

SAPISTON RIVER SUPPORT SCHEME

**TEST PUMPING OF
OBSERVATION BOREHOLES**

REPORT NO. 92/6/362

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ENVIRONMENT AGENCY



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SAPISTON RIVER SUPPORT SCHEME: TEST PUMPING OF OBSERVATION BOREHOLES

SUMMARY

Southern Science Ltd were instructed to carry out geophysical logging and constant rate testing on five observation boreholes near Bury St Edmunds, Suffolk as part of the Sapiston River Support Scheme. The logging and testing was completed in July 1992. The pumping tests showed that four of the five boreholes had yields in excess of the pumping rate used, and that water quality at the same four sites was satisfactory. The fifth site had a poor yield and pumped Hydrogen Sulphide during the test. Reliable transmissivity values were calculated for three of the sites. It is recommended that pilot production boreholes are drilled at four of the five sites.

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1.0 INTRODUCTION

The National Rivers Authority (NRA) Anglian Region plan to augment Summer flows in the Black Bourne River at Sapiston, Suffolk using groundwater pumped from boreholes drilled in the Chalk east of Sapiston. Five sites for the drilling of pilot boreholes have been identified by the NRA, (Figure 1) and the contract to develop these sites into production boreholes was awarded to Southern Science Ltd. This report describes the first part of the contract, the geophysical logging and constant rate testing of five observation boreholes, each of which is situated close to one of the pilot borehole sites. The report includes recommendations for development of the scheme.

2.0 AIMS OF TESTING

Five observation boreholes were chosen for testing, each one being close to one of the production borehole sites previously identified by the NRA. The testing was designed to decide if any of the production borehole sites were unsuitable for further development on yield or water quality grounds.

The Chalk in the region is a microporous limestone which is fissured by solution, and the yields of boreholes drilled into the Chalk are dependent upon the number of these fissures intercepted during drilling. The amount of fissuring in the Chalk varies significantly on both a local and regional scale, and yields of boreholes drilled only a few metres apart can have substantially different yields as a result. Because of this it is felt that a poor yield from an observation borehole may not provide enough justification to decide against development of the respective production borehole site. It is felt that water quality problems at an observation borehole provide more justification for non-development of a production site.

3.0 METHODS OF TESTING

3.10 Geophysical Logging

The five observation boreholes were geophysically logged using Southern Science's logging equipment. The tests run were caliper, temperature and conductivity (T.C.), and natural gamma radiation. The aims of the logging were to determine; firstly the maximum pump size which could be used for pump testing the boreholes; secondly the thickness of the deposits which overlie the Chalk at each site (this was used to determine the condition of the Chalk aquifer (confined or unconfined)); and thirdly the depths at which major flow occurs in the borehole.

3.20 Test Pumping

Each of the of the observation boreholes was tested using the highest yielding pump which could be provided by the contractor. It was planned to run each of the tests for a maximum of 24 hours, to be followed by a recovery test. Water discharged from each of the tests was discharged in a variety of ways. Instantaneous discharge rates were measured using both a weir tank with a V notch weir, and a "Tigermag" electromagnetic flow meter. Total discharge was measured using a "Kent" helical meter.

3.30 Water Quality Sampling

Samples were collected during each of the tests and analysed by Southern Science's laboratories for a variety of determinands, (see Section 4.13, 4.23, 4.33, 4.43 and 4.53). Reliable, on-site measurements of dissolved oxygen (D.O.) could not be taken because turbulence in the well head and discharge pipework caused water and air to mix.

4.0 RESULTS OF TESTING

4.10 Heath Road, Sapiston - Works 91

TL 97/145
TL 9260 7590
D = 35.51 m

4.11 Geophysical Logging

The borehole was logged on 18 June 1992, and copies of the logs are given in Appendix 1. The caliper log shows the borehole to be cased at approximately 8 inch diameter to approximately 32mBGL (metres below ground level). The borehole is 163m deep. Immediately below the bottom of the casing there is significant overbreak. Fissuring occurs throughout the depth of the borehole, but there are major fissures at 88, 100, and 112mBGL.

The natural gamma log shows overlying deposits to a depth of 22m. The T.C. log shows the water table at 16.5mBGL i.e. in the drift deposits, making the aquifer confined. There are slight changes in temperature and conductivity at 82 and 88mBGL, and a more significant change at 100mBGL indicating flow horizons at these depths.

Confined.

4.12 Test Pumping

The constant rate test was completed on 1 July 1992 and commenced at 06.34 hours. Copies of the dip sheets are given in Appendix 1. Start water level was 16.58mBGL. A Grundfos SP45 pump was installed at a depth of 60m. The pumping rate was monitored throughout the test and remained constant at 710 l/m (litres per minute). The test lasted for 8 hours by which time the drawdown was increasing by only 0.01m per hour. Water was discharged to a field ditch for the test, there was no evidence of recirculation between the ditch and the borehole.

The maximum drawdown at the end of the test as 1.64m. A recovery test was carried out, during which the water level rose to within 0.11m of the start water level after 21 minutes. Analysis of the drawdown and recovery data is discussed in Section 5.

4.13 Water Quality Analysis

A copy of the analysis certificate for the sample taken from Heath Road is Given in Appendix 1. There are no particularly significant results although conductivity levels at 740 μ sie/cm are quite high.

4.20 Field Lane Hepworth - Works 102

TL 97/148
TL 9770 7450
D = 46.91

4.21 Geophysical Logging

The borehole was logged on 17 June 1992, and copies of the logs are given in Appendix 2. The caliper log shows the borehole to be cased at approximately 8 inch diameter to approximately 9mBGL. The borehole is 128m deep. Fissuring occurs throughout the depth of the borehole, but there are major fissures at 42, 92, and 109mBGL.

Unconfined.
(11m)

The natural gamma log shows overlying deposits to a depth of 8m. The T.C. log shows the water table at 19mBGL i.e. in the Chalk, making the aquifer unconfined. The T.C. log shows flow horizons at 42, 79 and 99mBGL.

4.22 Test Pumping

The constant rate test was completed on 4 July 1992 and commenced at 09.55 hours. Copies of the dip sheets are given in Appendix 2. Start water level was

July 1992

19.32mBGL. A Grundfos SP45 pump was installed at a depth of 60m. The pumping rate was monitored throughout the test and remained almost constant at 836 l/m. The test was stopped after 6 hours of pumping because the site was rapidly flooding due to heavy rainfall. at the end of the test the drawdown was increasing by only 0.05m per hour. Water was discharged to a field ditch for the test, there was no evidence of recirculation between the ditch and the borehole.

The maximum drawdown at the end of the test was 1.95m. A recovery test was carried out, during which the water level rose to within 0.28m of the start water level after 2 hours of recovery, and had fully recovered after 24 hours. Analysis of the drawdown and recovery data is discussed in Section 5.

4.23 Water Quality Analysis

One sample was taken from the Field Lane borehole at the end of the test. The conductivity value is again high at 940 μ sie/cm but none of the other results show anything unusual.

4.30 Wash Lane - Works 103

4.31 Geophysical Logging

The borehole was logged on 18 June 1992, and copies of the logs are given in Appendix 3. The caliper log shows the borehole to be cased at approximately 8 inch diameter to approximately 12mBGL and the borehole is 130m deep. The caliper log shows there to be few, if any major fissures throughout the borehole.

The natural gamma log shows overlying deposits to a depth of 19m. The T.C. log shows the water table at 27mBGL i.e. in the Chalk, making the aquifer unconfined. The T.C. log shows flow horizons between 79mBGL and the bottom of the borehole. In particular there are large variations in conductivity below 79mBGL, though without depth sampling the borehole it is impossible to say what causes this increase in conductivity.

unconfined
(B-)

4.32 Test Pumping

The constant rate test was completed on 5 July 1992. Copies of the dip sheets are given in Appendix 3. Start water level was 27.90mBGL. As with the previous two tests it was planned to install a Grundfos SP45 pump at a depth of 60m however the contractor reported that there was a blockage in the borehole at 40mBGL, attempts were made to dislodge the blockage but these proved unsuccessful, and as a result it was only possible to install the pump at a depth of 40mBGL. The geophysical logging of the borehole showed no obstruction so it is felt most likely that the borehole was not drilled vertical throughout thus preventing the pump from being placed at the specified 60mBGL.

The test was started at 08.20hours at a rate of 840 l/m but within 45 seconds of pumping the water level had fallen to the level of the pump inlet and the pump started pumping air. It was decided to throttle back the pump until a constant pumping rate could be maintained. The test was then stopped, recovery allowed to take place and the test restarted at 08.45 hours at the new lower pumping rate of 222 l/m.

Because the pump was forced to run "throttled back", variations in pumping rate occurred and it was necessary to repeatedly adjust the flow control valve. The variations in flow rate caused the water level to fluctuate significantly throughout the test, however after 6 hours of pumping a constant discharge rate was maintained and approximate water level equilibrium had been reached. For the purpose of testing water was discharged to a nearby field ditch. Throughout the test there was a smell

of Hydrogen Sulphide (H_2S) coming off the water discharged from the observation borehole, and the water failed to clear during the test, in particular small amounts of fine silt or clay were pumped throughout the test.

4.33 Water Quality Analysis

Two samples were collected towards the end of the testing of this borehole. It was not possible to analyse the Sulphide levels in the sample collected. Conductivity levels in both samples were higher than expected at $840 \mu\text{sie/cm}$, iron concentrations in the second sample were also high at 1.14mg/l , Hydrogen Sulphide is sometimes derived from Iron Pyrites and is often associated with high Iron concentrations.

4.40 Six Bells, Bardwell - Works 96

4.41 Geophysical Logging

The borehole was logged on 15 July 1992, and copies of the logs are given in Appendix 4. The caliper log shows the borehole to be cased at approximately 5.75 inch diameter to approximately 24mBGL and the borehole is 99m deep. The caliper log shows there to be fissuring throughout the borehole but especially at 24 to 34 and 64mBGL.

The natural gamma log shows overlying deposits to a depth of 22m. The T.C. log shows the water table at 12mBGL i.e. in the overlying deposits, making the aquifer confined. The T.C. log shows flow horizons at 22, 58 and 78mBGL.

Confined

4.42 Test Pumping

The constant rate test was completed on 6 July 1992 and commenced at 13.00 hours. Copies of the dip sheets are given in Appendix 4. Start water level was 11.75mBGL. Because the borehole has narrow (5.75 inch) PVC liner installed throughout its top 24m it was not possible to install the Grundfos SP45 pump which had been used for the previous tests, and a smaller SP27 pump was therefore installed at a depth of 60m. The pumping rate was monitored throughout the test and remained almost constant at 200 l/m. Throughout the test water was discharged to a nearby village pond.

The water level in the borehole drew down 0.09m within the first fifteen seconds of the start of pumping, and after 4 hours had only fallen by a further 0.02m. Because of the very small drawdown it was decided to stop the test after 4.5 hours. During the recovery test, the water level rose to within 0.03m of the start water level after 15 seconds.

4.43 Water Quality Analysis

Two samples were taken, and both were found to have high conductivity values (each $890 \mu\text{sie/cm}$). There were no other determinands with high concentrations.

4.5 Bardwell Manor - Works 94

4.51 Geophysical Logging

The borehole was logged on 18 June 1992, and copies of the logs are given in Appendix 5. The caliper log shows the borehole to be cased at approximately 5.75 inch diameter to approximately 29mBGL and the borehole is 167m deep. The caliper log shows there to be fissuring throughout the borehole but especially at 34, 44, 105 and 109mBGL.

The natural gamma log shows overlying deposits to a depth of 12m. The T.C. log shows the water table at 5mBGL i.e. in the overlying deposits, making the aquifer confined. The T.C. log shows flow horizons at 15, 22mBGL, it also shows a steep temperature gradient between 144mBGL and the bottom of the borehole.

Confined.

4.52 Test Pumping

The constant rate test was completed on 7 July 1992 and commenced at 10.35 hours. Copies of the dip sheets are given in Appendix 5. Start water level was 11.75mBGL. Because the borehole has narrow (5.75 inch) PVC liner installed throughout its top 29m it was not possible to install the larger of the pumps used in three of the previous tests, and again the smaller SP27 pump was installed at a depth of 60m. The pumping rate was monitored throughout the test and remained almost constant at 206 l/m. Throughout the test water was discharged to a nearby roadside drain.

The water level in the borehole drewdown 0.15m within the first fifteen seconds of the start of pumping, and after 4 hours had only fallen by a further 0.11m. Because of the very small drawdown it was decided to stop the test after 4 hours. During the recovery test, the water level rose to within 0.07m of the start water level after 15 seconds.

4.53 Water Quality Analysis

Two samples were taken from this borehole, both samples had high conductivity (795 $\mu\text{sie/cm}$).

5.0 CALCULATION OF AQUIFER PROPERTIES

The drawdown and recovery data collected during each test is plotted in linear-linear format in Figures 2 to 11. Of the five sites tested it was only possible to completely analyse the results of three of the sites; the test pumping data for Wash Lane was seriously affected by changes in pumping rate, however the recovery data was analysed, the drawdown at Six Bells was too small for analysis. All analysis was done by hand plotting, the results are summarised in Table 1.

5.10 Test Pumping Analysis

5.11 Type Curve Fitting

The pumping test data from three sites was plotted on log-log paper (Appendices 6, 7 and 10) and Boulton and Theis curves were fitted, however only at Field Lane could a reasonable match be made.

5.12 Cooper-Jacob Analysis

Appendices 6, 7 and 10 show the pumping test data from the same three sites plotted on linear-log paper and the Cooper-Jacob method of analysis was completed on these plots. Realistic transmissivity values were obtained at all three sites using this method.

5.20 Recovery Analysis (Cooper-Jacob)

Cooper-Jacob method of analysis of recovery data (Appendices 6, 7, 8 and 10) was completed at all sites except Six Bell. The results of this analysis appear reasonable except for Wash Lane which has a very low T.

Table 1. Results of Test Pumping and Recovery Analysis: Values of T ($\text{m}^2/\text{day}^{-1}$)

Site Name	Aquifer Condition	PUMPING TEST		RECOVERY	
		Type Curve Fitting Boulton	Theis	Straight Line Cooper-Jacob	Straight Line Cooper-Jacob
Heath Road	Confined	n/a	no fit	1844 2115	1164 508
Field Lane	Unconfined	early 320 late 321	321	715	731
Wash Lane #	Unconfined	no fit	no fit	no fit	66.5
Six Bells *	Confined	n/a	no analysis	no analysis	no analysis
Bardwell Manor	Confined	no fit	no fit	1947	2635

Analysis of Test Pumping Data affected by variation in pumping rate
* Drawdown too small for analysis

6.0 CONCLUSIONS

The geophysical logging of the five observation boreholes shows that four of the boreholes have significant amounts of fissuring throughout their depth, while the fifth borehole at Wash Lane has little fissuring. The Wash Lane borehole has high conductivity water in the borehole below 79mBGL, it is not known what the cause of this high conductivity is.

The test pumping shows that four of the five boreholes have yields in excess of the rates they were pumped at. Maximum drawdowns at these four sites ranged from 0.05 to 1.95m. The fifth site, Wash Lane had a poor maximum yield (222 l/m).

Analysis of water samples collected at the sites shows that with the exception of conductivity levels which were somewhat higher than expected, there were no water quality problems except at Wash Lane which pumped Hydrogen Sulphide throughout testing.

Analysis of drawdown and recovery data shows that the Chalk aquifer has a transmissivity of between 320 and 2635 $\text{m}^2/\text{day}^{-1}$.

7.0 RECOMMENDATIONS

As stated in Section 2 it is felt that because of the fissured nature of the Chalk, a poor yielding observation borehole may not be sufficient justification to decide against development of any one production borehole site. However during the testing of the five observation boreholes one of the sites, Wash Lane, had a poor maximum yield and unacceptable water quality. As a result it is recommended that Wash Lane should not be developed as a production borehole site. The remaining four sites should be developed as the next stage of the scheme.

HEATH ROAD

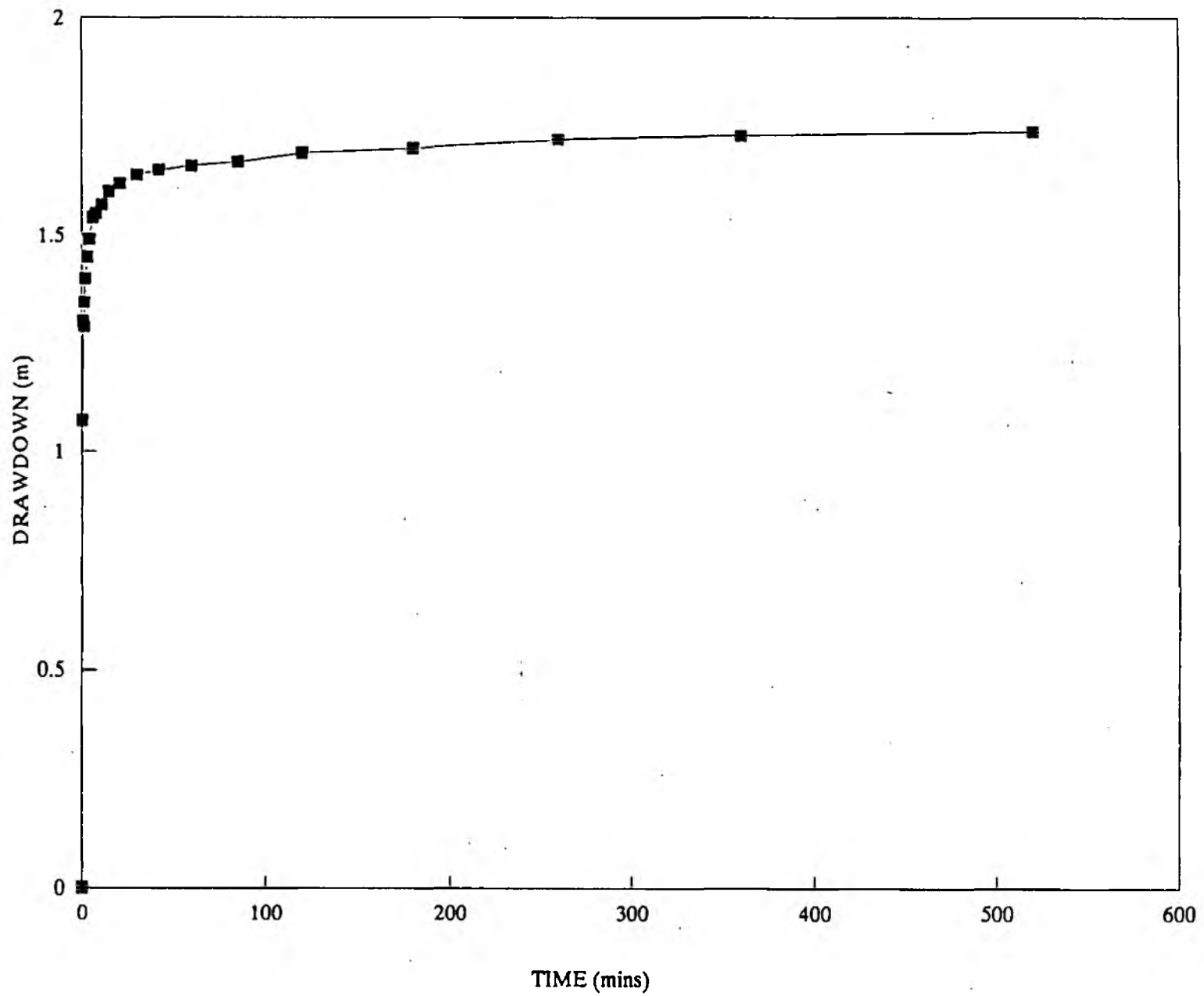


Figure 2

HEATH ROAD (RECOVERY)

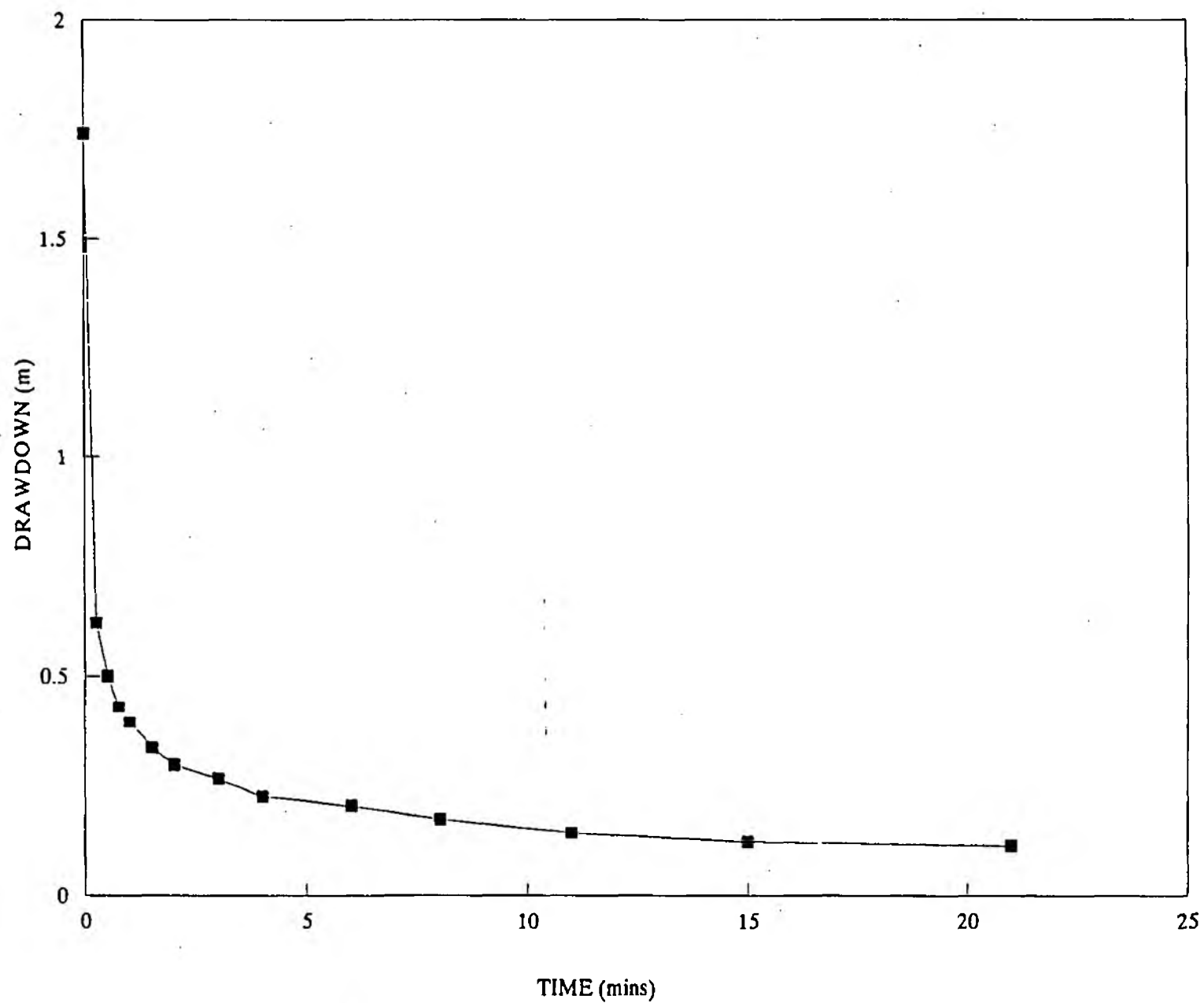


Figure 3

FIELD LANE

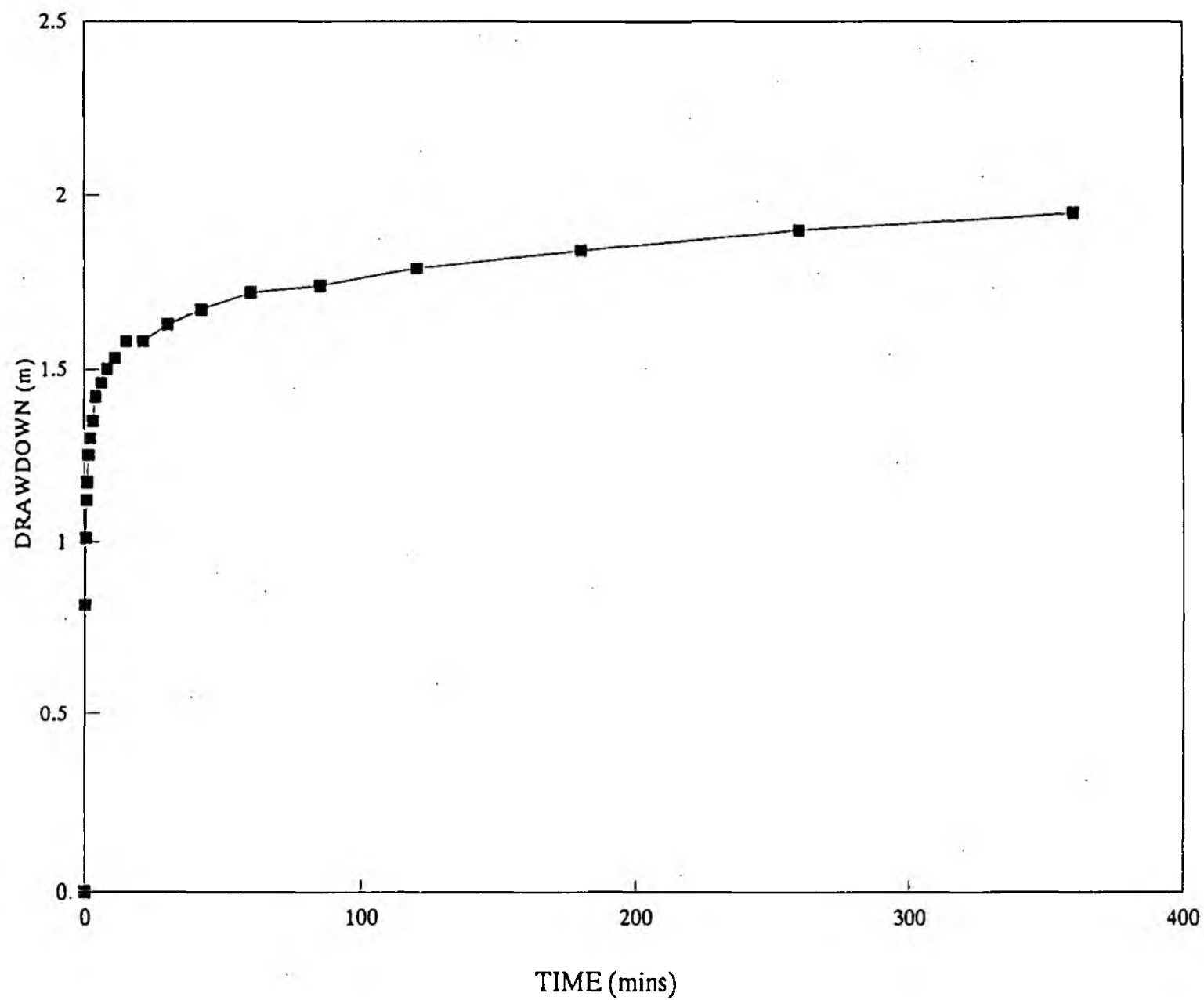


Figure 4

FIELD LANE (RECOVERY)

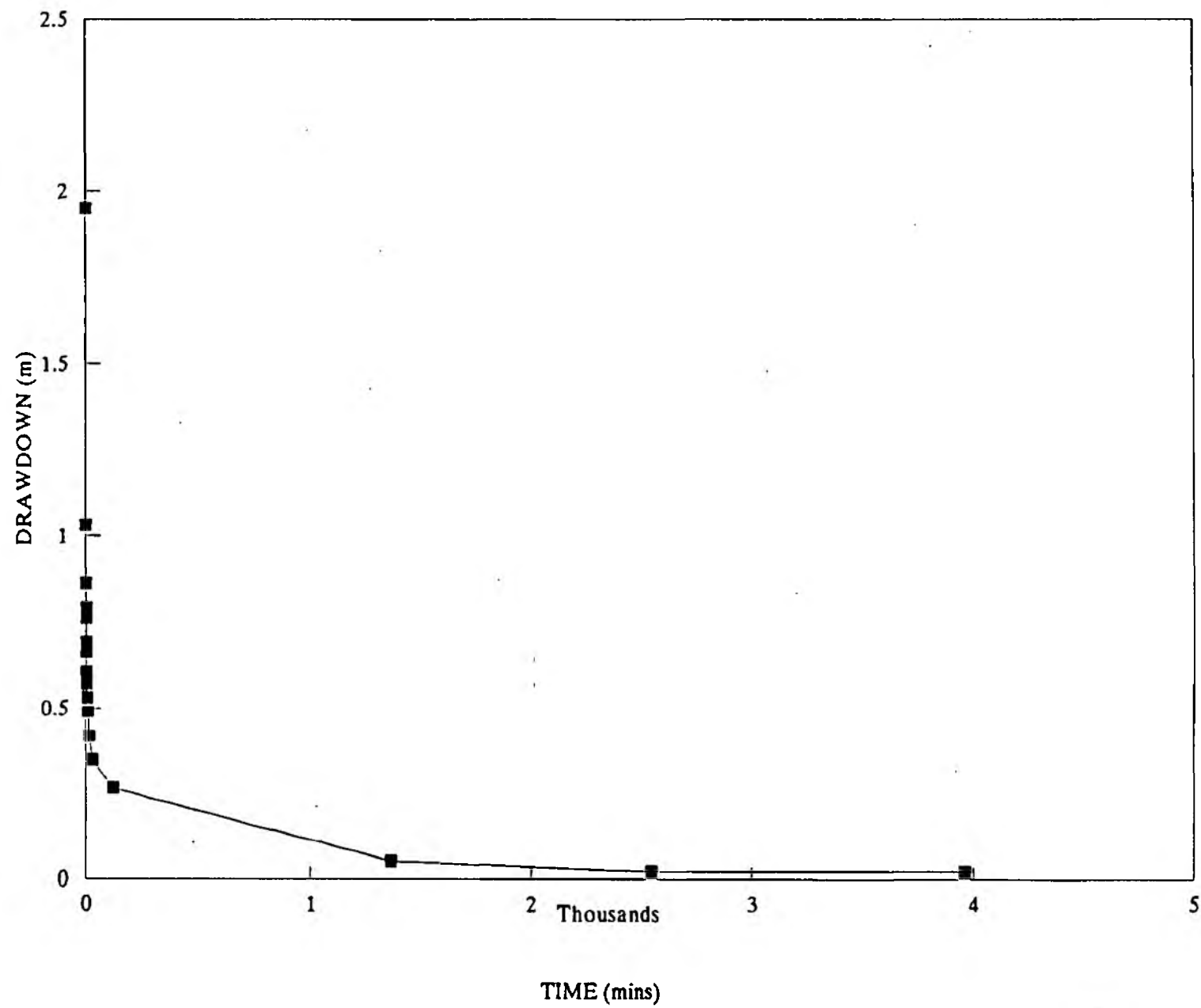


Figure 5

WASH LANE

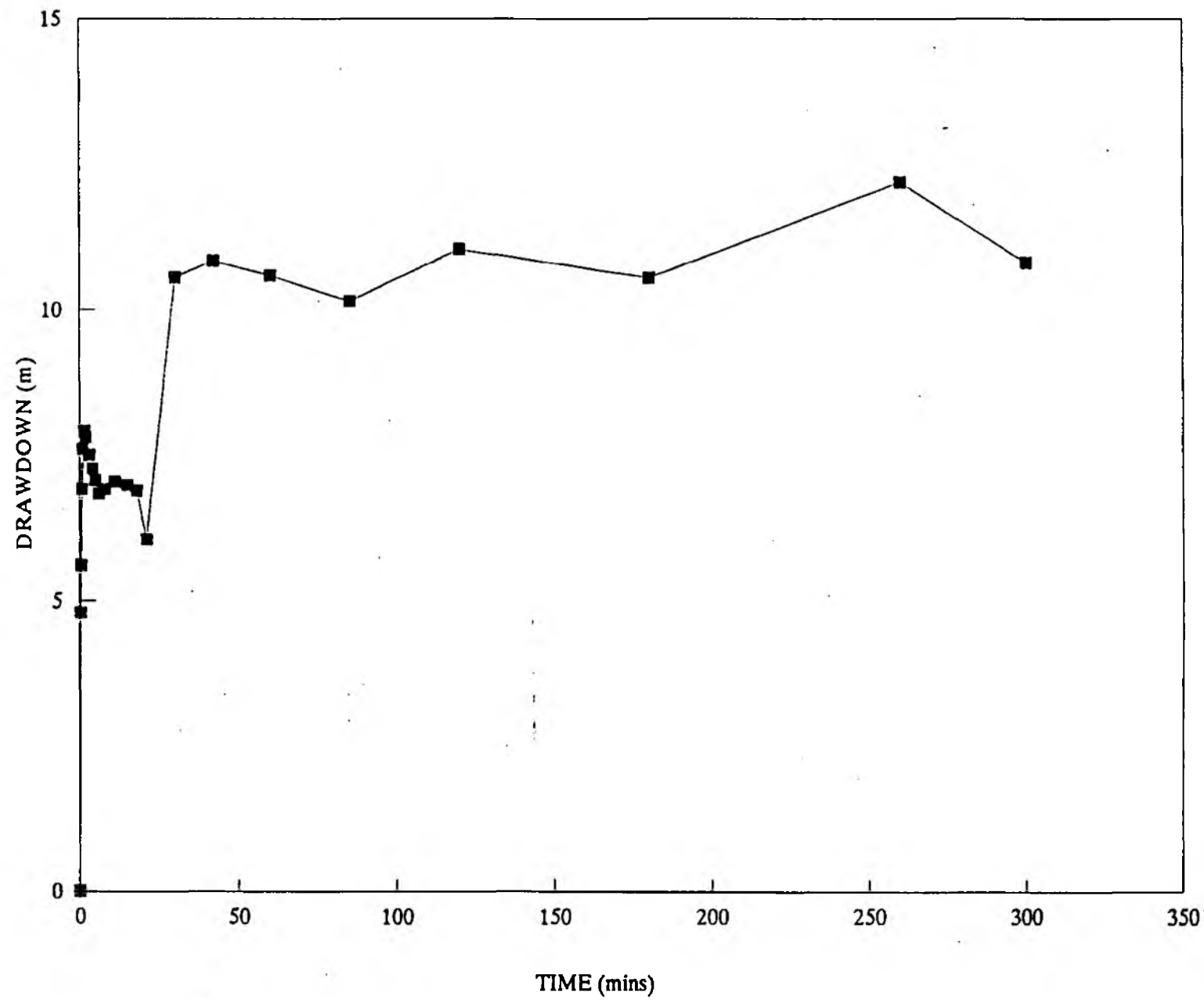


Figure 6

WASH LANE (RECOVERY)

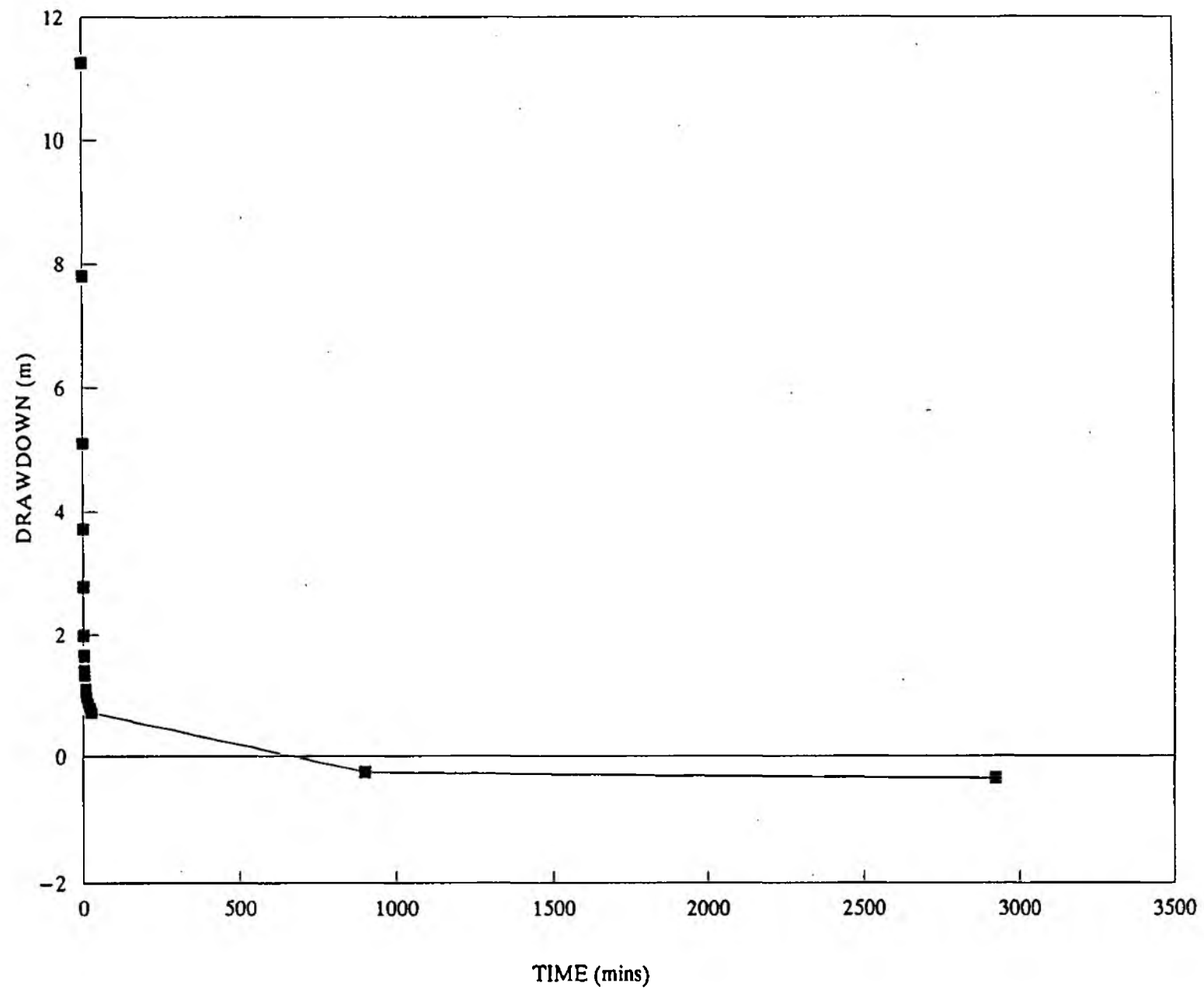


Figure 7

SIX BELLS

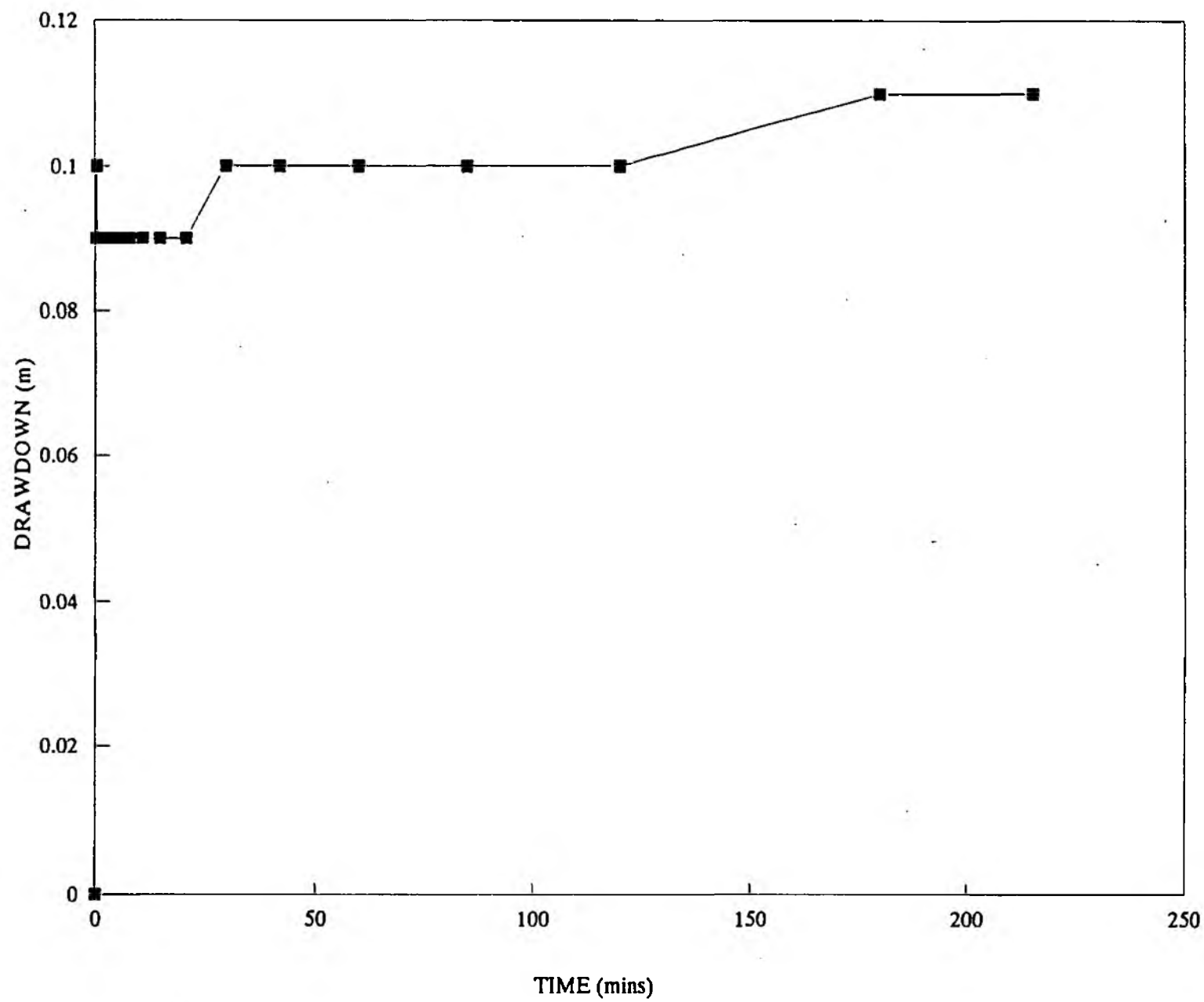


Figure 8

SIX BELLS (RECOVERY)

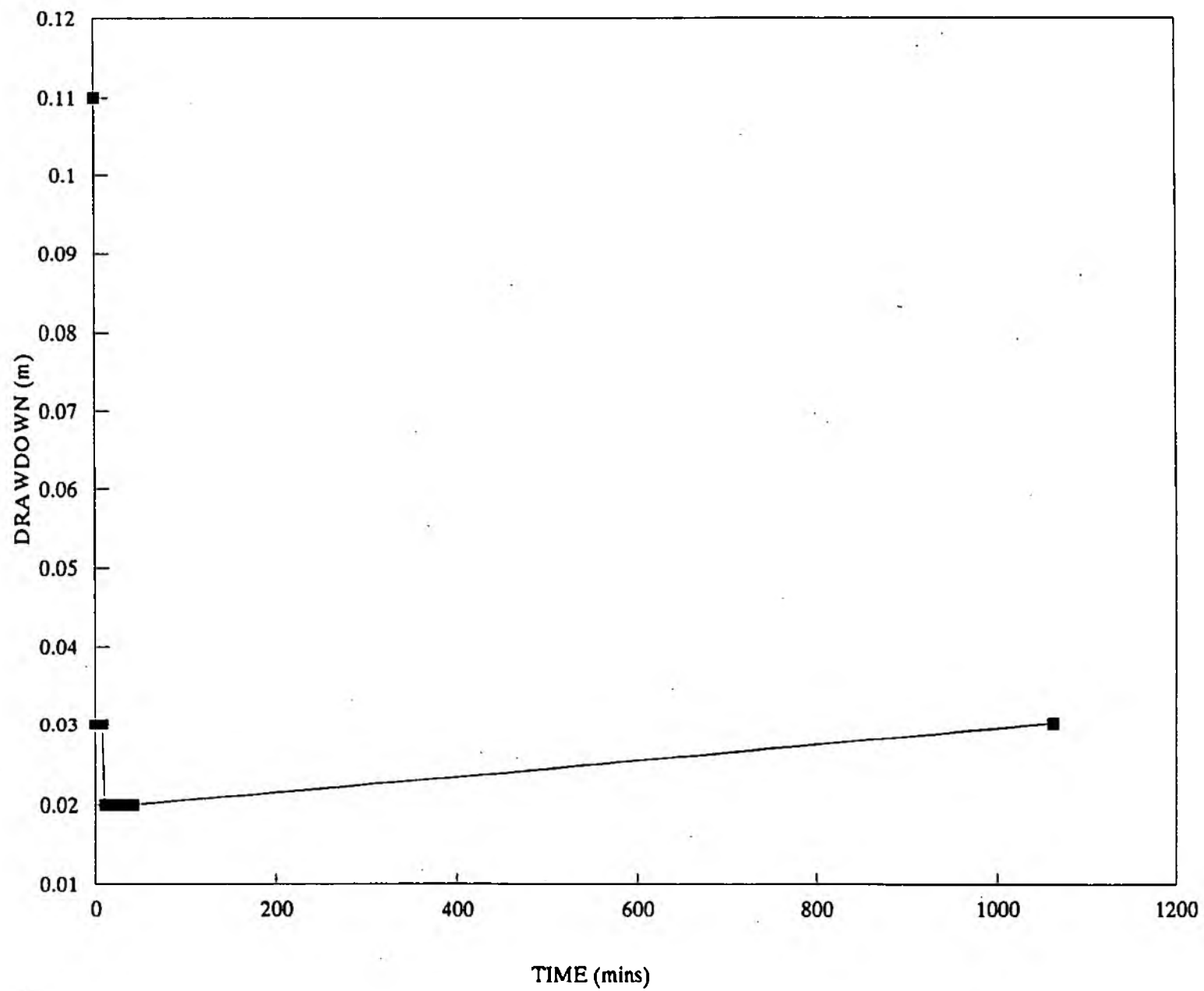


Figure 9

BARDWELL MANOR

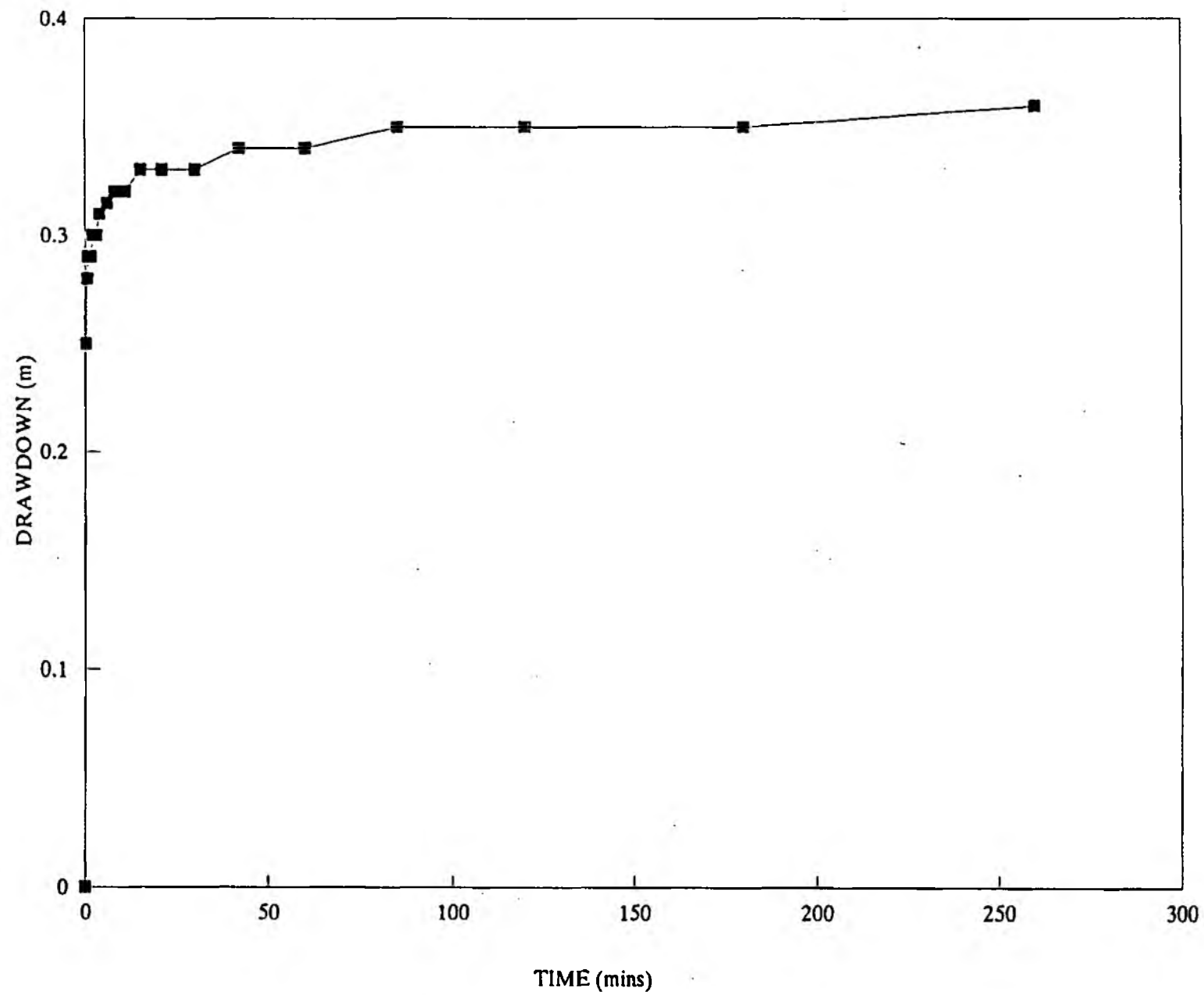


Figure 10

BARDWELL MANOR (RECOVERY)

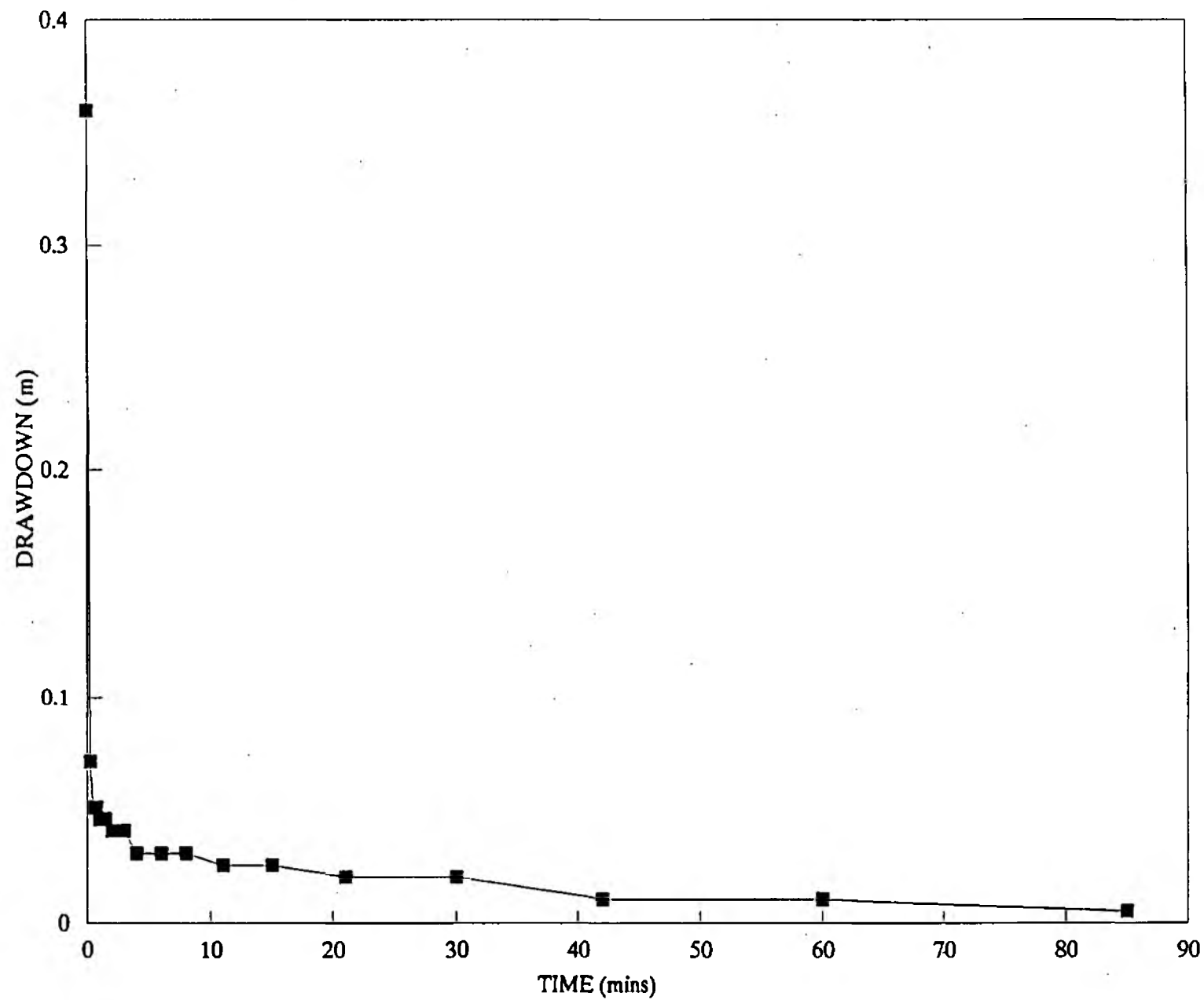


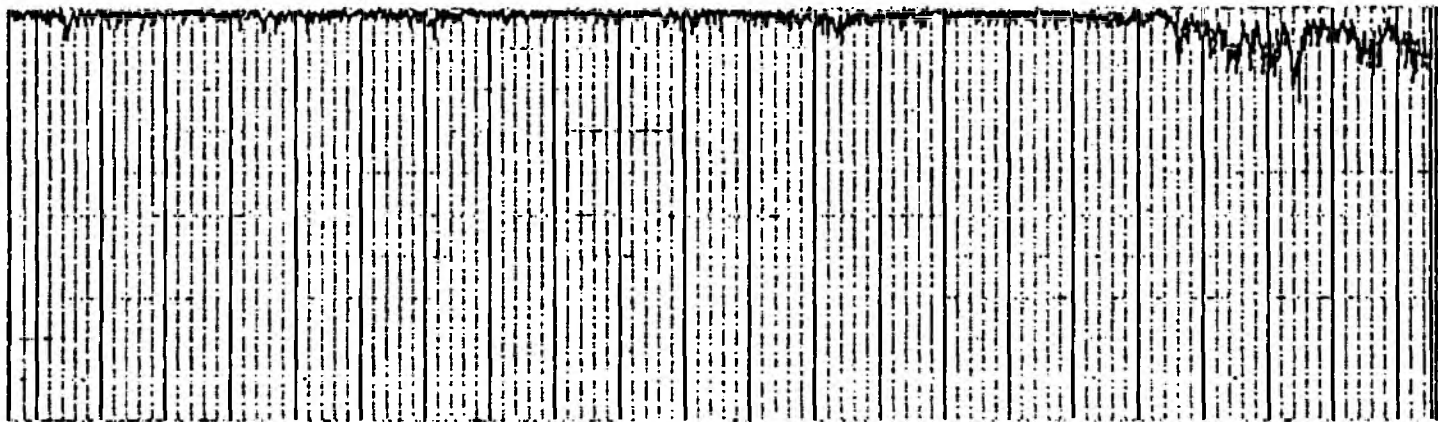
Figure 11

APPENDICES

1 RESULTS OF TESTING: HEATH ROAD

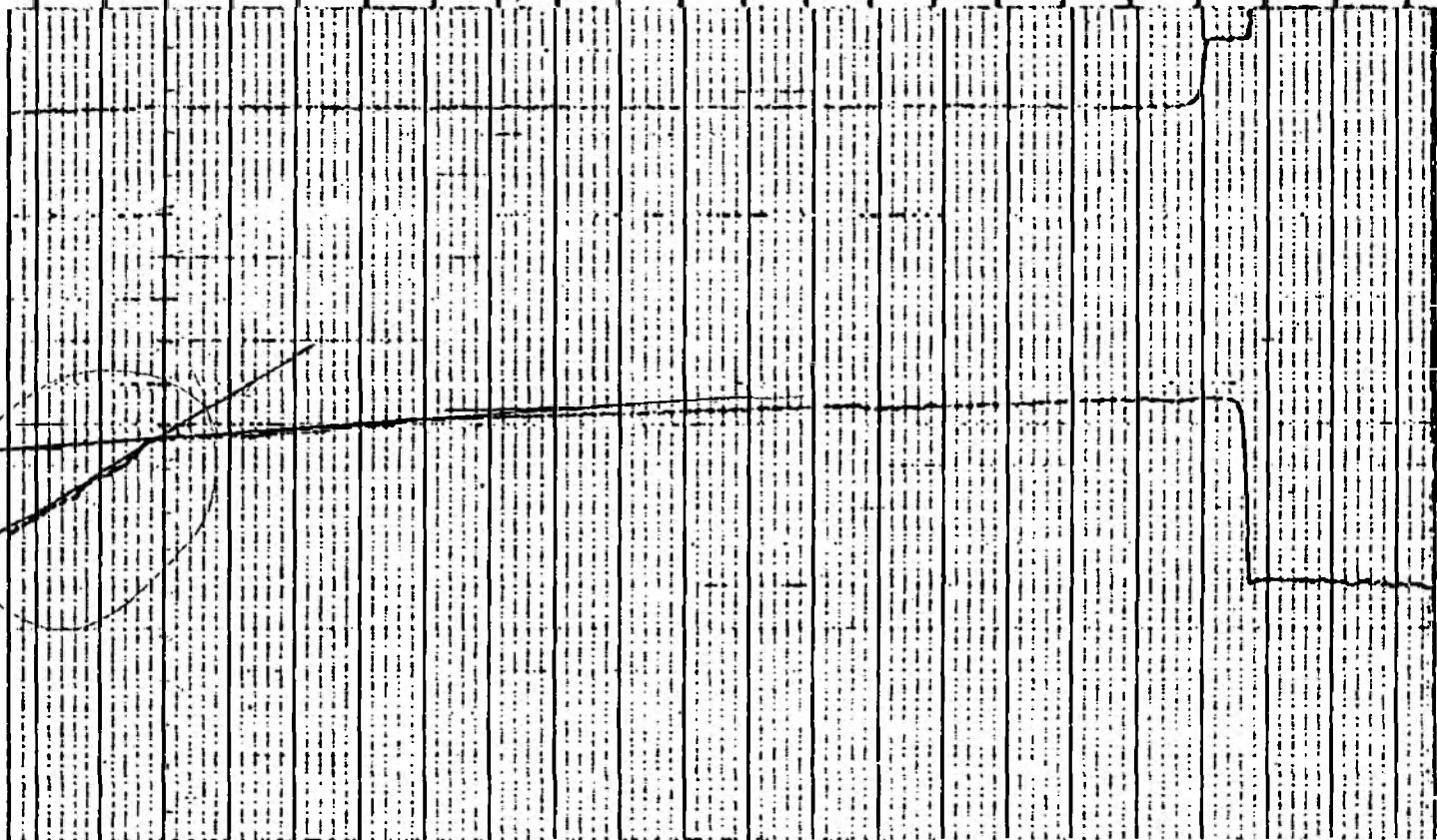
0.0 NSM CPS 200.0

0.0 NSM CPS 200.0



0.0 COND MS 5.0
EXP DEGC

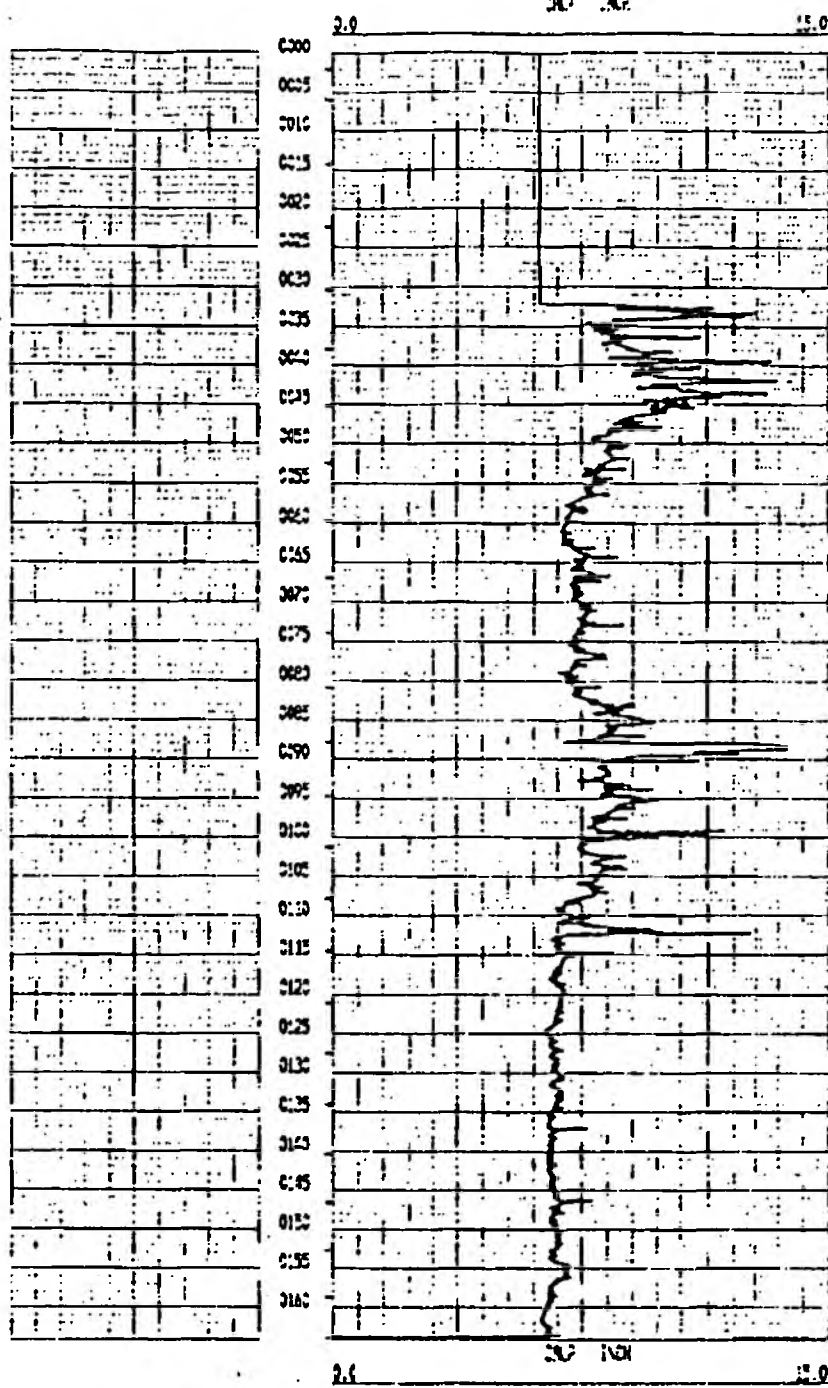
0.0 COND MS 5.0
TEMP DEGC



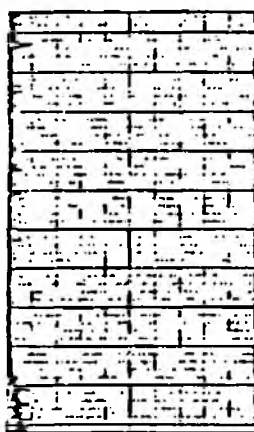
$\Delta T = 0.45^\circ \text{C} \rightarrow 11.3^\circ / 100 \text{m}$
 $\Delta \theta = 40$

$\Delta T = 1.7^\circ$
 $\Delta \theta = 15$
Gradient
 $\rightarrow 11.3^\circ / 100 \text{m}$

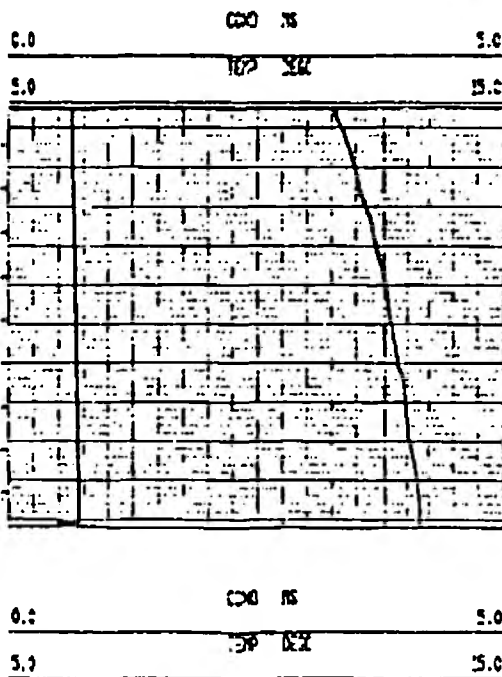
$1.5 \text{m} \rightarrow 1.1^\circ / 100 \text{m}$
 $100 \text{m} \rightarrow 11.3^\circ / 100 \text{m}$



0.0 0.0



0.0 0.0



PROJECT: SAPISTON

BOREHOLE: HEATH ROAD

TIME (mins)	DIP (m)	DRAWDOWN (m)	REMARKS
0	16.58	0.00	
0.25	17.65	1.07	
0.5	17.88	1.30	
0.75	17.88	1.30	
1	17.87	1.29	
1.5	17.92	1.34	
2	17.98	1.40	
3	18.03	1.45	
4	18.07	1.49	
6	18.12	1.54	
8	18.13	1.55	
11	18.15	1.57	746 l/min
15	18.18	1.60	
21	18.20	1.62	
30	18.22	1.64	
42	18.23	1.65	712 l/min
60	18.24	1.66	
85	18.25	1.67	
120	18.27	1.69	
180	18.28	1.70	
260	18.30	1.72	708 l/min
360	18.31	1.73	711 l/min
520	18.32	1.74	710 l/min

PROJECT: SAPISTON

BOREHOLE: HEATH ROAD (RECOVERY)

TIME (mins)	DIP (m)	DRAWDOWN (m)	REMARKS
0	18.32	1.74	
0.25	17.20	0.62	
0.5	17.08	0.50	
0.75	17.01	0.43	
1	16.97	0.39	
1.5	16.91	0.33	
2	16.87	0.29	
3	16.84	0.26	
4	16.80	0.22	
6	16.78	0.20	
8	16.75	0.17	
11	16.72	0.14	
15	16.70	0.12	
21	16.69	0.11	

Analysis Certificate

SAMPLE REF. NO. E 7526

SAMPLING POINT Consultancy Job No 66006

DATE & TIME SAMPLED 01/07/92 18:00:00 DATE OF CONFIRMATION 03/07/92

ANALYSIS REQUIREMENT GROUPS

PURPOSE Consultancy.
MATERIAL Consultancy Samples

CLIENT ADDRESS
Premium House

SAMPLE ADDRESS
Heath Road
Sapiston

SAMPLERS COMMENTS
A Ball

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FAIL
102 pH		7.6	pH units	
303 NITROGEN AMMONIACAL AS N mg/l	<	.03	mg/l	
303 NITROGEN NITRITE AS N mg/l	<	.003	mg/l	
303 NITROGEN NITRATE AS N mg/l		4.7	mg/l	
303 NITROGEN TOTAL OXIDISED AS N mg/l		4.7	mg/l	
303 ORTHOPHOSPHATE AS P mg/l		.05	mg/l	
303 CHLORIDE mg/l		42	mg/l	
303 ALKALINITY AS CaCO3 mg/l		270	mg/l	
303 HARDNESS TOTAL AS CaCO3 mg/l		400	mg/l	
303 SULPHATE AS SO4 mg/l		70	mg/l	
402 SODIUM mg/l		17.9	mg/l	
402 POTASSIUM mg/l		3.4	mg/l	
402 CALCIUM as Ca mg/l		143	mg/l	
402 MAGNESIUM as Mg mg/l		6.48	mg/l	
402 IRON TOTAL mg/l		.05	mg/l	
402 MANGANESE TOTAL mg/l	<	.005	mg/l	
112 CARBON TOTAL ORGANIC (TOC) AS C mg/l		1.2	mg/l	
102 FLUORIDE AS F mg/l		.4	mg/l	
102 CONDUCTIVITY AT 20 DEGREES C usie/cm		740	usie/cm	

AREA LABORATORY MANAGER J. Spence

DATE COMPLETED 20/07/92 21:00:16

PAGE 1 OF 1



A NAMAS
TESTING
LABORATORY

- 1) XXXX indicates no time of sampling provided.
- 2) Further information on methods of analysis may be obtained from the above address.
- 3) * indicates determined not included in NAMAS accreditation.
- 4) Opinions and interpretations expressed herein are outside the scope of NAMAS accreditation.

TESTING
No. 1113

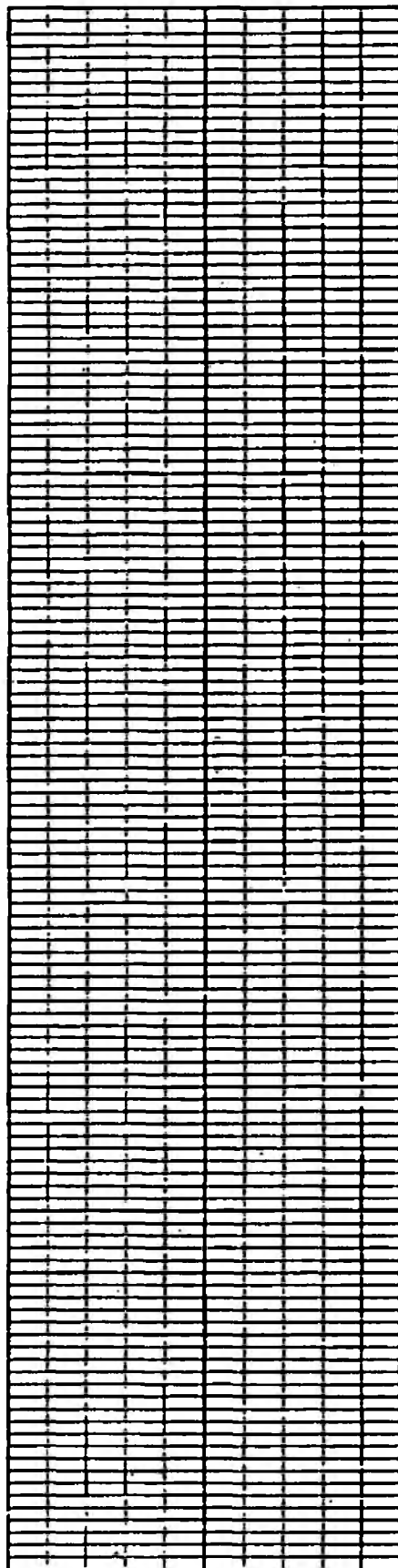
SOUTHERN SCIENCE LTD, INCORPORATED IN ENGLAND NO. 2315401, REG. OFFICE: SOUTHERN HOUSE, YEOMAN ROAD, WORTHING BN1 3NX.
SOUTHERN SCIENCE PROVIDES LABORATORY, RESOURCES AND ENVIRONMENTAL SERVICES.

2 RESULTS OF TESTING: FIELD LANE

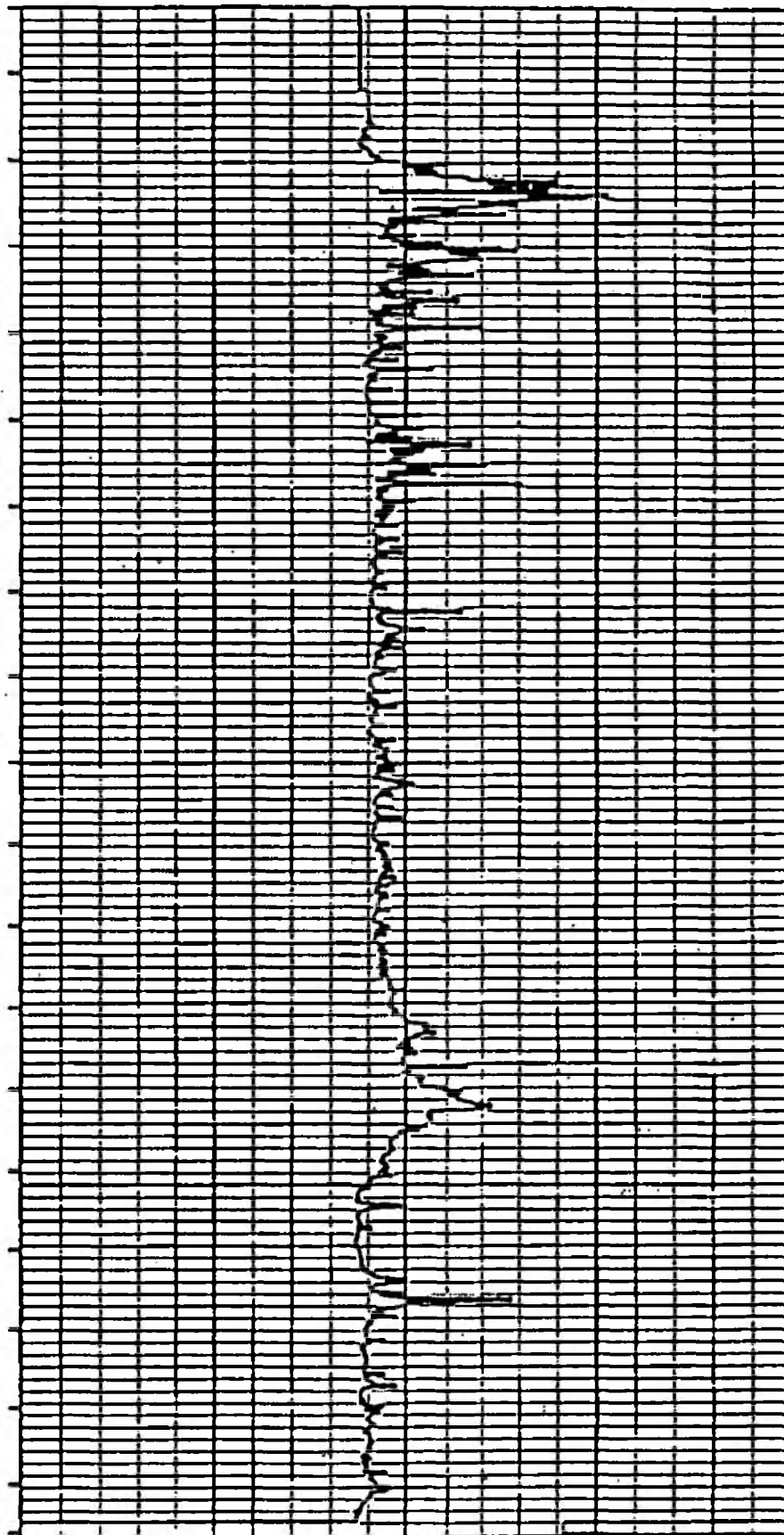
0.0

CALP INCH

20.0



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0025
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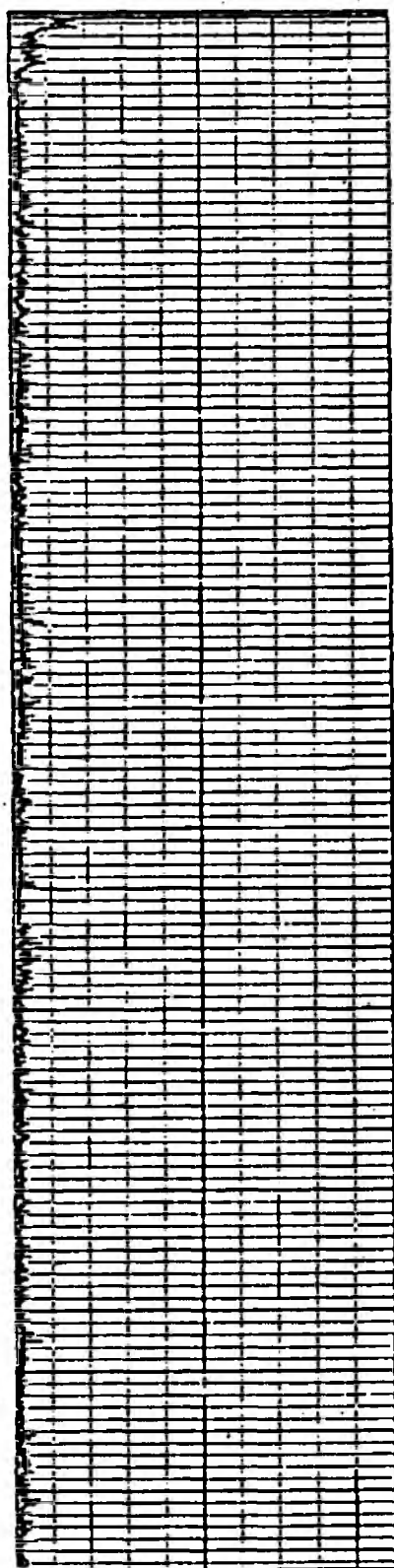


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CALP INCH

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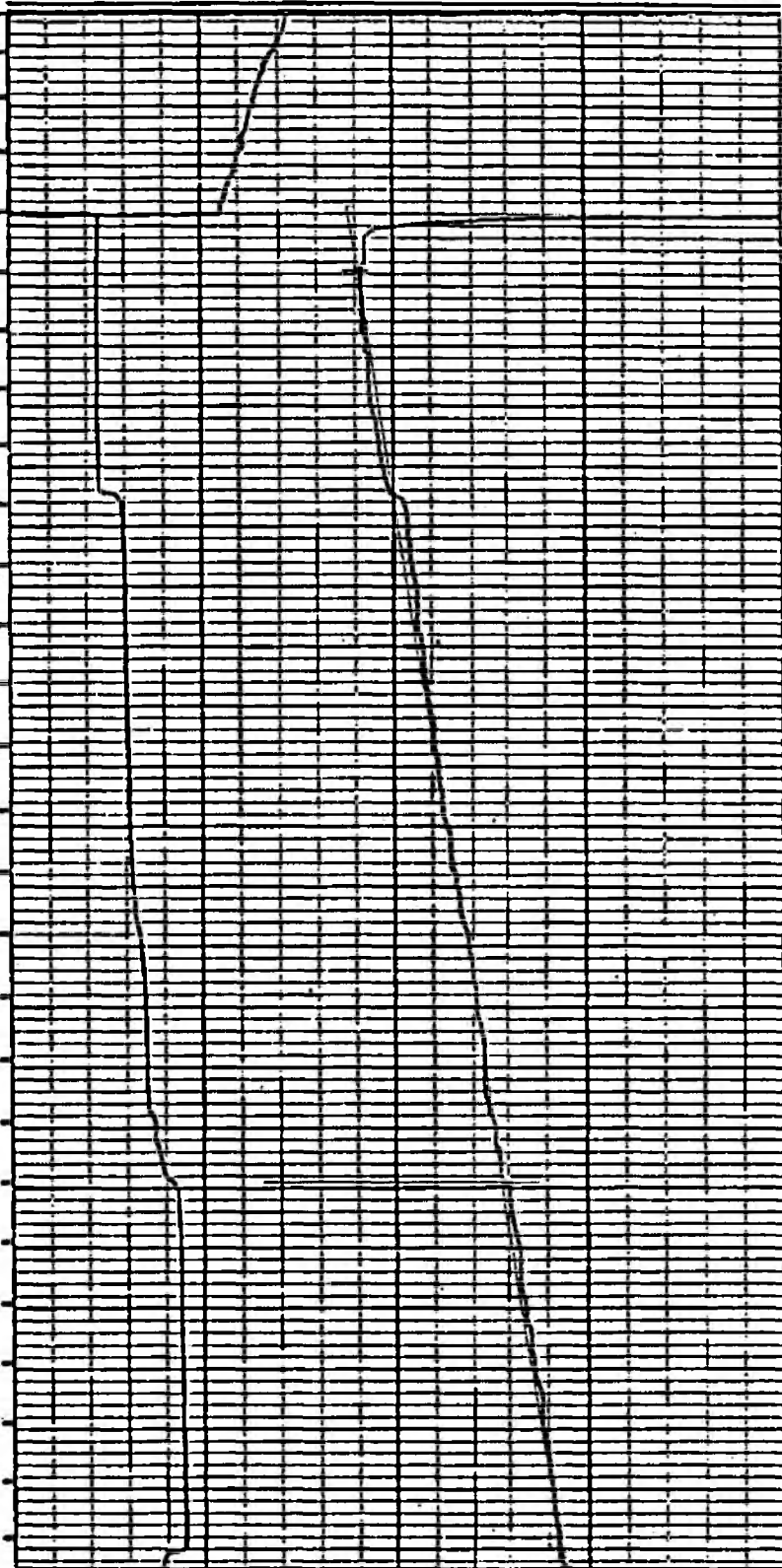
0.0 NGAM CPS 200.0



0.0 NGAM CPS 200.0

0.0 COND MS 5.0
5.0 TEMP DEGC 15.0

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$\Delta T = 1.5^\circ$
 $\Delta d = 75m$
Slope = $2.6^\circ/100m$

0.0 COND MS 5.0
5.0 TEMP DEGC 15.0

PROJECT: SAPISTON

BOREHOLE: FIELD LANE

TIME (mins)	DIP (m)	DRAWDOWN (m)	REMARKS
0	19.32	0.00	
0.25	20.14	0.82	
0.5	20.33	1.01	
0.75	20.44	1.12	
1	20.49	1.17	
1.5	20.57	1.25	
2	20.62	1.30	
3	20.67	1.35	
4	20.74	1.42	
6	20.78	1.46	
8	20.82	1.50	
11	20.85	1.53	
15	20.90	1.58	836 l/min
21	20.90	1.58	837 l/min.
30	20.95	1.63	
42	20.99	1.67	
60	21.04	1.72	
85	21.06	1.74	
120	21.11	1.79	
180	21.16	1.84	836 l/min
260	21.22	1.90	
360	21.27	1.95	

PROJECT: SAPISTON

BOREHOLE: FIELD LANE (RECOVERY)

TIME (mins)	DIP (m)	DRAWDOWN (m)	REMARKS
0	21.27	1.95	
0.25	20.35	1.03	
0.5	20.18	0.86	
0.75	20.11	0.79	
1	20.08	0.76	
1.5	20.01	0.69	
2	19.98	0.66	
3	19.92	0.60	
4	19.89	0.57	
6	19.85	0.53	
8	19.81	0.49	
15	19.73	0.41	
30	19.66	0.34	
120	19.58	0.26	
1365	19.37	0.05	
2545	19.34	0.02	
3960	19.34	0.02	

Analysis Certificate

SAMPLE REF. NO. E 8272

SAMPLING POINT Consultancy Job No 66006

DATE & TIME SAMPLED 08/07/92 15:20:00 DATE OF CONFIRMATION 09/07/92

ANALYSIS REQUIREMENT GROUPS

PURPOSE Consultancy.
MATERIAL Consultancy Samples

CLIENT ADDRESS
Premium House

SAMPLE ADDRESS
Field Carr Lane

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FAIL
102 pH		7.3	pH units	
303 NITROGEN AMMONIACAL AS N mg/l		.06	mg/l	
303 NITROGEN NITRITE AS N mg/l	<	.003	mg/l	
303 NITROGEN NITRATE AS N mg/l		6.6	mg/l	
303 ORTHOPHOSPHATE AS P mg/l	<	.04	mg/l	
303 CHLORIDE mg/l		38	mg/l	
303 ALKALINITY AS CaCO ₃ mg/l		295	mg/l	
303 HARDNESS TOTAL AS CaCO ₃ mg/l		385	mg/l	
303 SULPHATE AS SO ₄ mg/l		92	mg/l	
402 SODIUM mg/l		22	mg/l	
402 POTASSIUM mg/l		3.4	mg/l	
402 CALCIUM as Ca mg/l		157	mg/l	
402 MAGNESIUM as Mg mg/l		8.58	mg/l	
402 IRON TOTAL mg/l		.24	mg/l	
402 MANGANESE TOTAL mg/l		.008	mg/l	
112 CARBON TOTAL ORGANIC (TOC) AS C mg/l		1.4	mg/l	
102 FLUORIDE AS F mg/l		.435	mg/l	
102 CONDUCTIVITY AT 20 DEGREES C usie/cm		920	usie/cm	

AREA LABORATORY MANAGER

J. Spence

DATE COMPLETED 28/07/92 21:00:16

PAGE 1 OF 1



A NAMAS
TESTING
LABORATORY

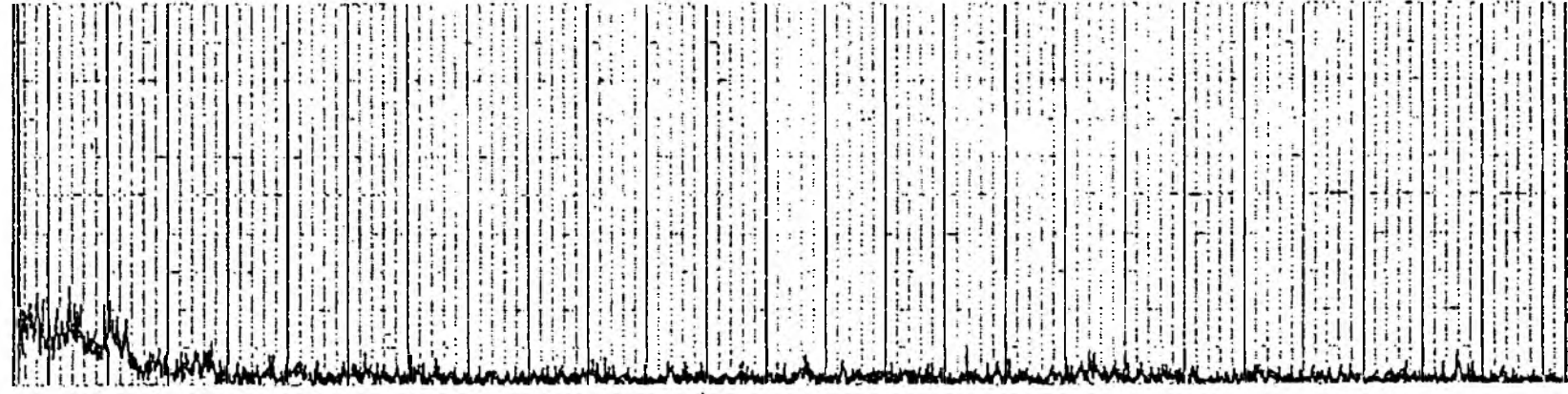
- 1) 0001 indicates no time of sampling provided.
- 2) Further information on methods of analysis may be obtained from the above address.
- 3) * Indicates determinand not included in NAMAS accreditation.
- 4) Opinions and interpretations expressed herein are outside the scope of NAMAS accreditation.

TESTING
No. 1113

SOUTHERN SCIENCE LTD, INCORPORATED IN ENGLAND NO. 2315011. REG. OFFICE: SOUTHERN HOUSE, YLOMAN ROAD, WORTHING BN1 3NX.
SOUTHERN SCIENCE PROVIDES LABORATORY, RESOURCES AND ENVIRONMENTAL SERVICES.

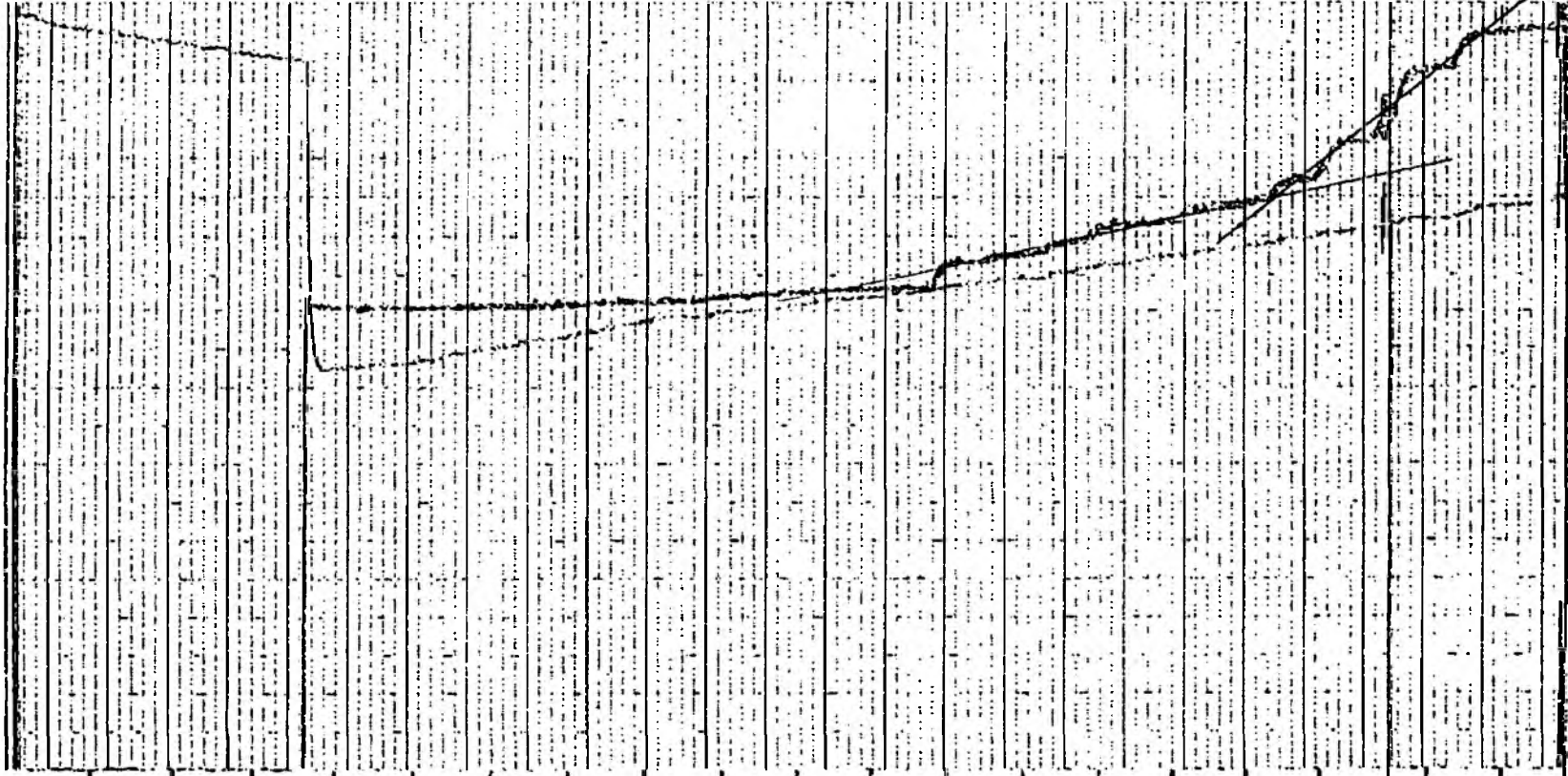
3 RESULTS OF TESTING: WASH LANE

NGM CPS 200.0



NGM CPS 200.0

CONC MS
TEMP DEG



CONC MS

TEMP DEG

100
ΔT = 20 → 12.7/100

105 → 0.7/100
80 → 3.6/100

0.0

CHLP INCH

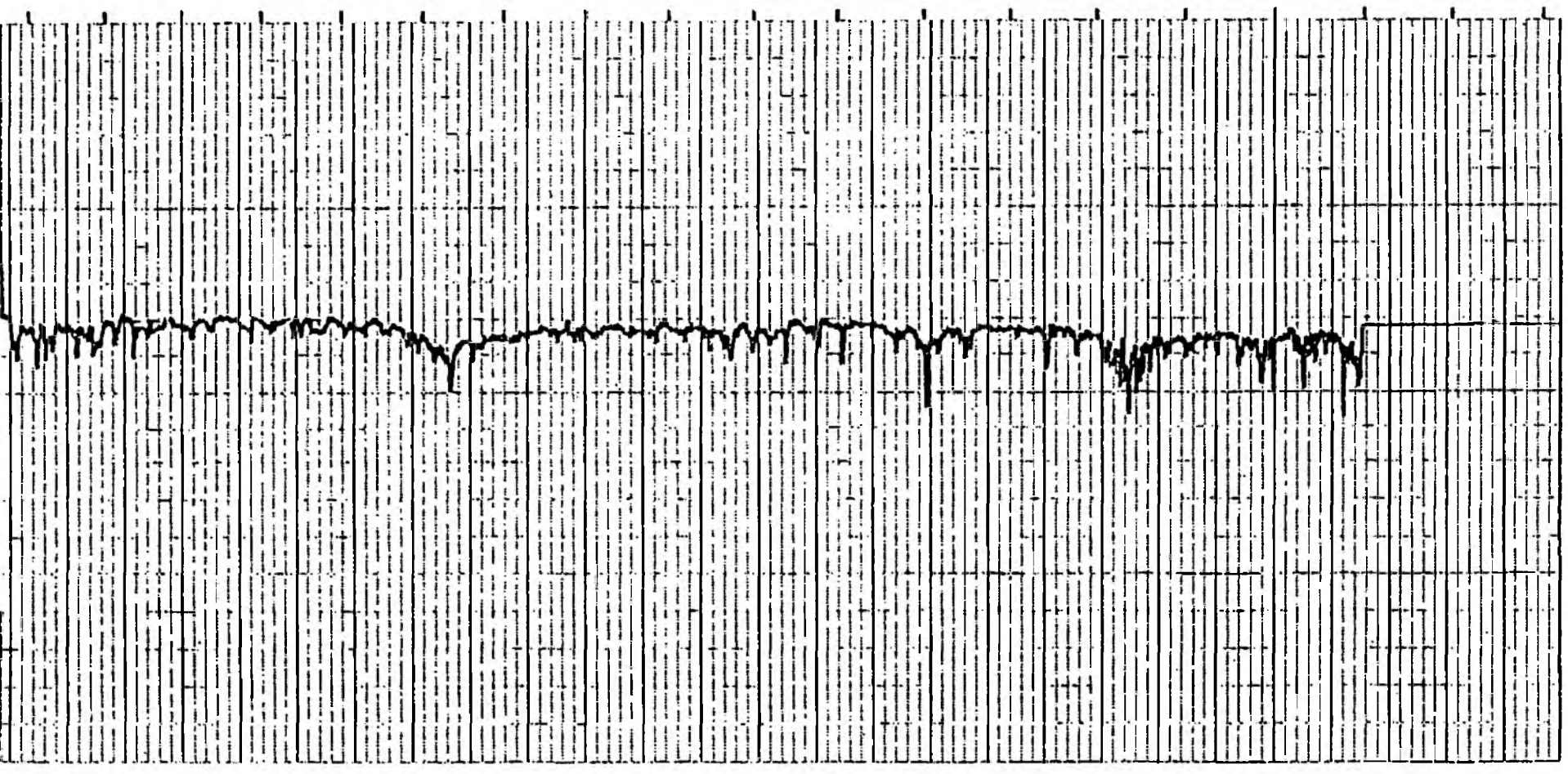
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CHLP INCH

15.0



PROJECT: SAPISTON

BOREHOLE: WASH LANE

TIME (mins)	DIP (m)	DRAWDOWN (m)	REMARKS
0	27.90	0.00	270 l/min well development
0.25	32.70	4.80	
0.5	33.50	5.60	
0.75	34.80	6.90	
1	35.50	7.60	
1.5	35.80	7.90	
2	35.69	7.79	
3	35.39	7.49	
4	35.15	7.25	
5	34.95	7.05	
6	34.72	6.82	180 l/min
8	34.80	6.90	180 l/min
11	34.92	7.02	
15	34.87	6.97	
18	34.77	6.87	240 l/min
21	33.94	6.04	
30	38.46	10.56	
42	38.75	10.85	228 l/min
60	38.49	10.59	
85	38.05	10.15	228 l/min
120	38.95	11.05	
180	38.45	10.55	216 l/min
260	40.10	12.20	216 l/min
300	38.71	10.81	
420	39.20	11.30	222 l/min
480	39.22	11.32	222 l/min
540	39.17	11.27	222 l/min

PROJECT: SAPISTON

BOREHOLE: WASH LANE (RECOVERY)

TIME (mins)	DIP (m)	DRAWDOWN (m)	REMARKS
0	39.17	11.27	
0.25	35.70	7.80	
0.5	33.00	5.10	
0.75	31.61	3.71	
1	30.69	2.79	
1.5	29.89	1.99	
2	29.58	1.68	
3	29.35	1.45	
4	29.27	1.37	
7	29.05	1.15	
8	29.00	1.10	
11	28.90	1.00	
15	28.77	0.87	
21	28.70	0.80	
25	28.60	0.70	
900	27.65	-0.25	
2924	27.55	-0.35	

Analysis Certificate

SAMPLE REF. NO. E 8275

SAMPLING POINT Consultancy Job No 66006

DATE & TIME SAMPLED 08/07/92 14:20:00 DATE OF CONFIRMATION 09/07/92

ANALYSIS REQUIREMENT GROUPS

PURPOSE Consultancy.
MATERIAL Consultancy Samples

CLIENT ADDRESS
Premium House

SAMPLE ADDRESS
Wash Lane

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FAIL
102 pH		7.5	pH units	
303 NITROGEN AMMONIACAL AS N mg/l		.79	mg/l	
303 NITROGEN NITRITE AS N mg/l	<	.003	mg/l	
303 NITROGEN NITRATE AS N mg/l		.2	mg/l	
303 ORTHOPHOSPHATE AS P mg/l	<	.04	mg/l	
303 CHLORIDE mg/l		33	mg/l	
303 ALKALINITY AS CaCO ₃ mg/l		320	mg/l	
303 HARDNESS TOTAL AS CaCO ₃ mg/l		355	mg/l	
303 SULPHATE AS SO ₄ mg/l		75	mg/l	
402 SODIUM mg/l		24.2	mg/l	
402 POTASSIUM mg/l		6.78	mg/l	
402 CALCIUM as Ca mg/l		125	mg/l	
402 MAGNESIUM as Mg mg/l		15.2	mg/l	
402 IRON TOTAL mg/l		.21	mg/l	
402 MANGANESE TOTAL mg/l		.01	mg/l	
112 CARBON TOTAL ORGANIC (TOC) AS C mg/l		3.7	mg/l	
102 FLUORIDE AS F mg/l		1.35	mg/l	
102 CONDUCTIVITY AT 20 DEGREES C usie/cm		840	usie/cm	

AREA LABORATORY MANAGER

J. SPENCER

DATE COMPLETED 28/07/92 21:00:16

PAGE 1 OF 1



A NAMAS
TESTING
LABORATORY

- 1) (000) indicates no time of sampling provided.
- 2) Further information on methods of analysis may be obtained from the above address.
- 3) * Indicates determined not included in NAMAS accreditation.
- 4) Opinions and interpretations expressed herein are outside the scope of NAMAS accreditation.

Analysis Certificate

SAMPLE REF. NO. E 8276

SAMPLING POINT Consultancy Job No 66006

DATE & TIME SAMPLED 08/07/92 17:45:00 DATE OF CONFIRMATION 09/07/92

ANALYSIS REQUIREMENT GROUPS

PURPOSE Consultancy.
MATERIAL Consultancy Samples

CLIENT ADDRESS
Premium House

SAMPLE ADDRESS
Wash Lane

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FAIL
102 pH		7.6	pH units	
303 NITROGEN AMMONIACAL AS N mg/l		.81	mg/l	
303 NITROGEN NITRITE AS N mg/l	<	.003	mg/l	
303 NITROGEN NITRATE AS N mg/l	<	.1	mg/l	
303 ORTHOPHOSPHATE AS P mg/l	<	.04	mg/l	
303 CHLORIDE mg/l		33	mg/l	
303 ALKALINITY AS CaCO ₃ mg/l		325	mg/l	
303 HARDNESS TOTAL AS CaCO ₃ mg/l		365	mg/l	
303 SULPHATE AS SO ₄ mg/l		75	mg/l	
402 SODIUM mg/l		24.2	mg/l	
402 POTASSIUM mg/l		6.82	mg/l	
402 CALCIUM as Ca mg/l		134.8	mg/l	
402 MAGNESIUM as Mg mg/l		15.29	mg/l	
402 IRON TOTAL mg/l		1.14	mg/l	
402 MANGANESE TOTAL mg/l		.02	mg/l	
112 CARBON TOTAL ORGANIC (TOC) AS C mg/l		3.6	mg/l	
102 FLUORIDE AS F mg/l		1.35	mg/l	
102 CONDUCTIVITY AT 20 DEGREES C usie/cm		840	usie/cm	

AREA LABORATORY MANAGER

J. Spence

DATE COMPLETED 28/07/92 21:00:16

PAGE 1 OF 1



A NAMAS
TESTING
LABORATORY

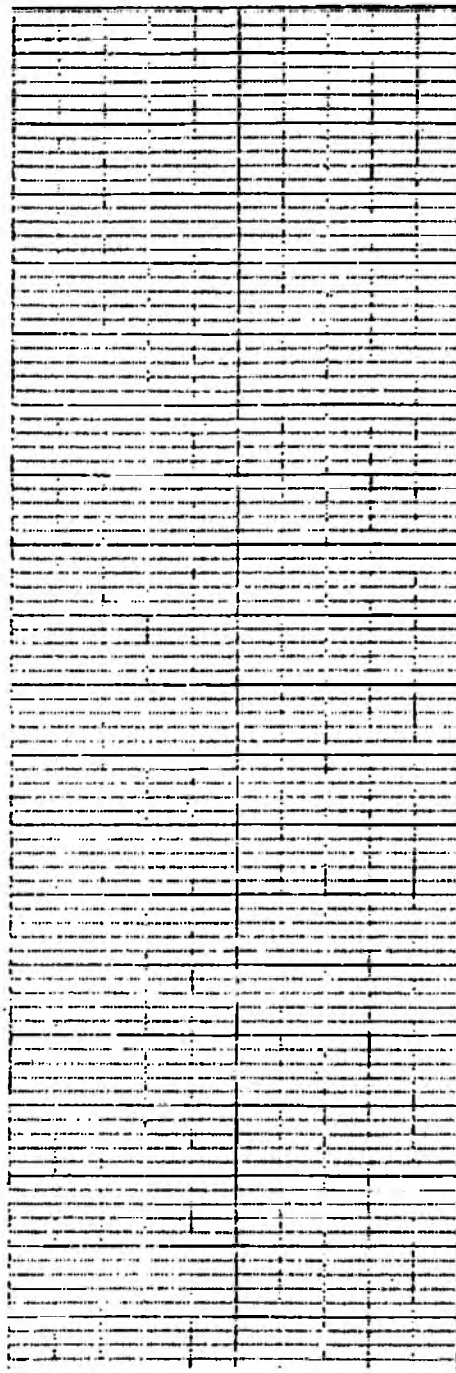
- 1) (XX) indicates no time of sampling provided.
- 2) Further information on methods of analysis may be obtained from the above address.
- 3) * Indicates determinand not included in NAMAS accreditation.
- 4) Opinions and interpretations expressed herein are outside the scope of NAMAS accreditation.

4 RESULTS OF TESTING: SIX BELLS

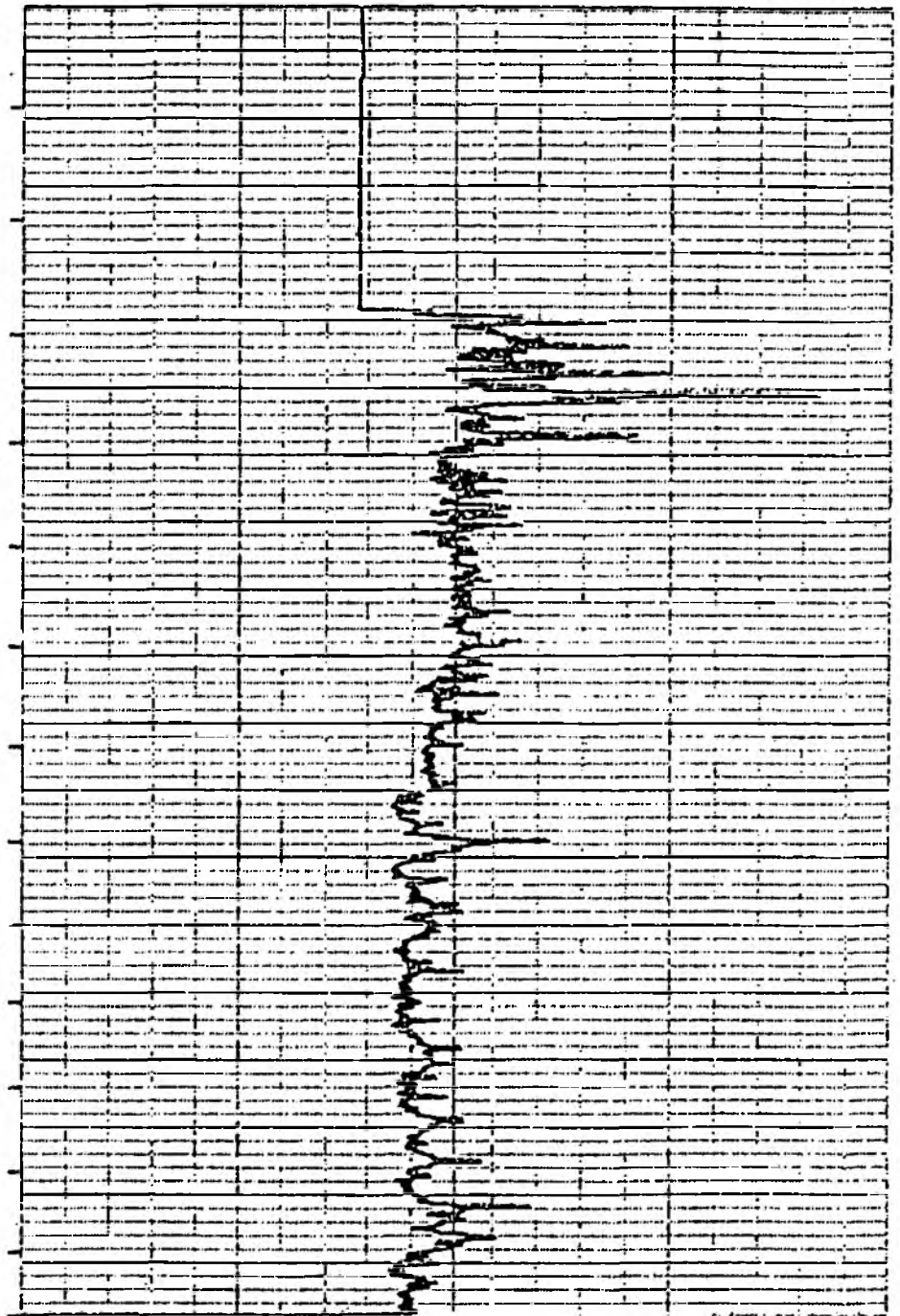
CALP INCH

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15.0



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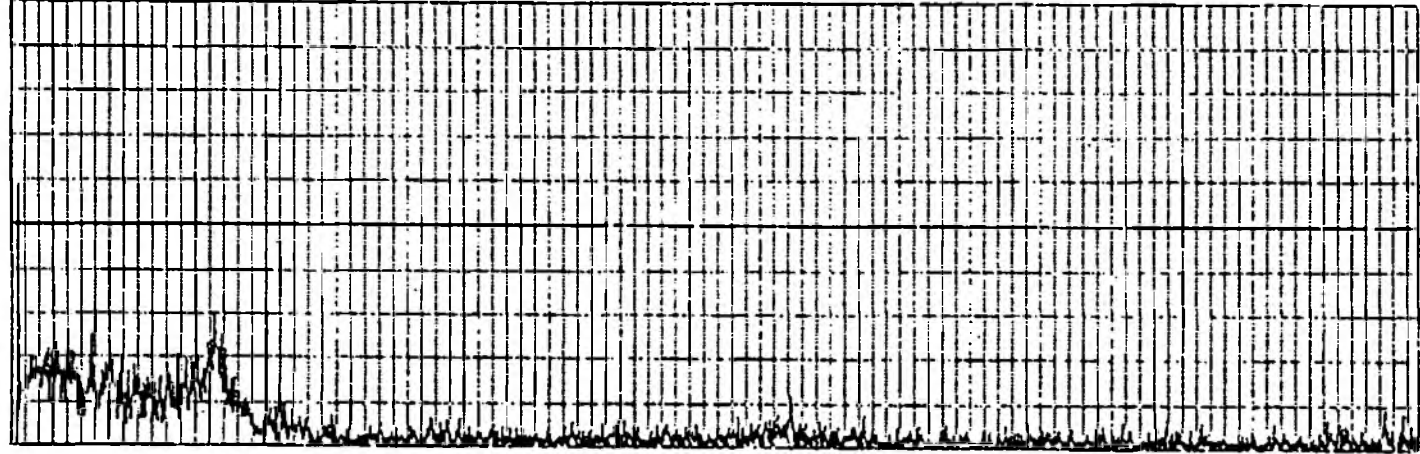


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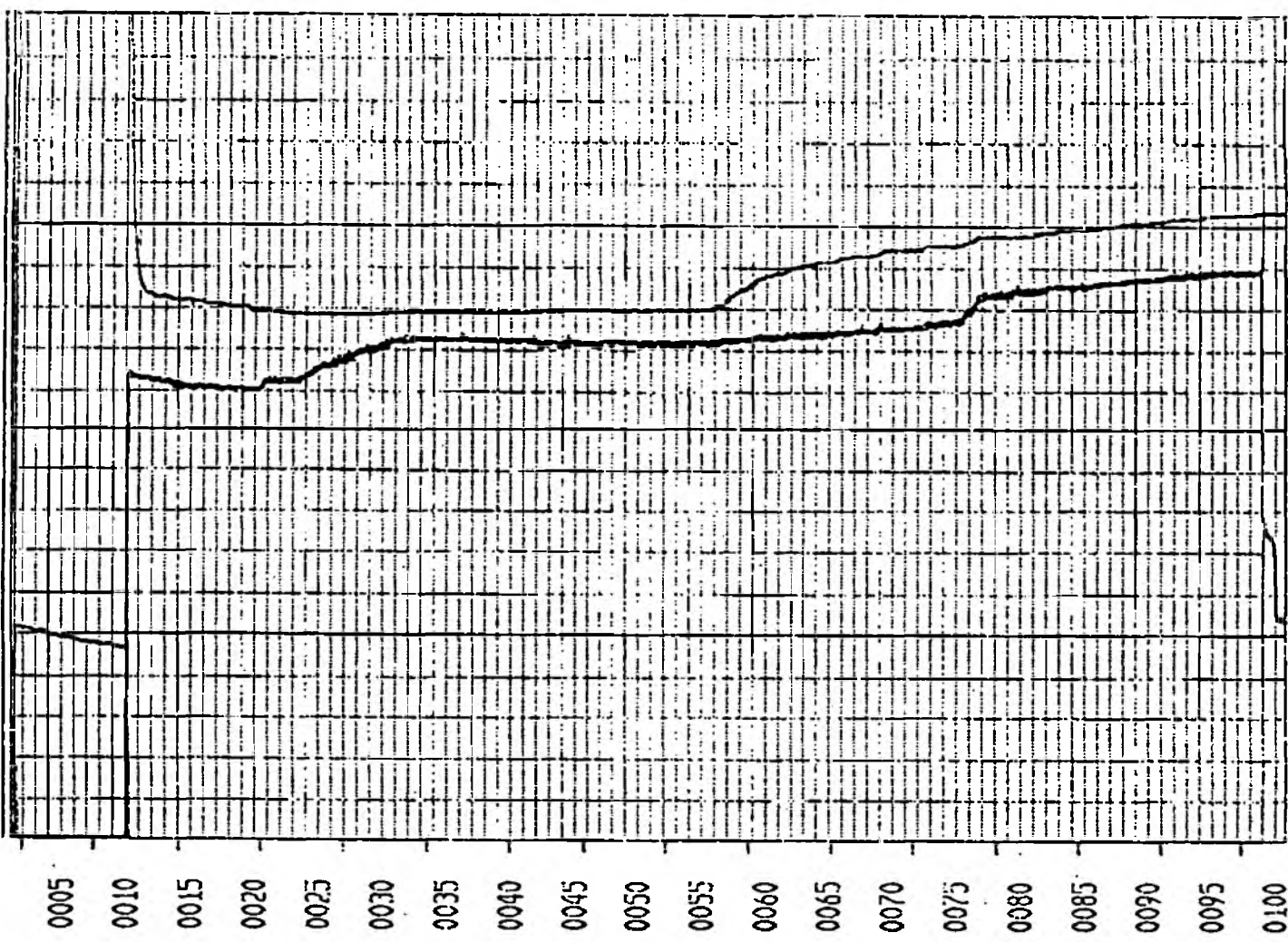
15.0

NGAM CPS
0.0 200.0



COND MS
0.0 1.0

TEMP DEGC
0.0 15.0



NGAM CPS
0.0 200.0

COND MS
0.0 1.0

TEMP DEGC
0.0 15.0

PROJECT: SAPISTON

BOREHOLE: SIX BELLS

TIME (mins)	DIP (m)	DRAWDOWN (m)	REMARKS
0	11.75	0.00	
0.25	11.84	0.09	
0.5	11.85	0.10	200 l/min
0.75	11.84	0.09	
1	11.84	0.09	200 l/min
1.5	11.84	0.09	
2	11.84	0.09	
3	11.84	0.09	
4	11.84	0.09	200 l/min
6	11.84	0.09	
8	11.84	0.09	200 l/min
11	11.84	0.09	
15	11.84	0.09	
21	11.84	0.09	200 l/min
30	11.85	0.10	
42	11.85	0.10	200 l/min
60	11.85	0.10	
85	11.85	0.10	
120	11.85	0.10	200 l/min
180	11.86	0.11	
215	11.86	0.11	200 l/min

PROJECT: SAPISTON

BOREHOLE: SIX BELLS (RECOVERY)

TIME (mins)	DIP (m)	DRAWDOWN (m)	REMARKS
0	11.86	0.11	
0.25	11.78	0.03	
0.5	11.78	0.03	
0.75	11.78	0.03	
1	11.78	0.03	
1.5	11.78	0.03	
2	11.78	0.03	
3	11.78	0.03	
4	11.78	0.03	
6	11.78	0.03	
8	11.78	0.03	
11	11.77	0.02	
15	11.77	0.02	
21	11.77	0.02	
30	11.77	0.02	
42	11.77	0.02	
1063	11.78	0.03	

Analysis Certificate

SAMPLE REF. NO. E 8273

SAMPLING POINT Consultancy Job No 66006

DATE & TIME SAMPLED 08/07/92 15:00:00 DATE OF CONFIRMATION 09/07/92

ANALYSIS REQUIREMENT GROUPS

PURPOSE Consultancy.
MATERIAL Consultancy Samples

CLIENT ADDRESS
Premium House

SAMPLE ADDRESS
6 Bello Inn

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FAIL
102 pH		7.3	pH units	
303 NITROGEN AMMONIACAL AS N mg/l	<	.03	mg/l	
303 NITROGEN NITRITE AS N mg/l	<	.003	mg/l	
303 NITROGEN NITRATE AS N mg/l		13	mg/l	
303 ORTHOPHOSPHATE AS P mg/l	<	.04	mg/l	
303 CHLORIDE mg/l		37	mg/l	
303 ALKALINITY AS CaCO ₃ mg/l		285	mg/l	
303 HARDNESS TOTAL AS CaCO ₃ mg/l		375	mg/l	
303 SULPHATE AS SO ₄ mg/l		54	mg/l	
402 SODIUM mg/l		20.9	mg/l	
402 POTASSIUM mg/l		11.2	mg/l	
402 CALCIUM as Ca mg/l		152.5	mg/l	
402 MAGNESIUM as Mg mg/l		6.02	mg/l	
402 IRON TOTAL mg/l		.04	mg/l	
402 MANGANESE TOTAL mg/l		.005	mg/l	
112 CARBON TOTAL ORGANIC (TOC) AS C mg/l		2.3	mg/l	
102 FLUORIDE AS F mg/l		.22	mg/l	
102 CONDUCTIVITY AT 20 DEGREES C usie/cm		890	usie/cm	

AREA LABORATORY MANAGER J. Spence

DATE COMPLETED 28/07/92 21:00:16

PAGE 1 OF 1



A NAMAS
TESTING
LABORATORY

- 1) 0001 indicates no time of sampling provided.
- 2) Further information on methods of analysis may be obtained from the above address.
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Analysis Certificate

SAMPLE REF. NO. E 8274

SAMPLING POINT Consultancy Job No 66006

DATE & TIME SAMPLED 08/07/92 16:30:00 DATE OF CONFIRMATION 09/07/92

ANALYSIS REQUIREMENT GROUPS

PURPOSE Consultancy.
MATERIAL Consultancy Samples

CLIENT ADDRESS
Premium House

SAMPLE ADDRESS
6 Bells Inn

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FAIL
102 pH		7.3	pH units	
303 NITROGEN AMMONIACAL AS N mg/l	<	.03	mg/l	
303 NITROGEN NITRITE AS N mg/l	<	.003	mg/l	
303 NITROGEN NITRATE AS N mg/l		13	mg/l	
303 ORTHOPHOSPHATE AS P mg/l	<	.04	mg/l	
303 CHLORIDE mg/l		37	mg/l	
303 ALKALINITY AS CaCO ₃ mg/l		290	mg/l	
303 HARDNESS TOTAL AS CaCO ₃ mg/l		375	mg/l	
303 SULPHATE AS SO ₄ mg/l		54	mg/l	
402 SODIUM mg/l		20.6	mg/l	
402 POTASSIUM mg/l		10.8	mg/l	
402 CALCIUM as Ca mg/l		147.9	mg/l	
402 MAGNESIUM as Mg mg/l		5.89	mg/l	
402 IRON TOTAL mg/l		.04	mg/l	
402 MANGANESE TOTAL mg/l	<	.005	mg/l	
112 CARBON TOTAL ORGANIC (TOC) AS C mg/l		2.5	mg/l	
102 FLUORIDE AS F mg/l		.228	mg/l	
102 CONDUCTIVITY AT 20 DEGREES C usie/cm		890	usie/cm	

AREA LABORATORY MANAGER

J. Spencer

DATE COMPLETED 28/07/92 21:00:16

PAGE 1 OF 1



A NAMAS
TESTING
LABORATORY

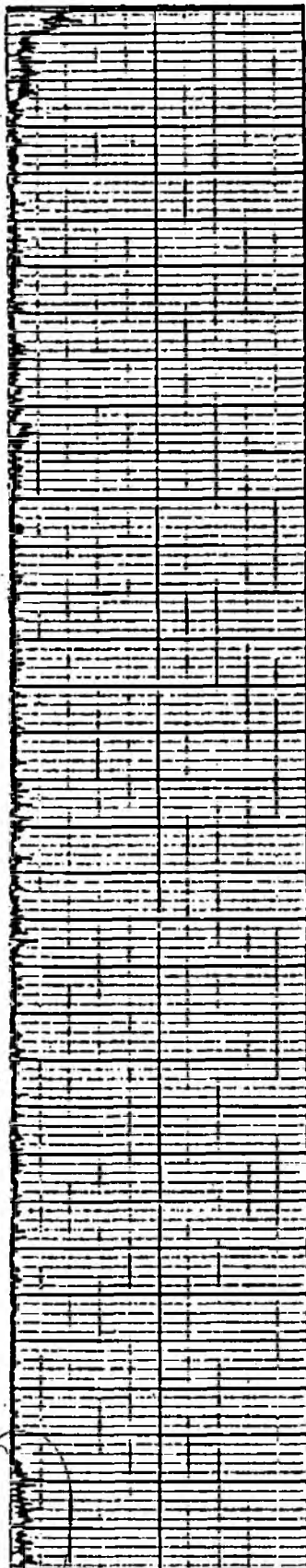
- 1) 0001 indicates no time of sampling provided.
- 2) Further information on methods of analysis may be obtained from the above address.
- 3) * indicates determinand not included in NAMAS accreditation.
- 4) Opinions and interpretations expressed herein are outside the scope of NAMAS accreditation.

5 RESULTS OF TESTING: BARDWELL MANOR

0.0

200.0

over
dip
x



0.0

NGAM CPS

200.0

COND MS

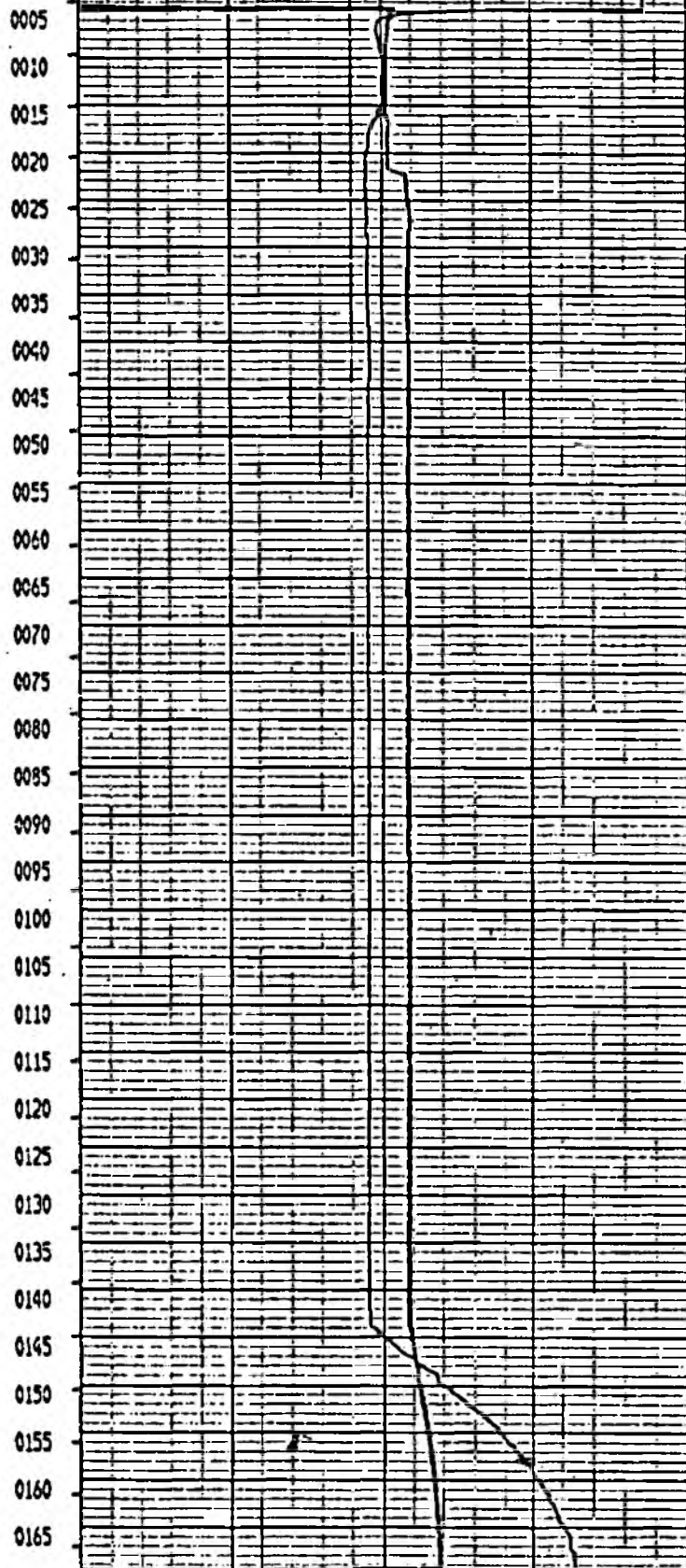
0.0

1.0

TEMP DEGC

5.0

15.0



0.0

COND MS

1.0

TEMP DEGC

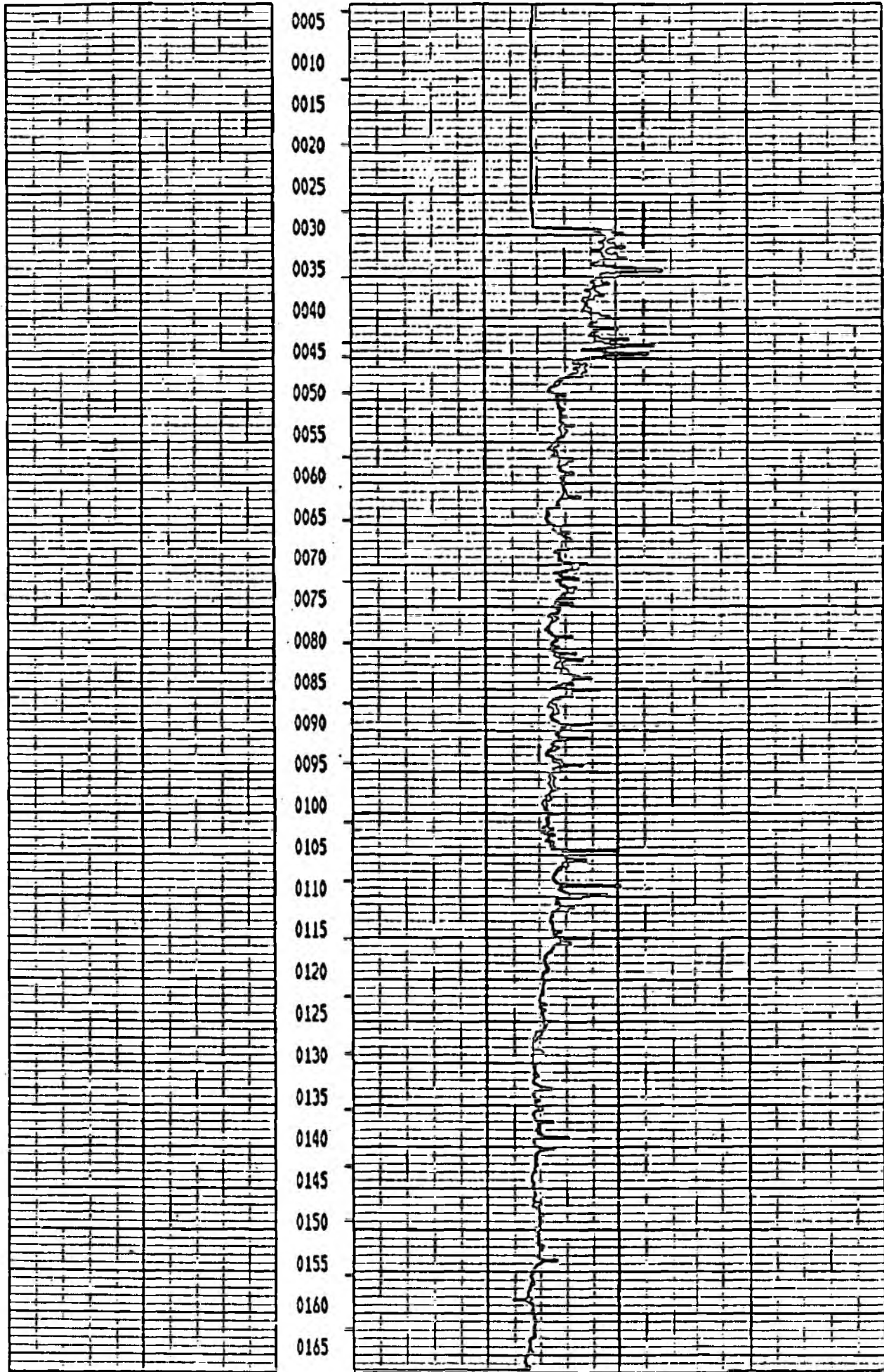
5.0

15.0

CALP INCH

0.0

20.0



CALP INCH

0.0

20.0

PROJECT: SAPISTON

BOREHOLE: BARDWELL MANOR

TIME (mins)	DIP (m)	DRAWDOWN (m)	REMARKS
0	5.21	0.00	206 l/min
0.25	5.46	0.25	
0.5	5.49	0.28	
0.75	5.50	0.29	
1	5.50	0.29	
1.5	5.50	0.29	206 l/min
2	5.51	0.30	
3	5.51	0.30	
4	5.52	0.31	
6	5.53	0.32	
8	5.53	0.32	206 l/min
11	5.53	0.32	
15	5.54	0.33	
21	5.54	0.33	
30	5.54	0.33	
42	5.55	0.34	
60	5.55	0.34	
85	5.56	0.35	
120	5.56	0.35	
180	5.56	0.35	
260	5.57	0.36	

PROJECT: SAPISTON

BOREHOLE: BARDWELL MANOR (RECOVERY)

TIME (mins)	DIP (m)	DRAWDOWN (m)	REMARKS
0	5.57	0.36	
0.25	5.28	0.07	
0.5	5.26	0.05	
0.75	5.26	0.05	
1	5.26	0.05	
1.5	5.26	0.05	
2	5.25	0.04	
3	5.25	0.04	
4	5.24	0.03	
6	5.24	0.03	
8	5.24	0.03	
11	5.24	0.03	
15	5.24	0.03	
21	5.23	0.02	
30	5.23	0.02	
42	5.22	0.01	
60	5.22	0.01	
85	5.22	0.01	

Analysis Certificate

SAMPLE REF. NO. E 8271

SAMPLING POINT Consultancy Job No 66006

DATE & TIME SAMPLED 08/07/92 12:45:00 DATE OF CONFIRMATION 09/07/92

ANALYSIS REQUIREMENT GROUPS

PURPOSE Consultancy.
MATERIAL Consultancy Samples

CLIENT ADDRESS
Premium House

SAMPLE ADDRESS
Bardwell Manor

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FAIL
102 pH		7.4	pH units	
303 NITROGEN AMMONIACAL AS N mg/l	<	.03	mg/l	
303 NITROGEN NITRITE AS N mg/l	<	.003	mg/l	
303 NITROGEN NITRATE AS N mg/l		11	mg/l	
303 ORTHOPHOSPHATE AS P mg/l	<	.04	mg/l	
303 CHLORIDE mg/l		34	mg/l	
303 ALKALINITY AS CaCO ₃ mg/l		245	mg/l	
303 HARDNESS TOTAL AS CaCO ₃ mg/l		340	mg/l	
303 SULPHATE AS SO ₄ mg/l		62	mg/l	
402 SODIUM mg/l		15.1	mg/l	
402 POTASSIUM mg/l		3.4	mg/l	
402 CALCIUM as Ca mg/l		145.1	mg/l	
402 MAGNESIUM as Mg mg/l		4.86	mg/l	
402 IRON TOTAL mg/l		.02	mg/l	
402 MANGANESE TOTAL mg/l	<	.005	mg/l	
112 CARBON TOTAL ORGANIC (TOC) AS C mg/l		1.5	mg/l	
102 FLUORIDE AS F mg/l		.195	mg/l	
102 CONDUCTIVITY AT 20 DEGREES C usie/cm		795	usie/cm	

AREA LABORATORY MANAGER J. Spence

DATE COMPLETED 28/07/92 21:00:16

PAGE 1 OF 1



A NAMAS
TESTING
LABORATORY

- 1) 0001 indicates no time of sampling provided.
- 2) Further information on methods of analysis may be obtained from the above address.
- 3) * Indicates determinand not included in NAMAS accreditation.
- 4) Opinions and interpretations expressed herein are outside the scope of NAMAS accreditation.

Analysis Certificate

SAMPLE REF. NO. E 8270

SAMPLING POINT Consultancy Job No 66006

DATE & TIME SAMPLED 08/07/92 14:30:00 DATE OF CONFIRMATION 09/07/92

ANALYSIS REQUIREMENT GROUPS

PURPOSE Consultancy.
MATERIAL Consultancy Samples

CLIENT ADDRESS
Premium House

SAMPLE ADDRESS
Bardwell Manor

METHOD CODE / DETERMINAND	QL	VALUE	UNITS	FAIL
102 pH		7.4	pH units	
303 NITROGEN AMMONIACAL AS N mg/l	<	.03	mg/l	
303 NITROGEN NITRITE AS N mg/l	<	.003	mg/l	
303 NITROGEN NITRATE AS N mg/l		11	mg/l	
303 ORTHOPHOSPHATE AS P mg/l	<	.04	mg/l	
303 CHLORIDE mg/l		33	mg/l	
303 ALKALINITY AS CaCO3 mg/l		240	mg/l	
303 HARDNESS TOTAL AS CaCO3 mg/l		365	mg/l	
303 SULPHATE AS SO4 mg/l		62	mg/l	
402 SODIUM mg/l		15	mg/l	
402 POTASSIUM mg/l		3.2	mg/l	
402 CALCIUM as Ca mg/l		146	mg/l	
402 MAGNESIUM as Mg mg/l		4.88	mg/l	
402 IRON TOTAL mg/l		.01	mg/l	
402 MANGANESE TOTAL mg/l	<	.005	mg/l	
112 CARBON TOTAL ORGANIC (TOC) AS C mg/l		2.3	mg/l	
102 FLUORIDE AS F mg/l		.18	mg/l	
102 CONDUCTIVITY AT 20 DEGREES C usie/cm		795	usie/cm	

AREA LABORATORY MANAGER J. Spence

DATE COMPLETED 28/07/92 21:00:16

PAGE 1 OF 1

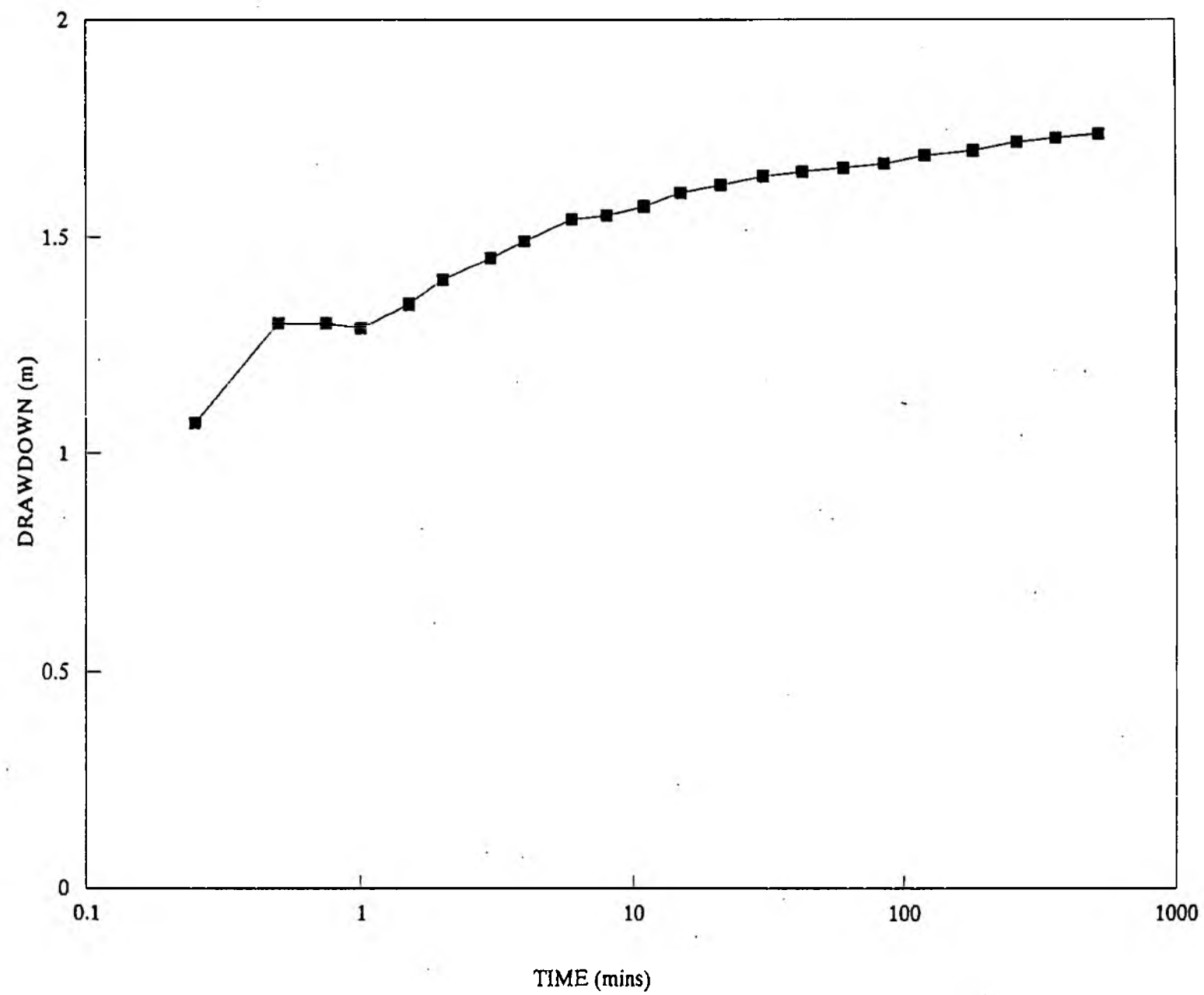


A NAMAS
TESTING
LABORATORY

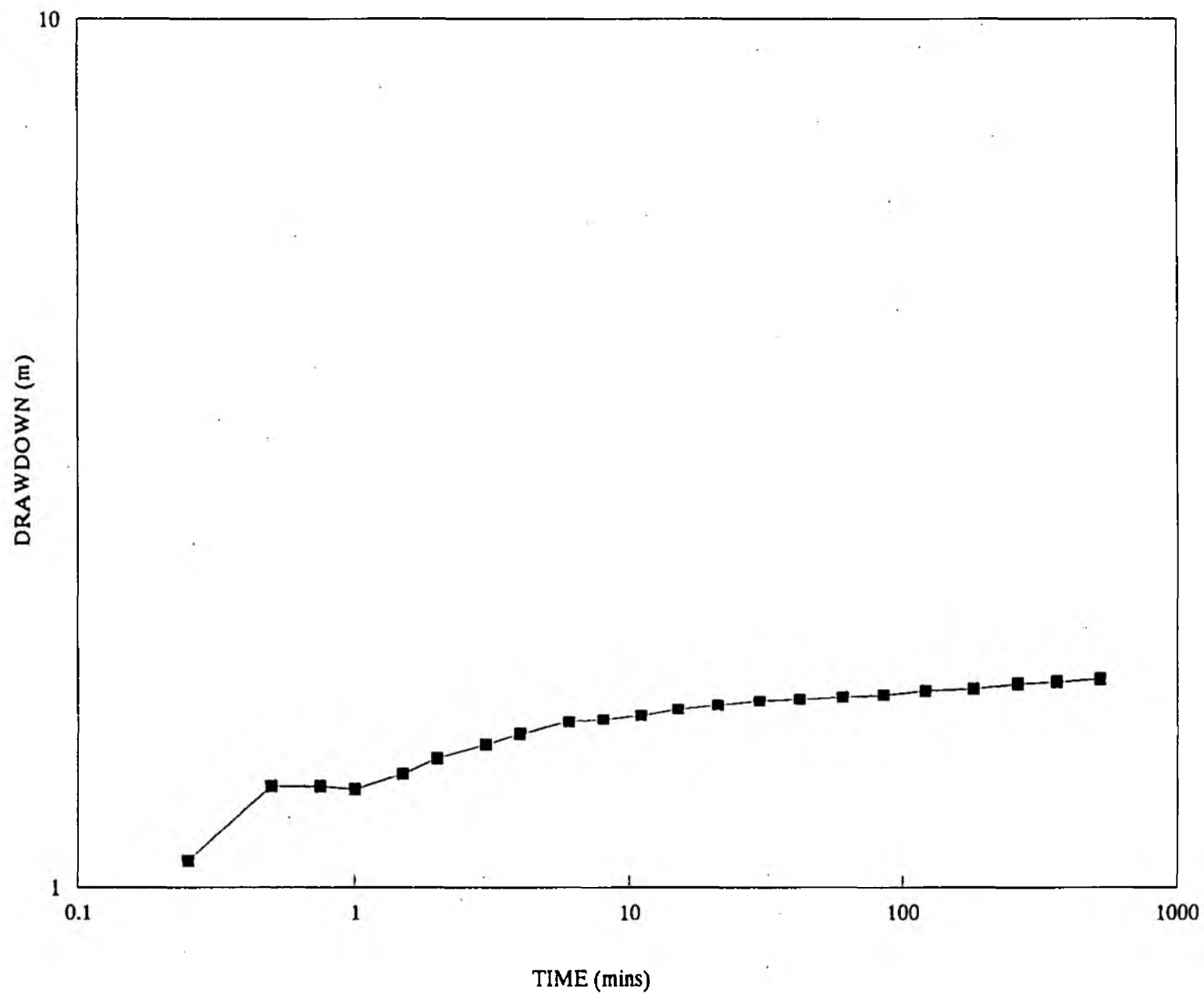
- 1) 0001 indicates no time of sampling provided.
- 2) Further information on methods of analysis may be obtained from the above address.
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- 4) Opinions and interpretations expressed herein are outside the scope of NAMAS accreditation.

6 PLOTS FOR CALCULATION OF AQUIFER PROPERTIES: HEATH ROAD

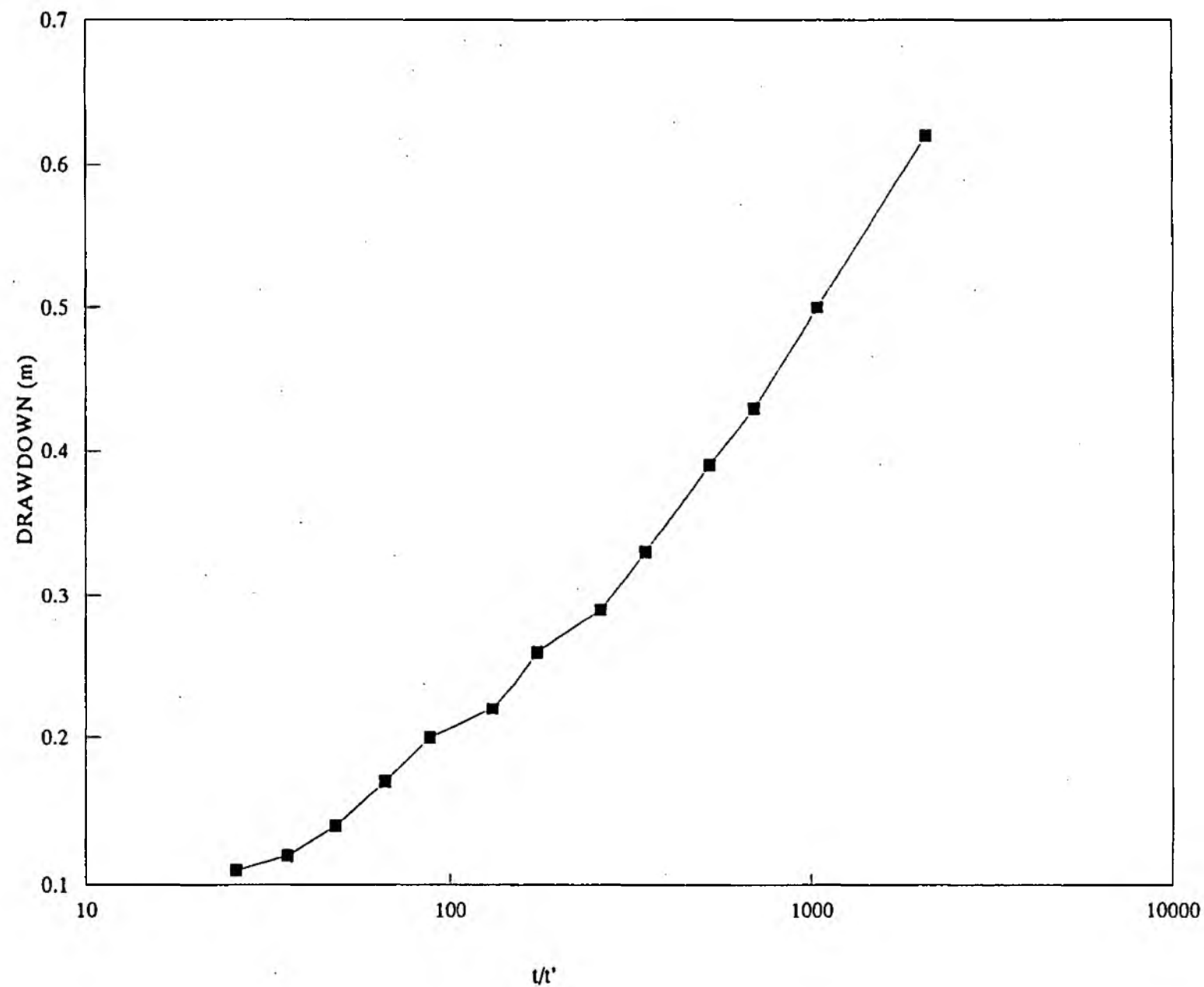
HEATH ROAD



HEATH ROAD

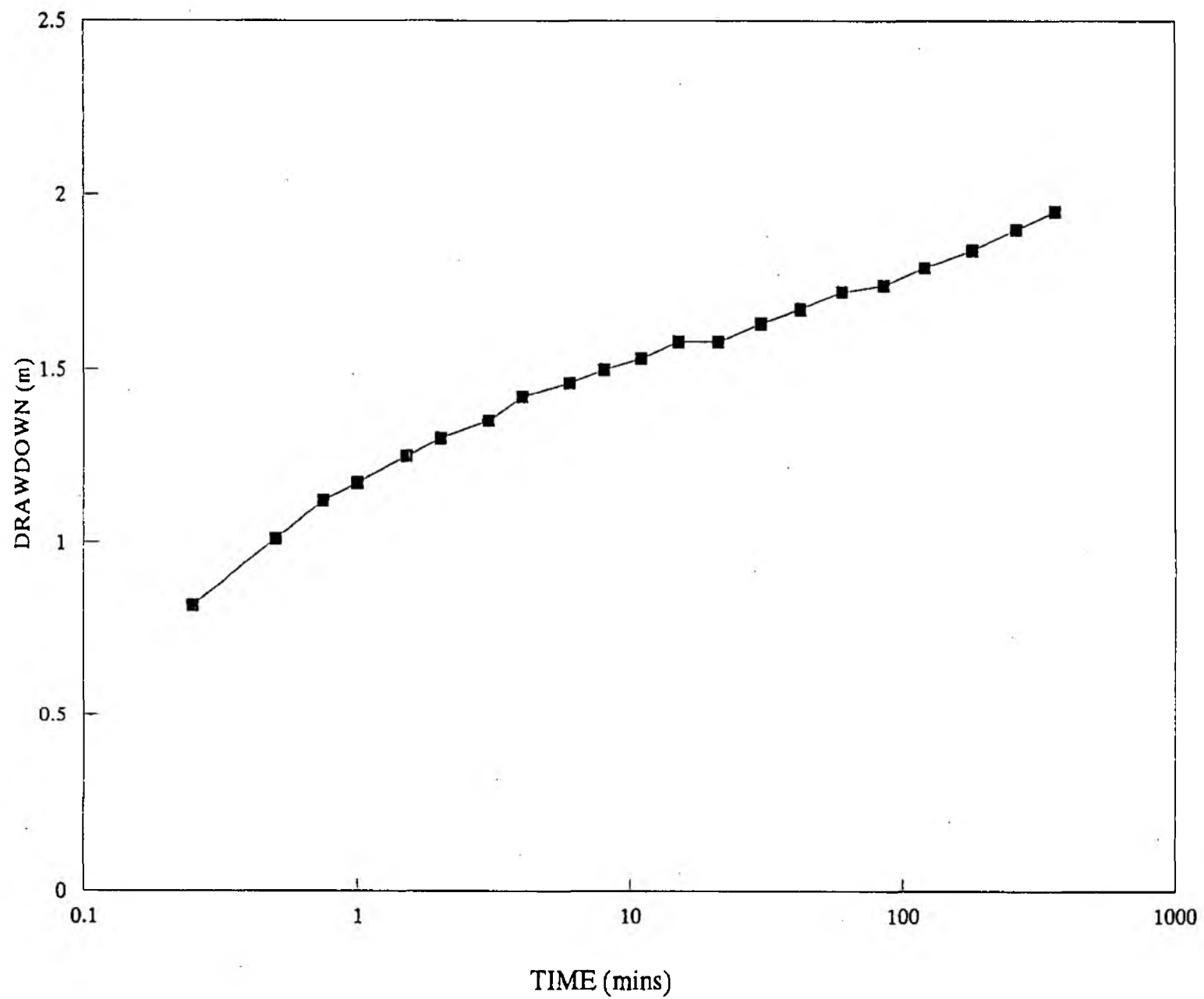


HEATH ROAD (RECOVERY)

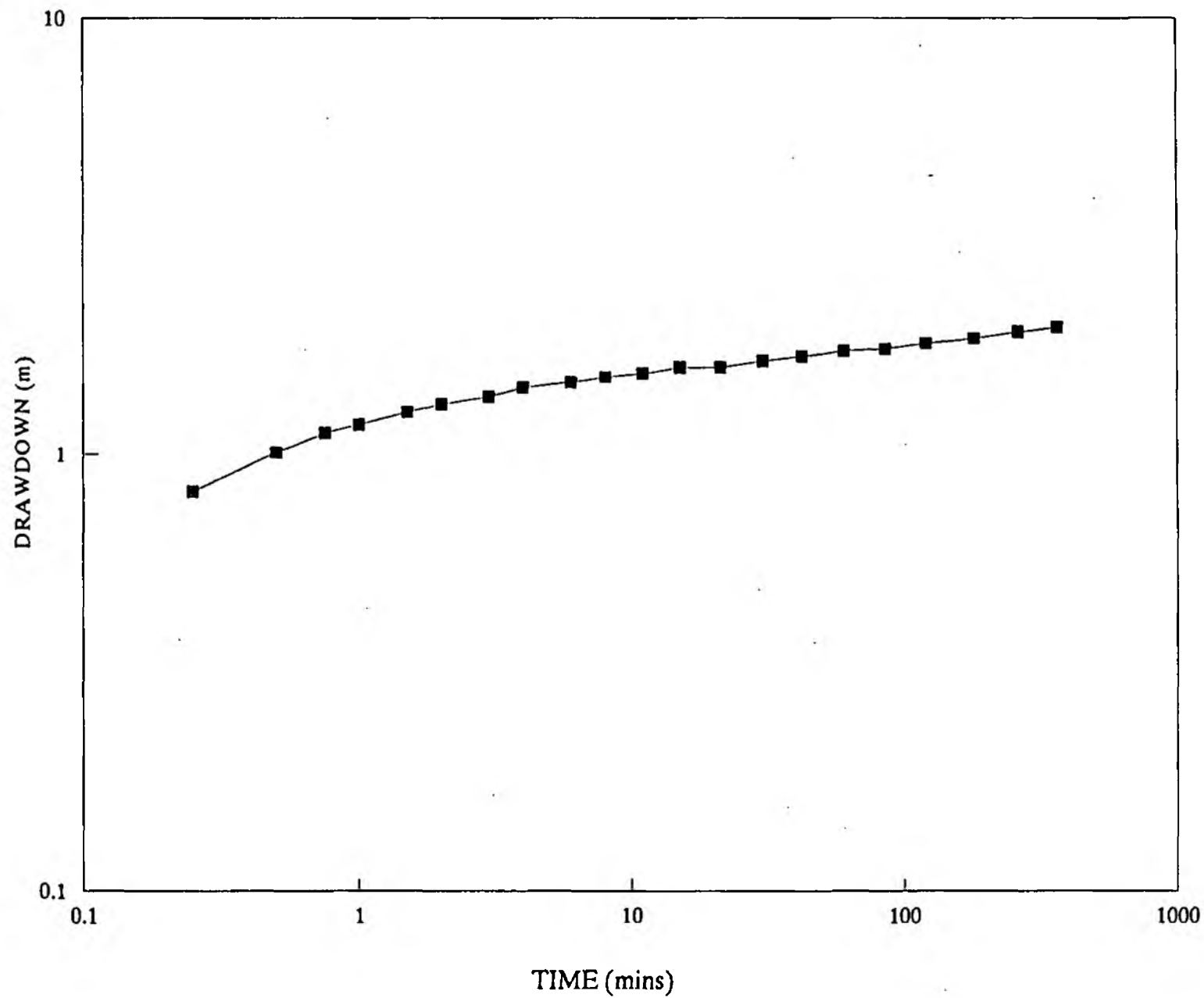


7 PLOTS FOR CALCULATION OF AQUIFER PROPERTIES: FIELD LANE

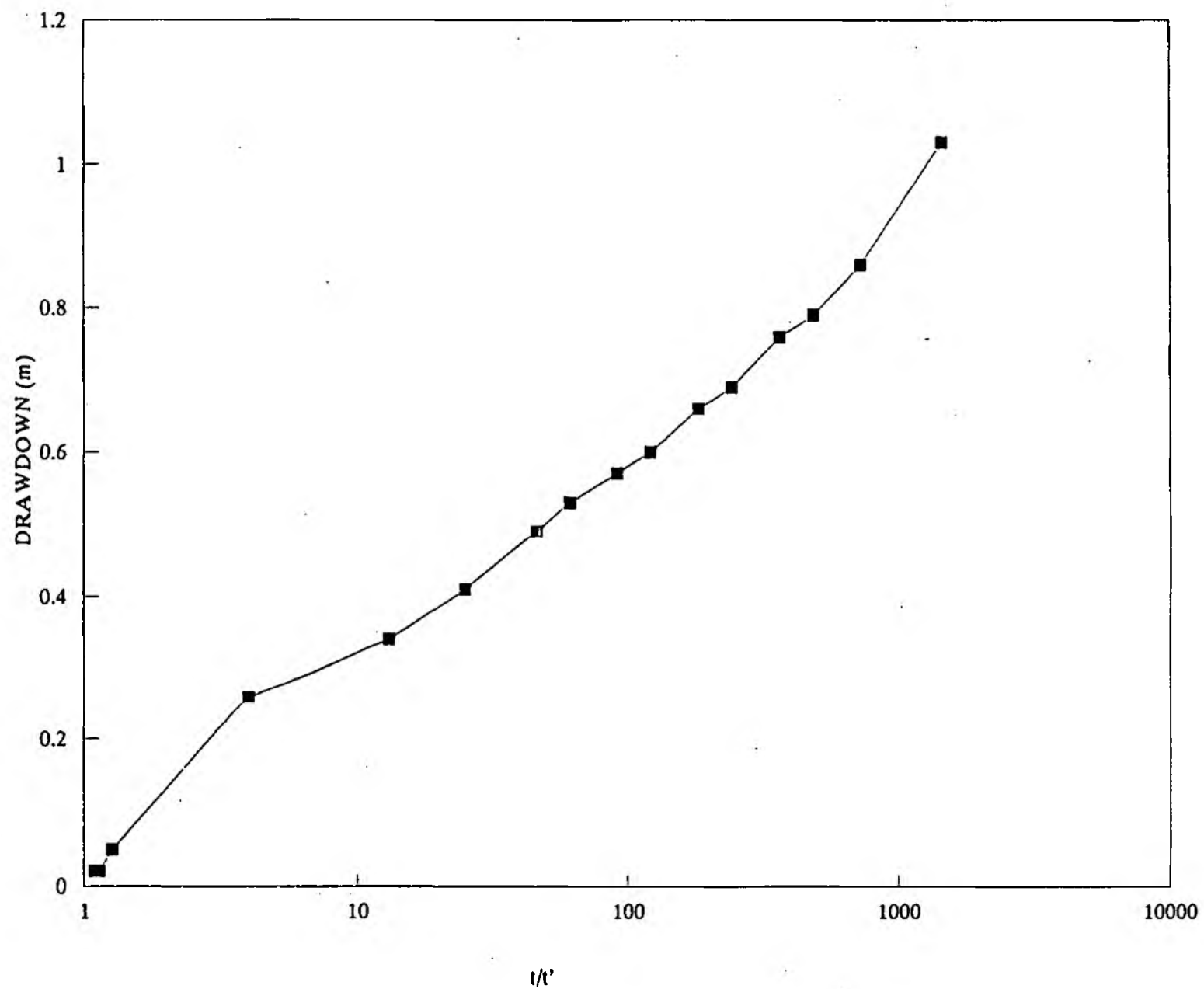
FIELD LANE



FIELD LANE

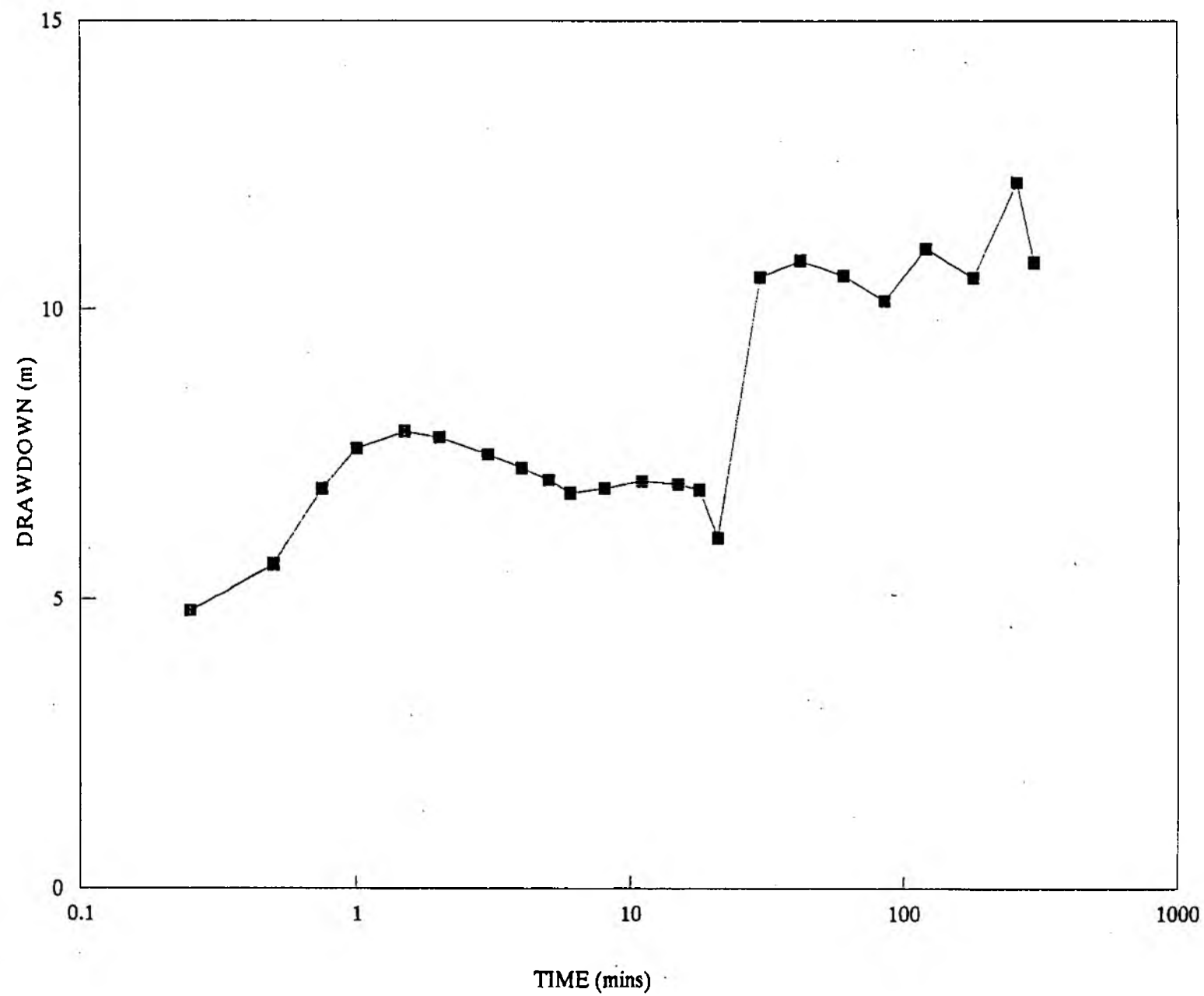


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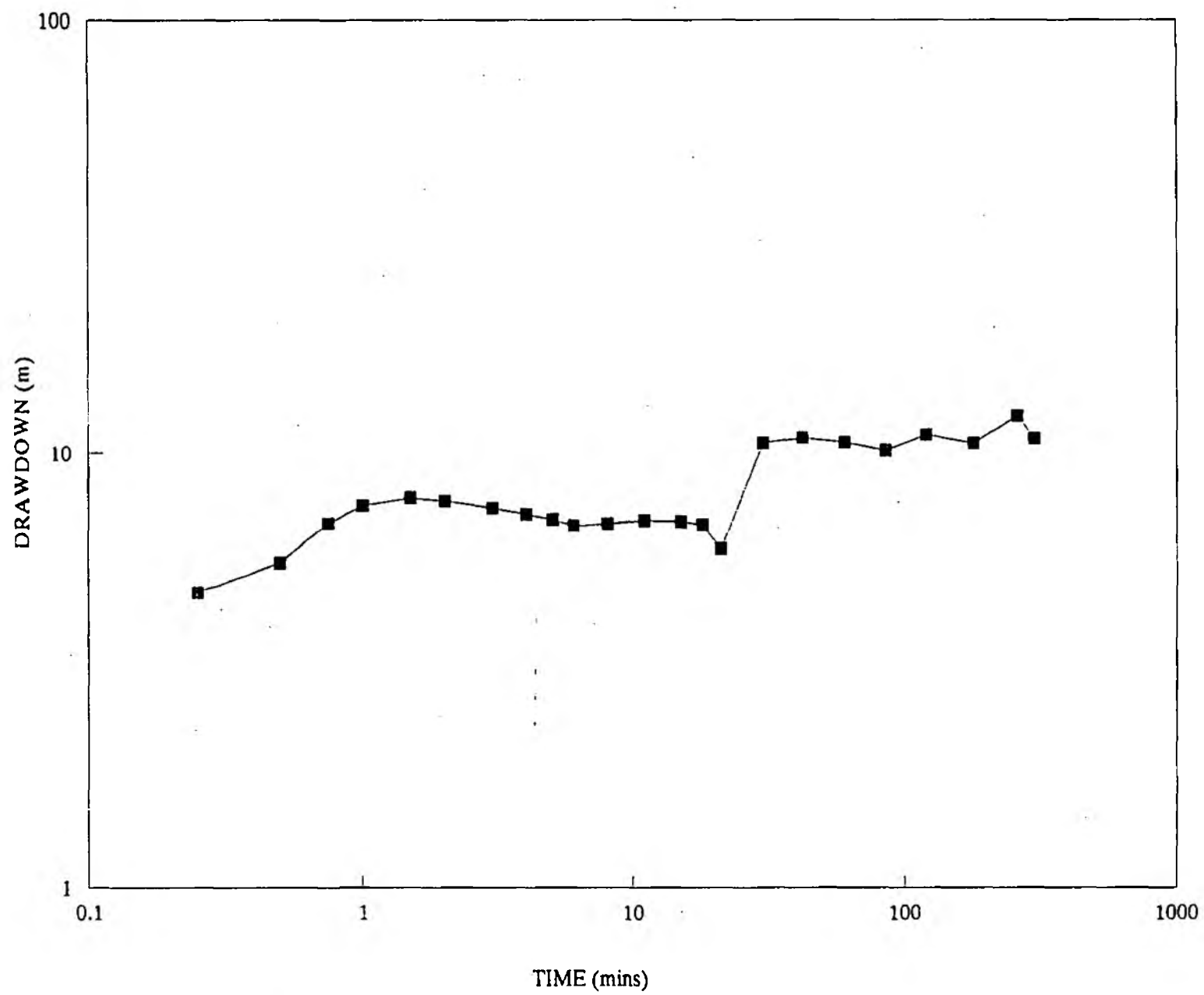


8 PLOTS FOR CALCULATION OF AQUIFER PROPERTIES: WASH LANE

WASH LANE

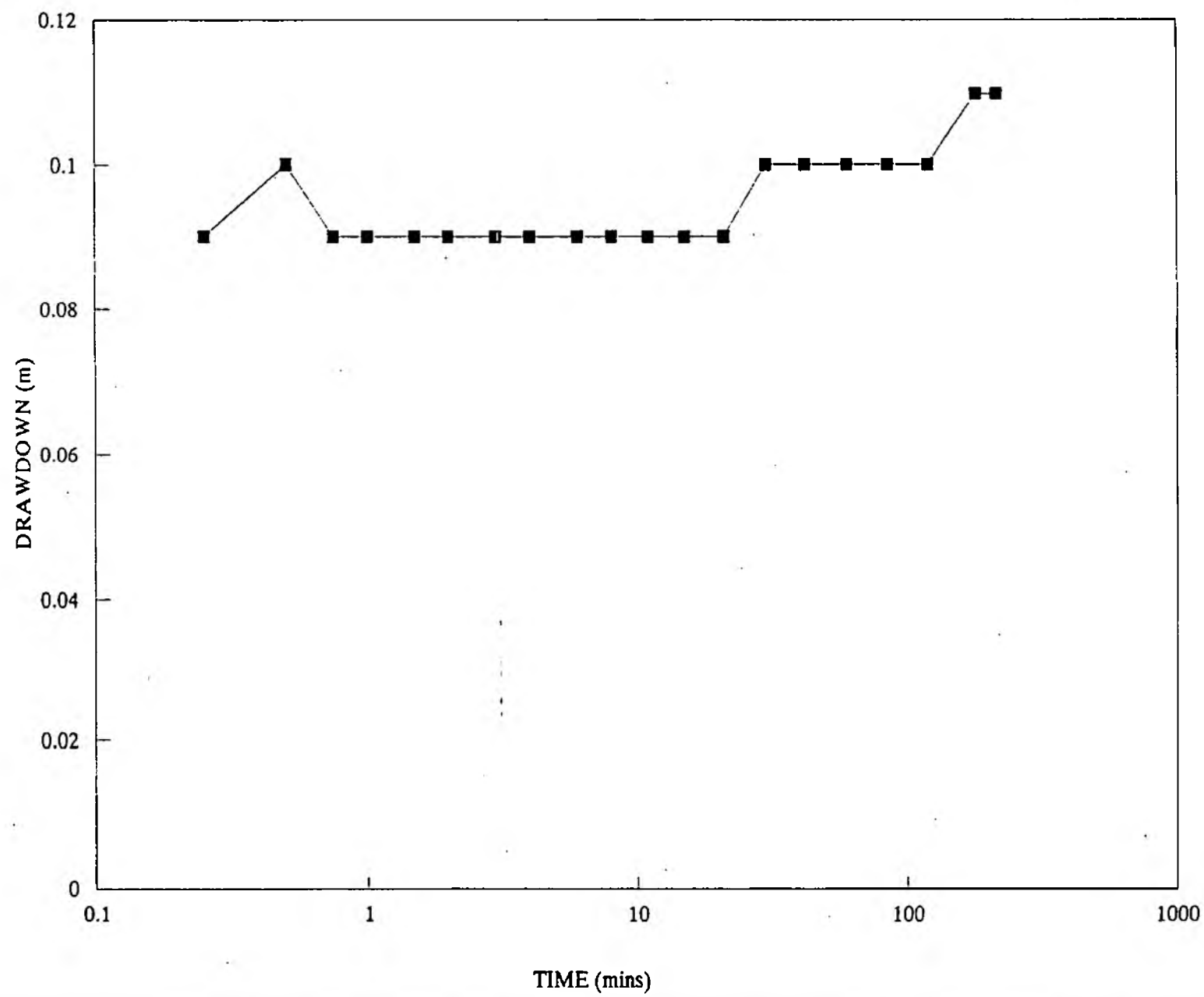


WASH LANE

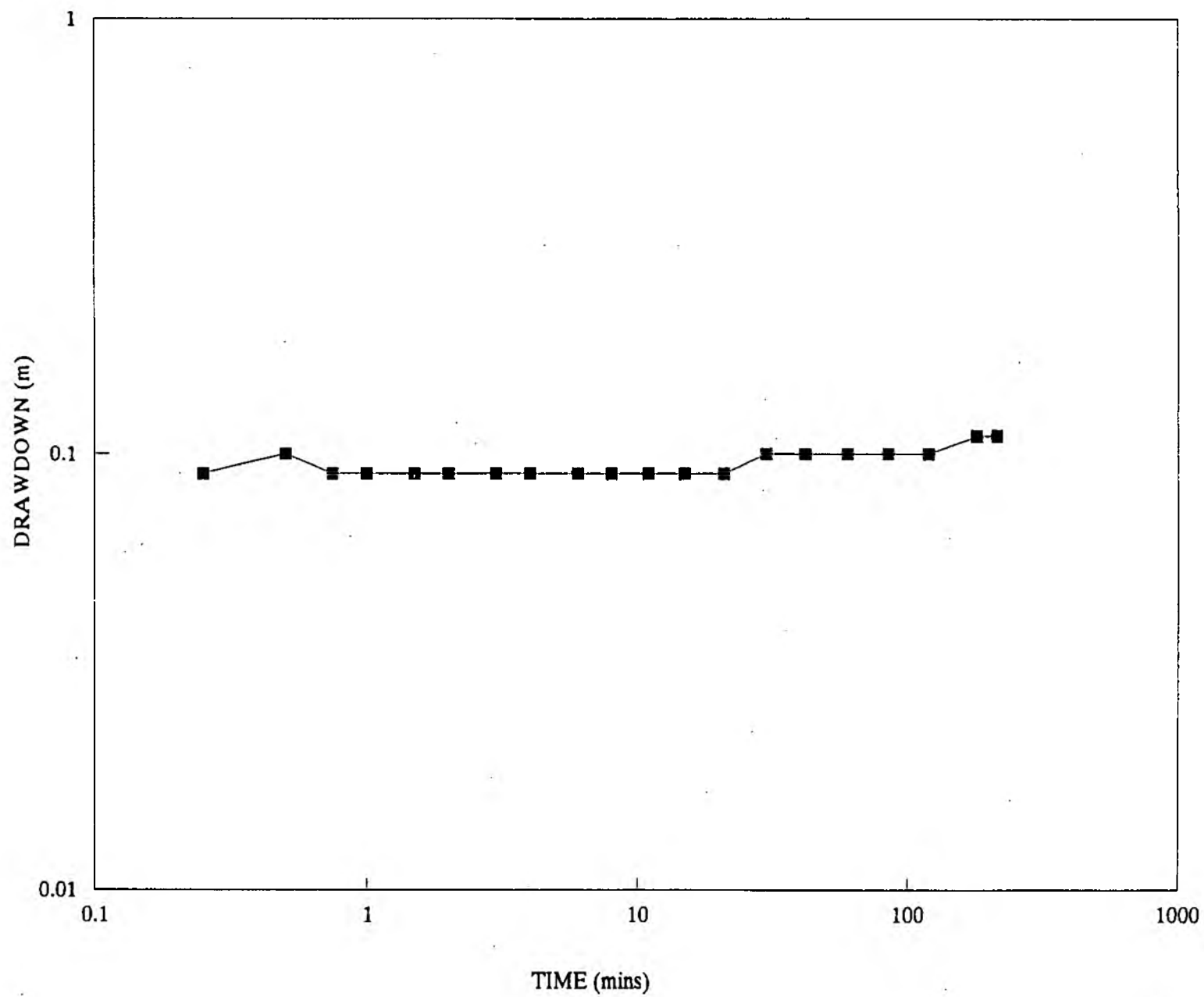


9 PLOTS FOR CALCULATION OF AQUIFER PROPERTIES: SIX BELLS

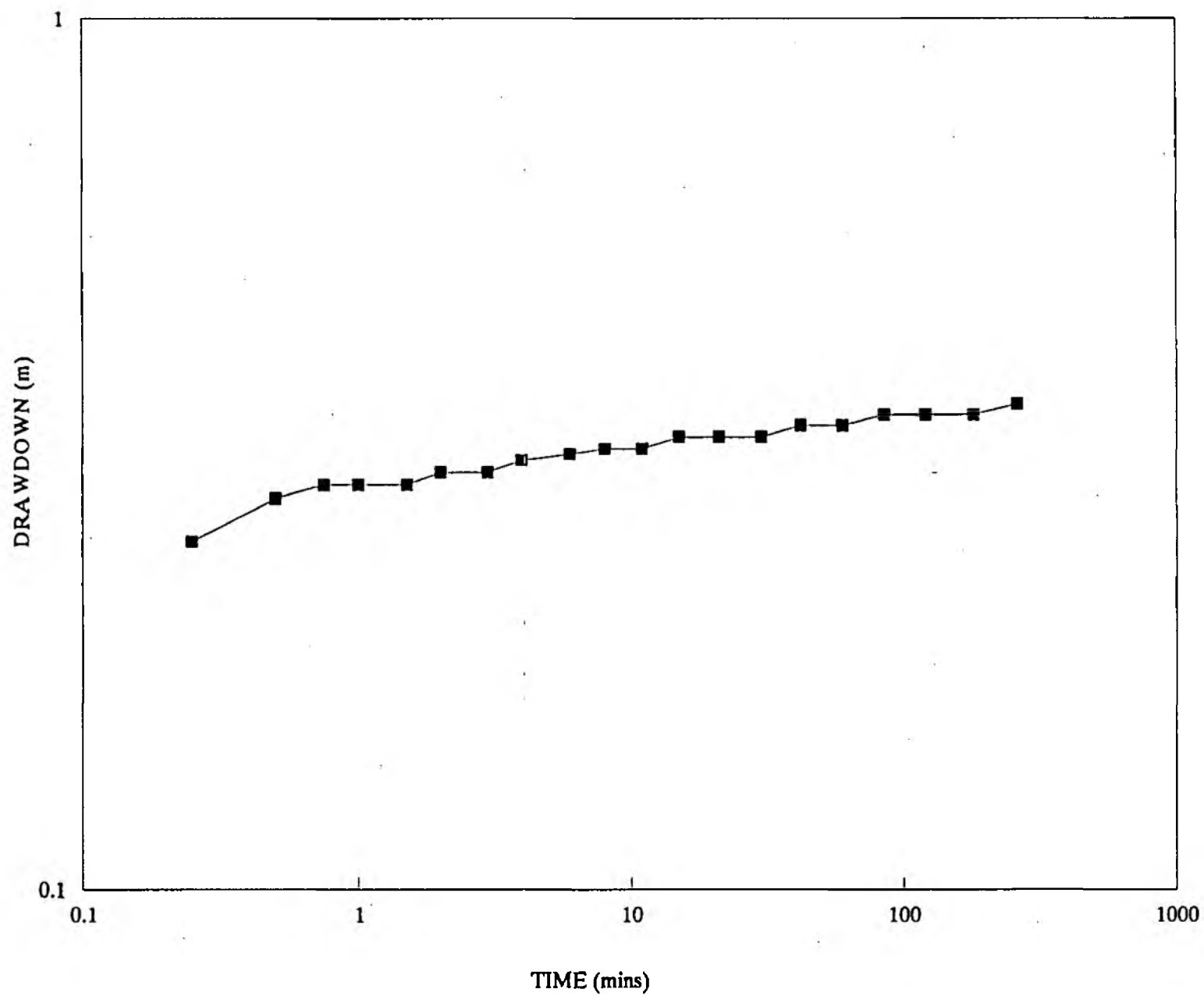
SIX BELLS



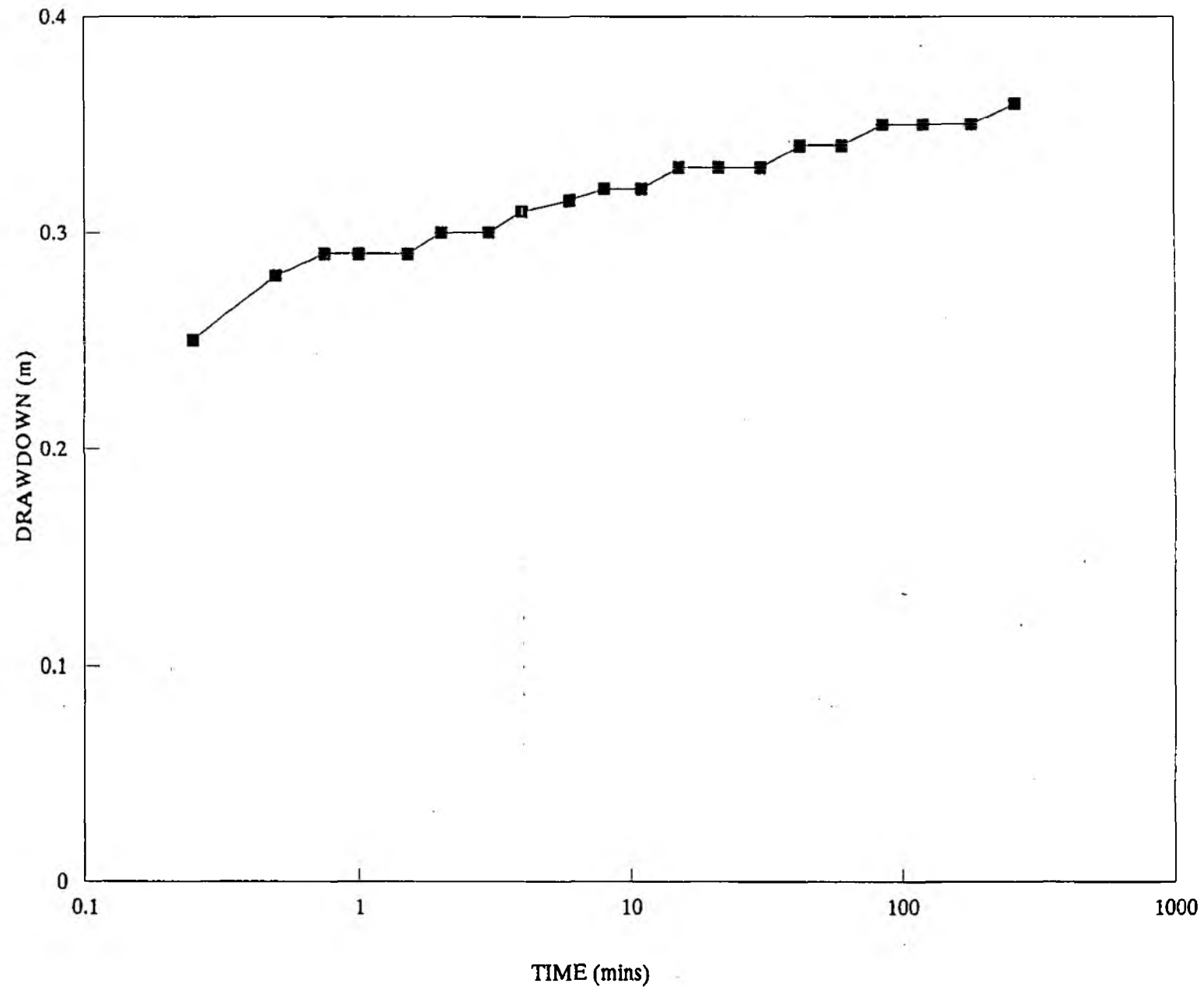
SIX BELLS



BARDWELL MANOR



BARDWELL MANOR



BARDWELL MANOR (RECOVERY)

