Chapter 9 Hydrogeology

9.1. Introduction

This chapter of the Environmental Impact Assessment Report evaluates the proposed road development in relation to hydrogeology. It has been prepared in accordance with the Transport Infrastructure Ireland (TII) publication '*Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes (2008)*' and *DN-DNG-03065 "Road Drainage and the Water Environment (including Amendment No. 1 dated June 2015)*."

The study entailed an assessment of published literature available from various sources and geological and geotechnical intrusive and geophysical investigation work carried out for the purposes of the proposed road development, to identify areas of subsurface karst limestone and the depth and type of subsoil underlying the proposed road development, thus enabling an assessment of groundwater vulnerability. Site specific aerial photography and LiDAR data has been reviewed to locate any potential features of hydrogeological interest, and these have been investigated on the ground by walkover surveys in order to assess their significance and the likelihood of environmental impacts on them associated with the proposed road development.

This assessment includes liaison with the agricultural and ecological specialists to obtain relevant information on private wells and sites of ecological importance along the proposed road development.

The scope of the study entails:

- Description of the hydrogeological setting underlying the proposed road development;
- Description and evaluation of the likely impacts of the proposed road development in terms of construction and operational phases including the character, magnitude and duration of such impacts;
- Description and development of proposed mitigation measures to minimise any potential impacts;
- Description of the residual impacts after mitigation; and
- Description of impact interactions and cumulative impacts.

9.2. Methodology

9.2.1 Data Sources

The following list of data sources were the main information sources reviewed as part of this Environmental Impact Assessment Report chapter:

Ordnance Survey (OSi)

- Discovery Series Mapping (1:50,000)
- Six Inch Raster Maps (1:10,560)
- Twenty Five Inch Vector Maps (1:2,500)
- Orthographic Aerial maps (1995, 2000, 2005)

Geological Survey of Ireland (GSI)

- Groundwater Newsletter (various issues)
- Bedrock Geology Mapping
- Aquifer Mapping
- Groundwater Vulnerability Mapping
- Groundwater Source Protection Mapping
- Geology of The Shannon Estuary: A Geological Description of The Shannon Estuary Region including parts of Clare, Limerick and Kerry with accompanying bedrock geology 1:100,000 scale map, Sheet 17

Teagasc

- Subsoil Classification Mapping
- Well Database
- Karst Features and Tracer Test Database
- Unpublished Turlough Database

Environmental Protection Agency (EPA)

- Water Quality Monitoring Database and Reports
- Water Framework Directive Classification
- Towards Setting Guideline Values for The Protection of Groundwater in Ireland

Limerick City and County Council

- Limerick County Development Plan 2010-2016 (as extended)
- Planning Register
- Water Services – Abstractions, Discharges & Supply Schemes
- Limerick Groundwater Protection Scheme Reports (2018)

National Parks and Wildlife Service (NPWS)

- Designated Areas Mapping
- Site Synopsis Reports

Other Sources

- Aerial survey photography (flown 2006, 2007, 2010, 2012 & 2015)
- LiDAR data (flown Feb 2015)
- Review of Office of Public Works (OPW) online mapping
- Met Eireann meteorological data
- Water Framework Directive River Basin Management Plans
- Department of the Environment, Heritage and Local Government (DoEHLG), Environment Protection Agency (EPA) and Geological Survey of Ireland (GSI) (1999). Groundwater Protection Scheme Reports

9.2.2 Legislation and Guidelines

This chapter is prepared having regard to the requirements of Section 50 Sub-section (2 and 3) of the Roads Act 1993 as amended, Annex IV of Directive 2011/92/EU (as substituted by Directive 2014/52/EU), and the following guidance:

- Transport Infrastructure Ireland (2008). Environmental Impact Assessment of National Road Schemes – A Practical Guide;
- Transport Infrastructure Ireland (2008). Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes;
- Transport Infrastructure Ireland (2015). DN-DNG-03065 - Road Drainage and the Water Environment (*including Amendment No. 1 dated June 2015).*
- Transport Infrastructure Ireland (2015). DN-DNG-03022 Drainage Systems for National Roads (including Amendment No. 1 dated June 2015)
- EPA (2017). Draft Guidelines on the Information to be contained in Environmental Impact Assessment Reports
- EPA (2015). Draft Advice Notes for Preparing Environmental Impact Statements
- DoEHLG (2010). Appropriate Assessment of Plans and Projects in Ireland - Guidance for Planning Authorities
- EPA (2002) Guidelines on the information to be contained in Environmental Impact Statements
- EPA (2003). Advice Notes on current practice (in the preparation of Environmental Impact Statements)
- Institute of Geologists of Ireland (2002). Geology in Environmental Impact Statements: A Guide
- Institute of Geologists of Ireland (2013). Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of Environmental Impact Statements

Additionally, the following legislation was taken into account:

- S.I. No. 296 of 2018, European Union (Planning and Development) (Environmental Impact Assessment) Regulations 2018.
- S.I. No. 473 of 2011, European Union (Environmental Impact Assessment and Habitats) Regulations 2011.
- S.I. No. 366/2016 - European Union Environmental Objectives (Groundwater) (Amendment) Regulations 2016.
- S.I. No. 366/2016 - European Union Environmental Objectives (Groundwater) (Amendment) Regulations 2016.
- S.I. No. 722 of 2003, European Community (Water Policy Regulations, 2003.
- S.I. No 272 of 2009, European Communities Environmental Objectives (Surface Waters) Regulations, 2009
- S.I. No. 9 of 2010, European Communities Environmental Objectives (Groundwater) Regulations, 2010.
- Directive 2000/60/EC – "The Water Framework Directive"
- Directive 2006/118/EC – "The Groundwater Directive"
- The Planning and Development Act, 2000, as amended,
- S.I. 600 of 2001 Planning and Development Regulations as amended.
- European Communities Environmental Objectives (Groundwater) Regulations 2010-2012.
- S.I. No. 122 of 2014 European Union (Drinking Water) Regulations
- European Communities (Water Policy) Regulations, 2003 (S.I. No. 722 of 2003),

- European Communities Environmental Objectives (Surface Waters) Regulations, 2009 (S.I. No. 272 of 2009)

9.2.3 Consultation with Regulatory and Other Bodies

Consultation was carried out with relevant bodies as follows:

- Geological Survey of Ireland (GSI);
- National Parks and Wildlife Service (NPWS)
- Office of Public Works (OPW)
- Limerick City and County Council (LCCC) Environment and Water Services Departments

Consultation with all of the other relevant specialists on the project team has been undertaken throughout the development of the proposed road development.

9.2.4 Field Surveys and Ground Investigations

Field surveys were carried out to assess the hydrogeological aspects of the proposed road development. Detailed site walkovers were made at any key areas of concern. At sensitive locations, water supply springs, wells and / or boreholes were visited and assessed in respect to use, well characteristics, yield and recharge area.

Ground investigations have been undertaken for the proposed road development during the period 2016-2019. These investigations consisted of boreholes, trial pits and dynamic probes to determine the characteristics of the overburden material, and rotary cores to determine the bedrock conditions and rock strength. In addition geophysical surveys were carried out at various locations along the route including at areas of known or suspected karst activity. Standpipes and piezometers were installed in areas of interest with respect to groundwater and monitoring of groundwater levels (both manually and digitally) was undertaken to ascertain seasonal groundwater fluctuations. Groundwater quality was monitored at sensitive locations in order to determine baseline conditions and, in areas of concern relating to potential ground contamination, environmental sampling of soil and groundwater was carried out to determine the nature and extent of any contaminants which may be present.

9.2.5 Impact Assessment for Hydrogeology

An impact assessment has been made of any key hydrogeological features identified along the proposed road development. The methodology follows guidelines for the completion of EIAR established by both the EPA and TII and was also completed with reference to the relevant Institute of Geologists of Ireland (IGI) EIAR guidelines and relevant TII design guidelines (e.g. DN-DNG-03065 and DN-DNG-03022) where appropriate.

The impact assessment also closely followed the methodology set out by the EPA in their guideline document "Guidelines on the Information to be contained in Environmental Impact Assessment Reports". For each hydrogeological feature the magnitude of the impact has been assessed in the absence of mitigation and, in combination with the importance of the attribute (i.e the significance of a potential impact), and an impact rating has been applied. The impact rating takes into account the sensitivity and importance of the feature in combination with the character/magnitude/duration/likelihood/and consequences of any potential impact. See below for magnitude and impact ratings from the TII Guidelines.

Table 9.1 Criteria for Rating Impact Significance at EIAR (EIS) Stage – Estimation of Magnitude of Impact on Hydrogeology Attribute (TII, 2008)

Magnitude of Impact	Criteria	Typical Examples
Large Adverse	Results in loss of attribute and /or quality and integrity of attribute.	Removal of large proportion of aquifer. Changes to aquifer or unsaturated zone resulting in extensive change to existing water supply springs and wells, river baseflow or ecosystems. Potential high risk of pollution to groundwater from routine run-off[1]. Calculated risk of serious pollution incident >2% annually[2].
Moderate Adverse	Results in impact on integrity of attribute or loss of part of attribute.	Removal of moderate proportion of aquifer. Changes to aquifer or unsaturated zone resulting in moderate change to existing water supply springs and wells, river baseflow or ecosystems. Potential medium risk of pollution to groundwater from routine run-off[1]. Calculated risk of serious pollution incident >1% annually[2].
Small Adverse	Results in minor impact on integrity of attribute or loss of small part of attribute.	Removal of small proportion of aquifer. Changes to aquifer or unsaturated zone resulting in minor change to water supply springs and wells, river baseflow or ecosystems. Potential low risk of pollution to groundwater from routine run-off[1]. Calculated risk of serious pollution incident >0.5% annually[2]e
Negligible	Results in an impact on attribute but of insufficient magnitude to affect either use or integrity	Calculated risk of serious pollution incident <0.5% annually[2].

1 Refer to Annex 1, Method C, Annex 1 of HA216/06

2 Refer to Appendix B3/Annex 1, Method D, Annex 1 of HA216/06

Table 9.2 Rating of Significant Environmental Impacts at EIAR Stage (TII, 2008)

	Negligible	Small Adverse	Moderate Adverse	Large Adverse
Extremely High	Imperceptible	Significant	Profound	Profound
Very High	Imperceptible	Significant / Moderate	Profound/ Significant	Profound
High	Imperceptible	Moderate / Slight	Significant / Moderate	Profound/ Significant
Medium	Imperceptible	Slight	Moderate	Significant
Low	Imperceptible	Imperceptible	Slight	Slight/ Moderate

9.3. Receiving Environment for Hydrogeology

9.3.1 Soils & Subsoils

GSI Mapping

According to GSI Quaternary Mapping, subsoils within the study area predominantly consist of limestone tills of moderate to low permeability. Subsoil cover is shallow along much of Section A (Foynes to Ballyclogh), Section B (Ballyclogh to Askeaton) and Section C (Ballyclogh to Rathkeale), of the proposed road development and areas of limestone bedrock crop out in many areas. Small isolated pockets of fen peat and Lake Marl are also present, located mainly between Askeaton and Rathkeale. Alluvium deposits are present along the path of the main rivers and their adjacent floodplains. More extensive deposits of Limestone Tills are present along the majority of Section D Rathkeale to Adare again with Alluvium deposits located adjacent to the main rivers which are encountered. An area of fen peat is located north of the alignment at Rathkeale and "Made Ground" is present where the proposed road development passes within urbanised areas such as Foynes, Askeaton, Rathkeale and Adare. Refer to Figure 9.1 EIAR Volume 3 for Quaternary mapping of the area and also to Chapter 8 Soil & Geology.

Intrusive Site Investigations

Borehole logs, Trial Pit Records, dynamic probes and in-situ and laboratory test results were reviewed during this assessment to determine the nature and extent of subsoils along the proposed road development. The intrusive site investigations largely confirmed the Quaternary Subsoil Mapping as described above. A number of trial pits encountered horizons of silts, sands and gravels some of which were between 1 – 2m in thickness. The more extensive deposits of silts and sandy gravelly silts and clays were generally located in Section C between Ballyclogh and Rathkeale. Silts were also encountered at the more western end of Section A near Foynes. Areas where these silts and lower permeability clays were located, were wetter with perched soil water encountered in a number of isolated locations. Clays encountered along Sections A- C generally contained sandy or sandy/gravelly fractions (some silty clays were encountered in isolated areas) and generally appeared moderately to well drained. In-situ soil infiltration tests (Bre365) were undertaken at selected Trial Pit locations and infiltration coefficients ranging between 1.9 x 10^{-6} and 8.2 x 10^{-7} ms^{-1} were determined for subsoils in Sections A – C. The Limestone Tills encountered in Section D were predominantly sandy clays, gravelly clays or sandy gravelly clays and appeared very well drained. In-situ soil infiltration tests (BRE365) were undertaken at selected Trial Pit locations and infiltration coefficients ranging between 3.6 x 10^{-3} and 2.08 x 10^{-3} ms^{-1} in Section D indicated the generally free draining nature of the soil matrix.

9.3.2 Bedrock Geology

GSI Mapping

Generalised bedrock geology mapping along the route of the proposed road development indicates that it is predominantly underlain by Dinantian Pure Un-bedded Limestone rocks which form the Waulsortian Limestone formation. The Waulsortian Limestone formation comprises massive un-bedded limestone and mudstone. The limestone bedrock crops out in many locations particularly in Sections A and C. The dark muddy limestone and shaly mudstones of the Rathkeale formation are crossed in Sections C and D in the vicinity of Rathkeale. At the eastern end of Section D the proposed road development crosses Pure Un-bedded (Visean) Limestones. Refer to Figure 9.2 EIAR Volume 3 for GSI Bedrock Geology mapping of the area.

Intrusive Site Investigations

In Sections A to C intrusive site investigations encountered moderately weak to strong Limestone and Mudstone at depths ranging between 0 – 17.1m below ground level (BGL). Generally, a weak weathered and broken zone of limestone and clay was encountered (1 – 4.7m thick) above more competent bedrock. Highly weathered zones were also encountered at subsequent depths in some borehole profiles. Calcite veins were noted to occur in some of the Limestone rocks which were encountered and in some areas these were noted as having been weathered to leave small voids in places.

In Section D intrusive site investigations encountered moderately weak to strong Pale to Dark Grey Limestone and Dark Grey to Black Mudstone at depths ranging between 0 – 17.6mBGL. Isolated Siltstone was also encountered towards the eastern end of the proposed road development in the vicinity of Adare. Moderately to highly weathered rock of between 1 – 4m in thickness was generally encountered above more competent bedrock. Minor calcite veining was noted in some of the Limestone horizons.

Contaminated Land

One area of possible ground contamination was identified along the proposed road development in the townland of Craggs some 4km east of Foynes just south of the existing N69. The site has historically been used as a fuel depot and large areas of coal storage are visible in aerial mapping of the location. Intrusive site investigations were carried out at the site which included a full suite or soil environmental sampling at various depths into the soil horizon and groundwater sampling. Whilst some evidence of soil contamination was present it was not extensive and was low in levels and toxicity. Any contaminated materials encountered during construction shall be removed off-site and disposed of in accordance with best practice and environmental licencing.

9.3.3 Groundwater Resources

The GSI has classified geological strata for hydrogeological purposes based on the value of the groundwater resource and the hydrogeological characteristics. There are three aquifer classifications of bedrock aquifer which the proposed road development passes through. Table 9.3 outlines the bedrock aquifer classifications that occur in the area for the different bedrock formations. Aquifer mapping for the area is illustrated in Figure 9.3 of Volume 3 of this EIAR.

Table 9.3 Aquifer Classification along the Proposed Road Development

Aquifer Classification	Code	Bedrock Formations
Regionally Important Aquifer - Karstified Conduit Flow	Rkc	Waulsortian Limestone (WA)
Regionally Important Aquifer – Karstified Diffuse Flow	Rkd	Waulsortian Limestone (WA)
Locally Important Aquifer – Bedrock which is moderately productive only in local zones	Ll	Durnish Formation (DU)
Locally Important Aquifer – Bedrock which is moderately productive only in local zones	Ll	Rathkeale Formation (RK)
Locally Important Aquifer – Bedrock which is moderately productive only in local zones	Ll	Visean Limestones (VIS)

Regionally Important Bedrock Aquifers

There are two classifications of regionally important aquifers present, namely:

- Regionally Important Aquifer - Karstified Conduit Flow (Rkc); and
- Regionally Important Aquifer – Karstified Diffuse Flow (Rkd).

Karstified conduit flow (Rkc) is classified where large conduits are present and the groundwater flow is concentrated within these preferential flow pathways. Karstified diffuse flow (Rkd) is present where the groundwater flow is considered to be more diffuse and regular. Waulsortian Limestone (WA) constitutes one of the most important aquifers in County Limerick and are classified as Regionally Important with both conduit and diffuse flow. The limestone aquifer underlying the area is predominantly karstified with conduit flow (RKc), however the degree of karstification reduces towards the east, and subsequently these rock formations are classified as having diffuse flow (Rkd). The regionally important aquifers cover the large majority of the area through which the proposed road development passes. These aquifers show evidence of karstification and dolomitisation which enhances permeability within the bedrock. Large abstraction rates have been developed within the aquifer and it is reported as being capable of supplying regional schemes with a number of Group Water Schemes (GWS) in Limerick exploiting groundwater resources from these Waulsortian Limestones.

Locally Important Aquifers

Locally Important Aquifers, Bedrock which is moderately productive only in local zones (Ll), are present at the west of the proposed road development near Foynes and at the east of the proposed road development near Adare. Smaller extents of locally important bedrock aquifer are also present near Rathkeale where the Rathkeale formation intersects the Waulsortian Limestone. Locally important aquifers are capable of providing relatively smaller groundwater supplies for local needs but are not usually capable of providing regional supplies.

9.3.4 Regional Hydrogeology

The majority of Sections A, B and C pass through the Askeaton Groundwater Body (GWB). The Askeaton GWB is mainly comprised of a Regionally important karstified (Rkd) aquifer dominated by diffuse flow. The main discharges from this GWB are to the streams and rivers crossing the GWB, particularly the Rivers Deel, Ahacronane and Shannon Estuary to the north. Groundwater flow is generally in a south-north direction with local variations where topographical highs and surface water bodies influence the water table. The rivers are in hydraulic continuity with the bedrock aquifer and drainage is generally good indicating a high transmissivity aquifer. Dry weather flows are relatively low across the Askeaton GWB indicating low aquifer storativity. This is consistent with limestone aquifers in general which offer poor primary porosity. A number of Group Water Schemes (GWS) are located within this GWB due to the productive nature of the limestone.

Section C passes in close proximity and adjacent to the western edge of the Groundwater-Dependent Terrestrial Ecosystem (GWDTE) Askeaton South Fens GWB between Ch.24+000 and 25+000. This GWB is the mapped extents of the groundwater system which feeds and maintains the Askeaton Fen SAC. The GWB drains via surface streams and ditches to the west and north as the bedrock is discharging to the ground surface at Askeaton Fen maintaining the wetland system. Section C also passes through a portion of the Shanagolden GWB which is a narrow GWB orientated north-south and discharging to rivers and streams generally orientated in a northerly direction towards the Shannon estuary and is generally poorly productive.

Section D of the proposed road development passes through the Fedamore Groundwater Body (GWB) for almost its entire length. The majority of this GWB is comprised of an Regionally important karstified (Rkd) aquifer dominated by diffuse flow. The main discharges are to the streams and rivers crossing the GWB, particularly the Rivers Maigue, Clonshire and Greanagh. The rivers are in hydraulic continuity with the bedrock aquifer and drainage is generally good indicating a high transmissivity aquifer. As for the Askeaton GWB, dry weather flows are relatively low across the GWB indicating low aquifer storativity. A number of GWS are located within this GWB due to the productive nature of the limestone. A small portion of the western end of Section D is within the Newcastle West GWB which is generally dominated by karst rocks.

9.3.5 Groundwater Vulnerability

The risk to groundwater from potential pollution is defined through assessments of groundwater vulnerability, aquifer potential and source protection areas. Groundwater vulnerability represents the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities. It depends on the travel time of infiltrating water (and contaminants), the amount of contaminants that can reach groundwater and the contaminant attenuating capacity of the geological materials through which the water and contaminants infiltrate. The final groundwater vulnerability rating is determined by both the thickness of the unsaturated subsoil which the contaminants move through and the attributes of the overlying subsoil and more specifically the subsoil permeability (DELG/EPA/GSI, 1999). The nature of groundwater recharge (point or diffuse) and how readily water is received also influences the final vulnerably rating of an area. Areas where water (and contaminants) can quickly move from the land surface to groundwater are deemed to be more vulnerable and in that regard groundwater vulnerability is primarily dependant on the permeability and depth of the overburden.

The GSI guidelines given in their Groundwater Protection Schemes (DELG/EPA/GSI, 1999) can be combined with site investigation data (geological and hydrogeological characteristics) to obtain appropriate vulnerability ratings for the ground along the proposed road development. Four groundwater vulnerability categories are defined: extreme (E), high (H), moderate (M) and low (L). A subset of the 'extreme' category is termed the extreme (X) category, and relates to areas of bedrock outcrop or sub-crop (<1m), or within 30m of a location of point recharge (i.e. karst feature). Table 9.4 outlines the geological and hydrogeological characteristics which determine the vulnerability of an area.

Table 9.4 Groundwater Vulnerability Mapping Guidelines

Vulnerability Rating	Hydrogeological Conditions				
	Subsoil Permeability (Type) and Thickness			Unsaturated Zone	Karst Features
	High permeability (sand/gravel)	Moderate permeability (e.g. Sandy subsoil)	Low permeability (e.g. Clayey subsoil, clay, peat)	(Sand/gravel aquifers only)	(< 30m radius)
Extreme (E)	0 – 3.0m	0 – 3.0m	0 – 3.0m	0 – 3.0m	n/a
High (H)	> 3.0m	3.0 – 10.0m	3.0 – 5.0m	> 3.0m	n/a
Moderate (M)	n/a	> 10.0m	5.0 – 10.0m	n/a	n/a
Low (L)	n/a	n/a	> 10.0m	n/a	n/a

<table>
<tr><th rowspan="3">Vulnerability Rating</th><th colspan="5">Hydrogeological Conditions</th></tr>
<tr><th colspan="3">Subsoil Permeability (Type) and Thickness</th><th>Unsaturated Zone</th><th>Karst Features</th></tr>
<tr><th>High permeability (sand/gravel)</th><th>Moderate permeability (e.g. Sandy subsoil)</th><th>Low permeability (e.g. Clayey subsoil, clay, peat)</th><th>(Sand/gravel aquifers only)</th><th>(< 30m radius)</th></tr>
<tr><td colspan="6">n/a = not applicable.
Precise permeability values cannot be given at present.
Release point of contaminants is assumed to be 1-2m below ground surface.</td></tr>
</table>

GSI Mapping

The GSI mapping indicates the vulnerability of the groundwater closest to the ground surface from contaminants assumed to be released 1m to 2m below the ground surface. Vulnerability mapping is used for guidance only and should be supported by site investigation data and contaminant specific assessments where appropriate. In this regard a detailed programme of ground investigations has been undertaken along the proposed road development allowing the site-specific vulnerability to be determined. In unsaturated bedrock aquifers the target for protection is the groundwater table within the bedrock unit, and for saturated aquifers it is the top of the bedrock.

In karst areas groundwater is particularly vulnerable to contamination with an extreme rating as:

- water ingress can be rapid through solution enlarged fissures
- sinking streams enable direct entry of water with little or no attenuation of contaminants
- karst features such as dolines can provide direct water entry routes through vertical shafts
- soil cover over karst limestone tends to be minimal or absent and so provides little or no protection (GSI, 2002).

A large proportion of the proposed road development crosses areas of High to Extreme Groundwater Vulnerability - refer to Figure 9.4 EIAR Volume 3 for GSI vulnerability mapping of the area. This is a consequence of the extensive areas where karst bedrock is exposed and/or where sub-soils are reported as being shallow (<3m thick).

There are areas of moderate and low groundwater vulnerability present along the River Maigue estuary as far upstream as Adare village and beyond. This is in areas where alluvium deposits are present.

The proposed road development crosses mapped vulnerability ratings of Extreme (E) and Extreme with outcropping (X) for long sections and therefore groundwater is potentially at risk in these areas from the proposed road development. The specific risk to groundwater from pollution (specifically relating to the associated road drainage) and the associated impact assessment are outlined in Section 9.4 and was undertaken as per the procedure outlined in the TII standard DN-DNG-03065 and with reference to the appropriate Groundwater Protection Response.

Intrusive Site Investigations

Section A

GSI mapping predominantly indicates a groundwater vulnerability rating of either Extreme (E) or Extreme (X) with rock close to or at the ground surface along Section A of the proposed road development. Areas of Moderate (M) and High (H) vulnerability are mapped in the vicinity of Ch2+000 near Foynes. The intrusive ground investigations did not agree with the extent of mapped areas of Extreme (X) groundwater vulnerability with a number of locations more likely High or even Moderate groundwater vulnerability due to depths of between 10.4m and 17m of moderate permeability subsoil above the limestone bedrock (e.g. RC02-05 & RC03-06 at Ch.2+650 & Ch.3+850, See Figures 8.1 – 8.24 in Volume 3).

Between Ch. 1+000 and 4+000 subsoil and depth to bedrock conformed to a groundwater vulnerability of High with bedrock at a depth of 3 – 10m below ground overlain by a Moderate to Low permeability subsoil.

Between Ch.4+000 and 10+000 bedrock was found to be extremely shallow ranging between 0.4m and 3m (e.g. RC05-04 & RC06-05 at Ch.5+450 & Ch.6+550 See Figures 8.1 – 8.24 in Volume 3) below ground level and therefore the mapped Extreme (X) groundwater vulnerability is appropriate.

Section B

The intrusive site investigations largely agreed with GSI groundwater vulnerability mapping in this section. GSI mapping predominantly indicates groundwater vulnerability ratings of Extreme (X) or Extreme (E) in Section B of the proposed road development. The intrusive ground investigations encountered the weathered limestone bedrock at less than 3m below ground level at all boreholes in this section of the proposed road development, confirming either the Extreme (E) of Extreme (X) vulnerability ratings.

Section C

The intrusive site investigations largely agreed with GSI groundwater vulnerability mapping in this section. GSI mapping indicates groundwater vulnerability rating of Extreme (X), Extreme (E) and High (H) in this section of the proposed road development. Bedrock was found to be undulating between 1.5m and 10.5m below ground level and was overlain by a moderate to low permeability subsoil. This generally agrees with the mapped High (H) or Extreme (E) vulnerability rating as per GSI mapping. The section of the alignment between Ch. 25+700 and 26+700 was found to consistently encounter limestone bedrock within 0-1m below ground level and is of Extreme (X) vulnerability.

Section D

The intrusive site investigations largely agreed with GSI groundwater vulnerability mapping in this section. GSI mapping predominantly indicates a groundwater vulnerability rating of either High (H) or Moderate (M) in this section. The intrusive ground investigations largely indicated High groundwater vulnerability due to bedrock being between 3-10m deep and overlain by high to moderate permeability subsoils. Localised zones of shallower bedrock of Extreme (E) vulnerability were encountered in the areas between Ch.53+000 to 54+000 and Ch.58+000 to 59+000 and also at discrete locations along the alignment.

9.3.6 Karst Features

Lough Selleher Turlough

Lough Selleher turlough is located in a basin between two peaks of elevated ground between Craggs and Mulderricksfield to the south of the existing N69 and also to the south of the proposed road development. The turlough forms a basin which is surrounded by dense scrub and trees and is surrounded by undulating farmland and pastures in the adjacent hillslopes. Given the elevation of the basin, it is likely that this feature is fed primarily by runoff from the steep adjacent hillslopes and drains slowly to bedrock. Two potential swallow hole or karst features were identified at the base of the turlough during the field survey, however the entire base of the basin has only a shallow cover of soils above the bedrock. The Ahacronane River is located c.780m to the north-west and it is possible that there is some hydrogeological link between the drainage of this feature and the river. A large quarry is located less than 400m directly south of the basin.

Tomdeely Turlough

This turlough forms a small depression in the land and is located in a field just south of the existing N69 at Tomdeely – approximately 1.5km north of the proposed alignment and some 5km east of Foynes. The base of the turlough is within the local groundwater table and has a permanent water level with some water observed during the drought of summer 2018. The winter water level extends further up the field towards the N69 and to the boundary of the adjacent local road.

Tomdeely North Turlough

This is a small feature located in scrubby lands to the north of the N69 at Tomdeely North approximately 2km north of the proposed alignment and some 5km east of Foynes. The feature may have been excavated historically to provide drinking water for livestock and was in use by cattle during the field survey. The base of the turlough is within the local groundwater table and has a permanent water level with some water observed during the drought of summer 2018.

Foleys Turlough

This feature forms a small depression in agricultural lands north of the existing N69 at Morgans North approximately 2km north of the proposed alignment and some 4.6km east of Foynes and floods during winter months draining to bedrock through areas of exposed outcropping bedrock and where subsoil is thin.

Karst Springs

There are three karst springs recorded in the GSI karst database located in the vicinity of Barrigone east of Foynes close to the turloughs described above - approximately 1 – 2km north of the proposed alignment. A spring is located in the townland of Ballyellinan some 170m south of the supply borehole for the Craggs/Barrigone GWS (described below). The supply borehole itself for the Craggs/Barrigone GWS encountered a large fissure or conduit zone at depth which is reported to supply the main body of the water to the borehole. Further to the north, two springs are located in low-lying lands which drain to local ditches and are used for agriculture supply in adjacent lands. A number of other springs and wells were also noted as occurring in these areas on Ordnance Survey Historic Mapping in the townlands of Morgans North/South, Tomdeely/Tomdeely North and Coolrahnee (approximately 2 - 3km north of the proposed alignment.

Pluvial / Groundwater Flooding at Rincullia

This is a low lying area of land which forms a portion of KER4 at Rincullia (refer to Chapter 7 (Biodiversity) for further details). Bedrock is shallow or exposed in this location and pluvial/groundwater flooding occurs at a low point in a field, which slowly percolates to bedrock following periods of extended rainfall. The rocky nature of the surrounding lands has led to the development of dense scrub woodland.

Site Investigations to Identify Karst Features

Geophysical surveys consisting of 2D-Resistivity and seismic refraction (p-wave) were carried as part of the site investigations. A total of 22 transects profiles were carried out along the proposed route with 11 profiles located within Sections A to C and a further 11 profiles carried out in Section D. For the majority of the profile transects carried out no evidence of karst features was detected, however, evidence of weathered limestone overlying more competent limestone bedrock was identified which is expected. A summary of the main findings in relation to karst features from the geophysical surveys is given below:

Section A – Profile GP01

Possible karst feature identified at approx. Ch.1+180 of the proposed alignment – see extract from the associated profile below in Plate 9.1 below. The location of the potential karst feature corresponds to the area identified as the location of a karst spring on GSI karst feature mapping. This feature is located below the proposed road development, which is in slight embankment through this section. See Table 9.18 for further details of proposed mitigation measures for this karst feature.

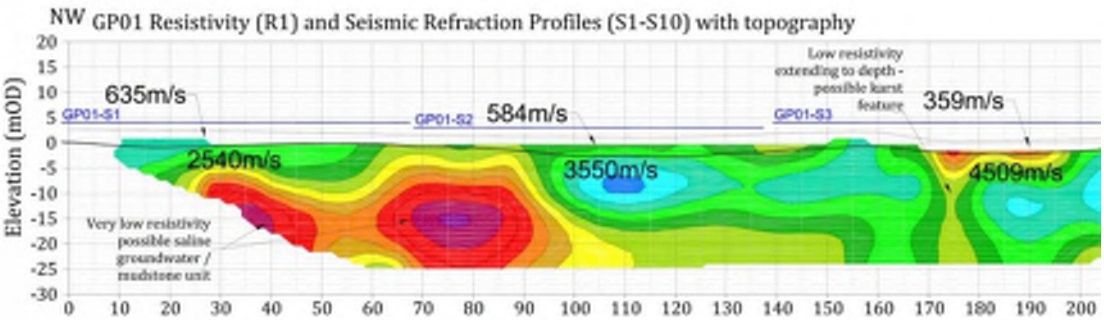

Plate 9.1 **Portion of the resistivity profile at GP01 in Section A of the proposed alignment.**

Section A – Profiles GP03 & GP04

Two geophysical profiles (GP03 & GP04) were undertaken along the length of the proposed deep bedrock cutting at Mulderricksfield over a combined length of 1150m. Competent limestone bedrock was encountered beneath the overburden along the entire length of these profiles with no karst features identified.

Section C – Profiles GP08 & GP09

Two geophysical profiles (GP08 & GP09) were undertaken along the length of the proposed road development as it passes through a wetland area south of the River Deel and west of Askeaton Fen Complex. Weathered limestone/mudstone was identified beneath the overburden above competent limestone bedrock at depth however no evidence of karst features was identified.

Section D – Profile GP03

A geophysical profile was undertaken along a portion of the proposed deep cutting near Croagh (between Ch.55+000 and Ch.55+500). Competent limestone bedrock was encountered beneath the overburden along the entire length of these profiles with no karst features identified.

9.3.7 Groundwater Recharge

The GSI Groundwater recharge map across the area indicates generally high recharge rates across the entire area. Recharge coefficients typically range between 35% and 85% (of effective rainfall) resulting in annual recharge depth of 200 - 676mm. Higher zones of recharge are indicated at areas of bedrock outcrops (450 – 676mm). The ability of the bedrock to accept recharge is based generally on the permeability of the weathered zone of bedrock likely extending 3 – 5m below the bedrock surface. This is due to the fact that the limestone bedrock offers very little primary porosity with storage occurring predominantly within fracture zones. Recharge caps are applied to the Locally Important Aquifers due to their inability to accept large volumes of water where fracturing is not extensive – these areas correspond to the lower recharge rates of 200mm per annum. In the karstic limestone aquifers, the shallow weathered zone together with the fractured bedrock are considered to be able to accept high recharge rates. The high recharge rates are facilitated by the generally moderate permeability subsoils which are shallow across the area.

9.3.8 Groundwater Abstractions

The study area is serviced by private and public water supply schemes, which are surface water and groundwater fed. Whilst the majority of the study area is serviced by public water schemes, a number of private group schemes within the area are groundwater fed. These include the group water schemes at Craggs-Barrigone in Section A at the north-western end of the proposed road development, Cappagh and Croagh-Farrandonnelly near Sections B & D north and northeast of Rathkeale and Coshma-Killeen east of Adare in Section D.

Given the rural nature of the study area, it is known that a significant number of houses are serviced by private groundwater supplies. Whilst the individual private wells may be considered to have low volume abstractions, large abstractions from private sources such as farms, creameries, hotels, and industrial premises are likely to be present as well.

The GWSs at Cappagh and Coshma-Killeen were assessed for potentially hydrogeological connectivity with the proposed road development and whether they were within any potential zone of impact from the proposed works. The Cappagh GWS is located more than 2km north of the proposed road development at Rathkeale and is separated by a groundwater divide. The Coshna-Killeen GWS is located over 1km south of the proposed road development near Adare and the proposed road development is down-gradient of the supply. Both of these GWSs are therefore outside the scope of the impact assessment.

There are therefore two Group Water Schemes (GWS) within the immediate vicinity of the proposed road development which are considered in the impact assessment:

- Craggs-Barrigone GWS
- Croagh-Farrandonnelly GWS

Craggs-Barrigone GWS

The Craggs-Barrigone Group Water Scheme is supplied from a borehole that is located in the townland of Ballyellinan 3km west of Askeaton – see Figure 9.2 below for details. The scheme supplies more than 63 connections with an average abstraction rate of 130m^3/day with a reported maximum yield of 180 – 240m^3/day (GSI, 2015). The wellhead and treatment system are located within two pump houses located in agricultural lands approximately 740m north of the proposed road development at its closest point as shown in Figure 9.3. Water is pumped from the supply borehole to the treatment works where both chlorination and Ultraviolet (UV) disinfection take place before the water is pumped to the supply reservoir. The reservoir is located c.1.8km southwest of the supply borehole and has a reported capacity of 50m^3. The Geological Survey of Ireland (GSI) in 2015 mapped the Zone of Contribution (ZOC) for the supply, see Figure 9.2 below.

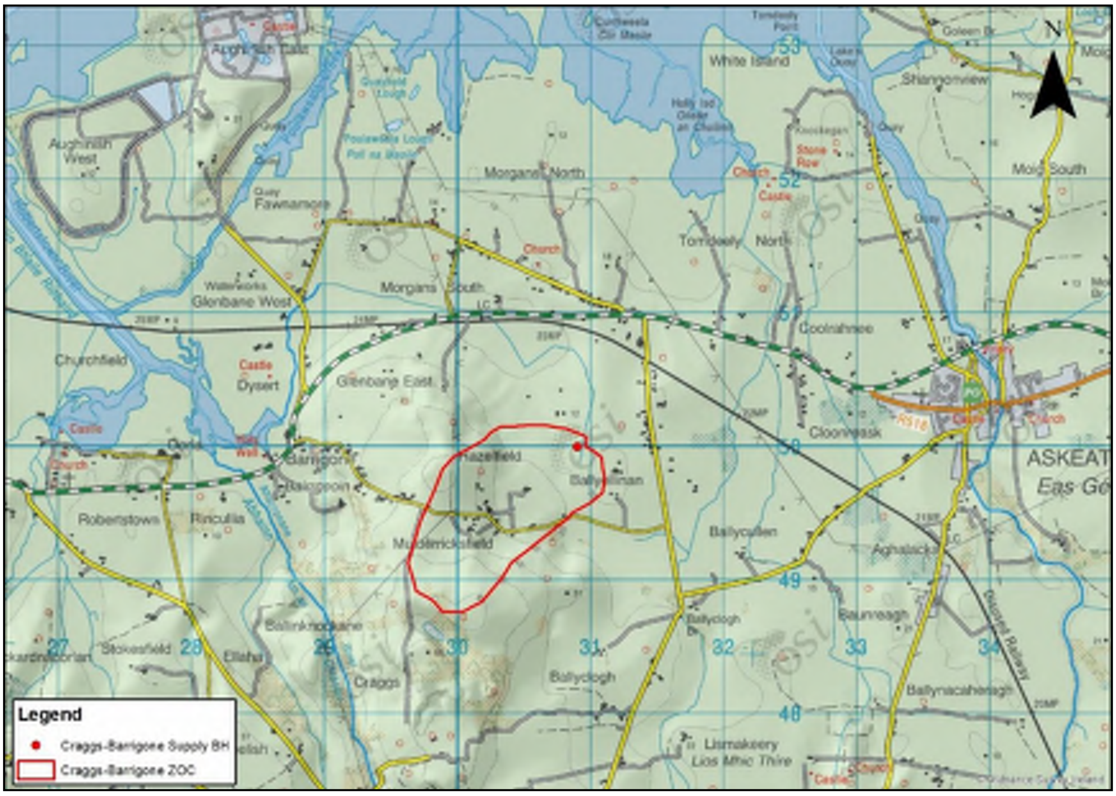

Plate 9.2 **Location of the Craggs-Barrigone Supply Borehole with approximate outline of mapped Zone of Contribution (ZOC)**

The GWS supply borehole is located within Dinantian Pure Un-bedded Limestones of the Waulsortian Limestone formation. These rocks are predominantly cropping out within the mapped zone of contribution at Hazelfield/ Mulderricksfield and are covered by a thin (<3m) layer of subsoil. There are no recorded faults in the immediate area. However minor faults are expected to be frequent and the bedrock is likely fractured to some degree across the catchment providing good secondary porosity within the aquifer. Ground investigations indicate sub-soils in the area to be thin or absent altogether. Where subsoils are present they were found to be of low to moderate permeability. The GSI vulnerability mapping of the area indicates a rating of Extreme (E) or Extreme (X) indicating subsoil depths of <3m across the area with large areas of outcrop. This mapping is generally consistent with what was discovered during ground investigations undertaken during this study – see Section 9.3.5 above. The ZOC for the GWS is therefore at risk from diffuse pollution across the catchment. The supply borehole is located in an area of relatively low-lying lands at the base of a topographical high to the south-west at Mulderricksfield which reaches a maximum elevation of 60m OD. Refer Plate 9.3. The ground elevations across the lands where the supply is located are at an elevation of c. 12m OD. The supply is from a 29m deep borehole with the main water strike reportedly encountered at a bedrock fracture c.24m BGL which is therefore at elevation of c.-12m OD.

In the context of the proposed road cutting within its zone of contribution the proposed road elevation is at 33mOD and the distance of the source from the proposed road cutting is c. 900m to the south-west.

The mapped ZOC area for this supply extends to an area of 1.2km^2 in an elliptical shape to the top of the hill at Craggs. The borehole is approximately 29 metres deep and therefore likely draws water from the shallow, epikarst layer with the majority of production reported from a deeper fracture or conduit intercepted at c. 24m BGL. Given the high recharge rates across the catchment the maximum abstraction rate of 195 m^3/day (150% of existing) requires a ZOC of less than 0.2 km^2 to sustain the required volume of recharge. The mapped ZOC has an area of 1.2km^2. The increase in size is due to the likelihood of distal point (or diffuse) recharge which is providing water to the main fracture within the borehole.

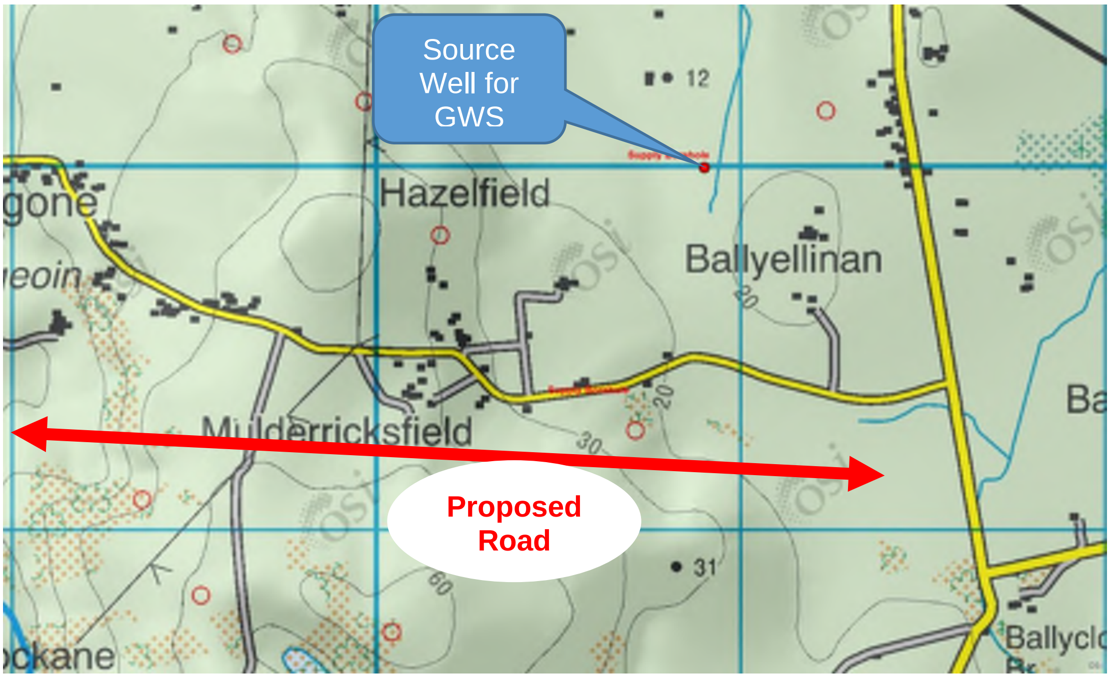

Plate 9.3 **Craggs-Barrigone Group Water Scheme Well Location and location of the Proposed Road Cutting**

Croagh-Farrandonnelly GWS

The Croagh-Farrandonnelly Group Water Scheme is supplied by a borehole located in the centre of Croagh Village adjacent to the existing N21 at a distance of c.600m to the south of the proposed road development (see Plate 9.4, below). The terrain rises gently from Croagh village northward and the level of the proposed road, which will be in cutting, is 6m higher than at the borehole. The supply borehole is c.80m deep with bedrock encountered at 5.5m. The ground elevation at Croagh where the supply is located c. 28m OD with an average static water level of c.26.8mOD. Multiple water strikes were encountered during drilling at elevations ranging between 22.5 – 27mOD. The average daily abstraction rate from the borehole is 54 m^3/day.

The Croagh-Farrandonnelly GWS supply borehole is located within Fedamore Groundwater Body and is within a Regionally important karstified aquifer dominated by diffuse flow (Rkd). Groundwater vulnerability in the area surrounding the Croagh-Farrandonnelly GWS supply, including the mapped Zone of Contribution (ZOC), is generally moderate to high. Ground investigations indicate sub-soils in the area to be of low to moderate permeability. The area is shown to have mainly moderate vulnerability indicating subsoil depths of >10m for a moderate permeability subsoil and 5 – 10m for a low permeability subsoil. Sub-soils along the line of the proposed road development were found to be generally less than 3m in thickness indicating a more vulnerable aquifer. Sub-soils tend to generally have a sandy or gravelly content indicating a higher degree of permeability.

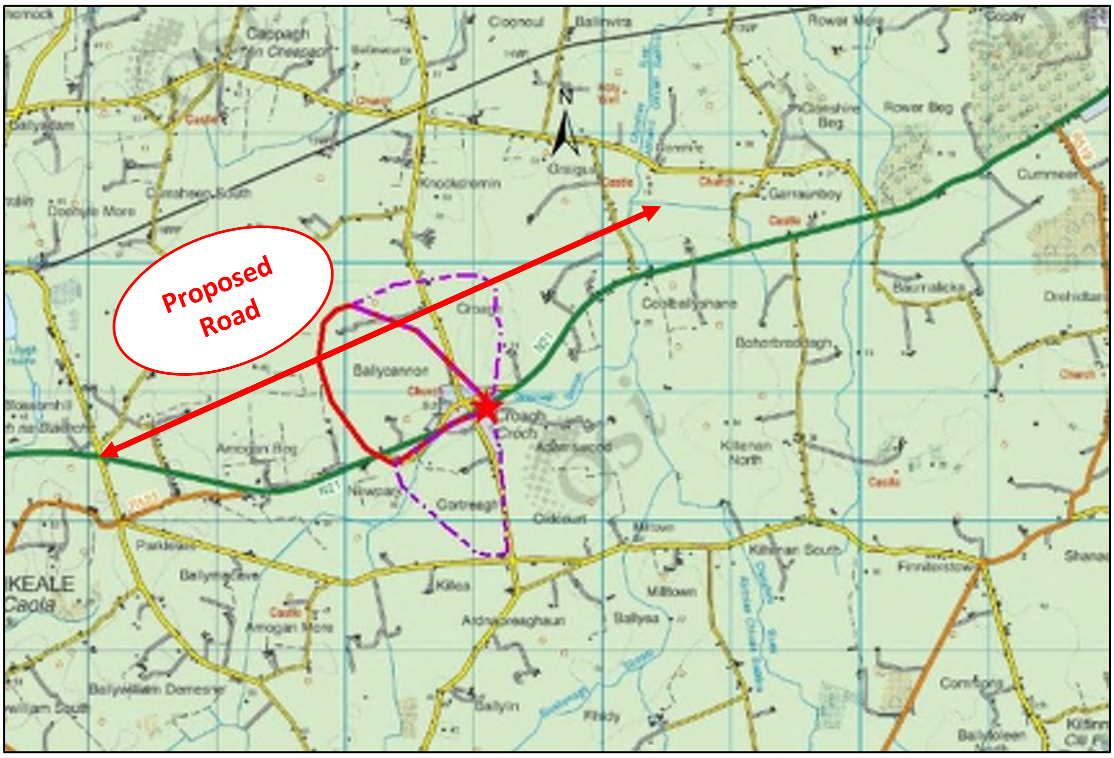

Plate 9.4 **Location of the Croagh-Farrandonnelly GWS Supply Borehole (red star) with approximate outline of mapped Zone of Contribution (ZOC) in red with potential additional areas shown in dashed purple**

During the Ground Investigations, 7 boreholes were sunk over a 2 km length between Km 53 and Km 55 through the Ballycannon-Croagh area, and these encountered ground water at an average depth of 5m below ground level (c.22mOD – 30mOD). The proposed road development will be in cutting at an average depth of 7m in this section, which will be 2m below the average groundwater level. The base of the proposed cutting (25 – 31mOD) will therefore be at or near to the same elevation as ground level at the Croagh Supply Borehole.

In the context of the proposed road development, the road crosses the boundary of the identified zone of contribution (approx. Ch54+200) of the supply at an elevation of 26.5mOD and the proposed road development is in cutting of c.7m (existing GL 33.1mOD). The proposed road development continues for c.1km through the mapped ZOC through to approx. Ch55+200 at an elevation of 21.5mOD (existing GL 26.9mOD).

Ground investigations data suggests a larger area of higher recharge occurring in the area of Ballycannon (north-west of Croagh village) due to shallow bedrock overlain by relatively free draining and thin sub-soils (1.2 – 3m). Bedrock permeability is likely to be dictated by the presence of a weathered zone and/or fracturing. A falling head test was carried out between 6 – 12m in BH54-03 (Ch.54+450) and resulted in no fall in water level during the test duration. A falling head test carried out between 6 – 10m in BH56-02 (Ch55+700) resulted in a permeability value $k = 2.79x10^{-7}$ $ms^{-1.}$ The ability of the bedrock to accept recharge is largely based on the permeability of the weathered zone of bedrock likely extending 3 – 5m below the bedrock surface. There is no recharge cap noted in this area. The GSI engaged a consultant to determine a Zone of Contribution (ZOC) map and report for the supply and the draft report and mapping were reviewed as part of this assessment. The main ZOC mapped for the supply (shown in red in Plate 9.4 above) extends to $0.96km^2$ in a fan shaped area extending to the north-west of the supply. The draft ZOC report also states that there may be an additional area of $1.14km^2$ also potentially contributing to the supply extending to the east and south-east of the ZOC as outlined in the purple dashed lines on Plate 9.4. This gives a combined total of $2.1km^2$ for the recharge area should the entire area be providing some contribution. The estimated daily peak demand is $82m^3$/day and with a Factor of Safety of 1.5, gives a peak demand of $123m^3$/day.

Domestic and Agricultural Groundwater Supplies

The majority of residential dwellings along the proposed road development are connected to either the Public Water Supply or to one of the Group Water Schemes detailed above. The majority of private well or borehole supplies located within 300m of the proposed landtake were identified during site visits and landowner meetings. In addition, an assessment was made of any potential supplies which may also exist but were not identified during the site visits. This was achieved by mapping the known supply network for both Public Water Supplies and Group Water Supplies and identifying properties which are not serviced by either and therefore likely to have their own private supply. More than 70 groundwater supply boreholes or springs for domestic and agricultural use were identified during the assessment of the study area. Some of these locations are also connected to a mains supplied water. A number of springs and seepages were identified that are used primarily for livestock.

9.3.9 European Sites / Natural Heritage Sites

There are a number of European sites which form part of the Natura 2000 network within the study area. Each of these sites were assessed in consultation with the project ecology team and two were considered to be sensitive in terms of either surface water and/or groundwater inputs and were therefore considered as part of this impact assessment – a detailed assessment of all European Sites is included in Chapter 7 Biodiversity.

The Lower River Shannon Special Area of Conservation (SAC) (site code no. 002165) extends to the north of the existing N69 and includes the estuary of the River Deel upstream to the N69 at Askeaton and the estuary of the River Ahacronane upstream to the N69 at Rincullia.

The Askeaton Fen Complex (SAC) (site code no 002279) includes a number of individual sites scattered to the north and south of the N69 between Askeaton and Kildimo. The fens are groundwater fed through a series of springs and seepages and occur in basins between undulating hills of Limestone in an otherwise intensive agricultural landscape.

In addition to the above, there are also a number of sites which are afforded protection under National Legislation (Natural Heritage Areas and/or proposed Natural Heritage Areas) located in the vicinity of the proposed road development. Four of these sites are sensitive in terms of groundwater (and/or surface water) all of which form part of the Askeaton Fen Complex SAC:

- Ballinvirrick Marsh pNHA (Site Code: 001427)
- Cappagh Fen pNHA (Site Code: 001429)
- Ballymorrisheen Marsh pNHA (Site Code: 001425)
- Gorteennamrock Fen pNHA (Site Code: 001433)

9.3.10 Key Ecological Receptors (KER's) with Hydrogeological Relevance

Fen Wetland at Ballyellinan (KER 7)

An area of Rich Fen Wetland (conforming to Annex I habitat Alkaline Fen) bordering the L6062-L1220 (refer to Chapter 7 Biodiversity and KER 7). Areas of exposed bedrock near the centre and along the perimeter of this site are likely providing groundwater to this wetland habitat. There is a karst spring source noted in the GSI karst database some 420m to the west of the western boundary of this fen wetland. The supply borehole for the Craggs/Barrigone GWS is located approximately 170m further north of this spring (c.500-600 north-west).

Fen Wetland at Lismakeery (KER 11)

An area which contains Rich Fen Wetland (conforming to Annex I habitat Alkaline Fen) and wet grassland is located to the north of Ballycullen House at Ballyellinan (refer to Chapter 7 Biodiversity and KER11). This wetland area is receiving groundwater inflow from seepages and springs located around the perimeter likely concentrated towards the south and south-western boundary. The area is noted as "Liable to Floods" on historic Ordnance Survey Mapping and has clearly been subject to extensive drainage in the past which has been only somewhat successful. A series of ditches and drains bisect the lands and drain north-west towards the adjacent Lismakeery Stream. Lands to the north-east of the central drain have been far less affected compared to lands to the south-west which has therefore been noted to contain a more diverse plant community – refer to Chapter 7 Biodiversity and KER 11 description for further details. One spring was identified by historic mapping to the north-west of these lands with other springs and seepages likely present in the area.

Fen Wetland at Blossomhill (KER21)

An area of rich fen wetland (conforming to Annex I habitat Alkaline Fen) and wet grassland is located between the existing N21 to the south and Doohyle Lough to the north – refer to KER 21 in Chapter 7 Biodiversity for further details. This area is listed as benefitted lands by the OPW following an arterial drainage scheme and a drainage channel flows a short distance west before turning and flowing north to a smaller Lough at Blossomhill. This lough then drains north to Doohyle Lough and then north-west to the River Deel. There are numerous springs and wells located in the vicinity of Blossomhill Lough which were identified on historic Ordnance Survey Mapping. This wetland area is therefore modified but still retains high ecological value with groundwater forming an important part of the hydrology of surrounding area.

9.3.11 Groundwater Quality

The Water Framework Directive (WFD) provides for the protection, improvement and sustainable use of waters, including rivers, lakes, coastal waters, estuaries and groundwater within the EU Member States. It aims to prevent deterioration of these water bodies and enhance the status of aquatic ecosystems; promote sustainable water use; reduce pollution; and contribute to the mitigation of floods and droughts. Under the Water Framework Directive large geographical areas of aquifer have been subdivided into smaller groundwater bodies (GWB) in order for them to be effectively managed. There are five groundwater bodies identified along or immediately adjacent to the proposed road development. The WFD Quality Status and Risk Status for each of these GWBs are summarised in in Table 9.5.

Three of the four GWB which were reported on for the WFD were assigned Poor quality status and being at risk of not achieving Good status.

Groundwater quality was monitored at 6 no. boreholes in Sections A,B and C between December 2016 and June 2017. Groundwater quality was found to be generally poor in terms of bacteria with elevated levels of E-coli and Total Coliforms at nearly all locations during the monitoring period indicating faecal contamination either by human or animal sources. Otherwise groundwater quality was found to be good with nitrate, phosphate (and total phosphorus) and other parameters of concern within acceptable drinking water limits.

Table 9.5 Groundwater Bodies (GWB)

Groundwater Body	Section	GWB Quality Status	Risk Status
Askeaton	A, B, C	Poor	1a - At Risk
GWDTE-Askeaton South Fens GWB	C (immediately adjacent)	N/a	N/a
Shanagolden	C	Good	2a – Probably Not at Risk
Newcastle West	D	Poor	1a - At Risk
Fedamore	D	Poor	1a - At Risk

9.3.12 Site Conceptual Model

For the purposes of developing a conceptual model for groundwater flow, the proposed road development is split in the four sections A, B, C and D as outlined previously.

Sections A & B

Groundwater flow is generally in a northern direction towards the Shannon Estuary. Groundwater seepage and springs are located in low-lying areas at the foot of elevated lands in the vicinity of the Shannon. Groundwater is also discharging locally to the main rivers and streams which are also flowing in a general northerly direction towards the Shannon Estuary. Groundwater quality is poor in terms of bacteria but appears to be otherwise of a moderate to good standard.

Section C

Groundwater flow is generally in a northern direction towards the Shannon Estuary. The River Deel provides a groundwater divide from Section A to the west and the Askeaton Fen Complex to the east. Groundwater is discharging locally to the main rivers and streams which are flowing in a general north-east direction towards the Shannon. Surface water outflow from groundwater discharges at Askeaton Fen enter the hydrological catchment of this section of the proposed road development. Groundwater quality is poor in terms of bacteria but appears to be otherwise of a moderate to good standard.

Section D

Regional groundwater flow is generally from north to south but will follow local topography and discharge locally to surface water bodies or as springs and seepages at the foothills of elevated ground where subsoil conditions permit. Groundwater quality is poor in terms of bacteria but appears to be otherwise of a moderate to good standard.

9.3.13 Summary of Hydrogeological Features

The main hydrogeological features of importance identified along the proposed road development are summarised in Table 9.6.

Table 9.6 Hydrogeological Features of Importance

Feature	Importance	Criteria / Justification
Bedrock aquifer classified by the GSI as a Regionally Important Aquifer (Rkc)	High	A regionally important aquifer is considered to have a high quality or value on a regional scale
Bedrock aquifer classified by the GSI as a Regionally Important Aquifer (Rkd)	High	A regionally important aquifer is considered to have a high quality or value on a regional scale
Bedrock aquifer classified by the GSI as a Locally Important Aquifer (Ll)	Low	A locally important aquifer is considered to have low value only in local zones
Askeaton Fen Complex SAC	Extremely High	European Site forming part of the Natura 2000 network
Lower River Shannon SAC	Extremely High	European Site forming part of the Natura 2000 network
Turloughs located in the townlands of Craggs and Tomdeely (Lough Selleher, Tomdeely, Foleys & Tomdeely North)	Moderate	A turlough is a priority habitat in Annex I of the Habitats Directive
Karst Springs located near the townland of Tomdeely & Morgans North	Low	Localised features important only in local zones. Does not form part of any wetland habitat.
KER4 Rincullia	Low	Localised bedrock drainage/flooding feature.
KER7 Fen Wetland at Ballyellinan	Moderate	Rich fen conforming to Annex I habitat Alkaline Fen.
KER11 Fen Wetland at Lismakeery	Moderate	Rich fen conforming to Annex I habitat Alkaline Fen.
KER21 Fen Wetland at Blossomhill	Moderate	Rich fen conforming to Annex I habitat Alkaline Fen.
Craggs/Barrigone GWS	High	A regionally important aquifer supplying a Group Water Scheme has high value on a local scale
Croagh-Farrandonnelly GWS	High	A regionally important aquifer supplying a Group Water Scheme has high value on a local scale
Private Groundwater Supplies along the entire proposed road development	Low	A small private supply has low importance at a local scale

9.4. Potential Impact Assessment for Hydrogeology

This section describes the potential impacts associated with the proposed road development before mitigation measures are applied. Both direct and indirect impacts are considered for the construction and operation of the proposed road development. The nature, extent and duration of the impacts are assessed. Each key hydrogeological feature summarised in Table 9.6 is assessed in terms of the potential impact arising from the proposed road development.

This assessment of hydrogeological impacts has been based on the analysis and interpretation of the data acquired during the Constraints Study and Route Corridor Selection phases, as well as site specific investigations undertaken as part of the Design, Environmental Impact Assessment Report (EIAR) and Natura Impact Statement (NIS), including the ecological study, intrusive site investigations, agricultural surveys and hydrogeological investigations. The procedure follows guidelines established by the TII in its 'Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes and the TII DN-DNG-03065 Road Drainage and the Water Environment 'as amended. The impact assessment also closely followed the methodology set out by the EPA in their guideline document "Guidelines on the Information to be contained in Environmental Impact Assessment Reports". For each Hydrogeological feature the magnitude of the impact has been assessed in the absence of mitigation and, in combination with the importance of the attribute (i.e. the significance of a potential impact), an impact rating has been applied. The impact rating takes into account the sensitivity and importance of the feature in combination with the character/magnitude/duration/likelihood/and consequences of any potential impact.

9.4.1 Impact on Groundwater Resources (Aquifers)

9.4.1.1 Cut Sections

Cut sections along a proposed road development have the potential to impact on the level of the groundwater table in the surrounding area as well as to cause a deterioration in aquifer water quality (i.e. to increase aquifer vulnerability). The main impact targets will be water supply springs, wells and boreholes as well as any nearby groundwater dependent habitats and karst related features. Typically, the impact increases:

- With increased depth of road cutting below groundwater table;
- With increased permeability of the soil and / or bedrock strata between the road cutting and groundwater feature;
- With increased lateral continuity and uniformity in soil and / or bedrock strata between the road cutting and groundwater feature, and
- In the absence of any hydrogeological boundaries such as watercourses, between the road cutting and water supply well or groundwater feature.

Road cuttings will increase the vulnerability of the underlying aquifer to pollution through either a complete loss of overburden where cuttings are into the bedrock or by reducing the protective overburden depth and thus increasing the vulnerability for contaminated road drainage if not transmitted in a sealed drainage system to infiltrate to and potentially contaminate the groundwater. Deep cuttings can locally change the GSI risk vulnerability classification for groundwater resources/aquifers.

Extensive road cuttings can if not mitigated significantly increase the runoff volume to be conveyed within the road drainage system and the volume to be ultimately discharged to receiving waters at road drainage outfalls. This can have an adverse effect on the receiving waters in terms of chemistry and water balance. Groundwater quality can be indirectly impacted if drainage systems are not adequately designed and maintained, to ensure conveyance of potentially contaminated surface run-off through these areas in sealed drains / channels where fissured/weathered bedrock is exposed and the aquifer is a regionally important karst bedrock aquifer.

Cut sections that intercept the groundwater table can impact on potential groundwater recharge and cuttings that intercept the groundwater table can cause dewatering of the intercepted aquifer. There is also the potential to intercept and truncate high yielding groundwater flows in preferential pathways within the karst aquifer.

It is assumed that where deep cut sections are located along the proposed road development, there will always be a direct potential temporary impact to the quality of the underlying aquifer during the construction phase and until appropriate measures are in place to prevent infiltration of contaminated run-off and drainage waters. However, in terms of the flow regime, there is the potential for a permanent impact on the underlying aquifer which will remain during the operational phase.

Cut sections will reduce the depth of subsoil from particular areas along the proposed road development. This will have a localised effect on the groundwater vulnerability rating, as the pathway for potential contaminants to migrate into the underlying aquifer is shortened. Areas where bedrock is at or close to surface will be particularly sensitive.

An assessment in relation to hydrogeological aspects at all significant proposed cut sections is summarised in Table 9.7 below.

Table 9.7 Rating of Significant Environmental Impacts Caused by Cut Sections

Attribute		Impact		
Site Name	**Importance**	**Description**	**Magnitude of Impact**	**Impact Rating**
Regionally Important Karstified Aquifer: Cut section Ch. 5+100 to Ch. 6+400	High	Potential interception of local groundwater table with maximum cut depths of up to 19m with Limestone bedrock encountered at depths of approximately 0 - 4m. Cutting will also intercept interflow, deeper percolation flow and overland runoff from the steep hillslope that would otherwise have flowed north-eastwards. Potential contaminated road drainage entering the underlying aquifer.	Moderate Adverse	Moderate

Attribute		Impact		
Site Name	**Importance**	**Description**	**Magnitude of Impact**	**Impact Rating**
Regionally Important Karstified Aquifer: Cut section Ch.52+400 to Ch.56+000	High	Potential interception of local groundwater table with maximum cut depths of up to 11m with Limestone bedrock encountered at depths of approximately 1 - 3m. Cutting will intercept interflow and overland runoff from the hillslope that would otherwise have flowed south-eastwards. Potential contaminated road drainage entering the underlying aquifer.	Moderate Adverse	Moderate

9.4.1.2 Road Drainage & Attenuation Ponds

Depending on the type of bedrock aquifer and its vulnerability to pollution (overburden cover and water table) there exists a potential for contamination of the underlying aquifer from contaminants in the routine drainage waters or as a result of spillage and road maintenance. Where the aquifer is classified as regionally important karst bedrock aquifer and of extreme vulnerability then this impact is classified as a potential moderate permanent impact. In order to protect a regionally important karst flow aquifer system from pollution the proposed storm drainage system will collect and convey the road pavement runoff waters to road drainage outfalls that will ultimately discharge to surface waters.

There are no proposed road drainage outfalls that will discharge directly to groundwater. A groundwater risk assessment has been carried out in line with the TII Document DN-DNG-03065 in relation to potential impacts on groundwater from the proposed road drainage system and specifically in relation to the use of permeable drainage systems. DN-DNG-03065 outlines the required methodology for carrying out such an assessment and the specific criteria involved.

Table A.4 of DN-DNG-03065 – Groundwater Protection Response Matrix for the use of permeable drains in road schemes is reproduced as Table 9.8 below. A significant portion of the proposed road development has a response of ***R4*** indicating that the use of permeable road drainage systems is ***Not Acceptable***. In this regard, where the proposed road development crosses areas of extreme (and high) aquifer vulnerability and where rock is at or close to the ground surface (i.e. all areas in which the overburden cover is less than 5m) a sealed drainage system will be provided so that infiltration to groundwater via the linear drainage system does not occur. This sealed system will also be used adjacent to sensitive ecological wetland areas.

In less vulnerable areas where the overburden depth is greater than 5m (aquifer vulnerabilities of moderate and low) unlined drainage systems will be used which will allow some infiltration to groundwater depending on the permeability of the overburden. These areas will correspond to the groundwater protection response **R2(1), R2(2) and R2(3)**. The response **R2(1)** states that the use of permeable drainage systems is:

- ***Acceptable,*** provided that there is a consistent minimum thickness of 2m of unsaturated subsoil (due to the presence of karstified rock) beneath the invert level of the drainage system. It is also noted that particular attention must be paid to the presence of karst features and receptors (such as; public wells, group schemes, industrial water supply sources and springs).

In addition to response **R2(1)**, the response **R2(2)** states that the use of permeable drainage systems is:

- ***Acceptable***, provided that there is a consistent minimum thickness of 2m of unsaturated subsoil beneath the invert level of the drainage system (where the subsoil is classed using BS5930 as; Sand, Gravel or Silt); or,
- ***Acceptable***, provided that there is a minimum consistent unsaturated thickness 1m of "appropriate material" beneath the invert level of the point of discharge.

In areas of Extreme vulnerability and karst bedrock aquifer setting, which is present along almost the entire development, response **R2(3)** states that the use of permeable drainage systems is ***Acceptable,*** provided that the drainage system is located at least 15m away from karst features that indicate enhanced zones of high bedrock permeability (e.g. swallow holes and dolines).

Table 9.8 Groundwater Protection Response Matrix for the Use of Permeable Drains in Road Schemes (TII DN-DNG-03065)

Vulnerability rating	Source protection area	Resource protection area (aquifer category)							
		Regionally Important Aquifer			Locally Important Aquifer			Poor aquifer	
		Rk*	Rf	Rg	Lg	Lm	Ll	Pl	Pu
Extreme: Rock near Surface or karst (X)	R4	R4	R4	R3(2)	R3(2)	R3(1)	R3(1)	R3(1)	R3(1)
Extreme (E)	R4	R2 (3)	R2 (2)	R3(2)	R3(2)	R2 (2)	R2 (2)	R2 (1)	R2 (1)
High (H)	R3(2)	R2 (2)	R2 (2)	R2(2)	R2(2)	R2 (2)	R2 (2)	R2 (1)	R2 (1)
Moderate (M)	R3(1)	R2 (1)	R2 (1)			R2 (1)	R2 (1)	R1	R1
Low (L)	R3(1)	R1	R1			R1	R1	R1	R1

A summary of the type of drainage systems proposed along the length of the proposed road development and the associated Groundwater Protection Response is given in Table 9.9 below. It must be noted that at each outfall there is typically either one or two attenuation ponds, which will be lined to prevent infiltration, prior to outfall to the watercourse. In order to simplify this assessment, it is considered that for each network and outfall listed below, the pond will receive the same level of treatment as the road drainage system. In this regard if a sealed drainage system is proposed then the associated ponds will be lined with both an impermeable geomembrane and cohesive material to prevent infiltration. In areas where permeable drains are permitted, the attenuation ponds will be lined with cohesive material only.

Table 9.9 Summary of Proposed Locations of Sealed Drainage Systems Along the Proposed Road Development and Associated Groundwater Protection Response

Section	Chainages	Groundwater Protection Response
A	3+625 to 4+300	Sealed drainage system / No outfalls
	5+100 to 7+300	Sealed drainage system / No outfalls
D	51+300 to 51+750	Sealed drainage system / No outfalls
	52+400 to 56+100	Sealed drainage system / No outfalls

The proposed drainage system will incorporate a range of appropriate pollution control features to limit the water quality impact to receiving waters. These include the use of filter drains, sealed drainage systems (as per Table 9.9) and the use of a vegetated sediment bay with a plan area of at least 10% of the total basin area for all attenuation ponds upstream of the drainage outfall – refer to TII DN-DNG-03022 standard for details. Further detention storage is provided within the storm attenuation pond system for settlement of suspended pollutants. The vegetated system will allow for the take up of nutrients from the drainage water. These treatment systems will be provided upstream of all proposed outfalls.

Attenuation ponds / wetland treatment areas that are located in hydrogeologically sensitive locations such as groundwater fed ecological receptors or where the groundwater vulnerability rating is Extreme have been assessed regarding their potential impact on the hydrogeological environment. The principal impact arises from poorly constructed ponds where contaminated water would be able to percolate / infiltrate downwards through the pond lining into the underlying aquifer, overspills during sustained heavy rainfall events, or where discharge outfalls into ecologically sensitive surface water features.

The proposed drainage system is designed based on the aquifer properties and its vulnerability and reduces the impact level from ***Slight/Moderate Permanent Impact*** to a ***Slight Permanent Impact*** as potential for leakage in such sealed drainage system remains as does the potential for losing channel sections of streams and rivers receiving the road drainage discharge to groundwater.

9.4.1.3 Aquifer Characteristics

There will be a very limited impact on the nature of the underlying aquifers as the road will normally only cover a very small fraction of a groundwater body. The majority of the proposed road development is underlain by a Regionally Important Aquifer which has an attribute rating of High. The remainder is underlain by Locally Important Aquifers of Low Importance.

A generalised assessment has been made for each aquifer type along the proposed road development, based on potential characteristic changes caused by cut and fill sections (Table 9.10).

Table 9.10 Rating of Significant Environmental Impacts on Aquifer Characteristics

Attribute		Impact		
Site Name	**Importance**	**Description**	**Magnitude of Impact**	**Impact Rating**
Regionally Important Karst Aquifer	High	Localised changes to groundwater levels in aquifer and / or overlying subsoil caused by dewatering at cut sections	Small Adverse	Slight
		Localised changes to down-gradient hydrochemistry in aquifer or overlying subsoil caused by routine surface runoff and spillages	Small Adverse	Slight / Moderate
		Localised changes to up-gradient groundwater levels and hydrochemistry caused by flow restriction	Small Adverse	Slight
Locally Important Aquifer	Low	Localised changes to up-gradient groundwater levels and hydrochemistry caused by flow restriction	Small Adverse	Imperceptible
		Localised changes to groundwater levels in aquifer and / or overlying subsoil caused by dewatering at cut sections	Small Adverse	Imperceptible
		Localised changes to down-gradient hydrochemistry in aquifer or overlying subsoil caused by routine surface runoff and spillages	Small Adverse	Imperceptible

9.4.2 Impact on European Sites / Natural Heritage Sites

Lower River Shannon SAC

The Lower River Shannon SAC is hydrologically linked to the proposed road development as a downstream receptor from each of the surface water features either crossed by the proposed road development or to which road drainage will be discharged. The Shannon Estuary is also a discharge target for the Askeaton GWB. Each of the five groundwater bodies which are crossed by the proposed road development are also linked to the major rivers and streams providing baseflow and therefore ultimately discharge to the SAC indirectly via the River Deel, the Maigue or the Ahacronane. Given that this SAC is predominantly a surface water system and is not sensitive in relation to groundwater flows, the main potential impact would relate to contamination of the aquifer impacting the SAC water quality as a downstream receptor. However, the proposed road development will incorporate best practice road drainage design collecting and treating road runoff before discharging to surface water. Only very limited infiltration of runoff will occur and only in areas where it is appropriate to do so as the subsoil provides protection to the aquifer. It is therefore extremely unlikely for any impact to this SAC arising from groundwater pollution and there will therefore be an ***Imperceptible Impact***.

Askeaton Fen Complex SAC

The Askeaton Fen Complex is groundwater fed and is sensitive in terms of groundwater levels and hydrochemistry. An assessment of the potential impacts of the proposed road development was carried out whereby the water balance of the fen was examined including all surface outflows and likely zones of groundwater seepage. Each of the sections of the proposed road development and their potential interactions with this SAC are summarised below.

Section A

Groundwater flow in this section is generally in a northerly direction towards the River Shannon Estuary. Locally groundwater will discharge to springs or streams at changes in topography or in low-lying basins. The River Deel provides a groundwater divide between this section of the proposed road development and the SAC. There is no hydraulic connection between this section of the road and the SAC and therefore there will be no change to the groundwater balance within the SAC.

Section B

Groundwater flow in this section is either to the north towards the River Shannon Estuary or to the east towards the River Deel. The Deel again provides a groundwater divide between this section of the proposed road development and the SAC. There is no hydraulic connection between this section of the road and the SAC and therefore there will be no change to the groundwater balance within the SAC.

Section C

Groundwater flow in this section is generally north-east or north-west towards the River Deel or north towards the Shannon. Locally groundwater will discharge to springs or streams at changes in topography or in low-lying basins. This section of the proposed road development is closest to the SAC (0.5km near Ch.25+000) and therefore has the greatest potential to have some impact. This entire section of the proposed road development is either at grade or in slight embankment and therefore cuttings into the bedrock are avoided. Notwithstanding this fact, the water balance of the Fen Complex indicates that this section of the proposed road development is actually located down-gradient of the SAC. A number of small watercourses flow out of the fen complex towards the River Deel and are crossed by the proposed road development at Nantinan and Feeagh. The drainage system proposed will be neutral in design and will not change the existing surface water flows. All existing channels will be piped or culverted to maintain existing flow conditions and any diversions and/or realignments will be carried out in a controlled manner and as per Inland Fisheries Ireland (IFI) best practice guidance. A Conceptual Site Model (CSM) of the SAC and the proposed road development is given in Plate 9.5. There will therefore be no change to the groundwater and/or surface water balance within the SAC.

Section D

This section of the proposed road development is located south of a topographical groundwater divide and is within a different groundwater body. Therefore there is no hydraulic connection between this section of the road and the SAC and as such there will be no change to the groundwater balance within the SAC.

Given the above, no impact to the SAC is predicted during either the construction or operational phase and there will therefore be an ***Imperceptible Impact*** rating – see Table 9.11 below.

Table 9.11 Rating of Significant Environmental Impacts on Natural Heritage/European Sites

Attribute		Impact		
Site Name	**Importance**	**Description**	**Magnitude of Impact**	**Impact Rating**
Lower River Shannon SAC	Extremely High	Localised changes to groundwater levels in aquifer and / or overlying subsoil caused by dewatering at cut sections	Small Adverse	Imperceptible
		Localised changes to down-gradient hydrochemistry in aquifer or overlying subsoil caused by routine surface runoff and spillages	Small Adverse	Imperceptible
Askeaton Fen Complex SAC	Extremely High	Localised changes to groundwater levels in aquifer and / or overlying subsoil caused by dewatering at cut sections	Small Adverse	Imperceptible
		Localised changes to down-gradient hydrochemistry in aquifer or overlying subsoil caused by routine surface runoff and spillages	Small Adverse	Imperceptible

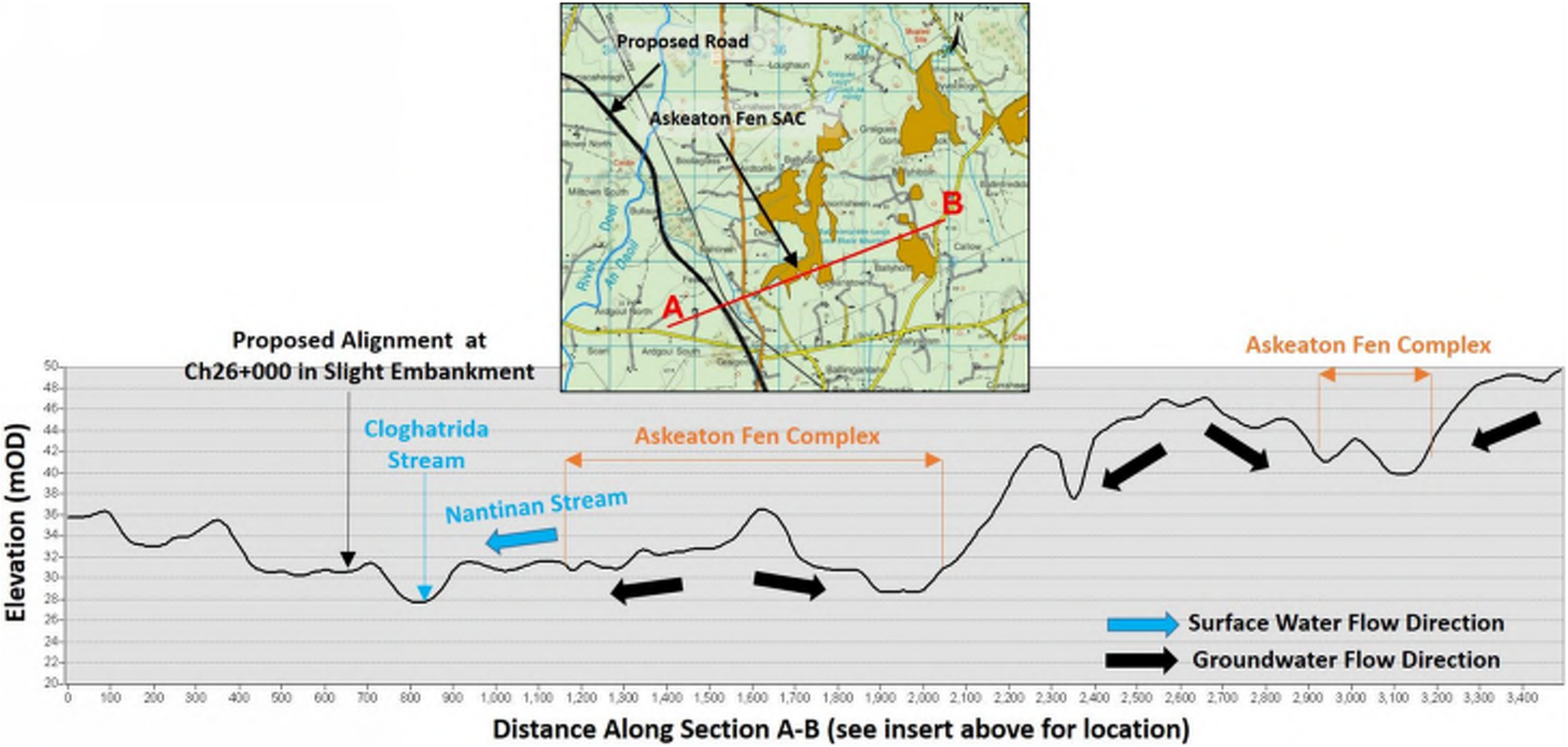

Plate 9.5: **Groundwater Conceptual Site Model of Askeaton Fen SAC and its interaction with the proposed road development**

9.4.3 Impact on Karst Features

Lough Selleher turlough is located c400m up-gradient of the proposed road development at Ch.5+500 which is in a deep cutting (up to 19m) as it passes through Mulderricksfield. The turlough itself is unusual being situated at the top of elevated ground and therefore does not have a large catchment. A deep quarry excavation is situated beyond a ridge some 400m to the north of Lough Selleher and has not altered the turlough's flooding cycle. It is likely that this feature is draining to the north-west towards the Ahacronane River however it is possible that some or all of the groundwater flow is towards the north-east and the proposed road cutting at Ch 5+700 and beyond. The groundwater catchment for this feature is small and is located up gradient of the proposed bedrock cutting. The Potential Impact is therefore assessed as ***Imperceptible*** – see Table 9.12 for Impact Rating assessment.

Three small turlough features and a number of springs are located in a low-lying basin in townlands of Tomdeely and Morgans North south of the Shannon Estuary. Two of the turloughs are within the local groundwater table and have permanent water at the lower stages. These turloughs and the springs appear to be resilient in terms of their groundwater supply as water was still present following a sustained drought period in summer 2018. Whilst the closest of these features is still well removed from the proposed road development (c.2.1km), the potential impact would relate to changes in the hydrogeological regime due to the deep bedrock cutting at Mulderricksfield. The groundwater catchment for these features is large given the elevated lands at Hazelfield and Mulderricksfield and the basin area itself all providing recharge and the loss of recharge due to the proposed cutting is relatively minor in comparison to their catchment area. The Potential Impact is therefore assessed as ***Imperceptible*** – see Table 9.4.6 for Impact Rating assessment.

Whilst turloughs are a priority habitat under the European Habitats Directive, none of the above are considered to be such given their poor status particularly due to evident nutrient enrichment and the resultant limited floristic diversity. On the basis of their non-designation and their obvious degraded state each of these hydrogeological features are therefore rated of moderate importance.

Table 9.12 Impact Rating of Significant Environmental Impacts on Karst Features

Attribute		Impact		
Site Name	**Importance**	**Description**	**Magnitude of Impact**	**Impact Rating**
Lough Selleher, Tomdeely, Foleys & Tomdeely North turloughs.	Medium	Localised changes to groundwater levels in aquifer and / or overlying subsoil caused by dewatering at cut sections	Small Adverse	Imperceptible
		Localised changes to down-gradient hydrochemistry in aquifer or overlying subsoil caused by routine surface runoff and spillages	Small Adverse	Imperceptible
Karst Springs located in Tomdeely	Low	Localised changes to groundwater levels in aquifer and / or overlying subsoil caused by dewatering at cut sections	Small Adverse	Imperceptible

Attribute		Impact		
Site Name	Importance	Description	Magnitude of Impact	Impact Rating
& Morgans North		Localised changes to down-gradient hydrochemistry in aquifer or overlying subsoil caused by routine surface runoff and spillages	Small Adverse	Imperceptible

9.4.4 Impact on Key Ecological Receptors (KERs)

The potential Impact of the proposed road development on each of the Key Ecological Receptors (KERs) is given in Table 9.13 below. Changes to localised flooding at Rincullia is assessed as a **Slight** Impact due to the localised nature of the potential impact. Any changes to the local groundwater and/or surface water flow regime of the fen wetlands caused by the proposed road development is assessed as **Moderate**. All localised pollution impacts on the bedrock aquifer or the fen wetland by routine surface runoff and spillages are assessed as **Imperceptible** due to the relatively low likelihood of such pollution occurring when best practice drainage design is followed.

Table 9.13 Rating of Significant Environmental Impacts on Key Ecological Features

Attribute		Impact		
Site Name	Importance	Description	Magnitude of Impact	Impact Rating
KER4 Rincullia	Low	Increased frequency or extent of localised groundwater/pluvial flooding of agricultural lands.	Small Adverse	Slight
		Localised pollution of the bedrock aquifer by routine surface runoff and spillages	Small Adverse	Slight
KER7 Fen Wetland at Ballyellinan	Medium	Changes to the groundwater flow regime causing a deterioration in the status of the fen as a wetland habitat.	Moderate Adverse	Moderate
		Localised pollution of the bedrock aquifer or the fen wetland by routine surface runoff and spillages	Moderate Adverse	Imperceptible
KER11 Fen Wetland at Lismakeery	Medium	Changes to the groundwater flow regime causing a deterioration in the status of the fen as a wetland habitat.	Moderate Adverse	Moderate
		Localised pollution of the bedrock aquifer or the fen wetland by routine surface runoff and spillages	Small Adverse	Imperceptible
KER21 Fen Wetland at Blossomhill	Medium	Changes to the groundwater flow regime causing a deterioration in the status of the fen as a wetland habitat.	Moderate Adverse	Moderate
		Localised pollution of the bedrock aquifer or the fen wetland by routine surface runoff and spillages	Moderate Adverse	Imperceptible Moderate

9.4.5 Impact on Groundwater Supplies

Group Water Schemes

Craggs/Barrigone GWS

The cutting for the proposed road development is c.19m (maximum cut depth) into the bedrock at Craggs/Mulderricksfield and c. 900m up-gradient of the **Barrigone** supply borehole. A groundwater Conceptual Site Model (CSM) of the area has been developed and is shown in Plate 9.7 with the relative levels of the proposed road development in cutting and the topography on a line that extends from the Ahacronane River to the top of the hill at Craggs/Mulderricksfield and then north-eastward to the supply borehole at Ballyellinan.

The ground level at the location of the proposed bedrock cutting is c.50m OD and the road formation in the cutting will be in the order of 31m OD. The base of the proposed cutting will therefore be c.20 above the ground level at the group water supply. The supply is from a 29m deep borehole with the main water strike reportedly encountered at a bedrock fracture encountered c.24m BGL which is therefore at an elevation of c.-12m OD. The main supply abstraction point is therefore more than 40m below the proposed level of the base of the deep cutting at 1km distance.

In order to fully understand the movement and flow of groundwater from the topographical high at Craggs/Mulderricksfield towards Ballyellinan a number of boreholes were drilled in a cross-sectional alignment as shown in Plate 9.7. RC05-10 and RC05-11 were located further up the slope above the proposed bedrock cutting. A number of boreholes were drilled along the line of the proposed road development (RC05-04, RC05-07, RC05-08, RC05-09 & RC06-02). A further down-gradient borehole was also drilled between the proposed cutting and the supply borehole (RC06-01). In addition, a geophysical profile was also carried out at this location along the line of the proposed road development (GP04). Refer to Figures 8.1 to 8.24 of Volume 3 for further details and locations of ground investigations undertaken.

The geophysical profile GP04 along the line of the proposed road development did not detect any voids or anomalies in the profile that would suggest potential conduit zones and indicated competent limestone bedrock at depths 4m below ground level along the full length of the cut profile.

An examination of the water levels in boreholes drilled after completion allowed the development of the conceptual site model (CSM) whereby the groundwater flow direction is in a north-west / north-east direction towards the Shannon Estuary. This conceptual model is validated by the presence of springs along the Shannon estuary and at northern foot of the hill at Mulderricksfield. The CSM delineation based on topography and ground investigation borehole data shows groundwater flowing towards the River Shannon as shown in Plate 9.6 below. The area of hill slopes and higher ground at Hazelfield and Mulderricksfield are providing recharge and head for groundwater flow towards the low-lying lands adjacent to the River Shannon. The upland areas (shown in blue in Plate 9.6) flow towards the Shannon with a discharge zone in the low-lying lands (shown in pink on Plate 9.6) which is evidenced by the presence of springs and semi-permanent ponds/turloughs in this area. Given the high recharge rates across the local catchment (c.400 – 500mm per annum), groundwater storages within this area are likely to be robust with the high yielding supply borehole for the Craggs-Barrigone scheme an example.

A summary of the geology and water strikes encountered during the intrusive site investigations is given below in Table 9.14.

Table 9.14 Summary of Ground Investigations in the area surrounding Craggs/Barrigone GWS

Location	Depth to bedrock (m)	Description of geology	Groundwater Strikes (m. OD)
RC05-04	0.4	Strong to very strong, dark grey, LIMESTONE.	None
RC05-07	0.2	Strong, dark grey, LIMESTONE	GW level at 35.37mOD
RC05-08	Not encountered	Dense SAND to a depth of 33m. Void encountered at 21.98mOD with a high flow rate of water.	GW level at 21.98mOD
RC05-09	3.9	Strong to very strong, dark grey, LIMESTONE.	None
RC05-10	0.7	Moderately strong, grey, LIMESTONE	GW level at 49.93mOD
RC05-11	2.8	Moderately strong, grey, LIMESTONE	GW level at 42.63mOD
RC06-01	1.0	Moderately strong, grey, LIMESTONE	GW level at 5.52mOD
RC06-02	0.2	Strong, grey, LIMESTONE	GW level at 24.9mOD

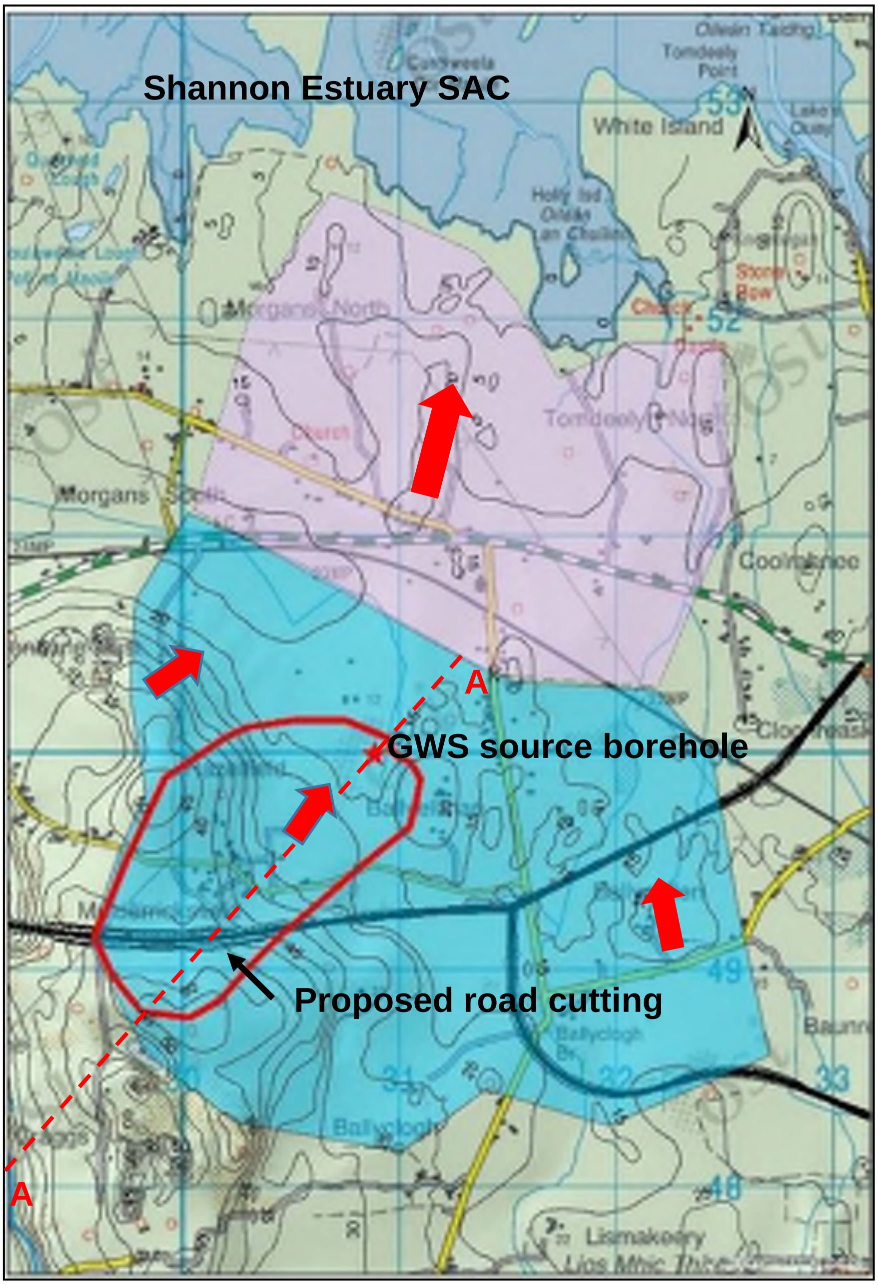

Plate 9.6 **Zone of Contribution (in Red) and Inferred Groundwater flows at Craggs/Ballyellinan area**

Groundwater levels were monitored at piezometers installed in the bedrock at RC05-10, RC05-11 and RC06-01 between January and October 2017 in order to establish the winter and summer water table and to confirm the groundwater gradient. A summary of the maximum and minimum groundwater levels are given in Table 9.15 below. A relatively steep groundwater table gradient from the top of Craggs hill towards Ballyellinan was confirmed. Large fluctuations of up to 18m were also observed at all three boreholes over the summer/winter period. Falling head permeability tests were also carried out at RC05-07 and RC06-01 in order to assess the permeability of the bedrock – the results are given in Table 9.16 below.

The main potential impact to the Craggs-Barrigone Group Water Scheme supply borehole from the proposed bedrock cutting at this location will be the loss of the weathered/epikarst zone of bedrock and groundwater recharge within the footprint of the proposed road development and associated lands on the up-gradient side of the proposed road development to the south-west. Whilst the recharge area represents 26% of the overall area of the Zone of Contribution (ZOC) for the supply borehole, it occurs at the topographic high within the catchment which is likely providing significant head within the epikarst driving groundwater flow to the north-east. The recharge rates in the area suggest that a ZOC area of less than 0.2km^2 is required to sustain the volume of abstraction. However the area mapped, which has a far larger area of 1.2km^2, was based on hydrogeological knowledge of the bedrock and the likelihood of point recharge sources from the overlying weathered zone or indeed the ground surface itself. Given this potential loss of up-gradient recharge and the possible presence of vertical and horizontal conduits or fractures within the bedrock in the vicinity of the proposed road cutting, it is not possible to discount some potential impact on the yield of the current supply at the Craggs-Barrigone borehole.

Table 9.15 Summary of Monitored Ground Levels in the area surrounding the Craggs/Barrigone GWS – refer to Plate 9.6 for locations (refer to Plate 9.7 for section A-A and CSM)

Location	Winter Water Level (m. OD)	Summer Water Level (m. OD)
RC05-10	50.06	32.66
RC05-11	47.50	30.13
RC06-01	15.12	-3.29

Table 9.16 Summary of Falling Head permeability tests undertaken in the area surrounding the Craggs/Barrigone GWS

Location	Bedrock Permeability (ms-1)
RC05-07	$6.12x10^{-04}$
RC06-01	No fall in water level. Permeability test not determined.

In addition, in the absence of appropriate mitigation there is an increased risk of pollution from the road development at both operation and construction stages given the road cutting and the presence of the road alignment within the zone of contribution. The potential impact rating to this groundwater supply is therefore assessed as ***Moderate*** – refer to Table 9.18 for details of Potential Impact Assessment for Groundwater Supplies.

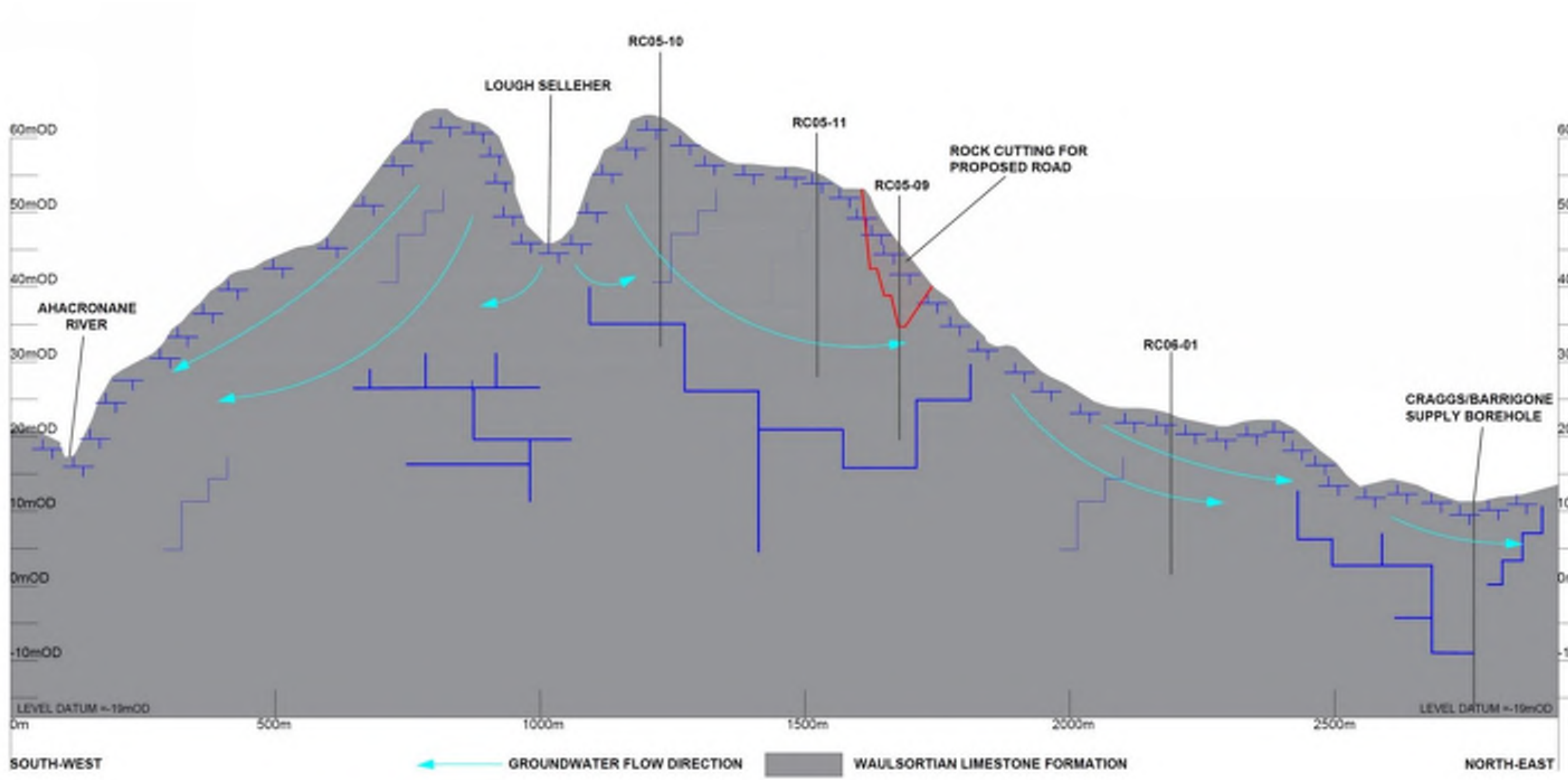

Plate 9.7 **Groundwater Conceptual Site Model of the area surrounding Craggs/Barrigone GWS supply borehole and its interaction with the proposed road development**

Croagh-Farrandonnelly GWS

The proposed cutting for the road development is up to c.7.5m into the bedrock at Ballycannon/Croagh c.600m up-gradient of the supply borehole. A groundwater Conceptual Site Model (CSM) of the area has been developed and is shown in Plate 9.9 with the relative levels of the proposed road development in cutting and the topography on a section line that extends from the peak of the hill at Ballycannon south-eastward to the supply borehole at Croagh.

For the section line selected the ground level at the proposed cutting is 33.1mOD and the road formation in the cutting will be in the order of 26.7mOD. The base of the proposed cutting will therefore be approximately at the same level as the ground level at the Croagh Supply Borehole which is at c.28.4m OD. The borehole is reported to be c.80m deep and therefore is at a level of c.-51.8mOD at its deepest point into the bedrock.

In order to fully understand the movement and flow of groundwater from the topographical high at Ballycannon towards Croagh a number of boreholes were drilled (as shown in Plate 9.9) along the line of the proposed road development (RC54-04, RC55-01, RC55-02). Two further down-gradient boreholes were also drilled between the proposed cutting and the supply borehole (RC55-06 and RC55-07). Refer to Chapter 8 Soils & Geology for further details of ground investigations undertaken, and to Fig 8.16 (Vol 3) and Plate 9.9 below for locations. A summary of the geology and water strikes encountered during the intrusive site investigations is given in Table 9.17 below:

Table 9.17 Summary of Ground Investigations in the area surrounding Croagh- Farrandonnelly GWS

Location	Depth to bedrock (m)	Description of geology	Groundwater Strikes (m. OD)
RC54-04	1.5	Strong, grey, LIMESTONE	31.92
RC55-01	1.0	Strong, dark grey, LIMESTONE	29.3
RC55-02	2.0	Strong, grey, LIMESTONE	27.23
RC55-06	1.5	Strong, grey, LIMESTONE	29.5
RC55-07	2.1	Strong, grey, LIMESTONE	25.81

The above data indicates a north-west to south-east groundwater gradient downhill towards Croagh – see Plate 9.9 for details in the (Conceptual Site Model) CSM. Bedrock permeability is likely to be dictated by the presence of a weathered zone and/or fracturing – refer to Figures 8.13 – 8.18 for locations of intrusive site investigations completed at this location. A falling head test was carried out between 6 – 12m in BH54-03 and resulted in no fall in water level during the test duration. A falling head test was also carried out between 6 – 10m in BH56-02 (further to the east) and resulted in a permeability value $k = 2.79x10^{-7}$ ms^{-1}. The ability of the bedrock to accept recharge is largely based on the permeability of the weathered zone of bedrock likely extending 3 – 5m below the bedrock surface.

An examination of the water levels in boreholes drilled after completion allowed the development of the conceptual site model whereby the groundwater flow direction is in a north-west to south-east direction towards Croagh. The CSM delineation based on topography and ground investigation borehole data shows groundwater flowing towards the Greanagh Stream in the valley as shown in Plate 9.9 below. The area of hill slopes and higher ground at Ballycannon and Croagh are providing recharge and head for groundwater flow towards the valley adjacent to Croagh/Adamstown. Ground investigations data suggests areas of higher recharge occurring in the area of Ballycannon due to shallow bedrock overlain by relatively free draining and thin sub-soils (1.2 – 3m). Recharge rates are moderate to high across the local catchment (c.300 – 470mm per annum).

The Geological Survey of Ireland (GSI) has mapped a preliminary draft Zone of Contribution (ZOC) area for the supply extending to 0.96km^2 to the north-west of the supply borehole in the area of Ballycannon – see Plate 9.8. The draft report also identifies the possibility of an additional area of up to 1.14km^2 to the north-east and south-east also potentially contributing recharge extending to the supply. This would give a combined total of 2.1km^2 for the recharge area. The estimated peak daily demand is 82m^3 and with a Factor of Safety of 1.5, gives a peak demand of 123m^3/day. Recharge calculations indicate a required maximum zone of contribution of 0.36km^2 assuming the lowest possible recharge rates to sustain this yield. This is 17% of the overall available ZOC. The mapped ZOC is therefore very conservative.

The main potential impact to the supply borehole from the proposed bedrock cutting at this location will be the loss of the weathered/epikarst zone of bedrock and groundwater recharge within the footprint of the proposed road development and associated lands on the up-gradient side of the proposed road development. Whilst the recharge area represents 24% of the overall area of the ZOC for the supply borehole, the ZOC area mapped is very conservative and may in fact incorporate lands to the north-east and/or south-east. In addition, the borehole is c.80m deep and receives inflows from a number of fracture zones down the bore. However, given the potential loss of up-gradient recharge at the more elevated end of the mapped ZOC it is not possible to discount some potential impact on the yield of the current supply at Croagh albeit unlikely. Should an impact occur, it is likely it would be small and that the borehole will have sufficient spare capacity to operate as per existing conditions. In addition, in the absence of appropriate mitigation, there is an increased risk of the risk of pollution from the road development at both operation and construction stages given the road cutting and the presence of the road alignment within the zone of contribution. The potential impact rating to this groundwater supply is therefore assessed as ***Moderate*** – refer to Table 9.18 for details of Potential Impact Assessment for Groundwater Supplies.

Plate 9.8 **Zone of Contribution (in Purple) with additional potential contribution areas (hatched Purple) at Croagh area (refer to Plate 9.9 for section B-B and CSM)**

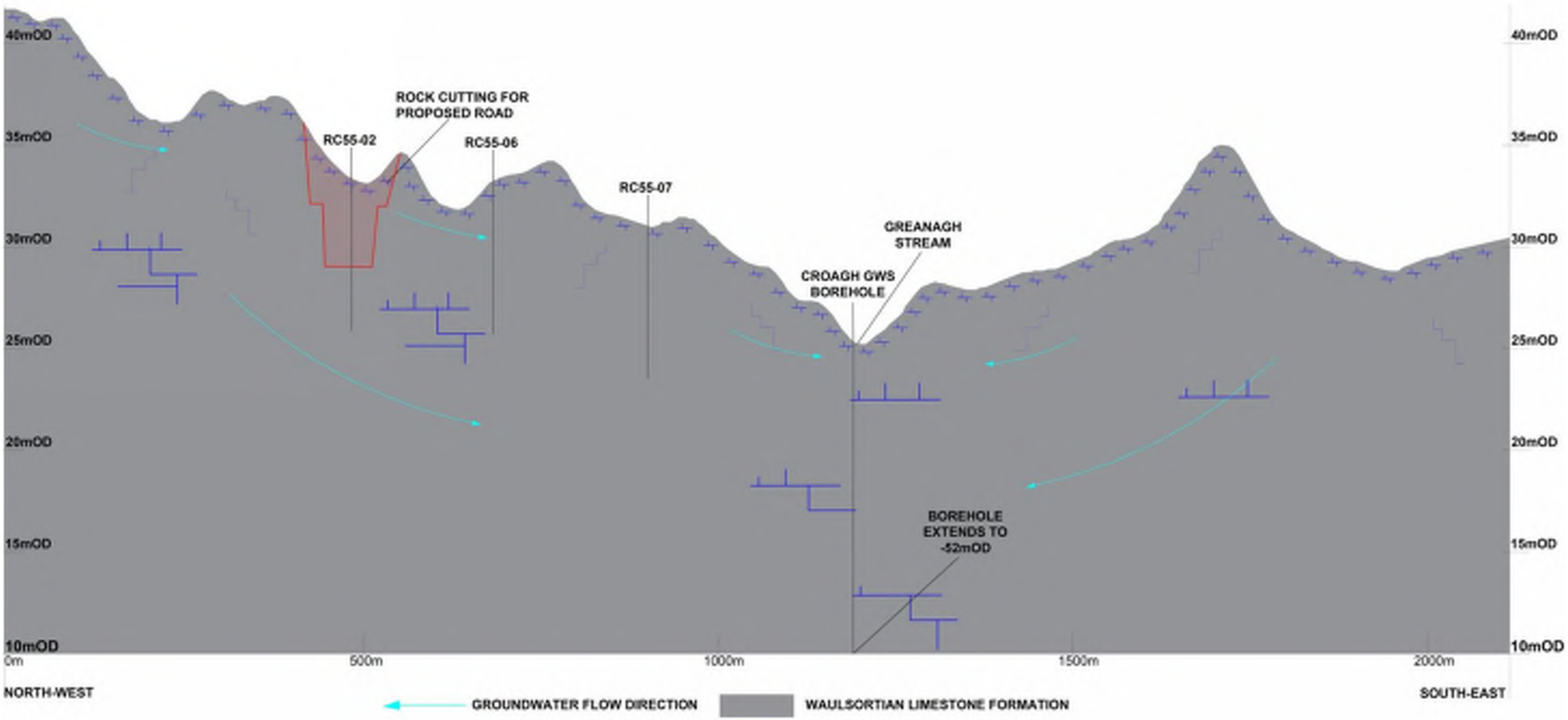

Plate 9.9 **Groundwater Conceptual Site Model of the area surrounding Croagh-Farrandonnelly GWS Supply Borehole and its interaction with the proposed road development**

Private Groundwater Supplies

An impact assessment was carried out for all known and/or potential private groundwater supplies within 300m of the proposed road development. Beyond this distance, the impacts of the proposed road development are unlikely to cause drawdown to a domestic supply. More than 70 groundwater supply boreholes or springs for domestic and agricultural use were identified during the desk study and site visits. Each of these supplies were assessed for any potential impact as a result of the proposed road development both during the construction and operational phase. The potential impact rating for the majority of these supplies were assessed as ***Imperceptible*** due to the road construction being at-grade or in embankment and the supply being located either up-gradient or well removed from the proposed road development. Locations with confirmed or reported private supplies that could be potentially impacted by the proposed road development and are of interest for ongoing water level and hydrochemistry monitoring during the proposed road development have been identified. These are summarised in Table 9.18 together with the associated potential impact rating. The locations of these supplies are shown in Figure 9.5; EIAR Volume 3

Table 9.18 Rating of Significant Environmental Impacts on Groundwater Resources (Refer to Figure 9.5, EIAR Volume 3 for Locations)

Attribute		Impact			
Site Name	**Importance**	**Nature of impact**	**Description of Impact**	**Magnitude of Impact**	**Impact Rating**
Craggs-Barrigone GWS Ch.6+000	High	Reduction in yield of water supply at the Group Water Scheme borehole	The proposed road development is in a deep cutting up-gradient of this supply and is within the south-western extent of the mapped ZOC. Changes to the hydrogeological regime in the area may impact the yield at the supply. This is mainly related to the deep cutting which has the potential to draw down groundwater levels locally. In addition, overland flow which enters the aquifer through the subsoil and the weathered bedrock up-gradient of the cutting may be redirected as part of the works impacting on the supply.	Moderate Adverse	Moderate
		Contamination of water supply from road drainage entering aquifer via weathered bedrock.	There is potential for silt laden or contaminated road drainage to enter and contaminate the local groundwater table through exposed bedrock and in turn the GWS supply borehole.	Moderate Adverse	Moderate
Croagh-Farrandonnelly GWS Ch.54+500	High	Reduction in yield of water supply at the Group Water Scheme borehole	The proposed road development is in a moderate cutting up-gradient of this supply and is within the northern extent of the mapped ZOC. Changes to the hydrogeological regime in the area may impact the yield at this supply. This is mainly related to the cutting which has the potential to draw down groundwater levels locally. In addition, overland flow which enters the aquifer through the subsoil and the weathered bedrock up-gradient of the cutting may be redirected as part of the works impacting on the supply.	Moderate Adverse	Moderate
		Contamination of water supply from road drainage entering aquifer via exposed bedrock	There is potential for silt laden or contaminated road drainage to enter and contaminate the local groundwater table through exposed bedrock and in turn the GWS supply borehole.	Moderate Adverse	Slight
Spring at Ch.1+150	Low	Loss of water supply for agricultural use	Spring is within the footprint of the proposed road development.	Large Adverse	Slight

Attribute		Impact			
Site Name	**Importance**	**Nature of impact**	**Description of Impact**	**Magnitude of Impact**	**Impact Rating**
feeding local stream		Contamination of water supply from road drainage entering aquifer via exposed bedrock	N/a	N/a	N/a
Spring/Well Agricultural Use at Ch.11+250	Low	Loss of water supply for agricultural usage	Spring/well is within the footprint of the proposed road development.	Large Adverse	Slight
		Contamination of water supply from road drainage entering aquifer via exposed bedrock	N/a	N/a	N/a
Spring at Ch 21,080 Approx	Low	Reduction in yield of water supply to fen area to the south-west	Spring is within the footprint of the proposed road development.	Moderate Adverse	Moderate
		Contamination of water supply from road drainage	N/a	N/a	N/a
Spring/Well Agricultural Use Ch.51+300	Low	Loss of water supply for agricultural usage	Spring/well is within the footprint of the proposed road development.	Large Adverse	Slight
		Contamination of water supply from road drainage entering aquifer via exposed bedrock	N/a	N/a	N/a
Domestic Well supply c.150m south of the proposed road development at Ch.55+200	Low	Reduction in yield or loss of water supply for domestic usage	Road is in cutting to a max depth of c.7.5m at this location.	Large Adverse	Slight
		Contamination of water supply from road drainage entering aquifer via exposed bedrock	There is potential for silt laden or contaminated road drainage to enter and contaminate the local groundwater table through exposed bedrock and in turn the domestic supply.	Large Adverse	Slight

Attribute		Impact			
Site Name	**Importance**	**Nature of impact**	**Description of Impact**	**Magnitude of Impact**	**Impact Rating**
Domestic Well supply c.200m south of the proposed road development at Ch.55+400	Low	Reduction in yield or loss of water supply for domestic usage	Road is in cutting to a max depth of c.7m at this location	Large Adverse	Slight
		Contamination of water supply from road drainage entering aquifer via exposed bedrock	There is potential for silt laden or contaminated road drainage to enter and contaminate the local groundwater table through exposed bedrock and in turn the domestic supply.	Large Adverse	Slight
A cluster of domestic Well supplies located down-gradient of a proposed cutting at Ch.55+600.	Low	Reduction in yield or loss of water supply for domestic usage	Cutting max depth of c.7.5m located between 100 – 450m up-gradient.	Large Adverse	Slight
		Contamination of water supply from road drainage entering aquifer via exposed bedrock	There is potential for silt laden or contaminated road drainage to enter and contaminate the local groundwater table through exposed bedrock and in turn these domestic supplies.	Large Adverse	Slight

9.5. Proposed Mitigation Measures for Hydrogeology

9.5.1 Mitigation Measures for Hydrogeology

Mitigation measures follow the principles of avoidance, prevention, reduction and offsetting. Where avoidance has not been possible, then consideration has been given to trying to locally modify the proposed road development both vertically and horizontally to reduce / minimise the extent of the impact.

9.5.1.1 General Mitigation Measures for Hydrogeology

Operational Mitigation

The impact of road construction on aquifers and groundwater resources can be minimised by applying sound design principles and by following good work practices as outlined by the TII in its 'Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes (2008)'.

For groundwater the following were the main responses and guidelines considered during the development of the hydrogeological mitigation measures for the proposed road development:

- Where possible, re-align the road down-gradient or an appropriate distance up-gradient of the source protection area for high yielding water supply springs and wells and natural hydrogeological features;
- Where possible, minimise the depth of road cutting within a source protection area or zone of contribution to minimise the impact on groundwater flows to down gradient springs, wells, wetlands and other hydrogeological features;
- Where possible, minimise the depth of road cutting below the permanent groundwater table in order to ensure that its zone of contribution does not extend up gradient to a hydrogeological feature or wetland;
- Provide sealed drains along sections of road overlying the vulnerable parts of locally important or regionally important aquifers;
- Provide site-specific measures to protect relatively small natural hydrogeological features such as springs, seeps or wetlands;
- Assess the potential impact of re-grading small streams on nearby wells or springs;
- Ensure all surface water run-off discharged to groundwater via soakaways or unlined attenuation ponds is passed through systems for settlement or filtration of suspended solids with the parallel effect of removing contaminants (certain heavy metals and hydrocarbons) associated with the suspended solids;
- Groundwater monitoring may be appropriate in certain instances, instead of automatically providing specific mitigation measures. In these circumstances however, thresholds should be set that will trigger the introduction of pre-defined mitigation measures;
- Specifying regular monitoring of groundwater during the construction period and for a defined period thereafter, following opening of the proposed road development;
- All wells abandoned as part of the road development should be sealed and abandoned in accordance with "*Well Drilling Guidelines (2007)"* produced by the Institute of Geologists of Ireland (IGI). Ground investigation boreholes should be backfilled using bentonite or cement bentonite grout in accordance with the *Specification and Related Documentation for Ground Investigation (2006)* published by the Institution of Engineers of Ireland; and

- Abandon obsolete ground investigation boreholes / water supply wells and springs in accordance with the appropriate well drilling guidelines.

The above guidelines have been considered during the development of the design such that impacts have been minimised. Site specific mitigation measures for the unavoidable impacts are detailed in Section 9.5.1.2.

In formulating hydrogeological mitigation measures, regard was made to the requirements of the Water Framework Directive (Directive 2000/60/EC of the European Parliament, 2000) and Groundwater Directive (Directive 2006/118/EC of the European Parliament, 2006) and the enabling national legislation. In developing mitigation measures, there was co-ordinated and ongoing consultation with the River Basin Management Projects, the National Parks and Wildlife Service (NPWS), Office of Public Works (OPW), Local Authorities, Group Water Schemes and Environmental Protection Agency (EPA) as required.

The following mitigation will be incorporated in respect of groundwater supplies:

- All groundwater supplies currently in use that are within the footprint of the proposed road development will be replaced either through the provision of a private supply or by providing a connection to an existing public or group water scheme;
- All groundwater supplies identified in Table 9.18 and existing private wells within 300m of areas of road cuttings greater than 5m will be monitored (for water level and quality). The proposed monitoring will consist of:
    - Quarterly monitoring for 12 months pre-construction
    - Bi-monthly monitoring during construction
    - Quarterly monitoring for 12 months post-construction
    - Monitoring of any private supplies is subject to agreement by the relevant land/ property owner. Should it be concluded that any of these monitored private supplies will be lost or contaminated as a result of the development, these shall be replaced either through the provision of a replacement private supply or by providing a connection to an existing public or group water scheme.

The incorporation of the above listed mitigation measures will ensure that there will be no likely significant residual effects on any private or group groundwater supply.

Construction Mitigation for Hydrogeology

During the construction phase any compound areas / service yards are to be located away from key hydrogeologically sensitive areas and features (Watercourse, wetlands habitats, etc.) – further details are set out in Section 9.5.1.2 below. In terms of avoiding regionally important aquifers, this was not possible as it is the dominant aquifer type along the route and therefore best environmental practices are required to protect against potential pollution. To minimise the risk of pollution to the groundwater, any fuel storage, refuelling and maintenance of construction vehicles will be carried out in protected areas to manage any spillages.

Procedures are set out in Chapter 10 Hydrology which will require that any hydrocarbon leakages or spillages during construction will be dealt with immediately. These measures will absorb the bulk of the contaminant immediately with absorbent material, storing it and the contaminated soil in a stockpile underlain and covered by plastic to prevent leachate generation, until such time as it can be removed off-site by an appropriately licensed waste management company.

Where significant groundwater flows are encountered in deep bedrock cut sections, mitigation will be provided to ensure the continued flow of same where possible. The mitigation may involve either piping, construction of gravel filled pathways or short diversions. The Contractor shall be made aware of any areas of potential karst features located at shallow depths, and site traffic in these areas should be kept to a minimum to reduce the potential compression and collapse of subsurface flow features.

Imported fill shall be in accordance with the requirements of the TII Specification for Road Works. Where water supply wells and springs are located underneath the proposed road development footprint, these will be sealed to prevent contaminants entering the aquifer (*Well Drilling Guidelines (IGI, 2007)*). The incorporation of such mitigation measures will ensure there will be no likely significant residual effects to any private or group groundwater supplies.

9.5.1.2 Site Specific Mitigation Required for Hydrogeology

Extreme Vulnerability Areas

Construction

Prior to the commencement of construction works, clean runoff water from lands adjacent to and up gradient of the works area will be diverted to local watercourses through the installation of cut-off ditches. Soiled construction runoff water will undergo treatment before discharge by being passed through a settlement pond (either temporary or permanent pond system). The treated water may be discharged to a surface water body and/or depending on the subsoil conditions may also discharge to ground so as to maintain the existing recharge conditions.

Operational

Throughout the proposed road development in areas of extreme and high vulnerability and near sensitive ecological receptors, a sealed drainage system will be used – see Table 9.9 above for details. This avoids the potential for infiltration to groundwater as a linear source and this approach is in accordance with best practice. Wetland systems will be provided at all outfalls to protect both surface and groundwater from any adverse quality and/or quantity impacts of the road drainage discharge.

Hydrogeological Features

Each of the hydrogeological features identified that are potentially at risk due to the proposed road development were assessed based on the potential magnitude of the impact. Where an impact rating was deemed to be slight or imperceptible it is considered that the adherence to good construction practices applies, as fully outlined in the Environmental Operating Plan (Appendix 4.1) and as further detailed in Chapter 10. Adoption of these measures can adequately mitigate the level of risk involved and no additional specific mitigation is required. Each of the features which were found to have an impact rating greater than slight have been considered to require some form of mitigation to reduce the magnitude of the risk posed. Table 9.19 gives details of the specific mitigation measures proposed at each hydrogeological feature.

Table 9.19 Proposed Mitigation Measures for Hydrogeological Features with the Corresponding Residual Impact Rating

Feature / Location	Description of Impact	Mitigation Measure	Residual Impact
KER4 Rincullia Km 4	Increased frequency or extent of localised groundwater/pluvial flooding of agricultural lands.	Fill with clean broken rock and wrap in geotextile prior to completing the road formation/embankment. Maintain north-south drainage beneath the road construction.	Imperceptible
	Localised pollution of the bedrock aquifer by routine surface runoff and spillages	Provide sealed road drainage at this location and treat prior to outfall.	
KER7 Fen Wetland at Ballyellinan Km 7	Changes to the groundwater flow regime causing a deterioration in the status of the fen as a wetland habitat.	No improvement to existing drainage systems in this area – provide a drainage neutral design. All existing surface water flow paths to be piped and culverted to match existing conditions. Provide a drainage blanket between Ch.6+600 and Ch.7+150 with a transverse barrier at either end to ensure north-south shallow drainage paths are not blocked and to ensure road formation does not act as a longitudinal drain. Base of the embankment for Side Road 5B and the L1220 shall be constructed of cohesive non-permeable material to ensure the road formation does not drain the wetland fen area located to the north of the alignment.	Imperceptible
	Localised pollution of the bedrock aquifer or the fen wetland by routine surface runoff and spillages	Road drainage to be treated prior to outfall as per good design practice. Appropriate drainage system to be used as per the assessment in Section 9.4.1.2	
KER11 Fen Wetland at Lismakeery Km 21	Changes to the groundwater flow regime causing a deterioration in the status of the fen as a wetland habitat.	No improvement to existing drainage systems in this area – provide a drainage neutral design. All existing surface water flow paths to be piped and culverted to match existing conditions. Provide a drainage blanket between Ch.21+000 and Ch.21+150 with a transverse barrier at either end to ensure north-south shallow drainage paths are not blocked and to ensure road formation does not act as a longitudinal drain. Any springs/groundwater seepages which may be encountered shall be filled with clean broken rock, wrapped in geotextile and piped/directed to its natural flow path which is likely towards this wetland. Hydrological management measures including a drainage link from the existing spring under the proposed road development at Ch.21+080 southward to the main fen area and sluice controls on the drainage outlet.	Imperceptible

Feature / Location	Description of Impact	Mitigation Measure	Residual Impact
	Localised pollution of the bedrock aquifer or the fen wetland by routine surface runoff and spillages	Road drainage to be treated prior to outfall as per good design practice. Appropriate drainage system to be used as per the assessment in Section 9.4.1.2	
KER21 Fen Wetland Blossomhill Km 51	Changes to the groundwater flow regime causing a deterioration in the status of the fen as a wetland habitat.	No improvement to existing drainage systems in this area – provide a drainage neutral design. All existing surface water flow paths to be piped and culverted to match existing conditions. Base of embankment on north side of alignment between Ch.51+050 and Ch.51+300 shall be constructed from cohesive material to ensure the road formation toes not act as a longitudinal drain away from this area.	Imperceptible
	Localised pollution of the bedrock aquifer or the fen wetland by routine surface runoff and spillages	Road drainage to be treated prior to outfall as per good design practice. Appropriate drainage system to be used as per the assessment in Section 9.4.1.2	
Craggs/Barrigone GWS Km 6	Reduction in yield be observed of water supply at the Group Water Scheme borehole	The principal mitigation measure proposed at this supply is to monitor the pre, during and post construction water level and water chemistry at the supply for any impacts. Whilst a moderate/significant impact to the yield of the existing supply at Craggs/Barrigone GWS cannot be discounted, the likelihood of a significant impact is low, and the more likely scenario is that the impact will be minor or imperceptible. However, in the absence of absolute certainty two alternative mitigation measures are proposed which will form a backstop should a reduction in yield be observed: (i) Connection of the public water supply to the Group Water Scheme reservoir in advance of the main scheme construction (ii) Should a significant impact in quality or yield be observed as a result of the proposed road development, installation of a new suitably located replacement/additional borehole and pump system connected to the existing group water scheme network. Mitigation measures are only provided for should a reduction in yield below the maximum abstraction rate occur and to ensure no interruption in supply.	Slight
	Contamination of water supply from road drainage entering aquifer via weathered bedrock.	Provide sealed drainage system between Ch.4+000 and Ch. 7+150 to ensure no pollution of the underlying aquifer in this area where bedrock is exposed/near the ground surface or will be exposed by the proposed cutting.	

Feature / Location	Description of Impact	Mitigation Measure	Residual Impact
Croagh-Farrandonnelly GWS Km 54	Reduction in yield of water supply at the Group Water Scheme borehole	Monitor pre, during and post construction water level and water chemistry at this supply. Should a significant impact in quality or yield be observed as a result of the proposed road development, take necessary steps which may include provision of a replacement borehole or connection to an adjacent supply.	Slight
	Contamination of water supply from road drainage entering aquifer via weathered bedrock.	Provide sealed drainage system between Ch.53+150 and Ch. 55+800 to ensure no pollution of the underlying aquifer in this area where bedrock will be exposed by the proposed cutting.	
Spring feeding local stream Km 1	Loss of water supply for agricultural use	Fill with clean broken rock, wrap in geotextile and pipe/redirect to adjacent stream/watercourse located to the north.	Slight
Spring/Well Agricultural Use Km 11	Loss of water supply for agricultural usage	Provide replacement borehole or connection to adjacent supply.	Slight
	Contamination of water supply from road drainage entering aquifer via exposed bedrock	Prior to completing road construction, fill with clean broken rock, wrap in geotextile and pipe/redirect to cut-off drain or adjacent stream/watercourse. If a well or bore is present follow the IGI guidance for the abandonment of wells.	Imperceptible
Spring/Well Agricultural Use Km 51	Loss of water supply for agricultural usage	Provide replacement borehole or connection to adjacent supply.	Slight
	Contamination of water supply from road drainage entering aquifer via exposed bedrock	Prior to completing road construction, fill with clean broken rock, wrap in geotextile and pipe/redirect to cut-off drain or adjacent stream/watercourse. If a well or bore is present, follow the IGI guidance for the abandonment of wells.	Imperceptible
Domestic well located c.150m south of the proposed alignment at Ch.55+200. Alignment is in cutting to a max depth of c.7.5m at this location.	Reduction in yield or loss of water supply for domestic usage	Monitor pre, during and post construction water level and water chemistry at this supply. Should an impact in quality or yield be observed provide a replacement borehole or connection to an adjacent supply.	Slight
	Contamination of water supply from road drainage entering aquifer via exposed bedrock	Road drainage to be treated prior to outfall as per good design practice. Appropriate drainage system to be used as per the assessment in Section 9.4.1.2	Imperceptible

Feature / Location	Description of Impact	Mitigation Measure	Residual Impact
Domestic well located c.200m south of the proposed alignment at Ch.55+400. Alignment is in cutting to a max depth of c.7.5m at this location	Reduction in yield or loss of water supply for domestic usage	Monitor pre, during and post construction water level and water chemistry at this supply. Should an impact in quality or yield be observed provide a replacement borehole or connection to an adjacent supply.	Slight
	Contamination of water supply from road drainage entering aquifer via exposed bedrock	Road drainage to be treated prior to outfall as per good design practice. Appropriate drainage system to be used as per the assessment in Section 9.4.1.2	Imperceptible
A cluster of domestic well supplies located down-gradient of a proposed cutting at Ch.55+600. Cutting max depth of c.7.5m located between 100 – 450m up-gradient.	Reduction in yield or loss of water supply for domestic usage	Establish locations of all domestic and agricultural supplies in the likely potential zone of impact. Monitor pre, during and post construction water level and water chemistry at these supplies. Should an impact in quality or yield be observed provide a replacement borehole or connection to an adjacent supply.	Slight
	Contamination of water supply from road drainage entering aquifer via exposed bedrock	Road drainage to be treated prior to outfall as per good design practice. Appropriate drainage system to be used as per the assessment in Section 9.4.1.2	Imperceptible

9.6. Residual Impacts for Hydrogeology

The incorporation of the mitigation measures outlined in Section 9.5 results in the magnitude of any impacts either during construction or operation to be considered as Negligible. As a result, the significance of all impacts is Imperceptible or Slight – see Table 9.20 below for details.

Table 9.20 Residual Impacts for all Hydrogeological Features

Hydrogeological Feature	Importance	Residual Impact
Bedrock aquifer classified by the GSI as a Regionally Important Aquifer (Rkc)	High	Imperceptible
Bedrock aquifer classified by the GSI as a Regionally Important Aquifer (Rkd)	High	Imperceptible
Bedrock aquifer classified by the GSI as a Locally Important Aquifer (Ll)	Low	Imperceptible
Askeaton Fen Complex SAC	Extremely High	Imperceptible
Lower River Shannon SAC	Extremely High	Imperceptible
Turloughs located in the townlands of Craggs and Tomdeely (Lough Selleher, Tomdeely, Foleys & Tomdeely North)	Moderate	Imperceptible
Karst Springs located near the townland of Tomdeely & Morgans North	Low	Imperceptible
KER4 Rincullia	Low	Imperceptible
KER7 Fen Wetland at Ballyellinan	Moderate	Imperceptible
KER11 Fen Wetland at Lismakeery	Moderate	Imperceptible
KER21 Fen Wetland at Blossomhill	Moderate	Imperceptible
Craggs/Barrigone GWS	High	Slight
Croagh-Farrandonnelly GWS	High	Slight
Private Groundwater Supplies along the entire proposed road development	Low	Imperceptible