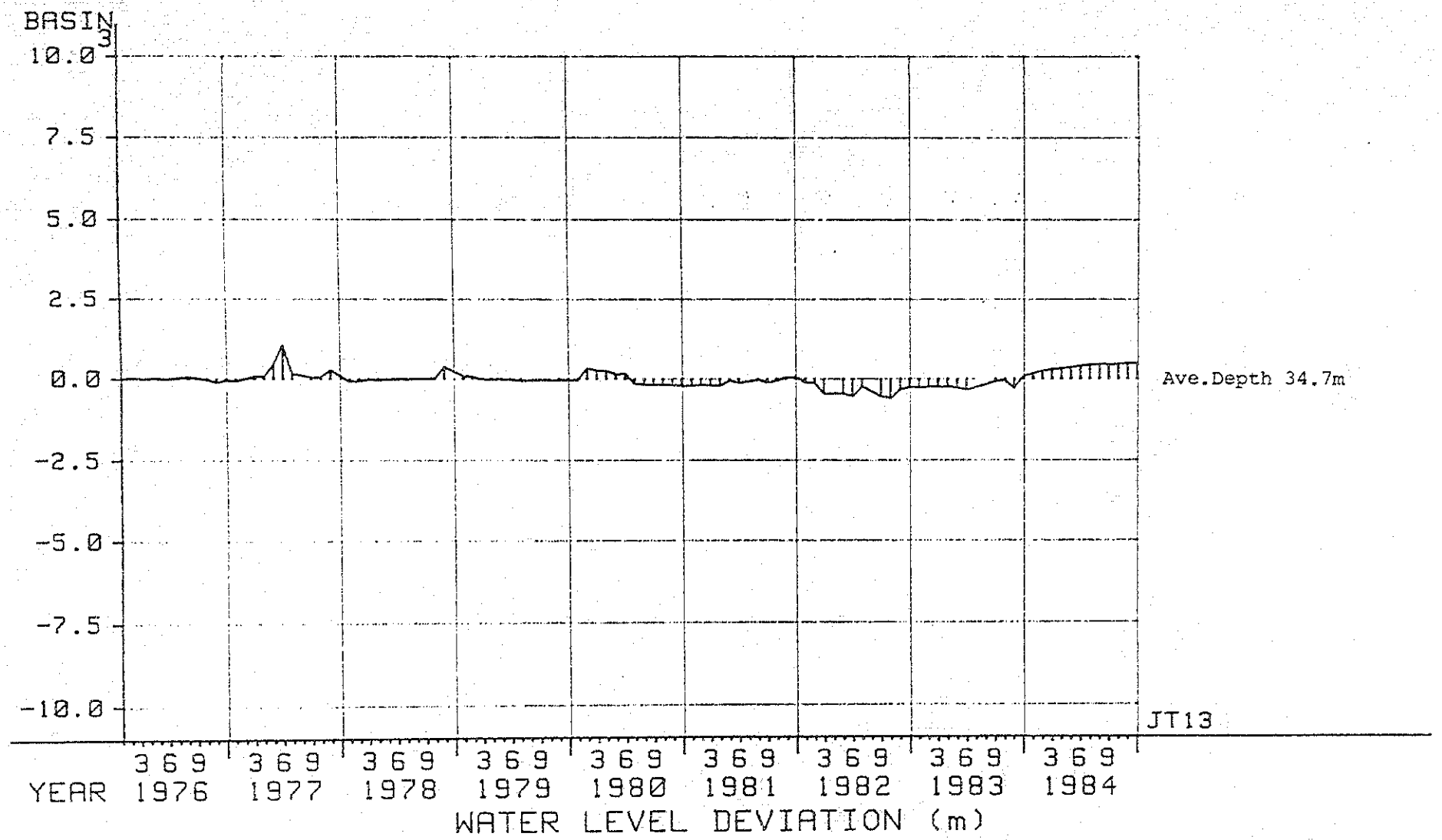
Well Hydrograph of: JT13

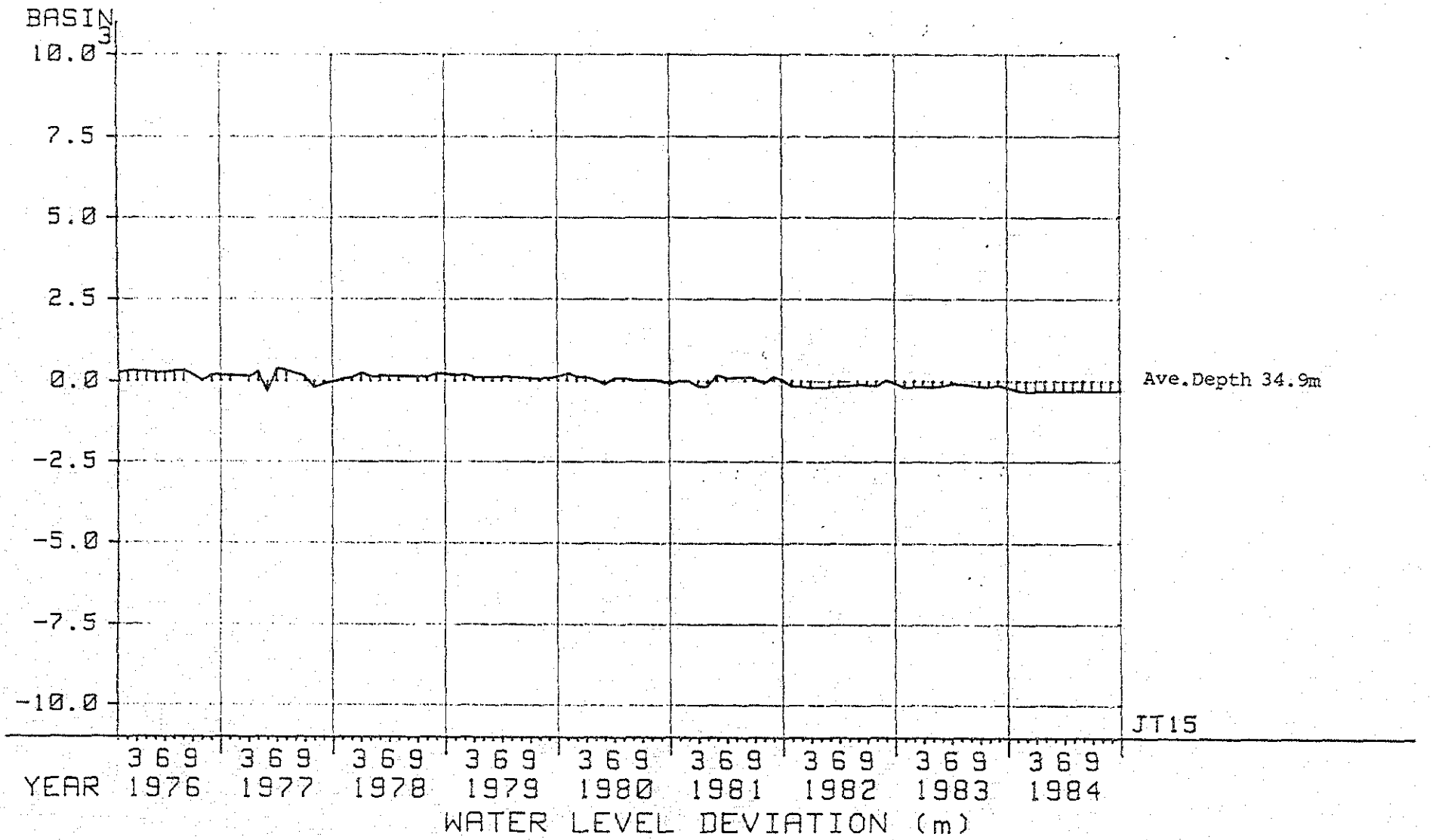
JT15

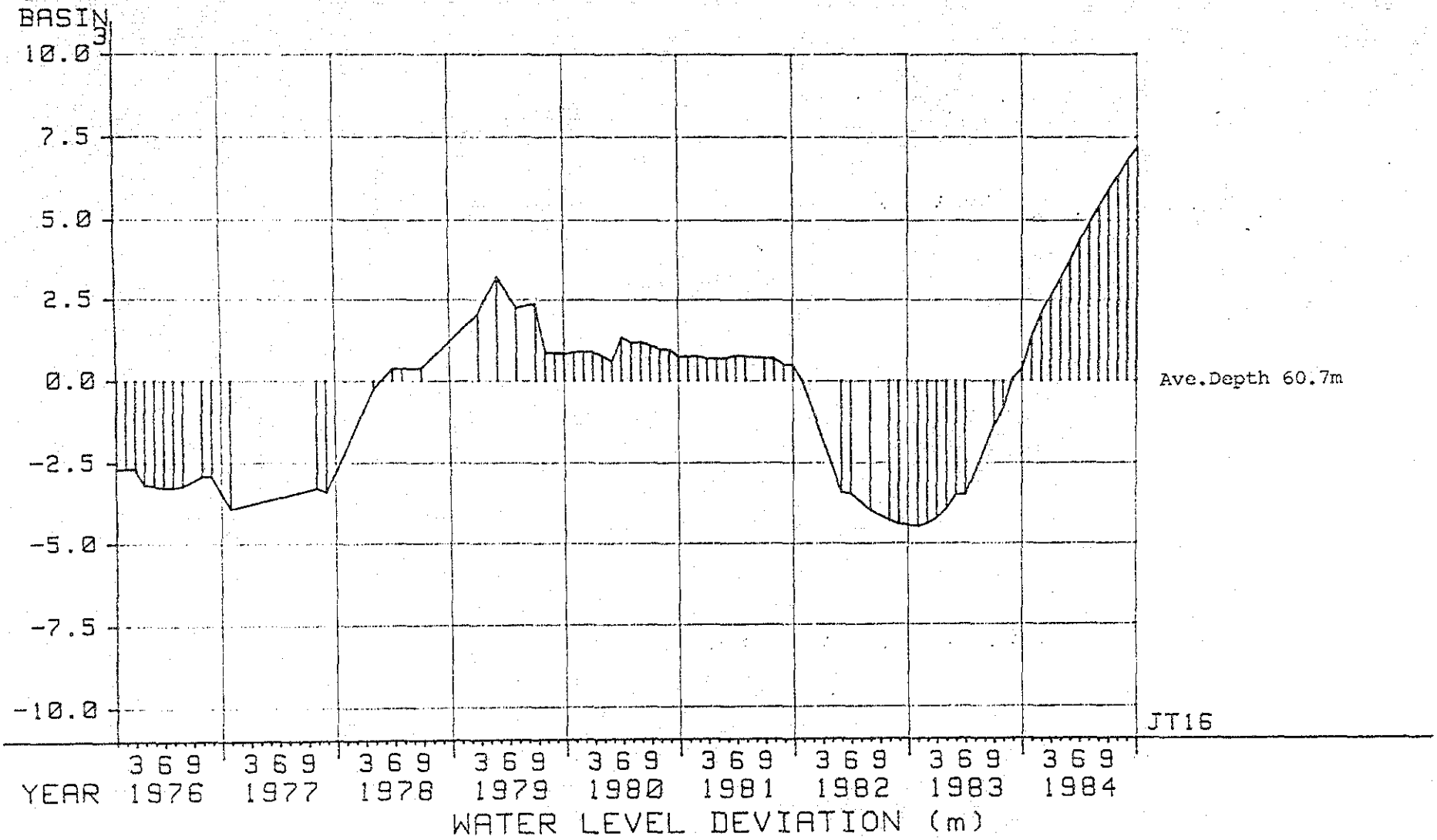
JT16

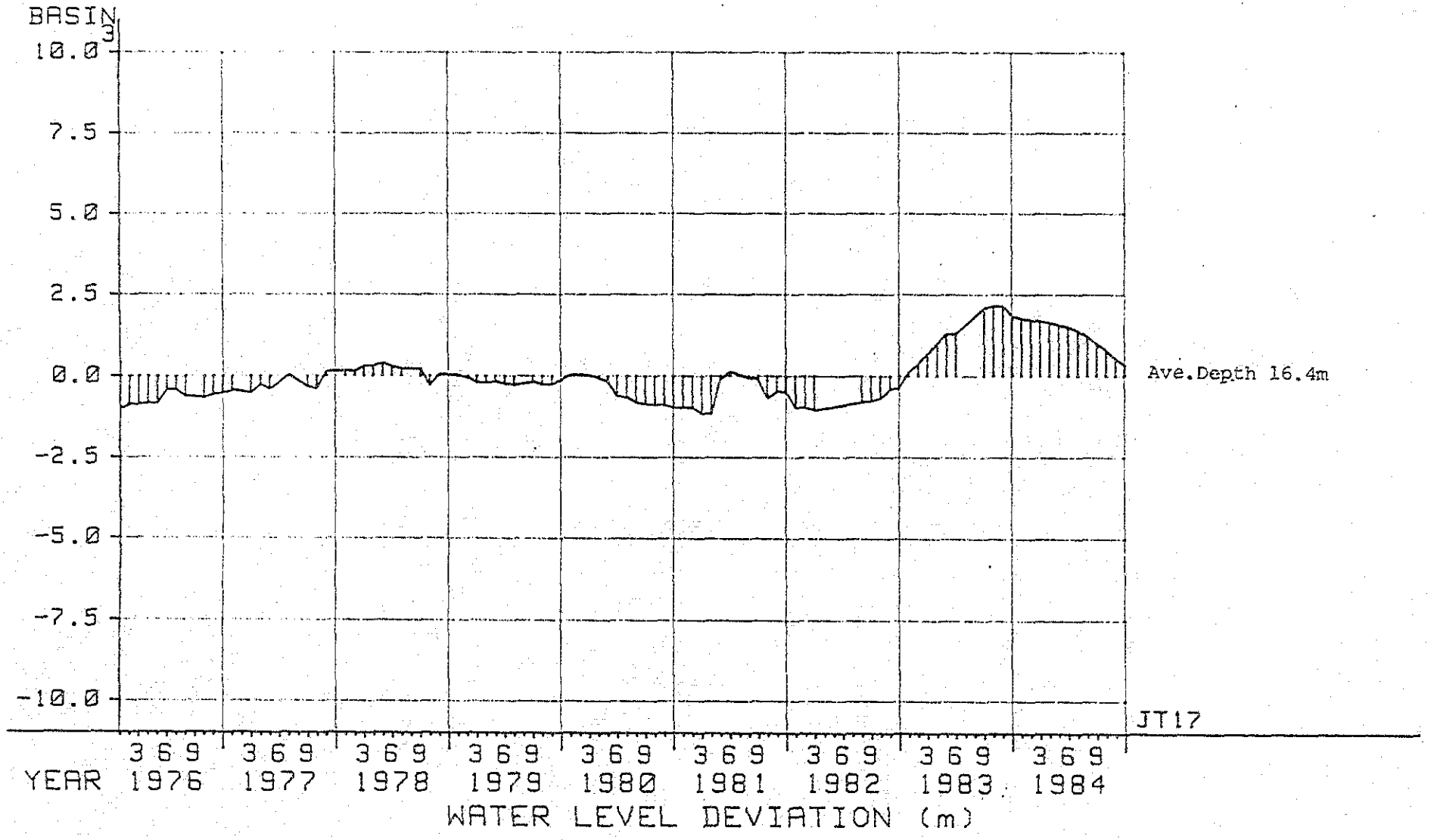
JT17

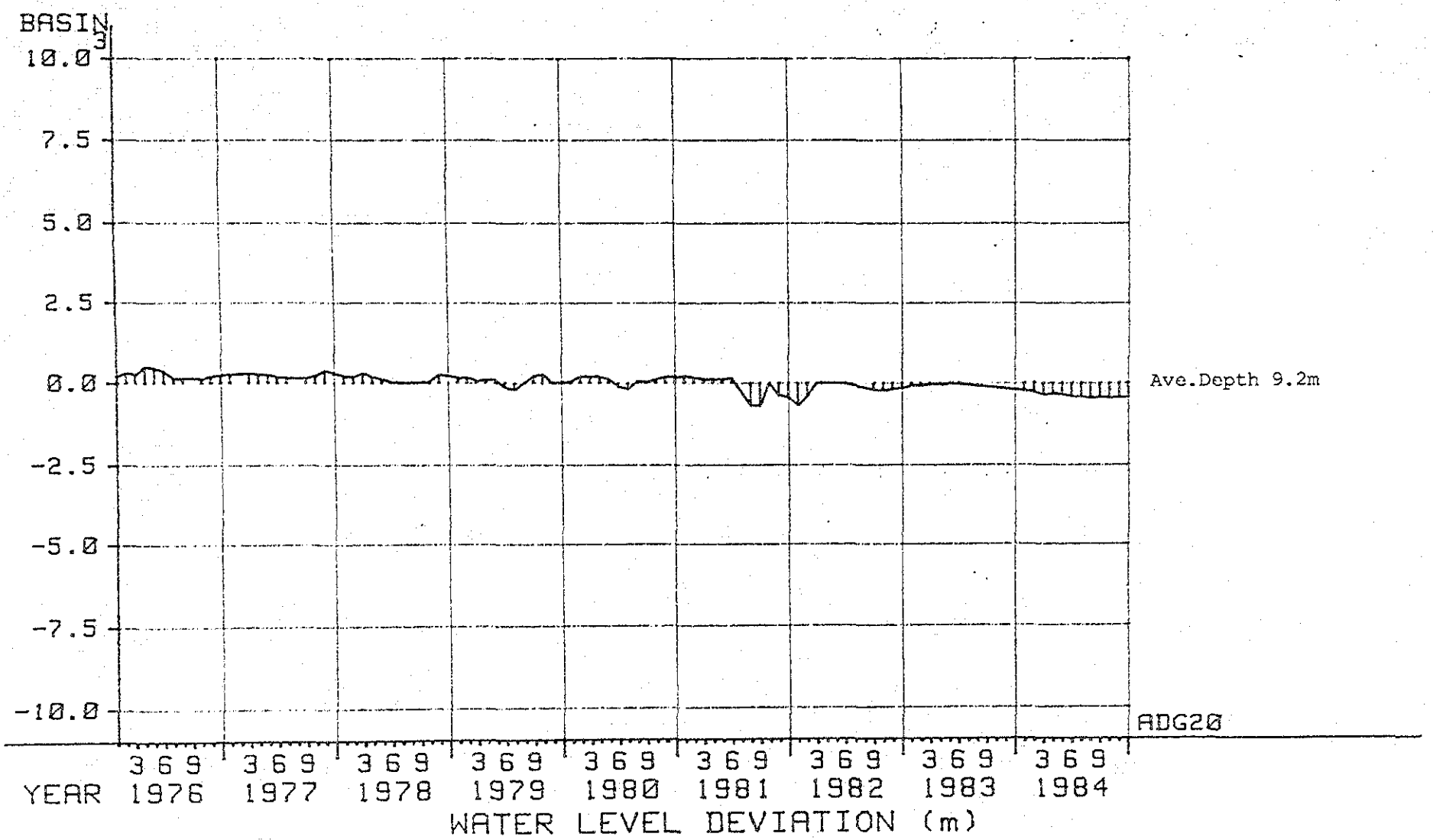
ADG20


BASIN 3
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 34.7m
JT13
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 3
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 34.9m
JT15
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 3
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 60.7m
JT16
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 3
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 16.4m
JT17
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 3
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 9.2m
ADG20
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)

4. Basin 4 ---- Wadi Bani Kharus

Well Hydrograph of: JT10

JT11

JT12

JT24

JT57

JT58

JT67

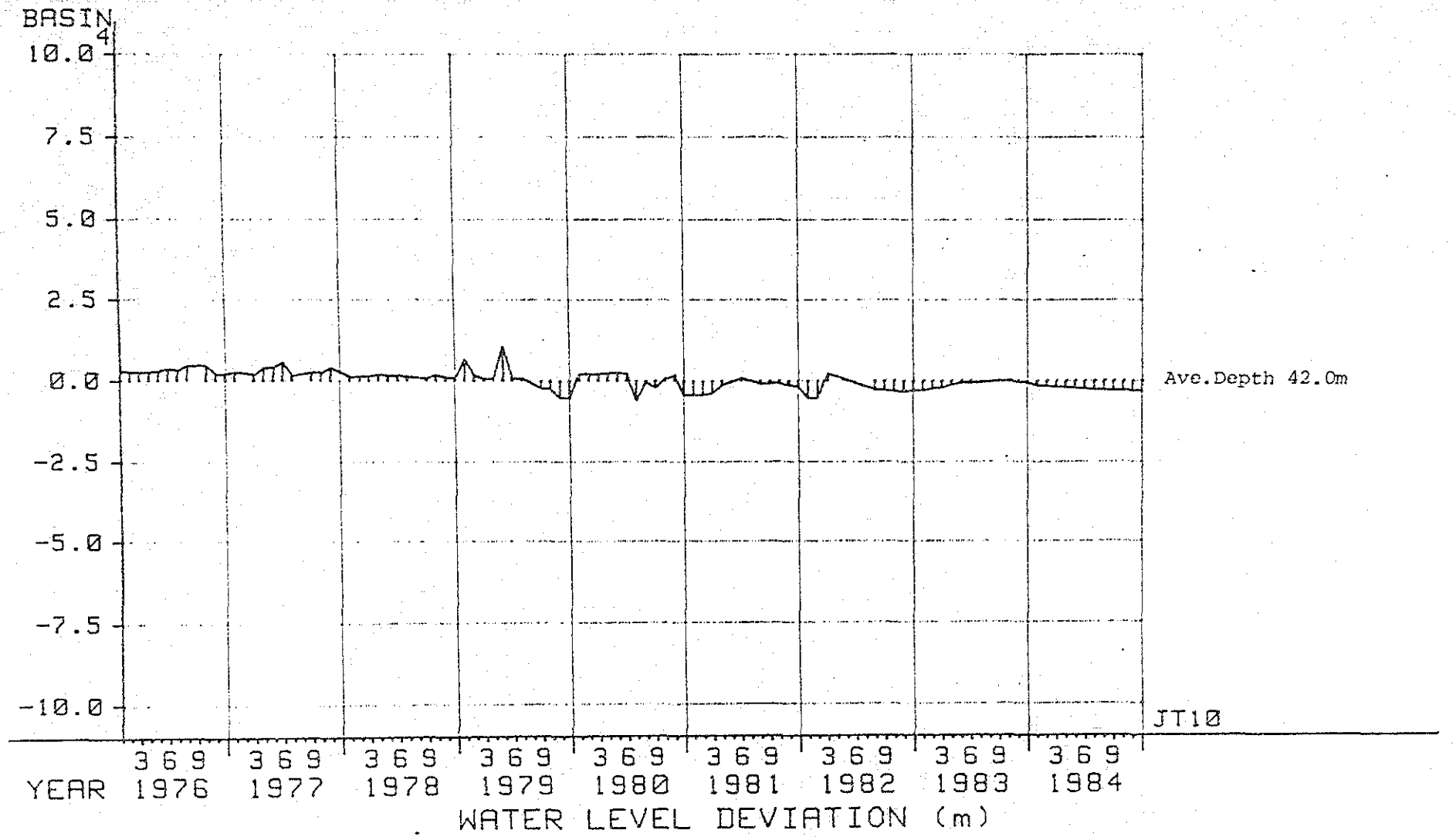
JT68

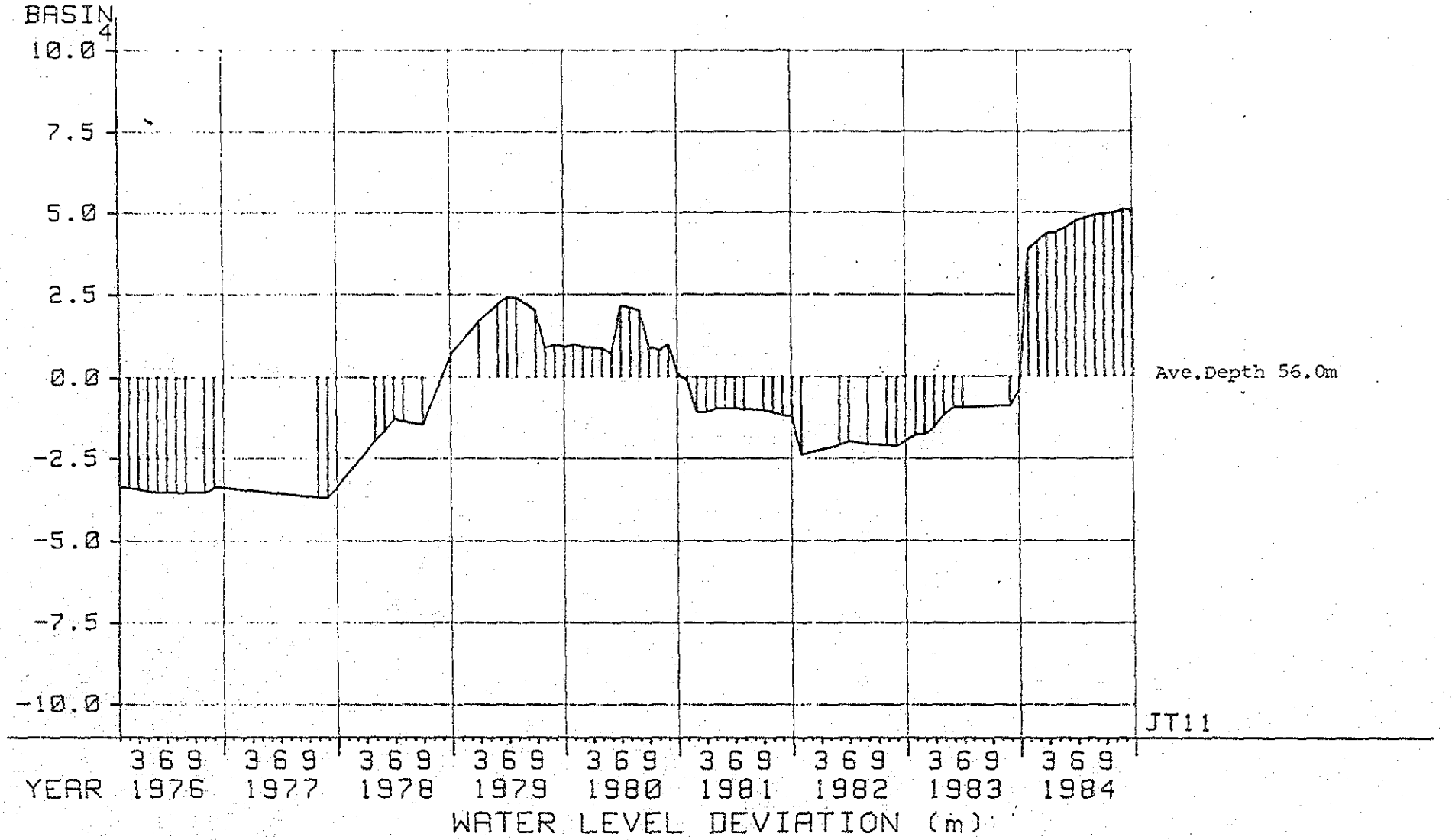
DW 3

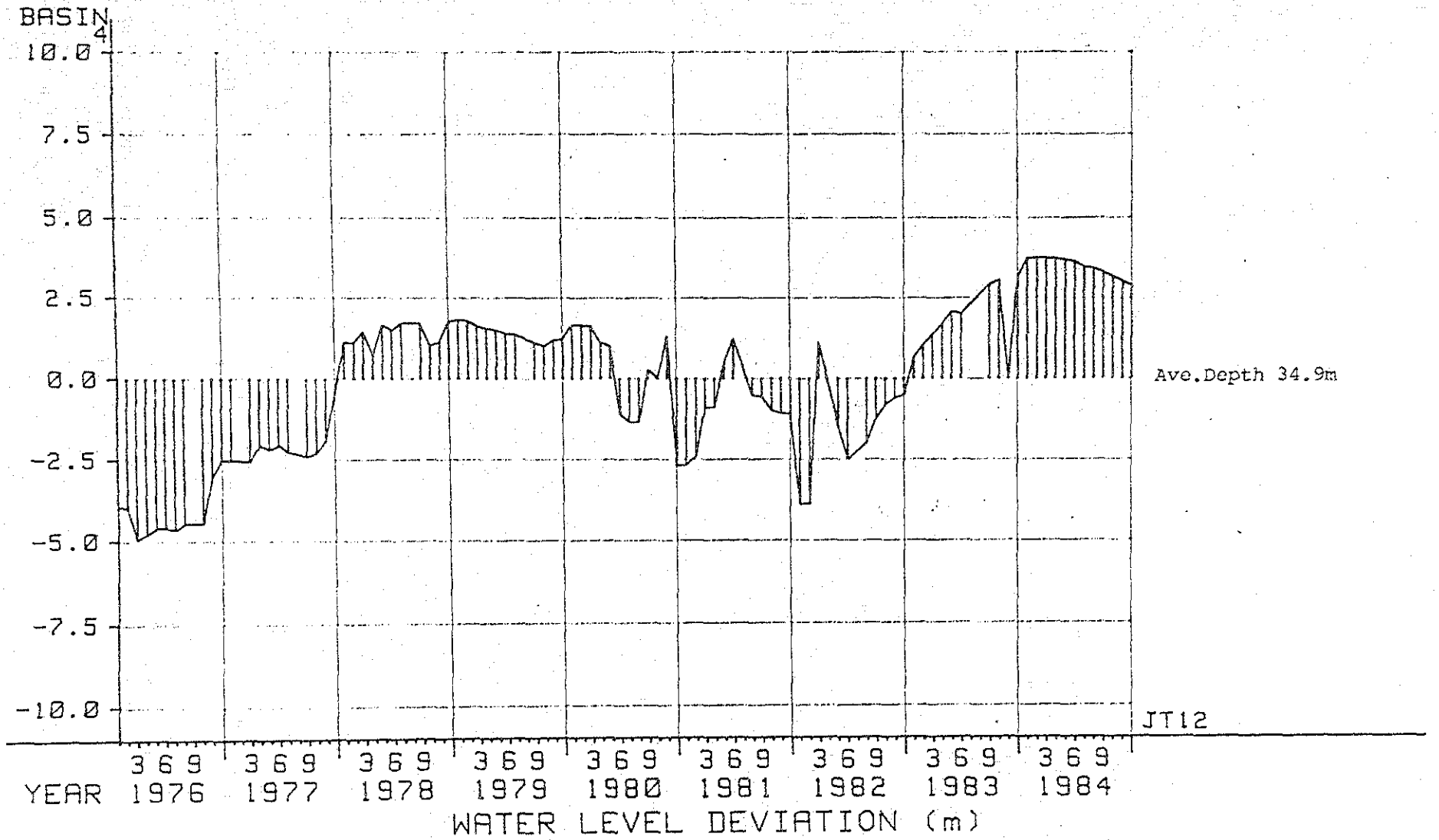
DW 4

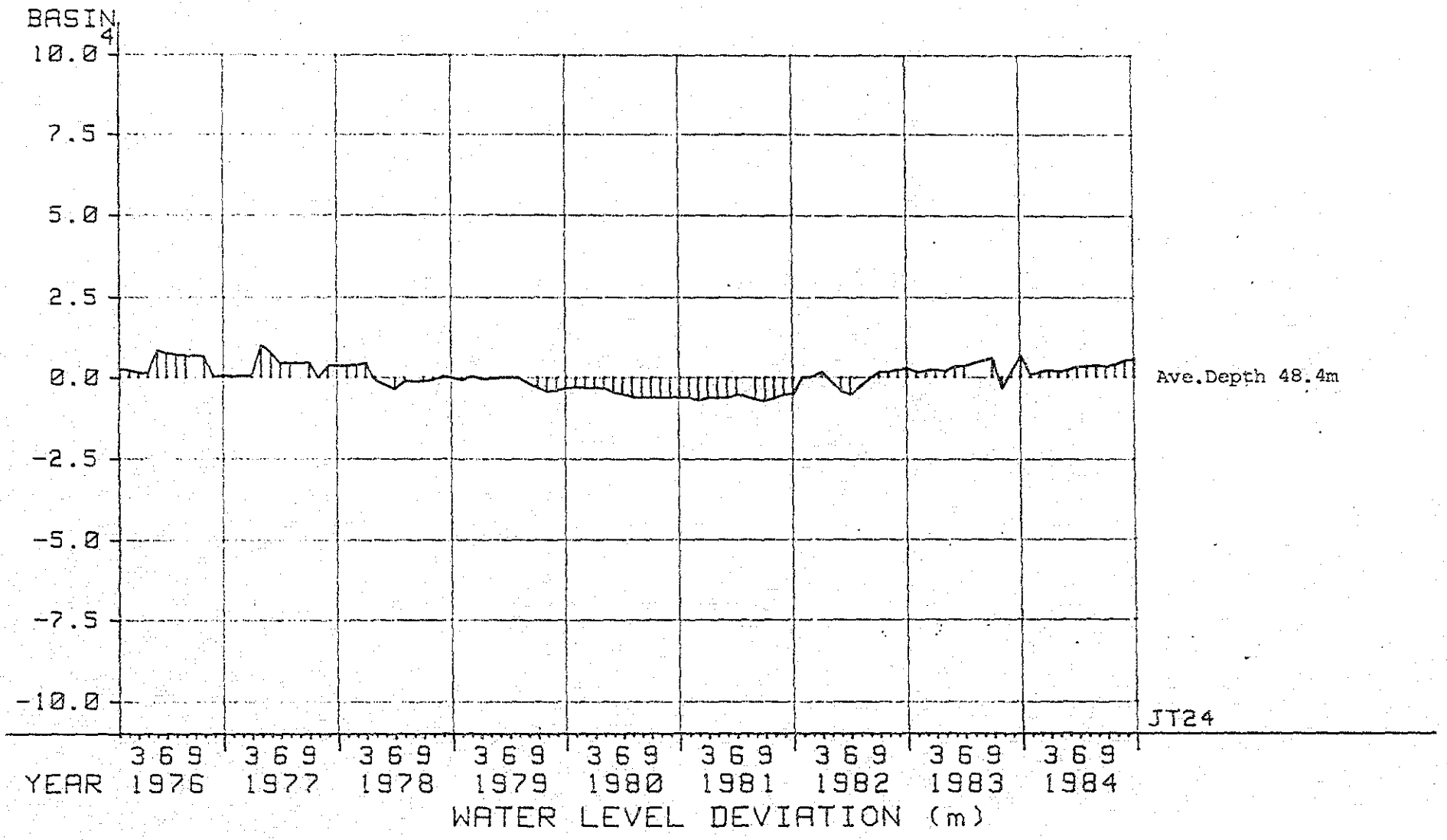
ADG23

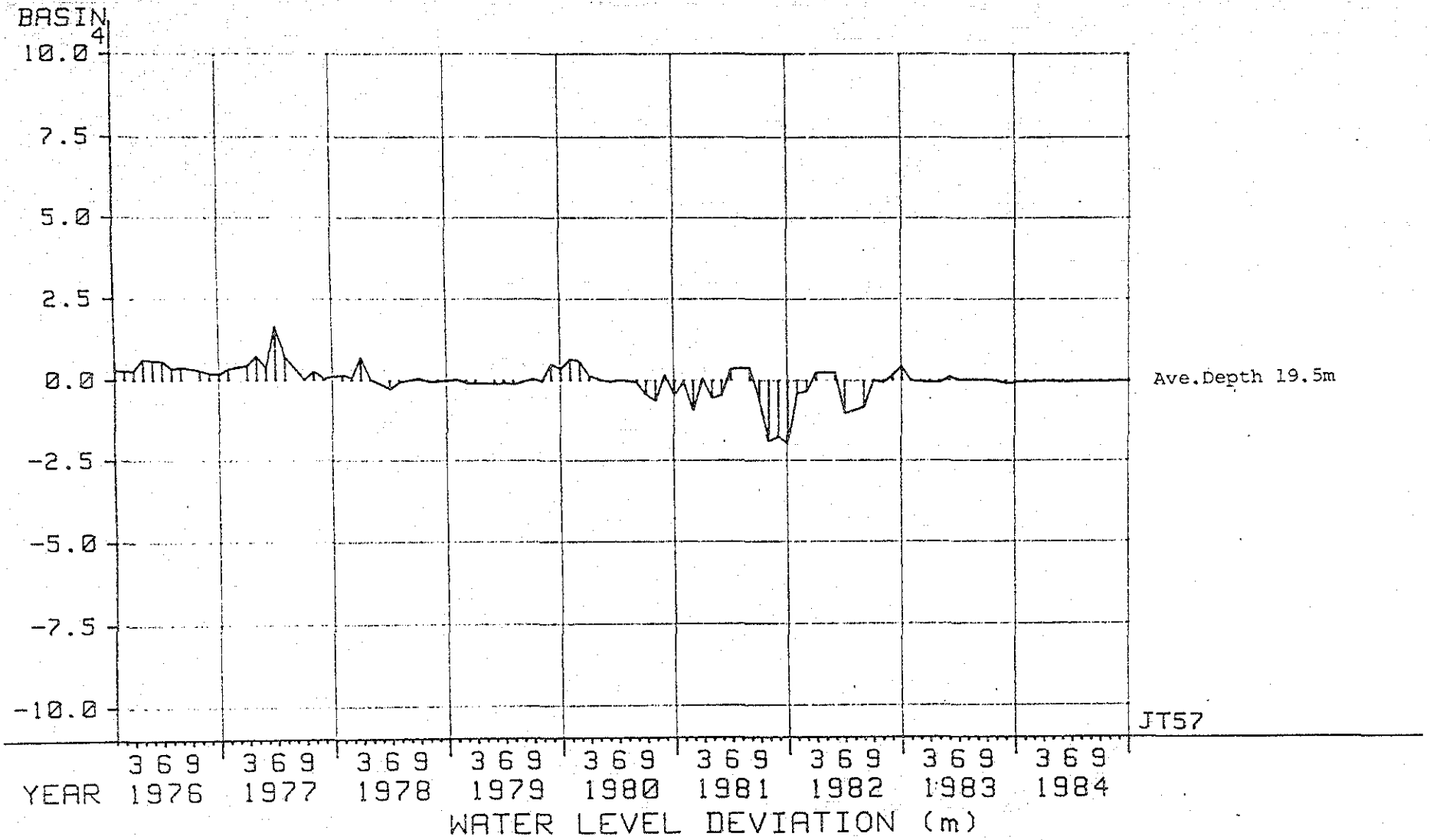
ADG24

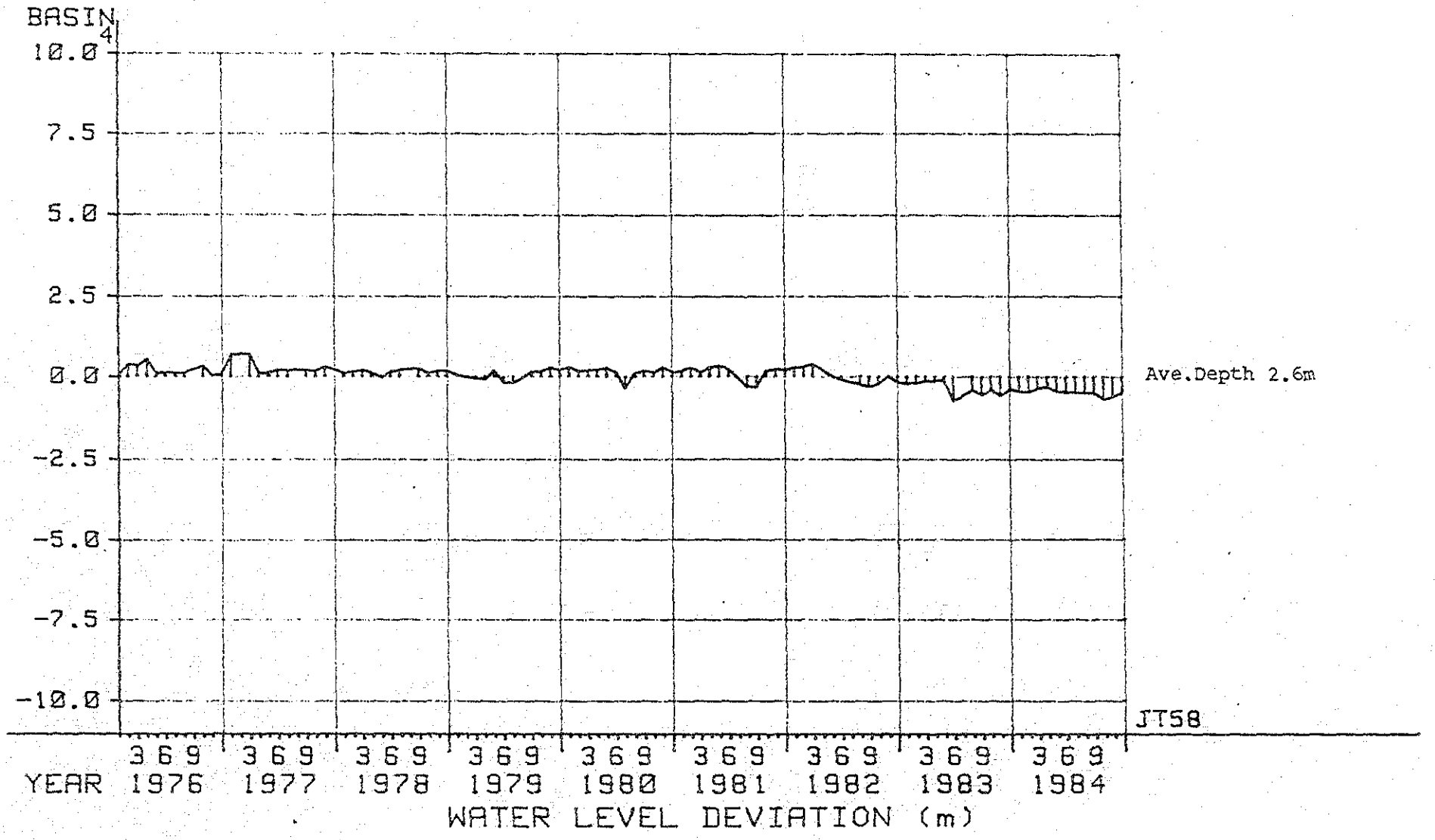

BASIN 4
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 42.0m
JT10
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)

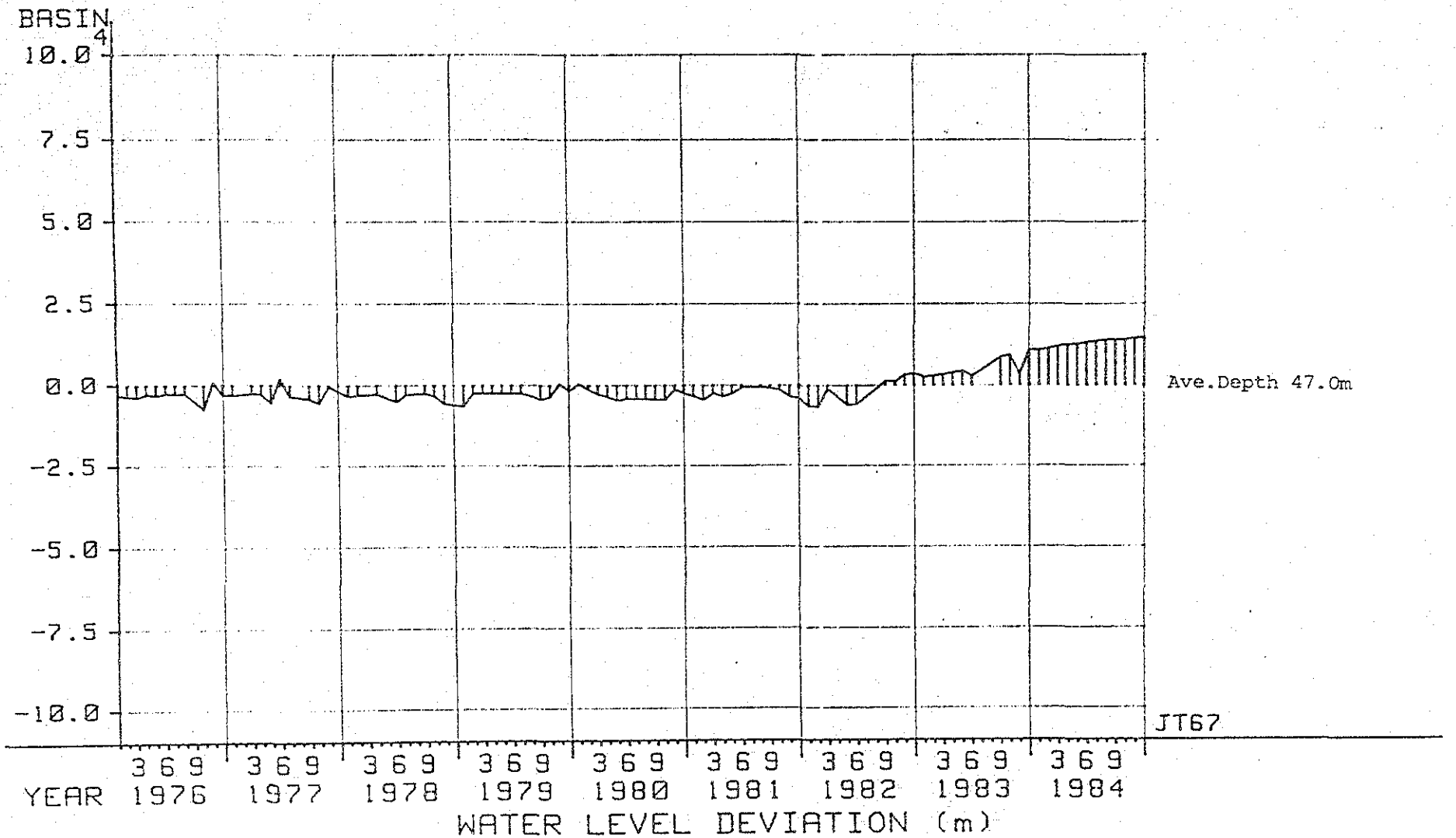

BASIN 4
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 56.0m
JT11
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)

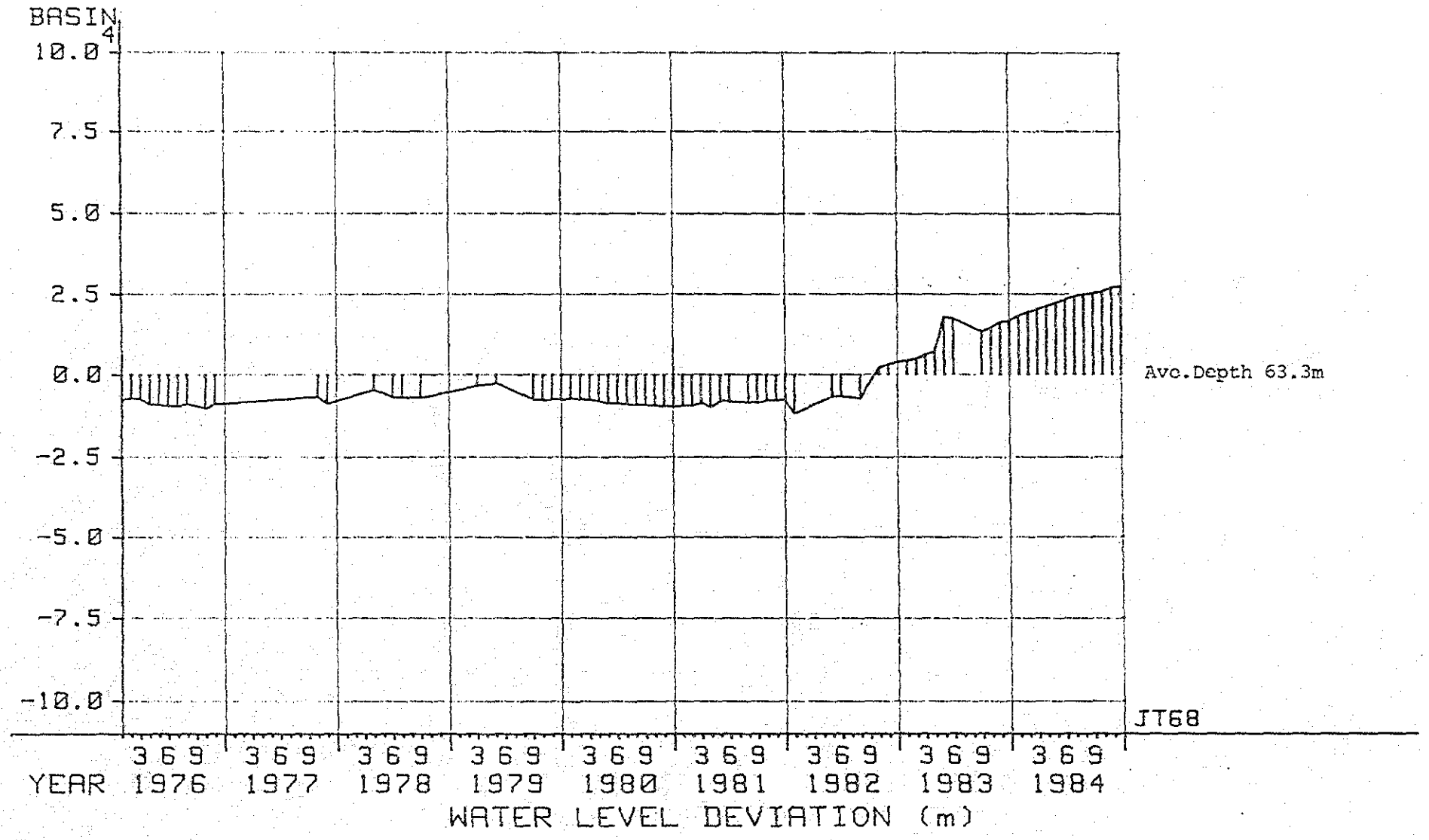

BASIN 4
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 34.9m
JT12
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)

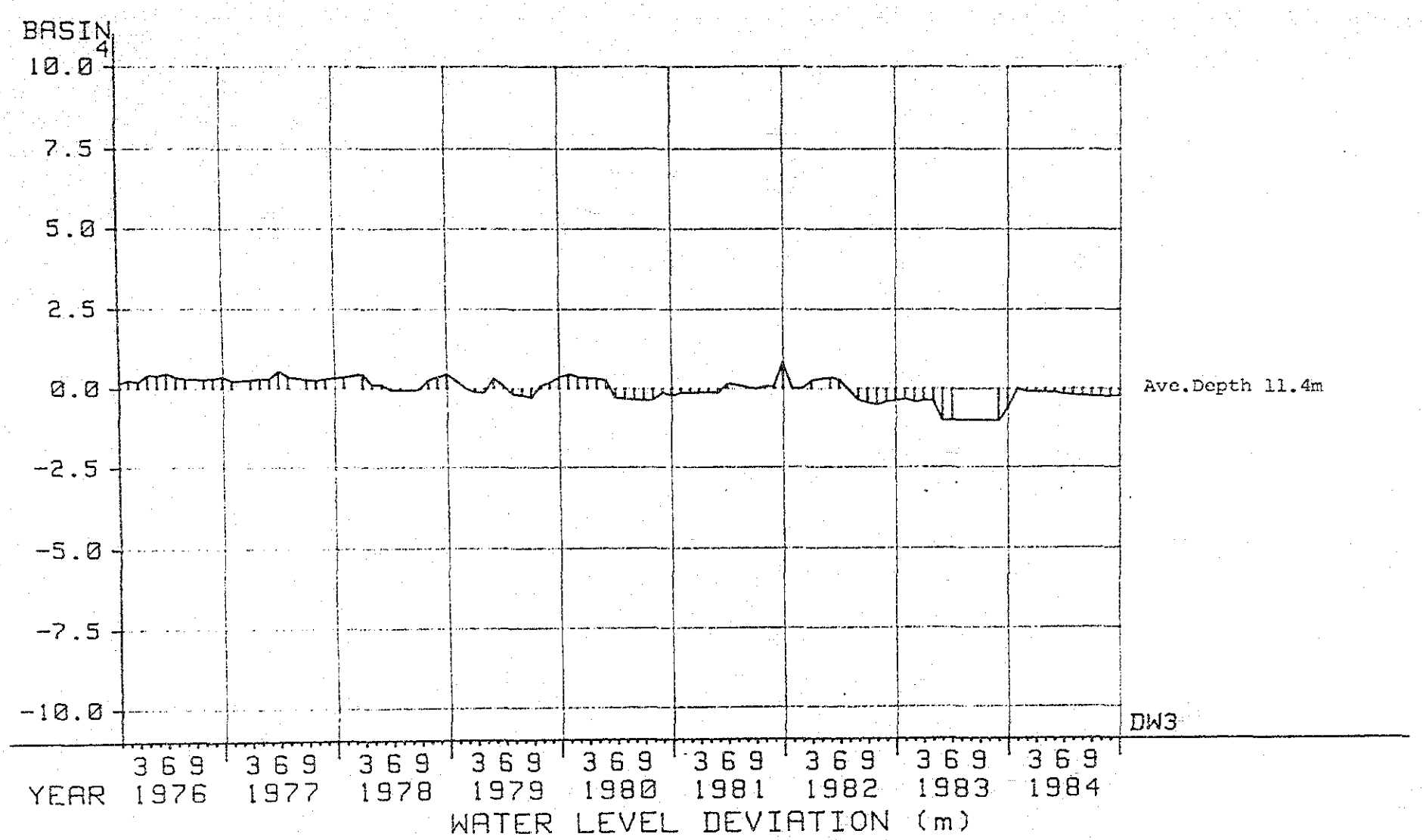

BASIN 4
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 48.4m
JT24
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 4
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 19.5m
JT57
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 4
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 2.6m
JT58
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 4
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 47.0m
JT67
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 4
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Avc.Depth 63.3m
JT68
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 4
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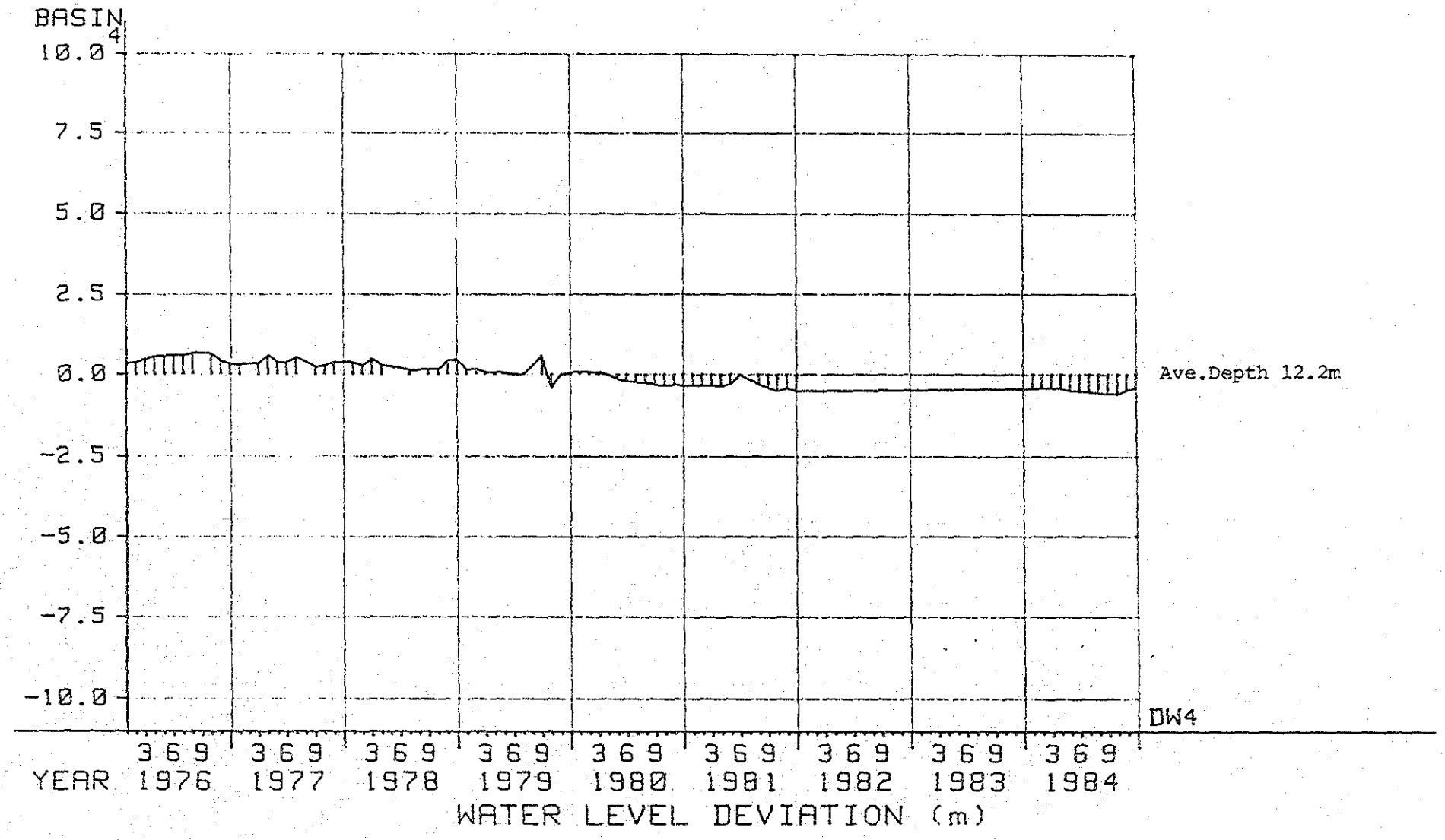
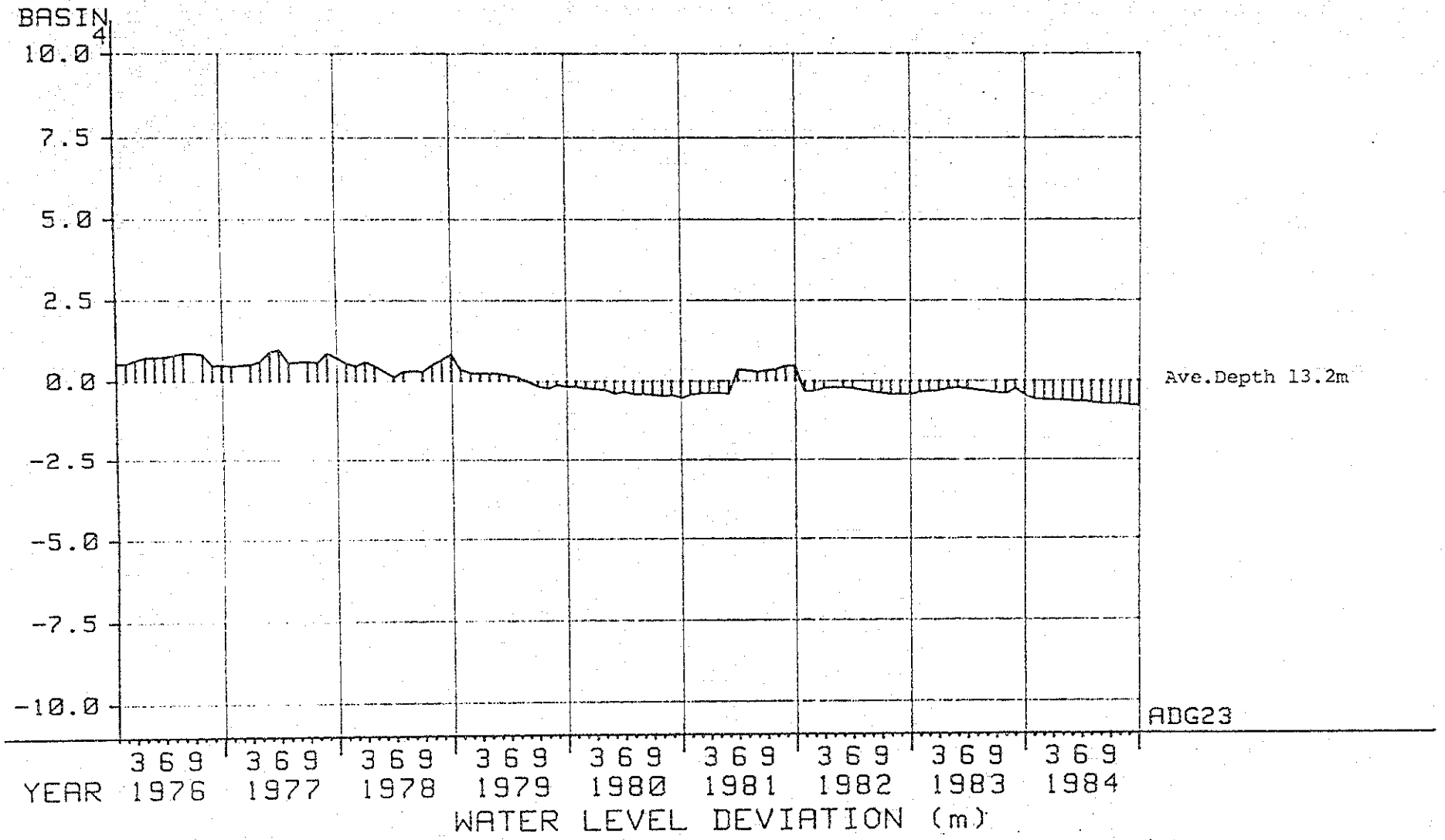
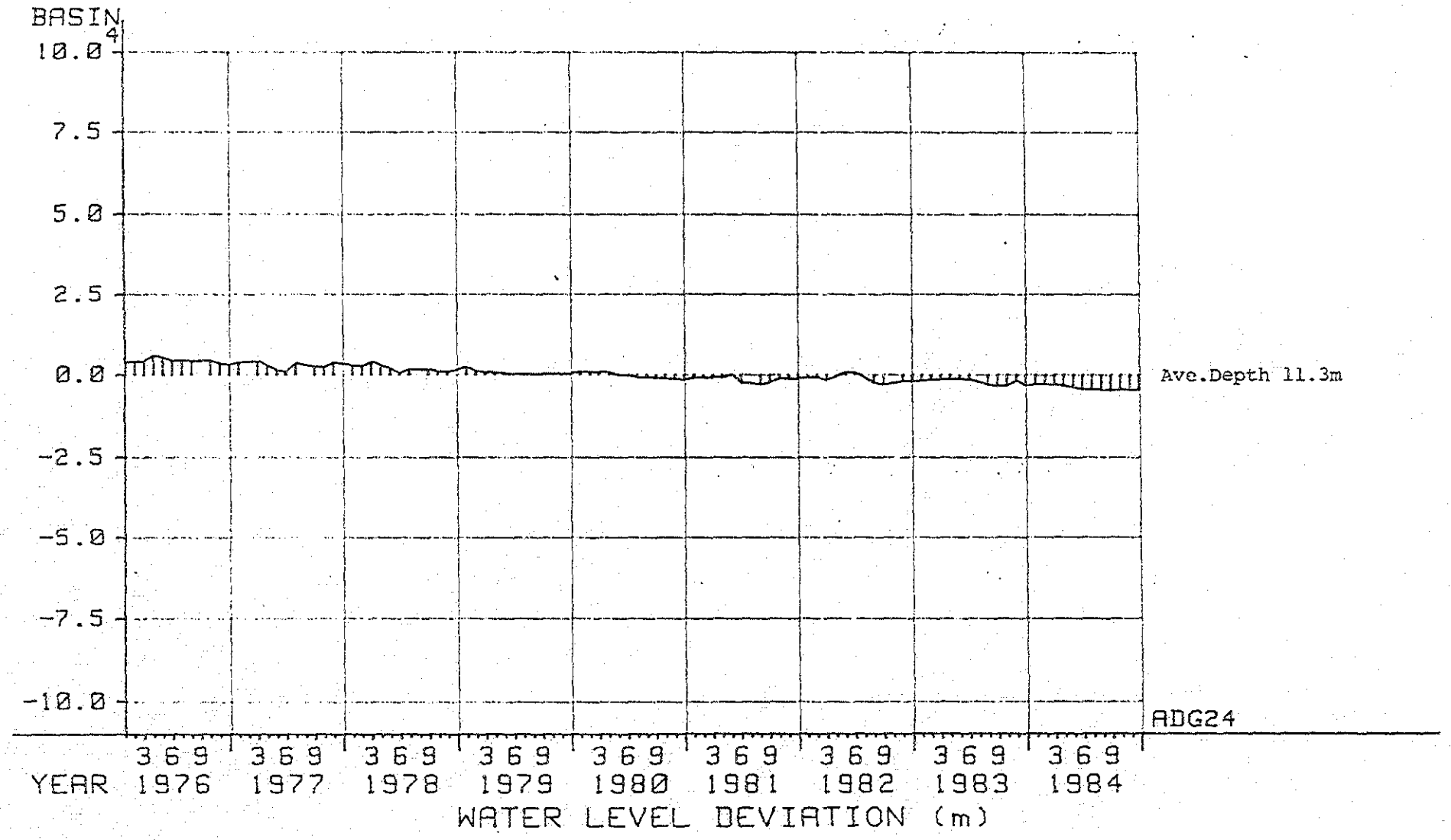
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 11.4m
DW3
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 4
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 12.2m
DW4
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 4
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 13.2m
ADG23
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)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10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 11.3m
ADG24
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)

5. Basin 5 Wadi Al-Ma'awil

WellHydrograph of: JT 5

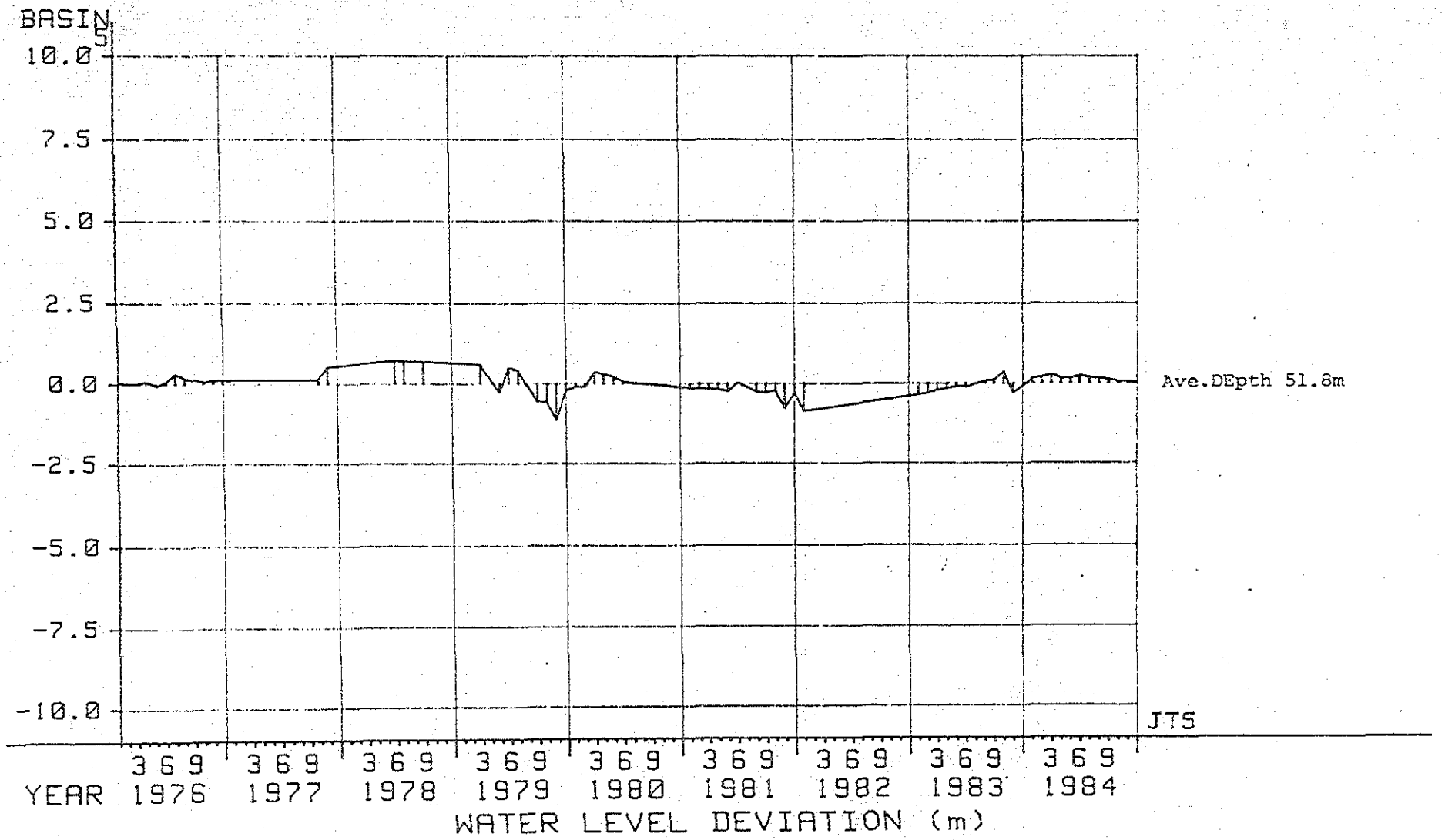
JT 7

JT 9

JT52

ADW 7

ADG17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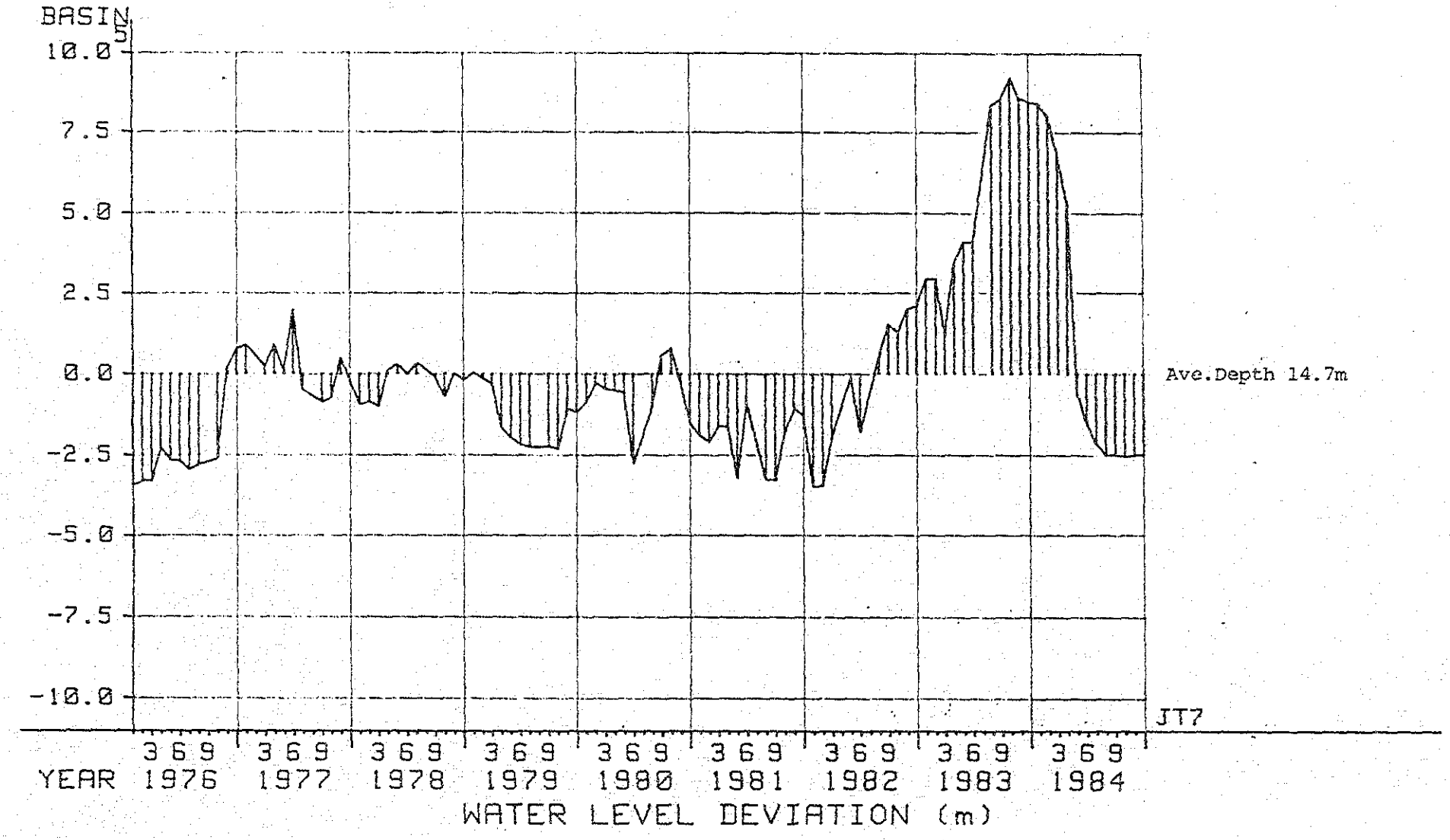
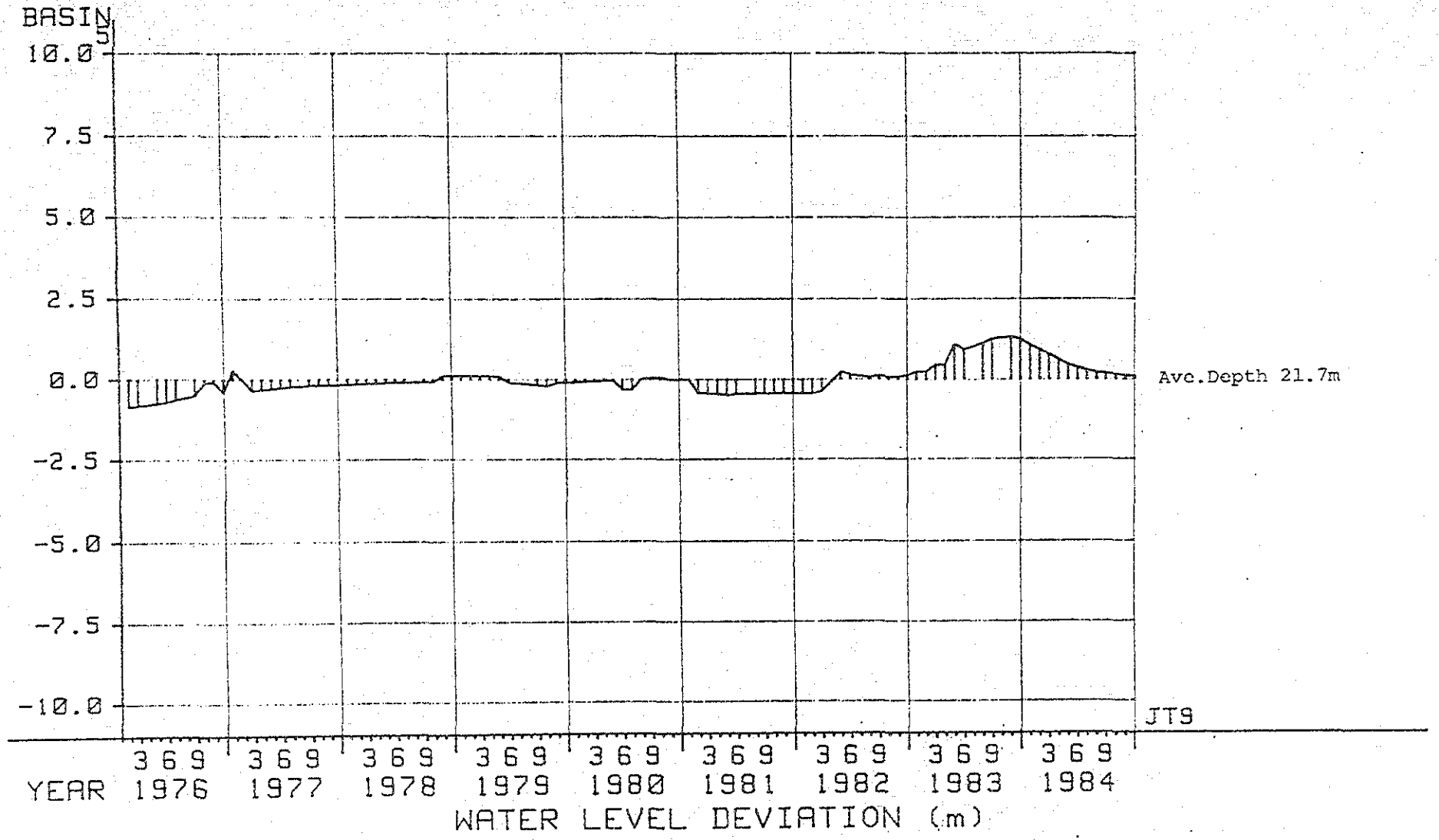
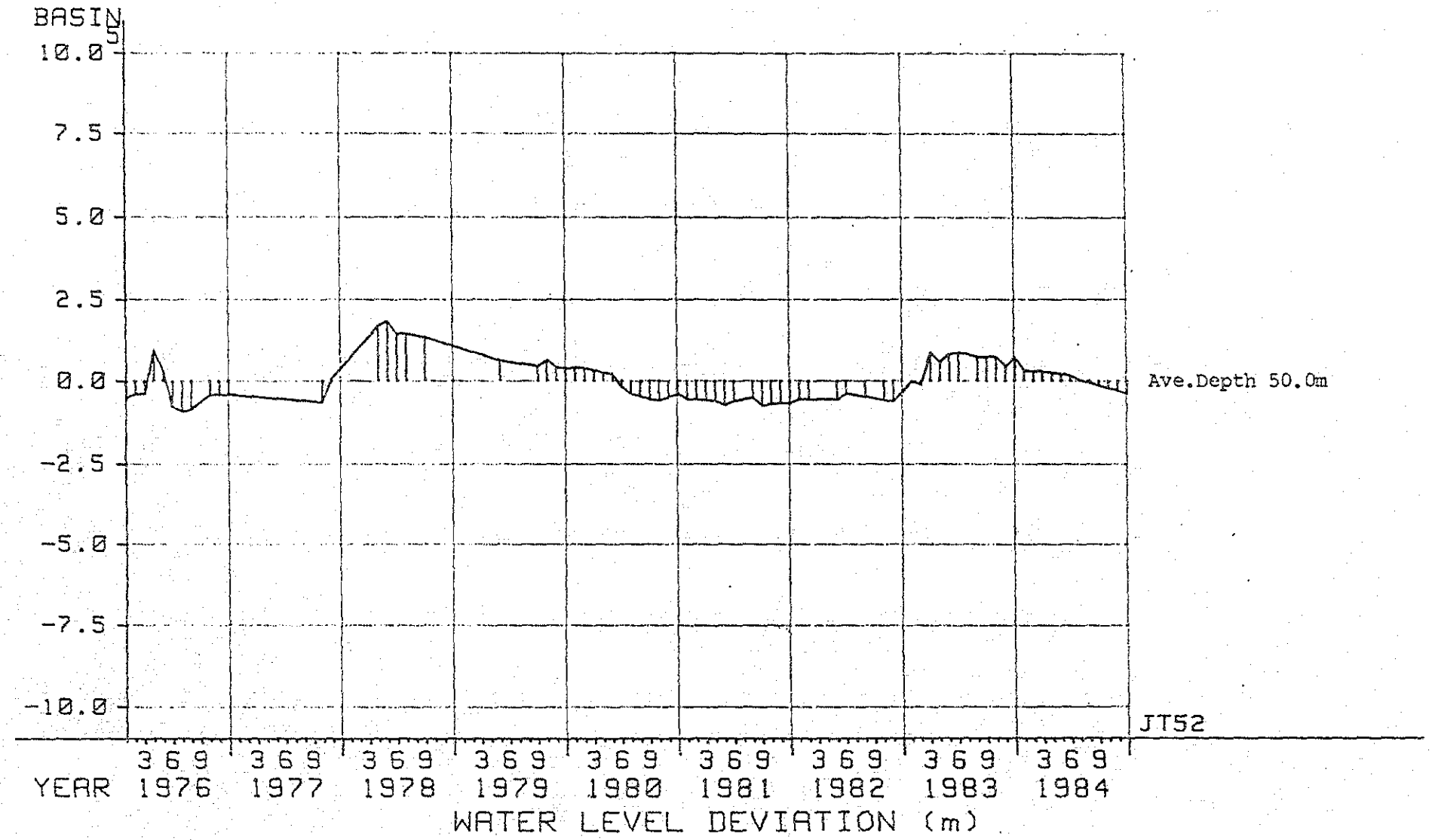
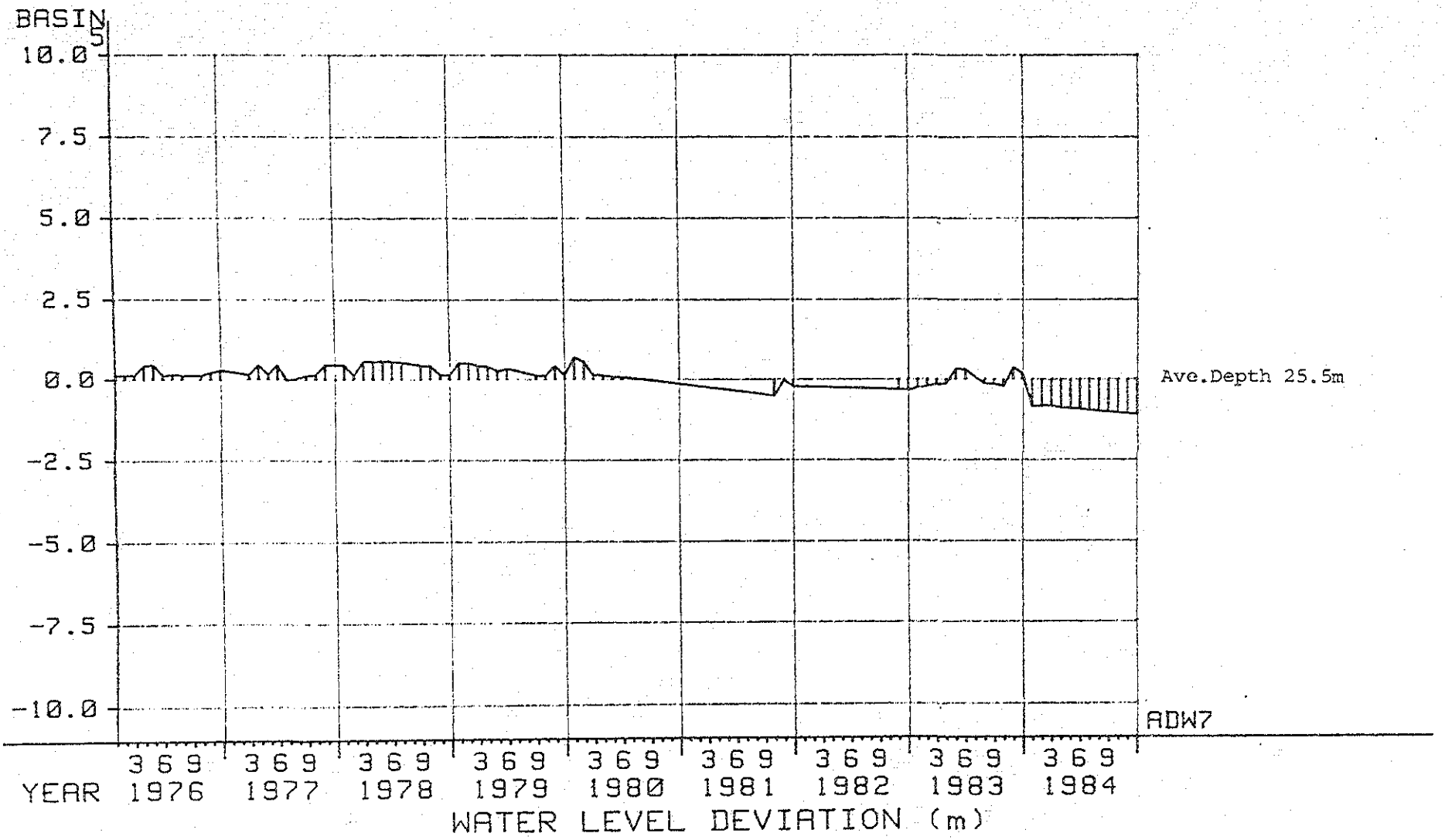
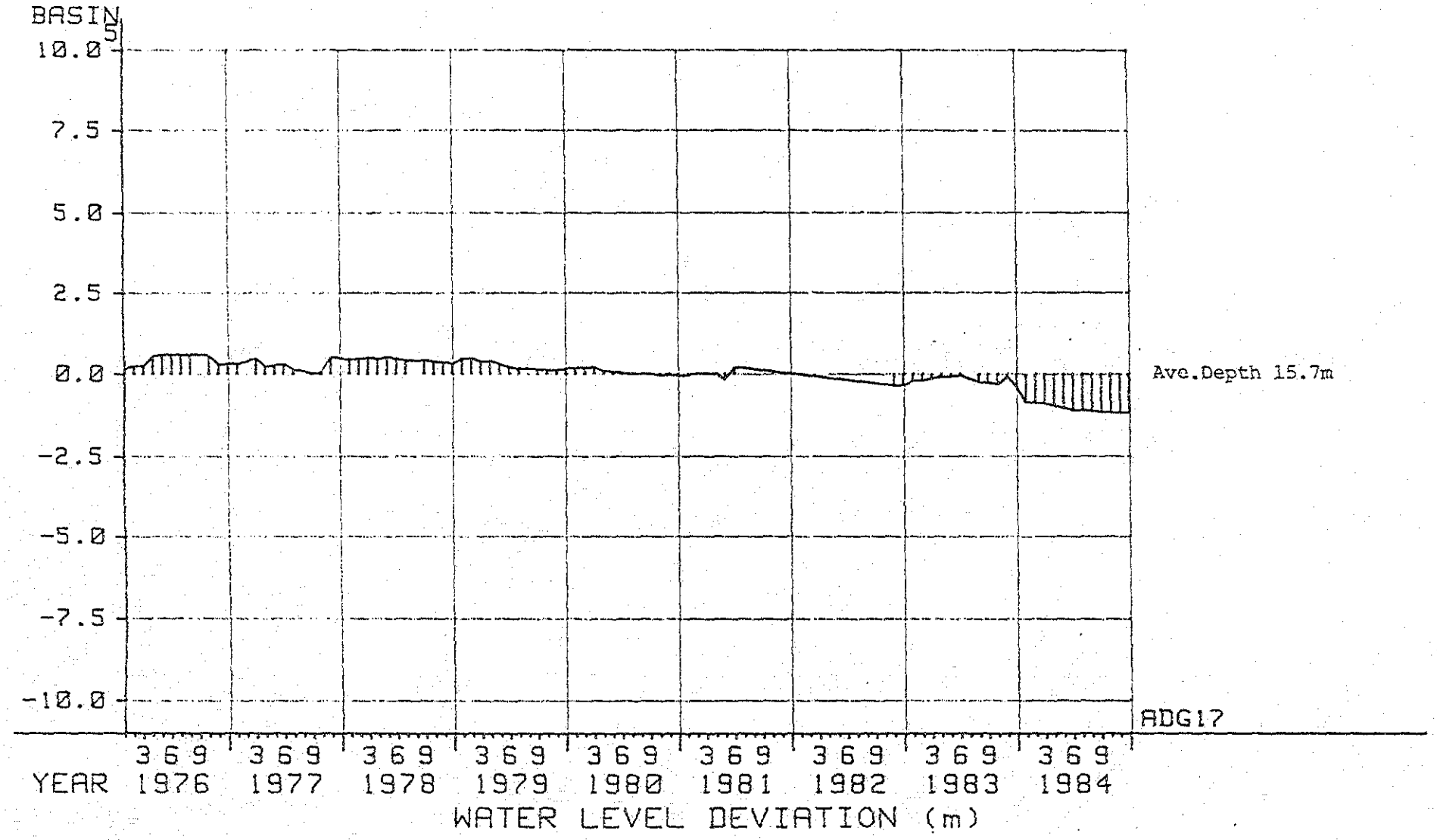
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.DEpth 51.8m
JTS
3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 14.7m
JT7
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 21.7m
JTS
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 50.0m
JT52
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 25.5m
ADW7
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)


BASIN 5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Ave.Depth 15.7m
ADG17
3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9 3 6 9
YEAR 1976 1977 1978 1979 1980 1981 1982 1983 1984
WATER LEVEL DEVIATION (m)

SUPPORTING REPORT D

GROUNDWATER

SUPPORTING REPORT D

GROUNDWATER

CHAPTER 1 SUMMARY OF PREVIOUS STUDIES ON GROUNDWATER CHEMISRY

In the previous studies (ILACO, 1975, and Gibb, 1976) geochemical studies on the groundwater were also carried out, using ordinary ionic analysis, stable isotopes and radio active tritium. However, except for ionic analysis, the number of analysed water samples was not satisfactory.

By the ionic analyses they discussed the property of groundwater in relation to the salt hazard in irrigation (Gibb, 1976). But concerning the groundwater system ionic analyses were not itensively applied. Only preliminary classification of groundwaters were done by the ionic analysis without entering the ground water flow system study.

Stable isotopes; oxygen-18 and deuterium, were analysed both in the previous studies. However, analysed sample number was not large enough to depict the local hydrologic cycle. However, stable isotopes were successfully used for the discrimination of deep-born brine water from the seawater (Gibb, 1976).

Tritium analysis was comparatively appreciable in clarifying the movement of coastal groundwater. Although analysed waters were not enough in number and in areal distribution, the results disclosed an important conclusion that most groundwater in the coastal plain had been recharged prior to 1950s (thermonuclear tests) (Gibb, 1976).

CHAPTER 2 SUMMARY OF NEW ASPECTS OF GROUNDWATER SYSTEM DERIVED FROM THE PRESENT GEOCHEMICAL STUDY

As presented in the three attached data sheets, ordinary ions, stable isotopes of oxygen-18 and deuterium, and tritium were analysed, considering the origin and locality.

Ionic analysis and stable isotope analysis clearly proved that floodwater was directly supplied by the local rain and received almost no contribution from the groundwater, which is otherwise predominant flood water source in temperate climate region. This result agrees with the poor infiltration at the surface of Sand/Gravel Plain. Ionic composition of coastal plain groundwater suggested groundwater up-welling at the depth of the midplain when the geographical distribution was drawn. Stable isotopes and tritium analyses gave the correlative results to support such phenomenon.

The origins of large limestone springs at the foot of Major Mountains were identified to be high altitude rain through the stable isotopic analysis. This is agreeable when their piezometric conditions and geologic structure of the massive limestone are considered.

The tritium analysis of the present work was carried out in a more intensive way than that of the previous study. Detailed sampling of coastal groundwater disclosed that there were local recharge zones near the coast which function to maintain the coastal aquifer to some extent. However, the majority of groundwater at the coast is of old inland groundwater, recharged at some specific zone.

D-1 IONIC COMPOSITION OF THE BATINAH WATER SAMPLES

IONIC COMPOSITION OF THE BATINAH WATER SAMPLES (1/11)

Sample No.	Sample Site	Date	pH	Cation (meq/l) Na^+	K^+	Ca^{++}	Mg^{++}	Anion (meq/l) $CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$
(Rain Water)											
OMN-291	Al-Rustaq	84/ 7/30	6.8	0.4	0.1	0.2	2.3	tr.	1.4	0.5	0.7
292	Madruj	84/ 7/31	6.7	0.4	0.0	tr.	1.4	tr.	0.6	0.6	0.8
(Flood Water)											
OMN- 70	Barka	83/ 2/13	6.6	0.1	0.0	0.8	0.8	tr.	1.4	0.2	tr.
71	W.Ma'awil	"	7.2	0.2	0.0	0.9	0.8	tr.	1.8	0.2	tr.
72	W.B.Kharus	"	7.2	0.2	0.0	0.9	1.2	tr.	2.0	0.3	tr.
73	W.Fara'	"	7.3	0.2	0.0	1.0	0.9	tr.	1.8	0.3	tr.
74	W.B.Ghafir	"	7.2	0.1	0.0	0.9	1.3	tr.	2.0	0.2	tr.
77	W.Ma'awil	83/ 2/16	7.1	0.1	0.0	0.7	0.8	tr.	1.3	0.2	tr.
(Wadi Stream Water)											
OMN- 75	Mazahit	83/ 2/13	7.6	4.0	0.1	2.1	4.4	tr.	5.7	2.9	1.4
78	W.Ahin	83/ 2/22	8.2	3.3	0.1	0.8	4.7	tr.	3.6	3.6	1.0
129	W.B.Ghafir	83/ 3/16	7.6	2.6	0.1	0.8	5.4	tr.	5.2	2.6	0.4
134	W.Ajal	"	7.9	5.3	0.1	0.8	4.2	tr.	2.8	3.4	1.9
148	W.Bahla	83/ 3/24	7.4	0.8	0.0	0.9	3.7	tr.	4.0	1.1	0.3
163	W.B.Ghafir	83/ 8/ 8	7.6	2.6	0.1	0.9	4.7	tr.	5.1	2.8	0.2
172	W.Wuqbah	83/ 8/10	7.4	1.9	0.1	1.7	3.9	tr.	4.2	2.0	1.0
215	Mazahit	83/ 9/ 5	7.3	2.8	0.1	1.3	5.2	tr.	5.3	2.2	1.4
226	W.Ajal	83/ 9/10	6.8	35.7	0.7	6.8	10.0	tr.	7.4	30.8	15.0
238	W.Ahin	83/ 9/12	8.0	2.4	0.1	0.5	4.3	tr.	3.2	2.5	1.0
254	W.B.Ghafir	83/ 9/22	8.0	1.2	0.1	0.6	4.0	tr.	3.3	1.3	0.7

IONIC COMPOSITION OF THE BATINAH WATER SAMPLES (2/11)

(Contd..2)

Sample No.	Sample Site	Date	pH	Cation (meq/l) Na^+	K^+	Ca^{++}	Mg^{++}	Anion (meq/l) $CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$
(Falaj Water)											
OMN-126	Hazam	83/ 3/15	7.4	3.3	0.1	2.4	4.9	tr.	5.8	3.0	1.7
127	Jamma'	"	6.9	3.0	0.1	1.2	3.8	tr.	4.4	2.7	1.0
128	"	"	7.0	3.0	0.1	1.2	3.9	tr.	4.3	2.7	1.0
131	Khatum	83/ 3/15	7.3	1.1	0.1	0.9	4.0	tr.	4.4	1.2	0.2
132	Hibra	83/ 3/16	7.1	3.8	0.1	2.0	4.2	tr.	5.1	3.3	1.4
136	Al-Awabi	83/ 3/18	7.0	1.0	0.1	2.0	3.3	tr.	4.7	1.0	0.4
138	Al-Wasit	83/ 3/19	6.7	6.1	0.1	2.9	6.4	tr.	7.4	5.3	2.4
154	Al-Mansur	83/ 3/29	7.2	2.7	0.4	1.1	3.3	tr.	4.5	2.1	0.4
197	Al-Awabi	83/ 8/26	7.2	1.1	0.1	1.6	3.4	tr.	4.5	1.0	0.7
199	Hazam	"	7.3	3.0	0.1	1.8	4.6	tr.	5.0	2.8	1.4
212	Al-Wasit	83/ 8/31	6.8	5.4	0.1	3.3	6.5	tr.	7.4	5.4	2.5
218	Jamma'	83/ 9/ 7	7.1	3.0	0.1	0.8	4.2	tr.	4.1	3.0	1.2
219	Al-Mansur	"	7.7	2.6	0.0	1.0	3.2	tr.	3.9	2.2	0.7
233	Khatum	83/ 9/11	7.4	1.3	0.1	0.7	3.6	tr.	4.1	1.1	0.2
271	Zamma'	84/ 2/21	8.5	2.4	0.1	1.9	4.3	0.1	4.6	2.0	2.2
274	Qarri	84/ 2/22	9.1	0.9	0.0	0.8	4.2	0.2	3.3	1.1	1.0

IONIC COMPOSITION OF THE BATINAH WATER SAMPLES (3/11)

(Contd..3)

Sample No.	Sample Site	Date	pH	Cation (meq/l) Na^+	K^+	Ca^{++}	Mg^{++}	Anion (meq/l) $CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$
(Spring Water)											
OMN-133	Al-Ajal	83/ 3/16	6.5	7.2	0.2	2.5	3.7	tr.	4.7	6.4	2.4
135	Al-Rustaq	83/ 3/18	6.8	3.9	0.1	2.6	3.0	tr.	4.1	4.1	1.2
147	Bahla	83/ 3/24	10.0	5.3	0.1	0.3	0.6	1.2		5.3	tr.
173	Al-Ain	83/ 8/11	6.9	69.6	1.2	23.8	21.0	tr.	2.2	105.0	8.2
198	Ain Al-Kesfah	83/ 8/26	6.7	3.3	0.1	2.6	2.8	tr.	4.0	3.5	1.2
251	Al-Houqain	83/ 9/22	9.4	4.6	0.2	tr.	1.5	0.8	1.2	4.1	0.4
256	Al-Ajal	83/ 9/25	6.4	7.4	0.2	3.1	3.1	tr.	4.6	6.5	2.9
272	Al-Hammah	84/ 2/22	7.9	0.9	0.0	1.5	3.4	tr.	4.1	1.1	0.4
275	Saijah	"	7.7	1.3	0.0	0.5	4.0	tr.	4.0	1.0	1.0
285	Saiq	84/ 5/24	7.5	1.0	0.0	1.5	4.7	tr.	6.1	0.9	0.4
293	Al-Khadrah	84/ 7/31	7.4	3.6	0.1	0.1	5.5	tr.	3.8	3.6	1.7
299	Ain Ghamur	84/ 8/15	9.0	27.8	0.1	tr.	25.8	tr.	0.3	43.3	10.4
301	Ain Ayun	84/ 8/20	11.0	12.8	0.3	tr.	3.4	5.7		10.6	0.4
316	Al-Khadrah	84/ 8/27	7.8	3.6	0.1	1.2	4.0	tr.	3.8	3.4	1.7

IONIC COMPOSITION OF THE BATINAH WATER SAMPLES (4/11) (Contd..4)

Sample No.	Sample Site	Date	pH	Cation (meq/l) Na^+	K^+	Ca^{++}	Mg^{++}	Anion (meq/l) $CO_3^=$	$HCO_3^=$	Cl^-	$SO_4^=$
(Well Water)											
OMN- 79	Shubaibah	83/ 2/22	7.2	26.3	0.0	1.6	4.8	tr.	10.3	9.1	13.3
80	Muqail	"	7.2	7.5	0.0	0.5	2.4	tr.	5.9	2.9	1.4
81	W.Faras	"	8.5	50.9	0.3	2.3	5.0	tr.	2.3	34.4	21.5
82	Tawi Sufai	"	7.2	4.1	0.1	1.5	2.9	tr.	4.6	2.8	1.2
83	OA3	83/ 2/23	10.2	8.1	0.1	0.1	0.6	2.9		5.5	tr.
84	Al-Khishdah	"	7.5	4.5	0.1	0.7	2.2	tr.	4.2	2.1	1.0
85	"	"	7.7	11.5	0.1	0.8	3.6	tr.	6.6	5.0	4.2
86	"	"	7.5	11.5	0.1	0.9	3.6	tr.	5.5	7.1	3.2
87	Al-Muladdah	83/ 3/ 6	6.9	40.4	0.2	4.1	13.0	tr.	5.7	30.6	21.3
88	"	"	7.0	6.3	0.1	2.0	6.2	tr.	3.9	6.5	3.4
89	Sur Batha	83/ 3/ 8	7.1	7.3	0.2	3.7	12.0	tr.	2.4	17.3	3.4
90	Batha Hilal	"	7.4	6.1	0.1	0.4	2.5	tr.	2.5	3.9	0.7
91	"	"	6.9	0.9	0.0	0.8	3.9	tr.	3.7	1.4	0.4
92	Khabbah	"	7.1	4.1	0.1	1.5	7.5	tr.	3.3	8.6	1.2
93	"	"	7.3	5.4	0.0	0.9	5.3	tr.	3.7	5.7	2.2
94	Mamfesh	83/ 3/ 9	7.1	9.8	0.1	2.1	8.1	tr.	3.0	12.9	4.2
95	"	"	7.1	3.9	0.1	1.3	4.5	tr.	2.9	5.2	1.7
96	Al-Qalat	"	7.2	4.6	0.1	1.2	3.8	tr.	3.5	5.1	1.0
97	Dudam	"	7.7	12.0	0.2	1.7	4.8	tr.	4.6	8.6	5.3

IONIC COMPOSITION OF THE BATINAH WATER SAMPLES (5/11)

(Contd..5)

Sample No.	Sample Site	Date	pH	Cation (meq/l)				Anion (meq/l)			
				Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$
OMN- 98	Oudam	83/ 3/ 9	7.7	16.3	0.2	0.7	3.9	tr.	5.0	11.0	4.9
99	Al-Musana'ah	"	6.9	5.2	0.1	1.7	5.9	tr.	4.3	6.7	1.9
100	"	"	6.9	4.8	0.1	2.2	8.2	tr.	4.8	7.5	2.9
101	Sha'ibah	83/ 3/10	7.0	4.8	0.1	2.7	8.7	tr.	3.4	9.7	3.1
102	"	"	7.3	6.1	0.6	0.8	4.2	tr.	4.3	4.9	1.9
103	Abu Abali	"	7.1	7.6	0.1	1.7	6.3	tr.	3.5	8.3	3.9
104	"	"	7.2	2.8	0.1	1.0	3.9	tr.	3.1	3.6	1.0
105	Al-Suwadi	"	7.2	4.4	0.1	1.5	5.8	tr.	3.0	7.6	1.0
106	Billah	"	7.1	8.7	0.3	1.7	6.6	tr.	3.0	9.6	4.7
107	"	"	7.5	2.4	0.1	0.9	3.4	tr.	2.8	3.7	0.3
108	"	"	7.2	2.7	0.1	1.1	3.6	tr.	3.7	3.2	0.7
109	Abu Mohar	83/ 3/13	7.0	4.4	0.1	2.5	6.0	tr.	2.5	9.2	1.0
110	Oqdah	"	7.1	3.9	0.1	0.9	3.0	tr.	3.7	3.7	0.4
111	"	"	7.1	14.8	0.1	3.5	7.0	tr.	2.7	16.3	6.0
112	Hifri	"	7.1	9.1	0.1	1.9	4.9	tr.	3.2	9.9	2.7
113	"	"	6.8	4.1	0.1	2.7	4.6	tr.	3.4	6.0	2.2
114	"	"	6.8	6.1	0.1	3.5	6.2	tr.	4.0	8.4	3.4
115	ADW19	83/ 3/14	7.3	1.3	0.1	0.7	2.7	tr.	3.3	1.1	0.2
116	JT22	"	7.8	2.4	0.1	0.5	1.7	tr.	2.7	1.5	0.2
117	Na'aman	"	6.9	3.3	0.1	1.9	3.9	tr.	3.9	4.4	0.8

IONIC COMPOSITION OF THE BATINAH WATER SAMPLES (6/11) (Contd..6)

Sample No.	Sample Site	Date	pH	Cation (meq/l)				Anion (meq/l)			
				Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$
OMN-118	Na'aman	83/ 3/14	6.9	11.3	0.2	3.0	7.7	tr.	5.0	11.6	5.4
119	Barka	"	6.8	7.4	0.1	3.2	7.5	tr.	3.6	10.0	4.4
120	"	"	6.8	9.1	0.1	3.7	7.6	tr.	3.7	10.6	6.2
121	"	"	6.8	3.3	0.1	2.5	4.1	tr.	3.8	3.9	2.2
122	HT1	83/ 3/15	7.4	2.3	0.1	0.7	3.2	tr.	3.1	2.2	0.7
123	HT2	"	7.1	2.1	0.1	0.7	2.9	tr.	3.1	1.9	0.4
124	DUTCO Camp	"	7.1	4.8	0.1	1.9	4.7	tr.	4.2	4.4	2.7
137	JT52	83/ 3/19	7.4	16.5	0.2	0.7	4.7	tr.	1.4	20.6	tr.
139	JT5	"	7.4	3.8	0.1	0.8	3.8	tr.	2.8	3.8	1.5
140	JT10	83/ 3/20	7.4	2.4	0.1	0.6	2.7	tr.	2.9	2.2	0.4
141	JT57	"	7.4	1.3	0.1	0.6	2.6	tr.	2.7	1.4	0.2
142	JT13	"	7.1	2.8	0.1	1.8	4.2	tr.	3.8	3.3	1.4
143	Al-Muladdah	"	7.0	28.7	0.4	8.0	21.0	tr.	4.2	38.4	15.4
164	Barka	83/ 8/ 9	7.1	3.6	0.1	2.4	4.3	tr.	3.8	5.3	1.0
165	"	"	7.0	8.0	0.1	2.9	6.0	tr.	3.7	9.2	3.9
166	"	"	7.0	5.2	0.1	2.9	5.2	tr.	3.7	7.0	2.4
174	Al-Muladdah	83/ 8/18	7.1	32.6	0.3	4.1	12.3	tr.	5.1	26.9	17.0
175	"	"	7.2	6.3	0.1	1.7	5.6	tr.	3.6	6.9	2.9
176	"	"	7.0	26.1	0.4	7.7	20.4	tr.	4.0	39.5	10.8
177	Al-Musana'ah	83/ 8/20	7.2	5.7	0.1	0.9	5.1	tr.	3.6	6.6	1.5

IONIC COMPOSITION OF THE BATINAH WATER SAMPLES (7/11)

(Contd..7)

Sample No.	Sample Site	Date	pH	Cation (meq/l)				Anion (meq/l)			
				Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	$HCO_3^=$	Cl^-	$SO_4^=$
OMN-178	Al-Musana'ah	83/ 8/20	6.8	7.2	0.1	2.0	6.8	tr.	5.3	7.9	2.5
179	Sha'ibah	"	7.1	7.6	0.1	2.8	8.3	tr.	3.3	10.3	5.1
180	"	"	7.3	8.3	0.1	1.4	5.6	tr.	4.4	8.0	2.9
181	Abu Abali	"	7.2	8.5	0.2	1.9	6.1	tr.	3.8	8.8	3.9
182	"	"	7.3	3.6	0.1	1.0	3.3	tr.	3.4	3.5	1.0
183	Al-Suwadi	"	7.3	6.4	0.1	1.8	5.9	tr.	3.3	10.0	1.0
184	Billah	"	7.3	9.1	0.3	1.8	6.7	tr.	2.8	10.9	4.1
185	"	"	7.3	3.6	0.1	0.9	3.4	tr.	3.8	3.2	1.0
186	Abu Mohar	"	7.2	5.2	0.1	1.9	5.7	tr.	2.9	8.6	1.4
187	Oqdah	83/ 8/21	7.4	3.9	0.1	0.8	3.1	tr.	3.3	3.7	0.7
188	"	"	7.0	12.8	0.1	3.8	9.7	tr.	2.8	16.6	6.7
189	Hifri	"	7.2	6.1	0.1	2.0	5.1	tr.	3.2	8.4	1.4
190	"	"	7.0	4.6	0.1	2.6	5.0	tr.	3.1	6.7	2.4
191	Na'aman	"	7.2	3.6	0.1	1.8	3.8	tr.	3.6	4.3	1.4
192	"	"	7.0	11.1	0.2	2.7	8.0	tr.	4.4	12.4	5.1
193	Hifri	"	7.0	7.6	0.1	3.7	7.1	tr.	3.6	10.2	4.7
194	Sur Batha	83/ 8/25	7.2	9.8	0.3	5.4	14.9	tr.	2.1	23.8	4.4
195	Batha Hilal	"	7.5	6.5	0.1	0.1	2.5	tr.	4.6	3.9	0.7
196	"	"	7.2	1.2	0.1	0.7	3.8	tr.	3.8	1.6	0.3
205	Khabbah	83/ 8/29	7.2	5.2	0.1	1.5	8.3	tr.	3.5	10.2	1.4

IONIC COMPOSITION OF THE BATINAH WATER SAMPLES (8/11) (Contd..8)

Sample No.	Sample Site	Date	pH	Cation (meq/l)				Anion (meq/l)			
				Na^{+}	K^{+}	Ca^{++}	Mg^{++}	$CO_3^{=}$	$HCO_3^{=}$	Cl^{-}	$SO_4^{=}$
OMN-206	Khabbah	83/ 8/29	7.6	6.5	0.1	0.7	5.5	tr.	4.0	6.2	2.9
207	Mamfesh	"	7.3	11.5	0.1	1.8	7.9	tr.	3.1	13.9	4.2
208	"	"	7.3	4.1	0.1	0.6	4.6	tr.	3.0	5.0	1.7
209	Al-Qalat	"	7.5	5.2	0.1	1.0	4.0	tr.	3.2	5.4	1.4
210	Oudam	"	7.3	11.5	0.3	1.7	5.7	tr.	5.1	8.8	5.2
211	"	"	7.8	15.7	0.2	0.4	4.1	tr.	4.9	11.1	4.4
213	HT1	83/ 9/ 5	7.4	2.0	0.1	0.4	3.5	tr.	2.9	2.3	0.7
214	HT2	"	7.4	1.8	0.1	0.5	3.4	tr.	2.9	1.9	0.7
216	DUTCO Camp	"	7.2	4.7	0.1	1.6	4.7	tr.	4.3	4.3	2.5
217	JT13	83/ 9/ 7	7.3	2.6	0.1	1.5	4.5	tr.	3.9	3.3	1.7
220	Al-Musana'ah	"	7.5	2.6	0.1	1.5	5.0	tr.	3.5	4.0	1.7
221	JT15	83/ 9/ 9	7.5	4.1	0.1	0.7	5.3	tr.	3.9	4.1	2.2
222	JT16	"	7.4	2.8	0.1	0.7	4.4	tr.	3.0	3.5	1.4
223	JT17	"	7.6	6.3	0.2	0.5	2.7	tr.	3.4	6.3	0.2
224	ADW7	83/ 9/10	7.7	2.8	0.1	1.1	4.4	tr.	3.5	4.0	1.2
225	JT5	"	7.5	3.6	0.1	0.7	3.8	tr.	2.9	3.8	1.4
227	JT52	"	7.7	8.0	0.2	0.6	2.4	tr.	2.0	9.2	0.2
228	JT68	83/ 9/11	7.9	3.0	0.1	0.2	2.0	tr.	3.2	1.3	0.8
229	JT67	"	7.8	1.6	0.1	0.1	2.6	tr.	2.7	1.2	0.4
230	JT57	"	7.7	1.5	0.1	0.2	2.6	tr.	2.5	1.4	0.4

IONIC COMPOSITION OF THE BATINAH WATER SAMPLES (9/11) (Contd..9)

Sample No.	Sample Site	Date	pH	Cation (meq/l)				Anion (meq/l)			
				Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	$HCO_3^=$	Cl^-	$SO_4^=$
OMN-231	JT10	83/ 9/11	7.7	3.2	0.1	0.2	2.9	tr.	2.8	2.3	1.0
232	JT12	"	7.8	3.0	0.1	0.2	2.7	tr.	2.4	3.1	0.5
235	Al-Khishdah	83/ 9/12	7.6	11.5	0.1	0.5	3.5	tr.	5.4	6.9	3.2
236	"	"	7.8	11.1	0.1	0.3	3.3	tr.	6.4	5.0	3.7
237	"	"	7.7	4.1	0.1	0.4	2.6	tr.	3.6	2.1	1.3
239	Shubaibah	"	7.4	18.7	0.0	2.3	4.7	tr.	4.2	10.2	11.3
240	W.Faras	"	7.6	46.5	0.1	2.0	5.9	tr.	7.0	27.7	19.6
241	Tawi Sufai	"	7.3	3.6	0.1	0.7	4.5	tr.	3.6	3.1	1.9
242	OA3	83/ 9/13	10.1	7.8	0.1	tr.	0.3	2.9		5.3	0.2
243	Mijaz	"	7.5	4.8	0.1	0.7	7.9	tr.	3.1	7.2	3.2
244	"	"	7.8	9.8	0.1	0.2	5.5	tr.	3.0	8.6	4.2
245	Awainat	"	7.5	2.4	0.1	0.3	4.1	tr.	3.3	2.3	1.0
246	Otob	"	7.4	9.4	0.1	1.0	12.5	tr.	3.6	12.4	7.2
247	JT22	83/ 9/15	7.7	2.5	0.1	0.3	1.9	tr.	2.7	1.5	0.7
248	JT21	"	7.7	2.9	0.1	tr.	3.4	tr.	2.6	2.8	1.0
249	ADW19	"	7.2	1.4	0.1	0.5	3.0	tr.	3.0	1.0	0.7
255	BG1	83/ 9/22	7.8	1.7	0.1	0.8	4.3	tr.	4.5	1.7	0.7
257	BG2	83/ 9/27	6.9	3.0	0.1	1.3	3.2	tr.	3.2	2.6	1.4
266	Barka	84/ 2/21	7.4	21.7	0.4	8.2	24.0	tr.	5.2	41.4	7.9
267	Oqdah	"	8.0	17.4	0.6	2.0	9.8	tr.	4.4	18.5	6.9

IONIC COMPOSITION OF THE BATINAH WATER SAMPLES (10/11) (Contd..10)

Sample No.	Sample Site	Date	pH	Cation (meq/l)				Anion (meq/l)			
				Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	$HCO_3^=$	Cl^-	$SO_4^=$
OMN-269	Abu Abali	84/ 2/21	7.7	17.0	0.3	3.1	11.3	tr.	4.5	17.7	9.6
273	Na'aman	84/ 2/22	8.3	2.0	0.0	1.5	5.3	tr.	5.3	2.3	1.0
277	ADG26	83/10/ 8	7.9	3.0	0.1	0.3	4.8	tr.	3.1	4.7	0.7
278	JT22	83/10/16	8.4	2.6	0.1	0.4	2.3	tr.	3.2	1.5	0.7
279	JT20	83/10/30	8.4	4.1	0.1	0.5	2.8	tr.	3.2	3.3	1.2
280	JT24	83/12/21	7.9	1.9	0.1	0.5	2.4	tr.	2.8	1.6	0.4
281	BM3	83/12/27	8.3	2.0	0.1	0.8	3.5	tr.	2.9	2.7	0.7
282	BF1	84/ 1/ 3	8.2	228.0	0.7	32.0	104.5	tr.	2.4	334.0	29.1
283	BA1	84/ 1/13	6.8	134.8	2.1	10.0	70.0	tr.	2.5	200.0	14.2
284	BMET	84/ 1/30	7.7	3.9	0.1	0.2	6.1	tr.	4.0	4.1	1.9
286	Saiq	84/ 5/24	7.5	2.4	0.1	1.9	9.0	tr.	8.6	2.5	2.2
288	JT14	84/ 7/26	7.9	3.6	0.1	0.2	3.1	tr.	2.5	3.2	1.4
297	EA3	84/ 8/14	8.9	3.9	0.3	tr.	0.3	tr.	1.2	2.5	1.0
298	EA4	"	7.8	2.4	0.1	tr.	2.0	tr.	2.3	2.0	0.4
302	DW4, 20m	84/ 8/22	8.2	2.2	0.1	0.6	2.9	tr.	3.0	2.4	0.4
303	" , 40m	"	8.1	2.2	0.1	0.6	2.8	tr.	2.9	2.4	0.7
304	" , 60m	"	8.2	2.3	0.1	0.5	2.8	tr.	2.9	2.4	0.4
305	" , 80m	"	8.0	69.6	0.5	7.3	23.2	tr.	1.0	91.6	7.9
306	" ,100m	"	8.1	47.8	0.3	6.0	16.8	tr.	2.2	214.1	20.0
308	" ,140m	"	7.4	382.0	1.7	36.0	141.6	tr.	1.1	522.0	38.0

IONIC COMPOSITION OF THE BATINAH WATER SAMPLES (11/11)

(Contd..11)

Sample No.	Sample Site	Date	pH	Cation (meq/l)				Anion (meq/l)			
				Na^{+}	K^{+}	Ca^{++}	Mg^{++}	$CO_3^{=}$	$HCO_3^{=}$	Cl^{-}	$SO_4^{=}$
OMN-309	WSI 24	84/ 8/23	8.6	6.7	0.2	0.5	6.5	tr.	3.1	7.5	3.7
310	BA1, 14m	"	8.2	9.2	0.1	0.3	3.6	tr.	3.7	7.4	2.2
311	" , 80m	"	7.6	174.0	1.4	50.0	225.0	tr.	1.1	426.0	23.2
312	BM1, 10m	84/ 8/25	8.0	37.4	0.6	5.0	25.1	tr.	3.8	43.8	20.8
313	" , 75m	"	7.7	615.2	6.3	30.0	122.0	tr.	3.7	680.0	89.5
314	BF1, 14m	"	8.2	39.6	0.2	2.6	13.4	tr.	4.6	37.8	13.5
315	" , 90m	"	7.6	287.0	0.5	48.0	163.5	tr.	2.1	456.0	40.7

D - 2 STABLE ISOTOPE (OXYGEN-18 and DEUTERIUM) CONTENT OF THE BATINAH WATER SAMPLES

STABLE ISOTOPE CONTENT OF THE BATINAH WATER SAMPLES (1/5)

Sample No.	Sampling site	Date	δO-18 (‰)	δD(‰)
(Rain Water)				
OMN- 2	Mutrah	82/ 3/29	-1.07	-0.6
3	"	"	-0.79	+2.5
38	"	82/ 4/18	+2.10	+15.9
42	"	82/ 4/30	+7.74	+42.3
43	"	"	+4.75	+27.5
44	"	82/ 3/29	-1.19	+4.5
58	Ruwi	82/12/ 2	+2.20	+25.9
61	Mutrah	82/12/11	-1.86	+12.5
62	"	82/12/19	+3.10	+33.0
63	"	82/12/20	+1.58	+25.6
64	"	82/12/21	+0.44	+21.4
65	Ruwi	83/ 2/ 9	-0.60	+12.1
67	"	83/ 2/12	-4.23	-25.4
68	Mutrah	83/ 2/12	-4.45	-27.3
151	Semail	83/ 3/14	+2.44	+18.8
325	RF 2	84/11/ 4	+4.16	+25.5
(Flood Water)				
OMN- 4	Wadi Lawami	82/ 3/30	-3.29	-6.9
5	Wadi Buhayyis	"	-2.01	-3.2
40	Wadi Sha'ibah	"	-2.59	-1.3
41	"	"	-2.72	-4.1
70	Wadi Khuwairat	83/ 2/13	-8.39	-43.1
71	Wadi Al-Ma'awil	"	-7.58	-39.2
72	Wadi Bani Kharus	"	-7.64	-39.2
73	Wadi Al-Fara'	"	-6.42	-33.2
76	Wadi Ahin	"	-6.54	-36.6
77	Wadi Al-Ma'awil	83/ 2/16	-3.74	-3.7
(Falaj Water)				
OMN- 18	Khatum	82/ 4/11	-1.23	-1.5
23	Al-Rustaq	82/ 4/12	-2.50	-7.6
45	Hazam	82/ 5/ 3	-2.40	-8.5
126	"	83/ 3/15	-2.48	-6.3
127	Jamma'	"	-2.33	+2.5

STABLE ISOTOPE CONTENT OF THE BATINAH WATER SAMPLES (2/5)

(Contd..2)

Sample No.	Sampling site	Date	δO-18(‰)	δD(‰)
OMN-131	Khatum	83/ 3/16	+0.14	+2.9
136	Awabi	83/ 3/18	-3.66	-12.5
138	Wasit	83/ 3/19	-3.17	-8.1
(Spring Water)				
OMN- 1	Saiq	82/ 3/26	-3.09	-10.9
7	Al-Khadrah,W.Sahtan	82/ 4/ 6	-2.67	-6.4
9	Al-Suwarah,Nakhal	82/ 4/ 7	-3.34	-11.1
15	Al-Kesfah,Al-Rustaq	82/ 4/ 9	-2.84	-9.8
48	Al-Suwarah,Nakhal	82/ 7/11	-2.54	-10.8
51	Al-Kesfah,Al-Rustaq	82/ 7/16	-2.41	-5.6
52	Al-Adhari	82/ 7/17	-4.86	-34.2
54	Al-Kesfah,Al-Rustaq	82/ 9/15	-2.80	-10.7
55	Al-Suwarah,Nakhal	"	-2.04	-7.1
145	Al-Kesfah,Al-Rustaq	83/ 3/22	-2.74	-12.8
(Sea Water)				
OMN- 47	Al-Bustan	82/ 5/16	+0.96	+5.9
155	Suwadi	83/ 3/29	+2.03	+8.1
(Mountain and Wadi Stream Water)				
OMN- 16	Al-Khadrah,W.Mistel	82/ 4/10	-3.29	-11.2
25	Al-Mebo,W.Sahtan	82/ 4/13	-2.75	-8.8
66	Madruj, "	83/ 2/ 8	-4.20	-14.4
6	Maihah, "	82/ 4/ 6	-2.21	-4.9
10	Nakhal	82/ 4/ 7	-3.10	-10.3
11	Mazahit,W.Fara'	82/ 4/ 8	-2.25	-3.2
12	Al-Houqain,W.B.Ghafir	"	-1.15	+2.5
13	" "	"	-0.85	+0.2
17	Al-Abyad,W.B.Kharus	82/ 4/11	-1.27	+0.1
20	Khafdi,W.B.Ghafir	82/ 4/12	-1.13	-1.8
21	Murji, "	"	-1.07	+2.7
22	Zaba', "	"	-0.72	-1.4
24	Fasah,W.Sahtan	82/ 4/13	-2.47	-5.0
26	Fara',W.Fara'	"	-1.67	-1.8
27	" "	"	-1.39	-4.5

STABLE ISOTOPE CONTENT OF THE BATINAH WATER SAMPLES (3/5)

(Contd..3)

Sample No.	Sampling site	Date	δO-18(‰)	δD (‰)
OMN- 28	Al-Muhassanah,W.B.Auf	82/ 4/13	-2.64	-12.5
29	Bidah,W.Ahin	82/ 4/15	+0.21	+5.2
30	Al-Hail, "	"	+0.73	+6.9
31	Haibi, "	82/ 4/17	-0.46	+2.3
37	Bahla,W.Bahla	82/ 4/18	-1.71	-2.8
50	Mazahit,W.Fara'	82/ 7/13	-1.76	-1.3
53	" "	82/ 9/15	-0.23	-2.6
75	" "	83/ 2/13	-1.27	-2.4
78	Al-Hail,W.Ahin	83/ 2/22	+2.49	+13.8
129	Al-Houcain.W.B.Ghafir	83/ 3/16	+0.17	+5.9
(Well Water)				
OMN- 8	Afi	82/ 4/ 7	-2.63	-5.9
14	Slil	82/ 4/ 8	-2.04	-7.2
19	JT20	82/ 4/11	-2.08	-7.3
32	Maqail Girula	82/ 4/17	+1.68	+5.6
33	Wadi Faras	"	-0.64	-1.6
34	Khishidah, W.Ahin	"	-1.56	-5.0
35	"	"	-2.70	-12.1
36	"	"	-2.74	-11.4
46	Slaiman,W.Mistel	82/ 5/ 9	-2.69	-11.9
60	Wuqbah	82/12/10	-0.35	+2.6
79	Shubaibah	83/ 2/22	-1.11	-0.9
80	Maqail Girula	"	+1.50	+5.6
81	Wadi Faras	"	-1.03	+0.7
82	Tawi Sufai	"	-0.39	+1.6
83	OA 3	83/ 2/23	+0.49	+4.9
84	Khishidah, W.Ahin	"	-1.17	-1.5
85	"	"	-2.51	-6.0
86	Saham	"	-2.54	-5.4
87	Muladdah	83/ 3/ 6	-2.24	-8.6
88	"	"	-2.68	-7.4
89	Sur Al-Batha	83/ 3/ 8	-2.52	-9.0
90	Batha Hilal	"	-3.21	-14.2
91	"	"	-3.11	-12.1
92	Al-Khabbah	"	-0.94	-7.6
93	Al-Khabbah	"	-2.41	-11.3

STABLE ISOTOPE CONTENT OF THE BATINAH WATER SAMPLES (4/5)

(Contd..4)

Sample No.	Sampling site	Date	δO-18 (‰)	δD(‰)
OMN- 94	Mamfesh	83/ 3/ 9	-1.20	-4.9
95	"	"	-1.71	-5.8
96	Al-Qalat	"	-2.19	-5.2
97	Owdam	"	-0.77	+2.5
98	"	"	+1.17	-0.3
99	Al-Musana'ah	"	-3.04	-10.3
100	Al-Tarif	"	-2.32	-7.3
102	Al-Musana'ah	83/ 3/10	-0.87	-5.3
104	Abu Abali	"	-0.33	-1.3
105	Suwadi	"	+0.11	-0.4
106	Billah	"	-1.93	-9.7
108	"	"	-1.87	-6.0
109	Abu Mohar	83/ 3/13	-1.66	-5.4
110	Oqdah	"	-1.65	-3.8
111	"	"	-2.45	-6.9
112	Hifri	"	-3.09	-10.2
113	Na'aman	"	-3.33	-11.3
114	Barka	"	-3.10	-10.0
115	ADW 19	83/ 3/14	-2.93	-13.5
116	JT22	83/ 3/15	-2.39	- 9.5
117	Na'aman	"	-3.34	-15.6
118	"	83/ 3/14	-2.84	-11.2
119	Barka	"	-2.98	-7.5
120	"	"	-1.50	-6.7
121	"	83/ 3/15	-3.16	- 9.3
122	HT 1, W.B.Ghafir	"	-1.57	-2.6
123	HT 2, W.B.Ghafir	"	-1.74	-1.3
124	DUTCO Camp	"	-1.86	- 5.6
125	JT 15	"	-2.28	-6.7
139	JT 5	83/ 3/19	-3.26	-9.9
140	JT 10	83/ 3/20	-1.85	-4.4
142	JT 13	"	-1.78	-2.2
143	Muladdah	"	-2.04	-6.4
222	JT 16	83/ 9/ 9	-2.15	-6.5
223	JT 17	"	-2.33	-7.7
283	BA 1	84/ 1/13	-0.67	+3.5

STABLE ISOTOPE CONTENT OF THE BATINAH WATER SAMPLES (5/5)

(Contd..5)

Sample No.	Sampling site	Date	δO-18(‰)	δD(‰)
OMN- 288	JT 14	84/ 7/26	-2.97	-9.1
297	EA 3	84/ 8/14	-0.93	+0.3
298	EA 4	"	+0.92	+2.8
309	WSI 24	84/ 8/24	-2.54	-7.6
302	DW 4, 20m	84/ 8/22	-2.14	-7.4
303	" , 40m	"	-1.71	-5.3
304	" , 60m	"	-2.46	-8.6
305	" , 80m	"	-2.33	-8.6
306	" , 100m	"	-2.45	-8.6
307	" , 120m	"	-1.04	-6.8
308	" , 140m	"	-0.20	-2.9
310	BA 1, 14m	84/ 8/23	-1.71	-6.5
311	" , 80m	"	-0.71	-3.2
312	BM 1, 10m	84/ 8/25	-2.97	-11.1
313	" , 75m	"	+0.19	+1.8
314	BF 1, 14m	"	-2.45	-9.8
315	" , 90m	"	-1.04	-4.5
326	Jamma'	84/12/24	-1.74	-4.5

D - 3 TRITIUM CONCENTRATION OF THE BATINAH WATER SAMPLES

TRITIUM CONCENTRATION OF THE BATINAH WATER SAMPLES (1/2)

Sample No.	Sampling Site	UTM Grid	Tritium Conc. (T.U.)
(Rain Water)			
OMN- 68	Mutrah, '83,2/12	40Q FB 590131	8.4 ± 0.4
(Flood Water)			
OMN- 73	Al-Musana'ah,'83,2/13	40Q EB 622258	6.4 ± 0.3
(Wadi Stream Water)			
OMN- 66	Madruj, Wadi Sahtan	40Q EA 297708	7.8 ± 0.4
78	Al-Hail, Wadi Ahin	40R DB 546600	10.7 ± 0.5
129	Al-Houqain, WG1	40Q EB 342043	9.1 ± 0.4
134	Al-Ajal	40Q EB 932006	8.1 ± 0.4
(Falaj Water)			
OMN-126	Hazam	40Q EB 483040	16.7 ± 0.6
127	Jamma'	40Q EB 571053	14.5 ± 0.6
131	Khatum	40Q EA 700970	10.6 ± 0.4
132	Hibra	40Q EB 862000	12.2 ± 0.5
(Spring Water)			
OMN-133	Ain Al-Ajal	40Q EA 945990	1.4 ± 0.2
135	Ain Al-Kesfah	40Q EA 940992	6.3 ± 0.3
(Well Water)			
OMN- 83	OA3	40R DB 685758	9.9 ± 0.5
84	Saham	40R DB 857765	13.1 ± 0.5
85	Saham	40R DB 856764	5.6 ± 0.4
86	Saham	40R DB 865758	0.3 ± 0.3
87	Al-Muladdah	40Q EB 579260	0.5 ± 0.2
88	Al-Muladdah	40Q EB 576263	<0.2
89	Sur Al-Batha	40Q EB 403351	0.4 ± 0.3
90	Batha Hilal	40Q EB 423352	1.7 ± 0.3
91	Batha Hilal	40Q EB 420344	3.7 ± 0.3
92	Al-Khabbah	40Q EB 468340	<0.2
93	Al-Khabbah	40Q EB 481330	0.1 ± 0.2
94	Mamfesh	40Q EB 517311	0.1 ± 0.3
95	Mamfesh	40Q EB 510315	0.2 ± 0.2

TRITIUM CONCENTRATION OF THE BATINAH WATER SAMPLES (2/2)

Sample No.	Sampling Site	UTM Grid	Tritium Conc. (T.U.)
OMN- 96	Al-Qalat	40Q EB 540299	3.5 ± 0.3
97	Oudam	40Q EB 557286	2.3 ± 0.3
98	Oudam	40Q EB 562278	0.2 ± 0.3
99	Al-Musana'ah	40Q EB 620266	<0.2
100	Al-Tarif	40Q EB 633261	0.7 ± 0.2
101	Al-Sha'ibah	40Q EB 650255	<0.3
102	Al-Sha'ibah	40Q EB 676253	<0.2
103	Abu Abali	40Q EB 686255	<0.2
104	Abu Abali	40Q EB 694249	<0.2
105	Al-Suwadi	40Q EB 738241	0.1 ± 0.2
106	Billah	40Q EB 753231	0.6 ± 0.4
107	Billah	40Q EB 747235	<0.3
108	Billah	40Q EB 771227	1.7 ± 0.4
109	Abu Mohar	40Q EB 789216	<0.4
110	Oqdah	40Q EB 797212	0.1 ± 0.2
111	Oqdah	40Q EB 815202	0.7 ± 0.3
112	Hifri	40Q EB 830195	<0.4
113	Na'aman	40Q EB 849186	0.3 ± 0.3
114	Barka	40Q EB 880175	0.5 ± 0.3
116	JT22	40Q EB 373221	0.7 ± 0.3
117	Na'aman	40Q EB 860180	<0.4
118	Na'aman	40Q EB 876193	<0.4
119	Barka	40Q EB 899173	1.3 ± 0.3
121	Barka	40Q EB 927176	0.6 ± 0.3
122	HT1	40Q EB 507288	0.2 ± 0.3
123	HT2	40Q EB 463236	2.4 ± 0.3
130	DUTCO Camp	40Q EB 562175	<0.3
137	JT52	40Q EB 935102	0.1 ± 0.3
139	JT 5	40Q EB 984114	0.4 ± 0.3
140	JT10	40Q EB 781141	<0.3
141	JT57	40Q EB 719202	<0.4
142	JT13	40Q EB 620179	<0.3
143	Al-Muladdah	40Q EB 582280	<0.2
222	JT16	40Q EB 542131	<0.3
223	JT17	40Q EB 511088	0.5 ± 0.3

SUPPORTING REPORT E

LAND AND WATER USE SURVEY

SUPPORTING REPORT E
(LAND AND WATER USE SURVEY)

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CHAPTER 1 LAND USE SURVEY

1.1 Natural Environment of the Study Area

The desert and arid zones, accounting for about 30% of the total land in the world, are characterized by distinctively different natural environment in terms of agricultural productivity as compared with humid and fertile agricultural zone like Japan and, therefore, are endowed with little, if any, arable land.

The gravel plains extending over the Study Area along the Batinah Coast are generally composed of gravels and silt that have accumulated in the long past. The plains, partly being covered with sand dunes, are generally arid and are rarely utilized as arable land. Geographically, the zone with an annual precipitation of 0 to 250 mm is classified as Arid Region and the Study Area belongs to this Region with an annual precipitation of about 100 mm.

However, the southern part of the Study Area where the mountains are as high as 3,035 m has an annual precipitation of 200 to 300 mm which eventually turns into precious water resources for agriculture in the Batinah Coast.

In addition, the Piedmont area gravel plains receive limited effective rainfall (1 - 5 times a year) during the winter period of December to March which allows various plants to grow and the Bedouin to engage in grazing goats and sheep.

The agricultural production is primarily located in the belt zone parallel with the coastline where the groundwater along the coast is available most readily in the shallow underground. (Refer to Fig. E-1-1)

In the lowlands in Wadi riverbeds of the gravel plains grow trees such as the acacia of arid zone and shrubs with protective thorns and other fleshy plants peculiar to the arid zone.

The main roots of these trees reach deep into the ground to constantly absorb the groundwater and, therefore, even in the summer with little rainfall, these trees provide valuable green leaves to the goat, sheep, camels, donkeys being grazed in the plains.

Plants in the mountain region are primarily found alongside the Wadi, in the valley where the groundwater springs out, or on the cracked rocks. Alpine shrubs are identified in the mountains upstream the Ghubrah Basin and on the top of the mountains.

1.2 Land Use Classification

Land use in the arid agricultural zone is largely influenced by the availability of water resources.

The Batinah Coast with a limited annual precipitation of 100 mm has no alternative but to rely on the groundwater resources instead of natural rainfall. The coastal agricultural area is irrigated by shallow wells and produces such crops as date, lime, mango, alfalfa and other vegetables. One to two pump stations per well are installed in each farm.

As the number of farm households increased lately, there has been a concomitant increase in the use of deep wells. This gave rise to the excessive pumping discharge of more than the groundwater resources can afford to supply. In particular, the development of newly reclaimed lands undertaken in the vast land along both sides of Highway No.1 in the Study Area is likely to lead to further excessive pumping of the groundwater resources (Fig. E-1-1).

These developed and newly developed areas have been sold by the government to individuals in parcels of 10 feddan (4.2 ha) per household. The number of farms registered at Ministry of Housing and Ministry of Agriculture in two years from 1981 reached approximately 12,200 with an estimate total parcelled area of about 10,000 ha (as of September 1985). Farms in the Study Area are classified, from the topographic viewpoint, into those along the coastal area that make use of the well water and those in the mountain region that utilize the spring water and falaj.

In terms of water use, these farms are further divided into the following four types (Table E-1-1), which are outlined below.

1) Traditional belt farms along the coastal line which are irrigated through pumping shallow wells.

Wadi Basin	Area (ha)
Wadi Ahin	540
Wadi Bani Ghafir	1,830
Wadi Al-Fara'	1,680
Wadi Bani Kharus	1,440
Wadi Al-Ma'awil	2,090
Total	7,580

2) Farms as old as a thousand years located in the gravel plains and at the foot of the mountains which make use of spring water or falaj..

Wadi Basin	Villages	Area (ha)	Sub-total (ha)	
Wadi Bani Ghafir	Daris	12.9		
	Wustah	19.6	3 villages	66.7
	Ali	34.2		
Wadi Al-Fara'	Jamma	71.4		
	Hazam	43.4		
	Shubaykah	22.7		
	Wishal	151.4	8 villages	894.9
	Al. Mazahit	5.0		
	Wabal	197.4		
	Rustaq	327.0		
	Al-Awabi	76.6		
Wadi Bani Kharus	Khatum	13.0	1 village	13.0
Wadi Al-Ma'awil	Ali Ajal	43.7		
	Hibra	116.4		
	Afi	137.6	6 villages	654.9
	Muslimat	111.7		
	Nakhal	236.5		
	Tawiyah	9.0		
Grand Total			1,629.5 ≈ 1,630	

3) Farms along the Wadi in the mountain region that make use of relatively flat land and head race. (These are on terrace fields because of canals along the contour line that distribute spring water, groundwater, surface water, and falaj.)

Wadi Basin	Area (ha)
Wadi Ahin	73
Wadi Bani Ghafir	231
Wadi Al-Fara'	189
Wadi Bani Kharus	256
Wadi Al-Ma'awil	46
Total	795

4) Newly developed farms irrigated by deep well along the coastal line located in the upper stream of type-1 farms above.

Wadi Basin	1981-82	1983-84	Total
Wadi Ahin	620	620	1,240
Wadi Bani Ghafir	1,100	440	1,540
Wadi Al-Fara'	1,960	1,010	2,970
Wadi Bani Kharus	1,030	670	1,700
Wadi Al-Ma'awil	1,280	1,340	2,620
Total	5,990	4,080	10,070

The present land use areas classified above are summarized below.

1.	Traditional farms along the coast (1981 Aerial Photographs)	7,580 ha
2.	Farms in the gravel plains and at the foot of the mountains (1981 Aerial Photographs and Field Survey)	1,630 ha
3.	Farms with head race in the mountain region (1981 Aerial Photographs and Field Survey)	795 ha
	Sub Total	10,005 ha
4.	Newly developed farms (1981 - 1982 Ministry of Housing Data)	5,990 ha
5.	Newly developed farms (1983 - 1984 Ministry of Housing Data)	4,080 ha
	Sub Total	10,070 ha
	Grand Total	20,075 ha

The Study area has a total farmland of about 20,000 ha in the five wadi basins.

1.3 Present Land Use

The Study Area extends in the South Batinah Coast and is traversed totally by five Wadi, namely Wadi ahin, Wadi Bani Ghafir, Wadi Al-Fara, Wadi Bani Kharus, Wadi Al-Ma'awill.

The Study Area is administratively composed of seven Wilayat (which correspond to a provincial government), namely, Barka, Musanaah, Suwayq and Saham along the Coast as well as Nakhal, Rustaq, and Awabi in the mountain region.

The crop production in the Batinah Coast is constrained by extremely unfavorable natural conditions, especially very scarce precipitation. The production, therefore, cannot solely rely on precipitation and has no alternative but to require pumping groundwater.

Thus, the area with potential groundwater resources is served by numerous irrigation canals stretching from the water source in all directions to ensure maximum use of the irrigable area. The groundwater obtained, however, is not effectively utilized and a substantial loss is taking place in the canal and the farm, for which the following reasons are identified.

1. Lack of conformity in canal construction
2. Waste of irrigation water through leakage in the canal
3. Water management is crude and there is excessive dependence on farm labor from abroad
4. Generally rough and intensive planting of crops
5. Contrary to the reason 4, wide areas are left unused and follow because of unscheduled planting

The date farms close to the coastline have often been deserted because of intensified salinity. In the case of Musanaah, the deserted areas amount to about 26% (80 ha) of the sample area or about 300 ha.

In addition, the villages along the coastline have, in an extensive area, farms which appear to have been cultivated some 10 years ago or so. These farms cover a wide area, however, the lack of data would not allow the accurate estimate.

Interviews with farmers were made in August 1985 for coastal farm owners who have cultivated the land more than fifty (50) years in the same location. According to the interviews, the reason for the desertion of the land is not only the salinity problem, but the lack of labor force, low crop productivities per unit farm and lack of funds for replacement of superannuated pumping facilities.

The farms are also being deserted in the mountain area and gravel plains in the upstream area and at other areas where falaj and spring water are made use of. There, farms are about 10% of the existing farm areas and sometimes reach 30 to 40% in certain villages.

There are some falaj poorly operated and maintained because these facilities were constructed deep in the ground more than a thousand years ago and there are also other falaj whose discharge has declined substantially because of the long-term changes in natural environment.

The farms with spring water or falaj under the above conditions are at present often left uncultivated for lack of water, however, in the previous year when the groundwater resources were sufficient, 15% or so of these farms were occasionally planted with upland crops in eleven (11) villages in the study area.

The following table lists the eleven villages with this type of farm.

Wadi Basin	Village	Total farm Area (ha)	Uncultivated Area (ha)	Percentage of Uncultivated Area (%)
Wadi Bani Ghafir	Daris	13	3	23
	Wustah	20	5	25
	Ali	34	15	44
Wadi al-Fara'	Wishal	151	32	21
	Wabal	197	9	4
	Rustaq	327	13	3
Wadi Bani Kharus	Layjah	36	7	19
Wadi Al-Ma'awil	Al-Ajal	44	13	29
	Afi	138	29	21
	Muslmat	112	19	16
	Nakhal	236	44	18
Total		1,308	189	14.5

1.4 Sample Area

Specific land uses in the study area have been surveyed in the selected four Wadi areas. The purpose of the field survey in the sample area was assesment of the present farm land use, namely, to enumerate the number of wells and pumping stations per farm as well as the number of farms with each different kind of crop. However, the farms were fenced with withered twigs and barbed wire and this made the preparation of land use maps quite difficult. (Fig. E-1-4)

Summary of the sample area is presented below.

1) Saham

The cultivated land 2 km wide in the sample area of Saham stretches almost paralled with the coast line and Highway. There are 53 farms of totally about 100 ha in the vicinity of the mouth of Wadi Ahin, of which 13 farms are deserted. There are 60 pumping stations, which implies a small irrigated area of about 1.33 ha per station.

Intercropping of date and lime is commonly practiced and there are two melon farms far away from the coastal area. (Fig. E-1-2)

Sample Area	:	100 ha
No. of Farms	:	53
No. of Pumping Stations	:	60
Irrigated Area per Station	:	1.3 ha
Major Crops	:	Date and Lime

2) Al-Musana'ah

The sample area of about 300 ha in Musana'ah covers the whole strip 5 km wide from the coast line toward the Highway and part of the area in the upper stream of Highway. Starting from the coastal area, it is characterized by seven distinctive land-use zone as follows: (Fig. E-1-2)

1) Outside the sample area, Musannah town is located on the coastal sand dune whereas schools, police station, and a newly developed residential area are located on the outskirts of the town.

2) The area in the second zone close to the coastline is characterized by soil with a high salinity level and, therefore, locally by special vegetation resistant to high salinity. Part of it used to be planted with date, but it is at present deserted. (Of the total 79 farms in the sample area, 30 farms or about 80 ha have been deserted)

3) The area in the third zone is primarily planted with date and partly with alfalfa and lime.

4) In the next zone, the area is mainly planted with lime and alfalfa and partly with old date.

5) The area in this fifth zone is located upstream the old national road and is mainly planted with vegetables and partly with some other crops like alfalfa, lime, and mango, etc.

6) The area in the sixth zone has newly been developed upstream the new Highway and is currently planted with alfalfa for sale. This area is still being developed to introduce crop rotation among various vegetable crops.

7) In addition to the above six types of farm areas, there is an area (outside the sample area further upstream from the above farm zone) which currently lies in the gravel plains but has been fenced and registered at Ministry of Housing and Ministry of Agriculture for the purpose of further future development.

Sample Area	:	About300 ha
No. of Farms	:	79
No. of Pumping Stations	:	99
Errigated Area per Station	:	2.3 ha
Major Crops	:	Date, Alfalfa, and Vegetables

3) Suwayq

The sample area of 31 farms abut 100 ha in Al-Suwaiq is located on a 4 km strip in between the coastline and the national highway and has mainly been planted with date, alfalfa and lime. Vegetables and other crops such as banana, mango etc. have been planted a little around the shallow well. Alfalfa is produced on a part of 20 farms and lime trees on 10 farms out of the total 31 farms. (Fig. E-1-4)

4) Barka

The sample area of about 100 ha in Barka is also located on a 5 km strip in between the coastline and the Highway and has primarily been planted with date for a long time.

Alfalfa for forage has also been cropped for some decades now on part of 37 farms out of the total 40 farms. Other crops produced are lime in 3 farms and some vegetables. (Fig. E-1-4)

Sample Area	:	100 ha
No. of Farms	:	40
No. of Pumping Station	:	44
Irrigate Area per Station	:	1.6 ha
Major Crops	:	Date and Alfalfa

In the total sample area, the primary crop planted is date, and lately alfalfa and vegetables are increasingly produced in many of the farms.

Farms near the coastal areas are often left uncultivated because the salt accumulated in the soil would not allow a profitable date production. The farms are usually tilled by farm labors from abroad such as Bengali and Indians while the landowners often engage in other commercial activities.

1.5 Crop Production (incl. livestock) and Planted Area

According to the Agriculture census in 1979, the planted areas by crop in the Study Area (the whole administrative area including the Study Area) are classified as follows: (Table E-1-6 to E-1-8)

Vegetables (Winter Crops)

Onion	72 ha
Peas	25 "
Maize	21 "
Potato	16 "
Eggplant	13 "
Garlic	11 "
Sorghum	11 "
Tomato	7 "
Pepper	7 "

Others (Cabbage, Radish, Carrot, Cucumber)

(Summer Crops)

Watermelon	131	ha
Melon	18	"
Okra	7	"
Squash	2	"

Fruits

Date	6,195	ha
Mango	1,005	"
Lime	604	"
Banana	271	"

Others (Guave, Almond, Fig, Orange, etc.)

Vegetables are cropped both in summer and winter. Winter crops are planted from September to October after the hot period is over, and harvested in February to April whereas summer crops are planted in February to March and harvested in June to August (Fig. E-1-5 Present Cropping Patterns).

There have been an increasing number of newly developed farm areas in the last few years (1981 - 84) where mainly vegetables and some fruit trees are planted. Forage crops such as alfalfa are planted making use of small strip of areas between the fruit trees, with a resultant increase in grazing and vegetable areas.

With respect to fruit areas, date farms particularly along the coastline are decreasing in number because of the salinity problem and the unit yield is also declining due to slow replacement of date trees over 30 years old. Dates of poor quality, therefore, are often used as animal fodder. As a result, not only date but also lime, mango and other fruit areas are declining.

Livestock raised traditionally in the Batinah Coast are goat, sheep, donkey and camel. The latter two used to be raised not only for farm tasks but also as a means of transportation. However, since 1970 with replacement by automobiles and tractors, they have become unprofitable.

In contrast, many farm households have started to raise 3 - 5 heads of cattle on the alfalfa produced in their farms. Goats and sheep are also expected to increase in number because these account for a large portion

of meat consumption in the Middle and Near East, and are consumed on ceremonial occasions several times a year. Chickens are raised on a large-scale commercial basis, but are capable of meeting only a small fraction of local demand.

The present crop intensity of different types of planted crops was estimated in the farm survey on 20 farms along the coastline of the Study Area.

In case of the mountain region, two representative households were sampled. The average farm size of these 22 sample households was about 10 feddans.

The average ratio of Planted area is as follows; (See also Table E-1-3)

Crops	Planted Area (%)
Date	25.2
Alfalfa	15.7
Vegetable	13.0
Lime	11.0
Mango	7.5
Banana	0.1
Grape	0.1
Fallow	27.4
Total	100.0

A field survey has been carried out so as to clarity the present cropping intensity of each crop grown in the coastal area of the Study Area at the selected 22 sample farms. As a result, the average acreage of the farm land owned by 22 sample farmers was found to be about 10.0 feddan (4.2 ha). The cropping intensity by crop is shown as about 25 percent for dates, about 11 percent for lime and about eight percent for mango, totaling about 44 percent for tree crops, with about 16 percent for alfalfa as forage and about 13 percent for vegetables. The balance about 27 percent of barbed-wire fenced arable land is left uncultivated due to its being located far from wells sources of water for irrigation.

The average number of livestock per farm household is as follows;

	Average Livestock per farm household	
Goat	7.5	head
Sheep	3.4	"
Cattle	1.5	"
Camel	0.3	"
Donkey	0.4	"

1.6 Study of Present Land Use

(1) General

The Agriculture census in 1979 has revealed the scale of farming in the coastal area of the Batinah Coast. About 44 percent of the farmers own less than 1.0 ha, about 45 percent own between 1.0 ha and 5.0 ha, about 10 percent own more than 5.0 ha, and about 15 percent are landless farmers. (Ref. Table E-1-4)

The said census clarified that almost all of the farmers in the mountainous area, about 79 percent, own an average of about 0.5 ha only, with about 13 percent owning between 0.5 ha and 1.0 ha, and only about eight percent owning more than 1.0 ha. In total, about 92 percent of the farmers in the mountainous area own less than 1.0 ha only.

Recently, however, the Government has begun to dispose of national land extending in the upper basin of the wadi in 10 feddan (4.2 ha) parcels to Omani citizens who want to carry out farming there. The policy of the Omani Government, thus, will increase the number of farmers owning 10 feddan in the area.

On the other hand, the scale of farming land is not expected to be expanded in the mountainous area, and the younger sons of the farming families (eldest sons are successors) are prone to leave their home village where the expansion of the farm land is not expected and further irrigation water sources are unavailable. Such influx of the farm children to towns has resulted in rapid depopulation of mountainous villages.

(2) Land disposal

As explained above, the Government has promoted farm land disposal to people who are well-qualified and land reclamation has been making good progress in the gravel plain. The very large acreage of these newly reclaimed farm land at the time of the Agriculture Census in 1979 was registered during the period between 1981 to 1985 when the land development act was enacted. The registered farm land was fenced with barbed wire and levelled for farming, and provided with tube-wells and/or houses for farm management.

The status of land reclamation by districts is described below. (Ref. Fig. E-1-1)

1) Saham Area (Wadi Ahin)

2) Al-Suwaiq Area (Wadi Bani Ghafir)

In this area as well, the land disposal has been promoted in the upper basin of the Wadi along the road to the villages.

3) Al-Musanaah Area (Wadi Al-Fara and Wadi Bani Kharus, and Wadi Bani Ghafir)

The land reclamation has been promoted on both sides of the Al-Rustaq Road for about 20 km distance (Al-Muladdah side) and on the both sides of the road to Jamma village for about 10 km.

4) Barka Area (Wadi Al-Ma'awil and part of Wadi Bani Kharus)

In this district, the land reclamation has mostly been carried out on both sides of the Rustac Road about 12 km long, and along the road to Hatum village. On the both sides along National Highway No.1, almost of all the land was reclaimed and disposed of in strips 3.0 to 4.0 km in width.

The newly reclaimed land has been increased in acreage along the national highway.

As a whole, in the area along the road, about 10,000 ha of the newly reclaimed land, almost equivalent to the acreage of the existing farm land, have been developed into farm land supported by groundwater sources.

"Sultan Decree No 5/80. Land Act" was issued in 1980 as regulation of the land, according to which the reclaimed farm land has been disposed of to individuals since then.

Recently, farm land disposal has been promoted to an extremely large extent in the area along the national highway of the Batinah Coast not far from Muscat, the capital of the country. On the other hand, the groundwater as irrigation water sources for the existing farm land has been adversely affected by sea water intrusion in the coastal area. Under the circumstances, the Water Resources Council has issued the regulation of the land disposal referred to below.

The areas where the regulation of land disposal is applied in the Study Area are as follows;

1 The area 48 km long x 3.0 km wide along National Highway No.1 between Seeb and Barka

2 The area 55 km long x 7.0 km wide along National Highway No.1 between Barka and Al-Suwaiq

3 The areas where the regulation has been applied since 1981 and new wells and aflaj digging is prohibited within 3.5 km from existing mother wells and aflaj.

The people who wish to have disposal of the reclaimed land should have the following qualificaitons;

1 To have Omani nationality

2 To engage in farming themselves

3 To be adults over 21 years of age

The well-qualified persons have the right to be owners of the newly reclaimed land, commonly of 10 average feddan, although 15 feddan (6.2 ha) is the maximum.

For the first three years after disposal, however, the said land is deemed as rented from Government. Thereafter, the land can be owned by the relevant persons with approval of the Central Committee of the Ministry of Housing. If the new land owners should not use the land for farming or should use it for any other purpose than those applied for in the procedures, the land ownership by such persons can be cancelled. When such persons wish to dispose of the land for other purposes than farming (namely, housing lots, commercial lots, industrial lots, etc.), the persons should obtain approval from Ministry of Housing after receiving permission of the authorities concerned and the local Chamber of Commerce.

(3) Evaluation

As mentioned in the previous paragraph, the agricultural land in the Study Area can be classified into four types of land in terms of water utilization patterns. The respective acreages are shown as follows;

1 Farm land in the coastal area irrigated by traditional hand-dug wells:
7,580 ha (38.0%)

2 Newly reclaimed and irrigated farm land in the coastal area:
10,070 ha (50.0%)

3 Farm land in the gravel plain and piedmont area, irrigated by springs or aflaj:
1,630 ha (8.05)

4 Farm land in the mountainous area, irrigated by water introduced through channel diversions acros the wadi:
795 ha (4.0%)

Total Acreage : about 20,000 ha

Based on the above, the farm land in the coastal area occupies about 88 percent of the whole farm land in the Study Area, while that in the mountainous area including piedmont is about 12 percent.

The agricultural land in the coastal area consists of the following, tree crops land 44 percent, alfalfa 16 percent, vegetables 13 percent, and the remaining land 27 percent is the left fallow land due to lack of irrigation facilities. For farm land under cultivation, the date palms are the major tree crop grown and cultivated on about 25 percent of the total farm land in the coastal area. Date palms are mainly grown on mixed farms. (Ref. Table E-1-3 and Fig. E-1-20)

The land use in the mountainous area including the gravel plain and piedmont area, different from that in the coastal area, is occupied mostly by date monoculture farms. The date farms occupy about 73 percent of the whole farm land except for the coastal area. Vegetable crop farms with winter crops as major crops occupy about 17 percent, and the fallow land about 10 percent. (Ref. Table E-1-2)

The land use ratio in the coastal area is about 73 percent, while that of the mountain area including the gravel plain and piedmont area is about 80 percent. There is not so much multi-cropping obsrved in the Study Area, although a considerable number of the date-vegetable mixed farms exist.

(4) Effective Land Use

For the existing farms in the coastal area, the water is conveyed through the channels for irrigating the farm land after being pumped up from shallow wells and temporarily stored in the concrete tanks. These channels, mostly earth lined, have heavy leakage and cause ineffective water use.

Crop production on the farms is ineffective as well. As a whole, it is considered that the farms are far from the planned farm management ideal with only several bananas trees or a single date palm planted around a water tank. In other words, many of these farms remain as backyard ventures. Under the circumstances, ineffective and inefficient farming on the existing farms should be improved by planned farm management and providing locally suitable irrigation system and on-farm facilities so as to raise the level of the farm economy in the Batinah Coast Area. It is also deemed necessary for experts to carry out irrigation system improvement and on-farm facilities as well as extension of improved farming techinques.

The successful realization of effective land use will require assignment of a task force (experts of hydrology, groundwater designing of channels, designing of on-farm facilities, irrigation, farm management agri-extension services, etc.) to the Directorate General of Water Resources and Irrigation and the Directorate General of Agriculture, Ministry of Agriculture, as well as increase in the number of the extension staff in each Wilayat extension office. Elaborate extension services should be provided for the farmers concerned about improvement techniques of on-farm facilities and channel systems. The Government should take positive measures to aid the farmers through subsidizing the costs of construction works, extension services, construction of an agricultural center, etc.

The farms in the mountainous area are small in their farming scale and limeted in both land and water resources. Furthermore, unfavourable mountainous topography causes the farming works to be ineffective due to differences in elevation of the fields. In addition, the long distance to the markets for agricultural products has resulted in their local consumption only. In the future, therefore, the major access to the markets should be improved one by one so as to break away from local consumption agriculture to commercialized agriculture with wide markets for the newly

developed products. In this connection, the Government should make a policy to provide farm road networks for effective farm land utilization under the Government as well as for stabilizing the social order.

Basically, farm roads which can handle tractors should be provided on both upper and lower sides of the respective fields. Furthermore, liana crops like vine should be introduced in the mountainous area for effective and efficient land use. The vine will be grown on irrigable land on lattices on the mountain-side fallow land of the fields. The farm roads should be constructed under the vine trellis for the best use of the land.

1.7 Interview Survey to Farmers

Recently, the farms in the coastal area have increasingly given up cultivation in acreage. An interview survey was made of the related farmers to confirm whether the farms are given up due to inability of cultivation by sea water intrusion or not.

The interviewee farmers were selected as those who are over 50 years of age and owners of farms in the coastal area but rather far from the seashore. The selected farmers are the owners of the farms located in the following wadi basins.

Wadi Bani Ghafir	2 Farmers
Wadi Al-Fara'	1 Farmer
Wadi Bani Kharus	1 "
wadi Al-Ma'awil	1 "

The results of the interview survey have illicited reasons why the farmers have given up their farms as follows.

1) In the farms located in the coastal area, the farmers have long cultivated the dates palms traditionally by irrigation with slightly salty well water. For some reason, however, certain farmers in the coastal area moved to upper wadi basin farms with good quality water resources, or the younger generation left the farms to look for new jobs in the neighbouring local towns or Muscat, the capital of the coutry, and thus the farms in the area have been deteriorated and given up one by one.

2) Thus, it seems that the reason why some farms in the coastal area have been given up is not so simple but is complicate with many factors combined.

   o Taste of Salty Well Water

   Some farmers said that they had memory of increasing salt contents in the irrigation water of the farms near the seashore. The farms in the coastal area have not traditionally been able to grow other crops except dates, and consequently, the farm productivity in the coastal area has been inferior to that in the upper wadi basin.

o Sea Water Intrusion

Salt contents have substantially increased in the groundwater, although the interview survey could not clarify the amount of increase in sea water intrusion to the well water. However, the low productivity of the coastal area farms does not only result from the sea water intrusion but has other cuases.

a. The farms in the coastal area have long suffered from low profitability of farm products which have been adversely affected by the comparatively high salt contents from irrigation waters.

b. The time-worn irrigation ficilities have been left unmaintained due to shortage in investment funds for repair.

c. There is a chronic shortage in labour force needed for successful farm management.

d. Cyclones, which have attacked the coastal area once in ten to fifteen years, have damaged the farms so seriously as to inevitably be given up. Furthermore, there have been no facts observed to show that the water quality was better before in the coastal area farms.

o Change in Social Environment

It is considered that the mechanized irrigation with powered pumping introduced in the latter half of 1950 has increased the water drafted per well.

3) Conclusion

A decisive judgement can not be given as to the amount or effect of seawater intrusion into the coastal area, since the interview survey failed to obtain the conclusive data and information.

Table E-1-1 Land Use Classification by Topographical Condition

(Unit: ha)

Wadi Basin	Location	Coastal area	Gravel plain	Piedmont area	Mountain cultivation	Total
Ma'awill	Barka area	2,090	-	-	-	2,090.0
	Al-Ajal	-	-	43.7	-	43.7
	Hibra	-	116.4	-	-	116.4
	Afi	-	137.6	-	-	137.6
	Al-Muslimat	-	111.7	-	-	111.7
	Nakhl	-	-	236.5	-	236.5
	Other Villages	-	9.0	-	46.0	55.0
	Sub Total	2,090	374.7	280.2	46.0	2,790.9
Bani Kharus	Bilah, Bu Abali area	1,440	-	-	-	1,440.0
	Al-Abiyad	-	-	-	53.5	53.5
	Layjah	-	-	-	36.1	36.1
	Istal	-	-	-	41.6	41.6
	Al-Musaynaah	-	-	-	58.0	58.0
	Other Villages	-	13.0	-	67.0	80.0
	Sub Total	1,440	13.0	0	256.2	1,709.2
Fara	Al-Musana'ah area	1,680	-	-	-	1,680.0
	Jammah	-	71.4	-	-	71.4
	Al-Hazam	-	43.4	-	-	43.4
	Al-Shubaykah	-	22.7	-	-	22.7
	Wishal	-	-	151.4	-	151.4
	Wabal	-	-	197.4	-	197.4
	Al-Rustaq	-	-	327.0	-	327.0
	Al-Awabi	-	-	76.6	-	76.6
	Al-Fashah	-	-	-	28.8	28.8
	Amq	-	-	-	18.9	18.9
	Other Villages	-	-	5.0	141.0	146.0
	Sub Total	1,680	137.5	757.4	188.7	2,763.6
Bani Ghafir	As Suwayq area	1,830	-	-	-	1,830.0
	Daris	-	12.9	-	-	12.9
	Al-Wustah	-	19.6	-	-	19.6
	Ali	-	34.2	-	-	34.2
	Al-Hawqein	-	-	-	83.7	83.7
	Other Villages	-	-	-	148.0	148.0
	Subtotal	1,830	66.7	0	231.7	2,128.4
Ahim	Khishdah area	540	-	-	-	540.0
	Al-Heil	-	-	-	8.4	8.4
	Al-Ghozeifah	-	-	-	23.5	23.5
	Other Villages	-	-	-	41.0	41.0
	Sub Total	540	0	0	72.9	612.9
Grand Total		7,580	591.9	1,037.6	795.5	10,005.0

Source: Aerial Photographs 1/10,000 1981 MAF, OMAN

Table E-1-2 Present Land Use in the Gravel Plain, Piedmont and Mountain Area

(Unit: ha)

	Wadi Basin	Villages	Dates	Seasonal Crops	Fallow	Total
1.	Ma'awail	AL-Ajal	29.0	2.1	12.6	43.7
2.	"	Al-Hibra	76.2	40.2	-	116.4
3.	"	Afi	85.7	22.4	29.5	137.6
4.	"	Al-Muslimat	61.4	31.4	18.9	111.7
5.	"	Nakhl	184.5	8.0	44.0	236.5
	Sub Total		436.8	104.1	105.0	645.9
6.	Bani Kharus	Al-Abiyad	51.4	2.1	-	53.5
7.	"	Layjah	28.3	0.8	7.0	36.1
8.	"	Istal	31.4	10.2	-	41.6
9.	"	Al-Musaynaah	50.0	8.0	-	58.0
	Sub Total		161.1	21.1	7.0	189.2
10.	Al-Fara'	Jammah	58.6	12.8	-	71.4
11.	"	Al-Hazam	36.0	7.4	-	43.4
12.	"	Al-Shubaykah	18.4	3.5	0.8	22.7
13.	"	Wishal	78.7	40.5	32.2	151.4
14.	"	Wabal	142.2	46.4	8.8	197.0
15.	"	Al-Rustaq	275.3	39.4	12.3	327.0
16.	"	Al-Awabi	61.7	14.9	-	76.6
17.	"	Al-Fashah	24.0	4.8	-	28.8
18.	"	Amq	12.8	6.1	-	18.9
	Sub Total		707.7	175.8	54.1	937.6
19.	Bani Ghafir	Daris	6.2	3.5	3.2	12.9
20.	"	Al-Wustah	9.0	5.6	5.0	19.6
21.	"	Ali	10.9	8.2	15.1	34.2
22.	"	Al-Hawq in	72.8	10.9	-	83.7
	Sub Total		98.9	28.2	23.3	150.4
23.	Ahin	Al-Heil	8.4	-	-	8.4
24.	"	Al-Ghozeifah	21.0	2.5	-	23.5
	Sub Total		29.4	2.5	-	31.9
	Grand Total		1,433.9	331.7	189.4	1,955.0
	Ratio		(73 %)	(17 %)	(10 %)	(100 %)

Source: Aerial Photographs 1/10,000 1981 MAF, OMAN

Table E-1-3 Crop Intensity in the Sample Farms

(Unit : Feddan)

Area	Barka					Musana'ah							Suwayq				Saham				Mountain Area		Total	
Sample farms / Crops	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	R.	A.	Feddan	Ratio (%)
Dates	-	11	1.4	-	2.6	0.5	-	2.7	1.5	6.0	3.3	2.5	1.0	6.0	6.0	2.0	1.9	0.7	1.2	3.0	2.5	0.5	56.3	25.2
Lime	-	5	0.5	-	-	-	-	-	-	-	-	-	1.0	3.0	3.0	1.0	0.8	0.15	2.0	7.0	1.0	0.1	24.55	11.0
Mango	-	0.1	-	-	-	2.0	3.2	-	-	0.5	-	2.0	-	-	0.3	-	1.2	0.05	0.5	7.0	-	-	16.85	7.5
Banana	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-	0.2	0.1
Grape	-	-	-	-	-	-	-	-	-	-	-	0.25	-	-	-	-	-	-	-	-	-	-	0.25	0.1
																								43.9
Alfalfa	-	5.0	-	5.2	1.9	2.9	2.8	1.2	-	3.0	0.6	2.0	2.3	1.0	1.4	1.0	-	0.1	0.3	0.2	1.5	2.8	35.2	15.7
Vegetables	8.6	-	-	3.9	2.1	3.5	3.6	-	-	0.5	-	2.75	-	-	2.5	-	-	-	-	-	-	1.6	29.05	13.0
Fallow	12.1	3.8	1.0	4.2	-	7.0	6.6	6.1	-	-	-	6.5	-	1.0	-	2.5	8.6	-	-	0.8	1.0	-	61.2	27.4
																								56.1
Total	20.7	25.0	2.9	13.3	6.6	15.9	16.2	10.0	1.5	10.0	3.9	16.0	4.3	11.0	13.2	6.5	12.5	1.0	4.1	18.0	6.0	5.0	223.6	100.0
Livestock																								Average
Goat	25	25	13	4	-	-	-	5	-	4	-	7	-	2	4	15	-	6	7	2	6	3	128	7.5
Sheep	6	4	1	-	-	-	-	5	5	-	-	-	-	13	8	-	5	4	3	-	4	-	58	3.4
Cattle	4	2	4	-	-	-	-	-	-	1	-	-	-	-	3	4	3	-	-	4	-	-	25	1.5
Camel	0	-	-	-	-	-	-	2	-	-	-	-	-	-	-	3	-	-	-	-	-	-	5	0.3
Dounkey	1	1	-	1	-	-	-	-	-	1	-	-	-	1	-	-	-	-	1	1	-	-	7	0.4

Source : Survey Team JICA, 1983.

Table E-1-4 Estimated Farm Size by Holding and by Area

(BATINAH REGION)

(HAJAR AL-GHARBI REGION)

SIZE (Ha.)	HOLDING (No.)		RATIO (%)		AREA (Ha.)		RATIO (%)	
	BATINAH	HAJAR	BATINAH	HAJAR	BATINAH	HAJAR	BATINAH	HAJAR
TOTAL	20,130	6,380	100	100	46,126	2,624		
WITHOUT LAND	308	44	1.5	0.7	-	-	-	-
UNDER 0.5	5,236	4,972	26.0	78.0	1,201	828	2.6	31.6
0.5 - 1	3,542	858	17.6	13.5	2,559	600	5.5	22.9
1 - 2	4,950	264	24.6	4.1	7,272	335	15.8	12.8
2 - 5	4,114	198	20.4	3.1	12,389	463	26.9	17.6
5 - 10	1,254	22	6.2	0.3	8,664	150	18.8	5.7
10 - 25	594	22	3.0	0.3	8,274	248	17.9	9.4
25 - 50	110	-	0.6	-	3,898	-	8.4	-
50 - 100	22	-	0.1	-	1,868	-	4.1	-
More than 100	-	-	-	-	-	-	-	-

Source: Final Results of the Census of Agriculture, 1978/1979.

Table E-1-5 Holding and Population in the Study Area

WILAYA	NO. OF HOLDING (a)	TOTAL NO. OF RESIDENTS (b)	AGRICULTURE (c)		OUTER (d)	
			MALE	FEMALE	MALE	FEMALE
SAHAM	3,036	22,176	6,446	5,610	4,840	5,280
AL-SUWAYQ	2,420	17,402	5,060	4,796	3,916	3,630
MUSANA'AH	1,430	10,780	2,486	2,420	3,256	2,618
BARKA	2,398	16,456	3,938	3,806	4,620	4,092
SUB-TOTAL	9,284	66,814	17,930	16,632	16,632	15,620
NAKHL	1,386	10,472	3,674	3,256	1,848	1,694
RUSTAQ	4,334	30,030	8,800	8,426	6,490	6,314
AWABI	660	3,630	990	858	924	858
SUB-TOTAL	6,380	44,132	13,464	12,540	9,262	8,866
TOTAL	15,664	110,946	31,394	29,172	25,894	24,486

* An average family number is 7.08 persons (b/a).

Source : Final Results of the Census of Agriculture, 1978/1979.

Table E-1-6 Estimated Number of Holdings and Area by Wilayt

WILAYA	NO. OF HOLDING	TOTAL AREA (ha)	CULTIVATED AREA (Irrigated) (ha)	USABLE AREA (ha)	UNUSABLE AREA AND OTHERS (ha)
SAHAM	3,036	6,217	2,137	4,016	64
AL-SUWAYQ	2,420	7,995	2,757	5,238	-
AL-MUSANA'AH	1,430	4,212	1,406	2,754	52
BARKA	2,398	4,630	1,779	2,820	31
SUB-TOTAL	9,284	23,054	8,079	14,828	147
NAKHL	1,386	603	491	112	-
AL-RUSTAQ	4,334	1,514	1,112	402	-
AL-AWABI	660	506	289	217	-
SUB-TOTAL	6,380	2,623	1,892	731	-
TOTAL	15,664	25,677	9,971	15,559	147

Source : Final Results of the Census of Agriculture, 1978/1979.

Table E-1-7 Area of Cereals and Vegetables Crops

(unit=ha)

WILAYA	Roots		Cereals			Vegetables										Total
	Onion	Potatoes	Maize	Sorghum	Wheat	Water Melon	Melon	Peas	Egg-plant	Toma-toes	Okura	Pep-per	Cab-bage	Squash	Radish	
SAHAM	11	8	8	9	-	-	-	-	-	1	-	-	-	-	1	38
AL-SUWAYQ	7	1	7	2	-	9	1	19	8	3	3	-	2	2	-	64
MUSANA'AH	2	-	6	-	-	6	-	-	-	-	-	-	-	-	-	14
BARKA	2	-	-	-	-	107	17	-	5	3	4	7	-	-	-	145
SUB-TOTAL	22	9	21	11	-	122	18	19	13	7	7	7	2	2	1	261
NAKHL	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14
RUSTAQ	29	7	-	-	-	9	-	6	-	-	-	-	-	-	-	51
AWABI	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
SUB-TOTAL	50	7	-	-	-	9	-	6	-	-	-	-	-	-	-	72
TOTAL	72	16	21	11	-	131	18	25	13	7	7	7	2	2	1	333

Source : Final Results of the Census of Agriculture, 1978/1979.

Table E-1-8 Area of the Main Fruit Trees and Alfalfa

(unit=ha)

WILAYA	Date	Lime	Mango	Guava	Figs	Oranges	Pomegramate	Almonds	Bananas	Alfalfa	Total
SAHAM	1,000	133	407	1	-	-	-	-	151	124	1,816
AL-SUWAYQ	1,731	190	403	-	-	3	-	-	92	259	2,678
AL-MUSANA'AH	1,022	76	134	-	-	-	-	-	14	133	1,379
BARKA	1,186	36	41	11	-	-	1	4	4	333	1,616
SUB-TOTAL	4,939	435	985	12	-	3	1	4	261	849	7,489
NAKHL	330	19	3	-	-	-	2	-	3	78	435
AL-RUSTAQ	763	103	14	-	1	-	-	-	3	82	966
AL-AWABI	153	47	3	-	1	-	-	-	4	58	266
SUB-TOTAL	1,246	169	20	-	2	-	2	-	10	218	1,667
TOTAL	6,185	604	1,005	12	2	3	3	4	271	1,067	9,156

Source : Final Results of the Census of Agricultrue, 1978/1979.

Fig. E-1-1 Present Land Use Map

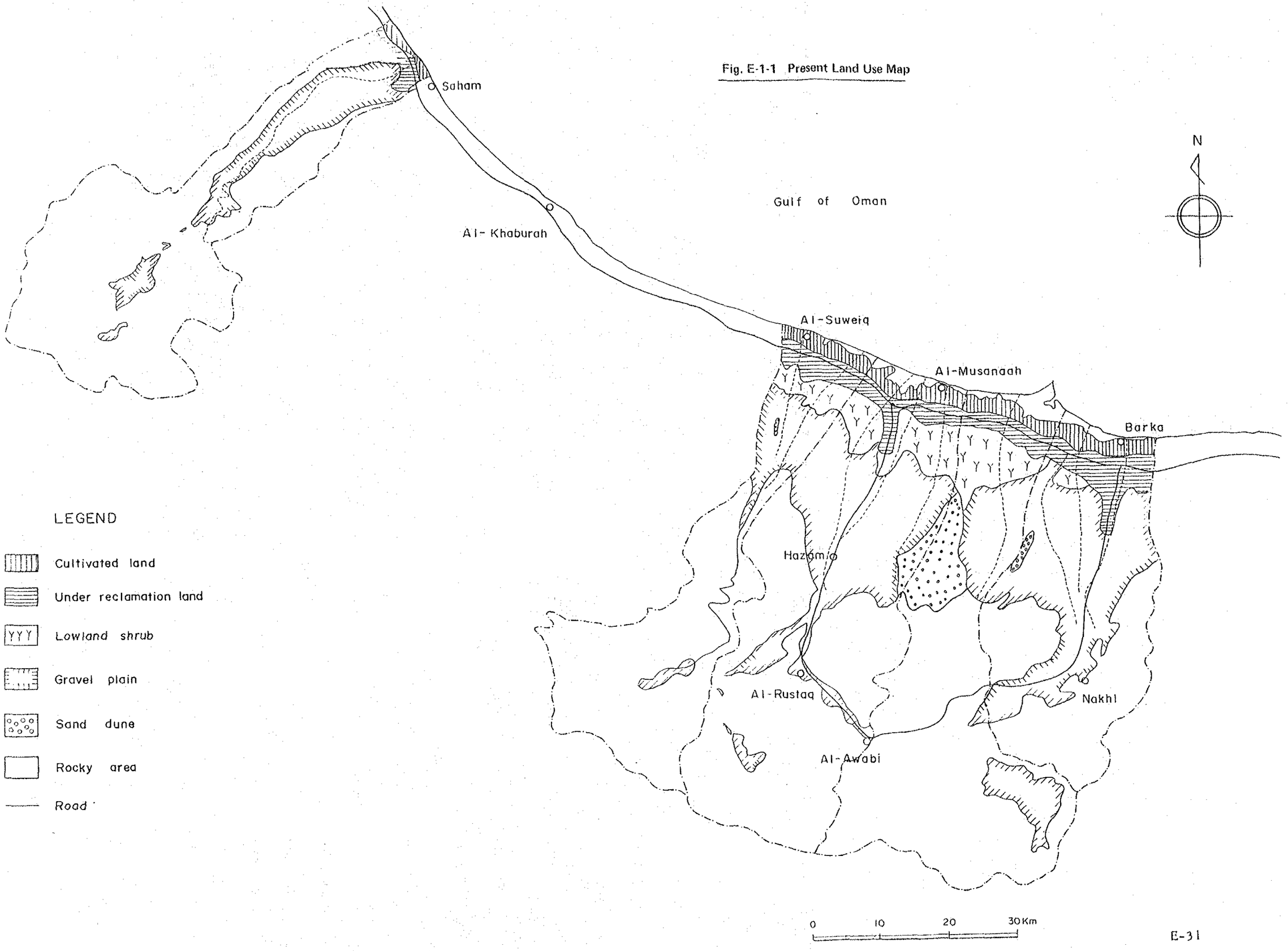
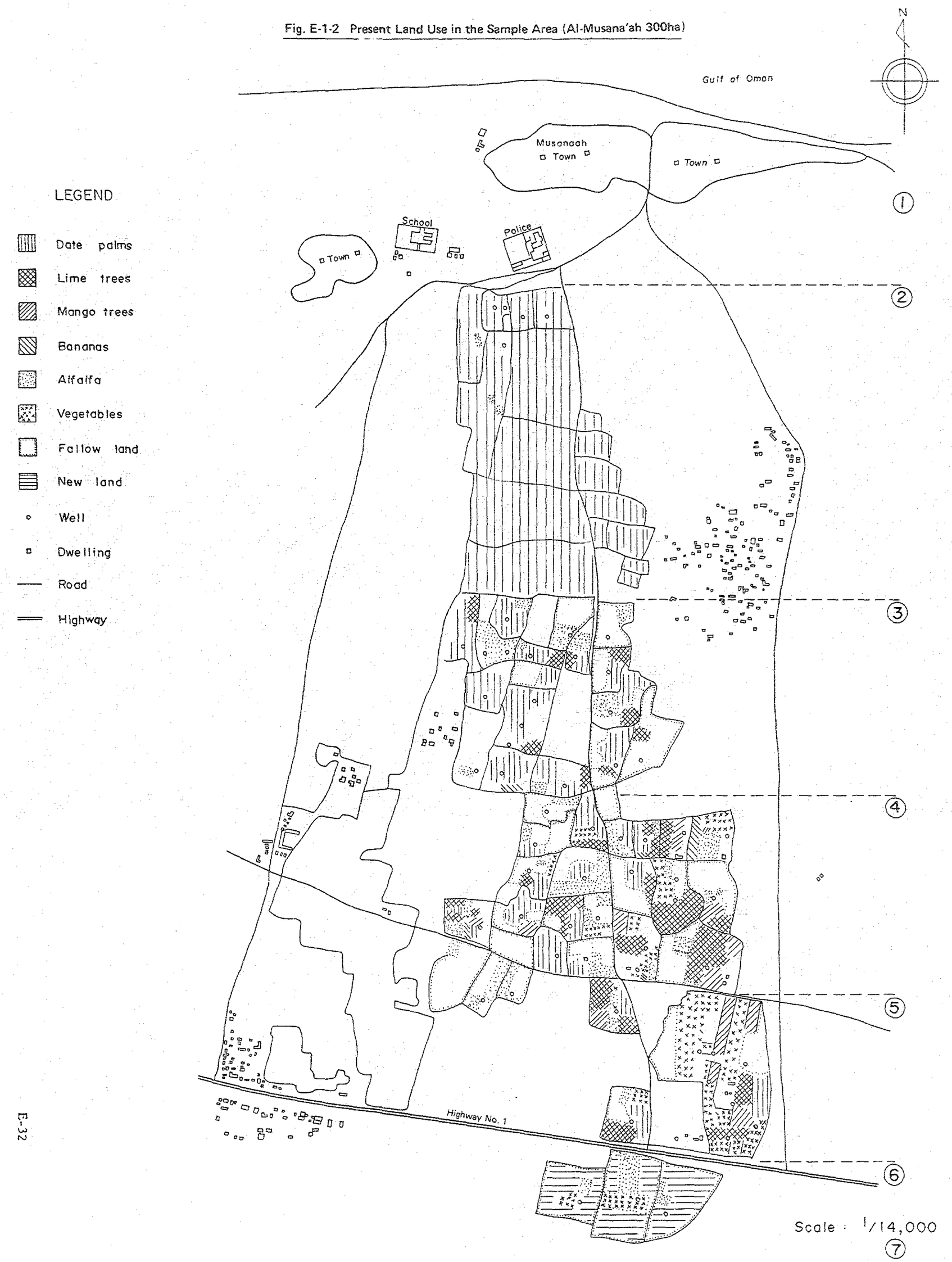


Fig. E-1-2 Present Land Use in the Sample Area (Al-Musana'ah 300ha)

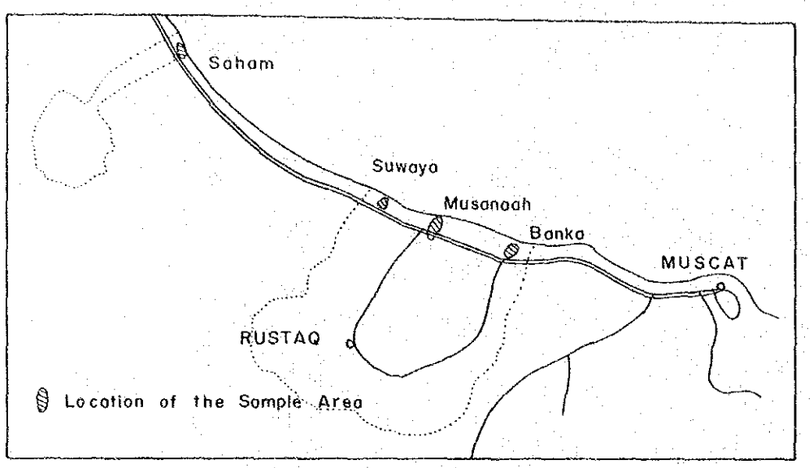


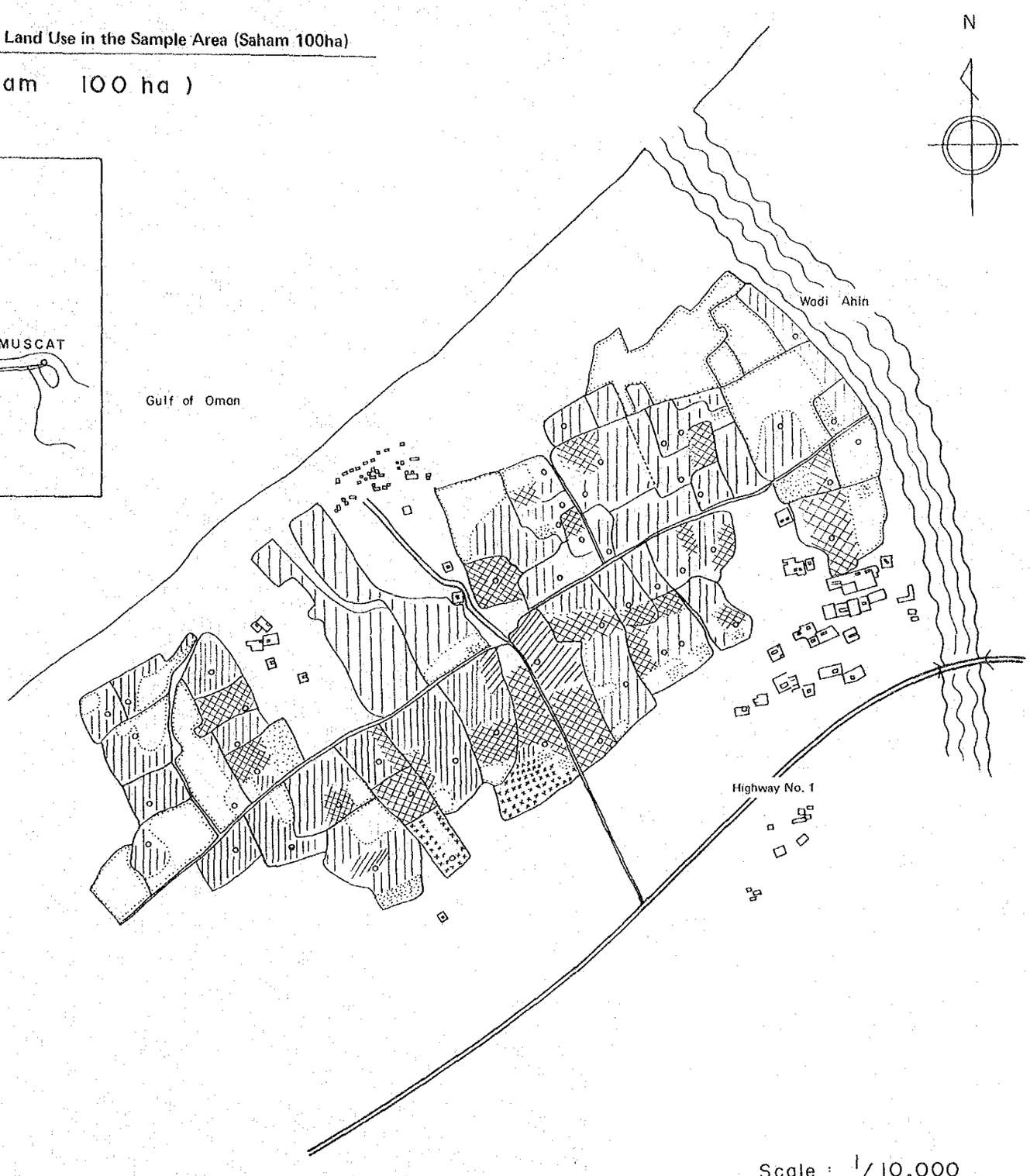
LEGEND

- Date palms
- Lime trees
- Mango trees
- Bananas
- Alfalfa
- Vegetables
- Fallow land
- New land
- Well
- Dwelling
- Road
- Highway

Fig. E-1-3 Present Land Use in the Sample Area (Saham 100ha)

(Saham 100 ha)





LEGEND

- Date palms
- Lime trees
- Mango trees
- Bananas
- Alfalfa
- Vegetables
- Fallow land
- New land
- Well
- Dwelling
- Road
- Highway

Scale : 1/10,000

Fig. E-1-4 Present Land Use in the Sample Area (Al-Suwaiq 100ha, Barka 100ha)

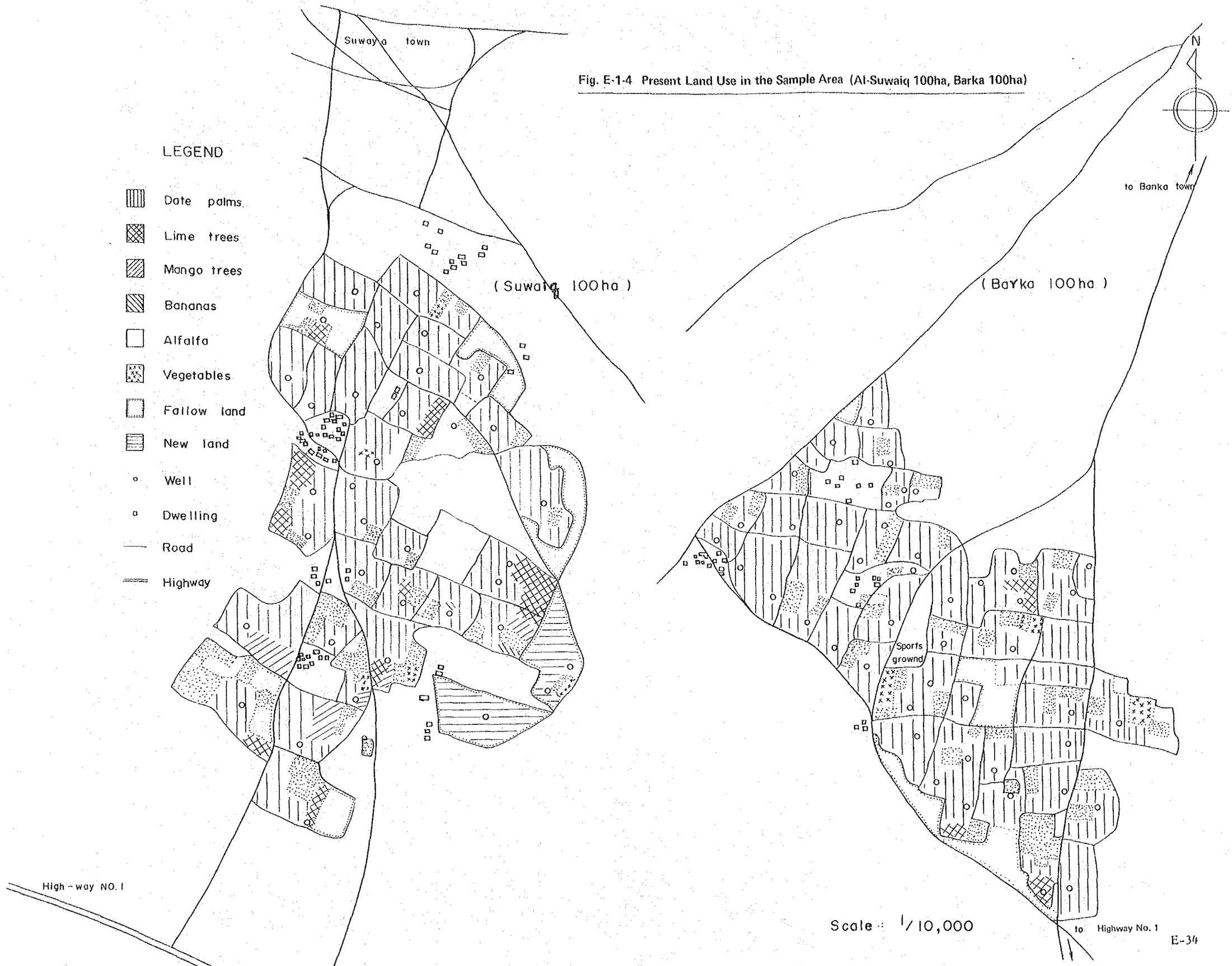


Figure E-1-5(1) Existing Cropping Calendar (1/5)

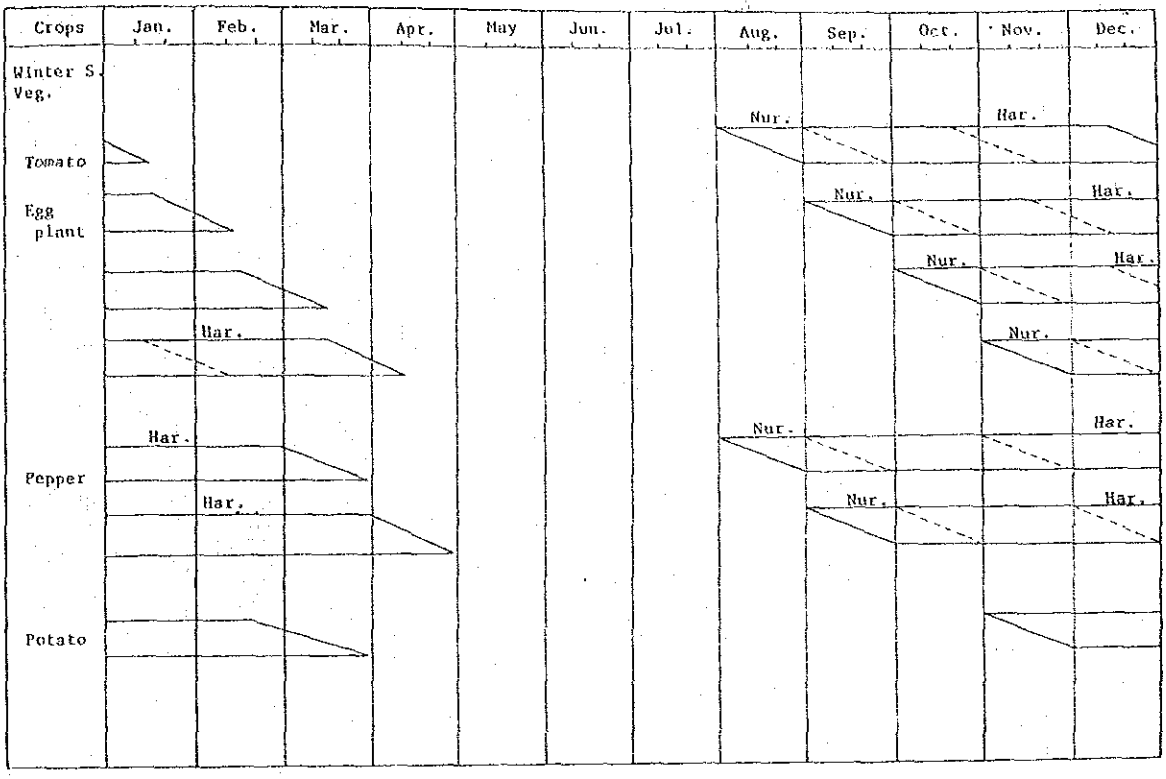


Figure E-1-5(2) Existing Cropping Calendar (2/5)

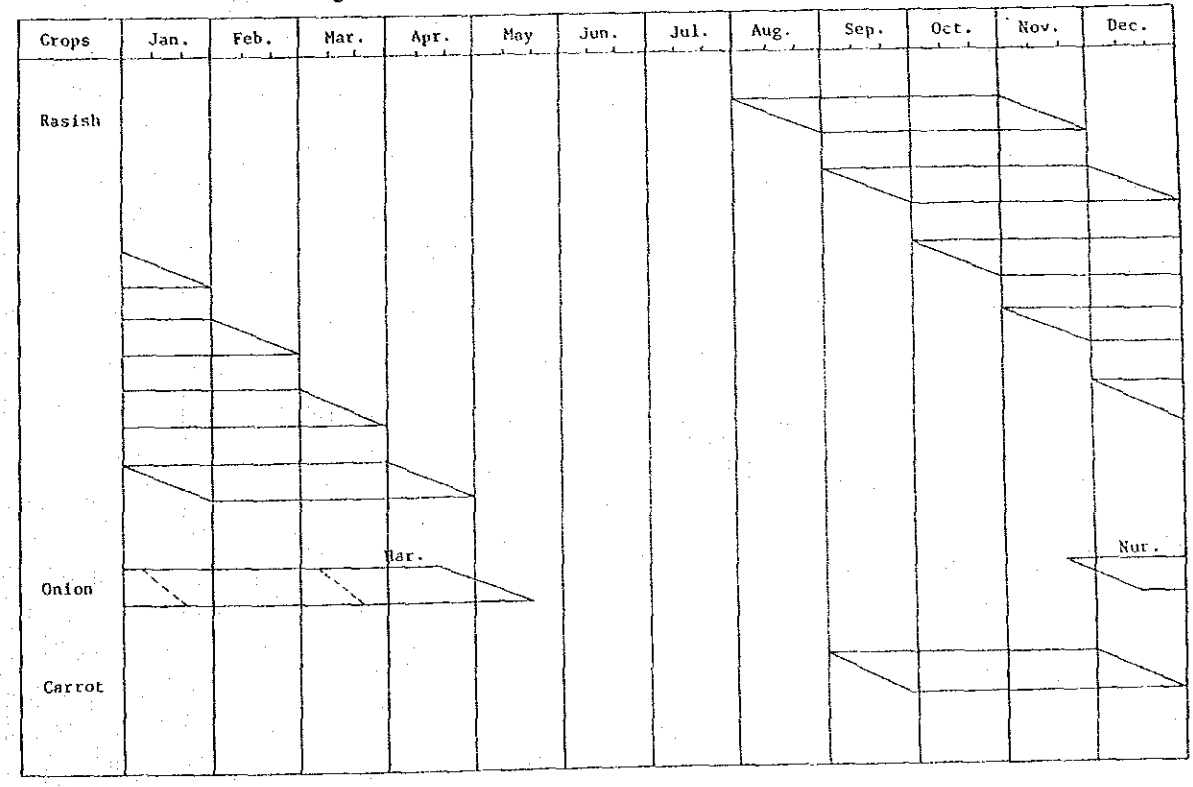


Figure E-1-5(3) Existing Cropping Calendar (3/5)

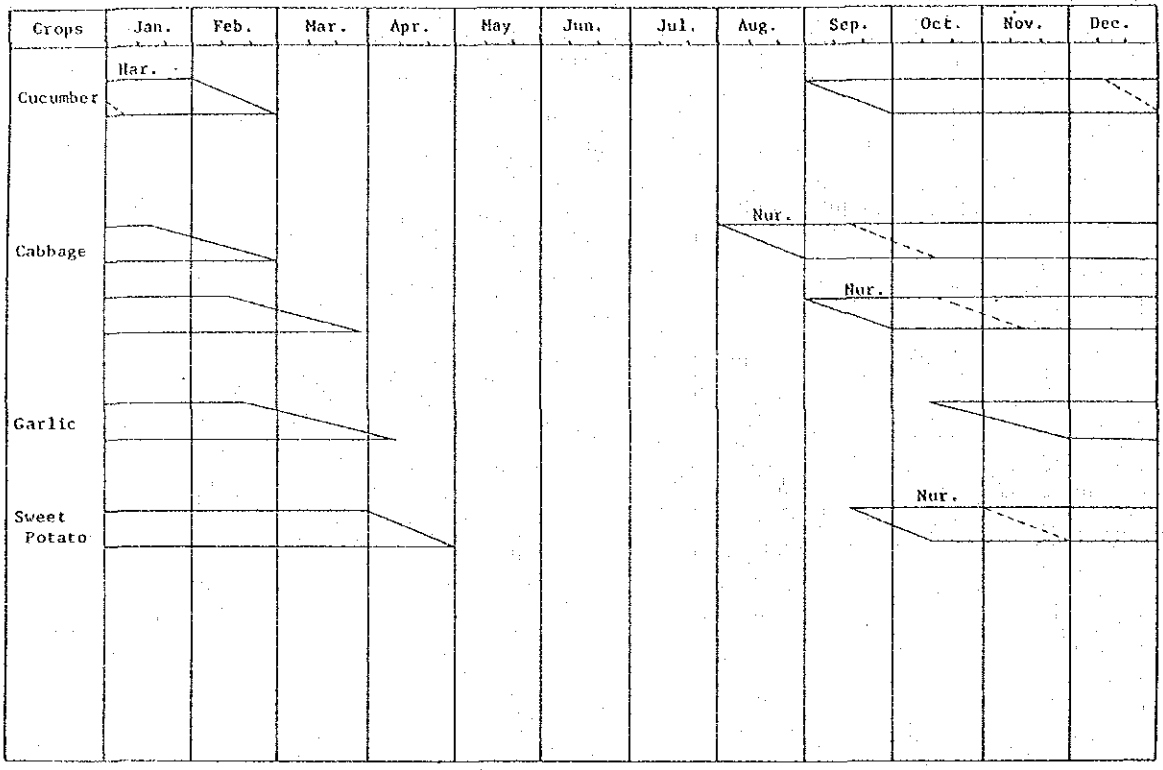


Figure E-1-5(4) Existing Cropping Calendar (4/5)

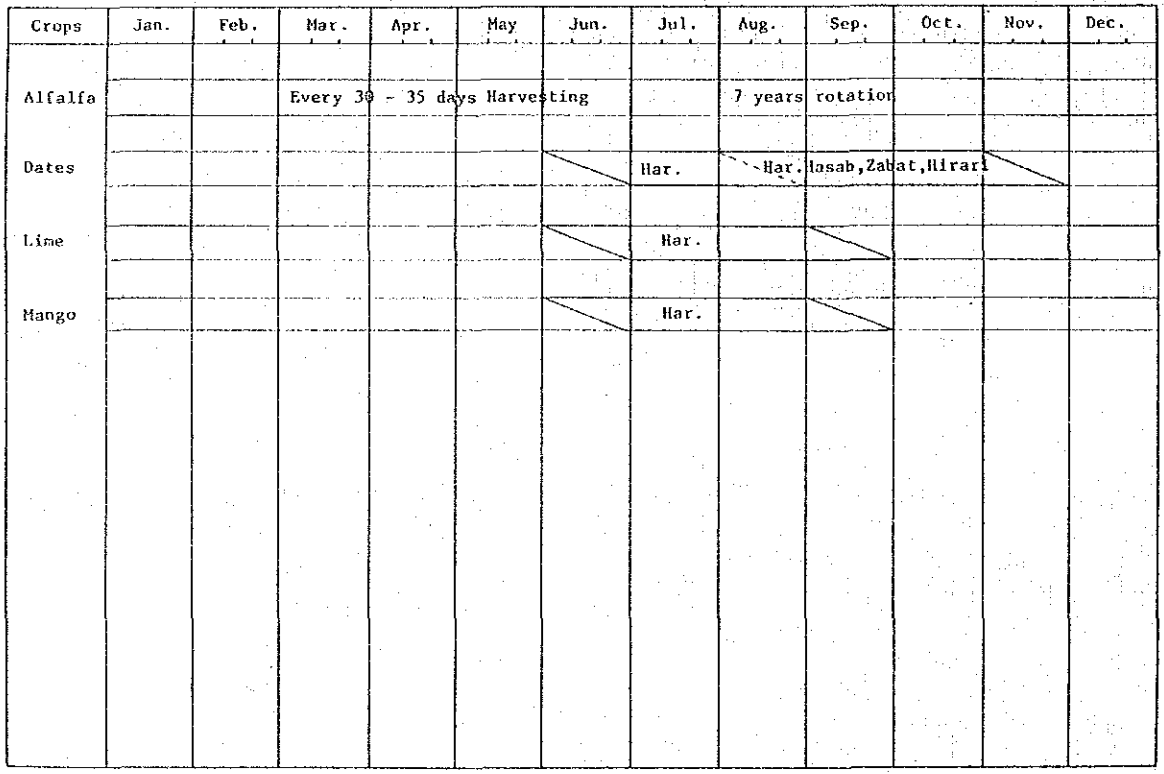
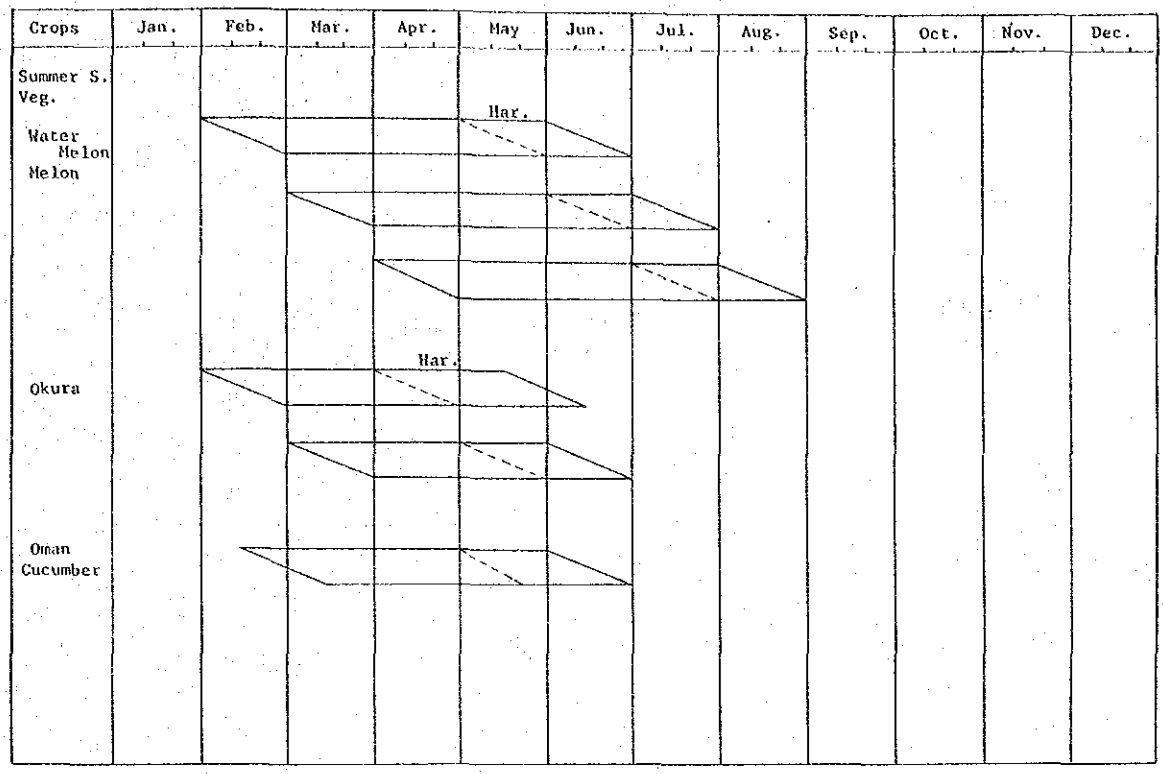


Figure E-1-5(5) Existing Cropping Calendar (5/5)



CHAPTER 2 WATER USE SURVEY

2.1 The Survey on Water Use

2.1.1 Objective

The Project aims to provide fundamental data and information on the Wadi Ma'awil and other four wadi in order to estimate the water balance of the Batinah Coast through meteorological hydrological, hydrogeological surveys on precipitation, wadi runoff discharge, and groundwater level.

The objective of the survey as part of hydrological observation is to assess the present water use in the Batinah Coast.

2.1.2 Items and Locations

The water use survey has been conducted for the following items:

(1) Survey on Present Water Sources

This survey was intended to identify the location, scale and water quality (E.C.) of water sources such as faraj, wells, and springs.

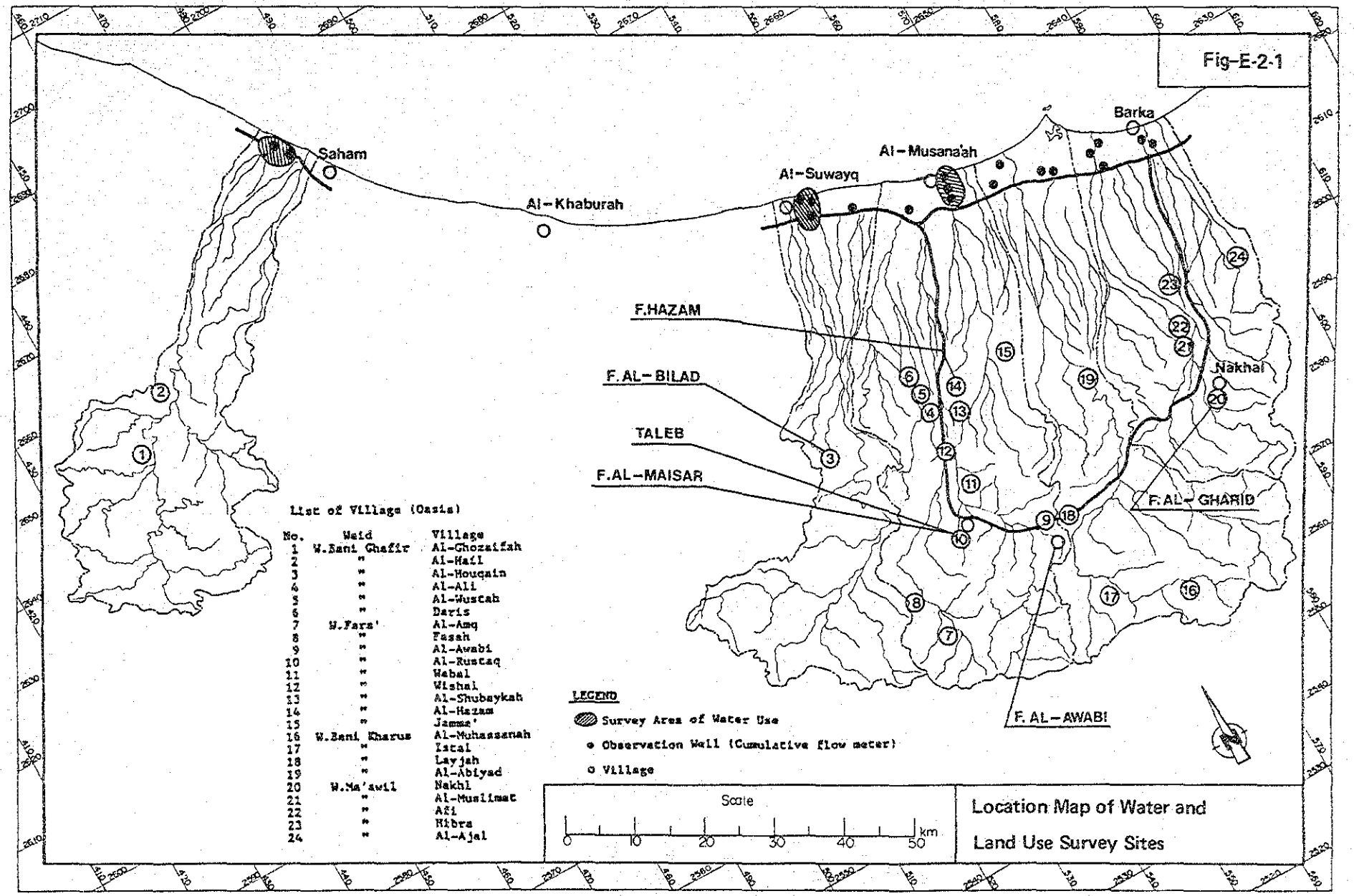
Diiferent patterns of water use have been observed between the foot of the mountain or mountainous area and the coastal plains.

The former is primarily served by a number of the faraj or springs. These sources are operated and maintained by the inhabitants of a falaj community. The latter areas usually make use of ground water by pumping.

However, the use of a well is confined to one farm and its operation and maintenance is taken care of by an individual household, resulting in a large number of water sources.

Under these circumstances, the survey has been conducted in 24 villages in the mountain area with respect to the location, type and discharge of the sources, whereas in the coastal plain area, sample survey areas have been selected a Barka, Al-Musana'ah, Al-Suwaiq and Saham to survey the number of wells, diameter of pumps, water quality, etc. (Table E-2-1, Fig. E-2-1 and E-2-2).

Fig-E-2-1



List of Village (Oasis)

No.	Wadi	Village
1	W.Bani Ghafir	Al-Ghozaifah
2	"	Al-Hail
3	"	Al-Houqain
4	"	Al-Ali
5	"	Al-Wustah
6	"	Daris
7	W.Fara'	Al-Amq
8	"	Fasah
9	"	Al-Awabi
10	"	Al-Rustaq
11	"	Wabal
12	"	Wishal
13	"	Al-Shubaykah
14	"	Al-Hazam
15	"	Jamma'
16	W.Bani Kharus	Al-Muhassanah
17	"	Istal
18	"	Layjah
19	"	Al-Abiyad
20	W.Ma'awil	Nakhl
21	"	Al-Muslimat
22	"	Afi
23	"	Hibra
24	"	Al-Ajal

Location Map of Water and Land Use Survey Sites

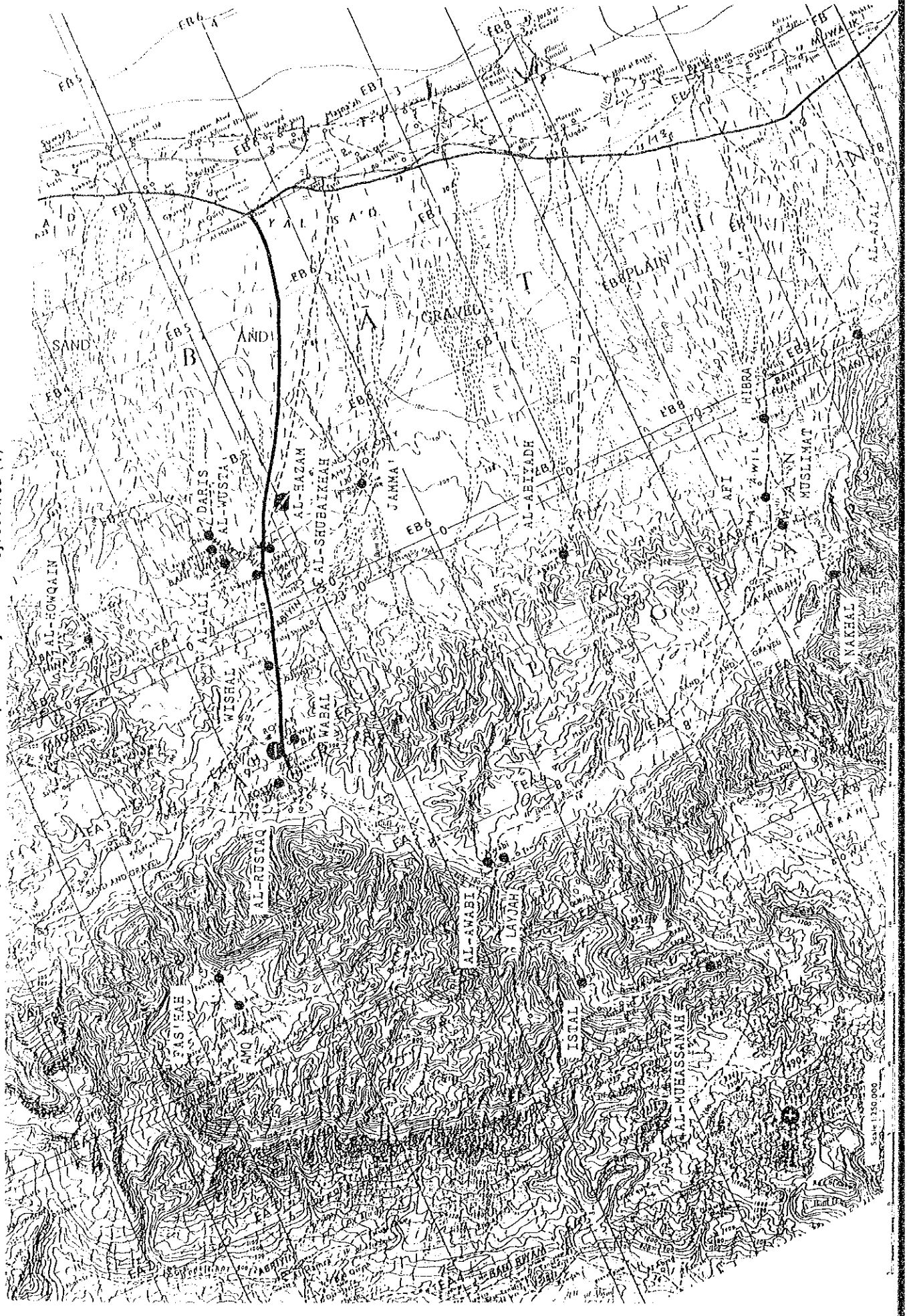


Fig. E-2-2 Location Map of Aflaj in the Project Area (1)

Table E-2-1 Villages Surveyed in the Mountain Area

No.	Wadi	Village	No.	Wadi	Village
1.	W. Al-Ma'awil	W. Al-Fara	13.	W.Al-Fara	Wishal
2.	"	Al-Hibrah	14.	"	Wabal
3.	"	Afi	15.	"	Al-Rustaq
4.	"	Muslimat	16.	"	Al-Awabi
5.	"	Nakhal	17.	"	Fasah
6.	W. Bani Kharus	Al-Abiyad	18.	"	Al-Amq
7.	"	Layjah	19.	W. Bani Ghafir	Daris
8.	"	Istal	20.	"	Al-Wustah
9.	"	Al-Muhassanah	21.	"	Al-Ali
10.	W. Al-Fara'	Jamma	22.	"	Al-Houqain
11.	"	Al-Hazam	23.	W. Ahin	Al-Hayl
12.	"	Al-Shubaykah	24.	"	Al-Ghozaifah

(2) Present Irrigation System

Irrigation requirement accounts for the most of the water utilization in the survey areas. Thus, the following observation was made to estimate the irrigation water supply.

- For irrigation water in the Mountain area, continuous observations were made on the irrigated area, water supply and water quality at the following falaj systems;

Falaj	Village	Wadi
F. Al-karid	Nakhal	W. Ma'awil
F. Hazam	Al-Hazam	W. Fara'
F. Al-Maisre	Al-Rustaq	"
F. Abu-Thalib	"	"
F. Awabi	Al-Awabi	"
F. Al-Bilad	Al-Howqain	W. Bani Ghafir

- As for the irrigation water in the coastal area, the pumped up volume was surveyed with a cumulative flow metre fixed to each of 20 pumping stations selected in the survey area.

Sample wells and pumping stations were selected with a view to meeting the following criteria.

a. Select samples uniformly from the whole area

b. Farm types, taking full account of the current field conditions, as follows: 1) date palm of mono-cropping farm, 2) mixed farm of date palm, mango, alfalfa, and 3) newly developed farm of vegetables, alfalfa and young tree of date palm.

(3) The Survey of Domestic Water Use

The survey of domestic water use was undertaken for several households randomly selected from the densely populated areas in Barka and Al-Musana'ah.