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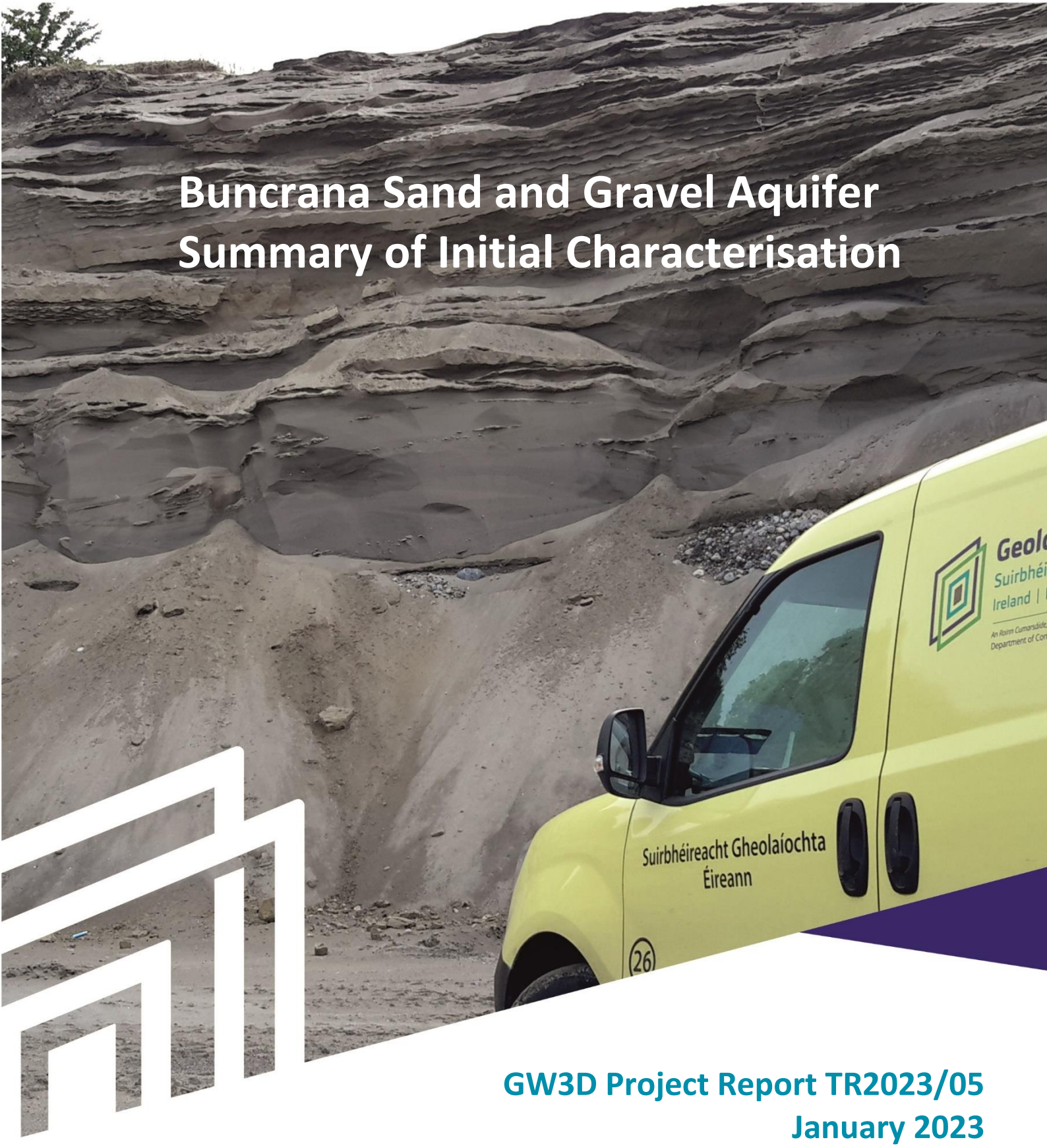

Buncrana Sand and Gravel Aquifer
Summary of Initial Characterisation

GW3D Project Report TR2023/05
January 2023

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

Buncrana 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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Buncrana Sand and Gravel Aquifer: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
39 – Lough Swilly Donegal County Council	**Rivers:** None **Streams:** Luddan Stream, Lisfannan Stream and several unnamed, minor streams **Lakes:** None	Lough Swilly SAC	0.6

Topography	A raised beach at Luddan, approximately 1.5 km south of Buncrana Town, occupies a relatively flat area along the coastline on the western coast of the Inishowen Peninsula. This deposit is bounded to the east by a steep-sided mountain ridge, which is composed of bedrock and which rises to approximately 250 m AOD. The elevation of the landscape at the beach locality is the result of isostatic rebound during and after deglaciation, which has been equated to a relative sea level drop of some 0.3 m per century (Cullen, 1991). Minor rivers flow from areas of high elevation in the southeast, across and through the beach sediment, and towards the coast.	
Geology and Aquifers	**Aquifer categories**	The Buncranna sand and gravel deposit is confirmed to be greater than 10 m thick, and has a saturated thickness greater than 5 m. Although the 1 km^2 areal criterion of an aquifer is not met, the deposit has been proven to have excellent yields, and therefore is considered to be a **Locally Important Sand and Gravel Aquifer (Lg)** (DELG/EPA/GSI, 1999; GSI, 2017).
	Main aquifer lithologies	The deposit is classified as marine gravels and sands (MGs) on the GSI Quaternary map (GSI, 2023a). Drilling logs indicate that the body is comprised interbedded SAND and GRAVEL.
	Key structures	Borehole logs show some variability in the aquifer material, which consists largely of sand and gravel, with occasional low permeability horizons which overlie and are interbedded within the deposit. These are known not to be laterally continuous as they are not met in all of the borehole logs (Cullen, 1991). The presence of less permeable layers in the deposit, even if thin, can create locally perched water tables. Four borehole logs record fine sand that becomes more pebbly with depth, over fine to coarse gravel with cobbles. There are differing amounts of fine grained material in these deposits, which suggests that the material may be of morainic origin, and has since been flooded (Lee and Fitzsimons, 2004). The deposit is intermittently in direct contact with the underlying bedrock which is classed as a 'Poor' Aquifer (GSI, 2023a). Due to the glacial history and sea level changes, it is thought that in some places, cleaner sand and gravel overlies an undulating till surface, which was encountered in one of the trial wells within the aquifer (Lee and Fitzsimons, 1994).
	Key properties	The groundwater is considered to be generally unconfined at Buncrana; however where clay layers are present within and above the sand and gravel deposit, the aquifer may be locally confined. Particle Size Analysis (PSA) of the sediments show fines less than 1%, and over 90% gravel-sized, or larger, clasts (Cullen, 1991). In the absence of permeability test data, gravels with a fines content of less than approximately 8% are generally considered to have sufficient permeability for aquifer development (O'Suilleabhain, 2000). Though permeability testing data are limited, productivity and borehole logging show that coarse material predominates and therefore suggest that permeability and storativity are high. Transmissivity is estimated using the Logan method (Misstear, 1998) to be in the range of 125 to 400 m^2/d. All water level measurements show that the water table is less than 3 m below ground level; therefore most of the deposit is considered saturated. The 'Poor' bedrock aquifer underlying the sand and gravel has a high degree of rejected recharge associated with it, which has the effect of retaining the water within the basal layers of the sand and gravel. Pumping test records indicate three wells with 'excellent' yields and one well with a 'good' yield (Cullen, 1991).
	Thickness	The thickness of the sand and gravel body varies between 3.6 m and 16 m (Cullen, 1991). The available drilling data for this aquifer suggests that the bedrock slopes seawards beneath the deposit. Recorded thicknesses of the sand and gravel deposit are: 16 m (TW1), 8 m (TW2), 5 m (TW3), 12.2 m (TW5) and 9.3 m (TW 6) (Cullen, 1991).

Buncrana Sand and Gravel Aquifer Description January 2023

<table>
<tr><td rowspan="4">Overlying Strata</td><td>Lithologies</td><td>There are no sediments overlying any portion of the Buncrana sand and gravel aquifer.</td></tr>
<tr><td>Thickness</td><td>N/A</td></tr>
<tr><td>% area aquifer near surface</td><td>100%</td></tr>
<tr><td>Vulnerability</td><td>All of the aquifer is at the surface and consequently pollutants can easily infiltrate the aquifer. Sand and gravel aquifers are categorised as having either ‘High or ‘Extreme’ vulnerability (DELG/EPA/GSI, 1999), with the vulnerability classification of a sand and gravel aquifer 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 at Buncrana range from 0.54 m to 2.75 m below ground level.</td></tr>
<tr><td rowspan="2">Recharge</td><td>Main recharge mechanisms</td><td>Diffuse recharge occurs via infiltration of rainfall through the unsaturated sand and gravel. The proportion of the effective rainfall that recharges the aquifer is largely determined by the thickness and permeability of the soil and subsoil, and by the slope (DoELG/EPA/GSI, 1999). Typically, the proportion of recharge that infiltrates to groundwater in sand and gravel is around 85% (Hunter Williams et al., 2011). Due to the permeability of sand and gravel, a high proportion of the available recharge will percolate down to the water table. Rejected recharge originating on the steep slopes to the southeast is also considered to recharge the aquifer. Where the elevation of the water table is lower than that of the streambed the aquifer may receive additional recharge from streams.</td></tr>
<tr><td>Est. recharge rates</td><td>The rainfall in the area of the Buncrana sand and gravels is 1,280 mm (Walsh, 2012), and the estimated recharge rate to the aquifer from direct recharge is 681 mm/year. The minimum groundwater throughput in the aquifer is estimated to be 1,448 m^3/d, with almost half of this volume coming from rejected recharge from the hills to the east.</td></tr>
<tr><td rowspan="2">Discharge</td><td>Large springs and large known abstractions (m^3/d)</td><td>Pumping tests were completed on four wells, TW1, TW2, TW5 and TW6 (Cullen, 1991).
<table>
<tr><th>Well</th><th>Yield (m^3/day)</th><th>Drawdown (m)</th><th>Yield class</th><th>Specific capacity</th><th>Productivity class</th><th>Largest safe yield (m^3/day) (Cullen , 1991)</th></tr>
<tr><td>TW1</td><td>507</td><td>1.49</td><td>Excellent</td><td>340.3</td><td>I</td><td>650</td></tr>
<tr><td>TW2</td><td>490</td><td>3.22</td><td>Excellent</td><td>152.2</td><td>I</td><td>400</td></tr>
<tr><td>TW5</td><td>490</td><td>4.73</td><td>Good</td><td>103.6</td><td>II</td><td>150 (due to tidal influence)</td></tr>
<tr><td>TW6</td><td>490</td><td>3.51</td><td>Excellent</td><td>139.6</td><td>I</td><td>490</td></tr>
</table></td></tr>
<tr><td>Main discharge mechanisms</td><td>“Fresh water discharges into the saline environment along the shore line as spring seepages which are visible at low tide. The extent of the mixing zone is unknown but will probably measure about 100 m in width and run parallel to the shoreline” (Cullen, 1991). Where the water table is sufficiently close to the surface such that the stream elevation is lower than it is, the aquifer will contribute groundwater to the baseflow of the streams which run across the aquifer.</td></tr>
</table>

Hydrochemical Signature

The groundwater at Buncrana has a calcium bicarbonate signature.
Groundwater chemistry data are available from the four wells on which pumping tests were completed (Cullen, 1991). Results shown in red in the Table below exceed EU drinking water limits (2014).

	TW1	TW2	TW3	TW4
Chloride (Cl mg/l)	40	80	38	34
Iron (Fe mg/l)	4.9	1	4.3	0.03
Manganese (Mn mg/l)	0.15	0.06	0.16	0.01
pH	7.3	7	7.6	7
Ammonium (NH4 mg/l)	0.08	0.17	0.16	<0.05
Nitrate (NO3 mg/l)	1.1	<0.5	2.3	7.3
Nitrite (NO2 mg/l)	<0.05	<0.05	<0.05	<0.05
Colour (mg/l Pt/Co)	5	25	5	<5
Conductivity (µS/cm)	514	557	489	365
Coliforms (MPN/100 ML)	0	0	0	0

In three wells iron and manganese exceed EU drinking water limits (2014). Chloride levels are elevated; this is probably due to the proximity of the wells to the coastline. Cullen, (1991) measured salinity over the course of the pumping tests in order to detect saltwater intrusion. Salinity levels in the discharged water remained constant.

Groundwater Flow Paths

Groundwater flow path length depends on the extent of the sand and gravel deposit, and also upon the spacing of internal groundwater divides and the distance between streams, if groundwater is discharging to them. In general, locally important sand and gravel aquifers are expected to have relatively short flow paths. The groundwater in the Buncrana body is generally assumed to flow in a north-westerly direction, and flow in the vicinity of any boreholes will be influenced by pumping.

Groundwater & Surface water interactions

Due to the shallow groundwater flow levels in this aquifer, the groundwater and surface waters are closely linked. Water may be able move into and out of the aquifer from the streams in certain locations depending on the time of year and the river stage. The groundwater is also considered to interact with sea water along the coast, with the extent of the mixing zone thought to measure about 100m in width (Cullen, 1991).

Conceptual model

- The Buncrana sand and gravel aquifer is situated along the coastline, at the base of a steep slope on a mountain ridge flank. The ridge rises in elevation to 250 m AOD.
- The area of the aquifer is limited by the extent of the sand and gravel deposit.
- The aquifer is made up of largely of SAND and GRAVEL with occasional low permeability horizons. It is considered to be largely unconfined.
- The productivity of the aquifer has been proven by Cullen, (1991) who drilled a number of wells and completed pumping tests on four of these. The wells produced 'Excellent' yields.
- These data have allowed the delineation of a deposit that does not satisfy the areal extent criterion of an 'Lg' aquifer, but the topographical setting of the deposit explains this inconsistency as increased recharge rejected from the surrounding hills and the underlying 'Poor' bedrock aquifer provides a greater amount of groundwater to the aquifer than expected for a body of this size.
- The water table within sand and gravel aquifers is often relatively shallow, and therefore its' depth below ground level varies with the exact elevation at any given point.
- The shallow water table in this aquifer suggests that the groundwater and surface waters are probably hydraulically connected.
- It is thought that the high recharge rate and topography of the locality has prevented saltwater intrusion along the coast. However there is a chloride signature in the groundwater, suggesting there is some influence from the ocean, probably from sea spray in the majority.

	• The flow paths within the aquifer are constrained by the extent of the deposit and therefore will not develop to a regional scale, so groundwater is thought to flow generally in a north-westerly direction. • Direct recharge occurs diffusely throughout the aquifer. Groundwater may discharge to the small streams crossing the aquifer, and to seeps. • The minimum groundwater throughput in the aquifer is estimated to be 1,448 m^3/d, with almost half of this coming from rejected recharge from the hills at the east.
Attachments	Figure 1: Location and extent Figure 2: Cross sections Figure 3: Groundwater vulnerability
Instrumentation	**Hydrometric gauges:** None Present **National Water Monitoring Stations;** **River:** RS39L170710 Lisfannann - Br u/s from Lough Swilly **Groundwater:** None Present
Information Sources	• Cullen, K. T. (1991). Report on the hydrogeological investigation and trial well drilling and testing programme at Buncrana county Donegal. • DELG/EPA/GSI (1999). Groundwater Protection Schemes. Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland. • EPA mapviewer. http://gis.epa.ie/Envision/ • European Union (2014). S.I. No. 122/2014 – European Union (drinking Water) Regulations 2014. • GSI (2017). A description of Irish aquifer categories. 3 pp. Available from: https://www.gsi.ie/documents/GSI%20Aquifer%20Category%20Descriptions.pdf • GSI (2023a). Geological Survey Ireland Spatial Resources Viewer. https://www.gsi.ie/en-ie/data-and-maps/Pages • GSI (2023b). Geological Survey Ireland. Internal Groundwater Database • 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. • Lee, M. and Fitzsimons, V. (2004). County Donegal, Groundwater Protection Scheme Volume I: Main Report. Geological Survey of Ireland. • Misstear, B.D.R. (1998). The Logan Method for Analysing Pumping Test Data. Article published in: The GSI Groundwater Newsletter, edited by: Donal Daly. GSI publication No. 34. • Ó'Súilleabháin, 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 Eireann, 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.
ffDisclaimer	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.

Buncrana Sand and Gravel Aquifer

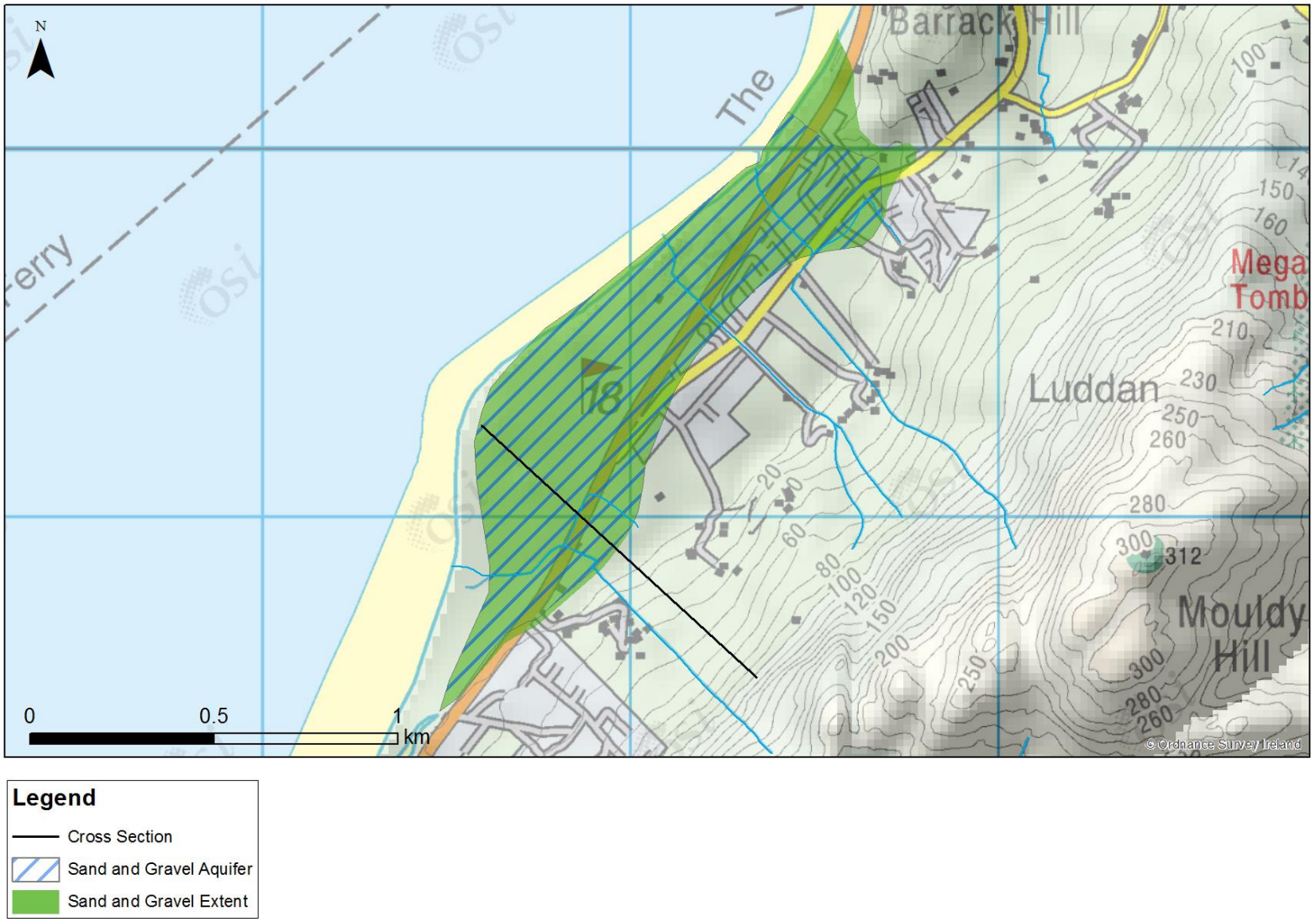

Figure 1. Buncrana Sand and Gravel Aquifer extent with cross section location.

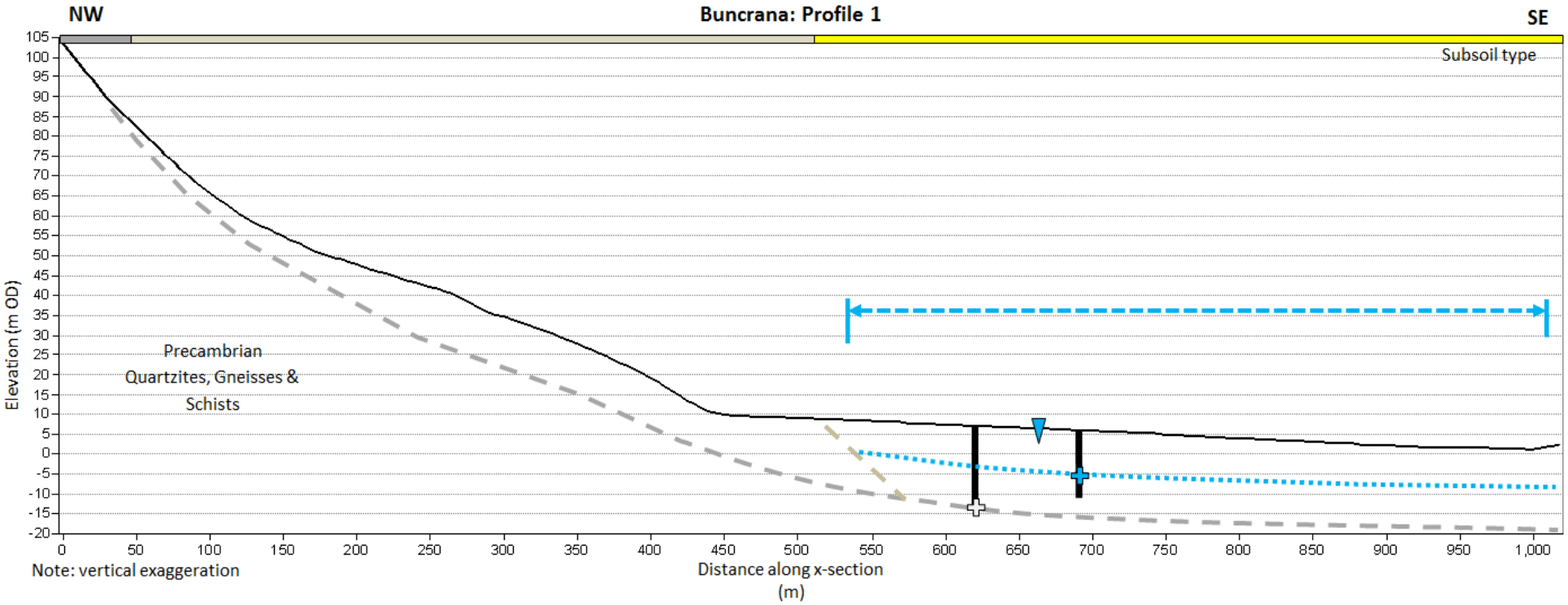

Figure 2. Cross section through the Buncrana Sand and Gravel Aquifer body.

Buncrana Sand and Gravel Aquifer Vulnerability

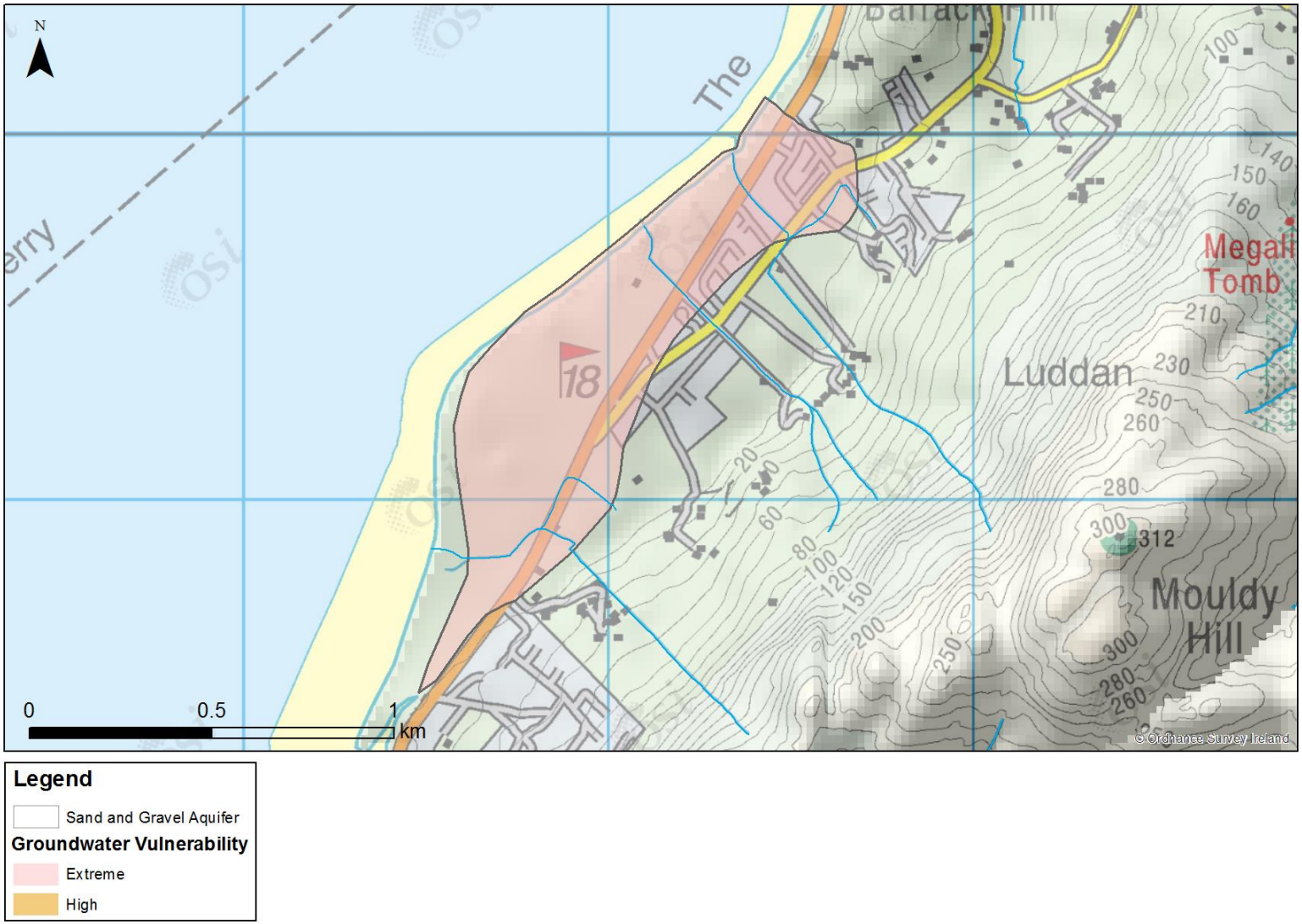

Figure 3. Groundwater vulnerability across the Buncrana Sand and Gravel Aquifer.