Appendix A.10.8

Eco-hydrologeology Reports

A.10.8.1 Moycullen Bogs

A.10.8.2 Lough Corrib SAC

A.10.8.1 Eco-hydrologeology Report

Moycullen Bogs NHA

Galway County Council

N6 Galway City Ring Road

Eco-hydrogeology Summary Report for Moycullen Bogs NHA

Reference: GCRR_4.04.03_30.9.10_A.10.8.1

Issue 3 | 28 March 2025

Job number 233985-00

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Document Verification

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		Name	Les Brown	Catherine Buckley	Mary Hurley
		Signature			
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		Description	Issue for 2025 RFI Response		
			Prepared by	**Checked by**	**Approved by**
		Name	Les Brown	Alison Orr	Gerry Baker
		Signature	[signature]	[signature]	[signature]

Issue Document Verification with Document ✓

Contents

Appendices

1. Introduction

1.1 Overview

This report is an updated version of the report produced during the 2020 Oral Hearing to inform the hydrogeology assessment for the updated EIAR and updated NIS as part of the response to the request by ABP for further information in December 2023. This Appendix has been updated to incorporate all data presented during the oral hearing. The data presented also includes subsequent data that has been collected during the intervening period since the 2020 Oral Hearing, which includes data that is publicly available, and data specifically collected for this project.

Moycullen Bogs NHA was identified as one of the Groundwater Dependant Terrestrial Ecosystems in Chapter 10 of the updated EIAR. The Moycullen Bogs NHA encompasses three separate bog sites including, from west to east, the main area near Lough Inch, and two isolated areas at Tonabrocky and Letteragh. The hydrogeology of the peatland water table has been assessed in detail in Section 10.3.3.1 of Chapter 10 of the updated EIAR and the impact assessment undertaken in Section 10.5.3 of Chapter 10 of the updated EIAR.

Areas of the Moycullen Bogs NHA at Lough Inch are either in a separate catchment or down gradient of the proposed N6 GCRR and therefore are not at risk from groundwater drawdown induced from cuttings.

The area of the Moycullen Bogs NHA at Tonabrocky lies in a distinct sub-catchment to that of the proposed N6 GCRR. Tonabrocky and the proposed N6 GCRR are separated by a surface watercourse, with the proposed N6 GCRR located 450m distant from Tonabrocky at its closest and the proposed N6 GCRR is raised on an embankment in that section. Accordingly, the area of the Moycullen Bogs NHA at Tonabrocky is not at risk from groundwater drawdown induced from cuttings.

The area of the Moycullen Bogs NHA at Letteragh lies on high ground west of the River Corrib. The NHA lies on the catchment divide between (i) groundwater that drains eastward and northwards to the River Corrib and (ii) groundwater that drains southward towards Galway Bay. In the granite area, the surface water and groundwater catchments are the same.

The proposed N6 GCRR in this location comprises:

- the main alignment, which is in a deep cutting at Letteragh
- the N59 Link Road North, which is at grade, or on embankment close to Moycullen Bogs and then in a cutting just before the N59 Moycullen Road

This Eco-Hydrogeology Report summarises the ecological and hydrogeological assessments which have been undertaken at the Moycullen Bogs NHA (Letteragh) from the mainline of the proposed N6 GCRR and the N59 Link Road North. The results of this assessment includes four cross-sections drawn between the proposed N6 GCRR at Moycullen Bogs NHA (Letteragh), which are presented in Appendix A of this updated A.10.8. The sections comprise:

- Section A-A: North south section between the mainline Letteragh cutting and the main area of the NHA that is permanently ponded
- Section B-B: North south section between the mainline Letteragh cutting and a satellite area of the NHA that is permanently ponded
- Section C-C: West east section from the N59 North Link Road cutting to both the main and satellite ponded areas
- Section D-D: North south section from N59 North Link Road to a closest point to the NHA

2. Groundwater Dependent Qualifying Habitat at Moycullen Bogs NHA

Moycullen Bogs NHA is designated as a Natural Heritage Area under the Wildlife Acts 1976 to 2019 for peatland habitats. The main habitat on the site is the Annex I habitat Blanket bog [*7130] but the site also supports a diversity of other peatland and fen habitats including Wet heath [4010], Dry heath [4030] and Alkaline fen [7230].

The Moycullen Bogs NHA lies immediately adjacent to the proposed N6 GCRR boundary at Letteragh. At Letteragh, the NHA comprises a mosaic of habitats including dystrophic lakes (FL1), reed and large sedge swamp (FS1), wet grassland (GS4), dry siliceous heath (HH1), wet heath (HH3), lowland blanket bog (PB3), poor fen and flush, (PF2), transition mire and quaking bog (PF3) and scrub (WS1). The Annex I habitat types present at Tonabrocky are Dystrophic lakes [3160], Wet heath [4010], Dry heath [4030], Blanket bog [*7130], Transition mires [7140] and Rhynchosporion depressions [7150].

The extent, distribution and condition of peatland habitats are predominantly controlled by hydrological processes, with water being supplied by a combination of precipitation, overland flow and flow through the peat layer. The depth of peat and the depth of the water table are also critical components of a peatland ecosystem in determining habitat extent and distribution.

The hydrogeological regime, particularly the natural groundwater table, must be maintained so that the area, distribution and depth of the peatland habitats and their constituent/characteristic vegetation zones and communities are not reduced or compromised in any way.

The Fossitt classifications of the habitats within Moycullen Bogs NHA at Letteragh, that lie in the immediate vicinity of the proposed N6 GCRR, are shown on Figures 8.19.5 and 8.19.6 of the updated EIAR. For ease of reference the habitats with Fossitt classifications are reproduced below in Figure 1 noting that this was considered in the application documentation (Figure 1 below is Figure 8.19.6 of the updated EIAR for the purposes of clarification).

The Annex I classifications of the habitats within Moycullen Bogs NHA at Tonabrocky, that lie in the immediate vicinity of the proposed N6 GCRR, are shown on Figures 8.22.5 and Figure 8.22.6 of the updated EIAR. For ease of reference the habitats with Annex I classifications are reproduced below in Figure 2 noting that this was considered in the application documentation (Figure 2 below is Figure 8.22.6 of the updated EIAR for the purposes of clarification).

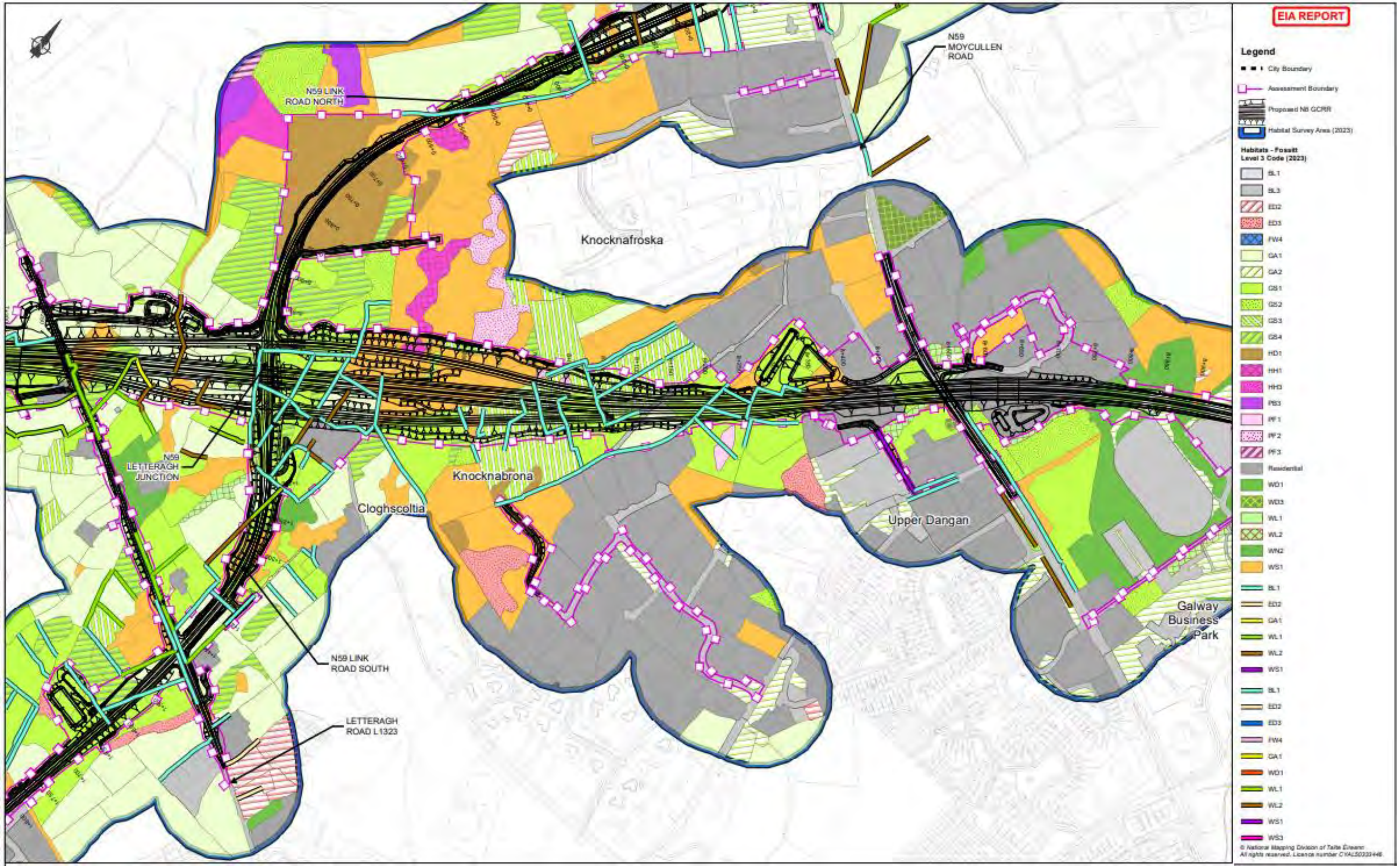


Figure 1 Fossitt classifications of the habitats within Moycullen Bogs NHA at Letteragh

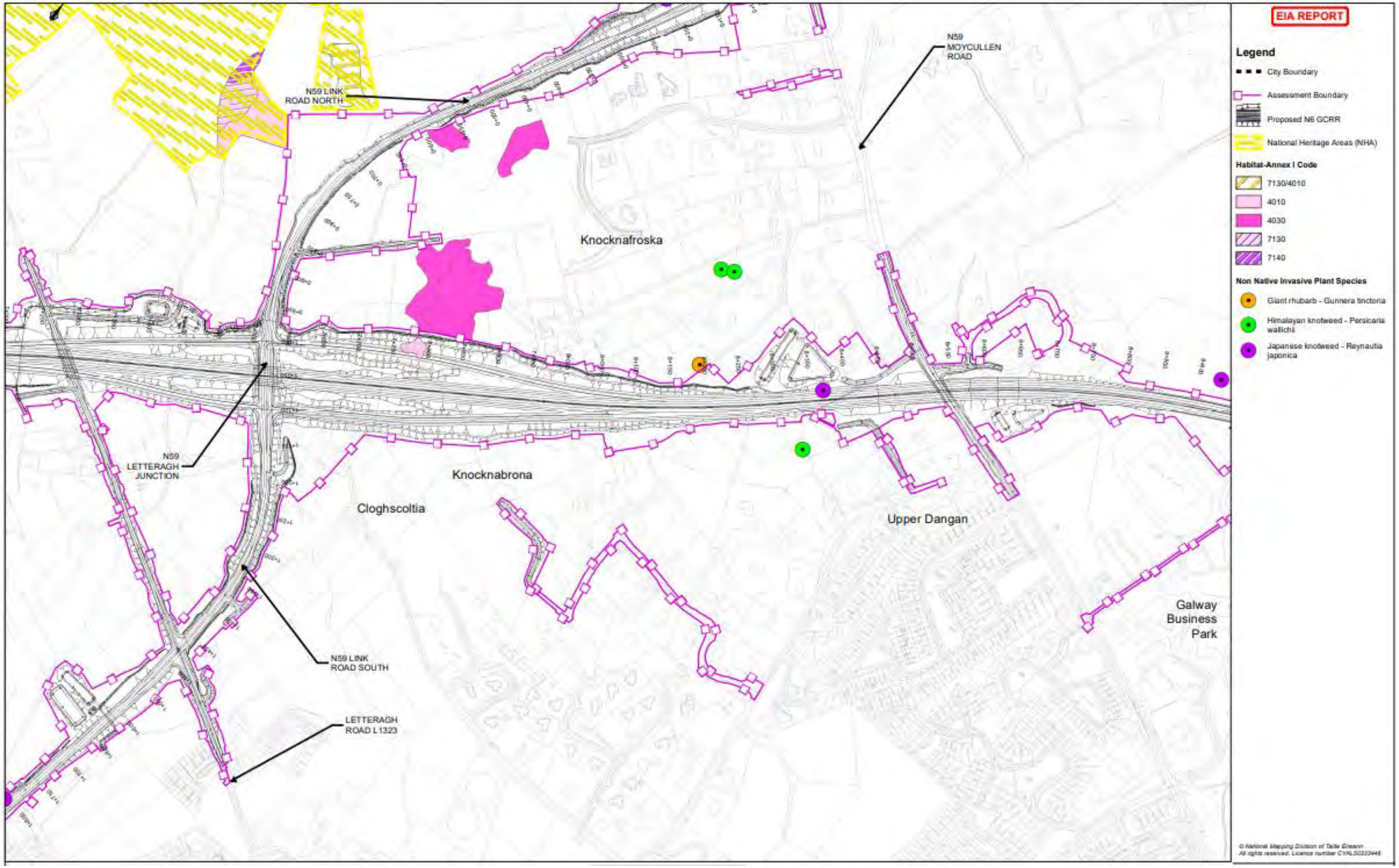


Figure 2 Annex I Classification of the habitats within Moycullen Bogs NHA at Letteragh

3. Hydrogeology Impact assessment

The hydrogeology of the Galway Granite Batholith includes areas where there is poor drainage and water ponding at the surface, and these areas include the Moycullen Bogs NHA. Where surface water ponding occurs, there is often little or no seasonal variation in the water level, with most areas remaining ponded throughout the summer.

The undulating topography of the Galway Granite Batholith includes areas of topographic highs where bedrock is near surface and topographic lows where the subsoils are thicker (up to 3m). On the topographic highs, rainfall runs off as overland flow whilst it is the low-lying ground where surface ponding, as discussed above, tends to occur.

The GSI vulnerability data and the Project ground investigation data together with the Tailte Éireann topographic data show that the granite has an undulating rock topography. As the granite is of low permeability, it will perch surface water and where drainage is poor, such in flat lying areas, surface water will be impounded and ponded. Due to the way that granite weathers, it forms an undulating rounded topography of ridges. The ridges occur where the rock is competent, hard and not weathered. The low points form where the granite has weathered, and these are the main areas where water collects and forms permanent ponds. The water level in these areas tends not to vary as it is limited to spill points in the surrounding rock topography.

Connectivity between groundwater and the ponded surface water will be slight. As such, the water ponding on the surface at the Moycullen Bogs is not groundwater from the bedrock but water ponded on the top of the bedrock that has saturated the subsoil, has no natural discharge point, and so breaches the ground surface (i.e. pluvial ponding).

The Letteragh cutting on the mainline is shown on Figure 10.6.006 (plan and profile) of the updated EIAR with minimum and maximum groundwater levels shown. The drawdown extents calculated for the Letteragh cutting and the N59 Link Road North are shown on Figure 10.7.106 (construction) and 10.8.106 (operation) of the updated EIAR.

As reference above, four additional cross-sections are included in Appendix A of this updated A.10.8 to show the extent of drawdown relative to the permanently ponded areas in Moycullen Bogs NHA (Letteragh). These cross-sections show drawdown from the mainline Letteragh cutting as well as the N59 Link Road North. Sections A-A and B-B show the drawdown from the mainline Letteragh cutting to the main permanent ponded area in the NHA as well as a satellite ponded area located to the southeast. Sections C-C shows drawdown from the main cutting on the N59 Link Road North and Section D-D shows the proposed road at its closest proximity to the Moycullen Bogs NHA (Letteragh).

For all granite cutting assessments, the lateral extent of drawdown is calculated using the Sichardt calculation, which is an empirical calculation based on the vertical extent to which the groundwater table is lowered at the point of groundwater dewatering and permeability. The Sichardt calculation is presented in Appendix A.10.6 to Chapter 10, of the updated EIAR and for clarity also presented below:

$$R_o = 3000\ h\sqrt{K} \qquad \text{(Sichart equation)}$$

Where,

R_o = Radius of influence (m)

h = Drawdown (m)

k = Hydraulic conductivity (m/sec)

The two variables used in calculating the lateral extent of drawdown, the vertical lowering and permeability, were assessed conservatively.

Vertical lowering is the height difference between drainage invert and peak recorded groundwater table (for granite the water table is often at, or near, surface). The dewatering level along any road level is the invert of trenches excavated for road drainage. To ensure that drawdown was assessed conservatively, the drainage invert was set to 1m deeper than the maximum invert level. On this basis a dewatering level of road surface minus 3m was set for the full alignment on granite. A conceptualisation of the cutting assessment is presented in Figure 3 below.

Further conservative measures were used in estimating the permeability which is the second variable in determining the lateral extent of drawdown. A permeability value of 4.6×10^{-6}m/s was used, which is considered high for granite except where significant fractures are present. It is noted that fracturing is identifiable by geophysics and both seismic and resistivity surveys were completed along the full length of the mainline cutting at Letteragh and the cutting at the N59 Link Road North. The mainline cutting does not show any significant zones of weathering along its length. The N59 Link Road North cutting has a vertical weathering zone at Ch 0+260 but as with the dominant fracture orientation in the area this feature is aligned generally north south and away from the Moycullen Bogs NHA (Letteragh).

Managing groundwater inflows at cuttings is included in the Construction Environmental Management Plan (CEMP) in Appendix A.7.5 of the updated EIAR and Appendix C of the updated NIS. Where significant inflows occur then the karst protocol detailed in the CEMP will be used to manage flows and prevent impact to receiving waters.

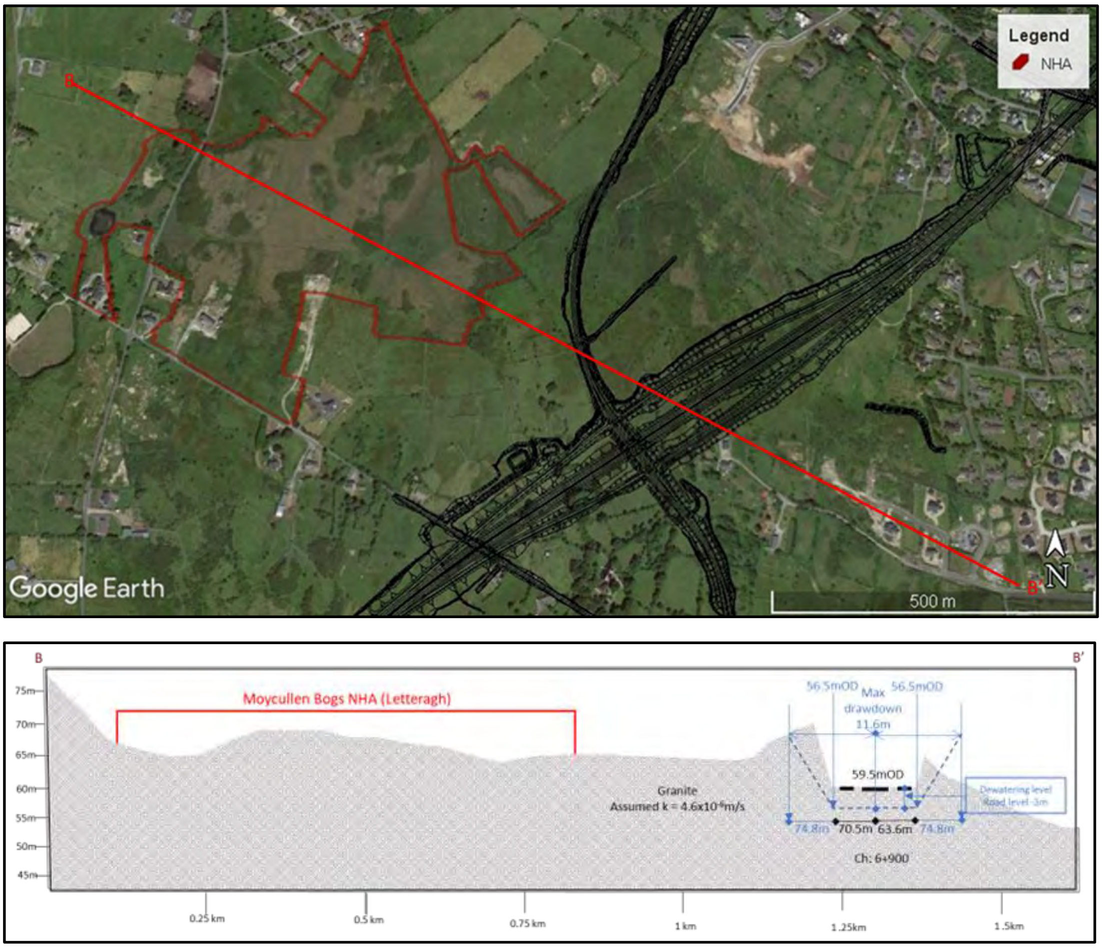


Figure 3 Conceptualisation of the cutting assessment at Letteragh Cutting Ch. 7+900

Using this assessment, the drawdown extent has been delineated and is presented in Figure 10.7 (construction) and 10.8 (operation) of the updated EIAR (for description of drawdown extent calculation refer to EIAR Chapter 10 section 10.4.6 and EAIR Appendix 10.6).

As part of the ground investigation undertaken at the Letteragh cutting, boreholes were drilled to prove the depth to bedrock as well as a geophysical survey. This data confirms that the bedrock at the Letteragh cutting is either at or consistently close to surface. On this basis, groundwater levels will not be lowered beyond the maximum conservative drawdown presented in the updated EIAR. Based on the assessment there is no risk to the Moycullen Bogs NHA at Letteragh from drawdown in the bedrock groundwater induced by the Letteragh cutting or N59 Link Road North cutting.

4. Conclusion

The Project poses no risk of affecting the hydrogeological/hydrological regimes supporting the peatland habitats in Moycullen Bogs NHA (Letteragh).

Mitigation measures proposed ensure that the proposed N6 GCRR does not affect the hydrogeological regime supporting the groundwater dependent habitats in Moycullen Bogs NHA (Letteragh).

In circumstances where the hydrogeological zone of influence does not extend to Moycullen Bogs NHA, and where neither construction nor operation of the proposed N6 GCRR will have any effect on the hydrogeological regime within Moycullen Bogs NHA, habitat degradation because of impacts on the existing groundwater regime in Moycullen Bogs NHA will not arise. Therefore, there are no residual direct or indirect groundwater related impacts that could have any likely significant residual effects on Moycullen Bogs NHA.

In conclusion, there will be no groundwater related impacts to the Moycullen Bogs NHA (Letteragh).

Appendix A

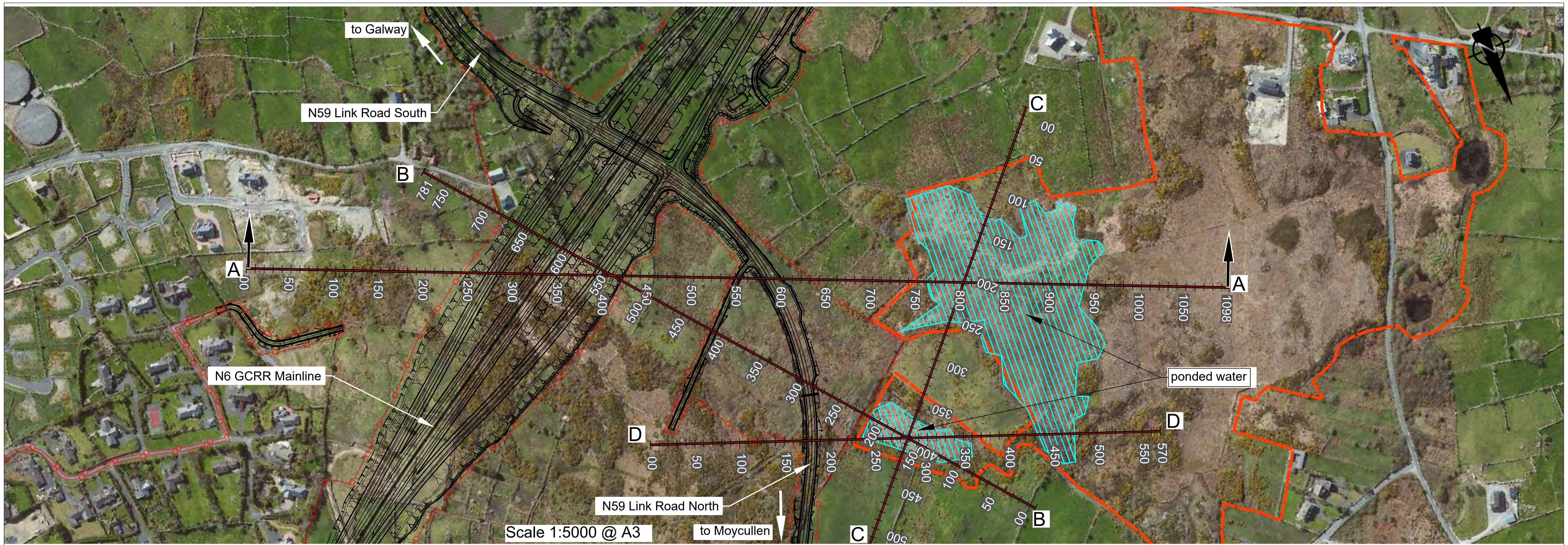
Cross-Sections

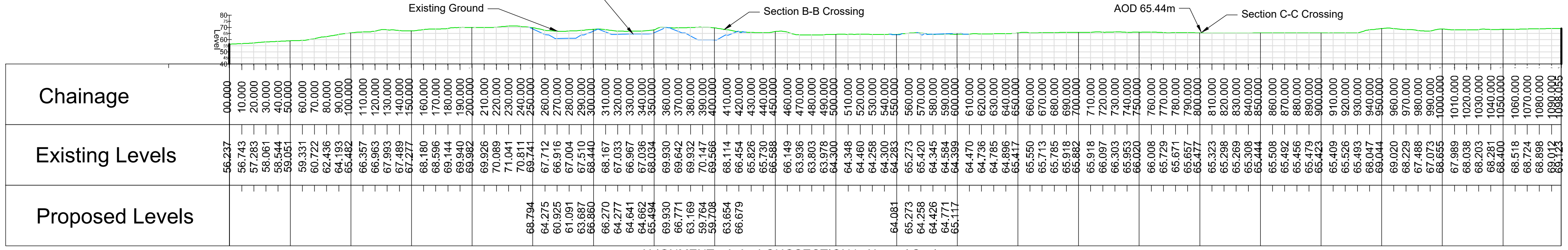
A.1 Cross-Sections

FOR INFORMATION

Legend:

- Proposed Development Boundary
- Proposed Road Development
- Cross-Section Path
- NHA Area Boundary





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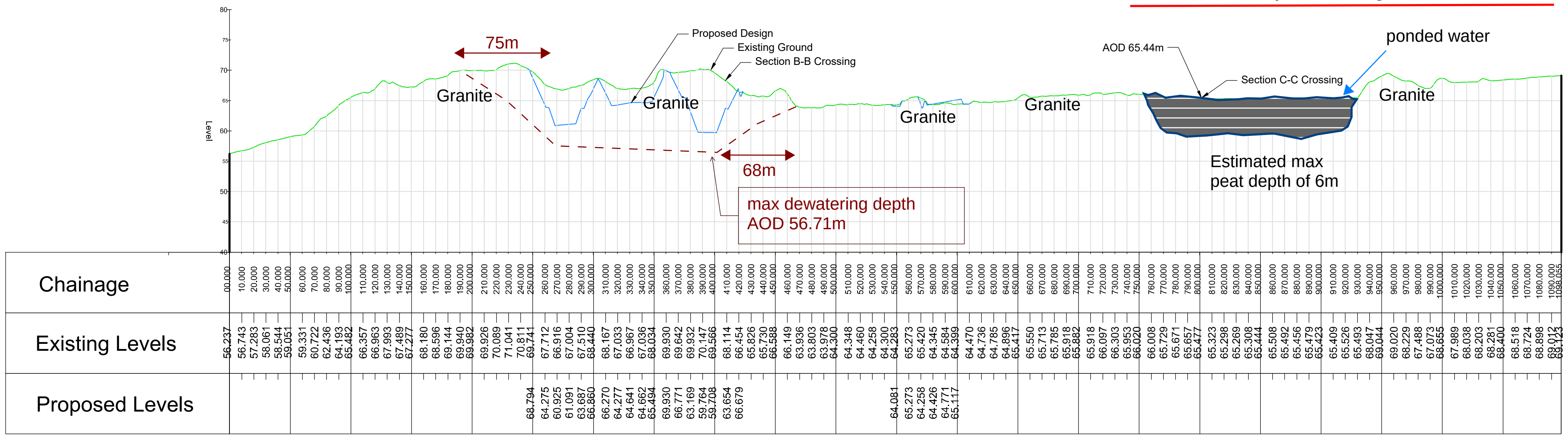
Moycullen Bogs NHA



ALIGNMENT - A-A - LONGSECTION in 5x Exaggeration Scale
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Job Title
N6 Galway City Ring Road

Scale: @A3 H 1:5000 , V - See Profile Scale

Date: March 2020

Issue	Date	By	Chkd	Appd
I2	05/03/2020	KJ	LB	EMC
I1	02/03/2020	KJ	LB	EMC

Drawing Title
Existing Ground & Proposed Design
Cross Section Letteragh A-A

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	GCOB-SK-OH-033	I2

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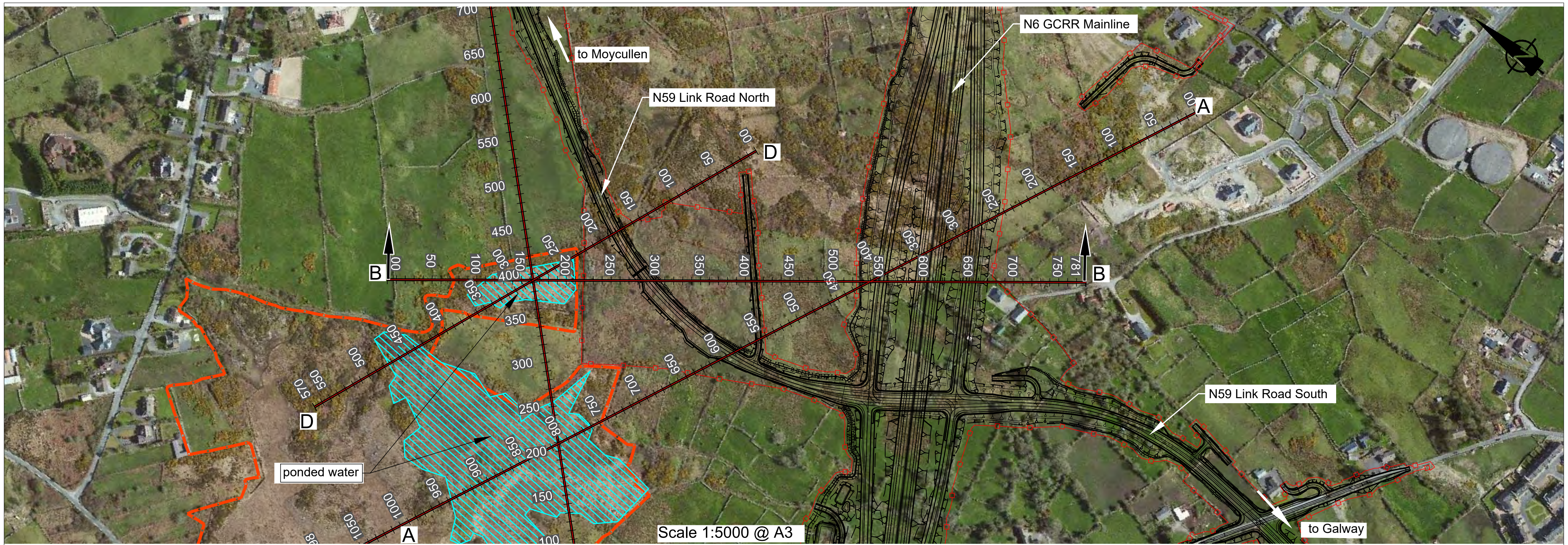
FOR INFORMATION



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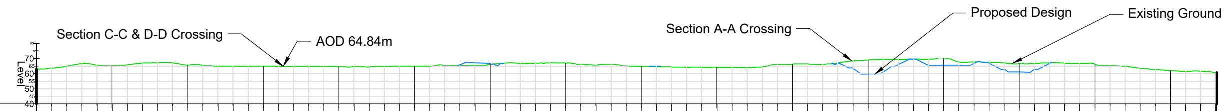

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60.000	65.714	
70.000	66.900	
80.000	67.154	
90.000	67.098	
100.000	65.646	
110.000	65.563	
120.000	64.970	
130.000	64.835	
140.000	64.794	
150.000	64.898	
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180.000	64.831	
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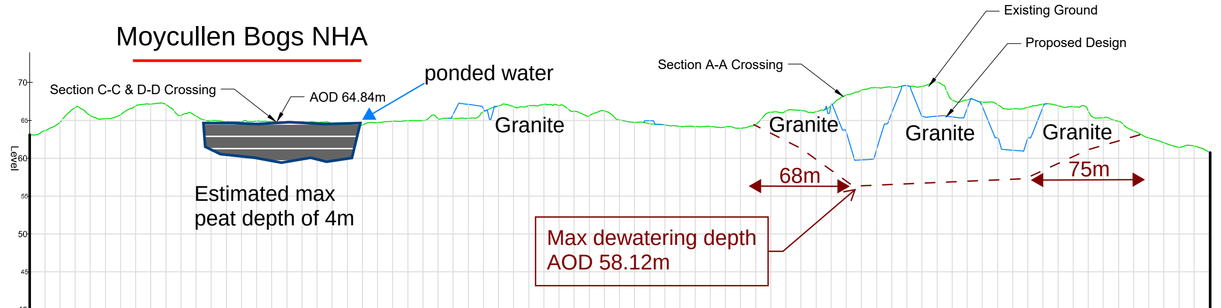

Chainage	Existing Levels	Proposed Levels
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20.000	64.785	
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710.000	65.351	
720.000	64.878	
730.000	63.600	
740.000	62.693	
750.000	62.076	
760.000	61.434	
770.000	61.598	
780.000	60.769	
780.604	60.802	

ALIGNMENT - B-B - LONGSECTION in 5x Exaggeration Scale
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Job Title
N6 Galway City Ring Road

Scale: @A3 H 1:5000 , V - See Profile Scale

Date: March 2020

Issue	Date	By	Chkd	Appd
I2	05/03/2020	KJ	LB	EMC
I1	02/03/2020	KJ	LB	EMC

Drawing Title
Existing Ground & Proposed Design

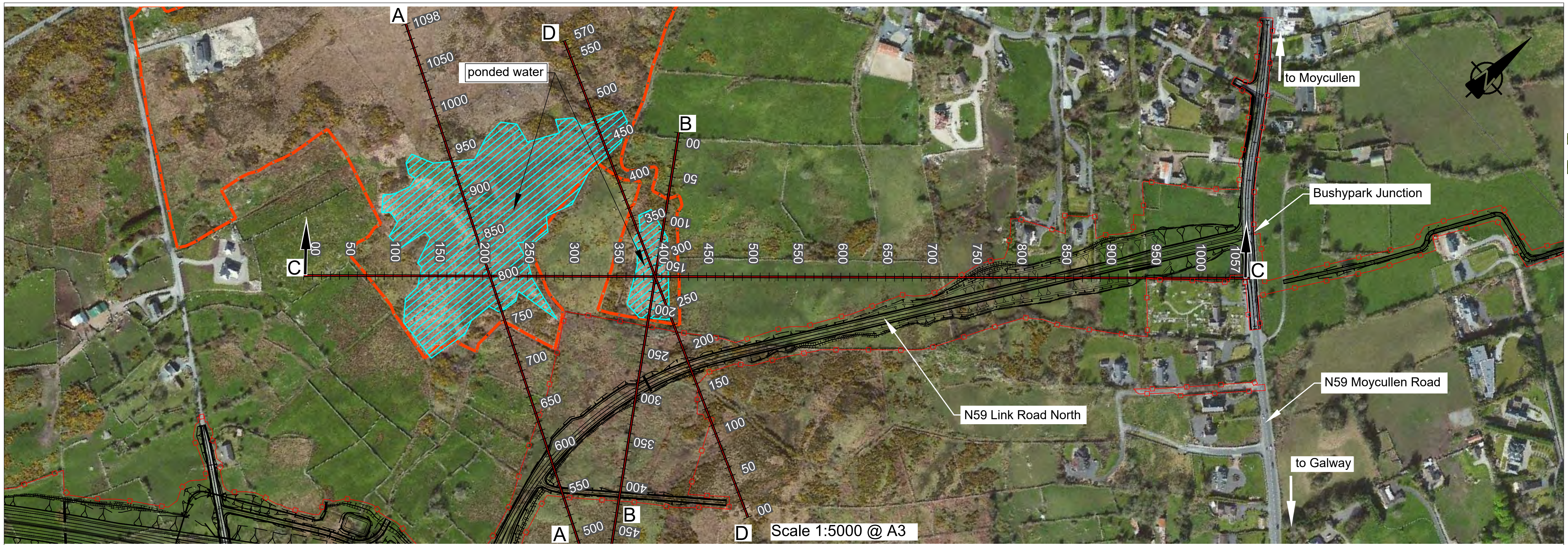
Cross Section Letteragh B-B

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	GCOB-SK-OH-034	I2

Do not scale

FOR INFORMATION



Legend:

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- Proposed Road Development
- Cross-Section Path
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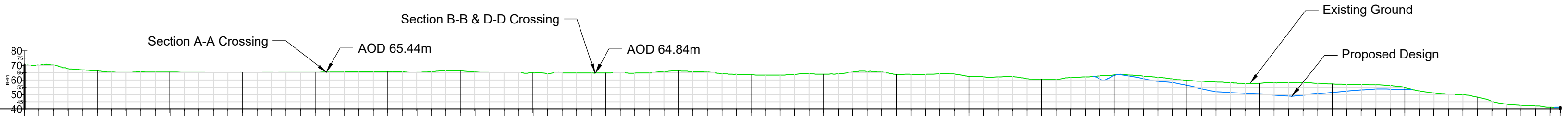

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770.000	62.649	60.920
780.000	61.896	59.052
790.000	60.702	58.216
800.000	59.756	56.217
810.000	59.195	54.109
820.000	58.669	52.001
830.000	58.151	51.415
840.000	57.448	50.831
850.000	57.716	50.246
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910.000	56.877	52.451
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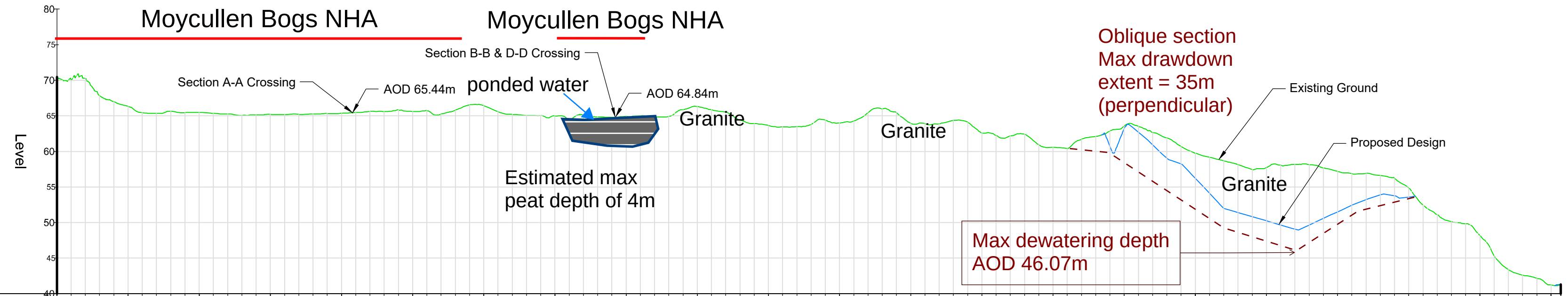

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1056.908	41.250	41.284

ALIGNMENT - C-C - LONGSECTION in 5x Exaggeration Scale
SCALE @ A3: H 1:5000,V 1:1000. DATUM: 40m AOD

Clients: An Roinn Iompair Turasóireachta agus Spóirt; Project Ireland 2040; N6 Galway City Transport Project; Comhairle Chontae na Gaillimhe Galway County Council; TII

Consultant: ARUP
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Job Title: N6 Galway City Ring Road

Scale: @A3 H 1:5000 , V - See Profile Scale

Date: March 2020

Issue	Date	By	Chkd	Appd
I2	05/03/2020	KJ	LB	EMC
I1	02/03/2020	KJ	LB	EMC

Drawing Title: Existing Ground & Proposed Design

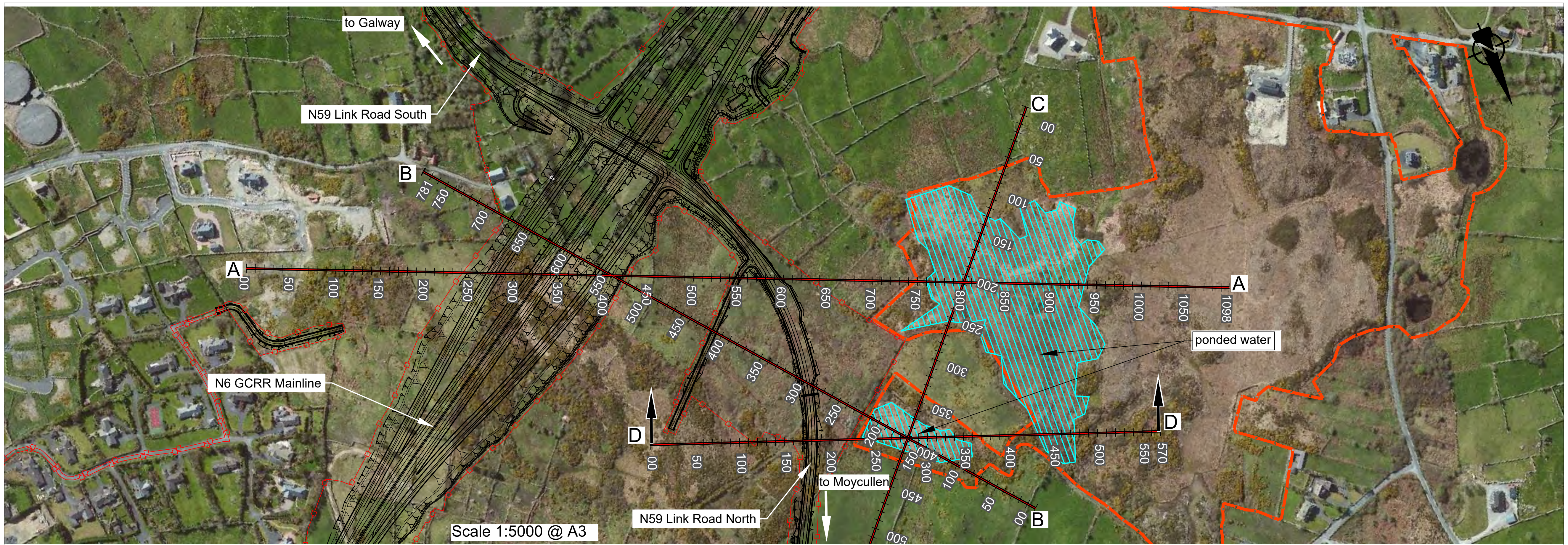
Cross Section Letteragh C-C

Drawing Status: For Information

Job No	Drawing No	Issue
233985-00	GCOB-SK-OH-035	I2

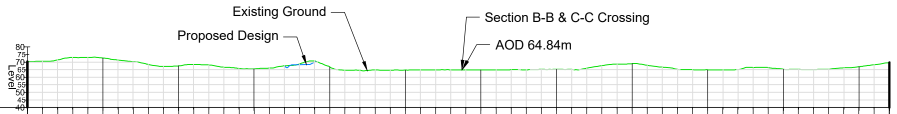
Do not scale

FOR INFORMATION



Legend:

- Proposed Development Boundary
- Proposed Road Development
- Cross-Section Path
- NHA Area Boundary



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ALIGNMENT - D-D - LONGSECTION in Natural Scale
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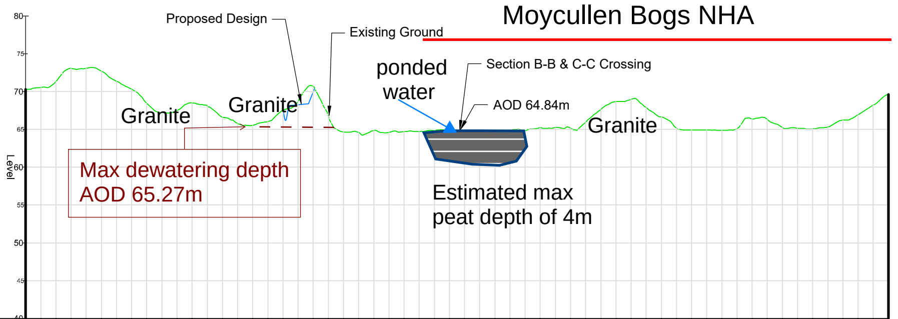

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180.000	68.722	68.273
190.000	70.705	69.966
200.000	66.773	
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Clients

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Project Ireland 2040
Galway City Transport Project
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I2	05/03/2020	KJ	LB	EMC
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Drawing Title
Existing Ground & Proposed Design
Cross Section Letteragh D-D

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	GCOB-SK-OH-036	I2

Do not scale

A.10.8.2 Eco-hydrologeology Report

Lough Corrib SAC

ARUP

Galway County Council

N6 Galway City Ring Road

Eco-hydrogeology Summary Report for Lough Corrib SAC

Reference: GCRR_4.04.03_30.9.10_A.10.8.2

Issue 3 | 28 March 2025

Job number 233985-00

Ove Arup & Partners Ireland Limited
Arup Corporate House
City East Business Park Ballybrit
Galway
Ireland
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Document Verification

Project title	N6 Galway City Ring Road
Document title	Eco-hydrogeology Summary Report for Lough Corrib SAC
Job number	233985-00
Document ref	GCRR_4.04.03_30.9.10_A.10.8.2
File reference	GCRR_4.04.03_30.10_Appendix A.10.8.2

Revision	**Date**	**Filename**	GCRR_4.04.03_30.9.10_A.10.8.2		
Issue 1	6 Mar 2020	**Description**	Issue 1 Issued during 2020 Oral Hearing		
			Prepared by	**Checked by**	**Approved by**
		Name	Les Brown	Catherine Buckley	Mary Hurley
		Signature			
Issue 2	10 Mar 2020	**Filename**	GCRR-4.03.34.17 Ecohydrogeology Coolagh Lakes I2.docx		
		Description	Issued during 2020 Oral Hearing		
			Prepared by	**Checked by**	**Approved by**
		Name	Les Brown	Catherine Buckley	Mary Hurley
		Signature			
Issue 3	28 March 2025	**Filename**	GCRR-4.04.03_30.9.10_A.10.8 Ecohydrogeology Coolagh Lakes I3.docx		
		Description	Issue for 2025 RFI Response		
			Prepared by	**Checked by**	**Approved by**
		Name	Les Brown	Alison Orr	Gerry Baker
		Signature	L Brown	Alison Orr	Gerry Baker

Issue Document Verification with Document ✓

Contents

Appendices

1. Introduction

1.1 Overview

This report is an updated version of the report produced during the 2020 Oral Hearing to inform the hydrogeology assessment for the updated EIAR and updated NIS as part of the response to the request by ABP for further information in December 2023. This Appendix has been updated to incorporate all data presented during the oral hearing. The data presented also includes subsequent data that has been collected during the intervening period since the 2020 Oral Hearing, which includes data that is publicly available, and data specifically collected for this Project.

1.2 Location of Coolagh Lakes

Coolagh Lakes are located to the east of the River Corrib and are part of the Lough Corrib SAC. The location of the Lough Corrib SAC is presented in Plate 1 relative to the buried valleys that form part of the palaeolandscape, which have been identified in the wider area.

Plate 1 Lough Corrib SAC

The River Corrib is a substantial river that is not dependent on groundwater. However, the Coolagh Lakes, which ultimately discharge to the River Corrib, are mainly groundwater fed. Groundwater contributions are a combination of flow from a karst spring (Western Coolagh Spring) as well as from seepages around the periphery of the lakes. The location of Coolagh Lakes and Western Coolagh Spring are shown on Plate 2.

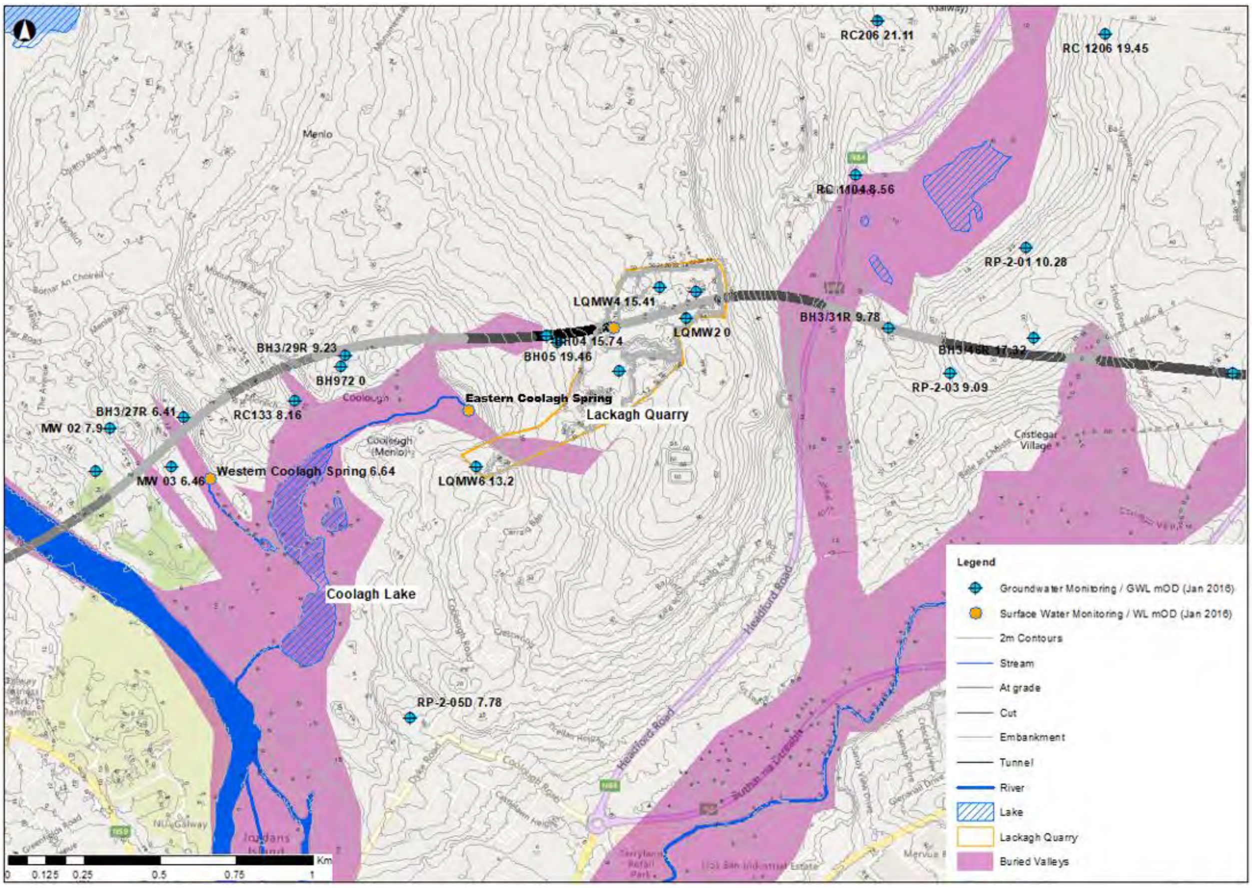


Plate 2 Location of Coolagh Lakes relative to Lackagh Quarry

1.3 Purpose of report

Biodiversity assessments have identified that the habitats at the Coolagh Lakes are dependent on the lake water level and lake water quality. On this basis, the groundwater dependant terrestrial ecosystems (GWDTE) around the lake margins are dependent on the groundwater contribution to Coolagh Lakes. The hydrogeological setting and interaction between groundwater, the Coolagh Lakes and the River Corrib are explored in terms of both water level and water quality in this summary report.

The Geotechnical and Hydrogeological Appraisal of the Lackagh Tunnel (EIAR Appendix A.7.3 of the updated EIAR and Appendix F of the updated NIS) and Chapter 10 of the updated EIAR assessed whether construction dewatering activities or the operational presence of the tunnel may act as a barrier to flow and intercept or divert the groundwater flow supplying Coolagh lakes, with the risk of compromising the integrity of the habitats.

Extensive assessments were undertaken to ensure that the hydrogeological regime was fully understood so that any potential impacts could be assessed.

To assess the potential for any impacts, the hydrogeological regime requires characterisation. This summary describes the major features of the hydrogeology and answers two critical concerns:

1. Does the groundwater from Lackagh Quarry drain to Coolagh Lakes?
2. What is the extent of the Coolagh Lakes groundwater catchment and by what flow mechanisms are the Lake water level and Lake water quality supported?

The nature of the groundwater dependant terrestrial ecosystems (GWDTE) at Coolagh Lakes are described below in Section 2 of this report. Section 3 outlines a summary of the data assessed. Section 4 summarises the hydrogeological conceptual model and explores the above two questions. Section 5 summarises the assessment of potential impacts.

Appendix A to this updated Appendix A.10.8.2 includes groundwater contour maps for winter (Appendix A-1) and summer (Appendix A-2) as well as three sets of Hydrographs. (Appendix A-3)

- Hydrograph i (Appendix A-3i) shows groundwater responses in Lackagh Quarry
- Hydrograph ii (Appendix A-3ii) shows groundwater responses related to a perched groundwater table from a shale bed
- Hydrograph iii (Appendix A-3iii) shows the groundwater levels recorded adjacent to Coolagh Lakes

This assessment includes both detailed and conceptual cross-sections to aid the understanding of the area. The conceptual cross-sections are presented in Section 3 below while the three detailed sections are presented in Appendix B to this updated Appendix A.10.8.2. The cross-sections comprise of:

- Appendix B Section A-A: Southwest to Northeast cross-section from the River Corrib to Ballindooley Lough via the Coolagh lakes and Lackagh Quarry (split over 4 drawings to allow sufficient detail)
- Appendix B Section B-B: A West to East cross-section through Lackagh Quarry along the alignment including the proposed Lackagh Tunnel
- Appendix B Section C-C: North to South section through Coolagh Lakes showing the relationship between the lake level and groundwater level

2. Groundwater Dependent Qualifying Habitat at Coolagh Lakes (Lough Corrib SAC)

The Coolagh Lakes and the associated fringing wetland habitat form part of the qualifying interests of Lough Corrib SAC.

The Coolagh Lakes themselves correspond with the qualifying interest Annex I habitat Hard water lakes [3140]. The lakes in turn support an associated wetland complex of wet grassland (GS4), wet heath (HH3), fen (PF1 and PF2) and reed swamp (FS1); areas of which correspond with the qualifying interest Annex I habitat types *Molinia* meadow [6410], *Cladium* fen [*7210] and Alkaline fen [7230]. Other Annex I habitat present which also form part of the associated wetland habitat complex are Residual alluvial forests [*91E0], Hydrophilous tall herb [6430], Wet heath [4010] and Transition mires [7140].

The full complex of wetland habitats associated with the Coolagh Lakes, including the fringing reed swamp, fen, marsh, wet heath, wet woodland and wet grassland habitats integrate with and support the structure and functions of the lake habitat. Equally, the area, distribution and quality of these habitats are dependent upon water levels and the water quality in the Coolagh Lakes.

The hydrogeological regime, particularly the groundwater contribution, must be maintained so that the area, distribution and depth of the lake habitat and its constituent/characteristic vegetation zones and communities are not reduced.

Critically, maintaining the area and condition of all fringing habitat, and not just those qualifying interest Annex I habitats, is a key component of the conservation objectives for Hard water lake [3140] habitat in Lough Corrib SAC.

An overview of where the qualifying interest Annex I habitat types of Lough Corrib SAC are located in relation to the Coolagh Lakes are shown on Plate 9.1 of the NIS.

Figure 11.3.3 of the NIS illustrates the collective extent of the groundwater dependent qualifying interest habitats of Lough Corrib SAC. It shows the extent of both the qualifying interest Annex I habitats and the other fringing habitats which provide a supporting role to the lake habitat itself.

The Fossitt classifications of the habitats associated with the Coolagh Lakes in the immediate vicinity of the proposed road development are shown on Figure 15.3 of the NIS.

The Annex I classifications of the habitats associated with the Coolagh Lakes in the immediate vicinity of the proposed road development are shown on Figure 1.7 of the NIS.

3. Hydrogeology background

3.1 Hydrogeological Overview

The ground investigations along the route of N6 Galway City Outer Bypass (2006 GCOB) and undertaken for the Project identify four locations where the geology is interrupted by deep buried valleys (River Corrib, Coolagh Lakes/Lackagh Quarry, N84 Headford Road and N83 Tuam Road). These buried valleys locally interrupt the regional groundwater gradient and either impound and/or deviate the regional trend. The location of these relative to Coolagh Lakes and Lackagh Quarry are presented in Plates 1 above and Plate 3 below.

The hydrogeological study undertaken to inform the EIAR and NIS for the proposed N6 GCRR identified 4 no. groundwater bodies (GWB) that contribute groundwater to the groundwater dependant habitats in the Lough Corrib SAC. They are Ross Lake GWB, Lough Corrib Fen 1 (Menlough) GWB, Lough Corrib Fen 2 GWB and the Clare-Corrib GWB. The location of these GWBs are explained and illustrated in Section 4.2 of NIS Appendix A. Plate 6 of NIS Appendix A (included below in Plate 3 for ease of reference) illustrates those groundwater bodies that contribute groundwater to the Lough Corrib SAC.

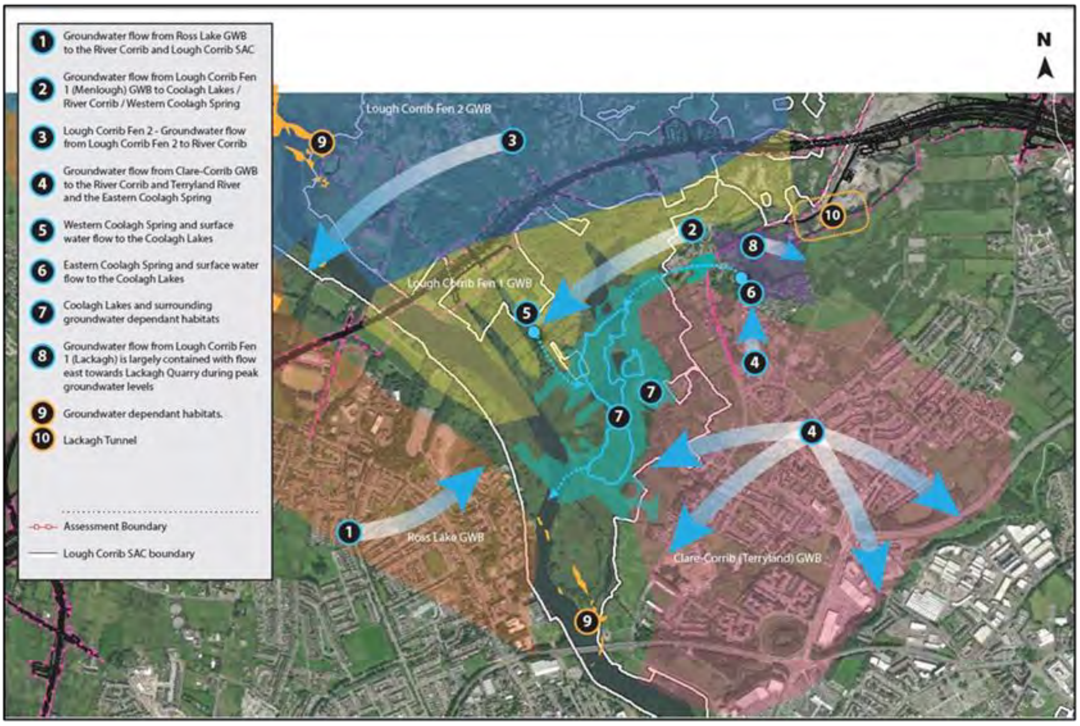


Plate 3 Generalised hydrogeology interactions with Lough Corrib SAC

The hydrogeological setting at Coolagh Lakes comprises of the lakes occurring in topographic depressions within an extent of thick, low permeability silt and clay subsoil deposits, which are bound to the north and east by limestone. The thick clay subsoils are part of the palaeolandscape in the limestone bedrock that have been infilled with fine grained sediment. A deep buried landscape at the eastern extent of the Lough Corrib Fen 1 (Menlough) GWB recorded a thickness of 106m of silty clay. The contact of the palaeolandscape is sharp and vertical, and not dissimilar to that of the head of canyon or gorge. The Western Coolagh Spring is located at the margin of this significant palaeolandscape feature, where limestone crops out and encompasses the northern, eastern and southern margins of the Coolagh Lakes. The Coolagh Lakes fill the topographic depression where the deep subsoil deposits occur. These features are shown on Plate 2 above.

Due to the thickness and low permeability of the fill sediment from its fines dominated nature, any groundwater contribution through the base of the lakes is considered insignificant. Other than Western Coolagh Spring, there are no other karst springs around the periphery of the lakes. It is noted that the only other 'spring' feature associated with Coolagh Lakes is a pond at the head of a drain, which has been named Eastern Coolagh Spring. Eastern Coolagh Spring is located within the thick clay deposits in the valley floor, approximately 35m away from limestone that rises steeply on the north and western sides from the valley floor. Although no flow is measurable at Eastern Coolagh Spring or immediately downstream of it, it is anticipated that groundwater in the surrounding subsoil will migrate to it as seepages. It is noted from walkover surveys that the margins of the lake remain permanently wet even during summer, indicating that constant groundwater seepage occurs at the limestone/buried valley interface around the lake periphery.

Manual groundwater level monitoring data is presented in Appendix A.10.3 of the updated EIAR which is discussed in Chapter 10 of the updated EIAR and Appendix A of the updated NIS. This data has been presented in Appendix A to this updated Appendix A.10.8.2 as groundwater level contours for Winter and Summer. Hydrographs are presented in Appendix A to show the seasonal variation.

3.2 Regional groundwater level

The regional hydraulic gradient was developed for the limestone area using groundwater levels recorded in monitoring boreholes both upgradient and downgradient of the proposed N6 GCRR, as well as groundwater levels measured along the proposed N6 GCRR and the receiving water level at the River Corrib, Terryland River and Galway Bay.

A triangulation net was constructed across limestone groundwater bodies to provide a comprehensive assessment of gradient and flow direction. This allowed hydraulic gradients between monitoring points to be calculated and used to plot groundwater contours beyond the centreline and in the wider extent of the aquifer. The groundwater monitoring network allows groundwater flow directions to be calculated. An example of the triangulation net used is presented below in Plate 4.

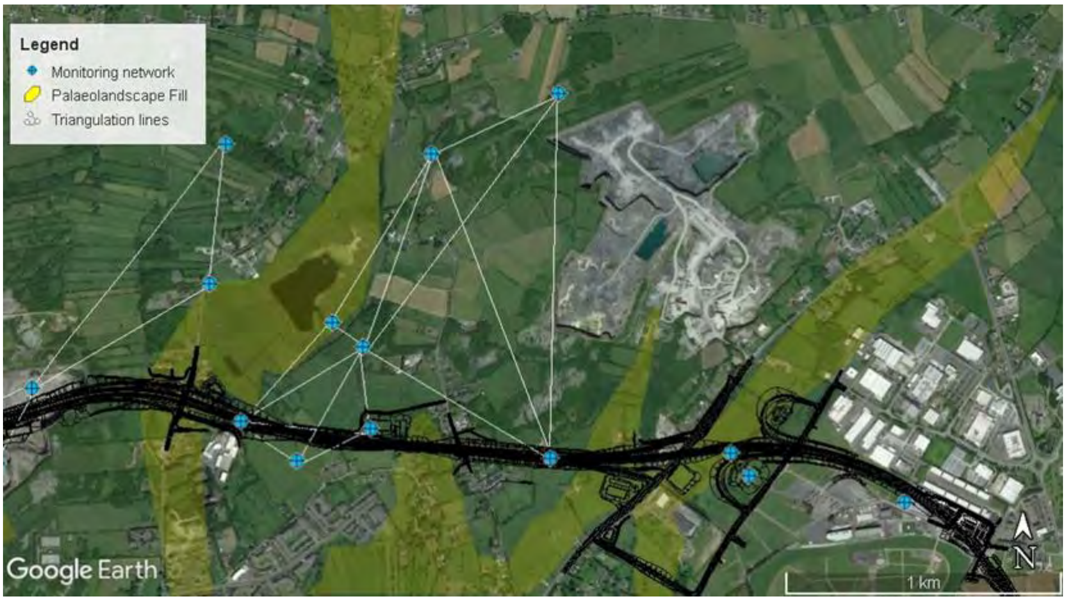


Plate 4 Example of the triangulation net used (June 2016 water levels)

Based upon the gradient calculations and generation of groundwater contours (Refer to Appendix A-Figure 1 and Figure 2) the predominant groundwater flow of the regional groundwater system is towards the surface water features (the River Corrib and Terryland River).

There are seven groundwater monitoring boreholes in the wider limestone bedrock area. These include monitoring boreholes from 2006 GCOB (RC and MW) and the four monitoring boreholes designed to monitor surface water groundwater interaction (RP-02 series). In addition, the three Lackagh Quarry monitoring wells (LQMW series), BH04 and BH05 installed as part of the Lackagh Tunnel investigation and three surface water monitoring locations (SW-02 series) were also used to develop hydraulic gradients. The River Corrib (including the OPW gauge for the River Corrib at Dangan) and the Terryland River were used as receiving water for groundwater and where appropriate used to triangulate groundwater flow directions and gradients.

Groundwater levels are available for five monitoring wells in or adjacent to Lackagh Quarry (LQMW4, LQMW5, LQMW6, BH04 and BH05) (refer to EIAR Appendix A.10.3 Figure 1). The hydrographs i, ii and iii included in Appendix A show the seasonal responses of groundwater levels for Lackagh Quarry and Coolagh lakes. Water levels at the River Corrib, Western Coolagh Spring, Eastern Coolagh Spring are included for completeness. Cross-Section A-A, B-B and C-C (Appendix B of this updated A.10.8.2) show the groundwater levels in the Lackagh Quarry and Coolagh lakes area.

The Lackagh Quarry monitoring wells (LQMW1 to LQMW6) were originally installed when the quarry was operational, and no geological logs are available. LQMW1 to LQMW3 were not included in the monitoring network as the groundwater levels recorded were identical to the level at LQMW4. LQMW4 was chosen as representative of all these wells as it was in the best condition.

LQMW1, LQMW2, LQMW3 and LQMW4 are in the quarry void. LQMW5 and LQMW6 are to the south-west, in the quarry yard area and quarry access road respectively. These locations are shown on Figures 1 and Figure 2 of Appendix A of this updated A.10.8.2.

The geology of these wells was determined based on the condition survey (which determined their depth), the geological mapping of the quarry and from boreholes drilled for the project.

3.3 Perched groundwater level

In additional to the regional groundwater system there is also local perching of groundwater at specific stratigraphic horizons. One horizon in particular, an argillaceous limestone observed in Lackagh Quarry, perches recharge in the Menlough/Lackagh Quarry area. The geometry of the ‘shale’ bed dips at 2 degrees with a strike of 288 degrees. Plate 5 (reproduced from Figure 3.15 of the Lackagh Tunnel Geotechnical and Hydrogeological report in Appendix A.7.3 of the updated EIAR and Appendix F of the updated NIS) illustrates this shale bed above the limestone. Cross-sections A-A, B-B and C-C in Appendix B of this updated A.10.8.2 show the geometry of the shale horizon in the Lackagh Quarry and Coolagh Lakes area.

Plate 5 Shale bed in Lackagh Quarry

The location of boreholes in Lackagh Quarry is presented in Appendix A – Figures 1 & 2 of this updated A.10.8.2. The seasonal variation of groundwater levels in Lackagh Quarry are presented in Appendix A Hydrograph (i), which is derived from Plate 10.5 in Chapter 10 of the updated EIAR and Appendix A.10.3 of the updated EIAR and Appendix F of the updated NIS.

This geological geometry of the shale bed controls perching of recharge in the local area between Menlough and Lackagh Quarry. The groundwater levels at BH05, LQMW6 and RP-2-05S reflect the interaction of groundwater levels influenced by the shale bed. BH04 and LQMW4 are included to show the water level measurements in regional groundwater table as they measure below the shale horizon.

From mapping the geology at the wells, LQMW4 is entirely in the limestone aquifer below the shale horizon as is the screen for BH04. As outlined above, the argillaceous limestone (also referred to as shale bed) observed in Lackagh Quarry, perches recharge in the Menlough/Lackagh Quarry area. LQMW5 is installed through the shale horizon into the lower aquifer and as such picks up both deeper and shallower groundwater. LQMW6 (by extrapolation of the geology geometry) is also installed through the shale horizon but on the opposite side of a buried valley to LQMW5. These monitoring locations of all these wells are shown on the water level contour plots (for the main aquifer) which are shown in Appendix A of this document.

The geological logging of the five boreholes installed as part of the proposed N6 GCRR along the alignment of Lackagh Tunnel was used to cross check this. These are shown in Plate 6 below (also refer below to Figure 5 in Appendix A of the Lackagh Tunnel Geotechnical and Hydrogeological Appraisal in Appendix A.7.3 of the EIAR and Appendix F of the NIS for completeness). Of these five boreholes, three (BH04, BH05 and BH06) were completed with piezometers.

BH04 and BH05 are located in the narrow strip of limestone that lies to the west of the quarry, between the quarry and the buried valley (refer to Plate 6 below). Both BH04 and BH05 also encountered the shale bed.

In BH04 the shale was reported as mudstone with clay above and below it in a unit from 13.77mOD to 12.62mOD. In BH05 a zone of core loss and clay occurred between 13.94mOD to 13.69mOD.

In both BH04 and BH05, the piezometer response zone is installed below the shale horizon.

- BH04: 9.49 to -2.83mOD
- BH05: 11.54 to -5.84mOD

Based on the geology encountered, whilst BH04 has a significant thickness of shale and perches recharge above it, the shale horizon in borehole BH05 is weathered and will leak. As such, although shale bed perches recharge in the local area, there are locations where leakage occurs down to the regional groundwater table below and in these locations there will be localised recharge spikes in the regional groundwater table. These responses will be storm event related and temporary as the regional groundwater table equilibrates.

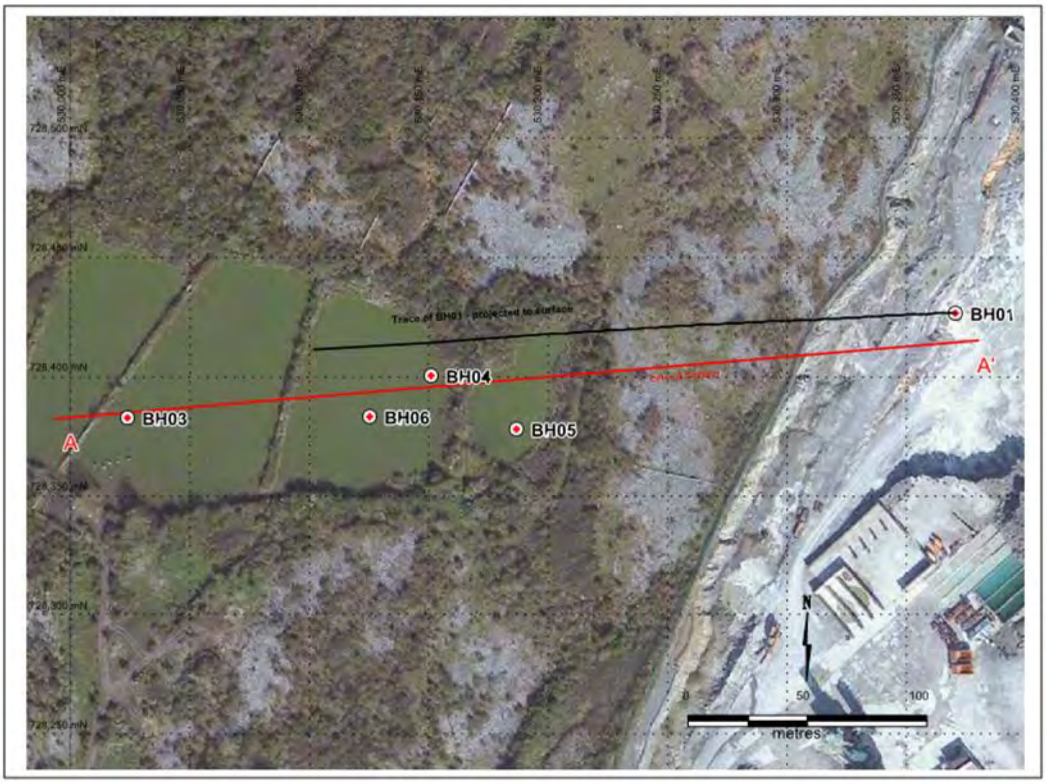


Plate 6 Locations of boreholes BH03, BH04, BH05 and BH06

3.4 Peak groundwater levels in Lackagh Quarry

Peak groundwater levels in the aquifer below the quarry floor were measured in LQMW4 at 15.4mOD, on 11 January 2016 which also matched the standing water level in the quarry on the day. This was the peak static water level recorded in the aquifer below the quarry floor (LQMW4) and for flooding on the main quarry floor. The level of 15.4m represents the peak groundwater flooding that occurred on the main quarry floor during the 2015/2016 winter from the groundwater table. After that time the water level and groundwater level receded.

The following groundwater levels were measured between 5 January and 11 January 2016 and are used to describe how the perched groundwater and main groundwater table responded to the storm event of early January 2016:

- BH04 was manually measured on 5 January 2016 at 14.29mOD and peaked on 11 January 2016 at 15.74mOD. The delayed peak response in BH04 is caused by the recharge percolating down to the main aquifer and then passing through the shale horizon, which is a leaky barrier.
- BH05 was manually measured on 5 January 2016 at 19.46mOD and on 11 January 2016 at 16.66mOD. The water perched above the shale horizon peaked early after the storm event and then took a few days for the perched groundwater to leak down through the shale and into the main aquifer below. As the perched groundwater table leaked into the main aquifer the water level in BH05 lowered and this was followed by a steady rise and subsequent peak response in nearby BH04 on 11 January 2016.

As was stated in Section 3.3, the shale horizon can be weathered and is expected to be extensively leaky. The short-lived high groundwater levels in BH05 on January 5, 2016 are a recharge response to the storm event but are not representative of the main regional groundwater table. Following rainfall, recharge will flow via multiple pathways through the thick unsaturated zone to where there are intercepted by the shale and become perched. Due to the leaky nature of the shale, the perched groundwater is able to drain through the shale and down to the regional groundwater table. Where natural weathered gaps in the shale bed occur then these will focus leakage down to the main regional groundwater table below. Where the perched water flows along the shale and into the quarry void, such as in the southwestern corner of the quarry, then this groundwater cascades down onto the quarry floor.

On 5 January 2016 a small area at the southwestern corner of the quarry floor had standing water at 15.69mOD. This was related to localised flow into the quarry from groundwater perched above the shale horizon. This localised flooding was not representative of the groundwater flooding occurring on the main quarry floor, instead it was caused by impoundment of runoff in that specific area by old quarry berms and mounds.

The hydrographs included in Appendix A ii show the seasonal responses of groundwater levels in wells that interact with the shale bed.

3.5 Water levels at Coolagh Lakes

As described in Section 10.3.3.2 of Chapter 10 of the EIAR, the water level in the Coolagh Lakes is controlled by a combination of flow from Western Coolagh Spring and flow from the Coolagh Lakes to the River Corrib. When groundwater level rises in the Lough Corrib Fen 1 GWB the flow at Western Coolagh Spring increases, conversely when groundwater levels lower, the flow at the spring reduces. On this basis the flow at Western Coolagh Spring is seasonal, with peak flows occurring in the winter and flow reducing in the summer to the extent that flow ceases.

The groundwater levels within the Lough Corrib Fen 1 (Menlough) GWB are included in the water level database presented in Appendix A.10.3 of the updated EIAR, which includes both groundwater levels recorded in monitoring boreholes, as well as the springs and Coolagh Lakes. The hydrographs included in Appendix A iii show the seasonal responses of groundwater levels at the River Corrib, Western Coolagh Spring, Eastern Coolagh Spring and groundwater levels in wells around the periphery of Coolagh Lakes.

The level of the River Corrib influences the water level in the Coolagh Lakes so that generally the levels of both are comparable. However, as the River Corrib responds more rapidly than the groundwater levels (and Western Coolagh Spring) the River Corrib can rise slightly higher than the Coolagh Lakes during storm events (by up to 25cm). This can lead to water from the river entering the lower lake and mixing with the lake water. The rise of the level in the lower lake will cause impoundment in the upper lake but it is unlikely that river water will enter the upper lake due to the narrow connecting channel between lakes.

The hydrographs included in Appendix A iii show the seasonal responses of groundwater levels in wells that interact with the shale bed.

3.6 Water quality at Coolagh Lakes

Water sampling was undertaken during the hydrogeological study to characterise the groundwater quality across the study area. Groundwater samples were taken from Western Coolagh Spring and monitoring boreholes around the periphery of Coolagh Lakes (RC133, RP-2-05S&D and MW03). The waters from these monitoring boreholes and also from Western Coolagh Spring are confirmed as having a high alkalinity (>180mg/l total alkalinity $CaCO_3$), which is in line with the habitat description for Coolagh Lakes supporting alkaline fen. On this basis the fen is dependent on both the quality and quantity of groundwater.

Of the water samples taken from limestone, the total alkalinity from Western Coolagh Spring and borehole RC133 was slightly lower than other boreholes. It is likely that Western Coolagh Spring and RC133, which is adjacent to turlough K31, discharges younger groundwater which has had a shorter and/or faster flow through the aquifer, which has the effect of a reduced limestone contact when compared to groundwater from deeper fracture flows sampled from boreholes. On this basis it would be expected that groundwater seeping from the margin of the limestone aquifer around Coolagh Lakes will be higher alkalinity than the water emergent from the karst system at Western Coolagh Spring.

The hydrographs included in Appendix A iii show the seasonal responses of groundwater levels at the Western Coolagh Spring, Eastern Coolagh Spring and groundwater levels in wells around the periphery of Coolagh Lakes. Water levels in the River Corrib (Dangan) are also presented (Source OPW http://waterlevel.ie).

As discussed in relation to water levels at Coolagh Lakes, there are times, particularly in response to storm events, when the River Corrib water enters the lakes, this occurs when the river rises more rapidly than groundwater. On these occasions there will be a temporary natural fluctuation in water quality at the lower Coolagh Lake, with total alkalinity reducing due to mixing. Whilst the upper lake can become impounded due to water level rise in the lower lake it is unlikely that a change in water quality at the upper lake occurs due to the restricted flow in the connecting channel between the two lakes.

4. Hydrogeological Conceptual Model

The information presented in the above section allows a conceptual model to be developed for the area between Lackagh Quarry and Coolagh Lakes. This conceptual model is based on all monitoring ground investigation data presented in the updated EIAR and is framed against the two questions posed above which are key to informing any potential impact assessment.

As outlined above detailed cross-sections have been prepared to illustrate the information available (refer to Appendix B Cross-sections A-A, B-B and C-C in Appendix B of this updated A.10.8.2).

A simple illustration of the conceptual hydrogeological model for Coolagh Lakes is presented in Plate 7 which is based on the information provided above and presented on the cross-sections (Appendix B).

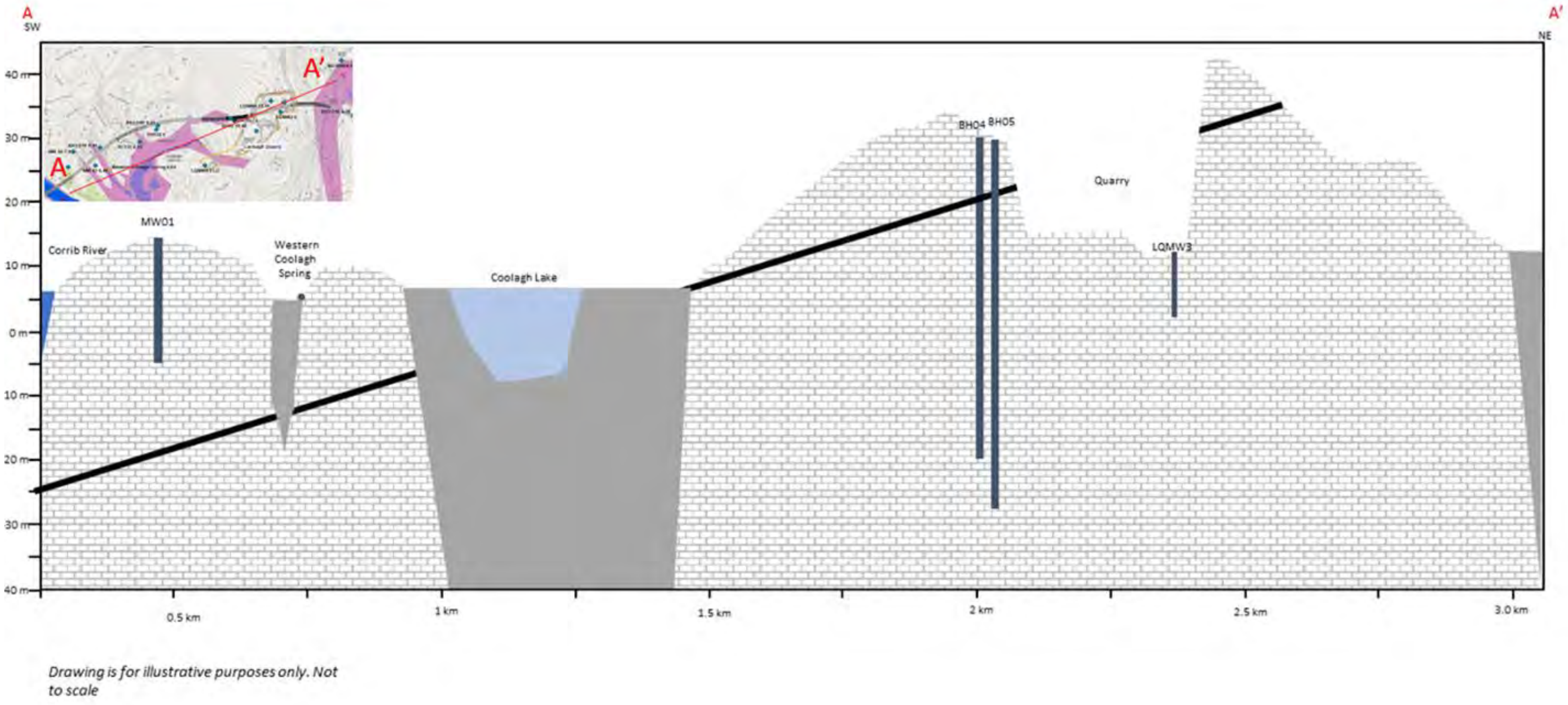


Plate 7 Conceptual model for Coolagh Lakes

4.1 Does groundwater from Lackagh Quarry drain to Coolagh Lakes?

The hydrogeology at Lackagh Quarry has been complicated by the quarry itself. Prior to the quarry operation groundwater was clearly divided into two regimes, a regional groundwater regime and a perched groundwater regime. With the development of the quarry, the perched groundwater regime has been removed from the aquifer at Lackagh Quarry. Rainfall now directly recharges the regional aquifer via the floor of the quarry and inflows to the quarry from perched groundwater occur from above the shale bed.

The regional groundwater regime is shown by the monitoring data to be south westwards towards the River Corrib south of Coolagh Lakes, with the groundwater flow direction being partially defined by the infilled buried valleys that form barriers to groundwater flow. Appendix A Figures 1 and Figure 2 of this updated A.10.8.2 show interpreted groundwater level contours for the Lackagh Quarry and Coolagh Lakes areas. These interpretations confirm that groundwater flows from the upland area north of Lackagh Quarry. This data also shows that the buried valley immediately west of Lackagh Quarry causes a bifurcation of the groundwater into two directions, part of the flow diverts west to the River Corrib and the other diverts flow south and then south westwards, via Lackagh Quarry and towards the River Corrib (south of Coolagh Lakes near Terryland).

Regarding the pre-quarrying groundwater flow directions: whilst the quarry has not changed the route of the regional groundwater flow, it has significantly altered the perched groundwater regime. Prior to the quarry, the perched groundwater would have flowed further west and would have contributed to Coolagh Lakes. Lackagh Quarry has severed the connection of the perched groundwater and drained these flows into the quarry void. As such, the perched groundwater regime of Lackagh Quarry is no longer connected to Coolagh lakes. The concept of the shale bed in Lackagh Quarry is clearly shown in Cross-sections A-A and B-B in Appendix B of this updated A.10.8.2.

On the basis that the regional groundwater table drains away from Coolagh Lakes and the perched groundwater table has been intercepted by the quarry, then neither the regional nor perched water table at Lackagh Quarry drains to Coolagh Lakes. Therefore, groundwater from Lackagh Quarry does not drain to Coolagh Lakes. This regime will not be modified by the proposed N6 GCRR and as such the groundwater at Lackagh Quarry will remain separate to Coolagh Lakes.

4.2 What is the extent of the Coolagh Lakes groundwater catchment and by what flow mechanisms are the lake water level and lake water quality supported?

Based on groundwater level monitoring and the description of the regional groundwater contours above, the catchment to Coolagh Lakes is limited to a reasonable small area that comprises of:

1. The catchment to Western Coolagh Spring (karst)
2. The seepages that emerge around the rock periphery of the Coolagh Lakes where the sediments fill the buried valley

On this basis the catchment can be divided into two flow types: (1) karst flow from the Western Coolagh Spring, which provides most of the volume to the lakes and (2) groundwater seepages from the surrounding limestone aquifer which keeps the margins wet and provides a year round supply of groundwater that is likely to be small in volume compared to Western Coolagh Spring but is very important in terms of the habitat in the marginal areas. Therefore, the only way there can be an impact to Coolagh Lakes water level or water quality is by way of an impact to the groundwater contribution from Western Coolagh Spring or by way of an impact to the groundwater seepages around Coolagh Lake.

The catchment to the Western Coolagh Spring comprises the Lough Corrib Fen 1 (Menlough) GWB. The catchment for seepages to Coolagh Lakes comprises Lough Corrib Fen 1 (Menlough) GWB, Lough Corrib Fen 1 (Lackagh) GWB and the Clare-Corrib GWB. The catchment to Coolagh Lakes does not include Lackagh Quarry.

Cross-sections C-C in Appendix B shows a section through Coolagh Lakes and confirms the high groundwater table around the periphery where limestone occurs. This high groundwater table provides source for constant seepage to the lakes all year round.

It is noted that prior to the quarry operations, the catchment would have included the perched groundwater regime at Lackagh Quarry, but it is important to recognise that the regional groundwater system at Lackagh Quarry has always been separate to Coolagh Lakes due to the buried valley that lies in between.

5. Impact assessment

The impact assessment for the habitats at Coolagh Lakes is considered in terms of potential for changes in the hydrogeological regime (water levels and flows) and the water quality during the construction and operation phases. The potential hydrogeological effects of the proposed road development on Lough Corrib SAC are detailed in Section 9.1.4.3 of the NIS.

Assessment of potential changes to the hydrogeological regime is based on the conceptual model presented in Section 4. The hydrogeological conceptual model provides a robust assessment of the groundwater regime at Lackagh Quarry that confirms that groundwater flow in Lackagh Quarry, both the perched and regional groundwater flows, do not drain to Coolagh Lakes (Section 4.1). The regional groundwater regime at Lackagh Quarry is isolated from Coolagh Lakes by a substantial buried valley that lies between them and the perched groundwater has been intercepted by the quarry void.

On this basis, the assessment of potential impacts below focuses only on those design elements that lie within the catchment to Coolagh Lakes, which is clearly stated in Section 4.2. These design elements include viaduct foundations, infiltration basins and small scale works to existing roads in the local area.

Mitigation is applied to Lackagh Tunnel and is included in the Schedule of Environmental Commitments comprising an enforcement of a no groundwater lowering in Lackagh Quarry. While the preceding text has illustrated the quarry is in a separate groundwater regime, this mitigation is highlighted here in recognition that Coolagh Lakes is a sensitive groundwater receptor less than 1km away from the quarry.

5.1 Potential Impacts to the Hydrogeological regime from proposed N6 GCRR

The potential hydrogeological effects of the proposed N6 GCRR on the Coolagh Lakes, and the associated groundwater dependent habitats that make up and support the qualifying interests of Lough Corrib SAC, relate to the two types of groundwater contribution (1) the karst spring and (2) groundwater seepages around the periphery of the lakes. As was described in Section 3 above (Hydrogeology Background), Eastern Coolagh Spring is included as part of the seepage that supplies the margins of the lakes and is not a karst feature.

Western Coolagh Spring, which is a karst spring with conduit flow, is a discharge point from a karst system in the Lough Corrib Fen 1 (Menlough) GWB. The limestone seepages that occur around the periphery of the Coolagh Lakes are maintained by a high groundwater table in the limestone aquifer that is impounded by the buried valley upon which the Coolagh Lakes formed.

Assessment of the proposed road development assesses potential impacts on both the karst and seepage system that are important for groundwater contribution to Coolagh Lakes. The section below identifies those elements of the design that (1) have the potential to lower groundwater levels and (2) potential impacts that may cause a reduction in water quality.

5.1.1 Groundwater Lowering and Groundwater Quality

Those elements of the proposed N6 GCRR in the catchment to Coolagh Lakes that have the potential to interact with groundwater during construction include viaduct foundations and infiltration basins. All areas of cutting in limestone in this location are located above the regional water table. The following risk assessment is based upon the conceptual hydrogeological model for the area in Section 4 above, (and also which is summarised in Appendix A and Appendix F of the updated NIS):

Except for the potential for intercepting groundwater conduits when constructing the supporting piers for the Menlough Viaduct, the construction of the proposed N6 GCRR will not affect the existing hydrogeological regime in terms of the quantity of water supply to the Coolagh Lakes or the frequency of flooding. To reiterate, groundwater dewatering during construction is not permitted within the design (see Section 5.2.1.2 of Appendix A of the updated NIS) in the catchments that drain to Coolagh Lakes.

In regard to the construction of the viaduct piers at Menlough, mitigation measures will ensure that flow in groundwater conduits will be maintained during construction of the Menlough Viaduct (refer to Section 10.5.3.1.2 of Chapter 10 of the updated EIAR and the CEMP in Appendix A.7.5 of the updated EIAR and Appendix C of the updated NIS). These mitigation measures include the control and treatment of site run-off during construction, preventing groundwater impacts arising from encountering karst features on site during construction works and ensuring that, during operation, the drainage system and infiltration basins function as designed over the life of the proposed road development.

The Clare-Corrib (Terryland) GWB overlaps with groundwater dependant habitats along the eastern edge of the Coolagh Lakes (Figures 11.3.7 and 11.3.8 of the updated NIS). Construction works at the Lackagh Quarry access road and along Bothar Nua and Sean Bothar have the potential to interact with groundwater. These works are small scale and do not include dewatering or require significant excavations.

As per all areas of the alignment of the proposed N6 GCRR, there is a risk that the accidental spillage of pollutants during construction could affect groundwater quality in the GWB, specifically the karst flows associated with Western Coolagh Spring, which in turn could affect the conservation objectives of the Lough Corrib SAC at Coolagh Lakes and the supported fringing wetland habitats. These issues are assessed in Section 10.5.3.1.2 of Chapter 10 of the updated EIAR and managed by the CEMP (Appendix A.7.5 of the updated EIAR and Appendix C of the updated NIS).

In the catchment of Coolagh Lakes, all runoff from construction drains either to infiltration basins or attenuation ponds (that themselves drain to the River Corrib), and hence the runoff risk to Coolagh Lakes is removed. The infiltration basins and attenuation ponds are designed to be used during both construction phase for site runoff and operational phase for road runoff and will be part of the initial works undertaken for the proposed N6 GCRR.

The design of each infiltration basin is specific to the local hydrogeology, taking into account the unsaturated zone available and including placement of engineered appropriate subsoil to provide the required infiltration capacity. All infiltration basins include pre-treatment by hydrocarbon interceptor and containment areas to provide an appropriate holding time to contain accidental spillages. All infiltration basins will be excavated into bedrock, with an over excavation to accommodate the thickness of appropriate subsoil. The sides of the excavation will be lined to control groundwater infiltration so that all discharges drain through a constructed subsoil appropriately placed for the thickness of the unsaturated zone. The design of the infiltration basins, coupled with the inclusion of hydrocarbon interceptor and containment area, will provide a robust level of protection to prevent contamination of groundwater from the infiltration basins during construction and operation.

Risk has been identified of accidental spills during construction for those areas where limestone outcrops, such as those areas where the groundwater has extreme or high vulnerability (Figure 3.01 and 3.02 of Appendix A of the updated NIS) and in cuttings and excavations. Mitigation measures will ensure that groundwater quality is not affected during construction (refer to Section 10.6.2 of Chapter 10 of the EIAR and by the CEMP (Appendix A.7.5 of the EIAR and Appendix C of the NIS).c

The drainage design (as described in Section 2, and Appendices A, F and D of the updated NIS) will ensure that groundwater quality will be maintained during operation, this includes inspection at maintenance intervals, with remediation actioned to ensure that karst features do not affect the functioning of the infiltration basins during operation. This will ensure that they continue to function as designed for the operational lifespan of the proposed road development (see Section 10.3.1.2 of the NIS).

5.2 Potential Effects to Lough Corrib SAC Qualifying Interest Habitats from hydrogeological impacts

This section examines how the groundwater dependent qualifying interest habitats of Lough Corrib SAC associated with the Coolagh Lakes would be affected by the potential hydrogeological impacts identified in Section 5.1.

These potential impacts are as follows and, in both instances, the risk of an impact occurring is highly unlikely:

- The potential of intercepting groundwater conduits in the Lough Corrib Fen 1 (Menlough) GWB when constructing the supporting piers for the Menlough Viaduct and the potential
- The potential of an accidental pollution event affecting groundwater quality in the Lough Corrib Fen 1 (Menlough) GWB, Lough Corrib Fen 1 (Lackagh) GWB and the Clare-Corrib GWB

Hard water lakes [3140]

As described above in Section 2, the conservation objectives for Hard water lakes [3140] includes the associated fringing lake habitats. Affecting water quality in the Coolagh Lakes and/or affecting the functioning or quality of the existing hydrogeological regime during construction (even though the risk of any perceptible effect is low) could affect the Annex I status of the lake thereby reducing habitat area and the distribution of this habitat type within Lough Corrib SAC. These impacts could also affect the type, abundance and distribution of the typical species supported by the lakes, the vegetation composition and distribution, the area and condition of the fringing aquatic vegetation, lake substratum quality and water chemistry.

Based upon the hydrogeological assessment outlined in Section 5.1 above, there will be no changes to the groundwater regime in this area. Minor water quality impacts associated with construction may occur and mitigation measures have been proposed as robust preventative measures to specifically manage accidental spills and sediment runoff (refer to Section 5.3). No impacts have been identified for the operational phase of the proposed N6 GCRR.

Molinia meadow [6410], *Cladium* fen [*7210] and Alkaline fen [7230]

Affecting water quality in the receiving environment and/or affecting the functioning or quality of the existing hydrogeological regime could affect ecosystem functioning and the condition of areas of these habitat types such that their area and distribution is reduced within Lough Corrib SAC. These impacts could also affect the vegetation composition and structure and the abundance and distribution of typical and locally distinctive species associated with QI habitats.

Introducing/spreading non-native invasive plant species could locally affect the extent, diversity, and vegetation composition or structure of these habitats within Lough Corrib SAC.

The assessment of potential groundwater impacts on the site specific conservation objectives for *Molinia* meadow [6410], *Cladium* fen [*7210] and Alkaline fen [7230] habitats in Lough Corrib SAC is presented in full in Table 9.16 of the NIS.

Based upon the hydrogeological assessment outlined in Section 5.1 above, there will be no changes to the groundwater regime in this area. Minor water quality impacts associated with construction may occur and mitigation measures have been proposed employed as robust preventative measures to specifically manage accidental spills and sediment runoff (refer to Section 5.3). No impacts have been identified for the operational phase of the proposed N6 GCRR.

5.3 Mitigation Measures

The mitigation measures in Lackagh Quarry to not lower the groundwater level are included as a precautionary approach even though Lackagh Quarry and Lackagh Tunnel do not drain to Coolagh Lakes.

The mitigation measures required to protect the existing groundwater regime supporting the groundwater dependent qualifying interest habitat of Lough Corrib SAC, including those associated with the Coolagh

Lakes, relate to potential groundwater quality impacts due to construction only. These potential impacts are mitigated by:

- Implementation of best practice construction practices and environmental controls to control the potential for, and respond to any, accidental groundwater pollution events on site as set out in the CEMP (Appendix A.7.3 of the EIAR and Appendix C of the NIS) – Section 10.3.1.1 of the NIS
- Application of the Karst Protocol to prevent groundwater impacts arising from encountering karst features on site during construction works – Section 10.3.1.2 of the NIS

These mitigation measures are robust and have been implemented successfully on other schemes and will be effective to ensure that the proposed N6 GCRR does not adversely affect the integrity of Lough Corrib SAC from hydrogeological impacts to the Coolagh Lakes.

6. Conclusion

Considering the design measures associated with the Project, particularly those related to the Lackagh Tunnel, groundwater supply supporting groundwater dependant habitats in Lough Corrib SAC will not be affected during operation.

The detailed mitigation strategy outlined above in Section 5 and described in Section 10.3 of the NIS will ensure that the proposed N6 GCRR will not affect groundwater supply to the Coolagh Lakes during construction of the Menlough Viaduct and will not affect the quality of groundwater contributing to the Coolagh Lakes during construction and/or operation. These mitigation measures include the control and treatment of site run-off during construction, preventing groundwater impacts arising from encountering karst features on site during construction works and ensuring that, during operation, the drainage system and infiltration basins function as designed over the life of the proposed road development.

These mitigation measures will be implemented through the CEMP during construction (construction pollution risk) and by Galway County Council/TII over the operational lifespan of the Project (maintenance) and will ensure that hydrogeological impacts do not occur.

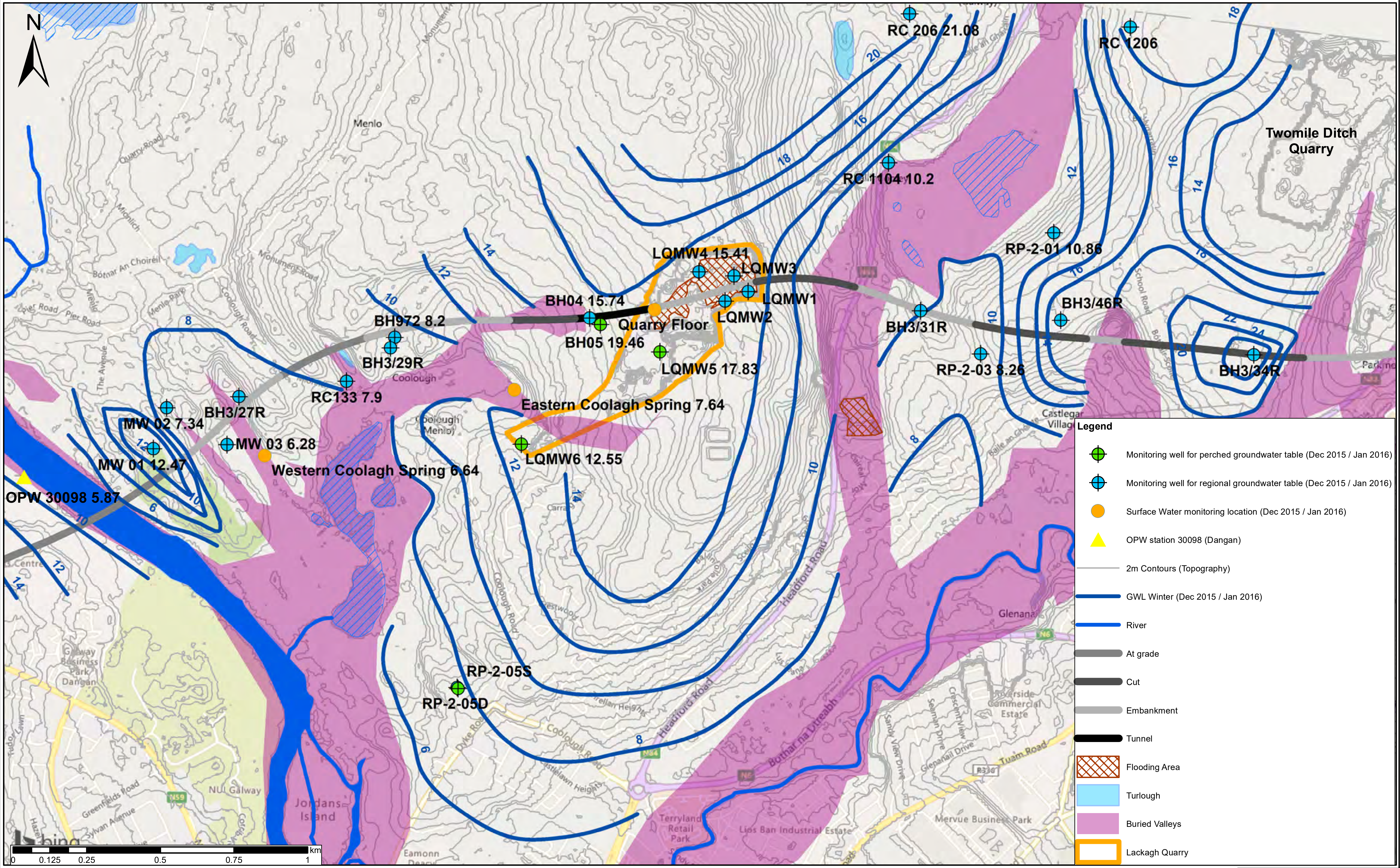
As a result, habitat degradation because of impacts on the existing groundwater regime will not occur or affect the conservation objective attributes and targets supporting the conservation condition of any groundwater dependent qualifying interest habitats and species of Lough Corrib SAC, including those associated with the Coolagh Lakes. Therefore, there are no residual direct or indirect groundwater related impacts that could adversely affect the integrity of Lough Corrib SAC.

Appendix A

Groundwater Monitoring and Hydrographs

A.1 Groundwater Monitoring and Hydrographs

A3



Clients

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Job Title
N6 Galway City Ring Road

Scale:

Date: **March 2020**

All elevations mOD

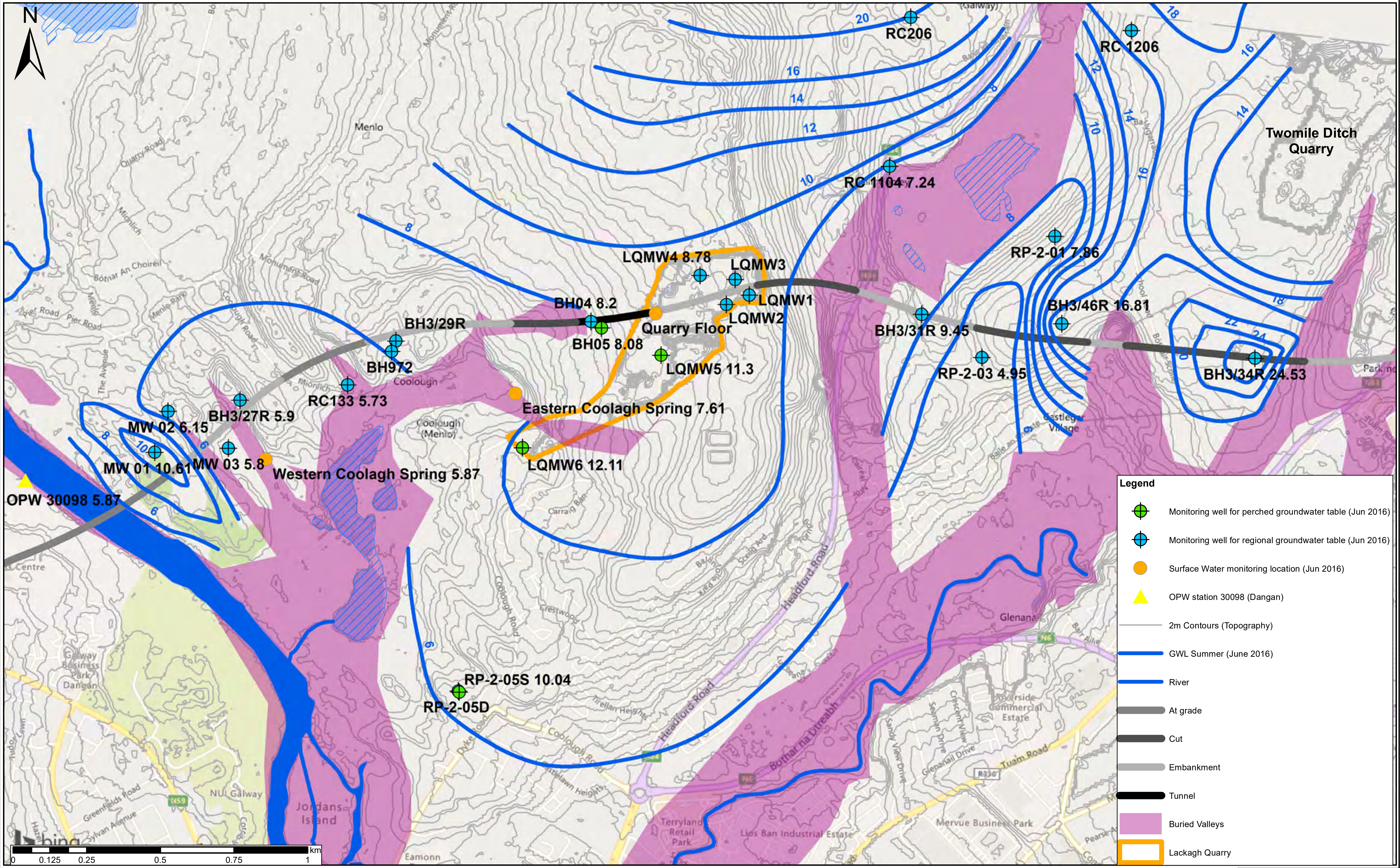
I1	04/03/2020	MK	LB	CB
Issue	Date	By	Chkd	Appd

Drawing Title
Winter Groundwater Levels

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	Appendix A-1	I1

A3



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Job Title

N6 Galway City Ring Road

Scale:

Date: **March 2020**

All elevations mOD

Issue	Date	By	Chkd	Appd
I1	04/03/2020	MK	LB	CB

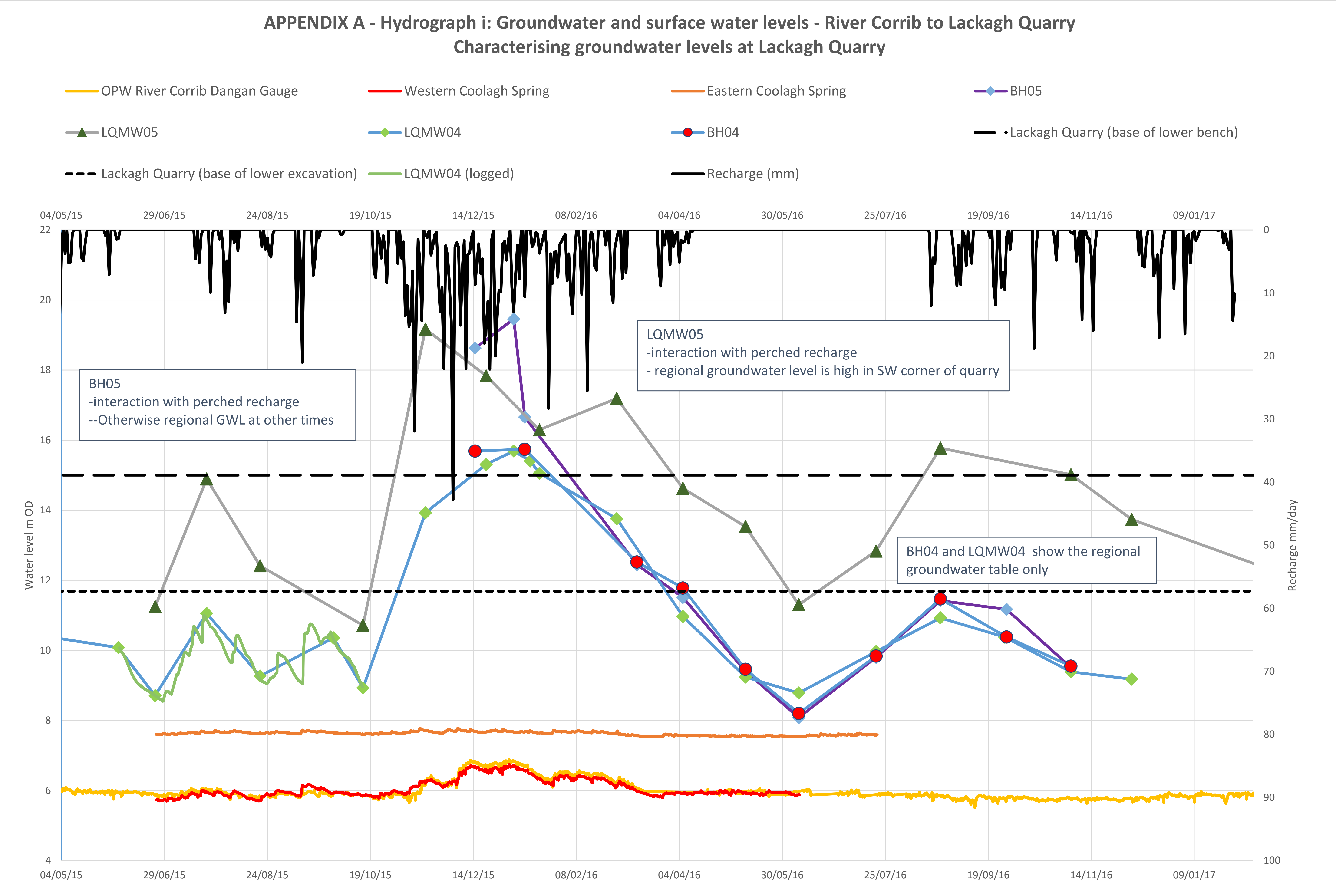
Drawing Title

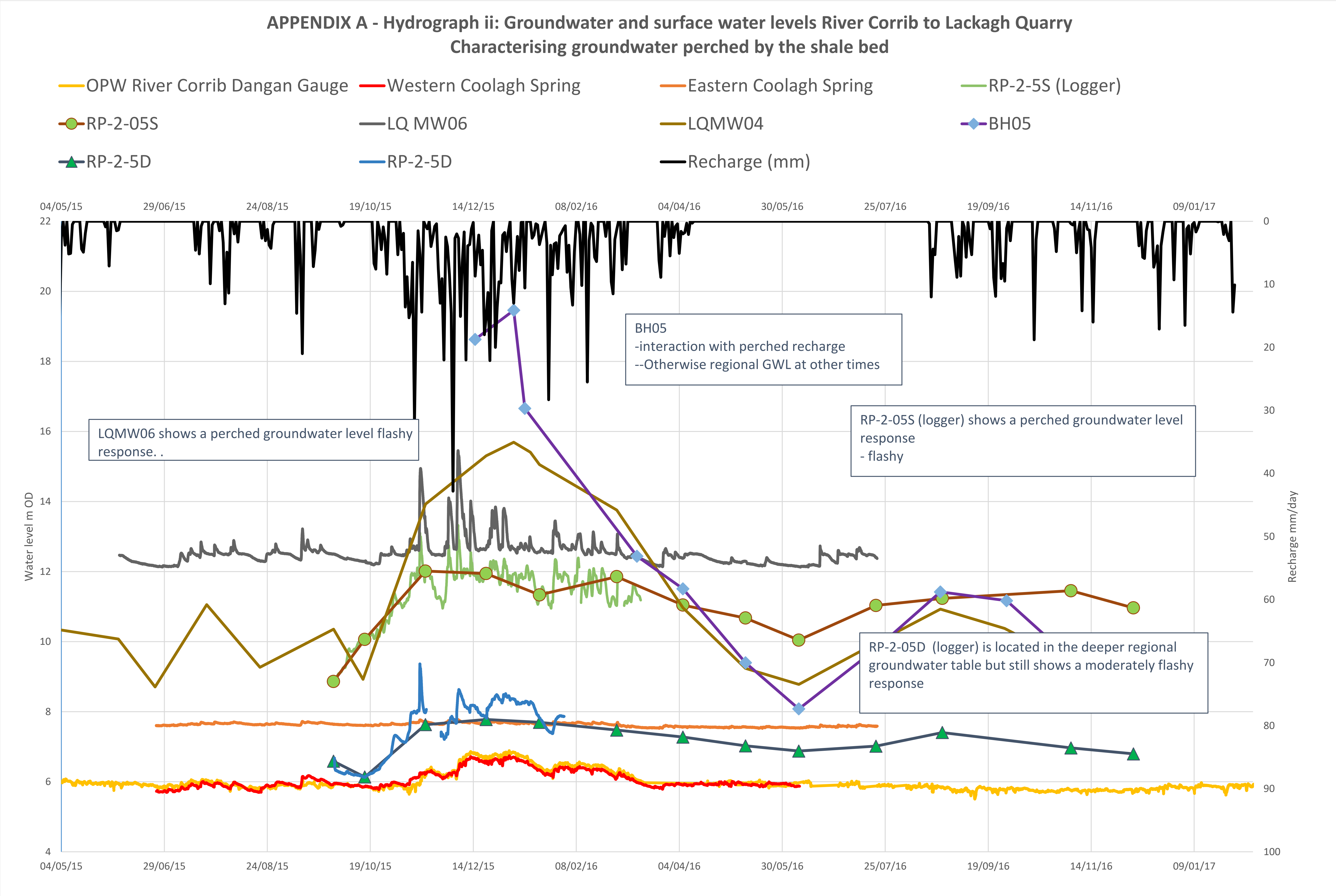
Summer Groundwater Levels

Drawing Status

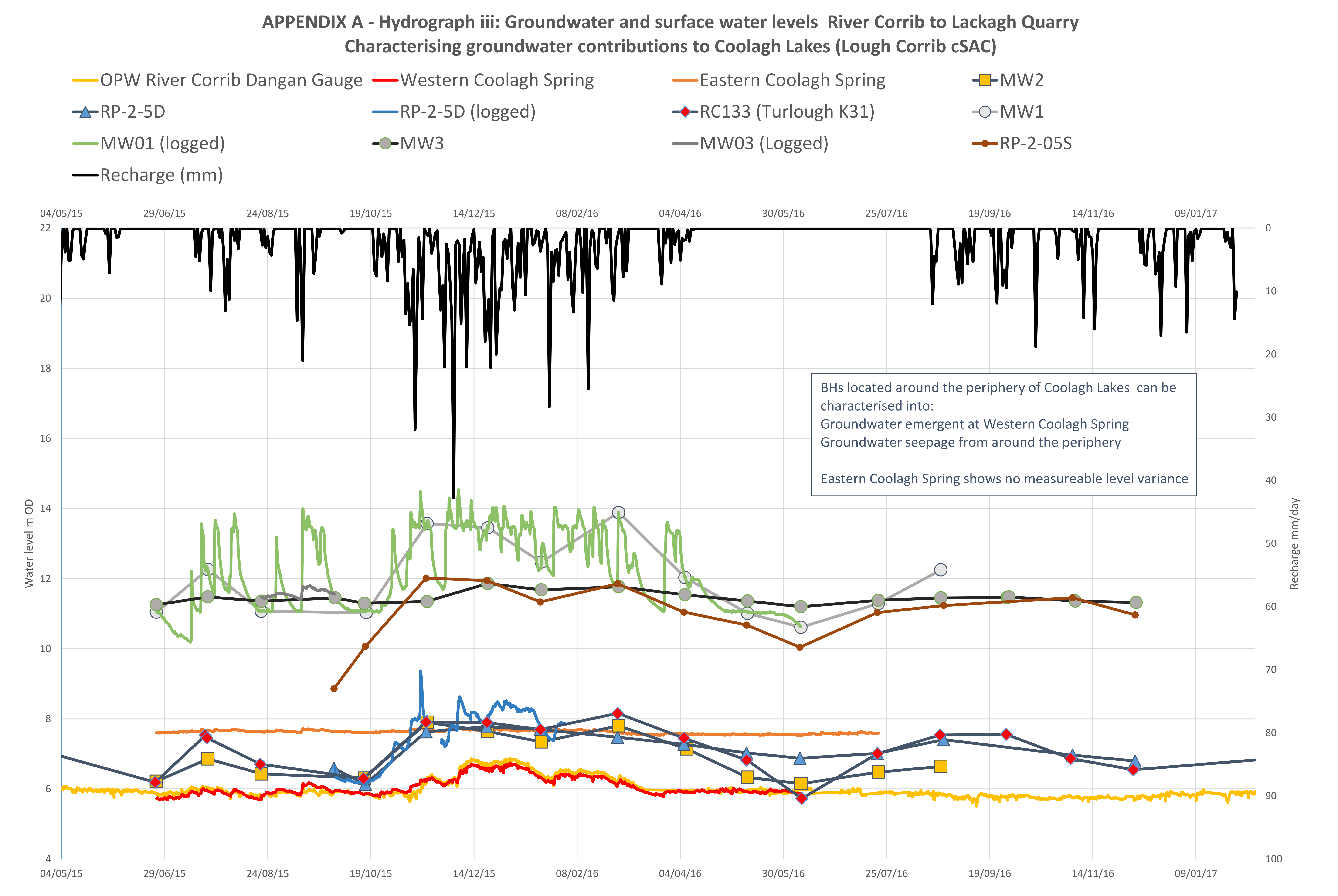
For Information

Job No	Drawing No	Issue
233985-00	Appendix A-2	I1


APPENDIX A - Hydrograph i: Groundwater and surface water levels - River Corrib to Lackagh Quarry
Characterising groundwater levels at Lackagh Quarry
OPW River Corrib Dangan Gauge
Western Coolagh Spring
Eastern Coolagh Spring
BH05
LQMW05
LQMW04
BH04
Lackagh Quarry (base of lower bench)
Lackagh Quarry (base of lower excavation)
LQMW04 (logged)
Recharge (mm)
BH05
-interaction with perched recharge
--Otherwise regional GWL at other times
LQMW05
-interaction with perched recharge
- regional groundwater level is high in SW corner of quarry
BH04 and LQMW04 show the regional groundwater table only
Water level m OD
Recharge mm/day
04/05/15
29/06/15
24/08/15
19/10/15
14/12/15
08/02/16
04/04/16
30/05/16
25/07/16
19/09/16
14/11/16
09/01/17



APPENDIX A - Hydrograph ii: Groundwater and surface water levels River Corrib to Lackagh Quarry
Characterising groundwater perched by the shale bed
OPW River Corrib Dangan Gauge
Western Coolagh Spring
Eastern Coolagh Spring
RP-2-5S (Logger)
RP-2-05S
LQ MW06
LQMW04
BH05
RP-2-5D
RP-2-5D
Recharge (mm)
BH05
-interaction with perched recharge
--Otherwise regional GWL at other times
LQMW06 shows a perched groundwater level flashy response. .
RP-2-05S (logger) shows a perched groundwater level response
- flashy
RP-2-05D (logger) is located in the deeper regional groundwater table but still shows a moderately flashy response
Water level m OD
Recharge mm/day
04/05/15
29/06/15
24/08/15
19/10/15
14/12/15
08/02/16
04/04/16
30/05/16
25/07/16
19/09/16
14/11/16
09/01/17

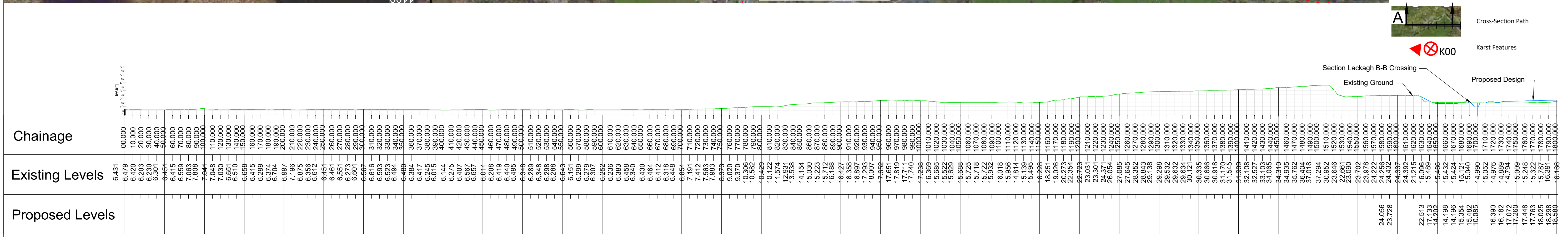


APPENDIX A - Hydrograph iii: Groundwater and surface water levels River Corrib to Lackagh Quarry
Characterising groundwater contributions to Coolagh Lakes (Lough Corrib cSAC)
OPW River Corrib Dangan Gauge
Western Coolagh Spring
Eastern Coolagh Spring
MW2
RP-2-5D
RP-2-5D (logged)
RC133 (Turlough K31)
MW1
MW01 (logged)
MW3
MW03 (Logged)
RP-2-05S
Recharge (mm)
BHs located around the periphery of Coolagh Lakes can be characterised into:
Groundwater emergent at Western Coolagh Spring
Groundwater seepage from around the periphery
Eastern Coolagh Spring shows no measureable level variance
Water level m OD
Recharge mm/day
04/05/15
29/06/15
24/08/15
19/10/15
14/12/15
08/02/16
04/04/16
30/05/16
25/07/16
19/09/16
14/11/16
09/01/17

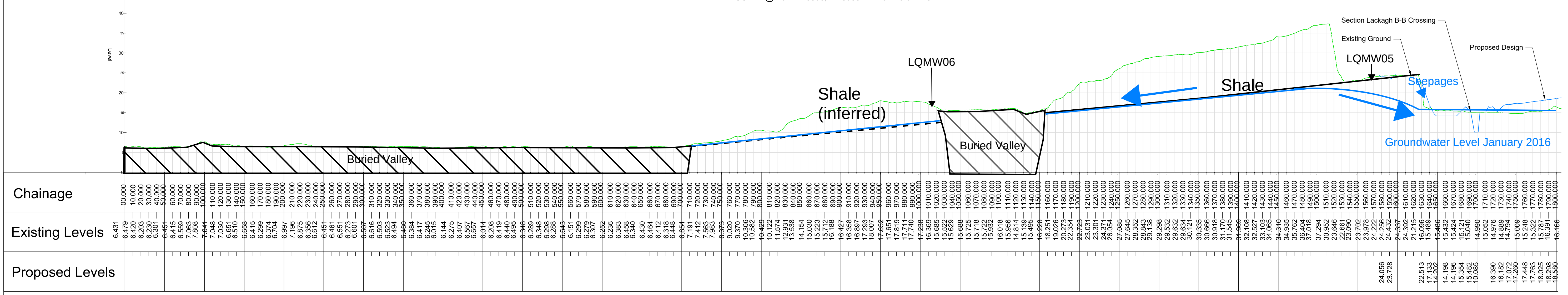
Appendix B

Cross-Sections

B.1 Cross-Sections



ALIGNMENT - Lackagh A-A - LONGSECTION in Natural Scale
SCALE @ A3: H 1:5000,V 1:5000. DATUM: 0.0m AOD



ALIGNMENT - Lackagh A-A - LONGSECTION in 5x Exaggeration Scale
SCALE @ A3: H 1:5000,V 1:1000. DATUM: 0.0m AOD

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Scale: @A3 H 1:5000 , V - See Profile Scale

Date: March 2020

Issue	Date	By	Chkd	Appd
I2	05/03/2020	KJ	LB	EMC
I1	02/03/2020	KJ	LB	EMC

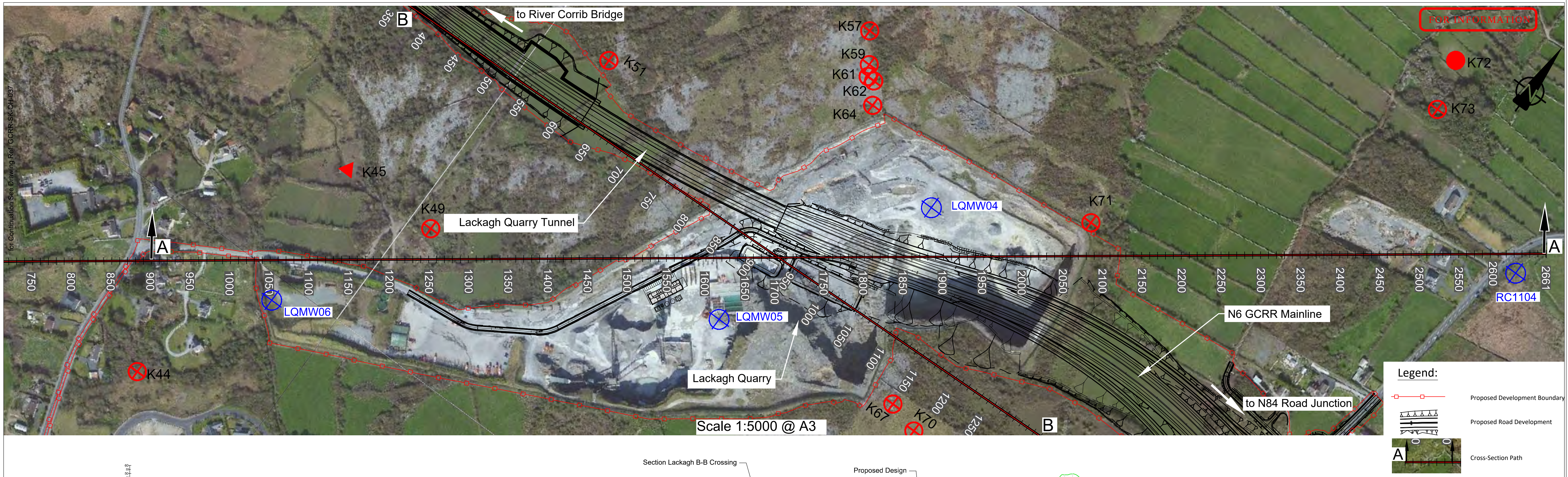
Drawing Title
Existing Ground & Proposed Design

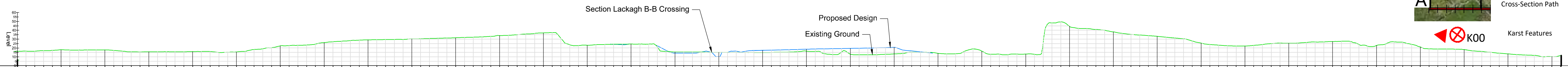
Cross Section Lackagh A-A Sheet 1 of 2

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	GCOB-SK-OH-037	I2

Do not scale





Chainage	Existing Levels	Proposed Levels
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910.000	16.358	
920.000	16.897	
930.000	17.293	
940.000	18.007	
950.000	17.652	
960.000	17.651	
970.000	17.819	
980.000	17.711	
990.000	17.740	
1000.000	17.238	
1010.000	16.369	
1020.000	15.685	
1030.000	15.522	
1040.000	15.629	
1050.000	15.688	
1060.000	15.725	
1070.000	15.718	
1080.000	15.722	
1090.000	15.932	
1100.000	16.018	
1110.000	15.956	
1120.000	14.814	
1130.000	15.139	
1140.000	15.495	
1150.000	16.228	
1160.000	18.251	
1170.000	19.026	
1180.000	20.273	
1190.000	22.354	
1200.000	22.723	
1210.000	23.031	
1220.000	23.301	
1230.000	24.371	
1240.000	26.054	
1250.000	27.085	
1260.000	27.645	
1270.000	28.352	
1280.000	28.843	
1290.000	29.138	
1300.000	29.298	
1310.000	29.532	
1320.000	29.632	
1330.000	29.634	
1340.000	30.121	
1350.000	30.335	
1360.000	30.666	
1370.000	30.918	
1380.000	31.170	
1390.000	31.545	
1400.000	31.909	
1410.000	32.108	
1420.000	32.527	
1430.000	33.103	
1440.000	34.065	
1450.000	34.310	
1460.000	34.935	
1470.000	35.762	
1480.000	36.404	
1490.000	37.018	
1500.000	37.294	
1510.000	30.952	
1520.000	23.646	
1530.000	22.661	
1540.000	23.090	
1550.000	23.702	
1560.000	23.978	
1570.000	24.222	
1580.000	24.256	24.056
1590.000	24.432	23.728
1600.000	24.337	
1610.000	24.392	
1620.000	21.215	
1630.000	16.096	22.513
1640.000	15.489	17.133
1650.000	15.486	14.202
1660.000	15.432	14.198
1670.000	15.424	14.196
1680.000	15.121	15.354
1690.000	15.040	15.482
1700.000	14.990	10.085
1710.000	15.052	
1720.000	14.976	16.390
1730.000	14.889	16.182
1740.000	14.794	17.072
1750.000	15.009	17.260
1760.000	15.248	17.448
1770.000	15.322	17.763
1780.000	15.787	18.025
1790.000	16.391	18.298
1800.000	16.166	18.580
1810.000	13.649	18.872
1820.000	12.495	19.057
1830.000	15.352	19.192
1840.000	12.905	19.340
1850.000	12.333	19.502
1860.000	12.360	19.676
1870.000	12.344	19.862
1880.000	12.827	20.084
1890.000	13.282	20.351
1900.000	13.828	20.643
1910.000	15.266	17.576
1920.000	14.938	16.596
1930.000	15.048	15.616
1940.000	13.910	14.521
1950.000	13.254	
1960.000	13.444	
1970.000	16.079	
1980.000	19.019	
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2000.000	12.877	
2010.000	13.075	
2020.000	12.473	
2030.000	13.087	
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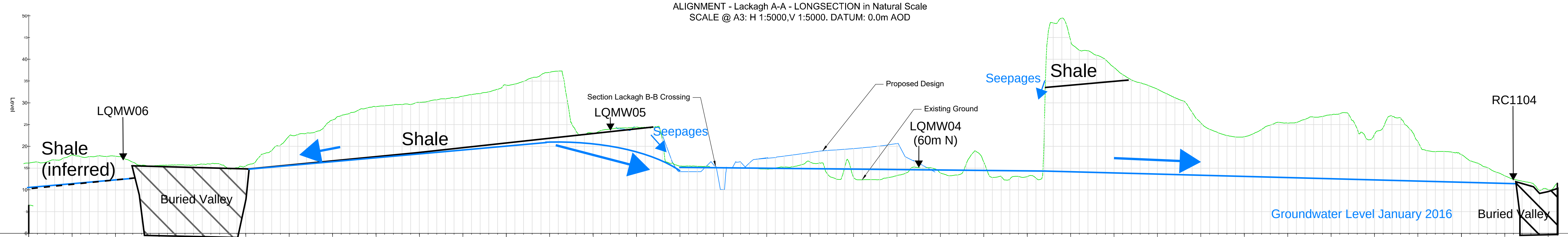
ALIGNMENT - Lackagh A-A - LONGSECTION in Natural Scale
SCALE @ A3: H 1:5000,V 1:5000. DATUM: 0.0m AOD



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2660.000		

ALIGNMENT - Lackagh A-A - LONGSECTION in 5x Exaggeration Scale
SCALE @ A3: H 1:5000,V 1:1000. DATUM: 0.0m AOD

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Scale: @A3 H 1:5000 , V - See Profile Scale

Date: March 2020

Issue	Date	By	Chkd	Appd
I2	05/03/2020	KJ	LB	EMC
I1	02/03/2020	KJ	LB	EMC

Drawing Title
Existing Ground & Proposed Design

Cross Section Lackagh A-A Sheet 2 of 2

Drawing Status
For Information

Job No	Drawing No	Issue
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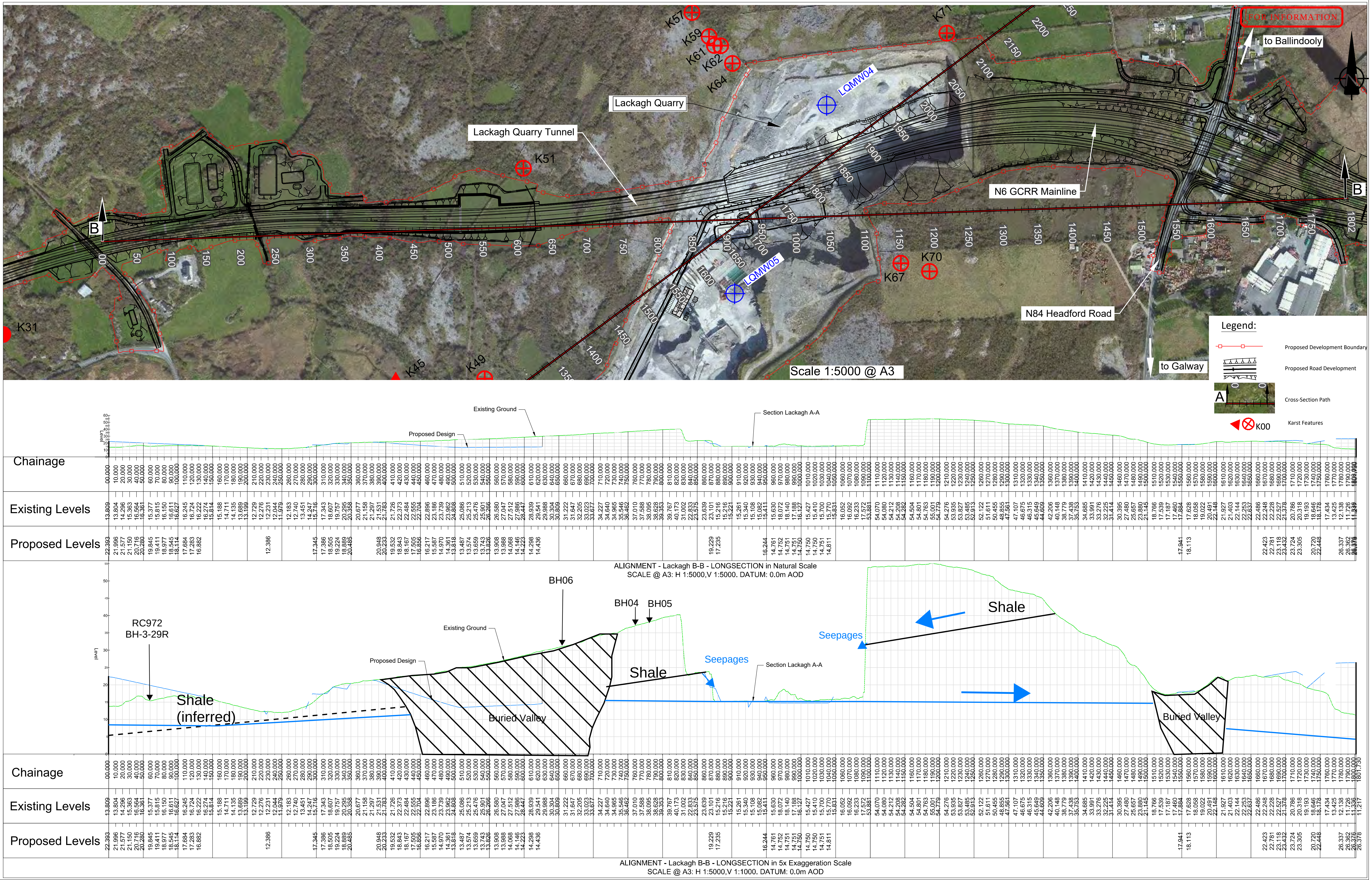

Clients

An Roinn Iompair, Turasóireachta agus Spóirt
Project Ireland 2040
N6 Galway City Transport Project
Comhairle Chontae na Gaillimhe
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Job Title: N6 Galway City Ring Road

Scale: @A3 H 1:5000 , V - See Profile Scale

Date: March 2020

Issue	Date	By	Chkd	Appd
I2	05/03/2020	KJ	LB	EMC
I1	02/03/2020	KJ	LB	EMC

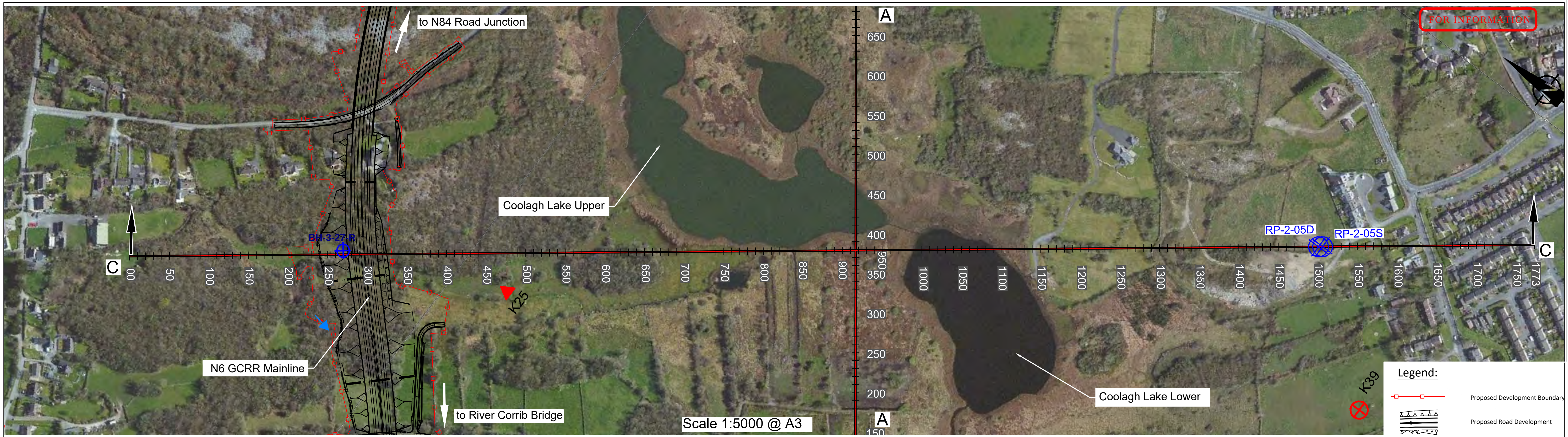
Drawing Title: Existing Ground & Proposed Design

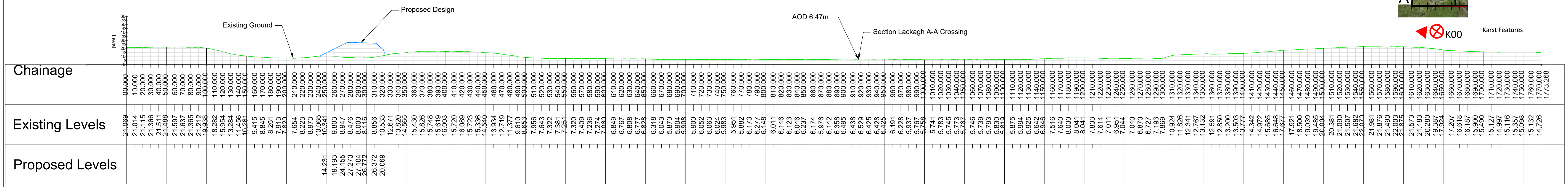
Cross Section Lackagh B-B

Drawing Status: For Information

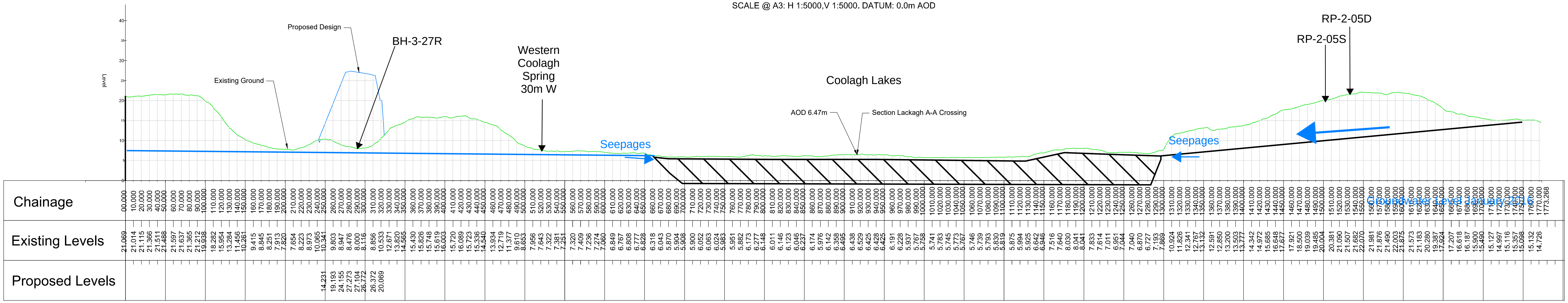
Job No	Drawing No	Issue
233985-00	GCOB-SK-OH-039	I2

Do not scale





ALIGNMENT - Lackagh C-C - LONGSECTION in Natural Scale
SCALE @ A3: H 1:5000,V 1:5000. DATUM: 0.0m AOD



ALIGNMENT - Lackagh C-C - LONGSECTION in 5x Exaggeration Scale
SCALE @ A3: H 1:5000,V 1:1000. DATUM: 0.0m AOD

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Job Title
N6 Galway City Ring Road

Scale: @A3 H 1:5000 , V - See Profile Scale

Date: March 2020

Issue	Date	By	Chkd	Appd
I2	05/03/2020	KJ	LB	EMC
I1	02/03/2020	KJ	LB	EMC

Drawing Title
Existing Ground & Proposed Design

Cross Section Lackagh C-C

Drawing Status
For Information

Job No	Drawing No	Issue
233985-00	GCOB-SK-OH-040	I2

Do not scale