Appendix E.1
Geotechnical Report - PSSR

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Preliminary Sources Study Report (PSSR)

Bus Connects Core Bus Corridor 6: Lucan to City Centre

National Transport Authority

Project number: 60599126

12 December 2019

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1. Introduction

1.1 Scope and Objective of Report

The scope and objective of this Preliminary Source Study Report (PSSR) is to address the geological, geotechnical, geomorphological, hydrogeological and geo-environmental aspects of the Bus Connects Core Bus Corridor, Route 6 – Lucan to City Centre. It also examines the historical development of the area. The PSSR provides a preliminary engineering assessment of the site to inform of likely hazards to construction.

The information contained within this report will be used to scope future Ground Investigations.

This report has been prepared in accordance with Managing Geotechnical Risk DN-ERW-03083 (October 2019), Section 6.1, specifically Appendix C.

1.2 Project Overview

In June 2018, the National Transport Authority (NTA) published the Core Bus Corridors Project Report. The report outlined proposals for the delivery of a core bus corridor network across Dublin. The bus corridor network will provide 230km of dedicated bus lanes and 200km of cycle lanes/tracks on sixteen key bus corridors.

AECOM Ireland Limited (AECOM) and Mott McDonald have been awarded Package A, comprising four bus corridor routes:

- Route 1 – Clongriffin to City Centre
- Route 6 – Lucan to City Centre
- Route 8 – Clondalkin to Drimnagh
- Route 9 – Greenhills to City Centre

Route 6 Lucan to Dublin City Centre is the focus of this report. The remaining routes (1, 8 and 9) are reported under separate cover.

Detailed descriptions of the proposed route are available in Section 4.

2. Sources of Information & Desk Study

The following table summarises the sources of information used within this desk study:

Table 1 Sources of Information used in the Desk Study

Source	Location	Available Information
Geological Survey Ireland (GSI) Spatial Resource	https://dcenr.maps.arcgis.com/apps/MapSeries/index.html?appid=a30af518e87a4c0ab2fbde2aaac3c228	• Bedrock Geology • Quaternary Sediments • Teagasc Soils • Verified Borehole with Logs • Borehole Locations (unverified) • External GSI Geotechnical Boreholes • Groundwater Resources (Aquifers) • Groundwater Vulnerability • Groundwater Recharge • Groundwater Karst Data • Groundwater Wells and Springs • Active Quarries
The Geology of Ireland (2nd Edition)	*Holland, C.H. and Sanders, I.S. (2009). The Geology of Ireland (2nd Edition). Dunedin Academic Press.*	• Bedrock Geology • Structural Geology • Quaternary Geology
Ordnance Survey Ireland (OSI) - Geohive	http://map.geohive.ie/mapviewer.html	• Historical Maps • Aerial Photos (1995, 2000, 2005, 2012) • Topographic Maps
Environmental Protection Agency (EPA) Map Viewer	https://gis.epa.ie/EPAMaps/	• Waste Facilities • River Network and Flow Direction • Protected Areas
Google Maps	https://www.google.co.in/maps?hl=en&tab=rl1	• Aerial Photos (2019)
Office of Public Works (OPW) Flood Maps	http://www.floodinfo.ie/map/floodmaps /?smau=iVVJQSqHPRMDv1lN	• River Flood Extent • Coastal Flood Extent • Past Flood Events
Bus Connects	https://busconnects.ie/media/1402/busconnects-cbc1-clongriffin-to-city-centre-final-for-web-low-res.pdf	• Background and scope for Bus Connects Core Bus Corridor Route 1 • Route Maps

3. Existing Ground Investigations

The following reports, available from GSI Geotechnical Data Viewer, indicate investigations completed with exploratory holes (EH) either on or near to the route.

Table 2. List of Relevant Ground Investigation Reports

GSI Ref.	Report Title	No. of EHs adjacent to site (GSI Ref. No.)	Year Completed	Soil conditions
121	Report on a Site Investigation at Ballydowd Bridge, Lucan	12 boreholes	1985	Dublin Boulder Clay - Rock (limestone) at about 6.5 m. Rockhead varied between 44.6m and 45.6m.O.D. using Poolbeg datum

GSI Ref.	Report Title	No. of EHs adjacent to site (GSI Ref. No.)	Year Completed	Soil conditions
160	Quarryvale		1996	Generally, Dublin Boulder Clay - Rock (limestone) within 3.4 to 6.8
3844	Pedestrian Bridge constructed over the N4	3 Trial Pits, Dynamic Probes, Plate Bearing Test	1999	Topsoil overlying what is presumed to be Limestone bedrock. No rock coring or proving was carried out. Allowable bearing capacity of 125 kPa derived from Probes.
524	Proposed road improvement scheme at Palmerston - Ballydowd.	BH 5	unknown	In borehole 5 the rock is overlain by 1.2 m of well graded gravelly sandy silt containing boulders. This is followed by 0.9 m of soft mottled grey sandy clayey silt containing some fine /medium gravel overlain by 1.4 m of firm mottled grey/brown silt with traces of fine sand and fine/medium gravel. Above this to ground surface is made ground consisting of firm/stiff grey/brown sandy silt with traces of clay and some gravel.
123	Palmerstown Retail Park	Four boreholes and two trial pits	1991	Generally, soft clayey fill below surface hardcore in places. At Borehole 1 the fill is underlain by soft grey brown silty slightly stony clay from 2.10 to 3.30 with firm to stiff grey stony clay over hard black very stony clay from 3.30 to 4.90. Fragments of grey limestone presumably the bedrock, were recovered from 4.90 to 5.40. In the remaining boreholes (2 to 4) the upper fill, which varies in thickness from 1.10 to 2.20, overlies firm mottled grey brown silty stony clay. Stiff to hard clays lie below this upper mottled clay with limestone just below 4.00 metres in each borehole indicating the fragments recovered presumed bedrock horizon.
956	Site investigation at Kylemore Road, Dublin Part of Chapelizod bypass three-span flyover bridge at Kylemore road	12 boreholes	1984	Fill varying in thickness from 2.50m in B.H.5A to 4.60m in B.H.1. This was followed in all cases by a stiff to hard gravelly silty clay with cobbles (boulder clay). In most boreholes a dark brown boulder clay was found under the fill and this faded into a grey/black boulder clay
953	Site Investigation at St Laurence Road (single -span flyover bridge)	12 boreholes 7 trial pits	1984	Beneath topsoil a layer of firm to stiff brown gravelly silty clay (glacial till) was found to depths ranging from 6.90m O.D. to 7.17m O.D. in the boreholes. This was followed in all cases by a sandy fine medium and coarse gravel with cobbles to depths ranging from 4.67m O.D. in B.H.1to 5.40m O.D. in B.H.12. The gravel was underlain by a stiff to hard dark brown to black gravelly silty clay with cobbles (boulder clay) and all boreholes ended in this material the maximum depth being 7.65m below existing ground level in B.H.11.
1048	Site investigation Longmeadows Ballyfermot (sewer replacement) where the new sewer crosses the proposed Chapelizod Bypass, close to First avenue and Liffey Street South	4 Boreholes	1986	Located in old city dump. Compact domestic waste from 4.6 to 11 m; overlying Glacial Till; overlying boulders/rock at 18 m. Site background: the site slopes from high ground down to the banks of the River Liffey and is in the old city refuse dump. Earthworks in association with the Chapelizod Bypass were underway and filling operations were being carried out at the borehole locations. The site appears be a present-day pitch and putt course.

GSI Ref.	Report Title	No. of EHs adjacent to site (GSI Ref. No.)	Year Completed	Soil conditions
955	Site investigation for footbridge over the new Chapelizod By-Pass to link the estate of St. Mary's Avenue (The Ranch) with the facility of the river Liffey	4 Boreholes	1989	In Boreholes Si and N1, bored at the lower level, a thin (0.50 to 0.70) layer of clayey fill was found overlying a hard-grey black silty stony clay (Boulder Clay). Boreholes S2 and N2 were bored from the top of the embankment slope. An increased thickness of fill was noted with 3.60m found in Borehole S2 and 1.40 metres in N2. In both holes the fill overlies stiff brown sandy gravelly clays which extend to depths of 7.90 and 4.00m in the respective boreholes. Hard black boulder clay is then encountered, and boreholes were terminated in this material at 9.50m and 8.00 metres.
2531	New Bridge at Island Bridge	8 boreholes	1987	0 to 3 m of Made Ground; overlying Glacial Till to about 18 m; overlying Limestone
7552	DART underground	9 boreholes along adjacent to Con Colbert and St John's Road West	2010	BHRC12: 1.2 of Made Ground overlying Glacial Till BHRC13: 2.6 m of road makeup and embankment fill; Glacial till with Gravel layers; Limestone/Mudstone at 21.5 m CCP02: 0.4 m of Made Ground; Glacial till to 1.8m; Glaciofluvial Gravels to 13.5 m (termination) BH03: Glaciofluvial Gravels to 26 m; Limestone BH04: 5.7 m of clayey gravels; Glaciofluvial Gravels to 24.5 m; Limestone CCP05: Pavement structure to 0.8 m; Glaciofluvial Gravels to 13.5 m (termination) CP09: Made Ground to 2 m; brown clay to 3 m; Glaciofluvial Gravels to 16 m (termination) CP11: Made Ground to 4.1 m; slightly peaty silt to 5.4 m, loose sand to 8.5 m, Glaciofluvial Gravels to 17 m (termination) CP13A: Made Ground to 4 m; Glaciofluvial Gravels to 14 m

Source: < GSI Geotechnical Data Viewer >

An assessment of ground and groundwater conditions has been completed using available information taken from published geology and existing ground investigation reports. Findings from this assessment are used to characterise the ground conditions in Section 6 and provide preliminary geotechnical recommendations in Section 7.

4. Field Studies

No field studies have been undertaken for this report.

5. Site Description

5.1 Route Overview

Sections 5.1.1 to 5.1.4 detail the proposed route alignment at the time of drafting of this report. The route alignment is shown in Appendix A.

5.1.1 Lucan to City Centre Overview

The Lucan to City Centre Core Bus Corridor (CBC) commences at Junction 3 on the N4 and is routed via the N4 as far as Junction 1 (M50), and via the R148 along the Chapelizod Bypass, Con Colbert Road, St John's Road

West and Frank Sherwin Bridge, where it will join the prevailing traffic management regime on the North Quays. Priority for buses is provided along the entire route, consisting primarily of dedicated bus lanes in both directions, with alternative measures proposed at particularly constrained locations.

5.1.2 Junction 3 to M50 Junction (Junction 7) - N4 Lucan Road

It is proposed to commence this corridor at Junction 3 on the N4 Lucan Road. It is intended to retain the existing bus lane layout on the overbridge. It is proposed to extend the existing bus lane on Ballyowen Road as far as the junction with Lucan Road. The junction will be modified to accommodate this bus lane and improved cycle facilities. On the Lucan Road it is proposed to extend the existing bus lane as far as the existing roundabout junction. A new cycle track is also proposed to be provided. To accommodate this change it is proposed to use limited land take from the adjacent green space.

On the westbound off slip ramp, it is intended to provide a continuous bus lane from the N4 to the junction with Ballyowen Road. It is proposed to widen the off-ramp on both sides to provide for this bus lane and a new cycle track. It may require some land take to the south of the off ramp. On a limited section of this route, a shared footway/ cycleway will be provided to reduce the requirement of land take in this area.

On the N4 it is proposed to maintain the existing city centre bound bus lane. A new segregated cycle track is also proposed on this side of the existing road requiring some limited land take from the adjacent green space. For outbound traffic it is intended to retain the existing segregated general traffic lane and to introduce a bus lane to east of the Ballyowen Lane junction. This will tie back into the existing bus lane to the east of the existing footbridge adjacent to Mount Andrew Court. This existing footway and cycleway facility will be upgraded. The revised layout will require some limited land take from adjacent properties.

At the Fonthill Road Junction, it intended to retain the existing bus lane and bus stop facilities on the eastbound off ramp and link the new cycle way to the existing cycle network at the junction. It is proposed to provide a new toucan crossing at this section of the junction, and to provide a new bus lane on the eastbound off slip road. It is also proposed to provide a bus lane in each direction on the overbridge. From the Fonthill Road junction, cyclists are directed onto the Lucan Road through the Quarryvale and Brooklawn area.

On the M50 junction, it is proposed to maintain the bus lane with two general traffic lanes in both directions through the junction. Cyclists will be directed over the existing foot/cycle bridge over M50 on to the Old Lucan Road.

M50 Junction (Junction 7) to Con Colbert Road and Chapelizod Bypass Between the M50 Junction and Kennelsfort Road Junction, it is proposed to maintain a single bus lane and two general traffic lanes on the city centre bound route and one general traffic lane for through traffic & a bus lane on the outbound route. It is intended to modify the Kennelsfort Road Lower junction to improve pedestrian crossing facilities, and to provide new cycling facilities along Kennelsfort Road. Cyclist will be directed along Lucan Road and will be linked to an existing shared footway/cycleway located on the north of the Chapelizod Bypass. This cycle route links to the R112 Lucan Road at Glenaulin Drive.

Between Kennelsfort Road Junction and Con Colbert Road Junction, it is proposed to maintain a single bus lane and two general traffic lanes in both directions. It is intended to provide a bus lane on the R112 Kylemore Road on-ramp road. It is also proposed to provide new bus stop facility and pedestrian footbridge serving Chapelizod Hill Road. Some limited land take will be required to facilitate these works. It is proposed to provide cycle tracks on both the on and off ramps at Con Colbert Road. Similarly, cycle lanes can be provided on Memorial Road.

5.1.3 Con Colbert Road to Frank Sherwin Bridge at John's Road West

Between the Con Colbert Road Junction and the South Circular Road Junction continuous bus lanes, two general traffic lanes and cycle tracks will be maintained in their current configuration. The existing South Circular Road Junction is proposed to be modified to accommodate additional bus lane and cycle track. Between the South Circular Road Junction and the junction into the Heuston South Quarter Development continuous bus lanes and two general traffic lanes will be maintained in their current configuration.

Between Heuston South Quarter Development Junction and the Frank Sherwin Bridge one bus lane and one single general traffic lane is proposed to be provided on both inbound and outbound directions. Cycle tracks are intended to be provided in both directions. This new arrangement will be accommodated by widening the road into the existing central median. It is proposed to retain the existing taxi rank at Heuston Station and to locate the cycle track between the footway and the taxi rank spaces. The proposed works tie into the road network at Wolfe Tone Quay and Victoria Quay.

5.2 Topography

The topography of the site is flat to gently undulating with elevations decreasing from west to east from approximately 50 m Ordnance Datum (OD) at Junction 3 M50 to approximately 10m OD at Frank Sherwin Bridge. From the Chapelizod Bypass to the city centre the elevation is generally between 10 and 20 m OD. The generally topography of the route is shown in Appendix A

5.3 Geology

A review of the sites underlying geology was completed using available data derived from the GSI spatial data viewer. Appendix A provides figures of the recorded superficial and solid geology that underlies the route. A brief summary is provided below.

The GSI Quaternary Sediments and Teagasc Soils Maps indicate the site is underlain by the following deposits:

Made Ground

According to the Teagasc Soils map almost the entire route is mantled by deposits of Made Ground.

Alluvium Deposits

The GSI Teagasc Soils and Quaternary Sediments map indicates a band of Alluvium flanking the River Liffey which potentially underlies the Chapelizod Bypass.

Glaciofluvial Deposits

The GSI Quaternary Sediments map indicates a deposit of glaciofluvial sand and gravel, located in the Islandbridge area. Deposits are described as being derived chiefly from Carboniferous limestone.

Till Deposits

The GSI Quaternary Sediments indicates the route is generally underlain by Glacial Till deposits known colloquially as Dublin Boulder Clay. Deposits are described as being derived chiefly from Carboniferous limestone.

5.3.1 Bedrock

The GSI Bedrock Geology map (scale 1:100,000) indicates the site is underlain by a sequence of Carboniferous limestone rocks comprising the following formations:

Lucan Formation

The route is generally underlain by the Lucan Formation comprising of dark-grey, argillaceous, cherty, specular micrites and shales, with horizons of graded, skeletal limestones containing ooids and other shallow water grains.

Tober Colleen Formation

This extends for approximately 750 m near the western approach to exit 3 of the N4.

The Tober Colleen Formation comprises dark-grey, calcareous, commonly bioturbated mudstones and subordinate thin micritic limestones.

Waulsortian Limestones

This extends for approximately 1 km across near the eastern approach to exit 3 of the N4.

The formation is described as massive unbedded lime-mudstone.

5.3.2 Structural Geology

There is a single north-south striking fault, which bisects the route along its' western extent. This is part of a more complex group of large-scale faults that are located to the north of the route.

Structural measurements taken from surrounding outcrops indicate bedding dips of between 5 and 30° with dip directions typically towards the east and south-east.

5.4 Hydrology

Appendix A provides figures of the Surface water features that are encountered along the route.

5.4.1 Surface Water Features

The GSI Surface Water Features map indicates the following:

- The River Liffey runs adjacent to the north of the route for the entirety of the alignment
- The River Camac runs adjacent to the south of the route from approximately Con Colbert Road. The culverted river crosses the route near the extent of St John's Road West.

5.4.2 Flooding

The Office of Public Works (OPW) Flood Maps indicates the route is not generally liable to flooding. However, there is a Low Probability (1 in a 1000 chance per year) chance of the River Camac flooding which would affect the extent of the route at Saint John's Road West.

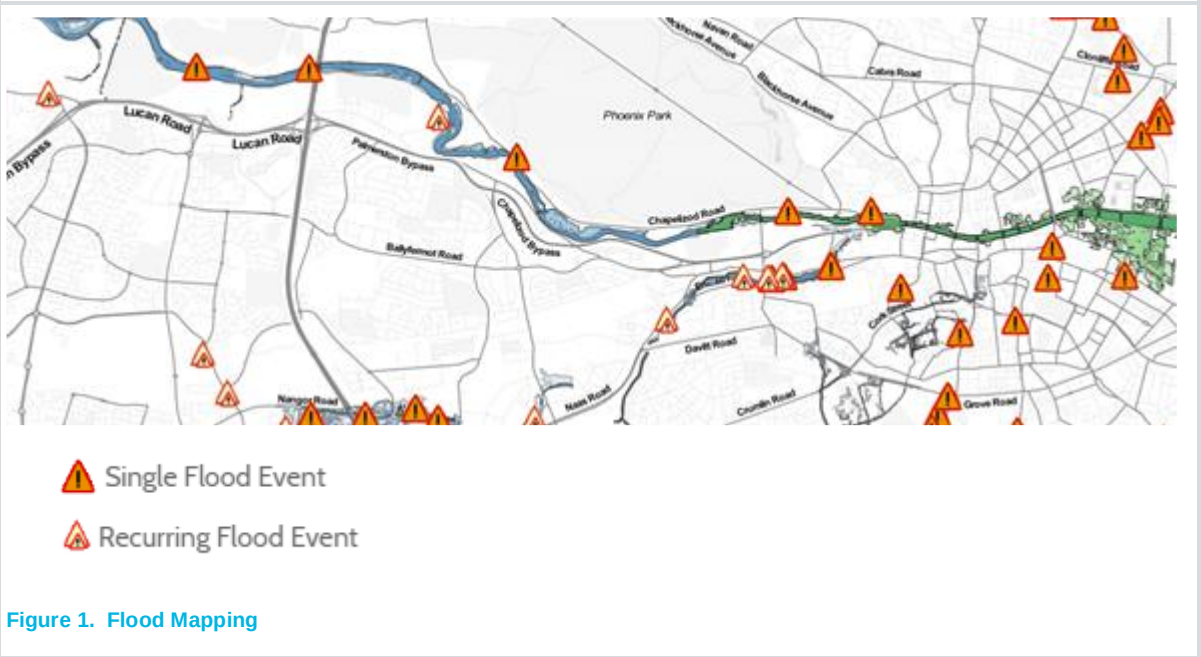


Figure 1. Flood Mapping

According to the OPW Past Flood Records there are multiple flooding events associated with the River Camac and Liffey within 500 m of the site. The flooding was localised and didn't appear to impact the proposed route.

5.5 Hydrogeology

Appendix A provides figures of the hydrological features that are encountered along the route and described in the following sections.

5.5.1 Aquifer Classification

According to the GSI Groundwater Resources (Aquifer) map, the Lucan Formation which predominantly underly the site, are classified as Locally Important Aquifers (Ll). These formations are moderately productive only in local zones.

Most of the subsoil permeability across the route and surrounding area is classified as low. Exceptions are as follows:

- N4 and M50 junction: this has not been classified
- Irish War Memorial Gardens near Con Colbert road: This is classified as high.

A figure showing the Ground Water recharge is provided in Appendix A.

The site does not lie within a Group Scheme or Public Supply Source Protection Area.

5.5.2 Groundwater Vulnerability

The GSI National Groundwater Vulnerability map for the route is provided in Appendix A. The map indicates that the groundwater vulnerability is variable. The route is generally “Low” to “High” with “Extreme” pockets also encountered.

5.5.3 Karst Landforms

According to the GSI Groundwater Karst Data map (Appendix A) there are no karst features recorded within 1 km of the route.

5.6 Man-Made Features & Historical Development

5.6.1 Mining and Quarrying

According to the GSI Active Quarries and Mineral Locality maps (Appendix A), there are no quarrying activities within 1 km of the route.

A disused, possibly now infilled, non-metallic quarry, which produced limestone flags, is located within 300 m south of the N4 between junctions 3 and 4.

A historical iron and lead mill are located south of the Liffey in Palmerston within about 1 km of the site.

5.6.2 Statutory Protected Sites

According to the EPA Protected Areas map and the GSI Irish Geological Heritage Sites map, the site does not lie within a statutory protected area.

5.6.3 Historic Maps and Aerial Photography

A review of historical maps and contemporary aerial photographs available from the OSI (Geohive) and Google Maps was completed. Findings of this review are summarised in the following table:

Table 3 Review of historical maps and aerial photographs

Year	Description
Historic Map 6” 1837-1842 (OSI)	The eastern extent of the site between Aston Quay and Kilmainham shows some signs of development during this period, which includes an iron works, the Kings Bridge, various hospital buildings, a Royal Artillery Barracks - including a ‘Magazine’, and Bully’s Acre Grave Yard. Four roads are recorded as coinciding with the line of the proposed site in this area; Steeven’s Lane, Military Road, Long Lane and Circular Road. Further to the west, between Kilmainham and Lucan, the site is shown to predominantly comprise agricultural land with occasional wooded areas, and intermittent residential and farm buildings connected by a various roads and tracks. Larger developed areas are recorded at Kilmainham and Palmerston. These areas, which are generally isolated from surrounding development, are typically shown to comprise an assortment of small to medium sized buildings, gardens, wooded areas, and interconnecting tracks. An unnamed road follows the route of the existing Lucan Road, coinciding with the line of the proposed site at Chapelizod, Palmerston and to the west of the N4 / M50 Interchange. At least three watercourses are recorded as crossing the site; the River Liffey and Cammock River at the eastern end of the site, and an unnamed watercourse at Kilmainham. It should be noted that at the location of the site the Cammock River is not shown on any subsequent historic or contemporary maps, with OPW records indicating that it has been culverted beneath the site. At Palmerston, a feature described as ‘stream underground’ is recorded approximately 100m to the south of the site. Three other water features are also recorded on the map within the vicinity of the site; a well to the south of Islandbridge, a pump at Chapelizod, and a pond between Palmerston and Lucan. Several gravel pits and quarries are recorded throughout the site, the most significant of these being located in the vicinity of Quarryvale and Cursis Stream approximately 800m to the west of the N4 / M50 Interchange.

Year	Description
Historic Map 25" 1888-1913 (OSI)	Further development in the eastern extent of the site is shown, with the most significant changes being the construction of the Kingsbridge Railway Terminus and adjacent Tramway Depot, St James's Brewery, the Great Southern & Western Railway Line and St. Johns Road. The building layout at the iron works appears to have changed and the area is no longer named, a latrine and gun platform are shown at the north end of the Kings Bridge and the Royal Artillery Barracks have been renamed Ordnance Depot and Island Bridge Barracks with an 'Ancient Monument' now recorded to the south. A tramway is recorded as passing over Kings Bridge, and Long Lane is no longer recorded, with the area now comprising railway sidings associated with Kingsbridge Railway Terminus. Various residential and religious buildings are now shown running adjacent to the railway line on the south side with the Inchicore Railway Works shown approximately 400m to the south west of the site. Further to the west the land surrounding the site remains relatively unchanged with the only significant development comprising a scavenging depot to the west of the Kingsbridge Railway Terminus, a residential development in Kilmainham and Fonthill Power Station approximately 600m to the north west of the existing N4 / M50 Interchange. The eastern section of the unnamed road is now recorded as St Laurence Road and the Dublin & Lucan Electric Railway is recorded as passing over the Chapelizod Bridge and following the line of Lucan Road heading west. Two minor bridges and three weirs are now recorded along the route of the unnamed watercourse at Kilmainham. The area surrounding the site between the existing R833 Sarsfield Road and the River Liffey is now recorded as 'Liable to Flood', with four potential drainage trenches shown as running approximately north to south. The feature marked 'Stream under Ground' is no longer shown; however, the map appears to indicate that a watercourse may intersect the line of the proposed site to the north east where the existing R148 Chapelizod Bypass passes over the R112 Kylemore Road. An increased number of water features comprising wells, pumps and springs are now recorded throughout the site, predominantly to the west of Chapelizod. A large proportion of the gravel pits and quarries previously recorded are no longer shown or are now shown as disused, with only three new gravel pits being recorded within the vicinity of the site. The large quarry in the vicinity of Quarryvale and Cursis Stream is now shown as disused, with some residential development now being recorded in the surrounding area.
6" Cassini 1930s (OSI)	Kings Bridge in the eastern end of the site is now recorded as Sean Heuston Bridge, and the site of the formerly named Phoenix Iron Works is now recorded as a Printing Works. The latrine, gun platform and Tramway Depot are no longer recorded. The Royal Hospital is now recorded as Garda Siochana Headquarters and a Post Office Factory and Depot are also now recorded. The Island Bridge Barracks are now recorded as Clancy Barracks and the unnamed road to the west of St Laurence road is now named Lucan Road. A factory is recorded directly to the west of Bully's Acre Burial Ground. Some further development is recorded further to the west of the site including a Burial Ground and Gardens at Kilmainham, a chocolate factory at Palmerston, and 10kV power lines crossing the line of the proposed site at Chapelizod and Palmerston. A 38kV powerline is also recorded as crossing to line of the proposed site approximately 200m to the west of the N4 / M50 Interchange. The Dublin & Lucan Electric Railway is no longer recorded, and the area of the scavenging depot is now recorded as a football ground. Some potential realignment works are recorded at the unnamed watercourse in Kilmainham. The three weirs are no longer shown with a larger crossing is now recorded further to the north. An embankment is now recorded to the north of the existing Sarsfield Road which is shown to intersect the line of the proposed site to the north of the existing Liffey Gaels GAA Club Grounds. It is likely that this embankment was constructed as a flood prevention measure, as the area to the north is still recorded as 'Liable to Floods'. It should be noted that no other water features appear to be recorded on this map. The majority of gravel pits and quarries are no longer recorded, with only three features now being recorded and shown as pits.

Year	Description
Aerial 1995 (OSI)	It should be noted that the 1995 aerial photography is in black and white and of poor resolution. The most significant developments at the eastern end of the site appears to be the construction of the Frank Sherwin Bridge, the dualling of St Johns Road - which is now recorded as St Johns Road West / R148 Chapelizod Bypass, and the construction of a significant junction passing over the existing Dublin–Cork Main Line to the south of Islandbridge. Kingsbridge Railway Terminus was renamed Heuston Station in 1966, Steevens Hospital is recorded as closing in 1987 and subsequently becoming the headquarters of the Health Service Executive, and the Garda Siochana Headquarters is recorded as becoming the Irish Museum of Modern Art in 1984. Bully's Acre Grave Yard is now recorded to be covered by trees. To the west of Kilmainham significant development is recorded, comprising the construction of the R148 Chapelizod Bypass, the M50 Motorway, N4 Lucan Road and the N4 / M50 Interchange. This development includes several structures which pass over St Laurence's Road, Chapelizod Hill Road, the R112 Kylemore Road. Three footbridges are also recorded at Kilmainham, Palmerston and to the west of the N4 / M50 Interchange. Significant residential development is recorded at Kilmainham, Chapelizod, Palmerston and to the south west of the existing Liffey Valley Shopping Centre, with potential commercial / industrial development also being recorded close to the site at Chapelizod and Palmerston, along with Hermitage Golf Club close to the western end of the site. The Burial Ground at Kilmainham is no longer recorded, neither are the 10kV and 38kV power lines or the unnamed watercourse – which now appears to have been culverted beneath the site. Kings Hospital School is now shown to the north west of the N4 / M50 Interchange and the Fonthill Power Station building is still visible; however, a welding supply shop is recorded as being at this location since the 1970's. The embankment or potential drainage trenches to the north of the existing Sarsfield Road are no longer visible with the R148 Chapelizod Bypass now shown to pass through the area previously recorded as 'Liable to Floods'. The unnamed watercourse which was previously recorded as intersecting the line of the proposed site where R148 Chapelizod Bypass passes over the R112 Kylemore Road is no longer recorded; however, an exposed section is visible to the west, potentially indicating that the watercourse has been culverted over and/or re-directed. There are no gravel pits or quarries visible. The N4 Lucan Road is now shown immediately to the north of the quarry previously recorded at Cursis Stream. This quarry now appears to have been infilled and is no longer visible.
Aerial 2000 (OSI)	No significant development is recorded at the eastern end of the site between Aston Quay and Palmerston to the west, with the only features of note being some minor remodelling works at the entrance to Heuston Station along with some minor residential development further to the west. The area to the south of the site and west of the N4 / M50 Interchange shows significant development, with the construction of various residential and commercial buildings being recorded as underway, including the existing Liffey Valley Shopping Centre along with significant junction realignment works at the existing Liffey Valley Interchange.
Aerial 2005 (OSI)	Only minor development is recorded at the eastern end of the site between Aston Quay and Palmerston, including minor realignment of the carriageway at the entrance to Heuston Station, some minor residential and commercial development further to the west and a pitch and putt course to the north of the R833 Sarsfield Road / St Laurence's Road Junction. The construction of various residential and commercial buildings previously recorded to the south of the site and to the west of the N4 / M50 Interchange is now shown as complete with no other significant changes noted.
Aerial 2019 (Google Maps)	Some development is recorded at the eastern end of the site, most notably office buildings directly to the west of the R148 Chapelizod Bypass / Military Road junction, along with residential redevelopment of the former Ordnance Depot & Clancy Barracks and the factory to the west of Bully's Acre Burial Ground. Further to the west significant development is recorded at the N4 / M50 Interchange, which has now undergone considerable improvement works. The footbridge directly to the west has been replaced and a new footbridge is recorded to the south of the Hermitage Golf Club and the Hermitage Medical Clinic is now recorded directly to the east of the previously named Fonthill Power Station. A plant machinery and equipment supplier are recorded to the east of the R112 Kylemore Road and an unnamed depot or yard is recorded to the north of the Liffey Valley Interchange. There are four petrol stations recorded along the proposed line of the site; three on the R148 Chapelizod Bypass, and one on the N4 Lucan Road.

5.6.4 Possible Sources of Contamination along the route

The presence of Made ground along the route means the possibility of contamination cannot be discounted. Samples for contamination testing shall be taken as part of the intrusive ground investigation.

EPA mapping indicates the following along the route:

- IPPC Facility: Diageo Ireland; St James Gate.

The Geohive map viewer indicates the following:

  - Historical gravel pit quarries to the north and south of the N4
  - Historical Power Station north of the N4 near Hermitage Golf Course

There is the possibility for contamination associated with the railway yard at Heuston Station and petrol stations along the route.

5.6.4.1 Historical geotechnical reports with reference to waste ground

Historical report GSI reference 1091 reported on a site investigation in Longmeadows Ballyfermot (sewer replacement) where the new sewer crosses the proposed Chapelizod Bypass, close to First avenue and Liffey Street South. The site was in the old city dump.

Compact domestic waste was encountered from 4.6 to 11 mbgl; overlying Glacial Till; overlying boulders/rock at 18 m. At the time of the investigation in 1989, the site sloped from high ground down to the banks of the River Liffey. Earthworks in association with the Chapelizod Bypass were underway and filling operations were being carried out at the borehole locations. The site appears be a present-day pitch and putt course.

6. Ground Conditions

Based on a review of the historical reports described in section 2.1. and published literature, typical idealised soil conditions to be anticipated along the route as follows:

- Made Ground: Made ground of various composition and thicknesses is to be expected along the entire route; overlying
- Glacial Till: Glacial Till consisting of sandy gravelly silt/clay with low to medium cobble content; occasionally soft to firm to 0.5 m; typically, firm / firm to stiff to maximum of 2.0m (**brown Dublin boulder clay**); and generally underlain by stiff / very stiff / hard soil**.** High cobble content and occasional boulders are typical below 2.0m bgl. (**black Dublin boulder clay).** Glacial Till is anticipated from the western extent of the route to approximately Con Colbert Road.
- Glacial and Glaciofluvial gravels: Gravels were encountered in Report 7552 (adjacent to Con Colbert and St John's Road West); however, they were generally overlain by layer of glacial till.

6.1 Made Ground

Made ground should be expected throughout the route and may vary from a thin layer (typically surfacing materials) to several metres of variable materials.

Highway fill is associated with existing roads or areas of hard standing; it typically comprises general fill of reworked clay/silt/sands and selected fills formed by silty sandy gravels.

Made ground consisting of variable soil composition and waste may be present when widening for additional land take. The possibility of contaminated ground cannot be discounted and should be investigated as part of the intrusive investigation.

Made ground is typically not considered a suitable foundation material and is typically excavated and replaced as part of the construction works. Exceptions may be made for low risk lightly loaded at grade construction where investigation shows that the made ground conditions are favourable.

6.2 Alluvium Deposits

There is the possibility for alluvial soil along the route at locations adjacent to the River Liffey and River Camac.

These are recent deposits of waterborne clay, silt, sand and gravel deposited close to watercourses, with the nature of the soil varying laterally and with depth. For the purpose of classification, alluvial deposits are generally split into two types:

- Cohesive (fine grained) alluvium: deposits mainly comprising silts and clays, sometimes peaty/organic, which were frequently soft in consistency.
- Granular (coarse grained) alluvium: deposits mainly comprising sands and gravels, occasionally with low cobble content, and frequently of loose relative density.

In many cases, the alluvial clays and silts are inter-bedded with alluvial sands or gravels.

6.3 Till Deposits

The Glacial Till is typical of the drift cover in much of the Dublin area, comprising boulder clay, a lodgement till deposited during the last ice age, about 10,000 years ago. Farrell et al. (1995) made the distinction between the 'Brown Boulder Clay' and the 'Black Boulder Clay', stating that the Brown Boulder Clay was a weathering product of the Black Boulder Clay, and is broadly similar to it in terms of particle size distribution.

The brown Dublin boulder clay generally consists of:

- sandy gravelly silt/clay with low to medium cobble content; occasionally soft to firm to 0.5 m; typically, firm / firm to stiff to maximum of about 3 m
- Plasticity Indices ranging from Non- Plastic to about 15
- An undrained shear strength of approximately 50 kPa is typically achievable assuming it is not excessively weathered, corresponding to a CBR % of about 2.0.

The black Dublin Boulder clay is found underlying the brown Dublin Boulder Clay and consists of:

- Generally stiff / very stiff / sandy gravelly silt/clay with high cobble content and occasional boulders are typical below 2.0m bgl.
- SPT blow counts are generally greater than 30 increasing to refusal within 1-2 m from the top of the stratum.
- BS8002 (British Standards Institute, 1994) can be used to relate plasticity index to θ'crit, the critical state angle of shearing resistance. Adopting a plasticity index of 15% for soils at greater than 1 m depth, Table 2 of BS8002 provides a "conservative" value for θ'crit of 30°. The relationship published by Knappet & Craig (Craig's Soil Mechanics, 8th Edition, 2012) provides a θ'crit of approximately 32°.

  Published case studies of construction in Dublin Boulder Clay report peak values of the angle of shearing resistance of 30 - 38°. The gravel content of the soils would provide additional frictional resistance, due to interlock, and there is likely to be some long-term effective cohesion.

6.4 Glaciofluvial Deposits

These deposits are the result of glacial meltwater flowing along the valleys of the main rivers or historical rivers in the area. A previous investigation has encountered relatively thick deposits of this predominantly granular material along Con Colbert Road. The deposits vary in thickness and are often inter-bedded with other ground types (typically glacial till).

The glaciofluvial deposits encountered along Con Colbert Road generally are overlain by made ground or glacial till which is more likely to be the route sub-formation.

Where glaciofluvial gravels are located near surface, this may negate the need for capping in the road structure providing they display a CBR greater than 15%.

6.5 Bedrock

The depth to bedrock varies from about 3 m to over 20 m in the historical geotechnical reports. There are bedrock outcrops in some locations north of the Chapelizod Bypass.

7. Preliminary Engineering Assessment

7.1.1 General

The following sections provide **preliminary** geotechnical recommendations for the proposed route, based on the currently available published information.

Geotechnical designs should be conducted in compliance with Eurocode 7 Part 1 and its Irish National Annex (National Standards Authority of Ireland, 2005a, and 2005b): abbreviated as EC7.

7.1.2 Classification and Acceptability for Re-use

7.1.2.1 General & Selected fills

General granular and cohesive fills will be classified in accordance with Table 6/1and Table 6/2 of TII Specification for Road Works (CC-SPW-00600 series). Selected fills will be classified in accordance with relevant sections of TII CC-SPW.

7.1.3 Re-use

There is not expected to be significant amount of reuse of material along the route due to a lack of proposed cut areas.

An assessment of the reusability of material will be made as part of the geotechnical reporting.

7.1.4 Engineering Fill Materials

Engineering Fill will be required on this project for the construction of embankments and retaining structures.

The primary types of fill materials required have been identified as follows:

- General Granular Fill (Class 1)
- General Cohesive Fill (Class 2) – consisting of fine–grained Glacial Till of adequate remoulded undrained shear strength. It is anticipated that this will require importation due to the lack of borrow areas along the route.
- Selected well graded granular material (Class 6A) –for use below water if required.
- Selected uniformly graded granular material (Class 6C) - for use as a starter layer if required.
- Selected granular fill (Class 6N1) –for use as a fill to structures.
- Selected granular fill (Class 6N2) –for use as a fill below structures.

The above granular fills will be formed by natural sand and gravel, crushed rock or recycled materials, imported from quarries in the locality.

7.1.5 Embankments

Embankments will be constructed with acceptable fill material derived generally from off-site sources and where available from on-site borrow areas. Embankment slopes are generally constructed at an inclination of 3H:1V for embankments less than 6 m except where constraints dictate a steeper slope of 2H:1V.

At the geotechnical reporting stage, analysis will be performed for both short term and long-term conditions as appropriate to confirm adequate stability of proposed side slope angles. Analyses will be carried out, using specialist software, applying two-dimensional Limit Equilibrium Methods in accordance with Eurocode 7 using characteristic design parameters. The design is considered safe if the calculated Factors of Safety for Combination 1 and 2 are both greater than unity (i.e. the Degree of Utilisation is less than 100%). Where the resultant factor of safety does not exceed this target, the design will be considered unacceptable.

The critical section will generally occur at the highest section of the embankment provided that ground and/or groundwater conditions do not differ significantly along the length of the embankment. In such cases more than one typical design section may be required for consideration of slope stability for the whole earthwork area.

Drainage measures will ensure significant surface water flow is not directed into the embankment, potentially causing softening of the fill material and increasing porewater pressure.

7.1.6 Cuttings

Cuttings for widening are anticipated to be generally shallow along the route. Cuttings at a maximum slope angle of 2H:1V should be achievable to most soil types. The presence of fine-grained alluvium or water bearing soils may require flatter slopes.

Slope stability analyses will be carried out in a similar manner to that described above in relation to embankments.

Cuttings shall incorporate appropriate in-slope drainage to manage and control water, including groundwater issues onto slope faces: e.g. herring-bone drains, counterforts and granular surface drainage layers. The sources of seepage and areas of potential seepage shall be observed for a period before applying topsoil, as they may not become active until sometime after exposure especially in periods of sustained dry weather.

Where there is insufficient room for permanent cuttings, consideration may be given to retaining walls, embedded retaining walls or soil nailing.

7.1.7 Pavement Design

The preparation of the subgrade and the construction of the pavement foundation shall comply with the Specification for Road Works (National Roads Authority, 2011)

Areas of made ground and soft, highly compressible or organic soil will not be suitable as subgrade and will be excavated as part of the construction works.

The performance of any subgrade in a road pavement depends on its strength in both the short and long term. Subgrades which are of low plasticity clayey or silty soils are highly susceptible to changes in moisture content. Glacial Till formations that are not adequately protected are subject to deterioration. Prior to carrying out a ground investigation, an average equilibrium CBR of 2.5% could be assumed, requiring a capping layer thickness of 400 mm, with 150 mm sub-base layer for new road construction (TII DN-PAV-03021).

Laboratory CBR testing of silty boulder clay soils can often provide unexpectedly low results, often attributed to dilatancy, migration of water from granular lenses, or excess pore water pressures within the remoulded specimen following its preparation. In addition to laboratory CBR tests, the ground investigation will include in-situ measurement of CBR using the Dynamic Cone Penetrometer.

Quality control testing shall be undertaken during construction, to confirm that the CBR of the exposed subgrade conforms with the design value. The testing shall be conducted using the Dynamic Cone Penetrometer: test method and frequency as described in Interim Advice Note 73/06 (Highway Agency, 2009)

It is important that, before construction of pavements, the excavated surface should be proof-rolled by at least two passes of a smooth-wheeled vibratory roller having a minimum mass per metre roll width of 2,100 kg, or other suitable method agreed with the Designer. Any soft fine-grained layers should be removed, or the capping thickness varied to be consistent with the quality of the exposed subgrade.

7.2 Structures

The following is a list of structures proposed at the time of writing this report.

- Potential retaining wall to facilitate widening along the N4 between Junction 3 to 5
- Potential cut slope/retaining system to form Greenway in Hermitage Golf Club
- Access Ramps and Replacement bridge near Liffey Valley Shopping Centre
- New Ramps to Pedestrian Bridge at Kennelsfort Road Lower
- New Ramps and steps to bus stops to Chapelizod Bypass from Chapelizod Hill Road

7.2.1 Foundations

An allowable bearing pressure of 150 kPa may be achievable in brown Dublin Boulder Clay provided the minimum acceptable undrained shear strength of the soils at the excavation base is 80 kPa. The Glacial Till in the Dublin area generally shows an increase in strength with depth.

Allowable bearing pressures in excess of 250 kN/m^2 may be feasible on the black Dublin boulder clay.

The excavation level required for each foundation should be confirmed by inspection and in-situ testing at the base of the excavation.

ST1 (lean mix) concrete should be used to backfill the excavation to the underside of the structural concrete foundation to minimise softening of the moisture susceptible Glacial Till. The alternative approach of using a well-graded, well-compacted granular fill could be problematic given that the confined base area of the foundation excavation would restrict the operation of compaction equipment.

Horizontal loads will be resisted by a combination of passive pressure on the vertical faces of the foundations and friction between the bottom of the foundation and the supporting soil. The passive pressure and frictional resistance can be estimated using a characteristic angle of shearing resistance of 30° for the Glacial Till and characteristic weight density of 21.5 kN/m^3.

Piled foundations may be considered feasible for heavily loaded structures or areas where excavation for shallow footings are considered uneconomical.

In areas of relatively shallow bedrock, piles may be designed as end bearing, deriving most of their capacity from a rock socket in the underlying bedrock. In areas of deeper bedrock, friction piles are achievable with the piles deriving most of their capacity through shaft adhesion with the Glacial Till.

A geotechnical investigation consisting of cable percussion boreholes in the Glacial Till and follow on rotary Geobor S coring in the very stiff to hard Glacial Till and underlying bedrock will be carried out to inform pile design.

7.2.2 Retaining Structures

Where the construction of stable full height embankment side slopes is not possible due to space constraints, strengthened earthworks or retaining walls (gravity or cantilever) may be required.

Similarly, where a stable cutting slope is not possible due to lack of land take, retaining walls (gravity, cantilever or embedded) or stabilisation methods such as soil nailing may be considered.

A characteristic angle of shearing resistance of 30° and characteristic weight density of 21.5 kN/m^3 can generally be adopted for the Glacial Till when calculating active and passive pressures, and wall and base friction.

The earth pressures arising from imported backfill to structures should be based on its measured properties. A characteristic angle of shearing resistance of 35° is appropriate for well graded, well compacted, granular material along with a characteristic weight density of 20 kN/m^3.

Annex C of EC7 (National Standards Authority of Ireland, 2005a) provides charts and equations to allow calculation of earth pressure coefficients for various design values of angle of shearing resistance, wall friction and backfill slope angle.

Unless drainage is installed, and maintained during the life of the development, structures should also allow for hydrostatic pressures arising from groundwater. Additional lateral pressures caused by loadings on the retained surface, and by compaction equipment used during backfilling, should be considered in the stability and structural design of retaining structures.

7.2.3 Soil Chemistry

Table C1 of BRE Special Digest 1 (Building Research Establishment, 2005) will be used to determine the Design Sulfate (DS) Class and the class necessary to meet the Aggressive Chemical Environment for Concrete (ACEC) requirements.

Part D of BRE Special Digest 1 provides guidance on the design of underground cast in-situ concrete: the maximum free-water / cement ratio, minimum cement content and cement types.

7.3 Contaminated Land

The possibility of contaminated ground cannot be discounted due to the presence of Made Ground and historical land use along the proposed route: reference Section 5.6.4.

Contamination testing and Waste Acceptance Criteria testing will be carried out as part of the geotechnical field investigation.

8. Geotechnical Risks

8.1 Geotechnical Category

The site has been designated a Geotechnical Category 2 project in accordance with the TII Publication No. DN-ERW-03083, Managing Geotechnical Risk.

8.2 Geotechnical Risk Register

This section contains the initial Geotechnical Risk Register established for the scheme. The register highlights the geotechnical design risks to be addressed in the design and construction, the consequence of those risks together with the measures taken to mitigate those risks. The identified risks will be taken forward and addressed within the preliminary and detailed design, and within the construction information.

Table 4 Geotechnical Risk Assessment

Risk Reference	Description of Risk	Initial Risk Rating (See matrix below)			Consequence	Control Measures to Reduce Risk	Residual Risk Rating (See matrix below)		
		P	I	R			P	I	R
1	Difference between assumed ground conditions and those encountered during construction.	4	5	20	ULS failure of the bridge or retaining walls. Potential for higher settlement magnitudes and/or settlements of a more time dependent nature. Increased maintenance.	Ground Investigation to determine soil conditions along route. Inspection of formation by Geotechnical Engineer to verify design assumptions. Proof rolling of formation and removal of any soft spots identified. Preloading of sub-soil and review of settlement monitoring data and hold period. Conservative parameters adopted for design.	1	5	5
2	Potential presence of fine-grained compressible material at depth resulting in longer term settlement	4	5	20	Long term settlement impact to structures due to consolidation settlement of fine-grained layers	Ground Investigation to determine soil conditions at settlement sensitive structures. Preload embankment constructed with review of settlement monitoring data and hold period to ensure majority of settlement complete and anticipated residual settlement negligible.	1	5	5

Risk Reference	Description of Risk	Initial Risk Rating (See matrix below)			Consequence	Control Measures to Reduce Risk	Residual Risk Rating (See matrix below)		
		P	I	R			P	I	R
3	Presence of Made Ground	4	5	20	Scheme located within heavily developed urban area. Soft/poorly compacted ground resulting in subsidence. Variable ground conditions over relatively small areas. Differential settlement. Risk of contaminated ground.	Ground investigation to determine presence, likely thickness and composition of Made Ground. Design to mitigate effects of made Ground	2	5	10
4	Subgrade deformation	3	4	12	Pavement serviceability problems. Reduced ride quality	Ground investigation to determine subgrade quality and appropriate design CBR values. Construction control and adequate drainage.	1	4	4
4	Possible high groundwater table above founding levels	4	5	20	Danger to construction personnel. Difficulty in compaction of Class 6N and construction of foundations. Dewatering of potentially contaminated groundwater required during construction.	Ground Investigation to determine groundwater conditions along route. Contractor to be informed of risk and provision to be allowed for dewatering and temporary drainage measures. Excavation levels reduced to minimum possible to achieve design requirements.	2	5	10
5	Presence of contaminated groundwater/soils.	5	4	20	Danger to construction personnel, particularly if groundwater is encountered during excavations. Potential transfer of contamination off-site and to watercourses.	Ground Investigation to determine soil conditions and presence of any potential contamination. Waste Acceptance Criteria determination to be carried to determine suitable disposal sites.	5	2	10
6	Possible presence of buried foundations and structures	4	4	16	Additional excavation required to remove historical foundations, buried structures. Possible differential settlements if not identified / removed.	Ground Investigation to determine soil conditions at structure locations. Review of historical maps when structure footprint finalised	2	4	8

Risk Reference	Description of Risk	Initial Risk Rating (See matrix below)			Consequence	Control Measures to Reduce Risk	Residual Risk Rating (See matrix below)		
		P	I	R			P	I	R
7	Presence of recorded / unrecorded utility services on site.	3	5	15	Rupture of services causing electrocution, asphyxiation, spraying of sewage. Risk of death or serious injury.	Contractor to determine location of all underground services and arrange provide for any necessary diversions with the relevant statutory undertakers prior to undertaking ground investigation Contractor to instigate safe systems of work to avoid damaging / encountering services. Vigilance on site during excavations. Permit to dig system.	1	5	5
8	Historical unrecorded shallow mining / quarrying	2	5	10	Potential presence of voids / infilled ground.	Historical quarrying in certain areas along the route. Contractor to remain vigilant during works and have safe systems in place.	1	5	5
9	Operatives/staff working close to/in excavations.	4	5	20	Risk of collapse of excavation. Danger to construction personnel.	Excavation depths kept to minimum required by design. Temporary excavations to be designed by Contractor to ensure safety of site staff. This may require benching or temporary supports. Safe system of work to be applied.	1	5	4

Table 5. Risk Rating

Impact (I)	Scale	Time
Very High	5	> 10 weeks on completion
High	4	> 1 week on completion
Medium	3	> 4 weeks, < 1 week on construction
Low	2	1 to 4 weeks on activity, none on completion
Very Low	1	1 week on activity, none on completion

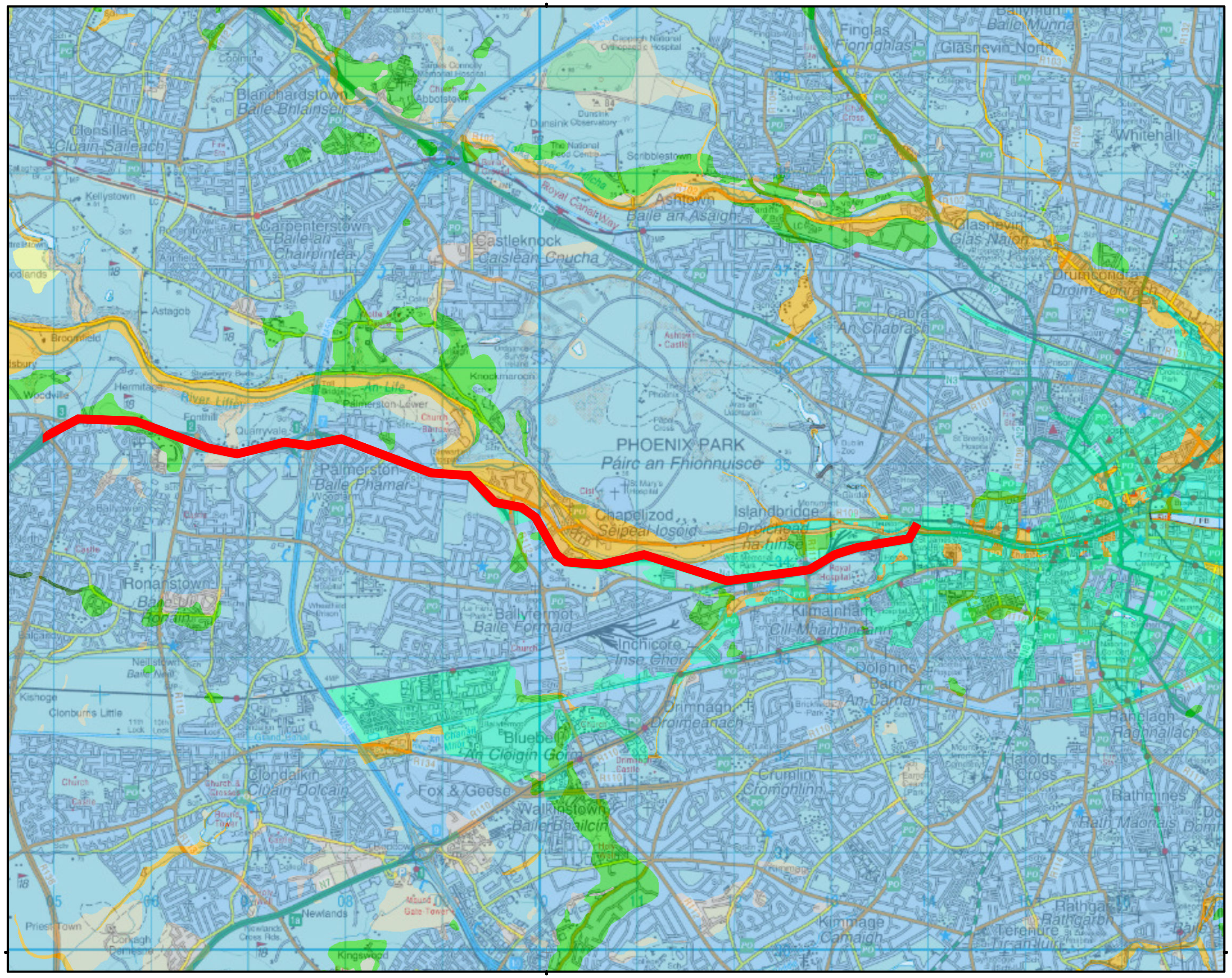
Probability (P)	Scale
Very Likely	5
Likely	4
Probable	3
Unlikely	2
Negligible	1

RISK (R) = PROBABILITY (P) x IMPACT (I)

Appendix A

Quaternary Sediments

710000



710000

730000

Legend

Quaternary Sediments

SYMBOLOGY

- A, Alluvium
- Ag, Alluvium (gravelly)
- BasEsk, Eskers comprised of gravels of basic reaction
- Embankment
- GCh, Gravels derived from chert
- GLs, Gravels derived from Limestones
- Landfill
- Lsi, Lacustrine silts
- Mbs, Marine beach sands
- Rck, Bedrock outcrop or subcrop
- TLs, Till derived from limestones
- Urban
- Water

Route 6 – Lucan to City Centre

Scale: 1:65,115

Geological Survey Ireland

0 0.475 0.95 1.9 mi

0 0.75 1.5 3 km

Map Centre Coordinates (ITM) 710,717 734,775

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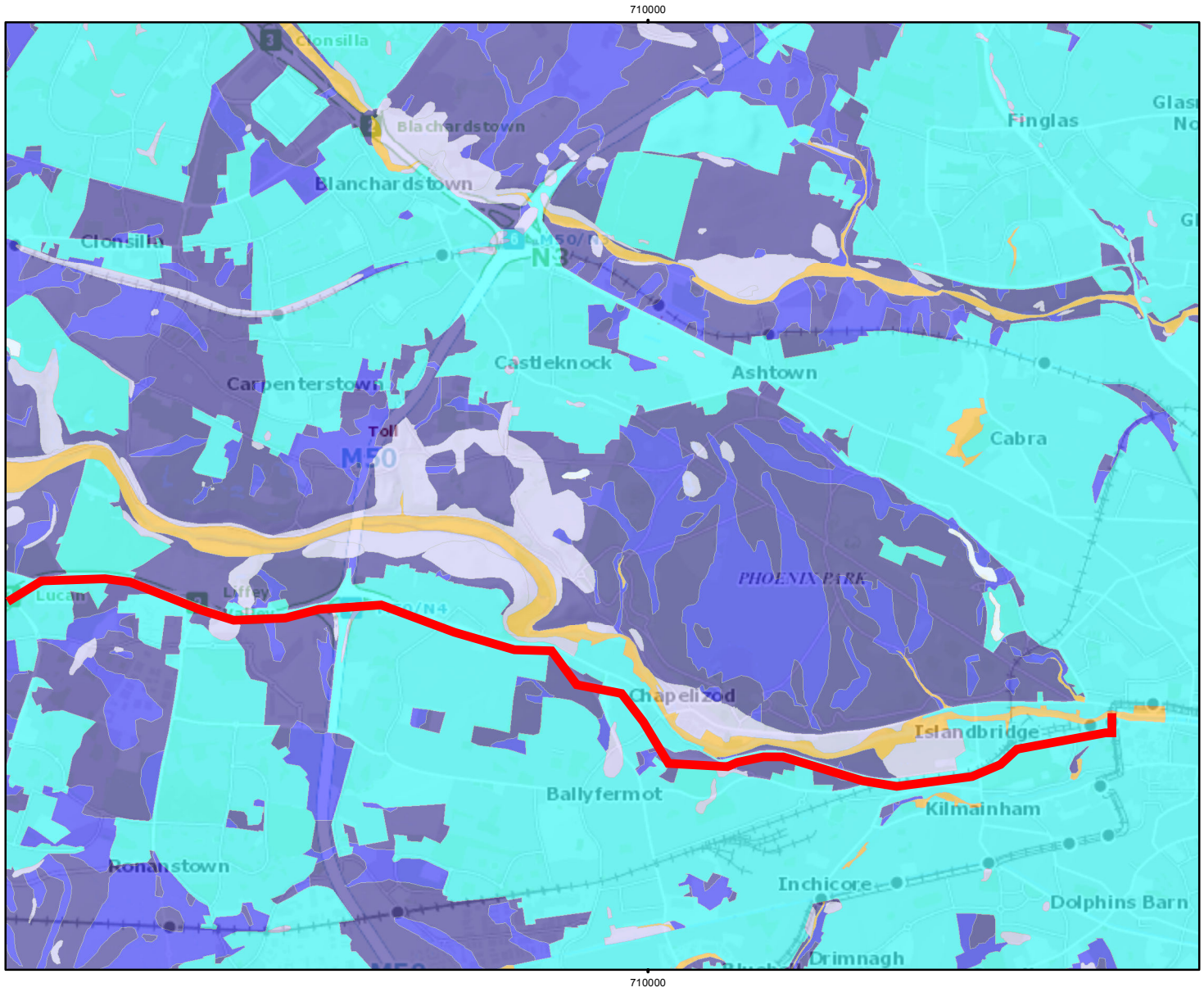
Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Teagasc Soils



Legend

- BminDW - Deep well drained mineral (Mainly basic)
- BminPD - Mineral poorly drained (Mainly basic)
- BminSW - Shallow well drained mineral (Mainly basic)
- AlluvMIN - Alluvial (mineral)
- Made - Made ground
- Water - Water

Route 6 – Lucan to City Centre

Scale: 1:50,000

Geological Survey Ireland

N W E S

0 0.35 0.7 1.4 mi
0 0.5 1 2 km

Map Centre Coordinates (ITM) 709,634 736,121
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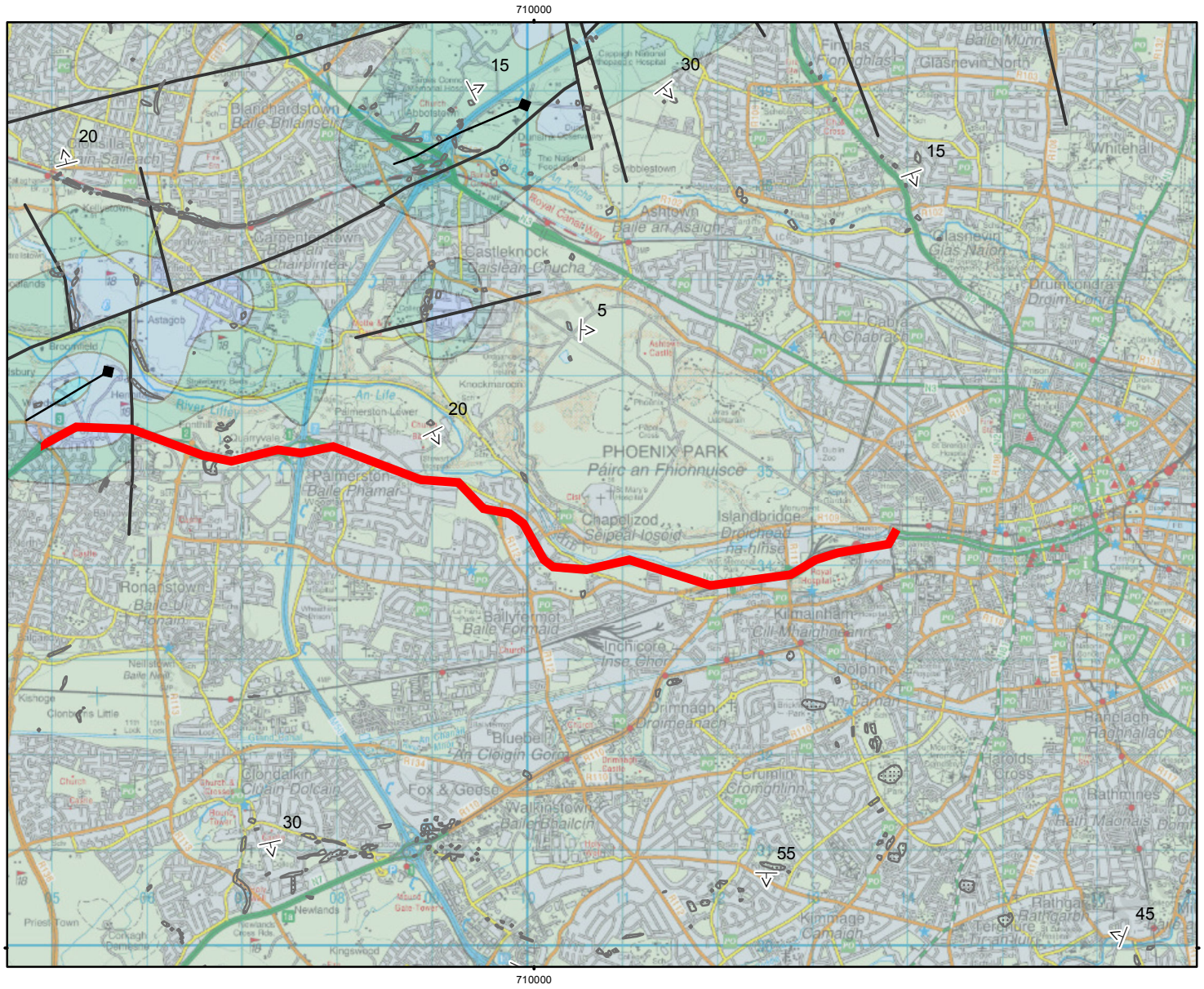
Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Bedrock Geology 100k



Legend

- Strike and dip of bedding, right way up
- Bedrock Outcrops 100 ITM 2018
- Anticlinal Axis
- Fault
- Ballysteen Formation
- Lucan Formation
- Tober Colleen Formation
- Waulsortian Limestones

Route 6 – Lucan to City Centre

Scale: 1:65,115

Geological Survey Ireland

N W E S

0 0.475 0.95 1.9 mi
0 0.75 1.5 3 km

Map Centre Coordinates (ITM) 710,717 734,775
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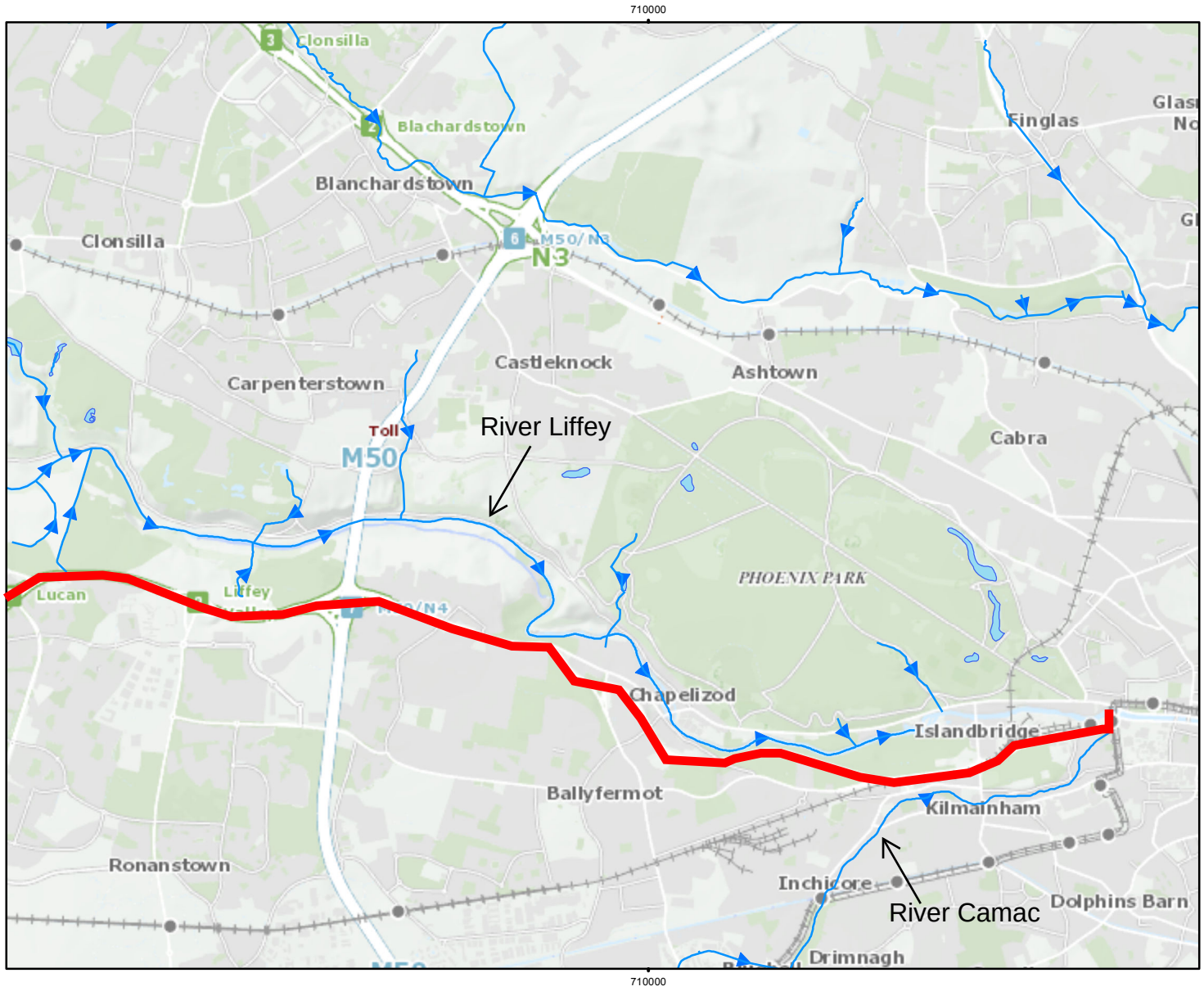
Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Surface Water Features



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Geological Survey Ireland

N W E S

0 0.35 0.7 1.4 mi
0 0.5 1 2 km

Map Centre Coordinates (ITM) 709,634 736,121
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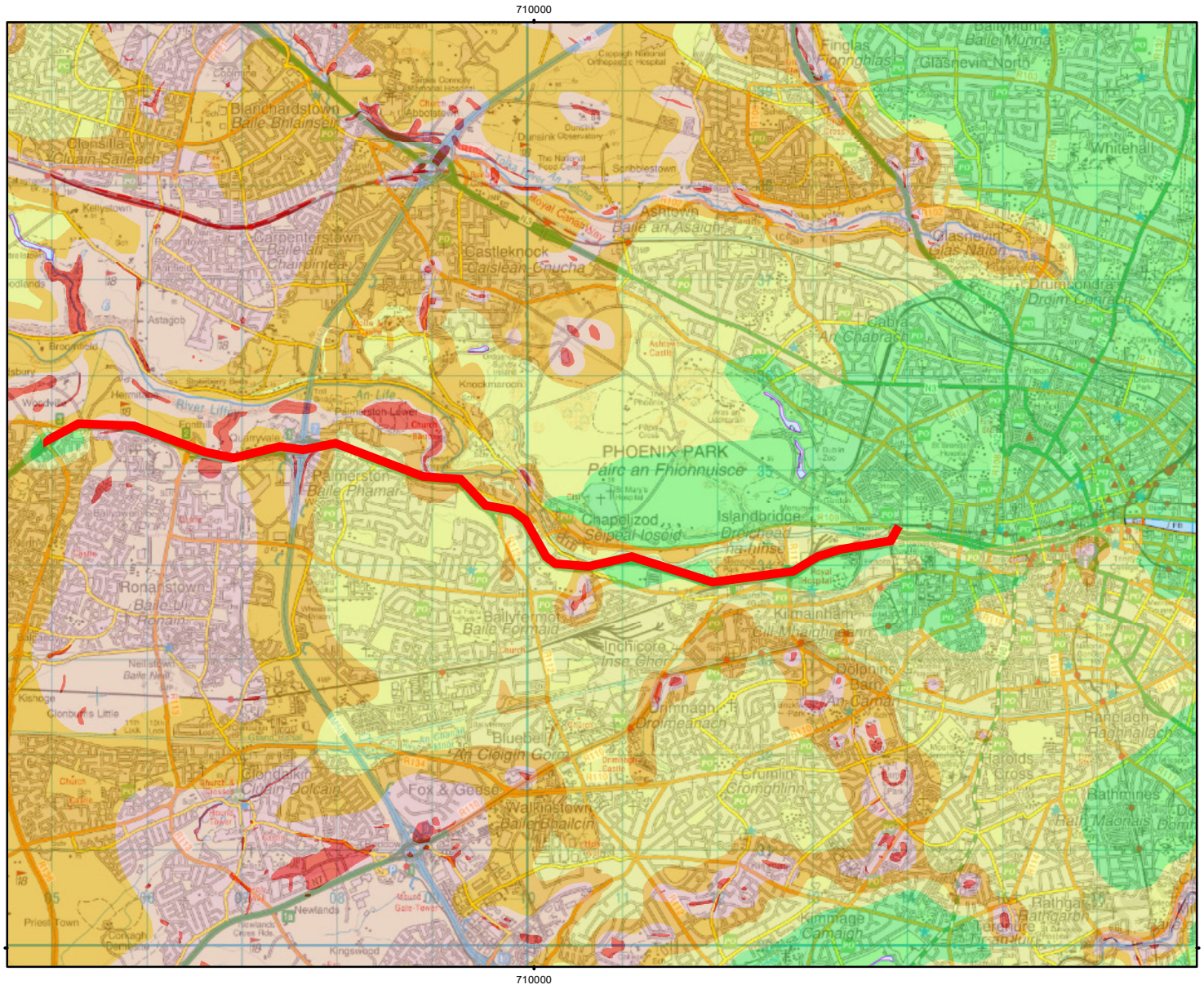
Legend

- River Network and River Flow Direction Arrows
- Lake Segments
- **Route 6 – Lucan to City Centre**

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Ground Water Vulnerability



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Geological Survey Ireland

N W E S

0 0.475 0.95 1.9 mi
0 0.75 1.5 3 km

Map Centre Coordinates (ITM) 710,717 734,775
19/11/2019 16:04:03

Legend

National Groundwater Vulnerability Ireland

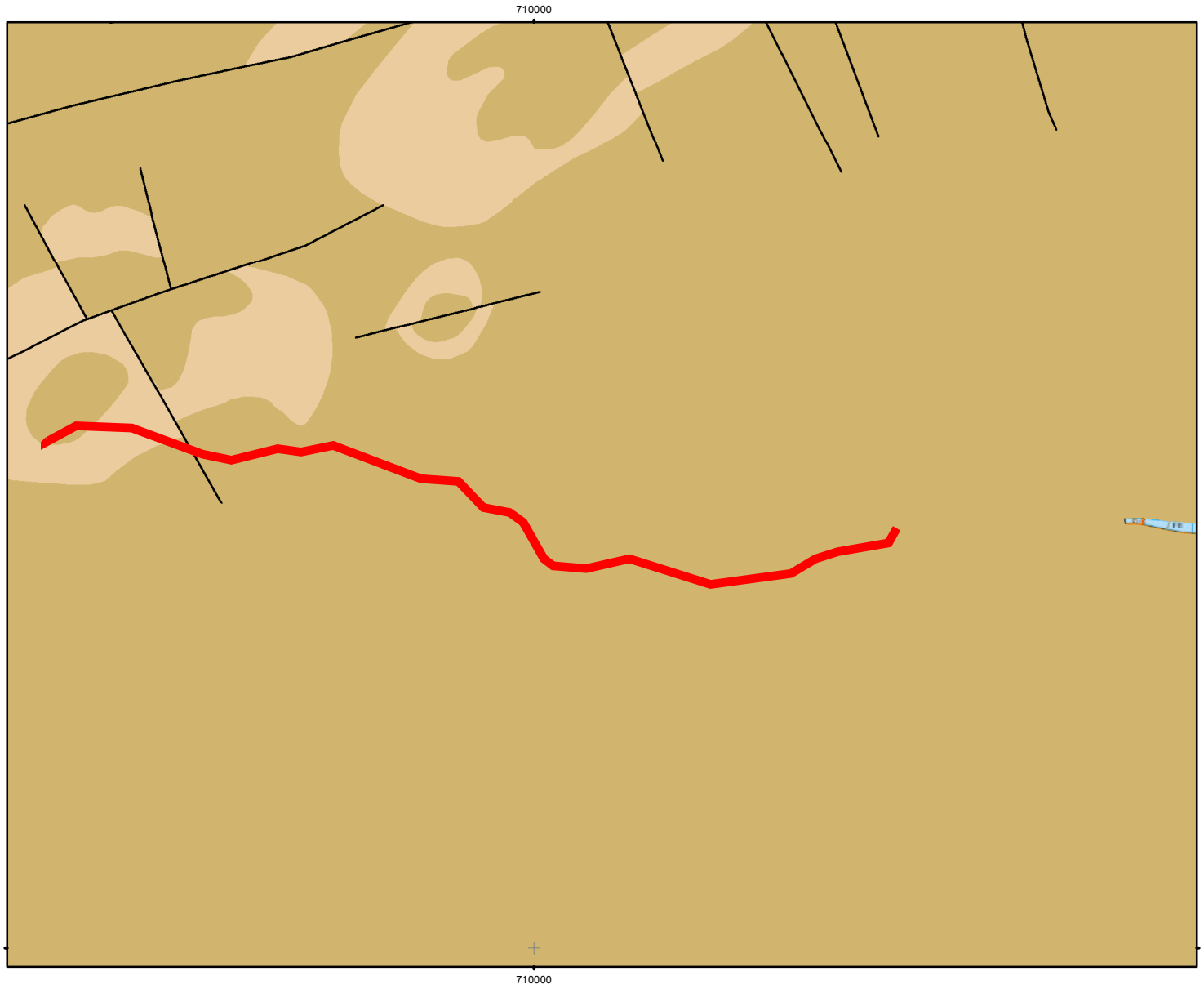
VULNERABILITY

- Rock at or near Surface or Karst
- Extreme
- High
- Moderate
- Low
- Water

Route 6 – Lucan to City Centre

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Aquifers



Legend

- Bedrock Aquifer Faults
- LI - Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones
- Pl - Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones
- LI - Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones
- Pl - Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones

Route 6 – Lucan to City Centre

Scale: 1:65,115

Geological Survey Ireland

N W E S

0 0.475 0.95 1.9 mi
0 0.75 1.5 3 km

Map Centre Coordinates (ITM) 710,717 734,775
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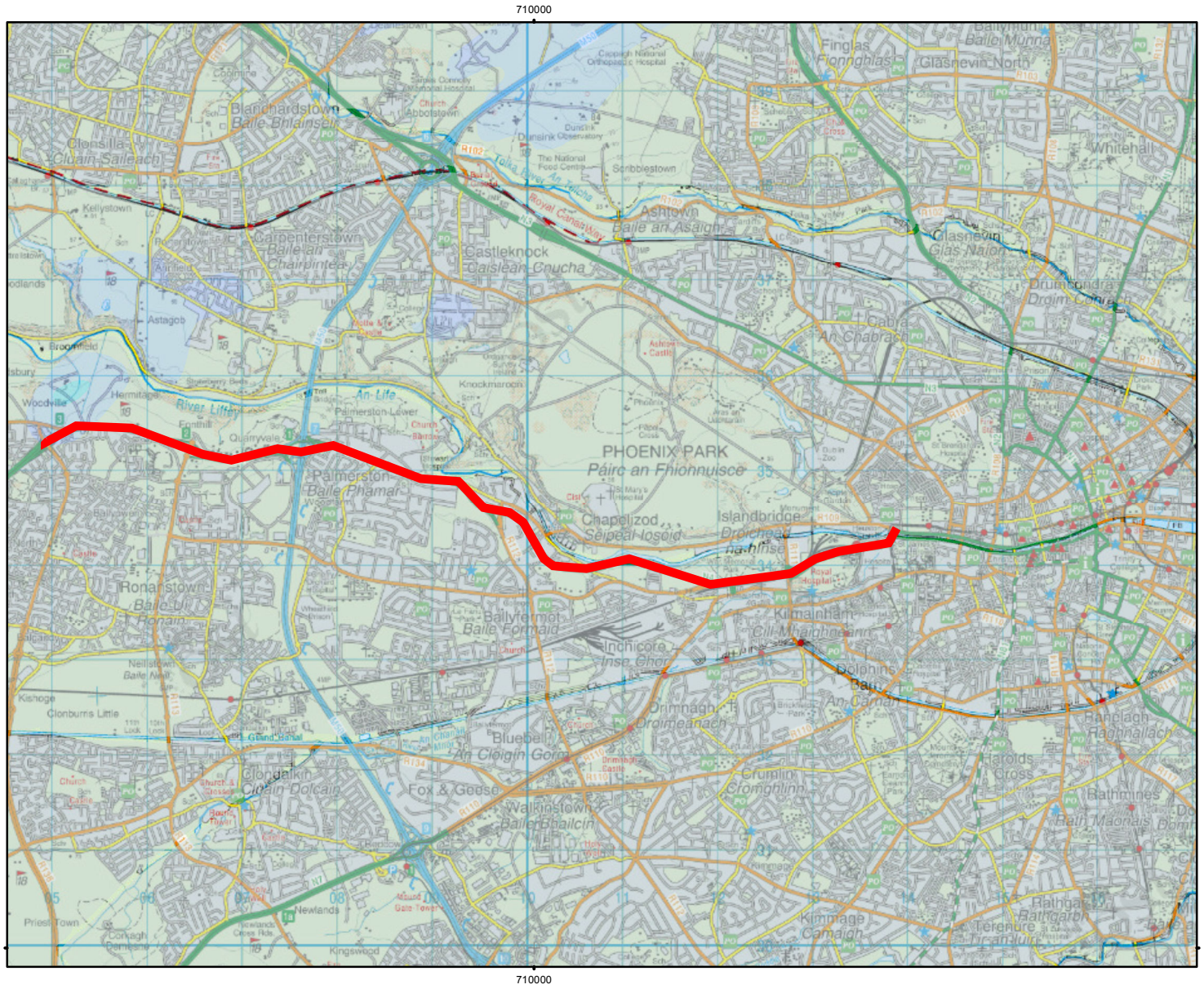
Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Hydrostratigraphic Rock Unit Groups



Legend

- Dinantian Upper Impure Limestones
- Dinantian Pure Unbedded Limestones
- Dinantian Lower Impure Limestones

Route 6 – Lucan to City Centre

Scale: 1:65,115

Geological Survey Ireland

N W E S

0 0.475 0.95 1.9 mi
0 0.75 1.5 3 km

Map Centre Coordinates (ITM) 710,717 734,775
19/11/2019 16:13:37

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Groundwater Recharge

Scale: 1:50,000

Geological Survey Ireland

N W E S

0 0.35 0.7 1.4 mi
0 0.5 1 2 km

Map Centre Coordinates (ITM) 709,634 736,121
28/11/2019 17:33:04

Legend

National Groundwater Recharge Ireland

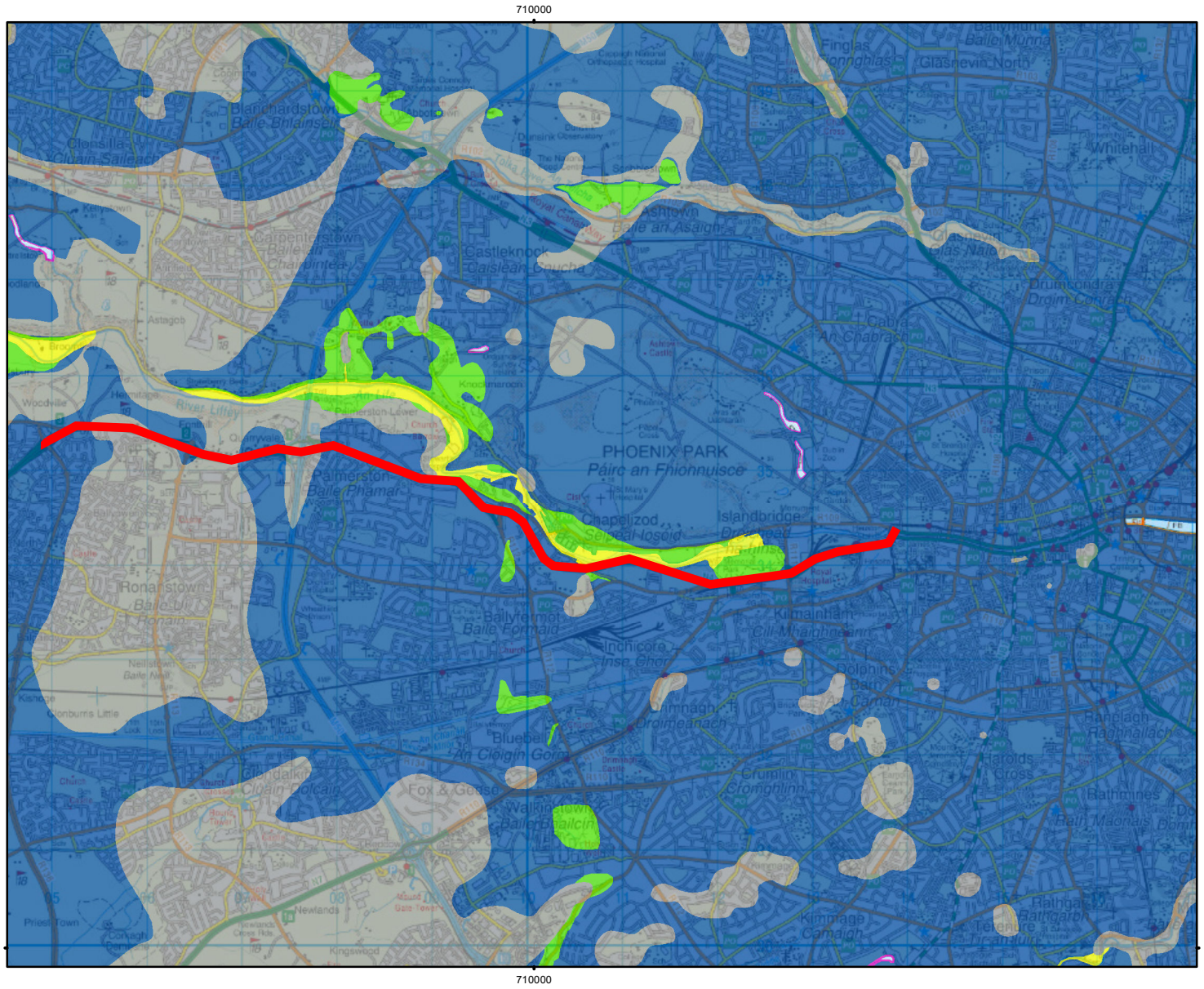
Annual Recharge (mm)

- 151-200 mm
- 101-150 mm
- 51-100 mm
- 1-50 mm
- Water

Route 6 – Lucan to City Centre

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Subsoil Permeability



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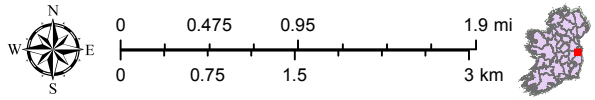

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Legend

Subsoil Permeability

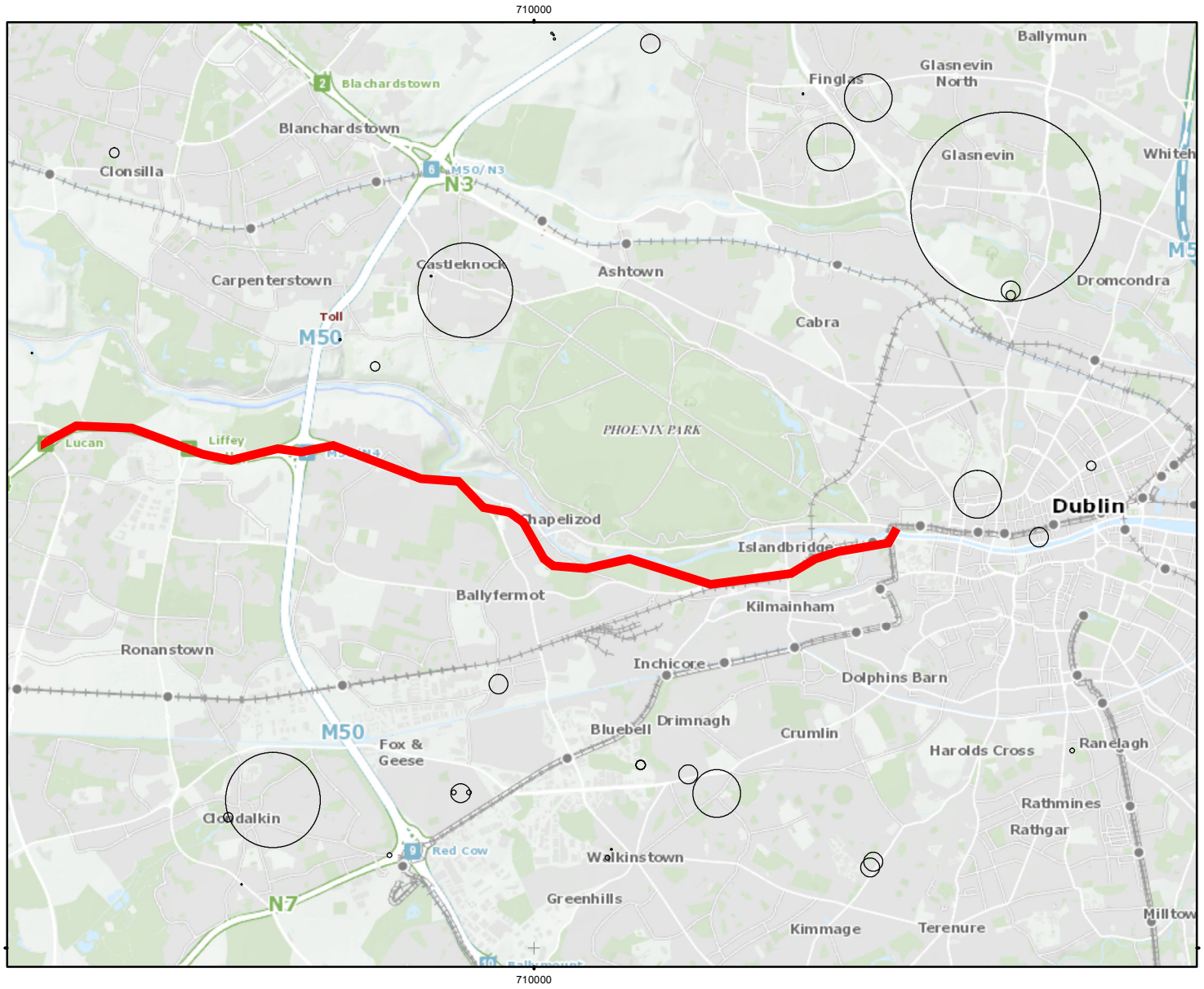
PERM

- High
- Medium
- Low
- Water
- Not mapped

Route 6 – Lucan to City Centre

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Groundwater Wells and Springs



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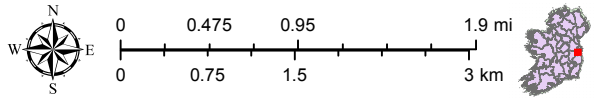
Geological Survey Ireland



Map Centre Coordinates (ITM) 710,717 734,775
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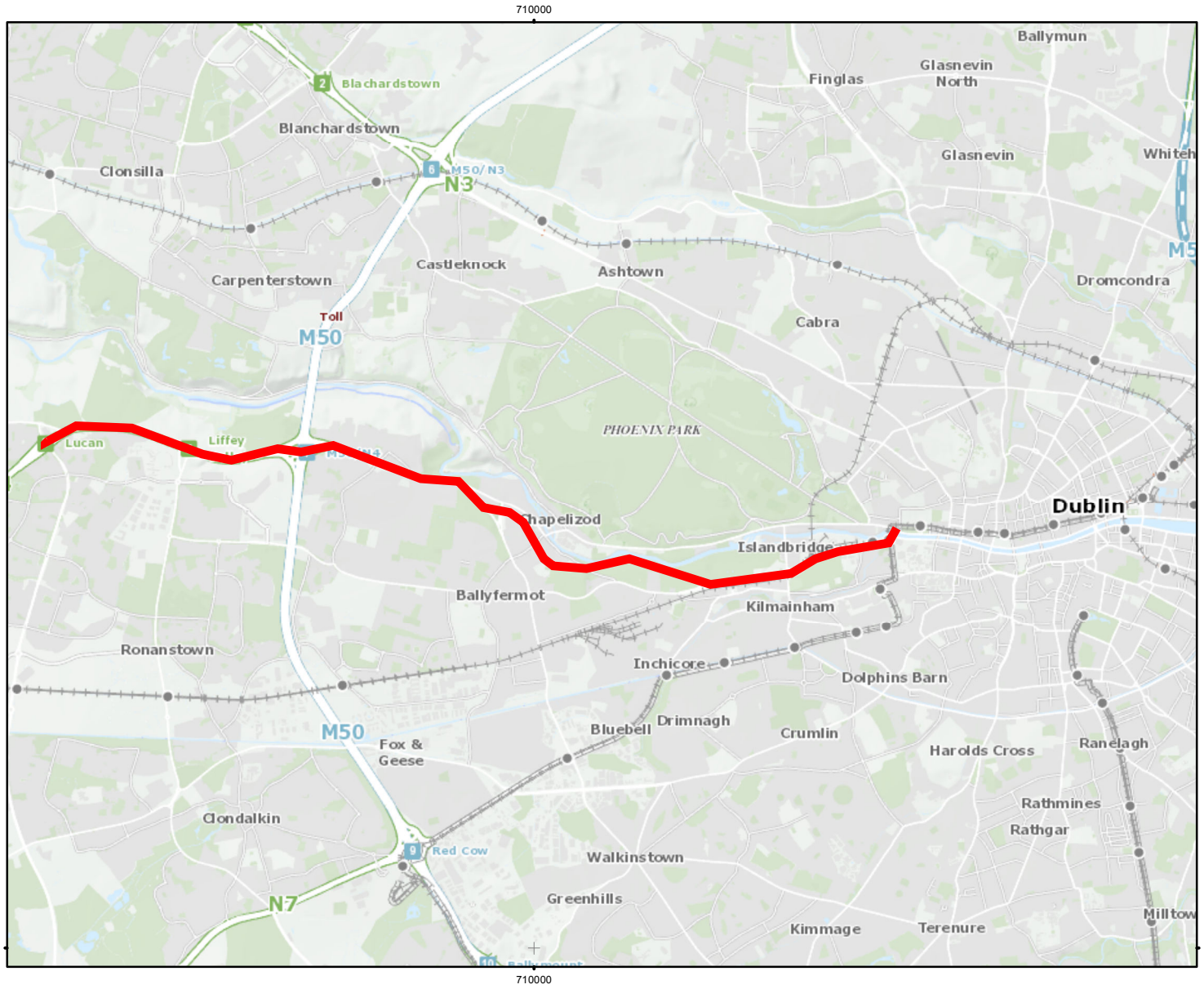
Legend

Groundwater Wells and Springs

Route 6 – Lucan to City Centre

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Karst Features



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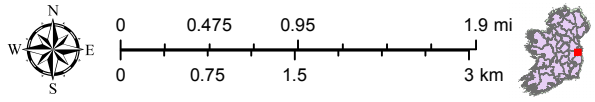
Geological Survey Ireland



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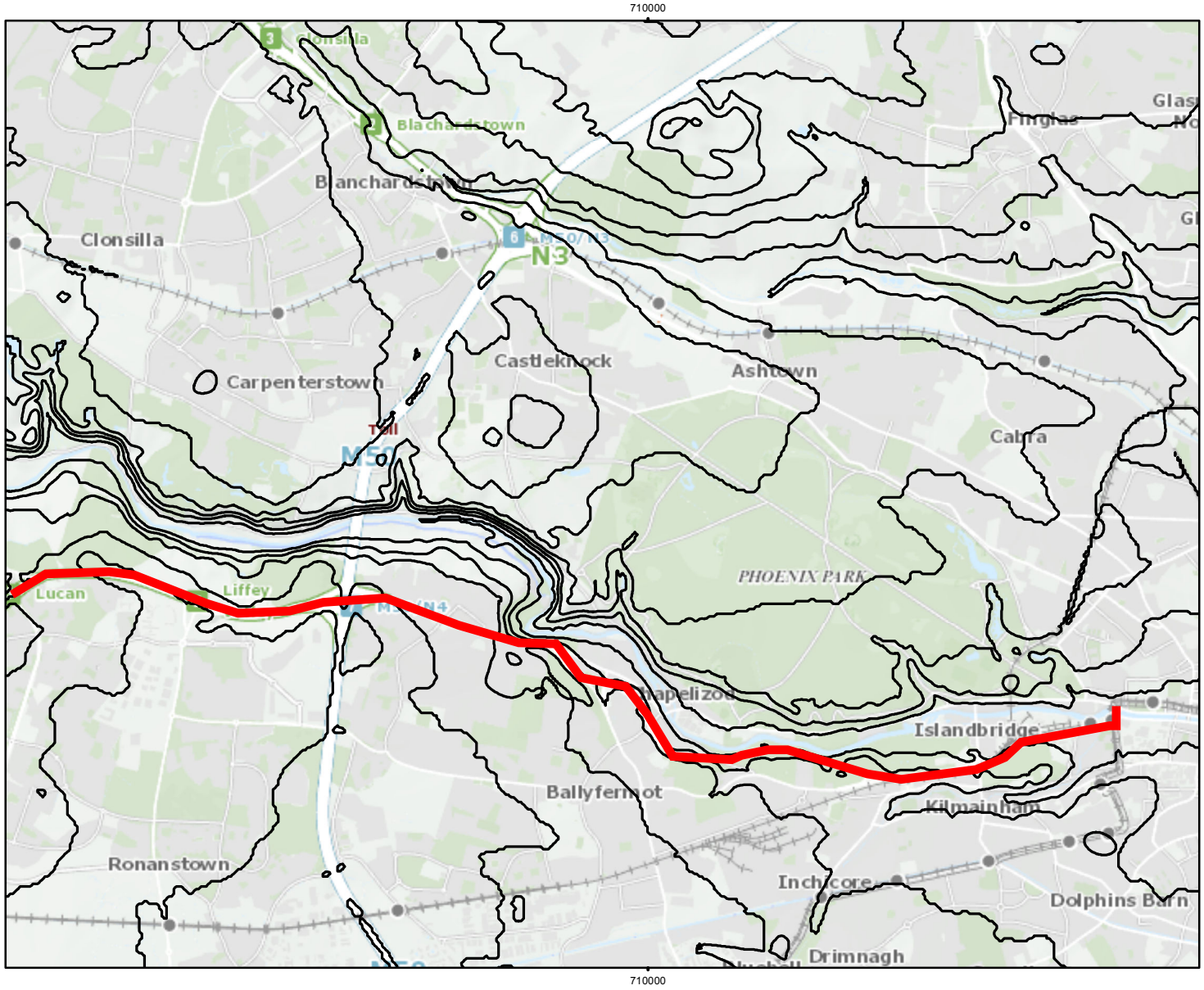
Legend

Route 6 – Lucan to City Centre

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Ground Elevation Contours



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Geological Survey Ireland

N W E S

0 0.35 0.7 1.4 mi

0 0.5 1 2 km

Map Centre Coordinates (ITM) 709,634 736,121
28/11/2019 17:34:02

Legend

EPA Contours

Route 6 – Lucan to City Centre