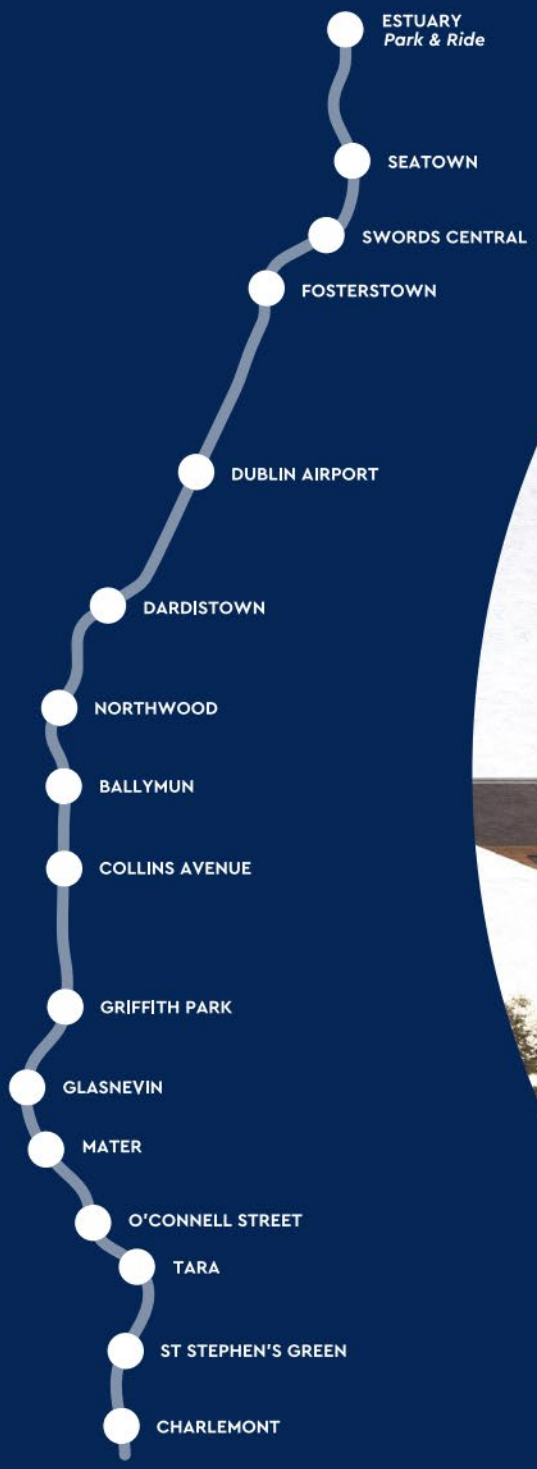


20 Soils and Geology

Contents

Table of Acronyms

Acronym	Meaning
AOD	Above Ordnance Datum
AZ	Assessment Zone
bgl	Below ground level
BOD	Biological Oxygen Demand
Bq	Becquerel
C&D	Construction and Demolition
CEMP	Construction Environmental Management Plan
CGS	County Geological Site
C4SL	Category 4 Screening Level
CIEH	Chartered Institute of Environmental Health
CIRIA	Construction Industry Research and Industry Association
CS	Characteristic Situation
CSM	Conceptual Site Model
CWSC	Controlled Water Screening Criteria
DAA	Dublin Airport Authority
DANP	Dublin Airport North Portal
DASP	Dublin Airport South Portal
DEFRA	Department for Environment, Food and Rural Affairs
DWS	Drinking Water Standard
EA	Environment Agency
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EPA	Environmental Protection Agency
EQS	Environmental Quality Standard
EU	European Union
GAC	Generic Assessment Criteria
GDR	Geotechnical Design Report
GI	Ground Investigation
GIR	Geotechnical Interpretive Report
GIS	Gas Insulated Switchgear
GHS	Geological Heritage Sites
GSI	Geological Survey Ireland
GSV	Gas Screening Value
HDD	Horizontal Directional Drilling
HSE	Health Service Executive
IGH	Irish Geological Heritage
IGI	Institute of Geologists of Ireland
IGSL	Irish Geotechnical Services Ltd
IGV	Interim Guidance Value
IEMA	Institute of Environmental Management & Assessment
Km	Kilometre

Acronym	Meaning
kV	Kilovolt
LI	Locally Important
LOD	Limits of Deviation
LQM	Land Quality Management
m	Metre
mg/kg	Milligram per kilogram
mg/l	Milligram per litre
NHA	Natural Heritage Area
NHBC	National House Building Council
NRA	National Roads Authority
OCC	Operations Control Centre
OSI	Ordnance Survey Ireland
PAH	Polycyclic Aromatic Hydrocarbons
PFAS	Perfluoroalkyl and polyfluoroalkyl substances
PFOS	Perfluorooctane sulfonate
pNHA	Proposed Natural Heritage Area
PPE	Personal Protective Equipment
RPA	Railway Procurement Agency
RPE	Respiratory Protective Equipment
RPII	Radiological Protection Institute of Ireland
S4UL	Suitable for Use Level
S.I.	Statutory Instrument
SOM	Soil Organic Matter
SURGE	Dublin Soil Urban Geochemistry Project
SVOC	Semi-Volatile Organic Compound
TBM	Tunnel Boring Machine
TDS	Total Dissolved Solids
TII	Transport Infrastructure Ireland
TPH	Total Petroleum Hydrocarbons
VOC	Volatile Organic Compound
WEL	Workplace Exposure Limit
WFD	Water Framework Directive
µg/kg	Micrograms per kilogram
µg/l	Micrograms per litre

20. Soils and Geology

20.1 Introduction

This Chapter of the Environmental Impact Assessment Report (EIAR) assesses the impact of the MetroLink Project (hereafter referred to as the proposed Project), on soils and geology during the Construction Phase and Operational Phase.

This chapter describes and assesses the likely direct and indirect significant effects of the proposed Project on soils and geology, in accordance with the requirements of Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment (i.e. the EIA Directive) (European Union, 2014a).

This Chapter should be read in conjunction with the following Chapters, and their Appendices, which present related impacts arising from the proposed Project and proposed mitigation measures to ameliorate the predicted impacts:

- Chapter 10 (Human Health);
- Chapter 18 (Hydrology);
- Chapter 19 (Hydrogeology);
- Chapter 22 (Infrastructure & Utilities);
- Chapter 23 (Agronomy);
- Chapter 24 (Materials & Waste Management); and
- Chapter 26 (Architectural Heritage).

Limits of deviation have been set for the proposed Project and this is addressed in the Wider Effects Report annexed at Appendix A5.19.

The assessment is based on identifying and describing the likely significant effects arising from the proposed Project as described in Chapters 4 to 6 of this EIAR. The proposed Project description is based on the design prepared to inform the planning stage of the project and to allow for a robust assessment as part of the Environmental Impact Assessment (EIA) Process.

Where it is required to make assumptions as the basis of the assessment presented here, these assumptions are based on advice from competent project designers and are clearly outlined within the Chapter.

20.1.1 Outline Project Description

A full description of the proposed Project is provided in the following chapters of this EIAR:

- Chapter 4 (Description of the MetroLink Project);
- Chapter 5 (MetroLink Construction Phase); and
- Chapter 6 (MetroLink Operations & Maintenance).

Table 20.1 presents an outline description of the key proposed Project elements which are appraised in this Chapter. Table 20.2 provides an overview of the four geographical areas (Assessment Zones, AZ1-AZ4) for the purpose of the EIAR.

Diagram 20.1 presents an outline of the main elements of the proposed Construction Phase that are appraised in this Chapter and Diagram 20.2 presents an outline of the main elements of the Operational Phase of the proposed Project that are appraised in this Chapter.

Table 20.1: Outline Description of the Principal Project Elements

Project Elements	Outline Description
Permanent Project Elements	
Tunnels	It is proposed to construct two geographically separate, single-bore tunnels, using a Tunnel Boring Machine (TBM). Each section of tunnel will have an 8.5m inside diameter and will contain both northbound and southbound rail lines within the same tunnel. These tunnels will be located as follows: ▪ The Airport Tunnel: running south from Dublin Airport North Portal (DANP) under Dublin Airport and surfacing south of the airport at Dublin Airport South Portal (DASP) and will be approximately 2.3km in length; and ▪ The City Tunnel: running for 9.4 km from Northwood Portal and terminating underground south of Charlemont Station.
Cut Sections	The northern section of the alignment is characterised by a shallow excavated alignment whereby the alignment runs below the existing ground level. Part of the cut sections are open at the top, with fences along the alignment for safety and security. While other sections are "cut and cover", whereby the alignment is covered.
Tunnel Portals	The openings at the end of the tunnel are referred to as portals. They are concrete and steel structures designed to provide the commencement or termination of a tunnelled section of route and provide a transition to adjacent lengths of the route which may be in retained structures or at the surface. There are three proposed portals, which are: ▪ DANP; ▪ DASP; and ▪ Northwood Portal. There will be no portal at the southern end of the proposed Project, as the southern termination and turnback would be underground.
Stations	There are three types of stations: surface stations, retained cut stations and underground stations: ▪ Estuary Station will be built at surface level, known as a 'surface station'; ▪ Seatown, Swords Central, Fosterstown Stations and the proposed Dardistown Station will be in retained cutting, known as 'retained cut stations'; and ▪ Dublin Airport Station and all 10 stations along the City Tunnel will be 'underground stations'.
Intervention Shaft	An intervention shaft will be required at Albert College Park to provide adequate emergency egress from the City Tunnel and to support tunnel ventilation. Following the European Standard for safety in railway tunnels TSI 1303/2014: Technical Specification for Interoperability relating to 'safety in railway tunnels' of the rail system of the European Union, it has been recommended that the maximum spacing between emergency exits is 1,000m. As the distance between Collins Avenue and Griffith Park is 1,494m, this intervention shaft is proposed to safely support evacuation/emergency service access in the event of an incident. This shaft will also function to provide ventilation to the tunnel. The shaft will require two 23m long connection tunnels extending from the shaft, connecting to the main tunnel. At other locations, emergency access will be incorporated into the stations and portals or intervention tunnels will be utilised at locations where there is no available space for a shaft to be constructed and located where required (see below).
Intervention Tunnels	In addition to the two main 'running' tunnels, there are three shorter, smaller diameter tunnels. These are the evacuation and ventilation tunnels (known as Intervention Tunnels): ▪ Airport Intervention Tunnels: parallel to the Airport Tunnel, there will also be two smaller diameter tunnels; on the west side, an evacuation tunnel running northwards from DASP for about 315m, and on the east side, a ventilation tunnel connected to the main tunnel and extending about 600m from DASP underneath Dublin Airport Lands. In the event of an incident in the main tunnel, the evacuation tunnel will enable passengers to walk out to a safe location outside the Dublin Airport Lands.

Project Elements	Outline Description
	▪ Charlemont Intervention Tunnel: The City Tunnel will extend 320m south of Charlemont Station. A parallel evacuation and ventilation tunnel is required from the end of the City Tunnel back to Charlemont Station to support emergency evacuation of maintenance staff and ventilation for this section of tunnel.
Park and Ride Facility	The proposed Park and Ride Facility next to Estuary Station will include provision for up to 3,000 parking spaces.
Broadmeadow and Ward River Viaduct	A 260m long viaduct is proposed between Estuary and Seatown Stations, to cross the Broadmeadow and Ward Rivers and their floodplains.
Proposed Grid Connections	Grid connections will be provided via cable routes with the addition of new 110kV substations at DANP and Dardistown. (Approval for the proposed grid connections to be applied for separately but are assessed in the EIAR).
Dardistown Depot	A maintenance depot will be located at Dardistown. It will include: ▪ Vehicle stabling; ▪ Maintenance workshops and pits; ▪ Automatic vehicle wash facilities; ▪ A test track; ▪ Sanding system for rolling stock; ▪ The Operations Control Centre for the proposed Project; ▪ A substation; ▪ A mast; and ▪ Other staff facilities and a carpark.
Operations Control Centre	The main Operations Control Centre (OCC) will be located at Dardistown Depot and a back-up OCC will be provided at Estuary.
M50 Viaduct	A 100m long viaduct to carry the proposed Project across the M50 between the Dardistown Depot and Northwood Station.
Temporary Project Elements	
Construction Compounds	There will be 34 Construction Compounds including 20 main Construction Compounds, 14 Satellite Construction Compounds required during the Construction Phase of the proposed Project. The main Construction Compounds will be located at each of the proposed station locations, the portal locations and the Dardistown Depot Location (also covering the Dardistown Station) with satellite compounds located at other locations along the alignment. Outside of the Construction Compounds there will be works areas and sites associated with the construction of all elements of the proposed Project, including an easement strip along the surface sections.
Logistics Sites	The main logistics sites will be located at Estuary, near Pinnock Hill east of the R132 Swords Bypass and north of Saint Margaret's Road at the Northwood Compound. (These areas are included within the 14 Satellite Construction Compounds).
Tunnel Boring Machine Launch Site	There will be two main tunnel boring machine (TBM) launch sites. One will be located at DASP which will serve the TBM boring the Airport Tunnel and the second will be located at the Northwood Construction Compound which will serve the TBM boring the City Tunnel.

Table 20.2: Geographical Areas

Ref.	Geographical Section	Description of Extent of Geographical Section
AZ1	Northern Section	Estuary Station to DANP. It includes the rail line crossing the Broadmeadow and Ward Rivers and associated flood plains on a viaduct. This section will include open, retained cut and cut-and-cover sections. This section includes the proposed Park and Ride Facility at Estuary Station.
AZ2	Airport Section	This section of the proposed Project includes DANP, the tunnel underneath Dublin Airport, Dublin Airport Station and DASP.
AZ3	Dardistown to Northwood	From south of DASP to the Northwood Portal. This section includes the proposed MetroLink Depot, the M50 Viaduct and the proposed Construction Compound and the TBM launch site at Northwood.
AZ4	Northwood to Charlemont	From south of the Northwood Portal to the tunnel termination location south of Charlemont Station.

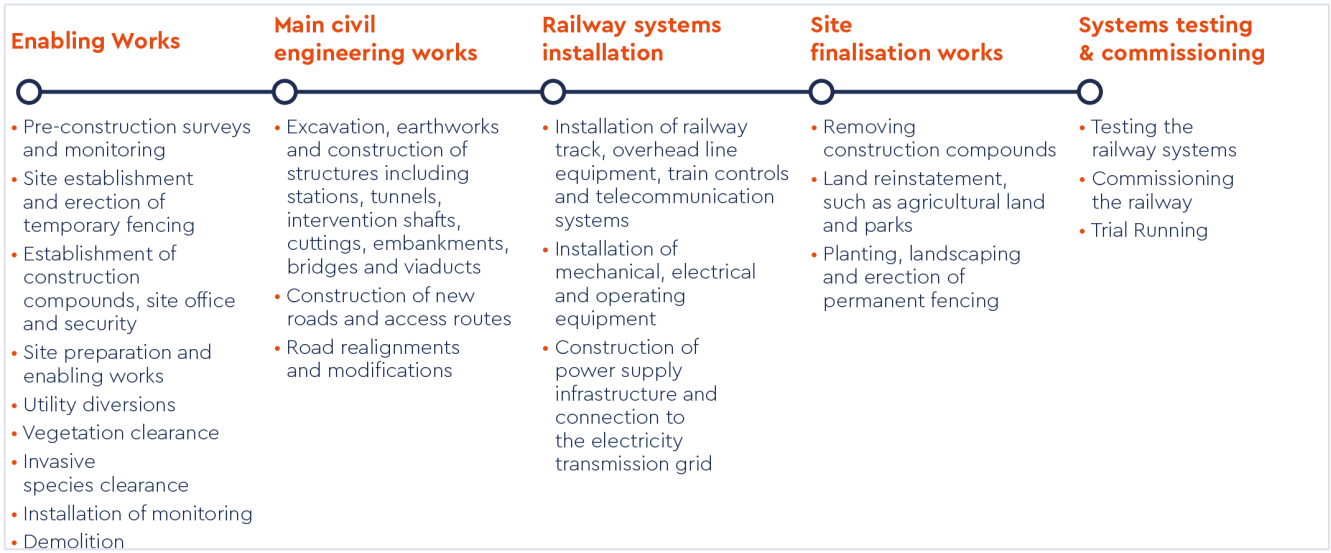


Diagram 20.1: Summary of Key Activities during the Construction Phase of the Proposed Project

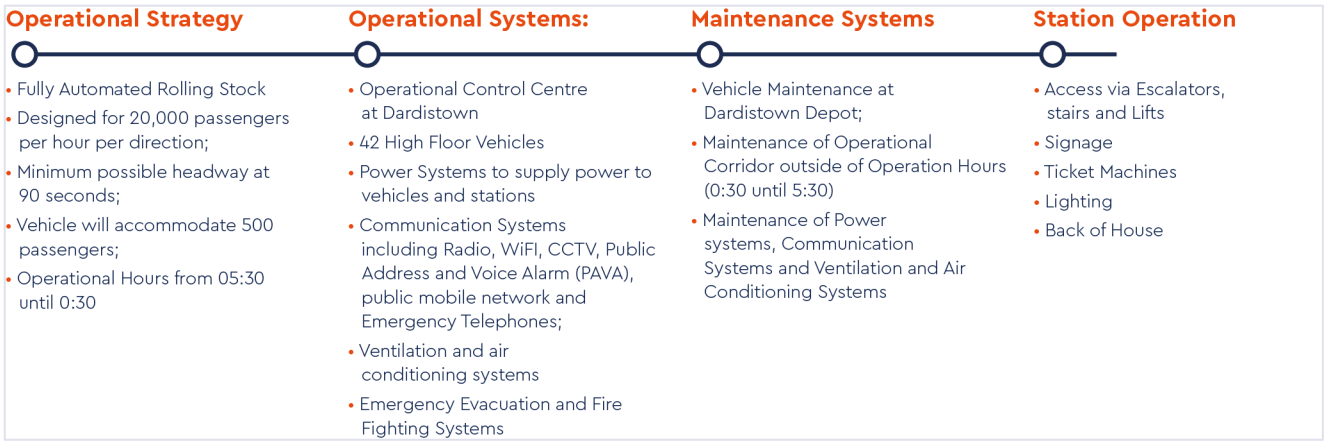


Diagram 20.2: Summary of Key Activities during the Operation Phase of the Proposed Project

20.1.2 Scope

This Chapter of the EIAR has been prepared in order to fulfil the requirement to address all soils and geology aspects of the environment including the following:

- Soils and superficial geology;
- Bedrock geology;
- Current and historic mining sites;
- Irish Geological Heritage (IGH) Sites;
- Radon and ground gas; and
- Contaminated land.

This chapter also presents an overview of the settlement analysis undertaken to identify settlement risk arising from the advancement of the Tunnel Boring Machine (TBM).

As detailed in Section 20.1, separate assessments have been conducted for some topics which have inter-relationships with soils and geology.

20.2 Methodology

The following Section outlines the legislation and guidelines considered, the information and data sources used and the adopted methodology for preparing this Chapter.

20.2.1 Legislative, Guidance, Policy and Planning Context

Relevant European and National legislation and other statutory policies and guidance including the following have been considered as part of this impact evaluation:

- Transport (Railway Infrastructure) Act, 2001;
- European Communities (Environmental Impact Assessment) (Amendment) Regulations, 2001 [Statutory Instrument (S.I.) No. 538/2001];
- Waste Management Acts 1996 as amended;
- European Communities (Water Policy) Regulations 2003, S.I. No. 722/2003 (the European Communities (Water Policy) Regulations, 2003);
- European Communities Environmental Objectives (Groundwater) Regulations 2010, S.I. No. 9/2010 (European Communities Environmental Objectives (Groundwater) Regulations 2010);
- European Union (EU) Environmental Objectives (Groundwater) (Amendment) Regulations 2016;
- Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy (Water Framework Directive);
- Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration (Groundwater Directive);
- European Communities Environmental Objectives (Surface Waters) Regulations 2009;
- EU Environmental Objectives (Surface Waters) (Amendment) Regulations 2019;
- Environmental Protection Agency (EPA) Advice Notes on Current Practice (in the preparation of Environmental Impact Statements) (EPA 2003a);
- Environment Agency (EA), Land contamination: risk assessment (EA 2021);
- BS 10175:2011 + A2:2017 Investigation of potentially contaminated sites. Code of practice (British Standards Institute 2017);
- Construction Industry Research and Industry Association (CIRIA) C552 Contaminated Land Risk Assessment: A Guide to Good Practice (CIRIA 2001);
- CIRIA C665 Assessing Risks Posed by Hazardous Ground Gases to Buildings (CIRIA 2007);
- EPA Guidelines on the Information to be Contained in Environmental Impact Assessment Reports (Draft), (EPA 2017);
- Guidelines on the Information to be Contained in Environmental Impact Assessment Reports (EPA 2022);
- Institute of Geologists of Ireland (IGI), Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of Environmental Impact Statements (IGI 2013);
- National Roads Authority (NRA), Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes (NRA 2009);
- Transport Infrastructure Ireland (TII), The Management of Waste from National Road Construction Projects (TII 2017);
- EPA, Guidance on the Management of Contaminated Land and Groundwater at EPA Licensed Sites (EPA 2013);

- EPA, Towards Setting Guideline Values for the Protection of Groundwater in Ireland (EPA 2003b) (a consultation document titled Determining Groundwater Pollution: A proposed approach for the development and application of guideline values for groundwater was issued during January 2017, although a finalised version is yet to be issued);
- Local Authority planning guidance as applicable, including the Fingal Development Plan 2017-2023 and the Dublin City Development Plan 2016-2022;
- Consolidated EIA Directive 2011/92/EU and 2014/52/EU;
- Behaviour of Foundations and Structures, Pages 495-456 of: proceedings of the 9th International conference of Soil Mechanics and Foundation Engineering, vol 2 (Burland et al 1977);
- Theme Lecture, Research on Tunnelling Induced Ground Movements and their Effects on Buildings – Lessons from the Jubilee Line Extension. Proceedings of the International Conference Held at Imperial College, London, UK, on 17-18 July 2001 (Mair, R. J. 2001);
- Prediction of Ground Movements and Assessment of risk of Building Damage due to Bored Tunnelling. In: Proceedings of the International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, 713-718, Balkema, Rotterdam (Mair et al 1996);
- Settlements above Tunnels in the United Kingdom – Their Magnitude and Prediction. Tunnelling '82, Edited by Jones, M.J. pp 173-181. London, IMM (O'Reilly et al 1982);
- Ground Movements Resulting from Urban Tunnelling: Predictions and Effects. Page 79-92 of: Engineering Geology of Underground Movements. The Geological Society, London (Rankin, 1988); and
- A New Perspective on Land and Soil in Environmental Impact Assessment. Institute of Environmental Management & Assessment (IEMA) guide. February 2022 (IEMA 2022).

20.2.2 Study Area

A Works Area has been defined based on the proposed Project footprint/boundary within which construction works will be undertaken and any areas required for temporary access, construction compounds, working platforms and other enabling activities. The extent of the study area is shown as the Project Boundary in Figure 20.1 to Figure 20.16.

The description of baseline ground conditions is based on a 250m corridor from the Works Area, termed the study area. This study area is considered a suitable distance to enable description of baseline conditions and allow assessment of soils and geology. In the absence of Ireland specific or more recent guidance (and in accordance with Irish guidance e.g. EPA 2013) this study area has been based on National House Building Council (NHBC) and Environment Agency (EA) guidance; Guidance for the Safe Development of Housing on Land Affected by Contamination R&D66 (NHBC and EA 2008). For Irish geological heritage sites, the 250m buffer is reflective of the study area as detailed in Chapter 25 (Archaeology & Cultural Heritage).

20.2.3 Data Collection

To identify and quantify the potential impacts of the Construction Phase and Operational Phase of the proposed Project, a detailed study of the existing (baseline) soils and geology environment of the study area has been undertaken. The existing soils and geology conditions in the area have been interpreted from both desk study information and project specific investigation as summarised in this Section (20.2.3.3 – 20.2.3.5).

20.2.3.1 Consultation

Consultation responses from key stakeholders, landowners and the public were reviewed and taken into account in compiling the Chapter. The consultation responses relevant to land, soils and geology are provided in Table 20.3. Further detail on project consultation and responses are included in Chapter 8 (Consultation).

Table 20.3: Summary of Issues Raised During Consultation

Consultee	Comment	Relevant EIAR Section
Dublin City Council	Meeting held to discuss the proposed Project and issues around the environment. Concerns raised around settlement and the potential effects on services (particularly sewerage).	The methodology around the settlement assessment is summarised in Section 20.2.4.6, the effects on services are further assessed in Chapter 22 (Infrastructure & Utilities).
Fingal County Council	Meeting held to discuss the proposed Project, no specific issues regarding soils and geology raised.	N/A
Dublin Airport Authority(DAA)	Initial meeting held to discuss the inter-relationships between the proposed Project and the airport. Co-ordination with DAA regarding proposed GI agreed. Design meetings commenced in December 2021; issues relating to soils and geology not raised to date, however, will be subject to furthermore detailed discussion.	N/A
Construction Industry Federation Meeting	Meeting held regarding material management. Discussion around options for management of the surplus excavated material: ▪ Article 27 (by-product); ▪ Article 28 (end-of-waste); ▪ Consideration of several possible locations for material; and ▪ Consideration of quarries for material disposal – there are a number within close proximity to the M50.	These issues are addressed in Chapter 24 (Materials & Waste Management).
Waterways Ireland	Identified that creosote application to railway sleepers occurred historically at a site to the south of the Grand Canal near the proposed Glasnevin Station (west of Shandon Gardens) resulting in contamination of the area and leakage into the canal.	Information has been taken into account in the baseline (Section 20.3) and the impact assessment (Section 20.4). Associated potential contamination source code C99C.
Department of Communications, Climate Action and Environment	Scoping Report Consultation highlighted the following as key areas for focus: ▪ Waste prevention measures; ▪ Opportunities for reuse of material on site; ▪ Scoping recycling/recovery of the material off-site in advance; ▪ Measures to encourage reuse on site; and ▪ Measures to ensure uncontaminated/contaminated soils are segregated.	Assessment of potential for contaminated ground to be encountered is considered in the baseline (Section 20.3) and the impact assessment (Section 20.4). Issues related to waste and materials management are primarily addressed in Chapter 24 (Materials & Waste Management).
Eastern Midlands Region Waste Management Planning Lead Authority	Email regarding spoil arisings from the proposed Project and their management. The email specifically covered the following: ▪ Significant quantity of potential spoil arising from the proposed Project; ▪ Lack of headroom within the current domestic market; ▪ Importance of characterisation of material as early as possible in order to identify management options; ▪ Identification of the five likely categories into which the spoil will fall;	Baseline characterisation of ground conditions is included in Section 20.3, assessment of potential impacts related to contaminated ground is included in Section 20.4. Issues regarding waste also addressed in Chapter 24 (Materials & Waste Management).

Consultee	Comment	Relevant EIAR Section
	▪ Highlighted the fact that non-hazardous landfills (Ballynagran, Knockharley and Drehid) also take municipal waste, which takes precedent over Construction and Demolition (C&D) waste; ▪ Recently there has been a need to export non-hazardous soils due to the lack of capacity within the domestic market, likely that this will be required for this proposed Project if the current circumstances continue; and ▪ Encourage TII to explore alternatives domestically and to adopt a Circular Economy approach.	
Environmental Protection Agency	Response to submission of EIA Scoping Report stating that the Environmental Licensing Programme does not respond to correspondence relating to non-licensable developments.	In the absence of a specific response the chapter has taken relevant EPA published guidance (refer to Section 20.2.1) into account.
Geological Survey Ireland (GSI)	No response on specific aspects of the scheme beyond a request for sharing of information on water strikes encountered during the scheme-specific Ground Investigation (GI).	N/A

20.2.3.2 Site Walkover

A site walkover survey of the study area was conducted by Jacobs on 5, 9 and 18 July 2018. The weather conditions were dry with some intermittent sun. In addition, a reconnaissance survey of the study area was undertaken by a member of the soils and geology team on 8 November 2018.

20.2.3.3 Desk Study Data Sources

The following is a list of published references and data used in this Chapter:

- An Foras Talúntais (1980) General Soil Map of Ireland (An Foras Talúntais 1980);
- Teagasc Irish Soil Information System online map (Teagasc 2022);
- Historic Mine Sites – Inventory and Risk Classification (EPA and Geological Survey Ireland (GSI) 2009);
- GSI online geology viewer (GSI 2022);
- 1:500,000 scale – Quaternary Geological Map of Ireland (GSI 2017);
- 1:1,000,000 scale – Bedrock Geology of Ireland (GSI 2014);
- Topographic-map.com online viewer (topographic-map 2022);
- GeoHive, Ordnance Survey Ireland (OSI) online spatial data viewer (OSI 2022);
- Soil Urban Geochemistry (SURGE) Project, Geochemical Baseline for Heavy Metals and Organic Pollutants in Topsoil in the Dublin Area (GSI 2012);
- Current and historical mapping; and
- EPA Interactive Map (EPA 2022).

20.2.3.4 Project Specific Ground Investigation and Reports

Five phases of ground investigation have been undertaken specifically for the proposed Project to inform assessment of ground conditions both from a geotechnical design perspective and to inform the soils and geology assessment. The five phases are summarised as follows:

- Metro Link Phase 1 Ground Investigation, Factual Report (Causeway 2019);
- Metro Link Phase 2 Ground Investigation, Factual Report (Causeway 2020a);

- Metro Link Phase 3 Ground Investigation, Factual Report (Causeway 2020b);
- Metro Link Phase 4 Ground Investigation, Factual Report (Causeway 2020c); and
- Metro Link Phase 5 Ground Investigation, Factual Report (Causeway 2022).

Information from groundwater and ground gas monitoring rounds including groundwater sampling and laboratory analysis from selected Phase 1 to 5 monitoring installations during 2021 has been included within the assessment. In addition, groundwater and ground gas monitoring data from the supporting ground investigation has been included where relevant. Groundwater monitoring data is available for a total of 86 no. locations, and a total of 23 no. locations for ground gas. The available groundwater and ground gas monitoring locations are summarised in Appendix A20.2.

The following scheme specific assessments and reports have also been completed:

- Metro Link, Ground Investigation Report (GIR) (Jacobs IDOM 2022a);
- Metro Link, Geotechnical Design Report (GDR) (Jacobs IDOM 2022b); and
- Land Contamination Interpretive Report (Jacobs IDOM 2022c).

The scope of each ground investigation is summarised in Appendix A20.1 and details of the exploratory holes consulted as part of this assessment are recorded in Appendix A20.2. Exploratory locations are shown on Figure 20.6.

20.2.3.5 Supporting Reports and Ground Investigation

A list of historic published reports and ground investigations used in this Chapter is detailed below. A number of these were undertaken for previous iterations of the proposed Project, and it should be noted that design has changed considerably since these took place and information relevant to the current design have been included. In addition, information from ground investigations and reports not directly related to the proposed Project have been included where relevant.

- Dublin Metro North, Technical Note 023, Desk Study Review B0307000-010/GEO.360/002/1 (Jacobs 2008);
- Environmental Impact Statement – Metro North. Railway Procurement Agency, 2008 (RPA 2008);
- Northern Cross Route Phase 2, Site Investigation Data Volume 1 (Dublin City Council 1992);
- Dublin Light Railway, Sandyford to Ballymun Line Tunnel Link Between St Stephen's Green and Broadstone, Factual Report Volumes 1 and 2 (Wimtec 2000);
- Geotechnical Desk Study, City Centre and Airport (Haswell 2002);
- Irish Geotechnical Services Ltd (IGSL) Mater & Children's Hospital Ground Investigation (Phase II) – Main Site, Ground Investigation Report (IGSL 2002a);
- Site Investigation Works for the Proposed Dublin Light Rail Track, Draft Ground Investigation Report (Factual) (IGSL 2002b);
- Dublin Metro North Ground Investigation, Factual Ground Investigation Report (Volume 1) (IGSL 2007);
- Dublin Metro North Alignments Study, Geotechnical Interpretive Report (Section 1 to 6) (Parsons Brinckerhoff 2007);
- Dublin Metro North, Main Ground Investigation – Sections 6 & 7 (Norwest Holst 2008);
- Dublin Metro North, Main Ground Investigation, Ground Investigation Report (IGSL 2008);
- Dublin Metro North, Technical Note 023, Desk Study Review B0307000-010/GEO.360/002/1 (Jacobs 2008a);
- Dublin Metro North, Reference Ground Conditions Report for Information (B0307000-010/GEO.28/007/1) (Jacobs 2008b);
- Mater Stop – Additional GI, Dublin (Norwest Holst 2009);
- Metro North – Mater to Parnell, Geotechnical Site Investigation Report (IGSL 2010);
- Metro North Depot, Dardistown, Dublin, Factual Report on Ground Investigation (Soil Mechanics 2011); and
- New Metro North, Ground Investigation Report (Ground Investigations Ireland (GII) 2018).

The scope of each ground investigation is summarised in Appendix A20.1 and details of the exploratory holes consulted as part of this assessment are recorded in Appendix A20.2. Exploratory locations are shown on Figure 20.6.

20.2.4 Impact Assessment Methodology

20.2.4.1 Introduction

The potential impact of the proposed Project on the soils and geology environment has been assessed by classifying the importance of the relevant attributes and quantifying the likely magnitude of any impact on these attributes. This impact assessment methodology is in accordance with the Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of Environmental Impact Statements (IGI 2013).

The assessment presented in this Chapter considers the potential for significant environmental impacts to affect the baseline conditions as a direct and/or indirect result of the proposed Project. The baseline conditions are defined as the existing state of the environment and how it may develop in the future in the absence of the proposed Project.

The proposed Project can impact the baseline conditions through both construction activities and operational activities. Construction effects can include temporary effects that would cease as soon as construction is finished (such as dust emissions from construction activities). They can also include permanent effects, such as the loss of a mineral resource. Operational effects include those that occur from the presence of the proposed Project (e.g. alterations to drainage patterns) or those that occur from the proposed scheme itself, such as pollution from vehicle use.

Environmental impacts in this assessment are expressed in terms of the significance of effects, which can be both positive and negative. The significance of the effect of an impact is derived from consideration of the baseline sensitivity of a receptor (sometimes referred to as its importance) and the magnitude of the potential impact upon the receptor. The significance of the effect is influenced by both of these variables. The assessment of the potential impact of the proposed Project on soils and geology has been undertaken in accordance with the Guidelines on the Information to be Contained in Environmental Impact Statements (EPA 2002;2015) and the draft Guidelines on the Information to be Contained in Environmental Impact Assessment Reports (EPA 2017) and the Guidelines on the Information to be Contained in Environmental Impact Assessment Reports (EPA 2022) which have been drafted with a view to facilitating compliance with the EIA Directive.

The definitions relating to magnitude of impacts from a project are provided in Table 20.4, as detailed in the Guidelines.

Table 20.4: Description of Effects adapted from the Guidelines (EPA 2022)

Impact Assessment Criteria	
Quality of Effects	
It is important to inform the non-specialist reader whether the effect is positive, negative or neutral.	**Positive Effects** A change which improves the quality of the environment (for example, by increasing species diversity or improving the reproductive capacity of an ecosystem; or removing nuisances; or improving amenities).
	Neutral Effects No effects or effects that are imperceptible, within normal bounds of variation or within the margin of forecasting error.
	Negative/Adverse Effects A change which reduces the quality of the environment (for example, lessening species diversity or diminishing the reproductive capacity of an ecosystem; or damaging health or property or by causing a nuisance).

Impact Assessment Criteria	
Significance of Effects	
'Significance' is a concept that can have different meanings for different topics – in the absence of specific definitions for the different topics the following definitions may be useful.	**Imperceptible** An effect capable of measurement but without noticeable consequences.
	Not significant An effect which causes noticeable changes in the character of the environment but without signficant consequences.
	Slight Effects An effect which causes noticeable changes in the character of the environment without affecting its sensitivities.
	Moderate Effects An effect that alters the character of the environment in a manner that is consistent with existing and emerging trends.
	Significant Effects An effect which, by its character, magnitude, duration or intensity alters a sensitive aspect of the environment.
	Very Significant Effects An effect which, by its character, magnitude, duration or intensity significantly alters the majority of a sensitive aspect of the environment.
	Profound Effects An effect which obliterates all previous sensitive characteristics.
Extent and Context of Effects	
Context can affect the perception of significance. It is important to establish if the effect is unique, or perhaps, commonly or increasingly experienced.	**Extent** Describe the size of the area, the number of sites and the proportion of a population affected by an effect.
	Context Describe whether the extent, duration or frequency will confirm or contrast with established (baseline) conditions (is it the biggest, longest effect ever?).
Probability of Effects	
Descriptions of the effects should establish how likely it is that the predicted effects will occur so that the CA can take a view of the balance of risk over advantage when making a decision.	**Likely Effects** The effects that can reasonably be expected to occur because of the planned project if all mitigation measures are properly implemented.
	Unlikely Effects The effects that can reasonably be expected not to occur because of the planned project if all mitigation measures are properly implemented.
Duration and Frequency of Effects	
'Duration' is a concept that can have different meanings for different topics – in the absence of specific definitions for different topics the following definitions may be useful.	**Momentary Effects** Effects lasting from seconds to minutes.
	Brief Effects Effects lasting less than a day.
	Temporary Effects Effects lasting less than a year.
	Short-term Effects Effects lasting one to seven years.
	Medium-term Effects Effects lasting seven to fifteen years.

Impact Assessment Criteria	
	Long-term Effects Effects lasting fifteen to sixty years.
	Permanent Effects Effects lasting over sixty years.
	Reversible Effects Effects that can be undone, for example through remediation or restoration.
	Frequency of Effects Describe how often the effect will occur (once, rarely, occasionally, frequently, constantly – or hourly, daily, weekly, monthly, annually).
Types of Effects	
	Indirect Effects (a.k.a Secondary of Off-site Effects) Effects on the environment which are not a direct result of the project, often produced away from the project site or because of a complex pathway.
	Cumulative Effects The addition of many minor or insignificant effects, including effects of other projects, to create larger, more significant effects..
	'Do-nothing Effects' The environment as it would be in the future should the subject project not be carried out.
	'Worst-case' Effects The effects arising from a project in the case where mitigation measures substantially fail.
	Indeterminate Effects When the full consequences of a change in the environment cannot be described.
	Irreversible Effects When the character, distinctiveness, diversity or reproductive capacity of an environment is permanently lost.
	Residual Effects The degree of environmental change that will occur after the proposed mitigation measures have taken effect.
	Synergistic Effects Where the resultant effect is of greater significance that the sum of its constituents (e.g. combination of Sox and NOx to produce smog)

The assessments in this Chapter are qualitative, and the definitions of the criteria used at each stage of the assessment are presented in Section 20.2.4.2 to Section 20.2.4.6. The assessment tables and matrix used are based on those in Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of Environmental Impact Statements (IGI 2013), which are in turn based on Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes (NRA 2008), which are consistent with the approach and criteria detailed in the draft Guidelines (EPA 2017).

Although topography is described in Section 20.3 is does not form part of the impact assessment as it is not considered to be a sensitive receptor in its own right with respect to soils and geology, topography is considered in Chapter 27 (Landscape & Visual). The potential impact on geomorphological features has been described, though this is a limited assessment as the features are not considered as sensitive receptors in the context of EIA. Details of the methodology used to assess settlement and contaminated land specifically are included in Section 20.2.4.5 and Section 20.2.4.6 respectively.

20.2.4.2 Criteria for Rating Site Sensitivity

The criteria for rating the importance of geological features based on IGI and NRA guidance, along with some examples of such sites, are detailed in Table 20.5.

Table 20.5: Criteria for Rating Site Importance of Geological Features (from NRA 2009, IGI 2013)

Sensitivity/Significance	Criteria	Typical Examples
Very High	Attribute has a high quality, significance or value on a regional or national scale. Degree or extent of soil contamination is significant on a national or regional scale[1]. Volume of peat and/or soft organic soil underlying alignment is significant on a local or regional scale.	Geological feature rare on a regional or national scale. Large existing quarry or pit. Proven economically extractable mineral resource.
High	Attribute has a high-quality significance or value on a local scale. Degree or extent of soil contamination is significant on a local scale[1]. Volume of peat and/or soft organic soil underlying alignment is significant on a local scale.	Contaminated soil on-site with previous heavy industrial usage[1]. Large recent landfill site for mixed wastes. Geological feature of high value on a local scale (County Geological Site). Well drained and/or high fertility soils. Moderately sized existing quarry or pit. Marginally economic extractable mineral resource.
Medium	Attribute has a medium quality, significance or value on a local scale. Degree or extent of soil contamination is moderate on a local scale[1]. Volume of peat and/or soft organic soil underlying alignment is moderate on a local scale.	Contaminated soil on-site with previous light industrial usage[1]. Small recent landfill site for mixed wastes. Moderately drained and/or moderate fertility soils. Small existing quarry or pit. Sub-economic extractable mineral resource.
Low	Attribute has a low quality, significance or value on a local scale. Degree or extent of soil contamination is minor on a local scale[1]. Volume of peat and/or soft organic soil underlying alignment is small on a local scale.	Large historical and/or recent site for construction and demolition wastes. Small historical and/or recent landfill site for construction and demolition wastes[1]. Poorly drained and/or low fertility soils. Uneconomically extractable mineral resource.

Notes:

[1] Refer to Section 20.2.4.5 for further details of methodology for assessment of land contamination

Recently published IEMA guidance provides additional guidance on classifying receptor sensitivity for in-situ soils based on soil resource and soil functions, which has also been taken into account and is provided in Table 20.6. The IEMA guidance provides examples of UK classifications which differ to classifications in the Republic of Ireland although there is some commonality and these sensitivity classifications have been used within the assessment where appropriate and applicable.

Table 20.6: Guidance on Rating Soil Receptor Sensitivity and Typical Soil Resource/Function Descriptions (from IEMA 2022)

Receptor Sensitivity	Soil Resource and Soil Functions
Very High	**Biomass production:** ALC Grades 1 & 2 or LCA Classes 1 & 2 (for Wales all BMV (Grade 1, 2 and 3 a) is considered very high*). **Ecological habitat, soil biodiversity and platform for landscapes:** Soils supporting protected features within a European site (e.g., SAC, SPA, Ramsar); peat soils; soils supporting a national park, or ancient woodland. **Soil carbon:** Peat soils. Soils with potential for ecological/landscape restoration. **Soil hydrology:** very important catchment pathway** for water flows and flood risk management. **Archaeology, Cultural Heritage, Community benefits and Geodiversity:** SAMs and adjacent areas; World Heritage and European designated sites; soils with known archaeological interest; soils supporting community/recreational/educational access to land covered by national park designation. **Source of Materials:** Important surface mineral reserves that would be sterilised (i.e. without future access).
High	**Biomass production:** ALC Grade 3a (for Wales all BMV is considered very high*), or LCA Grade 3.1. **Ecological habitat, soil biodiversity and platform for landscapes:** Soils supporting protected features within a UK designated site (e.g., UNESCO Geoparks, SSSI or AONB, Special Landscape Area and Geological Conservation Review sites); native Forest and woodland soils; Unaltered soils supporting semi-natural vegetation (including UKBAP priority habitats or Section 6 habitats in Wales). **Soil carbon:** Organo-mineral soils (e.g., peaty soils). **Soil hydrology:** Important catchment pathway** for water flows and flood risk management. **Archaeology, Cultural Heritage, Community benefits and Geodiversity:** Soils with probable but as yet unproven (prior to being revealed by construction) archaeological interest: Historic parks and gardens; RIGS; Soils supporting community/recreational/educational access to RIGS and AONBs. **Source of Materials:** Surface mineral reserves that would be sterilised (i.e. without future access).
Medium	**Biomass production:** ALC Grade 3b or LCA Grade 3.2. **Ecological habitat, soil biodiversity and platform for landscapes:** Soils supporting protected or valued features within non-statutory designated sites (e.g., Local Nature Reserves (LNR), Local Geological Sites (LGSs), Sites of Nature Conservation Importance (SNCIs), Special Landscape Areas; Non-Native Forest and woodland soils). **Soil carbon:** Mineral soils . **Soil hydrology:** Important minor catchment pathway** for water flows and flood risk management. **Archaeology, Cultural Heritage, Community benefits and Geodiversity:** Soils with possible but as yet unproven (prior to being revealed by construction) archaeological interest; soils supporting community/recreational/educational access to land. **Source of Materials:** Surface mineral reserves that would remain accessible for extraction.
Low	**Biomass production:** ALC Grade 4 & 5 or LCA Grade 4.1 to 7 or Urban soils. **Ecological habitat, soil biodiversity and platform for landscapes:** Soils supporting valued features within non-designated notable or priority habitats/landscapes. Agricultural soils. **Soil carbon:** Mineral soils. **Soil hydrology:** Pathway** for water flows and flood risk management. **Archaeology, Cultural Heritage, Community benefits and Geodiversity:** Soils supporting no notable cultural heritage, geodiversity no community benefits; soils supporting limited community/recreational/educational access to land. **Source of Materials:** Surface mineral reserves that would remain accessible for extraction.

Receptor Sensitivity	Soil Resource and Soil Functions
Negligible	As for low sensitivity, but with only indirect, tenuous, and unproven links between sources of impact and soil functions.

* All BMV in Wales is considered 'Very High' sensitivity due to the PPW wording *'....significant weight to protect [BMV] from development'*. Only if a development can demonstrate 'overriding need' would MBV grades need to be considered in the sequential test.

** As defined by the site and catchment characteristics according to the professional judgement of a catchment hydrologist.

20.2.4.3 Criteria for Assessing Magnitude of Impacts

Table 20.7 describes the assessment of the magnitude of impacts based on IGI guidance, which can be described as adverse or beneficial.

Table 20.7: Criteria for Assessing the Magnitude of Impact (IGI 2013)

Magnitude of Impact	Criteria	Typical Examples
Large Adverse	Results in loss of attribute.	Loss of high proportion of future quarry or pit reserves. Irreversible loss of high proportion of local high fertility soils. Removal of entirety of geological heritage feature. Requirement to excavate/remediate entire waste site[1]. Requirement to excavate and replace high proportion of peat, organic soils and/or soft mineral soils beneath alignment.
Moderate Adverse	Results in impact on integrity of attribute or loss of part of attribute.	Loss of moderate proportion of future quarry or pit reserves. Removal of part of geological heritage feature. Irreversible loss of moderate proportion of local high fertility soils. Requirement to excavate/remediate significant proportion of waste site[1]. Requirement to excavate and replace moderate proportion of peat, organic soils and/or soft mineral soils beneath alignment.
Small Adverse	Results in minor impact on integrity of attribute or loss of small part of attribute.	Loss of small proportion of future quarry or pit reserves. Removal of small part of geological heritage feature. Irreversible loss of small proportion of local high fertility soils and/or high proportion of local low fertility soils. Requirement to excavate/remediate small proportion of waste site[1]. Requirement to excavate and replace small proportion of peat, organic soils and/or soft mineral soils beneath alignment.
Negligible	Results in an impact on attribute but of insufficient magnitude to affect either use or integrity.	No measurable changes in attributes.
Minor Beneficial	Results in minor improvement of attribute quality.	Minor enhancement of geological heritage feature.
Moderate Beneficial	Results in moderate improvement of attribute quality.	Moderate enhancement of geological heritage feature.
Major Beneficial	Results in major improvement of attribute quality.	Major enhancement of geological heritage feature.

Notes:

[1] Refer to Section 20.2.4.5 for further details of methodology for assessment of land contamination

20.2.4.4 Criteria for Assessing Significance of Impacts

The significance of any particular effect was identified through the use of the matrix detailed in Table 20.8. This assigns significance by combining sensitivity with the magnitude of impact.

Table 20.8: Criteria for Assessing Significance of Impacts (IGI 2013)

		Magnitude of Impact			
		Negligible	**Small**	**Moderate**	**Large**
Importance of Attribute (Baseline Sensitivity)	**Very High**	Imperceptible	Significant/Moderate	Profound/Significant	Profound
	High	Imperceptible	Moderate/Slight	Significant/Moderate	Profound/Significant
	Medium	Imperceptible	Slight	Moderate	Significant
	Low	Imperceptible	Imperceptible	Slight	Slight/Moderate

The definitions of the terms used to describe the significance in Table 20.8 above are detailed in Table 20.9 below.

Table 20.9: Definitions of Significance Terms (NRA 2009)

Significance of Impact	Description
Imperceptible	An impact capable of measurement but without noticeable consequences.
Slight	An impact that alters the character of the environment without affecting its sensitivities.
Moderate	An impact that alters the character of the environment in a manner that is consistent with existing or emerging trends.
Significant	An impact, which by its character, magnitude, duration or intensity alters a sensitive aspect of the environment.
Profound	An impact which obliterates all previous sensitive characteristics.

20.2.4.5 Assessment of Land Contamination

As part of the risk-based approach to assessing the potential risk from contaminated land mandated by the EPA (EPA 2013; EPA 2007; EA 2021) a Conceptual Site Model (CSM) has been developed to describe the relationship between potential contamination sources, receptors that could be affected by contaminants and the potential linking pathways. The presence of a contamination source does not automatically infer a risk; if one or more of either a source, a linking pathway or a receptor are absent a viable or complete pollutant linkage is not present and therefore a risk is not present.

The preliminary CSM is presented in Appendix A20.3 and has been used as the basis for the contaminated land risk assessment. The methodology used to determine overall risk includes consideration of:

- The likelihood of the event (probability), which takes into account both the presence of the hazard and receptor and the integrity of the pathway; and
- The severity of the potential consequence, which takes into account both the potential severity of the hazard and the sensitivity of the receptor.

The classification of likelihood (based on Contaminated Land Risk Assessment: A Guide to Good Practice (CIRIA 552) (CIRIA 2001)) is detailed in Table 20.10 and the classification of severity is detailed in Table 20.11.

Table 20.10: Classification of Likelihood

Classification	Definition
High Likelihood	An event is very likely to occur in the short term, and is almost inevitable over the long term OR there is evidence at the receptor of harm or pollution.
Likely	It is probable that an event will occur. It is not inevitable, but possible in the short term and likely over the long term.
Low Likelihood	Circumstances are possible under which an event could occur. It is by no means certain that even over a longer period such an event would take place, and less likely in the short term.
Unlikely	It is improbable that an event would occur even in the very long term.

Table 20.11: Classification of Severity

Classification	Definition
Severe	▪ Acute risks to human health. ▪ Short-term risk of pollution of sensitive water resource (e.g. major spillage into the water environment). ▪ Impact on surface water or groundwater (e.g. large-scale pollution or very high levels of contamination). ▪ Catastrophic damage to buildings or property (e.g. explosion causing building collapse). ▪ Ecological system effects – irreversible adverse changes to a protected location. Immediate risks.
Medium	▪ Chronic risks to human health. ▪ Pollution of sensitive water resources (e.g. leaching of contaminants into the water environment). ▪ Ecological system effects – substantial adverse changes to a protected location. ▪ Significant damage to buildings, structures and services (e.g. damage rendering a building unsafe to occupy, such as foundation damage).
Mild	▪ Non-permanent health effects to human health. ▪ Pollution of non-sensitive water resources . ▪ Damage to buildings, structures and services (e.g. damage rendering a building unsafe to occupy, such as foundation damage). ▪ Substantial damage to non-sensitive environments (unprotected ecosystems e.g. crops).
Minor/Negligible	▪ Non-permanent health effects to human health (easily prevented by appropriate use of PPE). ▪ Minor pollution to non-sensitive water resources. ▪ Minor damage to non-sensitive environments (unprotected ecosystems e.g. crops). ▪ Easily repairable effects of damage to buildings, structures, services or the environment (e.g. discoloration of concrete, loss of plants in a landscaping scene).

To determine the overall risk to the identified receptor the likelihood and severity of the potential hazard are combined in accordance with the risk assessment matrix in Table 20.12. The definitions of the outcomes are summarised in Table 20.13.

Table 20.12: Risk Assessment Matrix

		Consequence			
		Severe	**Medium**	**Mild**	**Minor/Negligible**
Probability (Likelihood)	**High Likelihood**	Very high risk	High risk	Moderate risk	Moderate/Low risk
	Likely	High risk	Moderate risk	Moderate/Low risk	Low risk
	Low Likelihood	Moderate risk	Moderate/Low risk	Low risk	Negligible risk
	Unlikely	Moderate/Low risk	Low risk	Negligible risk	Negligible risk

Table 20.13: Definitions of Risk

Term	Description
Very high risk	Severe harm to a receptor may already be occurring OR a high likelihood that severe harm will arise to a receptor unless immediate remedial action works/mitigation measures are undertaken.
High risk	Harm is likely to arise to a receptor, and is likely to be severe, unless appropriate remedial actions/mitigation measures are undertaken. Remedial works may be required in the short term, but likely to be required over the long term.
Moderate risk	Possible that harm could arise to a receptor but low likelihood that such harm would be severe. Harm is likely to be medium. Some remedial works may be required in the long term.
Moderate/low risk	Possible that harm could arise to a receptor, but where a combination of likelihood and consequence results in a risk that is above low but is not of sufficient concern to be classified as medium. It can be driven by cases where there is an acute risk which carries a severe consequence, but where the exposure is unlikely.
Low risk	Possible that harm could arise to a receptor. Such harm would at worse normally be mild.
Negligible risk	Low likelihood that harm could arise to a receptor. Such harm unlikely to be any worse than mild.

20.2.4.6 Assessment of Settlement

A methodology to predict ground movement and assess building damage has been adopted based on an approach adopted in worldwide tunnel projects including London Crossrail and High Speed 2 in England. The assessment is undertaken in three phases with Phase 1 and the initial analysis for Phase 2 (Phase 2a) undertaken as part of the proposed Project preliminary design and the completion of Phase 2b and Phase 2 undertaken by the detailed designers of the Design and Build Contractor. The three phases are briefly summarised as follows with further detail included in the Building Damage Report (Appendix A5.17):

- **Phase 1**: Generic assessment of greenfield settlement contours using generic ground parameters, screening of sensitive receptors including building, structures and services;
- **Phase 2**: Assessment of potential damage to receptors identified from Phase 1 based on standard assumptions and classified into damage categories 0 – 5, receptors placed in damage category of 3 or greater carried to Phase 3; and
- **Phase 3**: Each receptor from Phase 2 considered individually to determine its behaviour using detailed information and assessment methods.

It should be noted that this Chapter only considers effects of settlement on receptors relevant to soils and geology. Settlement effects are considered in other chapters as follows:

- Chapter 21 (Land Take) (buildings)
- Chapter 22 (Infrastructure & Utilities) (utilities, services and infrastructure); and
- Chapter 26 (Architectural Heritage) (built environment).

Further details of the settlement assessment methodology are included in the Building Damage Report (Appendix A5.17) and summarised briefly as follows:

- **Phase 1**: Generic assessment based on greenfield settlement contours.
  - Phase 1 involves the assessment of the greenfield settlement contours induced by tunnelling and station box construction using generic ground parameters. This is followed by the identification of buildings that are within the 10mm settlement contour or with a ground settlement slope >1:500, and those buildings within the 1mm settlement contour subject to special considerations.
  - The tunnelling settlement assessment has been undertaken according to the 'Volume Loss' methodology, an empirical method based on the percentage of tunnel volume excavated that is over and above that required for the tunnel itself based on derivation of generic ground factors.
  - The assessment of settlement due to wall construction and bulk excavation (station boxes and retaining walls) based on the case history data documented within CIRIA Report C760 "Embedded Retaining Walls – Guidance for Economic Design' (CIRIA 2017).

- **Phase 2**: Preliminary damage assessment of receptors identified from Phase 1.
  - Phase 2 has been split into 2 sub phases (Phase 2a and Phase 2b):

- **Phase 2a**: Initial assessment undertaken as part of Preliminary Design of proposed Project using similar assumptions to Phase 1.
- **Phase 2b**: Confirmatory/refined analysis undertaken by the appointed detailed designer of the Design and Build contractor using refined parameters and construction methodology.
  - The building risk categories in Table 20.14 has been used to define the risk category and degree of building damage.

Table 20.14: Building Risk Categories (from Appendix A5.17)

Building and Structure Damage Classification (after Burland et al 1977) and Boscarding and Cording (1989))					Approximately Equivalent Ground Settlements and Slopes (after Rankin 1988)	
Risk Category	**Degree of Damage**	**Description of Typical Damage and Likely Forms of Repair for Typical Masonry Building**	**Approx. Crack Width (mm)**	**Limiting Max Tensile Strain (%)**	**Max Slope of Ground**	**Maximum Settlement of Building (mm)**
0	Negligible	Hairline cracks	<0.1	Less than 0.05		
1	Very Slight	Fine cracks easily treated during normal redecoration. Perhaps isolated slight fracture in building. Cracks in exterior brickwork visible upon close inspection.	0.1 to 1	0.05 to 0.075	Less than 1:500	Less than 10
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible some re-pointing may be required for weather tightness. Doors and windows may stick slightly.	1 to 5	0.075 to 0.15	1:500 to 1:200	10 to 50

Building and Structure Damage Classification (after Burland et al 1977) and Boscarding and Cording (1989))					Approximately Equivalent Ground Settlements and Slopes (after Rankin 1988)	
Risk Category	**Degree of Damage**	**Description of Typical Damage and Likely Forms of Repair for Typical Masonry Building**	**Approx. Crack Width (mm)**	**Limiting Max Tensile Strain (%)**	**Max Slope of Ground**	**Maximum Settlement of Building (mm)**
3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can me masked by suitable linings. Re-pointing and possibly replacement of a small amount of extent brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather tightness often impaired.	5 to 15 or a number of cracks greater than 3	0.015 to 0.3	1:200 to 1:50	50 to 75
4	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted.	15 to 25 but also depends on number of cracks	Greater than 0.3	1:200 to 1:50	Greater than 75
5	Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require shoring. Windows broken by distortion. Danger of instability.	Greater than 25 but also depends on number of cracks	Greater than 0.3	Greater than 1:50	Greater than 75

It should be noted that not all buildings have been assessed at Phase 2a, further details are included in the Building Damage Report (Appendix A5.17), Chapter 21 (Land Take) and Chapter 26 (Architectural Heritage). All buildings that have been classified as Damage Category 3 (Moderate) and above will be subject to Phase 2b assessment by the detailed designer of the Design & Build Contractor.

- **Phase 3**: Detailed assessment.

Phase 3 involves detailed assessment of all buildings that have been classified as Damage Category 3 (Moderate) or above at the end of Phase 2b, and all buildings classified as Special Buildings which have been subject to Phase 2a and 2b assessment. Phase 3 assessment will be undertaken by the detailed designer of the Design and Build Contractor.

In addition to buildings an appraisal of the potential impact on bridges and other assets within the settlement zone of influence has been undertaken (Appendix A5.17). The appraisal has been undertaken based the Phase 1 methodology detailed above (generic assessment of greenfield settlement contours using generic ground parameters and screening of sensitive receptors) to highlight areas and structures where a more detailed consideration and assessment is required during the detailed design phase.

20.3 Baseline Conditions

The regional setting of the proposed Project study area is described initially (Section 20.3.1), followed by a more detailed description of baseline conditions within each of the four geographical areas (AZ1 to AZ4) of the proposed Project route (Section 20.3.2 to Section 20.3.5). This Section should be read in conjunction with Figure 20.1 to Figure 20.15 along with an index of borehole information used to obtain information on the soil and superficial geology for each AZ in Appendix A20.2, and geological cross sections (GIR) in Appendix A20.9.

20.3.1 Regional Setting

20.3.1.1 Topography

The northern extent of the study area is near Malahide Estuary (approximately 230m east), adjacent to the Broadmeadow River with a low elevation of around 7m Above Ordnance Datum (AOD). The topography rises to a high of approximately 70mAOD within the vicinity of Dublin Airport, then with minor local variations reduces to sea level at the River Liffey crossing. To the south of the River Liffey, ground levels rise to around 20mAOD in the vicinity of Charlemont. Surface gradients are generally gentle, with small areas of higher gradients generally associated with river features.

20.3.1.2 Geomorphology

The morphology along the alignment is shaped principally from glacial activity, with most of the glacial sediments in the vicinity of the study area being deposited during the last glaciation and subsequent fluvial processes within the vicinity of watercourses (GSI 2022). The glacial features encountered are typically linear and oriented north west to south east (refer to Figure 20.2).

20.3.1.3 Geohazards

Geohazards occur when potentially hazardous earth processes and features interact with people and the environment. In the context of the Dublin area the primary potential geohazards are landslides and karst features.

A search of the GSI karst database (GSI 2022) does not indicate any karst features within the study area (refer to Figure 20.7). The GSI Landslide Susceptibility Map (GSI 2022) shows the majority of the study area is of low susceptibility to landslides, with small areas classified as moderately low or moderately high associated with areas of higher ground gradients (refer to Figure 20.8).

The associated risk definitions are as follows (GSI 2022):

- Low: The predominant soil type is Fine to Coarse Range material followed by Medium to Coarse Range material which together exceeds all others by a significant extent. Slopes are mainly in the lower ranges of 0-3° (degrees), 3-6° and 6-10° range;
- Moderately Low: The predominant soil type is Medium to Coarse and to a slightly lesser extent Fine to Coarse Range, Rock Near Surface or Peat which occur in equal proportions. Slopes are mainly in the 3-6° band with a significant proportion in the 6-10° range; and
- Moderately High: The predominant soil type is Rock Near the Surface and to a lesser extent Peat and Medium to Coarse Sand. Slopes are mainly in the 10-15° band with a significant proportion in the 6-10° and 15-20° range.

20.3.1.4 Hydrology

The majority of the study area is located within the Liffey and Dublin Bay Catchment (Water Framework Directive (WFD) Catchment ID 09). North of Dublin Airport, the study area is located within the Nanny Delvin Catchment (WFD Catchment ID 08). Watercourse flow is generally in an east to south-east direction. Further detail on the watercourses within each AZ is included in Section 20.3.2 to Section 20.3.5.

For further information refer to Chapter 18 (Hydrology).

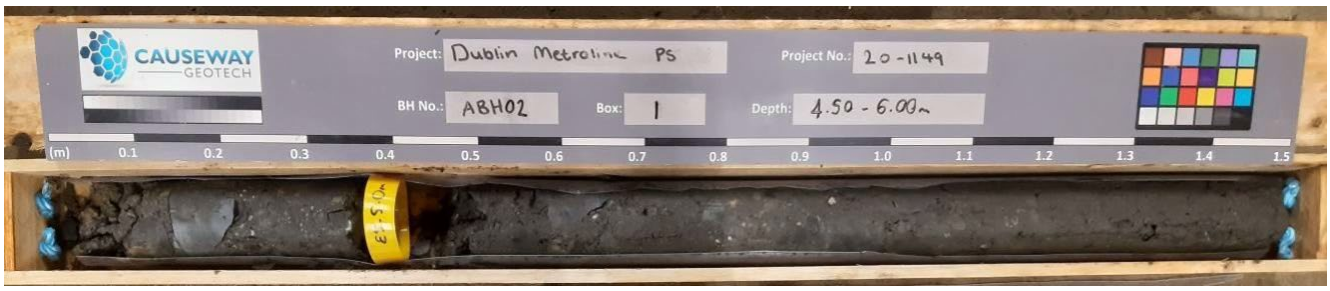
20.3.1.5 Soils and Superficial Geology

The General Soil Map of Ireland (An Foras Talúntais 1980) shows the footprint of the proposed Project outside urban areas is underlain by Grey Brown Podzolics, a mainly dry mineral soil comprising associated Gleys. Urban soils are the Teagasc classification referring to areas of soils within an urban area without any further classification, and which may include different soil types. Made ground is defined as soil/superficial geology with observed anthropogenic influence. 'Greenfield' areas are those that have not been subject to current or historical urban development.

Superficial geology is defined as the youngest geological deposits, generally formed during the Quaternary period (2.6 million years from the present) and generally comprising unconsolidated sediments overlying solid bedrock.

The Quaternary Geological Map of Ireland (GSI 2017) and GSI online maps (GSI 2022) suggest the subsoils primarily consist of till derived from limestone along with areas of alluvium and limestone derived gravels. The till is generally low permeability and cohesive apart from subordinate (although locally extensive) granular horizons, with high strength and low compressibility (Parsons Brinkerhoff 2007). Within Dublin these deposits are colloquially known as the black and brown boulder clays; the brown boulder clays are thought to be a weathered version of the underlying black boulder clay and typically have thicknesses of up to 4m. Total boulder clay thicknesses (black and brown boulder clay) in the region of the proposed Project are variable and have been recorded with thicknesses in excess of 30m.

These cohesive superficial deposits were encountered extensively within the ground investigation and described generally as firm to very stiff brown slightly sandy gravelly clay with variable cobble content. The granular horizons were typically described as gravelly clayey sand or sandy slightly clayey gravel. A typical example of a core extract of the cohesive glacial till (described as stiff dark grey sandy slightly gravelly clay with low cobble content recovered from ABH02, Causeway Phase 5) is included below.



The soil associations found within the study area are shown on Figure 20.1, and distributions of Quaternary sediments are shown on Figure 20.3.

The impact of the proposed Project on agricultural land is assessed in Chapter 23 (Agronomy).

20.3.1.6 Bedrock Geology

Geological maps (GSI 2014; GSI 2022) indicate that the regional bedrock geology comprises folded Carboniferous Tournasian limestone, and Viséan limestone and calcareous mudstone. The heavily faulted older Tournasian rocks are primarily present towards the north and include the Tober Colleen and Malahide formations, and the Waulsortian limestones. An anticline axis is present in the Swords area with an associated syncline access just to the south of the M50, both trending south east to north west. The Viséan limestone and calcareous mudstone of the Lucan Formation are primarily present south of the M50 Motorway. The regional bedrock setting is shown on Figure 20.4.

20.3.1.6.1 Malahide Formation

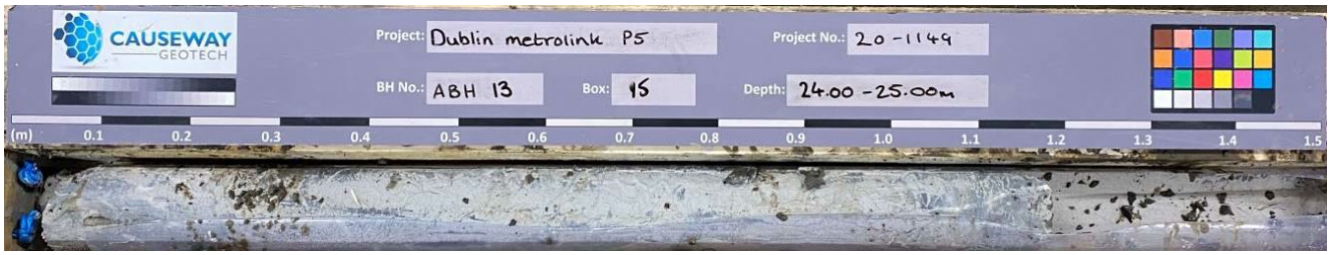
The Carboniferous Malahide Formation comprises argillaceous bioclastic (fossiliferous) limestone with interbedded shale; the lower part of this formation is composed of calcareous shales, siltstones and sandstones with occasional thin limestones at the base. Thicknesses of the Malahide formation are recorded from 300m to more than 1200m (GSI 2022; RPA 2008).

The Malahide formation is predominant towards the north of the Proposed Project (AZ1 and AZ2) and where encountered during ground investigations described as 'strong, locally medium strong indistinctly thinly laminated dark grey argillaceous bioclastic limestone'. A typical example of a core extract of the Malahide Formation (recovered from ABH05, Causeway Phase 5) is included below.

20.3.1.6.2 Waulsortian Limestones

The Carboniferous Waulsortian Limestone is a predominantly pale grey, crudely bedded or massive lime-mudstone, biomicritic in nature with distinctive stromatactis and generally formed mounds or reefs. The Waulsortian Limestones are generally dolomitised and have a typical thickness ranging 300-500m (GSI 2022; RPA 2008).

The Malahide Formation is only present within the vicinity of Dublin Airport (AZ2) and was typically described where encountered during the GI as 'strong to extremely strong bedded to massive greay and locally black fin-grained siliceous limestone'. A typical example of a core extract of the Waulsortian Formation (recovered from ABH13, Causeway Phase 5) is included below.



20.3.1.6.3 Tober Colleen Formation

The Tober Colleen Formation is generally described as dark-grey calcareous, commonly bioturbated mudstone and subordinate thin argillaceous micritic limestones. The lower levels of this formation can include reef derived debris and large slumped reef blocks. The thickness of Tober Colleen Formation is recorded to range from 50m to 250m (GSI 2022; RPA 2008).

The Tober Colleen Formation is present at the southern end of AZ2 and AZ3 and was typically described where encountered during the GI as 'strong to very strong interbedded or interlaminated dark grey to black calcareous mudstone and argillaceous limestone'. A typical example of a core extract of the Tober Colleen Formation (recovered from NBH202, Causeway Phase 2) is included below.

20.3.1.6.4 Lucan Formation

The Lucan (Calp) Formation refers to various units of basinal limestone and shale formed from carbonate sediment deposits. The Lucan Formation consists of muddy limestone beds inter-bedded with calcareous shale beds. The limestone beds are dark grey to black, fine grained, occasionally cherty and are classified as strong to very strong. Pyrite has also been recorded. Analysis of thin sections for the Dart Underground EIS (Irish Rail 2010) indicated pyrite concentrations ranging from <0.5% to 5% with detects in the majority of samples, with wide variation between close samples and no regional trends evident. Occasional exceptionally high concentrations of 10% to 40% were identified typically associated with lithology contact surfaces. The limestone hosts some limited fossils such as corals and brachiopods locally. The shale beds are less substantial and dark grey to black in appearance. These are typically moderately strong and more susceptible to weathering than the limestones. The typical thickness of the Lucan Formation is 300-800m. The bedrock surface is highly irregular with incised drainage channels including a large pre-glacial channel north of the River Liffey (GSI 2022; RPA 2008; Parsons Brinkerhoff 2007).

The Lucan formation is present throughout AZ4 and was typically described where encountered during the GI as 'strong to moderately strong thinly bedded to thickly laminated dark grey or black calcareous limestone'. A typical example of a core extract of the Lucan Formation (recovered from ABH52, Causeway Phase 5) is included below.

20.3.1.7 Hydrogeology

The groundwater bodies within the study area have been designated WFD management units (GSI 2022). WFD management units are defined as discrete water bodies classified under the provisions of the WFD. The study area falls within the Swords and Dublin groundwater bodies, which are both classified as Poorly Productive Bedrock. Smaller areas around Swords and Dublin Airport are designated as Industrial Facilities and classified as Poorly Productive Bedrock.

The GSI has classified the bedrock aquifers according to characteristics and productivity (GSI 2022). The majority of the study area is classified as a LI (Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones). Areas around Swords and Dublin Airport are classified as a PI (Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones).

The bedrock and superficial geology summarised in Section 20.3.1.5 and Section 20.3.1.6 influences the overall groundwater vulnerability (GSI 2022). The study area is largely classified as Low vulnerability to contamination, with areas up to Very High vulnerability around Swords, Dublin Airport and Dublin City Centre, typically associated with bedrock at the ground surface or more highly permeable superficial geological deposits.

Groundwater levels have been read from boreholes installed during the Phase 1 to 5 ground investigation works (refer to Section 20.2.3.4). Groundwater levels and ranges for each AZ are described in Section 20.3.2 to Section 20.3.5.

Hydrogeology has been described in this Chapter to support the soils and geology assessment; the assessment of impacts related to hydrogeology is presented in Chapter 19 (Hydrogeology).

20.3.1.8 Current and Historic Mining Sites

Available information does not indicate any active or historic mines within the study area.

Several historic gravel pits and quarries have been noted on the available historic mapping. There is also the potential that localised small-scale quarrying has taken place that is not shown on historic mapping. Quarried materials are likely to have comprised sand, gravel and limestone. Records indicate that there are no active quarries, sand pits or gravel pits within the study area.

The potential for future extraction of aggregate materials within the study area has been considered. Future aggregate potential of crushed rock and granular material across Ireland has been mapped by the GSI (GSI 2022). The majority of the study area is classified as a Low Potential for crushed rock (refer to Figure 20.10). Areas of Moderate Potential are recorded around Swords and Dublin City Centre, with areas up to Very High Potential recorded around Dublin Airport and Griffith Park Station. Areas of granular material potential are primarily focused in the vicinity of watercourses (refer to Figure 20.9). Areas of Very High Potential are recorded around Broad Meadow Water and the Tolka River, with areas ranging from Very Low to High recorded around smaller watercourses and in Dublin City Centre. The sensitivity of potential future mineral resources has been determined from the rating of the aggregate potential and the estimated economic viability of future extraction.

Further information can be found in Section 20.3.2 to Section 20.3.5.

20.3.1.9 Irish Geological Heritage Sites

The GSI provides scientific appraisal and interpretative advice on geological and geomorphological sites and is responsible for the identification of important sites that are capable of being conserved as County Geological Sites or Natural Heritage Areas (NHAs). The National Parks and Wildlife Service of the Department of Culture, Heritage and the Gaeltacht (now Department of Tourism, Culture, Arts, Gaeltacht, Sports and Media) have the responsibility of designation and management of sites, with appropriate advice from GSI. At present, the GSI has compiled a list of sites proposed for designation as Natural Heritage Areas (pNHAs) noted on the GeoHive interactive map.

The GSI has also determined a secondary list of County Heritage Sites, which may be considered for protection at local authority functional control level. County Geological Sites (CGS) are generally incorporated into County Development Plans.

Geological Heritage Sites within each AZ are detailed in Section 20.3.2 to Section 20.3.5, with locations are shown on Figure 20.5.

Architectural Heritage is considered in Chapter 26 (Architectural Heritage), while archaeological and cultural sites are considered in Chapter 25 (Archaeology & Cultural Heritage).

20.3.1.10 Radon and Ground Gas

Radon is a naturally occurring radioactive gas which originates form the decay of uranium in rocks and soils. It is colourless, odourless and tasteless. As radon decays, radiation is given off in the form of alpha particles. After inhalation, the alpha particles are absorbed by the lungs and cause localised damage, which can lead to lung cancer.

Radon can accumulate in enclosed or poorly ventilated spaces, such as buildings, houses and tunnels. The receptors to radon in relation to the proposed Project are construction and maintenance workers, future site users and adjacent residents.

Radon concentration is measured in becquerels per cubic metre of air (Bq/m^3). The Becquerel is a unit of radioactivity and corresponds to one radioactive disintegration per second.

The Radiological Protection Institute of Ireland (RPII, part of the EPA) has issued information and guidance on radon. The reference level for long-term exposure to radon in a house, above which the need for remedial action should be considered, is $200Bq/m^3$ (determined in accordance with the RPII's standard protocol). Based on current knowledge it is estimated that in Ireland, for the population as a whole, a lifetime exposure (i.e. 70 years) to radon in the home at the Reference Level of $200Bq/m^3$ carries a risk of about 1 in 50 of contracting fatal lung cancer.

Radon risk is determined by the percentage of homes in a given area that are estimated to be above the $200Bq/m^3$ Reference Level. The online Radon Map of Ireland (EPA 2022) has recently been updated (26 May 2022). The revised version contains more local detail on the likely risks than the previous map, which was based on classification of 10km squares. Both the current version and old versions of the map have been used to provide an indication of the level of risk associated with the scheme (refer to Figure 20.12). The radon risk in ach AZ is discussed in Section 20.3.2 to Section 20.3.5.

Radon risk is also considered in Chapter 10 (Human Health).

'Ground gas' refers to gases such as carbon dioxide, methane, carbon monoxide and hydrogen sulphide which can occur naturally and from anthropogenic sources. Volatile and Semi-Volatile Organic Compounds (VOCs/SVOCs) within the ground can produce potentially harmful vapours. Typical sources of ground gases and vapours include:

- Methane, carbon dioxide, carbon monoxide and hydrogen sulphide from breakdown of organic materials in the sub-surface from natural sources such as wetlands, peat and alluvium and anthropogenic sources such as landfills;
- Vapours from anthropogenic sources such as landfills or spillages/improper disposal of volatile materials such as petrol, oils or solvents;
- Methane, carbon dioxide, carbon monoxide and hydrogen sulphide from coal measures; and
- Carbon dioxide from carbonate-rich soils or bedrock.

Issues arising from the presence of ground gases are usually due to an accumulation or release of gas or vapours in an enclosed or confined space. Hazards associated with ground gases and vapours include:

- Explosion/flammability (methane, hydrogen sulphide, VOCs/SVOCs);
- Asphyxiation (methane, carbon dioxide, carbon monoxide); and
- Toxicity (carbon monoxide, hydrogen sulphide, VOCs/SVOCs).

A review of available ground gas monitoring records for each AZ is included in Section 20.3.2 to Section 20.3.5. Gas Screening Values (GSVs) for each borehole have been calculated based on the highest observed concentrations of carbon dioxide and methane and the highest gas flow. In accordance with the CIRIA C665 methodology (Assessing risks Posed by Hazardous Ground Gases to Buildings (CIRIA 2007), these values are used to derive characteristic situations (CS) ranging from CS1 (very low risk) to CS6 (very high risk). In addition, gas concentrations have been screened against Workplace Exposure Limits (WELs) for assessment of occupational health risks (Health Service Executive (HSE 2020)). Values in excess of the WELs indicate control measures for protection of occupational health may be required.

20.3.1.11 Contaminated Land

Land affected by contamination can pose constraints to the scheme in a number of ways (also refer to the preliminary CSM in Appendix A20.3), such as:

- Limitations to materials reuse and increased costs of handling and disposal;

- Impact to human health of construction workers, residents and adjacent land users;
- Mobilisation of contaminants impacting surface water, groundwater and ecological sites; and
- Impact to the integrity of construction materials.

Land contamination can be caused by activities such as historical industrial land use, waste disposal, historical mining and quarrying and pollution from accidents and spills. Potential contaminants can include a variety of elements and chemical compounds including heavy metals, asbestos, hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), VOCs, SVOCs, per- and polyfluoroalkyl substances (PFAS) and ground gas.

Rapid growth and expansion of Dublin occurred during the eighteenth century, including reclamation of land from the River Liffey. Development of the city is likely to have resulted in placement of fill, reuse of demolition materials and retaining of remnant infilled cellars and foundations. Though large scale heavy industrial land uses have not been identified within the study area the review of available records including historical and current maps, geological maps, regulatory information, consultation information and GI data has identified a number of potentially contaminative historical land uses and potential contamination sources. These include extractive industries, industrial estates and factories, transport infrastructure (e.g. airport, fuel stations and railways) and tanks, and are discussed in more detail for each AZ in Section 20.3.2 to Section 20.3.5. Each potential source has been assigned a reference (comprising a 'C' prefix and a number) and is considered in more detail in Appendix A20.5 and detailed on Figure 20.6.

For the purposes of this assessment the soil chemical data, with regard to chronic exposure risk, have been screened against human health generic assessment criteria (GAC). In the absence of any Ireland-specific screening values the assessment criteria are based primarily on UK publications including Land Quality Management (LQM)/Chartered Institute of Environmental Health (CIEH) (Nathanial et al. 2015) 'Suitable for Use Levels' (S4ULs) for residential and commercial/industrial land uses and Department for Environment, Food and Rural Affairs (DEFRA) Category 4 Screening Levels (C4SLs) (DEFRA 2014). GAC for acute short-term exposure risks are not currently available for the large majority of contaminants therefore the above GAC have been used to provide an indication of potential risk to construction and maintenance workers. For perfluorooctane sulfonate (PFOS), screening values have been published by the Environment Agency in England (EA 2022).

GAC for organic chemicals are dependent on the soil organic matter (SOM) of the soils. GAC are published for SOM contents of 1%, 2.5% and 6%. As SOM values are not available for all of the soil samples subjected to chemical testing the most conservative value of 1% has been selected for the assessment. Soil leachate and groundwater laboratory analysis data have been compared to relevant water quality standards, referred to as Controlled Waters Screening Criteria (CWSC). These are primarily derived from Irish EPA Interim Guideline Values (IGV) (EPA 2003). Where these are not available for determinands, UK freshwater Environmental Quality Standards (EQS) (WFD 2015) or UK Drinking Water Standards (UK DWS) (World Health Organization (WHO 2011)) have been used.

The results of the data screening are included within the Land Contamination Interpretative Report (Jacobs IDOM 2022a) in Appendix A20.8 for each AZ and element of the proposed Project. Tables of soil, leachate, groundwater and ground gas data screening are included in Appendix A20.5. Locations where assessment criteria have been exceeded are shown on Figure 20.13 (soils) and Figure 20.14 (groundwater. Locations where asbestos fibres have been identified within the soils are included on Figure 20.15.

20.3.1.12 Geochemical Baseline

Information on the baseline concentrations of heavy metals and PAHs obtained as part of the Dublin SURGE Project (GSI 2012) has been reviewed. This study subjected shallow soil samples (1,058 samples from the top 0.1m of the ground) to laboratory geochemical analysis to determine the background concentration of selected contaminants across the Dublin area.

The study found that concentrations of lead, copper, zinc and mercury are strongly influenced by human activities, such as industry, combustion and traffic. Other metallic elements are generally related to the

regional bedrock parent material. PAHs were detected across the city, with the greatest concentrations in the city centre. Polychlorinated biphenyl were detected at low concentrations in isolated samples.

The SURGE dataset concentrations of metals typically identified at high concentrations within the proposed Project soils dataset are summarised in Table 20.15, along with the residential and commercial GAC used within the assessment in Section 20.4. Sample locations for this dataset are included on Figure 20.11.

Table 20.15: Overall SURGE Dataset Concentrations, Metals (From GSI 2012)

Contaminant	Concentration – SURGE dataset (mg/kg)					GAC (mg/kg)	
	Min	Max	Mean (overall)	Median (Natural Soil)	Median (made ground)	Residential	Commercial
Arsenic	<3	402	15.5	13.4	13.7	37	640
Chromium	4.24	262	44.2	44.4	41.6	21*	49*
Lead	<3	3,120	123	70.9	130	200	2,300
Mercury	0.0135	23.9	0.339	0.20	0.29	1.2	58
Zinc	18	8,390	248	168	235	3,700	730,000

Notes

1 - Chromium (Hexavalent) – most conservative assessment criteria used.

The maximum metal concentrations from the SURGE dataset often exceed the residential GAC with some instances of lead concentrations also exceeding the commercial GAC.

The SURGE dataset concentrations of PAHs (total plus United States (US) EPA 16 congeners) are summarised in Table 20.16, along with the residential and commercial GAC used in within the assessment in Section 20.4.

Table 20.16: Overall SURGE Dataset Concentrations, PAH (From GSI 2012)

Contaminant	Concentrations – SURGE dataset (mg/kg)				GAC (mg/kg)	
	Min	Max	Mean	Median	Residential	Commercial
Naphthalene	<0.03	2.4	0.08	0.02	2.3	190
Acenaphthylene	<0.03	3.9	0.12	0.02	170	83,000
Acenaphthene	<0.03	17	0.21	0.02	210	84,000
Fluorene	<0.03	26	0.25	0.02	170	63,000
Anthracene	<0.03	50	0.56	0.06	2,400	520,000
Phenanthrene	<0.03	140	2.12	0.26	95	22,000
Fluoranthene	<0.03	130	3.28	0.55	280	23,000
Pyrene	<0.03	92	2.77	0.53	620	54,000
Benzo[a]anthracene	<0.03	51	1.58	0.29	7.2	170
Chrysene	<0.03	44	1.65	0.37	15	350
Benzo[a]pyrene	<0.03	28	1.15	0.26	5	77
Benzo[b]fluoranthene	<0.03	34	1.49	0.36	2.6	44
Benzo[k]fluoranthene	<0.03	14	0.53	0.12	77	1,200
Benzo[g,h.i]perylene	<0.03	14	0.78	0.22	320	3,900
Indeno[1,2,3-c,d]pyrene	<0.03	12	0.75	0.2	27	500
Dibenzo[a,h]anthracene	<0.03	4.4	0.2	0.05	0.24	3.5
Sum of 16 PAHs	0.24	661	17.52	3.47	N/A	N/A

Again, the maximum concentrations for several PAH congeners exceed the residential GAC, with Dibenzo[a,h]anthracene also exceeding the commercial GAC.

The above SURGE datasets are based on 1,058 sampling locations over the greater Dublin area. Of these locations only a small number are present within the study area for the proposed Project, as summarised in Table 20.17.

Table 20.17: Summary of SURGE Soil Sample Quantities Within the Study Area

AZ	No. of Locations
AZ1	7
AZ2	0
AZ3	2
AZ4	19
Total	**28**

20.3.2 AZ1 – Northern Section

20.3.2.1 Topography

The ground elevation at the northernmost extent of the proposed Project is in the range of 3-9mAOD within the vicinity of Estuary Station, with the lowest elevations recorded around Broadmeadow Water. Elevations gradually increase to the south, recorded around 10-20mAOD in the Swords area and 44-48mAOD in Fosterstown North. At the far southern extent of the Northern Section (Dublin Airport North Portal (DANP)), elevations increase sharply to 58-61mAOD.

20.3.2.2 Geomorphology

Near the northern extent of the AZ1 a glacial meltwater channel and Glaciofluvial Terraces are present associated with the Broadmeadow River. A Subglacial Lineation (Drumlin) is present where the alignment crosses the R132 Swords Bypass at Nevinstown, and a Mega Scale Glacial Lineation is present between the Naul Road and the Dublin Airport terminal buildings. The Sluice River System Glacial Meltwater Channel and Glaciofluvial Terraces are present just to the north of Naul Road. These geomorphological features are not designated as protected features on a local or national scale according to GSI records and in accordance with IGI guidance (IGI 2013) are considered to have a low sensitivity.

20.3.2.3 Geohazards

The majority of AZ1 is indicated as having a landslide susceptibility of Low. A small area of Moderately Low risk is recorded near the northern bank of the Broadmeadow River, approximately 75m west of Chainage (Ch) 1480. An area of Moderately Low risk is recorded from Chainage 4420 to 4520, in the vicinity of the Pinnock Hill Roundabout. Toward the south AZ1, a larger area of Moderately Low risk is recorded from Chainage 5900 to 6060. This is associated with the increase in elevation to the north of Naul Road.

20.3.2.4 Hydrology

Watercourses recorded in the AZ1 area are detailed in Table 20.18.

Table 20.18: Watercourses Recorded in the AZ1 Area

Watercourse Name	Location
Staffordstown River	300m north east of Chainage 1000
Broadmeadow River	Crosses proposed Project at Chainage 1540
Ward River	Crosses proposed Project at Chainage 1640
Seapoint	230m north east of Chainage 2640
Greenfields	90m east of Chainage 3120
Gaybrook River	230m east of Chainage 5140
Sluice River	Crosses proposed Project at Chainage 5960

20.3.2.5 Soils and Superficial Geology

The principal soil group in AZ1 is the Elton Association, comprising a fine loamy drift with limestones to depths of >0.8m. The Elton Association is comprised of six soil series (Elton, Dunboyne, Howardstown, Straffan, Kilrush and Rathowen) and has a moderate drainage potential. These soils are primarily associated with agricultural land (fields for crop production) at the northern and southern extents of AZ1 and no other designations or protections are in place. This soil is assigned a sensitivity of Medium according to the methodology detailed in Section 20.2.

The areas around Broadmeadow River and a watercourse at the southern extent of AZ1 near Naul Road are classified as River alluvium, comprised of 12 soil series (Boyne, Finisk, Aherlow, Clohamon, Suir, Kilgory, Lyre, Vicarstown, Feale, Camoge, Cornafulla and Kilcullen) with depths of >0.8m. The River alluvium is indicated as having poor drainage potential, has a limited lateral extent and either forms part of agricultural fields or has no specified land use. This soil is assigned a sensitivity of Low based on the methodology in Table 20.5 (soil with a greater drainage potential is considered to have a higher sensitivity).

A small area approximately 100m to the east of the Works Area at Estuary Station adjacent to Malahide Estuary is classified as tidal marsh, which has been assigned a Medium sensitivity.

An area around Swords Business Park is classified as the Crosstown Association, comprising a fine loamy drift with siliceous stone to depths of 0.4-0.8m. The Crosstown Association is comprised of 11 soil series (Crosstown, Crossabeg, Johnstown, Laughil, Dungarvan, Kilrush, Puckane, Moord, Gortavoher, Coolykereen, Ardeen) and has an imperfect drainage potential. This area is currently occupied by commercial/industrial units with areas of soft landscaping, and the soil is assigned a sensitivity of Low.

The majority of the remaining Swords area is classified as Urban Soil with an undefined composition, which has been assigned a Low sensitivity.

Geological mapping (GSI 2017; GSI 2022) indicates that the underlying subsoils along this section mainly comprise till derived from limestones (generally described as 'tightly packed, unsorted, unbedded, glacial deposits possessing many different particle sizes with commonly sharp, angular to sub-angular clasts'). Areas of alluvium, gravels derived from limestones and estuarine silts and clays are indicated adjacent to the Broadmeadow River near Estuary, adjacent to Fosterstown and adjacent to the airport tunnel north portal. Lacustrine sediments are also indicated at the Pinnock Hill Roundabout.

An index of borehole information used to obtain information on the soil and superficial geology of the Northern Section is included as Appendix A20.2, and geological cross sections are included as Appendix A20.9.

Where encountered during ground investigation topsoil was generally recorded at 0m - 0.40m below ground level (bgl).

Made ground is present in numerous exploratory locations and is primarily associated with the locations of road alignments and previous development within the urbanised area of Swords and Fosterstown. Where encountered, made ground was generally recorded at depths of around 0-1.2mbgl with the exception of five locations in the vicinity of the R132 Swords Bypass. Borehole location NBH402 north of Seatown encountered made ground to a depth of 2.5mbgl; ABH08, located near a motor breaking yard (potential source C31), and trial pits completed near Fingallians GAA Club (ATP04, ATP04A) and North Dublin Corporate Park (ATP10, ATP11) encountered made ground to depths of 3.8mbgl, 1.8mbgl, 2.5mbgl, 1.9mbgl and 4.6mbgl, respectively. Encountered made ground was described as sandy gravelly clay with gravel and/or cobbles, which has been interpreted mainly as reworked natural ground. In some locations, inclusions of brick, pottery, concrete, metal, plastic and/or wood were found, no obvious unusual discolouration, oil sheens or odours were noted. It should be noted that data are not available for the car dismantler yard (C46) as access was not possible during the GI. Given the historical use of this site there is the potential for land contamination from leaks and spills of mainly organic contaminants from car dismantling operations to be present in the sub-surface at this location.

Ground investigation information (refer to cross sections in Appendix A20.9) indicates superficial deposit thicknesses of between around 2m and in excess of 30m. Thicknesses are generally lower towards the north, at Estuary and the northern extent of Swords with greater depths towards the south and the approach to the DANP, with a maximum depth just to the south of Fostertown Station (BH65).

From the northern extent of AZ1 to Estuary Roundabout, the superficial deposits comprise sandy gravelly clays and sands and/or gravels with cobbles to depths of 3-9mbgl. From Estuary Roundabout to the proposed Seatown Station superficial deposits comprise sandy gravelly clay to 3mbgl - 5mbgl (refer to Sheet 1 to Sheet 3, Appendix A20.9). From the proposed Seatown Station to Pinnock Hill Roundabout the superficial units were recorded up to 10mbgl - 14mbgl and described as sandy gravelly clay with occasional cobbles interbedded with sands and gravels with cobbles and some boulders. A greater proportion of sandy gravelly clay is recorded from the Pinnock Hill Roundabout to the southern end of AZ1 (refer to sheets 4 to 8, Appendix A20.9). Clasts within the clay are primarily of limestone with some sandstone and chert.

The superficial geology in AZ1 has no geological designation and does not have a particular value or significance on a local scale, it is assigned a sensitivity of Low.

20.3.2.6 Bedrock Geology

20.3.2.6.1 Malahide Formation

The Carboniferous Malahide Formation comprises argillaceous bioclastic (fossiliferous) limestone with interbedded shale; the lower part of this formation is composed of calcareous shales, siltstones and sandstones with occasional thin limestones at the base. Thicknesses of the Malahide formation are recorded from 300m to more than 1200m (GSI 2019; RPA 2008). The Malahide Formation is present beneath the superficial deposits throughout AZ1. A north-west to south-east trending fault is indicated near the north of Swords and a south-west to north-east trending anticlinal axis is mapped in the Fosterstown area.

The Malahide Formation is generally recorded as moderately strong bedded dark grey or black argillaceous and sometimes fossiliferous limestone. The limestone is interbedded with moderately strong to weak dark grey or black calcareous mudstone. In some locations the limestone and mudstone are distinct beds and in others they are recorded as interbedded or interlaminated.

The bedrock geology in AZ1 has no geological designation and does not have a particular value or significance on a local scale, it is assigned a sensitivity of Low.

20.3.2.7 Hydrogeology

The bedrock in AZ1 is classified by the GSI as a LI (Locally Important) aquifer. The area to the north of Chainage 2400 and between Chainage 3600 and 4900 is designated under the WFD as the Swords Aquifer. Between Chainage 2400 and 3600, and Chainage 4900 and 5900 the area is designated under the WFD as the Dublin Aquifer. The areas to the west of the Ward River and between Chainage 5900 and the southern end of the AZ1 are classified under the WFD as Industrial Facilities (P0014-03 and P0480-02 respectively).

The majority of AZ1 is classified as low aquifer vulnerability with the following exceptions:

- The area to the north of Chainage 1760 classified as moderate to high vulnerability, and the far north-west as extreme vulnerability;
- An area to the west of the proposed Seatown Station associated with the Ward River is shown as moderate to extreme vulnerability; and
- The area between Chainage 5700 and the southern boundary of AZ1 is classified as moderate to high vulnerability.

Three groundwater abstractions are located approximately 400m west of Chainage 3200. One abstraction is recorded approximately 300m east of Chainage 4960.

Groundwater levels measured in monitoring standpipes are summarised in Table 20.19.

Table 20.19: Summary of Measured Groundwater Levels (AZ1)

Monitoring Well ID	Ground Elevation	Dates of Level Monitoring	Level Range (mbgl)	Level Range (mAOD)
NBH401	7.64	25 Jan - 21 May 2021	2.91 - 4.33	4.73 - 3.32
NBH402	7.54	25 Jan - 21 May 2021	2.74 - 4.17	4.80 - 3.37
NBH403-S	7.14	25 Jan - 21 May 2021	2.55 - 3.97	4.59 - 3.17
NBH406	11.73	25 Jan - 21 May 2021	4.19 - 5.00	7.54 - 6.73
NBH408	9.68	25 Jan - 21 May 2021	3.43 - 4.28	6.25 - 5.41

20.3.2.8 Current and Historic Mining Sites

The historic gravel pits and quarries identified in AZ1 by the desk study are summarised in Table 20.20, with locations shown on Figure 20.6. Further details of the available information on these features are presented in the review of potential contamination sources in Appendix A20.5.

Table 20.20: Historic Quarries and Gravel Pits Within AZ1

Source ID	Description	Dates Present	Approximate location	Sensitivity
C2	Historic Quarry	1837-1864	55m NW of Works Area	Low
C12	Multiple Historic Gravel Pits	1937	30m N of Works Area	Low
C13	Historic Gravel Pit	1837-1842	60m WNW of Works Area	Low
C15	Historic Gravel Pit	1837-1842	Within Works Area	Low
C16	Historic Gravel Pit	1888-1913	Within Works Area	Low
C24	Historic Quarry	1837-1864	180m WNW of Works Area	Low
C25	Multiple Historic Gravel Pits	1937	195m ESE of Works Area	Low
C41	Historic Gravel Pit	1837	100m NNW of Works Area	Low

Source ID	Description	Dates Present	Approximate location	Sensitivity
C42	Historic Gravel Pit	1837	125m NW of Works Area	Low

The granular and crushed rock aggregate potential within AZ1 is summarized in Table 20.21 and Table 20.22.

Table 20.21: Granular Aggregate Potential in AZ1

Granular Aggregate Potential	Location Description	Potentially viable?	Sensitivity
Very Low	Adjacent to Estuary Station Works Area, approximately 280m north east of Chainage 1000.	Yes – area largely greenfield	Low
	To the west and east of Pinnockhill Roundabout around Gaybrook Stream, approximate Chainage 4200 to 4340.	No – area largely developed	Low
	In the vicinity of the Sluice watercourse, approximate Chainage 5760 and 5960.	Yes – area largely greenfield	Low
Low	Near proposed Estuary Station, approximate Chainage 1040 to 1120.	Yes – area largely greenfield	Low
	In the vicinity of Broad Meadow Water, approximate Chainage 1500 to 2180.	Yes – area largely greenfield	Low
	Approximately 60m to 110m north west of Chainage 4200 to 4380.	No – area largely developed	Low
Moderate	Near proposed Estuary Station, approximate Chainage 1120 to 1340.	Yes – area largely greenfield	Medium
	To the south and south west of Pinnockhill Roundabout, approximate Chainage 4400 to 4720.	No – area largely developed	Low
	In the vicinity of the Sluice watercourse, approximate Chainage 5720 to 5760, Chainage 5820 to 5940 and Chainage 5980 to 6100.	Yes – area largely greenfield	Medium
High	In the vicinity of Broad Meadow Water, approximate Chainage 1360 to 1440 and Chainage 1600.	No – area largely developed	Low
	In the vicinity of the Sluice watercourse, approximate Chainage 5780 to 5820, and Chainage 6100 to 6140.	Yes – area largely greenfield	High
Very High	Approximately 25m east of the Works Area in the vicinity of Broad Meadow Water, approximate Chainage 1620 to 1780.	No – area largely developed	Low

Table 20.22: Crushed Rock Aggregate Potential in AZ1

Crushed Rock Potential	Location Description	Potentially viable?	Sensitivity
Low	Majority of the alignment from Chainage 1780 near Estuary Station to Chainage 5620 in the vicinity of the northern tunnel portal.	No – area largely developed	Low
Moderate	In the area of Estuary Station from Chainage 1000 to 1780.	Yes – area largely greenfield	Medium
	To the west of the alignment between Chainage 2100 and 3940.	No – area largely developed	Low
	In the vicinity of the northern tunnel portal from Chainage 5620 to 5820.	Yes – area largely greenfield	Medium

Crushed Rock Potential	Location Description	Potentially viable?	Sensitivity
High	In the area of Estuary Station from Chainage 1040 to 1120.	No – area largely developed	Low
	In the vicinity of the northern tunnel portal from Chainage 5820 to 6100.	Yes – area largely greenfield	High

20.3.2.9 Irish Geological Heritage Sites

One proposed area for designation as a Natural Heritage Area (pNHA) is recorded within the AZ1 study area. The Malahide Estuary is 230m east of the Works Area at Chainage 1700. The Malahide Estuary has a sensitivity of Very High as it is a Special Area of Conservation and therefore has value on a regional and/or national scale. However, this is on the basis of ecological value and as such is considered in Chapter 15 (Biodiversity).

20.3.2.10 Radon and Ground Gas

The pre 2022 online Radon Map of Ireland indicates that AZ1 is entirely within the lowest classification of radon potential (<1% of homes above reference levels). The updated map indicates that the majority of AZ1 lies within the lowest classification of radon potential (about 1 in 20 homes likely to have high radon levels), while small areas around the Broad Meadow Water and just north of Naul Road are in the second lowest classification (about 1 in 10 homes likely to have high radon levels).

Ground gas monitoring has been undertaken in two locations in Estuary and Swords, as summarised in Table 20.23.

Table 20.23: C665 Ground Gas Summary for AZ1

Area	BH Reference	Number of Monitoring Rounds	Max Methane %v/v	Max Carbon Dioxide %v/v	Max Gas Flow l/hr	Max Methane GSV l/hr	Max Carbon Dioxide GSV l/hr	Max CS Methane	Max CS Carbon Dioxide
Estuary	NBH72-S	2	0.1	2	0.7	0.0007	0.014	1	1
Swords	NBH403-S	2	0.8	1.8	0.8	0.0064	0.014	1	1

GSVs have been calculated based on the worst-case scenario (i.e. using the highest concentrations of methane and carbon dioxide and highest ground gas flow for boreholes in each area). Based on the monitoring results for all areas, the GSV for carbon dioxide and methane was <0.07litres/hour and therefore all areas would be classified as CS1 for both carbon dioxide and methane. This indicates a Very Low risk to buildings from ground gas based on the available data according to the CIRIA C665 methodology (CIRIA 2007).

Comparison of monitoring data with WELs is shown in Table 20.24. The carbon dioxide short-term exposure limit was marginally exceeded in the Swords area (likely due to natural sources within the ground).

Table 20.24: Comparison of AZ1 Gas Data with WELs

Area	BH Reference	Number of Monitoring Rounds	Max Carbon Dioxide %v/v	Max CO Steady State parts per million (ppm)	Carbon Dioxide Short Term Exposure Limit1 %	Carbon Monoxide Short Term Exposure Limit1 ppm
Estuary	NBH72-S	2	2	No data	1.5	100
Swords	NBH403-S	2	1.8	No data		

Area	BH Reference	Number of Monitoring Rounds	Max Carbon Dioxide %v/v	Max CO Steady State parts per million (ppm)	Carbon Dioxide Short Term Exposure Limit1 %	Carbon Monoxide Short Term Exposure Limit1 ppm
1. Refers to 15-minute reference period under EH40/2020 WELs						
Exceedances of WEL highlighted by grey fill						

20.3.2.11 Contaminated Land

Potential contamination sources identified by a review of the available documentary and ground investigation information are presented in Appendix A20.5 with locations shown on Figure 20.6. In addition, geological models of each station location in AZ1 including the results of the geochemical screening are included in Appendix 20.4. The majority of these potential sources are outside the Works Area and/or have a minor or mild assessed severity with no specific linked instances of made ground or contamination identified. Sources considered to have potential to affect the route include a sewage works (C14), historic gravels pits (C15 and C16), a petrol station (C45) and a car dismantlers yard (C46).

As summarised in Section 20.3.2.5, made ground has been identified in several parts of the Works Area, mostly associated with general urban made ground, road sub-base and re-worked natural subsoils rather than being specifically associated with the sources identified above. Anthropogenic material, generally inert in nature (brick, pottery, concrete, metal, plastic and/or wood) was found within some areas of made ground.

The chromium exceedances and the VOC/SVOC detections were recorded in the north of AZ1 on greenfield land to the south-east of the proposed Estuary Station. Chromium exceedances, one arsenic exceedance and one 1,2-Dichloroethane exceedance were also found in the area of the proposed Swords Station at the roundabout on the R132 Swords Bypass associated with made ground. The 1,2-Dichloroethane exceedances and VOC/ SVOC detections recorded in ABH09 in the south of AZ1 are likely to be associated with the historical use of the land for vehicle storage (Source C52), with detections of 2-methylnaphthalene in ABH08 likely associated with a car dismantling yard (Source C31). The PAH exceedances at ATP17 can be attributed to the made ground associated with the R132 Swords Bypass corridor.

The detections of VOCs were found on greenfield land to the north-east of the roundabout on the R132 Swords Bypass in the north of the proposed works area at depth and the source is unclear. The source of Isopropylbenzene in soil samples recovered from ABH02 within the proposed Seatown Station area are unclear. However, it should be noted that reported concentrations of 1.3µg/kg (micrograms per kilogram) are within the same order of magnitude as the laboratory method detection limit of 1.0µg/kg.

No asbestos was identified in the ground investigation records for AZ1.

Exceedances of CWSC were encountered in groundwater and leachability testing results, primarily for metals (manganese, antimony, selenium and chromium), many of these exceedances were associated with natural ground (soils and bedrock) and are considered to be representative of natural background. Instances of phenol and mercury, chloride and selenium above CWSC can be attributed to made ground associated with the R132 Swords Bypass south of Seatown Roundabout. Total Petroleum Hydrocarbons (TPH) concentrations at NBH72 in the Estuary area were around 10 times higher than IGV of 10µg/l (micrograms per litre), primarily comprising the aliphatic C12-C16 fraction (a large constituent of diesel).

Summaries of soil, leachate, ground gas and CWSC screening are included in Appendix A20.5, the data presented in full within the Land Contamination Interpretative Report (Jacobs IDOM 2022a) in Appendix A20.8.

20.3.3 AZ2 – Airport Section

20.3.3.1 Topography

Ground elevations at the northern portal (northern extent of AZ2) rise steeply from around 45mAOD (a local topographic low associated with a former meltwater channel) to 62mAOD - 64mAOD at Naul Road. The topography gently rises to around 67mAOD in the vicinity of the airport complex, then gently falls away to around 60mAOD at the southern extent of AZ2 at the DASP.

20.3.3.2 Geomorphology

No geomorphological features of interest are indicated within AZ2.

20.3.3.3 Geohazards

The whole of AZ2 is indicated as having a landslide susceptibility of Low.

20.3.3.4 Hydrology

The proposed alignment crosses Cuckoo Stream at Chainage 7760, though this appears to be culverted throughout the study area.

20.3.3.5 Soils and Superficial Geology

Urban soils with an undefined composition are indicated directly below the footprint of Dublin Airport (Teagasc 2022). Out with the footprint of the airport, soils are recorded as the Elton Association, comprising a fine loamy drift with limestones to depths of >0.8m. The Elton Association is comprised of six soil series (Elton, Dunboyne, Howardstown, Straffan, Kilrush and Rathowen) and has a moderate drainage potential. The entirety of AZ2 is occupied by buildings and runways associated with Dublin Airport, and areas not covered by hardstanding or structures comprises soft landscaping (grass). The Urban soil is assigned a sensitivity of Low and the Elton Association a sensitivity of Medium.

Geological maps indicate that the underlying subsoils within the footprint of the airport comprise till with an area of bedrock outcrop / sub crop present beneath the location of the airport terminal car park (GSI 2022). Ground investigation information suggests that made ground is present within the area of the terminal buildings, particularly at the location of a former quarry which coincides with the Dublin Airport Station location. Cohesive till with occasional granular layers is present within the remainder of AZ2.

Where encountered during ground investigation, topsoil was generally recorded at 0-0.30mbgl.

Made ground was encountered in the majority of the exploratory locations in AZ2. It was recorded at depths of up to 2.70mbgl and generally described as tarmac, concrete, sandy gravel or sandy gravelly clay. Pieces of rebar and red brick were recorded in the vicinity of the airport buildings. No obvious unusual discolouration, oil sheens or odours were noted with the exception of possible domestic waste/putrescible material within ABH12 (0.50-2.10mbgl). The area of the greatest depths of made ground (2.70mbgl at ABH13) is within an area marked as a former quarry on historical mapping (potential source C59, refer to Section 20.3.3.11)), which is also the proposed location of Dublin Airport Station. Made ground was identified at the DANP at depths of up to 0.4mbgl, described as firm, slightly sandy slightly silty gravelly clay.

Superficial deposit thickness is variable across AZ2, at the DANP depth to bedrock is 24.5mbgl (BH212) where rockhead elevation rises in a reflection of surface topography. Superficial deposit depths remain similar until a sharp reduction at the airport buildings, reducing to 2.6mbgl at the centre of the Dublin Airport complex. Rockhead elevation then drops away to the south and is recorded at 33mbgl at the south portal (refer to Sheet 8 to Sheet 11, Appendix A20.9).

The superficial deposits in AZ2 comprise sandy gravelly clay with occasional cobbles. This is frequently underlain or interbedded with sands and gravels, often with cobbles and boulders. Clasts are primarily of limestone. Sands and gravels are particularly notable to the south of Dublin Airport station, on the approach to the DASP.

The superficial geology in AZ2 has no geological designation and does not have a particular value or significance on a local scale and has been assigned a sensitivity of Low.

20.3.3.6 Bedrock Geology

20.3.3.6.1 Malahide Formation

The Carboniferous Malahide Formation comprises argillaceous bioclastic (fossiliferous) limestone with interbedded shale; the lower part of this formation is composed of calcareous shales, siltstones and sandstones with occasional thin limestones at the base. The Malahide Formation is indicated from the DANP to the Dublin Airport terminal buildings. The boundary with the adjacent Waulsortian Limestone is marked by a fault. Thicknesses of the Malahide Formation are indicated from 300m to more than 1200m (GSI 2022; RPA 2008).

The Malahide Formation is encountered in RC301, RC302 and RC303 at 14-25mbgl and described as moderately strong to strong bedded to laminated dark grey and black calcareous mudstone.

20.3.3.6.2 Waulsortian Limestones

The Carboniferous Waulsortian Limestone is a predominantly pale grey, crudely bedded or massive lime-mudstone, biomicritic in nature with distinctive stromatactis and generally formed mounds or reefs. The Waulsortian Limestones are generally dolomitised and have a typical thickness ranging 300-500m (GSI 2022; RPA 2008). The Waulsortian Limestone is present beneath the Dublin Airport terminal buildings, rockhead levels are generally shallower here, and bedrock is present near the ground surface at the proposed Dublin Airport Station (refer to Sheet 9 and Sheet 10 in Appendix A20.9).

The Waulsortian Limestone is encountered in RC305 to RC307 at 2.6mbgl - 5.8mbgl and is described as strong to extremely strong bedded to massive grey and locally black fine-grained siliceous limestone. It is generally fresh to slightly weathered, locally fossiliferous and with frequent styolites and calcite veining.

It can be inferred that the abrupt change in rockhead elevation may be representative of the north-east to south-west trending fault that just to the north Dublin Airport Station.

20.3.3.6.3 Tober Colleen Formation

The Tober Colleen Formation is generally described as dark-grey calcareous, commonly bioturbated mudstone and subordinate thin argillaceous micritic limestones. The lower levels of this formation can include reef derived debris and large slumped reef blocks. The thickness of Tober Colleen Formation is recorded to range from 50 – 250m (GSI 2022; RPA 2008). The Tober Colleen Formation is indicated to be present from the stratigraphic boundary with the Waulsortian Limestone at the southern edge of the Dublin Airport terminal buildings to beyond the southern boundary of the Airport Section (refer to Sheet 10 and Sheet 11, Appendix A20.9).

The Tober Colleen Formation is encountered to the south of the proposed Dublin Airport Station at depths of between 10mbgl and 34mbgl. It is described as strong to very strong interbedded or interlaminated dark grey to black calcareous mudstone and argillaceous limestone. Refer to the geological cross sections in Appendix A20.9 and Figure 20.4.

The bedrock geology in AZ2 has no geological designation and does not have a particular value or significance on a local scale and is assigned a significance/sensitivity of Low.

20.3.3.7 Hydrogeology

The bedrock around and to the north of the proposed Dublin Airport Station is classified by the GSI as a LI (Locally Important) aquifer, and the area to the south is classified as a PI (Poor) Aquifer. The area between the northern boundary of the Airport Section and Chainage 6900 is designated under the WFD as the P0480-02 (Industrial Facilities). The remainder of the Airport Section area is designated as the Dublin Aquifer.

The area from the northern end of AZ2 to Chainage 7700 is recorded as moderate to high vulnerability, with the area directly around the proposed Dublin Airport Station is recorded as extreme vulnerability with rock at or near the surface or karst. The remainder of the area is recorded as low vulnerability.

One groundwater abstraction is located approximately 65m south east of the proposed Dublin Airport Station.

Groundwater levels measured in monitoring standpipes in AZ2 are summarised in Table 20.25.

Table 20.25: Summary of Measured Groundwater Levels (AZ2)

Monitoring Well ID	Ground Elevation	Dates of Level Monitoring	Level Range (mbgl)	Level Range (mAOD)
NBH05-D	59.80	03 Dec 2019 - 09 Dec 2020	4.88 - 6.58	54.92 - 53.22
NBH05-S	59.80	03 Dec 2019 - 09 Dec 2020	4.92 - 6.01	54.88 - 53.70
NBH06A	60.18	03 Dec 2019 - 09 Dec 2020	4.53 - 6.44	55.65 - 53.75
NBH06W	60.31	03 Dec 2019 - 09 Dec 2020	5.26 - 6.27	55.05 - 54.04

These groundwater monitoring installations are at the Dublin Airport South Portal and indicate resting groundwater levels within the glacial till deposits.

20.3.3.8 Current and Historic Mining Sites

The historic gravel pits and quarries identified in AZ2 are summarised in Table 20.26. The location of the sites is shown on Figure 20.6. Further details of the available information on these features are presented in Appendix A20.6.

Table 20.26: Historic Quarries and Gravel Pits Within AZ2

Source ID	Description	Dates Present	Approximate Location	Sensitivity
C59	Historic Quarry (including re-opened extended quarry).	1837 to 1937	In location of Dublin Airport station	Low

The granular and crushed rock aggregate potential within AZ2 is summarised in Table 20.27 and Table 20.28.

Table 20.27: Granular Aggregate Potential in AZ2

Granular Aggregate Potential	Location Description	Potentially Viable?	Sensitivity
Moderate	At the northern end of AZ2, adjacent to the northern tunnel portal works area.	No – area largely developed	Medium

Granular Aggregate Potential	Location Description	Potentially Viable?	Sensitivity
High	At the northern end of AZ2, from approximate Chainage 6100 to 6140	No – area largely developed	Medium

Table 20.28: Crushed Rock Aggregate Potential in AZ2

Crushed Rock Potential	Location Description	Potentially Viable?	Sensitivity
Low	At the southern end of AZ2 from approximate Chainage 7660 to 8320	No – area largely developed	Low
Moderate	To the north east and south west of the Airport Station, approximate Chainage 6120 to 6660 and Chainage 7260 to 7640	No – area largely developed	Low
High	Approximately 200m to the north west and south east of Airport Station	No – area largely developed	Low
Very High	In the area of Airport Station	No – area largely developed	Low

20.3.3.9 Irish Geological Heritage Sites

There are no Irish Geological Heritage Sites recorded within the study area within AZ2.

20.3.3.10 Radon and Ground Gas

The pre 2022 online Radon Map of Ireland indicates that AZ2 is within the lowest classification of radon potential (< 1 % of homes above reference levels).The updated map indicates that the majority of AZ2 lies within the lowest classification or radon potential (about 1 in 20 homes likely to have high radon levels), with an area coinciding with the former quarry at Dublin Airport Station falling within the highest classification (about 1 in 5 homes likely to have high radon levels), coinciding with shallow bedrock.

Ground gas has been monitored at four locations in AZ2, as summarised in Table 20.29.

Table 20.29: Ground Gas Summary for AZ2

Area	BH Reference	Number of data points	Max Methane %v/v	Max Carbon Dioxide %v/v	Max Gas Flow l/hr	Max Methane GSV l/hr	Max Carbon Dioxide GSV l/hr	Max CS Methane	Max CS Carbon Dioxide
Dublin Airport	NBH04, NBH60, NBH61, NBH62	8	1.0	3.8	0.8	0.008	0.03	1	1
South Portal	NBH05-S, NBH07	5	0.3	1.2	0.8	0.0024	0.0096	1	1

GSVs have been calculated based on the worst-case scenario (i.e. using the highest concentrations of methane and carbon dioxide and highest ground gas flow for boreholes in each area). Based on the monitoring results for all areas the GSV for carbon dioxide and methane was <0.07 litres/hour and therefore all areas would be classified as CS1 for both carbon dioxide and methane. This indicates a Very Low risk to buildings from ground gas according to the CIRIA C665 methodology (CIRIA 2007).

Comparison of monitoring data with WELs is shown in Table 20.30. The carbon dioxide short-term exposure limit was exceeded in the vicinity of Dublin Airport, which may be due to the presence of the fill material within the former quarry.

Table 20.30: Comparison of AZ2 Gas Data with WELs

Area	BH Reference	Number of data points	Max Carbon Dioxide %v/v	Max CO Steady State ppm	Carbon Dioxide Short Term Exposure Limit[1] %	Carbon Monoxide Short Term Exposure Limit[1] ppm
Dublin Airport	NBH04, NBH60, NBH61, NBH62	8	3.8	No data	1.5	100
South Portal	NBH05-S, NBH07	5	1.2	No data		
[1] Refers to 15-minute reference period under EH40/2020 WELs						
Exceedances of WEL highlighted by grey fill						

20.3.3.11 Contaminated Land

Potential contamination sources identified by a review of the available documentary and ground investigation information are presented in Appendix A20.5 with locations shown on Figure 20.6. In addition, geological models of each station location in AZ2 including the results of the geochemical screening are included in Appendix A20.4. The majority of these potential sources are outside the Works Area and/or have a minor or mild assessed severity with no specific linked instances of made ground or contamination identified.

Sources considered to have potential to affect the route include a vehicle storage area near the north portal (C52), a petrol station (C58), the historical use of the area as an airport (C60) and an historic infilled quarry (C59). Within the historic quarry at the proposed Dublin Airport station location made ground up to 2.7m thick was found, mainly comprising gravel and gravelly sandy clay with anthropogenic inclusions including concrete, rebar and brick, below the present-day car park and bus terminals. One location (ABH12, towards the north end of the station) included a description of made ground including domestic waste as well as brick, glass, rebar and concrete between 0.5m and 2.1mbgl.

Residential GAC exceedances for metals (arsenic, lead and chromium), PAHs and TPH were encountered associated with made ground associated with the footprint of the infilled historic quarry (operational 1837 – 1937). In addition, commercial GAC exceedances were encountered for PAH congeners and some VOCs were detected in the made ground, also benzene (albeit below GACs) and phthalates were encountered within the bedrock. The exceedances are likely mainly attributable to the quarry fill material itself, there also is potential for the use of the area as a car park to affect sub-surface (e.g., by leaks/spills of fuel and lubricants from vehicles. There is no strong evidence of the influence of airport operations (e.g., fuelling, maintenance and de-icing) on the proposed Dublin Airport Station location.

Four soil samples from the airport and historic quarry area were subjected to PFAS analysis. All determinants were below the limit of detection with the exception of NBH60 0.5m, where PFOS was detected at 0.001mg/kg. This is equal to the analysis method detection limit and below the EA soil screening value of 0.014mg/kg.

One soil sample recovered from ATP27 at 0.3mbgl was found to contain amosite fibres with total asbestos measured at 0.001%. No other asbestos was recorded in AZ2.

The PAH congeners benzo(a)pyrene (0.042mg/l), benzo(ghi)perylene (0.023mg/l), fluoranthene (0.054mg/l) and indeno(123cd) pyrene (0.022mg/l) were encountered at NBH60 at concentrations of approximately 50 to 4000 times higher than IGV. IGV exceedances of total TPH were recorded at NBH04

and NBH60, with concentrations of 1.86mg/l and 1.81mg/l respectively, around 180 times the IGV. It should be noted that the distribution of individual hydrocarbon fractions was different at both boreholes NBH04 and NBH60 suggestive of different contamination sources. Additionally, these hydrocarbons were detected at different depths; the well screen interval of NBH60 is between 0.8 and 1.5 mbgl and the origin of encountered hydrocarbons is likely to be related with made ground as elevated concentration of TPH (420 mg/kg) was encountered at 0.5mbgl in made ground. NBH04 has a well screen interval between 16 and 30mbgl, within the bedrock.

The following metals exceeded IGV: barium, boron, cobalt, manganese, potassium and total iron. Chloride concentrations were above screening levels (IGV) at all locations, with ammoniacal nitrogen above DWS at one location. The EQS was slightly exceeded by Biological Oxygen Demand (BOD) at one location. Four selected locations from the airport and historic quarry were subjected to PFAS Total Oxidisable Precursor (TOP) analysis; all the PFAS/PFOA/PFOS compounds within the analysis suite were below the limit of laboratory detection (0.00005mg/l).

Comparison of the 2:1 ratio leaching values from the Waste Acceptance Criteria analysis of eight soil samples indicated exceedances of IGV (barium, lead, sulphate, phenols, and TDS) and DWS (antimony and selenium). All observed exceedances were marginally above the respective criteria.

The above indicates that the primary land contamination risk in AZ2 is associated with made ground in the former quarry at the proposed Dublin Airport Station. Organic and metallic contaminants are present within the sub-surface made ground itself at concentrations which could pose a risk to human health, and organic contaminants (hydrocarbons) are also present within the shallow groundwater (within the made ground) and underlying groundwater within the bedrock.

20.3.4 AZ3 – Dardistown to Northwood

20.3.4.1 Topography

Ground elevations are around 59-61mAOD at the northern extent of AZ3, rising to 65mAOD to the north of the M50 Viaduct, reducing to around 60mAOD at the proposed Northwood Station.

20.3.4.2 Geomorphology

Two Mega Scale Glacial Lineation's are indicated to the north and south of the M50 Viaduct, along with a Meltwater Channel just to the north of Gulliver's Retail Park (refer to Figure 20.2). These geomorphological features are not designated as protected features on a local or national scale and are considered to have a low sensitivity.

20.3.4.3 Geohazards

The whole of AZ3 is indicated as having a landslide susceptibility of Low.

20.3.4.4 Hydrology

Watercourses recorded in the AZ3 area are detailed in Table 20.31.

Table 20.31: Watercourses Recorded in the AZ3 Area

Watercourse Name	Location
Turnapin Stream	Ch 8648 (tributary to Mayne River)
Mayne River	210 m south east of Chainage 8800
Santry River	Crosses proposed alignment at Chainage 9980

20.3.4.5 Soils and Superficial Geology

The principal soil group in AZ3 is the Elton Association, comprising a fine loamy drift with limestones to depths of >0.8m. The Elton Association is comprised of six soil series (Elton, Dunboyne, Howardstown, Straffan, Kilrush and Rathowen) and has a moderate drainage potential. These soils are primarily associated with agricultural land (fields for crop production) at the southern boundary of Dublin Airport and no other designations or protections are in place. The areas around the M50 Motorway, the R108 Ballymun Road and Silloge Park Public Golf Course are classified as urban soil with an undefined composition. Urban soil is assigned a sensitivity of Low and the Elton Association a sensitivity of Medium.

Geological maps indicate that the subsoils predominantly comprise till with an area of alluvium present just to the south of the M50 Motorway (GSI 2022) associated with the Santry River.

Made ground was encountered at the ground surface throughout AZ3, primarily towards the northern and southern extents as well as at the embankments adjacent to the M50 Motorway. Where encountered, it was recorded up to a maximum depth of 2.5mbgl and described as sandy gravelly clay or sandy gravel, with anthropogenic materials such as brick, plastic, metal and pottery noted in some locations. The area of the greatest depths of made ground (2.50mbgl in ABH19) is located in the central reservation of the R108 Ballymun Road, which is also adjacent to the proposed location of the Northwood Station. No other obvious unusual discolouration, oil sheens or odours were noted within the ground investigation information.

The superficial deposits encountered during ground investigation generally comprise sandy gravelly clay over sandy gravelly clay with cobbles. Sandy and/or clayey gravel strata were encountered at the northern and southern ends of the Dardistown to Northwood Section. Clasts are primarily of limestone with some sandstone. Thicknesses of the superficial deposits varied from >38m in the far north of the section (BH32), to 16-18m in the centre and 15-20m in the south of AZ3.

The superficial geology in AZ3 has no geological designation and does not have a particular value or significance on a local scale and has been assigned a is assigned a sensitivity of Low.

20.3.4.6 Bedrock Geology

20.3.4.6.1 Tober Colleen Formation

The Tober Colleen Formation is generally described as dark-grey calcareous, commonly bioturbated mudstone and subordinate thin argillaceous micritic limestones. The lower levels of this formation can include reef derived debris and large slumped reef blocks. The thickness of Tober Colleen Formation is recorded to range from 50 – 250m (GSI 2022; RPA 2008). The Tober Colleen Formation is indicated within the northernmost extent of AZ3 in the area between the DASP and the M50 Motorway.

Ground investigation records describe the Tober Colleen Formation as strong to moderately strong, medium bedded to thinly laminated dark grey or black calcareous mudstone, interbedded with strong thinly bedded grey or pale grey limestone. Depth to rockhead is 32-34m at the northern extent of AZ3, and 16m to the north of the M50 Viaduct.

20.3.4.6.2 Lucan Formation

The Lucan (Calp) Formation refers to various units of basinal limestone and shale formed from carbonate sediment deposits. The Lucan Formation consists of muddy limestone beds interbedded with calcareous shale beds. The limestone beds are dark grey to black, fine grained, occasionally cherty and are classified as strong to very strong. Pyrite has also been recorded. Analysis of thin sections for the Dart Underground Environmental Impact Statement (Irish Rail 2010) indicated pyrite concentrations ranging from <0.5% to 5% with detects in the majority of samples, with wide variation between close samples and no regional trends evident. Occasional exceptionally high concentrations of 10% to 40% were identified typically associated with lithology contact surfaces. The limestone hosts some limited fossils, such as corals and brachiopods, locally. The shale beds are less substantial and dark grey to black in appearance. These are typically moderately strong and more susceptible to weathering than

the limestones (GSI 2022; RPA 2008; Parsons Brinkerhoff 2007). The Lucan Formation is indicated from the stratigraphic boundary with the Tober Colleen Formation to the north of the M50 Motorway, to the southern extent of AZ3.

Ground investigation records describe the Lucan Formation as strong to moderately strong thin to medium bedded dark grey argillaceous limestone interbedded with moderately strong thinly bedded to thickly laminated dark grey or black calcareous mudstone. Depth to rockhead is between 16m and 20m to the south of the M50 Viaduct. Refer to the geological cross sections in Appendix A20.9 and Figure 20.4.

The bedrock geology in AZ3 has no geological designation and does not have a particular value or significance on a local scale and is assigned a sensitivity of Low.

20.3.4.7 Hydrogeology

The area of AZ3 to the north of the M50 Motorway is designated as a Pl (Poor) Aquifer. To the south of the M50 Motorway the bedrock is designated as a Ll (Locally Important) Aquifer. The entire area is recorded as low vulnerability and designated as the Dublin Aquifer.

Five groundwater abstractions are located in the AZ3 area, three approximately 100m south-east of Chainage 9000, one approximately 420m of Chainage 8800 and one approximately 640m south-east of Chainage 8700.

Groundwater levels in the norther part of AZ3 ranged from 2.6mbgl to 11.2mbgl, with a fluctuation of 0.2m to 3.7m. The shallowest groundwater levels were recorded near the proposed Dardistown Station, and the deepest recorded in the vicinity of the M50 Motorway. In the vicinity of Northwood Station, groundwater levels ranged from 8.50mbgl to 14.33mbgl with fluctuations of 0.3m to 1.2m.

Groundwater levels measured in monitoring standpipes in AZ3 are summarised in Table 20.32.

Table 20.32: Summary of Measured Groundwater Levels (AZ3)

Monitoring Well ID	Ground Elevation	Dates of Level Monitoring	Level Range (mbgl)	Level Range (mAOD)
NBH202-D	58.34	14 Jul 2020 - 24 May 2021	7.71 - 9.44	50.63 - 48.90

20.3.4.8 Current and Historic Mining Sites

No quarries, pits or mines have been recorded within the study area in AZ3.

The granular and crushed rock aggregate potential within AZ3 is summarized in Table 20.33 and Table 20.34.

Table 20.33: Granular Aggregate Potential in AZ3

Granular Aggregate Potential	Location Description	Potentially Viable?	Sensitivity
Very Low	To the north west and south west of the M50/R108 roundabout	No – area largely developed	Low

Table 20.34: Crushed Rock Aggregate Potential in AZ3

Crushed Rock Potential	Location Description	Potentially viable?	Sensitivity
Low	All of AZ3	Yes – area partly greenfield	Low

20.3.4.9 Irish Geological Heritage Sites

There are no Irish Geological Heritage Sites recorded within the study area in AZ3.

20.3.4.10 Radon and Ground Gas

The pre 2022 online Radon Map of Ireland indicates that AZ3 is within the lowest classification of radon potential (<1% of homes above reference levels). The updated map indicates that the whole of AZ3 lies within the lowest classification of radon potential (about 1 in 20 homes likely to have high radon levels).

Ground gas has been monitored at four locations in AZ3, and the readings are summarised in Table 20.35.

Table 20.35: Ground Gas Summary for AZ3

Area	BH Reference	Number of data points	Max Methane %v/v	Max Carbon Dioxide %v/v	Max Gas Flow l/hr	Max Methane GSV l/hr	Max Carbon Dioxide GSV l/hr	Max CS Methane	Max CS Carbon Dioxide
Dardistown Depot	AWN01, AWN02	2	0.3	0.7	0.4	0.0012	0.0028	1	1
Northwood Station	NBH73-S	1	0.3	1.9	0.7	0.0021	0.0133	1	1

GSVs have been calculated based on the worst-case scenario (i.e. using the highest concentrations of methane and carbon dioxide and highest ground gas flow for boreholes in each area). Based on the monitoring results for all areas, the GSV for carbon dioxide and methane was <0.07 litres/hour and therefore all areas would be classified as CS1 for both carbon dioxide and methane. This indicates a Very Low risk to buildings from ground gas according to the CIRIA C665 methodology (CIRIA 2007).

Comparison of monitoring data with WELs is shown in Table 20.36. The carbon dioxide short-term exposure limit was marginally exceeded at both the Dardistown Depot and Northwood Tunnel monitoring locations.

Table 20.36: Comparison of AZ3 Gas Data with WELs

Area	BH Reference	Number of data points	Max Carbon Dioxide %v/v	Max CO Steady State ppm	Carbon Dioxide Short-Term Exposure Limit1 %	Carbon Monoxide Short-Term Exposure Limit1 ppm
Dardistown Depot	AWN01, AWN02	2	2	No data	1.5	100
Northwood Station	NBH73-S	1	1.9	No data		
1. Refers to 15-minute reference period under EH40/2020 WELs						
Exceedances of WEL highlighted by grey fill						

20.3.4.11 Contaminated Land

Potential contamination sources identified by a review of the available documentary and ground investigation information are presented in Appendix A20.5 with locations shown on Figure 20.6. In addition, geological models of each station location in AZ3 including the results of the geochemical screening are included in Appendix A20.4. The majority of these potential sources are outside the Works Area and/or have a minor or mild assessed severity with no specific linked instances of made ground or contamination identified. Sources considered to have potential to affect the route include a cooking oil wholesaler (C67), a vehicle tests centre (C69) and a fuel station (C72).

Made ground material was encountered over much of AZ3, the distribution of which is summarised in Section 20.3.4.5. Where recorded, exceedances were of residential GAC and were for chromium and PAHs. Where recorded, GAC exceedances were of chromium or PAHs. Chromium exceedances were recorded in the northern and southern extents of the AZ3 study area and were associated with shallow made ground, natural or reworked natural ground. PAH exceedances were associated with made ground in the vicinity of the proposed depot (NBH08) and the central reservation of the R108 Ballymun Road (ABH19). However, the locations of the made ground areas cannot be directly associated with any of the identified potential sources (Appendix A20.5) and are likely to be the result of historic unmapped activities.

No asbestos was identified in the GI records for AZ3.

Exceedances of ammoniacal nitrogen and chloride were widespread throughout the groundwater samples. Hydrocarbons were also recorded, though the concentrations were only marginally elevated above DWS. PAHs were also recorded in one sample.

Leachable barium in exceedance of IGV was widespread in the northern part of the section, with some instances of chloride, zinc and antimony. Leachable selenium was found to exceed DWS in multiple locations.

20.3.5 AZ4 – Northwood to Charlemont

20.3.5.1 Topography

Elevations of 63mAOD are present at the northern extent AZ4 at the Tunnel Boring Machine (TBM) launch point, steadily dropping to around 10mAOD in the vicinity of the Tolka River. Elevations then rise to approximately 28mAOD in the area of the Royal Canal, before dropping to sea level where the proposed Project crosses the River Liffey which is tidal in this section. To the south of the River Liffey, elevations gradually rise to around 20mAOD in the area of the proposed Charlemont Station.

20.3.5.2 Geomorphology

Two Mega Scale Glacial Lineation's are present to the north of Griffith Avenue, and to the north of Glasnevin Station. The Tolka River, just to the south of Griffith Park Station, runs within a Glacial Meltwater Channel, as does the River Liffey (refer to Figure 20.2). These geomorphological features are not designated as protected features on a local or national scale and are considered to have a low sensitivity.

20.3.5.3 Geohazards

The majority of AZ4 is indicated as having a landslide susceptibility of Low. Small areas of Moderately Low risk are recorded approximately 110m-160m west of Griffith Park Station.

20.3.5.4 Hydrology

Watercourses recorded in AZ4 are detailed in Table 20.37.

Table 20.37: Watercourses Recorded in the AZ4 Area

Watercourse Name	Location
Tolka River	Crosses proposed Project at Chainage 13920
Royal Canal	Crosses proposed Project at Chainage 14940
River Liffey	Crosses proposed Project between Chainage 17160 and 17240
Grand Canal	Crosses proposed Project at Chainage 19260

In addition to the above-named watercourses/water bodies which cross the proposed Project there are a number of other named and unnamed nearby water features, some of which are culverted, including the following (further details are included in Chapter 18 (Hydrology):

- Wad River and Wad Diversion present to the east of Collins Avenue Station and Griffith Park.
- St Stephen's Green Ponds (to the west of St Stephen's Green station), connected to the Grand Canal via 300m cast iron water main.
- The Stein River is a culverted watercourse that traverses the proposed Project near Tara and St Stephen's Green stations.
- Gallows Stream (culverted watercourse that does not traverse the proposed Project) near Tara and St Stephen's Green stations.
- Swan River (culverted watercourse near Charlemont Station).

20.3.5.5 Soils and Superficial Geology

The whole of the study area in AZ4 is underlain by urban soils with an undefined composition associated with the urbanisation of the Dublin City area, which has been assigned a sensitivity of Low. An area around the Tolka River approximately 100m to the west of the proposed Griffith Park Station is classified as River alluvium, comprising 12 soil series (Boyne, Finisk, Aherlow, Clohamon, Suir, Kilgory, Lyre, Vicarstown, Feale, Camoge, Cornafulla and Kilcullen) with depths of >0.8m. The River alluvium is recorded as having poor drainage potential and is assigned a sensitivity of Low based on the methodology provided in Section 20.2 (also refer to Figure 20.1).

Geological maps indicate that the majority of the subsoils comprise till, with alluvial sediments present adjacent to within the vicinity of the Tolka River and River Liffey (refer to Figure 20.3). 'Urban' ground is indicated within the central area of Dublin, between the Mater Station and Charlemont Station.

Made ground was encountered in the majority of ground investigation exploratory holes in AZ4 to depths typically up to 2mbgl, with local variations and a maximum recorded depth of 7mbgl in the vicinity of Charlemont Station. Made ground was generally described as sandy gravelly clay with cobbles and/or boulders and anthropogenic material in many locations (typically comprising bricks and rubble). Hydrocarbon or bitumen odours were noted within the areas of the proposed stations at Collins Avenue, Tara and O'Connell Street.

Ground investigation records indicate that cohesive till predominates towards the north of AZ4 with isolated pockets/lenses of granular material (sand and gravel) present; these granular horizons are more prevalent towards the south of AZ4 and within the vicinity of the River Liffey. The thickness of the superficial deposits is typically 10m to 30m, with greater thicknesses generally present towards the north of AZ4.

Details of the made ground and superficial geology encountered at each proposed station location are shown in Table 20.38, and reference should be made to the geological cross sections in Appendix A20.9 and geological models in Appendix A20.4. Details of the depths to bedrock are shown for each station location in Table 20.39.

Table 20.38: Summary of Superficial Ground Conditions for Each Station Location in AZ4

Station Location	Strata	Summary of Superficial Ground Conditions
Ballymun	Made ground	Encountered in all exploratory holes to depths of 0.2-4.1mbgl. Generally comprising tarmac, concrete or sandy gravelly clay with inclusions of brick, concrete and/or plastic in some locations. No other obvious unusual discolouration, oil sheens or odours were noted within the GI information.
	Superficial	Generally comprising interbedded sandy gravelly clay and sandy gravelly clay with occasional cobbles. Strata of gravel and/or cobbles encountered in some exploratory locations at greater depths (>16mbgl).

Station Location	Strata	Summary of Superficial Ground Conditions
Collins Avenue	Made ground	Encountered in most exploratory holes to depths of 0.3-2.5mbgl. Generally comprising sandy gravelly clay with cobbles and inclusions of concrete, brick, asphalt, glass, plastic and ceramics in some locations. A slight hydrocarbon odour was noted at 0.4-1.2mbgl in TP603.
	Superficial	Generally comprising sandy gravelly clay or sandy gravelly clay with cobbles, interbedded with strata of gravel and/or cobbles. Proportion of granular strata generally increases with depth.
Albert College Shaft	Made ground	Encountered in 2 of 3 exploratory holes to depths of 1.3mbgl. Generally comprising sandy gravelly clay with inclusions of brick and concrete observed in NBH208. No other obvious unusual discolouration, oil sheens or odours were noted within the GI information.
	Superficial	Generally comprising sandy gravelly clay or sandy gravelly clay with low to medium cobble content, interbedded with strata of gravel and/or cobbles. Proportion of granular strata generally increases with depth.
Griffith Park	Made ground	Encountered in the majority of exploratory holes to depths of 0.75-2.3mbgl. Generally comprising sandy gravelly clay with cobbles and inclusions of brick, ceramic, glass, ash, wood and/or bitumen/tar.
	Superficial	Sandy gravelly clay interbedded with sandy gravelly clay with cobbles and occasional boulders, and strata of sand and/or gravel.
Glasnevin	Made ground	**Station Box and Adjacent Road** Made ground encountered up to 2.3mbgl (GBH01) comprising a 0.1m thick layer asphalt (in some locations) over gravel (mixed lithologies) and sandy gravelly clay with fragments of red brick. No other obvious unusual discolouration, oil sheens or odours were noted within the GI information. **Railway tracks (east)** 4 no. boreholes and several inspection pits (TPCC04, TPCC06, TPCC09 to TPCC12) were undertaken on the tracks to the east of the station box, encountering Ballast (fine to coarse gravel) to a maximum depth of 1.1mbgl (GBH20, GBH21). No other obvious unusual discolouration, oil sheens or odours were noted within the GI information. **Railway tracks (west)** Made ground was encountered in the vast majority of exploratory holes to depths between 0.5 and 3.5mbgl (GBH13, adjacent to the Royal Canal). Generally comprising a layer of Ballast (up to 0.6m thick) in trackside areas directly overlying natural deposits or over sandy gravelly clay with very occasional inclusions of brick, plastic and concrete. Greater made ground thicknesses were overall found in the track areas towards the east, nearer the station box; further to the west ballast directly overlying natural deposits was encountered. No other obvious unusual discolouration, oil sheens or odours were noted within the GI information.
	Superficial	**Station Box and Adjacent Road** Firm to very stiff sandy gravelly clay with cobbles and strata of sandy gravel and gravel with cobbles (granular horizons generally at depths of greater than 10mbgl). **Railway tracks (east)** Firm to very stiff sandy gravelly clay with low cobble content, investigated to a maximum depth of 2.0mbgl. **Railway tracks (east)**

Station Location	Strata	Summary of Superficial Ground Conditions
		Firm to very stiff sandy gravelly clay interbedded with sandy gravelly clay with cobbles and strata of sandy gravel or gravel with cobbles (granular horizons generally at depths of greater than 9mbgl).
Mater	Made ground	Encountered in most exploratory locations to depths of 2.9mbgl, generally comprising concreate/asphalt over clayey sandy gravel or gravelly clay with inclusions of brick, glass and/or pottery. No other obvious unusual discolouration, oil sheens or odours were noted within the GI information.
	Superficial	Sandy gravelly clay interbedded with sandy gravelly clay with cobbles and strata of sandy gravel or gravel with cobbles.
O'Connell Street	Made ground	Encountered in most exploratory locations to depths of 1.0-4.50mbgl, generally comprising paving and/or concrete over sandy gravelly clay or silt with brick and/or concrete. Inclusions of glass, pottery, wire, tile, metal and ash were recorded in some location. A bituminous odour was noted at 1.1-3.6mbgl in BH10.
	Superficial	Generally sandy gravel overlying sandy gravelly clay with cobbles and/or boulders. Gravel with cobbles was frequently encountered in the strata overlying rockhead.
Tara	Made ground	Encountered in all exploratory locations to depths of 1.2-3.8mbgl. Generally comprising concrete and/or tarmac over sandy gravel and sandy gravelly clay with brick and some ash. Animal bone was recorded in NBH25 and NBH26C.
	Superficial	Generally comprising sandy gravelly silt or sandy gravelly clay over gravel. BH38 recorded sand with a diesel odour from 2.5-3.1mbgl and sandy gravel with cobbles with a faint hydrocarbon odour from 3.1-4.5mbgl.
St Stephen's Green	Made ground	Encountered depths of up to 3.8mbgl comprising sandy gravel including brick and concrete over sandy gravelly clay or clayey gravelly sand with inclusions of brick, concrete, glass and wood.
	Superficial	Comprising sandy gravelly clay with occasional cobbles and boulders over gravel or clayey gravel.
Charlemont	Made ground	Encountered in most exploratory locations to depths of 0.8-7bgl, generally comprising clayey sandy gravel or sandy gravelly clay, often with inclusions of brick. No other obvious unusual discolouration, oil sheens or odours were noted within the GI information.
	Superficial	Silty or sandy gravelly clay over sandy gravelly clay with cobbles and boulders.

The superficial geology in AZ4 has no geological designation and does not have a particular value or significance on a local scale and has been assigned a is assigned a significance/sensitivity of Low.

20.3.5.6 Bedrock Geology

20.3.5.6.1 Lucan Formation

The Lucan (Calp) Formation refers to various units of basinal limestone and shale formed from carbonate sediment deposits. The Lucan Formation consists of muddy limestone beds interbedded with calcareous shale beds. The limestone beds are dark grey to black, fine grained, occasionally cherty and are classified as strong to very strong. Pyrite has also been recorded. Analysis of thin sections for the Dart Underground Environmental Impact Statement (Irish Rail 2010) indicated pyrite concentrations ranging from <0.5% to 5% with detects in the majority of samples, with wide variation between close samples and no regional trends evident. Occasional exceptionally high concentrations of 10% to 40% were identified typically associated with lithology contact surfaces. The limestone hosts some limited fossils, such as corals and brachiopods, locally. The shale beds are less substantial and dark grey to

black in appearance. These are typically moderately strong and more susceptible to weathering than the limestones. The bedrock surface is highly irregular with incised drainage channels including a large pre-glacial channel north of the River Liffey (GSI 2022; RPA 2008; Parsons Brinkerhoff 2007).

Details of the bedrock encountered at each station location are presented in Table 20.39. Refer to the geological cross sections in Appendix A20.9, geological models in Appendix A20.4 and Figure 20.4.

Table 20.39: Summary of Bedrock Conditions in AZ4

Station Location	Summary of Ground Conditions
Ballymun	Bedrock encountered in at 19.9-24.3mbgl. Strata recorded as moderately strong bedded to laminated dark grey to black calcareous mudstone interbedded with strong to very strong medium to thinly bedded dark grey argillaceous limestone.
Collins Avenue	Bedrock encountered at 19.5-24.2mbgl, comprising strong to very strong medium to thinly bedded grey to dark grey limestone, locally fossiliferous, interbedded with moderately strong to strong medium bedded dark grey to black argillaceous mudstone.
Albert College Shaft	Bedrock encountered between 17.2 and 20.1mbgl, comprising strong to very strong medium to thinly bedded grey to dark grey limestone, locally fossiliferous, interbedded with moderately strong to strong medium bedded dark grey to black argillaceous mudstone.
Griffith Park	Depth to bedrock varies from 4.1mbgl to the south of the Tolka River to 16.1mbgl to the northeast of the proposed Griffith Park Station. Bedrock is described as strong grey argillaceous limestone interbedded with weak to strong black carbonaceous limestone.
Glasnevin	**Station Box and Adjacent Road** Bedrock was recorded at depths of between 17.0mbgl (ABH37) and 20.2mbgl (NBH19, just to west of station box), generally comprising medium strong thinly bedded dark grey limestone with occasional beds of mudstone. **Railway tracks (east)** Not encountered **Railway tracks (west)** Encountered at a depth of 18.7mbgl in one borehole (GBH02) near the station box.
Mater	Depth to bedrock recorded at 24.5mbgl to 27.25mbgl, comprising moderately strong dark grey limestone interbedded with moderately strong dark grey to black calcareous mudstone.
O'Connell Street	Depth to bedrock recorded at 14.9-25mbgl. Bedrock is described as moderately strong to strong thin to medium bedded dark grey often argillaceous limestone interbedded with weak to moderately strong laminated dark grey or black shale or mudstone, often calcareous.
Tara	Depth to bedrock recorded at 6.0-9.0mbgl. Bedrock is described as laminated to medium bedded dark grey argillaceous limestone interbedded with weak black carbonaceous mudstone.
St Stephen's Green	Recorded in one exploratory location at 6.3mbgl, comprising strong dark grey argillaceous limestone interbedded with weak to moderately strong black calcareous mudstone.
Charlemont	Depth to bedrock recorded at 4.8-9.12mbgl and comprising medium strong laminated to medium bedded dark grey to black sometimes argillaceous limestone with widely spaced medium beds of weak black carbonaceous mudstone.

The bedrock geology in AZ4 has no geological designation and does not have a particular value or significance on a local scale and is assigned a sensitivity of Low.

20.3.5.7 Hydrogeology

The whole AZ4 area is classified as a LI (Locally Important) Aquifer and designated as the Dublin Aquifer.

The majority of the area is recorded as low aquifer vulnerability. The area between Chainage 13520 and Chainage 14220 is recorded as medium and high vulnerability, related to the alignment of the Tolka River. The area between Chainage 17240 and the southern end of AZ4 is recorded as moderate vulnerability.

Five groundwater abstractions are located in AZ4. One is located to the west of the alignment around Chainage 13400, though the exact location is unknown. Two groundwater abstractions are recorded approximately 175m north-west of Chainage 14400, one 950m south-west of Chainage 15960 one 180m east of Chainage 16440 and one 590m south-west of Chainage 16860.

Groundwater levels measured in monitoring standpipes in AZ4 are summarised in Table 20.40.

Table 20.40: Summary of Measured Groundwater Levels (AZ4)

Nearest Proposed Station	Monitoring Well ID	Ground Elevation	Dates of Level Monitoring	Level Range (mbgl)	Level Range (mAOD)
Ballymun Station	NBH203A-D	61.99	23 Jun 2020 - 24 May 2021	7.83 - 13.25	54.17 - 48.74
	NBH204	59.36	14 Jul 2020 - 24 May 2021	10.82 - 12.45	48.54 - 46.91
Collins Avenue Station	NBH206	51.95	23 Jun 2020 - 24 May 2021	8.33 - 9.38	43.62 - 42.58
	NBH207-D	50.96	23 Jun 2020 - 24 May 2021	9.34 - 10.69	41.62 - 40.27
	NBH207-S	50.96	23 Jun 2020 - 24 May 2021	10.77 - 16.38	40.19 - 34.58
Griffith Part Station	NBH211	19.09	23 Jun 2020 - 24 May 2021	-0.06 - 8.00	19.15 - 11.09
	NBH223-D	18.85	23 Jun 2020 - 24 May 2021	0.34 - 2.28	18.51 - 16.57
	NBH223-S	18.85	27 Jun 2020 - 24 May 2021	0.83 - 2.25	18.02 - 16.61
Glasnevin Station	GBH02-D	25.96	04 Aug 2020 - 18 Aug 2020	10.94 - 11.18	15.02 - 14.78
	GBH02-S	25.96	29 Jul 2020 - 18 Aug 2020	10.11 - 10.59	15.85 - 15.37
	NBH18-D	24.25	03 Dec 2019 - 22 May 2020	10.43 - 11.71	13.82 - 12.54
	NBH18-S	24.25	03 Dec 2019 - 09 Dec 2020	6.72 - 8.44	17.53 - 15.81
	NBH19A	26.1	03 Dec 2019 - 16 Dec 2020	9.35 - 11.38	16.75 - 14.72
	NBH19W	26.17	03 Dec 2019 - 16 Dec 2020	8.44 - 10.88	17.73 - 15.29
Mater Station	NBH215-D	22.81	23 Jun 2020 - 28 May 2021	14.10 - 16.11	8.71 - 6.70
	NBH215-S	22.81	17 Jun 2020 - 25 May 2021	13.95 - 16.63	8.86 - 6.18

Nearest Proposed Station	Monitoring Well ID	Ground Elevation	Dates of Level Monitoring	Level Range (mbgl)	Level Range (mAOD)
	NBH216A-D	21.99	23 Jun 2020 - 25 May 2021	15.64 - 18.87	6.35 - 3.12
	NBH216A-S	21.99	23 Jun 2020 - 25 May 2021	14.69 - 18.34	7.300 - 3.65
O'Connell Street Station	NBH23A	5.06	04 Dec 2019 - 16 Dec 2020	4.52 - 5.15	0.54 - -0.09
	NBH23W	5.13	04 Dec 2019 - 09 Dec 2020	4.53 - 5.83	0.60 - -0.70
	NBH24-D	5.12	28 May 2020 - 16 Dec 2020	4.65 - 4.97	0.47 - 0.15
	NBH24-S	5.12	04 Dec 2019 - 16 Dec 2020	4.39 - 4.86	0.73 - 0.26
Tara Station	NBH25-D	3.51	04 Dec 2019 - 09 Dec 2020	3.29 - 4.08	0.22 - -0.57
	NBH25-S	3.51	04 Dec 2019 - 09 Dec 2020	3.14 - 4.17	0.38 - -0.66
	NBH26CA	3.96	04 Dec 2019 - 17 Dec 2020	3.56 - 4.35	0.40 - -0.39
	NBH26CW	4.02	04 Dec 2019 - 17 Dec 2020	3.77 - 4.36	0.25 - -0.34
St Stephen's Green Station	NBH219B-D	12.52	13 Jul 2020 - 24 May 2021	4.51 - 7.85	8.01 - 4.67
	NBH219B-S	12.52	13 Jul 2020 - 24 May 2021	3.90 - 5.11	8.62 - 7.41
	NBH220-D	12.34	23 Jun 2020 - 24 May 2021	3.81 - 6.58	8.53 - 5.76
	NBH220-S	12.34	23 Jun 2020 - 28 May 2021	2.54 - 4.69	9.800 - 7.65
Charlemont Station	NBH29	16.04	04 Dec 2019 - 03 Feb 2020	4.21 - 4.67	11.83 - 11.37
	NBH30W	15.8	04 Dec 2019 - 03 Feb 2020	3.09 - 4.95	12.71 - 10.85

20.3.5.8 Current and Historic Mining Sites

No quarries, pits or mines have been recorded within the study area in AZ4.

The granular and crushed rock aggregate potential within AZ3 is summarised in Table 20.41 and Table 20.42.

Table 20.41: Granular Aggregate Potential in AZ4

Station Area	Granular Aggregate Potential	Location Description	Potentially Viable?	Sensitivity
Collins Avenue	Very Low	Approximately 100m northwest of Works Area.	No – area largely developed	Low
Griffith Park	Very Low	Approximately 120m west and 320m south.	No – area largely developed	Low

Station Area	Granular Aggregate Potential	Location Description	Potentially Viable?	Sensitivity
	Low	Approximately 40m west of Works Area and adjacent to south east of Works Area along the alignment of the Tolka River.	No – area largely developed	Low
	Moderate	Area around and to the west of the Works Area.	No – area largely developed	Low
	High	Immediately south of the Works Area, approximately 25m north east of the Works Area and approximately 130m west of the Works Area.	No – area largely developed	Low
	Very High	Approximately 150m south and west of the Works Area.	No – area largely developed	Low
O'Connell Street	High	Isolated areas in the immediate Works Area and 25m south west, 200m south west and 150m south east of the Works Area.	No – area largely developed	Low
Tara	High	Approximately 85m north of the Works Area on the northern bank of the River Liffey.	No – area largely developed	Low
St Stephen's Green	Low	Approximately 25m north of the Works Area.	No – area largely developed	Low
Ballymun, Intervention Shaft, Mater, Charlemont	No potential			

Table 20.42: Crushed Rock Aggregate Potential in AZ4

Station Area	Crushed Rock Potential	Location Description	Potentially Viable?	Sensitivity
Ballymun	Low	Whole station study area.	No – area largely developed	Low
Collins Avenue	Low	Whole station study area.	No – area largely developed	Low
Intervention Shaft	Low	Whole station study area.	No – area largely developed	Low
Griffith Park	Low	Approximately 120 to 200m north and east of the Works Area.	No – area largely developed	Low

Station Area	Crushed Rock Potential	Location Description	Potentially Viable?	Sensitivity
	Moderate	25 to 150m in all directions from the Works Area.	No – area largely developed	Low
	High	In the immediate surrounds of the Works Area.	No – area largely developed	Low
	Very High	Approximately 25m west of the Works Area, along the alignment of the Tolka River.	No – area largely developed	Low
Mater	Low	Whole station study area.	No – area largely developed	Low
O'Connell Street	Low	Whole station study area.	No – area largely developed	Low
Tara	Low	Immediately north east of the Works Area.	No – area largely developed	Low
	Moderate	In the vicinity of and to the south west of the Works Area.	No – area largely developed	Low
St Stephen's Green	Moderate	Whole station study area.	No – area largely developed	Low
Charlemont	Moderate	Whole station study area.	No – area largely developed	Low

20.3.5.9 Irish Geological Heritage Sites

Two pNHAs are recorded within AZ4. The Royal Canal crosses the proposed alignment at Chainage 14940 to Chainage 14960, within the Works Area at Glasnevin Station. The Grand Canal crosses the proposed alignment at Chainage 19240 to Chainage 19260, 10m north of the Works Area at Charlemont Station. These sites have been designated as pNHAs on the basis of high ecological value on a local scale, and, as such are considered further in Chapter 15 (Biodiversity).

Five Geological Heritage Sites (GHS) are recorded in AZ4, these are described below and summarised in Table 20.43.

20.3.5.9.1 Glasnevin Cemetery

Glasnevin Cemetery is described as a very large public cemetery of 120 acres (around 49 Hectares), first used in 1832. The site has been designated as important and given an IGH theme of Economic Geology as it provides an unparalleled range of worked rock types accessible to view in the gravestones and memorials (GSI 2014; OSI 2021).

20.3.5.9.2 General Post Office

The General Post Office located on O'Connell Street is designated as a CGS due to the materials used in the decoration of the interior. The post office opened in the early 1800s with interior restoration occurring in 1928. The post office is heavily panelled with Irish Marbles, namely: Connemara Green Marble, Cork Red Marble and black marble (either from Kilkenny or Galway). The black marble is highly fossiliferous with corals and brachiopod shells present. The exterior of the post office is also of geological interest as the building has been built using two key building stones, granite from Golden Hill in Wicklow and Portland Limestone, imported from Dorset in England (GSI 2014; OSI 2022).

20.3.5.9.3 Museum Building, Trinity College

The Museum building of Trinity College was completed in 1857 and has been classed as having a fine demonstration of rock types in building construction and ornamentation. The building is notable for the variety and use of different marbles and other building stones in its interior hall. The internal columns and staircase are made from a wide range of polished limestones and metamorphic marbles including green Connemara Marble, black Kilkenny Marble and mottled Cork Red Marble (GSI 2014; OSI 2022).

20.3.5.9.4 Oscar Wilde Statue

The statue is a modern, life size statue of Oscar Wilde made of sculpted rocks and placed on top of a large boulder of quartz, located on Merrion Square. The rocks used in its construction are of varying ages and geographical location including Canadian green nephrite jade, Guatemalan white jade, thulite (rare pink stone) from Norway, iridescent larvikite from the Oslo Fjord in Norway and polished and unpolished Indian Granite. The large boulder of quartz on which the sculpture rests, is from Wicklow, derived from a major fault zone (GSI 2014; OSI 2022).

20.3.5.9.5 51 St Stephen's Green

Also known as the Museum of Irish Industry, 51 St Stephen's Green entrance lobby was built in mid 1800s. The lobby contains large, polished panels of numerous Irish marbles and polished building stones of varying ages (GSI 2014; OSI 2022).

Table 20.43: Geological Heritage Sites within AZ4

Site Name	Location and Distance from the Proposed Project	Irish Geological Heritage (IGH) Theme	Sensitivity
Glasnevin Cemetery	140m north of Works Area at Glasnevin Station.	IGH 15 – Economic Geology	Medium
General Post Office	Within Works Area at O'Connell Street Station.	IGH 15 – Economic Geology	Medium
Museum Building, Trinity College	200m south of Works Area at Tara Station.	IGH 15 – Economic Geology	Medium
Oscar Wilde Statue	160m east of the alignment, Merrion Square.	IGH 15 – Economic Geology	Medium
51 St Stephen's Green	Adjacent to Works Area at St Stephen's Green Station.	IGH 15 – Economic Geology	Medium

20.3.5.9.6 Radon and Ground Gas

The pre 2022 online Radon Map of Ireland indicates that the northern extent of AZ4 is within the lowest classification of radon potential (<1% of homes above reference levels). To the south of around Ballymun Station, AZ4 is within the second lowest classification of radon potential (1%-5% of homes above the reference levels). The updated map indicates that the large majority of the study area falls within the lowest classification of radon potential (about 1 in 20 homes likely to have high radon levels), with an area to the south east of Griffith Park Station associated with Tolka River falling into the second lowest classification (about 1 in 10 homes likely to have high radon levels).

Ground gas has been monitored at 26 locations in AZ4, and the readings are summarised in Table 20.44, the CS for all installations was CS1 Very Low Risk.

Table 20.44: Ground Gas Summary for AZ4

Area	BH Reference	Number of data points	Max Methane %v/v	Max Carbon Dioxide %v/v	Max Gas Flow l/hr	Max Methane GSV l/hr	Max Carbon Dioxide GSV l/hr	Max CS Methane	Max CS Carbon Dioxide
Albert College Shaft	ABH30i	1	0.6	1.6	0.6	0.0036	0.0096	1	1
Griffith Park Station	NBH223-S	2	0.4	0.6	0.9	0.0036	0.0054	1	1
Glasnevin Station	GBH02-S, GBH04-S, NBH18-S	7	0.4	2.7	0.9	0.0027	0.0243	1	1
Mater Station	C, E2	12	0.0	3.7	0.0	0.0	0.0	1	1
O'Connell Street Station	NBH22-S, NBH24-S, NBH63	7	0.3	1.1	0.8	0.0024	0.0088	1	1
Tara Station	NBH25-S, NBH64	6	1.0	4.3	0.9	0.009	0.0387	1	1

Comparison of monitoring data with WELs is shown in Table 20.45. The carbon dioxide short term exposure limit was exceeded in the proposed Albert College Shaft, Glasnevin, Mater and Tara Station.

Table 20.45: Comparison of AZ4 gas data with WELs

Area	BH Reference	Number of data points	Max Carbon Dioxide %v/v	Max CO Steady State ppm	Carbon Dioxide Short Term Exposure Limit[1] %	Carbon Monoxide Short Term Exposure Limit[1] ppm
Albert College Shaft	ABH30i	1	1.6	No data	1.5	100
Griffith Park Station	NBH223-S	2	0.6	No data		
Glasnevin Station	GBH02-S, GBH04-S, NBH18-S	7	2.7	No data		
Mater Station	C, E2	12	3.7	10		
O'Connell Street Station	NBH22-S, NBH24-S, NBH63	7	1.1	No data		
Tara Station	NBH25-S, NBH64	6	4.3	No data		

[1] Refers to 15-minute reference period under EH40/2020 WELs

Exceedances of WEL highlighted by grey fill

20.3.5.10 Contaminated Land

Potential contamination sources identified by a review of the available documentary and ground investigation information are presented in Appendix A20.5 with locations shown on Figure 20.6. In addition, geological models of each station location in AZ4, including the results of the geochemical screening are included in Appendix A20.4. The majority of these potential sources are outside the Works

Area and/or have a minor or mild assessed severity with no specific linked instances of made ground or contamination identified. The main potential contamination sources considered to have potential to affect the route include the following:

- Ballymun Shopping Centre and associated tanks (C78 and C79);
- Fuel station near Intervention shaft (C86);
- Oil filled cable leaks 29, 63, 20 and 9 (C88, C106, C119 and C130);
- Potentially infilled ground at Griffith Park station (C94);
- Railway land, stations and former creosote application yard near Glasnevin station (C99A, C99B, C99C, C100 and C101);
- Mater Hospital (C105);
- Former gas testing station and hospital at Tara Station (C120 and C121); and
- Railway land at Charlemont Station (C131).

In addition to the above made ground (from the urban development of Dublin City) which has not been attributed to specific sources has been identified within the Works Areas at the stations and intervention shaft where surface works will be undertaken. A summary of a comparison of the soil and groundwater geochemical data with GACs for each proposed station location is presented in Table 20.46.

Table 20.46: Summary of Contamination Assessment for Station Locations Within AZ4

Station Location	Summary of Contamination Assessment
Ballymun	One exceedance of the residential soil GAC for chromium was encountered approximately 100 m south of the Works Area within made ground associated with the road network. VOCs and SVOCs were detected in the north and centre of the Works Area, associated with urban made ground and an area of fill at the derelict Ballymun Shopping Centre. Marginal detections of VOCs (toluene and trimethylbenzene) were found at depth (19.24mbgl) in ABH23. Asbestos was found in two no. samples (amosite, quantified at <0.001%) in NBH80 around 380m north of the Works Area. TPH (both aliphatic and aromatic) were detected in NBH203A-D and NBH203A-S during one monitoring round, however, were not detected during a second monitoring round. Other exceedances of groundwater CWSC were recorded for manganese, potassium, chloride, biological oxygen demand, ammoniacal nitrogen, vinyl chloride and bis(2-ethylhexyl) phthalate. Exceedances of CWSC for leachate samples were primarily for metals (selenium, arsenic and chromium), which were encountered from samples within natural deposits and may represent natural background conditions. Leachable phenols were encountered in two samples (ABH24B) at shallow depths, associated with made ground.
Collins Avenue	Soil GAC Exceedances were not recorded within the Works area, however, chromium and PAHs exceeded residential GAC at shallow depths within made ground within 250m of the Works Area (NBH206 and NBH207, near the northern and southern boundaries of the Works Area respectively); asbestos (chrysotile) was also recorded at 0.002% in these locations at 0.5m depth. The VOC pentachlorophenol was also detected within NBH207. Exceedances of groundwater CWSC for manganese, chloride, ammoniacal nitrogen and boron were encountered in both locations monitored, with an exceedance of iron in one location. Leachable metals (selenium, antimony, barium) were encountered above CWSC in samples of made ground and natural soils/bedrock and are likely to represent natural background concentrations. Fluoride, nickel and zinc were encountered in a sample from NBH207 at 0.5mbgl, associated with made ground.
Albert College Intervention Shaft	One GAC exceedance was encountered for arsenic at 13mbgl, in natural superficial deposits which may represent natural background concentrations. Chromium was recorded above the residential GAC at shallow depths within the study area as well as a detection of Bromodichloromethane. These instances are from natural ground with no obvious attributable potential source. CWSC exceedances were encountered for metals (selenium, manganese, potassium, boron) and inorganic compounds (ammoniacal nitrogen, chloride and nitrite) during both monitoring rounds. Leachable antimony and phenols exceeded the CWS, from bedrock (ABH30i) and shallow made

Station Location	Summary of Contamination Assessment
	ground (NBH208) respectively. No clear potential source of contamination has been identified in this area.
Griffith Park	Exceedances of residential GAC for chromium were encountered at shallow depths, associate with the made ground. Several TPH fractions exceeded the residential GAC within ABH32 at 14.5mbgl, with the aliphatic >C8-C10 TPH fraction also exceeding the commercial GAC at this location in addition to which benzene and toluene were detected. These samples are from limestone 0.6m below rockhead, hydrocarbons were not evident in samples from other depths in ABH32 and no obvious evidence of discolouration or unusual odours were identified. There is no clear source for these hydrocarbons. The nitrogen species nitrate, nitrate and ammoniacal nitrogen as well as chloride were identified in several locations in groundwater above CWSC; these compounds often result from organic decay and could be a result of the presence of a former burial ground at this location. In addition, some metals (manganese, potassium boron, manganese, iron barium) have been identified Leachable antimony and mercury above CWSC have been encountered in samples from within the Works Area, albeit the antimony exceedances are associated with natural superficial deposits and bedrock and may represent natural background concentrations. Within 250m of the Works Area CWSC exceedances for molybdenum, chloride, fluoride and Total Dissolved Solids (TDS) were encountered in a sample from made ground adjacent to St Mobhi Road.
Glasnevin	Within the station box area exceedances of residential GAC were encountered for metals (arsenic, lead, mercury), PAHs and dichloroethane associated with made ground at shallow depths. VOCs (carbazole, 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene) were also detected in the made ground. Mercury was above the residential GAC at 10.5mbgl in the natural deposits which may be indicative of background concentrations. No exceedances were encountered in the samples from the track to the east of the station box. To the west of the station box residential exceedances were widespread for metals (arsenic, chromium, lead), various PAH congeners and TPH, all associated with the made ground and track ballast. Detections of VOCs/SVOCs were also recorded within the works area at NBH19A, GTP25 and TPCC04. These exceedances and detections are associated with the existing railway line and surrounding made ground. Ammoniacal nitrogen and chloride appear to be widespread above CWSC both within the Works Area (station box and west of the station box) and adjacent to the Works Area. These determinants could result from a variety of sources including cemeteries which are present in the area. In addition, metals are present including iron, manganese, potassium and boron as well as elevated hardness and biological oxygen demand. Leachable arsenic, antimony, selenium, barium, molybdenum, barium and chloride concentration exceeded their respective DWS and IGV within and outside the Works area, primarily associated with the made ground although antimony and selenium are present within a bedrock sample (ABH38 at 24.3mbgl) which may represent natural background concentrations. In addition, phenols were identified in one location (GBH11) outside the Works Area.
Mater	The majority of the soil samples tested in the study area recorded residential GAC exceedances, located in the north eastern area of Mater Hospital, within the Works Area and in the far north west and south east of the study area. Exceedances comprised metals (primarily arsenic, chromium and lead) aromatic hydrocarbons and PAHs within the made ground within the Works Area. Mercury was found at depth within natural ground in the superficial deposits (ABH40 and ABH41 and 14.6 and 13mbgl respectively) which may represent natural background concentrations. In NBH216 (to the south east of the Works Area) exceedances of chromium, aromatic hydrocarbons and PAHs were recorded throughout the made ground. VOCs/SVOCs were also detected within and adjacent to the Works Area. PAH concentrations also exceeded the commercial GAC within the made ground. Within ABH41 and NBH216A. The exceedances beneath the footprint of Mater Hospital are likely to be attributed to historic construction and hospital operation activities on the site, however, due to the distance from the Works Area this is unlikely to affect the proposed Project. Petroleum hydrocarbons and PAHs were identified in several locations in the groundwater at the proposed Mater Station location above CWSC which may be reflective of the hydrocarbon

Station Location	Summary of Contamination Assessment
	content associated with the made ground. Nitrogen species (ammoniacal nitrogen, nitrite) and some metals (manganese, iron, boron and arsenic) are also present above CWSC. Leachable arsenic, antimony, selenium, molybdenum, and chloride concentrations exceeded CWSC within and outside the Works rea, primarily associated with the made ground although antimony and selenium are present within bedrock samples (ABH40 at 29.6mbgl and ABH39 and 23.7mbgl) which may represent natural background concentrations. In addition, phenols were identified in one location (ABH40) at depth in the natural soils within the Works Area.
O'Connell Street	Exceedances of residential GAC are widespread within the made ground for PAHs, TPH and some metals (arsenic, chromium); the commercial GACs were also exceeded for PAHs in ABH45 and NBH23A at 0.5mbgl and 1.2mbgl. The residential GAC were also exceeded within the natural deposits and bedrock for dibenz[a,h]anthracene (ABH45 at 6mbgl), trichloroethene (ABH45 at 6mbgl and 10.5mbgl), benzene and 1,2-dichloroethene (ABH46 at 29.8mbgl). Organic contaminants were identified in the groundwater towards the south of the Works Area (TPH, tetrachloroethene in NBH24-S), elsewhere exceedances of criteria were mainly for inorganic (nitrite, chloride, phosphorous) and metals (manganese, potassium, boron and selenium). Leachable arsenic, phenols, coper and chromium concentrations exceeded CWSC within the Works area, primarily associated with the made ground although antimony and selenium are present within bedrock samples (ABH45A at 22.0mbgl and ABH46 and 20.0mbgl) which may represent natural background concentrations.
Tara	Exceedances of GAC were recorded in two clusters, one within the Works Area and one in the northwest of the study area. Those in the northwest comprise lead and PAHs, though are unlikely to influence the proposed Project due to the distance to the Works Area and position in the vicinity of the River Liffey. The exceedances within the Works Area comprise arsenic, mercury, lead and PAHs, and are associated with the made ground. VOCs/SVOCs were also recorded in the same locations, although the majority of the detections were recorded near the boundary of the study area. Exceedances of assessment criteria were primarily for inorganic (ammoniacal nitrogen, chloride, sulphate, TDS and phosphorous) and metallic (cobalt, magnesium, manganese, nickel, potassium, sodium barium, boron, calcium, iron) contaminants, likely to be associated with the urban nature of the area. Leachable arsenic, antimony, molybdenum, chloride and sulphate concentrations exceeded CWSC within the Works area, primarily associated with the made ground although antimony, arsenic and selenium are present within bedrock samples (ABH49 at 17.7mbgl, ABH50 at 13.5 and 23.5mbgl) which may represent natural background concentrations.
St Stephen's Green	Exceedances of GAC were recorded within and approximately 65m south of the Works Area and comprised lead, aromatic hydrocarbons and PAHs. One location within the Works Area recorded VOCs/SVOCs. Both areas are associated with urban made ground up to 3.8m thick comprising sandy gravel and sandy gravelly clay with inclusions of brick, concrete, glass and wood. Exceedances of assessment criteria were primarily for inorganic (chloride) and metallic (iron, manganese, potassium and boron) contaminants, likely to be associated with the urban nature of the area with one instance TPH being present Leachable antimony, mercury, molybdenum and arsenic concentrations exceeded CWSC in samples from within the Works area, primarily associated with the made ground. Antimony within ABH55 at 23.0mbgl is a bedrock sample and may represent natural background concentrations.
Charlemont	The majority of samples tested in the study area exceeded GAC. The greatest number of exceedances was recorded in NBH222B in the north of the study area; however, this is separated from the Works Area by the Grand Canal and is unlikely to influence the proposed Project. Within the Works Area, exceedances comprised arsenic, nickel, chromium, mercury and lead and were associated with the made ground, and 1,2,4-trichlorobenzene was detected in one sample. Exceedances of assessment criteria were primarily for inorganic (chloride, ammoniacal nitrogen and chloride) and metallic (manganese and boron) contaminants, likely to be associated with the urban nature of the area. Leachable antimony, selenium and chloride concentrations exceeded CWSC within the Works Area, primarily associated with the made ground. Antimony within ABH56 at 25.5mbgl, ABH57 at

Station Location	Summary of Contamination Assessment
	15.5mbgl and ABH59 at 22.2mbgl are bedrock samples and may represent natural background concentrations.

20.4 Predicted Impacts

20.4.1 Introduction

This Section provides an outline of the potential impacts considered under soils and geology with respect to the proposed Project design under a 'Do-Nothing' scenario, the Construction Phase and the Operational Phase. Chapter 5 (MetroLink Construction Phase) and Chapter 6 (MetroLink Operations & Maintenance) include a detailed description of the construction and operation of the proposed Project. The primary features of the proposed Project with respect to interactions with soils and geology are summarised in Table 20.47.

Table 20.47: Summary of Primary Design Features

AZ	Design Feature		Station	Approximate Chainage
AZ1	Surface section		Estuary	1238 – 1300
	Retained Cut		Seatown	2824 – 2889
			Swords Central	3792 - 3857
	Surface section		Fosterstown	4758 – 4823
AZ2	North Portal	Tunnel		4823
	Dublin Airport station		Dublin Airport	7016 – 7081
	South Portal			9012
AZ3	Retained Cut		Dardistown Depot	
	M50 Viaduct			
	North Portal	Tunnel	Northwood	10296 – 10361
AZ4	Tunnel		Ballymun	11237 – 11302
			Collins Avenue	12050 – 12380
			Intervention Shaft	12780 – 12860
			Griffith Park	13778 – 13843
			Glasnevin	14835 – 14900
			Mater	15615 – 15680
			O'Connell Street	16630 – 16695
			Tara	17371 – 17436
			St Stephen's Green	18452 – 18571
			Charlemont	19339 – 19404

Activities relating to aspects of soils and geology considered in this Chapter that may impact on baseline conditions include:

- Loss of soil cover and soil sealing;
- Degradation in chemical or organic quality resulting from the stripping, storage and reinstatement of soils during construction;
- Soil erosion and compaction;
- Stability of relevant receptors from disturbance of both superficial deposit and bedrock geology during earthworks and tunnelling, including settlement effects;

- Removal, storage, placement and disposal of soils, superficial geological deposits and bedrock from earthworks and tunnelling;
- Loss of geological heritage and scientific value;
- Loss of economic value;
- Risk of encountering contaminated ground, including potential human health and environmental impacts arising from the excavation, handling, on-site processing, transport and off-site disposal and recovery;
- Risk of contamination of uncontaminated soils and geology by construction activities such as accidental fuel spills and the introduction of new contaminant migration pathways via temporary storage of contaminated materials and piling;
- Contamination of soil and water by materials used for construction (e.g. via use of TBM); and
- Removal and/or obscuring of any features of geological or geomorphological interest and importance.

As noted in Section 20.1, there are inter-relationships with other chapters where impacts on subjects such as land take, Resource & Waste Management, agronomy and human health are considered.

During construction a considerable quantity of material will be produced from a number of activities including:

- Excavation from retained cut and station construction in AZ1;
- Excavation from construction of underground stations and shafts in AZ2 and AZ4;
- Excavation from park and ride (AZ1), and surface works and depot construction (AZ3);
- Excavation associated with bridges and viaducts; and
- Tunnel boring within AZ2 and AZ4.

The estimated material quantities, as provided within the business case for the proposed Project are summarised in Table 20.48.

Table 20.48: Summary of Material Quantities (Based on the Proposed Project Business Case)

Design Feature	Material Quantity Estimate (m^3)				
	Made Ground	Natural Superficial Deposits	Mixed (Soil and Rock)	Rock	Total
AZ1					
Park & Ride		24,530		1,047	25,577
Northern Extent to Seatown Station	6,420	102,370		2,941	111,731
Seatown Station to Malahide Roundabout	7,073	98,823		13,250	116,146
Malahide Roundabout to Pinnockhill Roundabout	6,678	114,947		3,821	125,446
Pinnockhill Roundabout to North Portal	6,872	154,718		4,055	165,645
AZ2					
Dublin Airport Station	6,530		1,500	67,730	75,760
DANP	845	10,508		139	11,492
DASP	3,704	37,039			40,743
AZ3					
Central Section Surface Works	25,056	255,553		7,950	289,768
Dardistown Depot	25,124	255,553			280,677
Northwood Portal	1,170	11,427		10,800	23,397
AZ4					
Northwood Station	3,300	45,222	1,500	26,521	76,543

Design Feature	Material Quantity Estimate (m^3)				
	Made Ground	Natural Superficial Deposits	Mixed (Soil and Rock)	Rock	Total
Ballymun Station	4,077	44,295	1,500	27,157	77,029
Collins Avenue Station	8,515	29,291	1,500	37,201	76,507
Griffith Park Station	4,154	28,857	1,500	55,137	89,648
Glasnevin Station	14,063	106,619	1,500	18,448	140,630
Mater Station	4,299	54,425	1,500	24,310	84,534
O'Connell Street Station	10,223	88,283	1,500	20,966	120,972
Tara Station	4,867	6,240	1,500	60,343	72,950
St Stephen's Green Station	6,134	13,466	1,500	65,763	86,863
Charlemont Station	4,354	31,797	1,500	47,944	85,595
Albert College Park Shaft		17,031		4,607	21,638
South of Charlemont Shaft		2,530		879	3,409
Route Wide					
TBM Tunnels		204,121	138,802	473,561	816,484
Bridges, Viaducts		6,404			6,404
Total Excavated Material	**153,458**	**1,742,258**	**155,302**	**974,570**	**3,025,588**
Backfill required					99,931
Total Surplus Excavated Material					**2,925,657**

Impacts on receptors relevant to soils and geology associated with excavation, handling and storage on-site of sub-surface material are considered in this Chapter. Consideration of impacts related to the transport and the off-site reuse or disposal of excavated materials can be found in Chapter 9 (Traffic & Transport) and Chapter 24 (Materials & Waste Management).

As noted in the introduction to this Chapter (Section 20.1) Limits of Deviation (LOD) have been set for the proposed Project to account for variations which may be required due to currently unknown constraints during development of detailed design and construction. The assessment takes into account variations that could occur within the LOD, variations which exceed the LOD may require additional assessment to be undertaken. This is standard practice in large infrastructure projects of this scale and complexity.

20.4.2 Do-Nothing Scenario

The Do-Nothing scenario is the scenario in which the proposed Project does not go ahead, and no development occurs. Under this scenario, the absence of a Construction Phase would result in no disturbance or other change in baseline conditions for the following:

- Soils and superficial geology;
- Bedrock geology;
- Current and historic mining sites;
- Irish geological heritage sites; and
- Radon.

There is the potential that in the absence of the proposed Project and the associated development, some areas of potential land contamination would remain in place and remain un-addressed. This would occur from a combination of the absence of remedial or land management actions and the continuation of natural migration processes such as infiltration, groundwater flow and surface water flow.

In the context of the proposed Project baseline conditions as detailed in Section 20.3, however, such impacts are considered unlikely to have more than a negligible effect in the short-term and have therefore been assessed as having an imperceptible significance of impact.

20.4.3 Construction Phase

20.4.3.1 Geomorphology

Geomorphological features such as glacial lineation's and meltwater channels have been identified in AZ1, AZ3 and AZ4. Construction work will result in a permanent loss of parts of these features where they intersect with surface works, and as such, the magnitude of impact can be considered to be small adverse, resulting in an overall imperceptible significance of impact given the 'Low' sensitivity of these features.

20.4.3.2 Soils and Superficial Geology

As detailed in the baseline (Section 20.3), much of the proposed Project, particularly within AZ1 and AZ4 are in urbanised areas (Swords, Dublin City) and Dublin Airport (AZ2) where the soil has a low sensitivity 'urban soil' classification. The exceptions are primarily within AZ1 and AZ3 where a greater proportion of 'greenfield' areas are present (made ground is considered in more detail under land contamination in Section 20.4.3.7).

The superficial geological deposits within the study area primarily comprise glacial till (colloquially known as the black and brown boulder clays) with smaller areas of alluvium associated with watercourses and minor deposits of lacustrine and estuarine clays and silts. The interface with the underlying bedrock geology is commonly marked by a transition layer of gravel derived from limestones. None of the superficial deposits is considered to have significant economic value or assigned a geological significance and have been assigned a 'Low' sensitivity.

The predicted impacts on soils and superficial geology within each AZ are detailed under the following sub-headings and summarised in Table 20.49 (soils) and in Table 20.50 (superficial geology). It should be noted that during construction there will be a temporary benefit in areas of cut or other excavation as new areas of subsurface geology will be exposed allowing refining of geological information for the Dublin area.

20.4.3.2.1 AZ1 – Northern Section

The Estuary Station and Park and Ride Facility are present at the northern extent of AZ1 within an area occupied by fields. The soil type is the Elton Association, which is considered to have a sensitivity of Medium, with an area of alluvium present adjacent to the Broadmeadow River which is considered to have a Low sensitivity. Construction activities in this area will include enabling works such as soil stripping and construction of a development platform leading to permanent loss from the site of some of the Elton Association soils and sealing of and loss of organic matter from soils within the development footprint of the proposed Project. In addition, soil outside areas of new structures may be compacted and eroded by plant movement, although it should be noted that soils within the development boundary will no longer be subject to agricultural use. Overall, a small adverse magnitude of impact has been assigned.

A viaduct is present in the area of alluvium associated with the Broadmeadow River, alluvium can contain organic matter and typically has poor geotechnical characteristics and may require removal or treatment as part of construction resulting in a small adverse magnitude of impact. The area of tidal marsh to the east of Estuary Station will not be disturbed as part of construction, resulting in negligible impact. Removal of the underlying glacial till deposits will also be required in this area resulting in permanent removal albeit excavation depths will be relatively shallow, and the impact is considered to be negligible. The estuarine silts and clays are approximately 200m from the Works Area at nearest approach and will not be affected by the works in this area.

There is also the option of piles being used as a foundation to support the Broadmeadow River viaduct. Piling methodologies vary; some result in removal of sub-surface material and/or the creation of new contaminant migration pathways in the short term and long term. There is, however, an absence of potential contamination from current and historic sources within the Broad Meadow Viaduct area, and Construction Phase risks will be primarily associated with leaks/spills of from plant and fuel/lubricant storage during construction.

The section of AZ1 through Swords to Fosterstown is to be retained cut, which will require excavation to around 5m depth. The soil classification for the majority of this area is 'urban' with a 'Low' sensitivity, and while there will be permanent loss of this material, the magnitude of impact is considered negligible. An area of the 'Low' sensitivity Crosstown Association soils is also present along part of this area. The relatively small area affected is considered to result in a negligible effect. Lacustrine sediments are also indicated by geological maps in this section. However, little evidence of this material was encountered in the ground investigation records.

Excavation of large quantities of subsoil is going to be required as part of construction of the retained cut section (refer to Table 20.47) which will primarily affect the till and underlying gravels derived from limestones. While the excavation volumes are high the shallow geology does not have heritage value and is not considered to have future economic value, and the magnitude of impact has been assessed as negligible.

To the south of Fosterstown Station, an surface section leads to the DANP for the Airport Tunnel section. This is a mainly greenfield area occupied by soils of the Elton Association. As at the northern extent of AZ1, construction will require soil removal, albeit on a smaller scale, along with removal of the underlying till. In addition, soil outside areas of new structures may be compacted and eroded by plant movement, although it should be noted that soils within the development boundary will be no longer subject to agricultural use. A small adverse magnitude of impact is assessed based on the removal of soil, with a resulting slight significance of impact.

20.4.3.2.2 AZ2 – Airport Section

The majority of AZ2 comprises tunnel, with ground surface interactions confined to the areas of the DANP and DASP and Dublin Airport Station. The Elton Association is present at both portal locations and construction will result in a permanent loss of soil albeit at a fairly small scale resulting in a small adverse impact.

Urban soils are indicated at the Dublin Airport Station location by soil maps. However, this location is currently occupied by a car park, and ground investigation information indicates that made ground is present beneath the asphalt hard standing which in turn overlies bedrock. As such soil and natural superficial deposits are likely to be completely absent in this location.

Tunnelling and construction of the portals will result in the production of large quantities of glacial till (refer to Table 20.48). While these excavation volumes are high, the shallow geology does not have heritage value and is not considered to have future economic value, and the magnitude of impact has been assessed as negligible.

20.4.3.2.3 AZ3 – Dardistown to Northwood

The area of AZ3 to the north of the M50 Viaduct includes a length of retained cut and the construction of the Dardistown Depot; the proposed Project alignment crosses the M50 on a viaduct before entering a tunnel portal and the underground station at Northwood at the southern extent of AZ3.

The primary soil type is the Elton Association, which is considered to have a sensitivity of Medium, with smaller areas of urban soils present. Construction of the retained cut, surface section areas and the tunnel portal will lead to permanent loss from the site of some of the Elton Association soils and sealing of and loss of organic matter from soils within the development footprint of the proposed Project. In addition, soil outside areas of new structures may be compacted and eroded by plant movement, although it should be noted that soils within the development boundary will no longer be subject to

agricultural use. Overall, a small adverse magnitude of impact. The magnitude of effect on urban soils is considered to be negligible.

The excavation for depot construction, retained cut and tunnel will result in production and permanent loss of large quantities of superficial deposits (refer to Table 20.48) primarily comprising glacial till. While the excavation volumes are high, the shallow geology does not have heritage value and is not considered to have future economic value, and the magnitude of impact has been assessed as negligible. A small area of alluvium is present associated with the Santry River. Alluvium can contain organic matter and have poor geotechnical characteristics and may require removal or treatment as part of construction resulting in a small adverse magnitude of impact.

20.4.3.2.4 AZ4 – Northwood to Charlemont

AZ4 is a tunnel section with surface works confined to station and intervention shaft locations. Mapping indicates that the soils within the study area are classified as 'urban', and while a small area of river alluvium is present to the west of Griffith Park Station this will not be affected by the proposed construction work. Ground investigation records indicate the presence of varying quantities of made ground at all locations affected by surface works with only minor instances of topsoil. The magnitude of impact on the urban soils in AZ4 is considered negligible.

Tunnelling and station construction will result in the production of large quantities of the superficial deposits (refer to Table 20.48), the majority of which comprises glacial till with some smaller volumes of alluvium and gravels derived from limestones. While the excavation volumes are high the shallow geology does not have heritage value and is not considered to have future economic value. The magnitude of impact has been assessed as negligible for the glacial till and gravels derived from limestone. While not encountered in any quantity during the ground investigation, there is the potential for alluvial sediments to be present in some locations near the River Liffey (e.g., O'Connell Street Station) which could contain organic material and have poor geotechnical properties and require removal or treatment, leading to a small adverse magnitude of impact.

20.4.3.2.5 Soils and Superficial Geology: Summary Impact Significance

Table 20.49: Summary of Predicted Impacts on Soils During Construction.

AZ	Soil Group	Sensitivity	Magnitude of Impact	Significance of Impact
AZ1	Elton Association	Medium	Small adverse	Slight
	River Alluvium	Low	Small adverse	Imperceptible
	Tidal Marsh	Medium	Negligible	Imperceptible
	Urban	Low	Small adverse	Imperceptible
	Crosstown Association	Low	Negligible	Imperceptible
AZ2	Urban	Low	Negligible	Imperceptible
	Elton Association	Medium	Small adverse	Slight
AZ3	Urban	Low	Negligible	Imperceptible
	Elton Association	Medium	Small adverse	Slight
AZ4	Urban	Low	Negligible	Imperceptible
	River Alluvium	Low	Negligible	Imperceptible

Table 20.50: Summary of Predicted Impacts on Superficial Geology During Construction

AZ	Unit	Sensitivity	Magnitude of Impact	Significance of Impact
AZ1	Glacial Till	Low	Negligible	Imperceptible

AZ	Unit	Sensitivity	Magnitude of Impact	Significance of Impact
	Alluvium	Low	Small adverse	Imperceptible
	Gravels derived from limestones	Low	Negligible	Imperceptible
	Estuarine silts and clays	Low	Negligible	Imperceptible
	Lacustrine Sediments	Low	Negligible	Imperceptible
AZ2	Glacial Till	Low	Negligible	Imperceptible
AZ3	Glacial Till	Low	Negligible	Imperceptible
	Alluvium	Low	Small adverse	Imperceptible
AZ4	Glacial Till	Low	Negligible	Imperceptible
	Gravels derived from limestones	Low	Negligible	Imperceptible
	Alluvium	Low	Small adverse	Imperceptible

The significance of impact is considered to be imperceptible for most units of both soil and subsoil with the exception of loss of Elton Association soils in AZ1, AZ2 and AZ3. Reference should be made to Chapter 24 (Materials & Waste Management) with respect to the assessment of impacts from management of sub-surface material arising from the proposed Project.

20.4.3.3 Bedrock Geology

Tunnelling and station construction will result in the production of large quantities of bedrock (refer to Table 20.48) comprising Carboniferous limestones of the Malahide, Waulstortian, Tober Colleen and Lucan Formations. While the excavation volumes are high, the bedrock geology affected by the proposed Project does not have heritage value and is not considered to have future economic value, and the magnitude of impact has been assessed as negligible for all formations. It should be noted that during construction there will be a temporary benefit as new areas of subsurface geology will be exposed allowing refining of geological information for the Dublin area. The predicted effects on bedrock geology during construction are summarised in Table 20.51.

Table 20.51: Summary of Predicted Impacts on Bedrock Geology During Construction

AZ	Unit	Sensitivity	Magnitude of Impact	Significance of Impact
AZ1	Malahide Formation	Low	Negligible	Imperceptible
	Waulsortian Limestone	Low	Negligible	Imperceptible
AZ2	Malahide Formation	Low	Negligible	Imperceptible
	Waulsortian Limestone	Low	Negligible	Imperceptible
	Tober Colleen Formation	Low	Negligible	Imperceptible
AZ3	Tober Colleen Formation	Low	Negligible	Imperceptible
	Lucan Formation	Low	Negligible	Imperceptible
AZ4	Lucan Formation	Low	Negligible	Imperceptible

The Lucan Formation has high concentrations of pyrite, which may be susceptible to expansion when exposed to air, moisture and heat. This may limit the reuse of this rock within the project for uses such as structural fill, contact with concrete or confined conditions without specific testing of rock properties although restrictions may not apply for bulk fill or landscaping/restoration material.

Karst features are not indicated in the study area by published information. The Waulsortian Limestone is present at the proposed Dublin Airport Station in AZ2 near the ground surface which has been quarried

in the past. Limestone near the ground surface could be prone to formation of solution features which could affect ground stability and engineering properties of rock; however, GI conducted to date at this location has not shown the presence of solution features or voids and these features form over long time periods (thousands or millions of years) so the risk of these being present or forming is considered low.

20.4.3.4 Current and Historic Mining Sites

Effects on mineral resources may occur where mineral reserves or resources are wholly or partly sterilised. This can be permanent or temporary, or where access to the resource is impaired. Mineral extraction identified within the study area is historic, with no active extraction occurring. In addition, the majority of the study area is developed to some degree, with many historic former sites (such as gravel pits) already sealed. It is considered unlikely that mineral extraction within the study area will be economically or environmentally viable, and therefore, the construction effect on former sites is assessed as negligible (refer to Section 20.4.3.7 for the assessment of these sites with regard to contaminated land).

The impact assessment on potential aggregate is summarised in Table 20.52 and Table 20.53. The majority of the study area comprises land that is already developed, therefore, any potential adverse impacts are concentrated in the areas that remain as agricultural land or undeveloped land, primarily in AZ1, AZ2 and AZ3. Potential construction effects comprise removal or alteration of the potential resource and the proposed Project limiting site access. Only two locations in AZ1, near the proposed Estuary Station and near the southern extent have a potential slight significance of impact.

Table 20.52: Summary of Predicted Impacts on Granular Aggregate Potential During Construction

AZ	Granular Aggregate Potential	Location Description	Sensitivity	Magnitude of Impact	Significance
AZ1	Very Low	Adjacent to Estuary Station Works Area, approximately 280m north east of Chainage 1000.	Low	Negligible	Imperceptible
		To the west and east of Pinnockhill Roundabout around Gaybrook Stream, approximate Chainage 4200 to 4340.	Low	Small adverse	Imperceptible
		In the vicinity of the Sluice watercourse, approximate Chainage 5760 and 5960.	Low	Small adverse	Imperceptible
	Low	Near proposed Estuary Station, approximate Chainage 1040 to 1120.	Low	Small adverse	Imperceptible
		In the vicinity of Broad Meadow Water, approximate Chainage 1500 to 2180.	Low	Small adverse	Imperceptible
		Approximately 60m to 110m north west of Chainage 4200 to 4380.	Low	Negligible	Imperceptible
	Moderate	Near proposed Estuary Station, approximate Chainage 1120 to 1340.	Medium	Small adverse	Slight
		To the south and south west of Pinnockhill Roundabout, approximate Chainage 4400 to 4720.	Low	Small adverse	Imperceptible
		In the vicinity of the Sluice watercourse, approximate Chainage 5720 to 5760, Chainage 5820 to 5940 and Chainage 5980 to 6100.	Medium	Small adverse	Slight
	High	In the vicinity of Broad Meadow Water, approximate Chainage 1360 to 1440 and Chainage 1600.	Low	Small adverse	Imperceptible

AZ	Granular Aggregate Potential	Location Description	Sensitivity	Magnitude of Impact	Significance
		In the vicinity of the Sluice watercourse, approximate Chainage 5780 to 5820, and Chainage 6100 to 6140.	Low	Small adverse	Imperceptible
	Very High	Approximately 25m east of the Works Area in the vicinity of Broad Meadow Water, approximate Chainage 1620 to 1780.	Low	Small adverse	Imperceptible
AZ2	Moderate	At the northern end of AZ2, adjacent to the northern tunnel portal works area.	Low	Negligible	Imperceptible
	High	At the northern end of AZ2, from approximate Chainage 6100 to 6140.	Low	Negligible	Imperceptible
AZ3	Very Low	To the north west and south west of the M50/R108 roundabout.	Low	Negligible	Imperceptible
AZ4 - Collins Avenue	Very Low	Approximately 100m north west of Works Area	Low	Negligible	Imperceptible
AZ4 - Griffith Park	Very Low	Approximately 120m west and 320m south.	Low	Negligible	Imperceptible
	Low	Approximately 40m west of Works Area and adjacent to south east of Works Area along the alignment of the Tolka River.	Low	Negligible	Imperceptible
	Moderate	Area around and to the west of the Works Area	Low	Small adverse	Imperceptible
	High	Immediately south of the Works Area, approximately 25m north east of the Works Area and approximately 130m west of the Works Area	Low	Small adverse	Imperceptible
	Very High	Approximately 150m south and west of the Works Area	Low	Negligible	Imperceptible
AZ4 - O'Connell Street	High	Isolated areas in the immediate Works Area and 25m south west, 200m south west and 150m south east of the Works Area	Low	Small adverse	Imperceptible
AZ4 - Tara	High	Approximately 85m north of the Works Area on the northern bank of the River Liffey	Low	Negligible	Imperceptible
AZ4 - St Stephen's Green	Low	Approximately 25m north of the Works Area	Low	Negligible	Imperceptible

Table 20.53: Summary of Predicted Impacts on Crushed Rock Aggregate Potential During Construction

AZ	Crushed Rock Aggregate Potential	Location Description	Sensitivity	Magnitude of Impact	Significance
AZ1	Low	Majority of the alignment from Chainage 1780 near Estuary Station to Chainage 5620 in the vicinity of the northern tunnel portal.	Low	Small adverse	Imperceptible
	Moderate	In the area of Estuary Station from Chainage 1000 to 1780.	Medium	Small adverse	Slight
		To the west of the alignment between Chainage 2100 and 3940.	Low	Small adverse	Imperceptible
		In the vicinity of the northern tunnel portal from Chainage 5620 to 5820.	Medium	Small adverse	Slight
	High	In the area of Estuary Station from Chainage 1040 to 1120.	Low	Small adverse	Imperceptible
		In the vicinity of the northern tunnel portal from Chainage 5820 to 6100.	High	Negligible	Imperceptible
AZ2	Low	At the southern end of AZ2 from approximate Chainage 7660 to 8320.	Low	Negligible	Imperceptible
	Moderate	To the north east and south west of the Airport Station, approximate Chainage 6120 to 6660 and Chainage 7260 and 7640.	Low	Negligible	Imperceptible
	High	Approximately 200m to the north west and south east of Airport Station.	Low	Negligible	Imperceptible
	Very High	In the area of Airport Station.	Low	Small adverse	Imperceptible

AZ	Crushed Rock Aggregate Potential	Location Description	Sensitivity	Magnitude of Impact	Significance
AZ3	Low	All of AZ3.	Low	Small adverse	Imperceptible
AZ4 - Ballymun	Low	Whole station study area.	Low	Small adverse	Imperceptible
AZ4 - Collins Avenue	Low	Whole station study area.	Low	Small adverse	Imperceptible
AZ4 - Intervention Shaft	Low	Whole station study area.	Low	Small adverse	Imperceptible
AZ4 - Griffith Park	Low	Approximately 120 to 200m north and east of the Works Area.	Low	Negligible	Imperceptible
	Moderate	25 to 150m in all directions from the Works Area.	Low	Negligible	Imperceptible
	High	In the immediate surrounds of the Works Area.	Low	Small adverse	Imperceptible
	Very High	Approximately 25m west of the Works Area, along the alignment of the Tolka River.	Low	Negligible	Imperceptible
AZ4 - Mater	Low	Whole station study area.	Low	Small adverse	Imperceptible
AZ4 - Tara	Low	Immediately north east of the Works Area.	Low	Negligible	Imperceptible
	Moderate	In the vicinity of and to the south west of the Works Area	Low	Small adverse	Imperceptible
AZ4 - St Stephen's Green	Moderate	Whole station study area	Low	Small adverse	Imperceptible
A4 - Charlemont	Moderate	Whole station study area	Low	Small adverse	Imperceptible

20.4.3.5 Irish Geological Heritage Sites

Glasnevin Cemetery is 140m north of the Works Area at Glasnevin Station and will not be directly affected by the proposed Project. Given the distance from the works this receptor is outside the zone of predicted measurable settlement effects from construction (refer to Settlement Assessment Appendix C, Settlement Contours, Sheet 20 in Appendix A22.1) and given the nature of the designation (rock types accessible to view in gravestones and memorials) the assessed impact from settlement is considered negligible.

The General Post Office is near the Works Area at O'Connell Street Station, and also overlies the tunnel alignment. The designation as a Heritage site is on the basis of decorative stone used in its construction, which may be subject to impact from settlement effects during construction. The Phase 2a settlement assessment indicated a slight (2) damage classification and was recommended for Phase 2b assessment on the basis of being a 'Special Building' (refer to settlement assessment in Appendix A22.1 for further

detail). The Vibration assessment for this receptor is provided in Chapter 14 (Groundborne Noise & Vibration).

The Trinity College Museum building is 170m west of the proposed Project (tunnel section) at its closest approach. The designation as a heritage site is on the basis of building and decorative stone used in its construction, which may be subject to impact from settlement effects during construction. This receptor is outside the zone of predicted measurable settlement effects from tunnelling (refer to Settlement Assessment Appendix C, Settlement Contours, Sheet 25), and the magnitude of impact is considered negligible (refer to settlement assessment in Appendix A22.1 for further detail).

The Oscar Wilde Statue is 170m east of the proposed Project (tunnel section) at its closest approach. The designation as a heritage site is on the basis of geological materials used in its construction. The statue is outside the zone of measurable settlement effects from tunnelling (refer to Settlement Assessment Appendix C, Settlement Contours, Sheet 25 in Appendix A22.1), and the magnitude of impact is considered negligible.

51 St Stephen's Green is adjacent to the St Stephen's Green Station and shares a building with the Department of Justice. The designation is on the basis of the entrance lobby containing decorative marbles, which may be subject to impact from settlement effects during construction. The Phase 2a assessment indicated a negligible damage category; the building was however recommended for Phase 2b assessment on the basis of being a 'Special Building' (refer to Settlement Assessment Appendix C, Settlement Contours, Sheet 26 in Appendix A22.1). The Vibration assessment for this receptor is provided in Chapter 14 (Groundborne Noise & Vibration).

The predicted impacts for geological heritage sites are summarised in Table 20.54.

Table 20.54: Summary of Predicted Impacts on Irish Geological Heritage Sites During Construction (Based on Stage 2 Settlement Assessment)

AZ	Description	Location	Sensitivity	Magnitude of Impact/Damage classification	Significance of Impact	Recommended for Phase 2b
AZ4	Glasnevin Cemetery GHS	140m N of Works Area	Medium	Negligible	Imperceptible	No
AZ4	General Post Office	35 m S or Works Area at O'Connell Street Station	Medium	Negligible	Imperceptible	Yes ('Special Building')
AZ4	Museum Building, Trinity College	200m S of Works Area at Tara Station, 170 m W of tunnel.	Medium	Negligible	Imperceptible	No
AZ4	Oscar Wilde Statue	170 m East of the tunnel alignment, Merrion Square	Medium	Negligible	Imperceptible	No
AZ4	51 St Stephen's Green	Adjacent to Works Area at St Stephen's Green Station	Medium	Negligible	Imperceptible	Yes ('Special Building')

20.4.3.6 Radon and Ground Gas

Construction will involve surface section sections, excavation of retained cut (AZ1), tunnelling and excavation of station boxes and intervention shafts. Construction activities will therefore create voids in which radon can accumulate, potentially to hazardous levels (i.e. above the reference level of 300Bq/m3 for workplaces), or the presence of new underground structures creating new pathways for radon to migrate to areas it was not previously recorded.

While the proposed Project is in an area of generally low radon potential rankings (with a consequent assessed significance of Low), these classifications are based on assessment of surface buildings rather than based on detailed classifications of specific geological units. As such, the potential for accumulation of radon in the confined spaces that will be developed as part of the proposed Project cannot be discounted, and a potential moderate adverse magnitude of impact has been assigned.

The predicted impacts from radon during construction are summarised in Table 20.55.

Table 20.55: Summary of Predicted Impacts from Radon during Construction

AZ	Radon Potential	Significance	Magnitude of Impact	Significance of Impact
AZ1	Mainly lowest classification, small area of second lowest.	Low	Moderate adverse	Slight
AZ2	Mainly lowest classification, small area of highest classification at Dublin Airport	Low	Moderate adverse	Slight
AZ3	Lowest classification	Low	Moderate adverse	Slight
AZ4	Mainly lowest classification, small area of second lowest.	Low	Moderate adverse	Slight

Similar to radon, excavation and construction can result in ground gases accumulating in voids or other enclosed spaces. However, effects of ground gas, such as asphyxiation, toxicity and explosion are acute and largely observed over a much shorter timescale.

A major potential source of ground gas was not identified by the desk study review or ground investigation information, and gas concentrations and flows were generally low across the study area, resulting in a Characteristic Situation 1 classification (Very Low Risk) with respect to risks of gas accumulation within buildings according to the C665 methodology (CIRIA 2007). However, in all AZs, carbon dioxide concentrations were recorded in excess of WELs, and, due to the potential for accumulation within excavations and enclosed spaces during construction, a moderate severity of impact has been assigned. The predicted impacts associated with ground gas during construction are summarised in Table 20.56.

Table 20.56: Summary of Predicted Risk from Ground Gas During Construction

Potential Risk	AZ	C665 Characteristic Situation	WEL exceedances	Likelihood	Severity	Consequence
Risks to Property and adjacent residents/workers /transient foot traffic)	AZ1 to AZ4	CS1 – Very Low Risk		Unlikely	Mild	Negligible
Risks to human health (construction workers)	AZ1		2 locations in Estuary & Swords Areas.	Likely	Medium	Moderate
	AZ2		Several locations in the proposed Dublin Airport Station area.	Likely	Medium	Moderate
	AZ3		3 locations in the proposed Dardistown Depot	Likely	Medium	Moderate

			and Northwood Station areas.			
	AZ4		Several locations in the proposed Albert College Shaft, Glasnevin Station, Mater Station and Tara Station area.	Likely	Medium	Moderate

20.4.3.7 Contaminated Land

Construction activities have the potential to result in both adverse (e.g. exposure of construction workers to contaminants in the sub-surface) and beneficial (e.g. removal of contaminated material from the site) effects on baseline land contamination conditions. As mandated by current best practice (EPA 2013; EA 2022) a CSM has been developed for the proposed Project to define the relationships between potential contamination sources, receptors which could be affected by contamination and the exposure pathways (refer to Appendix A20.3).

The preliminary CSM has been updated on the basis of the baseline conditions for the Construction Phase, as presented in Appendix A20.3 and summarised in Table 20.57. The likelihood of a risk being realised is not uniform across the alignment (as detailed in the baseline, Section 20.3), and the updated CSM is presented on the basis of the worst-case scenario for each potential pollutant linkage.

Consumables used during TBM operation include spoil conditioning additives, bentonite slurry and grease (main bearing grease, labyrinth seal grease and tail seal grease). These are summarised as follows with further detail included in the TBM Consumables Technical Note, included in Appendix A5.14:

- Spoil conditioning additives: these are used to render cut ground more consistent and easier to handle, reduce cutterhead friction and torque, and help the TBM maintain face pressure. The additives comprise a detergent mixed with water in foam generators within the TBM as well as polymers for injected in locations around the cutter head. The foam additives are biodegradable with a degradation half-life of a few hours to a few days with no harmful residual chemicals.
- Grease: grease for the main bearing and labyrinth seals are typically lost to the spoil arisings and pumped back to the surface with the bentonite slurry. Both of these greases are biodegradable.
- Bentonite slurry: bentonite is used as a transport medium to remove the cuttings from the TBM in slurry and variable density modes. Bentonite is a natural clay which is typically transported in dried powder or pellet form and manufactured into a slurry via addition of water at site on the surface and pumped to the TBM, then back to the surface where spoil is removed. Bentonite does not result in an environmental hazard and very little of the slurry is left in the ground as it is continuously re-cycled and mixed with fresh slurry as the tunnel and pipelines are extended.

Overall the TBM consumables are biodegradable, pose a low environmental hazard (or both), as such the predicted impact are considered to be negligible.

Piling is a potential foundation option in some parts of the route, particularly the Broadmeadow River viaduct in AZ1. The risks from introduction of new contamination pathways at the Broadmeadow River location is considered to be Low from historical potential contaminant sources given the absence of previous contaminative activities, however leaks and spills of fuel or other liquids from plant and materials storage during construction and entering groundwater or surface water causing an adverse effect could present a risk.

Table 20.57: Land Contamination Risk Summary - Construction Phase

Source	Receptor	Pathway	Pollutant Linkage	Severity	Likelihood	Risk
Contaminants within soil and groundwater	Human health (construction workers)	Dermal contact, ingestion and inhalation of impacted soil, dust, fibres (asbestos) and waters.	PL1	Medium	Likely	Moderate
		Migration of ground gases and vapours to shallow pits or enclosed spaces.	PL2	Medium	Likely	Moderate
	Human health (adjacent residents/workers, transient foot traffic	Dermal contact, ingestion and inhalation of windblown soil, dust, fibres (asbestos) during construction.	PL3	Medium	Likely	Moderate
		Migration of ground gases into homes or workplaces via preferential pathways during construction.	PL4	Mild	Unlikely	Negligible
	Groundwater	Leaching and migration of contaminants through natural deposits and made ground.	PL5	Medium	Low Likelihood	Moderate/Low
		Surface water run-off from stockpiled excavated material.	PL6	Medium	Low Likelihood	Moderate/Low
		Leaks and spills from site plant and materials storage.	PL7	Severe	Low Likelihood	Moderate
		Discharge of intercepted contaminated groundwater during passive or active dewatering.	PL8			Not assessed (refer to Chapter 19, Hydrogeology)
	Surface water, ecological receptors	Migration / mobilisations of contaminated shallow groundwater through drift deposits / made ground.	PL9	Mild	Low Likelihood	Low
		Surface water run-off from stockpiled excavated material.	PL10	Medium	Low Likelihood	Moderate/Low
		Leaks and spills from site plant and materials storage.	PL11	Severe	Low Likelihood	Moderate
		Discharge of intercepted contaminated groundwater during passive or active dewatering.	PL12			Not assessed (refer to Chapter 19, Hydrogeology)
	Property	Direct contact with sub-surface materials including made ground.	PL13	Mild	Likely	Moderate/Low
		Migration of ground gases into property through preferential pathways posing a potential explosion risk from ignition of explosive gases.	PL14	Medium	Unlikely	Low

20.4.4 Operational Effects

The majority of effects on soils and geology are expected during the Construction Phase when physical disturbance of the sub-surface will occur. Potential impacts are still possible during the Operational Phase where effects can include:

- Soil erosion and degradation via surface run off from scheme drainage;
- Limiting access to mineral resources reducing potential for future extraction;
- Alteration of groundwater flows and/or introduction of permanent new migration pathways for migration of contaminants;
- Introduction of new confined/enclosed spaces resulting in gas and vapour accumulation with consequent risks to human health (maintenance workers and end users);
- Leaks/spills of contaminative materials from trains and other plant required to operate the proposed Project; and
- Direct exposure of end users and maintenance workers to contaminated materials in the sub- surface.

20.4.4.1 Soils and Superficial Geology

During operation, the proposed Project will lead to little or no long-term loss or degradation of any existing undisturbed soil or subsoil. With the exception of areas of the Elton Association soils and Tidal Marsh (Medium sensitivity) the majority of the soils and subsoils throughout the study area have a low sensitivity rating.

Where sections of track and other construction features such as the Park and Ride and Depot are present at the surface (primarily AZ1 and AZ3), the potential for surface water runoff to cause erosion of soil (including made ground and soils of Medium sensitivity) and sub-soil will be reduced by the installation of a trackside and surface water drainage system (details are provided in Chapter 4 (Description of the MetroLink Project), and Chapter 18 (Hydrology). Other features such as underground stations, intervention shafts and portals will also include drainage systems to manage surface water and reduce interactions with soils. With the use of drainage systems, the magnitude of impact on soils and superficial geology is considered to be negligible, resulting in an imperceptible significance of impact across the proposed Project.

20.4.4.2 Bedrock Geology

No further disturbance or excavation of bedrock geology will occur during the Operational Phase. As such, there will be no measurable change in conditions and a negligible magnitude of impact, resulting in an assessed imperceptible significance of impact for bedrock geology across the proposed Project.

20.4.4.3 Current and Historic Mining Sites

Impacts to mineral resources during operation are confined to the presence of the proposed Project limiting access to future extraction. However, as it has been assessed that future economically viable mineral extraction in the study area is unlikely, then the operational effects on mineral resources are negligible. Refer to Section 20.4.3.7 for the assessment of these sites with regard to contaminated land. The operational impact assessments on future aggregate resources are summarised in Table 20.58 and Table 20.59.

Table 20.58: Summary of Predicted Impacts on Granular Aggregate Potential During Operation

AZ	Granular Aggregate Potential	Location Description	Sensitivity	Magnitude of Impact	Significance
AZ1	Very Low	Adjacent to Estuary Station Works Area, approximately 280m north east of Chainage 1000.	Low	Negligible	Imperceptible
		To the west and east of Pinnockhill Roundabout around Gaybrook Stream, approximate Chainage 4200 to 4340.	Low	Negligible	Imperceptible
		In the vicinity of the Sluice watercourse, approximate Chainage 5760 and 5960.	Low	Negligible	Imperceptible
	Low	Near proposed Estuary Station, approximate Chainage 1040 to 1120.	Low	Negligible	Imperceptible
		In the vicinity of Broad Meadow Water, approximate Chainage 1500 to 2180.	Low	Negligible	Imperceptible
		Approximately 60m to 110m north west of Chainage 4200 to 4380.	Low	Negligible	Imperceptible
	Moderate	Near proposed Estuary Station, approximate Chainage 1120 to 1340.	Medium	Negligible	Imperceptible
		To the south and south west of Pinnock Hill Roundabout, approximate Chainage 4400 to 4720.	Low	Negligible	Imperceptible
		In the vicinity of the Sluice watercourse, approximate Chainage 5720 to 5760, Chainage 5820 to 5940 and Chainage 5980 to 6100.	Medium	Negligible	Imperceptible
	High	In the vicinity of Broad Meadow Water, approximate Chainage 1360 to 1440 and Chainage 1600.	Low	Negligible	Imperceptible
		In the vicinity of the Sluice watercourse, approximate Chainage 5780 to 5820, and Chainage 6100 to 6140.	Low	Negligible	Imperceptible
	Very High	Approximately 25m east of the Works Area in the vicinity of Broad Meadow Water, approximate Chainage 1620 to 1780.	Low	Negligible	Imperceptible
AZ2	Moderate	At the northern end of AZ2, adjacent to the northern tunnel portal works area.	Low	Negligible	Imperceptible
	High	At the northern end of AZ2, from approximate Chainage 6100 to 6140.	Low	Negligible	Imperceptible
AZ3	Very Low	To the north west and south west of the M50/R108 roundabout.	Low	Negligible	Imperceptible
AZ4 - Collins Avenue	Very Low	Approximately 100m north west of Works Area.	Low	Negligible	Imperceptible
AZ4 - Griffith Park	Very Low	Approximately 120m west and 320m south.	Low	Negligible	Imperceptible
	Low	Approximately 40m west of Works Area and adjacent to south east of	Low	Negligible	Imperceptible

AZ	Granular Aggregate Potential	Location Description	Sensitivity	Magnitude of Impact	Significance
		Works Area along the alignment of the Tolka River.			
	Moderate	Area around and to the west of the Works Area.	Low	Negligible	Imperceptible
	High	Immediately south of the Works Area, approximately 25m north east of the Works Area and approximately 130m west of the Works Area.	Low	Negligible	Imperceptible
	Very High	Approximately 150m south and west of the Works Area.	Low	Negligible	Imperceptible
AZ4 - O'Connell Street	High	Isolated areas in the immediate Works Area and 25m south west, 200m south west and 150m south east of the Works Area.	Low	Negligible	Imperceptible
AZ4 - Tara	High	Approximately 85m north of the Works Area on the northern bank of the River Liffey.	Low	Negligible	Imperceptible
AZ4 - St Stephen's Green	Low	Approximately 25m north of the Works Area.	Low	Negligible	Imperceptible

Table 20.59: Summary of Predicted Impacts on Crushed Rock Aggregate Potential During Operation

AZ	Crushed Rock Aggregate Potential	Location Description	Sensitivity	Magnitude of Impact	Significance
AZ1	Low	Majority of the alignment from Chainage 1780 near Estuary Station to Chainage 5620 in the vicinity of the northern tunnel portal.	Low	Negligible	Imperceptible
	Moderate	In the area of Estuary Station from Chainage 1000 to 1780.	Medium	Negligible	Imperceptible
		To the west of the alignment between Chainage 2100 and 3940.	Low	Negligible	Imperceptible
		In the vicinity of the northern tunnel portal from Chainage 5620 to 5820.	Medium	Negligible	Imperceptible
	High	In the area of Estuary Station from Chainage 1040 to 1120.	Low	Negligible	Imperceptible
		In the vicinity of the northern tunnel portal from Chainage 5820 to 6100.	High	Negligible	Imperceptible
AZ2	Low	At the southern end of AZ2 from approximate Chainage 7660 to 8320.	Low	Negligible	Imperceptible
	Moderate	To the north east and south west of the Airport Station, approximate Chainage 6120 to 6660 and Chainage 7260 and 7640.	Low	Negligible	Imperceptible
	High	Approximately 200m to the north west and south east of Airport Station.	Low	Negligible	Imperceptible
	Very High	In the area of Airport Station.	Low	Negligible	Imperceptible

AZ	Crushed Rock Aggregate Potential	Location Description	Sensitivity	Magnitude of Impact	Significance
AZ3	Low	All of AZ3.	Low	Negligible	Imperceptible
AZ4 - Ballymun	Low	Whole station study area.	Low	Negligible	Imperceptible
AZ4 - Collins Avenue	Low	Whole station study area.	Low	Negligible	Imperceptible
AZ4 - Intervention Shaft	Low	Whole station study area.	Low	Negligible	Imperceptible
AZ4 - Griffith Park	Low	Approximately 120 to 200m north and east of the Works Area.	Low	Negligible	Imperceptible
	Moderate	25 to 150m in all directions from the Works Area.	Low	Negligible	Imperceptible
	High	In the immediate surrounds of the Works Area.	Low	Negligible	Imperceptible
	Very High	Approximately 25m west of the Works Area, along the alignment of the Tolka River.	Low	Negligible	Imperceptible
AZ4 - Mater	Low	Whole station study area.	Low	Negligible	Imperceptible
AZ4 - Tara	Low	Immediately north east of the Works Area.	Low	Negligible	Imperceptible
	Moderate	In the vicinity of and to the south west of the Works Area.	Low	Negligible	Imperceptible
AZ4 - St Stephen's Green	Moderate	Whole station study area.	Low	Negligible	Imperceptible
A4 - Charlemont	Moderate	Whole station study area.	Low	Negligible	Imperceptible

20.4.4.4 Irish Geological Heritage Sites

Settlement effects will occur over the short-term, with any effects expected during construction. Long-term effects are considered unlikely, and, as such operational impacts on the General Post Office, the Trinity College Museum Building, Oscar Wilde Statue and 51 St Stephen's Green are considered to be negligible, as summarised in Table 20.60. Effects from vibration on these receptors are detailed in Chapter 14 (Ground-borne Noise & Vibration.

Table 20.60: Summary of Predicted Impacts on Irish Geological Heritage Sites During Operation

AZ	Description	Location	Significance	Magnitude of Impact	Significance
AZ4	Glasnevin Cemetery GHS	140m North of Works Area.	Medium	Negligible	Imperceptible
AZ4	General Post Office	Within Works Area at O'Connell Street Station.	Medium	Negligible	Imperceptible
AZ4	Museum Building, Trinity College	200m South of Works Area at Tara Station.	Medium	Negligible	Imperceptible
AZ4	Oscar Wilde Statue	160 m East of the alignment, Merrion Square.	Medium	Negligible	Imperceptible

AZ	Description	Location	Significance	Magnitude of Impact	Significance
AZ4	51 St Stephen's Green	Adjacent to Works Area at St Stephen's Green Station.	Medium	Negligible	Imperceptible

20.4.4.5 Radon and Ground Gas

Post development, underground areas of the proposed Project will be fully sealed from the surrounding sub-surface to prevent water ingress, which in addition will limit the potential for any radon from the surrounding sub-surface to enter below ground spaces. Furthermore, below ground spaces will be ventilated which will reduce the likelihood of gas build up in enclosed spaces.

Post development, there is considered to be a negligible magnitude of impact from radon and ground gas, leading to an imperceptible significance of impact.

20.4.4.6 Contaminated Land

Following construction, land contamination remaining within the development footprint may present risks to future site workers (such as asset maintenance and railway staff) or end users (passengers). Contamination may also be introduced to the surface, sub surface or waterbodies (surface and groundwater) through leaks and spillages or from trains or other plant, or from structures associated with the proposed Project acting as a preferential pathway for contaminant transport.

The preliminary CSM for operations has been updated on the basis of the baseline conditions as presented in Appendix A20.3 and summarised in Table 20.61. The likelihood of a risk being realised is not uniform across the route (as detailed in the baseline, Section 20.3), and the updated CSM is presented on the basis of the worst-case scenario for each potential pollutant linkage. The operational assessment assumes that material established to be potentially harmful to human health or the environment is either appropriately treated and reinstated or disposed of appropriately during construction.

Table 20.61: Land Contamination Risk Summary – Operational Phase

Source	Receptor	Pathway	Pollutant Linkage	Severity	Likelihood	Risk
Contaminants within soil and groundwater	Human health (maintenance workers)	Dermal contact, ingestion and inhalation of soil, dust, fibres (asbestos) and waters during routine maintenance.	PL15	Medium	Low Likelihood	Moderate/Low
		Migration of ground gases and vapours to enclosed spaces.	PL16	Medium	Low Likelihood	Moderate/Low
	Human health (end users, adjacent residents, workers)	Dermal contact, ingestion and inhalation of wind-blown soil, dust, fibres (asbestos) from retained surface soils.	PL17	Medium	Unlikely	Low
		Migration and accumulation of ground gases into homes or workplaces via preferential pathways created during construction.	PL18	Mild	Unlikely	Negligible
	Groundwater	Leaching and migration of contaminants.	PL19	Mild	Unlikely	Negligible
		Surface water runoff from placed excavated material.	PL20	Medium	Low Likelihood	Moderate/Low
		Migration of contaminated shallow groundwater through drainage channels and associated granular bedding materials.	PL21	Medium	Low Likelihood	Moderate/Low
		Discharge of intercepted contaminated groundwater.	PL22			Not assessed (refer to Chapter 19, Hydrogeology)
		Leaks/spills from trains and other operational plant.	PL23	Mild	Low Likelihood	Negligible
	Surface water, ecological receptors	Leaching and migration of contaminants.	PL24	Mild	Unlikely	Negligible
		Surface water runoff from placed excavated material.	PL25	Medium	Low Likelihood	Moderate / Low
		Migration of contaminated shallow groundwater through drainage channels and associated granular bedding materials.	PL26	Medium	Low Likelihood	Moderate / Low
		Discharge of intercepted contaminated groundwater.	PL27			Not assessed (refer to Chapter 19, Hydrogeology)
		Leaks/spills from trains and other operational plant.	PL28	Mild	Low Likelihood	Negligible
	Property	Direct contact with sub-surface materials including made ground.	PL29	Mild	Likely	Moderate/Low

Source	Receptor	Pathway	Pollutant Linkage	Severity	Likelihood	Risk
		Migration of ground gases into property through preferential pathways posing a potential explosion risk from ignition of explosive gases.	PL30	Mild	Unlikely	Negligible

20.5 Proposed Project Options

20.5.1 O'Connell Street Station

Two options for O'Connell Street Station are currently being considered, one including Hammerson's above ground development and one without. Both these options include a very similar scope of below ground works, hence there is no significant difference in potential impacts with respect to soils and geology.

20.5.2 MetroLink Grid Connections

To provide power to the proposed Project, two new gas insulated switchgear (GIS) transmission substations are required (Dardistown and North Portal) along with installation of new transmission cable circuits. Three potential cable routes outside the Study Area for the proposed Project detailed earlier in this Chapter are under consideration (B, C and D, refer to Figure 22.5) and are considered in this Section.

20.5.2.1 Construction Methodology

Construction methodology is detailed in the Mott MacDonald Technical Note for the installation of Metrolink 11kV Power Supplies (Mott MacDonald, 2022). For all the options under consideration construction of the cable routes is primarily along existing roads, with some areas where the cable route will be laid in areas of fields/soft landscaping and Horizontal Directional Drilling (HDD) under utilities, watercourses and crossing the M1 motorway.

In areas of road installation the process will comprise excavation of a trench 0.6m to 1.1m wide and 1.25m deep, followed by placing of bedding material (sand, concrete or sand/cement mix) onto the trench base. The cable ducts are laid upon the bedding, surrounded and covered with suitable fill material and protective tiles and hazard marker tape, then the trench is backfilled with suitable excavated material and the road reinstated. Excavated material will be temporarily stored adjacent to the excavation location and reused (if suitable) or disposed of off-site. Concrete lined joint boxes up to 8m x 2.5m plan area and to a depth of 2.3m are required at intervals along the cable route.

In greenfield areas the installation method is similar although a wider working area is used and vegetation clearance may be required as well as temporary access roads.

HDD involves the construction of launch and reception pits with temporary hardstanding on a geotextile base (typically around 10m by 10m in plan area) to accommodate the drilling rig. Drilling will be undertaken using a steerable rotary assembly with a closed loop fluid (bentonite) flush and circulation system to clear and lubricate the borehole. Once the desired diameter is achieved via reaming a number of times a duct lining (such as High-Density Polyethylene) is inserted to house the cable.

Two new 11kV GIS substations are required at Dardistown and the North Portal; these will comprise building approximately 50m in length by 15m width and 15 in height. Both of the proposed substations are within the Works Area already assessed.

The route for each option and baseline conditions (according to the methodology described in Section 20.2) are summarised in Section 20.5.2.2.

20.5.2.2 Baseline Conditions

The three route options are detailed on Figure 22.5 with the proposed routes summarised below:

- **Option B**: Connection leading from the Dardistown Depot to Clonshaugh Business Park to the south east via Swords Road, the M50 and the M1. HDD likely required beneath the M50 and M1.
- **Option C**: Connection between Naul Road/Swords Road Junction to the North east of Dublin Airport and Dardistown Depot either via Swords or around the western boundary of Dublin Airport.

- **Option D**: Connection between Naul Road/Swords Road Junction to the North east of Dublin Airport and location on the R139 either via Stockhole Lane or via Baskin Lane and the R107.

The baseline conditions for each of the options are summarised in Table 20.62.

Table 20.62: Summary of Baseline Conditions for Each MetroLink Cable Route Option

Attribute	Option B	Option C	Option D
Soil and Superficial Deposits	Soil types are split between the Elton association (primarily around the Dardistown Depot area) and urban soils. Much of this option passes below/adjacent to roads so disturbance of virgin soil will be minimal. The subsoils consist of till derived from limestone, primarily cohesive with low permeability with some local granular higher permeability layers.	Outside the Dublin Airport area (urban soils) the soil groups mainly comprise the Elton association with an area of the Straffan association (fine loamy drift with limestones) to the west of Dublin Airport. Much of this option follows the existing road network so disturbance of virgin soil will be minimal. The subsoils comprise till derived from limestone (low permeability cohesive with some local granular higher permeability layers), with an area of gravels derived from limestones along Naul Road.	Soil types are split between urban soils (primarily around Dublin Airport) and the Elton association. Much of this option passes below/adjacent to roads so disturbance of virgin soil will be minimal. The subsoils consist of till derived from limestone, primarily cohesive with low permeability with some local granular higher permeability layers. Isolated ribbons of alluvium associated with minor watercourses are present towards the east, near Saint Doolaghs.
Geomorphology	A glacial meltwater channel is present from the south of the Dublin Bus Depot running south east associated with Santry River. Mega Scale Glacial Lineation's are present near to the route between the M50 westbound and Turnapin Green, as well crossing the proposed cable route in the vicinity of Clonshaugh Business and Technology Park. A further Mega Scale Glacial Lineation is present beneath the junction of Old Airport Road and the R132. These geomorphological features are not designated as protected features on a local or national scale according to GSI records and in accordance with IGI guidance (IGI 2013) are considered to have a low sensitivity.	A glacial meltwater channel is present from the south of the Dublin Bus Depot running south east associated with Santry River. The Sluice River System Glacial Meltwater Channel and Glaciofluvial Terraces are present just to the north of Naul Road. A Mega Scale Glacial Lineation is present between the Naul Road and the Dublin Airport terminal buildings which extends to the north west where it crosses beneath the path of the proposed cable route along the R108 road. These geomorphological features are not designated as protected features on a local or national scale according to GSI records and in accordance with IGI guidance (IGI 2013) are considered to have a low sensitivity.	The Sluice River System Glacial Meltwater Channel and Glaciofluvial Terraces are present just to the north of Baskin Lane. Further Glacial Meltwater Channels are present beneath the R107 near to Balgriffin Cemetery and Saint Doulough's Park Nursing Home, respectively. Mega Scale Glacial Lineations cross the proposed cable route on Stockhole Lane, the R107 near to Posey Row. These geomorphological features are not designated as protected features on a local or national scale according to GSI records and in accordance with IGI guidance (IGI 2013) are considered to have a low sensitivity.
Geohazards	Landslide susceptibility of Low within Study Area.	Majority of the Study Area has a landslide susceptibility of Low. An area of Moderately Low susceptibility is present associated with a slope to	Majority of the Study Area has a landslide susceptibility of Low. An area of Moderately Low susceptibility is present associated with a slope to

Attribute	Option B	Option C	Option D
		the north of Naul Road at the northern/eastern extent of the route option.	the north of Baskin Lane and Balgriffin Cemetery.
Hydrology	Santry River to the south of Dublin Bus Depot approximately 450m south at its nearest point.	Sluice River approximately 340m north at its nearest point.	Tributary to Mayne River (Cuckoo Stream) and the Mayne River cross the R107 near to Balgriffin Cemetery and Parkside Boulevard respectively.
Hydrogeology	Groundwater vulnerability is classified as Low. Three groundwater wells are located in the area to the south of the R108 road, to the west of this option.	Groundwater vulnerability is classified as low in the south and south eastern areas of the proposed cable route. The cable route proposed to the north (Naul Road) and west (R122) are located in areas classified between Moderate and extreme with some areas of shallow rock (<1m) recorded.	Groundwater vulnerability is classified as low in the south and south western areas, and western section of Baskin Lane. The eastern section of Baskin Lane and the R107 is predominantly classified as moderate with the exception of an area of high and extreme classification to the north west of Balgriffin Cemetery with two associated groundwater abstractions (St Doolagh's Well and St Catherine's Well).
Karst Features	No karst features within study area.	No karst features within study area.	St Doolagh's Well (Spring) present approximately 30m to west of R107 near St Doolagh's Church.
Bedrock Geology	Tober Colleen Formation present in the Dardistown Area, transitioning to the Lucan (Calp) formation near the M50 and in the eastern part of the route. Depth to bedrock around 20 to 25mbgl in Dardistown area, uncertain in the M50 and to the east of M1.	Route predominantly passes over Tober Colleen and Malahide formations. Small area of Waulsortian Limestone present along Swords Road. Rockhead was encountered between 25 – 28m depth in the Dardistown area, with uncertainty on depths to the west towards the N2. Groundwater vulnerability mapping highlights high to extreme vulnerability based on bedrock depths of <1 – 5m in the western areas (R108, R122) and Naul Road.	Route predominantly passes over Tober Colleen and Malahide formations. Small area of Waulsortian Limestone present in eastern parts of option, and Lucan (Calp) formation to the south. No ground investigation works have been completed in the proposed area of the site. Groundwater vulnerability mapping highlights high to extreme vulnerability based on bedrock depths of <1 – 10m in the eastern areas (R107, R139) and Naul Road.
Granular Aggregate Potential	Area of very low to low potential located adjacent to the south boundary of Clonshaugh Business and Technology Park. Area is beneath or adjacent to the existing roadways and are unlikely to be viable for use.	A small area of low potential located beneath the western end of R108. Moderate to high potential located along R122. Moderate to high potential located along the eastern end of Naul Road towards the R132 roundabout. Areas are beneath or adjacent to the existing roadways and are	Areas of the R107 (from Posey Row southbound to R139) vary from very low to moderate potential. Areas of moderate potential are also located beneath the R139. Areas are beneath or adjacent to the existing roadways and are unlikely to be viable for use. However, areas of greenfield adjacent,

Attribute	Option B	Option C	Option D
		unlikely to be viable for use. However, areas of greenfield adjacent, to the roadways, may be viable.	to the roadways, may be viable.
Crushed Rock Aggregate Potential	Area of low potential.	Eastern and southern areas are of low potential. Large area of moderate to very high potential beneath the western end of R108, the R122, and Naul Road. Areas are beneath or adjacent to the existing roadways and are unlikely to be viable for use. However, areas of greenfield adjacent, to the roadways, may be viable.	Areas of the R107 (from Posey Row southbound to R139) and the intersection with the R139 vary from moderate to very high potential. The remaining areas are of low potential. Areas are beneath or adjacent to the existing roadways and are unlikely to be viable for use. However, areas of greenfield adjacent, to the roadways, may be viable.
Irish Geological Heritage Sites	No IGH sites within study area.	No IGH sites within study area.	No IGH sites within study area.
Ground Gas and Radon	Study area within lowest classification of radon potential (about 1 in 20 homes likely to have high radon levels) Also lowest potential under pre-2022 classification (<1% of homes above reference levels).	Majority of study area within lowest classification of radon potential (about 1 in 20 homes likely to have high radon levels), small areas of route fall into medium/high radon potential areas (1 in 10 and 1 in 5 homes likely to have high radon levels respectively). Study area within lowest radon potential under pre-2022 classification (<1% of homes above reference levels)	Majority of study area within lowest classification of radon potential (about 1 in 20 homes likely to have high radon levels), small areas of route fall into medium/high radon potential areas (1 in 10 and 1 in 5 homes likely to have high radon levels respectively). Under pre-2022 classification majority of study area within lowest classification of radon potential (<1% of homes above reference levels). The eastern extent of the Study Area in second lowest classification of radon potential (1%-5% of homes above the reference levels).
Current and Historic Mining Sites	No current or historical mining sites noted.	No current mining sites noted. An historical quarry was noted on the historical mapping from c.1906 approx. 80m south of Stockhole Lane. A feature annotated as Site of Lead Mine is also present on the c.1906 map approx. 60m south of Stockhole Lane.	No current or historical mining sites noted.

20.5.2.3 Impact Assessment

The assessment methodology is the same as that used for the other aspects of the proposed Project as outlined in Section 20.2. The following attributes have been scoped out of the assessment of impacts:

- Karst features for Options B and C (none present within study area);

- Irish Geological Heritage sites (none present within study area);
- Current mining sites for all options, and historic mining sites for Options B and D;
- Bedrock geology for Option B (will not be affected by the proposed shallow excavations and HDD).

In addition, the following attributes, while relevant to detailing baseline conditions, are addressed in different chapters and not discussed further here:

- Hydrology (Chapter 18);
- Hydrogeology (Chapter 19);
- Infrastructure & Utilities (Chapter 22);
- Agronomy (Chapter 23); and
- Materials & Waste Management (Chapter 24).

20.5.2.3.1 Construction

Geomorphological features such as glacial lineations and meltwater channels have been identified for all three options. Construction work will result in a permanent loss of parts of these features where they intersect with surface works, however, the magnitude of impact can be considered to be small adverse, resulting in an overall imperceptible significance of impact given the 'Low' sensitivity of these features.

Predicted impact to soils and superficial geology from the proposed shallow excavations are considered to be negligible to small adverse based on the predominantly low sensitivity of soils (urban classification) and medium sensitivity of soils (Elton Association classification) in the proposed areas.

The bedrock geology is not expected to be observed within the majority of proposed shallow excavations. Some areas near to the R122 and R107 are noted to have "extreme" groundwater vulnerability due to shallow (<1m) bedrock. No ground investigation has been completed in these areas of the site to confirm the depth to bedrock. Where encountered, bedrock does not have heritage value and is not considered to have future economic value, and the magnitude of impact has been assessed as negligible for all formations.

Mineral extraction identified within the study area is historic, with no active extraction occurring. In addition, the majority of the study area has been developed to some degree, with many historic former sites (such as gravel pits) already sealed. It is considered unlikely that mineral extraction within the study area will be economically or environmentally viable, and therefore, the construction effect on former sites is assessed as negligible.

Construction will involve excavating trenches up to 1m in depth which create voids in which ground gas and radon can accumulate, potentially to hazardous levels (i.e. for radon above the reference level of 300Bq/m3 for workplaces), or the presence of new underground structures creating new pathways for ground gas and radon to migrate to areas it was not previously recorded. While the proposed Project is in an area of generally low radon potential rankings (with a consequent assessed significance of Low), these classifications are based on assessment of surface buildings rather than based on detailed classifications of specific geological units. As such, the potential for accumulation of radon in the confined spaces that will be developed as part of the proposed Project cannot be discounted, and a potential slight adverse magnitude of impact has been assigned. For ground gas given the potential for accumulation in excavations and enclosed spaces a Moderate risk has been assigned.

Although excavation activities will be limited to excavated trenches largely adjacent to existing roadways, the proposed routes include various potentially contaminative land uses as detailed in Table 20.62. Limited investigation information is available for areas to the east and the west of Dublin Airport, therefore the baseline conditions for the Construction Phase are largely unknown. Based on the information review significant sources of contamination (e.g. current or former heavy industrial land use) have not been identified and risks associated with land contamination are likely to be of similar nature and magnitude as those identified for the surface areas of the proposed Project rail route. The updated CSM is presented in Appendix A20.3 on the basis of the worst-case scenario for each potential pollutant linkage.

20.5.2.3.2 Operation

During operation the proposed cable routes will lead to little or no further long-term loss or degradation of existing or undisturbed soil, subsoil, or bedrock geology. The magnitude of operational impact on soils and superficial/bedrock geology is considered to be negligible, resulting in an imperceptible significance of impact across the proposed cable routes.

Impacts to mineral resources during operation are confined to the presence of the proposed Project limiting access to future extraction. However, as it has been assessed that future economically viable mineral extraction in the study area is unlikely, then the operational effects on mineral resources are considered to be negligible.

Post development, all excavation trenches will be backfilled with site won or imported granular material compacted to engineering specification. Availability of subsurface voids will therefore be minimal which will limit the potential for radon or ground gas from the surrounding sub-surface to enter or build up in enclosed spaces. Accumulations will, however, be possible where joint boxes or other sub-surface access points are present which may present a moderate/low risk to maintenance workers.

Following construction excavations will be backfilled to match previous surface level which will limit any potential risks of land contamination to future site users (such as road users/pedestrians), assuming that any sub-surface material established to be potentially harmful to human health or the environment is either appropriately treated and reinstated or disposed of during construction.

20.5.2.4 Summary

The assessment of the MetroLink cable route options indicates that the potential impacts are similar to those assessed for the main rail line construction and operation for the proposed Project. This assessment is, however, largely based on a desk-based review and information gaps remain with respect to ground conditions along sections of the route options. Further GI will therefore be required to confirm that the assumptions made within this report are appropriate for the MetroLink cable route options.

20.6 Mitigation Measures

Mitigation measures are additional actions not embedded in the proposed Project design but are required to further avoid, reduce or offset impacts associated with it. This Section sets out mitigation measures which apply to the subjects associated with soils and geology. It should be noted that some mitigation measures apply across different chapters; such cross-topic mitigations, are summarised in Section 20.6.1.5. Mitigation measures associated with groundwater and other dewatering and discharge activities are considered in Chapter 19 (Hydrogeology).

As a negligible magnitude of impact has been assessed for geomorphology, current and historic mining sites and bedrock geology, no specific mitigation measures are considered necessary.

20.6.1 Soils and Superficial Geology

20.6.1.1 Construction Environmental Management Plan

20.6.1.1.1 Mitigation Item SG1

While permanent loss of soil during construction is unavoidable, the Outline Construction Environment Management Plan (CEMP) in Appendix A5.1 (refer to mitigation item RMW4 in Section 20.6.1.5) will include a strategy and methods for addressing impacts associated with excavation, movement, temporary storage and removal of topsoil. Mitigation measures associated with the excavation, disposal and reuse of material are outlined in Mitigation Items RWM4, RWM5, RWM6 and RWM7 in Section 20.6.1.5.

20.6.1.2 Irish Geological Heritage Sites

20.6.1.2.1 Mitigation Item SG2

Phase 2b of the settlement analysis will require completion during development of the detailed design, post Railway Order application which will inform the requirement for any mitigation measures to protect the heritage value of the General Post Office and 51 St Stephen's Green.

20.6.1.3 Radon and Ground Gas

20.6.1.3.1 Mitigation Item SG3

A potential construction risk has been identified of naturally produced radon from the surrounding natural soil and rocks entering underground/excavated and enclosed spaces and building up to potentially hazardous levels (i.e. above the reference level of 300Bq/m3 for workplaces). Article 65 of S.I. No. 30/2019 - Radiological Protection Act 1991 (Ionising Radiation) Regulations 2019 places a duty on employers to test for radon. If the reference level is exceeded employers are required to take remedial action or implement a system of radiation protection for the duration of the work (RPI 2019a).

To mitigate potential risks from radon migration into tunnels, excavations and other enclosed spaces during construction, an occupational monitoring programme will be implemented to identify whether radon migration and build up is occurring. The monitoring will be undertaken in accordance with the EPA Protocol for the Measurement of Radon in Homes and Workplaces (EPA 2019b). If the workplace reference level of 300Bq/m3 is exceeded (EPA 2019a), mitigation measures will be required during construction, such as the development of safe systems of work to ensure protection of construction personnel, potentially including measures such as use of respiratory equipment (RPE) and working time restrictions.

20.6.1.3.2 Mitigation Item SG4

Risks to construction workers from ground gas when working within confined spaces will be mitigated by the development and adoption of safe systems of work, including use of personal protective equipment (PPE) and RPE as a last resort.

20.6.1.4 Contaminated Land

20.6.1.4.1 Mitigation Item SG5

Prior to construction, and to inform the detailed design, further ground investigations and ground gas/groundwater monitoring will be undertaken and will be sufficient to allow detailed risk assessments and selection of appropriate construction procedures, as well as any additional mitigation or remedial design that may be required. The additional investigations will also be used to inform the materials management strategy and beneficial reuse of suitable soils (refer to mitigation items RWM6 and RWM7).

20.6.1.4.2 Mitigation Item SG6

During additional ground investigation and construction works, a watching brief is to be implemented to identify the potential presence of previously unidentified contamination. Personnel appointed by the appointed contractor(s) are to be appropriately trained if involved in earthworks activities. Such instances of previously unidentified contamination will be recorded, and the associated risks assessed, and a remedial strategy developed to manage the identified risks as appropriate.

20.6.1.4.3 Mitigation Item SG7

Prior to construction, appropriate health and safety and waste management procedures for working with potentially contaminated soils (including asbestos) and water will be established. In respect of potential risks to construction workers associated with the presence of asbestos fibres and dust, it is recommended that the appointed contractor(s) should produce the necessary risk assessments for

construction within potentially asbestos contaminated ground. They should develop appropriate method statements and procedures to manage the potential risks in accordance with The Safety, Health and Welfare at Work (Exposure to Asbestos) Regulations, 2006 and 2010, the Safety and the Health and Welfare at work (Construction) Regulation, 2013 (S.I. No. 291 of 2013). Waste management procedures including material containing asbestos will take into account the provisions of the Waste Management Act (as amended). Refer also to mitigations for airborne dust in Chapter 16 (Air Quality).

20.6.1.4.4 Mitigation Item SG8

Risks to construction and maintenance staff working with/near land contamination and neighbouring site users will be mitigated by the implementation of Mitigation Item SG7 in combination with the adoption of appropriate systems of work, including the use of PPE as a last resort. In the event that unrecorded contamination is encountered, works should be stopped, and the working procedures re-assessed to confirm the working methods remain appropriate.

20.6.1.4.5 Mitigation Item SG9

Development of a monitoring programme to be followed during construction works to determine whether construction activities are affecting the groundwater and surface water quality in areas of high receptor vulnerability. Should the monitoring programme indicate a change in baseline conditions and/or unacceptable risk further mitigation may be required (refer also to mitigation in Chapter 18 (Hydrology) and Chapter 19 (Hydrogeology).

20.6.1.4.6 Mitigation Item SG10

Development of a stockpile and materials movement management plan as part of the Outline Construction Environmental Management Plan (CEMP) with measures including but not limited to construction of stockpile bunds and covers to reduce potentially contaminated runoff and generation of leachate, isolating from open excavations and drainage points, damping down to prevent wind-blown dust and monitoring of stockpile emissions (refer also to mitigations for airborne dust in Chapter 16 (Air Quality).

20.6.1.4.7Mitigation Item SG11

Fuelling and maintenance of construction vehicles will be undertaken in designated and controlled zones with measures incorporated to prevent the spread of potential spillages from storage and transfer (e.g. bunds around storage containers and drainage interceptors). An incident response plan will be developed detailing the procedures to be implemented by the appointed contractor(s) in the event of spillage of fuel, lubricant or other potentially hazardous substance. The response plan will include requirements for staff training, equipment requirements (e.g. spill kits), response plans for likely incident scenarios and methods for logging incidents as well as non-compliance with procedures which could result in pollution events.

20.6.1.4.8 Mitigation Item SG12

Prior to construction, a detailed assessment will be undertaken to determine the most appropriate building material is used for construction with respect to the existing ground conditions and the potential for chemical attack via direct contact with contaminants in soil and groundwater. Where concrete materials are proposed to be used, appropriate guidance such as 'Building Research Establishment (BRE) SD1:2005' and 'British Standard (BS) BS8500' should be followed to ensure that ground conditions are appropriate for the use of concrete at each given location

20.6.1.4.9 Mitigation Item SG13

Prior to reuse and placement of any excavated material within the proposed Project, location specific risk assessment will be required to demonstrate that it will take into account the provisions of the Waste Management Act (as amended) and relevant guidance such as The Management of Waste from National

Road Construction Projects (TII 2017) and that it is suitable for reuse (i.e. does not pose a risk to human health or the environment).

20.6.1.4.10 Mitigation Item SG14

Specific assessment of the presence of pyrite within the project will be required for the Lucan Formation which will be excavated during construction to account for potential swelling properties and environmental risks and to inform potential reuse options (applies to reuse of material within the project only, assessment conducted under A27 for use as by-product external to the proposed Project takes into account geochemical properties). Material will be required to comply with an appropriate specification for earthworks such as the NRA Specification for Road Works Series 600 – Earthworks (TII 2013).

20.6.1.4.11 Mitigation Item SG15

While the risks associated with introduction of new pollution pathways for the option of piling in some areas of the route are considered to be low, where piling is proposed at detailed design piling risk assessments will be undertaken to inform appropriate piling techniques and designs. These assessments should adhere to appropriate guidance including the 'Piling and Penetrative Ground Improvement on Land Affected by Contamination: Guidance on Pollution Prevention, national Groundwater and Contaminated Land Centre Report NC/99/73' (Environment Agency 2001).

20.6.1.4.12 Mitigation Item SG16

Investigation of ground conditions for the MetroLink cable route options to determine whether the risks assessed in this report are appropriate and determine any requirements for additional mitigation as necessary.

20.6.1.5 Cross-Topic Mitigation

The topics considered within some other chapters have potential interactions with the topics considered within this Chapter. Given these interactions, some of the proposed mitigation measures for these chapters are also applicable to soils and geology, and where relevant, are briefly summarised below (reference should be made to the relevant chapter for full details).

The following mitigation measures detailed in Chapter 24 (Materials & Waste Management) relate to the management of waste and excavated materials.

20.6.1.5.1 Mitigation Item RWM4

The Principal Contractor will be responsible for the compliant management of all waste generated by construction activities and will be responsible for preparing and implementing a detailed CEMP, identifying construction methodologies for the proposed Project and standard operating procedures that will be implemented to minimise the impact. The CEMP will include all mitigation measures as outlined in this EIAR. An outline CEMP has been prepared as part of this EIAR and can be found in Appendix A5.1.

20.6.1.5.2 Mitigation Item RWM5

The detailed CEMP will include a Construction and Demolition Waste Management Plan (C&D WMP), which will incorporate all of the measures outlined in the Spoil Management Strategy (Mitigation WM6). The C&D WMP will identify roles and responsibilities and how waste arisings are to be controlled and managed during the course of the proposed Project, in particular how waste prevention principles will be applied and how on-site waste will be minimised.

20.6.1.5.3 Mitigation Item RWM6

An Excavated Material Management Strategy has been prepared for the proposed Project and included within the EIAR as Appendix A24.1. The overall objective of which is to provide an initial summary of

excavated material arisings that will be generated during construction of the proposed Project according to the Preliminary Design and highlight potential methods and sites for reuse, recovery, recycling and disposal with the aim of minimising disposal as waste. This Excavated Material Management Strategy is to be used by the Contractor(s) to develop an Excavated Materials Management Plan to be followed during the excavation phases of the project.

20.6.1.5.4 Mitigation Item RWM7

In so far as is possible, options for beneficial reuse of clean, suitable soil and stone material in accordance with Article 27 of the Waste Management Act will be sought. This will prevent the need to classify all of the 2.9 million m3 of excess excavated material as a waste. Locations and projects which identify a deficit of soil and stone material will be identified. Where it is deemed that the clean excavated material from the proposed Project is suitable for use in another identified project (i.e. complies with the Article 27 criteria), agreements will be put in place for a defined amount of by-product material to be sent to that project and a notification will be made to the EPA. Material not included within the A27 application would be classified as waste and require disposal. Should an A27 application be unsuccessful for any reason then secondary mitigation would involve consignment of suitable excavated material to Soil Recovery Facilities (SRFs).

The following mitigation item included in Chapter 19 (Hydrogeology) relates to the management and control of discharges to ground and water.

20.6.1.5.5 Sediment Erosion and Pollution Control Plan

This plan will form part of the detailed CEMP and include measures to manage soil and silt-laden water on site as well as accidental leaks spills to ground and water monitoring to ensure compliance with relevant environmental quality standards.

The following mitigation items are included in Chapter 23 (Agronomy) relate to management of dust and loss of agricultural land.

20.6.1.5.6 Dust Management

A Dust Management Plan will be formulated to ensure that construction activities are managed to minimise dust emissions, including ensuring that material loads leaving site will be assessed and covered where necessary to reduce dust impacts. Appropriate mitigation measures will be taken to reduce levels of dust generation, including wheel washing and road sweeping. These measures are described in the outline CEMP and further mitigation and monitoring requirements are detailed in Chapter 16 (Air Quality) of this EIAR.

20.6.1.5.7Loss of Agricultural Land

The loss of agricultural land as a result of the construction of the proposed Project is a permanent loss which will be addressed in the statutory compensation process. The proposed Project has been designed to minimise the land take so that only lands required for the proposed Project are acquired. Land acquired on a temporary basis during the Construction Phase will be reinstated by agreement and returned to the landowner.

20.7 Residual Impacts

The significance of each residual impact is assessed in Table 20.63 after mitigation has been applied. Following implementation of the mitigation measures, potential impacts and risks are reduced to imperceptible or negligible for many of the aspects considered, with the remainder assessed as low risk.

Table 20.63: Summary of Significant Impacts after Mitigation

Element	Baseline Rating	Description of Potential Impacts	Mitigation	Post Mitigation		
				Significance Criteria	Impact Criteria	Residual Significance of Effect/Risk
Topsoil	Slight	Degradation of topsoil through construction activities including excavation, handling, temporary access and erosion.	**SG1**	**Medium**	**Negligible**	**Imperceptible**
Irish Geological Heritage Sites	Slight	Potential for settlement during construction to affect the geological heritage value of the General Post Office and 51 St Stephen's Green via damage to buildings.	**SG2**	**Medium**	**Negligible**	**Imperceptible**
Radon	Slight	Potential for accumulation of radon in enclosed spaces open to the subsurface resulting in risks to construction workers from inhalation.	**SG3**	**Low**	**Negligible**	**Imperceptible**
Ground Gas	Moderate	Potential for accumulation of ground gas (mainly methane and carbon dioxide) to accumulate in enclosed spaces resulting in asphyxiation or toxicity effects on construction workers.	**SG4**	**Medium**	**Unlikely**	**Low**
Presence of contaminants within subsurface	Moderate	Potential for information gaps as design evolves to detailed design stage, potential for previously unidentified contamination to be present.	**SG5, SG6**	**Medium**	**Unlikely**	**Low**
Presence of contaminants within subsurface	Moderate	Risks to construction workers from dermal contact, ingestion and inhalation of impacted soil, dust and waters, risks to adjacent residents/workers and transient foot traffic.	**SG7, SG8**	**Medium**	**Unlikely**	**Low**
Water Pollution (made ground disturbance)	Low	Groundwater and surface water could be affected by disturbance of made ground/contamination during construction works, leading to increased pollution load to surface and groundwater.	**SG9, SG15**	**Mild**	**Unlikely**	**Negligible**
Water Pollution (stockpiles)	Moderate/Low	Surface water run-off and infiltration through stockpiles mobilising contaminants and causing pollution of surrounding environment.	**SG10**	**Medium**	**Unlikely**	**Low**
Leaks and spills (plant)	Moderate	Potential for leaks and spills from construction plant operation and maintenance.	**SG11**	**Medium**	**Unlikely**	**Low**
Risks to buildings/infrastructure	Moderate/Low	Direct contact of buildings and infrastructure with aggressive ground conditions	**SG12**	**Mild**	**Unlikely**	**Negligible**
Risks from ground contamination	Moderate	Risks from made ground/material containing contaminants retained on site (not excavated as part of construction) to human health (e.g. maintenance workers, end users) and the environment (groundwater and surface water)	**SG5, SG7, SG6**	**Medium**	**Unlikely**	**Low**
Risks from material reuse	Moderate/Low	Risks from reused placed material to human health (e.g. maintenance workers, end users) and the environment (groundwater and surface water)	**SG13**	**Medium**	**Unlikely**	**Low**

20.8 Difficulties Encountered in Compiling Information

In general, no significant difficulties were encountered in undertaking this assessment. Items of note primarily relating to access constraints during ground investigation works are outlined as follows:

- Access to the Boland Car Dismantlers yard was not possible during GI works. As such uncertainty remains regarding the presence of contamination and ground conditions in this area. Given the current and historical use of the site as a car dismantlers yard it is expected that some ground contamination is likely to be present from local emissions and spills mainly of fuel and lubricants.
- In built up and city centre areas, particularly the proposed station boxes (such as Tara and O'Connell Street stations), ground investigation access was only possible to areas outside current buildings and structures and where services are present. While some residual uncertainty remains regarding ground conditions and the presence of contamination in these areas (and will only be resolved on removal of the buildings and structures) the investigations conducted to date are considered to be sufficient for the current stage and Preliminary Design of the proposed Project.

20.9 Limitations

The following general limitations apply to the assessment presented in this chapter, in addition to those previously noted within the chapter:

- Ground investigation, while conducted according to best practice (according to the documents referenced within this assessment) and considered suitable for the current stage of the project, only investigated and sampled a small quantity of the sub-surface. As such, uncertainty is inherent in such investigations and final confirmation ground conditions is only possible at construction stage.
- The assessment is based on the information available at the time of writing. There is potential for additional information that becomes available at a later date to alter the assessment presented here.
- The findings conveyed via this report are based on information obtained from a variety of sources as detailed within this report and which are believed to be reliable. Nevertheless, the authenticity and reliability of the information cannot be guaranteed.

20.10 Glossary of Technical Terms

Acronym	Meaning
Aquifer	A subsurface layer or layers of rock that store and transmit water in significant quantities.
Catchment	The entire surface area feeding water to a given surface or groundwater feature.
Fault	A planar fracture in rock in which the rock on one side of the fracture has moved with respect to the rock on the other side.
Fracture	A discontinuity across which there has been separation.
Groundwater	That part of the subsurface water that is in the saturated zone, i.e. below the water table.
Groundwater vulnerability	Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities.
Karst	Terrain created by limestone solution and characterised by a virtual absence of surface drainage, a series of surface hollows, depressions and fissures, collapse structures and an extensive subterranean drainage network.
Karstification	Formation of the features of karst topography by the chemical, and sometimes mechanical, action of water in a region of limestone, dolomite, or gypsum bedrock.
Made Ground	Deposits/reworked subsoils which have accumulated through human activity and may consist of natural materials, e.g. clay and/or manmade materials.
Outcrop	An exposure of bedrock at surface.
Permeability	A measure of the ability of a given rock or overburden material to transmit water.
Rockhead	A raised rocky area or prominence; a summit or extremity of rock. The upper surface of bedrock.
Run-off	Water leaving a drainage area or water running across the land surface.
Water table	The surface in an unconfined aquifer or confining bed at which pore water pressure is atmospheric.

20.11 References

An Foras Talúntais 1980. General Soil Map of Ireland

British Standards Institute 2017. BS 10175:2011 + A2:2017 Investigation of potentially contaminated soils. Code of practice

British Standards Institute 2019. BS8500:2019 Concrete - Complementary British Standard to BS EN 206

Building Research Establishment 2005. Concrete in aggressive ground (SD 1)

Burland et al 1977, Behaviour of foundations and Structures, Pages 495-456 of: proceedings of the 9th International conference of Soil Mechanics and Foundation Engineering, vol 2

Causeway 2019. Metro Link Phase 1 Ground Investigation, Factual Report.

Causeway 2020a. Metro Link Phase 2 Ground Investigation, Factual Report

Causeway 2020b. Metro Link Phase 3 Ground Investigation, Factual Report

Causeway 2020c. Metro Link Phase 4 Ground Investigation, Factual Report

Causeway 2022. Metro Link Phase 5 Ground Investigation, Factual Report.

CIRIA 2001. Contaminated Land Risk Assessment: A Guide to Good Practice (CIRIA C552)

CIRIA 2007. Assessing risks posed by hazardous ground gases to buildings (CIRIA C665)

CIRIA 2017. Embedded Retaining Walls – Guidance for Economic Design (CIRIA C760)

DEFRA 2014, Department for Environment, Food and Rural Affairs Category 4 Screening Levels (C4SLs).

Dublin City Council 1992. Northern Cross Route Phase 2, Site Investigation Data Volume 1

Dublin City Council 2016. Dublin City Development Plan 2016 - 2022

EPA and GSI 2009. Historic Mine Sites – Inventory and Risk Classification

Environment Agency 2001. Piling and Penetrative Ground Improvement on Land Affected by Contamination: Guidance on Pollution Prevention, national Groundwater and Contaminated Land Centre Report NC/99/73

Environment Agency 2020. Environment Agency, Land Contamination: Risk Management (LC:RM).

Environment Agency 2022. Derivation and use of Soil Screening Values for Assessing Ecological Risks.

EPA 2003a. Advice Notes on Current Practice (in the preparation of Environmental Impact Statements)

EPA 2003b. Environmental Protection Agency, Towards Setting Guideline Values for the Protection of Groundwater in Ireland (a consultation document titled Determining Groundwater Pollution: A proposed approach for the development and application of guideline values for groundwater was issued during January 2017, although a finalised version is yet to be issued);

EPA 2013. Environmental Protection Agency, Guidance on the Management of Contaminated Land and Groundwater at EPA Licensed Sites.

EPA 2017. Guidelines on the Information to be Contained in Environmental Impact Assessment Reports (Draft)

EPA 2019a. Advice on setting a reference level for Radon concentrations in long-stay institutions.

EPA 2019b. EPA Protocol for the Measurement of Radon in Homes and Workplaces

EPA 2020, Radon Map of Ireland.

EPA 2022. EPA Interactive Map.

EPA 2022. Guidelines on the information to be contained in Environmental Impact Assessment Reports, May 2022.

Environment Agency 2021. Land Contamination: Risk Assessment

European Commission 2011. Consolidated EIA Directive 2011/92/EU

European Commission 2014. Directive 2014/52/EU

European Communities (Environmental Impact Assessment) (Amendment) Regulations, 2001 [S.I. No. 538/2001].

European Communities 2003. European Communities (Water Policy) Regulations 2003, S.I. No. 722/2003

European Communities 2009. Environmental Objectives (Surface Waters) Regulations 2009.

European Communities 2010. European Communities Environmental Objectives (Groundwater) Regulations 2010, S.I. No. 9/2010

European Union 2016. Environmental Objectives (Groundwater) (Amendment) Regulations 2016

European Union 2019. Environmental Objectives (Surface Waters) (Amendment) Regulations 2019.

Fingal County Council 2017. Fingal Development Plan 2017 – 2023.

GII 2018. New Metro North, Ground Investigation report

Government of Ireland 1996. Waste Management Act (as amended)

Government of Ireland 2001. Transport (Railway Infrastructure) Act, Section 39(2)(b)

Government of Ireland 2010. Safety, Health and Welfare at Work (Exposure to Asbestos) Regulations, 2006 and 2010.

Government of Ireland 2013. Safety and the Health and Welfare at work (Construction) Regulation, 2013 (S.I. No. 291 of 2013)

Government of Ireland 2019, Article 65 of S.I. No. 30/2019 - Radiological Protection Act 1991 (Ionising Radiation) Regulations 2019

Groundwater Directive 2006. Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration

GSI 2012. SURGE Project: Geochemical baseline for heavy metals and organic pollutants in topsoils in the greater Dublin area. Geological Survey of Ireland, 2012.

GSI 2014. Bedrock Geology of Ireland - 1:1,000,000 scale

GSI 2017. Quaternary Geological Map of Ireland - 1:500,000 scale

GSI 2022. Geological Survey Ireland Public Data Viewer.

Haswell 2002. Geotechnical Desk Study, City Centre and Airport.

IEMA 2022. A New Perspective on land and Soil in Environmental Impact Assessment. Institute of Environmental Management & Assessment (IEMA) guide.

HSE 2020. EH40/2005 Workplace exposure limits (Fourth Edition 2020). Health and Safety Executive.

IGI 2013. Institute of Geologists of Ireland, Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of Environmental Impact Statements

IGSL 2002a. Mater & Children's Hospital Ground Investigation (Phase II) – Main Site, Ground Investigation Report

IGSL 2002b. Site Investigation Works for the Proposed Dublin Light Rail Track, Draft Ground Investigation Report (Factual)

IGSL 2007. Dublin Metro North Ground Investigation, Factual Ground Investigation Report (Volume 1)

IGSL 2008. Dublin Metro North, Main Ground Investigation, Ground Investigation Report

IGSL 2010. Metro North – Mater to Parnell, Geotechnical Site Investigation Report

Irish Rail 2010. Dart Underground Environmental Impact Statement.

Jacobs 2008a. Dublin Metro North, Technical Note 023, Desk Study Review B0307000-010/GEO.360/002/1

Jacobs 2008b. Dublin Metro North, Reference Ground Conditions Report for Information (B0307000-010/GEO.28/007/1)

Jacobs IDOM 2022a. Metro Link, Ground Investigation Report

Jacobs IDOM 2022b. Metro Link, Geotechnical Design Report

Jacobs IDOM 2022c. Land Contamination Interpretive Report

Jacobs IDOM 2022d. Building Damage Report

LQM/CIEH 2015. Suitable for Use Levels' (S4ULs) for residential and commercial/industrial land uses.

Mair, R. J. 2001. Theme Lecture, Research on Tunnelling Induced Ground Movements and their Effects on Buildings – Lessons from the Jubilee Line Extension. Proceedings of the International Conference Held at Imperial College, London, UK, on 17-18 July 2001

Mair et al 1996. Prediction of Ground Movements and Assessment of risk of Building Damage due to Bored Tunnelling. In: Proceedings of the International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, 713-718, Balkema, Rotterdam.

Mott MacDonald 2022. Outline Construction Methodology – HV Cables.

NHBC and Environment Agency 2008. Guidance for the Safe Development of Housing on Land Affected by Contamination R&D66: 2008

NRA 2009. National Roads Authority, Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes

Norwest Holst 2008. Dublin Metro North, Main Ground Investigation – Sections 6 & 7

Norwest Holst 2009. Mater Stop – Additional GI, Dublin

O'Reilly et al 1982. Settlements above Tunnels in the United Kingdom – Their Magnitude and Prediction. Tunnelling '82, Edited by Jones, M.J. pp 173-181. London, IMM

OSI 2022. GeoHive, Ordnance Survey Ireland online spatial data viewer

Parsons Brinckerhoff 2007. Dublin Metro North Alignments Study, Geotechnical Interpretive Report (Section 1 to 6)

Rankin, 1988. Ground Movements Resulting from Urban Tunnelling: Predictions and Effects. Page 79-92 of: Engineering Geology of Underground Movements. The Geological Society, London

RPA 2008. Environmental Impact Statement – Metro North. Railway Procurement Agency, 2008

Soil Mechanics 2011. Metro North Depot, Dardistown, Dublin, Factual Report on Ground Investigation

Teagasc 2022. Teagasc Irish Soil Information System online map

TII 2013. Transport Infrastructure Ireland, NRA Specification for Road Works Series 600 – Earthworks.

TII 2017. Transport Infrastructure Ireland, The Management of Waste from National Road Construction Projects

Topographic-map 2022. Topographic-map.com online viewer

Water Framework Directive. Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy

Water Framework Directive 2015. (Standards and Classification) Directions (England and Wales) 2015.

Waste Management Acts 1996, as amended

Wimtec 2000. Dublin Light Railway, Sandyford to Ballymun Line Tunnel Link Between St. Stephen's Green and Broadstone, Factual Report Volumes 1 and 2

World Health Organization 2011, Guidelines for drinking water quality, fourth edition.