

APPENDIX 8.5
Hydraulic Permeability Test Results

**Report on Groundwater Sampling and
Permeability Testing at Srahmore Bog,
Bangor, Co. Mayo**

TES Consulting Engineers

MEL Brief 1322-Q1
MEL Doc. Ref.:1322-2546

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Appendices

Appendix	Title	Pages	MEL Doc. Ref.
Appendix A	Summary of Pre-Sampling Borehole Purging Results	1 x A4	1322-028.xls
Appendix B	Summary of Permeability Test Results	1 x A4	1322-019.xls
Appendix C	Aqtesolv Curve Fitted Graphs	12 x A4	1322-2548.aqt

1. Introduction

On 30th October 2003 Minerex Environmental Limited (MEL) were commissioned by Morgan Burke of TES Consulting Engineers to undertake groundwater sampling and permeability testing at Srahmore Bog, Bangor, Co Mayo. A detailed work specification was drafted up and agreed. The main elements of this specification are outlined below. MEL carried out site work over a three day period from the 4th to the 6th of November 2003. This report outlines the methodologies and equipment used, the results obtained and the software used for data analysis and presentation.

2. Work Specification

The following outlines the main elements of the site work undertaken at Srahmore Co. Mayo. The work is subdivided into two sections.

- A. Water sampling:
A total of seven (7) monitoring wells (four overburden and three bedrock) were purged and sampled. The samples were analysed by Alcontrol Laboratories Limited.

- B. Permeability testing:
Permeability tests were undertaken following sampling of the four overburden boreholes. Field data was used to determine K-values for the overburden sands and gravels.

3. Groundwater Sampling

3.1 Purpose

The installation of monitoring points allows for water levels and water samples to be taken. Seven (7) monitoring wells were drilled and installed in the week prior to sampling. The wells were drilled in four nested couples; the first three (1A/1B, 2A/2B, 3A/3B) consisting of a shallow overburden well and a deep bedrock well; and the fourth consisting of a deep overburden well (4A). The purpose of the sampling is to provide baseline data with respect to the investigation area.

3.2 Locations

Water samples were taken from the following boreholes: 1A, 1B, 2A, 2B, 3A, 3B and 4A. The locations of these boreholes were supplied to MEL by TES prior to fieldwork. MEL does not possess a map in electronic format for the site, and the production / reproduction of same is not included in the scope of this work item.

3.3 Methods and Materials

In the context of MEL's investigations, static water levels were taken in both wells within each couple prior to any purging of the groundwater. Borehole volumes were calculated to include the annulus volume and assuming an annulus porosity of 35%. At least 2 borehole volumes were removed from each monitoring point prior to sampling. Appendix A outlines a summary of borehole volumes removed prior to sampling.

A standard dipmeter was used to record water levels. All measurements were recorded in metres to the top of steel plinth (tosp) which is MEL's reference point. It should be noted that MEL was not commissioned to survey the monitoring points installed at Srahmore and does not possess reduced levels for any of the investigation points. A 2" Honda pump was used to purge the monitoring points. Due to adverse weather conditions and poor access to the monitoring points at the site, it was not possible to purge and sample all monitoring wells within one working day. 1A and 1B were purged on the 4th of November, while 2A, 2B, 3A, 3B and 4A were purged on the morning of 5th of

November. During purging of the first borehole volume an attempt made to remove silt from the bottom of the overburden wells using the Honda pump. This was unsuccessful as the purged water continued to have a high silt content throughout purging. All monitoring wells except 4A were sampled on the evening of the 5th of November using a 1litre designated, disposable bailer. Borehole 4A was subsequently sampled on the morning of the 6th of November. Before sampling, one borehole volume was removed from each overburden well using a disposable bailer and 5 litres were removed from each of the bedrock wells. This was undertaken to remove any stagnant water within the well 24 hours post-purging, prior to sampling. Samples taken from overburden wells had a high silt content and the laboratory was requested to filter as required for analysis.

Sample containers were supplied by Alcontrol Laboratories Ltd. These were filled directly from the disposable bailer without filtering. The samples were then placed in a battery operated coolbox for transportation to the Laboratory. The samples were received by the laboratory on the evening of the 6th of November. A chain of custody was completed during the transport of the samples to the laboratory.

4. Permeability Testing

4.1 Purpose

Permeability tests were undertaken at Srahmore to produce K-values (hydraulic conductivity) for each of the overburden monitoring points installed.

4.2 Locations

The permeability tests were carried out at each of the established overburden wells: 1A, 2A, 3A and 4A. Four tests were undertaken in total.

4.3 Methods and Materials

Both rising head permeability tests and single post-purging recovery tests were undertaken on the four overburden boreholes. The methodology for rising head tests involves the sudden removal of a small volume of water "slug" from the well after which the rise in recovering water level is measured. This displacement of water should not exceed 10% of the equilibrium piezometric head (Ref. 1). MEL used a bailer to perform these slug tests.

A second method of permeability testing was undertaken on most of the overburden boreholes on site. This involved the manipulation of the borehole purging procedure prior to sampling. Immediately after the purging was completed (by means of a 2" Honda pump) borehole water level recovery was monitored. This recovery data was used to provide a K-value for the aquifer and is likely to represent a larger volume of aquifer around the monitoring well than for the slug test results (scale factor). A summary of all permeability testing is provided in Appendix B.

The data collected was processed using aquifer analysing software, AQTESOLV. This software provides a suite of analytical solutions for determining aquifer properties from pumping tests and slug tests. From the data supplied on borehole installation design and from the static water levels recorded during fieldwork, an unconfined sands and gravel aquifer is identified at the site. In this context, two analytical solutions were used to derive K-values for the overburden aquifer. These are Hvorslev (1951) and Bouwer-Rice (1976) (Ref. 2).

5. Results

Results of the MEL's investigation work are presented in the Appendices A (summary of pre-sampling borehole purging results), Appendix B (summary of permeability test results), Appendix C (aqtesolv cuve fitted graphs) at the back of this report.

6. References

1. British Standards Institution (1999). *Code of Practice for Site Investigations - BS 5930*.
2. Kruseman, G. P., and de Ridder, N. A., (1992). *Analysis and Evaluation of Pumping Test Data*. ILRI Publication 47, The Netherlands.

Appendix A

Summary of Pre-Sampling Borehole Purging Results

VARIABLE DATA									
Seasonal monitoring data									
General			Date (dd/mm/yy)	Water levels		Pre-Sampling Purging			
Site ID	Weather	MEL operatives		Static Water level (mbRef)	Measured Depth (mbRef)	One (1) borehole volume (BHV) (Litres)	Three (3) borehole volume for purging (Litres)	Volume withdrawn (Litres)	BHV's withdrawn
BH 1A	Wet and Windy	LD	11/04/2003	2.57	8.40	24.8	74.25	103.00	4.16
BH 1B	Wet and Windy	LD	11/04/2003	2.85	23.65	79.5	238.41	275.00	3.46
BH 2A	Wet and Windy	LD	11/05/2003	3.25	6.04	10.6	31.74	42.00	3.97
BH 2B	Wet and Windy	LD	11/05/2003	3.23	23.50	78.0	234.00	165.00	2.12
BH 3A	Wet and Windy	LD	11/05/2003	2.02	5.56	11.5	34.38	52.00	4.54
BH 3B	Wet and Windy	LD	11/05/2003	2.24	15.78	53.0	158.85	155.00	2.93
BH 4A	Wet and Windy	LD	11/05/2003	2.51	29.00	105.8	317.37	384.00	3.63

Appendix B

Summary of Permeability Test Results

Summary of Permeability Tests

Borehole & Aquifer Details		* ² K Values according to Methodology Used (up to 3 types)				
Borehole ID	Aquifer* ¹	Rising Head Test (Hvorslev)	Rising Head Test (Bouwer-Rice)	Recovery (Hvorslev)	Recovery (Bouwer-Rice)	Average
BH-1/A	Unconfined	N/a	N/a	3.654E-07	2.553E-07	3.104E-07
BH-2/A	Unconfined	2.030E-07	1.143E-07	7.092E-07	4.130E-07	3.599E-07
BH-3/A	Unconfined	1.210E-06	7.194E-07	N/a	N/a	9.647E-07
BH-4/A	Unconfined	2.632E-06	2.273E-06	N/a	N/a	2.453E-06

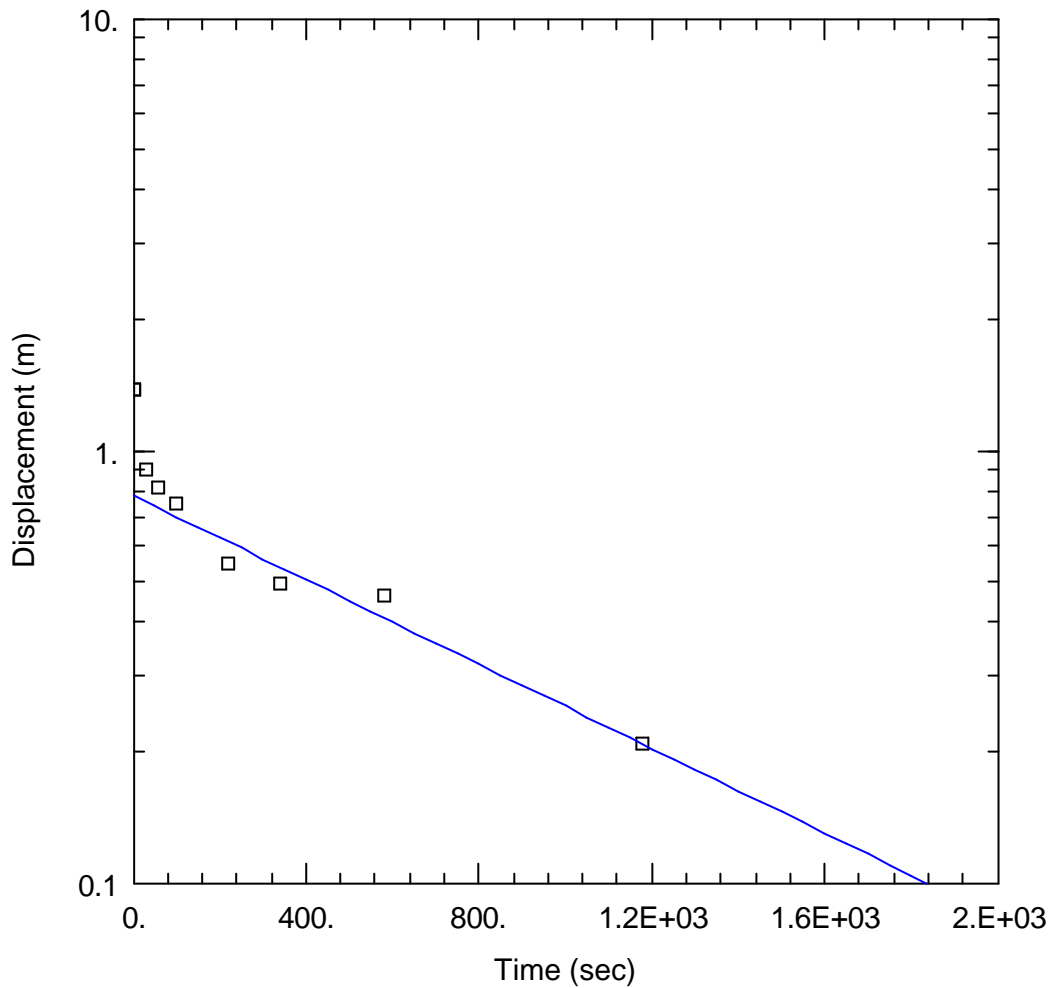
Average	1.348E-06	1.036E-06	5.373E-07	3.342E-07	1.022E-06
Max	2.632E-06	2.273E-06	7.092E-07	4.130E-07	2.453E-06
Min	2.030E-07	1.143E-07	3.654E-07	2.553E-07	3.104E-07

*¹ The aquifer is identified as being unconfined based on well installation data supplied (MEL Doc. Ref. 1322-2543) and from water levels recorded on 04-06/11/03.

*² Where duplicate tests were undertaken, an average is provided per analytical solution

Appendix C

Aqtesolv Curve Fitted Graphs



1A - RECOVERY TEST 1

Data Set: P:\1322 (Shell)\aqt\1322-2548\1A\1A data Recovery.aqt
 Date: 11/18/03 Time: 16:55:53

PROJECT INFORMATION

Company: Minerex Environmental Limited
 Client: TES Consulting Engineers
 Project: 1322-Q1
 Test Location: Srahmore, Bangor, Co. Mayo
 Test Well: 1A
 Test Date: 04-11-03

AQUIFER DATA

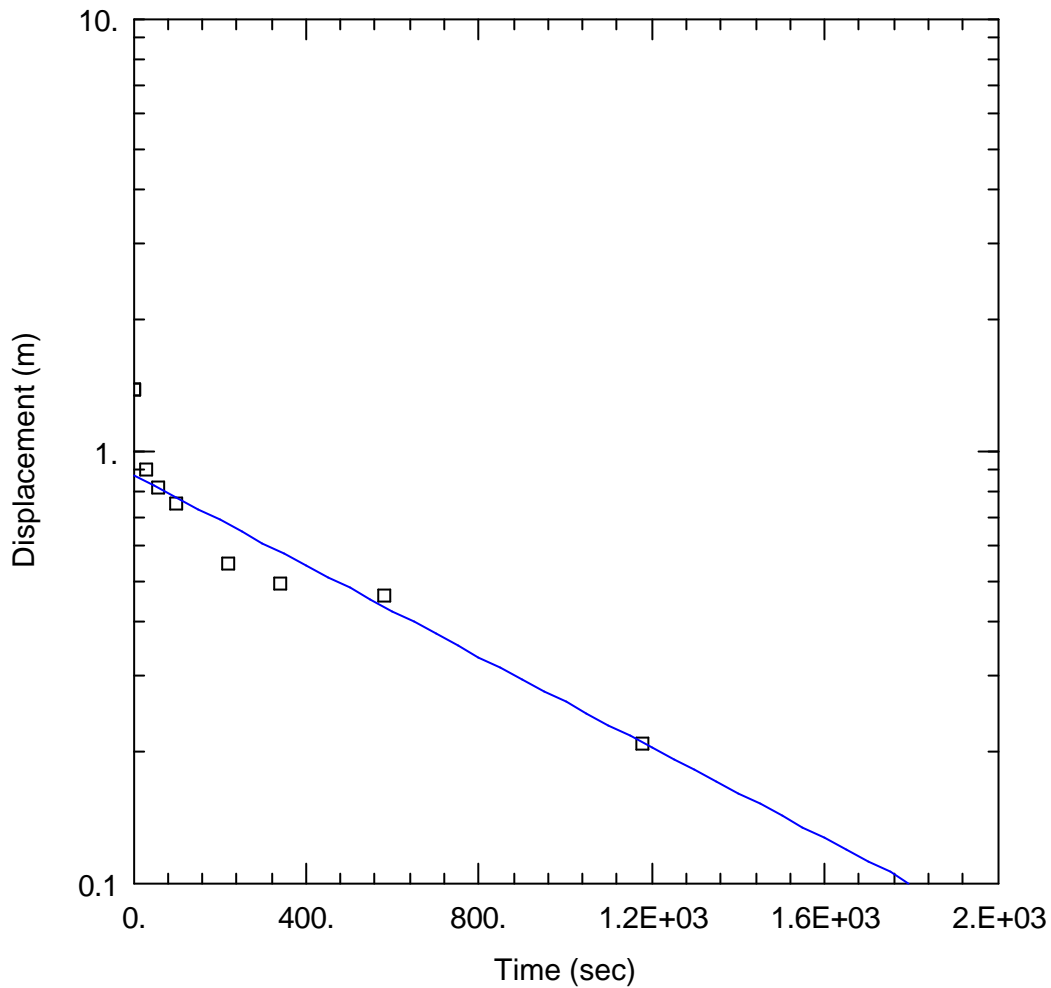
Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (1A)

Initial Displacement: 1.38 m Water Column Height: 6.28 m
 Casing Radius: 0.026 m Wellbore Radius: 0.05 m
 Screen Length: 8. m Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev
 K = 4.687E-07 m/sec y0 = 0.7864 m



1A - RECOVERY TEST 1

Data Set: P:\1322 (Shell)\aqt\1322-2548\1A Data Recovery 1.aqt
 Date: 11/18/03 Time: 17:00:02

PROJECT INFORMATION

Company: Minerex Environmental Limited
 Client: TES Consulting Engineers
 Project: 1322-Q1
 Test Location: Srahmore, Bangor, Co. Mayo
 Test Well: 1A
 Test Date: 04-11-03

AQUIFER DATA

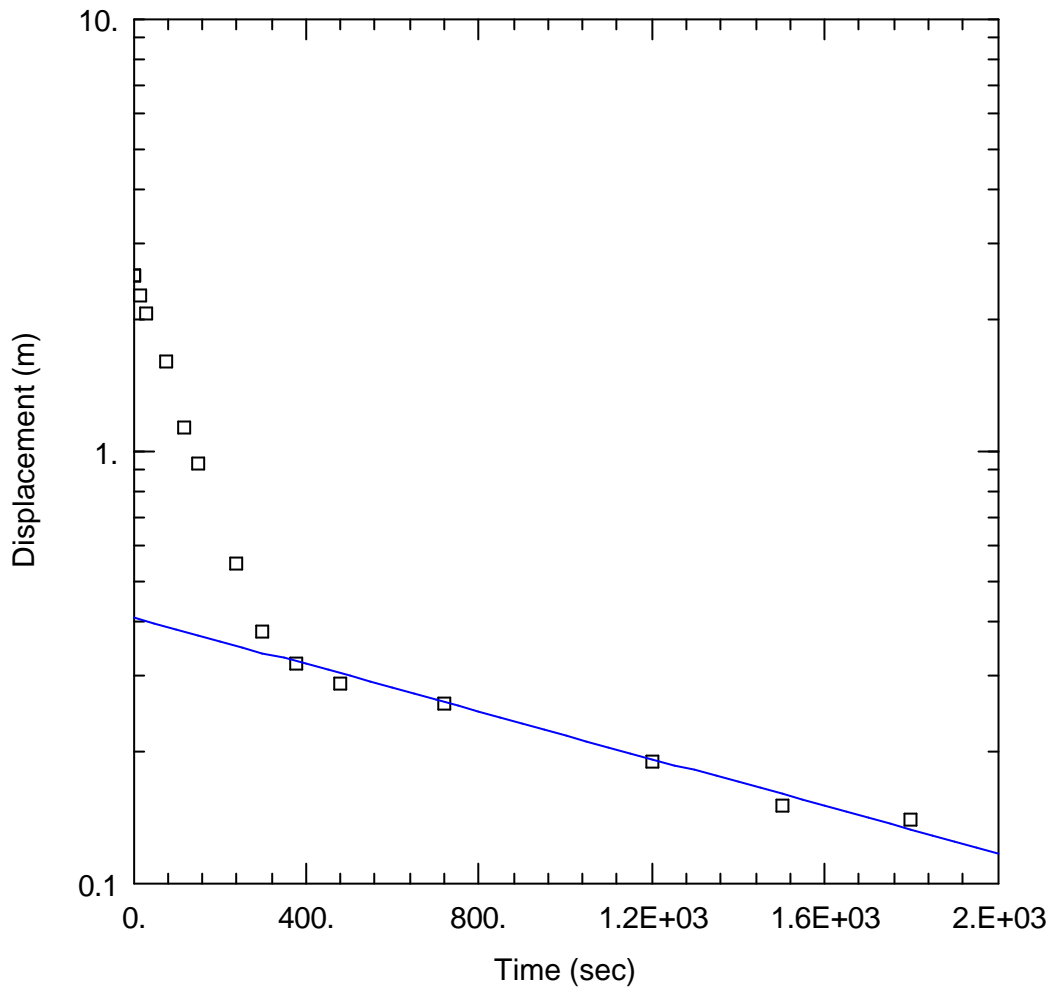
Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (1A)

Initial Displacement: 1.38 m Water Column Height: 6.28 m
 Casing Radius: 0.026 m Wellbore Radius: 0.05 m
 Screen Length: 8. m Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
 K = 3.443E-07 m/sec y0 = 0.8784 m



1A - RECOVERY TEST 2

Data Set: P:\1322 (Shell)\aqt\1322-2548\1A - FINAL\1A Data Recovery 2.aqt
 Date: 11/18/03 Time: 17:05:15

PROJECT INFORMATION

Company: Minerex Environmental Limited
 Client: TES Consulting Engineers
 Project: 1322-Q1
 Test Location: Srahmore, Bangor, Co. Mayo
 Test Well: 1A
 Test Date: 04-11-03

AQUIFER DATA

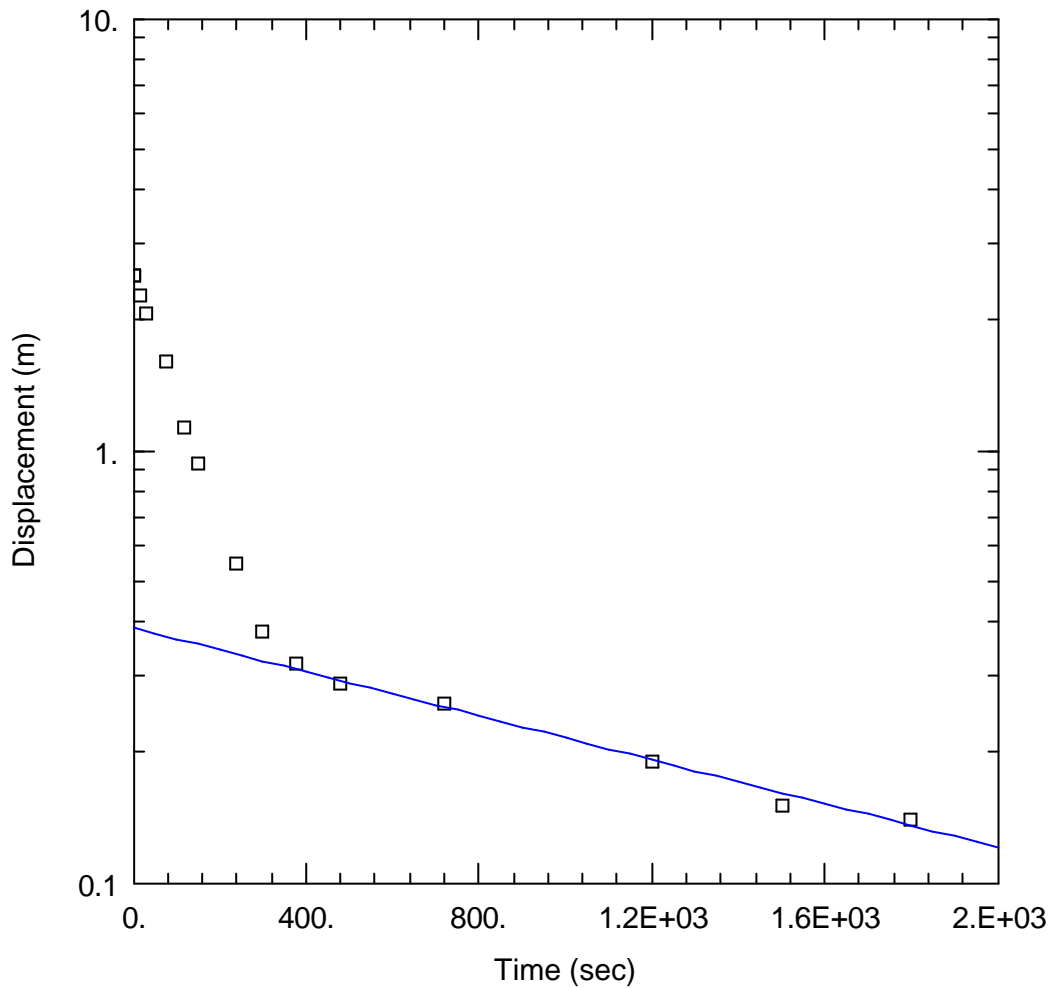
Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (1A)

Initial Displacement: 2.53 m Water Column Height: 6.28 m
 Casing Radius: 0.026 m Wellbore Radius: 0.05 m
 Screen Length: 8. m Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev
 K = 2.621E-07 m/sec y0 = 0.4114 m



1A - RECOVERY TEST 2

Data Set: P:\1322 (Shell)\aqt\1322-2548\1A - FINAL\1A Data Recovery 2.aqt
 Date: 11/18/03 Time: 17:04:50

PROJECT INFORMATION

Company: Minerex Environmental Limited
 Client: TES Consulting Engineers
 Project: 1322-Q1
 Test Location: Srahmore, Bangor, Co. Mayo
 Test Well: 1A
 Test Date: 04-11-03

AQUIFER DATA

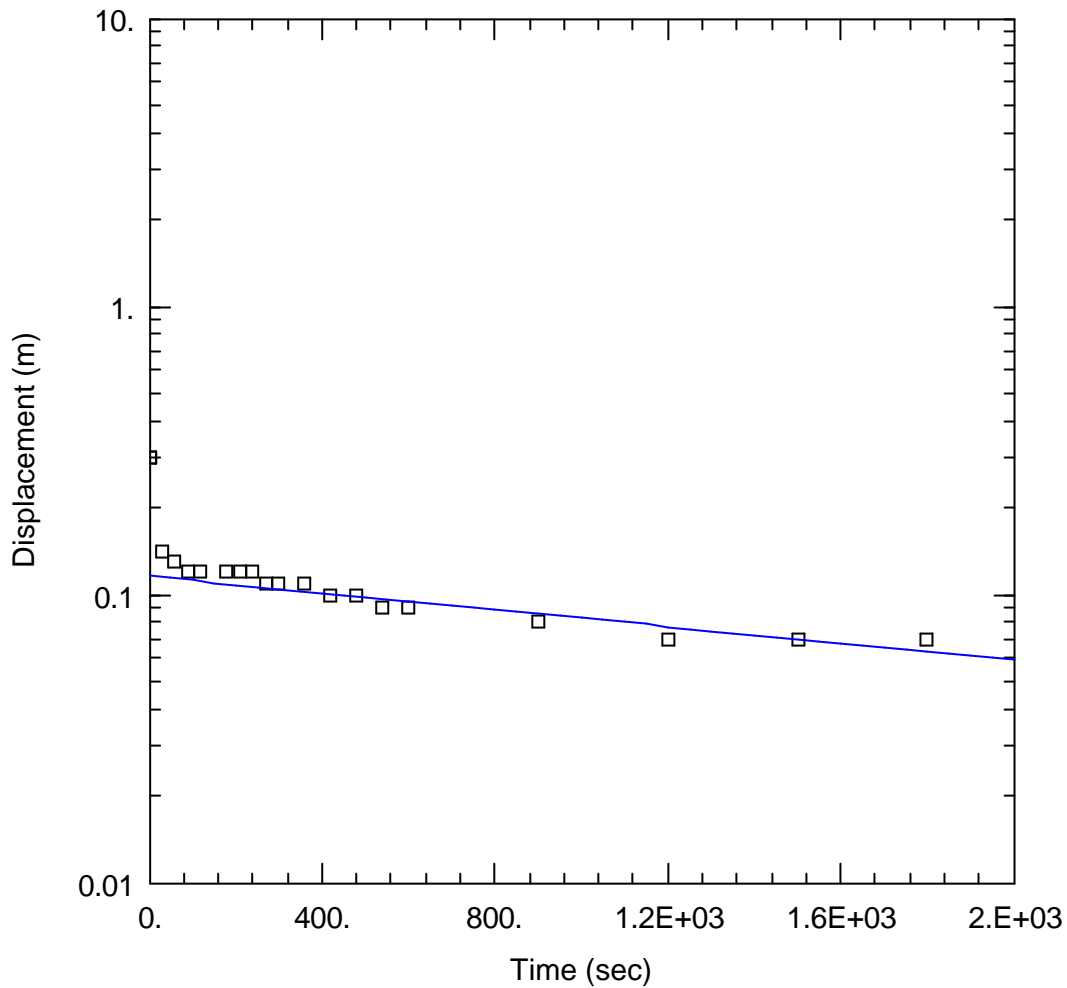
Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (1A)

Initial Displacement: 2.53 m Water Column Height: 6.28 m
 Casing Radius: 0.026 m Wellbore Radius: 0.05 m
 Screen Length: 8. m Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
 K = 1.663E-07 m/sec y0 = 0.3884 m



2A - SLUG TEST

Data Set: P:\1322 (Shell)\aqt\1322-2548\1A - FINAL\2A SLUG.aqt
 Date: 11/18/03 Time: 17:17:45

PROJECT INFORMATION

Company: Minerex Environmental Limited
 Client: TES Consulting Engineers
 Project: 1322-Q1
 Test Location: Srahmore, Bangor, Co. Mayo
 Test Well: 2A
 Test Date: 04-11-03

AQUIFER DATA

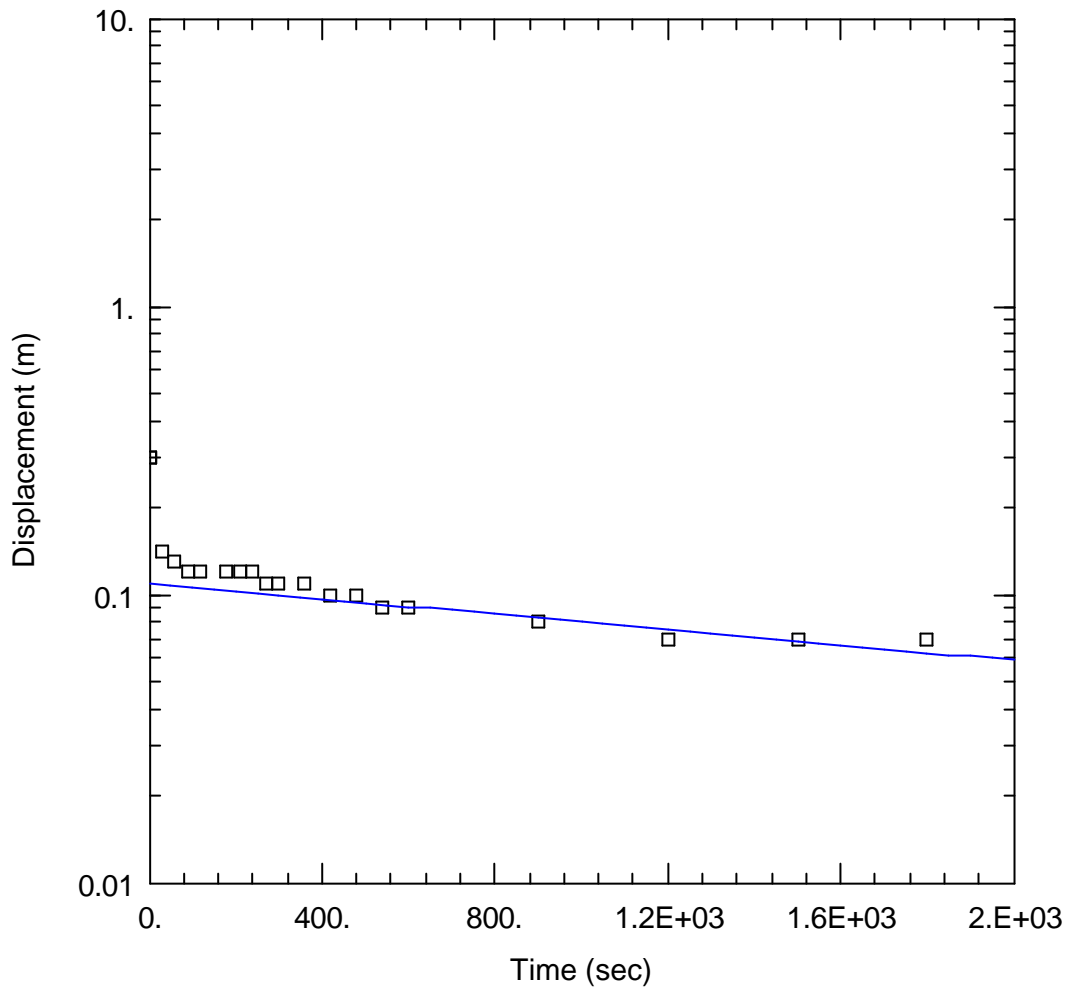
Saturated Thickness: 7. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (2A)

Initial Displacement: 0.3 m Water Column Height: 2.64 m
 Casing Radius: 0.026 m Wellbore Radius: 0.05 m
 Screen Length: 5. m Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev
 K = 2.03E-07 m/sec y0 = 0.1157 m



2A - SLUG TEST

Data Set: P:\1322 (Shell)\aq\1322-2548\1A - FINAL\2A SLUG.aqt
 Date: 11/18/03 Time: 17:18:43

PROJECT INFORMATION

Company: Minerex Environmental Limited
 Client: TES Consulting Engineers
 Project: 1322-Q1
 Test Location: Srahmore, Bangor, Co. Mayo
 Test Well: 2A
 Test Date: 04-11-03

AQUIFER DATA

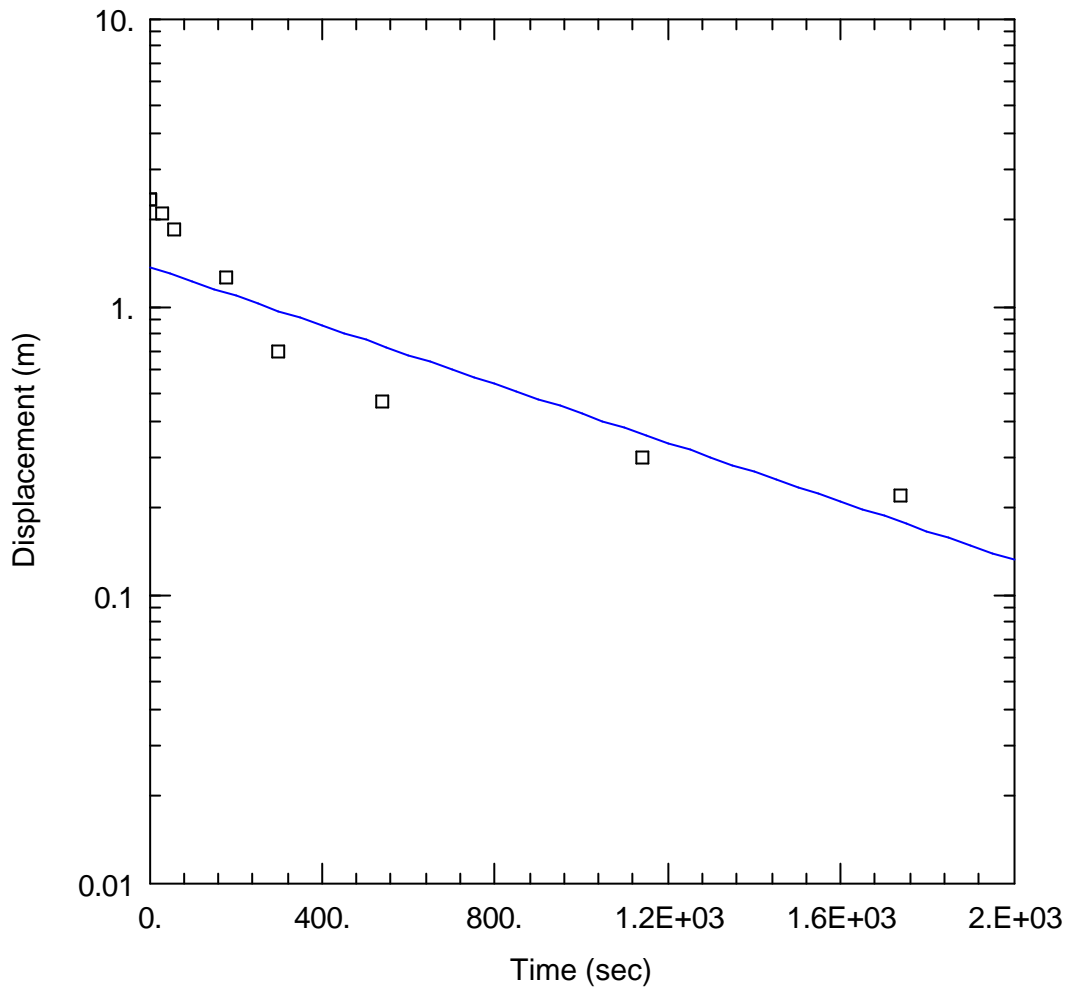
Saturated Thickness: 7. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (2A)

Initial Displacement: 0.3 m Water Column Height: 2.64 m
 Casing Radius: 0.026 m Wellbore Radius: 0.05 m
 Screen Length: 5. m Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
 K = 1.143E-07 m/sec y0 = 0.1093 m



2A - RECOVERY

Data Set: P:\1322 (Shell)\aqt\1322-2548\1A - FINAL\2A Recovery.aqt
 Date: 11/18/03 Time: 17:24:58

PROJECT INFORMATION

Company: Minerex Environmental Limited
 Client: TES Consulting Engineers
 Project: 1322-Q1
 Test Location: Srahmore, Bangor, Co. Mayo
 Test Well: 2A
 Test Date: 04-11-03

AQUIFER DATA

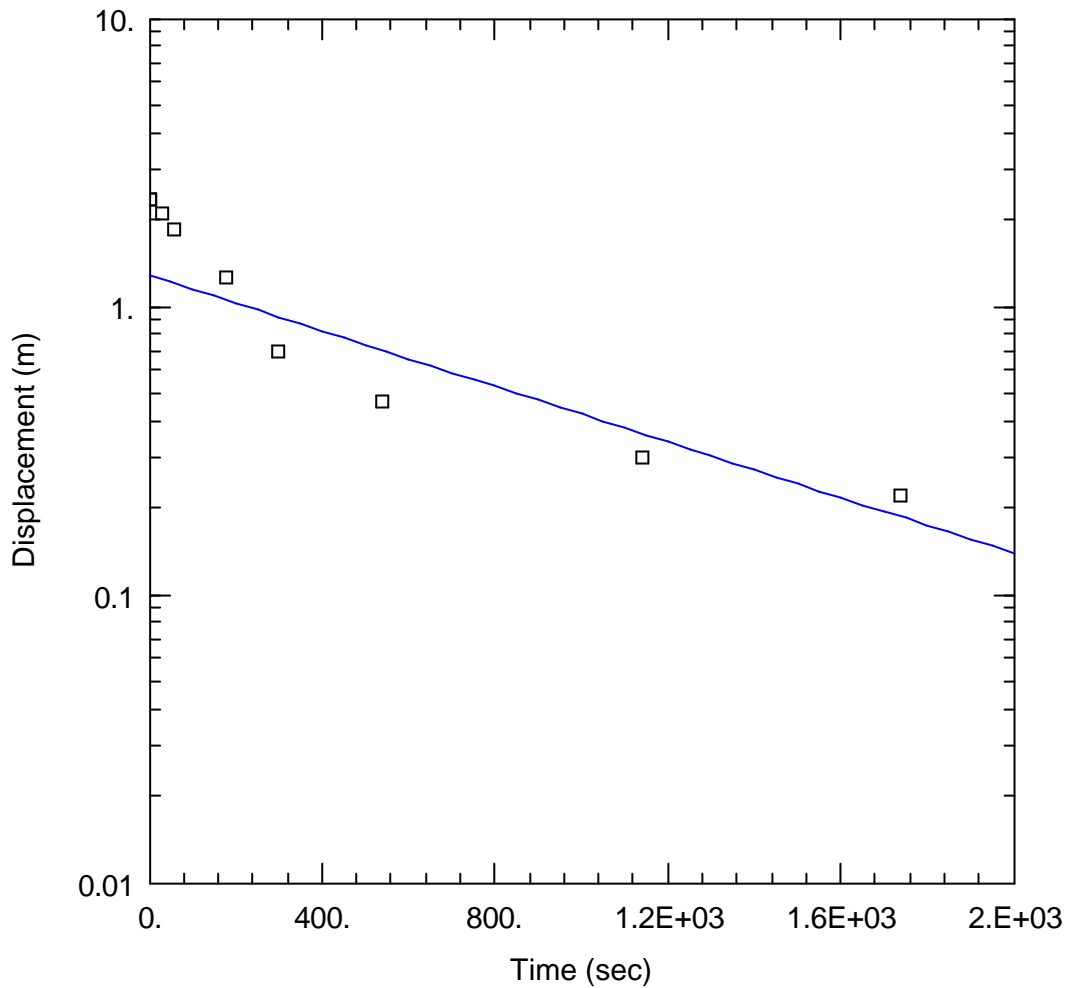
Saturated Thickness: 7. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (2A)

Initial Displacement: 2.34 m Water Column Height: 2.64 m
 Casing Radius: 0.026 m Wellbore Radius: 0.05 m
 Screen Length: 5. m Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev
 K = 7.092E-07 m/sec y0 = 1.371 m



2A - RECOVERY

Data Set: P:\1322 (Shell)\aqt\1322-2548\1A - FINAL\2A Recovery.aqt
 Date: 11/18/03 Time: 17:24:19

PROJECT INFORMATION

Company: Minerex Environmental Limited
 Client: TES Consulting Engineers
 Project: 1322-Q1
 Test Location: Srahmore, Bangor, Co. Mayo
 Test Well: 2A
 Test Date: 04-11-03

AQUIFER DATA

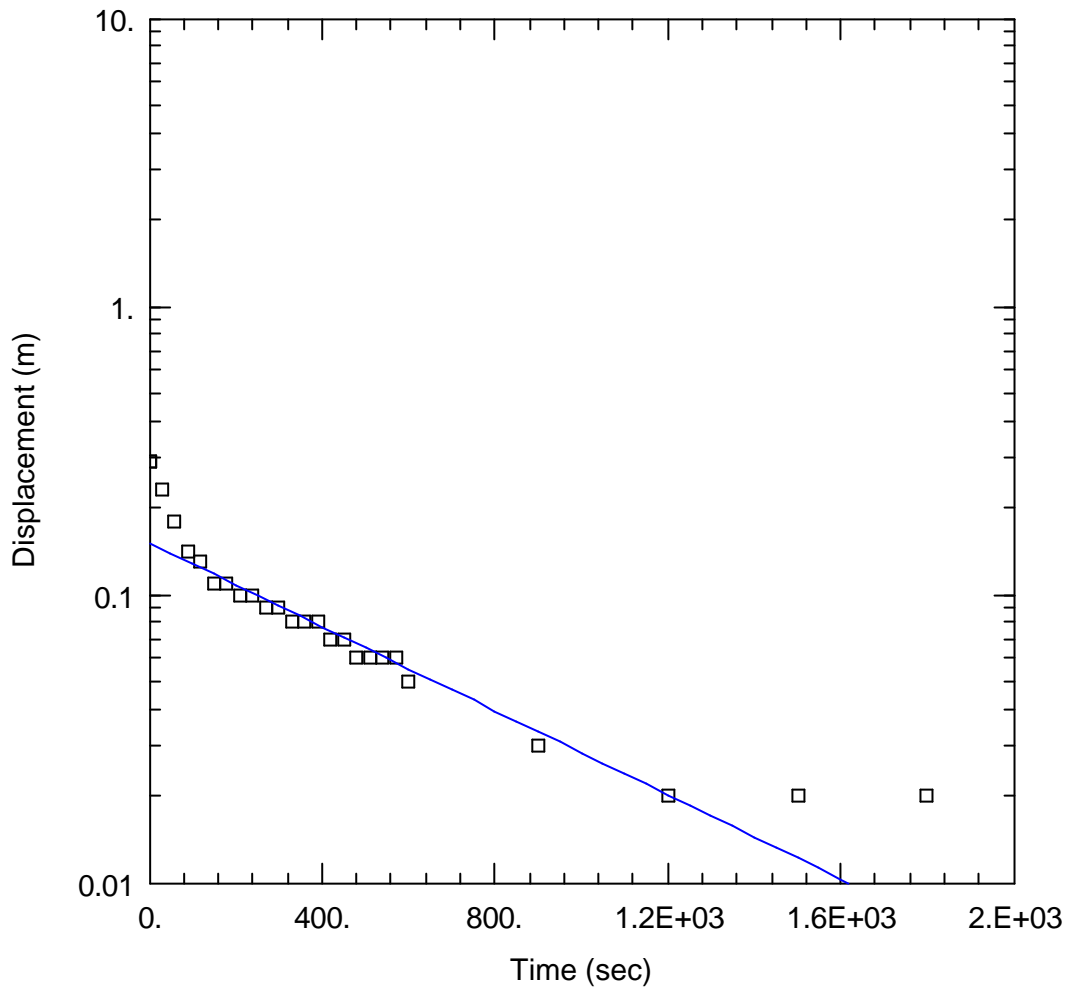
Saturated Thickness: 7. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (2A)

Initial Displacement: 2.34 m Water Column Height: 2.64 m
 Casing Radius: 0.026 m Wellbore Radius: 0.05 m
 Screen Length: 5. m Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
 K = 4.13E-07 m/sec y0 = 1.284 m



3A - SLUG

Data Set: P:\1322 (Shell)\aqt\1322-2548\1A - FINAL\3A SLUG.aqt
 Date: 11/18/03 Time: 17:33:49

PROJECT INFORMATION

Company: Minerex Environmental Limited
 Client: TES Consulting Engineers
 Project: 1322-Q1
 Test Location: Srahmore, Bangor, Co. Mayo
 Test Well: 3A
 Test Date: 04-11-03

AQUIFER DATA

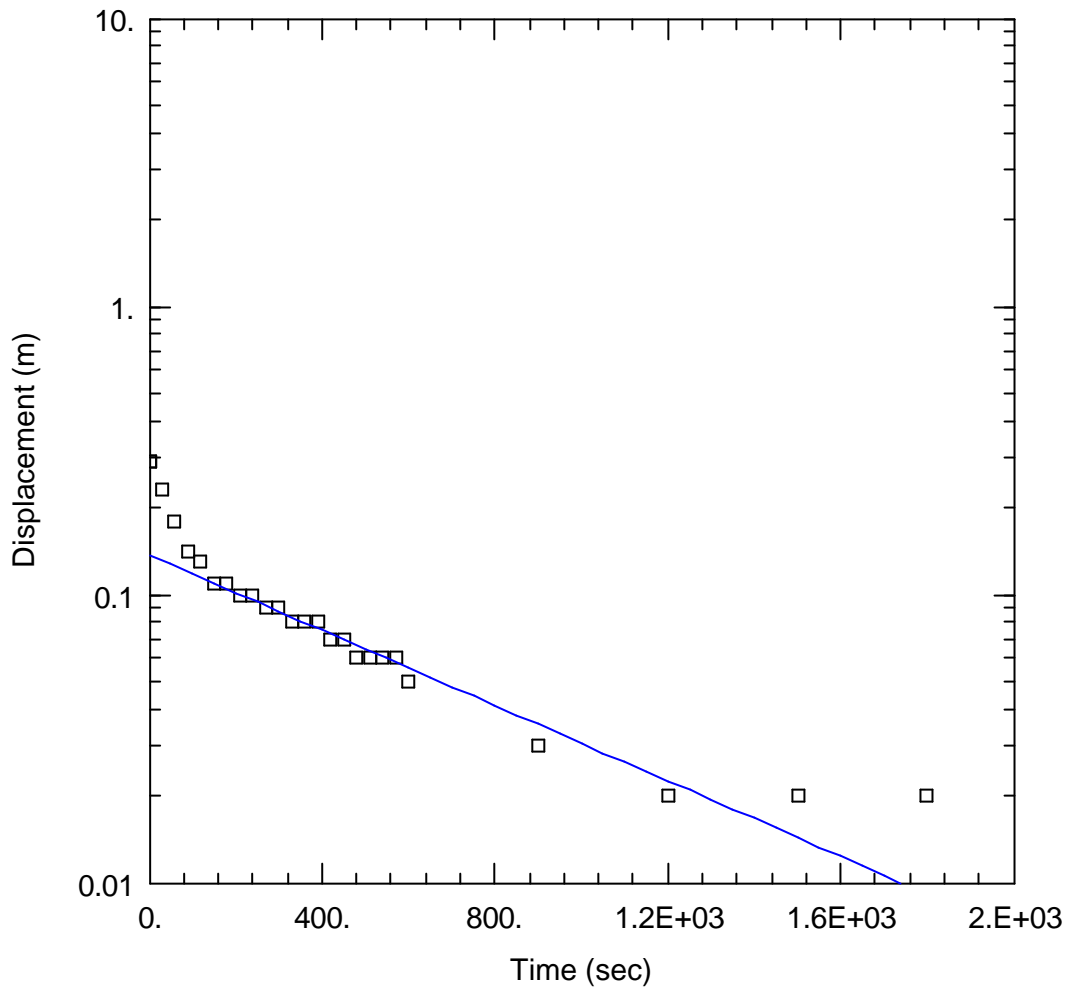
Saturated Thickness: 5. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (3A)

Initial Displacement: 0.29 m Water Column Height: 3.12 m
 Casing Radius: 0.026 m Wellbore Radius: 0.05 m
 Screen Length: 4. m Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev
 K = 1.21E-06 m/sec y0 = 0.1515 m



3A - SLUG

Data Set: P:\1322 (Shell)\aqt\1322-2548\1A - FINAL\3A SLUG.aqt
 Date: 11/18/03 Time: 17:34:25

PROJECT INFORMATION

Company: Minerex Environmental Limited
 Client: TES Consulting Engineers
 Project: 1322-Q1
 Test Location: Srahmore, Bangor, Co. Mayo
 Test Well: 3A
 Test Date: 04-11-03

AQUIFER DATA

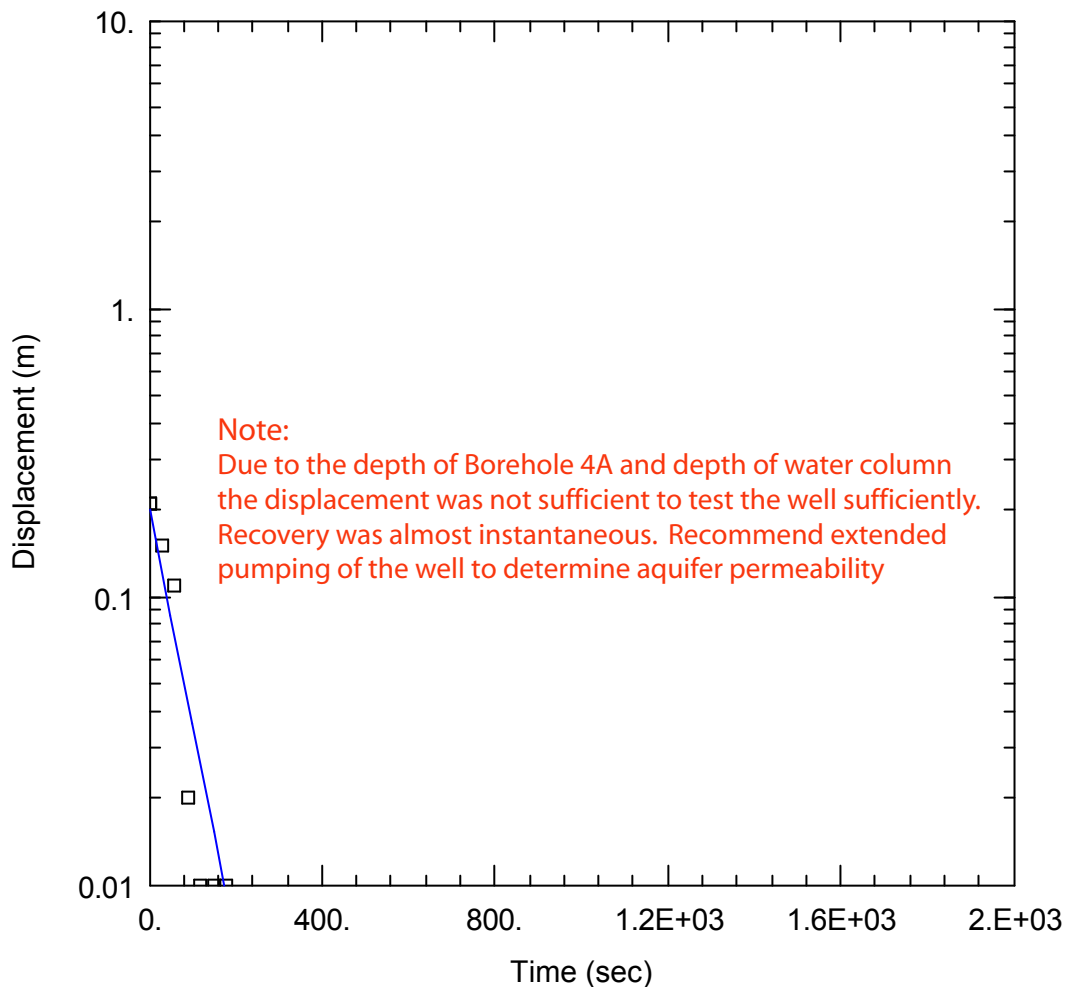
Saturated Thickness: 5. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (3A)

Initial Displacement: 0.29 m Water Column Height: 3.12 m
 Casing Radius: 0.026 m Wellbore Radius: 0.05 m
 Screen Length: 4. m Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
 K = 7.194E-07 m/sec y0 = 0.1373 m



4A - SLUG

Data Set: P:\1322 (Shell)\aqt\1322-2548\1A - FINAL\4A SLUG (erroneous).aqt

Date: 11/18/03

Time: 18:00:36

PROJECT INFORMATION

Company: Minerex Environmental Limited

Client: TES Consulting Engineers

Project: 1322-Q1

Test Location: Srahmore, Bangor, Co. Mayo

Test Well: 4A

Test Date: 04-11-03

AQUIFER DATA

Saturated Thickness: 28. m

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (4A)

Initial Displacement: 0.21 m

Water Column Height: 27.3 m

Casing Radius: 0.026 m

Wellbore Radius: 0.05 m

Screen Length: 27. m

Gravel Pack Porosity: 0.35

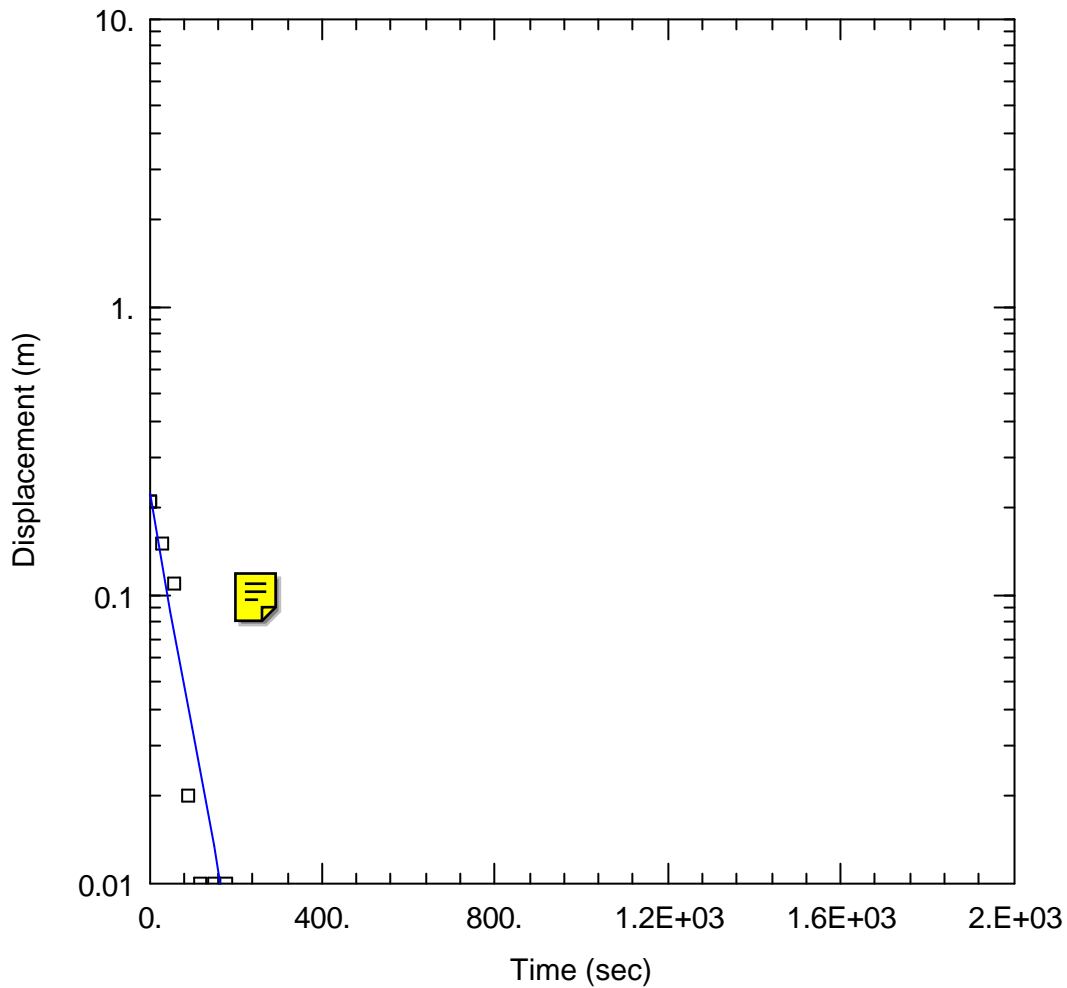
SOLUTION

Aquifer Model: Unconfined

Solution Method: Hvorslev

K = 2.632E-06 m/sec

y0 = 0.2015 m



4A - SLUG

Data Set: P:\1322 (Shell)\aqt\1322-2548\1A - FINAL\4A SLUG (erroneous).aqt
 Date: 11/18/03 Time: 17:58:52

PROJECT INFORMATION

Company: Minerex Environmental Limited
 Client: TES Consulting Engineers
 Project: 1322-Q1
 Test Location: Srahmore, Bangor, Co. Mayo
 Test Well: 4A
 Test Date: 04-11-03

AQUIFER DATA

Saturated Thickness: 28. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (4A)

Initial Displacement: 0.21 m Water Column Height: 27.3 m
 Casing Radius: 0.026 m Wellbore Radius: 0.05 m
 Screen Length: 27. m Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
 K = 2.273E-06 m/sec y0 = 0.2239 m