Carrigtohill Flood Risk Assessment Study

Groundwater Flood Risk Assessment

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Prepared by:
Peter Conroy
On behalf of Cork County Council

In Collaboration with:
JBA Consulting

Peter Conroy
Independent Hydrogeologist

Shantraud, Killaloe
Co. Clare
Phone: +353 (0)85 7786 864

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1 INTRODUCTION

Cork County Council has appointed Peter Conroy (Independent Hydrogeologist) and JBA Consulting to carry out the Carrigtohill Flood Risk Assessment Study.

Peter Conroy is carrying out the groundwater flood risk component of the study. JBA Consulting is carrying out the surface water flood risk part of the study.

The brief for the groundwater flood risk component is outlined in the Project Brief (Cork County Council, 2011) and requires:

- an assessment of the risk of groundwater flooding associated with the limestone aquifer in the south of the catchment;
- that the assessment must take account of the impacts of quarry dewatering within the catchment on the current and future risk of groundwater flooding;
- that as far as reasonably possible, all relevant stakeholders should be contacted and all available data relevant to groundwater flooding within the study area collated; and,
- analysis of the available data to determine the potential impacts of cessation of quarry dewatering on groundwater levels.

The required project outcomes are:

- an indicative assessment of current and potential future groundwater flood risk:
    - including areas potentially affected and the degree and extent of flooding;,
    - based as far as possible on quantitative data;
- detailed recommendations for future monitoring and work to assess the groundwater hazard and risk quantitatively.

2 METHODOLOGY

The following steps were carried out in preparing this groundwater flood risk assessment:

- A comprehensive desk study of hydrogeological data relevant to the study area including historical groundwater level and discharge data held by the Geological Survey of Ireland (GSI), the Environment Protection Agency (EPA), Cork County Council, Quarry operators in the study area, IPPC License holders in the study area, Ordnance Survey Ireland (OSI), the Office of Public Works (OPW), the South-western River Basin District and other stakeholders.
- Consultation with key stakeholders on groundwater flood risk in the study area including Cork County Council, Quarry operators, GSI, EPA, OPW, IPPC License Holders, Carrigtohill Community Council and other stakeholders;
- A catchment visit and drive-over survey in conjunction with key stakeholders to map known groundwater flooding extents, and carry out preliminary hydrogeological mapping of groundwater flooding factors such as karst features and groundwater elevation;
- Integrated analysis of the full groundwater dataset plus outcomes of the surface water flood risk modelling to develop a hydrogeological conceptual model of the study area; and,
- Assessment of the groundwater flood risk of the study area based on the hydrogeological conceptual model.

3 DESK STUDY

The desk study consultations carried out and the relevant datasets obtained are detailed in Table 1.

All desk study mapping and spatial database data were analysed using GIS. Relevant features from the mapping datasets were identified and added to the project hydrogeological database.

All desk study reports were interrogated to extract relevant hydrogeological data. Relevant mapping was extracted, georeferenced and analysed using GIS. Relevant point spatial data were added to the project hydrogeological database and analysed using GIS.

The location of the study area is shown on Figure 1. The relevant features from the desk study datasets are shown in Figure 2 and in Tables A to E.

4 STAKEHOLDER CONSULTATIONS

The stakeholder consultations carried out and the relevant datasets obtained are detailed in Table 2. Details of the quarry stakeholder consultations are provided in Table 3.

All mapping and relevant hydrogeological data were analysed using GIS. Relevant features from the mapping and groundwater monitoring datasets were identified and added to the project hydrogeological database.

All reports obtained from consultations were interrogated to extract relevant hydrogeological data. Relevant mapping was extracted, georeferenced and analysed using GIS. Relevant point spatial data were added to the project hydrogeological database and analysed using GIS.

The relevant features from the stakeholder consultation datasets are shown in Figure 2 and in Tables A to E.

5 SITE VISIT

A site visit was carried out on 17 July 2011 in the company of various key stakeholders within the catchment. The site visit activities and the stakeholders involved are detailed in Table 4.

The relevant groundwater features identified during the site visit are shown in Figure 2 and in Tables A to E.

Table 1. Desk Study Datasets

Stakeholder	Datasets obtained during desk study	Source
GSI	National Groundwater Mapping and Databases: - Mapping: Bedrock, Bedrock Aquifer, Sand and Gravel Aquifer, - Mapping: Groundwater Vulnerability, Source Protection Zones (Cloyne, Dower) - Databases: Karst, Well, Exploration Borehole, Quarry	www.gsi.ie
	Groundwater Body Initial Characterisation Summaries: Midleton GWB, Ballinhassig GWB	
	A review of Gravel Aquifers of Ireland (Wright, G., 2001. IAH Conference Proc.)	
EPA	National Groundwater Mapping and Databases: - Mapping: Subsoil, Soil, Rivers, Groundwater Bodies - Databases: Groundwater Level Stations, Hydrometric Stations, Chemical WQ Stations	www.epa.ie
	IPPC License Information: P057103 (Merck Millipore), P026401 (Georgia Holdings)	
	IPPC License Information: P031601 (James O'Brien)	
	Waste License: W002201 (East Cork Landfill)	
OSI	Historical Mapping: 25" to 1mile 1888-1913 series; 6" to 1mile 1837-1842 series on OSI website Historical Databases: Land and Water Thematic layers from 25" & 6" series	http://maps.osi.ie/publicviewer/
	Current Mapping: 1:5000 and 1:2500 scale series on OSI website	
	Orthophotos: 1995, 2000 and 2005 series on OSI website	
OPW	Flood Mapping: Benefitting Lands, Drainage Districts, Flood Extents	
	Flood Databases: Flood Points	www.floodmaps.ie
SWRBD	Groundwater Abstractions Pressure Assessment (CDM, 2009)	www.swrdb.ie
	South Western River Basin Management Plan (SWRBD, 2010)	

Table 2. Stakeholder Consultations

Stakeholder	Datasets obtained following consultation	Source
GSI	Historical Groundwater Level Monitoring data: Ballynabointra Monitoring Well (1977 - 2003)	GSI Groundwater Section
EPA	Spring Discharge Data: Dower PWS	EPA Hydrometric Section
	Historical Groundwater Level Monitoring Data: Ballynabointra Monitoring Well (1996 - 2005)	EPA Hydrometric Section
	Groundwater Quality Monitoring Data: Cork - IDA Well, Cloyne, Dower	EPA Hydrometric Section
Cork County Council Water Services	Carrigtohill Public Water Supply Borehole: Discharge data; Groundwater Level Data Carrigtohill Public Water Supply Borehole: Hydrogeological Report (Not yet received)	Charlie Brannigan/Liam Lynch
	W002201 Rossmore Landfill: Groundwater level monitoring data (not yet received)	Charlie Brannigan
	Cork Speleological Society Records: Carrigtohill Caves	Charlie Brannigan
	Local anecdotal knowledge of flooding and karst characteristics of the catchment	Robert O'Sullivan/Pat Fitzgerald
Cork County Council Planning	Quarry Planning Files: Database of Registered Quarries (S.261 of P&D Act 2000) - SW Cork	Tadhg McNamara
	Quarry Planning Files: Hydrogeological data for Carrigtohill area Quarries (see Table 3)	Planning Counter
OPW	OPW data on Ballyadam Turlough	OPW FRAM Section
SWRBD	Data on Midleton GWB Poor Quantitative Status	Fergal O'Sullivan
Cork Speleological Society	Data on Carrigtohill Caves (Note: the society is currently defunct)	Peter Barry
IDA	Hydrogeological Data on IDA Carrigtohill Developments (not yet received)	Paul Gavin
	Data on Infilling of Part of Ballyadam Turlough (Etender ID: 131331) (not yet received)	Paul Gavin/J Duggan (Arup)
Individual Quarries	Groundwater level and discharge data (see Table 3)	Various
Carrigtohill Community Council	Local anecdotal knowledge of flooding and karst characteristics of the catchment	Oliver Sheehan
Merck Millipore	Groundwater Level data from IPPC License Groundwater Monitoring	Ross Daly

Table 3. Quarry Consultations

Quarry	Quarry Operator	Cork County Council Planning File	Data Source	Data
Barryscourt	RoadstoneWood	QR23	CCC Planning File	No groundwater data in Planning File
			RoadstoneWood	No Data; Very minor site.
Ballyvodock West	RoadstoneWood	QR27	CCC Planning File	Very little groundwater data on File; Letter from 2010 indicates Quarry about to start groundwater monitoring
			RoadstoneWood	No monitoring infrastructure installed Dewatering ceased and quarry closed in July 2010
Coppingerstown, Midleton	RoadstoneWood	03/5527	CCC Planning File	Groundwater level data for Sept. 2008; No dewatering occurs (they went slightly below groundwater level before Planning Permission obtained
			RoadstoneWood	Groundwater Level Monitoring Data (not yet received)
Carrigshane, Midleton	RoadstoneWood	QR08	CCC Planning File	Groundwater level data for July 2006; Aquifer properties data; No dewatering occurs
			RoadstoneWood	Groundwater Level Monitoring Data (not yet received)
Ballynabointra (Milebush)	Lagan Cement	QR78	CCC Planning File	Groundwater level data for Aug. 2006 and Mar. 2001; Interpreted groundwater flow direction Dewatering discharge rate and location
			Lagan Cement	Groundwater Level Monitoring and historical dewatering Rates Data (not yet received); Dewatering ceased in June 2012
Rossmore	Lagan Asphalt	05/7886	CCC Planning File	Groundwater level data for Oct. 2005; Planning Permission refused - Quarry never opened up

Quarry	Quarry Operator	CCC Planning File	Data Source	Data
Rossmore	Lagan Asphalt	02/5476 & 05/7362	CCC Planning File	Groundwater level data for Sept. 2002; Onsite well discharge Rate; No Dewatering
			Lagan Asphalt	Groundwater Level Monitoring data (not yet received)
Rossmore (Western Site) (Limestone extraction)	Readymix	99/3411 & 03/4570	CCC Planning File	Groundwater level data for Mar. 1997 and Feb. 1999; Dewatering discharge rate for Nov. 1999; Aquifer Properties data
			Readymix	Groundwater Level Monitoring and Dewatering Rates Data (not yet received)
Rossmore (Eastern Site) (Sand & Gravel Extraction)	Readymix	QR60	CCC Planning File	Extraction of S&G by dredging, no active dewatering; No Groundwater level data on file
			Readymix	Groundwater Level Monitoring data (not yet received)
Ballyvodock East	Tim O'Connor	92/3286	CCC Planning File	Minor site; No Groundwater data on File; File relates to a proposed Dump; Site not considered further
Ballynabointra	David Walsh	08/4711	CCC Planning File	Tiny site across the road (east) from Milebush Quarry. No groundwater data on file; Site not considered further
Lackenbehy	Whelans	08/8434	CCC Planning File	Sandstone quarry in northeast of catchment; Groundwater level and dewatering data obtained; Dewatering discharge <100 m3/day; Quarry not considered relevant to groundwater flood risk; Site not considered further
Barryscourt	Louis O'Regan	QR22	CCC Planning File	No Groundwater data on file; CorkCoCo decided the site is no longer used as a quarry; Site not considered further
Knockraha	Ollie Sheehan	06/6016	CCC Planning File	No Groundwater data on file; Planning file is an application for a farm shed; Site not considered further
Carrigane	William Kelleher	QR90	CCC Planning File	No GW data on file; Small site on Sandstone; Site not considered further

Table 4. Site Visit Details (17/07/2012)

Stakeholder	Site visit activities
Robert O'Sullivan & Pat Fitzgerald (Cork County Council	• Visited Cork CoCo PWS borehole at Carrigtohill IDA Estate. Boreholes were for supply to IDA estate. Not currently in use. Logged water level in borehole 04_018 (also used as an EPA groundwater quality monitoring borehole) • Discussed Ballyadam turloughs. Mapped known extent of flooding & noted Cork CoCo experience of road flooding and mitigatory pumping plus comments on impact of IDA infilling of part of Turlough. • No other groundwater flooding locations known to Cork County Council Area staff
Frank Glennon (Lagan Cement, Milebush)	• Visited Lagan Cement Milebush quarry • Logged water levels in monitoring boreholes • Observed flooded quarry void and took photographs • Logged location of swallow hole used historically for dewatering discharge
Tim O'Mahony (RoadstoneWood, Ballyvodock West)	• Visited RoadstoneWood Ballyvodock West Quarry • Searched for possible monitoring wells onsite but none present • Observed flooded quarry void and took photographs
Oliver Fitzgerald (Carrigtohill Community Council Chairperson)	• Discussed Carrigtohill Caves and Terrysland Swallow Hole` • Discussed flooding issues at Ballyadam IDA site • Discussed discharge at Ballintubrid Spring – O Sheehan not familiar with the site • Discussed dried out dug wells in Rossmore area • Discussed historical drainage of Slatty Water/Barryscourt area plus springs at Barryscourt
Catchment Drive over	• Measured water level at Ballynabointra monitoring borehole • Visited Terrysland swallow holes and caves • Visited Ballyadam area and viewed IDA site plus swallow hole discharge point for Cork County Council flood pumping • Drive over survey of study area with emphasis on areas with possible karst features

6 ENVIRONMENTAL SETTING

6.1 CATCHMENT LOCATION

The Carrigtohill catchment is located on the south coast approximately 15 km east of Cork City centre. Carrigtohill town lies in the southern third of the catchment approximately mid-way between the eastern and western catchment boundaries at approximately NGR 182300E, 73000N. The catchment has the typical east-west oriented ridge and valley landscape of southeast cork. The northern two thirds of the catchment sits on the sandstone ridge north of Carrigtohill, while the southern third occupies the limestone valley at the base of the ridge. The catchment extends east to west approximately 6.5 km from Killacloyne to Ballyadam townlands along the N25 road, and north to south approximately 6.5 km from Ballynakilla to Barryscourt townlands. The catchment is shown on Figure 1. Photos of the catchment are shown in Photos 1 and 2 below.

Photo 1 View northeast from Ballintubrid West

Photo 2 View north from Ballintubrid West

6.2 HYDROMETEOROLOGY

Hydrometeorological data was obtained from Met Eireann.

Annual rainfall: 1076 mm. This is the average of the Standard-Period Average Annual Rainfall (SAAR) (1961-1990) data for the 20 Catchment Descriptor points located on surface water courses in the southern third of the catchment (i.e., on the limestone valley). The Catchment Descriptor points are taken from the Flood Studies Update (OPW, on-going).

Annual evapotranspiration losses: 514 mm. The average of the Standard-Period Average Annual Potential Evaporation (SAAPE) (1961-1990) data for the 20 Catchment Descriptor points located on surface water courses in the southern third of the catchment (i.e., on the limestone valley) is 541 mm. The Catchment Descriptor points are taken from the Flood Studies Model. Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits giving an Actual Evapotranspiration of 514 mm.

Annual Effective Rainfall: 562 mm. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall.

6.3 TOPOGRAPHY

The study area for the groundwater flooding assessment occupies the floor of an east west trending limestone valley. The valley is bounded to the north and south by parallel east west trending sandstone ridges. The valley floor is generally flat to gently undulating and ground elevations range from approximately 0 to 40 mAOD. The southern boundary of the study area forms the shoreline of Cork Harbour from Slatty Water east as far as the Owenacurra Estuary.

There are numerous gravel pits and limestone quarries in the valley which over time have significantly altered the natural topography on the local scale. The largest quarries are the RoadstoneWood and Lagan Cement limestone quarries at Ballyvodock West and Ballynabointra, which have created large voids in the landscape to depths of -15 mAOD and -22 mAOD respectively. The RoadstoneWood void is approximately 550 m long north to south and 350 m wide east to west. The Lagan Cement quarry has two voids, one with a radius of 100 m and a second approximately 400 m long east to west and 200 m wide north to south. There are also several significant gravel pits and limestone quarries along the shoreline at Rossmore Bay. These include the Readymix Rossmore limestone quarry, which has excavated to at least -18 mAOD, based on the LIDAR topographic survey of the study area. The approximate boundaries of the quarries are shown on Figure 2.

The topography in the vicinity of Slatty Bridge, Tullagreen and Barryscourt is very low lying. Anecdotal evidence indicates that historically this area was tidal east as far as Barryscourt Castle and north as far as the N25 road. The area was reclaimed by the installation of sluice gates at Slatty Bridge and drainage of the area to the east. The drainage is currently accomplished via a pumping station at Slatty Bridge.

6.4 HYDROLOGY

The study area is drained by streams which runoff the sandstone ridge onto the limestone valley floor. In the west of the study area a small stream discharges to the harbour from Killacloyne. A large stream descends through Springhill and Tullagreen and discharges into the pond at Slatty Bridge. Two other small streams discharge into the same pond with one flowing south from Terrysland and the other flowing east from Barryscourt Castle. A further stream (HEP 4[1]) flows southwest out of Poulaniska and sinks at two swallow holes in Terrysland (Section 6.5.1). To the east of this surface water drains towards the Owenacurra River.

To the south and east of Carrigtohill there is an approximately 9 km^2 area across the townlands of Gortagusta, Ballyadam, Clyduff, Burgesland, Ballynabointra, Ballintubrid and Ballyvodock where no surface water features are mapped. This suggests that the soil and subsoil permeabilities are high and that all effective precipitation infiltrates to groundwater (Sections 6.5.1 and 6.8)

The hydrology of the study area is described in detail in the surface water flood risk assessment hydrology report (JBA, 2012).

6.5 BEDROCK GEOLOGY

Sheet 22, the Geology of East Cork-Waterford published by the GSI indicates that the area is underlain by the bedrock types described in Table 5 (Sleeman and McConnell, 1995). Table 5 shows the strata in stratigraphic order from youngest to oldest. The bedrock distribution is shown in Figure 3.

[1] See Hydrology Report (JBA, 2012)

The Carrigtohill catchment lies on the north side of and slightly to the east of the midpoint of the east—west orientated Cork syncline (trough of a bedrock fold). The syncline forms the large valley between the sandstone ridge to the north of Carrigtohill and a second sandstone ridge to the south, which underlies Great Island and Cobh. The ridges are anticlines i.e. the crests of bedrock folds. The axis of the syncline runs east-west through Foaty Island and the townlands of Ballintubrid East and West. A minor topographic divide along the syncline axis constrains the surface water catchment to the northern half of the syncline. The bedrock strata on the northern limb of the syncline dip south towards the axis.

Mapped bedrock faults in the area are typically parallel or perpendicular to the east-west syncline axis.

Table 5: Bedrock Descriptions around the Carrigtohill study area

Bedrock Formation	Generalised Rock Unit Classification	Geological Description	Thickness (m) (from Sleeman & McConnell, 1995)
Clashavodig Formation (CV)	Dinantian Pure Bedded Limestone (DPBL)	Oolitic, peloidal, cherty, fine limestone	No data
Little Island Formation (LI)	Dinantian Pure Unbedded Limestone (DPUL)	Massive and crinoidal fine limestone	500 m
Cork Red Marble Formation (CK)	Dinantian Pure Bedded Limestone (DPBL)	Red brecciated calcilutite limestone	80 m
Waulsortian Limestone (WA)	Dinantian Pure Unbedded Limestone (DPUL)	Massive, unbedded lime-mudstone	> 600 m
Ballysteen Formation (BA)	Dinantian Lower Impure Limestone (DUIL)	Dark muddy Limestone, shale	> 125 m
Cuskinny Member (Kncu)	Dinantian Mudstones and Sandstones (Cork Group) (DMSC)	Flaser-bedded sandstone & mudstone; (in Kinsale Formation)	> 235 m
Old Head Sandstone Formation (OH)	Dinantian Mudstones and Sandstones (Cork Group) (DMSC)	Flaser-bedded sandstone & minor mudstone	No data
Gyleen Formation (GY)	Devonian Old Red Sandstones (DORS)	Sandstone with mudstone & siltstone	No data
Ballytrasna Formation (BS)	Devonian Old Red Sandstones (DORS)	Purple mudstone & sandstone	No data

6.5.1 Karst Features

The GSI karst database indicates the presence of three caves, two swallow holes and two turloughs within the limestone component of the surface water catchment.

Two of the caves (1707SWK001 & 002) and a swallow hole (1707SWK004) occur at the disused quarry in what is now the Cúl Ard housing estate in the Terrysland townland. The swallow hole was observed during the site visit and is adjacent to south side of Fearann na Carraige street on the west side of a ruined castle/lime kiln and receives inflow from stream HEP 4. A second swallow hole (KF15) was observed in the southwest wall of the disused quarry during the site visit. KF15 currently receives the outfall from the constructed reedbed which has been installed in the quarry floor (Photo 3).

Photo 3 Swallow Hole KF15 at Cúl Ard Housing Estate, Terrysland

Photo 4 Swallow Hole KF14 at base of attenuation pond at IDA site in Ballyadam

The two caves are likely to be the caves discovered by JC Coleman (Coleman, 1943) and the Cork Speleological Society (CSL) (Devoy, 1990). Recent information on the condition of the caves was provided by Peter Barry (Personal Communication, 10 May 2012) and Oliver Sheehan (Personal Communication, 17 July 2012). Cave 1707SWK001 is referred as the "Old Carrigtohill Cave" by the CSL, while cave 1707SWK002 is referred to as the "Pluais an Sciathán Leathar" (PaSL) cave. Swallow hole KF15 is the entrance to the PaSL cave. A small natural stream (now the reedbed outfall) was observed sinking into the cave system at KF15 on 23 March 1990 (Devoy, 1990).

Maps of the Old Cave and the PaSL caves were provided by Peter Barry and Oliver Sheehan. These have been roughly geo-referenced and the mapped cave extents are shown in Figure 4. The maps show that large conduits and chambers extend up to 200 m south from the PaSL entrance (underneath recently constructed housing estates) with further passages branching off to the southwest. At the Old Cave the main passages and chambers have a south-westerly orientation and are linked by shorter south-easterly oriented branches. At the old cave the mapped system extends over an area approximately 100 m long and 100 m wide underneath a recently constructed housing estate. The third cave in the GSI database (1707SWK009) lies in the town centre approximately 600 m southwest of the Old Cave and PaSL cave.

The two turloughs (1707SWK005 & 006) and the second swallow hole (1707SWK007) in the GSI karst database are mapped approximately 1.4 km east and east-northeast of the Terrysland karst features in the townland of Ballyadam. None of the features were in evidence at the GSI recorded locations during the site visit. The actual (historical) location of the turloughs was approximately 300 m south of the recorded locations (Personal Communication, Oliver Sheehan, 17 July 2012). In the same area two turlough-like water features (KF01 & KF02) are shown on the Osi 1:5,000 scale map of the area. This area was developed to be used as an industrial estate by the IDA in 2010. Only groundworks had been carried out at the site at the time of the site visit (17 July 2012).

The groundworks carried out inlcuded infilling of a "man made lake" (IDA, 2010); however it seems likely that the infilled feature(s) in question were the turloughs and swallow hole recorded by the GSI karst database. A nature-pond feature appears to have been created along the western boundary of the site. A large reservoir/attenuation pond has been constructed along the southern boundary of the site adjacent to the N25 road. Since the IDA work was carried out the local road adjacent to the western boundary of the site has flooded regularly and Cork County Council have been required to pump large volumes of flood water to the attenuation pond in order to render the road passable (Personal Communication, Robert O'Sullivan, Area Engineer, Midleton, Cork County Council). Investigation of the attenuation pond during the site visit on 17 July 2010 showed that a new swallow hole (KF14) (not in the GSI Karst Database) has opened up at the base of the pond and the pond now drains into the underlying limestone bedrock.

In the surrounding limestone bedrock (outside the Carrigtohill surface water catchment) south as far as Rossmore Bay and east as far as Midleton a further ten caves, two karst springs, a karst borehole, two swallow holes and a doline (enclosed depression) have been recorded in the GSI karst database. An additional swallow hole (KF16) not in the GSI Karst Database was also recorded during the site visit. The relevant subset of these features is shown in Table 6.

Table 6. Relevant Karst Features oustide surface water catchment

Name	**Reference**	**Distance from Catchment**	**Comment**
Ballintubrid Spring	1707SWK003 (Coleman, 1943)	2.6 km south of the Ballyadam karst features	Possible discharge point for Ballyadam karst features.
Ballynabointra swallow hole	KF16 (Site Visit)	1.4 km west of the Ballyadam karst features	Received dewatering discharge from Lagan Cement Milebush Quarry up to June 2012.
Water-Rock House swallow hole	1707SEK014 (Coleman, 1943)	2 km west of the Ballyadam karst features	Groundwater flows south to Baneshane spring (Coleman, 1943).
Baneshane Spring	1707SEK016 (Coleman, 1943)	2.2 km west of the Ballyadam karst features	Coleman (1943) indicates that this spring is fed by the Water-Rock House swallow hole.

During the site visit several further karst features not recorded in the GSI karst database were recorded. These were the karst springs at Barryscourt castle (KF03), and at the south end of well lane in the town centre (KF12). These lie approximately 1 km south-southwest of the Terrysland swallow holes, which may contribute flow to the springs.

Examination of historical topographical mapping and aerial photos suggests that a further 7 dolines (enclosed depressions), one karst spring and two sinking streams maybe present across the study area. The karst spring occurs clsoe to Barryscourt castle (KF04).

The study area also includes numerous flooded limestone quarries and gravel pits which may be connected to the bedrock aquifer and, hydrogeologically may act similarly to natural karst features.

There are no data on the occurence of individual karst features such as caverns and conduits during the excavation of the large quarries in the study area; however the large dewatering volumes at the RoadstoneWood and Lagan Cement quarries in Ballyvodock West and Ballynabointra respectively, indicate that significant saturated, karst conduits were present at depth within the bedrock. Highly weathered limestone bedrock and clay filled cavities were also a common feature at these quarries (personal communications, David Tobin (Lagan Cement) and Tim O'Mahony (RoadstoneWood), July 2012).

The large quarry pits at Ballynabointra (Milebush) and Ballyvodock West were excavated into the limestone to depths of approximately -15 mAOD and -22 mAOD respectively. The quarries stopped dewatering in June 2012 and July 2010 respectively and are now flooded with groundwater. The flooded pits will act like very large turloughs henceforth.

Tracer testing of karst features associated with the Dower Public Water Supply (1707SEK010) source east of Castlemartyr suggests that karst solution of the bedrock occurs along north-south and east-west oriented fractures and fault zones within the syncline. The joint sets are typically spaced at 0.5 m to 2 m intervals with karst conduits known to be spaced at intervals of 1 m to 6 m in the Castlemartyr area (GSI, 2004).

The karst features from the GSI karst database, features confirmed during the site visit and potential additional karst features suggested by maps and aerial photos are shown on Figure 2. The details of the karst features from the GSI karst database are shown in Table A. The details of the karst features not in the GSI database and confirmed during the site visit or suggested by mapping and aerial photos are shown in Table B.

6.6 SUBSOIL AND SOIL GEOLOGY

The distribution of subsoil and soil across the area are illustrated in Figures 5 and 6 respectively.

The study area south of the sandstone ridge is predominantly underlain by till derived from sandstone bedrock. The sandstone till in the west of the catchment at Killacloyne and Tullagreen is mapped as a gravel aquifer (Section 6.8.1) indicating a high sand and gravel content in the till in this area. Some limestone till is mapped on the eastern flank of Foaty Island and on the headland south of Slatty Water.

Small pockets of karstified bedrock outcrop occur throughout the sandstone till but are particularly common in two east-west strips, one between the railway and the N25 road, and the other from Ballyannan to Ballintubrid West in the south of the study area. Large expanses of karstified bedrock outcrop are mapped over the footprints of the large quarries in Ballynabointra, Ballyvodock West and Rossmore.

The flood plain of the Slatty Water stream is mapped as underlain by alluvial deposits. This area was previously tidal prior to drainage works in the 1800s (personal communication, Oliver Sheehan, 17 July 2010). As such, estuarine deposits are likely to be present at depth. Estuarine deposits are mapped at surface at the estuary at Ballintubrid Spring and at Brick Island. Made ground is mapped underlying Carrigtohill.

The area is predominantly underlain by deep, well-drained, acidic mineral soils (AminDW). Alluvial soils are mapped in the vicinity of Slatty Water.

6.6.1 Subsoil Permeability

The Midleton GWB Initial Characterisation Summary (GSI, 2004) indicates that west of Castlemartyr the subsoil overlying the limestone bedrock is generally of moderate permeability, while pockets of high permeability sand and gravel also occur. High permeability sand and gravel is particularly prevalent in the gravel aquifer west of Carrigtohill. The alluvial deposits are likely to comprise sands, silts and clays and to have moderate permeability. The estuarine deposits are likely to comprise silts and clays and to have low permeability.

6.6.2 Depth to Bedrock (DTB)

The Midleton GWB Initial Characterisation Summary (GSI, 2004) indicates that DTB of >20 m has been recorded in the gravel aquifer west of Carrigtohill. The GSI Well Database indicates DTB ranging from 23 to 58 m beneath the IDA industrial estate in that area. Elsewhere in the study area and away from areas of bedrock outcrop the GSI Well Database suggests that DTB generally varies between 3 m and 10 m. Available DTB data are shown on Figure 5.

6.7 GROUNDWATER VULNERABILITY

The groundwater vulnerability map of the area is shown in Figure 7. This suggests that the majority of the study area has high groundwater vulnerability, punctuated with zones of extreme (E) and extreme (X) vulnerability occurring around the areas of mapped bedrock outcrop. In the north of the study area the groundwater vulnerability varies from high to extreme (X).

The vulnerability map does not take account of the sinking streams at the swallow holes at Terrysland (1707SWK004 and KF39) and Water-Rock (1707SEK014). Vulnerability mapping guidelines state that such streams should be mapped with a 10 m buffer to either side (30 m in the case of losing streams) and classified as extreme (X) groundwater vulnerability.

6.8 HYDROGEOLOGY

6.8.1 Aquifer

The pure unbedded limestones of the Waulsortian, Cork Red-Marble, Clashavodig and Little Island Formations are classified as a Regionally Important Aquifer (*Rk_d*) with karstified, diffuse flow mechanisms. The Ballysteen Formation impure limestones and the sandstones and mudstones of the ridge to the north of Mogeely are classified as a Locally Important Aquifer *(Ll)*, which is moderately productive only in local zones. The bedrock aquifer distribution is shown in Figure 8.

The *Ll* aquifer (except for the Ballysteen Formation Limestones) is included in the Ballinhassig groundwater body (GWB) while the *Rk_d* aquifer and Ballysteen Formation limestone are included in the Midleton GWB.

Rk_d Aquifer General Characteristics

Groundwater flow will occur in fractures in the limestone *Rk_d* aquifer. There is likely to be a highly karstified zone (epikarst) at the top of the bedrock which will support groundwater flow. The epikarst zone will be interconnected with flow in less frequent deeper fractures, typically up to 30 m below rockhead but possibly deeper (GSI, 2004). The *Rk_d* aquifer will have a high frequency of fracturing of the bedrock allowing significant diffuse flow. This in turn leads to high levels of karstification of those fractures and eventually to the development of karst conduits, which are fed by the diffuse fractures. The conduits then channel flow through the aquifer towards discharge points at springs and rivers. The karst pathways are typically oriented along E-W and N-S joints and fractures at 1 m to 6 m intervals, although caving explorations have also identified NE to SW trends in caves at Carrigtohill (Section 6.5.1).

In the past sea level is estimated to have been approximately 50-60 m below present day OD (GSI, 2004). This allowed the development deep karstification, which subsequently became flooded as sea levels and groundwater levels rose. These flooded cave systems act as major conduits for groundwater flow in the present day aquifer.

Borehole logs from a proposed Healy Brothers (now Lagan Cement) quarry in Rossmore indicates that water bearing fissures were found in three boreholes at elevations of -8.7 mAOD to -30 mAOD and gave yields of up to 216 m^3/day (DixonBrosnan, 2005). A site investigation borehole (PW1) at the RoadstoneWood quarry at Carrigshane (2 km southeast of Midleton) encountered a water filled fissure at -4.5 mAOD (26.7 mbgl) (TOBIN, 2006).

Groundwater flow velocities are expected to be high along the karst pathways. Tracer testing in the *Rk_d* aquifer suggests flow velocities of up to 30 m/h between swallow holes and the Dower Spring (east of Castlemartyr) (GSI, 2004).

The GWB summary suggests that transmissivity in the Rk_d aquifer can range up to a few thousand square metres per day. Borehole yields are generally good (100 to 400 m^3/d) to excellent (>400 m^3/d) (GSI, 2004). Borehole PW1 at the RoadstoneWood Carrigshane quarry produced a yield of approximately 527 m^3/day for a specific capacity of 1,597 m^3/d/m (TOBIN, 2006). Analysis of pumping test data for the borehole suggests an aquifer transmissivity range of 1,104 to 2208m^2/d and a storativity range of 0.002 to 0.02 (TOBIN, 2006).

The high yield of the Rk_d aquifer is also shown by the large quarry dewatering volumes in the Carrigtohill area.

Quarry Dewatering in the Rk_d Aquifer

Quarry dewatering is on-going at the Readymix Rossmore limestone quarry. The dewatering rate in 1999 was 1,567 m^3/day (quarry floor at 1 mAOD) (OGE, 1999). By 2003 the quarry floor was at -7 mAOD and was planned to go to -43 mAOD. This was predicted to give a rise of 25% in dewatering rates compared to the 2003 rate (TPA, 2003). The 2003 dewatering rate is unknown, however adding 25% to the 1999 rate suggests current dewatering is likely to be at least 2,000 m^3/day.

The historical dewatering discharge from the RoadstoneWood Ballyvodock West quarry varied between 18,000 m^3/day in summer and 25,000 m^3/day in winter (JAW, 2007). Anecdotal evidence suggests that there may have been a significant saline component in the discharge, perhaps up to 50% (personal communication, Tim O'Mahony, RoadstoneWood, 17 July 2012). Dewatering at this quarry ceased in July 2010.

The dewatering discharge from the Lagan Cement Milebush quarry in Ballynabointra varied between 1,400 m^3/day in summer and 6,000 m^3/day in winter in 2006 (GES, 2006). The dewatering discharge increased significantly following cessation of pumping at the adjacent RoadstoneWood Ballyvodock West Quarry (personal communication, David Tobin, Lagan Cement, 5 July 2012). Dewatering at this quarry ceased in June 2012. During the site visit of 17 July 2012 there was an on-going minor discharge of approximately 86 m^3/day (1 l/s) from the quarry to the swallow hole at KF40. The swallow hole was coated in a mat of dead algae indicating that the site was flooded prior to the recent cessation of major dewatering. There was a strong saline odour from the saturated ground at the swallow hole, suggesting that this quarry dewatering may also have had a saline component.

The saline indicators associated with the quarry dewatering in the study area suggest that the karst pathways in the Rk_d aquifer are in hydraulic continuity with the estuary to the south.

Quarrying and other impacts on the Rk_d Aquifer

Quarrying of the limestone bedrock has impacted on the physical characteristics of the Rk_d aquifer in the Ballynabointra, Ballyvodock, and Rossmore areas with the creation of large voids in the bedrock down to depths of -22 mAOD. These voids create large storage reservoirs in what would otherwise be a low storage and highly flashy aquifer. The removal of clay from infilled conduits, blasting of rock, and exposure of multiple conduits to a large flooded void will increase the transmissivity of the aquifer and create new interconnections between conduits.

The infilling of the Ballyadam Turloughs has also altered the physical characteristics of the aquifer. Infilling of the turlough void space has displaced groundwater flooding of the voids to the adjacent road way to the west, while pumping of the flood waters to the IDA attenuation pond has created a new swallow hole pathway.

These physical changes may be diverting groundwater flow from historical flowpaths through the system into new flowpaths. Such changes in the flow volume through parts of the system may change the flooding behaviour of the system compared to what has been observed historically.

Ll Aquifer General Characteristics

Groundwater flow in the *Ll* aquifer will also occur in fractures. Again there is likely to be a zone of weathered rock at the top of the bedrock which will support groundwater flow. In this case the weathered layer is likely to be a few metres thick with a zone of interconnected fractures beneath extending to about 15 m below rockhead (GSI, 2004b). In the *Ll* aquifer the magnitude of deep flow is likely to be much lower than in the Rk_d aquifer due to the lower frequency of fracturing and because karstification does not occur in the sandstone bedrock.

Lg Aquifer General Characteristics

The sand and gravel deposits in the till in the west of the study area are classified as an *Lg* aquifer, i.e. a locally important gravel aquifer. Porous groundwater flow will occur in the gravel aquifer and the aquifer transmissivity and storage are likely to be high. In the Tullagreen area at the Merck Millipore site, glacial till comprised of gravelly CLAY was found to have permeability in the range of 3.7E-06 to 1.4E-04 m/s. This was underlain by high permeability clayey GRAVEL (OCM, 2008). The hydraulic gradient across the site was calculated at 0.002 to the southwest (OGE, 2008). Groundwater resources explorations at the IDA site in Killacloyne found the aquifer to be up to 58 m thick and generally with finer deposits above and coarser deposits below (Wright, 2001). The GSI Well Database records two production wells at the IDA site with yields of 1109m^3/d and 600 m^3/d and specific capacities of 43.5m^3/d/m and 17.8m^3/d/m. The boreholes are 1707SWW116 and 1707SWW117 respectively. The specific capacities suggest a transmissivity range of 22 m^2/d to 53 m^2/d for the gravel aquifer based on the Logan Approximation[2].

6.8.2 Groundwater Level, Flow Direction and Gradient

GSI/EPA groundwater level monitoring borehole COS073

Groundwater levels in the limestone Rk_d aquifer were monitored continuously by the GSI using a chart recorder at monitoring borehole COS073 in Ballynabointra from 1977 to 2003. Spot levels were also recorded regularly by the EPA between 1996 and 2005. The GSI have partially digitised the chart record by capturing one data point per month for the 1977 to 2003 period. An additional spot level was measured during the site visit on 17 July 2012. The monthly GSI data have been combined with the EPA and site visit spot measurements and are presented in Figures A and B.

The data show that between 1977 and 2005 the rest water level at the borehole varied between 0.29 mAOD and 8.32 mAOD. The largest annual range on record was 7.06 m and occurred in 2002, while the minimum annual range was 1.47 m and occurred in 1993. The red line in Figure A shows the annual water level range for each year. The variation in the annual range shows no correlation with the onset of significant dewatering in the late 1990s.

The borehole is only 600 m east of the edge of the Milebush Quarry northern pit and 1.5 km northeast of the RoadstoneWood Ballyvodock West pit. As such, it might have been expected that the quarry dewatering of up to 31,000 m^3/yr in the 2000s would result in drawdown of the groundwater elevation, compared to the 1970s and 1980s baseline. Nonetheless, Figure A shows a steady long term rising trend in the groundwater elevation at the borehole between 1977 and 2012. This may be due to the fact that the Milebush Quarry dewatering of up to 6,000 m^3/d was discharged into swallow hole KF16, only 85 m south of the borehole. This discharge may have kept water levels artificially high in the vicinity of the monitoring well (and even rising as

[2] T = 1.22 * Specific Capacity, where T is the transmissivity in m^2/d

dewatering rates increased). On the ground at the quarries, the dewatering activities had a clear impact on groundwater level in the vicinity of the quarry pits with water levels reduced to -15 mOD at the Milebush pit and -22 mOD at the Ballyvodock West pit.

Figure A. Hydrograph for borehole COS073 1977 to 2012

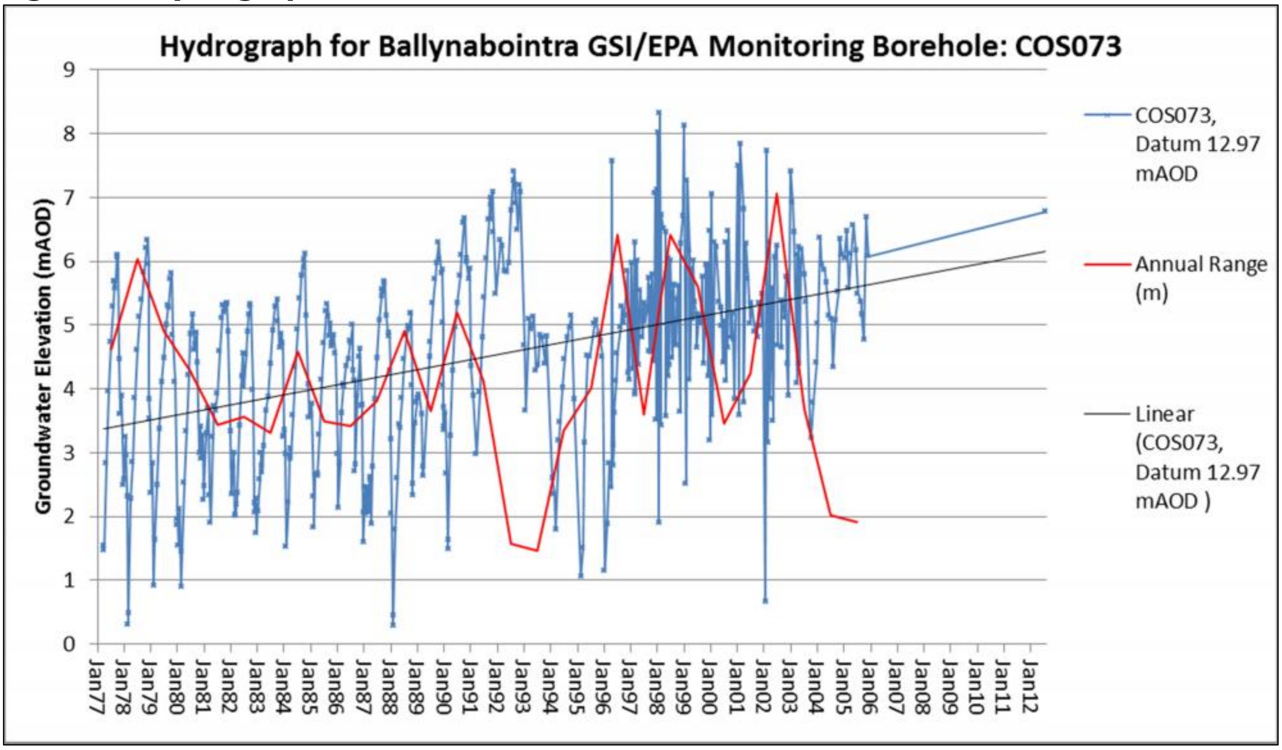

Figure B. Hydrograph for borehole COS073 1997 to 2002

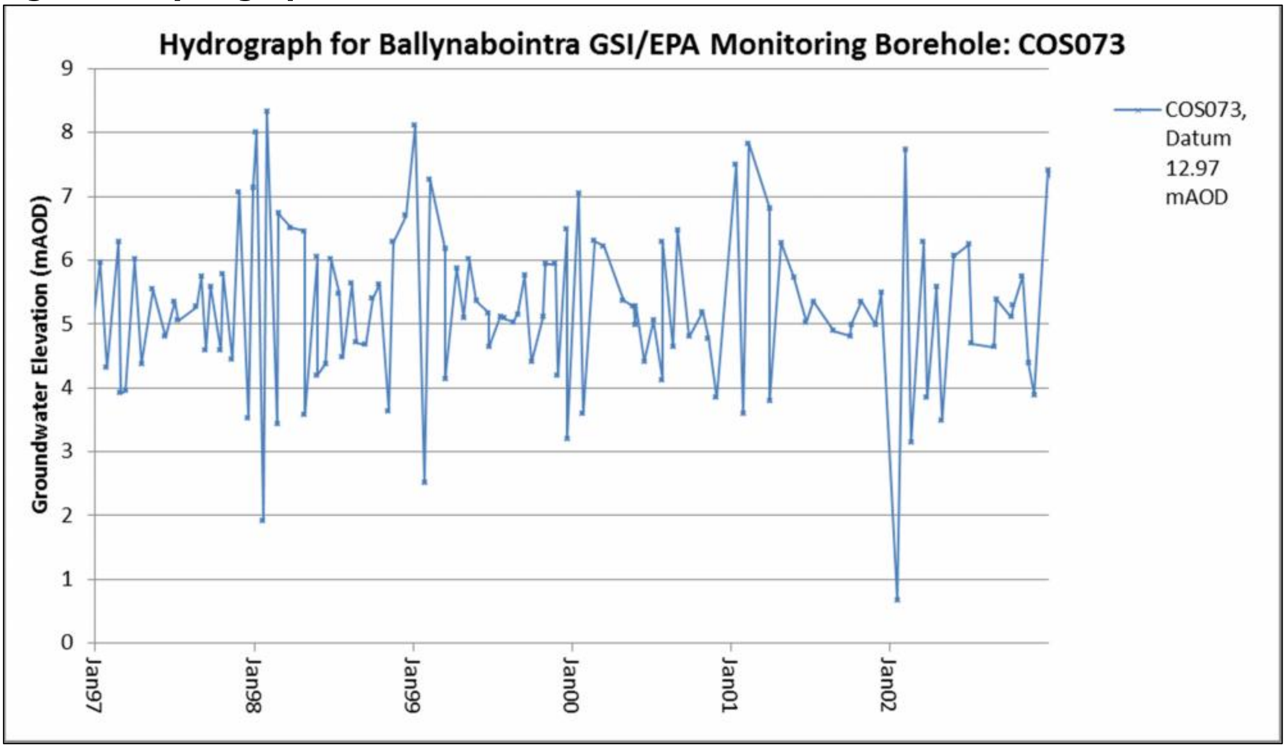

Figure B shows that the over short time periods the groundwater elevation can be highly variable, e.g. the change in water level of 7.06 m in 2002 occurred as a rise in level between 18 January and 02 February 2002. The level then dropped again by 4.58 m to 3.15 mOD by 19 February 2002. This is typical of the flashy response of groundwater levels in karst aquifers under the influence of rapid recharge from point sources such as swallow holes. It is likely that if the full GSI chart record for borehole COS073 were digitised the water level flashiness would be demonstrated to occur over days or even hours, rather than the weeks demonstrated by the current dataset. The flashiness in these systems usually occurs in response to extreme rainfall events. In the case of the level at borehole COS073 it is possible that intermittent pumping from a quarry sump may have generated "artificial flashiness" at swallow hole KF16.

Overall the hydrograph data do not show a clear dewatering impact on groundwater elevation compared to the pre-dewatering baseline. As such, the data reveal little with respect to potential maximum regional groundwater elevation rebound in the post dewatering scenario, which is currently evolving. The rising trend in water level may be unreliable due to the influence of KF16. Given the pre-1990 baseline data it seems likely that groundwater elevation in the Ballynabointra area will remain below 9 mAOD, if not lower.

Other historical groundwater elevation data

Review of quarry planning applications and IPPC license files uncovered a dataset of spot measurements of (mostly) autumn groundwater elevation (August to October) across the study area in Ballynabointra, Ballyvodock West, Rossmore and Tullagreen in the period 2003 to 2008. Dewatering activities were proceeding at full tilt across the study area at this time. The data are summarised in Table 7. Detailed data are provided in Table C.

Table 7. Groundwater elevation data across study area

Area	Site	Groundwater Elevation (mAOD)	Date	Reference	Comment
Ballynabointra	Milebush Quarry Monitoring Wells	0.8 to 8.46	August 2006	Murphy McCarthy (2005)	Dewatering at 1400 to 6000 m^3/day
Rossmore	Lagan Asphalt Limestone Quarry	-4.57 to 0.25	September 2002	Brassil (2002)	No dewatering; adjacent Readymix quarry dewatering
Rossmore	Readymix Limestone Quarry	-3.35 to 0.8	February 1999	OGE (1999)	Dewatering at 1,567 m^3/d
Tullagreen	Merck Millipore	0.4 to 1.7	October 2008	OCM (2008)	No dewatering; Lg gravel aquifer

Current groundwater elevation data

Groundwater levels were monitored at the Lagan Cement Milebush Quarry monitoring wells and at monitoring borehole COS073 during the site visit on 17 July 2012. The data show that groundwater elevation in this part of the study area currently varies between 1.52 mAOD and 6.78 mAOD. The groundwater elevation at the IDA industrial estate in the *Lg* aquifer was measured at approximately 2.8 mAOD on 17 July 2012.

There are no data available on the current water level in the flooded quarry pits at Lagan Cement Milebush and RoadstoneWood Ballyvodock West quarries. Photos of the flooded pits are shown in Photos 5 and 6.

Photo 5 Rising water level at Lagan Cement Milebush Quarry (North Pit; 17/07/2012)

Photo 6 Stabilised water level at RoadstoneWood Ballyvodock West Quarry

Groundwater Abstraction Data

The GSI well database shows 69 known boreholes in the study area. The database records yields for 19 of the boreholes. The maximum recorded yield is 1,296 m^3/day (1707SWW084; in the IDA industrial estate; *Lg* aquifer) while the minimum is 10.9 m^3/day (1707SEW040; Baneshane townland; Rk_d aquifer). The total potential abstraction for all 19 boreholes abstracting at maximum yield would be 8,340 m^3/day. For private domestic boreholes the abstraction is likely to return to the aquifer via percolation areas while for industrial abstractions the groundwater is likely to be discharged to surface water via wastewater treatment plants.

Hydraulic gradients, Groundwater Flow Directions and Groundwater Discharge

In the ***Lg* gravel aquifer** groundwater flow will occur in the direction of the hydraulic gradient, which is likely to be south and southwest towards the sea. As such flow in the aquifer is likely to be directed south in the western part of the aquifer and southwest in the eastern part (e.g. groundwater flow is to the southwest at the Merck site in Tullagreen (OCM, 2008). The groundwater is likely to discharge to the Slatty Water estuary. In the southeast of the aquifer some groundwater is likely to discharge as baseflow to the drains flowing into the Slatty Water pond and into the pond itself.

In the **Rk_d limestone aquifer** the hydraulic gradient across the study area is likely to be directed from the sandstone hills towards the sea. As such, once post dewatering groundwater levels have stabilised, the gradient in the west of the catchment would be likely to be directed towards Slatty water and Rossmore, while in the east it will be directed towards the estuary of the Owenacurra River. In the centre of the catchment it is likely to be directed south towards Ballintubrid. At the local scale individual abstractions will generate gradients towards the abstraction point. There is still likely to be a gradient towards the Lagan Cement Milebush Quarry as the quarry void is still flooding following the recent cessation of dewatering in June 2012 (Photo 5). The RoadstoneWood Ballyvodock West quarry water level is considered to have stabilised (personal communication, Tim O'Mahony, 17 July 2012), such that there is unlikely to be a gradient towards that quarry any longer (Photo 6).

In the Rk_d aquifer the groundwater flow direction will be broadly in the direction of the hydraulic gradient on the regional scale; however at the local scale the flow direction will follow tortuous paths along the orientation of the individual saturated karst pathways and fractures. The available data suggest that these pathways are typically oriented east-west and north-south and also NE to SW and NW to SE.

The distribution of surface water and karst features across the study area suggest potential groundwater flow directions in what are likely to be significant karst conduits. The surface water sinking at swallow holes 1707SWK004 and KF15 is likely to flow south-southeast towards the springs KF03 and KF04 at Barryscourt. The groundwater flooding pumped to the IDA pond swallow hole (KF14) in Ballyadam is likely to flow south towards the Ballintubrid Spring (1707SWK003). A component of this flow may currently be lost to ongoing flooding of the Lagan Cement Milebush Quarry voids. The inputs to the swallow holes at Ballynabointra (KF16) and Water Rock (1707SEK014) are likely to flow east and south respectively towards the Baneshane Spring (1707SEK016).

Diffuse groundwater flow in the surrounding areas, recharged by diffuse infiltration through the ground surface, is likely to be directed towards the major conduit flow paths.

Closer to the coast in areas such as Rossmore, Ballyvodock East and Ballyannan, diffuse groundwater flow is likely to coalesce around less significant conduit pathways which discharge to the sea or to discharge directly to the sea via diffuse seepage.

The assumed groundwater flow directions are shown on Figure 9. The footprint of the diffuse groundwater flow towards the Barryscourt Springs flowpath and the Slatty Water is also shown on Figure 9. This assumes that flow to the pathway derives from the area west of the Ballyadam Turloughs/IDA Development and from north of the topographical divide between Barryscourt and Rossmore. East of the footprint flow is assumed to go to south to Ballintubrid or east toward Baneshane/Ownacurra. South of the footprint flow is assumed to discharge to the estuary at Rossmore.

A study at Mogeely (east of Midleton) indicated a large head loss across the boundary between the sandstone *Ll* aquifer and the limestone Rk_d aquifer to the south, which suggested limited interconnected transmissivity between the two aquifers (Conroy, 2012). As such, groundwater throughflow from the *Ll* aquifer to the Rk_d aquifer is likely to be limited. Spring discharges and baseflow into the sandstone streams followed by surface flow and subsequent sinking at swallow holes is the main mechanism for transfer of groundwater between the two aquifers.

6.8.3 Recharge

Recharge is the proportion of the effective rainfall (ER) (562 mm/yr, Section 6.2) that infiltrates through to groundwater. The limestone component of the study area generally has a low to moderate slope, well drained soils and an absence of poor drainage indicators. The groundwater vulnerability of the area is predominantly high with pockets of extreme (E) and Extreme (X) vulnerability at areas of outcrop and quarries. These characteristics suggest that recharge coefficients (i.e. the proportion of ER that goes to recharge) are likely to range from 0.8 in areas of high vulnerability to 1.0 in areas of extreme (X) vulnerability (IWWG, 2004).

Available recharge is therefore calculated as between 450 mm/yr and 562 mm/yr. This diffuse recharge will be significantly supplemented by point recharge at the various swallow holes identified across the study area.

The areal footprint assumed to recharge the Barryscourt Springs and downgradient drains which feed into the Slatty Water is 4.2 km^2 (Figure 9). As such, the diffuse recharge component of the discharge at the springs is estimated at between 5,100 m^3/day and 6,500 m^{3}day. This is in addition to the surface water component assumed to reach the springs from swallow holes KF15 and 1707SWK004.

6.9 HYDROGEOLOGICAL CONCEPTUAL MODEL

Recharge to groundwater occurs diffusely through the high permeability subsoils and is supplemented by runoff from the sandstone ridge, particularly where point recharge occurs at swallow holes and enclosed depressions. There is also likely to be a small component of groundwater throughflow from the Ll aquifer to the Rkd aquifer.

Groundwater flow is expected to be directed towards discharge points at the coast. In the west of the catchment diffuse and point groundwater recharge in the vicinity of Carrigtohill town are expected to discharge at Barryscourt. Recharge to the central part of the study area is assumed to flow south to the Ballintubrid spring (through the area previously dewatered by quarry operations). In the east of the study area point and diffuse recharge are expected to flow east to discharge at the Baneshane Spring and into the Owenacurra estuary.

Groundwater flow occurs along karstified fissures and conduits typically oriented north-south and east-west. The groundwater flow generally follows a tortuous path down gradient in the general direction of the regional hydraulic gradient, which is assumed to be directed towards the shoreline. The main flowpaths are fed by point recharge and by diffuse inputs from smaller joints and fissures throughout the aquifer.

Groundwater flow in the gravel aquifer in the west of the study area is likely to discharge to streams and to the shoreline as baseflow seepage. Groundwater flow in the gravel aquifer is by porous flow.

The large quarry voids in the east of the study area at Ballynabointra and Ballyvodock West and in the southwest at Rossmore will add significant additional storage capacity to the limestone aquifer and should help to attenuate the rapid transmission of flashy point recharge through the karst system.

A schematic plan of the hydrogeological conceptual model is shown in Figure 9.

7 GROUNDWATER FLOODING ASSESSMENT

7.1 KARST GROUNDWATER FLOODING MECHANISMS

Groundwater flooding related to karst limestone can occur at the inputs to and discharge points from the system and at surface linked attenuation points along the flow paths through the system. The types of groundwater flooding which could occur in the karst study area are described below. The likely flooding mechanisms at the karst features across the study area are discussed in Table 8.

7.1.1 Flooding at Inputs to the Karst System

Swallow holes are the main feature of concern in this respect. The area around a swallow hole may become flooded when:

- Extreme rainfall generates influent stream flows which overload the transmissivity of the swallow hole entry point, resulting in ponding of water at the swallow hole; and,
- The available recharge (diffuse and point recharge) exceeds the transmissivity of the saturated groundwater flow system, such that excess recharge fills up available aquifer storage (i.e. groundwater levels rise). Ultimately water levels may exceed the elevation of the swallow hole and water may start to pond at the swallow hole. This situation would be most likely during prolonged extreme rainfall events and would be exacerbated where:
    - Regionally rising groundwater levels reduce the available storage in the aquifer under normal conditions, such that there is less attenuation capacity available at the start of an extreme event;
    - Physical changes in the aquifer cause a decrease in the aquifer transmissivity such that aquifer storage is exhausted more rapidly (e.g., infilling of a dewatered quarry pit with low permeability overburden or highly weathered waste rock could block previously highly transmissive conduit pathways).

7.1.2 Flooding at discharge points from the Karst System

The karst system discharges at springs and by baseflow to surface water features. As baseflow contributions are integrated into the surface water flood risk assessment, groundwater flooding at springs is the main concern here. Spring discharges may result in flooding when:

- The spring discharge exceeds the capacity of the pond or channel draining out of the spring and the flow overtops the channel;
    - This situation can be exacerbated by physical changes to the aquifer such as the infilling of turloughs. Such activities reduce the overall storage in the flow system such that the groundwater head increases more than it would have done under the original natural conditions. Overall an increase in head[3] will drive additional water through the system resulting in increased spring flows;
- The spring discharge exacerbates stress on a downstream surface water channel resulting in surface water flooding. In hydraulic modelling of surface flooding during extreme rainfall events spring discharges into a surface water system are not automatically accounted. Baseflow and surface runoff downstream of the spring input will be calculated; however the spring discharge will likely need to be input directly, based on field data. The discharge will comprise inputs from point recharge features such as swallow holes and inputs from diffuse recharge upgradient of the spring.

[3] The increased head of groundwater could also result in flooding at swallow hole input points

7.1.3 Flooding at attenuation points along the karst groundwater flow paths

Attenuation points linked to the ground surface are the features of interest in this case. The relevant features are turloughs, enclosed depressions and limestone quarry pits.

Typical porosity in a limestone aquifer is only about 1%. As such, when a conduit is hydraulically connected to a large, unsaturated, surface depression with 100% porosity (e.g. an empty turlough or quarry pit) it provides a large reservoir to attenuate extreme groundwater flows through the system. Excess groundwater flow wells up through the connection and fills the surface depression. In the absence of the turlough the 1% porosity in the aquifer would fill more rapidly, resulting in a more rapid rise in groundwater level. This in turn would increase the likelihood of ponding at input points and would increase the discharge from springs. The turlough allows more water to enter the system for a given groundwater level and therefore relieves flooding pressure at input and discharge points.

Nonetheless the attenuation points themselves can become overloaded and result in flooding of the surrounding areas. This can happen when:

- A turlough is not recognised as a flood attenuation mechanism but is considered itself to be a flood which needs to be remediated;
- The increase in groundwater elevation during an extreme rainfall event brings groundwater elevation above the bank elevation of the turlough or other feature for long enough to completely fill and overtop the feature, such that groundwater floods into the surrounding area. This scenario can be exacerbated where:
    - A turlough is infilled without sealing the hydraulic connection to the aquifer. The infill material reduces the storage in the turlough such that for a given extreme rainfall event it is more likely to become completely full and flood into the surrounding area;
    - Rising regional groundwater levels (e.g. following cessation of large scale aquifer dewatering) result in a decrease in the unsaturated porosity of the feature under normal conditions, such that overtopping of the feature happens during extreme events of shorter duration than before.
- Karst features such as turloughs and dolines also receives direct water inputs from rainfall and surface runoff on top of any input from upwelling groundwater. In small features with a low permeability connection to underlying aquifer (e.g. most dolines), pluvial flooding may be more significant than flooding from upwelling groundwater.

7.1.4 Creation of new groundwater driven surface flooding

As can be seen from Sections 7.1.1 to 7.1.3 the input, attenuation and output features of the karst system are interlinked and changes to one feature will generally have impacts at each of the others. As such, infilling of an existing pathway or turlough may displace groundwater flow along another pathway which may result in the flooding of nearby dolines or turloughs which had previously remained dry.

Table 8. Groundwater flooding mechanisms at karst fetures within the study area

Area	NAME	TYPE	COMMENT	Possible Flooding Mechanisms
Terrysland & Carrigtohill Town Centre	1707SWK004	Swallow Hole	Swallow holes in Cúl Ard housing estate in Carrigtohill	Excessive inflows or rising groundwater levels may flood the swallow hole area. The swallow hole entry points are large (Photo 3) and as such flooding due to inflow restriction is unlikely
	KF15	Swallow Hole		
	1707SWK001	Cave	Caves in Cúl Ard housing estate in Carrigtohill	Regionally rising groundwater levels may lead to flooding of previously dry caves
	1707SWK002	Cave		
	1707SWK009	Cave	Cave in Carrigtohill town centre	
Ballyadam	1707SWK005	Turlough	GSI Ballyadam Turloughs. Recorded location approx. 350 m north of actual site.	These turloughs appear to have been infilled by IDA site works. The infilling appears to have diverted the upwelling groundwater to the adjacent local road. It is not clear if the current upwelling derives from overtopping the infilled turloughs or if a new pathway has been created.
	1707SWK006	Turlough		
	KF01	Enclosed Depression / Turlough	Small mapped floods which are likely to have been the actual Ballyadam Turloughs prior to infilling by the IDA	
	KF02			
	KF06	Enclosed Depression	A possible additional enclosed depression in the Ballyadam area	Pluvial flooding or regionally rising groundwater levels may cause flooding
	1707SWK007	Swallow Hole	GSI mapped swallow hole in the Ballyadam area. Recorded location is beneath the footprint of the IDA site works	Appears to have been infilled by IDA site works. Possibly no longer acts as a swallow hole. Blocked inflows may now contribute to flooding of adjacent local road.
	KF14	Swallow Hole	IDA Attenuation Pond Swallow Hole. Cork County Council pump flood water from adjacent local road into the swallow hole. Local landowners say the road flooding only occurred since IDA site works filled in the Ballyadam karst features	Excessive inflows may cause flooding although this may be unlikely given that the swallow hole is at the base of a man made attenuation pond.

Area	NAME	TYPE	COMMENT	Possible Flooding Mechanisms
Ballynabointra & Ballyvodock	Lagan Cement Milebush	Quarry Pit	Large flooded quarry pits. Likely to provide significant attenuation for extreme rainfall/groundwater flow events.	These pits are currently flooded. There is up to 20 m of freeboard above current water levels in the large quarry voids which will provide significant attenuation of extreme rainfall/groundwater flow events
	RoadstoneWood Ballyvodock West	Quarry Pit		
	KF16	Swallow Hole	Former discharge point for Lagan Cement Milebush Quarry dewatering	No natural stream input, just local runoff. Capable of accepting up to 6,000m^3/day input. Groundwater level currently 5mbgl. Possible flood risk to N25 road if regional groundwater level continues to rise significantly following end of dewatering at Milebush Quarry
	KF10	Enclosed Depression	Possible Enclosed Depressions southeast of flooded quarries	Pluvial flooding or regionally rising groundwater levels may cause flooding
	KF11	Enclosed Depression		
	KF19	Enclosed Depression	Possible Enclosed Depression west of flooded quarries	
Barryscourt	KF03	Spring	Springs at Barryscourt Castle.	Regionally rising groundwater levels may cause increased discharge leading to flooding at the springs or in downstream surface water
	KF04	Spring		
	KF12	Spring	Village Well at base of Well Lane in Carrigtohill town centre	
Ballintubrid	1707SWK003	Spring	Ballintubrid Spring	Regionally rising groundwater levels may cause increased discharge leading to flooding at the spring or in downstream surface water
	KF05	Enclosed Depression	Enclosed depression/historical quarry beside Ballintubrid Spring	Regionally rising groundwater levels may cause flooding
	KF13	Enclosed Depression	Well approximately 30ft below field level recorded by Coleman (1943)	
	1707SWK008	Cave	Goat Hole cave NW of Ballintubrid spring	
Rossmore	Readymix Rossmore Limestone	Quarry Pit	Large quarry pit with on-going dewatering. Likely to provide significant attenuation for extreme rainfall/groundwater flow events.	Large quarry void and on-going dewatering will provide significant attenuation of extreme rainfall/groundwater flow events

Area	NAME	TYPE	COMMENT	Possible Flooding Mechanisms
Midleton	1707SEK016	Spring	Baneshane spring adjacent to N25 on west side of Midleton.	Regionally rising groundwater levels may cause increased discharge leading to flooding at the spring or in downstream surface water. Changes to flowpaths due to IDA Ballyadam site works may cause additional discharge here
	1707SEK025	Enclosed Depression	Southwest of Midleton town centre	Pluvial flooding or regionally rising groundwater levels may cause flooding
	KF07	Enclosed Depression	Possible Enclosed Depressions by Baneshane Spring	
	KF08	Enclosed Depression		
	1707SEK014	Swallow Hole	Water Rock Swallow hole on west side of Midleton - likely to drain to Baneshane spring	Excessive inflows or rising groundwater levels may flood the swallow hole area
	1707SEK018	Swallow Hole	Swallow hole on northeast side of Midleton	
	1707SEK005	Borehole	Karst borehole in Midleton.	Could cause flooding if high groundwater levels caused the borehole to become artesian.
	1707SEK001	Cave	Midleton College Cave	Regionally rising groundwater levels may cause flooding
	1707SEK002	Cave	Caves northeast of Midleton town centre	
	1707SEK003	Cave		
	1707SEK004	Cave		
	1707SEK015	Cave	Cave at Water Rock swallow hole	
	1707SEK017	Cave	Fox's Quarry Cave, NE of Midleton town centre	
	1707SEK019	Cave	Caves north of Midleton town centre	
	1707SEK020	Cave		
	1707SEK023	Cave	Cave at Carrigshane quarry, SW of Midleton town centre	

7.2 KNOWN GROUNDWATER FLOODING SITES IN THE STUDY AREA

During the site visit the stakeholders listed in Table 4 were consulted with respect to known groundwater flooding within the study area. Large scale maps of the area were annotated on-site by the stakeholders to show the approximate extent of groundwater flooding areas. The identified areas are shown in Figure 9.

Only one area of known groundwater flooding was identified. This was the groundwater flooding of the local road adjacent to the western boundary of the IDA site in Ballyadam. The stakeholders reported that the flooding is a recent development, which has only manifested since the adjacent IDA site works were carried out in approximately 2010 and 2011. The flooding was reported to occur frequently and the flood waters are pumped to the newly opened swallow hole in the base of the IDA onsite attenuation pond.

7.3 CURRENT AND PREDICTED GROUNDWATER FLOODING RISK IN THE STUDY AREA

The available dataset is not suitable for carrying out a quantitative assessment of current or future flood risk in the study area. There are insufficient data both temporally and spatially to accurately assess ground water level, groundwater flow paths, groundwater flow directions or groundwater discharge. Instead a qualitative assessment has been carried out based on the available data and stakeholder information.

7.3.1 Current Groundwater Flooding Risk in the Study Area

Current groundwater flooding risk varies across the study area:

- The risk is considered to be high in Ballyadam where flooding occurs regularly on the local road adjacent to the IDA site (Figure 9 and Section 7.2);
- The risk is considered to be moderate at all of the other karst features detailed in Table 8 and shown on Figures 2 and 9; and,
- The risk is considered to be low away from the features in Table 8.

The available data are insufficient to delineate possible flooding extents around the karst features.

A key concern in the project brief relates to the groundwater flooding risk associated with the cessation of dewatering of limestone quarries within the study area.

The two main quarries of concern in this respect are the RoadstoneWood Ballyvodock West quarry and the Lagan Cement Milebush Quarry. The former stopped dewatering in July 2010 and the operator considers that it is now flooded up to its rest groundwater level. The latter quarry stopped dewatering on approximately 21 June 2012. The water level in the pit rose by 5 m in the first week and more slowly thereafter (Personal Communication, David Tobin, Lagan Cement, 5 July 2012). The operator considered that the water level was still rising at the time of the site visit on 17 July 2012 (Personal Communication, Frank Glennon, Lagan Cement, 17 July 2012). There are no data on the groundwater elevation in either pit; however the monitoring boreholes at Milebush Quarry showed elevations of between 1.52 mAOD and 5.44 mAOD on 17 July 2012. Depths to groundwater at Milebush quarry varied between 5.18 mbgl and 23.81 mbgl.

There is no anecdotal evidence from stakeholders that the quarry flooding has had any impact on groundwater flooding occurrence in the study area. As the RoadstoneWood quarry stopped dewatering in 2010 it is possible that rising water levels in the quarry and its vicinity may have exacerbated the flooding seen in Ballyadam adjacent to the IDA site since 2010.

Overall, it appears that to date cessation of dewatering in the quarries has not led to a significant increase in groundwater flooding at karst features up or downgradient of the quarries. As the groundwater level has not yet stabilised at the Milebush Quarry it cannot be ruled out that flooding of the Milebush and Ballyvodock West quarries could cause or exacerbate groundwater flooding in the future.

The Readymix Quarry at Rossmore has on-going dewatering works, which are likely to be drawing down groundwater levels in the surrounding area. The dewatering discharge is to a Readymix gravel pit 1 km to the east from which the water infiltrates to ground. The on-going dewatering activities are not considered to be causing any current groundwater flooding risk.

7.3.2 Future Groundwater Flooding Risk in the Study Area

There are insufficient data available to quantify future groundwater flooding risk and delineate potential future groundwater flooding extents.

It is likely that groundwater flooding will continue in the Ballyadam area until such time as remedial works, such as restoration of the original hydrogeology of the IDA site, are carried out.

The Lagan Cement Milebush Quarry is expected to reach its rest groundwater level in the short to medium term. Based on the hydrograph for borehole COS073 it is considered unlikely that the groundwater elevation at the quarry will rise above 9 mAOD. The quarry is likely to be close to its rest level already. The RoadstoneWood Ballyvodock West Quarry has already reached its rest level. As such, it is considered that there will be minimal additional future impact on groundwater flooding risk over the current risk levels due to the cessation of dewatering at these two quarries.

The Readymix Rossmore limestone quarry is adjacent to the shoreline of Rossmore Bay. Rest water levels post-dewatering are likely to be close to sea level. Groundwater elevation at the site in 1997 when the quarry floor was above 1 mAOD was between -3.35 mAOD and 5.23 mAOD (17.4 mbgl to 3.65 mbgl). There is no anecdotal evidence of groundwater flooding in the area from prior to the onset of dewatering. As such in the post-dewatering scenario groundwater levels are expected to rise compared to the current situation, but without causing significant groundwater flooding.

The most likely additional future flooding risk due to cessation of dewatering at the quarries in the study area will be at Ballyadam. The groundwater flooding frequency at Ballyadam may increase due to the further increase in regional groundwater level as the Milebush Quarry reaches its rest water level.

Once the the flooded quarry pits reach their rest groundwater level they will act as attenuation features for extreme groundwater flow events.

Elsewhere in the study area groundwater flooding risk is likely to stay the same as in the current scenario.

8 CONCLUSIONS

- A qualitative assessment of current and future groundwater flooding risk has been carried out for the Carrigtohill area based on all available data from statutory databases and local stakeholders and taking account of the potential impact of quarry dewatering on the risk outcomes.
- Current and future groundwater flooding risk is considered to be high in the Ballyadam area at the known flooding site adjacent to the IDA site in Ballyadam.
- The current and future groundwater flooding risk is considered to be moderate in the vicinity of other surface karst features across the study area.
- There is a limited distribution of surface karst features across the study area such that the majority of the study area has a low risk of groundwater flooding.
- The groundwater elevation in the Ballyvodock and Ballynabointra areas has almost returned to its rest level following cessation of dewatering works at the Roadstone and Lagan Cement quarries in 2010 and 2012 respectively. The associated rise in groundwater elevation in the study area does not appear to have significantly increased the risk of groundwater flooding.
- Once the flooded quarry pits reach their rest groundwater level they will act as attenuation features for extreme groundwater flow events.

9 RECOMMENDATIONS

The following actions are recommended in order to facilitate monitoring of groundwater levels across the study area and quantitative assessment of the groundwater flooding risk:

- A groundwater level monitoring network should be established across the study area. This will provide information on local groundwater elevations and allow interpretation of the regional hydraulic gradient driving groundwater flow through the karstified limestone aquifer. The following steps should be carried out:
    - Incorporate into the network existing boreholes and monitoring wells at the IDA Killacloyne industrial estate, Merck Millipore, Rossmore quarries, Milebush Quarry and borehole COS073;
    - A detailed well and karst survey should be carried out to identify additional bedrock boreholes and karst features across the study area in the townlands of Terrysland, Gortagousta, Ballyadam, Tullagreen, Barryscourt, Clyduff, Baneshane, Ballintubrid and Ballyvodock. A number of key boreholes and flooded karst features identified should be incorporated into the monitoring network;
    - If sufficient number and distribution of existing boreholes cannot be found, a number of groundwater monitoring boreholes should be drilled at key locations to fill data gaps. All drilling work should be carried out under the full time supervision of a hydrogeologist to ensure that adequate hydrogeology data are recorded to characterise the monitoring locations;
    - The current review of quarries under Section 261A of the Planning and Development Act 2000 should be used to achieve the following measures:
        - Drill three bedrock groundwater monitoring wells at the RoadstoneWood Ballyvodock West Quarry. Two of the boreholes should be sited close to the quarry pit, one each at the northern and south-eastern ends of the pit. The third should be sited at the western boundary of the property (e.g. close to the site entrance)
        - Install staff gauges in the RoadstoneWood Ballyvodock West and Lagan Cement Milebush Quarries flooded quarry pits. The gauges should be topographically surveyed to allow all water level readings to be converted to a reduced level in metres above Ordnance Datum;
        - Monthly monitoring of groundwater levels by the quarry operators in the quarry pits and in the monitoring wells of all quarries in the study area followed by regular submission of the data to Cork County Council for incorporation into the groundwater level monitoring database
    - Install staff gauges at all flooded karst features in the study area. The gauges should be topographically surveyed to allow all water level readings to be converted to a reduced level in metres above Ordnance Datum;
    - Install continuous groundwater level data loggers at key boreholes across the study area and carry out monthly manual water level measurements at all boreholes and karst features on the network. Install a barometric pressure logger at a suitable location in the catchment to correct water level logger data for barometric pressure variations;
    - Carry out a topographic survey of all boreholes on the network to allow all water level readings to be converted to a reduced level in metres above Ordnance Datum; and,
    - Setup a database for recording all groundwater level data for the catchment.
- Carry out dye-tracer testing on all known swallow holes in the study area and any additional swallow holes identified during the karst feature survey, in order to identify groundwater flow paths through the karst aquifer. Monitoring during the tracer testing should be carried out at all known springs and other suitable karst features and boreholes within the study area.

- Install weirs with continuous discharge monitoring at all known springs in the study area, in order to quantify groundwater discharge rates from the aquifer;
- Install continuous flow gauging on all known sinking streams in the study area, in order to quantify surface water point recharge inputs to the aquifer;
- Adapt the surface water hydraulic model to predict dry weather flow from streams sinking into known swallow holes, in order to quantify baseline point recharge to the aquifer;
- Following completion of tracer tests and collection of at least two years of groundwater level monitoring data, carry out appropriate numerical modelling of the groundwater system. The model should aim to:
    - quantify groundwater flow through the system;
    - predict groundwater elevation across the study area;
    - predict potential groundwater flooding extents. This will require a detailed topographic survey of the entire study area (e.g. LIDAR survey), particularly at known karst features;
    - couple modelled groundwater discharges with the surface water model to incorporate groundwater discharges explicitly into the surface water flood risk assessment.

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Figures

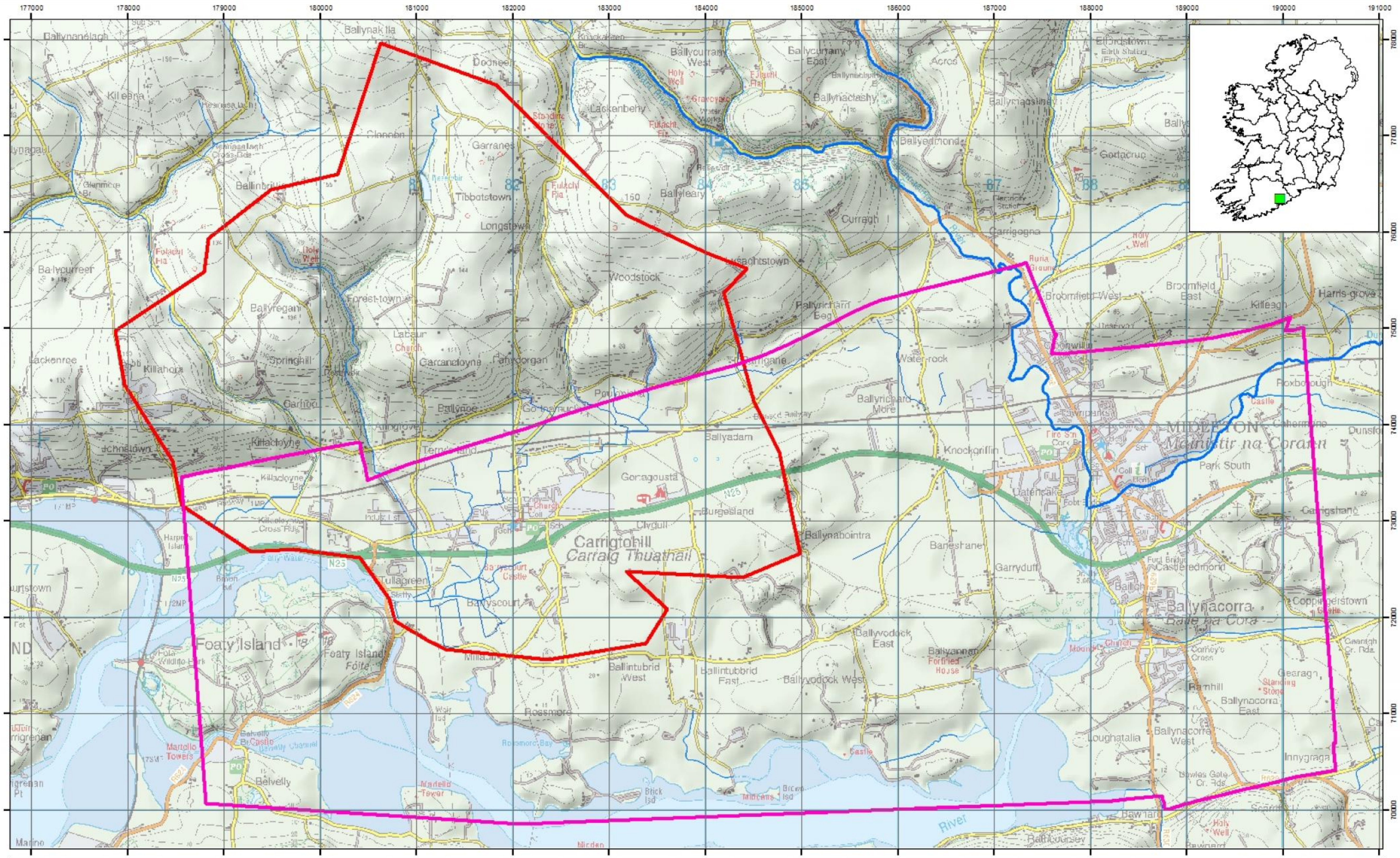

Figure 1 Carrigtohill Flood Risk Assessment - Groundwater Flooding Study Area

- Carrigtohill Catchment Boundary
- Surface Water Course
- Footprint of Limestone Valley Floor Study Area

N

0 0.5 1 2 3 km

INSERT FIGURES 2A and 2B

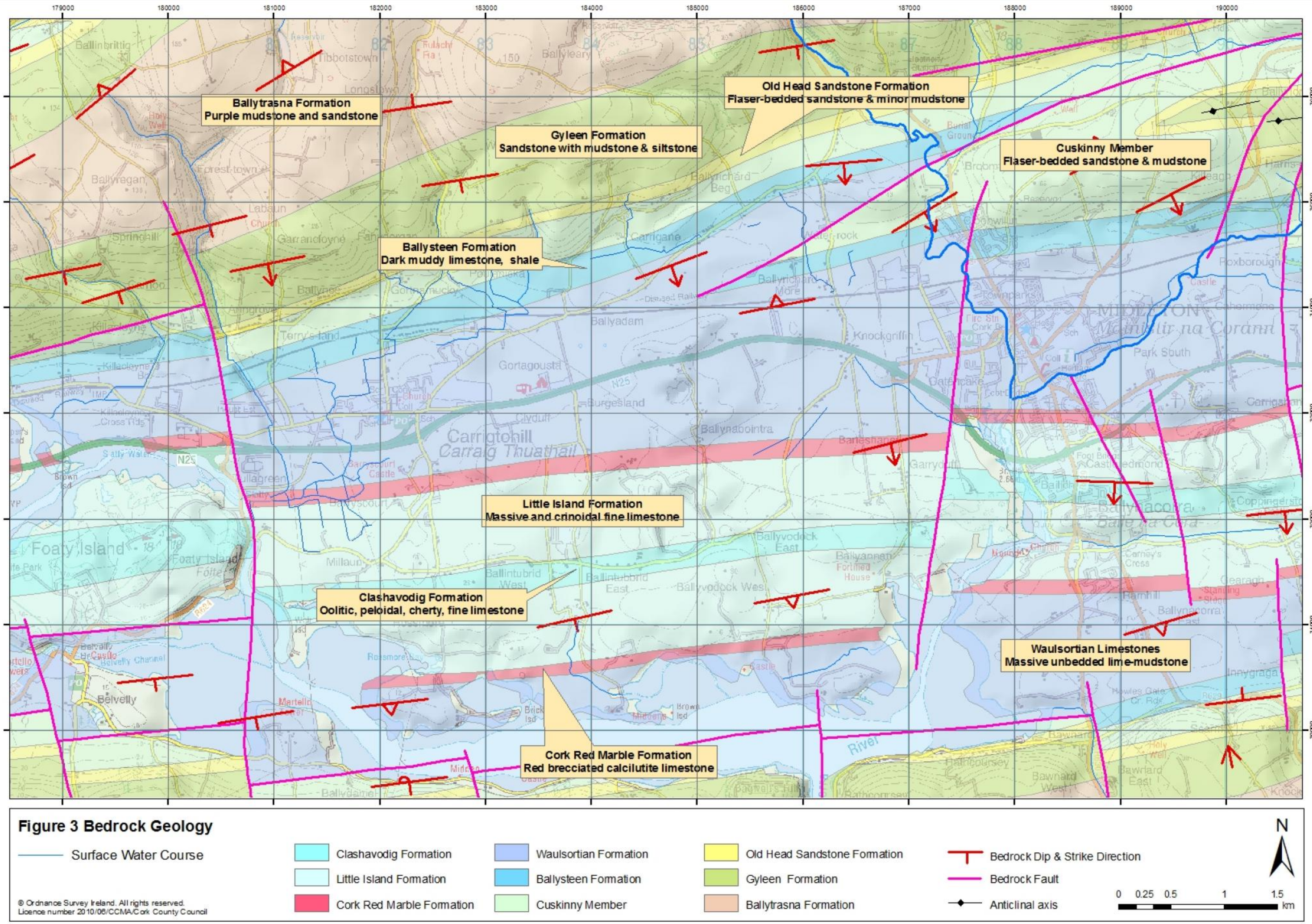

Figure 3 Bedrock Geology

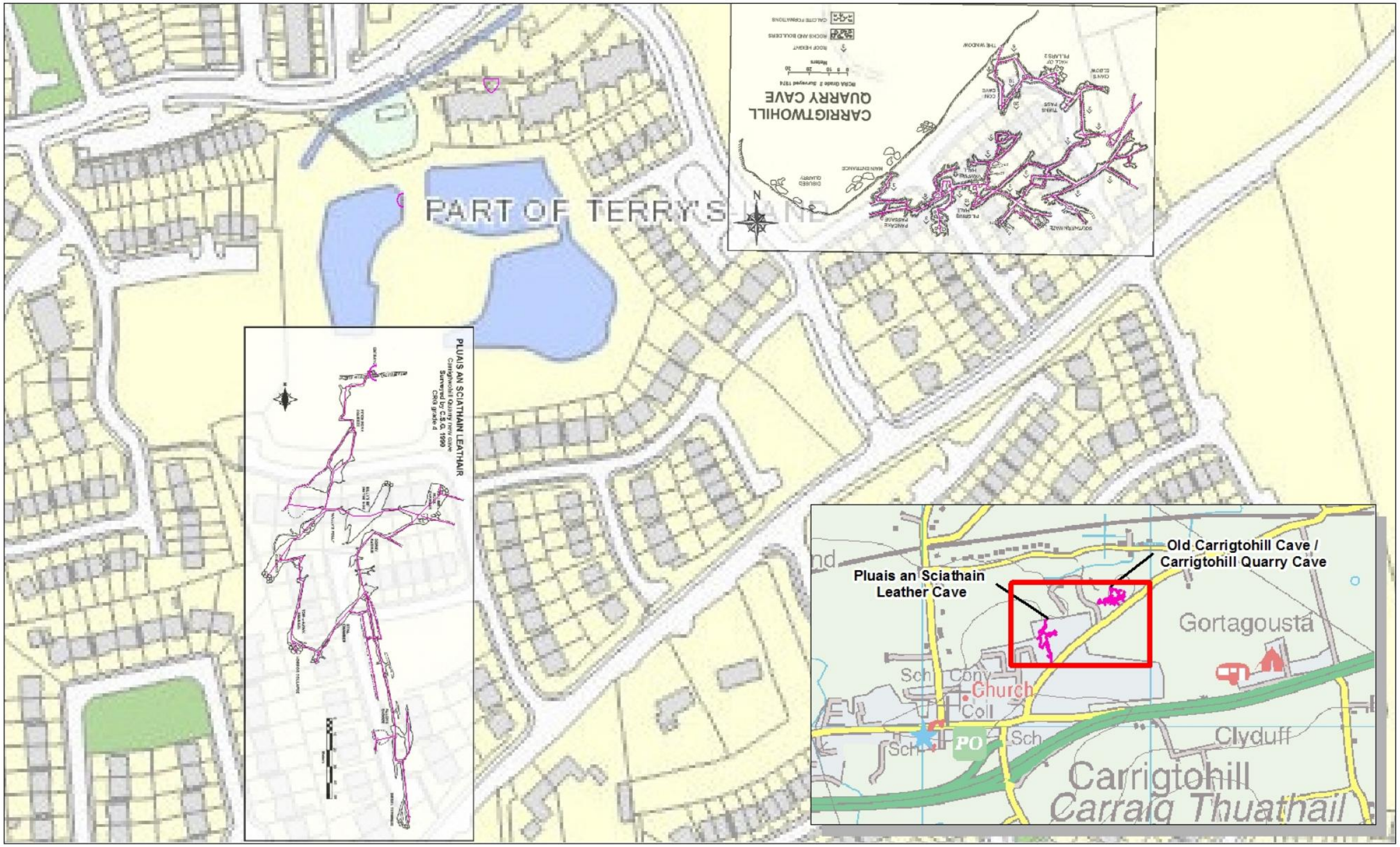

Figure 4 Mapped Cave Extents in the Terrysland area of Carrigtohill

Mapped Extent of Carrigtohill Caves (Courtesy of Peter Barry and the Cork Speleological Society; CSS, 1990)

N

0 25 50 100 1

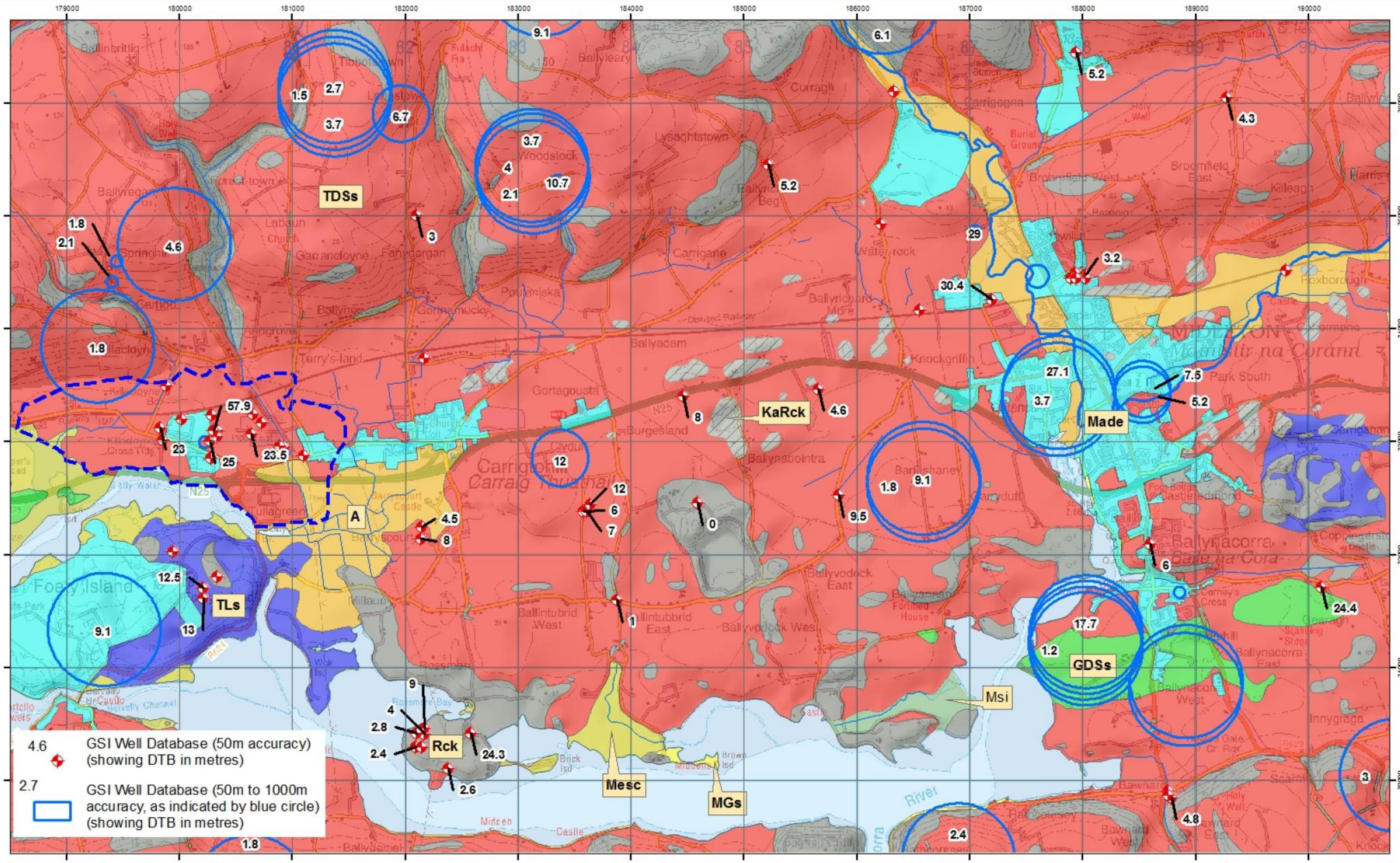

Figure 5 Subsoil Geology

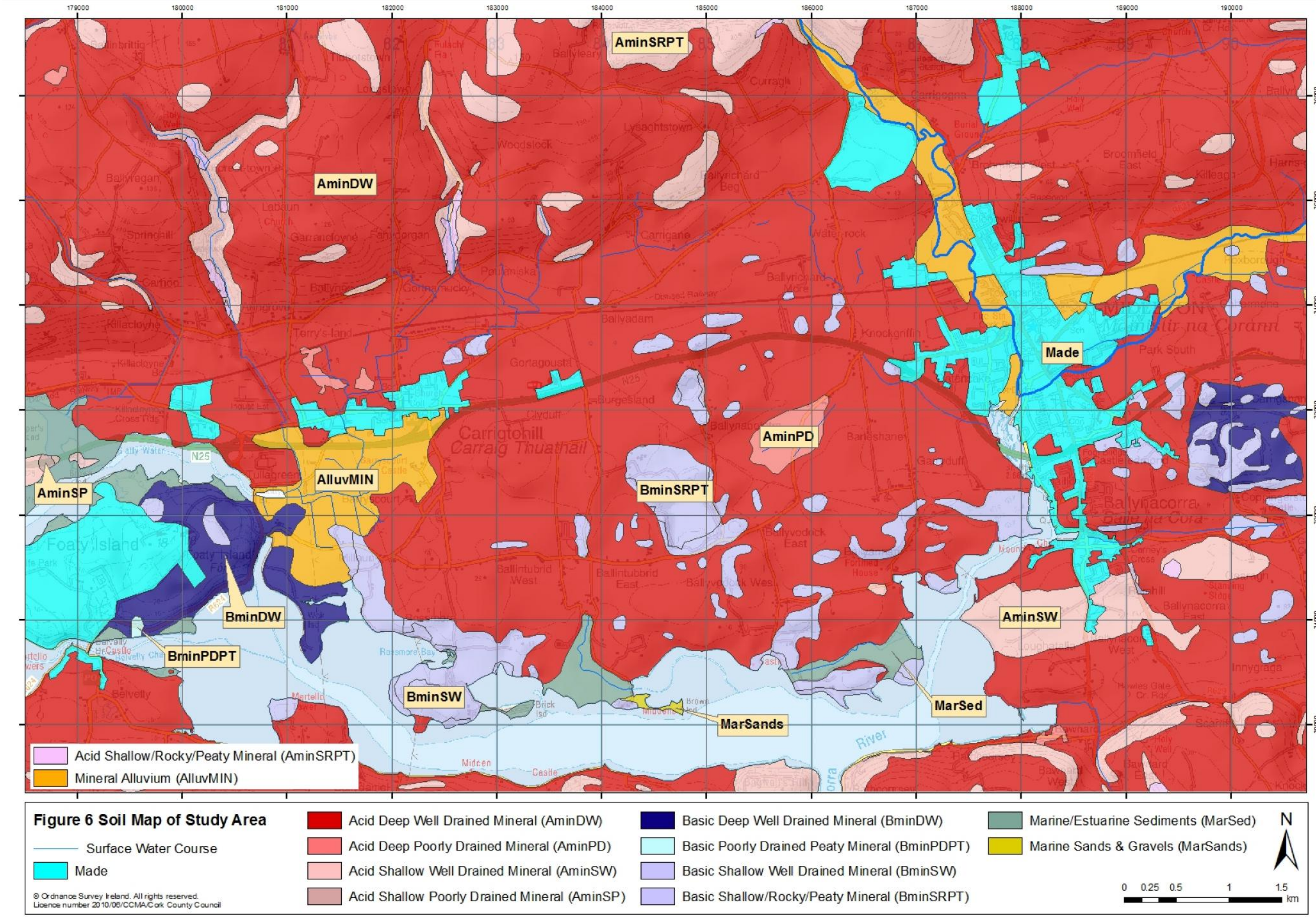

Figure 6 Soil Map of Study Area

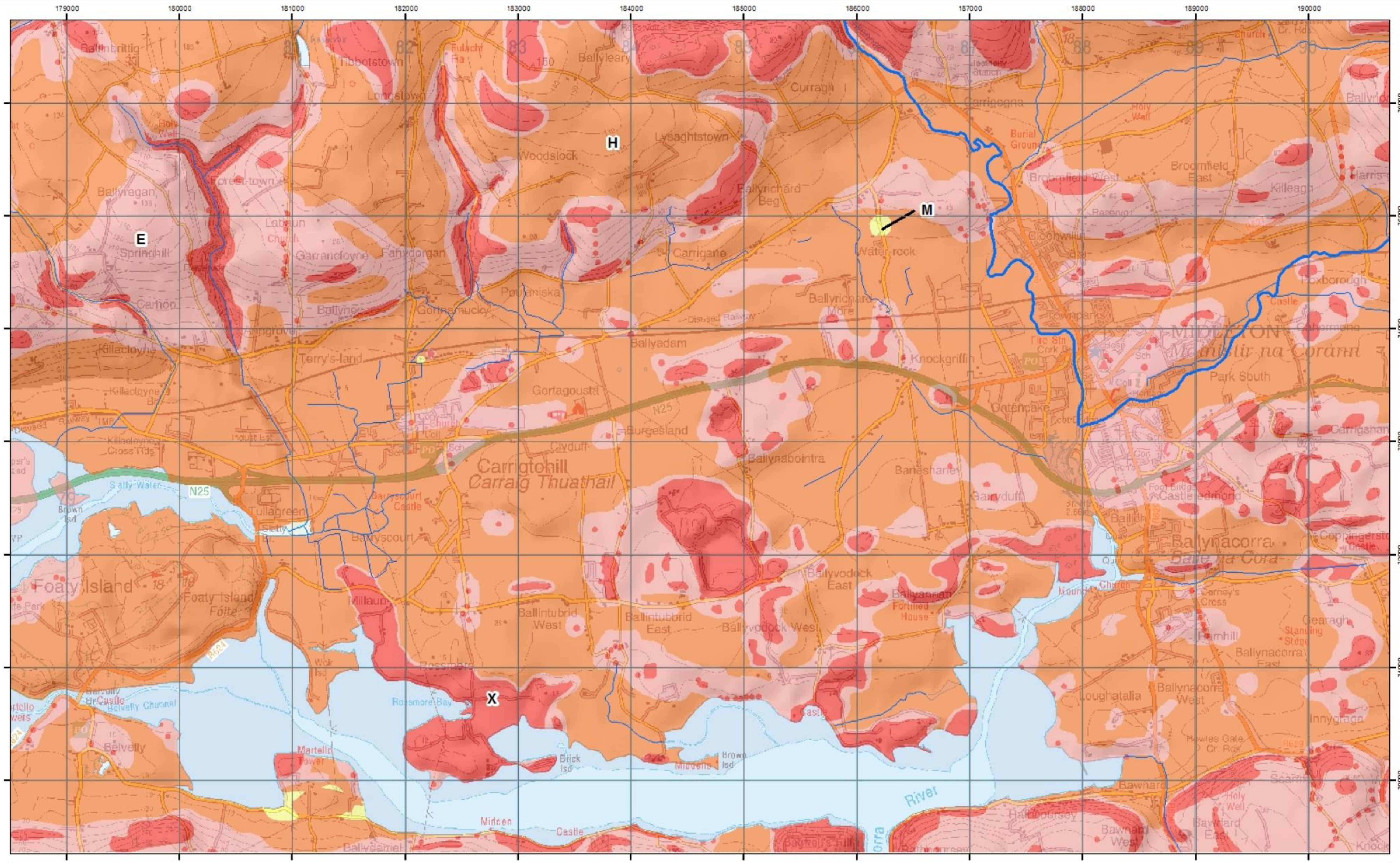

Figure 7 Groundwater Vulnerability

- Surface Water Course
- Extreme (X)
- Extreme (E)
- High (H)
- Moderate (M)

N

0 0.25 0.5 1 1.5 km

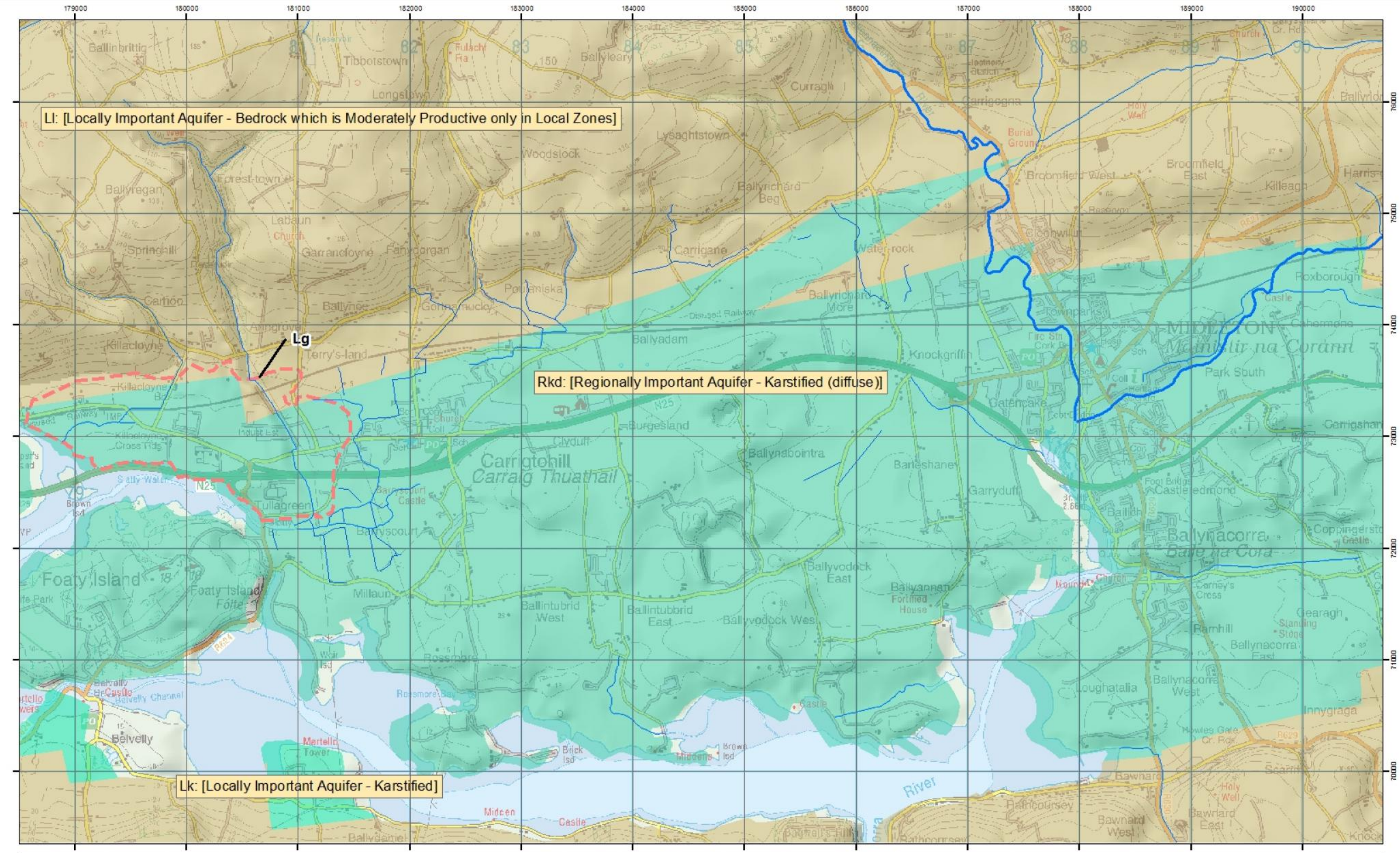

Figure 8 Bedrock and Gravel Aquifers

Surface Water Course

Boundary of Locally Important Gravel Aquifer (Lg)

Rkd

Lk

Ll

N

0 0.25 0.5 1 1.5 km

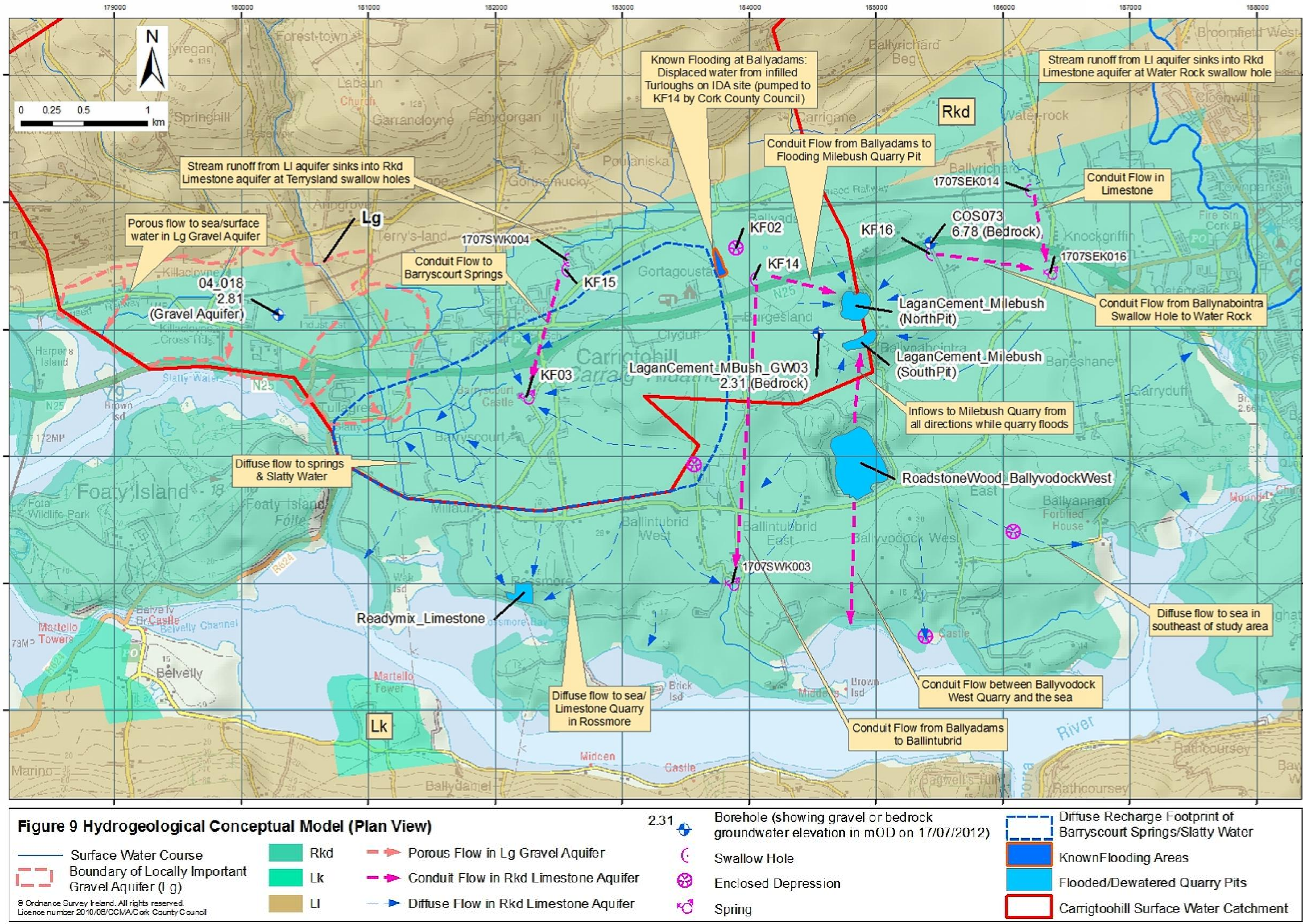

Figure 9 Hydrogeological Conceptual Model (Plan View)

Tables

Table A - GSI Karst Database records for the Study Area

FNUM	FTYPE	FNAME	X	Y	TOWNLAND	COUNTY	SIXINCH	TWENTYFIVE	GRID_ACCUR	OD	STRAT	LITH
1707SWK009	Cave	N/A	182230	73080	CARRIGTWOHILL	Cork	75	1707SW	to within 20 m	0	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SWK001	Cave	CARRIGTWOHILL Q.C.	182800	73640	TERRYS LAND	Cork	76	1707SW	to within 20 m	16	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SWK002	Cave	SCIATHAN LEATHAIR	182600	73600	TERRYS LAND	Cork	76	1707SW	to within 50 m	16	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SWK003	Spring	N/A	183860	71000	BALLINTUBBRID EAST	Cork	76	1707SW	to within 20 m	4	LI	Limestone, clean (>=90% CaCO3), unbedded
1707SWK004	Swallow Hole	CARRIGTWOHILL STR. S	182560	73550	TERRYS LAND	Cork	76	1707SW	to within 20 m	11	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SWK005	Turlough	N/A	184120	74100	CARRIGANE	Cork	76	1707SW	to within 20 m	15	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SWK006	Turlough	N/A	184000	73950	BALLYADAM	Cork	76	1707SW	to within 20 m	15	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SWK007	Swallow Hole	N/A	184270	73700	BALLYADAM	Cork	76	1707SW	to within 20 m	14	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SWK008	Cave	GOAT HOLE	183520	71350	BALLINTUBBRID	Cork	76	1707SW	to within 20 m	0	LI	Limestone, clean (>=90% CaCO3), unbedded
1707SEK025	Enclosed Depres	N/A	188960	72880	MIDLETON	Cork	76	1707SE	to within 100 m	0	CK	Limestone, clean (>=90% CaCO3), unbedded
1707SEK001	Cave	MIDLETON COLLEGE CAVE	188550	73660	SCHOOL-LAND	Cork	76	1707SE	to within 20 m	13	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK002	Cave	N/A	188640	73900	PARK NORTH	Cork	76	1707SE	to within 20 m	13	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK003	Cave	N/A	189940	74500	ROXBOROUGH	Cork	76	1707SE	to within 20 m	14	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK004	Cave	N/A	190000	74480	ROXBOROUGH	Cork	76	1707SE	to within 20 m	14	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK005	Borehole	BH3,WD12,21,32,34,36	188450	73530	MIDLETON	Cork	76	1707SE	to within 50 m	0	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK014	Swallow Hole	N/A	186200	74100	WATER-ROCK	Cork	76	1707SE	to within 20 m	11	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK015	Cave	N/A	186260	74080	WATER-ROCK	Cork	76	1707SE	to within 20 m	11	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK016	Spring	N/A	186370	73450	WATER-ROCK	Cork	76	1707SE	to within 20 m	7	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK017	Cave	FOXS QUARRY CAVE	188910	74050	PARK NORTH	Cork	76	1707SE	to within 20 m	15	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK018	Swallow Hole	N/A	188900	74050	PARK NORTH	Cork	76	1707SE	to within 20 m	15	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK019	Cave	BROOMFIELD Q.C.EAST	187990	74500	BROOMFIELD WEST	Cork	76	1707SE	to within 20 m	15	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK020	Cave	BROOMFIELD Q.C. WEST	187930	74460	BROOMFIELD WEST	Cork	76	1707SE	to within 20 m	15	WA	Limestone, clean (>=90% CaCO3), unbedded
1707SEK023	Cave	N/A	189950	72870	CARRIGSHANE	Cork	76	1707SE	to within 20 m	16	WA	Limestone, clean (>=90% CaCO3), unbedded

Table B - Karst Features Confirmed During SIte Visit or
Inferred from Review of Mapping and Aerial Photos

NAME	X	Y	TYPE	Reference	COMMENT
KF01	184129	73645	Enclosed Depression	Osi 1:50,000	Small Flooded Lake Just west of Ballyadam Swallow Hole
KF02	183896	73643	Enclosed Depression	Osi 1:50,000	Small Flooded Lake Just west of Ballyadam Swallow Hole
KF03	182242	72474	Spring	Site Visit	At Barryscourt Castle
KF04	182107	72336	Spring	1:25inch Historical Map	At Barryscourt Castle
KF05	183829	71085	Enclosed Depression	1:25inch Historical Map	Flood?Enc Depression?
KF06	184634	73639	Enclosed Depression	Osi Aerial Photo	Ballyadam Turlough?
KF07	186505	73365	Enclosed Depression	1:25inch Historical Map	Possible Enclosed Depression
KF08	186453	73368	Enclosed Depression	1:25inch Historical Map	Possible Enclosed Depression
KF09	184276	73003	Enclosed Depression	OSi Streetmap	Flooded Enclosed Depression
KF10	185387	70582	Enclosed Depression	OSi Streetmap	Pond on Streetmap
KF11	186081	71410	Enclosed Depression	1:25inch Historical Map	Possible Enclosed Depression
KF12	182108	72768	Spring	Site Visit	Village Well at base of Well Lane
KF13	183562	71938	Enclosed Depression	Coleman (1943)	Well approx 30ft below field level
KF14	184035	73399	Swallow Hole	Site Visit	IDA Attenuation Pond Swallow Hole
KF15	182548	73474	Swallow Hole	Site Visit	PaSL Cave Swallow Hole
KF16	185420	73600	Swallow Hole	Site Visit	Swallow Hole at Milebush Quarry

Name	X	Y	Type	Ref	Lithology	TD	DTB	GWFlow	i	GWL Reference	GWL Datum mOD	GWL mbgl or m below Datum	GWL mAOD	GWLdate	Discharge Ref	Discharge (m3/d)	Discharge Date	Comment
RoadstoneWood_Ballyvodock_Sump	184670	71890	Sump	QR27						JAWLtr20100218			-31		JAWLtr20070130	18000 to 25000	Summer v Winter	Approx Sump Coords; GWL based on planned final Quarry floor level; Discharge is to sea via pipeline; OCM letter 20070307 says quarry fllor at -22mOD = approx 40m below natural GWL, & Q = 24,300m3/d.
LaganCement_Milebush_GW01	184880	72950	Borehole	QR78						MMCDwg2506001	26.7	(23.81)	0.8 (2.89)	01/08/2006 (17/07/2012)				GWL taken from DWG of Sept06, assume GWL from AUg06
LaganCement_Milebush_GW01A	184970	72990	Borehole	QR78						MMCDwg2506001	27.2							
LaganCement_Milebush_GW02	184860	72700	Borehole	QR78						MMCDwg2506001	17.7	(15.18)	0.33 (2.52)	01/08/2006 (17/07/2012)				GWL taken from DWG of Sept06, assume GWL from AUg06
LaganCement_Milebush_GW03	184550	72970	Borehole	QR78						MMCDwg2506001	21.2	(19.68)	2.31 (1.52)	01/08/2006 (17/07/2012)				GWL taken from DWG of Sept06, assume GWL from AUg06
LaganCement_Milebush_GW04	184710	73260	Borehole	QR78						MMCDwg2506001	24		8.46	01/08/2006				GWL taken from DWG of Sept06, assume GWL from AUg06; Destroyed by July 2012
LaganCement_Milebush_GW05	184920	73480	Borehole	QR78						MMCDwg2506001	26.2	(20.76)	1.82 (5.44)	01/08/2006 (17/07/2012)				GWL taken from DWG of Sept06, assume GWL from AUg06
LaganCement_Milebush_GW06	185410	73610	Borehole	QR78						MMCDwg2506001	10.2	(5.18)	6.54 (5.04)	01/08/2006 (17/07/2012)				GWL taken from DWG of Sept06, assume GWL from AUg06
LaganCement_Milebush_BH03	184730	73030	Borehole	QR78						GESLtr20060929	26.2	24.7	1.5	01/03/2001	GESLtr20060929	1400 to 6000	Summer v Winter	Not sure where on site discharge pumping is from; Quarry floor at -15.2mOD on 26/09/2006 (15.2 is planned max depth)
LaganCement_Milebush_BH02	184770	72930	Borehole	QR78						GESLtr20060929	25.7	24.57	1.13	01/03/2001				
LaganCement_Milebush_BH01	184850	72960	Borehole	QR78						GESLtr20060929	27.2	22.7	4.5	01/03/2001				
KF16	185420	73600	Swallow Ho	QR78						MMCDwg2506001								Discharge Point for Quarry dewatering
Whelans_Lackenbehy_MW01	183026	77554	Borehole	`08/8434						OGWEIS08/8434	130.29	18.21	112.08	18/07/2008				OGE Report says GW flow is NNE to Leamlara river; Quarry floor will be at 92mOD => dewatering, but low inflows due to low bedrock K, est deep GW inflow at 4.2m3/d; Direct input to Quarry floor (568m3/d) + Inflows across quarry faces from seepages of interflow and shallow bedrock recharge above 92mOD (1356m3/d) est at 1924m3/d
Whelans_Lackenbehy_MW02	182963	77689	Borehole	`08/8434						OGWEIS08/8434	115.89	11.68	104.21	18/07/2008				Measured total outflows from quarry range from86m3/d (Jul08) to 289m3/d (may 08); 96m3/d (May 07); 173m3/d (31 Mar 08)
Whelans_Lackenbehy_MW03	182892	77594	Borehole	`08/8434						OGWEIS08/8434	125.67	18.35	106.65	18/07/2008				
Whelans_Lackenbehy_BH01	182793	77135	Borehole	`08/8434						OGWEIS08/8434	118.64	7.96	110.68	18/07/2008				
Whelans_Lackenbehy_BH02	182624	77289	Borehole	`08/8434						OGWEIS08/8434	103.39	1.18	102.21	18/07/2008				
LaganCement_Rossmore_BH_B	182620	70760	Borehole	05/7886	Gravel/Limestone		3.05			DIXBROSEIS05/7886	5		0	01/10/2005				GWL taken from DWG of Oct06 assume GWL from Oct06; No Dewatering - no extraction below 2m above watertable; BHb yield = 300 gph from fissure at -8.7mOD
LaganCement_Rossmore_BH_A	182960	70980	Borehole	05/7886	Gravel/Limestone		3.05			DIXBROSEIS05/7886	22		1	01/10/2005				BHA yield = 2000 gph, dirty, from fissure at -30 mOD; Frac Zone 2.2 to 4.3mOD
LaganCement_Rossmore_BH_C	182690	71450	Borehole	05/7886	Gravel/Limestone		3			DIXBROSEIS05/7886	27.5		7	01/10/2005				BHC yield = 1000 gph, from fissure at -24.32 mOD; Frac Zone 0.7 to -1.5mOD; Cavity 17.14 to 18.36 mOD
Readymix_Limestone_BH_A	182040	70990	Borehole	99/3411	3-4m of Clay, silt and sand/Limestone					FLBENEIS99/3411	8.88		(5.23) -0.59	(03/97) 22/02/99	OGERpt99/3411	1567	08-Nov-99	No tidal impacts on water level over 12 hr monitoring in 1999. Quarry at approx 1mOD in 1999 with PP to go to -7mOD; By Sept 2003 base of quarry at -7mOD; PP03/4570 increased allowed depth to -43mOD.
Readymix_Limestone_BH_B	182000	71130	Borehole	99/3411	3-4m of Clay, silt and sand/Limestone					FLBENEIS99/3411	5.38		(1.73) -0.26	(03/97) 22/02/99				
Readymix_Limestone_BH_C	182270	71120	Borehole	99/3411	3-4m of Clay, silt and sand/Limestone					FLBENEIS99/3411	14.05		(-3.35)	(03/97)				
Readymix_Limestone_BH_D	182030	70970	Borehole	99/3411	3-4m of Clay, silt and sand/Limestone					FLBENEIS99/3411	8.76		-0.47	22/02/99				Water strike at 9.5mbgl; cavities at 10 & 15 mbgl; T=2.05m2/d; S=1e-3
Readymix_Limestone_BH_E	182260	70970	Borehole	99/3411	3-4m of Clay, silt and sand/Limestone					FLBENEIS99/3411	1.12		0.8	22/02/99				Water strike at 18mbgl; cavity at 0.5m; T = 0.13m2/d; S = 6e-4
Readymix_Limestone_Sump	182120	70910	Sump	99/3411											OGERpt99/3411	1567	08-Nov-99	Sump of active quarry in Nov 99, flows to Rossmore Estuary; OGE Water Mgt Plan - pump water to a disused quarry to the east to infiltrate to GW there (this was in place by 2003 TPRpt). Sump coords guessed.
Readymix_Limestone_Sump	182120	70910	Sump	03/4570						TPRpt03/4570			2	Restored GWL	TPRpt03/4570	1958.75		TPRpt ests that increase of quarry depth to -43mOD (from -7mOD) will increase GW inflow by 25% (doesn't give an actual discharge rate). Sump coords guessed; Restoration x-sect shows flooded quarry GWL at 2mOD
Readymix_Gravel	183120	70520	Sump	QR60	Sand & Gravel													Lowest point in base of S&G is -12 mOD = base of extraction; Extraction by dreding => no active dewatering; Dredged water accumulates in a settlement laggon and infiltrates thru the base - no active pumping; Discharge from western Readymix site also infiltrates here. No GWL data.
LaganAsphalt_BH01	182572	70860	Borehole	02/5476						DBrassilRFI02/5476			0.25	07/09/2002				DBrassilRFI says there is no dewatering & that GWLs will be at least 2m below the proposed quarry floor; Abs from an onsite well in 2005 was approx 35m3/d.
LaganAsphalt_BH02	182538	71104	Borehole	02/5476						DBrassilRFI02/5476			-0.23	07/09/2002				
LaganAsphalt_BH03	182509	71303	Borehole	02/5476						DBrassilRFI02/5476			-0.81	07/09/2002				
LaganAsphalt_BH04	182367	71166	Borehole	02/5476						DBrassilRFI02/5476			-4.57	07/09/2002				
LaganAsphalt_BH06	182369	70964	Borehole	02/5476						DBrassilRFI02/5476			-2.91	07/09/2002				
RoadstoneWood_Coppingerstown_BH02	190500	72480	Borehole	03/5527	Thin overburden/grey limestone					DIXBROS03/5527	25.016	19.21	5.81	09/09/2008				Location of BH01 not on available maps; 0.5 to 3.2m drop in GWL from 04/06 to 09/09/03 across BHs 1 to 4. GW flow direction locally NW (due to unintentional minor dewatering) but regionally expect flow to West. Quarry floor level = 8 mOD, i.e. above the water table => no dewatering
RoadstoneWood_Coppingerstown_BH03	190570	72130	Borehole	03/5527	Thin overburden/grey limestone					DIXBROS03/5527	27.816	21.39	6.43	09/09/2008				
RoadstoneWood_Coppingerstown_BH04	190440	72080	Borehole	03/5527	Thin overburden/grey limestone					DIXBROS03/5527	22.432	16.21	6.22	09/09/2008				
RoadstoneWood_Coppingerstown_Well	190540	72310	Borehole	03/5527						DIXBROS03/5527								Site potable water abstraction well; WQ shows high EC, Cl & Na - poss saline intrusion?; No data on abstraction rate
Roadstone_C'Shane_PW1	190122	72556	Borehole	QR08		48				Tobin2006	22.2	15.67	6.5					Pumping Well. 168mm uPVC liner: 24 blank, 24m screen
Roadstone_C'Shane_MW1	189985	72428	Borehole	QR08						Tobin2006	22	16.3	5.7					Monitoring Well
Roadstone_C'Shane_MW2	190137	72659	Borehole	QR08						Tobin2006	22	15.18	6.82					Planned as a pumping well but yield < 1l/s; converted to a monitoring well
Roadstone_C'Shane_MW3	190247	72590	Borehole	QR08						Tobin2006	22	14.6	7.7					Monitoring Well
Roadstone_C'Shane_BH1	189909	72329	Borehole	QR08						Tobin2006	18.24	12.92	5.32					Disused borehole used as a Monitoring Well

Table D - IPPC Boreholes and Other Boreholes within the Study Area

Name	X	Y	Type	Ref	Lithology	TD	DTB	GWFlow	i	GWLRef	GWLrefmOD	GWLmbgl	GWLmAOD	GWLdate	Comment
MerckMillipore_GW01	180718	72419	Borehole	IPPC_P057103	3.5m sandy CLAY till over gravels to 6.5m	6.5	>20m?	SW	0.002	OCMReport		~1.5	0.65	08/10/2008	OCM report mentions an Abs BH in NE corner of site
MerckMillipore_GW02	180713	72488	Borehole	IPPC_P057103	6m of sandy CLAY till over gravels to 8.0m	8	>20m?					~1.5	0.9	08/10/2008	
MerckMillipore_GW03	180714	72590	Borehole	IPPC_P057103	7.5m of sandy CLAY till over GRAVEL to 9.5m	9.5	>20m?					~1.5	1.5	08/10/2008	
MerckMillipore_GW04	181070	72420	Borehole	IPPC_P057103			>20m?					~1.5	1.7	08/10/2008	
MerckMillipore_GW05	180886	72417	Borehole	IPPC_P057103	3.5m of Sandy CLAY till over GRAVEL to 6.5m	6.5	>20m?					~1.5	1	08/10/2008	
MerckMillipore_GW06	180716	72362	Borehole	IPPC_P057103			>20m?					~1.5	0.4	08/10/2008	
RossmoreLandfill_BH04	182690	70345	Borehole	W002201						AER2009	3.28	2.2	1.08	01/08/2009	Approx BH Coords; GWL ref from DWG200500402011
COS073	185487	73606	Borehole	EPAGWMON		19				EPASpdSht_ May2012	12.97	7.4 (7.61) [6.19]	5.57 (5.36) [6.78]	24/08/1977 (24/08/2005) [17/07/2012]	EPA Historical Monitoring Well. GSI datum given as 15.68mOD Poolbeg = 12.97mOD Malin
04_018	180295	73121	Borehole	EPAGWMON											EPA Historical Monitoring Well. WQ only. IDA Well - Coords lie very close to 2 no. GSI Dbase wells.

GSINAME	ORIGNAME	SRCNAME	TYPE	DEPTH M	DPTH RCK M	DTRCONFID	DRILLDATE	EASTING	NORTHING	LOC ACC	TOWNLAND	TOWN	COUNTY	SIXIN SHTNO	SOURCEUSE	YLDCLASS	PROD CLASS	YIELD M3D	ABSTR M3D	ABSTR DDM	SC M3DM	CAS1DIA MM	WTRSTRK1 M	WTRSTRK2 M	GENCOMMS	DRILLCOMMS	CASINGCOMS
1707SEW029			Borehole	20.1	4.6		01/07/1969	185660	73470	to 20m	BALLYNABOINTRA		Cork	76	Unknown	Poor			32.7						wtb/ck 7052		
1707SEW101	1707SE D9		Borehole	9.5	9.5	Bedrock Met	08/08/2001	185840	72530	to 10m	BALLYVODOCK EAST		Cork	76													
1707SWW044	TW1		Borehole	61	6	Bedrock Met	01/02/1986	183580	72390	to 20m	BALLINTUBBRID WEST		Cork	76	Industrial use	Moderate		47							Info from KT Cullen originally, Trial Well no 1		
1707SWW045	TW2		Borehole	122	7	Bedrock Met	01/02/1986	183610	72390	to 20m	BALLINTUBBRID WEST		Cork	76	Industrial use								30		Info from KT Cullen. Trial well No 2		
1707SWW046	TW3		Borehole	42.5	12	Bedrock Met	01/02/1986	183640	72450	to 20m	BALLINTUBBRID WEST		Cork	76	Industrial use	Excellent		852				200	18	24	Kt Cullen Info, Trial Well no 3		
1707SWW048	PW #1		Borehole	31.1		Bedrock Not Met	00:00:00	179850	73020	to 20m	KILLACLOYNE		Cork	75	Industrial use	Good		381.8				200			no 1 bore		
1707SWW072		CORK CO CO	Borehole	20	2.4	Bedrock Met	09/08/1991	182090	70300	to 50m	ROSSMORE		Cork	75	M										Rossmore landfill site invest for waste liscence well 1		
1707SWW073		CORK CO CO	Borehole	4		Bedrock Not Met	20/08/1991	182150	70300	to 50m	ROSSMORE		Cork	75	M										Rossmore landfill site invest for waste licence well 2		
1707SWW074		CORK CO CO	Borehole	5	4	Bedrock Met	21/08/1991	182170	70410	to 50m	ROSSMORE		Cork	75	M										Rossmore landfill site invest for waste licence-well 3		
1707SWW075		CORK CO CO	Borehole	9.2	9		22/08/1991	182170	70470	to 50m	ROSSMORE		Cork	75	M										Rossmore landfill site invest for waste license - well 4		
1707SWW076		CORK CO CO	Borehole	5	2.8	Bedrock Met	29/08/1991	182100	70420	to 50m	ROSSMORE		Cork	75	M										Rossmore landfill site invest for waste licence well5		
1707SWW077		CORK CO CO	Borehole	30.3	24.3	Bedrock Met	27/01/1998	182580	70420	to 50m	ROSSMORE		Cork	75	M										Rossmore landfill site invest for waste licence bh-f1		
1707SWW078		CORK CO CO	Borehole	15.5	2.6	Bedrock Met	02/02/1998	182380	70110	to 50m	ROSSMORE		Cork	75	M										Rossmore landfill site invest for waste licence bh-f2 cavities		
1707SWW083	GSI 99/69		Borehole	1	1	Bedrock Met	00:00:00	183880	71600	to 20m	BALLINTUBBRID EAST		Cork	76	Other										GSI 99/69. Depth to bedrock augering.		
1707SWW084	PW #3		Borehole	41.1		Bedrock Not Met	01/04/1970	180020	73200	to 20m	KILLACLOYNE		Cork	75	Industrial use	Excellent		1296	1296			305			register of abstr. This is b/h25N. Is also a 32W & a disused		Believed drilled by Fondedile company of France
1707SWW104			Borehole				01/11/1998	179880	73500	to 50m	KILLACLOYNE		Cork	75	Unknown										data compiled by a.allen - noted as killacloyne""		
1707SWW105		NO NAME GIVEN	Borehole	22.6	23		01/11/1998	179830	73130	to 50m	KILLACLOYNE		Cork	75	Agri & domestic use										data compiled by a.allen - noted as killacloyne""		
1707SWW106			Borehole	24		Bedrock Not Met	01/11/1998	180280	72860	to 50m	TULLAGREEN		Cork	75	Unknown										data compiled by a.allen - noted as carrigtohill""		
1707SWW107		NO NAME GIVEN	Borehole	24.1	25		01/11/1998	180270	73010	to 50m	ANNGROVE		Cork	75	Agri & domestic use										data compiled by a.allen - noted as killacloyne""		
1707SWW108			Borehole	45	0		01/11/1998	184590	72460	to 50m	CARRIGTOHILL		Cork	76	Unknown										data compiled by a.allen - noted as carrigtohill""		
1707SWW116	PW #1		Borehole	40		Bedrock Not Met	01/07/1977	180340	73100	to 20m	ANNGROVE		Cork	75	Industrial use	Excellent	II	1109			43.5	250	16		Production Well no 1		
1707SWW117	PW #2		Borehole	44.5		Bedrock Not Met	01/07/1977	180930	72960	to 20m	TERRYS-LAND		Cork	75	Industrial use	Excellent	III	600		33.7	17.8				Production Well no2		
1707SWW125	BH #1		Borehole	23		Bedrock Not Met	15/03/1977	180900	72950	to 20m	TERRYS-LAND		Cork	75	Other										Exploration Hole no.1		
1707SWW126	BH #2		Borehole	21		Bedrock Not Met	23/03/1977	181100	72880	to 20m	TERRYS-LAND		Cork	75	Other										Exploration Hole no.2		
1707SWW127	BH #3		Borehole	28.5		Bedrock Not Met	31/03/1977	180910	72870	to 20m	TERRYS-LAND		Cork	75	Other										Exploration Hole no.3		
1707SWW128	BH #4		Borehole	41		Bedrock Not Met	16/04/1977	180890	72970	to 20m	TERRYS-LAND		Cork	75	Other										Exploration Hole no 4		
1707SWW129	BH #5		Borehole	38		Bedrock Not Met	27/04/1977	180730	73170	to 20m	ANNGROVE		Cork	75	Other										Exploration Hole no.5		
1707SWW130	BH #6		Borehole	34		Bedrock Not Met	04/05/1977	180330	73050	to 20m	ANNGROVE		Cork	75	Other										Exploration hole no.6		
1707SWW133	ILC 5022	GEOLOGICAL SURVEY	Borehole	81.7	4.5	Bedrock Met	25/09/1987	182150	72250	to 50m	BARRYSCOURT		Cork	75	Agri & domestic use										LAND COMMISSION WELL 5022	In front of Castle	
1707SWW134	ILC 5021	On IDA Industrial Estate	Borehole	59.1	57.9	Bedrock Met	30/01/1987	180300	73100	to 50m	ANNGROVE		Cork	75	Agri & domestic use										LAND COMMISSION WELL 5021		
1707SWW159	1707SW D5		Borehole	8	8	Bedrock Met	09/08/2001	182140	72140	to 10m	BARRYSCOURT		Cork	75													
1707SWW161	1707SW D7		Borehole	8	8	Bedrock Not Met	08/08/2001	184460	73410	to 10m	BURGESLAND		Cork	75													
1707SWW171	BH #7	IDA Industrial Estate, Carrigtwohill	Borehole	46		Bedrock Not Met	07/05/1977	180290	73240	to 20m	ANNGROVE	Carrigtwohill	Cork	75	Agri & domestic use												
1707SWW172	BH #8	IDA Industrial Estate, Carrigtwohill	Borehole	25		Bedrock Not Met	01/05/1977	180480	72820	to 20m	TULLAGREEN	Carrigtwohill	Cork	75													
1707SWW173	BH #9	IDA Industrial Estate, Carrigtwohill	Borehole	5		Bedrock Met	01/05/1977	180650	73250	to 20m	ANNGROVE	Carrigtwohill	Cork	75													
1707SWW177	BH #10	IDA Industrial Estate, Carrigtwohill	Borehole	24.7	23.5	Bedrock Met	01/05/1977	180640	73070	to 20m	ANNGROVE	Carrigtwohill	Cork	75													
1707SWW180	BH 1	FOTA ISLAND ESTATE - UCC	Borehole	22.5		Bedrock Not Met	00:00:00	179940	72030	to 50m	FOTA ISLAND		Cork	75	Other											Report By UCC April 1986 report no. 86/3	WL below 10m OD
1707SWW181	BH 2	FOTA ISLAND ESTATE- UCC	Borehole	20		Bedrock Not Met	00:00:00	180330	71810	to 50m	FOTA ISLAND		Cork	75	Other											Report By UCC April 1986 report no. 86/3	WL below 10m OD
1707SWW182	BH 3	FOTA ISLAND ESTATE - UCC	Borehole	12.5	12.5	Bedrock Met	00:00:00	180210	71710	to 50m	FOTA ISLAND		Cork	75	Other											Report By UCC April 1986 report no. 86/3	WL below 10m OD
1707SWW183	BH 4	FOTA ISLAND ESTATE - UCC	Borehole	13	13	Bedrock Met	00:00:00	180210	71620	to 50m	FOTA ISLAND		Cork	75	Other											Report By UCC April 1986 report no. 86/3	WL below 10m OD
1707SWW049	PW #2		Borehole	27.4		DTB Unknown	00:00:00	180220	73000	to 100m	KILLACLOYNE		Cork	75	Industrial use	Good		272.7							no 2 Bore		
1707SWW059			Borehole	36.6	12	Bedrock Met	08/01/1901	183370	72860	to 500m	CLYDUFF		Cork	76	Unknown										yield not recorded. Lined 15.7m		
1707SWW160	1707SW D6		Borehole	11		Bedrock Not Met	08/08/2001	182170	73740	to 10m	TERRYS-LAND		Cork	75													
1707SEW055			Borehole				01/01/1997	186560	74170	to 50m	KNOCKGRIFFIN		Cork	76	Industrial use	Excellent		1200	1200						from register of abstractions. Used to be 2 wells when IMP.		
1707SEW062		NO NAME GIVEN	Borehole	50	6	Bedrock Met	01/11/1998	188600	72100	to 50m	CASTLEREDMOND		Cork	76	Unknown										data compiled by A. Allen - noted as ballincurrig/ballynacorra		
1707SEW063		NO NAME GIVEN	Borehole	60.9	30.4	Bedrock Met	01/11/1998	187200	74260	to 50m	KNOCKGRIFFIN		Cork	76	Unknown										data compiled by A. Allen - noted as midleton""		
1707SEW070	GSI 99/205		Borehole	5		Bedrock Not Met	01/08/1999	189810	74520	to 20m	KILLEAGH		Cork	65	Other	Failure									Depth to rock augering, GSI 99/205		
1707SEW090	BH1		Borehole	8		DTB Unknown	03/08/2000	187940	74500	to 50m	BROOMFIELD WEST	Midleton	Cork	76	Unknown											Avoncore Estate. Location from site map included in report. Cable percussion rig	no groundwater encountered
1707SEW100	1707SE D8		Borehole	11		Bedrock Not Met	00:00:00	186220	74930	to 10m	WATER-ROCK		Cork	65													
1707SEW108	TP4		Dug well	3.4	3.2	Bedrock Met	25/07/2000	188030	74480	to 50m	BROOMFIELD WEST	Midleton	Cork	76	Other										unknown	Location from site map in report	no water encountered
1707SEW109	TP23		Dug well	3.2		Bedrock Not Met	21/08/2000	187900	74450	to 50m	BROOMFIELD WEST	Midleton	Cork	76	Other										unknown	Location from site map in report	No water encountered
1707SEW110	BH2		Borehole	5		DTB Unknown	03/08/2001	188030	74450	to 50m	BROOMFIELD WEST	Midleton	Cork	76	Unknown										unknown	location from site map in report.Cable percussive rig	No groundwater encountered slotted standpipe to 4.9m
1707SEW111	BH3		Borehole	10		DTB Unknown	04/10/2000	187950	74450	to 50m	BROOMFIELD WEST	Midleton	Cork	76	Unknown										unknown	location from site map in report	No groundwater encountered
1707SEW124	DWG 3482		Borehole	24.4	24.4	Bedrock Presumed	01/11/2003	190120	71720	to 50m	GEARAGH	Midleton	Cork	76	Agri & domestic use	Moderate		55				152	22.9		Drilled by Jim Harte, Midleton		2 hr test
1707SEW056			Borehole				01/01/1997	188860	71670	to 100m	BALLYNACORRA WEST		Cork	76	Industrial use	Poor			18.2						from register of abstractions		
1707SEW082			Borehole	54.9	29	Bedrock Met	00:00:00	187050	74870	to 100m	KNOCKGRIFFIN		Cork	65	Domestic use only	Moderate	IV	54.5			8.94	152	48.8				
1707SEW076			Borehole	42.7		DTB Unknown	00:00:00	187600	74470	to 200m	MIDLETON		Cork	76	Other										REF 95C45 O\B MARINE MUD		

GSINAME	ORIGNAME	SRCNAME	TYPE	DEPTH M	DPTH RCK M	DTRCONFID	DRILLDATE	EASTING	NORTHING	LOC ACC	TOWNLAND	TOWN	COUNTY
1707SEW088	MW 1		Borehole	13	7.5	Bedrock Met	00:00:00	188530	73470	to 500m	PARK NORTH		Cork
1707SEW089	TW		Borehole	82	5.2	Bedrock Met	15/02/2000	188530	73420	to 500m	PARK NORTH		Cork
1707SEW033			Borehole	15.2		DTB Unknown	01/03/1963	188030	71320	to 1km	BALLYNACORRA WEST		Cork
1707SEW034			Borehole	19.2	17.7	Bedrock Met	01/12/1962	188030	71270	to 1km	BALLYNACORRA		Cork
1707SEW035			Borehole	30.5		DTB Unknown	01/07/1961	188020	71220	to 1km	BALLYNACORRA		Cork
1707SEW036			Borehole	42.7	1.2	Bedrock Met	00:00:00	188030	71170	to 1km	BALLYNACORRA		Cork
1707SEW037			Borehole	42.7	3.7	Bedrock Met	01/10/1964	187780	73380	to 1km	MIDLETON		Cork
1707SEW039			Borehole	30.5	9.1	Bedrock Met	29/01/1969	186590	72680	to 1km	BANESHANE		Cork
1707SEW040			Borehole	18.6	1.8	Bedrock Met	01/09/1963	186590	72620	to 1km	BANESHANE		Cork
1707SEW075			Borehole	85.3	27.1	Bedrock Met	08/07/1996	187790	73440	to 1km	MIDLETON		Cork
1707SEW104	BH#1		Borehole	31.1		DTB Unknown	00:00:00	188920	70880	to 1km	BALLYNACORRA WEST	Middleton	Cork
1707SEW105	BH#2		Borehole	15.2		DTB Unknown	00:00:00	188910	70810	to 1km	BALLYNACORRA WEST	Middleton	Cork

GSINAME	SIXIN SHTNO	SOURCEUSE	YLDCLASS	PROD CLASS	YIELD M3D	ABSTR M3D	ABSTR DDM	SC M3DM	CAS1DIA MM	WTRSTRK1 M	WTRSTRK2 M	GENCOMMS	DRILLCOMMS	CASINGCOMS
1707SEW088	76	Industrial use							150					
1707SEW089	76	Industrial use												
1707SEW033	76	Unknown	Good		218.3							info from Mr Navratil		
1707SEW034	76	Unknown	Poor		27.3							wtb/ck 2129		
1707SEW035	76	Unknown	Good		196.4							biological tests in progress contminated by salt marsh cra'6		
1707SEW036	76	Unknown	Excellent		655									
1707SEW037	76	Unknown	Excellent		764									
1707SEW039	76	Unknown	Moderate		54.5									
1707SEW040	76	Unknown	Poor		10.9							w/ck 7277		
1707SEW075	76	Industrial use	Good		327.3							O\B SAND\GRAVEL		
1707SEW104	76	Unknown										unknown Drilled March 1963		Big Yield
1707SEW105	76	Unknown	Good		218							Unknown Drilled March 1963		