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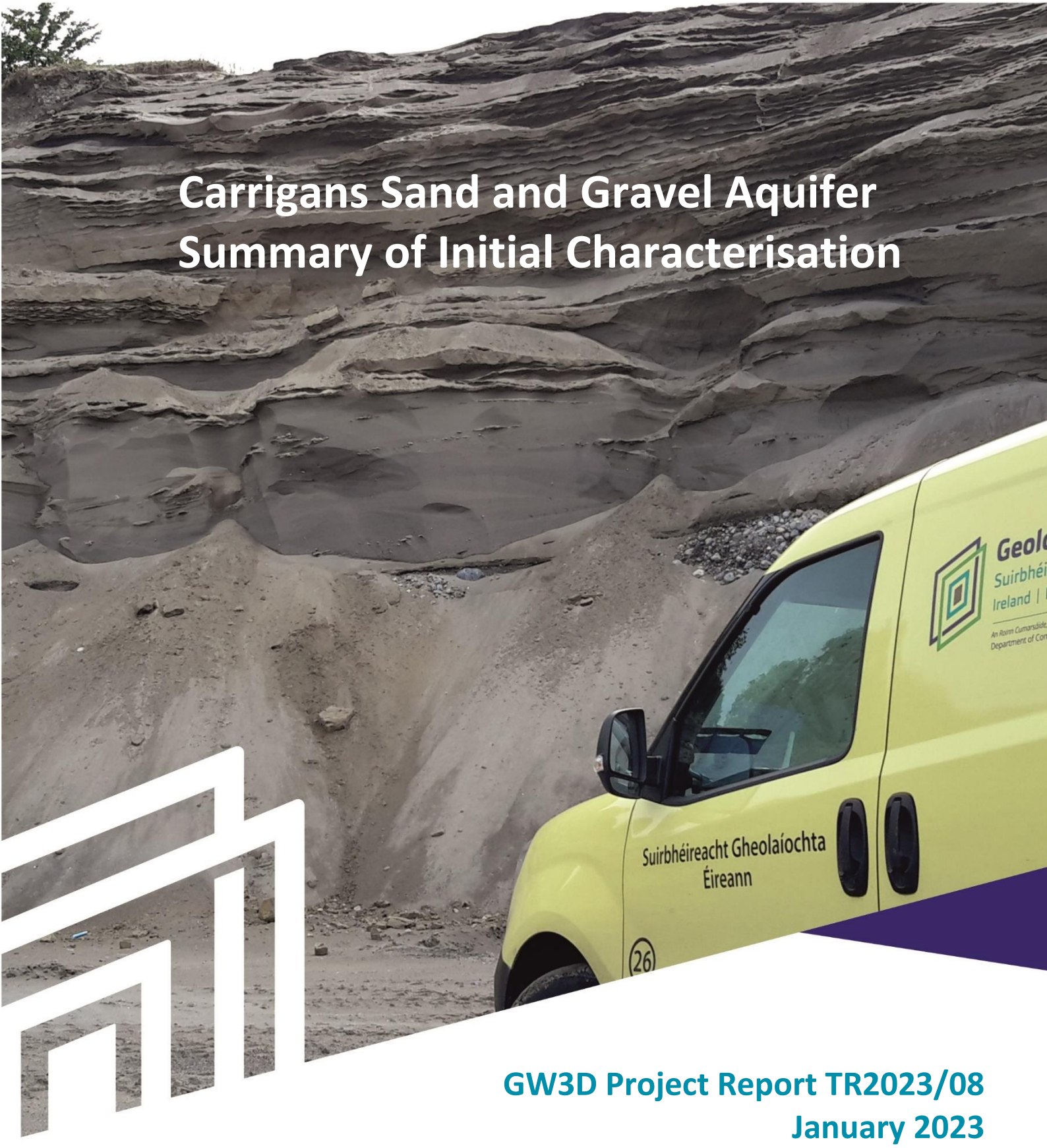

Carrigans Sand and Gravel Aquifer
Summary of Initial Characterisation

GW3D Project Report TR2023/08
January 2023

Geological Survey Ireland is a division of the Department of the Environment, Climate and Communications

Carrigans Sand and Gravel Aquifer Description January 2023

This sand and gravel report forms part of a series representing the output of a body of work undertaken to re-evaluate previously mapped sand and gravel aquifers and to identify new sand and gravel aquifers. This study resulted in the refinement of existing sand and gravel aquifer mapped extents, the modification of some sand and gravel aquifer categories, and the removal of some previously mapped sand and gravel aquifers, as well as identification of new aquifers. In addition to mapping the extent and depths of the sand and gravel aquifers, the investigations consider the hydraulic properties.

The study, undertaken as part of the GW3D project (2015-2019), comprised three parts:

1) Desk study and fieldwork preparation

Sand and gravel bodies above a minimum size criterion were extracted from the GSI Quaternary Sediments 1:50,000 map. Where it was known that the surface expression of the sands and gravels was only a small portion of the subsurface body, such areas were retained. This process left several hundred sand and gravel bodies remaining as a starting point for field work.

2) Fieldwork including mapping and data collection

Field work included a visit to each of the areas which had the potential to be (at least) a Locally Important Sand and Gravel Aquifer owing to its area. In such areas, gravel pits and sand pits were visited and depth and type of sediment recorded, other exposures into the subsurface were visited and logged, wells (whether Public Supply, Group Scheme or private farm or domestic) were dipped and any information on depths recorded, and data was collected where geological and hydrogeological data existed for the area.

3) Data collation, analysis and reporting.

All field data, and information from earlier reports and studies, were compiled and analysed. Where a sand and gravel body had qualifying aquifer properties (either 10 m depth sand and gravel, or 5 m depth saturated sediments), these areas were digitised in a GIS. The aquifer area was then ascertained and drawn up. Such areas formed the basic building blocks for the sand and gravel aquifer map, which included details on the aquifer name, area, aquifer resource value (Rg or Lg), confidence level, county, and any important aspects to note for each body.

The updated mapped sand and gravel aquifers are found on the Geological Survey Ireland site https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx#Aquifers

The GW3D Mapping Team involved in the current revision of delineated sand and gravel aquifers were:

Geological Survey Ireland staff:

- Dr. Sophie O'Connor, Groundwater Programme / Land Mapping Unit
- Dr. Sarah Blake, Groundwater Programme

Consultant support:

- Dr. Robbie Meehan, Talamh Ireland
- Coran Kelly, Tobin Consulting Engineers
- Damien Doherty, independent Consultant Geologist/ Tobin Consulting Engineers
- Natalie Duncan, independent Consultant Geologist
- Sara Raymond, independent Consultant Geologist
- James McAteer, Gavin and Doherty Geosolutions

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Carrigans Sand and Gravel Aquifer: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
1 – Foyle Donegal County Council	**Rivers:** River Foyle, Deele River, Swilly Burn **Streams:** Several unnamed streams **Lakes:** None	River Finn SAC River Foyle, Mongavlin to Carrigans pNHA, Feddyglass Wood pNHA	19.2

Topography	The Carrigans Sand and Gravel Aquifer comprises an alluvial deposit set in flat-lying ground along three connected river valleys – those of the Deele, Swilly Burn and the Foyle. The gravel body is about 15 km long in a N-S direction and, in the southern part, branches 6 km westwards along the Deele and Swilly Burn Valleys. The alluvial sands and gravels are set predominantly at elevations less than 10 m AOD, excepting areas along the Deele River, where elevations are slightly higher than this. On the western side of the deposits, the valley sides rise relatively steeply from the river floodplains to elevations up to 180 m AOD. The Foyle River is tidal at least as far south as the confluence with the Swilly Burn (~7.5 km south of the northern edge of the aquifer body). Flooding of the locality is common, and there is a high density of natural and artificial drainage ditches.	
Geology and Aquifers	**Aquifer categories**	Though the sand and gravel deposit covers an area greater than 10 km^2, drilling and yield data indicate that the proportions of coarse and fine materials are spatially variable, with good yields dependent on the proportion of coarse material at any given location (Lee and Fitzsimons, 2004). The sand and gravel deposit is confirmed to be greater than 10 m deep, and has a saturated thickness greater than 5 m, though it's yields are somewhat uncertain. Accordingly, the thickness, saturated thickness and areal extent satisfy the criteria of a **Locally Important Sand and Gravel Aquifer (Lg)** (DELG/EPA/GSI, 1999; GSI, 2017).
	Main aquifer lithologies	Alluvial deposits (Meehan, 2006) along river floodplains are thought to comprise sands and gravels at depth, overlain by finer material of silts and clays (Lee and Fitzsimons, 2004). Nearby geophysical investigations indicate 10 m to 20 m depth of sands and gravels, with some clay at 10 m - 20 m bgl (Minerex Environmental Ltd., 1998). Nearby drilling found 11 m depth of clay over 4 m - 7 m silty sand/gravel (K.T. Cullen and Co. Ltd., 1996). The sand and gravel aquifer overlies bedrock aquifers which are either Moderately Productive only in Local Zones (Ll) or Generally Unproductive except for Local Zones (Pl).
	Key structures	There are a number of borehole logs from within this area of the aquifer which provide some insight into the structure of the body, and which record the variability within the sediments. Clay and silt layers are interbedded with the sand and gravel throughout the deposit. The sand and gravel is generally deposited directly on bedrock for the most part; however, discontinuous till deposits may also be found separating the gravel and the bedrock (Meehan, 2006). The sand and gravel deposit sits mainly upon a 'Poor' bedrock aquifer which has a high degree of rejected recharge associated with it. This has the effect of retaining the water within the basal layers of the sand and gravel aquifer.
	Key properties	Sand and gravel aquifers generally consist of unconsolidated coarse-grained material, usually containing less than 8% fines (Ó'Suilleabháin, 2000). However, this aquifer contains greater proportions of fines in places. Productivity and yield data from two wells located 80 m apart recorded a 'good' yield with productivity class I, and a 'moderate' yield with productivity class III (Lee and Fitzsimons, 2004). In zones where the grains are coarse, transmissivity will probably range from 200 m^2/d to more than 400 m^2/d. In areas where the aquifer is more fine-grained, transmissivity will be lower. Storativity is expected to be high (10-20%). In this floodplain area, water levels will generally be very close to ground surface. The groundwater is likely to be unconfined, but may be confined by low permeability clay layers in places. Groundwater gradients will be very low (estimated as 0.0005).
	Thickness	Thicknesses of alluvium of more than 10 m are likely along the axes of the rivers, thinning towards the margins of the deposits (Minerex Environmental Ltd., 1998).

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Overlying Strata	**Lithologies**	Alluvial clay and silt layers overlie the sand and gravel deposit in places. The sand and gravel aquifer is defined mainly on the basis of the mapped alluvium, and there are some small areas mapped by Teagasc as till derived from metamorphic rocks (TMp) within the aquifer body also (Meehan, 2006).
	Thickness	The overlying alluvial clay and silt layers vary in thickness from 4 m to 14 m, but are generally within the range of 5 m to 7 m in thickness.
	% area aquifer near surface	Unknown, but estimated at less than 40%.
	Vulnerability	It is thought that much of the sands and gravels are overlain by low permeability sediments, which provide some protection to the underlying sand and gravel aquifer. However this thickness and the areal of extent of these low permeability deposits varies and their spatial extent are not mapped in any detail. Sand and gravel aquifers are categorised as having either 'High or 'Extreme' vulnerability (DELG/EPA/GSI, 1999), with the vulnerability classification determined by the depth to the water table from ground level. In areas where the water table is less than 3 m below ground level the aquifer vulnerability is mapped as 'Extreme' and where it is greater than 3 m below ground level the aquifer vulnerability is mapped as 'High'. Measured water levels range from 1 m to 3 m below ground level in the Carrigans Sand and Gravel Aquifer. Thus, 'Extreme' vulnerability dominates completely within the area of this aquifer.
Recharge	**Main recharge mechanisms**	The aquifer receives both direct and indirect recharge. Diffuse recharge occurs directly *via* infiltration of rainfall through the unsaturated sand and gravel. This may be inhibited slightly across some of the aquifer body by the presence of overlying silt and clay deposits. Minerex Environmental Ltd. (2001) consider that most of the recharge is likely to be at the top of the valley at the top of the glaciofluvial gravels, with smaller amounts seeping through the silts above them throughout the valley area. It is also likely that there is more recharge through the silts to the sides of the valley as they are thinner, as well as through the alluvial sediments up valley as these are more porous (Minerex Environmental Ltd., 2001). Typically, the proportion of recharge that infiltrates to ground water in sands and gravels is around 85% (Hunter Williams *et al*., 2011). Rejected recharge from the surrounding hills will also increase the amount of available recharge to this valley-setting aquifer. Depending on the relationship between the water table and river stage, some of the streams may recharge the aquifer in some localities.
	Est. recharge rates	The rainfall in the area of the Carrigans sands and gravels averages at 1,250 mm (Walsh, 2012), and the average recharge rate from diffuse recharge across the aquifer extent is estimated to be 250 mm/yr. The minimum groundwater throughput in the aquifer is estimated to be 13,137 m^3/d, with a significant portion of this volume coming from rejected recharge from the hills to the west.
Discharge	**Large springs and large known abstractions (m^3/d)**	There are a number of wells within the Carrigans Water Supply Scheme (WSS) that have either 'Moderate' or 'Good' yields (65 m^3/d to 272 m^3/d, GSI, 2023).
	Main discharge mechanisms	Groundwater discharges to the river and stream tributaries at low elevations, as well as along the coast to Lough Foyle.
	Hydrochemical Signature	There are no data available to assess the hydrochemistry of this aquifer.

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Groundwater Flow Paths	The length of groundwater flow paths depends on the extent of the sand and gravel deposit, and also upon the spacing of internal groundwater divides and the distance between streams. In general, locally important sand and gravel aquifers are expected to have relatively short flow paths *i.e*. up to several hundred metres. The variability in the composition of this aquifer disrupts flow, shortening groundwater flow paths. In general, groundwater will flow at high angles to the Rivers Deele, Swilly Burn and Foyle, and to smaller streams, thus the flowpaths typically will be considerably less than about 500 m. However, where low permeability subsoils above the gravels confine groundwater locally, groundwater flowpaths may be longer. Flow direction in this case will be parallel to the river.
Groundwater & Surface Water interactions	In general groundwater from sand/gravel deposits located in river valleys discharges to the streams/rivers flowing through the valley. The hydraulic connection between the groundwater in the aquifer and the stream or river is expected to be variable due to spatially varying subsoil permeabilities. Water may be able move into and out of the aquifer from the river in certain locations depending on the river stages and permeability of the subsoils.
Conceptual model	• The Carrigans Sand and Gravel Aquifer consists of sand and gravel deposits lying along the River Foyle north of Strabane, and along east-west trending, steep-sided river valleys that feed into the Foyle Valley. • The deposits are located beneath river floodplains, and are situated at elevations less than 10 m AOD. The surface drainage is westwards and northwards. Surface drainage is poor, and the areas are prone to flooding. The River Foyle is tidal at least as far south as the confluence with the Swilly Burn (~7.5 km south of the northern edge of the aquifer body). • The aquifer is comprised of alluvial deposits, which drilling data indicate are comprised of sands and gravels interspersed with some clay layers. • Transmissivity is expected to be 400 m^2/d or less, depending on the grain size and sorting of the deposits. The grain size of the deposits varies laterally as well as vertically. • The sand and gravel aquifer is likely to be greater than 10 m thick, excepting at it's margins. • Ground level data and surface drainage indications suggest that groundwater gradients are very low (estimated as 0.0005). • Diffuse recharge occurs *via* rainfall percolating through the unsaturated sands and gravels. Recharge is likely to be inhibited by the high groundwater levels and, in places, by low permeability deposits overlying the sands and gravels. Groundwater will also flow laterally into the deposits as rejected recharge from the underlying bedrock aquifers. • Groundwater discharges to the rivers and streams that flow through the deposits. • Due to the geometry of the deposits, groundwater flow paths are likely to be less than 500 m in areas where groundwater is unconfined. In areas where the hydraulic connection between ground and surface waters is low due to low permeability deposits, groundwater flow paths are likely to be longer; they will also be parallel rather than at an angle to the rivers. • The minimum groundwater throughput in the aquifer is estimated to be 13,137 m^3/d, with a significant portion of this volume coming from rejected recharge from the hills to the west.

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Attachments	Figure 1: Location and extent Figure 2: Cross sections Figure 3: Groundwater vulnerability	
Instrumentation	**Hydrometric gauges:**	01041 Sandy Mills 01048 Ballindrait
	National Water Monitoring Stations; **River:**	RS01C010300 0.5km d/s Br in Carrigans (d/s STW) RS01S030300 Br due N of Ballindrait RS01S010400 Rly Br just u/s Foyle R confl. RS01S030500 Br u/s Foyle R confl. RS01S030250 Br Near Massmore RS01S030400 Swilly Br. RS01D010700 Br at Murlough RS01D010660 d/s Ballindrait outlet RS01F011500 d/s Lifford STW RS01F011400 u/s Lifford STW
	Groundwater:	None present
Information Sources	• DELG/EPA/GSI (1999). Groundwater Protection Schemes. Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland. • GSI (2005). Swilly Gravel Groundwater Body Description. 8pp. • GSI (2017). A description of Irish aquifer categories. 3 pp. Available from: • https://www.gsi.ie/documents/GSI%20Aquifer%20Category%20Descriptions.pdf • GSI (2023). Geological Survey Ireland Spatial Resources Viewer. https://www.gsi.ie/en-ie/data-and-maps/Pages • Hunter Williams, N., Misstear, B., Daly, G., Johnston, P., Lee, M., Cooney, P. and Hickey, C. (2011). National Groundwater Recharge Map for Ireland. Geological Survey Ireland and Department of Civil, Structural and Environmental Engineering, Trinity College Dublin. • K.T. Cullen and Co. Ltd. (1996). Report on a Trial Well Drilling and Testing Programme at Lagan, East Donegal. Prepared at the Request of: Donegal County Council. No. 813. • Lee, M. and Fitzsimons, V. (2004). County Donegal Groundwater Protection Scheme. Volume 1 Main Report, Draft, July 2004. 58 pp. Geological Survey of Ireland. • Meehan, R.T. (2006). Subsoils Map for County Donegal. Map produced as part of EPA Soil and Subsoil Mapping Project (formerly FIPS-IFS). Teagasc, Kinsealy. • Minerex Environmental Ltd. (1998). Report on Lund Imaging Geophysics. Letter to P. Barr, Eurocement, Lifford. • Minerex Environmental Ltd. (2001). Letterkenny Water Supply – No. 2 Augmentation Scheme. Groundwater resource development in Glen Swilly. Data Review, Geophysics, Core Logging, Replacement Well Drilling, Pumping Tests & Reporting. Fieldwork July – November 2000. MEL Report Ref:- 1009-828 (Final).doc. • Ó'Riain, G. (2004). Water Dependent Ecosystems and Subtypes Draft Report. WFD Support Projects. Compass Informatics in association with National Wildlife and Parks Service (DEHLG). • Ó'Suilleabháin, C. (2000). Assessing the boundary between high and moderately permeable subsoils. Unpublished MSc., University of Dublin. Department of Civil, Structural and Environmental Engineering, Trinity College Dublin. • Walsh S. (2012). A Summary of Climate Averages 1981-2010 for Ireland, Climatological Note No.14, Met Éireann, Dublin. • Wright, G.R., Aldwell, C.R., Daly, D. and Daly, E.P. (1982). Groundwater resources in the Republic of Ireland, vol 6. In: European community's Atlas of groundwater resources, SDG, Hannover, Germany.	
Disclaimer	Note that all calculation and interpretations presented in this report represent estimations and assumptions based on the information sources described above and established hydrogeological formulae. Figures 1, 2 and 3 are used for illustrative purposes only.	

Carrigans Sand and Gravel Aquifer

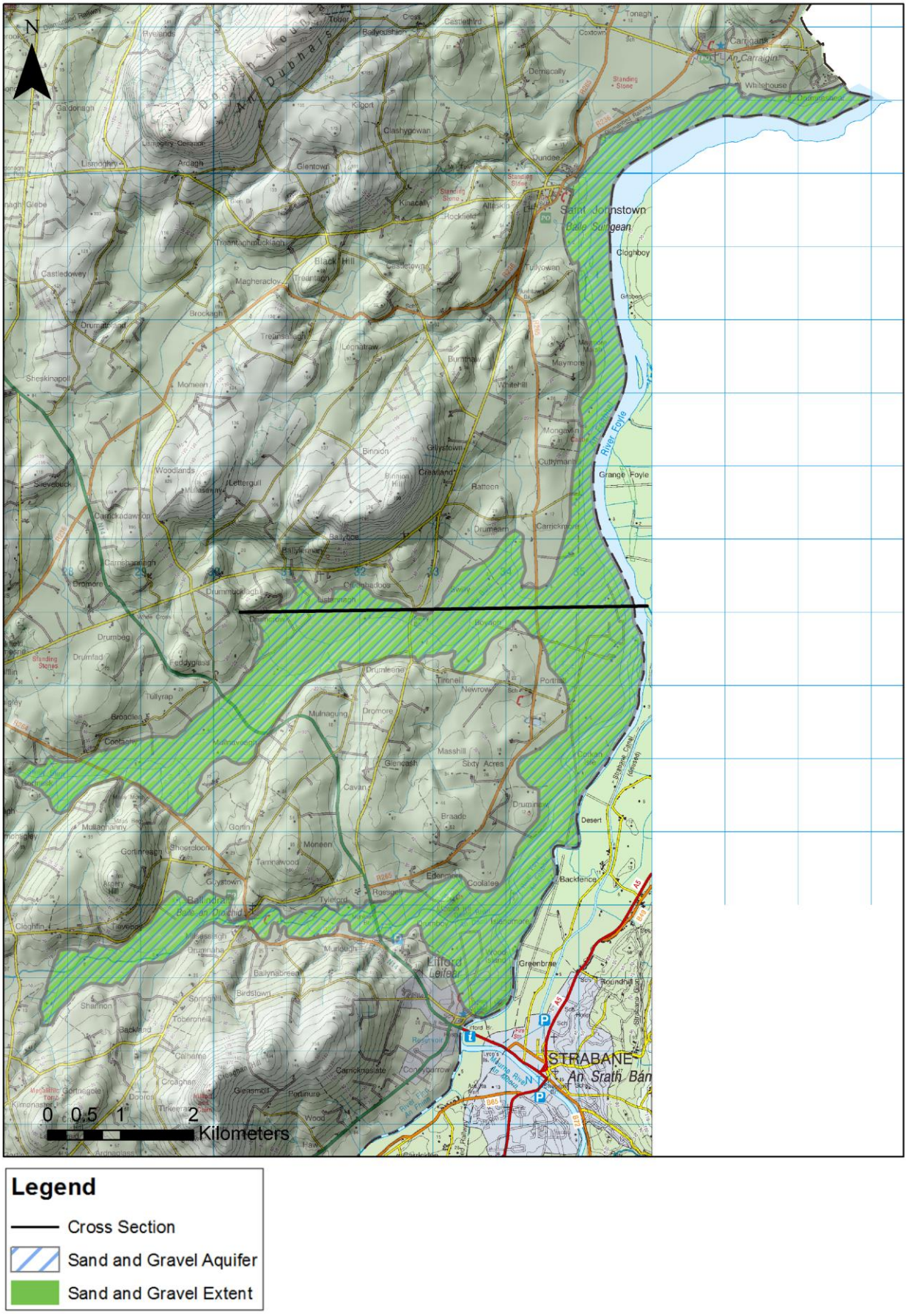

Figure 1. Carrigans Sand and Gravel Aquifer extent with cross section location.

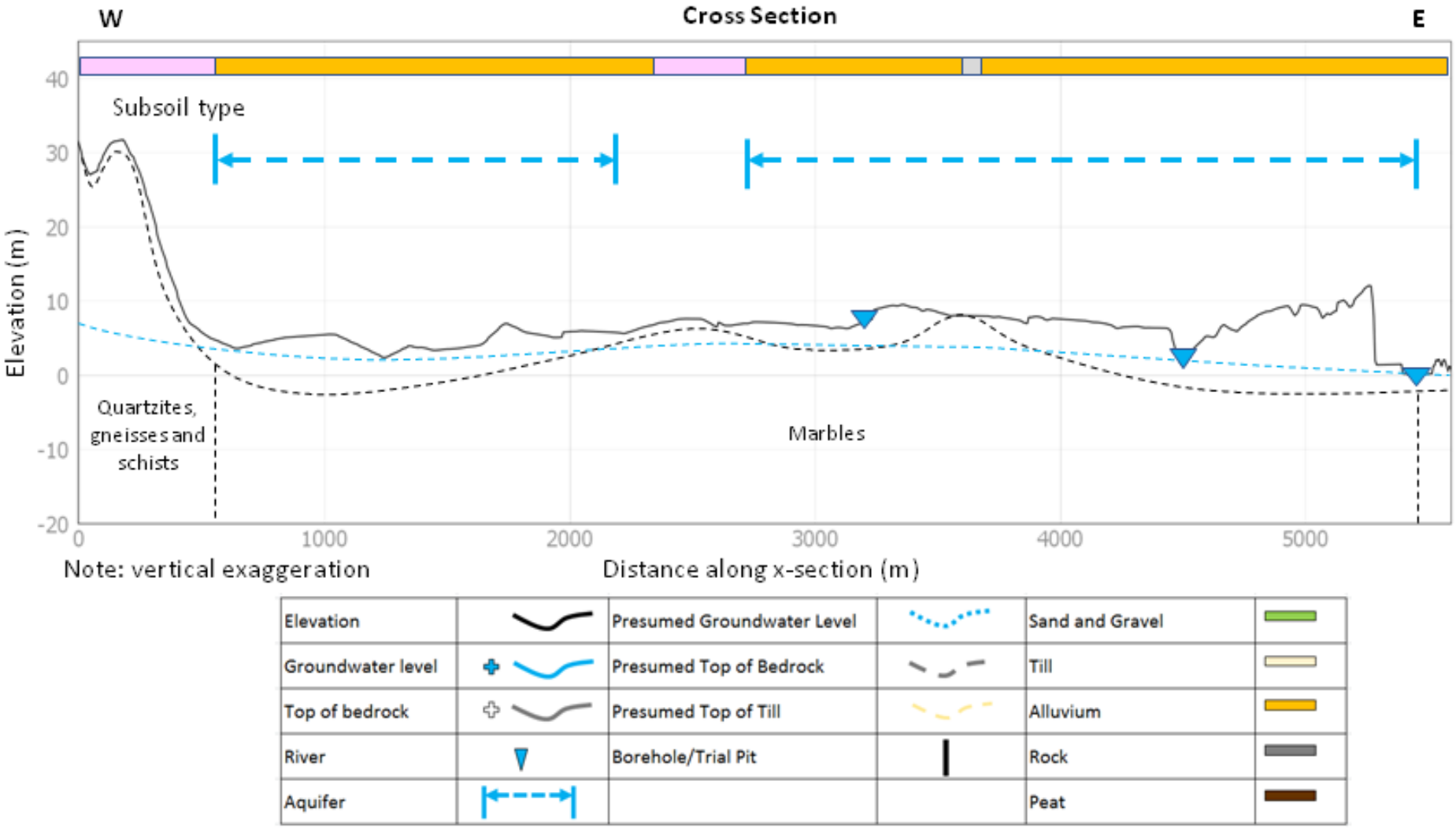

Figure 2. Cross section through the Carrigans Sand and Gravel Aquifer body.

Carrigans Sand and Gravel Aquifer Vulnerability

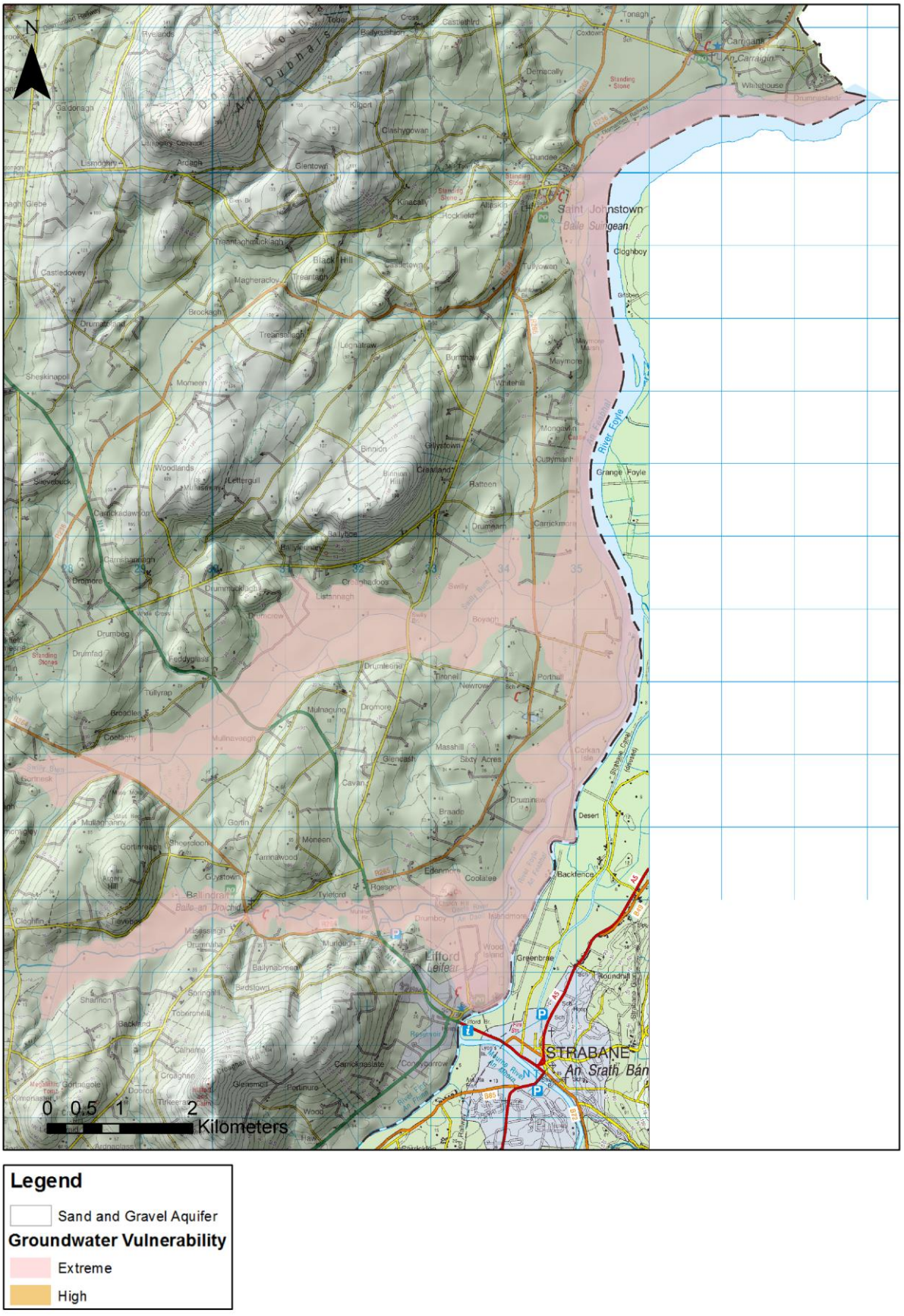

Figure 3. Groundwater vulnerability across the Carrigans Sand and Gravel Aquifer.