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BUREAU OF SUGAR EXPERIMENT STATIONS

QUEENSLAND, AUSTRALIA

A REPORT TO THE WOONGOOLBA FLOOD MITIGATION ADVISORY COMMITTEE

CONSEQUENCES OF FUTURE MANAGEMENT OPTIONS FOR THE BREMERHAVEN DRAINAGE SYSTEM

by

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Bundaberg

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EXECUTIVE SUMMARY

Watertable elevation and salinity data collected in the Bremerhaven System between September 1982 and July 1984 formed the basis for advice to the Woongoolba Flood Mitigation Advisory Committee on questions raised in relation to future management of the system.

The study showed that lowest watertables in the study period were recorded during February and March 1983 in response to drought conditions in spring and summer. Watertables in an area along Holmstead Rd fell to 0.2 m below the current sill level at Bremerhaven. While salinity of all wells increased during the period of low watertables, the character of only three wells deteriorated significantly; the deterioration was reversed by wet weather. These changes are explained.

There was a general flow of water from the more elevated sandy country towards the drainage system. A sufficient head of fresh water is moving from these soils to prevent back flow of saline water from the drainage system.

The Bremerhaven System would benefit from ability to further lower watertables because more rapid clearing of flood and drainage waters would reduce yield losses from waterlogging and salinity. Time taken to reach the new equilibrium watertable cannot be predicted at this stage; watertables should be monitored for depth and quality as an aid to management of the system.

If use of part of the drainage system for water exchange by the existing prawn farm results in artificially high water levels in the drains, it is considered that this would limit prospects for drainage, particularly of lower lands. Any expansion of inland mariculture in the area would exacerbate the situation because of the need for a greater exchange volume and higher water levels in drains.

1.0 INTRODUCTION

The following questions were referred to BSES by the Woongoolba Flood Mitigation Advisory Committee:

1. The possible short and long-term effect on all classes of land of lowering the watertable in the Bremerhaven System.

2. The possible effect of the continued use of a designated part of the system for water exchange for the existing prawn farm.

These questions will be answered in relation to data acquired in the area of the Bremerhaven System during the Rocky Point Watertable Study from September 1982 to July 1984, and on the basis of sill height determinations at Bremerhaven on 28/8/91 and 19/9/91.

2.0 ROCKY POINT WATERTABLE STUDY

2.1 Methods

In August 1982 a series of 164 shallow wells was installed to a depth of 1.5 m on a nominal 600 x 600 m grid over most of the Rocky Point area to study watertable fluctuations. Location of the 25 wells relevant to the Bremerhaven system is shown on Figure 1a in relation to major roads, landmarks, the major drainage system and the flood gate. Wells are numbered 14.20, 15.22, 17.23 etc. Site locations and the drainage system are reproduced on Figure 1b for use as an overlay on groundwater contour Figures 2 to 6.

Depth of the watertable below ground level and electrical conductivity (EC) of the water were measured, usually on a monthly basis. EC, expressed in deci-Siemens per metre (dS/m), is a measure of the salinity of the water; good quality irrigation water has an EC of less than 1.0 dS/m, while the value for sea water can vary between 35 and 50 dS/m. The EC value reported for the watertables was determined after vigorous stirring of water in the tube, because a small density (salinity) gradient was noted at some sites.

Ground surface at each site was related to the State Datum to allow examination of the reduced level for the watertable, and to determine potential flow gradients for groundwater.

Rainfall data were obtained from the Rocky Point Sugar Mill and are shown in Table 1.

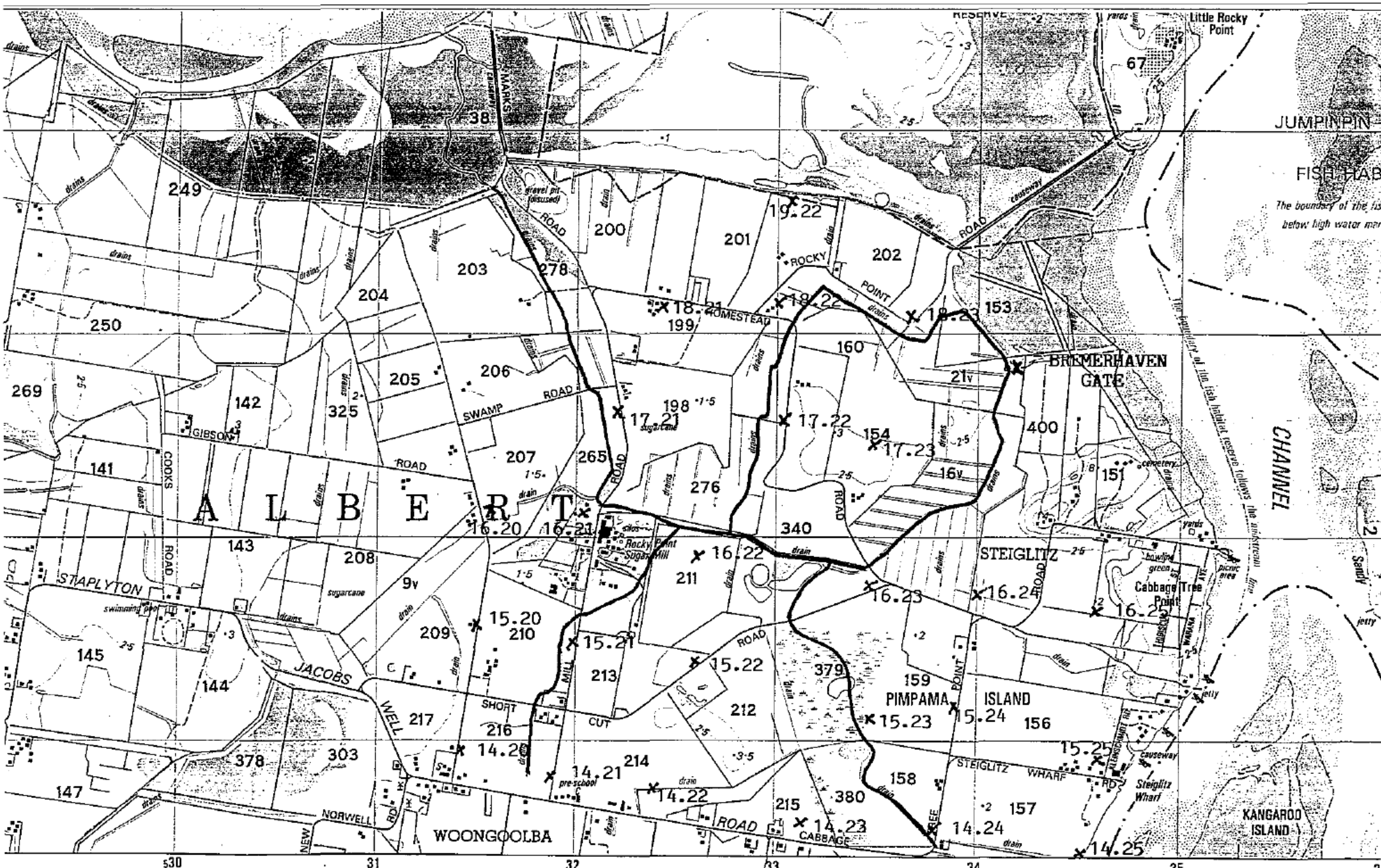


FIGURE 1a - Location of wells and the Bremerhaven Drainage System

Jacobs Well 5km

W A R D BOONNAHBA

1" of longitude = 27 metres

20'

JOINS PIMPAMA 9542-24

SCALE 1 : 25 000

500 0 1 2 3 kilometres

CONTOUR INTERVAL 5 METRES

WORLD GEODETIC SYSTEMS: To convert World Geodetic System 1972 to Australian Geodetic Datum 1966 co-ordinates on which this map is based:
Increase the numerical value of latitudes by 5·6", equivalent to 174 metres.
Decrease the numerical value of longitudes by 3·3", equivalent to 89 metres.

Table 1

Monthly rainfall for Rocky Point (mm)

Month	1982	1983	1984
January	341.0	81.2	153.8
February	114.3	49.8	60.2
March	156.5	103.0	73.2
April	161.0	128.0	233.2
May	105.5	400.4	39.7
June	4.0	308.4	87.6
July	14.0	67.6	141.4
August	47.0	76.4	42.5
September	60.0	64.7	29.4
October	89.5	90.3	130.0
November	5.0	172.8	129.7
December	132.5	350.0	45.2

2.2 Results

2.2.1 Depth of the watertable below ground level

Data for depth of the watertable below ground level for each of the 25 wells between September 1982 and July 1984 are shown in Appendix I. These data have been combined with EC data of groundwater from Appendix III to produce graphs in Appendix V which demonstrate variation in watertable depth and quality with time, in response to rainfall and drainage events. Four periods which represent significant events have been selected for discussion:

Period	**Comment**
February/March 1983	Dry, very low watertables
June 1983	Wet, heavy rain May and June
August 1983	Watertable recession
January 1984	Rain in December, watertable recession

Watertables at most sites dried to their lowest levels, 1.4 to 1.5 m below ground level, in February and March 1983 in response to low rainfall in late spring and early summer. However, sites 16.25 (near Cabbage Tree) and 17.22 (Holmstead Rd near Zipf's prawn farm) dried to around 1.25 m, and 15.23, 16.24 and 18.23 dried to only 1.0 m.

In June 1983 water in all wells, except for 16.21, rose to within 0.25 m of the surface, as a result of heavy rain in May and June (see Table 1). The watertable at 16.21 (near the old cookhouse at the mill) rose to only 0.8 m.

By August 1983 watertable recession had commenced because rainfall had declined to 68 and 76 mm in July and early August respectively. These measurements showed that all wells in the Jacob's Well Rd line, Short Cut Rd line, 16.23 and 16.24 still had water levels at approximately 0.25 m below ground level; watertables at the remaining 12 sites ranged between 0.5 and 1.0 m below the surface.

Watertable recession was more advanced in January 1984, with most sites having watertables between 0.5 and 0.75 m below ground level.

The graphs in Appendix V show that the drainage system took from mid-June to October 1983 to dispose of enough water to generally stabilise watertables around 0.5 to 0.75 m below ground level. This slow drainage would have had an effect on the progress of the 1983 harvest, and a more severe effect on yield had the high watertables occurred during the months of major growth. BSES research has shown that a yield loss of 0.46 tonnes cane/ha/day results for each day the watertable is closer to the surface than 0.5 m; similar results have been reported for South Africa and Louisiana.

2.2.2 Reduced level of the watertable surface

Expression of watertable depth relative to a common datum allows the watertable to be viewed as a surface across the study area and shows the potential for water to flow from higher to lower levels, in a direction perpendicular to contour lines.

Contour maps of the reduced level (RL) of the water surface have been produced from data in Appendix II for the following periods:

Period	**Figure No**
February 1983	Figure 2
March 1983	Figure 3
June 1983	Figure 4
August 1983	Figure 5
January 1984	Figure 6

Contour maps were prepared with the SURFER computer program; contour lines generated beyond the area covered by well sites should be ignored.

Suggested directions for movement of water have been marked on Figures 2 to 6, as heavier dotted lines terminating in arrows. It should be noted that the top of the inner and flow limiting sill at the Bremerhaven Gate is placed at 0 m RL.

Data in Figures 2 to 6 indicate potential for a general flow of water into the lower lands to the east and north of the mill. During the period of lowest watertables in February/March 1983 wells 16.23 and 17.22 (Holmstead Rd) showed water levels of approximately -0.2 m RL. A similar level was achieved at well 15.20 (near the old piggery shed on School Rd), but data suggest that this water may be draining towards Langfeldt's Swamp.

Topographic levels for the above sites have been checked on three occasions; therefore, there is a high degree of confidence in the negative RL data for February and March. No clear explanation for the lowest RL data can be extracted from the results, except for the fact that 16.23 and 17.22 were at the lowest points in the landscape after 15.23 and 16.24 (Appendix IV is a contour map of reduced level of the land surface). Watertables at 16.23 and 17.22 were only some 1.3 m below ground level; by no means the deepest values recorded in the area. It is possible that crop water use could have contributed to the drawdown below sill height; whereas, at the lower landscape (15.23 and 16.24) greater salinity restricted plant growth and use of groundwater.

Use of the transparent overlay of site locations and the drainage system (Figure 1b, pocket on rear cover) in association with Figures 2 to 6 shows that water is basically flowing into the drainage system. Water from the Steiglitz Wharf Rd area appears to flow to the south-east, away from the Bremerhaven System.

Results in Appendix V show that drainage was required to lower watertables to prevent crop losses from waterlogging in the June to October period in 1983. During those months the watertable head above current sill height ranged between 0.5 to 0.9 m in the low country to 1.1 to 1.5 m in the higher lands.

2.2.3 Water quality

Detailed EC (salinity or water quality) data for each well are contained in Appendix III, but the time based trend for most sites is summarised in graphs in Appendix V.

Lowest salinity water was found at 14.20 (near the Woongoolba school), 15.20 (Piggery on School Rd), 15.22 (Short Cut Rd), 17.21 (Mill Rd to the north of the mill), 18.21 (Holmstead Rd) and 18.23 (Rocky Point Rd). These wells were associated with higher land and generally sandier phases of the humic gley soil type.

During the August 1983 and January 1984 recession periods, most of the Bremerhaven System supported watertables with salinity lower than 2.0 dS/m.

A tongue of higher salinity water projected into the area from 14.22 to 14.24 along Jacob's Well Rd to 15.23 and 16.24 for the duration of the study. On the northern side of the area 18.22 and 19.22 always contained very saline water.

Graphs in Appendix V can be used to make a general statement that salinity of most bores was highest in the period September 1982 to February/March 1983 when watertables were low because of poor rainfall. After heavy rain of May/June 1983 salinity of some watertables stabilised at a lower level, eg 15.25, 16.22, 16.23, 16.25 and 17.22; whereas, salinity of other bores declined but then varied in response to further rainfall, eg 14.21, 14.25, 15.23, 16.21, 16.24, 17.21 and 17.23. It should be noted that the character of waters at only three wells changed dramatically in response to wet weather. These were 14.25, 15.25 and 16.23.

Reduced level of watertable : February 1983

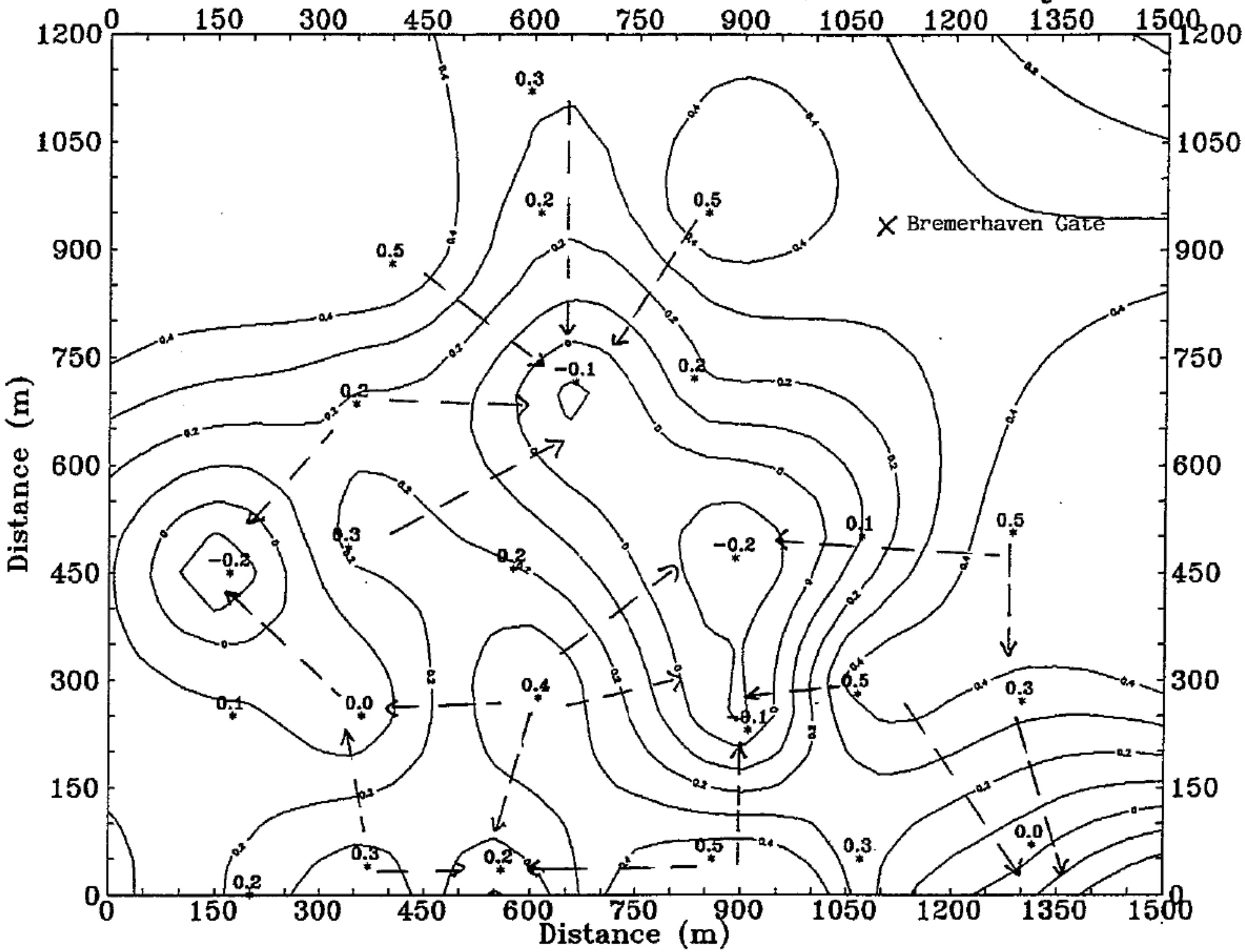


FIGURE 2

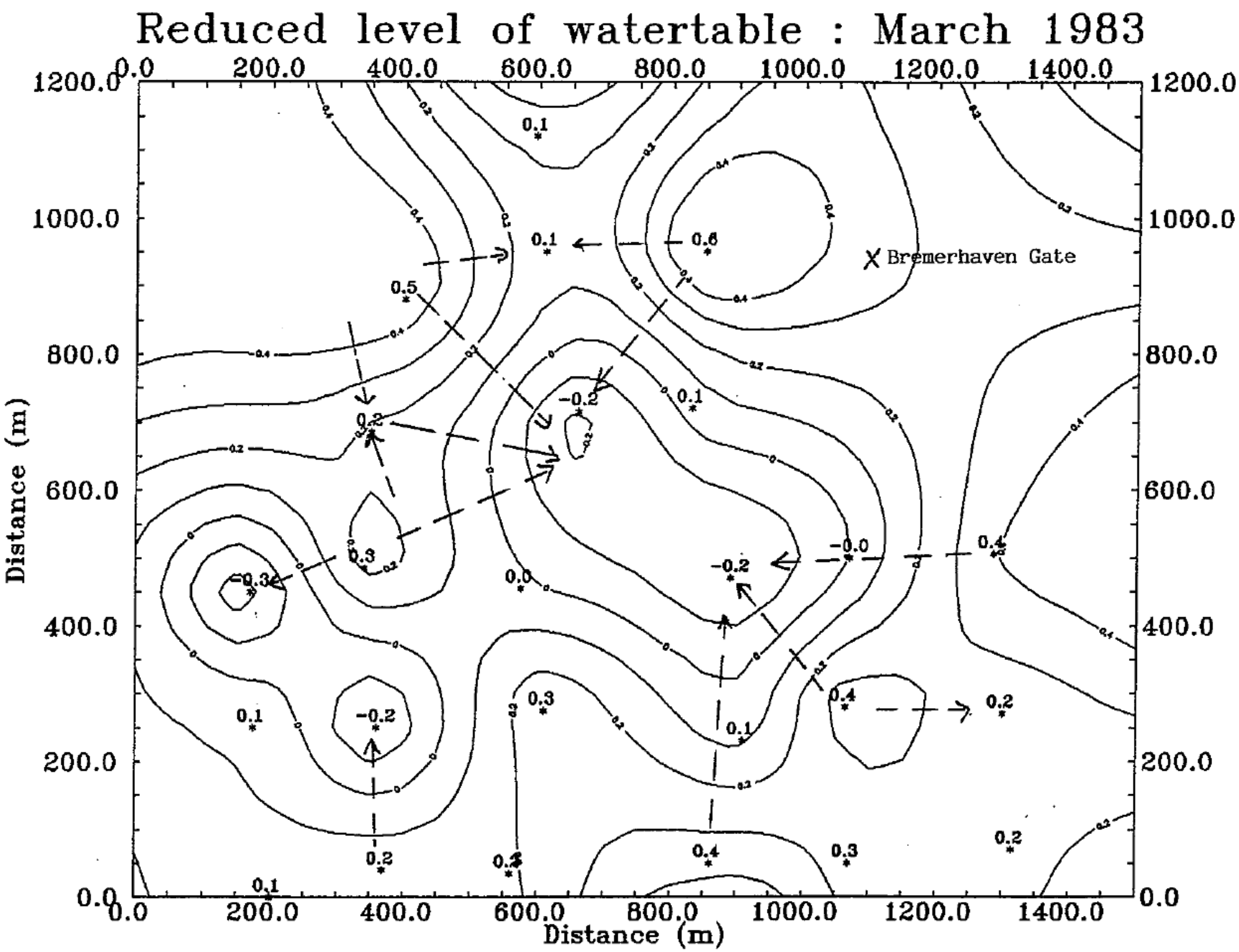

Reduced level of watertable : March 1983
Distance (m)
Distance (m)
Bremerhaven Gate
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0

FIGURE 3

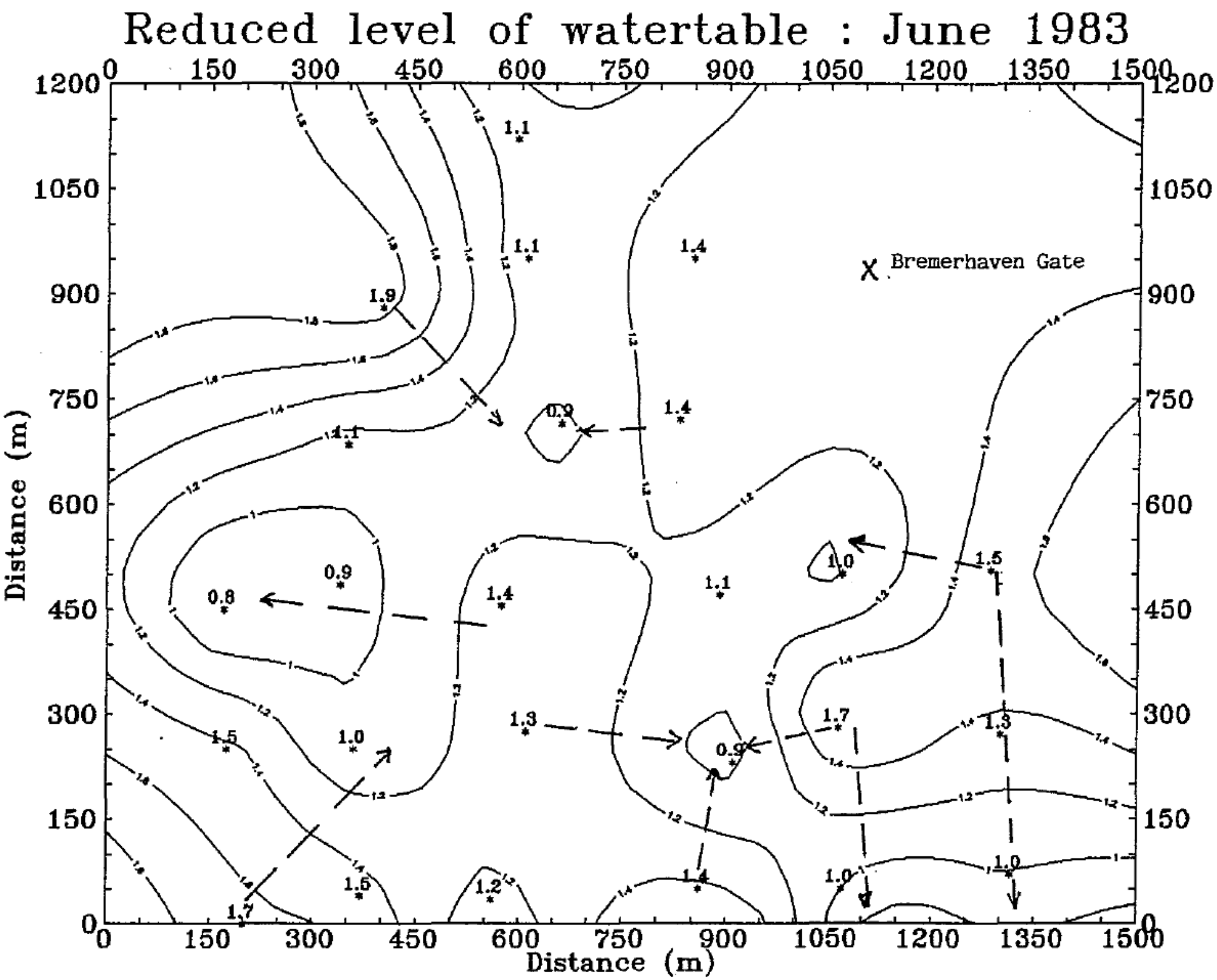

Reduced level of watertable : June 1983
Distance (m)
Distance (m)
0
150
300
450
600
750
900
1050
1200
1350
1500
X Bremerhaven Gate
1.1
1.1
1.4
1.9
0.9
1.4
1.1
0.8
0.9
1.4
1.1
1.0
1.5
1.3
1.7
1.3
1.5
1.0
0.9
1.7
1.5
1.2
1.4
1.0
1.0

FIGURE 4

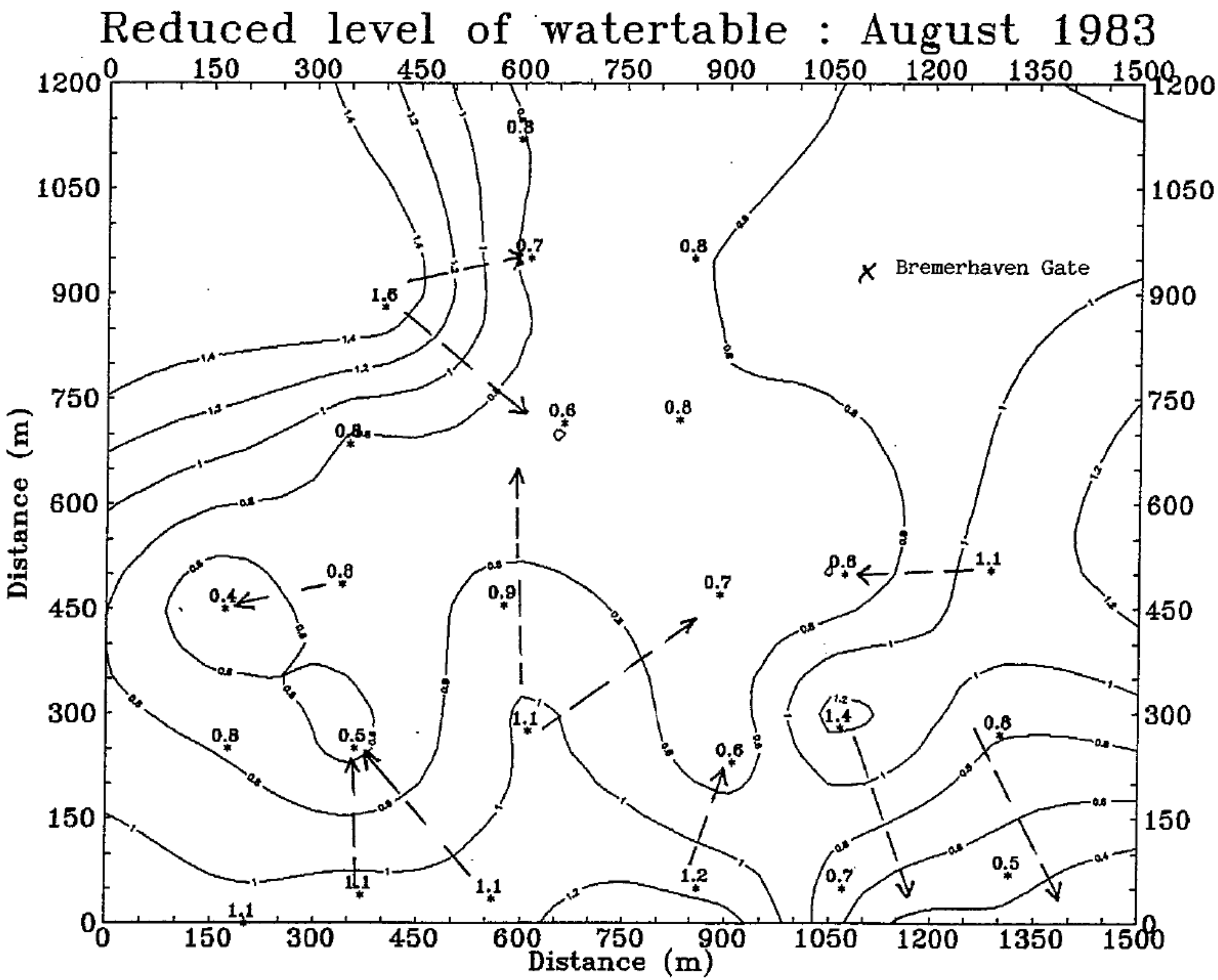

Reduced level of watertable : August 1983
Distance (m)
Distance (m)
Bremerhaven Gate
0 150 300 450 600 750 900 1050 1200 1350 1500
1200 1050 900 750 600 450 300 150 0
1.6
0.7
0.8
0.8
0.6
0.8
0.8
0.4
0.8
0.9
0.7
0.8
1.1
0.8
0.5
1.1
0.6
1.4
0.8
1.1
1.1
1.2
0.7
0.5
1.1

FIGURE 5

Reduced level of watertable : January 1984

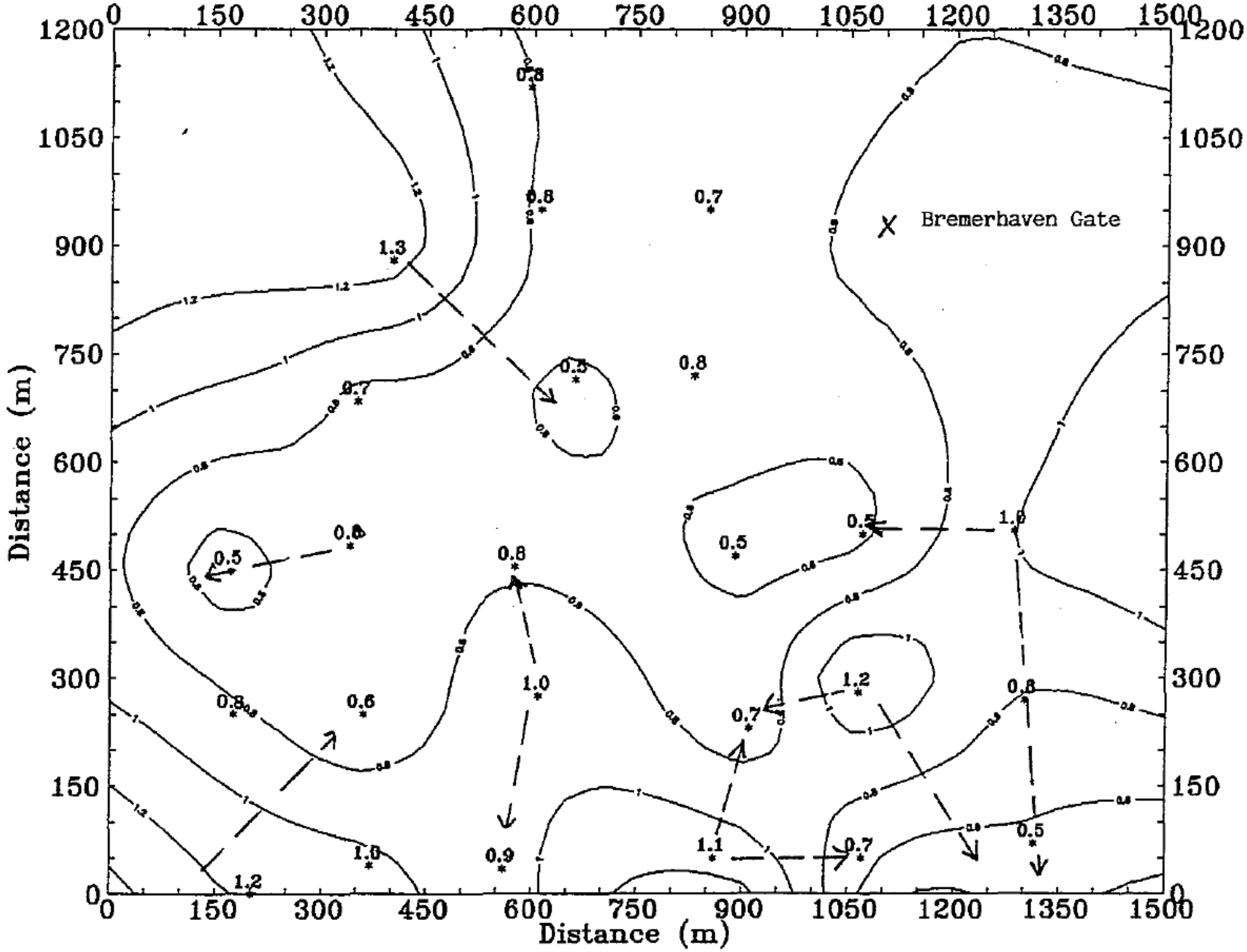


FIGURE 6

Wells with lowest salinity waters did not show any significant deterioration in water quality during the period of lowest watertables.

During a visit to Rocky Point on 29/8/91, BSES staff used electromagnetic induction earth conductivity meters to study salinity levels to approximately 7.5 and 15 m depth at several of the old well sites. These readings have confirmed that saline water and salty soil are not present in the surface 7.5 m of earth under the sandy and more elevated soils which contain good quality groundwater.

3.0 SILL HEIGHT AT THE BREMERHAVEN FLOOD GATE

The inner and highest sill at Bremerhaven is currently placed at 0 m RL, while the outer energy dissipating sill is placed at -0.2 m RL. The spillway inside the inner sill is at -0.63 m, while it is at -0.75 m on the discharge side of this sill. Reference to the 1991 Tide Tables showed 54 low tides in 1991 which would have overflowed the outer sill, but none should have been higher than the inner sill.

During discussion with representatives of the Woongoolba Flood Mitigation Advisory Committee the members canvassed the possibility of lowering the inner sill by 0.3 m. There would have been 133 low tides higher than -0.3 m RL in 1991. The overtopping of sills by low tides would occur during neap tides of the first and last quarters of the moon in each month.

Lowering of the sill by 0.3 m would mean that the gate flap would close about 1 h 20 min earlier during spring tides and 1 h 50 min earlier during neap tides, if there was no significant head of water flowing outwards through the gate. There were not sufficient data to predict gate open time for a wide range of conditions; the gate will stay open during the early part of the flood tide until tidal head is greater than discharge head.

Lowering of the sill would allow a greater discharge rate of drainage water to occur during each ebb tide sequence.

3.1 Consequences of lowering sill height

3.1.1 Benefits

The Bremerhaven System is likely to have three types of beneficial response to lowering of sill height and an increased drainage discharge:

1. Flood and drainage waters will be able to be cleared from the area more quickly. This will lead to more rapid drawdown of watertables.

2. A lower equilibrium watertable should be established over the area.

3. Low lying and more saline caneland should benefit from lowering of the watertable because of reduced saline accessions to the root zone from capillary action; a lower watertable will also allow flushing of salt during rainfall events.

There are no data which allow definition of the time frame within which lower watertables will develop over the area. It is recommended that a new network of wells be installed to monitor watertable elevation and quality, to assist with management and to provide factual data for any public relations exercise associated with the Bremerhaven System.

3.1.2 Concerns

Concern is expressed by some growers in the Rocky Point area that lowering of watertables will lead to inversion of the salt/fresh water interface, and *over drainage* of higher sandy land.

No situations, in the surface 1.5 m of earth, were identified during the two-year study which could be classified as major freshwater lenses above saline water.

In July 1983, all 164 sites were tested for EC at the top of the watertable and also after vigorous stirring. The stirred value was usually marginally higher than the unstirred value; but the overall classification or character of the water was not changed by mixing top water with deeper water.

EC of most waters was at highest values during the period of lowest watertables in February/march 1983; however, as mentioned in 2.2.3 this increase in concentration changed the character of only three waters in the Bremerhaven System, eg 14.25, 15.25, and 16.23. Wells 14.25 and 15.25 are adjacent to the South Passage, near Steiglitz Wharf, and had average EC from July 1983 to July 1984 of 0.45 and 2.38 dS/m respectively. EC values rose to a maximum of 5.74 and 10.34 dS/m respectively during periods of low watertables. These sites could be affected by marine influences, and well 14.25 could also receive saline water flow from 14.24.

Opportunity for sea water to intrude and influence near-surface ground water will depend on the relativity in head of lower salinity ground and tidal waters and the duration of any adverse relativity. High water means for spring and neap tides at Cabbage Tree Point are 0.92 and 0.49 m RL respectively. These values, viewed in association with location of wells 14.25 and 15.25 (Figure 1a) and RL data for their watertables in February/March 1983, further indicate potential for marine influences at these sites. There was little potential for entry of sea water into most of the area during the selected June, August or January observations. RL data indicated that water in the Steiglitz area did not flow into the Bremerhaven System; therefore, changes to water levels in that system should not have an impact in the Steiglitz area.

Well 16.23 is at one of the lowest sites in the area, and was located in the area of watertable drawdown to -0.2 m RL in February/March 1983. EC at the site was 2.6

dS/m during this period, but fell to around 0.3 dS/m after wet weather in May/June. The February/March value of 2.6 dS/m, though not strongly saline, was possibly elevated by saline water moving along the drainage line from 15.23 and into the cone of the depressed water surface.

Water quality did not alter markedly during the drier months at wells 17.21, 17.23, 18.21 and 18.23 which contain generally good quality water under sandier phases of the humic gley soil type. There appears to be sufficient head of fresh water discharging from these areas towards the drains to halt any advance of poor quality water into these areas. Further, deep soundings with earth conductivity meters indicated that there was no store of saline soil or saline water within the surface 7.5 m of earth at these sites.

Cane roots should be able to follow and exploit any receding watertable at sites with good quality groundwater and clayey sand subsoils. It would not be unreasonable to expect root development to 1.5 m or more in these humic gley soils under such conditions. Results in Appendix V show that watertables dropped to around 1.5 m at such sites during the drought of 1983. *Overdrainage* is therefore unlikely to be a problem.

4.0 EFFECTS OF SALINE WATER EXCHANGE FOR THE EXISTING PRAWN FARM

EC (salinity) of the drainage system could vary between 10 and 50 dS/m, depending on weather conditions and water level in the drains. Drains were not tested for EC during recent visits to Rocky Point because the gate had been boarded up for repair and normal drainage exchanges were not occurring. It is assumed that water required for the prawn farm will approximate sea water at around 35 ds/m.

4.1 Scenario I - Bremerhaven sill height is unchanged

The prawn farmer can obtain exchange water during periods of low drain level by opening the gate and allowing sea water to flow back to the inlet pump, consequently raising the level of water in the drainage system well above 0 m RL. Any elevation of the water level in the drain, caused by leaking gates or water pumped in during the gate closed period, limits the potential for drainage particularly in the lower lands. It was shown on 28/8/91 that the water level in a drain on portion 379 (near Short Cut Rd) was at 0.14 m RL, when water level inside the boarded gate was 0.06 m RL. At that time water level in the drain at portion 379 was only 0.45 m below ground level.

It is unlikely that allowing seawater exchange through a part of the drainage system would have a major effect on soil and water salinity in most areas adjoining the drains. There is usually a higher head of water in the soil than in the drain, so drain water is unlikely to move a significant distance from the drain.

However, during very dry periods such as February/March 1983 when some watertables were as low as -0.2 m RL, a head of salt water, eg 0.15 to 0.2 m RL in the drains, could cause salt water to move from drains. This would have an adverse effect on soil and groundwater salinity around the drains in the cone of depression.

4.2 Scenario II - The sill at Bremerhaven has been lowered

The comments made above are still relevant. However, if lowering the Bremerhaven sill caused lower overall water levels in drains and the prawn farm pump could not obtain enough water without significantly raising the head in the drain above 0 m RL, then drains would have to be deepened or water piped directly to the farm using a marine pump.

4.3 Conclusion

The use of part of the drainage system as an inlet for water exchange for the prawn farm may be disadvantagous to the agricultural benefits of the system, by restricting drainage efficiency and possibly allowing spread of saline water into part of the area during dry times.

If more prawn farms were established on inland parts of the district the greater volume of water required for exchange would result in a need to further elevate water levels in the drainage system.

APPENDIX I

Depth of watertables in relation to ground-level (m).

SITE	9/82	10/82	2/83	3/83	4/83	5/83	6/83	7/83	8/83	9/83	10/83	11/83
14.20	-1.19	-.87	-1.37	-1.45	-1.45	-.48	.07	-.08	-.53	-.02	-.62	-.03
14.21	-.91	-.68	-1.17	-1.35	-1.44	-.68	-.02	-.17	-.44	-.05	-.65	-.26
14.22	-.65	-.52	-1.06	-1.04	-.91	-.11	-.05	-.09	-.15	-.07	-.44	-.16
14.23	-.64	-.64	-1.03	-1.14	-1.04	-.34	-.07	-.14	-.34	-.10	-.65	-.28
14.24	-.74	-.69	-1.02	-1.02	-.89	-.51	-.26	-.42	-.56	-.37	-.66	-.34
14.25	-1.20	-1.04	-1.44	-1.23	-1.15	-.91	-.50	-.94	-1	-.92	-1.11	-.92
15.20	-1.33	-1.20	-1.56	-1.60	-1.59	-.76	-.23	-.51	-.90	-.48	-1.13	-1.05
15.21	-.55	-.73	-1.21	-1.43	-1.33	-.50	-.18	-.27	-.68	-.28	-.84	-.45
15.22	-.86	-.75	-1.09	-1.22	-1.16	-.42	-.17	-.29	-.45	.01	-.79	-.38
15.23	-.34	-.42	-1.01	-.82	-.74	-.20	0	0	-.24	-.07	-.54	-.14
15.24	-.90	-.63	-1.25	-1.37	-1.37	-.55	-.07	-.18	-.40	-.08	-.74	-.21
15.25	-1.17	-.98	-1.34	-1.46	-1.49	-.74	-.35	-.70	-.88	-.64	-.96	-.82
16.20	-1.03	-1.07	-1.56	-1.62	-1.63	-.84	-.58	-.78	-.95	-.81	-1.13	-.80
16.21	-1.33	-1.27	-1.60	-1.59	-1.54	-1.03	-.92	-.98	-1.06	-1.01	-1.26	-1.06
16.22	-.88	-.77	-1.19	-1.39	-1.28	-.41	-.05	-.39	-.52	-.41	-.88	-.54
16.23	-.86	-.85	-1.32	-1.32	-1.18	-.34	.02	-.09	-.46	-.02	-.89	-.45
16.24	-.53	-.54	-.85	-.95	-.89	-.30	.02	-.23	-.34	-.06	-.59	-.10
16.25	-1.01	-.90	-1.31	-1.39	-1.40	-.59	-.26	-.57	-.68	-.41	-.92	-.63
17.21	-1.27	-1.12	-1.45	-1.45	-1.45	-.78	-.51	-.87	-.88	-.81	-1.13	-1.06
17.22	-.75	-.77	-1.27	-1.36	-1.26	-.67	-.22	-.32	-.55	-.37	-.81	-.63
17.23	-1.05	-.89	-1.35	-1.50	-1.44	-.52	-.18	-.58	-.76	-.56	-.94	-.61
18.21	-1.38	-1.20	-1.58	-1.61	-1.61	-.88	-.21	-.59	-.51	-.66	-1.06	-.81
18.22	-.72	-.62	-.97	-1.06	-.97	-.39	-.12	-.23	-.47	-.28	-.68	-.21
18.23	-1.02	-.95	-1.09	-1.02	-1.10	-.62	-.21	-.62	-.80	-.60	-.96	-.75
19.22	-.29	-.34	-.74	-.99	-.72	-.20	.06	-.18	-.24	-.17	-.35	-.14

SITE	12/83	1/84	2/84	4/84	7/84
14.20	-.66	-.42	-.60	-.72	-.86
14.21	-.68	-.46	-.72	-.58	-.77
14.22	-.44	-.28	-.47	-.18	-.51
14.23	-.55	-.37	-.53	-.46	-.57
14.24	-.66	-.60	-.65	-.64	-.61
14.25	-1.06	-.92	-1.10	-1.01	-.97
15.20	-1.02	-.85	-1.14	-.94	-1.13
15.21	-.76	-.59	-.71	-.71	-.60
15.22	-.79	-.53	-.76	-.64	-.73
15.23	-.39	-.23	-.32	-.26	-.18
15.24	-.73	-.52	-.80	-.75	-.98
15.25	-.95	-.91	-1.07	-.91	-1.18
16.20	-1.02	-.86	-1.12	-.95	-.96
16.21	-1.18	-1.04	-1.22	-1.05	-1.23
16.22	-.83	-.62	-.85	-.68	-.92
16.23	-.74	-.58	-.83	-.68	-.81
16.24	-.17	-.40	-.48	-.43	-.47
16.25	-.91	-.78	-.88	-.84	-.92
17.21	-1.20	-.89	-1.17	-.97	-.89
17.22	-.53	-.60	-.77	-.69	-.69
17.23	-.80	-.76	-.91	-.81	-.92
18.21	-1	-.81	-1.18	-1.08	-1.16
18.22	-.41	-.44	-.68	-.59	-.69
18.23	-.94	-.85	-1.08	-.88	-.79
19.22	-.22	-.25	-.37	-.32	-.50

APPENDIX II

Depth of watertable above State Datum (m RL)

SITE	9/82	10/82	2/83	3/83	4/83	5/83	6/83	7/83	8/83	9/83	10/83	11/83
14.20	.40	.72	.22	.14	.14	1.11	1.66	1.51	1.06	1.57	.97	1.56
14.21	.59	.82	.33	.15	.06	.82	1.48	1.33	1.06	1.45	.85	1.24
14.22	.57	.70	.16	.18	.31	1.11	1.17	1.13	1.07	1.15	.78	1.06
14.23	.86	.86	.47	.36	.46	1.16	1.43	1.36	1.16	1.40	.85	1.22
14.24	.56	.61	.28	.28	.41	.79	1.04	.88	.74	.93	.64	.96
14.25	.26	.42	.02	.23	.31	.55	.96	.52	.46	.54	.35	.54
15.20	.35	.48	.12	.08	.09	.92	1.45	1.17	.78	1.20	.55	.63
15.21	.67	.49	.01	-.21	-.11	.72	1.04	.95	.54	.94	.38	.77
15.22	.65	.76	.42	.29	.35	1.09	1.34	1.22	1.06	1.52	.72	1.13
15.23	.54	.46	-.13	.06	.14	.68	.88	.88	.64	.81	.34	.74
15.24	.85	1.12	.50	.38	.38	1.20	1.68	1.57	1.35	1.67	1.01	1.54
15.25	.51	.70	.34	.22	.19	.94	1.33	.98	.80	1.04	.72	.86
16.20	.31	.27	-.22	-.28	-.29	.50	.76	.56	.39	.53	.21	.54
16.21	.52	.58	.25	.26	.31	.82	.93	.87	.79	.84	.59	.79
16.22	.52	.63	.21	.01	.12	.99	1.35	1.01	.88	.99	.52	.86
16.23	.26	.27	-.20	-.20	-.06	.78	1.14	1.03	.66	1.10	.23	.67
16.24	.41	.40	.09	-.01	.05	.64	.96	.71	.60	.88	.35	.84
16.25	.78	.89	.48	.40	.39	1.20	1.53	1.22	1.11	1.38	.87	1.16
17.21	.36	.51	.18	.18	.18	.85	1.12	.76	.75	.82	.50	.57
17.22	.38	.36	-.14	-.23	-.13	.46	.91	.81	.58	.76	.32	.50
17.23	.52	.68	.22	.07	.13	1.05	1.39	.99	.81	1.01	.63	.96
18.21	.72	.90	.52	.49	.49	1.22	1.89	1.51	1.59	1.44	1.04	1.29
18.22	.48	.58	.23	.14	.23	.81	1.08	.97	.73	.92	.52	.99
18.23	.57	.64	.50	.57	.49	.97	1.38	.97	.79	.99	.63	.84
19.22	.76	.71	.31	.06	.33	.85	1.11	.87	.81	.88	.70	.91

SITE	12/83	1/84	2/84	4/84	7/84
14.20	.93	1.17	.99	.87	.73
14.21	.82	1.04	.78	.92	.73
14.22	.78	.94	.75	1.04	.71
14.23	.95	1.13	.97	1.04	.93
14.24	.64	.70	.65	.66	.69
14.25	.40	.54	.36	.45	.49
15.20	.66	.83	.54	.74	.55
15.21	.46	.63	.51	.51	.62
15.22	.72	.98	.75	.87	.78
15.23	.49	.65	.56	.62	.70
15.24	1.02	1.23	.95	1	.77
15.25	.73	.77	.61	.77	.50
16.20	.32	.48	.22	.39	.38
16.21	.67	.81	.63	.80	.62
16.22	.57	.78	.55	.72	.48
16.23	.38	.54	.29	.44	.31
16.24	.77	.54	.46	.51	.47
16.25	.88	1.01	.91	.95	.87
17.21	.43	.74	.46	.66	.74
17.22	.60	.53	.36	.44	.44
17.23	.77	.81	.66	.76	.65
18.21	1.10	1.29	.92	1.02	.94
18.22	.79	.76	.52	.61	.51
18.23	.65	.74	.51	.71	.80
19.22	.83	.80	.68	.73	.55

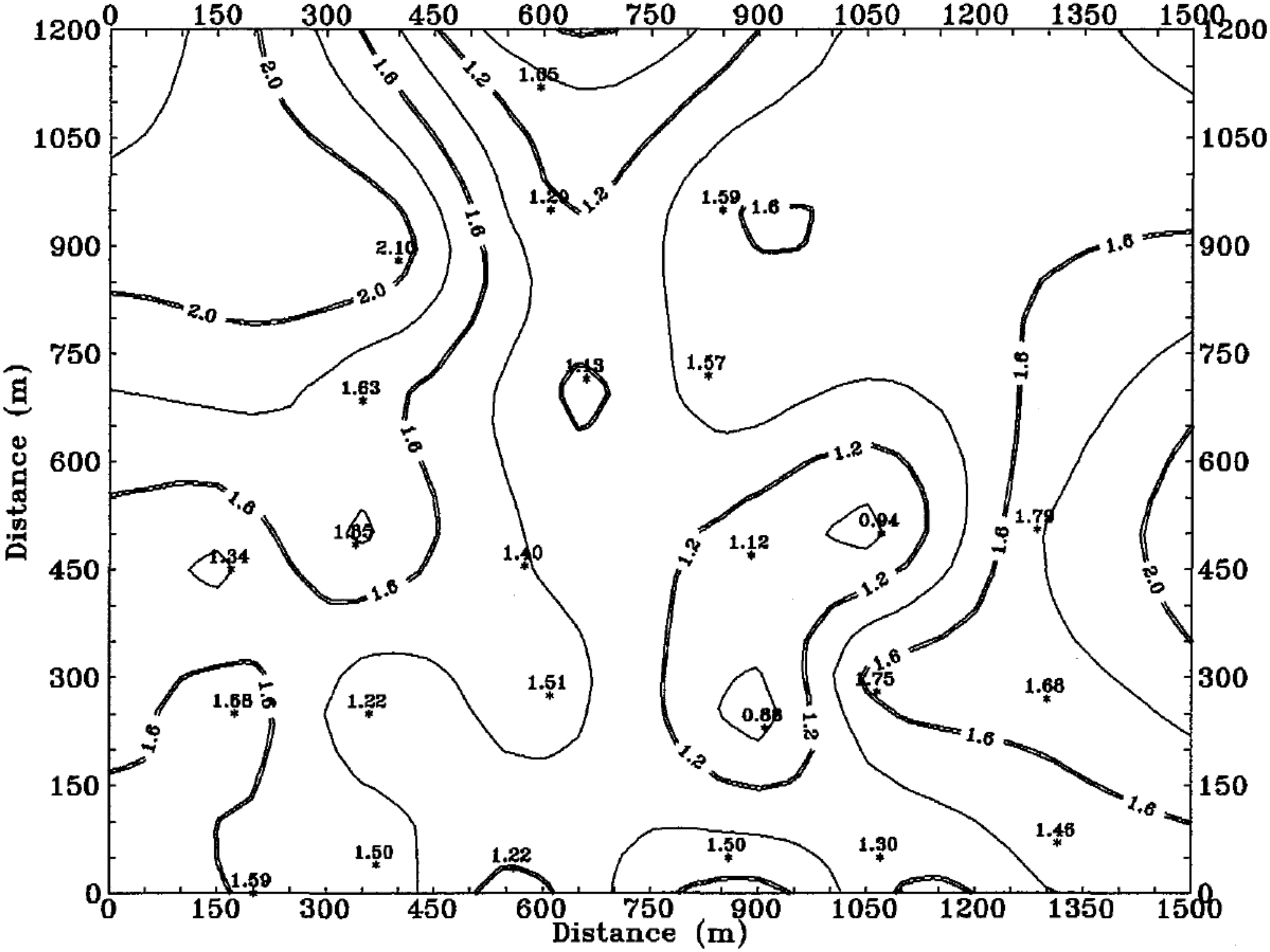
APPENDIX III

EC of watertables (dS/m)

SITE	9/82	10/82	2/83	3/83	4/83	5/83	6/83	7/83	8/83	9/83	10/83	11/83
14.20	.65	.42	.26	.45	.47	.12	.18	.15	.21	.11	.19	.28
14.21	1.47	1.37	1.19	.52	.81	.53	1.20	1.30	1.41	1.61	.89	.43
14.22	5.73	14.07	18.10	14.40	10.20	4.78	13.20	8.55	10.20	7.77	12.89	16.80
14.23	1.51	1.35	.88	1.22	1.28	.68	1.29	1.23	1.50	1.27	1.37	.88
14.24	7.55	19.35	25.60	12.10	7.72	9.20	16	15.30	18.30	4.49	19.50	5.10
14.25	6.28	10.34	8.20	9.40	8.70	.49	.49	.45	.88	1.59	2.73	4.35
15.20	.87	1.29	.31	.30	.30	.25	.26	.33	.31	.28	.22	.13
15.21	1.23	1.15	1.52	1.51	1.52	1.10	1.50	1.25	1.01	.61	.96	1.01
15.22	.57	.23	.22	.30	.18	.15	.23	.21	.19	.29	.30	.18
15.23	17.64	22.28	24.30	19.60	18.15	12.20	11.95	21.95	29.30	11.60	23.50	19.50
15.24	.35	.64	.47	N/R	N/R	.15	.27	.28	.23	.29	.28	.28
15.25	3.56	4.17	5.20	5.74	5.15	.69	.42	.46	.46	.38	.44	.64
16.20	4.45	5.46	5.50	N/R	N/R	1.22	3.70	1.63	1.66	4.61	4.05	3.90
16.21	1.80	2.70	N/R	N/R	1.12	1.95	1.81	1.92	2.38	1.88	2.14	2.49
16.22	.42	.57	.95	.87	.63	.78	.79	.60	.47	.41	.50	.46
16.23	3	.68	1.80	2.22	2.62	.54	.35	.28	.25	.32	.37	.31
16.24	4.16	8.51	7.70	4.30	1.81	3.59	5.88	6.80	6.05	3.10	3.55	3.80
16.25	.97	.59	.57	N/R	N/R	.17	.22	.27	.26	.26	.31	.27
17.21	.87	.94	N/R	N/R	N/R	.21	.22	.30	.25	.50	.63	.78
17.22	3.15	4.46	4.70	3.49	2.94	1	1.66	1.71	.89	1.51	1.67	.98
17.23	1.64	1.34	2.10	1.32	1.39	.99	2.19	1.83	1.51	.52	1.43	.67
18.21	.94	1.17	.90	N/R	N/R	.14	.17	.25	.45	.30	.27	.19
18.22	7.65	10.30	13.70	N/R	12	6.10	8.55	11.30	5.54	4.46	6.38	8.05
18.23	N/R	.37	N/R	N/R	N/R	.25	.23	.24	.32	.21	.29	.25
19.22	10.04	35.87	33.40	26.80	20.80	16.23	27.50	18.60	31.90	11.60	33.20	27.60

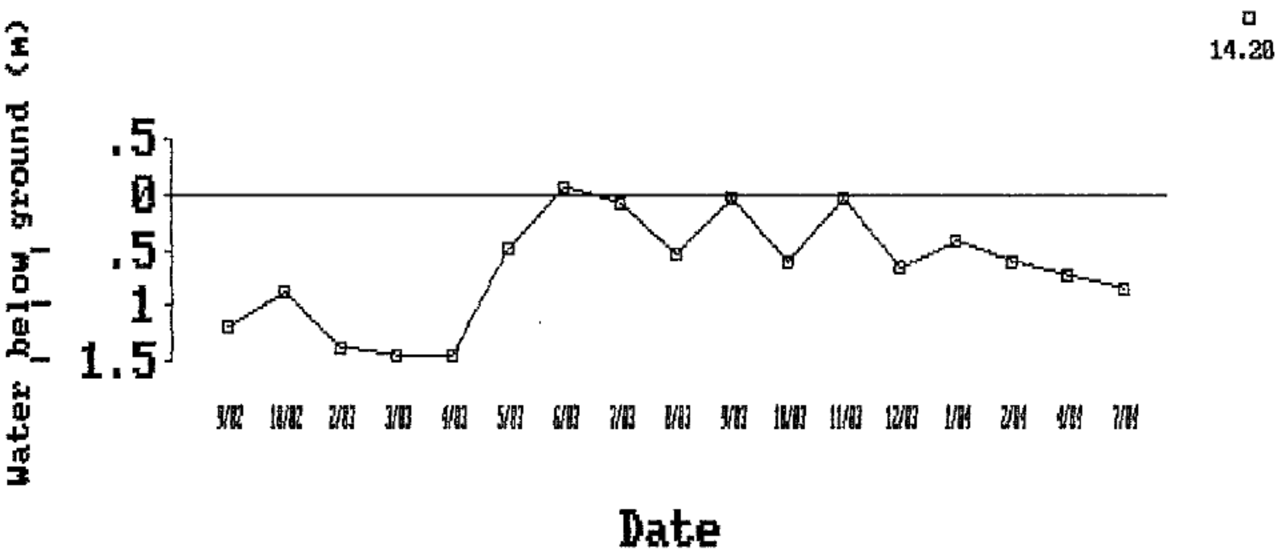
SITE	12/83	1/84	2/84	4/84	7/84	MAX	MIN	AVG (ALL)	AVG(Jly-Jly)
14.20	.16	.18	.16	.17	.26	.65	.11	.26	.19
14.21	.76	.73	.64	.54	.78	1.61	.43	.95	.91
14.22	11.10	10.30	11.20	6.20	11.40	18.10	4.78	10.99	10.64
14.23	1.07	1.25	1.25	1.18	.85	1.51	.68	1.18	1.19
14.24	12.60	20.10	10.85	15.90	10.50	25.60	4.49	13.54	13.26
14.25	3.05	1.75	3.15	1.84	4.02	10.34	.45	3.98	2.38
15.20	.23	.42	.21	.31	.19	1.29	.13	.37	.26
15.21	1.12	1.04	1.04	.87	.72	1.52	.61	1.13	.96
15.22	.26	.24	.19	.15	.16	.57	.15	.24	.22
15.23	23.30	27	24.30	15.90	22.50	29.30	11.60	20.29	21.89
15.24	.29	.29	.34	.23	.52	.64	.15	.33	.30
15.25	.52	.39	.49	.31	N/R	5.74	.31	1.81	.45
16.20	3.60	3.09	3.37	4.90	5.15	5.50	1.22	3.75	3.60
16.21	2.06	1.63	1.70	1.78	1.88	2.70	1.12	1.95	1.99
16.22	.57	.29	.42	.37	.51	.95	.29	.57	.46
16.23	.25	.32	.37	.29	.25	3	.25	.84	.30
16.24	2.55	1.44	2.21	3.31	4.24	8.51	1.44	4.29	3.71
16.25	.16	.13	.19	.13	.15	.97	.13	.31	.21
17.21	.50	.22	.16	.25	.42	.94	.16	.45	.40
17.22	1.44	1.52	2.46	1.62	1.55	4.70	.89	2.16	1.54
17.23	1.48	1.52	1.79	1.37	.83	2.19	.52	1.41	1.30
18.21	.21	.22	.42	.12	.14	1.17	.12	.39	.26
18.22	10.85	11.50	12.35	7.50	9	13.70	4.46	9.08	8.69
18.23	.23	.21	.25	.27	.19	.37	.19	.25	.25
19.22	22.40	35	26.50	31.30	22.60	35.87	10.04	25.37	26.07

Reduced level of soil surface for well sites.

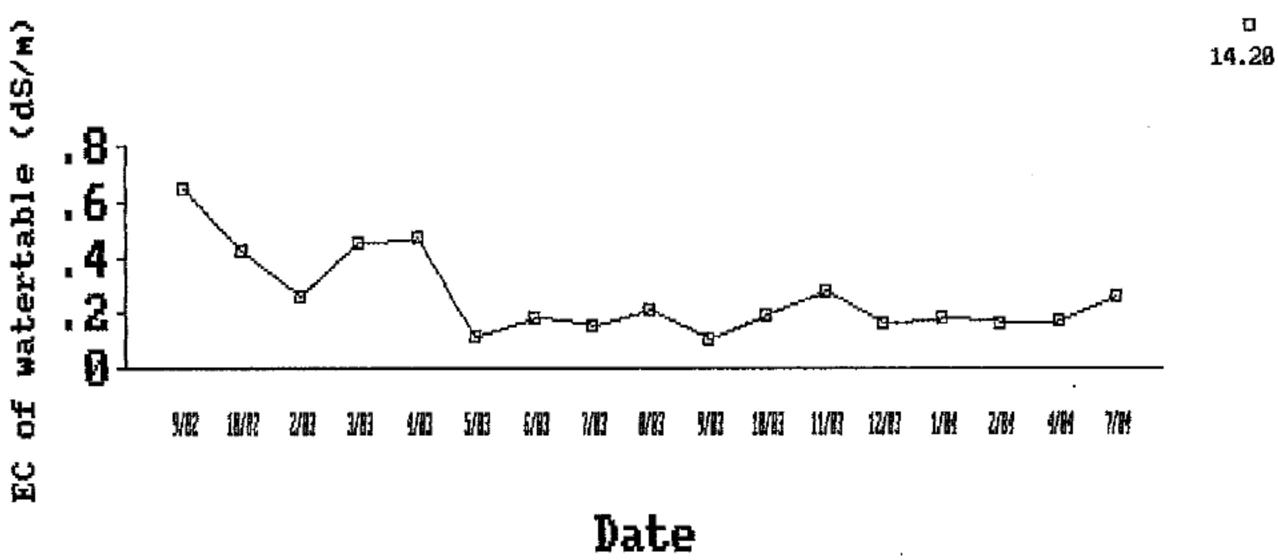


APPENDIX V

Depth of watertable below ground : Sept 1982 to July 1984

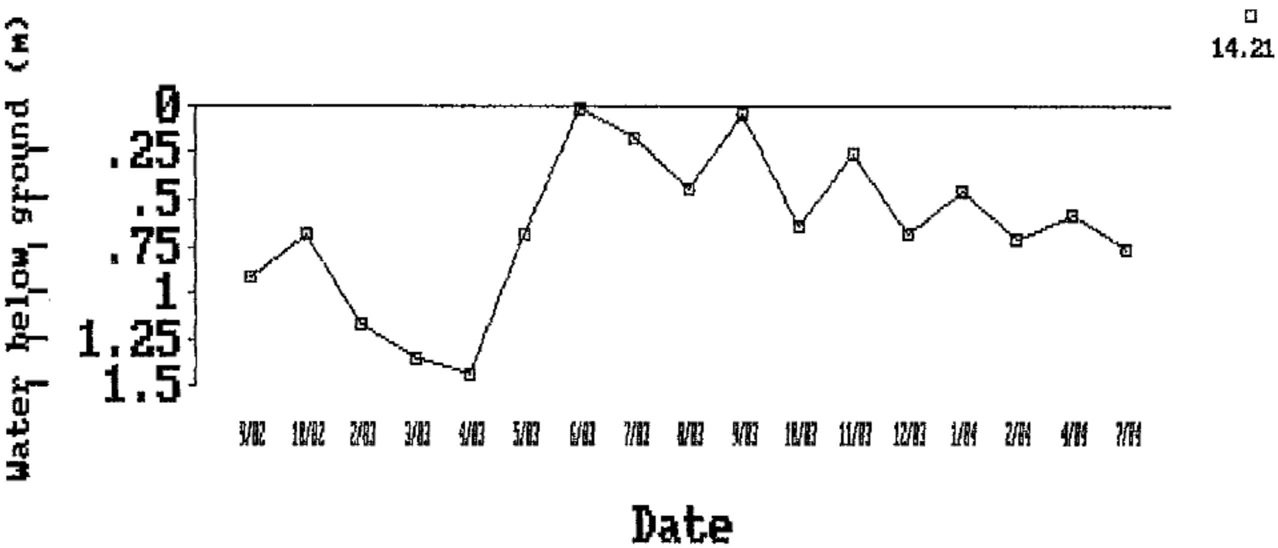


EC of watertable : Sept 1982 to July 1984

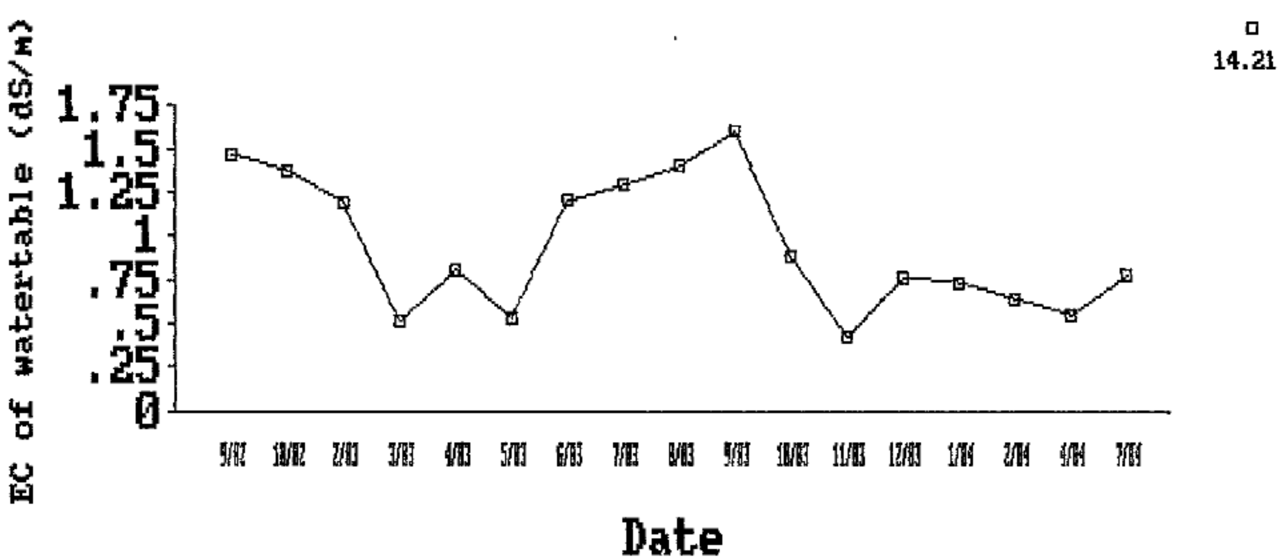


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984

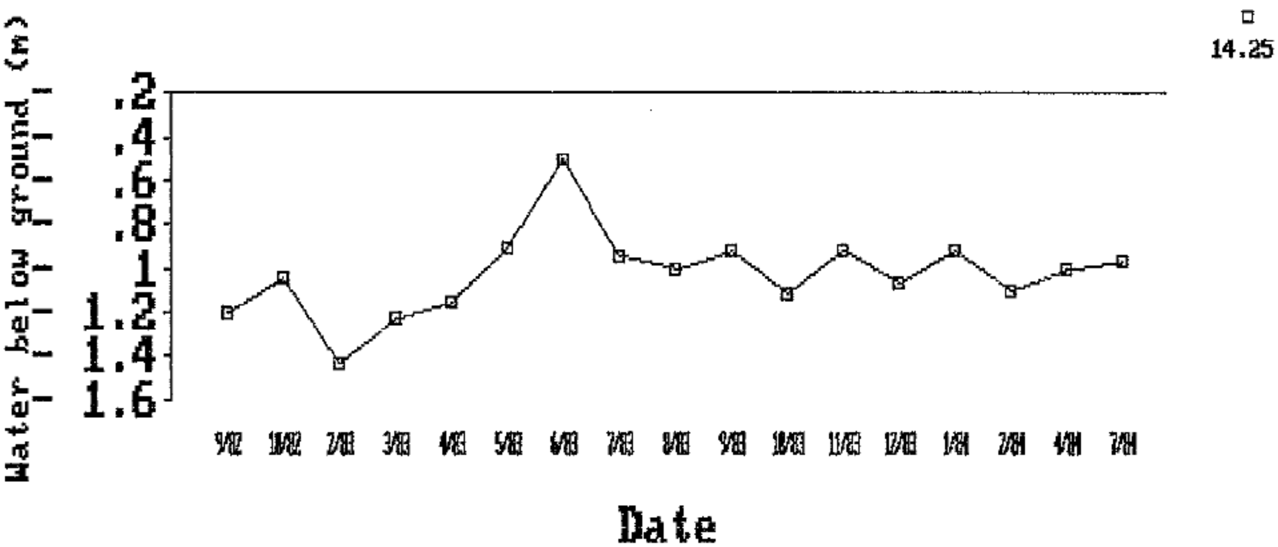


EC of watertable : Sept 1982 to July 1984

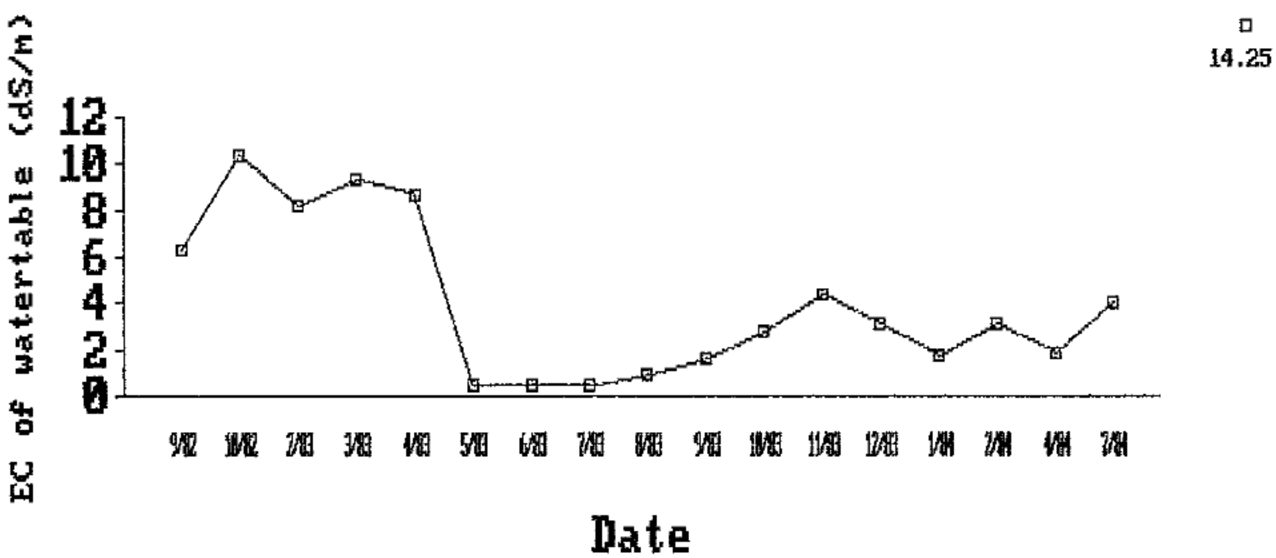


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984

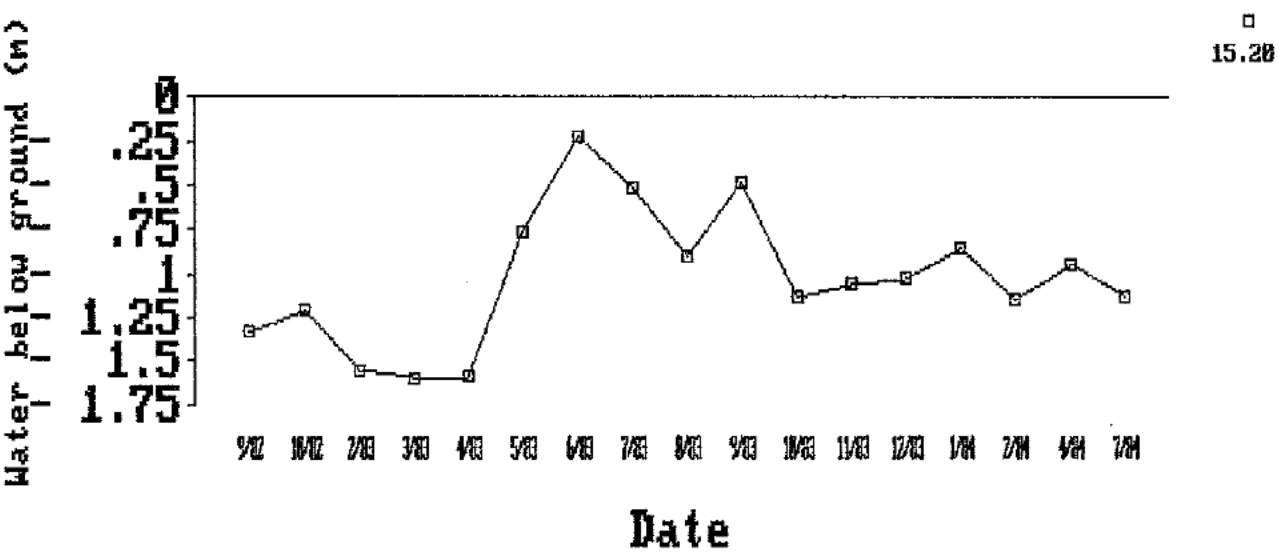


EC of watertable : Sept 1982 to July 1983

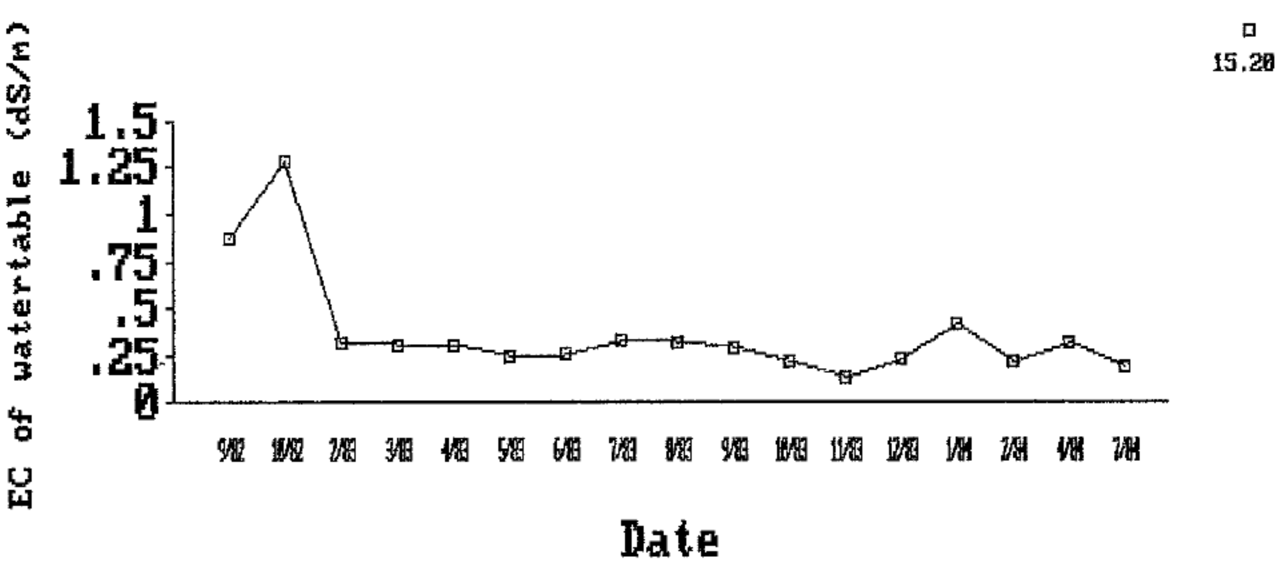


APPENDIX V (continued)

Depth to watertable : Sept 1982 to July 1984

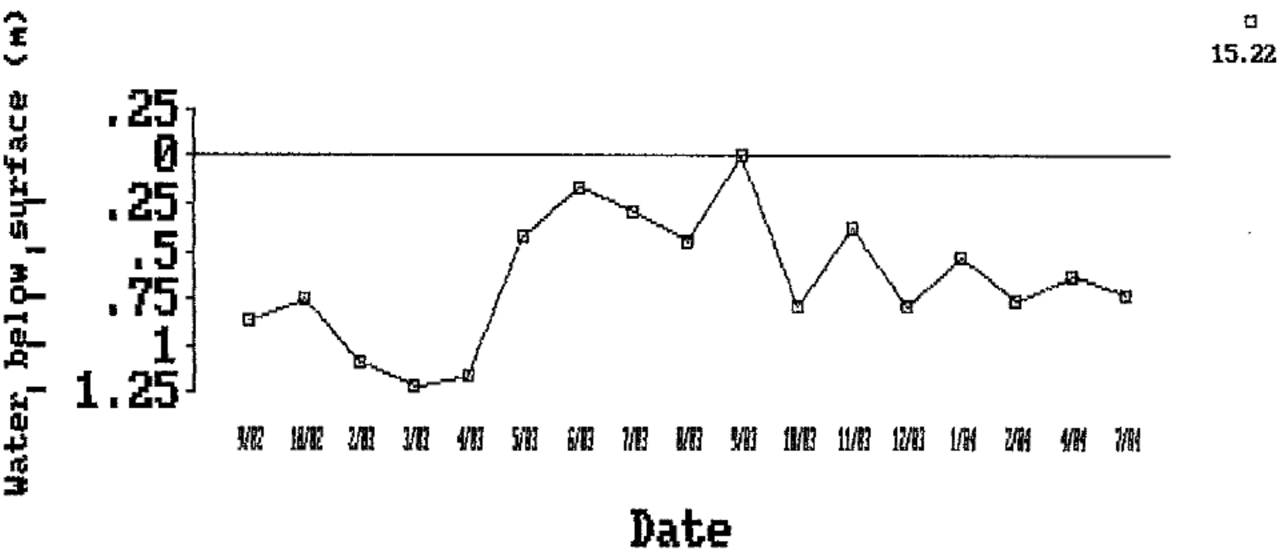


EC of watertable (dS/m) : Sept 1982 to July 1984

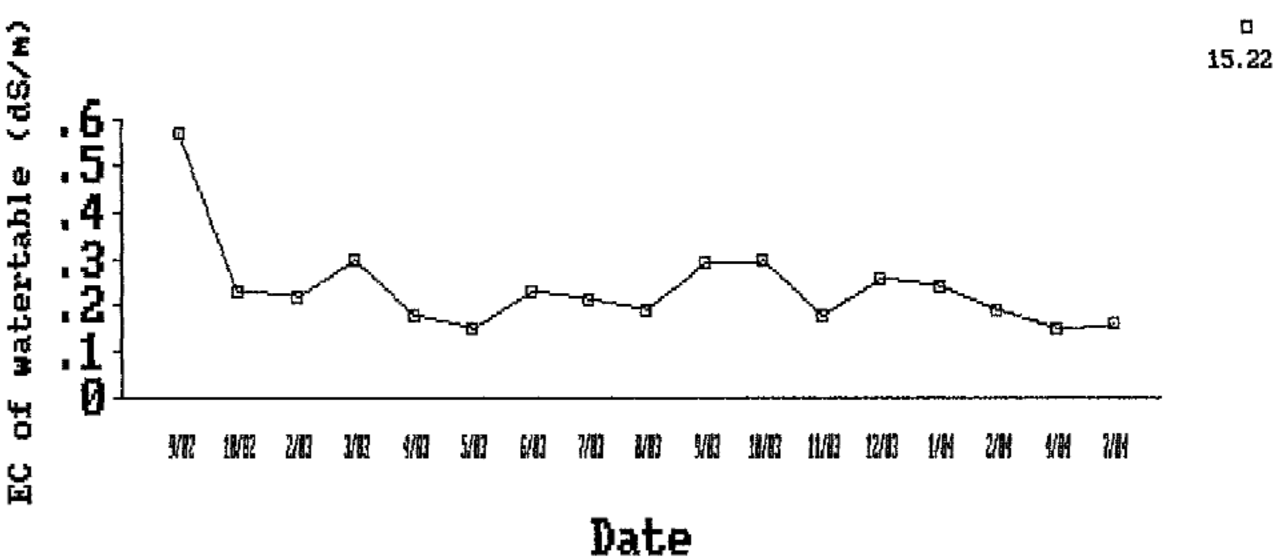


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984.

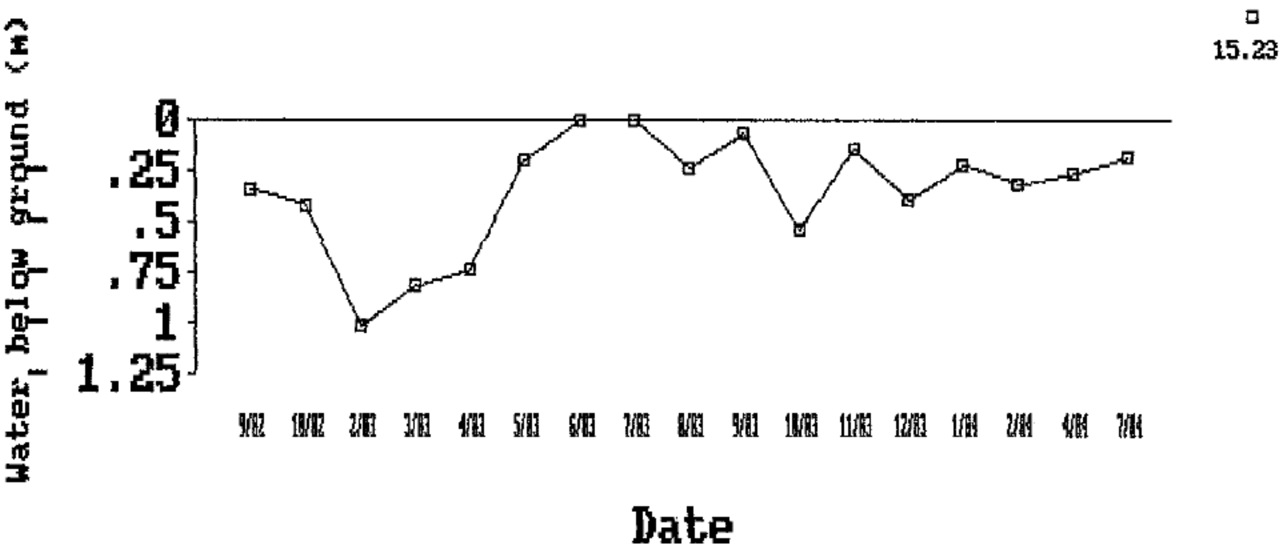


EC of watertable : Sept 1982 to July 1984.

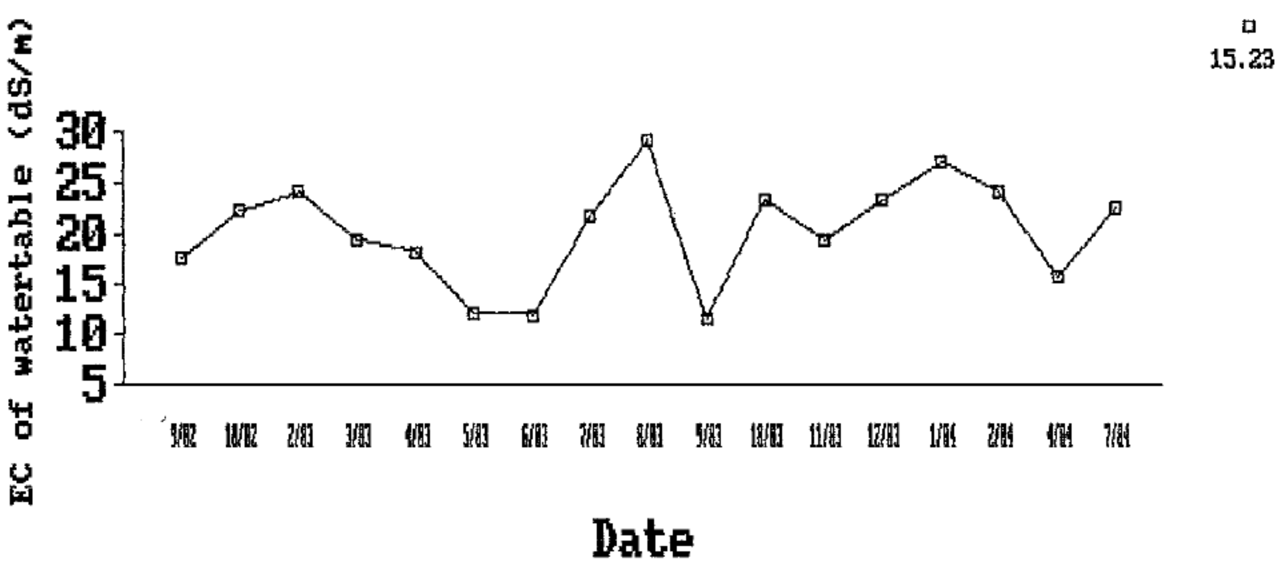


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984.

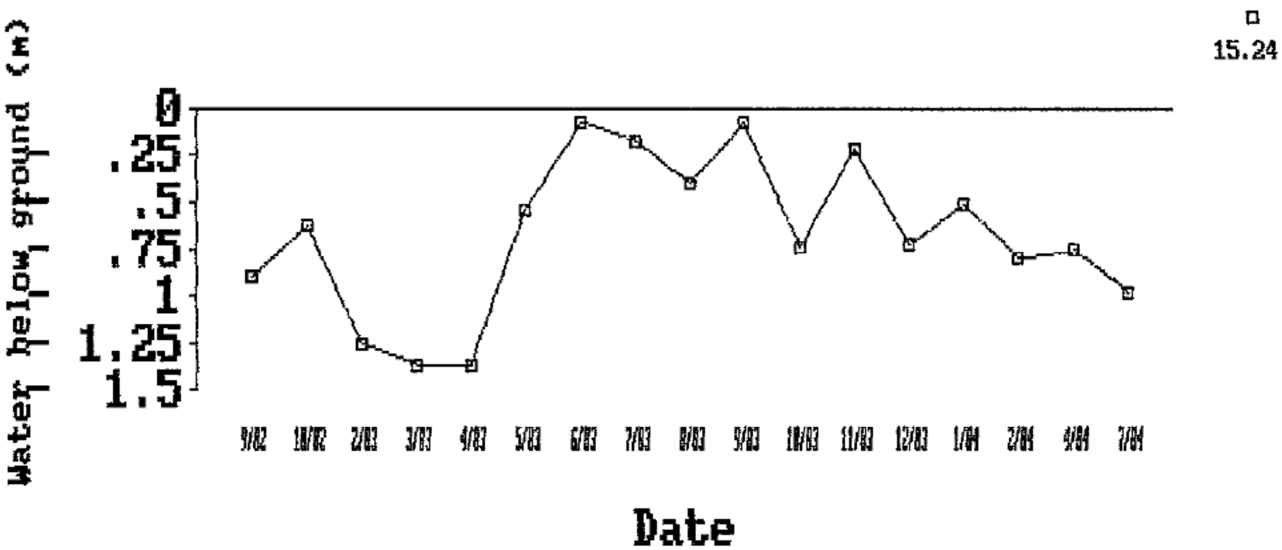


EC of watertable : Sept 1982 to July 1984.

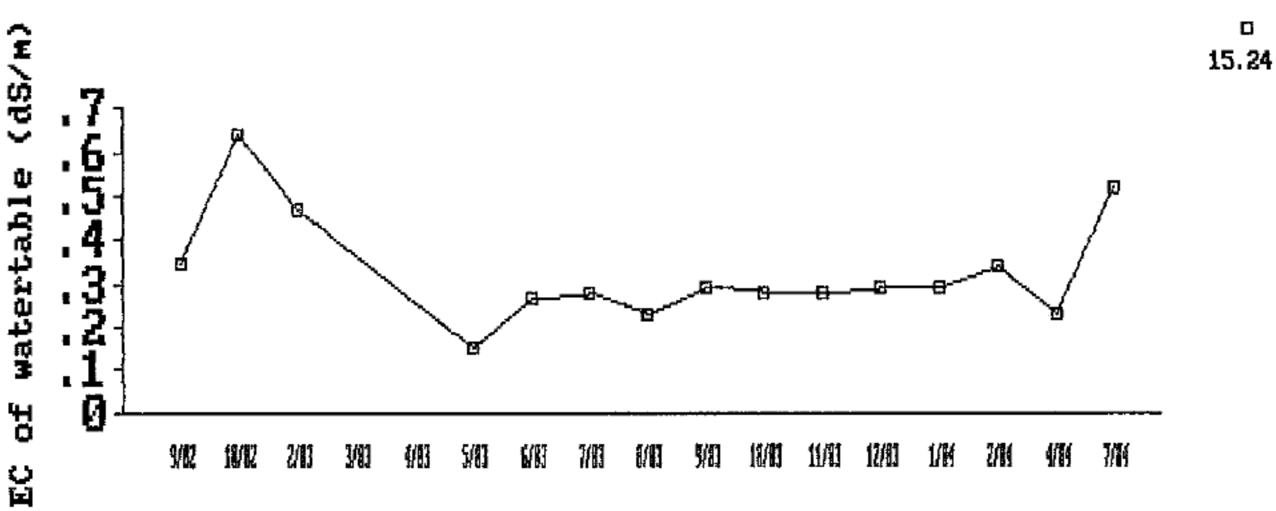


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984.

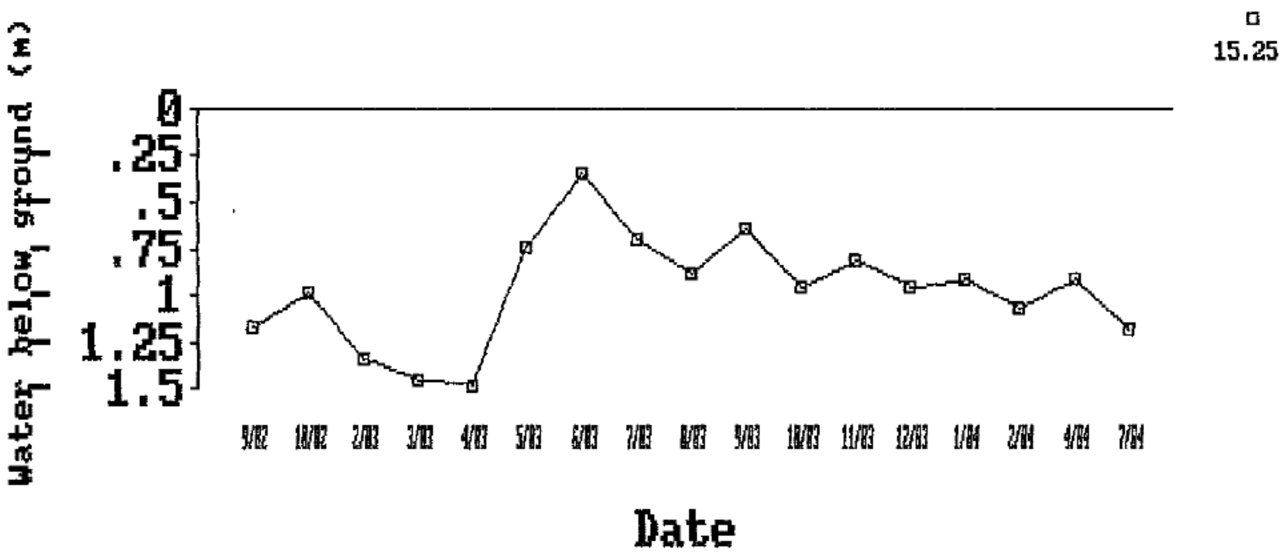


EC of watertable : Sept 1982 to July 1984.

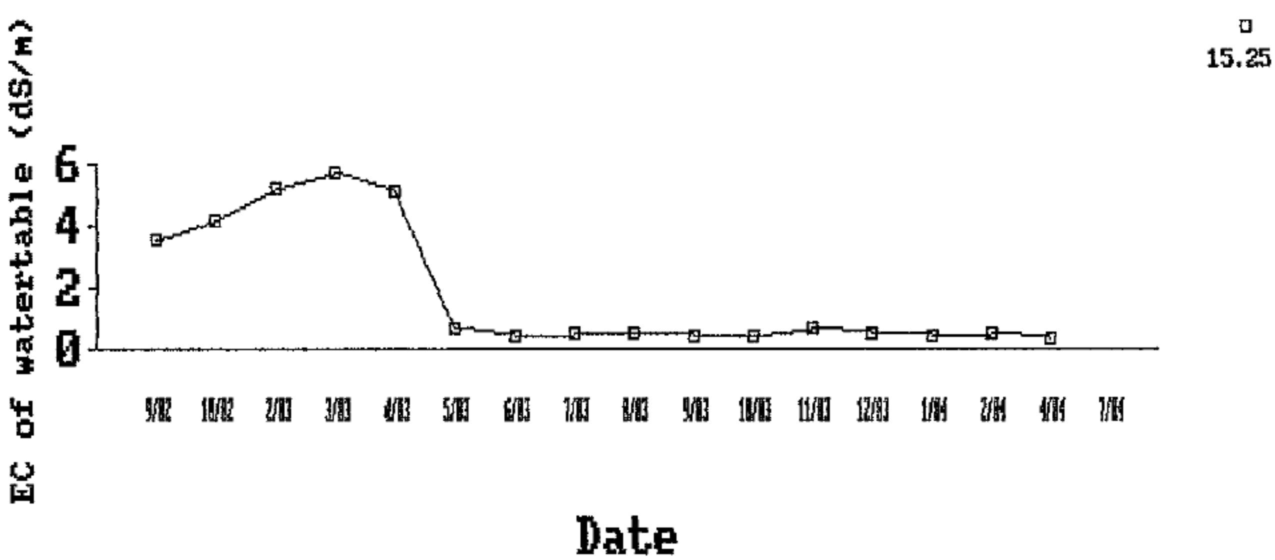


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984

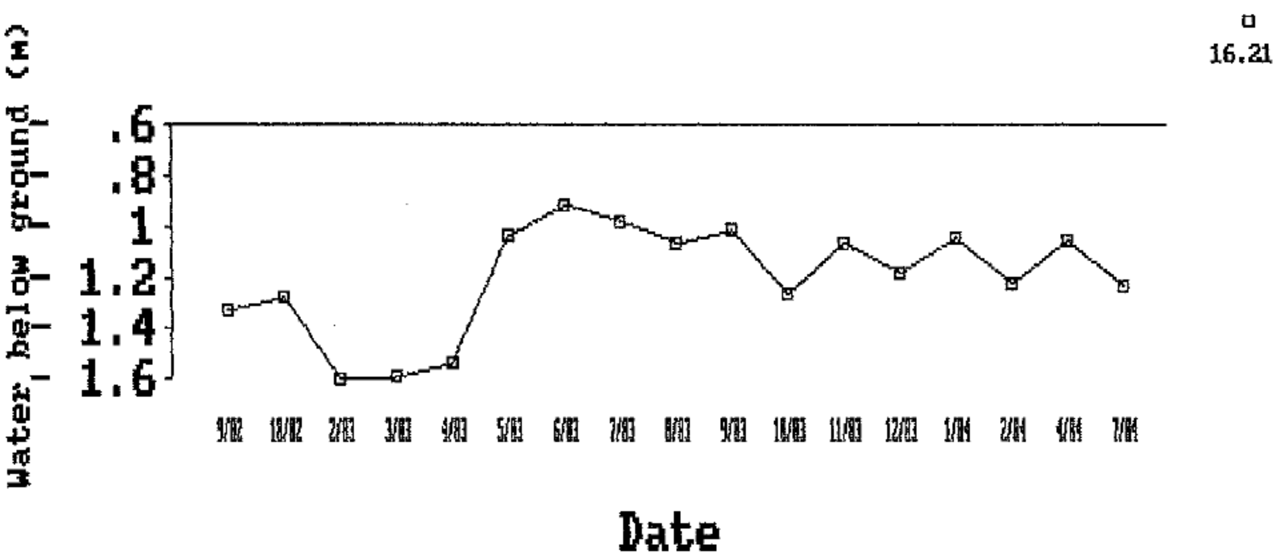


EC of watertable : Sept 1982 to July 1984

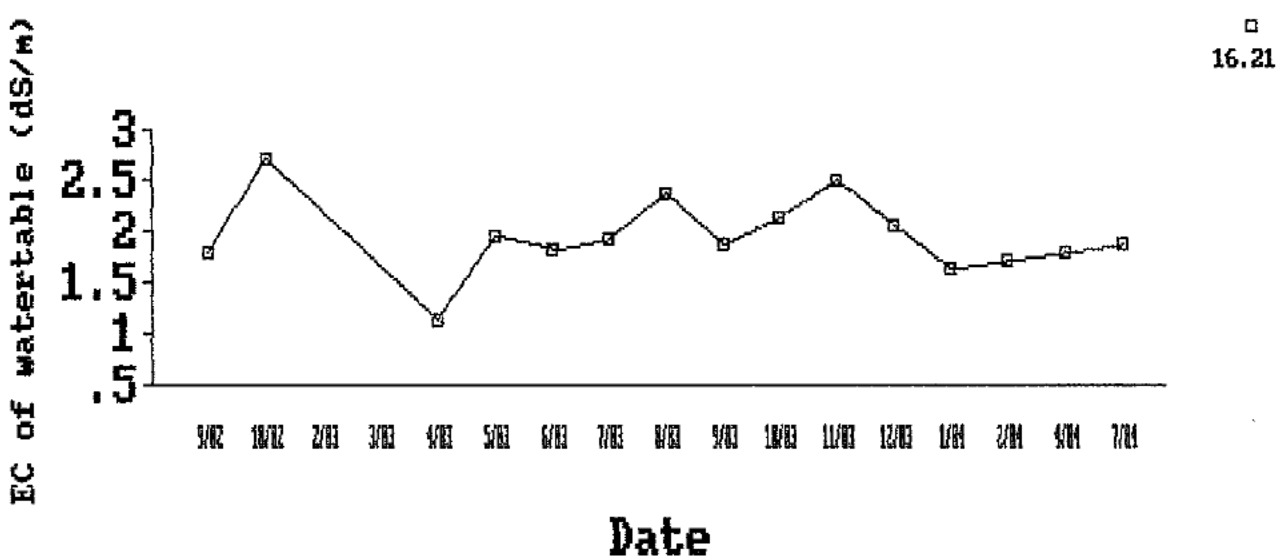


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984

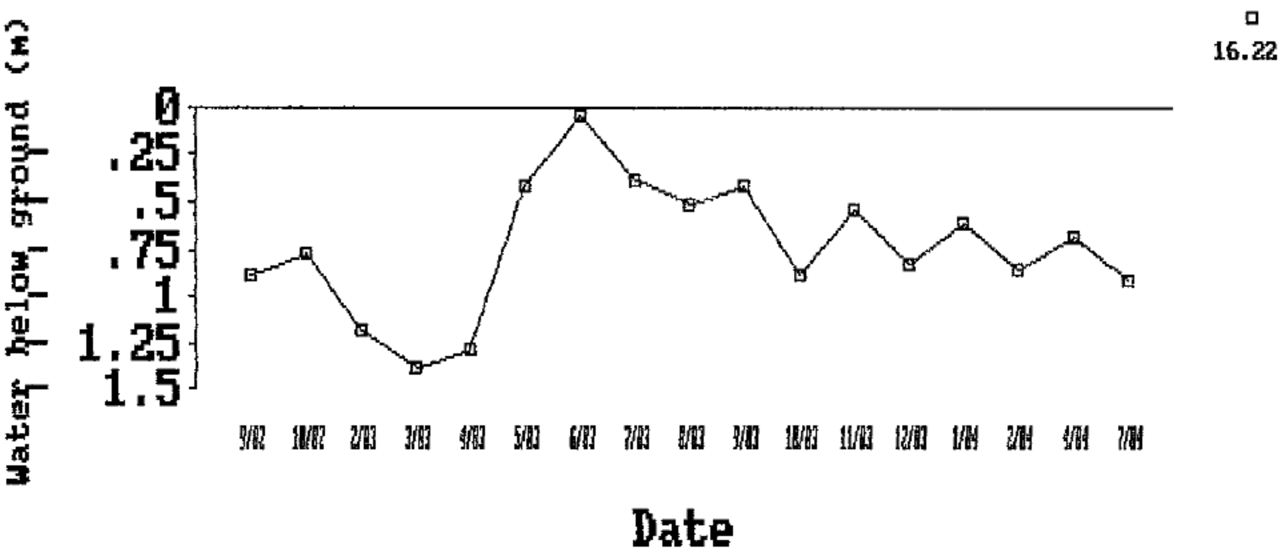


EC of watertable : Sept 1982 to July 1984

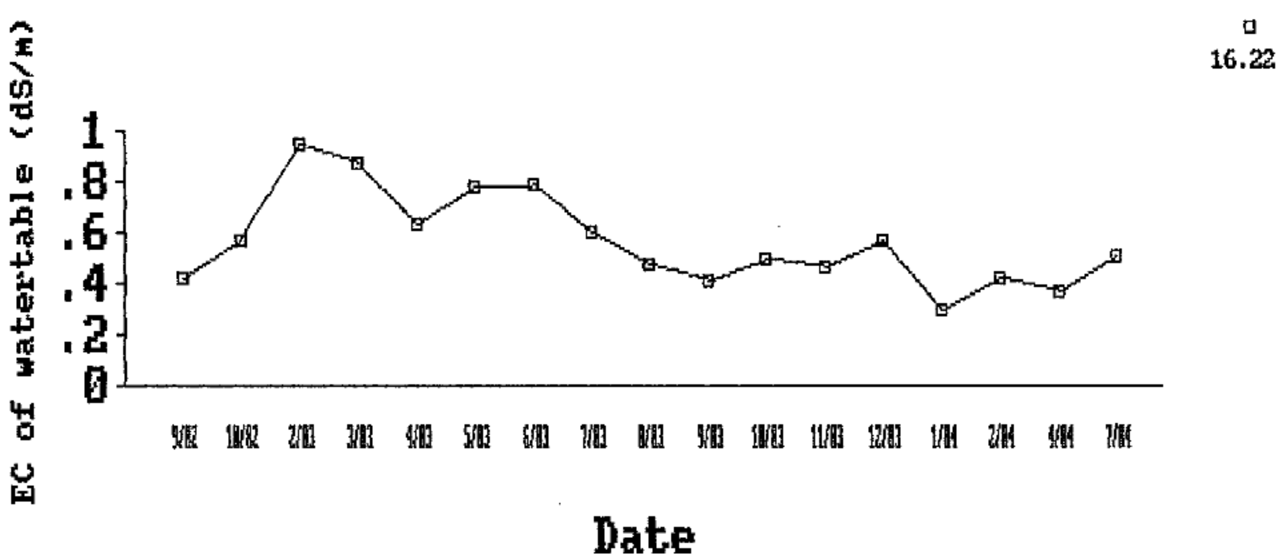


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984.

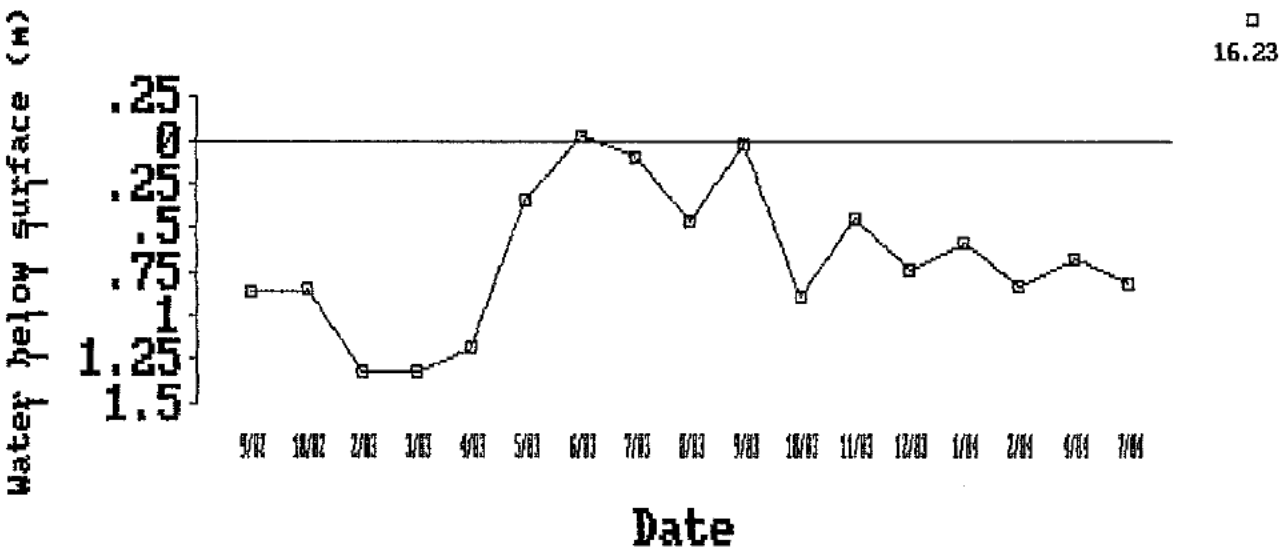


EC of watertable : Sept 1982 to July 1984.

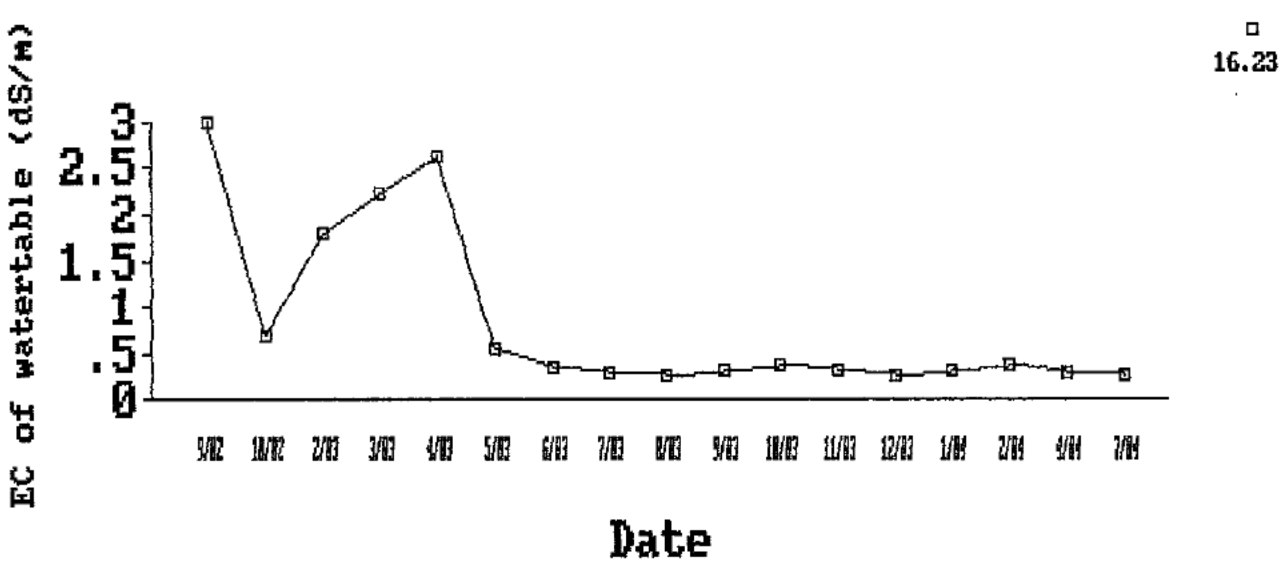


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984.

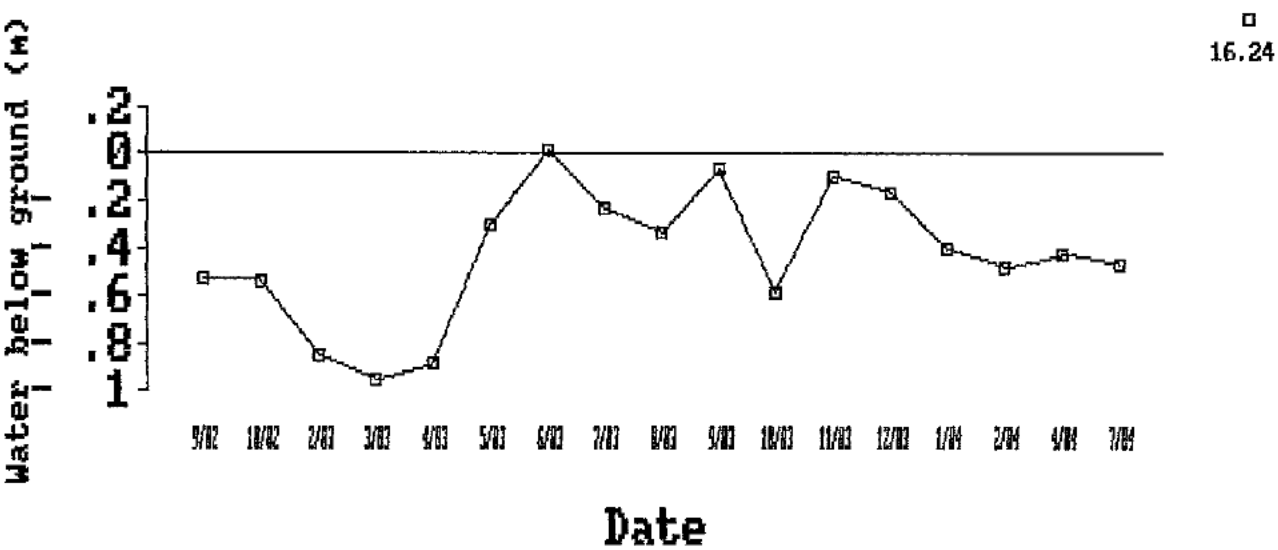


EC of watertable : Sept 1982 to July 1984.

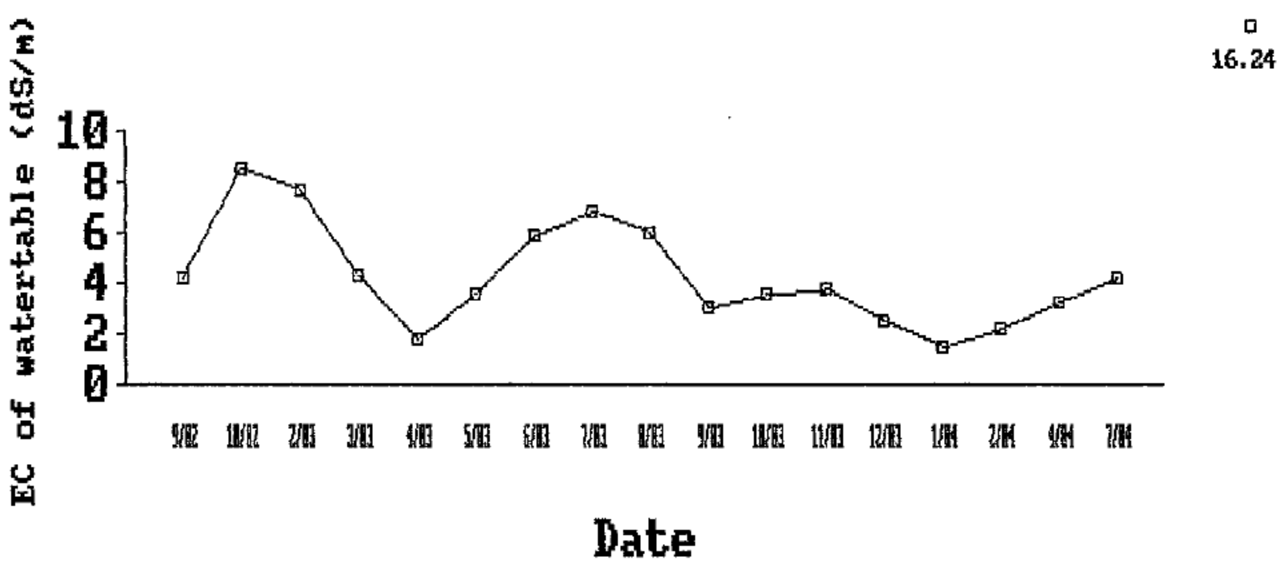


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984.

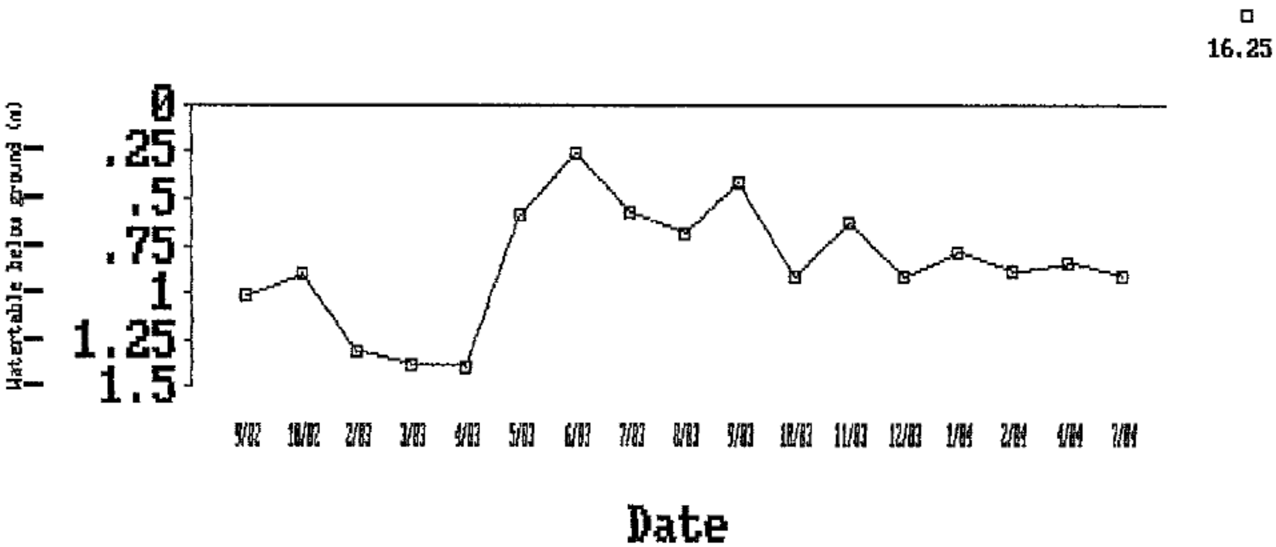


EC of watertable : Sept 1982 to July 1984.

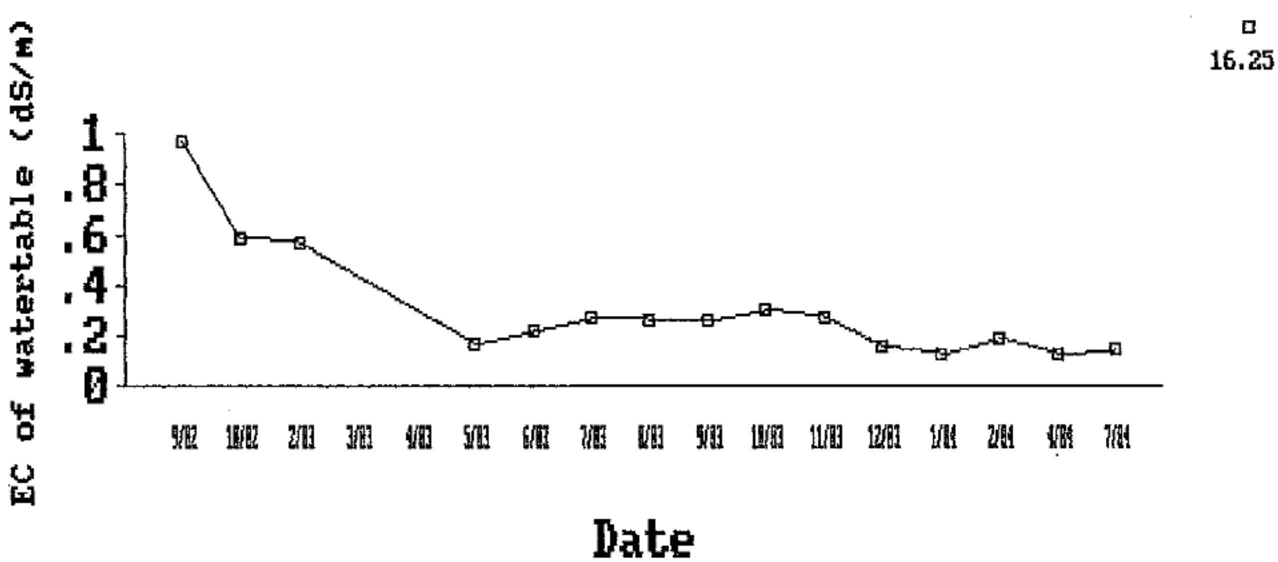


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984

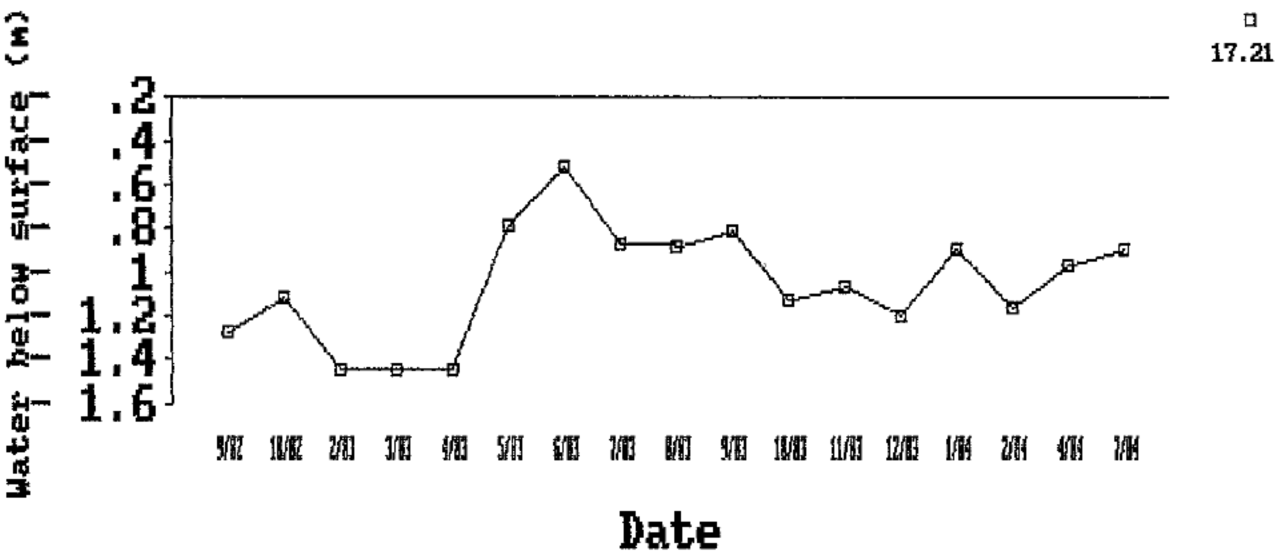


EC of watertable : Sept 1982 to July 1984

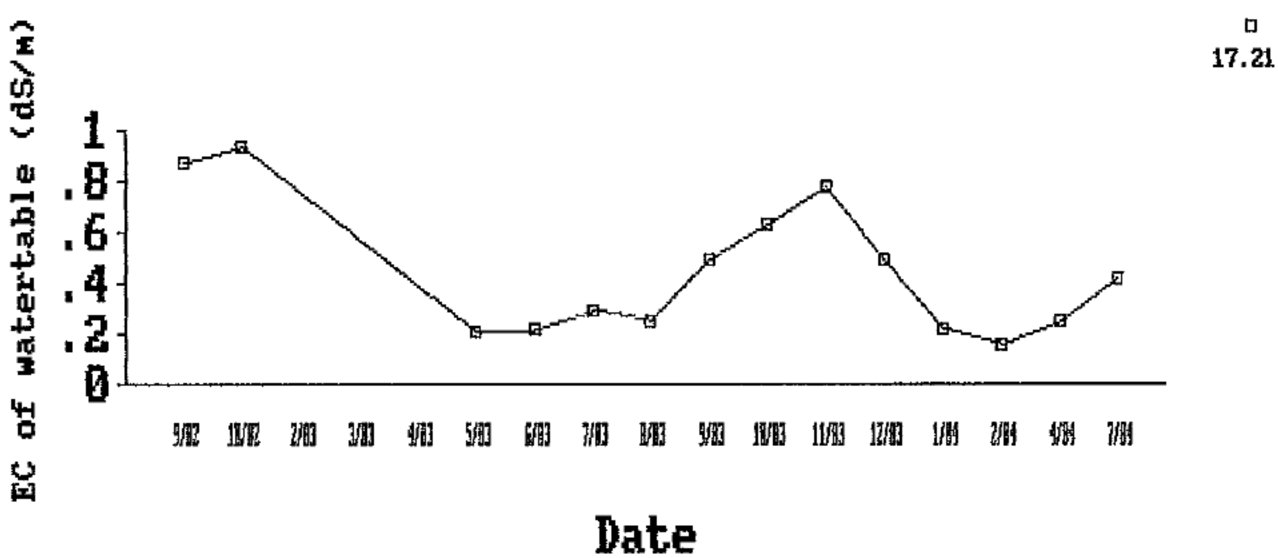


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984.

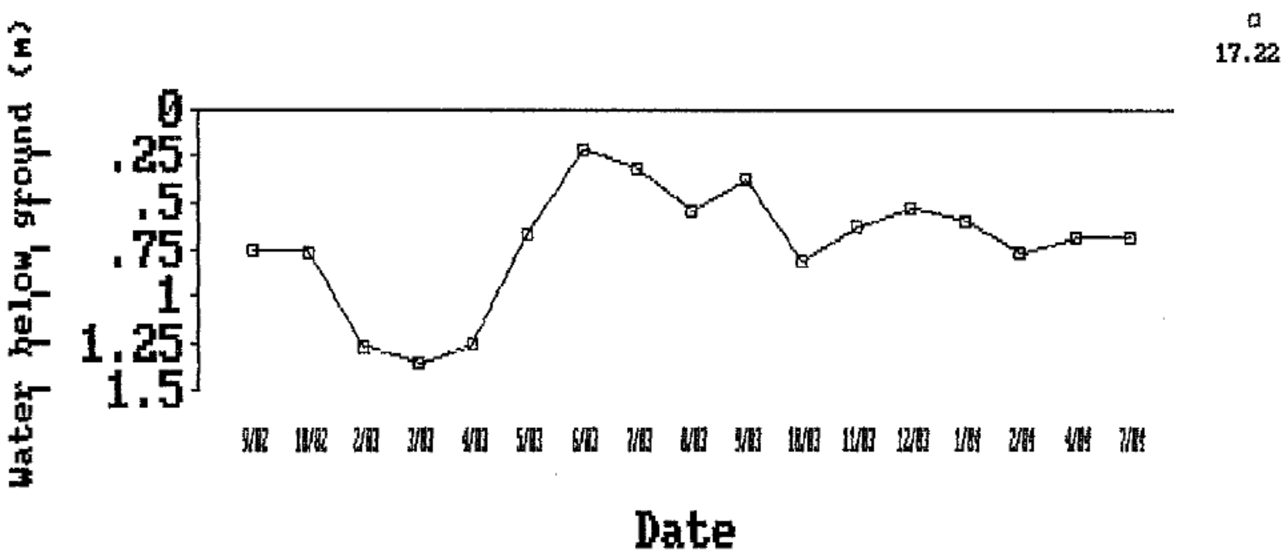


EC of watertable : Sept 1982 to July 1984.

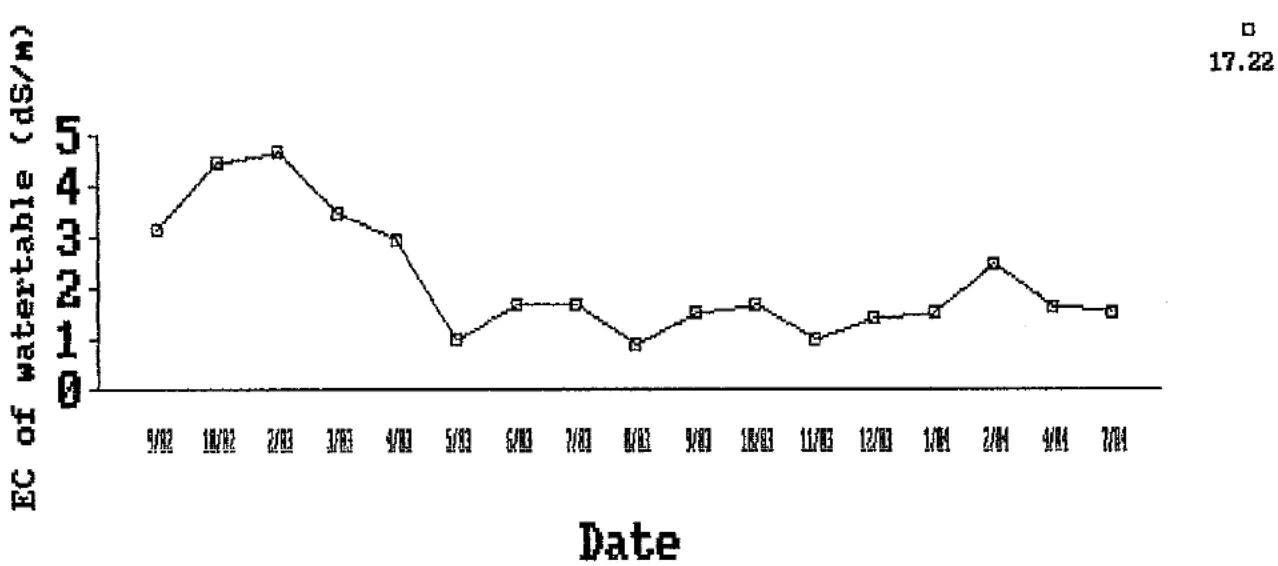


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984.

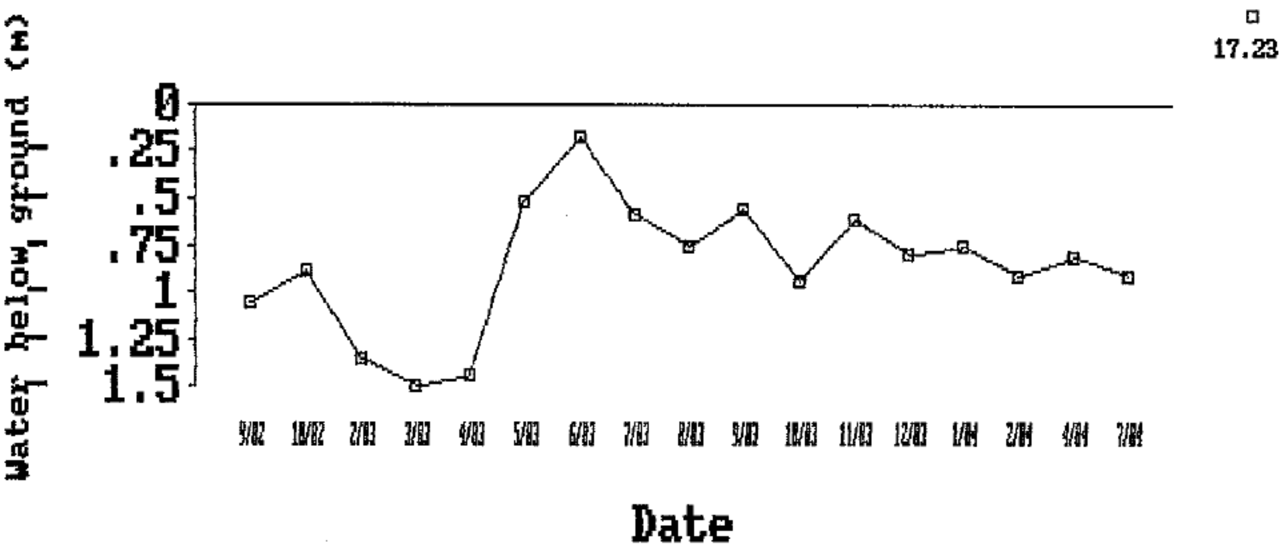


EC of watertable : Sept 1982 to July 1984.

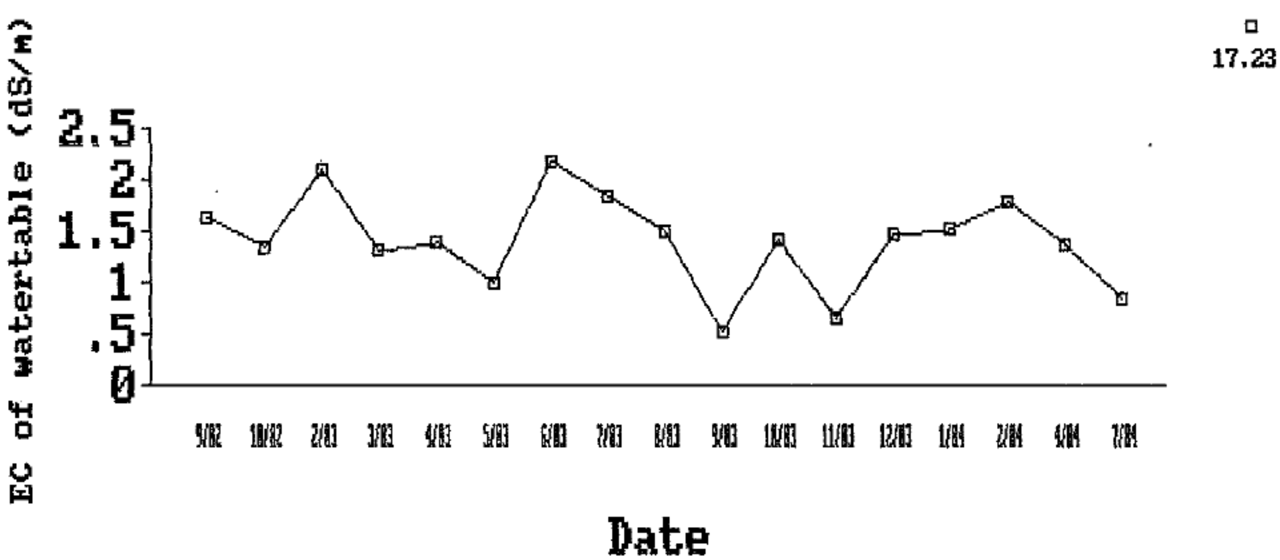


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984.

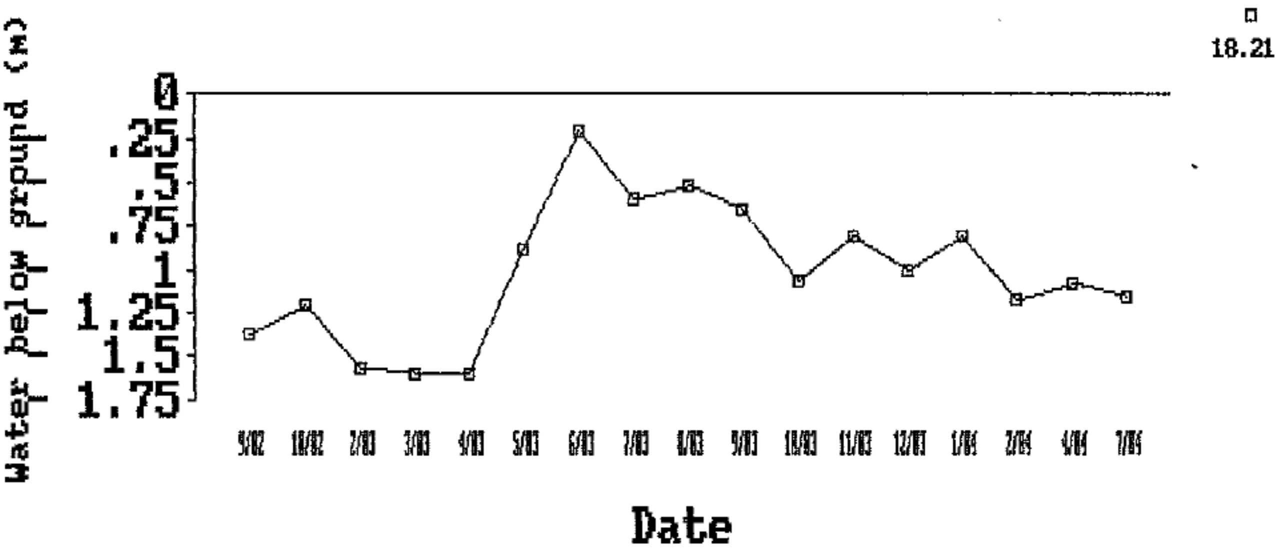


EC of watertable : Sept 1982 to July 1984.

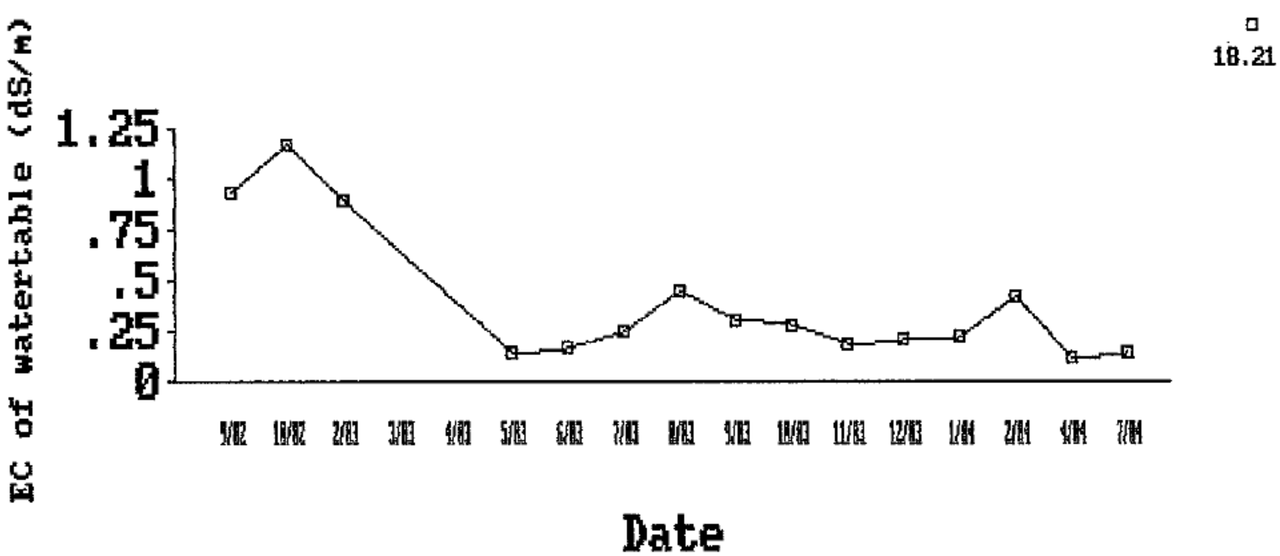


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984.

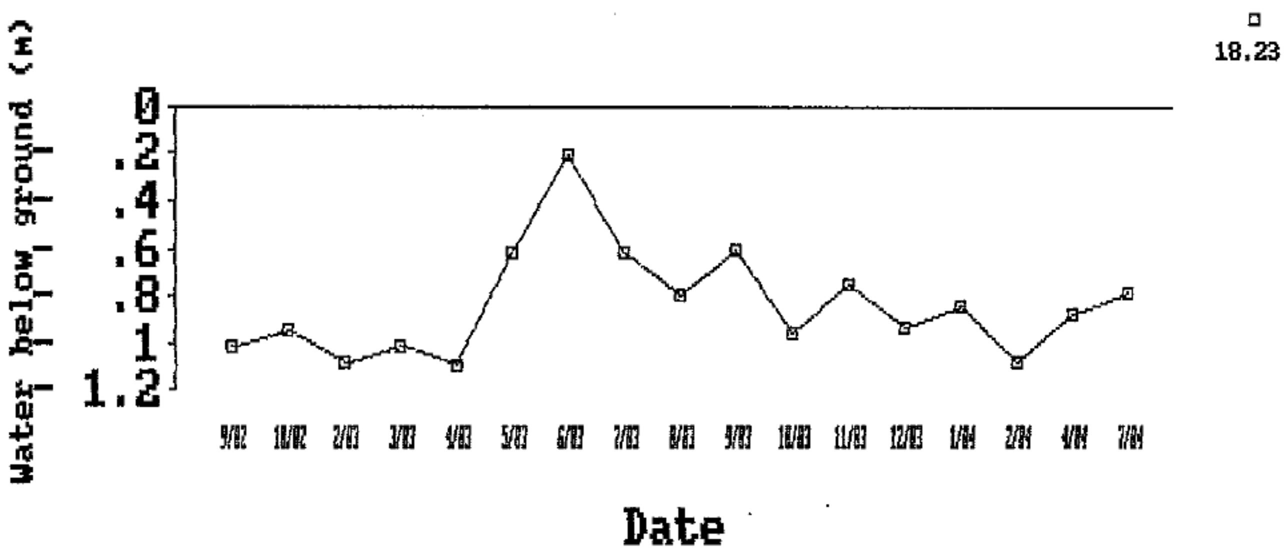


EC of watertable : Sept 1982 to July 1984.

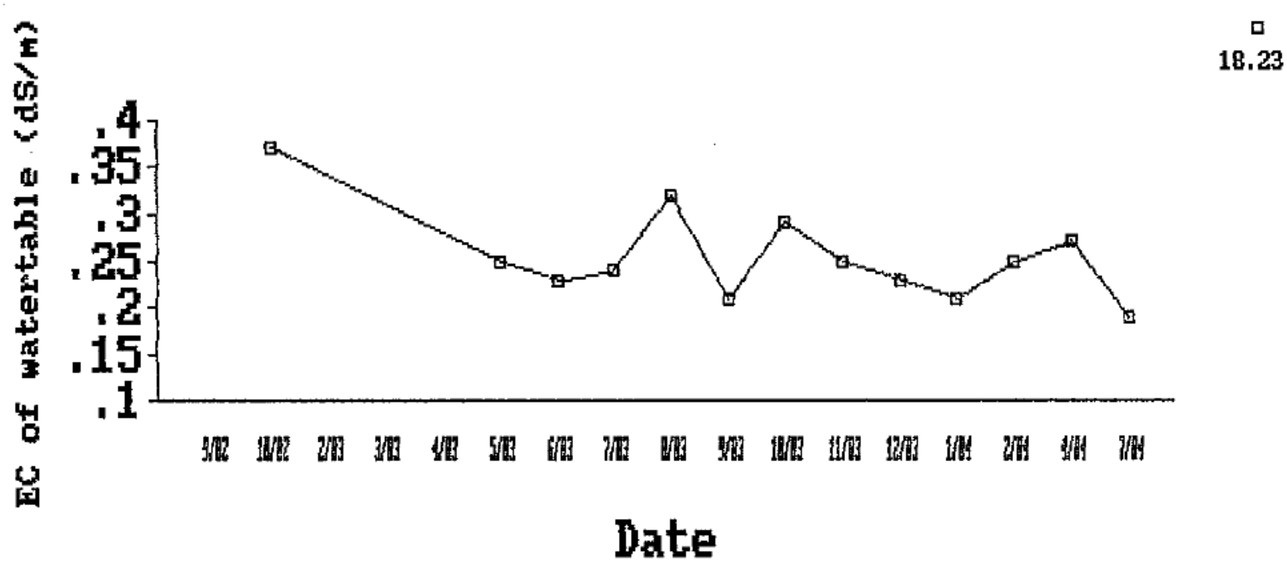


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984.

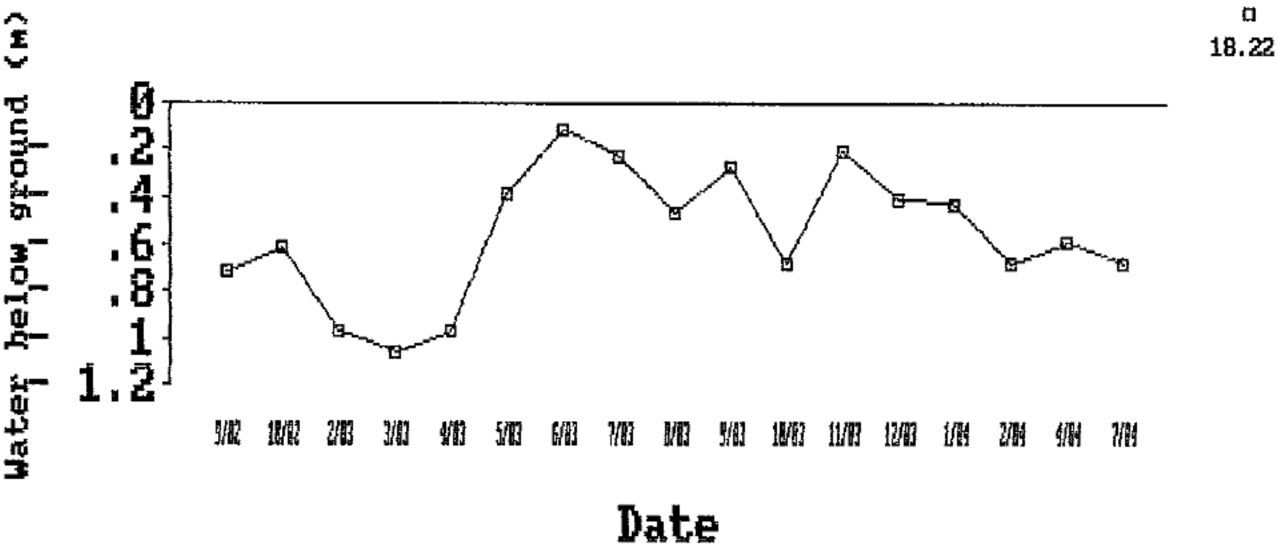


EC of watertable : Sept 1982 to July 1984.

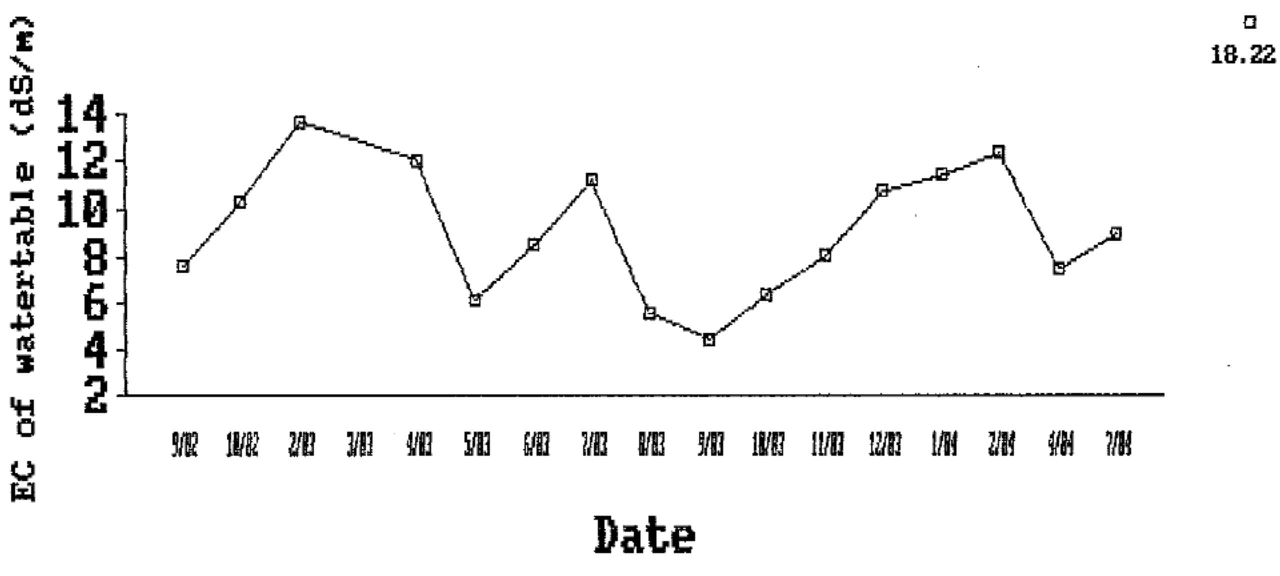


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984

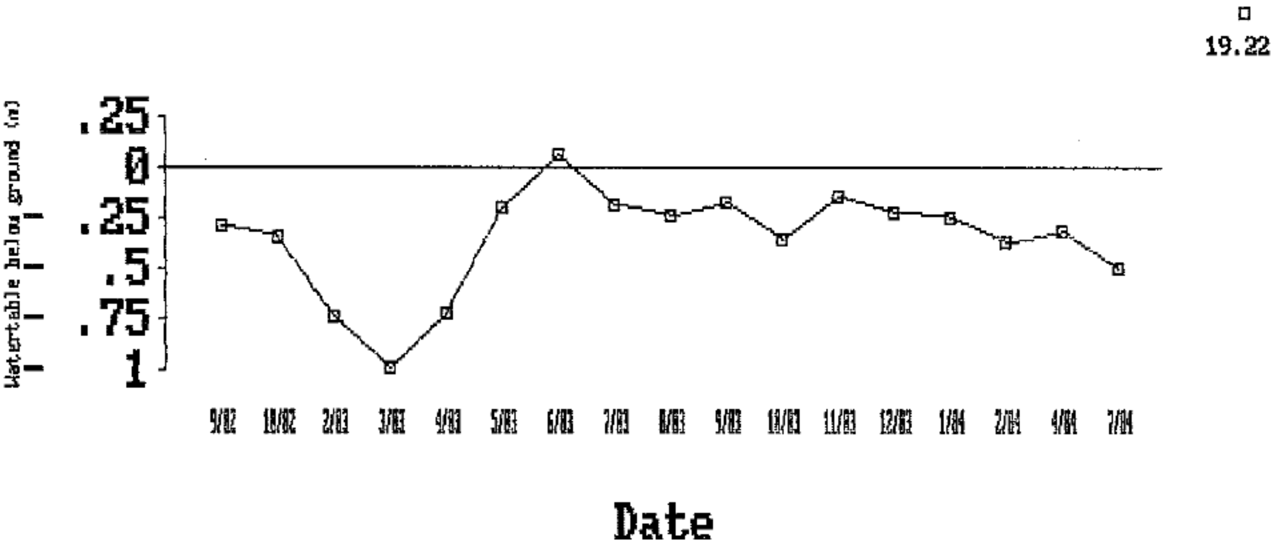


EC of watertable : Sept 1982 to July 1984

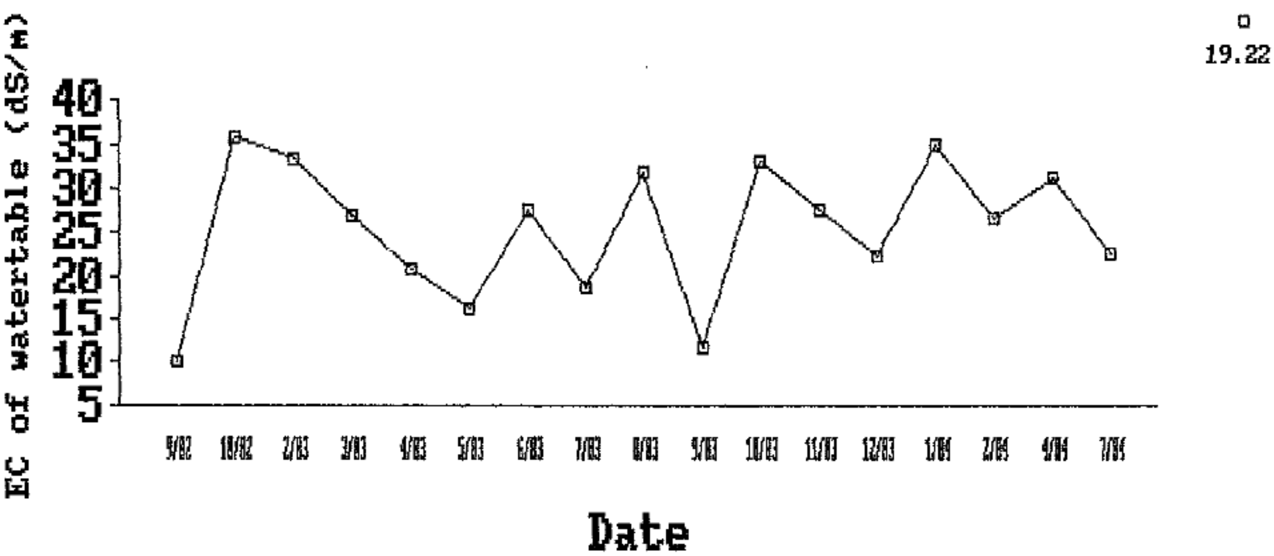


APPENDIX V (continued)

Depth of watertable below ground : Sept 1982 to July 1984



EC of watertable : Sept 1982 to July 1984



Location of watertable bores.

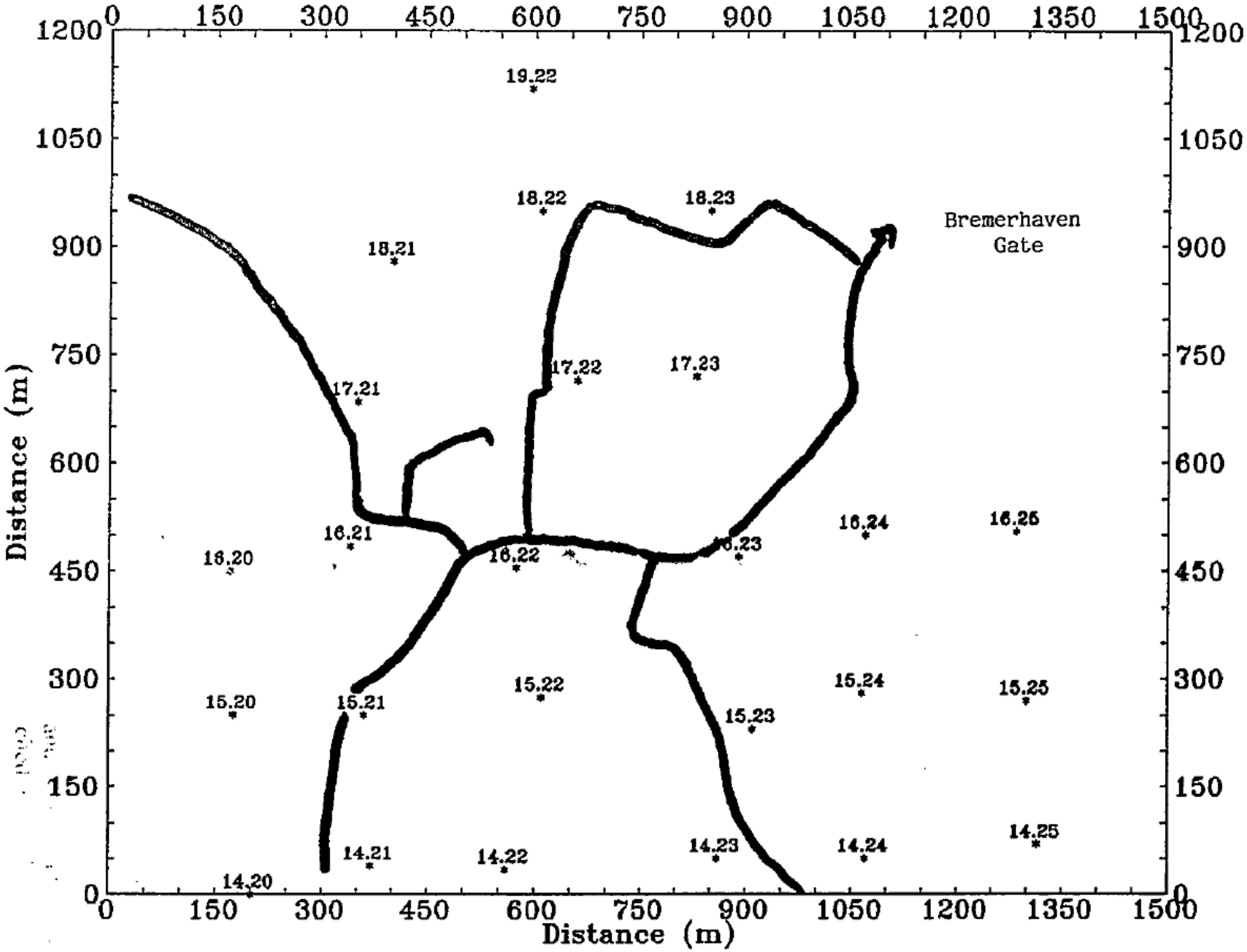


FIGURE 1b