Appendix A.10.5

Aquifer Tests Report

A.10.5

Galway County Council

N6 Galway City Ring Road

Aquifer Tests

GCOB-04.04-019_A.10.5

Issue 1 | 26 July 2018

Job number 233985-00

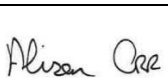
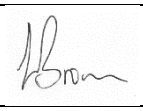
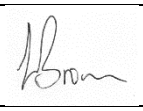
Ove Arup & Partners Ireland Ltd

Arup
Corporate House
City East Business Park
Ballybrit
Galway
H91 K5YD
Ireland
www.arup.com

ARUP

Document Verification

ARUP

Job title		N6 Galway City Ring Road			**Job number** 233985-00
Document title		Aquifer Tests			**File reference**
Document ref		GCOB-04.04-019_A.10.5			
Revision	**Date**	**Filename**	Appendix A.10.5.docx		
Issue 1	26 Jul 2018	**Description**	Issue		
			Prepared by	Checked by	Approved by
		Name	Alison Orr	Les Brown	Les Brown
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
				Issue Document Verification with Document	✓

Contents

Appendices

1 Aquifer Testing

Aquifer testing undertaken as part of the N6 GCRR ground investigations comprises of:

- One pumping test (PW01)
- 15 (No.) variable head tests
- Eight packer tests (BH04 and BH05)

1.1 Pumping Test

The pumping test was undertaken in PW01, which lies immediately east of the existing N6 junction with the Monivea Road. The design of the pumping test comprised of a step test followed by a constant head test. During the step test the recharge rate to the well proved to be too low to complete either the step test or the constant rate test.

The recovery of the groundwater level in PW01 was recorded for two weeks following the aborted test. Analysis of the residual drawdown data by this recovery method estimates a permeability K value of 2x10-8m/s. Further details of this pumping test is contained in **Appendix A.10.5.1**.

1.2 Variable Head Tests

Variable head tests were undertaken as part of the N6 Galway City Transport Project Phase III Ground Investigation Contract 2 works and were supplemented with additional data from rising head tests undertaken where groundwater sampling was performed. This data is summarised below in **Table 1** and comprises of five variable head tests undertake in granite and ten variable head data undertaken in limestone. Refer to **Appendix A.10.3** for the location of the monitoring well locations.

Table 1: Summary of variable head tests

Borehole	Geology	Variable Head test Horslev Method K m/s
BH3/04	Granite	4.60E-06
BH3/06	Granite	1.59E-06
BH3/17	Granite	9.65E-07
BH3/18	Granite	2.38E-06
BH3/20	Granite	2.29E-06
BH3/35	Limestone	2.64E-06
BH3/38	Limestone	3.45E-06
BH3/40	Limestone	5.80E-07
BH3/41	Limestone	2.59E-06
BH3/42	Limestone	2.93E-07
BH3/46	Limestone	1.46E-06

Borehole	Geology	Variable Head test Horslev Method K m/s
BH3/47	Limestone	3.70E-07
BH3/48	Limestone	4.39E-05
LQMW3	Limestone	4.96E-09
BH05	Limestone	5.26E-04*

1.3 Packer Test Data

A total of eight packer tests were undertaken under N6 Galway City Transport Project Phase III Ground Investigation Contract 2of the ground investigation. All packer tests were completed in limestone. These tests comprised of four tests undertaken in BH04 and four tests undertaken in BH05. The focus of these tests was to target fractures and voids in the bedrock to determine the potential higher permeabilities in the formation. The data from the packer tests (**Table 2**) indicates permeabilities that range from $1.5x10^{-5}$m/s to $5.8x10^{-6}$m/s. A number of these Lugeon tests failed to attain the high pressures.

Table 2: Summary of packer tests

Borehole *1	Test Zone	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Interpreted Permeability K*2
	mBGL	m/s	m/s	m/s	m/s	m/s	m/s
BH04	18-20	5.9E-06	6.3E-06	4.5E-06	6.5E-06	5.9E-06	5.8E-06
BH04	21-23	1.5E-05	1.1E-05				1.3E-05
BH04	24-26	3.8E-06	4.4E-06	4.9E-06	6.4E-06	7.1E-06	5.3E-06
BH04	28-30	1.1E-05					1.1E-05
BH05	20-23	1.7E-05	1.4E-05	1.2E-05	1.3E-05	1.8E-05	1.5E-05
BH05	27-29	1.7E-05	1.4E-05	1.2E-05	1.3E-05	1.8E-05	1.5E-05
BH05	30-32	1.8E-05	1.4E-05	1.2E-05	1.5E-05	2.0E-05	1.5E-05
BH05	36-38	2.0E-05	1.5E-05	1.2E-05	1.5E-05	2.0E-05	1.5E-05

*1- BH04 and BH05 are completed in limestone

*2- Interpretation as per Quiñones-Rozo, Camilo (2010):Lugeon test interpretation, revisited. In: Collaborative Management of Integrated Watersheds, US Society of Dams, 30th Annual Conference, S. 405–414.

2 Conclusions

Based on the data a range of permeability is present for both the granite and limestone areas that the proposed road development traverses.

The permeability data for granite provides a range of k values from 9.7 $x10^{-7}$ to 4.6 x 10^{-6}m/s, which is considered to be appropriate for the Galway Granite Batholith. It is however recognised that locally if faulting is present that the permeability can be locally higher, although for very limited distances. On this basis of the testing undertaken, a permeability k value of $4.6x10^{-6}$m/s is considered to be a conservative estimation of groundwater flow in the Galway Granite Batholith.

The permeability data measured for the limestone has a range k values from $5.0x10^{-9}$m/s to $5.3x10^{-4}$m/s. The lower permeability data is from a borehole in Lackagh Quarry, where the borehole intersected few fractures, whilst the highest permeability was recorded less than 1km away in BH05, which includes karst. The range of permeability is typical of karst and the types of flow paths that can develop.

Based on the permeability data recorded an estimate k value of $1.5x10^{-4}$m/s is taken as a conservative value for the Visean Undifferentiated Limestone. This estimate is based upon one order of magnitude greater than the highest permeability calculated from the packer tests in BH05, where the test was focused on measuring high flows but not as high as the permeability k value of $5.3x10^{-4}$m/s which was recorded in karst.

Appendix A.10.5.1

Pumping Test PW01 Report

A.10.5.1

Galway County Council

N6 Galway City Ring Road

Pumping Test PW01

Pumping Test PW01

Issue 1 | 1 June 2017

Job number 233985-00

Ove Arup & Partners Ireland Ltd

Arup
50 Ringsend Road
Dublin 4
D04 T6X0
Ireland
www.arup.com

ARUP

Document Verification

ARUP

Job title		N6 Galway City Ring Road		**Job number** 233985-00
Document title		Pumping Test PW01		**File reference**
Document ref		Pumping Test PW01		
Revision	**Date**	**Filename**		
Issue 1	1 Jun 2017	**Description**	Issue	
			Prepared by	Checked by	Approved by
		Name	Alison Orr	Christoper Newton	Les Brown
		Signature			
		Filename		
		Description		
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename		
		Description		
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename		
		Description		
			Prepared by	Checked by	Approved by
		Name			
		Signature			
				Issue Document Verification with Document	✓

Contents

1 Introduction

A pumping test was carried out in the area between the Monivea Road and the existing N6.

The pumping test site lies immediately east of the existing N6 junction with the Monivea Road, adjacent to the Galway Technology Park and Galway Racecourse. The location forms part of the high ground east of Galway City and has a gentle topography that lies between 40-50m OD (EPA topography, GSI Data Viewer). The site in which the pumping tests were carried out is currently agricultural land.

1.1 Objective

The objective of this factual report is to present a summary of the results of a pumping test carried out at the site to inform the design of any proposed dewatering.

1.2 Outline of the pumping test

The pumping test was carried out as part of N6 Galway City Transport Project Phase III Ground Investigation Contract 3 in accordance with BS ISO 14686:2003. The pumping well was drilled by Dempsey Drilling (Sub-contracted by Priority Drilling) on the 30 of November 2016. The pumping test was carried out by Priority Drilling between the 24 and 25 of January 2017. The test comprised:

- Drilling of the pumping well
- A step testing
- Recovery

A summary of the pump test is presented in Section 3

2 Background

2.1 Site investigations

Site investigations, including trial pits and boreholes, were carried out in February to March 2016 as part of N6 Galway City Transport Project Phase III Ground Investigation Contract 1. The results of this investigation are presented in the IGSL report dated January 2017, included in Appendix A.9.1.

The ground investigations as part of Phase III Contract 1 include:

- Five boreholes; BH3/40, BH3/41, BH3/42, BH3/43 and BH3/48. The boreholes were drilled by cable percussion with rotary follow on and standpipes were installed
- Two trial pits; TP3/30 and TP3/32

An additional two monitoring boreholes, RC03-63 and RC03-64 and one pumping well, PW01, were drilled as part of N6 Galway City Transport Project Phase III

Ground Investigation Contract 3. The monitoring boreholes were completed with 50mm diameter standpipes to allow for groundwater monitoring.

2.2 Geology

A summary of the geology proven is presented in **Table 1**.

Table 1: Geological description

Stratum	Depth to top of strata (mBGL)	Thickness (m)
Topsoil	0	0 to 0.3
Sandy gravelly CLAY	0 to 0.15	0.35 to 0.4
Sandy gravelly SILT	0.1 to 0.5	0 to 0.45
Weathered rock	0.4 to 5.0	0.6 to 4.8
Limestone described as fresh to slightly weathered with occasional clay filled fractures.	1.2 to 5.0	>19

The site investigation has shown that competent bedrock lies1.2 to 5.0m below ground level in the area of the pumping test. Above the competent rock the borehole log records no recovery, observed by the driller as weathered rock or as cobbles and boulders.

3 Pumping test

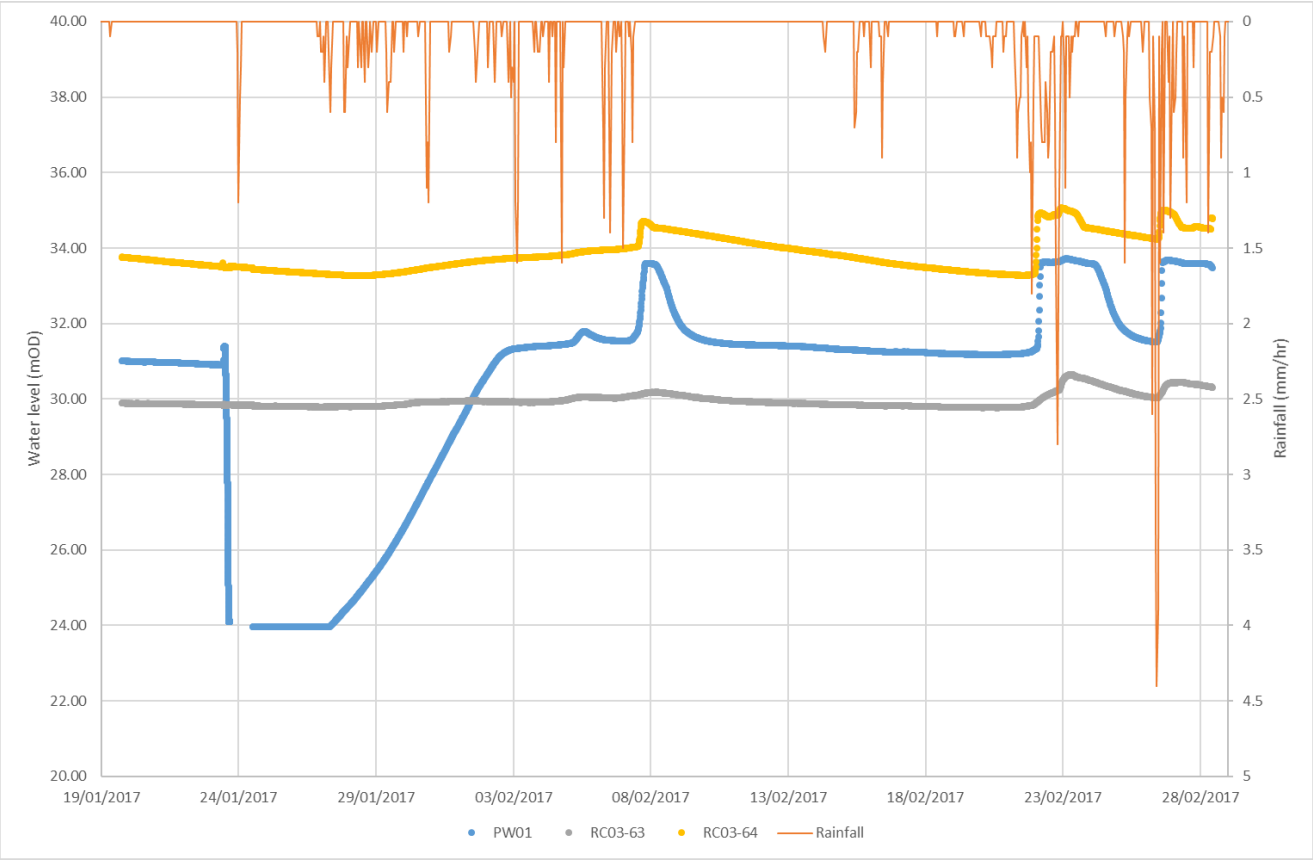
A pumping test was carried out in pumping well PW/01. A log of PW/01 and the details of the construction is presented in Annex 1 of this report.

3.1 Monitoring

Groundwater levels were continually monitored in PW01 and observation wells, RC03-63 and RC03-64 prior to, during and after the pumping test. The results of the water level monitoring are presented in a hydrograph in **Figure 1**.

.

Figure 1: Hydrograph of water levels in pumping well PW01 and monitoring wells RC03-63 and RC03-64



The methodology for the pumping test was to carry out a step test with a pumping rate of 0.5l/s, followed by sequential increases to 1l/s, 2l/s and 3l/s. A constant rate test would have followed recovery of the well at a rate indicated from the step test data. However, during the first step test that water level was drawn down very rapidly at a constant rate without stabilisation. On the basis of the result the initial step the pumping rate was continued for 3hours to see if the water level stabilised. However, the rate of drawdown remained constant and after 3 hours the water level dropped to the level of the pump intake and the test was stopped. The drawdown achieved during the step test was 7.8m.

A response to the pumping test in PW01 showed no initial drawdown in either monitoring wells BH03-63 and BH03-63 (**Figure 1**).

Recovery of the borehole occurred 7 days following the pumping test following significant rainfall. Responses in the groundwater level were observed following rainfall events on the 8/02/2017 and 22/02/2017 (**Figure 1**).

4 Conclusion

The step test in PW01 was unable to be completed due to the groundwater level lowering below the level of the pump intake during the first step pumping rate (0.5l/s). Recovery of groundwater level to the initial level took seven days following the step test. The data from the step test was used to determine permeability based on the residual drawdown data using this recovery method, which indicates a permeability of 2×10^{-8}m/s.

Annex 1 - PW01 Borehole log

ARUP

Borehole Log

Job No.	Hole ref	Page
233985-00	**PW01**	1 of 2

Contractor: Dempsey Drilling

Galway City Transport Project

NG co-ordinates	Ground Level (mOD)	Date
		30/11/2016

Samples & tests			Water	Strata log				Geology	Instrument/ Backfill
Depth	Sample Type Ref	Test Result		Red. Level	Legend	Depth (Thick-ness)	Description		
						(3,00)	Dark grey or black WEATHERED LIMESTONE. Recovered as limestone chippings. (BURREN FORMATION)		
						3,00			
						(12,00)	Dark grey or black LIMESTONE. Recovered as limestone chippings. Driller noted that the limestone was harder (BURREN FORMATION)		

Open hole between 3 and 15 mBGL

Client

Logged by: Laura McGrath

Database check:

ARUP	Borehole Log	Job No. 233985-00	Hole ref **PW01**	Page 2 of 2
		Contractor Dempsey Drilling		
Galway City Transport Project		NG co-ordinates	Ground Level (mOD)	Date 30/11/2016

Samples & tests			Water	Strata log				Geology	Instrument/ Backfill
Depth	Sample Type Ref	Test Result		Red. Level	Legend	Depth (Thick-ness)	Description		
							Dark grey or black LIMESTONE. Recovered as limestone chippings. Driller noted that the limestone was harder (BURREN FORMATION) *(continued)*		
							.... 11,00 - 15,00 Limestone is dark grey		
						15,00			
							Borehole completed at 15m depth		

Open hole between 3 and 15 mBGL

Client	Logged by: Laura McGrath	Database check: