INSTITUTE of HYDROLOGY

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DOHA GROUNWATER MODEL
WATER LEVEL CHANGES, 1983-1988

May 1989

INSTITUTE of HYDROLOGY

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DOHA GROUNDWATER MODEL
WATER LEVEL CHANGES, 1983-1988.

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Institute of Hydrology
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Oxon, UK

December ~~May 1989~~ 1990

Contents

Title

1. Background

A report on an investigation into the rising water levels beneath Doha was presented in May 1983 [1]. This included maps of the depth to water level and water table elevation for February 1983 based on data from 180 boreholes. A mathematical model of the Upper Dammam aquifer was developed to infer recharge and flow from the aquifer system.

Only a limited appraisal of the rate of water level change could be undertaken in 1983 as only 22 sites had monitoring data for one year or more. However, since then, water levels have been monitored regularly in a network of about 110 boreholes.

At the request of Balfours International, acting on behalf of the Water Department of the Ministry of Water and Electricity, the new water level data have been used to examine the present recharge situation using the existing model. A brief review of the current water level situation and trends in water level changes has also been undertaken.

2. Review of water level data

2.1 INTRODUCTION

The natural, pre-development water table elevation was about 1m aQND (Qatar National Datum) with a gradient towards the coast. By 1983 the combination of imported water and reduced abstraction associated with urban development had created a recharge mound beneath the city with water level elevations of up to 9 m aQND.

The hydrogeological conditions of the area are rather complex due to the occurrence of local karstic zones of higher permeability. Inflow and outflow from the system was estimated using both a water balance approach and a groundwater model.

By February 1983 a monitoring network of 180 wells and boreholes had been established. However, many of these sites had less than a 4 month record, 46 had records of between 4 months and one year and only 22 had monitoring data available for more than one year. The water level data were used to prepare a water level contour map and depth to water level map for February 1983. Water levels were shown to be less than 2m below ground level in some areas, ~~mainly in~~ mostly associated with local topographic depressions.

The new water level data have been used to prepare maps of the water level situation at the end of 1988. The spatial distribution of monitoring points varies somewhat from the distribution in 1983, particularly in the western and southern areas, and this influences the water level contour interpretation and the subsequent estimates of recharge and boundary flows. Consequently, undue emphasis should not be placed on local changes as these may be due merely to differences in the data available in 1983 and in 1988.

As far as possible all of the new data have been considered in preparing the new maps, except those recognised as being influenced by pumping. The data from a total of 90 boreholes were used to prepare the contour maps, of which 68 had data for December 1988, 9 had data collected during the last few months of 1988 and a further 13 were influenced by pumping and had only an approximate rest water level.

2.2 WATER LEVEL CONFIGURATION, 1988

Figure 1 shows the water table elevation for December 1988. The main points to note are:-

1 - The general configuration has remained broadly similar to that observed in February 1983: two local recharge mounds are superimposed upon a more regional mound extending south-west, west and north-west and bounded on the east by a steep gradient.

2 - Water level elevations of about 8 to 10m now occur in the local recharge mounds and of about 6 to 7.5m over much of the western area.

- A low area of about 3m elevation at Muraikh is revealed by the data for 1988 in an area where there were no data in 1983.

2.3 CHANGE IN WATER LEVELS, FEB 1983 TO DEC 1988

The net change in water levels between February 1983 and December 1988 is shown in Figure 2.

A rise in water level has been recorded over most of the area but the main rise has taken place in the west where increases of about 1 to 3m have been observed. The rise in water level in this area can be attributed to the lateral flow of groundwater from the peak of the mound, such that water levels have now risen beyond the boundaries of the existing model in particular to the west and south. Water levels have risen by about 1.5m in the western part of the area but by as much as 3m in the south west towards Ghanim El Jadid.

The apparent decline in water levels at Madina Khalifa and Muraikh is due to differences in the availability of data in 1983 and 1988.

The coastal area has shown increases of between 0.5 and 1m in the West Bay area and declines of 0.5 and 1m south of the bay. The low area between the two local recharge mounds shows declines of between about 0.4 and 0.9m.

2.4 DEPTH TO WATER LEVEL, DEC 1988

Figure 4 shows the depth to water table in December 1988. The pattern is similar to that of 1983. Most of the central area has water levels of more than 5 m bgl. Areas having water levels less than 2.5 m occur along the coast, near Old Rayyan, Muraikh, Wadi Musheirib, and in the low area extending north of Abu Hamur.

The areas having shallow water levels ~~are likely to~~ may be more extensive than indicated since ~~and~~ other low topographic areas are ~~also~~ likely to have shallow water levels but at them lack water level monitoring ~~points.~~ data

2.5 WATER LEVEL TRENDS

The water level data are presented as hydrographs in Annex A. The average annual trend in water level for 59 sites with longer term records are tabulated in Annex B.

The hydrographs indicate a relatively constant rise in water level from 1982 to 1987. The average annual rise in water level at those sites where a trend can be defined is 0.164 m/y (range -0.137 to +0.35 m/y). Assuming a specific yield of 2% this represents a net gain to storage of 0.53 Mm^3/y over the area of the model of ~~164~~ 159 km^2. This gain is only 3.7% of the estimated annual recharge of 14 Mm^3/y.

In 1987/1988 there would appear to be a more marked seasonal change, which may be due to the exceptional rainfall in early 1988. However, it is considered likely that the water level trends observed prior to 1987 will become re-established in 1989, although the local situation has become more complex due to the installation of a unified wastewater system.

There is no clear relationship between the rate of water level rise and the depth to water level.

3. Update of recharge and boundary flows

3.1 MODEL DESCRIPTION

A full description of the model is given in the 1983 report. An inferred recharge model was applied in which the area of concern is discretised by a grid of nodal points. The total recharge comprises known and inferred recharge components. Based on a consideration of the engineering water balance, which was undertaken as part of the earlier study, and the hydrogeology, a limited number of nodal grid points were constrained as having zero inferred recharge. It was then possible to determine the inferred recharge for the unconstrained nodes using the observed heads, known recharges, zero inferred recharges and a finite difference approximation matrix. Best-fit groundwater levels were then calculated for each nodal point from the combined fixed and inferred recharges.

3.2 MODIFICATIONS TO THE MODEL

A minor modification in the procedure for determining inferred recharges at nodal points was introduced which resulted in improved estimates of the inferred recharge, as indicated by the decrease in the sum of squared residuals given in Table 1.

3.3 MODEL RESULTS

Two model runs were undertaken, both with the minor modification in the model procedure:

- a re-run of the model with the 1983 water levels
- a model run with the 1988 water levels

The results are presented in Table 1. The results for 1988 are shown in Figure 5 for each of the grid blocks. The main points to emerge from this exercise are:-

1- A revised net recharge of 14.34 Mm^3/y was derived for 1983 using the improved model procedure. The recharge was calculated to be 14.73 Mm^3/y for 1988, an increase of only 2.7%. This would suggest that recharge has remained constant.

2- Whilst the annual volume of recharge would appear to have remained the same, there are some apparent changes in the distribution of recharge:

  * there are significant increases in areas A and E (Table 1), which would appear to be due to the rise in water levels in the western area. The decrease in area B may be due to the increased contribution into area A.

  * whilst the recharge has decreased in area C, it has increased in area D such that the total recharge for areas C and D remains constant at about 12.5 Mm^3/y.

1- Water level declines, typically of up to 1m, have occurred in central Doha (area D), although the model suggests an increase in recharge. This may be due to the rise in water levels and more extensive recharge mound to the south-west of the bay and the localised recharge mound just south of the bay.

There is some uncertainty as to the occurrence of a recharge mound to the north-west of the bay which corresponds to a peak observed in 1983 and supported by the water balance study. A model sensitivity test was performed by increasing the 1988 water level by 3m in this area, but this had a negligible effect on the total recharge.

It should be noted that the model results will include the effects of differences in the data available for 1983 and 1988. At present the level of uncertainty introduced by differences in these data sets has not been quantified. In addition, the expansion of the recharge mound may invalidate certain nodes where the inferred recharge was constrained as zero, which, for example, could also account for the increased recharge in area D. It would be desirable to extend the model boundary to the west due to the expansion of the recharge mound in the north-west and south-west.

insert new section 4

5 ~~4.~~ Recommendations for further work

5.1 ~~(a)~~ **Monitoring.**

Water level monitoring data are now available which could be used to assist management, for example, to establish priorities for the control of rising water levels or to observe the success of control measures.

There are some deficiencies in the monitoring network. ~~which limit the preparation of reliable maps and the model.~~ For example, many of the monitoring points are clustered in the eastern area whereas large areas to the north and west have only sparse data. The frequency of measurement, the need for additional monitoring sites, or sites where automatic recorders might be useful could be related to those areas where a further rise in water level would be undesirable. The network could be extended to provide additional control points for the preparation of water level maps and to ensure that areas at risk are monitored.

Statistical techniques could be usefully applied to examine the present network and suggest where the distribution or number of monitoring points and the frequency of readings could be optimised in terms of the data collection objectives and costs of obtaining the data. It is also recommend that a computerised data base system could be applied to allow maps or hydrographs to be produced easily so that the situation can be updated and reviewed at regular intervals.

Only a brief review of water level trends in relation to water level depths has been undertaken during this study. The water level records, together with other relevant information, such as topography or population distribution, could be used to establish those areas which are likely to be at greatest risk from a continued rise in water level. This would require risk criteria to be defined.

~~Some consideration could also be given to monitoring water quality at abstraction wells.~~

check LW's note

5.2 oc

~~(b)~~ **Modelling**

The boundaries of the existing model need to be extended to incorporate the spread of the recharge mound. Uncertainty in the spatial distribution of data needs to be quantified for any further modelling studies. ~~The results of the planned engineering water balance study should be tested with the model so that the most up-to-date situation is incorporated.~~

expand

References

1. Rising Water Table Project, May 1983. ASCO (Qatar) for Ministry of Electricity and Water Department, Qatar.

Description of what model can do ??

Table 1 Recharge and boundary flows

Model run	Region	Area (km^2)	Net recharge (Mm^3/yr)	Flow to sea (Mm^3/yr)	Flow across eastern boundary (Mm^3/yr)	Other boundary flow (Mm^3/yr)
1983 water levels (as presented in Table 6.9 of 1983 report)	A	24.0	0.47			0.15
	B	25.5	0.49	1.00	-	0.17
	C	35.125	8.77	6.48	0.83	-
	D	4.925	3.43	3.60	-	-
	E	69.25	0.78	-	0.38	1.22
Total			13.94			
Sum of squared residuals			56.5			
Root mean square residual			0.82			
Re-run of 1983 water levels	A	24.0	0.47	-		0.18
	B	25.5	0.56	0.92	-	0.42
	C	35.125	9.11	6.74	0.88	-
	D	4.925	3.43	3.82	-	-
	E	69.25	0.77	-	0.38	1.15
Total			14.34			
Sum of squared residuals			15.3			
Root mean square residual			0.43			
1988 water levels	A	24.0	1.09	-		0.51
	B	25.5	0.14	1.49	-	0.35
	C	35.125	5.63	4.90	0.73	-
	D	4.925	6.85	6.12	-	-
	E	69.25	1.02	-	0.55	0.51
Total			14.73			
Sum of squared residuals			18.0			
Root mean square ~~resisudals~~ residuals			0.46			

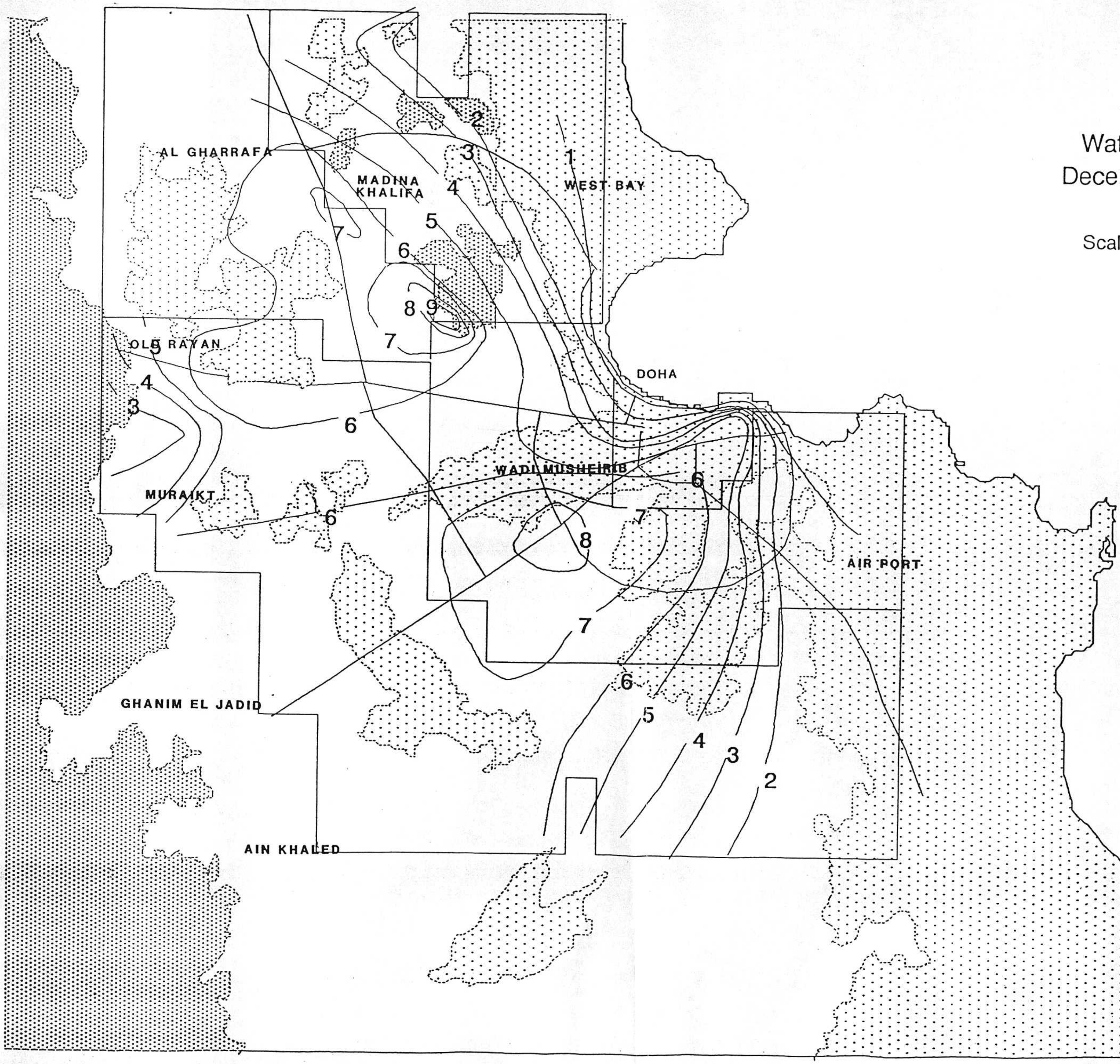


Figure 1
Water Table Elevation
December 1988 (maQND)

Scale 1:75,000 approx

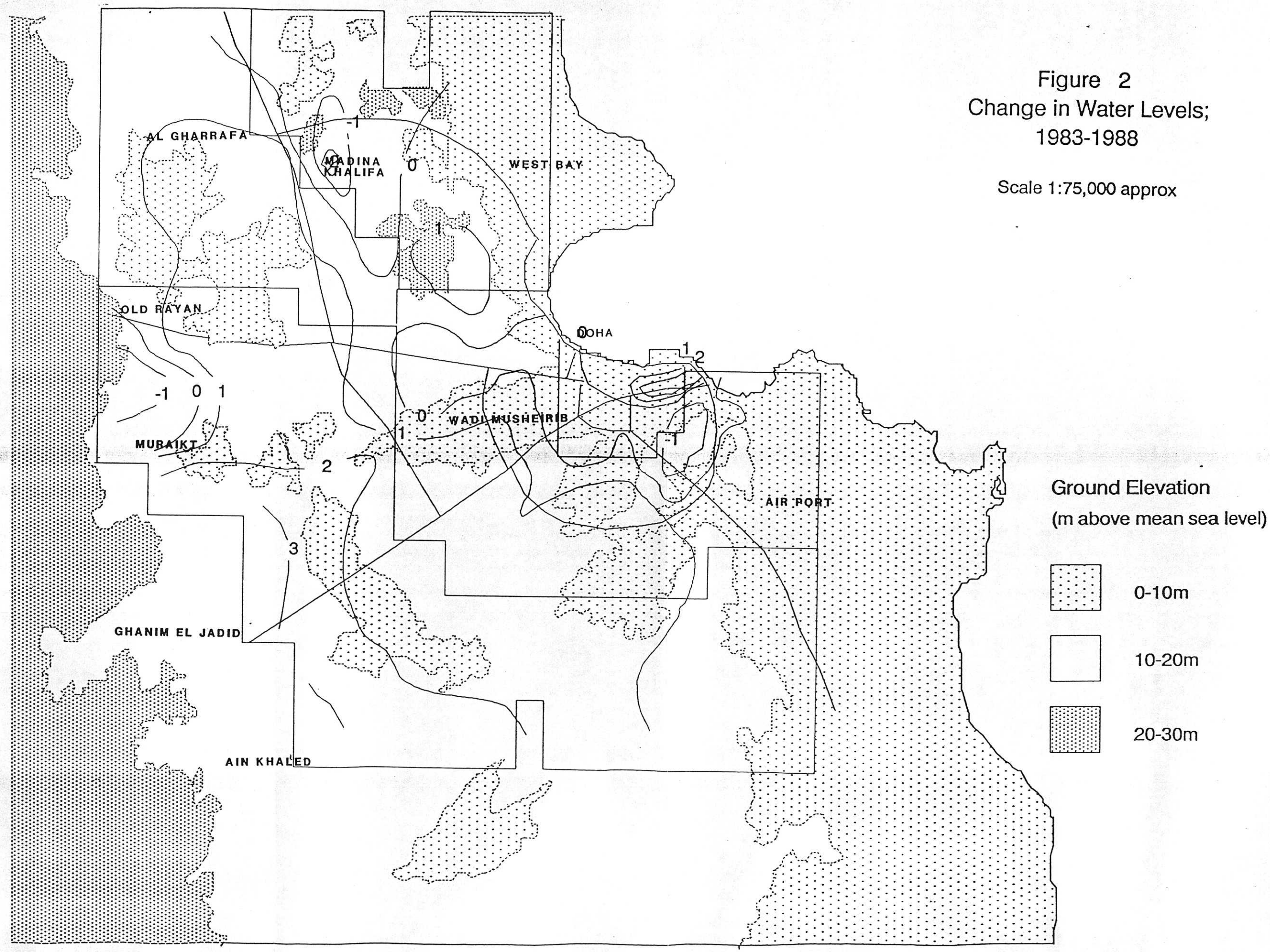
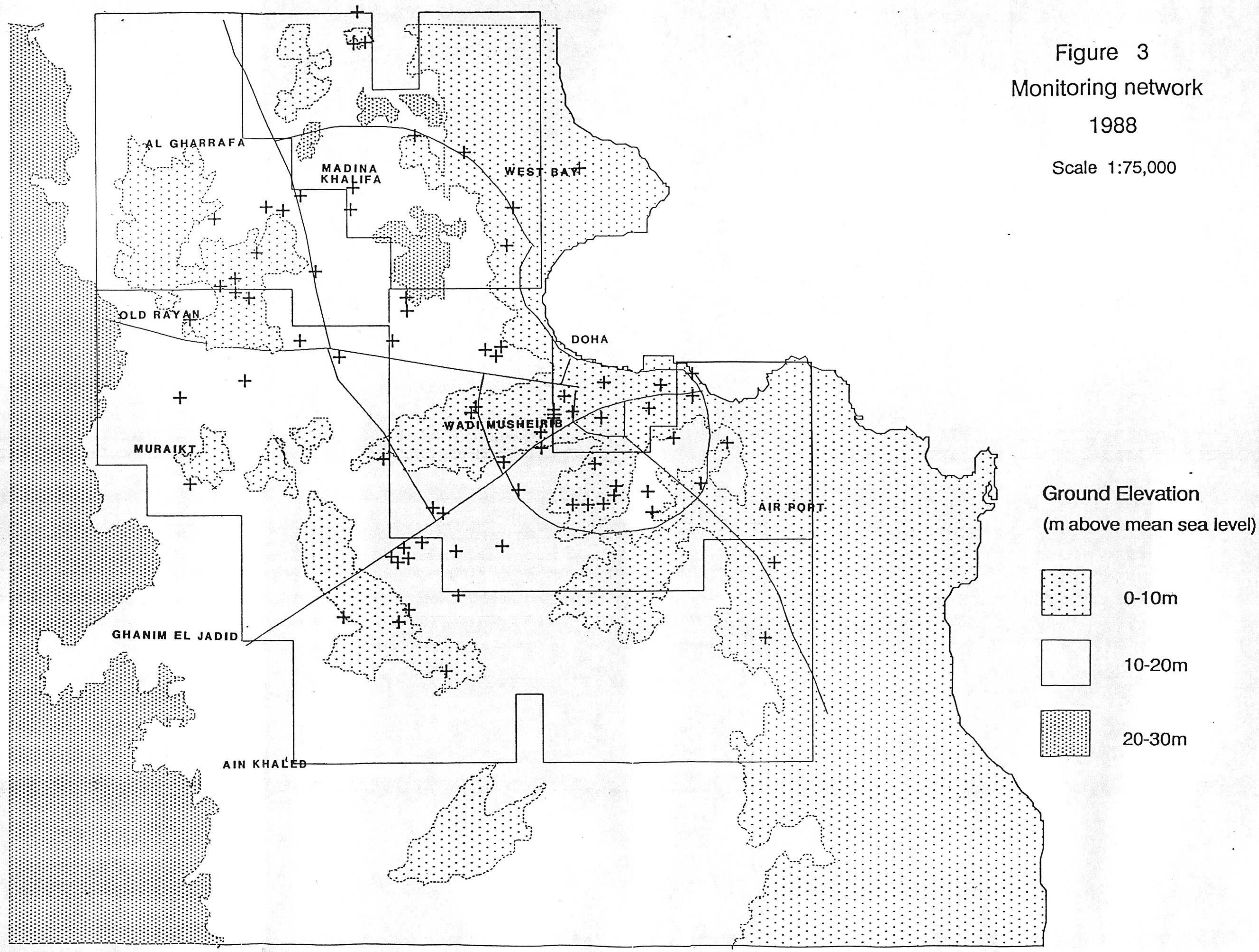


Figure 2
Change in Water Levels;
1983-1988

Scale 1:75,000 approx


AL GHARRAFA
MADINA KHALIFA
WEST BAY
OLD RAYAN
DOHA
WADI MUSHEIRIB
MURAIKT
AIR PORT
GHANIM EL JADID
AIN KHALED
Figure 3
Monitoring network
1988
Scale 1:75,000
Ground Elevation
(m above mean sea level)
0-10m
10-20m
20-30m

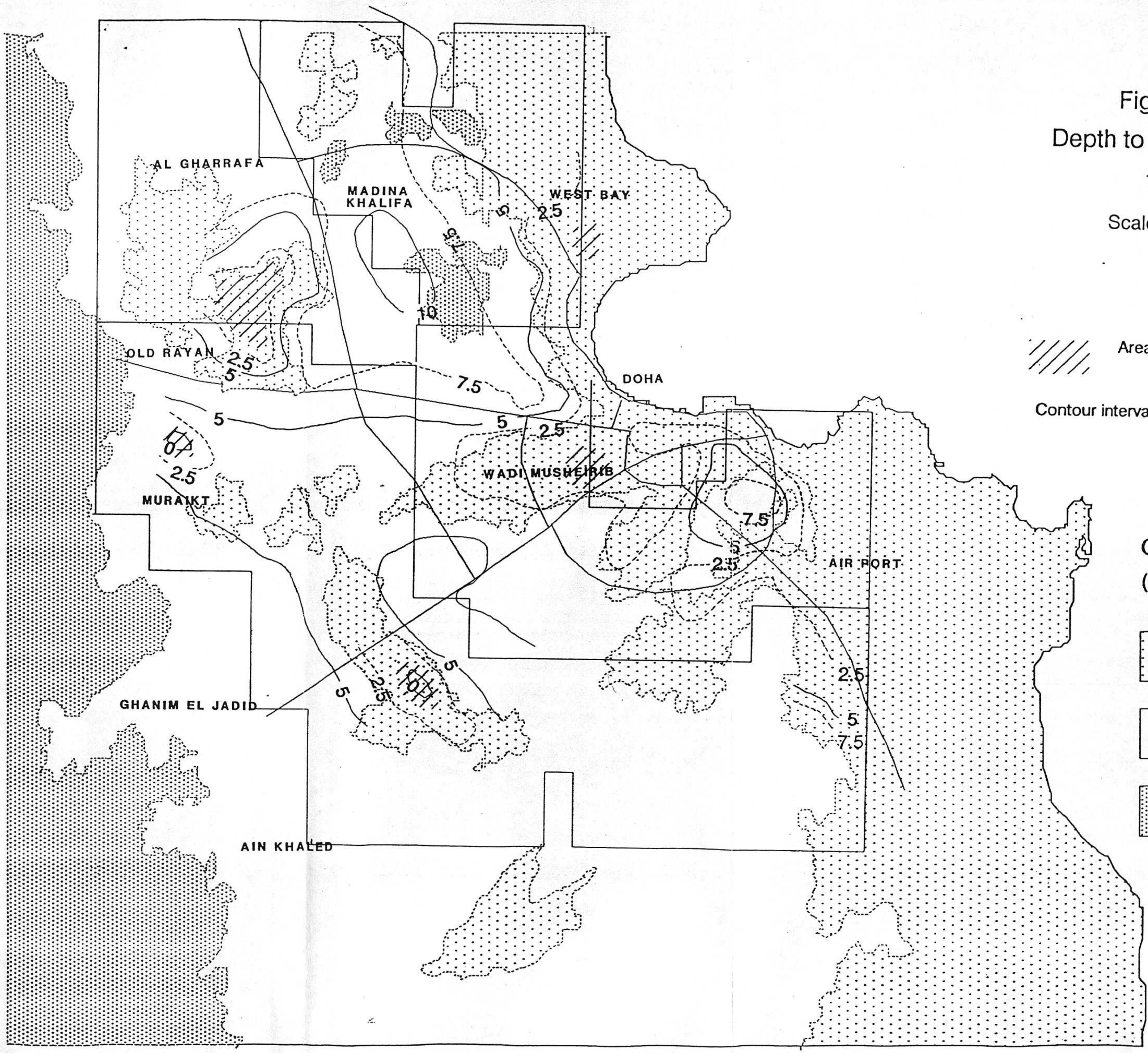


Figure 4
Depth to Water Table (m)
1988
Scale 1:75,000
Areas < 1m (Based on water level monitoring network)
Contour interval 2.5m
Ground Elevation
(m above mean sea level)
0-10m
10-20m
20-30m
AL GHARRAFA
MADINA KHALIFA
WEST BAY
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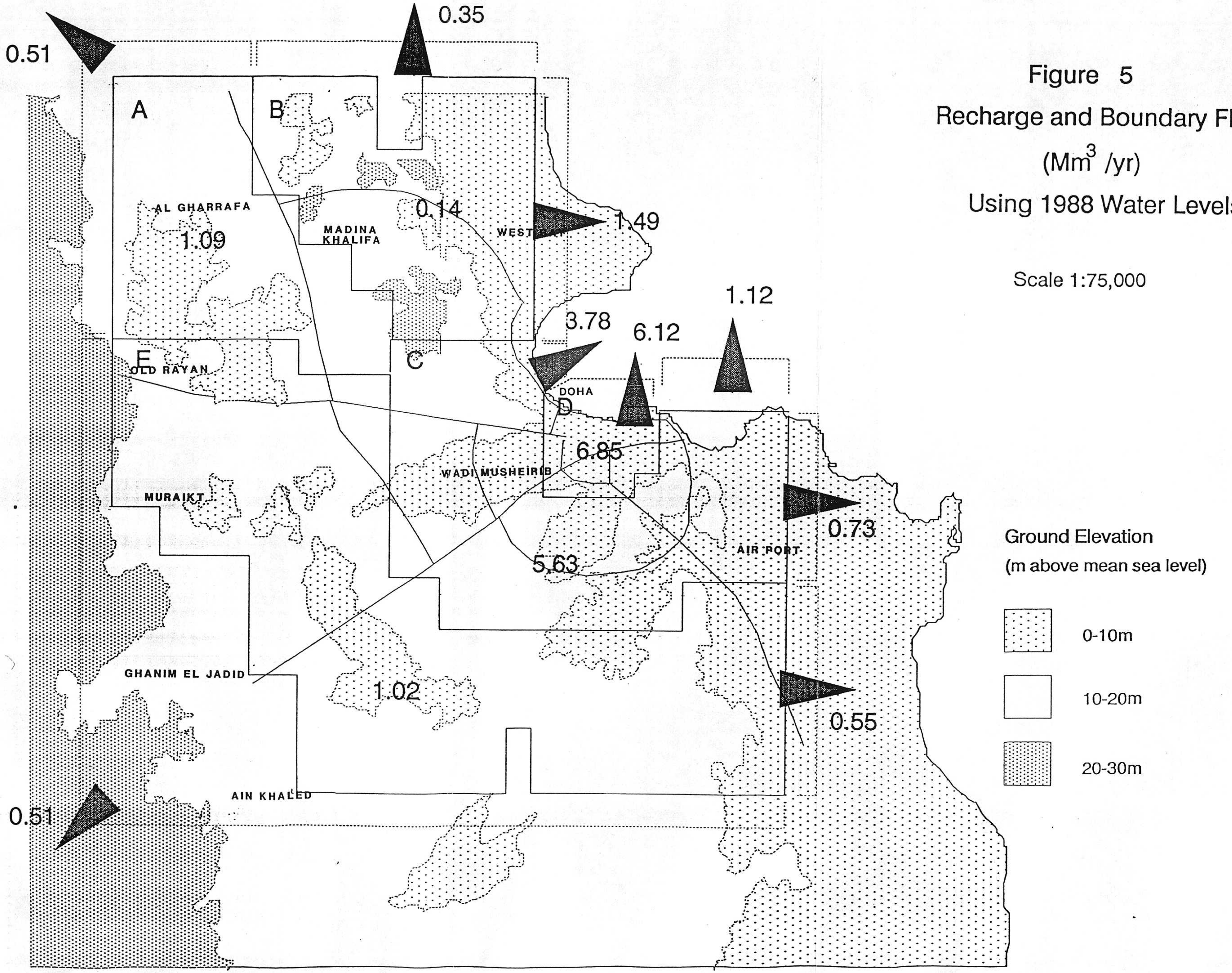

Figure 5

Recharge and Boundary Flows

(Mm^3 /yr)

Using 1988 Water Levels

Scale 1:75,000

Annex A
WATER LEVEL HYDROGRAPHS

DOHA - BOREHOLE WATER LEVELS 1981-1988
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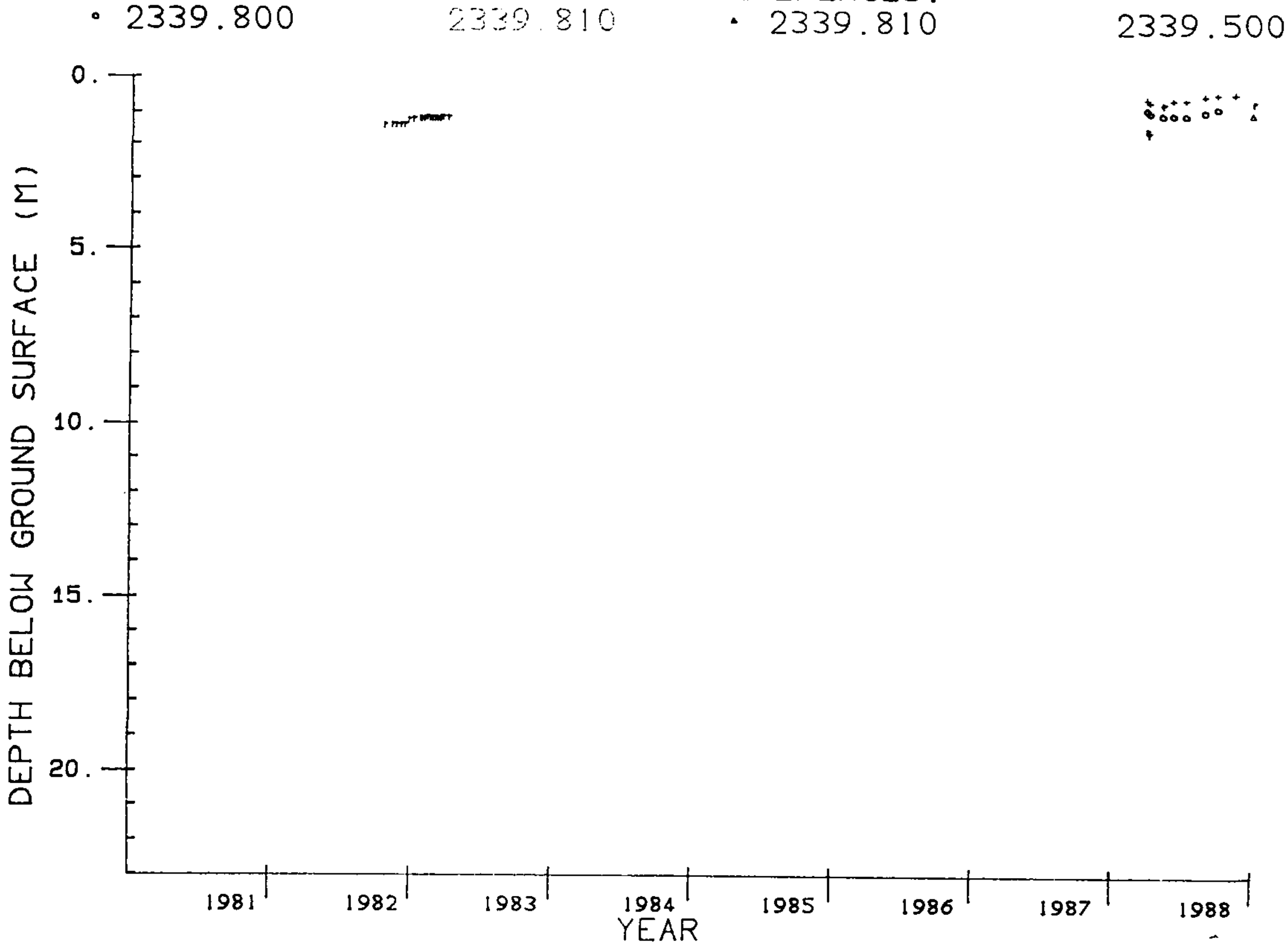

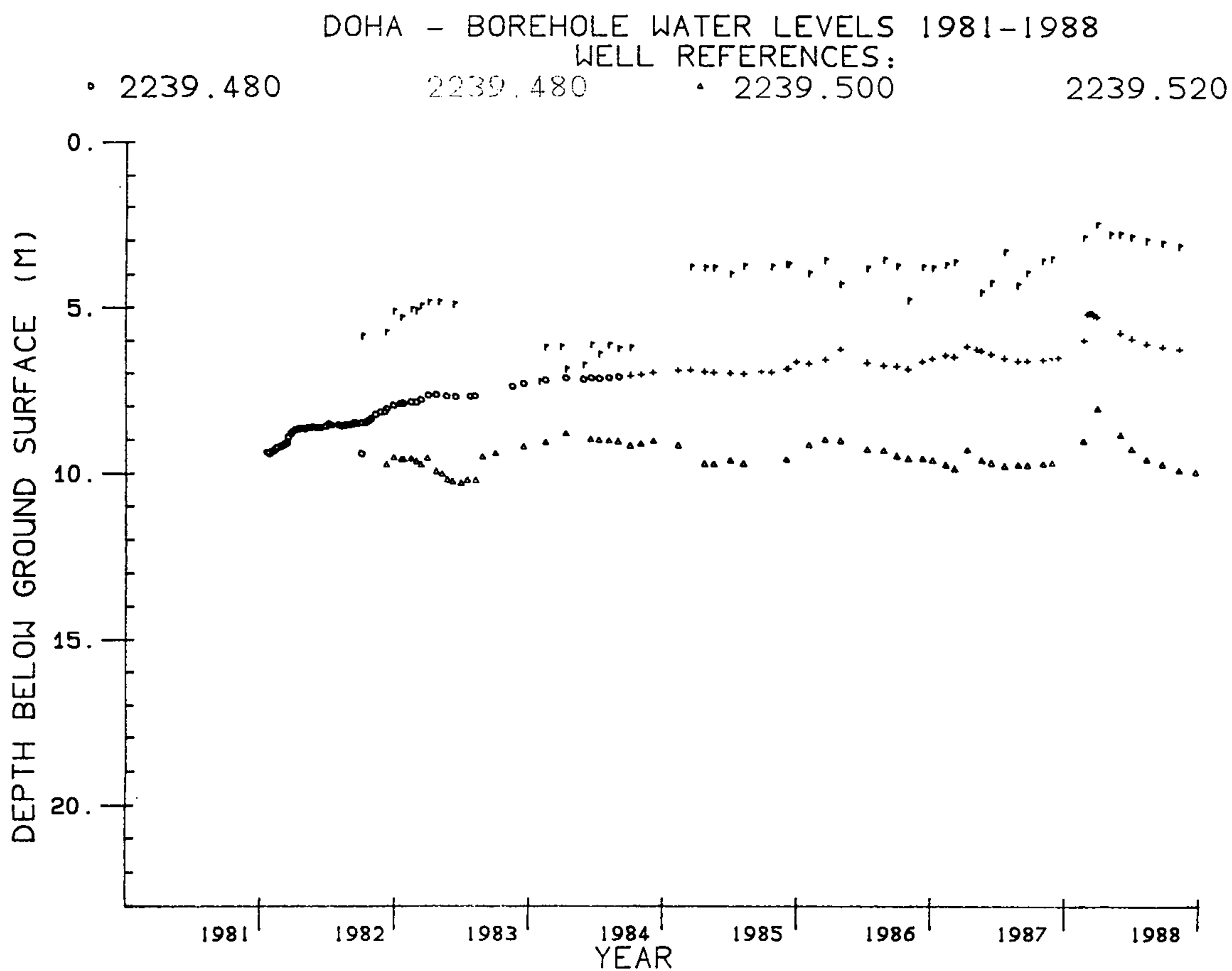
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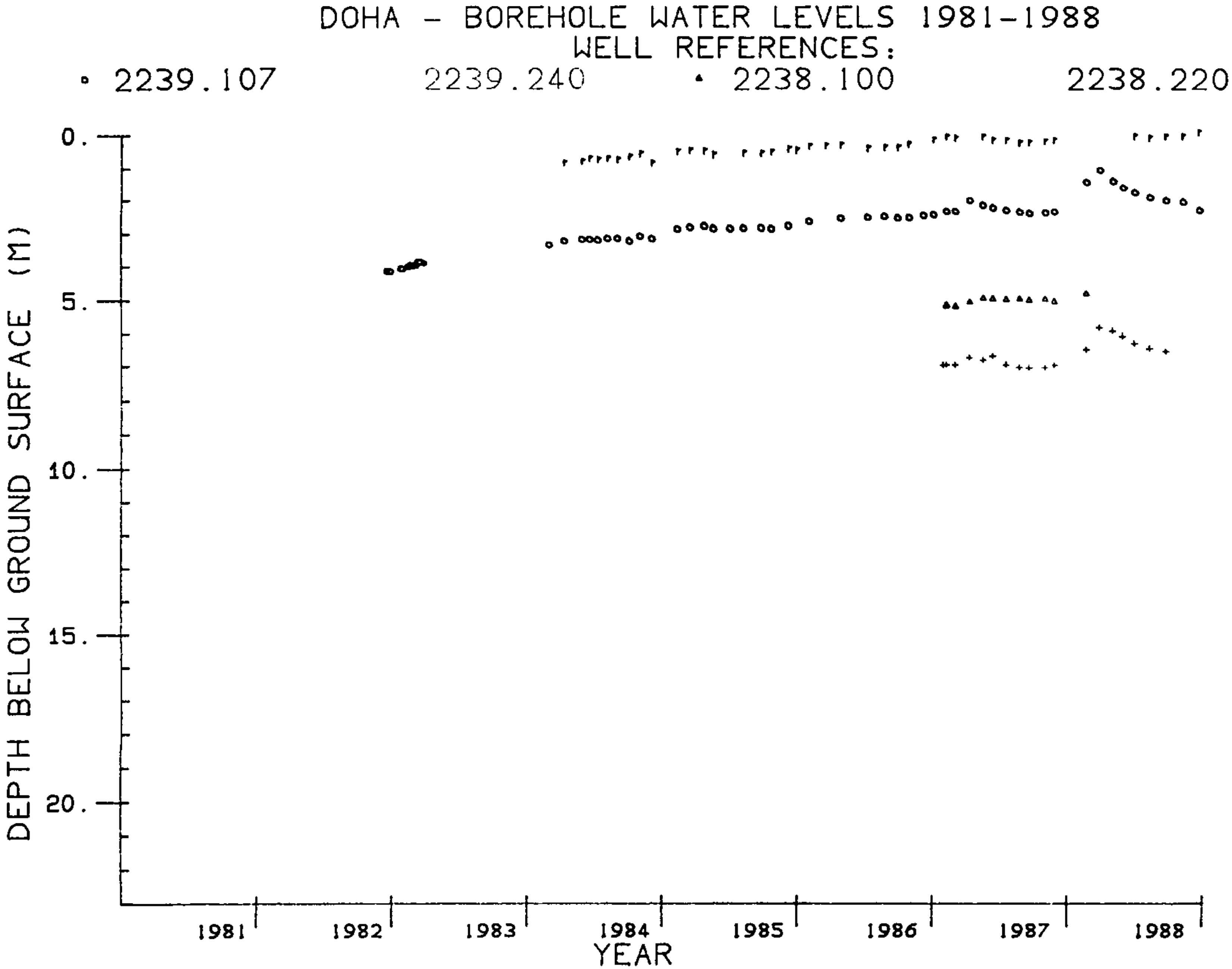
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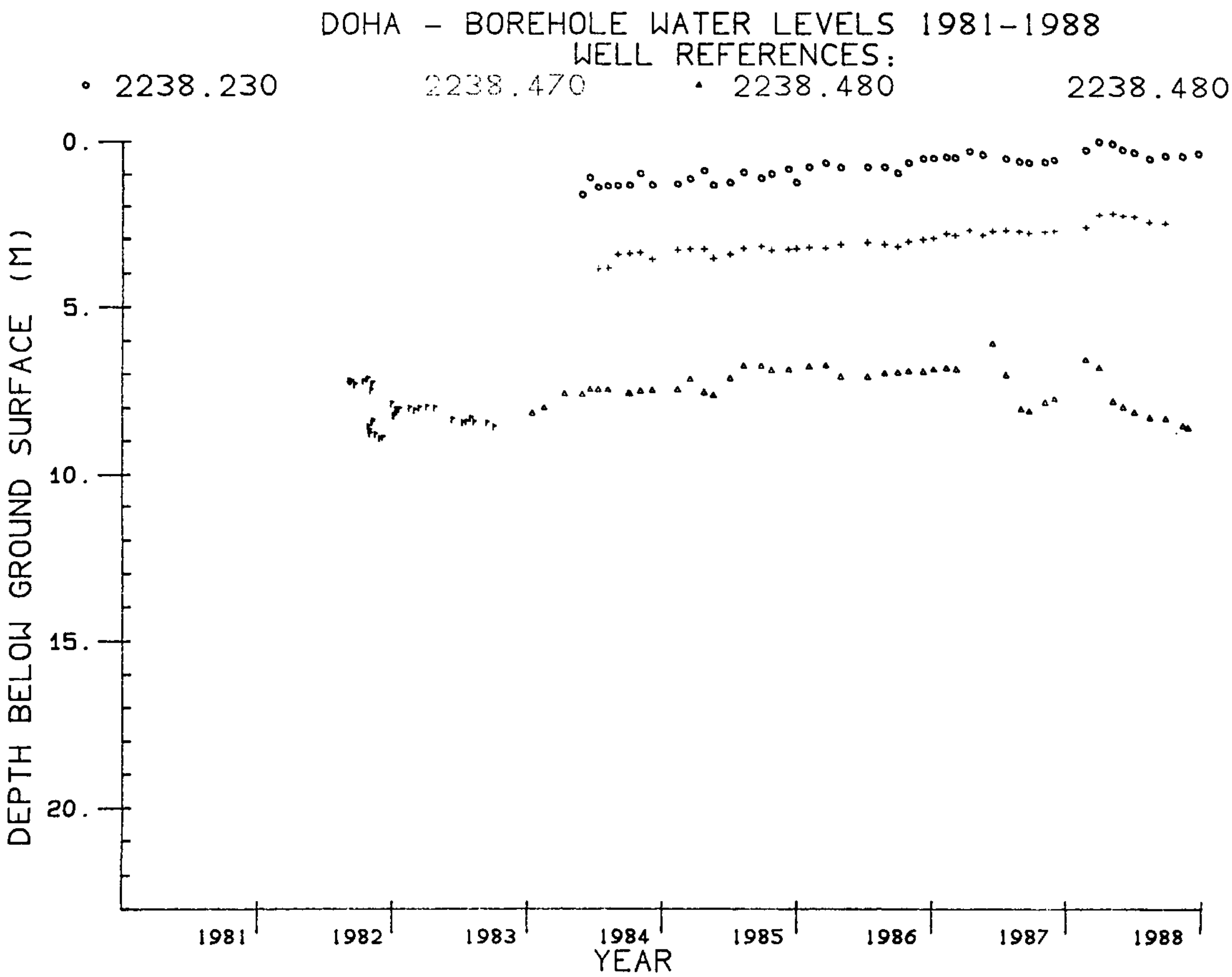

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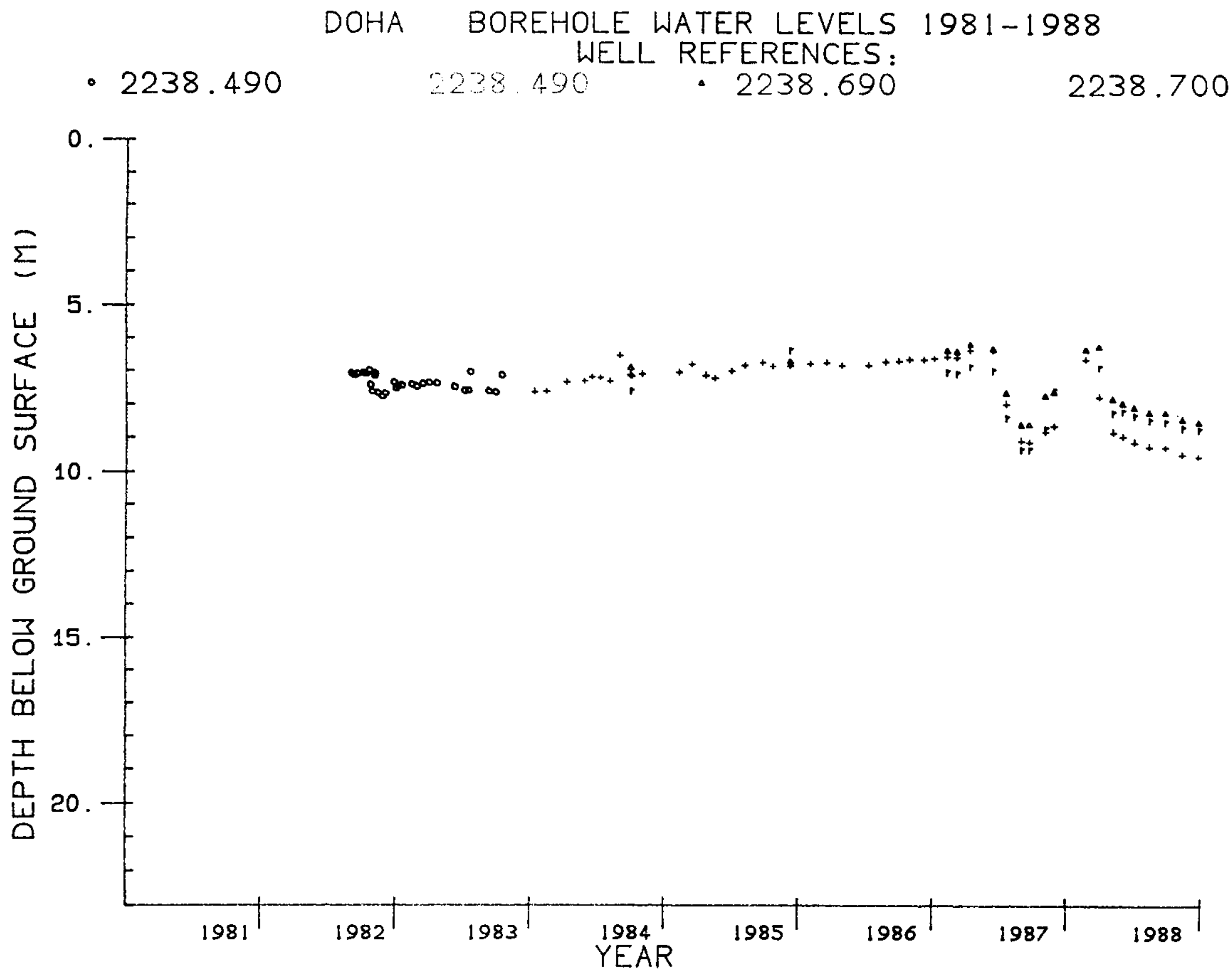
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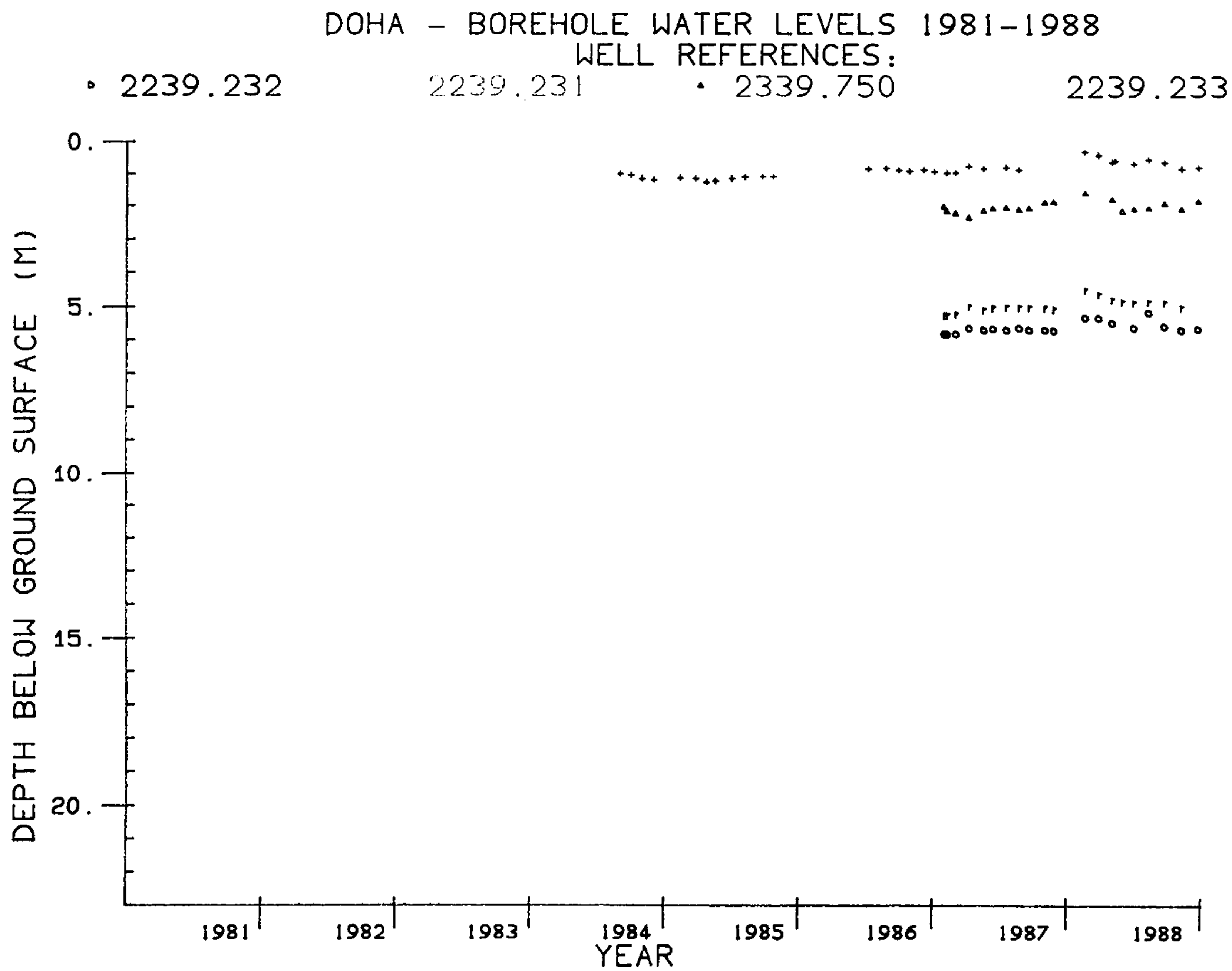

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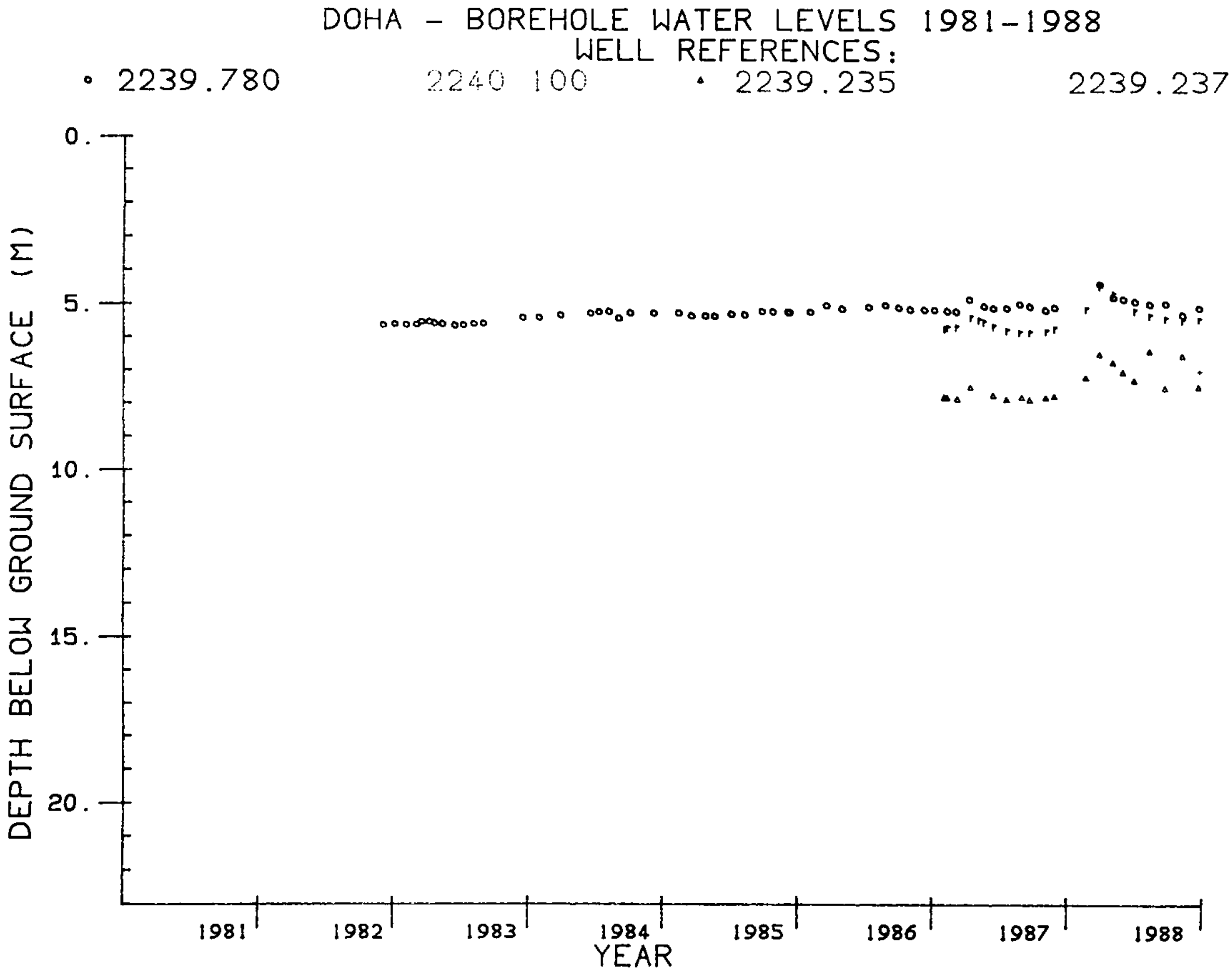
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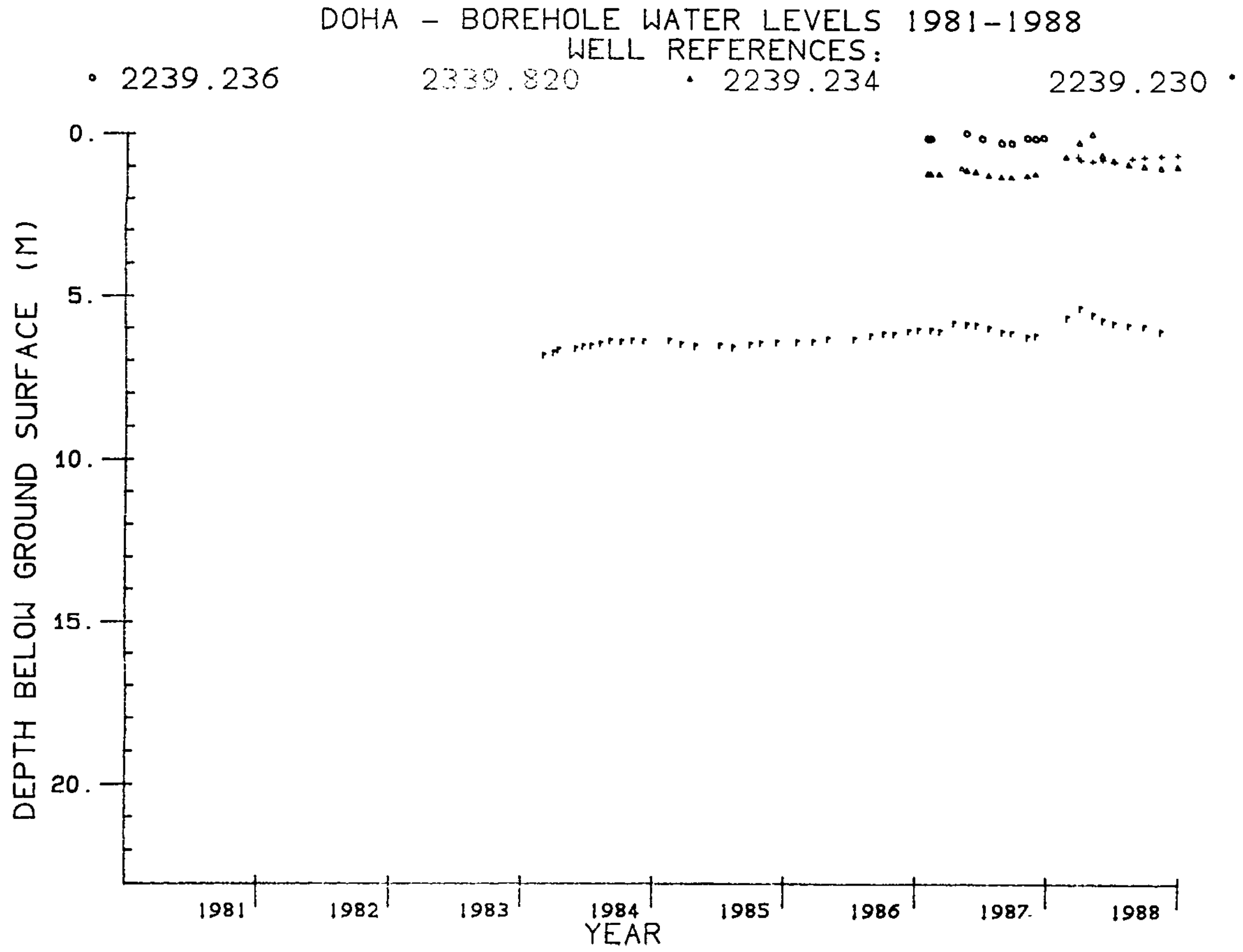

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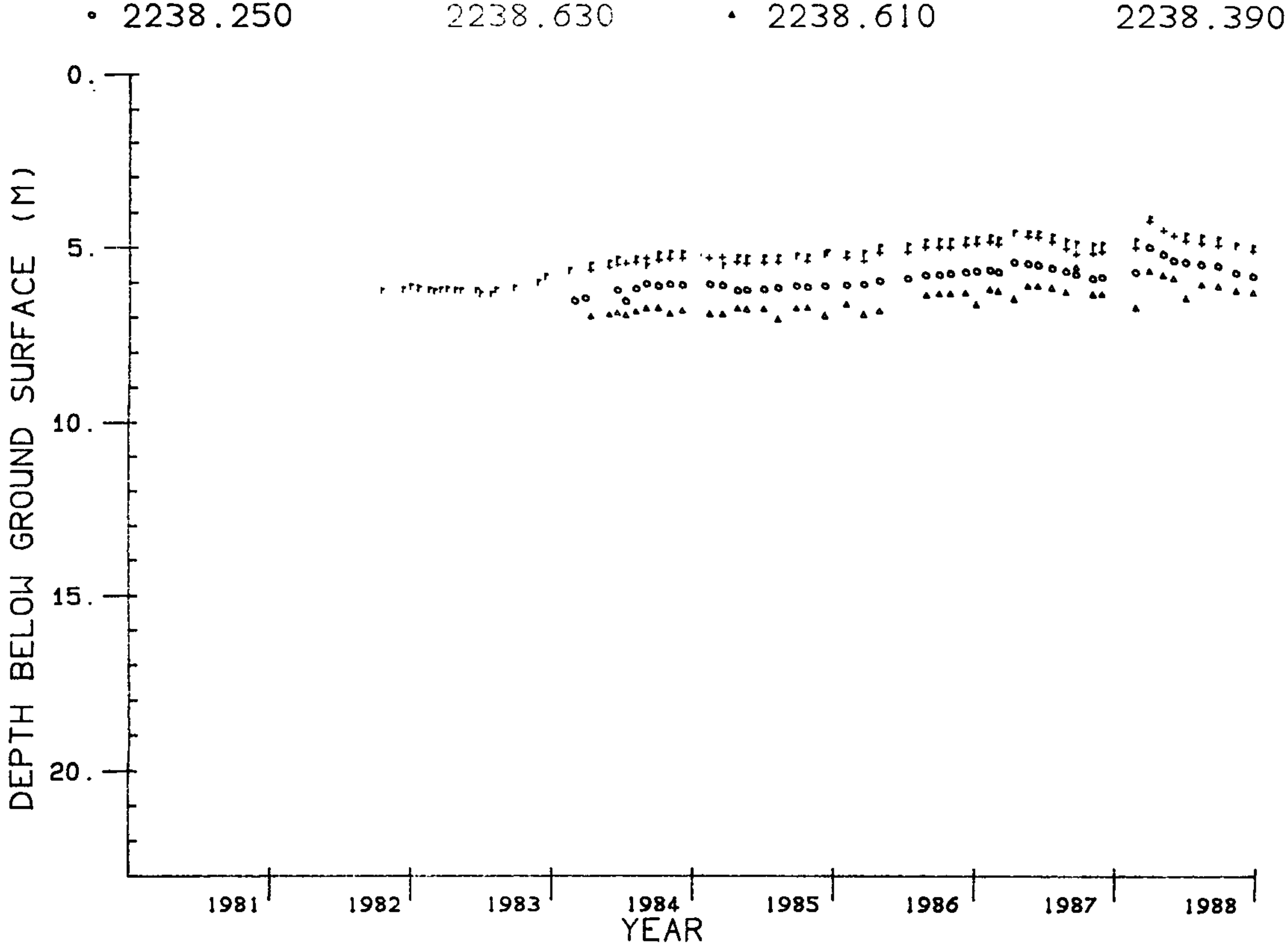

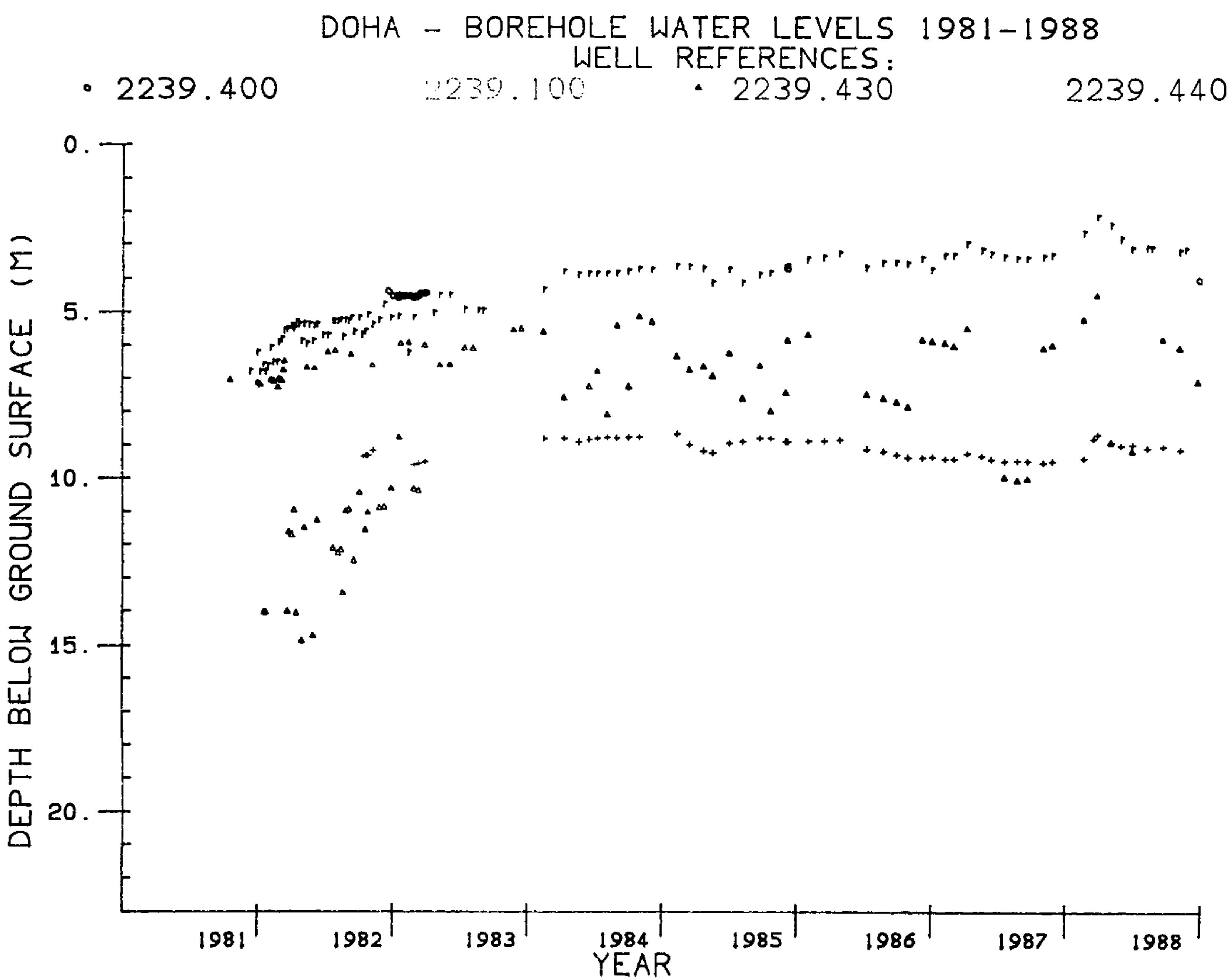

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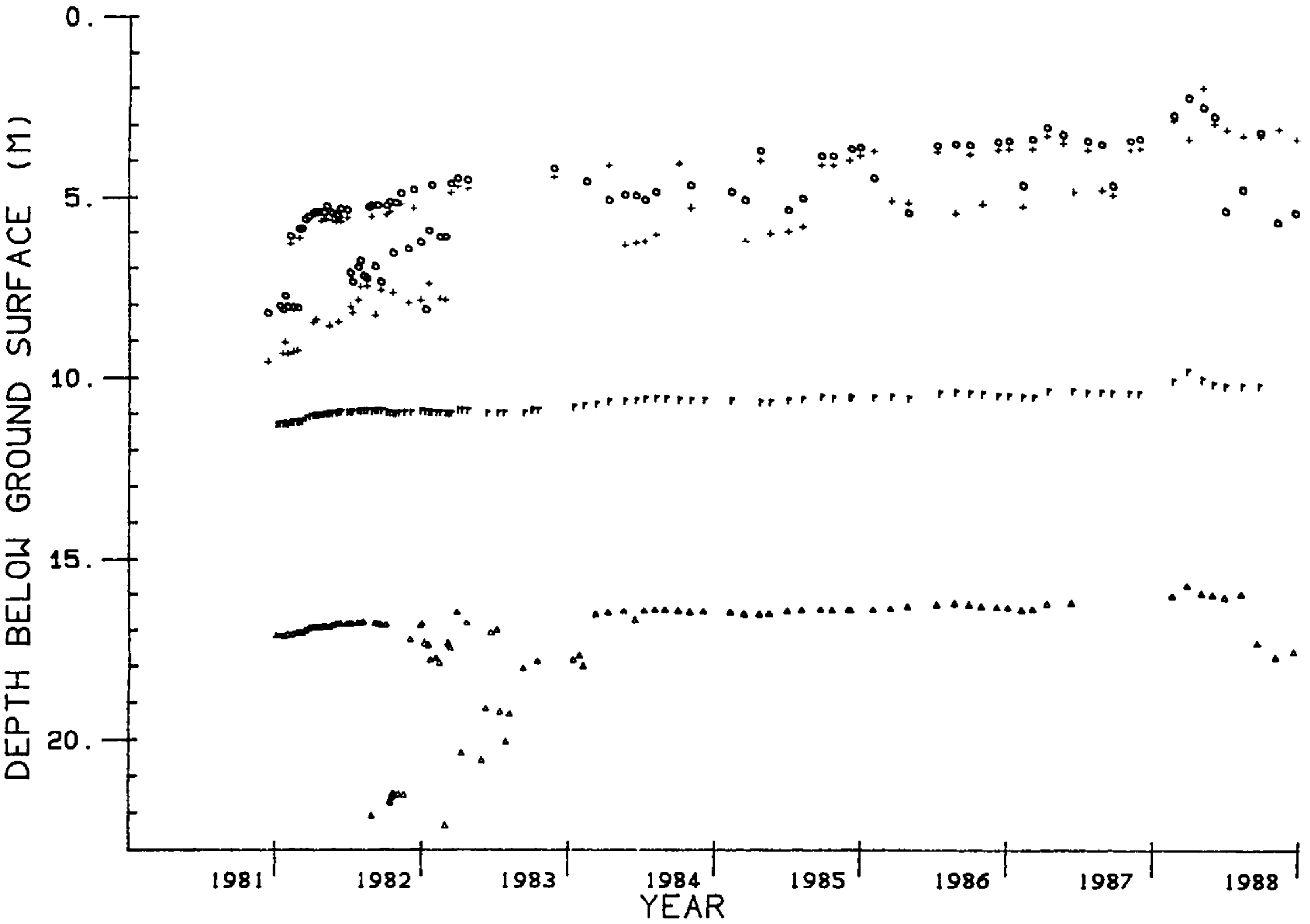

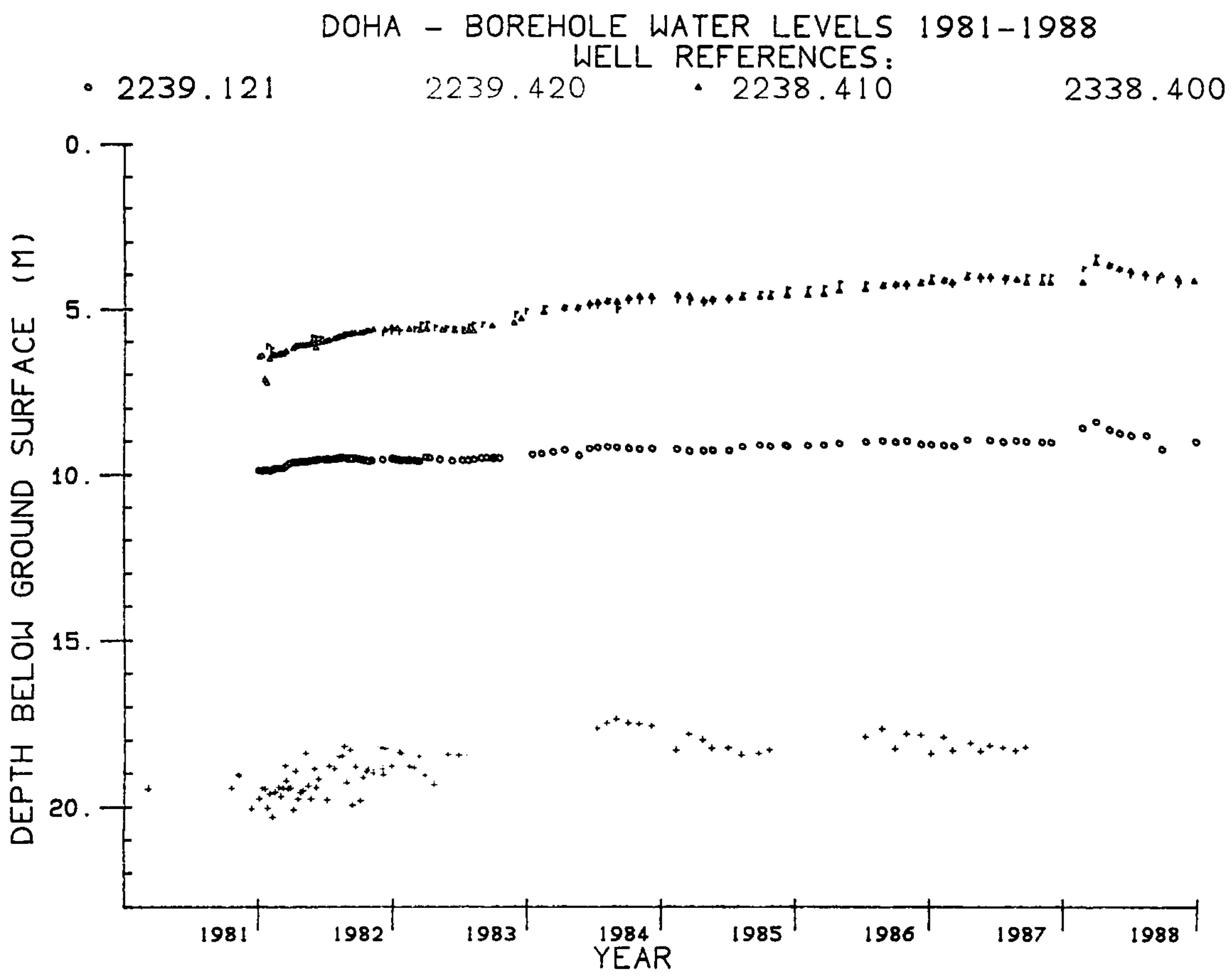

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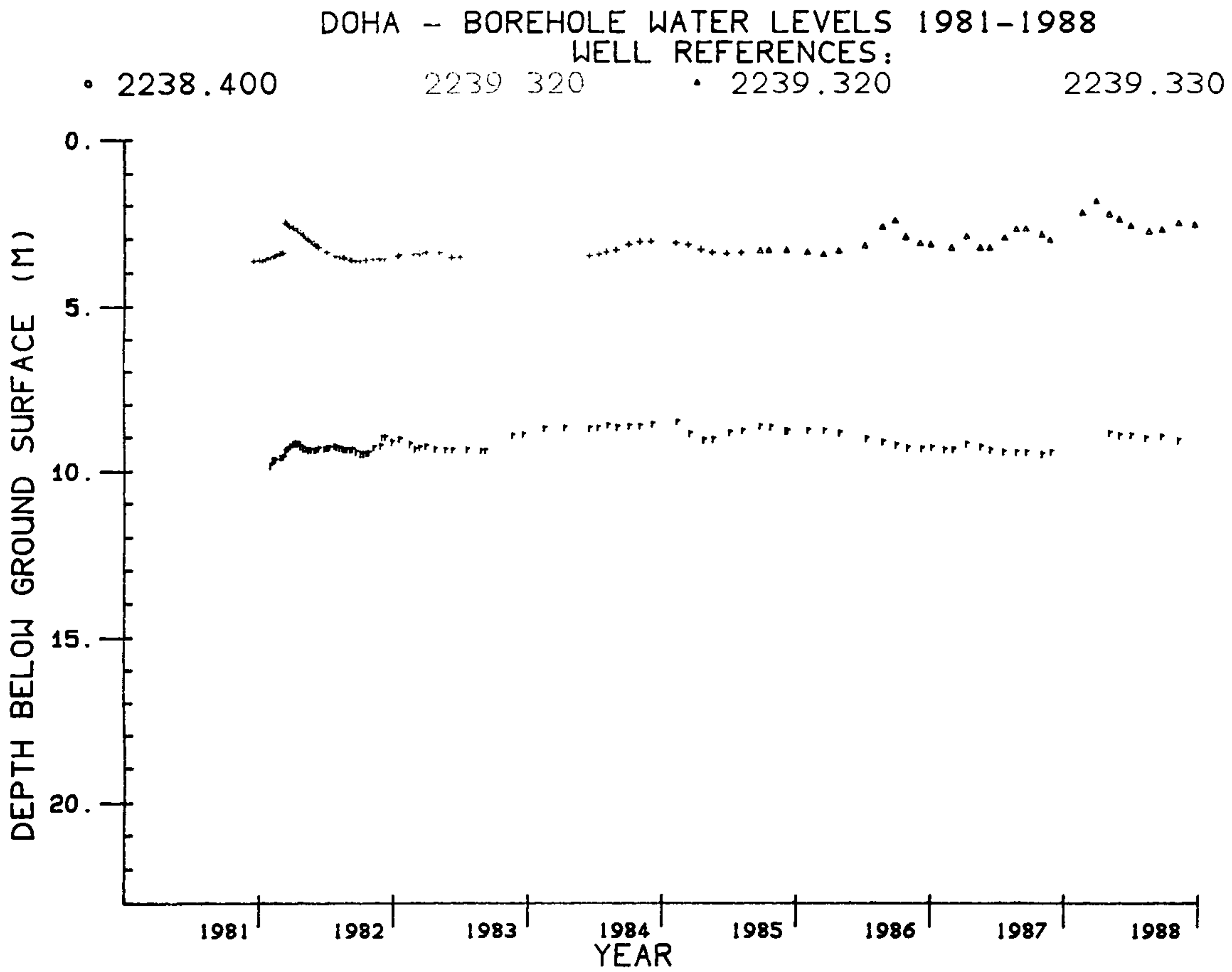
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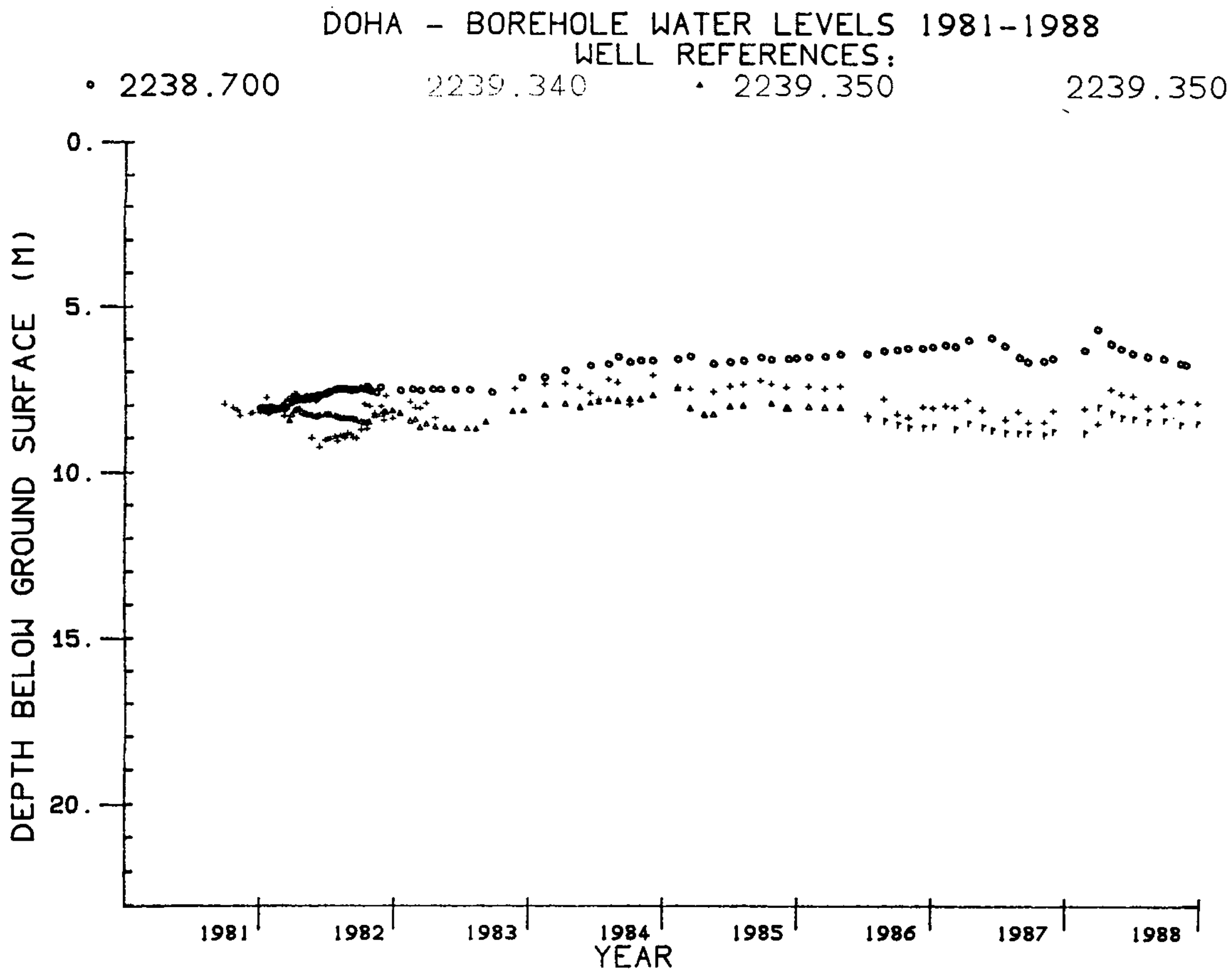
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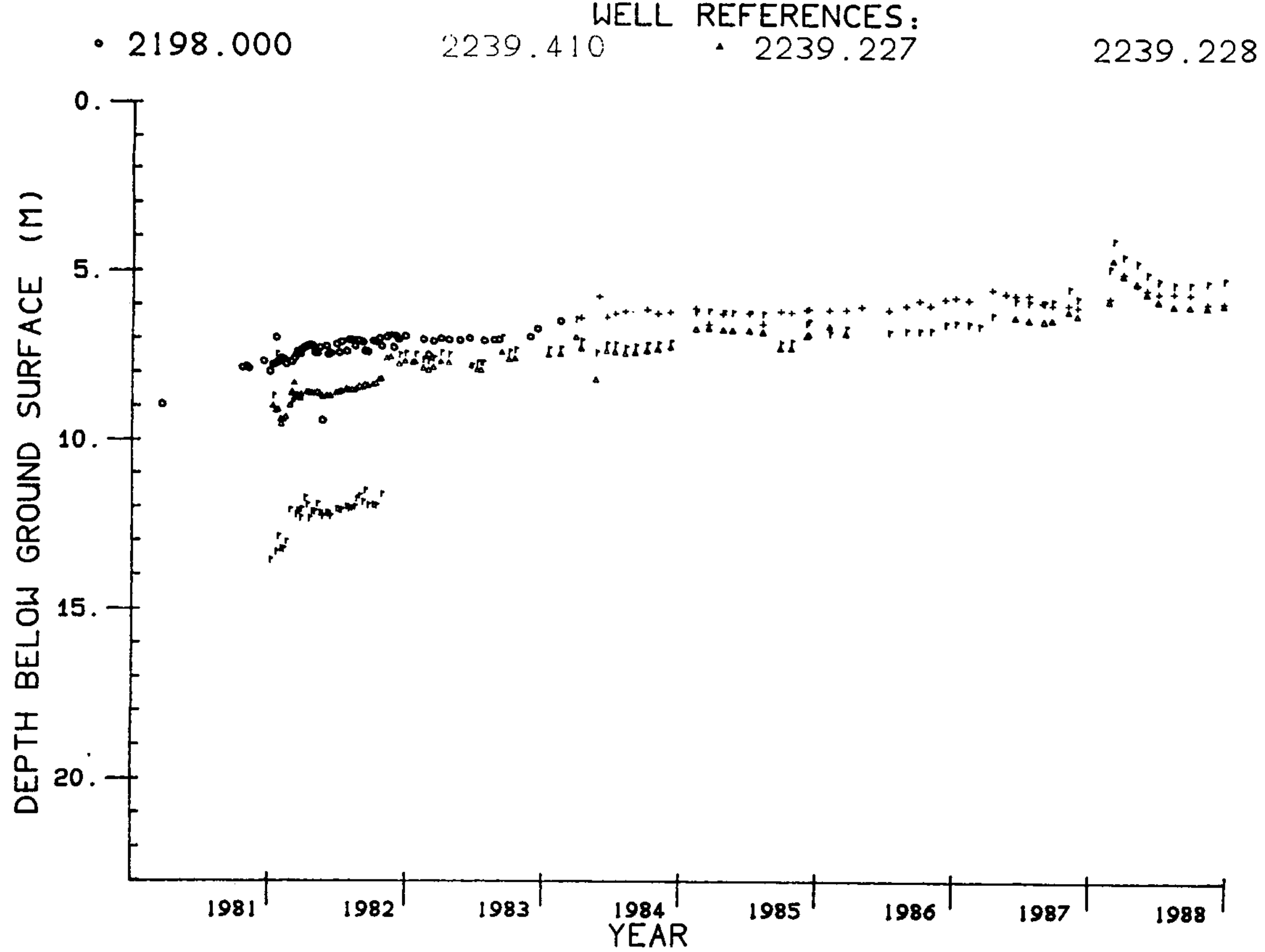

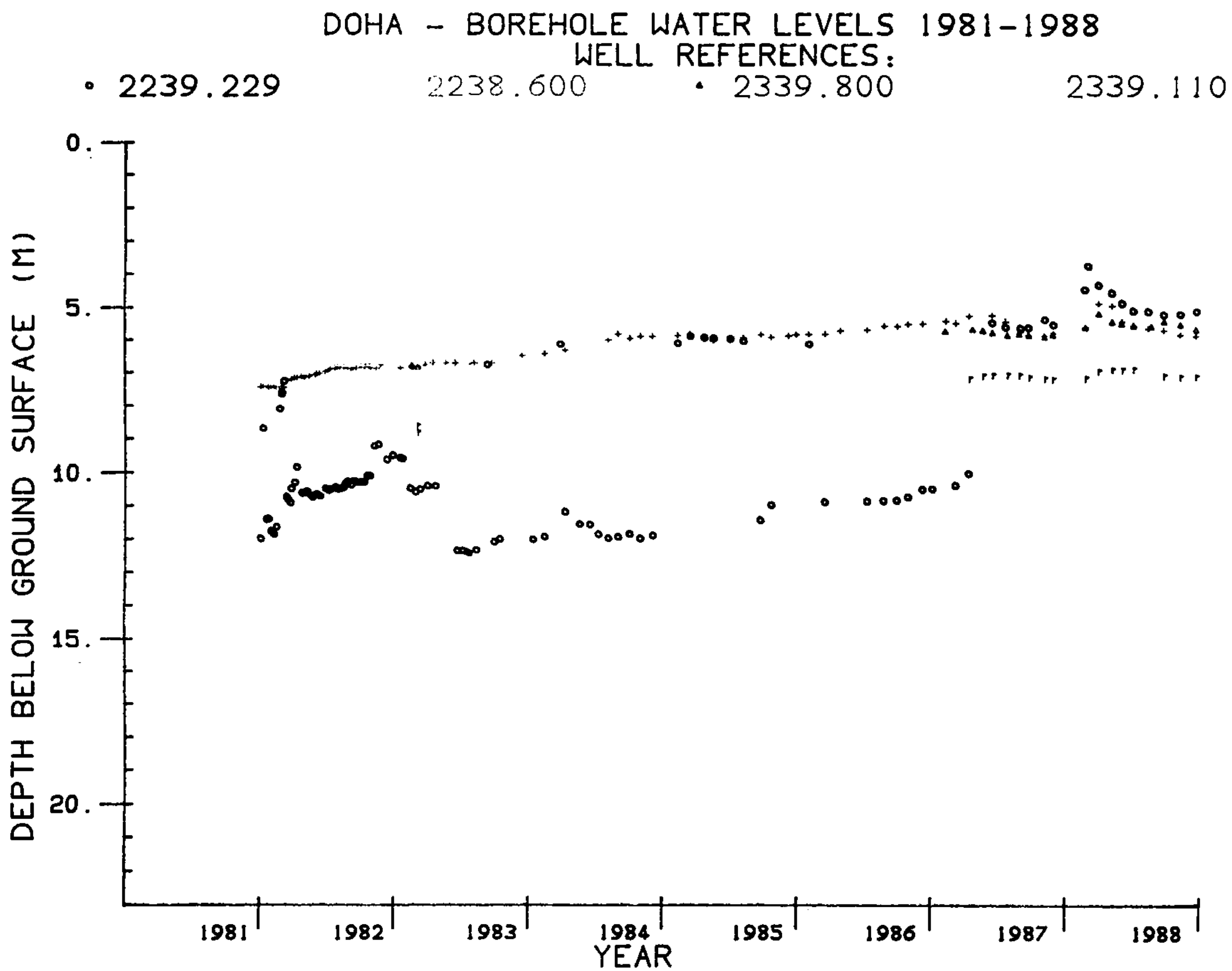
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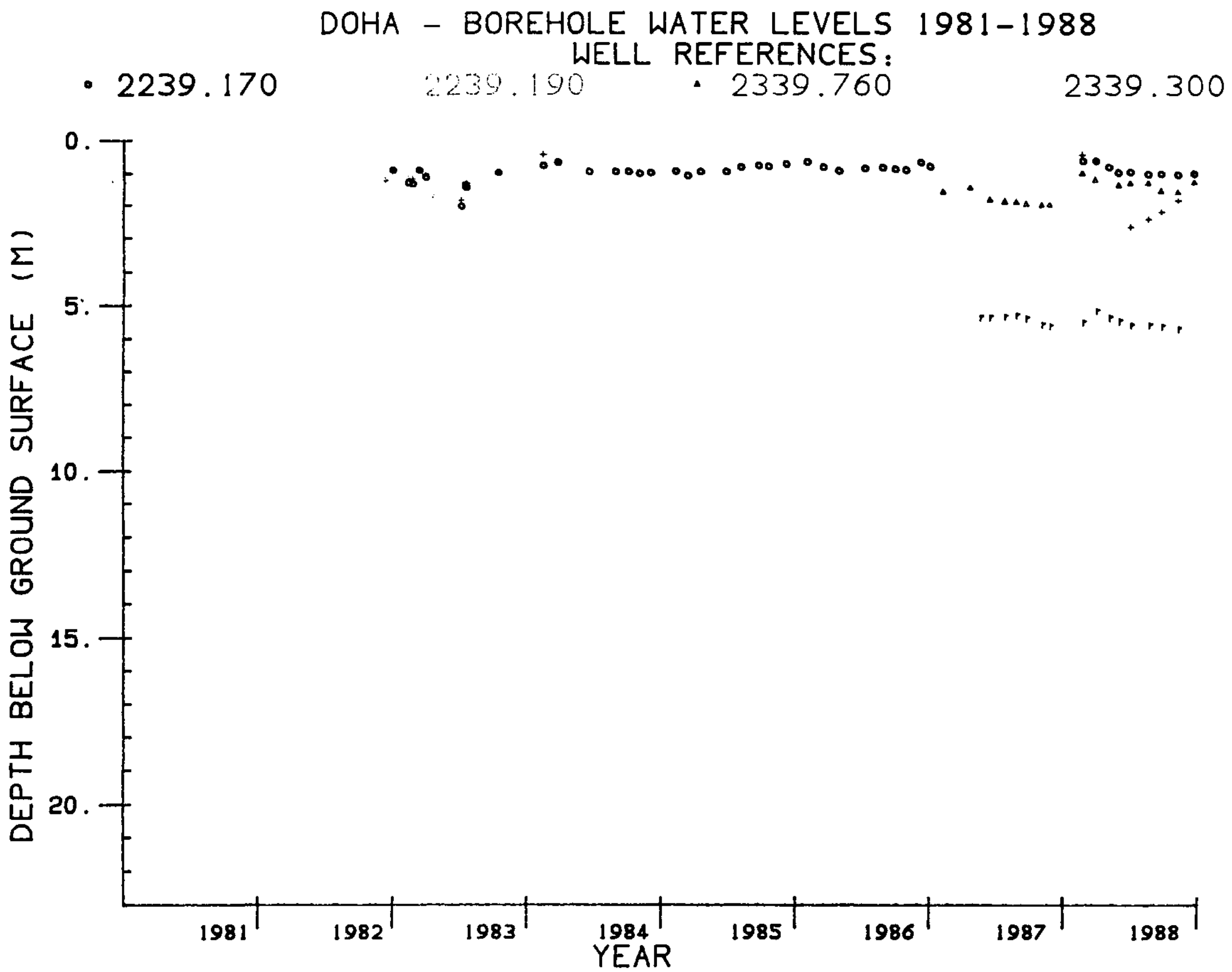
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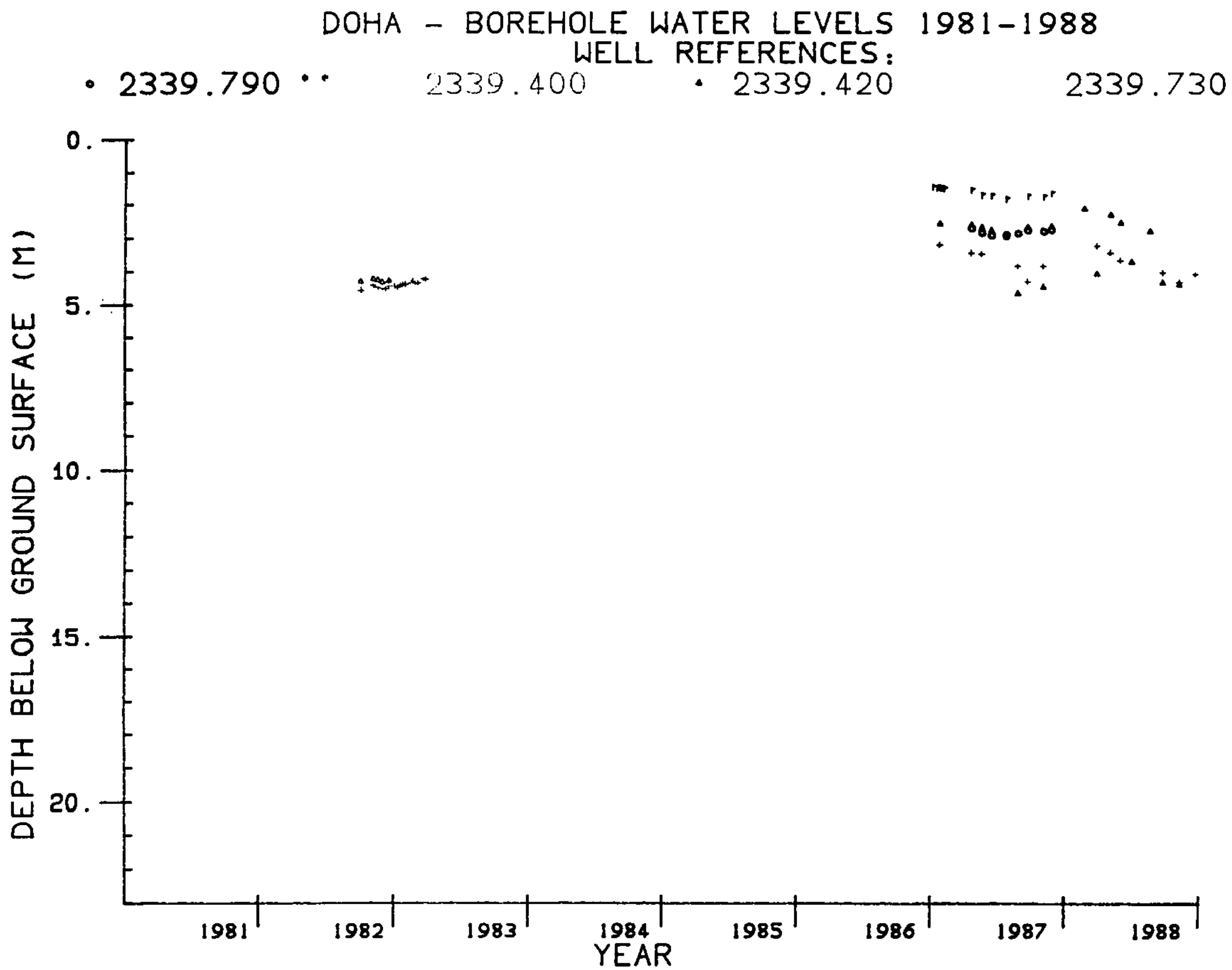
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DOHA - BOREHOLE WATER LEVELS 1981-1988
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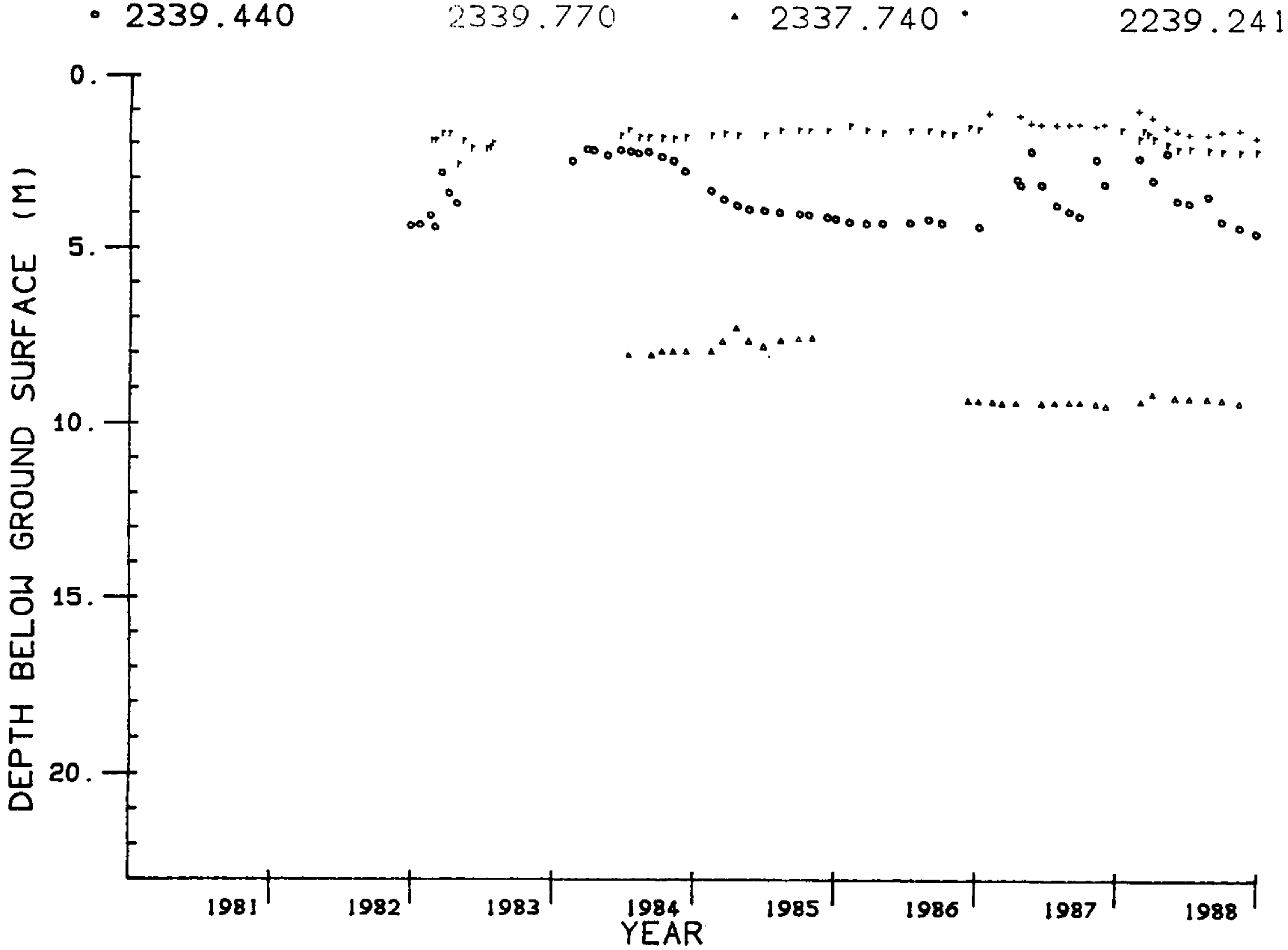

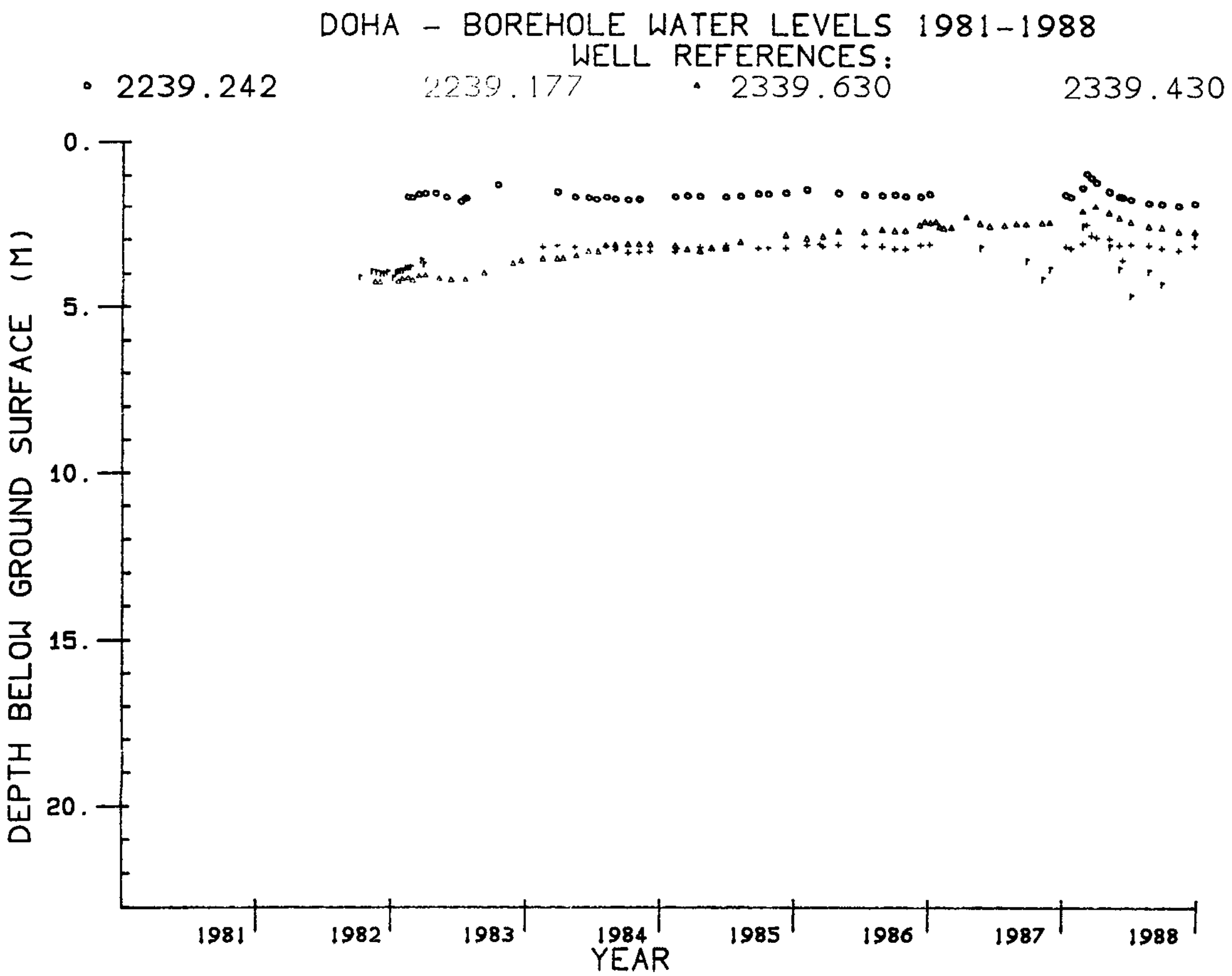
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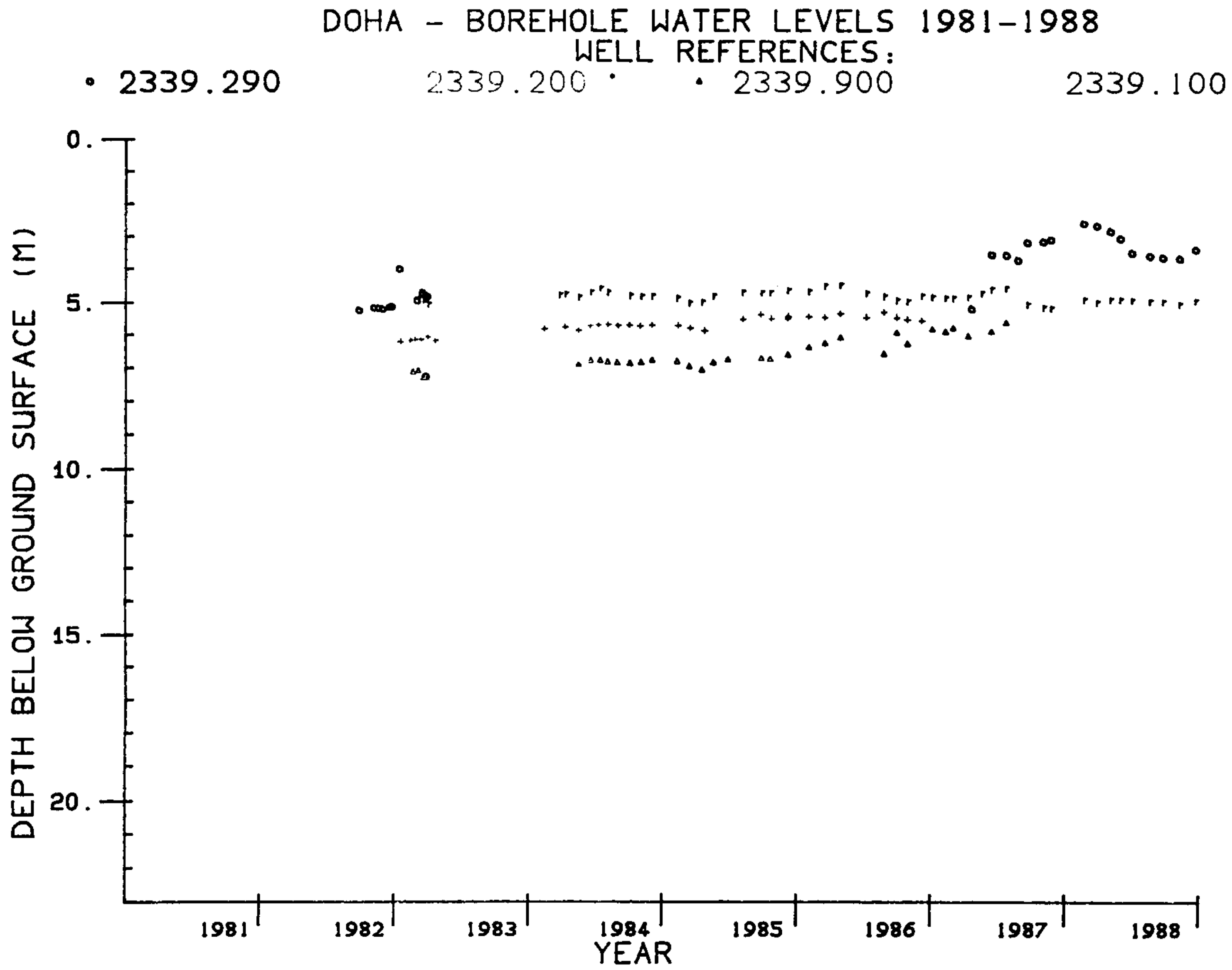
20.
DEPTH BELOW GROUND SURFACE (M)
1981
1982
1983
1984
1985
1986
1987
1988
YEAR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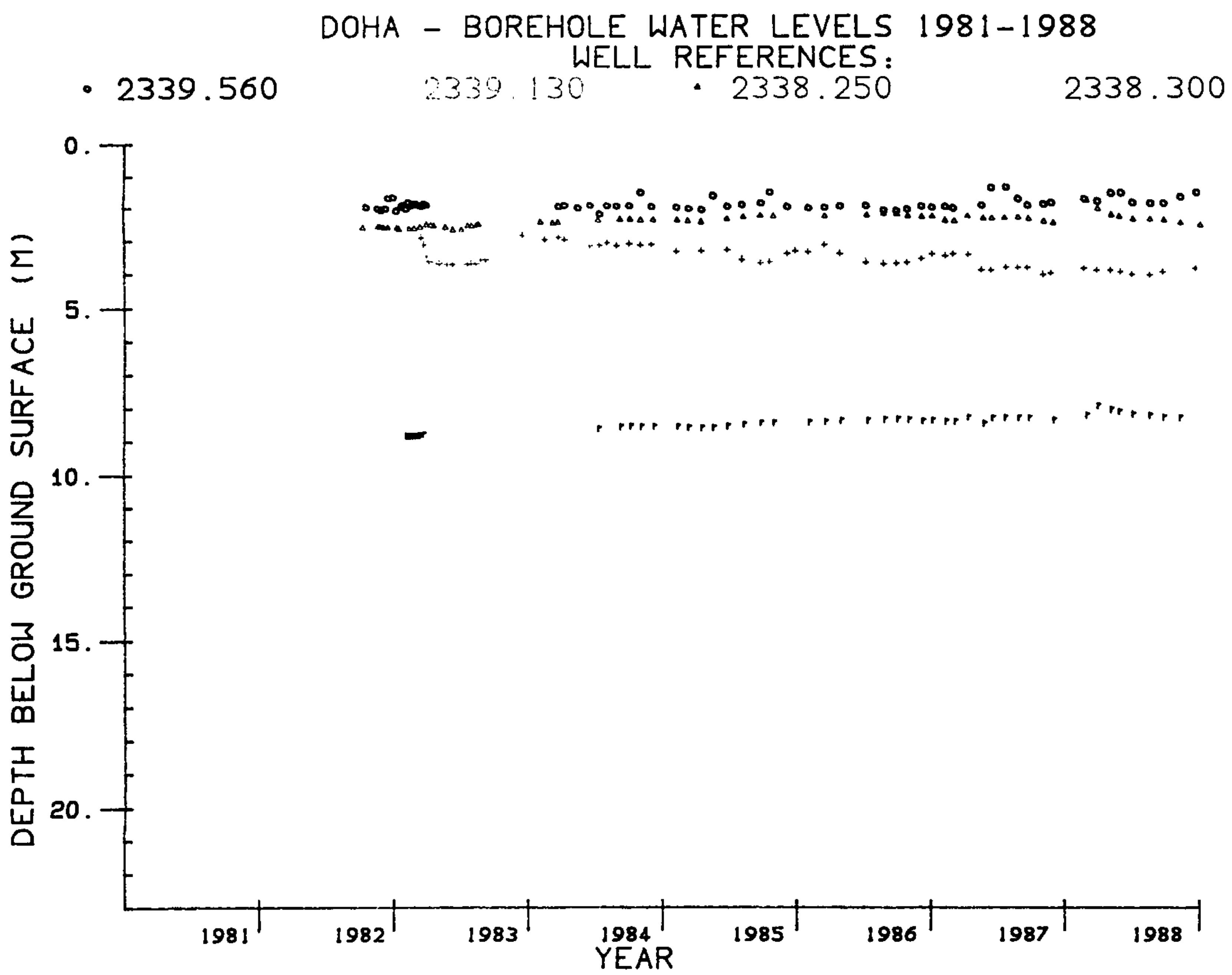
5.
10.
15.
20.
1981
1982
1983
1984
1985
1986
1987
1988
YEAR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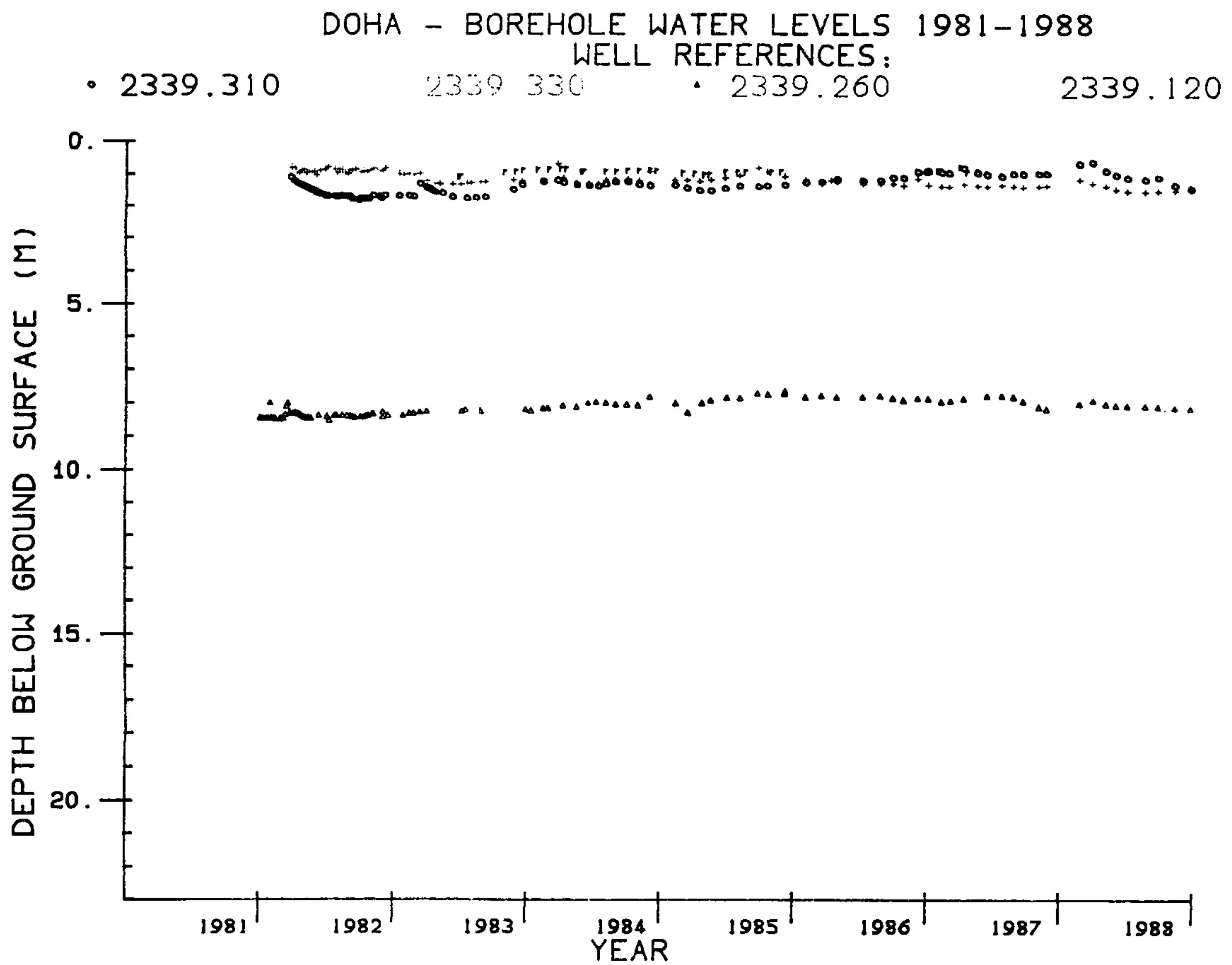
15.
20.
DEPTH BELOW GROUND SURFACE (M)
1981
1982
1983
1984
1985
1986
1987
1988
YEAR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2339.120
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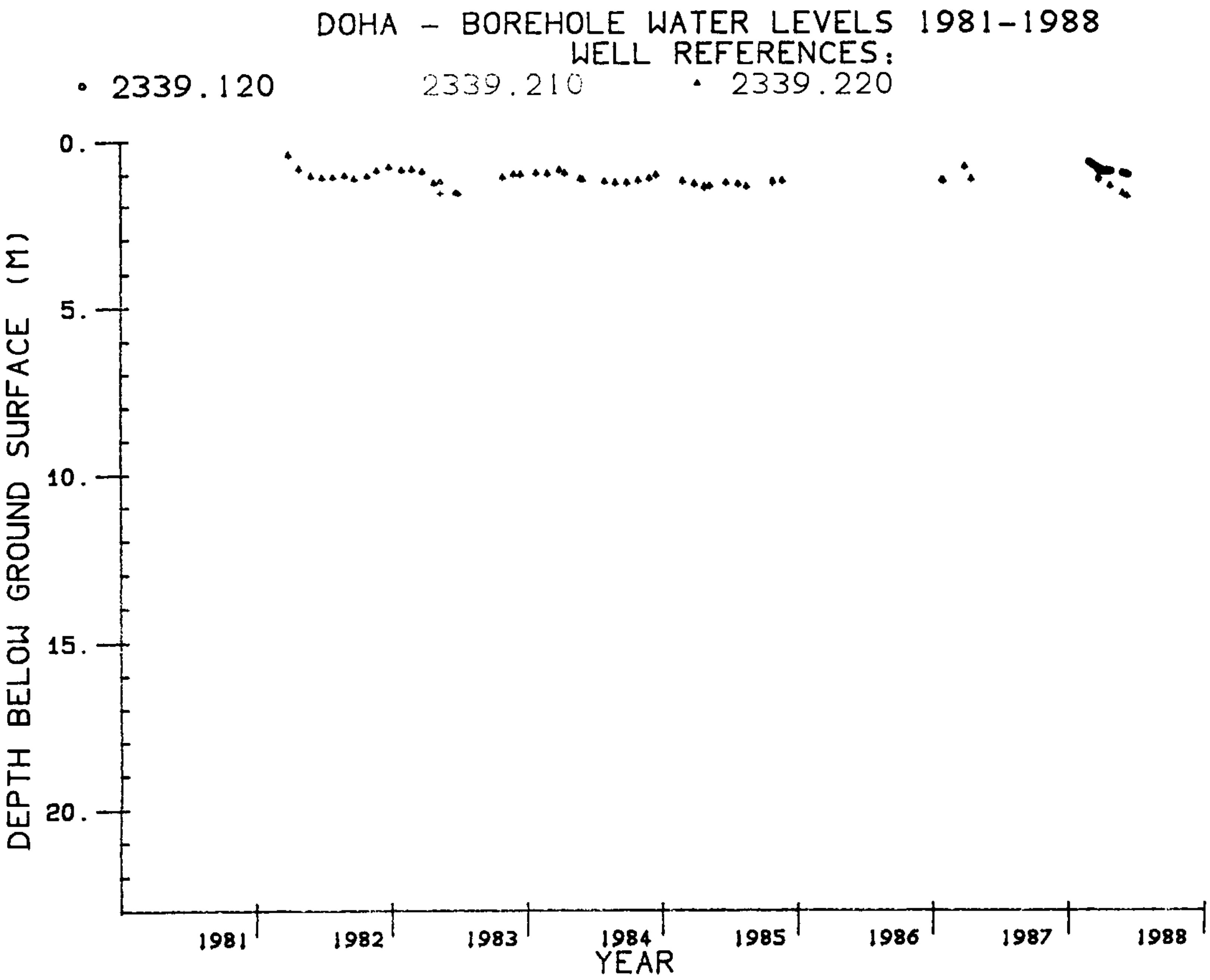
10.
15.
20.
1981
1982
1983
1984
1985
1986
1987
1988
YEAR


DOHA - BOREHOLE WATER LEVELS 1981-1988
WELL REFERENCES:
2339.120
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DEPTH BELOW GROUND SURFACE (M)
0.
5.
10.
15.
20.
1981
1982
1983
1984
1985
1986
1987
1988
YEAR

Annex B

Annex B

Water Level Trends

Borehole Number	Estimated Annual Rate of Change in Water Level (m/year)
2339.310	0.137
2339.330	-0.050
2339.260	0.087
2239.700	0.137
2239.900	0.137
2239.128	0.112
2239.120	0.037
2239.480	0.212
2239.500	0.200
2239.520	0.212
2239.107	0.275
2238.220	0.175
2238.230	0.250
2238.470	0.300
2238.480	0.187
2238.490	0.250
2238.700	0.250
2239.231	0.075
2239.780	0.100
2240.100	0.137
2239.230	0.137
2238.250	0.200
2238.630	0.162
2238.610	0.212
2238.390	0.162
2239.100	-0.050
2239.430	0.175
2239.440	0.237
2239.460	0.300
2239.119	0.112

Borehole Number	Estimated Annual Rate of Change in Water Level (m/year)
2239.120	0.137
2239.121	0.075
2239.420	0.175
2238.410	0.300
2338.400	0.300
2239.320	0.287
2239.330	0.000
2238.700	0.162
2239.340	0.125
2239.350	0.075
2239.410	0.175
2239.228	0.137
2238.600	0.337
2239.800	0.262
2339.110	0.350
2339.200	0.250
2339.900	0.262
2339.100	0.087
2337.740	0.225
2239.241	0.150
2239.242	0.087
2239.177	0.100
2339.630	0.312
2239.170	0.075
2339.300	0.225
2339.560	0.037
2339.130	-0.137
2338.250	0.100
2338.300	0.125

Annex C

Annexe C

Site Listing

GRID REFERENCE		WELL REF. NO.	DATUM ELEVATION (M)	SURFACE ELEVATION (M)
0	0	2339.790	-9.900	-9.900
223036	392370	2339.120	4.620	4.145
223303	393930	2239.237	11.570	11.570
223320	390664	2239.240	12.476	12.416
223668	396257	2239.235	13.409	13.409
223690	395910	2239.229	11.490	11.150
223750	395920	2239.228	11.730	11.370
223840	395910	2239.227	12.370	11.370
224017	394598	2239.243	6.100	5.800
224217	394714	2239.236	5.621	5.461
224250	394470	2239.980	6.650	5.450
224392	392703	2239.238	11.587	11.587
224560	394340	2239.910	6.660	6.580
224695	395240	2239.234	7.100	7.017
224900	396200	2239.460	9.720	9.620
225100	396200	2239.450	9.820	9.420
225200	396100	2239.440	9.410	9.410
225560	393510	2239.700	14.240	14.140
225570	396380	2239.430	14.550	13.850
225930	394870	2239.900	14.690	14.690
226380	393190	2239.480	13.100	12.620
226380	393190	2239.480	13.120	12.620
226520	387970	2238.100	11.190	11.090
226630	396120	2239.128	17.020	16.470
226630	396600	2239.500	15.390	15.190
226660	399150	2239.119	18.440	18.200
226680	399440	2239.120	12.580	12.280
226720	400060	2240.100	9.100	8.500
226790	399450	2239.121	11.170	10.870
227250	391120	2239.520	10.070	9.770
227460	393460	2239.120	13.110	12.900
227460	393470	2239.100	12.950	12.800
227460	393480	2239.110	13.000	12.900
227470	389180	2238.430	13.680	12.860
227500	389200	2238.480	13.680	12.860
227500	389200	2238.490	14.140	12.860
227520	389150	2238.490	14.140	13.290
227530	389030	2238.690	13.900	13.300
227620	387900	2233.220	6.840	6.440
227690	389040	2238.700	13.800	13.300
227720	394980	2239.124	16.950	16.640
227730	389170	2238.700	13.710	13.410
227747	394363	2239.239	19.603	19.500
227800	389300	2238.600	13.290	12.740
227810	388120	2233.230	7.280	6.970
227900	397600	2239.780	8.870	8.080
228050	389450	2238.630	12.830	12.350
228200	396060	2239.420	21.710	21.360
228290	390130	2239.230	-9.900	-9.900
228300	390100	2198.000	13.680	13.460
228390	390180	2239.410	13.680	13.460
228430	389990	2238.250	13.060	13.060
228520	336880	2238.470	9.130	8.540

GRID REFERENCE	WELL REF. NO.	DATUM ELEVATION (M)	SURFACE ELEVATION (M)
228690 389270	2238.390	12.770	12.240
228810 388410	2238.610	14.060	13.510
228956 397285	2239.233	6.469	6.469
229020 392060	2239.190	6.840	5.960
229030 392150	2239.241	7.220	6.700
229030 392160	2239.242	7.280	6.780
229030 392140	2239.177	7.070	6.710
229090 392150	2239.170	6.950	6.290
229300 393300	2239.340	12.940	12.610
229400 393200	2239.350	13.620	13.280
229420 393170	2239.350	13.620	13.280
229600 393400	2239.330	14.030	13.680
229610 393410	2239.100	14.140	13.830
229700 391100	2239.320	11.750	11.450
229710 389350	2238.410	11.950	11.580
229710 389350	2238.400	11.950	11.580
229710 391050	2239.320	11.750	11.450
229747 395398	2239.232	7.689	7.309
229880 396080	2239.231	2.465	2.215
230010 390480	2339.800	14.390	14.290
230010 390470	2339.110	14.440	14.370
230450 391310	2339.440	11.840	11.140
230462 391613	2339.770	8.322	8.322
230718 392087	2339.800	4.905	4.905
230732 392040	2339.810	5.729	5.422
230732 392040	2339.810	4.922	5.422
230748 391967	2339.820	5.060	4.962
230900 392400	2339.120	4.620	4.145
230900 392400	2339.210	4.400	4.040
230900 392400	2339.220	4.550	4.000
230980 392040	2339.500	5.350	5.350
231060 390210	2339.630	9.320	9.300
231310 396943	2339.750	2.049	2.049
231395 390200	2339.730	8.412	8.200
231480 391030	2339.310	9.000	8.620
231670 390210	2339.400	9.260	8.920
231670 391920	2339.330	7.310	7.010
231690 392680	2339.130	6.350	6.100
231890 390400	2339.430	8.470	8.270
231910 390490	2339.420	8.910	8.810
232010 389360	2338.400	10.520	9.790
232560 390450	2339.290	10.320	9.320
232608 392204	2339.760	7.097	7.157
232626 390060	2239.107	8.400	7.950
232813 392600	2239.400	10.520	10.420
233150 391550	2339.900	11.220	10.960
233420 392830	2339.560	2.640	2.230
233460 392350	2339.100	9.200	9.000
233630 390660	2339.300	7.780	7.600
233680 390670	2339.200	7.650	-9.900
234210 391470	2339.260	9.800	9.200
234990 387500	2338.300	9.970	9.890
235110 389020	2338.250	4.430	3.870
236800 379400	2337.740	3.800	-9.900

Legend

-9.9 No elevation available

0 No grid reference available

Annex D

Annexe D

Water Levels, December 1988

GRID REFERENCE	WATER LEVEL DECEMBER 1988 (METRES B.G.L.)
223036 392370	0.00
223303 393930	5.45
223320 390664	6.40
223668 396257	7.49
223690 395910	5.14
223750 395920	5.20
223840 395910	5.95
224017 394598	0.60
224217 394714	0.03
224250 394470	0.25
224392 392703	4.98
224560 394340	0.57
224695 395240	0.97
224900 396200	3.38
225200 396100	3.15
225560 393510	7.78
225570 396380	6.10
225930 394870	8.18
226380 393190	6.20
226520 387970	4.25
226630 396600	9.95
226630 396120	10.92
226680 399440	10.40
226720 400060	5.16
226790 399450	8.98
227250 391120	3.13
227460 393460	6.06
227460 393470	6.38
227460 393480	6.29
227470 389180	6.08
227520 389150	6.64
227530 389030	6.27
227620 387900	-0.08
227720 394080	9.25
227730 389170	6.74
227747 394363	9.43
227800 389300	5.37
227810 388120	0.37
227900 397600	5.11
228050 389450	5.06
228300 390180	5.35
228430 389990	5.81
228520 386380	2.46
228690 389270	4.98
228810 388410	6.29
228956 397285	5.00
229020 392060	0.93
229030 392150	2.09
229030 392160	1.91
229030 392140	3.14
229090 392150	1.05
229300 393300	7.38
229420 393170	3.49
229600 393400	9.14
229610 393410	9.21
229710 389350	4.16
229710 389350	4.16
229710 391050	2.61
229747 395398	5.67
229880 396030	0.76
230010 390430	5.70
230010 390470	7.12
230450 391310	4.54
230462 391613	1.77
230718 392087	0.80
230732 392040	0.50
230748 391967	0.67
230900 392400	1.67
230900 392400	1.65
230980 392040	0.61
231060 390210	2.78
231310 396943	1.82
231395 390200	0.96
231480 391030	1.47
231670 390210	4.06
231670 391920	1.47
231690 392680	3.82
231890 390400	2.89
231910 390490	2.80
232560 390450	3.42
232608 392204	1.30
232626 390060	2.28
232813 392600	4.03
233150 391550	7.31
233420 392330	1.59
233460 392350	4.97
233630 390660	5.72
234210 391470	3.14
234990 387500	8.36
235110 389020	2.52

The demand for long-term scientific capabilities concerning the resources of the land and its freshwaters is rising sharply as the power of man to change his environment is growing, and with it the scale of his impact. Comprehensive research facilities (laboratories, field studies, computer modelling, instrumentation, remote sensing) are needed to provide solutions to the challenging problems of the modern world in its concern for appropriate and sympathetic management of the fragile systems of the land's surface.

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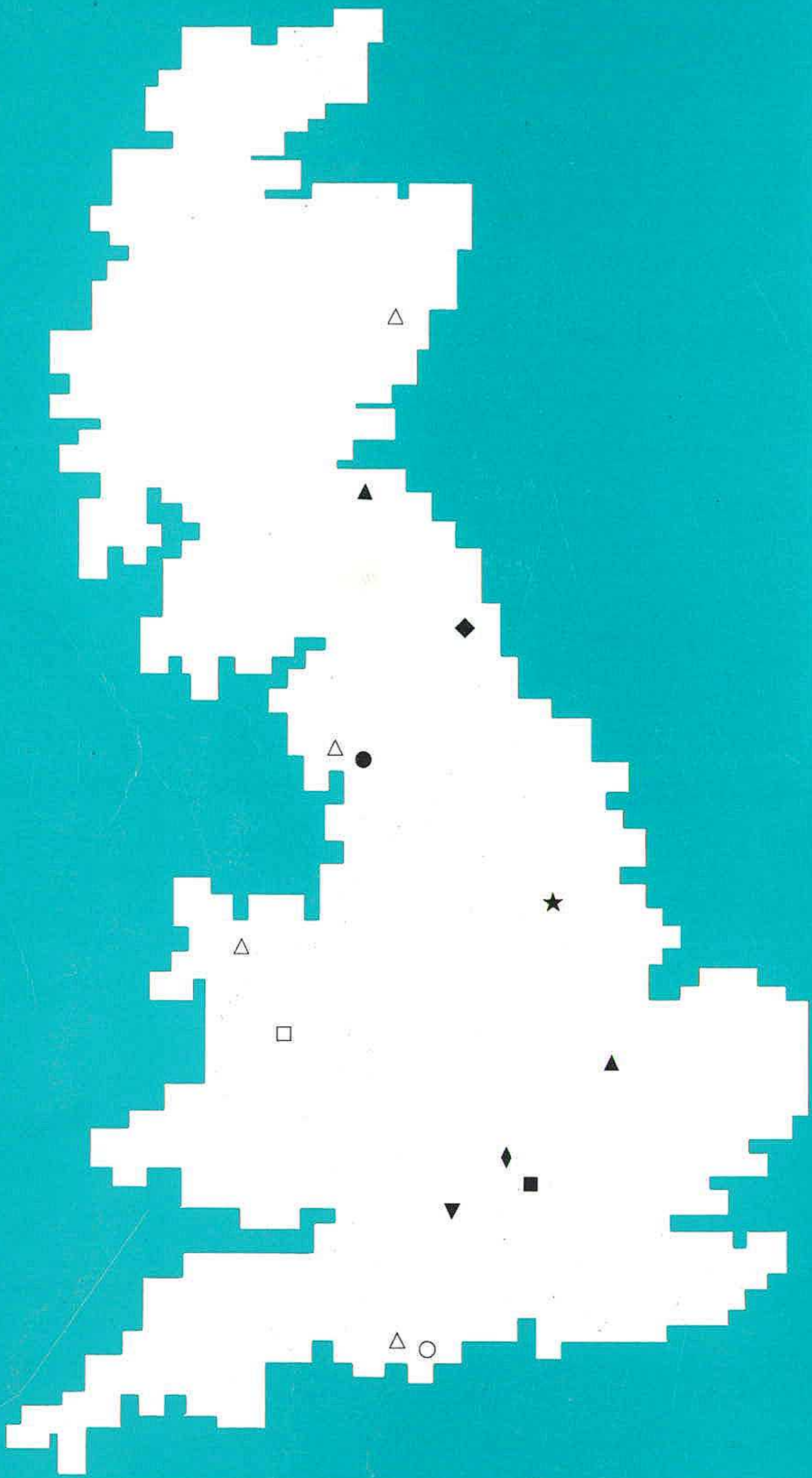

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