METROLINK,

REF. ABP-314724-22

TECHNICAL REVIEW

Final Report

2025-07-23

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Participating

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Executive Summary

This report provides the outcome of a Technical Assessment (Review) of the Environmental Impact Assessment Report (EIAR) that forms part of the application for a Railway Order submitted for the proposed MetroLink project by Transport Infrastructure Ireland (TII). The Assessment incorporates the additional documents and submissions made during the Oral Hearing in February and March 2024 for the MetroLink project. The Assessment has been carried out to support An Bord Pleanála (the Board) in their consideration of the Railway Order application for the MetroLink project.

The Technical Assessment has focused on the impact from construction activities together with groundborne noise and vibration issues during operation of the MetroLink system.

The MetroLink scheme is a high-capacity modern metro system linking the South of Dublin at Charlemont, where it connects with the Luas Green Line, and running through the city centre North to Dublin Airport and further North to Swords. The system has been designed with a higher capacity, circa 20,000 people per hour, than some metros in other comparable cities, with an overhead catenary traction power system and consequently larger structures and a larger impact on the urban landscape than would be the case with a lower capacity system.

The EIAR and supporting documents provide a thorough documentation of the project and its impacts and use methodology which is comparable to those used in other recent metro projects.

During the Oral Hearing the Applicant (TII) introduced a substantial number of new and revised documents and also proposed a number of changes to the proposed development, a number of which were in response to submissions from Observers and also arising from questioning from the Inspectors and the authors of this report. These changes include:

- Lowering of the tunnel alignment between St. Stephens Green and Charlemont to prevent potential clashes with existing foundations.
- Reducing the length of open cut trough at Seatown Villas and Pinnock Hill, Swords.
- Committing to directly engage the Independent Monitoring Engineer (IME) rather than they be engaged by the Design & Build Contractor
- A commitment that operational groundborne noise levels in lawfully occupied housing will be maintained below 35 Db $L_{Amax,}$S.
- Substantially increasing the sections of floating track slab essentially resulting in the majority of the City centre section having floating slab track
- A considerable number of additional environmental commitments, as outlined in the document entitled Final Schedule of Additional Environmental Commitments (OH376)

The findings from the Assessment review may be summarised as:

The Applicant has carried out a thorough assessment of the impact from the construction of the MetroLink in line with current best practice for major infrastructure projects. The impact from the construction of such a large project through a densely populated urban area is substantial and cannot be fully mitigated. These impacts are present for all the major aspects of the construction such as the deep stations, the tunnels and the retained cuts. The Applicant has incorporated reasonable mitigation measures into the project to minimise the impact in line with current good practice. The Assessment has identified a number of additional mitigation measures that can be implemented by the Applicant to further mitigate the impact and the Assessment has provided recommendations to the Board regarding additional conditions that should be imposed on the Applicant if it decides to grant the Railway Order.

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1 Introduction

The National Roads Authority (operating as Transport Infrastructure Ireland) (also referred to as “TII” or the Applicant) has applied to An Bord Pleanála (the Board, or ABP) under section 37(1) of the Transport (Railway Infrastructure) Act 2001 (as amended and substituted) for a Railway Order in order to construct a modern automated metro, known as MetroLink. The MetroLink will be approximately 18.8 km in length with 16 stations and will run from north of Swords at Estuary station through Swords, Dublin Airport, Ballymun, Glasnevin and the City Centre to Charlemont in the South of Dublin City Centre.

The Railway Order if granted will authorise the Applicant to construct, maintain and operate the metro system as specified in the Railway Order.

1.1 Definitions & Terminology

The following terminology is used in the report:

Table 1 Terminology used in the report

Terminology	Abbreviation	Description
An Bord Pleanála,	ABP or The Board	The planning authority responsible for granting approval of the Railway Order
The Applicant	TII	Transport Infrastructure Ireland making the application for the Railway Order
Observers or Third Parties	3rd Parties	Observers are Third Parties affected by the Railway Order who have made Submissions to the Board either in writing or orally at the Oral Hearing
Submissions	SXXX, 1FSXX, 2FSXX	Written submissions to the Board from Observers. The Board has assigned a unique submission number to each, SXXX, 1FSXX, 2FSXX.
Oral Hearing Documents	OHXXX	Documents submitted to the Board either from Observers or from the Applicant. The Board has assigned a unique submission number to each Oral Hearing Document submitted, OHXXX.

1.2 Assessment Team

The Board has appointed an Inspector to examine and report on the Railway Order Application. The Board has also appointed Tyréns AB a Swedish Engineering and Consulting Company to assist the Inspector in

his assessment of the application and in particular the Environmental Impact Assessment Report (EIAR).

Tyréns AB is a leading Swedish independent engineering and design consultancy, specialising in the fields of urban development and infrastructure. It has a staff of approximately two thousand working in Sweden, Lithuania and in the UK.

The Board has appointed the following staff from Tyréns AB to undertake the review and assist the Inspector:

Peter Jackson, Assignment Leader
Peter is a project manager in Tyréns who has thirty years of experience with the design of major infrastructure projects and has extensive experience from international rail and metro projects such as the Doha Metro Red and Green Lines and HS2 the high speed rail in UK. He has been working on a similar metro project, the Copenhagen metro, through its different phases for the last twenty five years. Peter brings particular experience in the underground construction and in building damage assessments.

Bo Tvede Jensen, Tunnelling and Construction Impacts
Bo is an experienced tunnel engineering and design manager, with over 20 years experience. He has been the design lead for a series of major tunnel projects in Scandinavia and Internationally, with such projects as the Femern Tunnel linking Denmark and Germany, the Copenhagen Cityringen Metro Line, Doha Metro Red Line, Abu Dhabi Step project and major wastewater tunnels in Copenhagen.

Ragnar Glav, Airborne, Groundborne Noise and Vibration
Ragnar is a professor of acoustics at the Royal Institute of Technology in Stockholm (KTH), with 30 years experience, who also works as a consultant in the fields of airborne and groundborne noise and vibrations. He has extensive experience from railway projects, including the Stockholm metro and has assisted the Swedish Transport Administration with noise and vibration studies for a number of major railway projects in Sweden such as the Mälarbanan in Stockholm.

1.3 Assessment Scope

The scope of the assignment as defined by the Board in their Letter of Appointment ref. 14724-22 dated 18th July 2023 and is as follows:

I. Review the Environmental Impact Assessment Report and associated appendices and drawings as it relates to soils, geology and hydrogeology, including geotechnical aspects of tunnelling

works, groundwater impacts, groundborne noise, vibration and settlement for both the construction and operational phases.

II. Review those submissions made in relation to the application that relate to the above mentioned environmental topics.

III. Identify any further information that may be required from the applicant for the purposes of the Board's planning and environmental assessment.

IV. attend oral hearings as required

V. make a written report to the presiding Inspector in relation to the above application and

VI. be an authorised person for the purpose of section 252 of the Planning and Development Act, 2000 as amended.

The scope of the assignment was subsequently amended to include airborne noise and vibrations during both construction and operations by way of an addendum to the Letter of Appointment dated 27th Sept 2023.

1.4 Assessment Methodology

The assignment methodology has been as follows:

I. Carry out a review of the Railway Order application focussing on the EIAR and its Appendices, with particular regard to relevant predicted impacts during construction and operations.

II. Walkover inspection of the alignment and surrounds carried out in a number of stages during September 2023 and further walkover inspections during the period of the Oral Hearings.

III. In person attendance at the Oral Hearings during Module 1, between 19th February 2024 and 6th March 2024, and remote attendance on 21st March 2024.

IV. Review all Observer submissions made before and during the Oral Hearings.

V. Review all additional material submitted by the Applicant during the Oral Hearing.

VI. Review all Observer submissions made during the 2nd Consultation, which followed closure of the Oral Hearing and the Applicant's further information submission.

VII. Prepare a technical assessment report to outline the Assessors findings and provide recommendations to the Board (this report).

The Assessment has focussed on the following issues:

1.4.1 Impacts during Construction from:

- Tunnelling
- Station construction
- Cut and cover and retained cut works
- At grade works

That mainly relate to:

- Settlement and building damage
- Blasting induced vibration and damage
- Groundwater lowering induced settlement and the effects of groundwater abstraction on the groundwater resources and contamination
- Noise and vibrations

1.4.2 Operation and Maintenance

- Trackform, track requirements
- Switch layout and requirements
- Ventilation from tunnel, shafts and stations

That relate to:

- Airborne Noise
- Groundborne noise and vibration

1.5 The Report

This report provides the outcome of the assessment of the EIAR and supporting documents, together with additional documents and submissions made during the Oral Hearing and additional documentation and submissions made following closure of the Oral Hearing during the 2nd Consultation.

The report documents the basis for the Assessment, provides a commentary on the main aspects of the project's design where they are relevant to the Observers submissions. It assesses the ground and groundwater conditions and reviews the applicability of the construction methods to the prevailing conditions.

The report assesses the predicted environmental impacts during construction and operation, together with the Applicant's proposed measures to mitigate the impacts.

In the case of specified predicted impacts and construction methods proposed by the Applicant, the Assessors have "Benchmarked" them against similar modern metro projects.

The report also considers the Observers (Third Party) submissions and the responses to same from the Applicant. Where there are significant disagreements between the parties, the Assessors have provided an independent view of the issues under dispute.

The report provides recommendations to the Board regarding additional requirements and mitigation measures that they may wish to impose if they decide to grant the Railway Order.

1.6 Assessment Basis

The basis for the Assessment Report comprises of the following documents:

- Draft Railway Order and drawings
- The EIAR, supporting appendices, and other documents forming part of the application.
- Observers' submissions, received before, during and after the Oral Hearing, and the Applicant's responses to same.
- The Applicant's additional material submitted during the Oral Hearing.
- The Applicant's further information submission, following closure of the Oral Hearing, i.e. the 2nd Consultation.

The assessment has focused on the significant impacts identified and how they are dealt with in the EIAR, together with the additional EIAR-related documents submitted during the Oral Hearing by the Applicant and the submissions from Observers. Regard has also been had to the other Railway Order application documents such as the detailed Railway Order Drawings.

The Applicants geographical zoning system, as listed in Table 2 has been used through the report to reference sections of the alignment.

Table 2 Alignment Zones (defined by the Applicant)

Area/Category	Sub-Area / Sub-Category	Description
AZ1 Northern Section	**AZ1(a)**	Estuary Station (including Park & Ride facility) to Seatown Station to northern end of Swords Central Station.
	AZ1(b)	Swords Central Station to Fosterstown Station to Dublin Airport North Portal (DANP).
AZ2 Airport Section	**AZ2**	Section AZ2 includes the ESB Networks connection and new substations, the Dublin Airport North Portal (DANP), the tunnel running beneath Dublin Airport lands, Dublin Airport Station and Dublin Airport South Portal (DASP) and associated intervention and ventilation tunnels.
AZ3 Dardistown Section	**AZ3**	Section includes embankment, elevated, open and retained cut, and cut and cover sections of the alignment. AZ3 extends from south of Dublin Airport South Portal (DASP) to the Northwood Portal, and includes Dardistown Station, the Dardistown Depot, ESB Networks connection and substations, the M50 viaduct crossing, Northwood Station and the TBM launch site at Northwood.
AZ4 City Section	**AZ4 (a)**	Northwood Portal to Ballymun Station, Ballymun Station and running tunnel to Collins Avenue Station.
	AZ4 (b)	Collins Avenue Station and running tunnel to Griffith Park Station, including Albert College Park Intervention Shaft.

Area/Category	Sub-Area / Sub-Category	Description
	AZ4 (c)	Griffith Park Station and running tunnel to Glasnevin Station.
	AZ4 (d)	Glasnevin Station and running tunnel to Mater Station.
	AZ4 (e)	Mater Station and running tunnel to O'Connell Street Station.
	AZ4 (f)	O'Connell Street Station and running tunnel to Tara Station.
	AZ4 (g)	Tara Station and running tunnel to St. Stephen's Green Station.
	AZ4 (h)	St. Stephen's Green Station and running tunnel to Charlemont Station.
	AZ4 (i)	Charlemont Station and tunnel turnback south of the Station.
General or Multi-Area	MULT AZ's	Submissions that extend over more than one of the four Assessment Zones. MULT AZ4 Submissions that span more than one AZ4 sub-area.
	GEN	General overview or non-geographic specific submissions.

2 Oral Hearing

The Oral Hearing was split into two modules:

- Module 1 from 19th February 2024 to 6th March 2024, Days 1 to 11, which dealt with construction related impacts such as tunnelling, noise and vibration and alignment issues.
- Additional Module 1 day, 21st March 2024
- Module 2, from 7th March 2024 to 28th March 2024, Days 12 to 22, dealt with other issues and were not attended by the Assessors.

The Assessors/Review team attended Module 1 in person and the additional Module 1 day held on the 21st March 2024 remotely.

It was noted that in some sections of the alignment there were significant concerns regarding the impact from the construction works and the MetroLink operations and a number of concerns regarding the MetroLink alignment. These concerns included some of the station and shaft locations together with the tunnel alignment particularly in AZ4 (City section). Some of these submissions also concerned the impact of the MetroLink on the urban landscape at a number of locations such as St. Stephens Green, Charlemont and further north at Albert college Park and Collins Avenue. There were also significant concerns regarding ground borne noise and vibrations during operations of the metro.

One common theme from the Observers submissions was complaints regarding the Applicant's lack of engagement or a perceived lack of engagement with Observers.

The key issues that arose from the Observers submissions and the Applicant's responses are addressed in the relevant sections below where they are relevant to the Assessors scope. Where an Observer has engaged an engineering consultant to make independent assessments of the impact from the project these have been reviewed in detail together with the

Applicant's responses. An independent view has been taken where the Applicant and Observer substantially differ in their assessments.

3 Overall Scheme Design

The proposed MetroLink is a major new piece of public transport infrastructure, which will comprise of a high-capacity, high-frequency, modern and efficient driverless metro rail service. It will have 16 new stations running from Swords to Charlemont. The alignment will link Dublin Airport, Irish Rail, DART, Dublin Bus and Luas services, contributing to integrated public transport services. The MetroLink alignment is shown in Figure 1.

Figure 1 Metrolink Alignment

As well as linking major transport hubs, MetroLink will connect key destinations in the city such as Ballymun, the Mater Hospital, the Rotunda Hospital, Dublin City University (DCU) and Trinity College Dublin (TCD).

Much of the 18.8 km route will run underground, either in bored tunnel, in a cut and cover tunnel or in a retained cut, with only the most Northerly section running at grade as shown in Figure 1.

It is intended to carry up to 20,000 passengers per hour in each direction, with the travel time from Swords to Dublin city centre being approximately 25 minutes. It is estimated that MetroLink will carry up to 53 million passengers annually.

3.1 Layout and Overall Impact

The overall layout of the Metrolink is described in the EIAR *Non Technical Summary* and *Vol 2 Chapter 4 Description of the MetroLink Project*. The overall layout and impact of the MetroLink scheme is discussed below linking to the choices made by the Applicant for the scheme layout where relevant to the Observer submissions.

The main section of the alignment through the City Centre, known as alignment section AZ4 and which runs from the Northwood tunnel portal to the Southern terminus station at Charlemont, will have a tunnel length of 9.4 km. This is to be constructed using a tunnel boring machine (TBM) with an internal tunnel diameter of 8.50 m. This is a large diameter for a metro tunnel, which is due to the chosen single bore twin track running tunnel solution.

The airport section of tunnel, AZ2, with a tunnel length of 2.4 km, is a similar single bore twin track tunnel with an internal diameter of 8.50 m. The tunnel alignment crosses below the airport operational area.

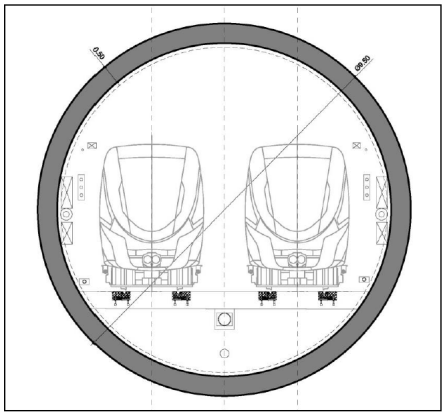

Figure 2 Tunnel cross-section of proposed twin track tunnel

3.2 Status of the Design and Contract Strategy

The design on which the EIAR and the Railway Order is based on is a Preliminary Design, also known as a Basic Design, with a level of design maturity or detailing such that the main space requirements have been defined. The main dimensions of the structures are defined, the layouts and architectural concepts defined together with the main requirements of the Railway and Mechanical and Electrical Plant (MEP). These have been defined such that the main dimensions, concepts and visual appearance will not change during the development of the design to the Detailed Design level which will be used for construction of the works.

The Applicant has stated in EIAR Chapter 5 that the MetroLink civil engineering construction will be let in three major Design and Build (D&B) Contracts where the Contractor is responsible for the Detailed Design of

the Works. The railway system, MEP and architectural works will be contracted separately either as D&B or as an Employer's detailed design.

There are many commitments from the Applicant regarding the construction methods which have been stated in the EIAR, the Oral Hearing and the Final Schedule of Additional Environmental Commitments that will need to be maintained during the next stages of the project development and into construction in order to keep the impacts to the level described by the Applicant in the Railway Order application. This includes such measures as the "top down" construction sequence for the deep stations and the use of deep diaphragm walls and grouting to maintain the groundwater levels outside the excavation. Such measures during the D&B design development could be changed by the Contractor unless clear requirements are in place to prevent such changes. The Board may wish to give consideration to introducing specific conditions when granting the Railway Order to ensure that the construction methods are not changed from the methods stated in the EIAR and the submissions made by the Applicant during the Oral Hearing.

4 Geotechnical Issues

The geology of the project area and the geotechnical conditions that the construction of the metro needs to accommodate are described in the EIAR Chapter 20 Soils and Geology.

The Applicant has made a thorough investigation of the ground conditions along the alignment based on desk studies, existing boreholes from the previous metro studies and specific geotechnical investigations for the MetroLink project.

The geotechnical conditions are generally good for tunnelling and underground construction although they are complex at some station locations such as Glasnevin. The ground conditions can be summarised as:

A sedimentary sequence formed by a Carboniferous basement, with mudstones and limestones, and minor sandstones and shales, covered by glacial, fluvioglacial, fluvial, and recent marine deposits of Quaternary age.

The solid (bedrock) geology of the region comprises a sequence of sedimentary rocks that are assigned to the Lower Carboniferous period, ranging in age from Courceyan to Brigantian with the Quaternary Soils are overlying bedrock. The soils include topsoil, made ground, drift and alluvial and recent marine sediments

The Glacial Deposits mainly include firm to very stiff, silty, sandy, gravelly clay (lodgement till) with sparse cobbles and boulders and 200-600mm thick embedded strata. The glacial deposits comprise lenses of fine to coarse gravel and cobbles with scarce, silty and fine, sandy matrix and occasional boulders (subglacial channels, fluvial–glacial, braided rivers and

outwash deposits). The till is locally named Dublin Boulder Clay and it is traditionally subdivided into brown and black strata.

The geotechnical conditions have been interpreted in a series of reports that do not form part of the EIAR but which are referenced in Ch 20 Soils and Geology and the interpretations are summarised in a series of long sections along the alignment and cross sections for each of the stations in Volume 5 Appendices Ch 20.

The geotechnical investigations and evaluations have been carried out in line with industry best practice and are appropriate given the stage of the project. Further investigations will need to be carried out during the next phases of design development and also probably by the D&B Contractor in order to bring the investigations to a level required by the applicable standards and also to investigate in further detail geotechnical conditions at particularly sensitive locations such as the locations of the pumping sumps and sensitive buildings in AZ4 like AerCap House and the Cadenza Building.

An example of a station cross section for St. Stephens Green is shown below in Figure 3 Geological Cross Section St. Stephens Green Station (extract from A20.4), illustrating the typical ground conditions in the City Centre.

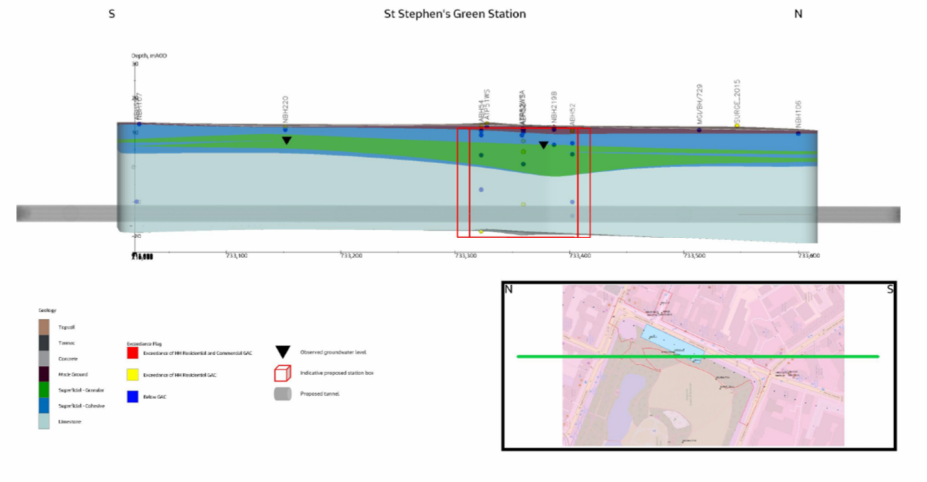

Figure 3 Geological Cross Section St. Stephens Green Station (extract from A20.4)

4.1 Assessors Comments

Several issues have arisen regarding the ground conditions during the Oral Hearing, the review of the EIAR regarding the ground conditions and from the submissions from Observers. These are addressed below:

4.1.1 Blasting

The Applicant has stated in the Construction methods for the deep stations and for the intervention tunnel at Charlemont that blasting may be used for excavation. The Applicant's approach to blasting is described in the EIAR *A5.20 Blasting Strategy.*

From a review of the rock strength data the use of blasting for excavation at the deep stations appears to be unnecessary although the Applicant states that it wants to use blasting for programme reasons and that not blasting would result in a longer construction period. If the rock strengths were very high and excavation by blasting was needed, then the rock strengths would be unlikely to be compatible with the use of diaphragm walls as the main retaining wall and groundwater cut-off solution, as the common diaphragm wall excavation equipment such as the hydro-fraise would not be effective given high rock strengths and it would require specialist types of diaphragm wall equipment.

It is normal in urban metro construction to forbid the use of blasting unless it is absolutely necessary, for instance for hard rock excavations using drill & blast techniques, as blasting, as well as causing disturbance to neighbours, may induce damage to adjacent buildings.

The Assessors and Inspectors questioned the Applicant at the Oral Hearing on Day 9 regarding the need for blasting and the Applicant stated that they wished to maintain the option of using blasting at the deep station locations. The Applicant agreed that blasting would not be used for the Intervention tunnel at Charlemont and that blasting vibrations would be limited as much as possible and their effects limited to the area covered by the Property Owner's Protection Scheme. Although it was not stated at the Oral Hearing, this commitment should also apply to the Albert College Park intervention tunnels and all the SCL works. It was understood that the Applicant had intended to apply it to all the SCL works and it is recommended that the Board applies a condition in this regard.

These commitments were captured in OH376 Final Schedule of Additional Environmental Commitments, where:

- Ref. 3.6, Charlemont Intervention tunnel, TII confirm blasting will not be used.
- Ref 3.1, Control of blasting, whilst a commitment is made to carryout trials and limit the effect of blasting, the commitment does not confirm that any effects will be limited to the zone covered by the Property Owners Protection Scheme as was stated at the Oral Hearing by the Applicant on Day 9.

The use of blasting for the deep station construction at the more sensitive locations should also be avoided despite the Applicant undertaking to limit the effects of blasting. It is recommended that the Board place a condition

on the Applicant to forbid blasting at the more sensitive locations, see Section 4.2 below.

4.1.2 Ground Conditions in Area AZ4

The issue of ground conditions and the validity of the Applicants interpretation of the ground conditions was questioned by Earldev and their consultants, AGL Consulting (S79), regarding ground conditions in the vicinity of the Arthur Cox building at 13-14 Earlsfort Terrace on Day 8 and their findings provided in OH126 to OH133. The Assessors note that a letter from Earldev was subsequently submitted at the Oral Hearing on Day 18, confirming that Earldev had reached an agreement with TII in relation to matters of concern and that they support the project.

A number of issues were raised by AGL including that some of the most relevant boreholes for this section of the alignment were not shown on the EIAR long sections and that relevant site-specific ground investigations were not included. AGL claimed that this had led to the interpretation of the ground conditions by the Applicant being incorrect and that the ground loss parameters used for the settlement predictions may also be incorrect. The Applicant responded on Day 10 of the Oral Hearing and with the submission of OH155, defending the Applicant's assessments, but not responding in detail to the AGL comments.

The Applicant further responded to this issue with the submission of OH191 and OH345 where these borehole issues were addressed. Whilst this issue was closed, as Earldev reached an agreement with the Applicant for the Arthur Cox building, it raises concerns that the Applicant had not obtained all the available existing ground investigation information and had correctly interpretated the ground conditions at particularly sensitive locations. It is expected that issues such as this will be addressed during the Detailed Design by the D&B Contractor, however it is recommended that the Expert Panel overviews the adequacy of the investigations at sensitive locations such as AerCap House and the Cadenza Building and a suitable condition is placed on the Applicant by the Board when granting the Railway Order.

4.2 Recommendations

The Applicants assessment of the ground conditions has been made in accordance with normal practice for such a large project and the risks associated with ground conditions have been satisfactorily identified and addressed.

The main issue identified in the review has been those around blasting which seems not to be required given the rock strengths identified from the geotechnical investigations.

The following conditions are recommended to be placed on the Applicant by the Assessors, in addition to those in the Final Schedule of Additional Environmental Commitments:

1) No blasting shall take place for the Sprayed Concrete Lined (SCL) works such as the construction of the Albert College Park shaft and intervention tunnels, the SCL pumping sumps, and SCL works at Dublin Airport in addition to the Applicant's commitment to not use blasting for the Charlemont Intervention tunnel construction.
2) Blasting shall not be carried out for the construction of the deep stations at:
   - Charlemont
   - St. Stephens Green
   - Tara Street
   - O'Connell St. Station
   - Mater Station
3) At other locations, the Applicant shall ensure that the effects from blasting would not extend beyond the zone covered by the Property Owners Protection Scheme.
4) The Expert Panel shall review the scope of the additional Detailed Design geotechnical investigations and the adequacy of the interpretation of them at sensitive locations. This shall include the locations where SCL works are to be carried out and where buildings that require a Phase 3 Building Damage Assessment are located.

4.3 Assessors Conclusions

With the additional conditions as specified above, the Applicants interpretations of the ground conditions and their proposals for dealing with geotechnical risks are deemed to be acceptable by the Assessors.

5 Hydrogeological Issues

The hydrogeology conditions pertaining to the project area are discussed in Chapters 19 *Hydrogeology* and 20 *Soils and Geology* of the EIAR. The Applicant has modelled the inflow into the excavations and the results of the modelling have been presented in *Appendix A19.8 Seepage Rates Assessment in Stations Executed with Cut & Cover Method (Plaxis2D Modelling).*

The issues regarding contamination of the ground and groundwater have been addressed in EIAR Chapter 20 *Soils and Geology* and also in Appendices A20.6 *Review of Potential Contamination Sources* and A20.8 *Land Contamination Interpretative Report.*

The issues regarding water disposal have been addressed by the Applicant in EIAR Chapter 18 Hydrology and in Appendix 5.11 *Water Management*.

In addition, the Applicant has prepared a document addressing the hydrogeological issues in the Tara and Swords areas, Appendix A19.11 *Hydrogeological Review for Tara Street and Swords Central*.

The issues regarding the control of groundwater were discussed at the Oral Hearing on several days, and the Applicant presented a number of documents related to the issue, the final conclusions from these exchanges at the Oral Hearings is understood to be document OH189 presented on Day 11 where the Applicant confirmed his intentions for groundwater control.

The issue of existing contamination at Dublin Airport with PFAS (perfluoroalkyl and polyfluoroalkyl substances) which are common synthetic chemicals found in many products, and in this case used in fire-fighting foams which may have leached into the soil and groundwater from fire fighting training, was raised at the Oral Hearing by Sabrina Joyce Kemper and Wild Ireland Defence CLG on day 21, OH369. The Applicant subsequently submitted a response to these issues, including a PFAS Management Strategy for Dublin Airport.

5.1 Assessors Comments

The hydrogeological impact from the works is one of the major impacts from the construction as the major structures of the MetroLink are to be constructed beneath the existing water table, and it may cause:

- Settlement and building damage, as any layers of compressible soils which may be exposed to groundwater lowering outside the station boxes and from the SCL works such as from the intervention tunnel at Charlemont and for the pumping sump construction may settle.
  The settlement risk is particularly present in Area AZ4, South of the Liffey, where the groundwater water level is near the existing ground surface and where fills may be present. The risk is also present at Glasnevin where a particularly large excavation is to be made and where the ground conditions are complex.
- Movement of contamination in the soils and groundwater, this risk is particularly present at the Dublin Airport works where there is a risk of hydrocarbons in the groundwater from aviation fuels and also from fire fighting chemicals (PFAS).
  There is also a general risk of the movement of contaminants in the ground and groundwater at all the sites where significant dewatering is to be carried out, i.e. the deep stations, intervention tunnels, and cut & cover and trough. Some of these contaminants have been identified by the Applicant, however there is always a risk of unexpected contaminated ground and groundwater being encountered.

5.1.1 Hydrogeological Background

From the information presented by the Applicant in Chapters 19 *Hydrogeology* and 20 *Soils and Geology* of the EIAR all the overlying soils and the underlying limestone appear to have significant permeability with the boulder clays having permeable beds within the sequence and superficial soils being present in many areas of the alignment. This would allow any drawdown produced by dewatering from for instance the underground stations, that would abstract groundwater from the limestone to spread and lower the groundwater level though the boulder clays and up into the superficial soils. The same mechanism would occur during the construction of the intervention tunnels and the pumping sumps in AZ4 that are to be constructed using the SCL method, if groundwater inflows were allowed to occur during construction.

It is clear that in the permanent operational phase all the structures are designed to be watertight so there are no issues regarding any permanent lowering of the groundwater. The only issue identified with regard to the permanent groundwater situation is the potential barrier effect caused by the MetroLink structures blocking the natural groundwater flows and this issue pertains only to the retained cut and cut & cover works through the Swords area. The Applicant has identified the importance of this issue and has examined its effect in EIAR Appendix A19.9 *Barrier Effect Assessment with Visual Modflow Software: Seatown-Fosterstown, Dardistown, and O'Connell St.*

The Applicant has carried out extensive hydrogeological investigations both as desk studies and site-specific investigations, these are presented in EIAR Chapter19 Hydrogeology and in Appendices 19.1 to 19.5.

The investigations are in line with normal practice but will need to be supplemented during the next phase of design development and most probably further by the D&B Contractor during the Detailed Design phase.

The superficial soils and fills in the city centre may be susceptible to settlements if significant groundwater lowering occurs and such groundwater lowering should be avoided. The Applicant has identified this risk in EIAR Chapter19 Hydrogeology.

The issues and impacts regarding hydrogeology vary along the route. These are summarised as follows:

- In the Southern part of the Area AZ4 alignment passing through the city centre and in the vicinity of the Liffey the groundwater levels are near the surface with any significant groundwater lowering outside the station boxes giving a potential risk of settlements.
- North of the city centre the terrain raises and the groundwater level is further below ground level giving less risks of settlements, however there are other issues that need to be considered such as existing water courses and the movements of existing contaminants.

- At Glasnevin a large excavation is to be constructed which will be open and needed to be pumped for a considerable period. The impact from this groundwater lowering will be substantial unless adequately mitigated by grouting or other means as the unmitigated drawdown will be large with a consequential large impact on the aquifer. This will affect existing groundwater levels which may lead to settlement and the movement of existing contamination.
- From the Northwood portal to Dardistown (AZ3) and the section from Estuary Roundabout to Dublin Airport North Portal (AZ1) that are constructed using retained cuts and cut & cover sections, there are potential impacts from the movements of existing contaminants in the groundwater and there is the impact from the long term barrier effect influencing groundwater flow from the long retaining walls through these sections of the works.
- Further North in the Section that passes underneath Dublin Airport, whilst the station is landside, part of the tunnel alignment is airside and both the station construction and the intervention tunnels give rise to a risk of moving pollutants that may be airside. Typically there are issues with hydrocarbons caused by historic leaks from the airside fuel infrastructure, together with de-icing chemicals and fire fighting chemicals (including PFAS) that may have migrated into the more permeable layers beneath the Airport.
- The sections essentially constructed at grade or elevated i.e. the Northern section of AZ1 North of Estuary Roundabout and the elevated/at grade sections of AZ3 should not have an impact on hydrogeology.

The potential for the movement of existing contaminants in the groundwater is a general risk that has to a certain extent been mitigated by the Applicant in the EIAR collecting data on existing known groundwater contamination. However, this risk cannot be completely mitigated, as not all sources of pollution are known and their extent may be uncertain. There are obvious risk areas along the alignment such as at Dublin Airport and these have been identified in EIAR Appendices *A20.6 Review of Potential Contamination Sources and A20.8 Land Contamination Interpretative Report.* It is likely that there will be other sources of pollution from for example old industries, dry cleaners and abandoned fuel tanks where mobile pollutants may have percolated to some depth in the aquifers. This is a common risk and problem in the construction of urban metros that can give rise to unforeseen contaminated spoil from the excavations and from contaminated groundwater that needs to be treated prior to disposal. These contaminants can percolate to the depth of the TBM tunnel giving rise to Working Heath issues and problems with the disposal of the TBM spoil which was assumed to be “clean” unpolluted soil.

There are also common risks from groundwater lowering along the alignment such as adversely affecting wetlands, springs, wells and other

groundwater abstractions both public and private. Groundwater lowering may also adversely affect groundwater quality and not all wells and abstractions may be mapped and registered.

The main impacts are discussed below together with the Applicants mitigating measures.

5.1.2 Groundwater Dewatering

The Applicant describes the impact of the dewatering from the construction in EIAR Chapter 19 Hydrogeology and has predictions of the amounts of groundwater to be abstracted in Appendix A19.8 *Seepage Rates Assessment in Stations Executed with Cut & Cover Method (Plaxis2D Modelling)*.

Appendix A19.8 presents predicted abstraction rates for the structures with two hypotheses for the groundwater cutoff measures:

- Extending the retaining walls to a reasonable depth below the base of the excavation, within a range from 4m to 7m.
- Incorporating bottom plugs generated with the Jet-Grouting technique in soils or the rock fracture sealing injection technique.

The predictions have been made using a 2D model and the PLAXIS software, which whilst a common method does not take into account three dimensional effects and does not take into account any interaction between the sites.

It is noted that no predictions of the groundwater inflows from the SCL construction works such as those for the Charlemont intervention tunnel, the Albert College Park shaft and intervention tunnel, the caverns/shafts at Dublin Airport and SCL pumping sumps in Area AZ4 introduced during the Oral Hearing have been made by the Applicant.

The model predictions that have been made appear to use reasonable permeability values which have been validated by pumping tests where available. They do not, however, use a range of values and do not consider what could be likely “Worst Case” permeabilities, and the risk of abstraction rates exceeding the predicted rates. It is noted that the Applicant has carried out a desk study looking at previous dewatering projects in Dublin, experience and abstraction rates, and this is reported in EIAR Appendix A19.6 *Historical Inflows*. However, there is little experience of such deep excavations in Dublin as the previous deep basement construction projects are not as deep as the proposed metro stations. The two hypotheses considered in the modelling have a number of assumptions associated with them, these include:

- The hypothesis without a grout plug uses a range of retaining wall embedment depths, i.e. length of wall below excavation depth of between 4m and 7 m. These assumptions have not been fully

implemented in other documents for instance Chapter 19 *Hydrogeology* Table 19.38 indicates toe grouting of 1.5 m. It is thus not clear that the predicted abstraction rates will be achieved.

- The hypothesis of the grout plug uses an assumption of a permeability of the base plug (K) of $1x10^{-8}$ m/s which in the Assessors experience is one or two orders of magnitude lower than could be expected from fissure grouting in such weak rocks, i.e. limestone which are the predominant material where the base of the excavations will be located. The predictions using the base plug hypothesis are therefore not considered as a reliable estimate of the groundwater inflow rates.

The Applicant has presented the expected groundwater abstraction rates for the stations in EIAR Chapter 19 Table 19.23, which shows typical abstraction rates for the deep station in AZ4 such as Charlemont of approximately 200 m^3/day and 600 m^3/day for Glasnevin. Dublin Airport shows a predicted abstraction rate of 32 m^3/day. These abstraction rates are consistent with the predictions given in *Appendix A19.8 Seepage Rates Assessment in Stations Executed with Cut & Cover Method (Plaxis2D Modelling)* for the hypothesis without a grouted plug.

In other documents significantly different abstraction rates are quoted, for example in EIAR Appendix 5.11 *Water Management* a rate of 43m^3/day is stated for the deep stations (section 4.2.6 Dewatering).

There is therefore uncertainty from the Applicant regarding how dewatering abstractions will be controlled and what flow rates are to be expected. It is clear that the values proposed for the inflows in the EIAR Chapter 19 Table 19.23 do not assume a grouted base plug will be used and this assumption is not consistent with the Applicant's statements and Commitments that no groundwater lowering will occur outside the station boxes.

The Assessors have made recommendations to the Board for addressing this issue in Section 5.2 below.

5.1.3 Discharge of Dewatering Water

The Applicant has taken the approach of discharging the dewatering water to the sewer system and not discharging to adjacent water courses. The issues regarding groundwater disposal have been addressed by the Applicant in EIAR Chapters 5 *MetroLink Construction Phase* and 18 *Hydrology* and in Appendix 5.11 *Water Management*.

It is typical on such major infrastructure projects to keep the dewatering groundwater flows separate from general site drainage water, as the dewatering groundwater is essentially clean water, and to discharge it into suitable watercourses and surface recipients after treatment. The treatment would include removal of sediment and iron, correction of pH and, if the groundwater is contaminated, treatment with carbon filters. This reduces the additional load on the sewer system.

EIAR Appendix 5.11 *Water Management* provides a list of the available sewers (Table 3.1).

The Assessors understand that the Applicant will be required to enter into a connection agreement with Uisce Éireann, the water utility company, regarding the available capacity in the sewers and the proposed discharge of water to these sewers and any issues regarding discharges such as allowable discharge rates and pre-treatment requirements will be dealt with in the consenting process with Uisce Éireann.

5.1.4 Oral Hearing

The Applicant's approach to dewatering and particularly the measures they propose for cutting off the groundwater inflows was discussed at the Oral Hearing on Days 4, 8 & 10, and the Applicant presented additional documents, OH92, 75, 172, 189 regarding the groundwater issues. On day 8 the Applicant was questioned regarding the dewatering approach and Applicant (Mr. Jose Antonio Aparicio Redondo from Jacobs Idom) responded to the issues and presented OH172 on Day 10. The issue was first asked regarding Glasnevin Station due to the large excavation and the high rate of abstraction at this site. It was also raised by the Inspectors as a general issue as to whether the Applicant was intending to use a grout plug at the base of the excavations or a grout curtain formed by toe grouting. The responses from Applicant were not clear and there was some confusion regarding what type of grouting was to be used, jet grouting or fissure grouting. The Applicant presented OH172 which presented a different basis for justifying that the abstraction rates would be 0.5l/s (43 m^3/day) stating that toe grouting would be used and different cut-off depths than those stated in Chapter19 *Hydrogeology* and *Appendix A19.8* of the EIAR. The document further states that a pumping test will be carried out after construction of the diaphragm wall and toe grouting. If too large abstraction rates are found then the Applicant stated that a grout plug will be implemented.

The Assessors have concerns that if a grout plug needed to be implemented at that time, and that if these works had not been included in the time schedule, then it could have a major consequence on the construction programme. Such a grout plug at a deep station taking probably one year to implement.

The Applicant's document OH172 was subsequently updated to V2 and submitted as OH189 on Day 11. The document includes amendments to the V1 document, it removed reference to the 43m^3/day abstraction rate and reconfirmed that there would be no drawdown outside the station boxes. It also provided further arguments for the fissure grouting at the base of the excavation. The document also contains a description of how the groundwater will be managed for the construction of the Charlemont intervention tunnel using probe drilling and fissure grouting. The methods

described are in line with good practice, however no target was set for the inflow and the consequent effects evaluated. It is also noted that the methods described are not incorporated into the mitigations committed to by the Applicant, i.e. the Final Schedule of Additional Environmental Commitments, OH376.

The Assessors were left after the Oral Hearing still with the uncertainties remaining as to how the Applicant would achieve the stated abstraction rates and what approach would be adopted, curtain grouting (toe grouting) or a grout plug.

The Assessors have made recommendations to the Board for addressing this issue in Section 5.2 below.

5.1.5 Benchmarking with the Copenhagen Metro

The Copenhagen metro represents a similar project to the MetroLink and is constructed in similar ground and groundwater conditions, with glacial soils overlying limestones.

From the Applicants submissions it is understood that whilst the Applicant has considered the use of groundwater recharge, they are not intending to carryout recharge of the abstracted groundwater. However, in Section 19.5.3.4.5 of the EIAR it is stated that:

The actual technique used during the Construction Phase will be refined based on the results of further ground investigation and assessments. However, design for the RO will entail the use of a deep well dewatering system including periphery wells for groundwater level monitoring and for use in stabilizing of levels as required i.e. where approved [geotechnical based] recharge to ground is employed.

The Applicant also refers in Chapter 19 Section 19.5.3.5.1 of the EIAR to studies carried for the Metro North where the use of recharge was considered but not deemed to be necessary.

The above suggests a lack of clarity by the Applicant regarding the groundwater control measures and specifically if groundwater recharge needs to be applied.

Groundwater recharge is sometimes considered as complex/difficult and has been applied on relatively few metro projects around the world. It has however been applied on the Copenhagen metro since the construction of the first phase in the late nineties and through to the just completed Sydhaven Extension.

In Copenhagen strict controls are applied to any groundwater lowering with a requirement that in the City centre any lowering shall not exceed the normal seasonal variation in groundwater level. This has proved to be successful in controlling the risks from groundwater lowering and managing potential claims from groundwater lowering induced building damage, as

staying within the seasonal variation essentially means that the project is having no effect and therefore cannot be blamed for any building damage.

The recharge in Copenhagen is also used to limit the movement of contamination in the groundwater, thus minimising the impact from the project.

The Copenhagen ground conditions are very similar to those in Dublin and it is likely that groundwater recharge could be successfully used in Dublin, if it is needed.

5.1.6 Dewatering Related Settlement & Building Damage

The issues related to settlement and building damage that are related to dewatering have been addressed in EIAR Appendix A5.17, Section 4.7 where it is stated that:

No external dewatering (outside of the site boundaries) will be permitted during the construction of the station boxes, that increases the impact due to settlement on others, beyond the natural ground water fluctuation. Any settlement due to the short-term lowering of the water table outside of the station box will therefore be constrained to within the site boundaries. Similarly, no dewatering outside the cut and cover tunnel sections or other retained cuttings will be permitted that increases the impact due to settlement on others.

The documents submitted by the Applicant as part of the Oral Hearing, OH172 and OH189, make similar statements that there will be no drawdown outside the station boxes.

As a consequence of assuming no drawdown outside the station boxes Appendix A5.17 makes no assessment of any groundwater lowering on settlement and building damage.

However, in EIAR Chapter 19 *Hydrogeology* the Zone of Influence (ZOI) from the dewatering at the deep stations is identified as extending up to 200 m, (Table 19.22) i.e. a radius of approximately 200 m from the station where drawdown is predicted to occur. The statements in Appendix A5.17, OH172 and OH189 therefore appear to be in contradiction with the Applicant's predictions and models of the groundwater lowering.

One of the measures proposed by the Applicant to manage the risk of settlement and Building Damage, is the Property Owners Protection Scheme. (POPS) This was submitted at the Oral Hearing on Day 1, OH5 and was subsequently updated on Day 11 OH186 and OH187. The POPS scheme covers an area of 50m from the station boxes and 30m from the tunnel. It therefore does not cover the predicted Zone of Influence from the deep station dewatering and from any groundwater lowering from the SCL works, the Charlemont Intervention tunnel, Albert College Park and pump sumps. However, as the Applicant has confirmed during the Oral Hearing

that no groundwater lowering will occur outside the construction works then the Zone of Influence will not be relevant and settlement/building damage should not occur from groundwater lowering.

The Assessors have made recommendations to the Board for addressing this issue in Section 5.2 below.

5.1.7 Barrier Effect

The ‘barrier effect’ from the metro construction blocking the natural flow of groundwater and causing a potential mounding of groundwater upstream of the structures is a consideration at the station sites and particularly for the retained cut section through Section AZ1. It was also raised on Day 3 of the Oral Hearings in response to concerns from Observers regarding the potential for a barrier effect from the construction of Collins Avenue Station. The Applicant has considered the barrier effect and prepared a document, Appendix A19.11 *Hydrogeological Review for Tara Street and Swords Central*, addressing the issue in the Swords area.

The issue has been the subject of several Observers submissions, such as in the Seatown & Swords area in S14 where the Applicant has responded that drainage below the retained cut section will be incorporated into the design. This in the Assessors view is quite a normal approach and will be able to satisfactorily deal with the barrier risk if they are designed in accordance with good practice.

Concerns were raised by Estuary Court with S89, regarding the project increasing groundwater levels and increasing the flooding risk. The Applicant has responded to these concerns and stated that the drainage issues will be dealt with in the detailed design but they do not see any concerning issues with regard to the drainage and flooding risk. The Assessors find this response acceptable and do not see any issues that cannot be solved in the detailed design.

5.1.8 Dublin Airport Contamination

Groundwater lowering will be required for the construction of the Dublin Airport station box and the associated construction of the intervention tunnels, chambers and shafts. The airside airport area is understood to have experienced historic contamination, associated with a variety of pollutants including hydrocarbons and PFAS compounds that were highlighted by Ms Joyce Kemper/ Wild Ireland Defence on Day 21 OH369. It therefore prudent for the Applicant to reduce the volumes of abstracted water from the dewatering to as low as reasonably possible in order to reduce the risk of spreading contaminants in the ground and groundwater.

The Assessors have made recommendations to the Board for addressing this issue in Section 5.2 below.

5.2 Assessors Recommendations

From the review of the Applicant's EIAR documents related to hydrogeology and further to questioning of the Applicant at the Oral Hearing, which included the submission of additional documents on the issue, it is clear that there is contradictory information in the documents and some uncertainty in the Applicants intentions regarding dewatering and groundwater lowering. In particular:

- The assumptions made in the predictions of the abstraction rates such as the depth of the cut-off walls and toe grouting.
- The abstraction rates used in the assessments.
- The practicality of the contingency measures stated, i.e. implementation of a grout plug if abstraction rates exceed the predictions.
- The measures intended to control groundwater ingress for the SCL works, i.e. the Charlemont Intervention tunnel, Albert College Park intervention tunnel and the AZ4 pump sumps.
- The handling of the settlement and Building risk associated with groundwater lowering.
- The lack of coverage of the Zone of Influence by the POPs scheme.
- Whilst many good statements are made in the various documents clear requirements are not captured in the "Final Schedule of Additional Environmental Commitments" regarding groundwater lowering.

It is understood that the Applicant's final confirmation of their intentions regarding groundwater was given on Day 11 in document OH189, titled "*Supplemental Note: Dewatering Assessment in Station Boxes and SCL Tunnels (Version 2)* dated 06/03/2024" where the Applicant confirmed that:

For the deep stations, Section 1 states that "*Lowering of the water table will not take place outside of the station boxes*."

In the Assessors opinion it is likely that this statement will require that the Applicant carries out a grout blanket beneath the station base rather than toe grouting as has been implied in the EIAR Chapter 19 Appendix A19.8.

Document OH189 also states the Applicant's intentions regarding the Charlemont Intervention tunnel, it does not however describe the Applicant's intentions regarding the Albert College Park intervention tunnel/SCL works and the pumping sumps in Area AZ4. Section 1.4 of the document (OH189) states that "*Rock mass fissure grouting will be conducted ahead of the face of the tunnel excavation within rock for two main targets, firstly reduce water ingress and in consequence prevent dewatering. This approach will prevent any requirement for dewatering and hence the potential for water table lowering outside of any of the planned intervention tunnels."*

It is therefore recommended that the Board places conditions on the Applicant as follows:

1. The Applicant shall take such measures that are necessary for controlling groundwater dewatering from the deep station construction that ensures that no groundwater lowering shall occur outside the station boxes as stated by the Applicant in OH189. This requirement shall be applied to all deep stations.
2. The Applicant shall take such measures that are necessary for controlling the groundwater dewatering from the Sprayed Concrete Lining works (e.g. Charlemont Intervention tunnel, Albert College Park intervention tunnel and Area AZ4 pumping sumps), to ensure that No groundwater lowering occurs as stated by the Applicant in OH189.
3. The definition of No groundwater lowering shall be that no lowering occurs outside the normal seasonal variation of groundwater levels as determined by at least 1 year of pre-excavation monitoring.
4. The Applicant's Expert Panel as described in OH26 document title Ground Movement Monitoring Information Paper ML1-JAI-COM-ROUT_XX-PL-Z-00001| P03.1 dated 2024/02/12 shall review and approve the groundwater control measures to be adopted by the Applicant's Contractor prior to implementation.
5. The Expert Panel shall follow the execution and monitoring of the groundwater control works and shall have the power to instruct the Applicant to carry out any additional measures the Expert Panel requires to ensure that No Dewatering occurs outside the station boxes and SCL works.
6. The Applicant shall implement groundwater control measures to limit the abstraction at Dublin Airport Station and associated tunnels, caverns and shafts to a maximum of 32m^3/day and implement the measures set out in the PFAS Management Strategy for Dublin Airport, submitted to the Board on the 31st January 2025.

5.3 Conclusions

With the imposition of the recommended conditions, as described above, the Assessors conclude that the groundwater control measures and dewatering are acceptable.

6 Building Damage & settlement

The impact from and the risk of damage to buildings from settlement due to the station, shaft and tunnel construction is one of the largest potential impacts from the MetroLink construction and the Applicant has primarily addressed it in EIAR Appendix A5.17 *Building Damage Report*.

6.1 The Applicants Approach

The settlement and building damage issue has been an issue of concern for a broad range of Observers along much of the City tunnel (AZ4) alignment and has been the subject of both written submissions and further submissions being made at the Oral Hearing. The Applicant's written responses largely comprised a restatement of information given within the EIAR and, in the Assessors opinion, the Applicant have in general not engaged well with the Observers regarding this issue.

Oral Hearing responses again largely comprised restatement of information given in the consultation responses and within the EIAR. However, over the course of questioning by the Inspectors and the Assessors, they issued a number of new or revised documents to further address the building damage issue and have confirmed a number of additional commitments in the *Final Schedule of Additional Environmental Commitment*s (OH 376) on Day 21. Additional documents issued during the Oral Hearings include:

- OH26, Ground Movement Monitoring Information Paper
- OH175, Risk Management Plan – Trigger Action Plan (TAP)
- OH182, Methodology used for assessment of the likely significant effects on building from ground movement and settlement
- OH276, Draft Trigger Action Plan
- OH316 Building Desk Study

The Applicant has, in addition to the measures in the EIAR, also proposed a scheme for addressing building damage to nearby residential properties by defining a Property Owners Protection scheme (POPS) as there will be some but limited damage, usually of a cosmetic nature. The POPS was not incorporated into the EIAR and was submitted to the Board on Day 1 of the Oral Hearing as OH5. It was later updated during the Oral Hearing as OH187 & OH188 on Day 11. The report addresses the POPS Scheme in Section 6.3 below.

Building risk arises from settlement caused by ground relaxation and ground loss from the construction activities, where for instance excavation from the tunnel construction causes the volume of material removed from the excavation to be greater than the theoretical volume:

For the deep stations, cut and cover tunnels and retained cuts, it arises from:

- The retaining wall installation works. When the secant piles or diaphragm walls are installed, excess soil can be removed which may lead to settlement or vibration, particularly from secant pile installation. This is normally confined to a limited distance from the retaining wall installation works, i.e. around 10 m, but this cause of settlement can be one of the largest causes of building risk if existing buildings are very

near to the retaining walls. This is normally predicted based on experience.

- Deflection of the retaining walls from earth and soil loads on the retaining walls and displacement of the toe of the wall. It is dependent on the excavation depth, the soil stiffness and the propping system and is normally predicted using empirical methods from curves defined in CIRIA 760.
  For the deep stations of the MetroLink these settlements will be small as the Applicant has committed to a “top down” construction sequence, where the permanent roof slab of the station is constructed prior to excavation. This is illustrated in the EIAR Chapter 5 Figure 5.25 shown below.

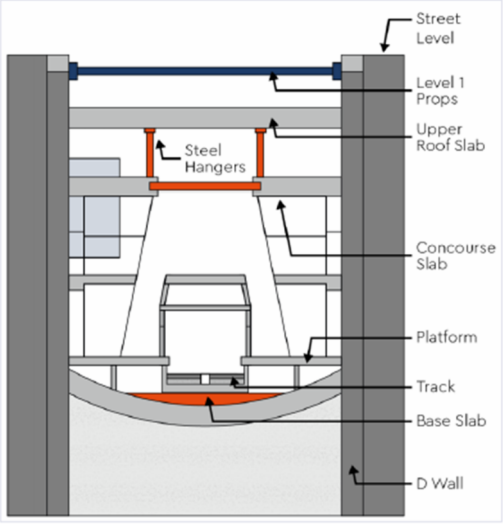

Figure 4 Typical Deep Station illustrating permanent and temporary propping (extract from Chapter 5 Fig 5.25)

This results in a relatively stiff retaining wall system and, as the soils are predominantly stiff, low settlement should be experienced from the deep station excavations. However, this is not a commitment by the Applicant in the cut & cover and retained cut sections of the tunnel and there may therefore be larger excavation induced settlements in these areas. Settlement may also be caused by groundwater lowering, where the effective stress is increased due to the groundwater lowering, or there may be settlements induced by the compression of organic soils. These issues are dealt with in Section 5 Hydrogeology above.

The phased approach used by the Applicant for dealing with building damage risk is in line with normal practice for such a metro project where three stages are used. This approach was developed and first used for the construction of the London Underground Jubilee Line Extension project in early nineties and has been extensively used since. It has been used for instance on all phases of the Copenhagen metro since the first phase of construction in the late nineties and most recently on the Crossrail project in London. It comprises of the following phases:

- **Phase 1** defines the buildings that could be potentially impacted by the project. It involves the calculation of the greenfield settlement contours using ground model parameters derived from published case history data and ground investigation work undertaken and the identification of buildings that are:
    - enclosed within the 10mm contour or with a ground settlement slope > 1 in 500, and
    - enclosed within the 1mm contour and subject to 'special' considerations. E.g., Designated Protected Structures, or prominent or sensitive buildings.
- **Phase 2** involves the classification of the buildings into pre-defined risk categories based on the predicted maximum tensile strain that would be experienced by the building if it deformed to the predicted greenfield settlement profile. Those buildings that fall into a damage category of 3 or greater, and those subject to "special" considerations are carried through to Phase 3.
- **Phase 3** involves the individual detailed assessment of each identified building, to determine its behaviour using detailed information and more sophisticated assessment methods. From the Phase 3 assessment the need for protection measures will be determined in order to protect the building from an unacceptable level of damage.

For the tunnels, the normally applied volume loss approach has been applied to determine the Phase 1 Greenfield settlements and the Phase 2a assessments, using relatively conservative parameters. The volume loss approach is described in the EIAR Chapter 4.2 where a volume loss of a percentage of the theoretical volume of excavation which is typically 0.5 to 2%. This volume is distributed with a gaussian distribution to provide a settlement trough and give a surface settlement, slope and horizontal strain. The settlements may be summarised as follows.

- The TBM constructed tunnels, i.e. the AZ4 City Tunnel and AZ2 Airport Tunnel, give rise to settlements of the order of 30 mm above the tunnel and the risk of higher than expected settlements is low, subject to appropriate TBM specification and control measures being implemented. There is however a risk of higher than expected settlement if the tunnelling operations are not correctly controlled. There are also larger risks associated with the TBM entering and exiting the deep stations and when interventions are carried out, which is required in order to maintain the cutting tools and cutter head.
- For the intervention tunnels constructed using the Sprayed Concrete Lining (SCL) method, the Applicant has used the same approach as for the TBM tunnels, however; they have increased the volume loss used in the predictions by 50% in order to cover the different technique and uncertainties.

The three phases described above are normally split across the project life cycle and between the parties, particularly so when the final Detailed Design is to be carried out by the Design & Build Contractor.

With the Applicant carrying out the Preliminary Designer role for the EIAR in this instance, they have undertaken the Phase 1 and an initial Phase 2 (termed as Phase 2a) Building Damage Assessment. The appointed D&B Contractor will review and update the Phase 2a Building Damage Assessment, designated Phase 2b, taking account of any changes to the project and the latest information. This will determine which buildings should be progressed to Phase 3 and will then carry out the Phase 3 Assessment.

The Applicant has, as part of the building damage risk management approach, carried out a review of the alignment to identify buildings that could be impacted by MetroLink subsurface construction and would be considered typical of their type. This review identified 219 typical buildings, hereafter referred to as “representative” buildings. The Applicant’s building survey also identified “special” buildings, defined as buildings in proximity to the excavation, with deep basements, or those identified as Protected Structures or sensitive buildings.

EIAR Appendix A15.7 *Building Damage Report* contains a list of the “representative” and “special” buildings, together with their assessed damage category according to the categories developed by Professor Burland et. Al. (1977), as reproduced below, and also the predicted greenfield settlements. Updates to Appendix A15.7 were also submitted at the oral hearing to correct errata and missing buildings.

Table 3 Damage Categories (extract from Chp. 5 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 Buildings**	**Approx. Crack Width (mm)**	**Limiting Max Tensile Strength (%)**	**Max. Slope of Ground**	**Max. 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 repointing may be required	1 to 5	0.075 to 0.15	1:500 to 1:200	10 to 50

		for weather tightness. Doors and windows may stick slightly				
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	0.15 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

The Applicant also produced a set of drawings showing the Greenfield settlement predictions as contour plots within Appendix A5.17 and these were updated a number of times during the Oral Hearing, as OH78 on Day 5 finally as OH300 on Day 18. An extract from a typical section of the alignment is shown in Figure 5.

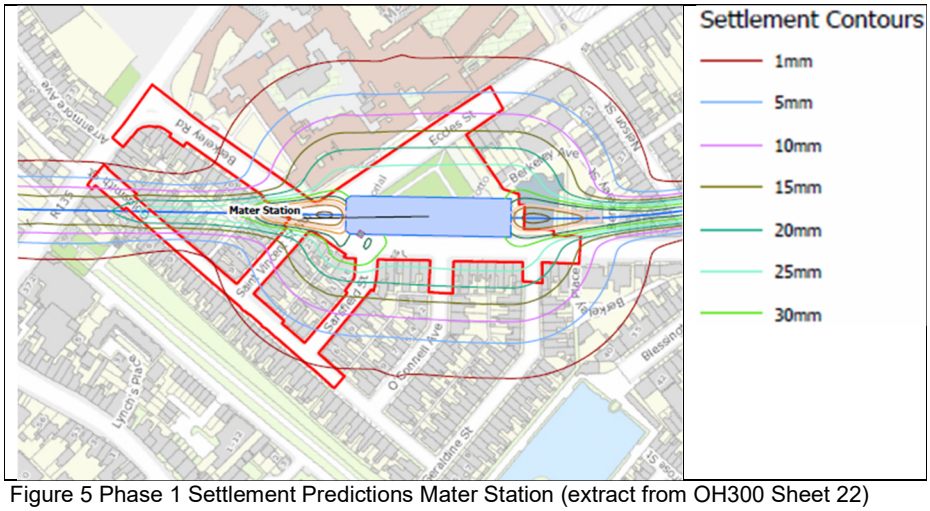

Figure 5 Phase 1 Settlement Predictions Mater Station (extract from OH300 Sheet 22)

The typical settlements derived from the Phase 1 Greenfield settlement predictions above the main tunnel are in the range of approximately 30 mm and at the ends of deep stations approximately 40 mm.

For the example of Mater Station shown in Figure 5 above, it indicates approximately 40 mm settlement for St. Joseph's Church (building denoted B-101 in A5.17) at the Southern end of the box and 30 mm at the corner of the Mater Hospital building at the Northern end of the box. The Applicant has committed that appropriate measures will be put into place for the entry and exit of the TBMs through the deep stations such as Mater and has addressed this in OH116 submitted on Day 8 with a generic note describing the Applicant's intentions for the break-in and break-out of stations boxes. However, it is likely that St. Joseph's Church, which is just above the break-out of the Mater Station box and thus sensitive to any ground losses caused by the break-out and ensuing settlement, will need some careful consideration. It is likely that tailored mitigation measures will need to be put into place to ensure that no building damage beyond Category 1 is caused.

Settlements along the remainder of Area AZ4 are similar and are typically 30 mm above the tunnel. It is noted that the Applicant states that the Greenfield settlements are conservative and have been derived from conservative assumptions of volume loss from the tunnelling. This is standard engineering practice, and it can be expected that settlements significantly less than the Greenfield predictions will be achieved in practice. However it should be acknowledged that if the settlements resulting from the tunnelling works are of the magnitude predicted at this stage (Phase 1), then it is likely that damage beyond the cosmetic/aesthetic category i.e. Damage Category 1 will be caused and this magnitude of settlement will pose a challenge for the protection of sensitive buildings, including sensitive commercial buildings that were discussed at the Oral Hearing, e.g.. AerCap House and the Cadenza Building. The Applicant will need to ensure that the Civil Works contractor carries out the tunnelling operations creating significantly less settlement than the conservative Greenfield predictions show. Recommendations to the Board regarding these matters are included in Section 6.6 , Section 7 and Section 14 .

6.2 Submissions Regarding Building Risk

Many of the Third Parties made submissions regarding the risk of building damage, including both commercial and residential property owners.

For instance on Day 2 of the Oral Hearing Senator Marie Sherlock raised the general issues of settlement, building damage and the Property Owner's Protection Scheme (POPS) in her witness statement with the Applicant responding and describing what their intentions were, essentially

restating what was described in the EIAR but not providing any new information regarding the issue.

Examples of the submissions from commercial properties are from Irish Life Assurance PLC (S129-132, OH139-146 and OH283-287), Hines Real Estate Ireland Limited (S117, OH136-138 and OH279-282) and Wynn's Hotel (S317 and OH102). These written and oral submissions included engineering and other specialist inputs.

It is understood that the Applicant reached agreement with many of the commercial property owners, however there were several not agreed at the time of the Oral Hearing, such as Hines Real Estate Ireland, Irish Life Assurance PLC and Wynns Hotel. Two submissions are discussed in detail in the Tunnelling section 10.6 of this report, S117 (Hines Real Estate Ireland) and S129 (Irish Life Assurance PLC) as these have had an impact on the tunnel alignment. These submissions were also supported by detailed engineering assessments by independent consulting engineers and detailed presentations regarding these two submissions were made at the Oral Hearing.

Also, no agreement was reached between the parties regarding the Carrolls Building at Charlemont, which is covered by S305 submitted by Union Investment Real Estate GmbH.

Examples of Submissions from residential property owners are S40-42 from the Charlemont and Dartmouth Community Group. Other Observers also made submissions regarding settlement/building damage risk, such as Louise Boughton and Glenn Sharpe (S173, OH62-65 and OH220) who expressed concerns regarding settlement and the construction of the Albert College Park Intervention Shaft.

6.2.1 The Office of Public Works (OPW)

The Office of Public Works (OPW) made a number of submissions (S213-240) covering the main heritage buildings they are responsible for that are potentially affected by the MetroLink. These submissions include heritage buildings in AZ4 such as Leinster House, the National Gallery and other buildings which are some of the most important buildings in Dublin. The submissions were very detailed covering comments on the building risk assessments carried out by the Applicant and the monitoring requirements. The Submissions were in some instances supported by work from the tunnelling specialist Gall Zeidler Consultants, a leading Austrian tunnelling consultant.

It is noted that the Applicant has reached an agreement with the OPW regarding the publicly owned heritage assets above the alignment, with the exception of St. Stephens Green park.

The agreement between the Applicant and the OPW is documented in OH73 and contains a list of conditions and clarifications agreed between

the parties pertaining to settlement and building damage. Commitments given to the OPW include the requirements for the Applicant to agree with the OPW the criteria and methodologies they will use for the Building Damage Assessments and to provide two additional phases of the assessment. A Stage (Phase) 4 where all surveys, monitoring and mitigation measures to be adopted are agreed with the OPW and a close out Stage (Phase) 5, where all data is reported together with any repairs which are to be carried out to the satisfaction of OPW. The Applicant is also required to agree the instrumentation and monitoring with the OPW.

6.2.1.1 Assessors Recommendations

The agreement reached between the Applicant and the OPW for the heritage buildings is considered to represent normal best practice in dealing with heritage buildings and it is anticipated that the OPW will have the support during the MetroLink works of a tunnelling specialist such as they had during the consultation process. It is therefore recommended that the following additional condition is applied to the heritage buildings that the OPW is responsible for:

1. That the Expert Panel provides detailed scrutiny of the building risk measures and monitoring for all OPW heritage buildings and that the Expert Panel “signs off” on such measures.

6.2.2 Charlemont Settlement

A combined presentation was made at the Oral Hearing on Day 9 by the Charlemont and Dartmouth Community Group and their consultants, covering soils and hydrogeology, settlement and noise & vibration (OH151-153). The community group was represented by McCabe Durney Barnes Planning Consultants (Jerry Barnes), Garland Consulting Engineers (Brian Kavanagh), Gavin and Doherty Geotech Solutions (Paul Quigley) and Malone O’Regan Consulting Engineers (Kenneth Goodwin).

Concerns were raised regarding Soils and Hydrogeology and settlement, particularly for the houses located in Dartmouth Square West, Cambridge Terrace and Dartmouth Road.

These properties are located adjacent to the proposed Charlemont Station, where they will be influenced by the station box construction and a shallow extension of the box. The greenfield settlement prediction given on drawing No. ML1-JAI-EIA-ROUT_XX-DR-Y-21147 (OH300) indicates (also shown in Figure 5) that the residential properties on Dartmouth Square West are close to the station box and have predicted settlements of approximately 20-30 mm which may cause some damage beyond cosmetic damage as a result.

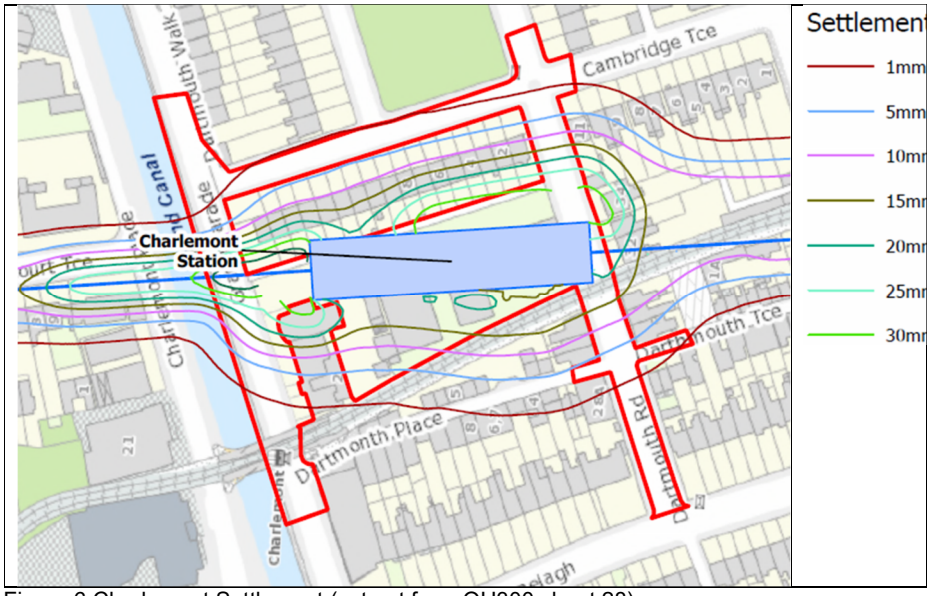

Figure 6 Charlemont Settlement (extract from OH300 sheet 28)

Mr. Paul Quigley and Mr. Brian Kavanagh gave presentations on their review of the Applicants documents, focusing on two themes covering the Dartmouth Square West properties: Building damage and hydrogeology. Mr. Quigley expressed the view that the Applicants strategy for the handling of geotechnical risks was inadequate given the stage of the project and that excessively high settlements are predicted and are not adequately mitigated. Mr Quigley also expressed concern regarding the Applicants approach to building damage risk, that results in the detailed assessments not being carried out until late in the process by the D&B Contractor which is essentially shortly before construction commences.

Mr. Quigley expressed concern that not all the information has been made available to observers, such as the Geotechnical Interpretative Report that is referenced in the EIAR but not included in the documents made available by the Applicant.

Technical concerns were also expressed regarding the Phase 1 and Phase 2a Building Assessments carried out and documented in EIAR Appendix A5.17 and the possible effects from dewatering induced settlements on the buildings.

The main concern expressed was understood to be that, if the Board approves the Railway Order on the present basis, i.e. the predicted settlement, it will allow the Applicant to cause significant damage to buildings on Dartmouth Square West and Dartmouth Road, which would be unacceptable to the owners of the properties.

The Applicant's response to Mr. Quigley was essentially to restate their approach to building damage and that the detailed assessments (Phase 3) would be undertaken by the D&B Contractor after award of the main Civil Works contracts. The Applicant did not submit to the Board an Enhanced

Building Assessment for this area as he had done for AerCap House and the Cadenza Building (OH273 to 275) and provided no explanation as to why he was not doing so. The Applicant could have provided these Enhanced Phase 2a Assessments to reassure the Charlemont/Dartmouth Square residents which may have resolved the issue.

As a result, some of the Charlemont/Dartmouth Square residents made further submissions during the 2nd Consultation. The Applicant responded to these submissions, where in Section 4.2.4.9.2 of the response document, settlement, they responded to the comments from Brian Kavanagh, that the predicted ground settlement (up to 30mm) could severely damage the Victorian 3-storey brickwork houses. The Applicant responded that:

the Phase 2a assessment, which utilises conservative parameters, shows that the expected damage falls into the "Slight" category for the properties on Dartmouth Square West. This classification implies that any cracks are minor, in the range of 1 to 5 mm crack width, these are cosmetic are not structural and can easily be filled, with some redecoration likely needed

The "Slight" damage Category, is damage Category 2 according to the building damage classification (see 6.1 above) which is higher than would normally be accepted and many projects make provisions to keep damage to Category 1 or less, i.e. "very slight".

6.2.2.1 Assessors Recommendations

The Assessors have reviewed the documents submitted by the Charlemont and Dartmouth Community Group regarding settlement and building damage and the Applicant's responses. The Applicant has clarified the situation in the further submissions response document, where they state that the damage will be limited to "Slight" i.e. Category 2. This is however greater damage than cosmetic damage, which should be avoided. The Assessors have made recommendations to the Board regarding this issue in Section 6.6 .

6.2.3 Carrolls Building

The Carolls Building is located immediately next to Charlemont station at 2 Grand Parade and MetroLink enabling/accommodation works have been constructed, with secant pile walls and a transfer slab constructed as part of an extension of the Carrolls Building. The original Carrolls Building is a protected structure and the building owners Union Investments have made a submission to the Board regarding the impact of the Charlemont station construction on the building as submission S305. The submission raises a series of objections to the scheme regarding how the scheme impacts the Carrolls Building during construction and a series of objections regarding permanent and temporary land take by the Applicant in order to develop the

scheme. The submission also raises objections regarding landscape, the architectural design of the Charlemont Station and fire safety.

The land take, architectural, landscape and fire safety issues will not be commented on in this Assessment. The submission also raises concerns regarding noise and vibration both during construction and during operations and raised particular concerns regarding the use of blasting. The issue of blasting is addressed in Section 4.1.1 and it is recommended that the Board imposes a condition on the Applicant that blasting is not permitted at the city centre stations such as Charlemont. Other noise and vibration aspects are dealt with in Section 13 .

Also raised in the submission are issues regarding settlement and the consultants for the building owner state that protection measures may need to be put in place for the Carrolls building.

6.2.3.1 Assessors Recommendations

Whilst the new 2 Grand Parade building should not be affected significantly by settlement, the older Carrolls Building will need careful consideration during the Phase 3 Building Assessment and may need protection works to be put in place. It is recommended that the Phase 3 Building Assessment should have the involvement of the Expert Panel and be “signed off” by them.

6.2.4 Glasnevin Area

Concerns have been raised regarding settlement in the area surrounding Glasnevin Station and the tunnel in the Glasnevin area, these include Anne Confrey S12, Anne G Meehan S13 + OH83, Lesley Hewson S168 + OH81, Dympna Rooney S75 + OH82, Lorraine Rooney S171 + OH82, Marie McMahon S180 and the Prospect Architectural Conservation Area S260.

The submissions are quite general stating that the houses in the area are mid Victorian and may be poorly founded with several complaints regarding the Applicant not engaging with the Third Parties and concerns regarding traffic management, noise and vibrations.

The Applicant has responded to these submissions stating that what the Applicant intentions are for the various mitigation measures. The Applicant identified only a small number of buildings in Appendix A5.17 that will fall into the sight Build Damage Category 2. As per our analysis of Charlemont above, we make recommendations in Section 6.6 below regarding this matter.

6.3 Property Owners Protection Scheme

The Applicant has proposed a scheme for addressing the risk of building damage to nearby residential properties, by defining a Property Owners

Protection Scheme (POPS) in a similar manner to the scheme proposed for the previous Metro North project. The POPS was refenced in, but not incorporated into, the EIAR and was submitted to the Board on Day 1 of the Oral Hearings as OH5. It was later updated during the Oral Hearing as OH187 & OH188 on Day 11, following questions from the Board and the scheme now covers repairs up to a value of €75,000.

The POPS scheme allows residential property occupiers within a zone 30 m from the tunnel and 50 m from the station boxes to sign up to a voluntary scheme for dealing with limited residential property damage. It also covers properties connected to a property that falls within the zone. If an occupier agrees to join the scheme, an independent building surveyor will be appointed to carryout pre and post construction surveys in order to establish if the project has caused any damage to the property.

It was subject of several observer submissions, with concerns raised regarding how it would be operated, the amount of damages covered and the duration of the scheme post-construction.

The Applicant also responded further to comments received during the 2nd Consultation, within the document *MetroLink Railway Order 2nd Statutory Consultation Responses to Submissions Received*, stating that they have confidence in the POPS scheme and that building damage at Dartmouth Square West and Dartmouth Road would be limited to the “slight” category and only be cosmetic in nature. The applicant further confirmed that damage beyond the POPS coverage would be dealt with by the project’s insurances. In response to a request for indemnification, the Applicant confirmed that it would not grant individual indemnities to property owners, however, to provide further reassurance they stated at Section 4.2.4.9.17 of the document that:

Notwithstanding the standard requirements of its insurance policies, however, TII will establish Local Liaison Officers to help facilitate “hands on” Stakeholder engagement and responsiveness in addition to technical support available to residents from the Independent Engineering Expert service

6.3.1 Assessors Comments on POPS

The POPS appears to have been developed from an earlier scheme that was proposed for the previous Metro North project and it remains largely the same. It is essentially a way of formalising what the project promoter (in this case TII) and its Delivery Partner does on many projects whereby:

- Pre and post condition surveys are carried out by project promoter, either as directly engaged surveyors or incorporated into the scope of work of the main civil works Contractor.

- A dedicated team is put in place to deal with complaints and claims. They carry out inspections of any damage and arrange for cosmetic repairs.
- If damage is larger than cosmetic in nature, then it is dealt with through the project's insurance and a loss adjuster is normally involved in the agreements of such claims.

The Applicant has rejected requests for specific indemnities for Third Parties (*TII Response to Submissions Received – Secondary Consultation 4.2.4.9.17)* however other projects such as the Crossrail Project in London do provide indemnities in the form of "Deeds of Settlement" between the Third party and the Statutory Undertaker.

In contrast the Copenhagen metro project does not provide such indemnities, however the project promoter (Metroselskabet) plays a direct role in building damage and neighbour relations providing Third Parties with confidence that their claims are handled promptly and fairly.

6.3.2 Assessors Recommendations

The Assessors find that the POPS scheme is an acceptable way of dealing with residential properties provided the Applicant puts into place all the other measures he has proposed to manage building risk and manages the works through his Project Delivery Partner in a proper manner.

6.4 Dublin Port Tunnel

The Dublin Port tunnel has been referenced by several Observers as an example where settlement was caused by tunnelling operations and which resulted in unacceptable building damage. The issue was raised on a number of occasions at the Oral Hearing and was discussed at length by the Applicant.

The Dublin Port Tunnel was constructed in the period 2001 to 2006, the section constructed with TBM comprised of twin bored tunnels with an outer diameter of 11.7 m and 2.8 km in length. The section of the alignment where settlements and building damage occurred was in the residential area of Marino, where the ground conditions were complex with post-glacial deposits being present. In this area approximately 32 properties presented aesthetic defects and three properties experienced serviceability defects. The experience from these works is described by Gillarduzzi et.al. (OH114) and the Applicant discussed the experience of the Port Tunnel in relation to the MetroLink on Day 7 and summarised the experience in OH113.

It was clear from the presentation that the settlement and building damage problems experienced on the Port Tunnel should not be experienced on the MetroLink, as the circumstances are very different between the two projects. The Applicant further addressed this issue in the 2nd Consultation

Response to Submissions document, Section *4.2.4.9.1 Confidence in the Assessment*, where further explanation and reassurance was given.

6.4.1 Assessors Comments

The Assessors accept the Applicant's responses regarding the Port Tunnel construction and the tunnelling industry has moved on significantly from when the Port Tunnel was constructed. However, to avoid the problems experienced on the Port Tunnel it will require that the Applicant procures and manages the execution of the tunnel works in the manner described in the EIAR and in the *Final Schedule of Additional Environmental Commitments* (OH376), which will ensure that best practice is followed.

6.5 Benchmarking from the Copenhagen Metro

The Copenhagen metro has been constructed in similar geotechnical conditions to those in Dublin with a similar mix of properties along the alignment and with similar construction methods.

A similar approach to the management of building risk was adopted on the Copenhagen metro to the approach proposed for the MetroLink and which is now essentially normal practice on urban metro projects.

On the Copenhagen Metro the equivalent of the Applicant was Metroselskabet, which managed the interface with Third Parties internally. Metroselskabet also maintained its own database system for managing the monitoring results, where the Contractor would input data into this database as soon as it was available giving Metroselskabet the data to deal effectively with Third Parties and to ensure that the Contractor carried out the works in the required manner.

A large effort was made regarding monitoring on the different stages of the Copenhagen Metro, including real time monitoring of settlements around the stations and in the vicinity of the tunnelling operations with Baseline deformation and groundwater monitoring carried out for more than a year prior to construction. Detailed specifications were included in the procurement documents, covering the monitoring and how Metroselskabet expected the Contractor's organisation to behave. This essentially required that current best practice be followed and with the latest instrumentation employed.

Allowable damage was restricted to cosmetic damage, i.e. damage categories 0 and 1 of the building damage classification and, should damage exceed this, then the Contractor was responsible for the cost. In Copenhagen, the Contractor was responsible for pre-construction and post construction surveys that had to be carried out by suitably qualified local surveyors. On the MetroLink it is not clear who will be responsible for these surveys, except where the POPS is applied.

Experience has been good through the different phases of the metro since the late 1990's, with relatively few problems with building damage. The largest problems occurred where secant pile walls were constructed very close to shallow founded buildings and where piles installation was not carried out in accordance with best practice and excess soil was removed during the pile construction.

In Copenhagen there was no Expert Panel or Independent Monitoring Engineer, with the Contractor being responsible for the monitoring but with close supervision from Metroselskabet.

6.6 Comments and Recommendations

Settlement and building risk is one of the major impacts from the project and will need to be monitored closely by the Applicant, its Delivery Partner, the Expert Panel, and the Independent Monitoring Engineer to ensure that the works are executed according to the Railway Order, best practice and in accordance with the Design & Build Contract.

The procurement of the responsible parties also has to reflect the Railway Order commitments, with regard to settlement and building damage, and the respective roles and responsibilities of the following parties being clearly defined:

- The Applicant and its Project Delivery Partner (PDP)
- The Expert Panel (EP)
- The Independent Monitoring Engineer (IME)
- The D&B Contractors

The Assessors have identified additional requirements that it recommends the Board should place on the Applicant regarding settlement and building damage if it decides to grant the Railway Order.

1. Damage shall not exceed Building Damage Category 1 and suitable measures shall be taken by the Applicant to prevent damage exceeding Category 1.
2. The Expert Panel shall review and sign off on Phase 3 Building Assessments and the measures to be undertaken at sensitive locations of the alignment, these shall include:
    a. the area around Charlemont Station
    b. sensitive buildings with deep basements or settlement sensitive facades such as AerCap House and the Cadenza Building
    c. heritage buildings including buildings where the OPW is responsible and heritage buildings on the Trinity College estate.
    d. The Carrolls Building at Charlemont
    e. Buildings adjacent to tunnel break-in break-out zones from the station boxes.

f. Special buildings and protected buildings as defined in the Phase 1 and Phase 2 Building Assessments.

7 Monitoring

Monitoring is an important part of an urban metro construction, in relation to the main construction impacts, i.e. noise, vibration, groundwater and settlement, deformation and stress and strain in critical structures. It is required as part of the design codes to confirm that the structures are performing as intended in the design, such as the retaining walls moving within the predicted values and that stress in props and other structural elements are within the design.

It is also required to monitor that settlement and consequent movement of buildings is within the predictions and that groundwater levels are kept within the seasonal variations. Monitoring of construction noise and vibrations are also important as they present one of the largest sources of complaints from neighbours to the construction sites.

Modern monitoring methods allow much of the monitoring to be carried out automatically and uploaded into a database for visualisation on an almost real time basis. For instance, robotic automatic theodolites can be installed in the vicinity of the active tunnelling works such as the TBM location, automatically scanning fixed prisms on buildings and ground markers to measure building and ground movements. These are then fed back to a central database and can be visualised in almost real time and combined with the operational parameters from the TBM to ensure that it is being operated within the required parameters. These automatic measurements are usually backed up by manual levelling on settlement pins located on pavements and bolts installed on building facades in to order to verify the automatic measurements. These robotic theodolites are then leapfrogged along the tunnel alignment measuring the active tunnelling zone and long term monitoring carried out with manual measurements.

On recent large projects such as Crossrail, independent settlement monitoring has been carried out, with satellite methods known as InSAR. Where satellite Interferometric Synthetic Aperture Radar can be used to determine settlements. This type of measurement can be repeated every few days and although it cannot be used for the more frequent monitoring required during construction, it provides a very useful independent measurement method which can give further confidence to all parties.

The settlement/movement monitoring is normally combined with TBM operational data, such as the pressure at the TBM face, the speed and torque of the cutter head and the density of the excavated material. It can therefore be verified that the Contractor is operating the TBM in the required manner to minimise settlement.

The data can be shared with Third Parties in several ways. After checking it can be transferred to a publicly available web site where other information can be given to the public such as the location of the TBMs.

The Applicant had not described in detail the monitoring proposals within the EIAR, however on Day 1 of the Oral Hearing he submitted a document entitled *Ground Movement Monitoring Information Paper (OH26),* which presented an outline of the Applicant's intentions and described the roles of the TII Client/Delivery Partner who will manage the project on the Applicant's behalf. The document also described the roles of the Independent Monitoring Engineer (IME) and an Expert Panel to give oversight regarding the monitoring.

The Applicant submitted further documents to the Board during the Oral Hearing regarding monitoring, these are listed below:

- OH175, Risk Management Plan – Trigger Action Plan (TAP)
- OH182, Methodology used for assessment of the likely significant effects on building from ground movement and settlement
- OH276, Draft Trigger Action Plan
- OH316 Building Desk Study

The Applicant also gave further commitments regarding monitoring in OH376 *Final Schedule of Environmental Commitments*.

The Applicant stated in OH26 that the IME would be engaged by the main Civil Works D&B Contractor. This was questioned by the Board as to whether this represented an independent organisation and on Day 10 the Applicant confirmed that it would engage the IME directly, superseding earlier statements on the matter. This was confirmed in the Final Schedule of Additional Environmental Commitments (OH376), Reference 16.1, together with a series of additional commitments regarding settlement, References 15.1-15.7 and 16.2 regarding the sharing of monitoring data with the public.

The Applicant did not address noise and vibration monitoring in any detail and it would be expected that noise and vibration monitoring is dealt with in a similar manner to settlement/deformation and groundwater monitoring with the monitoring being carried out by the IME and overseen by the Expert Panel. It is also expected that the noise monitoring data will be shared almost real-time with the public through a web portal.

7.1 Assessors Comments

The technical aspects of the monitoring proposal appear to be in line with normal practice for such a large infrastructure project, if properly implemented and managed by the Applicant.

The Applicant has not stated how it will be determined that the requirement for No groundwater lowering outside the station boxes and SCL works will be verified and it is recommended that the seasonal variation of the ground water in the different aquifers is determined at each of the sites and these levels are used to define trigger levels for the groundwater control. This is discussed further in Section 5

The approach to monitoring proposed by the Applicant and the respective roles of the D&B Contractors and IME has been clearly defined by the Applicant. It is understood that the Applicant is intending to broadly follow the approach used on the London Crossrail project, where monitoring was divided into two categories:

- Monitoring of structures to determine if they perform as intended in the design, examples of this included the retaining wall deformation and loads in props. This would be the responsibility of the D&B Contractor and be designed and implemented by the D&B Contractor.
- Monitoring to verify the influence of works on existing buildings and structures along the alignment, i.e. buildings settlements and noise and vibration outside the worksites This would be the responsibility of the Independent Monitoring Engineer (IME) who the Applicant has committed to engaging directly.

The Applicant has also proposed to form an Expert Panel to provide advice to the Applicant and IME regarding settlement and Building risk. Given the large number of heritage buildings and other sensitive structures that the tunnel and station construction will impact, the Assessors recommend that the role of the Expert Panel is expanded from an advisory role as proposed by the Applicant to also included a “sign off” role for the Building Assessments, mitigation measures and ground water measures associated with any sensitive buildings and Heritage buildings. This would include the important heritage buildings that the OPW are responsible for, the sensitive buildings such as the Cadenza Building, AerCap House, the buildings adjacent to Charlemont Station and the Carrolls Building.

It would also be important that the Expert Panel is engaged sufficiently early in the procurement process for both the IME and the Main Civil Works contracts to ensure that the relevant provisions for management of the building damage risks, groundwater and monitoring are included in the procurement and final awarded contracts. If the Expert Panel are only engaged at a late stage after procurement of the IME and Main Civil Works contracts there is a risk that not all the relevant provisions are included.

The Applicant has in OH26 mentioned synthetic aperture satellite monitoring of settlements, known as InSAR. This provides measurements of settlements independently of ground observations at intervals of a few days and has been successfully used on the Crossrail project in London amongst other recent projects. The Assessors recommend that the Board

place a requirement on the Applicant to implement an InSAR monitoring system to ensure that a fully independent monitoring data is available to the affected properties and Third Parties.

7.2 Assessors Recommendations

The Assessors propose that the Board places additional conditions on the Applicant as follows, if the Railway Order is granted:

1. The Applicant shall carry out baseline monitoring of at least one year prior to construction commencing to establish Baseline movement of representative, heritage and special buildings and all buildings anticipated to require a Phase 3 Building Assessment
2. The Applicant shall engage the Expert Panel (EP) prior to starting the procurement of the Independent Monitoring Engineer (IME) and the Main Civil Works contracts and the EP shall verify the scope of the IME and the Contract requirements for building damage risk assessments
3. The Applicant shall ensure that the Expert Panel has a verifying and “sign off” role rather than the advisory role stated by the Applicant.
4. The Applicant shall put into place an InSAR monitoring of the alignment commencing at the start of the baseline monitoring period, continuing through construction and up to the completion of the close-out monitoring period. The InSAR data shall cover a zone approximately 100 m either side of the tunnel centre line.

7.3 Conclusions

With the recommendations as listed above in Section 7.2 the Assessors find the proposals from the Applicant acceptable.

8 Future Development Rights

Future developments rights is a major issue for such urban metro projects as the construction of the tunnels and stations inevitable results in restrictions on what can be built in the future in close proximity to the metro structures. The Applicant has issued a document Guidance For Developers firstly at the commencement of the Oral Hearings on Day 1 as OH7, titled Draft Guidance Note for Developers and later on Day 21 as OH378 Outline Guidance Note for Developers.

The measures in the Guidance focus on maintaining the structural integrity, safety, and operability of MetroLink through the enforcement of Exclusion Zones and Protection Zones and comprise of:

Exclusion Zones: These zones are subsoil volumes along the bored tunnels, cut-and-cover sections, and retained cuts where no development

or work are permitted to encroach. Surface-level developments are allowed above the Exclusion Zone, provided their foundations do not intrude into the zone or adversely affect MetroLink structures.

Protection Zones: These zones include volume of subsoil and surface areas where developments could impact the MetroLink structures. Works in the protection zone are permitted provided it does not adversely affect the MetroLink structures and is subject to written agreement with TII

These zones are applied to structural profiles such as the retained cuts, cut and cover sections, tunnels, underground stations, portals, shafts, and temporary site areas. The extent of the Exclusion and Protection Zones varies by location, with details and figures provided in the Railway Order.

The “Outline Guidance Note for Developers” specifies following main requirements:

Structural Design Parameters:

Retained cut and cut-and-cover structures are designed to withstand imposed surcharge loads of 20kN/m², while bored and mined tunnels are designed for 75kN/m².

Developer Responsibilities Prior to Construction of the MetroLink:

Developers seeking permission for works near MetroLink infrastructure prior to its construction must demonstrate “that the foundations of their proposed development do not obstruct or interfere with the proposed MetroLink infrastructure and does not adversely affect the future construction and operation of Metro-Link. Developers are required to take due cognisance of the Exclusion and Protection Zones”.

Developer Responsibilities during or after the Construction of the MetroLink:

“Any Developer seeking permission to carry out works in the vicinity of MetroLink infrastructure where MetroLink is already built or is under construction will need to demonstrate that the integrity of the MetroLink infrastructure is not adversely impacted. Developers are required to take due cognisance of the Exclusion and Protection Zones.”

8.1 Submissions

The Guidance for Developers has been the subject of several submissions from Observers with some concerns being expressed about the limitations being imposed on their future development rights.

The relevant submissions include Lidl Ireland (S169), the OPW (S231 to 240) and several commercial developers such as Irish Life Assurance (S129 to 132) and Hines Real estate Ireland (S117).

8.2 Comments

The objective of the “Outline Guidance Note for Developers” is to establish comprehensive safeguarding requirements to ensure the structural integrity and operational reliability of the MetroLink infrastructure. Simultaneously, the guidance is intended to provide developers with clear technical limitations and parameters for developments in proximity to MetroLink assets.

It is understood that an Exclusion Zone has been defined above underground stations and Cut-and-Cover sections. However, this designation does not appear to extend to shaft structures. It is expected that an equivalent Exclusion Zone will be defined for shaft structures to maintain consistency in safeguarding measures.

The following should be considered when agreements are made between Third Parties and the Applicant:

Requirements to existing structures:

Load conditions from existing structures should remain unchanged in case of, for example, modifications to an existing building or where a building is rebuilt. The Applicant should not require reduced loads.

Risk to Developers:

Developments near the MetroLink alignment currently carry inherent risks for developers. It is recommended that the Applicants requirements are clearly defined to enable external developers to assess potential impacts on their projects.

The current requirements in the Guidance state that:
“*Any Developer … will need to demonstrate that the integrity of the MetroLink infrastructure is not adversely impacted*” and *“Works in the protection zone… is subject to written agreement with TII*”
are insufficiently specific. It is recommended that the Guidance establishes explicit, pre-approved criteria for permissible works. For deviations from these requirements, evaluations should proceed on a case-by-case basis

8.3 Recommendations

It is recommended that the Board includes the conditions set out in the following sections if it decides to grant approval of the Railway Order:

8.3.1 Surcharge Load Requirements

The current allowable surcharge load of 75 kN/m^2 for future developments above the tunnel is understood to be defined at tunnel level based on statements made by the applicant at the oral hearing. This value is

understood to represent the combined permanent and temporary loads. The Applicant provided further clarification of the issue and reference to the Crossrail requirements in their response to the 2nd Consultation.

For comparison, Metro Copenhagen uses surcharge loads of 120 kN/m^2 or 200 kN/m^2 at ground level to ensure adequate flexibility for future development scenarios.

It is recommended the Applicant ensures that the tunnel is designed to facilitate overlapping (superimposed) loads from adjacent properties to ensure flexibility for developers and the adequate robustness of the tunnel.

There is limited soil cover on top of the underground stations, Cut and Cover sections and shaft. The Applicant has proposed allowing future loading of 20 kN/m^2 at the surface for these structures, the Assessors agree to this, however during the Detailed Design there may be the need for larger loadings to be incorporated in certain structures

8.3.2 Excavation Depth Limitations

It is recommended to define an acceptable excavation depth above the tunnel; if it is not intended to allow excavation down to the Exclusive zone.

The compensation to landlords due to the introduced easements is outside the technical scope and should be addressed separately within the appropriate legal or financial frameworks.

For the tunnel, the tunnel lining will be designed for a certain amount of additional ground loading from future buildings but there is a limit on what can be allowed for in the design. Also unloading of the ground above the tunnel for instance during the construction of a deep basement can cause uplift of the tunnel and thus future deep excavations need to be considered and to some extent limited. It is normal that an exclusion zone is defined around the tunnel where no future construction may take place and loading and loading above the tunnel is limited. A zone is also defined where future developments needs to engage in a dialogue with the metro tunnel Operator/Owner with detailed assessments being made of the influence from any proposed construction. It is usual that such a dialogue can solve the issues to proceed without undue restraint on development, however it does limit to some extent future development and may make the development more expensive if for instance a load distributing raft needs to incorporated into the development to limit loads on the tunnels.

8.3.3 Assessors Recommendations

That the Board should include the following requirements when granting the railway order:

1. The document “Outline Guidance for Developers” shall be developed further during the preparation of the procurement

documents to clearly identify the level at which the allowable 75kN/m^2 load is applied and it shall be “signed off” by the Expert panel prior to inclusion in the D&B tender.

2. Suitable provisions shall be included in the D&B tender documents to ensure the tunnel design has suitable robustness to cope with the anticipated loading from adjacent developments and not unduly constrain future development.

9 Station Design and Construction

The Applicant has defined three different station typologies, these are:

- Surface stations
- Retained Cut Stations
- Underground Stations

The station typology applicable to each station location is shown in Table 4.

Table 4 Station Typology

Surface Station	Retained Cut Stations	Underground Stations
Estuary	Seatown Swords Central Fostertown Dardistown	Dublin Airport Northwood Ballymum Collins Avenue Griffith Park Glasnevin Mater O’Connell Street Tara St Stephen’s Green Charlemont

Except for the surface station at Estuary, all other stations are underground stations, to limit the impact at ground level after construction. For each of the station locations the station layout has been adjusted to suit the local landscape, however the main station typology is maintained.

9.1 Surface Stations

As detailed in Chapter 4 of the EIAR, the scheme only contains one surface station located in Estuary. The main components of the construction works are described in Chapter 5 Section 5.5.7 and 5.7.2 and summarized below:

- Piling to provide foundation support for the station structure
- Minimal ground excavation (1m-2m of existing ground level)
- Construction of the station and associated buildings
- Excavation and construction of a pedestrian underpass

9.1.1 Comments on the Surface Station

From a technical point of view there are no comments on the proposed surface station. The works are considered very traditional when constructing a new railway station at ground level.

9.1.1 Conclusion

The construction method chosen is common practice and can be accepted

9.2 Retained Cut Stations

The Retained Cut Stations are to be constructed at 4 locations as listed in Table 4

The main components of the works are described in Chapter 5 Section 5.5.8 and summarized below:

- Construction and installation of secant pile walls
- Construct capping beam and excavate down to the underside of the permanent props and cast roof slab connecting to the piling walls.
- Excavate to underside of permanent props and roof slab and install temporary props.
- Excavate down to the underside of the bottom slab and cast bottom slab. Remove temporary props.
- Install track bed, platform walls and platform slab.

The construction sequence presented by the Applicant is known as ‘top-down’ i.e. it is a relatively stiff construction sequence that minimises settlements compared to a “bottom up” sequence.

9.2.1 Comments on the Retained Cut Stations

The following provides comments on the main aspects of the construction method for the Retained Cut Stations which are shallow underground stations.

Secant piles:

The use of secant piles is a common construction method for retained excavations due to the several advantages that this technique offers in terms of structural integrity, excavation support, and adaptability to urban environments and each of these advantages is equally applicable to the retained cuts and retained cut stations. The use of secant pile walls is used at most of the locations for the Copenhagen metro. The use of secant piles is often limited to a depth of approx. 25 meters. By using deeper piles it is difficult to ensure the cut between the primary and secondary piles and thus the water tightness of the retaining walls.

Below are the main reasons why secant piles are often chosen for underground stations:

1. Groundwater Control

- Secant pile walls create a nearly impermeable barrier, which is highly effective in controlling groundwater infiltration during excavation. Groundwater only enters the station from the base.
- This feature is particularly important for underground stations located below the water table.

2. Excavation Support

- Secant piles act as a retaining wall, providing excellent lateral support for the surrounding soil during excavation.
- They prevent soil collapse and minimize settlement of nearby structures, which is critical in urban environments where underground stations are often built near existing buildings or infrastructure.
- Only limited excavation is required before the piles are installed

3. Space Constraints

- Underground stations are typically constructed in dense urban areas with limited space. Secant piles can be installed in tight spaces with minimal disruption to surrounding activities.
- The construction process involves drilling rather than large-scale excavation, making it suitable for constrained areas.

4. Versatility in Soil and Rock Conditions

- Secant piles can be used in a wide range of soil and rock conditions, making them adaptable to different geological contexts.
- It is important that the secant pile is cased above stable ground
- They can be installed as hard/ soft or hard/hard, depending on the structural and geotechnical requirements.

5. Reduced Vibration

- The installation of secant piles involves drilling rather than driving piles, which generates less vibration.
- This makes the method suitable for construction in urban areas where minimizing disturbance to residents and businesses is essential.

6. Structural Integration

- Secant pile walls can serve dual purposes by acting as both a temporary excavation support system and a permanent structural wall for the underground station.
- This reduces construction time and materials, leading to cost efficiencies.

7. Minimizing Environmental Impact

- The method reduces the need for extensive dewatering systems, which can disrupt local ecosystems and water tables.

- Additionally, the precision of the technique minimizes excess excavation and material waste.

8. Flexibility in Design

- Secant piles allow for curved or irregularly shaped walls, which is particularly useful in designing underground stations that need to follow specific alignment constraints or fit into tight spaces.

The Top-Down construction method:

The proposed construction method is known as “top-down” construction method. The method involves constructing the station, starting from the surface and working downward. Initially, the retaining walls are constructed to support the surrounding soil and ground water, using secant piles (or Diaphragm walls). The permanent roof slab is then cast connecting the retaining walls. Excavation proceeds beneath the roof slab in stages, with support systems added as needed. This method allows utilisation of the surface station surface at ground level during construction. It is commonly used in urban areas with limited space or significant surface constraints, minimizing disruption while ensuring structural stability during excavation. Installation of the top slab before main excavation also limits noise and dust.

9.2.2 **Assessors Comments**

The use of top-down construction and secant piles as retaining walls to construct the retained cut stations is considered a suitable solution. The secant piles provide excellent groundwater control, limited ground movement, structural integrity, and adaptability to complex urban environments. Their ability to minimise vibration and environmental impact enhances the suitability.

The top-down method ensures the walls are connected already after limited excavation inside the stations and hence surface settlements due to horizontal deformations are kept to a minimum. The minimum distance from the station box to the site fence/ road must consider the pre-excavation for the guide wall and the works needed to construct the roof slab below ground. This often requires a shallow retaining wall to be constructed outside the main retaining wall which requires an additional space which needs to be allowed for in the site planning.

The method ensures that it is safe to construct the station near the existing roads or structures.

9.3 Underground Stations

The underground stations are to be constructed at 11 locations as listed in Table 3. They comprise a large part of the construction works, together with the bored tunnel, and are the generator of much of the construction impacts

from the project and are in the more sensitive, constrained urban areas. The underground stations will therefore be considered in more detail in the review than the surface stations and retained cut stations, where the construction impact is significantly less.

The typical station layout is shown in Figure 7, most of the underground stations are similar in size and depth. Glasnevin, however, is an exception as it is an interchange station with the existing Iarnród Éireann heavy rail network. The typical station is a simple box structure with the metro tunnel projecting at each end and with a platform on each side. Each station consists typically of 3 public levels: Concourse, Mezzanine and Platform level.

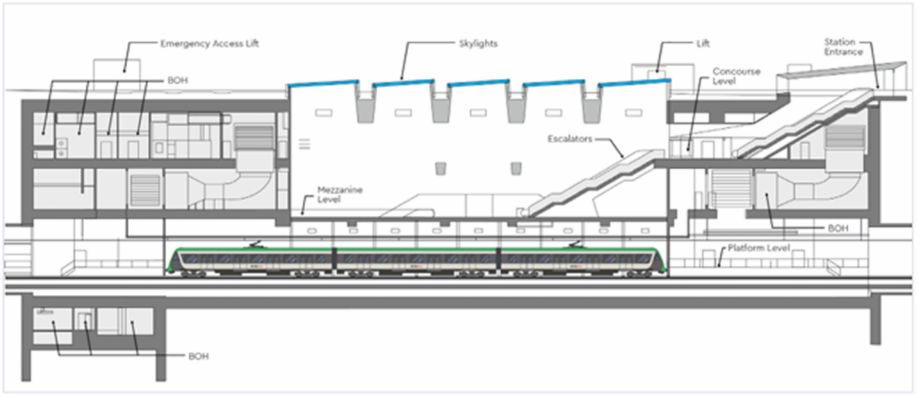

Figure 7 Long Section of Underground Station (Diagram 4.16 from 4 Description of Project)

The retaining walls for the station box structures are intended to be diaphragm-walls (D-walls) below the roof slab. Stations will also be constructed using the “top-down” construction method. Some external more shallow structures will be constructed using secant piled retaining walls.

The main components of the works are described in Section 5.5.9 of the EIAR and are summarized below:

- Construction and installation of D-walls around the underground stations.
- Grouting of the sub-soil below the stations. Grouting can be either toe grouting below the D-Walls or grouting of the soil mass below the whole base slab. In the document Supplemental Note: *Dewatering Assessment in Station Boxes and SCL* Tunnels v2 (OH189) the depth of toe grouting is described as 5m below the depth of the D-walls.
- Excavate down to the underside of the roof slab and cast roof slab connecting to the D-walls.
- Top down excavation. Excavate to underside of roof slab.
- During excavation the D-walls will be braced by either permanent concrete structures or temporary props. The bracing minimises the horizontal deformation of the D-walls and therefore the ground movement outside the station.

- Installation of base slab vs when the TBM passage through the station. The Applicant has developed two concepts for the construction of the bottom of the station, depending on the stage of advancement of TBM construction. According to the construction programme shown in the EIAR Appendix 5.2, the four stations Mater, O'Connell Street, St Stephen's Green and Charlemont should follow the right figure in Figure 8 where the final excavation is completed down to the underside of the bottom slab and cast base slab before TBM arrival.
  All other underground stations are scheduled are to follow the left figure in Figure 8 with the TBM driving through the station before final excavation and casting of base slab.

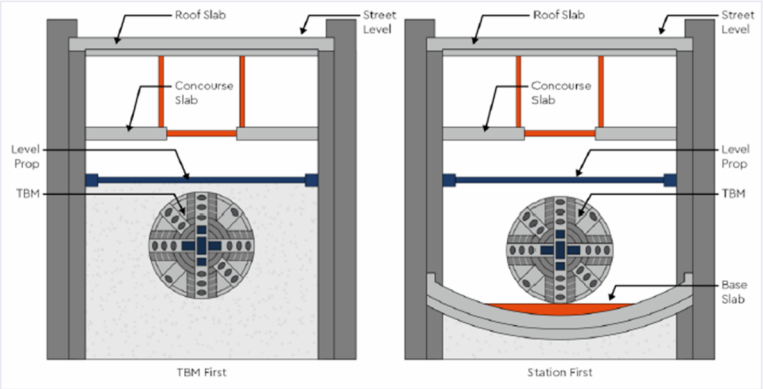

Figure 8 Two concepts for the TBM to pass through the station box. Left: TBM before base slab; right: TBM after base slab (Chapter 5, Diagram 5.26)

- Internal concrete and civil works, install track bed.
- Architectural finishing.
- Mechanical and electrical fit out, testing, commissioning and trial running.

Excavation of Stations

The Applicant foresees excavation likely to require drilling and blasting in the EIAR Chapter 5 where it is written: "*Drilling and blasting is a method commonly used to excavate hard rock by using small charges to break up the rock*".

However, alternatively, the rock can also be excavated by mechanical breakers and road headers. It is written in the EIAR Chapter 5 that: "*Rock can also be excavated using mechanical breakers, but for bulk excavation in the harder rock would result in a significantly longer construction programme and result in continuous high noise and ground borne vibration levels; hence drilling and blasting is the preferred method for rock excavation*".

In Section 4 the Assessors recommend that the Board imposes a condition that blasting should not be used at a number of the deep station sites to avoid unnecessary disturbance and reduce the risk of building damage.

9.3.1 Assessors Comments

The impact on the surroundings from dewatering of the underground station sites may be significant and was a subject discussed with the Applicant at the Oral Hearing. This is further discussed in Section 5 .

Settlement of the area surrounding the deep stations also has the potential to have a significant impact and has been dealt with in EIAR Appendix A5.17 *Building Damage Report*. This is further discussed in Section 6 .

The underground station construction has some of the largest impacts in terms of construction noise and vibration and other impacts such as dust and impacts from the temporary site occupancy. Another significant impact may be potential building damage caused by blasting vibrations. This is further discussed in Section 4 .

The D-wall box around each underground station forms a horizontal groundwater cut-off wall, within which groundwater lowering will take place. The outcome of the groundwater flow analysis is presented in Table 5.10 of the EIAR Chapter 19 Hydrogeology. The table presents "*the maximum potential calculated underground water flow coming into the station in an excavation with free water flow*". The inflow is in the range of 8-20 litres per second. The inflow represents the potential flow below the D-walls into the stations.

It is also mentioned in Table 5.10 that "*It is assumed Main Works Contractors will implement groundwater control measures reducing resultant groundwater inflow to 0.5 litres/second*".

Section 1.1 of the document *Supplemental Note: Dewatering Assessment in Station Boxes and SCL Tunnels v2* (OH189) submitted to the Oral Hearing on Day 11 states that "*Lowering of the water table will not take place outside of the station boxes*". This is achieved by:

- "*D-Walls will be installed according to structural design, followed by installation of fissure grouting (i.e. toe grouting) to a further 5 metres depth*"
- "*The fissure grouting mitigation, …, has been designed to ensure no lowering of the water table will occur*"

The Report has addressed the groundwater management in further detail in Section 5

The chosen construction methods, D-walls and grouting, does allow the Applicant to reduce the groundwater flow. The target not to lower the groundwater table outside the station box is acceptable and will ensure a minimum impact to the surroundings. Based on the commitments made in OH189 it is considered a requirement for the project not to lower the groundwater table outside the station beyond normal seasonal variation

and the Assessors have recommended a condition in relation to this in Section 5

9.3.2 Assessors Comments on Construction Methods for Underground Stations

Top-Down Method

The proposed construction method known as “top-down” is described in Section 9.2.1 .

Additional to the comments given in Section 9.2.1 , this method provides several benefits, particularly in relation to dust and noise:

- Reduced Dust Dispersion:
  The top-down method involves less extensive soil handling in open air, as excavation is performed gradually beneath the installed top slab. This limits the amount of dust released into the surrounding environment compared to traditional methods, where the entire excavation area remains exposed for longer periods.
- Noise Reduction:
  Once the top slab is constructed, it acts as a barrier that absorbs and reduces noise generated by excavation and construction activities happening below ground. This significantly lowers noise levels for the surrounding areas, which is particularly beneficial in densely populated urban environments.
- Minimized Exposure to the Surroundings:
  Construction activities are largely conducted underground, meaning the surrounding environment is less affected by disturbances. This reduces both dust and noise pollution in areas close to the construction site.

Other Environmental Advantages include:

- Beyond dust and noise, the top-down method also minimises traffic disruptions and enables a more efficient construction process, which collectively reduces the environmental footprint of the project.
- Top-down method is however a slower construction method compared to an open excavation pit “bottom-up” method.
- In summary, the top-down method is particularly advantageous for stations in urban areas, where controlling dust and noise is critical for maintaining the well-being of the surrounding community and ensuring compliance with environmental regulations.

’Station First’ Vs ‘TBM First’ Scenarios

The two methods are described above and illustrated in Figure 8 i.e. TBM crossing the stations before or after base slab construction, both methods proposed are established engineering practice in metro construction.

Constructing the base slab of a station ***before*** the TBM passes through the station offers several engineering, logistical, and safety advantages:

- Improved Groundwater Control:
  A completed base slab acts as a full barrier against groundwater ingress. It reduces the need for dewatering systems.
- Efficient TBM maintenance:
  An open station box allows for a safe and quick intervention of the TBM including cutter head and change of tools.
- Excavation of station:

If the final excavation level is reached before the TBM passes through the station the excavation of the station is simple. If the TBM passes through the station before final excavation the TBM will install a tunnel lining inside the station. The safe dismantling of the segment complicates and slows down the excavation and construction of the station permanent works afterwards.

Following the Assessors and Board's questions at the Oral Hearing, the applicant presented details of how this would be achieved on Day 8 (OH120). The approach proposed by the Applicant is considered to be normal practice for such a situation.

- TBM Logistics
  The TBM will be supplied with material such as tunnel segments from the Northwood Portal and tunnel spoil also removed from the Northwood Portal.
  No supply or spoil removal from the tunnel is planned from the intermediate stations.

This is standard approach and any supply through any of the intermediate stations should not be carried out.

Constructing the base slab of a station ***after*** the TBM passes through the station offers other advantages:

- Launch and reception of the TBM:
  The critical stage of launching the TBM or receiving it inside the station is mitigated by having in-situ soil around the tunnel when the TBM drives through the station.

Whether to excavate the station before or after the TBM also depends on the overall construction scheme, safety aspects e.g. interventions, how to supply the TBM, construction sequence of the station etc.

9.3.3 Assessors Comments on Excavation Technique of Underground Stations

Drill and blast tunnelling is a common method for constructing tunnels in rock, but performing this method inside a city requires careful planning and execution due to the potential impacts on urban infrastructure, residents, and the environment. This is addressed in Section 4 and it is recommended that it is avoided in the city centre.

The limestone in Dublin can be categorized as weak rock, like the underground in Copenhagen and Malmö. The metro stations and underground railway stations in those cities were excavated by mechanical breakers e.g. hydraulic hammer and excavator or road header. Drill and blast is not allowed in either Copenhagen or Malmö.

Drill and blast is effective in a wide range of rock conditions, but blasting generates vibrations that can potentially damage nearby buildings, infrastructure and utilities. Drill and blast may cause movement resulting in settlement, affecting roads, railways and buildings. It is important that construction activities in the city stations do not interfere with traffic and require careful management of underground utilities (e.g., water, gas, electricity).

There are mitigation measures for using the drill and blast method in an urban setting, e.g.

- controlled blasting techniques, such as micro-blasting to limit vibration levels.
- Use of experienced contractors and engineers familiar with urban drill and blast projects to ensure safe and efficient operations.
- Completion of detailed pre-construction surveys to understand ground conditions, assess risks, and design an appropriate blasting plan; which is also proposed the Applicant in the *Final Schedule of Additional Environmental Commitments* OH376.
- Optimize the drilling and blasting pattern to achieve efficient rock breakage while minimizing vibration and noise.
- Extensive monitoring system on the buildings impacted by the blasting.

Drill and blast tunnelling can be successfully carried out in urban environments if the challenges are carefully managed through advanced planning, technical expertise, and robust mitigation measures. However, there are also good alternative solutions for the excavation and the Applicant has committed to not using blasting for the intervention tunnel at Charlemont and the Assessors recommend that this is also applied to the Albert College Park SCL works and any other SCL works such as the pumping sumps and SCL works at Dublin Airport. This is discussed further in Section 4 of the report and recommendations are given in Section 4 of the Report in regard of blasting.

The following provides comments on the main aspects of the construction method for the typical Underground Stations.

The Underground Stations are deep stations with a general depth from street level to Top of Rail (ToR) of 24-25m. Only Northwood station is shallower, with a Top of Rail (ToR) depth of approx. 17m.

Section 9.2.1 describes the benefits of using Secant piles. The same benefits apply to D-Walls, however; D-walls can be used for deeper structures (below 25m) and still ensure a watertight retaining wall.

Considering the depth of the stations, the retaining walls for the underground station are in excess of the depths for the use of secant piles with the exception of Northwood Station which could be constructed by using secant piles.

Two stations are discussed further below, Charlemont and Glasnevin which are sites with a significant number of Observer Submissions.

9.4 Charlemont Underground Station

The Charlemont Station has been the subject of a considerable number of Third Party submissions regarding its location, design and the impact from the construction of the station.

It is the Southern terminating station of the current MetroLink project but includes provisions for a potential future extension to the South or South West. It is located in a quite constrained setting between the existing Carrolls Building, Dartmouth Square, Dartmouth Road and the Grand Canal. It provides an interconnection with the Luas Green Line, however this interchange is not direct.

This Assessment has not considered the landscape architectural aspects of the Station nor the aspects of the interchange between the Luas and the MetroLink that have been the subject of a number of submissions.

The impact during construction has been assessed in the relevant sections of this Report, i.e. settlement, groundwater, stations, tunnelling and noise and vibrations. A considerable number of written and oral submissions were made by both individual local residents and the Charlemont & Dartmouth Community Group (OH151, to 153). These submissions were supported by independent engineering consultants with detailed well considered submissions concerning settlement, building risk groundwater and geotechnical conditions.

The issues raised are discussed in detail in the relevant sections of this Report, i.e. Sections 4, 5, 6 & 7 regarding settlement, groundwater lowering and geotechnical conditions and the status of the Applicant’s responses are summarised in the Applicant’s 2nd Consultation Document.

A number of the submissions raised the issue of the type of retaining wall used at Charlemont for the external more shallow structures and have proposed the use of secant piles rather than diaphragm walls. As discussed in Section 9.3 secant piles and diaphragm walls will fulfil the same function up to a maximum excavation depth of approximately 25 m, beyond that depth only diaphragm walls are suitable. Both methods have a similar

impact during construction and it is recommended that the choice of method should be left up to the D&B Contractor.

9.4.1 Comments and Conclusions on Charlemont Underground Station

The Applicant has responded to the settlement, building risk and groundwater issues and with the additional conditions that the Assessors recommend placing on the Applicant, if the Railway Order is granted, the Assessors find the situation to be satisfactory and the risks to the surrounding properties are properly managed.

9.5 Glasnevin Underground Station

Glasnevin Station is a complex part of the project with the station having to be constructed around two existing heavy rail lines and the adjacent Royal Canal. The Applicant has addressed the construction in a specific EIAR report, Appendix A5.5 where the interfaces with the existing heavy rail and the Royal Canal are addressed together with the complex sequencing of the work. The Assessment has noted that the groundwater will be one of the major challenges given the size of the station box, the Board questioned the Applicant regarding the groundwater control measures on Days 4, 8 & 10 of the Oral Hearing, and the Applicant presented additional documents, OH92, 75, 172, 189 regarding the groundwater issues. On day 8 the Applicant was questioned by the Board regarding the dewatering approach at Glasnevin and Applicant (Mr. Jose Antonio Aparicio Redondo from Jacobs Idom) responded to the issues and presented OH172 on Day 10.

The issue is addressed in Section 5 of the Report as there was a lack of clarity in the Applicant's proposals which were particularly concerning given the large size of the Glasnevin excavation and the Applicant had predicted inflows of 600 m^3/day at this location. The Applicant maintained the position that he would use grouting to manage the inflows, however it was not clear whether the grouting would comprise of a grout curtain extending below the diaphragm walls or it would be a grout plug, i.e. a blanket of grouting below the excavation level. Should the blanket approach be needed then it will be likely to considerably extend the construction programme.

The issue was concluded at the Oral Hearings by the Applicant's document OH189 submitted to the Board on Day 11. The document reconfirmed the Applicant's commitment that there would be no drawdown outside the station boxes. It also provided further arguments for the fissure grouting at the base of the excavation.

9.5.1 Comments and Conclusion on Glasnevin Underground Station

With the Applicant's issue of OH189 submitted to the Board on Day 11 and the additional recommended conditions to be placed on the Applicant for groundwater, settlement, building risk and monitoring the Assessors find the Applicant's proposed construction at Glasnevin acceptable.

9.6 Recommendations regarding Underground Stations

The underground stations are planned to be constructed using a robust construction sequence with deep diaphragm walls and a "Top Down" construction sequence, which reduces retaining wall deflections and thus minimises settlements. However, a number of issues have been identified during the review which require the Applicant to take particular attention over in order particularly during the procurement process but also during construction in order to minimise the risks. These include:

Preventing changes by the D&B Contractor that increases the settlement risks such as changing construction sequence such as changing from "Top Down" to "Bottom Up" is one major issue.

The Applicant's measures for the control of groundwater remained unclear at the end of the Oral Hearing, however the Applicant confirmed his commitment that there would be no drawdown outside the station boxes, this is addressed in Section 5 of the report. This will be challenging to achieve and the Assessors have recommended that the Expert Panel is involved in the "sign off" of the groundwater control measures.

The sequence of construction between the AZ4 tunnel drive and construction of the stations is complex and delays in station construction can have consequential delays to the tunnel drive. This may lead to the D&B Contractor attempting acceleration measures and omitting planned mitigation measures and commitments made by the Applicant. If the Board decide to grant the Railway Order it is recommended that they impose suitable conditions to ensure that the Applicant is required to implement all mitigation measures and commitments made.

The Glasnevin Station is the largest and most complex station, with complex ground conditions and with interfaces to the Royal Canal and two existing rail lines that will have to be constructed around. There are likely to be considerable difficulties in controlling the groundwater lowering given the large station footprint and the Applicant has committed to no groundwater lowering outside of the station box which will be difficult to achieve.

The Assessors have recommended conditions to be imposed by the Board to address these issues in the relevant Sections of this report, i.e. geotechnical, hydrogeology, building risk/settlement and monitoring and the recommendations are summarised in Appendix A.

10 Tunnel Design and Construction

There is always a significant risk associated with the construction of tunnel structures that are often associated with unforeseen ground conditions and these are addressed in the EIAR, in particular in Chapters 5, *MetroLink Construction Phase*, and 28, *Risk of Major Accidents and Disasters*, and Appendices A5.13 *Tunnelling,* A5.14 *TBM consumables* and A5.17 *Building Damage Report*. The proposed tunnel construction methods presented within the EIAR were evaluated in the EIAR based on the risks identified and the introduced risk mitigations. The objective was to limit the impacts above and in the vicinity of the tunnel construction to an acceptable level.

The choice of a single bore twin track tunnel in comparison to a twin bored single track tunnel has several implications for the scheme, a comparison between the two solutions is given in Chapter 7 *Consideration of Alternatives* and a detailed comparison between twin and single bore tunnel solutions is given in the ARUP *Tunnel Configuration Study for new Metro North and Dart Underground,* TII April 2017 which is referenced in the Chapter 7 *Consideration of Alternatives*. The choice of a single bore tunnel was discussed at the Oral Hearing on Day 4 and the Applicant presented document OH108 on Day 7, *Derivation of the Single Bore Tunnel as the Proposed MetroLink Tunnel Option*.

The choice of single vs twin bore tunnels has a number of implications that include:

- Significant alignment constraints and larger minimum horizontal radii than would be the case for twin running tunnels.
- There are significant differences in the operational safety concept between single bore and twin bore tunnels.
- There are significant layout difference for the underground stations, with the single bore (chosen) concept have side platforms vs a twin bored tunnel having island platforms.
- The single bored tunnel results in slightly wider underground stations.
- The single bore tunnel gives more flexibility in the location of crossover switches.
- The single bore tunnel reduces the need for cross passages which may be needed for safe evacuation.
- The excavation quantities are similar from both single bore and twin bore tunnels and are dependent on the cross section chosen. Previous studies for the Dublin North Metro have indicated that a twin bore tunnel has a smaller cross sectional area.
- The larger single bore tunnel gives a larger settlement.

The principal tunnel structures to be constructed as part of the MetroLink are:

- Airport Tunnel, AZ2, from Dublin Airport South Portal north to Dublin Airport North Portal.
- City Tunnel, AZ4, from the Northwood tunnel portal to Charlemont.
- One Airport Evacuation tunnel and One Ventilation tunnel are to run parallel to the main tunnel from the Dublin Airport South Portal to ensure ventilation (5.65m ID and emergency (clearance profile of 2.3m wide and 2.4m high). At the end, the tunnels will be connected to the main tunnel via short connection tunnels. The Evacuation tunnel and Ventilation tunnel are approx. 600m and 315m long, respectively.
- Charlemont Intervention tunnel from the south of Charlemont Station to the end of the City tunnel is to provide an evacuation route and ventilation, measuring approx. 300m long.
- Short connection tunnels are to connect the shaft in Albert College Park and the intervention tunnels to the main tunnel.

The tunnel works are the part of construction that will have the greatest potential impact on the surrounding buildings, in terms of ground displacement, settlement, groundwater and building damage. This is evidenced by the significant settlement and building risk issues experienced during the construction of the Dublin Port Tunnel in the early 2000's.

The tunnel works also induce ground borne vibrations during the excavation, either from the tunnel boring machine (TBM) or from the conventionally mined tunnels. The main aspects of the tunnel construction are discussed below:

10.1 Two Main Bored Tunnel Stretches AZ2 and AZ4

Bored tunnels will be constructed below the Airport (AZ2) and from the Northwood tunnel portal to Charlemont (AZ4). The two main tunnels will be constructed using tunnel boring machines (TBM), one for each tunnel.

The Applicant has evaluated various TBM types based on the actual ground conditions relevant for the project and documented this in EIAR Chapter 5 and in Appendix A5.13 *Tunnelling*. Only closed-mode TBMs were defined as feasible and therefore the Applicant decided to evaluate the following TBM types: An Earth Pressure Balance (EPB) TBM, a Slurry TBM and a Variable Density Slurry TBM.

Based on the assessment the Applicant has proposed a *"variable density slurry TBM"* for both the main tunnel stretches.

The main technical benefit of a variable density slurry TBM is that it can operate in four modes: Open mode, Earth Pressure Balance (EPB) mode, Slurry mode and High-density slurry mode. Operation in High-density slurry

mode reduces the risk of slurry loss in the tunnel face through cracks, fissures, voids and mixed face. If the TBM loses face pressure during the tunnel drive, this could result in excessive settlements, blow-outs and/or sink holes depending on the actual ground conditions.

Section 4.4.7 of Appendix A5.13 *Tunnelling* outlines that during the procurement process the Contractors bidding for the project shall prepare a detailed specification for the TBM as part of their tender design and that the TBM must be procured and operated based on this specification, presumably once it is approved by the Applicant's Delivery Partner who will be overseeing the construction.

10.2 Comments on the TBM Tunnels

The following provides comments on the main aspects of the tunnels.

11.2.1 TBM Choice

TBMs are suitable and often used in heavily urbanized areas where settlement must be kept to a minimum, hence the proposed TBM scheme is similar to many other comparable projects worldwide.

The evaluation of the TBM type performed as part of the EIAR is acceptable. It is expected that the tunnel will be operated in a full face of limestone bedrock, some in a full face of glacial till, some in glacial sands and some in mixed faces of bedrock and the tills and sands.

The recommended TBM reduces the risks associated with constructing a TBM tunnel in the variable ground conditions by only allowing closed mode TBM drive. The closed mode TBM mitigates the risk of loss of face-pressure in the tunnel face, and hence the risk of settlement or creating sinkholes. The close-mode TBM further ensures that the groundwater table can be controlled during the tunnel drive, thus preventing groundwater related settlement. The benefit is that the Variable Density Slurry TBM can ensure this in the expected range of geotechnical conditions along the whole tunnel stretch. It does not require different TBMs for operation in different areas, due to changes in ground conditions.

However, due to the complexity and costs of a Variable Density Slurry TBM and, noting that it is not a common TBM type like the EPB TBM and Slurry TBM, some Contractors may not have experience using this type of TBM, and may wish to specify a more common closed-mode TBM (EPB or Slurry) which likely will also come with a cost optimisation. The chosen TBM also influences the site setup, efficiency and performance. This will also impact the Contractor's commercial and financial considerations when proposing the TBM to use during the procurement process.

From a technical point of view, the Assessors consider It is important that the Applicant should provide clear minimum requirements and evaluation criteria for the TBM choice in the procurement process, in line with the

EIAR, to ensure there is a clear understanding of proposed mitigations and that the measures, mitigations and commitments in the EIAR are carried forward into the construction.

As also defined in the EIAR, for the use of slurry mode in limestone, the operation and the reuse of the slurry is a critical aspect. Before agreeing the particular TBM type with the Contractor, this must be evaluated further by the Applicant during the Civil Works procurement process for especially a slurry TBM, but also for the Variable Density Slurry TBM. Operating the Slurry TBM is beneficial in ground types with less fines. The actual consumption of bentonite as described (A5.14) is very much linked to the type of soil.

An important consideration when assessing risks associated with TBM construction work is the past experience and competence of the Contractor in using a particular construction technique. The Contractor (or subcontractor) must document experience from work with the proposed method under similar geological and geotechnical conditions. Such consideration needs to be incorporated into the procurement process by the Applicant.

10.2.1 Interventions

The TBMs have a number of cutters at the face of the TBM comprising both disk cutters to cut harder materials and large cutting teeth to excavate the softer materials. These cutters need to be replaced at regular intervals and also the cutter head of the TBM checked for wear and repairs carried out if necessary. This process is known as an intervention.

The cutter replacement and repair needs to be carried out at regular intervals during the tunnel construction and require an intervention into the cutter head by workers to carryout the work. This work would be carried as much as possible during station crossing but would also be needed between stations and requires the use of compressed air to balance the groundwater head whilst carrying out the work. It is known as hyperbaric working and requires highly trained staff, essentially trained as divers and also requires decompression facilities and emergency medical hyperbaric facilities at the Northwood portal.

The EIAR specifies that an Intervention Strategy is to be prepared. In the Assessors experience, it is important that such a document will be part of the procurement process (tender documents) to ensure the Contractor will perform the needed interventions to limit the project risk and that they are performed at the predetermined locations, maybe in the locations predetermined as “possible” locations and not inside the sections defined as prohibited areas, in line with Section 5.4 of EIAR Appendix A5.13. It is acceptable that the Intervention Strategy is not defined as a part of the EIAR, but the interventions shall be at locations with large soil cover to ground level and preferable with no direct building above and particularly

that there are no heritage or special buildings above so that minor settlements above and next to the tunnel are not critical. There is increased risk of settlements during interventions and during the restart after an intervention. As the interventions will most likely need to be carried out under compressed air (hyperbaric conditions) there are other risks associated with the work such as the loss of compressed air into basements or escaping to the surface, causing damage.

10.2.2 Launching and reception

Launching the TBM from the station box is always associated with increased risk. This is, however, only relevant for the “Station first” scenario (see Section 9.3 above). The Applicant prepared a technical note entitled “Provisions for Control of TBM Launch and Reception at Station Boxes” (OH116) to clarify this further after being questioned at the Oral Hearing by the Board.

The Applicant proposes (Section 19.6.2.1.1 of the EIAR) that appropriate measures must be put in place to enable full pressure in the cutter head before entering in-situ soil conditions outside the retaining walls of a station box and this will be done by providing a 20m x 20m x 15m ground treated zone adjacent to each station box for both launching and reception as well as a dedicated survey/monitoring scheme. The ground treated zone, can be constructed either by a form of grouting such as jet grouting or soft diaphragm (slurry walls) i.e. a diaphragm wall without reinforcement and using a low strength concrete made with cement and bentonite. This would prevent the loss of stability during the launch and recovery operations. These mitigations were not confirmed in OH376 Final Schedule of Additional Environmental Commitments submitted to the Board on Day 21 of the Oral Hearings and it is recommended that the Board impose additional requirements on the Applicant when granting the Railway Order that the measures described in the Technical Note entitled “Provisions for Control of TBM Launch and Reception at Station Boxes” (OH116) shall be implemented.

This is most critical when launching in soft ground or mixed face and having nearby structures, e.g. Mater Station box where immediately after launch from the south headwall the TBM drives beneath the nave of St Joseph’s Carmelite Church.

10.2.3 Settlement and Monitoring

Problems during TBM tunnelling, including damage to structures and buildings on the ground, are usually caused by “unforeseen events”, such as unexpected geological conditions, poor workmanship and lack of quality control. Therefore, a strict quality management and control system should be set up and implemented. It is recommended that the Applicant as a minimum identifies critical stretches due to e.g. ground conditions, distance

to foundation or critical buildings, where the Applicant ensures external supervision of the TBM drive (TBM parameters) and the ground level monitoring data.

On recent metro projects this has carried out with the development of a document call the "*Plan for the Advancement of the Tunnel*" (PAT) where the TBM operating parameters are defined together with the anticipated geology and hydrogeological conditions. The PAT and its use in urban metro projects is described in "*Mechanized Tunnelling in Urban Areas Design methodology and construction control"* by Guglielmetti et. al.

The ground level monitoring data shall be evaluated along the whole tunnel stretch vs the TBM parameters, but with extra focus in advance of a critical stretch to ensure the TBM parameter settings reduces the risk of ground movements. It is not only the face pressure generating settlements, in poor conditions also the quality of the annulus grouting is important.

It is recommended that the Applicant or its Delivery Partner and the IME has real time access to the TBM data together with the settlement data in order to be able to perform external qualified supervision of the tunnelling works. From the Assessors experience, it is advisable to define the type of IT system to be used for the TBM operating parameters and monitoring before the procurement i.e. tender of the tunnelling works to ensure compatibility with the selected TBM. An example of such software & hardware is TPC from Tunnelsoft.com or similar. This should be carried out in conjunction with the IME to ensure that the IME has in its monitoring database both monitoring instrumentation results and the TBM operating data which can be analysed together.

The Assessors recommendation is that the Board place additional conditions on the applicant when granting the Railway Order with regard to the Applicant so that a *Plan for the Advancement of the Tunnel* (PAT) is developed for each stretch of tunnel and that appropriate system are put in place for the real time integration of the TBM parameters and monitoring data is put into place.

The settlement building damage and monitoring issues are dealt with in Section 6 of this report.

10.3 Oral Hearing

During the Oral Hearing on Day 8 the Applicant confirmed the following commitments for the TBM operations:

- The TBM will be operated to limit the settlement and there will be no groundwater drawdown.
- The TBM will be operated without using trains in the tunnel, excavated soil will be removed by slurry pipes or conveyor belt and segments will

be transported by rubber-tyred vehicles. This will reduce groundborne noise and vibration during construction.

- Interventions are foreseen both under hyperbaric pressure and without hyperbaric pressure depending on the geology
- Between Tara Street Station and St. Stephens Green Station, a low point pumping sump intended by the Applicant had initially been omitted from the alignment drawings and Applicant provided the location of the low point sump by the submission of EIAR Addendum: Leinster Street Pumping Station (OH262) on Day 17 of the Oral Hearing. No change in the alignment was made as a consequence of this and, subsequently, updated alignment drawings were submitted on Day 19 (OH323).
- Between St. Stephens Green and Charlemont Station the alignment was lowered during the Oral Hearings by approximately 5.0m, to provide greater clearance between the tunnel and the lowest foundation piles of two buildings, the Arthur Cox Building and the Cadenza Building (Irish Life). Several versions of updated alignment drawings were submitted to the Board during the Oral Hearing, with the last version (OH185) submitted on Day 11.

10.4 Assessors Comment

Construction of the two pumping stations (sumps) may result in higher settlement than anticipated for the TBM, as the pumping sumps are substantial chambers constructed using the SCL technique, it is recommended not to construct the pumping station directly below critical pile foundations; hence the location of the low points shall be carefully considered.

Whilst the locations shown on the alignment drawings given on drawing No. OH186 St Stephens Green to Charlemont and OH262 Tara Street Station to St. Stephens Green respect this, the locations are close to sensitive buildings with:

- The low point sump between Tara Street Station and St. Stephens Green is located at Ch. 17+947 on Leinster Street South which is an acceptable location on the far side of the road from existing buildings.
- The low point sump between St. Stephens Green and Charlemont located at Ch. 18+915 which is approximately 5 m from the Arthur Cox Buildings which is a modern commercial building with a deep basement construction and is close to the building foundations.
  The alignment passes approximately 4.2 m beneath the foundations of the Cadenza Building (Irish Life).

Outline construction methods for the pumping sumps and their impact on the environment have been submitted to the Board with OH262 and a typical drawing showing the pumping sumps in OH150C. The final construction methods will be determined by the D&B Civil Works Contractor with the impact staying within the impact stated in the EIAR and the

commitments made during the Oral Hearing. The impact of settlement from the pumping sump construction on the adjacent Arthur Cox building should be considered and incorporated into the Stage 3 assessment for the Arthur Cox Building.

10.5 Programme

The tunnel construction programme foresees two TBM drive sites;

1) Dublin Airport South Portal

2) Northwood Portal.

As also identified by the Applicant, there is a large time schedule risk inherent in the programme for the TBM drives, especially so for the main AZ4 drive from Northwood Portal to Charlemont which passes through 9 stations before it is buried in the ground at the end of the run out tunnel beyond Charlemont Station. Hence the whole City Tunnel (AZ4) tunnel construction will be supported through the tunnel and deep stations that are under construction at the same time.

The programme does not mitigate the risk of a major TBM break-down and the critical path for the whole project is dependent on the operation of the City Tunnel (AZ4) TBM. This is a residual risk accepted by the Applicant. There are also programme risks associated with the interfaces at each of the deep stations that the AZ4 TBM will have to pass through as delays in the station construction can cause delays to the passage of the TBM through the station. For instance, if groundwater issues require major grouting works at any of the deep stations which had not been incorporated into the time schedule, then this could delay the tunnel and consequentially the overall project.

10.6 AZ4 City Tunnel Alignment

The tunnel alignment in this section passes beneath a series of important buildings south of the River Liffey, including Trinity College and Leinster House, as well as a number of commercial properties some with deep basements together with residential properties.

Of particular note in this section were the submissions made by three commercial property owners who were also present at the Oral Hearing, raising concerns regarding the alignment and potential conflict with their buildings. This resulted in the Applicant having to lower the vertical alignment between St. Stephens Green and Charlemont by approx. 5m and adding a low point sump in this section.

As noted above, the Applicant also advised at the Oral Hearing that an intended low point sump had been inadvertently omitted between Tara Street and St. Stephens Green in the EIAR and alignment drawings. The

location for this was submitted to the Board during Oral Hearings with OH262 and the inclusion of the low point sump did not result in an alignment change in this section.

Written and oral submissions relevant at the commencement of the Oral Hearing were:

- Earldev Properties, Arthur Cox Building, S79
- Hines Real Estate Ireland, AerCap House, S117
- Irish Life Assurance plc, Cadenza Building, S129

Subsequently, a letter was submitted on behalf of Earldev Properties during the Oral Hearing, confirming that their concerns had been addressed and they supported the project. This left only the two commercial properties associated with Submissions S117 for AerCap House and S129 for the Cadenza Building not agreed between the Third Parties and the Applicant.

It was apparent from the submissions made at the Oral Hearing, that the Applicant had not assessed the correct current buildings at the AerCap House and the Cadenza Building locations and that the building owners were not satisfied with the assessments provided by the Applicant. These two submissions are discussed below:

10.6.1 Hines Real Estate Ireland, AerCap House, S117

The Hines Real Estate Ireland (HRE) building known as AerCap House which was formerly 65-68 St. Stephens Green, it is located just south of St. Stephens Green and immediately above the tunnel alignment on the route to Charlemont. AerCap House is a 6 storey concrete framed building, with two basement levels. There is a secant piled wall around the basement which is toed into the rock a few meters above the crown of the tunnel. AerCap House is founded on competent limestone, the excavation was continued until this was encountered and it is understood from HRE that any soft areas excavated were filled with mass concrete infill up to base slab level. Based on the information provided by HRE, the building has a very stiff façade with large glazing panels with low tolerances which makes it sensitive to settlement and any distortion of the building frame.

HRE’s written submission raised a number of concerns regarding the impact of construction on AerCap House, related to building damage, groundborne noise and vibrations during construction and operation of the MetroLink and future development rights. HRE also raised the issue that the Applicant had the right to move the tunnel alignment within the Limits of Deviation (LOD) and that could result in a raising of the tunnel by 5 m.

The Applicant’s Response to Submission document responded to the submission, stating that the building had been assessed using the Building Assessment process where it had been subject to a Phase 1 and 2a assessment and that the building falls into the 'Negligible Damage''

category. The Applicant further responded that a Phase 3 assessment would be carried out during the Detailed Design phase of the Design Building stage of the project. The Applicant also responded regarding the groundborne noise and vibration issues essentially restating what was in the Applicants assessments, that there would not be any significant impacts. The Applicant also responded regarding the issue of development rights.

HRE made further submissions at the Oral Hearing on Day 9 and were represented by Waterman Moylan a consulting company. On day 9 HRE submitted OH136, OH137 & OH138 and presented their assessments to the Board. It was apparent during the HRE presentation that the Applicant had assessed the building that previously occupied the site known as “Canada House” that was demolished in 2013 and not the current building AerCap House and the two building had significantly different construction forms. HRE made further submissions on Day 18, OH279, OH280, OH281 & OH282 particularly concerning the façade issues and future development of the site

The issue of the Applicant not using updated building information for its Building Damage Assessments was obviously a serious issue and HRE therefore made their own assessments of building damage and presented it to the Board and in documents OH137 & OH138. HRE concluded that

“The level of damage AerCap House could reasonably accommodate is Negligible (cracks less than 0.1mm). Even at this level, there are still concerns the Basement waterproofing System is going to be compromised and require remedial works to an occupied building.” (extract from summary of OH138)

During the Day 9 presentation by HRE the Applicant responded and subsequently lowered the tunnel alignment in this section of the alignment by introducing a low point sump between St. Stephens Green Station and Charlemont. Revised alignment drawings were submitted to the Board with, OH179, OH180, OH185 and OH186.

The Applicant submitted a revised Building Damage Assessment for AerCap House, OH275 and presented it to the Board on Day 18 and OH192 a Note titled Working Draft / Process for the oversight and implementation of Phase 3 assessments which described the process the Applicant proposed to follow for the preparation of the Phase 3 Assessments during the main Civil Works tender process and after award of the main Civil Works contract.

The Assessors have considered the submissions from HRE and their Consultants and the responses from the Applicant and consider the four key issues raised by HRE as follows:

10.6.1.1 Building Damage

The Applicant's error in not assessing the correct building, i.e. a building that had been demolished in 2013 during the EIAR process does not provide confidence in the Applicant's processes for the identification of the buildings that need to be assessed for building damage.

The updated assessment provided to the Board in OH274 titled *AerCap House Enhanced Building Damage Assessment Report* | P02 2024/03/16 provides an enhanced Phase 2 Building Assessment using the methodology from Section 4.2 of the CIRIA Guidance document C796 (London, 2021) for non masonry buildings and repeats the Applicants stated approach that the detailed Phase 3 assessment will not be undertaken until the Detailed Design stage by the Design and Build Contractor that will be engaged by the Applicant.

The Enhanced Assessment, uses a combination of empirical and frame analysis to consider the behaviour of the building to the tunnel induced settlement which they state as being approximately 11mm after taking into account the buildings stiffness and the lowered tunnel alignment. This still induces significant distortion and strains in the building which may cause damage to the basement waterproofing and to the façade system as assessed by HRE in the assessment carried out for them.

The Applicant also submitted on Day 18 in OH276 a *Draft Trigger Action Plan* stated by the Applicant to cover AerCap House and the Cadenza Building. The *Draft Trigger Action Plan* sets out the Applicants commitments and processes that he will implement in developing the Phase 3 assessments and in managing the building damage risk on such special buildings as the AerCap House. On Day 18 and in OH274 and OH276 the Applicant maintained his position that a Phase 3 assessment would only be undertaken when the D&B Contractor will be in place, however OH276 the *Draft Trigger Action* provides a description of the processes that will be implemented for the Phase 3 assessments.

Experience from the Copenhagen Metro is that for such a sensitive structure the equivalent of a Phase 3 assessment would be prepared by the Owner, i.e. the equivalent of the Applicant at the preliminary design stage and for the EIAR assessments to ensure that the project as being carried forward to procurement can be built without unacceptable damage being caused and to determine what mitigation measures were needed. The assessment may not be called a Phase 3 assessment as the Phase 3 assessment would still be carried out during Detailed Design by the D&B Contractor. However, there would be a good basis to proceed with the project approvals and procurement. These detailed assessments were provided to the tenderers to ensure that they understood what was required by the Owner and that they include the necessary mitigation measures in their tender.

The Applicant has described the process they propose for the development of the Phase 3 assessments by the D&B Contractor in OH192, & OH276 and the role of the Independent Monitoring Engineer (IME) and Expert panel (EP) in this process. Whilst the IME's role strengthens the governance over the Building Damage Assessments developed by the Contractor the role of the Expert Panel is limited essentially to advice. It is recommended that the role of the Expert Panel is strengthened so that it has a role to review and verify the Assessments, i.e. "sign-off".

This issue remained unresolved at the closure of the Oral Hearing and it is recommended by the Assessors that appropriate Conditions are applied by the Board to address the issue, if they decide to grant the RO. A proposal for these conditions are given below in Section 14 .

10.6.1.2 Groundborne Noise & Vibration

The Applicant extended the lengths of alignment where a floating track slab would be implemented and the section of alignment where AerCap House is now included within the floating slab track area. The groundborne noise and vibrations should therefore be able to be able to be brought down to an acceptable level and the Applicant had during the Oral Hearing reduced the groundborne vibration maximum threshold level for residential dwelling to 35 dBA. The revised requirement therefore does not apply to such a commercial building and the Assessors recommend that the Board imposes a condition that the groundborne vibration maximum threshold level as committed to for residential buildings is also applied to commercial buildings

10.6.1.3 Future Development Rights

HRE have raised concerns in their submissions OH138 regarding restrictions on their rights for future development of the site. The Applicant has issued a Draft Guidance Note for Developers as OH7 on Day 1 of the Oral Hearings which deals with this issue. A second revision of the document OH378 was issued on Day 21 without the draft in the title.

The development rights issue is discussed in Section 8 .

10.6.1.4 Limits of Deviation (LoD)

HRE have raised concerns regarding the LoD that allowed the Applicant to raise the tunnel alignment up to 5 m which would clash with their secant piled retaining wall/ basement if carried out.

The Applicant confirmed in the *Final Schedule of Additional Environmental Commitments* (OH376) that the LoD would be amended to not allow any raising of the tunnel alignment in this section of the alignment.

This concern has therefore been closed.

10.6.2 Irish Life, Cadenza Building, S129

The Cadenza Building located at 19-20 Earlsfort Terrace on the corner with Adelaide Road and is owned by Irish Life Assurance (ILA). The building is located just south of St. Stephens Green and immediately above the tunnel alignment on the route to Charlemont in alignment section AZ4(h).

The Cadenza Building has a deep two level basement and a façade system with large glazed panels, suggesting that it is sensitive to deformation and vibration.

Similar to AerCap House, the Applicant had assessed in the EIAR a building (Davitt House) that was demolished in 2019 and therefore the Building Damage Report A5.17 in the EIAR is not valid for the current building. This resulted in the Applicant not recognizing the presence of a deep secant pile wall and uplift ground anchors beneath the building. The tunnel will pass a few meters below the basement of the building and with the alignment given in the EIAR it would have conflicted with the ground anchors.

Irish Life Assurance (ILA) had made an initial submission during the Consultation process as S129 for 19-20 Earlsfort Terrace and 65A Adelaide Road, expressing a number of concerns regarding the affect the MetroLink construction will have on the Cadenza Building, including settlement/building damage, groundborne vibration and development rights similar to Hines Real Estate's concerns for AerCap House. The Applicant in the Consultation response did not fully engage with ILA's concerns and gave its essentially standard responses such as for the settlement issue would be addressed in the Phase 3 Building Assessment prior to construction.

ILA and their consultants Waterman Moylan, BDA Façade Consultants and AGL Consulting gave a number of presentations at the Oral Hearing on Day 9 and presented a series of documents, OH139 to OH146 documenting their concerns. The Applicant's responses were essentially to restate that the building would be assessed with a Phase 2 Assessment before construction.

The Applicant on Day 10 presented a revised alignment, lowering it by approximately 5m and introducing two low point sumps, one between tar Street and St. Stephens Green (AZ4(g) and a second between St. Stephens green and Charlemont AZ(h) in revised alignment drawings submitted as OH179 and OH180. These drawings were further updated and submitted on Day 11 as OH185 and in an Addendum to the EIAR assessing the impact of the lowering in OH193. The alignment lowering was also committed to in the *Final Schedule of Additional Environmental Commitments* submitted as OH376

The Applicant also gave a further description of the Phase 3 Building Assessment Process on Day 11 and submitted OH192 further describing

the process, document titled *Working Draft- Process for the Oversight and Implementation of Phase 3 Assessments* as discussed above.

The concerns as set out in by ILA in OH139 and presented at the Oral Hearing on Day 10 are:

Item 1 Structural Damage Settlement

ILA presented the issues with the clash of the tunnel alignment with the uplift anchors and the Applicant's categorization of the building damage as slight/very slight and the issues of not undertaking a Phase 3 assessment until shortly before construction commences.

ILA consultants rebutted the Applicant's assessment and requested from the Applicant a comprehensive response.

The Applicant submitted an Enhanced Phase 2a Building Assessment Report for the Cadenza Building on Day 18 as OH275. This Enhanced Building Assessment was however not at the level that a Phase 3 Building Assessment would be expected to be produced for such a complex building as the Cadenza building and did not significantly advance the understanding of the impact from the tunnelling works on the building.

Item 2 Noise Receptors

ILA had concerns regarding structural noise caused by groundborne vibration during the tunnel construction.

Such structural noise would only affect the building for a short period of time (a few days) as the TBM progress rate is in the order of 10 m per day. It is normal practice to monitor groundborne vibration at sensitive building.

It is noted that the Cadenza Building has not been identified by the Applicant for a Trigger Action Plan (TAP) in the *Final Schedule of Additional Environmental Commitments* (OH376). The Assessors recommend that the Board place a condition on the Applicant that a TAP is developed for the Cadenza Building and that noise and vibration monitoring is put into place during the passage of the TBM beneath the building.

The Applicant may also need to come to a commercial arrangement with ILA regarding the short period when the building may not be suitable for occupation.

Item 3 Settlement

This issue overlaps with Item 1 where ILA had further concerns regarding settlement and building damage.

Item 4 Noise

ILA and their Consultants expressed concern regarding noise and vibration during the MetroLink operational phase which was a common concern from many Third Parties.

The Applicant has taken on board many of these concerns and has extended the areas where a floating track slab will be implemented in OH69 which will reduce the groundborne vibrations during operations. The lengthened sections of floating track slab have been included in the Final Schedule of Additional Environmental Commitments (OH376 reference 5.3) and has reduced the groundborne noise levels from 40 dB LA_{max},as stated in the EIAR to a value of 35 dB LA_{max} (OH376 reference 5.6) which represents a significant reduction in the operational noise level. However this commitment was not given by the Applicant for commercial buildings and the Assessors recommend that the Board applies a condition on the Applicant that the noise and vibration criteria applies also to commercial buildings.

The Applicant has also made other commitments regarding switch types and rail grinding (OH376 reference 5.4, 5.5 & 5.6).

On the basis of the Applicants additional commitments and subject to the Board placing an additional condition on the Applicant regarding groundborne noise & vibration (see Section 13) the Assessors find the Applicants proposals in line with best practice and are an acceptable response to the Third Parties concerns regarding groundborne noise and vibration.

The Applicant submitted to the Board an updated building assessment on Day 18 in OH275 titled Cadenza Building *House Enhanced Building Damage Assessment Report* which provided an enhanced Phase 2 Building Assessment using the methodology from Section 4.2 of the CIRIA Guidance document C796 (London, 2021) for non masonry buildings and repeats the Applicants stated approach that the detailed Phase 3 assessment will not be undertaken until the Detailed Design stage by the Design and Build Contractor that will be engaged by the Applicant.

The Applicant also submitted on Day 18 in OH276 a *Draft Trigger Action Plan* covering, it was stated by the Applicant, AerCap House and the Cadenza Building. The *Draft Trigger Action Plan* sets out the Applicants commitments and processes that he will implement in developing the Phase 3 assessments and in managing the building damage risk on such special buildings as the Cadenza Building.

The Enhanced Assessment, uses a combination of empirical and frame analysis to consider the behaviour of the building to the tunnel induced settlement which they state as being approximately 11mm after taking into account the buildings stiffness and the lowered tunnel alignment. This still induces significant slopes and strains in the building which may cause damage to the building with further presentations made on Day 18 by ILA and its Consultants regarding the risks to the building and façade. The discussions closed on Day 18 with no resolution between the Applicant and ILA regarding how the risk were to be resolved.

10.7 Recommendations

Whilst the Applicant has come some way to accommodating the concerns of Third Parties by:

- lowering the alignment in AZ4 between St. Stephens Green and Charlemont by the introduction a low point sump.
- Extending the sections of the alignment with floating track slab
- Reducing the maximum groundborne vibration to 35 dB LA_{max} S (OH376 reference 5.6) and applying this to commercial, residential and heritage buildings.
- By submitting the Enhanced Phase 2a assessments for three buildings and submitting further details and commitments for the Phase 3 assessments in OH192 on Day 11 and OH276 on Day 18.

The Assessors understand the concerns of Third Parties with sensitive buildings such as AerCap House and the Cadenza Building and that their concerns will also apply to other sensitive and heritage buildings although not necessarily raised in submissions.

As the Applicant has not provided the equivalent of a Phase 3 Building Assessment during the development of the EIAR for such sensitive building where special mitigation measures may be needed, there is a risk that during the procurement process and the Tender Documents preparation for the D&B Main Civil work contract, the required mitigation measures may not be included. In the Contract. It is noted that the *Final Schedule of Additional Environmental Commitments* OH376 submitted on Day 21 contains in Section 15 additional commitments in terms of settlement and building damage assessments, however it does not commit to implement the stated process in OH276 and OH192 in their entirety. Nor does it provide clear commitments regarding the role of the Expert Panel in verifying the building risk assessment process, merely giving it an advisory role.

The Assessors therefore recommend that the Board places additional conditions on the Applicant if it decides to grant the Railway Order to address these matters. The conditions are listed in Section 7 and set out below, together with additional recommended conditions.

1. The Applicant shall engage the Expert Panel (EP) prior to starting the procurement of the Independent Monitoring Engineer (IME) and the Main Civil Works contract and the EP shall verify the scope of the IME and the Contract requirements for building damage risk assessments.
2. The Applicant shall ensure that the Expert Panel has a verifying and “sign off” role rather than the advisory role stated by the Applicant.
3. The Applicant shall procure the Main Civil Works and implement the work to respect the commitments made in OH192 and OH376.

4. The Applicant shall include in the D&B Civil Works Contract additional requirements to those stated in the EIAR for the tunnel works as follows:
    a. A Plan for the Advancement of the Tunnel (PAT) shall be prepared for each section of tunnel in accordance with the methods as described in “Mechanized Tunnelling in Urban Areas Design methodology and construction control” by Guglielmetti et. al. and each PAT shall be reviewed and signed off by the IME and Expert Panel.
    b. The Applicant shall ensure that provisions are included in the D&B Main Civil Works contracts to ensure that the appropriate software and hardware is included in the TBM specifications to allow the Applicant and IME to have access to real time data from the tunnelling operations and that it is integrated with other monitoring such as settlement and displacement in realtime.

10.8 Conclusion

Based on the EIAR and the recommendations above the Applicant has presented an acceptable evaluation for the chosen TBM type for the two main bored tunnel stretches.

10.9 Two intervention tunnels at Dublin Airport South Portal

Section 5.5.4 of the EIAR states that the construction technique for the two airport emergency and ventilation tunnels (aka intervention tunnels) will be via closed face TBM, although in the EIAR imagery these tunnels are shown as having an elliptical cross section thus implying that they would be constructed with the SCL technique. The Applicant confirmed on Day 6 of the Oral Hearing that they were to be constructed by TBM and revised drawings for these tunnels were submitted to the Board (OH91). The assessment of the construction method performed for the main TBM tunnels also covers the two intervention tunnels, hence the Applicant indicates these TBMs to be proposed as Variable Density TBM “*The construction of these tunnels is by closed face TBM and is described in Section 5.5.3.1...*” following Chap 5, section 5.5.3.1.2. However, in Section 4.7 of Appendix A5.13 it is stated that “*These tunnels are likely to be built using a close-face TBM*”.

In addition to the two emergency and ventilation tunnels (intervention tunnels) there will also be some SCL caverns constructed to connect the intervention tunnels and there will also be two shafts constructed using the SCL technique (i.e. at DASP and DANP). The Assessors have concerns therefore regarding the handling of groundwater from these sections of the works although groundwater lowering induced settlement is not considered

to be a major issue at the Airport, the movement of contaminants is an issue from any groundwater abstraction. The issue has been considered in Section 5 and the Applicant will need to ensure that no major dewatering and groundwater abstraction occurs from these works.

10.9.1 Recommendations

The EIAR outlines that the Contractors shall prepare a detailed specification for the TBM as part of the tender design and that the TBM will be procured based on this specification. Even though the EIAR indicates the use of a Variable Density TBM for the main Airport tunnel, the TBM type for the two smaller intervention/ventilation tunnels has not been specified in the EIAR.

It is recommended that similar requirements are placed on the TBM selection and tunnelling works as those specified for the AZ4 tunnel although these requirements may be relaxed to require a closed face TBM rather than a requiring a variable density TBM. The Assessors recommend that the Board places an additional condition on the Applicant if granting the Railway Order to ensure that the above is implemented by the Applicant.

10.9.2 Conclusion

Based on the statement in the EIAR Chap 5, section 5.5.4, requiring a Variable Density TBM and the recommendations for the TBM construction the proposed construction method can be accepted for the two smaller tunnels.

10.10 Charlemont Intervention tunnel

The excavation technique for the Charlemont intervention tunnel is described in Section 5.5.5 of the EIAR as conventional tunnelling (Sprayed Concrete Lining, SCL), using mechanical excavation by roadheader machine for many areas, whereas drill and blast will be needed for some of the excavation. Mechanical excavation by hydraulic breakers is only foreseen for limited periods of time.

Rock support

The rock support for the first 50m is described as steel frames or lattice girders. As the tunnel advances further into the rock the support is rock bolts and reinforcement mesh in conjunction with sprayed concrete lining (SCL) for weaker strata.

Tunnel lining

The tunnel lining is divided into a primary and secondary lining. The temporary primary lining is SCL with a waterproof membrane. Following completion of the primary watertight membrane SCL lining the secondary

permanent lining will be installed. Secondary lining most likely as in-situ concrete.

Groundwater management

It is assumed that due to the slope of the tunnel a continuous sump pumping operation inside the tunnel is expected to be required during the whole construction phase.

10.10.1 Further technical clarifications provided during the Oral Hearing

Due to the questions raised during the Oral Hearing and the further risk assessment of the Charlemont intervention tunnel the Applicant has committed to the following:

Excavation method SCL

Ref. OH 125_Chapter 5, section 5.5.4 and in OH376 the *Final Schedule of Additional Environmental Commitments.*
Due to the further risk assessment of the Charlemont intervention tunnel during the hearing process the Applicant in OH376 has committed not to use blasting in the Charlemont Intervention tunnel. This will reduce the risk of settlement at the ground level and exceedance of groundborne vibration avoiding building damage.

Tunnel lining

Ref. OH 125_Chapter 5, section 5.5.5 and in OH376 the *Final Schedule of Environmental Commitments*:
An early iteration of the Schedule of Additional Commitments submitted at the oral hearing (OH125) included a statement that:

“Sprayed concrete lining (SCL) tunnel construction will not be used during the construction of the evacuation/ ventilation tunnel south of Charlemont.”

It was subsequently confirmed by the Applicant that this statement had been included in error, as it is intended that the intervention tunnel will be constructed with the SCL method. The final Schedule (OH376) omits this statement.

10.10.2 Comments

Excavation method conventional tunnel and SCL

It is common practice to use a conventional tunnel and SCL techniques to construct smaller tunnels and connections where the ground conditions allow for this and the soil cover to ground level is large enough to avoid collapses and unacceptable settlements.

Based on the updated commitment for the excavation method not to use drill and blast for the intervention tunnel there are no further comments.

Rock support and primary lining

The EIAR does not describe the interface between the TBM tunnel and the conventional tunnel. The distance between the intervention tunnel and the segmental lining shall ensure that the construction method and primary lining does not change the support conditions of the segmental tunnel lining resulting in deformations.

Further, the text in the EIAR does not describe the use of spiling as shown in Diagram 5.23. It is recommended that the Applicant provides functional evaluation criteria for the proposed method and that the estimated maximum settlements are defined in the tender documents for the Contractor to meet. The use of spiling, excavation length, tunnel support etc. impacts the design, costs and construction time. The maximum settlements are a combination of TBM drive, conventional tunnelling and ground water lowering.

Further, it is not very clear how and where the waterproofing membrane will be applied as part of the primary lining. However, it is understood that the primary lining must be made watertight to avoid excessive groundwater lowering during construction. This requirement must be defined by the Applicant in the procurement/tender documents as well as the maximum draw down of the ground water at surface allowed during construction, which, as committed to by the Applicant, is No groundwater lowering beyond the seasonal variations. The tunnel geometry shown in Diagram 5.23 does not allow the primary lining to resist the water pressure, hence if the secondary lining is not following immediately after the primary lining the Figure 5.23 must be updated. Mitigation methods to reduce ground water lowering must be defined and submitted by the Contractor for evaluation as part of the tender. This issue is further discussed in Section 5 Hydrogeology and it is recommended that the Expert Panel have oversight and “sign off” of these measures.

Secondary lining:

If the primary lining does not include a waterproof membrane for the whole lining including the base slab this must be added to the secondary lining. When to install the secondary lining must be defined by the Contractor based on the defined maximum settlements and groundwater management.

Groundwater management

See above “Rock support and primary lining” and “Secondary lining”.

Monitoring system:

The text in the EIAR does not describe the monitoring system for the intervention tunnel. A detailed monitoring system of the primary and secondary lining must be established. Further, a geotechnical monitoring

scheme must be developed to ensure the estimated ground movements/ settlements are met.

This issue is further discussed in Section 7 Monitoring and will need to be a combination of the monitoring carried out by both the Contractor and the IME.

10.10.3 Conclusion

Based on the EIAR including the updates and commitments the Applicant has presented a feasible solution for the Charlemont intervention tunnel. It is required that the recommendations above are followed and all EIAR design and risk mitigations are included as requirements to the tender. The tender must define maximum acceptable settlements with limited impact to the buildings within the influences zone and ensure that damage beyond Building damage Category 1 is not caused. The comments are anticipated to be in line with the spirit of the EIAR.

10.11 Connections tunnels and low point sumps

Short connection tunnels will be used for 1) connecting the small bored tunnels at the airport to the main tunnel 2) connection from the Albert College Park to the main tunnel 3) connection of the evacuation and ventilation tunnel south of Charlemont Station to the main tunnel and 4) Connection and construction of the two low point sumps in AZ4.

10.11.1 Conclusion

Even though the description in the EIAR is short for the connection tunnels and pump sumps it is common in tunnelling works to use conventional tunnel technique and SCL. It is considered feasible to construct the connection tunnels and pump sumps with small settlements at the ground level and limited draw down of the ground water. Hence the impact from the small conventional tunnels shall be negligible to the third parties. Therefore, it is considered a feasible solution presented by the Applicant.
The same comments apply to these works as for the Charlemont Intervention tunnel with no blasting permitted, no groundwater lowering being caused and Building Damage being limited to Category 1.

11 Tunnel Outfitting

The tunnel outfitting comprises of substantial works inside the tunnel with all the logistic being provided from the Northwood Portal for the main AZ4 tunnel and from one or both of the Airport tunnel portals for the Airport AZ2 tunnels. The work comprises of the following major elements:

- Installation of the First Stage concrete track bed and track bed drainage system

- Installation of the Second Stage concrete track bed track slab system either a normal track slab or a floating track slab, rails and switches.
- Installation of walkway and Electromechanical systems.

The tunnel outfitting is intended to be carried out 24 hrs/day 7 days per week. The noise and vibration impacts from the works will be limited and it is not foreseen to create any problematic impacts.

The Applicant during the Oral Hearing has substantially extended the sections of alignment that will incorporate floating track slab in order to mitigate the operational groundborne noise and vibrations. This issue is dealt with further in the Report in Section 13

12 Working Hours

The Applicant has described his intentions for working hours in the EIAR Appendix A5.1 Outline *Construction Environmental Management Plan (CEMP)* Section 5.

The Applicant's intended working hours are defined as Standard Working hours, i.e. day shift Monday to Friday and Saturday to 13:00 hrs and Additional Working hours. The Additional working hours are defined for activities that need to be carried out outside the Standard Working hours. Three types of Additional Working hours have been defined for different types of activities, as:

- Regular Works, 7-day working 24 hours
- Regular Works below ground, 7-day working, day shift only
- Occasional Hours, needing approval from the Local Authorities.

The Applicant presented a note on Day 7 of the Oral Hearing OH117 "*Update to Chp.A5.1 Metrolink Construction Phase: Working Hours*" providing further details on proposed working hours and subsequently presented on Day 20 OH348 "*Updated Appendix 5.1 Outline Construction Environmental Management Plan* which we understand consolidates all revisions to the A5.1 CEMP from the Oral Hearings. The Updated Appendix A5.1 defines the working hours intended to be used on the project by the Applicant and are the working hours reviewed.

12.1 Comments

A number of observers in locations along the proposed alignment contend that the proposed working hours are excessive and comments regarding Working Hours are a common theme in a number of Submissions. It particularly has arisen in the areas where the works are carried out in close proximity to residential properties, such as at Charlemont, Glasnevin, Mater, Albert College Park and Collins Avenue. The Applicant has

responded to the Submissions during the Consultation process and has tried to answer the Observers concerns.

The main site working hours have a considerable influence on the impact from the construction, particularly on nearby residential properties, they primarily influence the following:

- Airborne noise and vibrations
- Traffic, (addressed by the Inspector's Report)
- Lighting, (addressed by the Inspector's Report)

Whilst the working hours need to be restricted for activities that have an influence on the impact from the construction, such as airborne noise, vibration and traffic, other activities need to be carried out 24 hr/day for safety and productivity reasons. Unduly restricting the construction working hours will extend the duration of the construction works and increase the costs of the project and for the main TBM tunnel operations are essentially impracticable.

For the main tunnels constructed using Tunnel Boring Machines (TBM) it is normal to run the TBMs 24 hrs per day and seven days per week although at least one working shaft will be used for maintenance. Running the TBMs 24 hrs per day helps to ensure that pressure is maintained in the front cutting chamber of the TBM, which prevents inflow of groundwater and maintains the stability of the tunnel face and thus minimising ground movement, settlement and the risk of building damage. Not running the TBMs 24 hrs/day 7 days per week on the Dublin Port Tunnel was one of several reasons for the settlement and building damage problems that the project suffered. This was discussed by the Applicant on day 10 of the Oral Hearings and a paper was presented regarding the Dublin Port Tunnel, ref: OH156 regarding the issues related to settlement and building damage that occurred on the project. The Assessors agree with the Applicant that the issues associated with the Dublin Port Tunnel should not occur on the Metrolink and that the working hours for the TBM operations should not be restricted.

Similarly, the Sprayed Concrete works (SCL) should be run 24 hr/day to maintain the stability of the tunnel excavation as this is ensured by spraying concrete on the exposed rock/soil together with installing steel ribs and other rock reinforcement measures. However, the SCL techniques differs from the TBM method in that it can be paused with the tunnel faced secured by spayed concrete and rock reinforcement measures. Thus, while the applicant wishes to undertake the SCL works on a 24/7 basis, the Assessors recommendation is that weekend working for SCL works is not required.

Some sites and activities are particularly complex, such as the construction of Glasnevin station which is constrained and interfaces with the two existing rail lines, an adjacent canal and major road and where residential

properties are situated close to the site. It will be challenging for the Applicant to construct these works within the proposed time schedule and it is likely that the Applicant will seek relaxations to Working Hours during construction at this site.

At the Dublin Airport worksites, as the airport operates almost on a 24/7 basis and there are no residential properties nearby, the working hours could be relaxed during construction in agreement with the Local Authority and Airport Authorities. However, for the Railway Order the Assessors recommend that the Applicants stated Working Hours should not be relaxed.

The CEMP makes a number of statements in Section 5 such as:

For the Tunnel construction sites "*Where reasonably practicable, material will be stockpiled within the relevant main construction compound for removal during standard working hours*".

It is also stated that: *If activities require work outside the hours set out in Table 5.2, an approval will be sought from the relevant Local Authority for these on a case-by-case basis. For example, the contractor(s) may seek to extend the working hours for a particular activity, to take advantage of daylight hours during the summer at a location where standard 7am to 7pm working hours (5.5 days) are scheduled*

It also states that: at some stations excavation of rock will be carried out during standard hours, but on a 7 day a week basis and for all intervention tunnels (drilling and moving rock underground) will be carried out on a 24 hour a day basis for seven days per week.

These statements are ambiguous and leave room for the Contractor to carryout work that will have an unnecessary impact on the neighbours.

The revised A5.1 CEMP has essentially the same working hours requirements except for tightening up the text to be less ambiguous and is in the Assessors view in accordance with normal practice on such a large infrastructure project. It has addressed the comments raised at the Oral Hearing and the ambiguous text regarding exceptions has been clarified. However, it still contains the text as follows regarding the intervention tunnel construction:

Excavation in rock: at some stations excavation of rock will be carried out during standard hours, but on a 7 day a week basis and for all intervention tunnels (drilling and moving rock underground) will be carried out on a 24 hour a day basis for seven days per week;

The Charlemont Intervention tunnel is to be constructed using the SCL method and whilst 24 hour working is normal for such SCL tunnels, it is not necessary to have 7 day working for such a tunnel and the inevitable

disturbance to residents above the tunnel can and should be avoided at weekends.

The SCL technique will also be used for the construction of the two pump sumps introduced during the Oral Hearings in the sections of tunnel between Tara Street and Charlemont (AZ4). It will also be used for the construction of the intervention tunnel at the Albert College Park emergency shaft and for works linking the main tunnel and intervention tunnels at Dublin Airport.

Similarly to the Charlemont intervention tunnel, the pumping sumps in Area AZ4 and the SCL works at the Albert College Park are located in close proximity to residential properties, and weekend SCL works should be avoided.

As no residential properties are influenced by the works at Dublin Airport the Applicant should be free to work 24/7 on these works if permitted by the Airport and Local Authorities.

It is recommended that it is made a requirement by the Board that no work on the Charlemont intervention tunnel, the pump sumps in Area AZ4 and the Albert College Park SCL works are carried out at weekends, i.e. later than 13:00 on Saturdays and no work on Sundays and public holidays.

The Assessors recommendation for allowable working hours is shown in Table 5 below.

With the only exceptions to the allowable working hours being for essential safety related works and isolated works where the Local Authority, i.e. DCC or FCC approves such works on an individual basis.

Table 5 Recommended Working Hours

Working Hours Scenarios		Days and Hours	Activities
Standard Working Hours		**07:00 – 19:00 on weekdays (excl. Bank/Public Holidays)** **07:00 – 13:00 on Saturdays**	Piling, concreting and excavation of the stations and alignment structures. Vast majority of deliveries.
Additional Working Hours	**Regular Works**	**24 hours per day, 7 days per week** Notes 2 3	Tunnelling works and associated activities which will be undertaken from each of the tunnel portal launch compounds. Passage of the TBM through the station and associated activities. Low impact MEP i.e. fit out at

		4	the stations and tunnels. Dewatering of excavations Track bed and track laying Construction of intervention tunnels (SCL activities, subject to note 3).
	Regular Works Below Ground	**07:00 – 19:00, 7 days per week, day shift only** Note 5 6	Following the completion of excavation works, works will be undertaken on a 7-day, day shift at some deep stations to avail of TBM stoppages. Final minor civil, building, and architectural finishing works.
	Occasional Hours	**Working hours outside of the standard working hours required on an occasional basis for certain activities** Note 7 8	Completion of large concrete pours. Night-time rail possession activities at Glasnevin, subject to agreement with Irish Rail. Utilities, traffic management, and roadworks. Night-time works for major road work, with durations and timings agreed with the NTA and FCC.

Notes
1. Includes a ½ hour 'shoulder' period at each end of the day to prepare the sites
2. Excavated material will be stockpiled within the tunnel portal launch compound and disposed of during standard working hours
3. With the exception of the SCL works for the Intervention Tunnels at Charlemont, Albert College park and the pumping sumps in AZ4.
4. Associated delivery activities will be undertaken during standard working hours.
5. Where the station construction is top down and after the top slab has been constructed
6. Associated delivery activities will be undertaken during standard working hours.
7. Other specific activities, such as local traffic management and special/ abnormal deliveries
8. To be agreed with the local authorities

12.2 Conclusion

The proposed construction working hours, subject to the additional restrictions as set out above, are reasonable and consistent with normal working practices for such large-scale construction projects.

13 Noise and Vibration, Airborne and Groundborne

Noise and vibration both during construction and operations are likely to have the largest impact on the environment that will affect Third Parties, as can be seen by the large number of submissions made regarding these subjects. The character of the noise and vibration issues are significantly different during the construction and operational phases and this report will address them separately. In the EIAR, construction and operational noise and vibrations are considered in the same reports with separate chapters for airborne noise & vibrations and groundborne noise and vibrations, i.e. Chapter 13 Airborne Noise and Vibration and Chapter 14 Groundborne Noise and Vibration.

In the following sections the issues regarding noise and vibrations are assessed, together with the relevant parts of the EIAR and the additional material submitted during the Oral Hearing with respect to noise and vibration impacts. The resulting noise and vibration impacts for both the construction and operational phases as well as a number of representative submissions from Observers are also assessed.

To minimise the impacts from noise and vibration, a systematic working approach has been used by the Applicant, which has applied:

- defining requirements for measurable parameters that reflect the perceived noise and vibrations,
- performing simulations and measurements of these quantities in the initial stages of the project to identify potential impacts and problems,
- identifying suitable mitigation measures for the identified impacts,
- monitor by performing measurements of noise and vibration at selected locations to verify the predicted noise and vibration levels,
- implementing improvements to reduce the noise and vibration levels where possible during the construction period.

It is important to separate the impacts regarding noise and vibration into those concerning the construction phase and those concerning operational phase as they have quite different characteristics. Noise and vibration problems during the construction phase, even though they can cause significant disturbance, and may be impossible to fully avoid or mitigate are inherently limited in time. Therefore, in many cases the most realistic solution may be simply to seek to gain acceptance from the affected parties through the implementation of the best practical mitigation measures together with good communication, or ultimately rehousing for the period affected. Noise and vibration problems during the operational phase, on the other hand, will not disappear and have to be considered and addressed in the design stage, as in most cases it will be impractical to mitigate at a later stage. For instance to change the track form to a different type, i.e. change to a floating slab track after construction is complete would not be practical

as it would involve stripping out all the tunnel internal works and replacing them. This would result in major expense and the metro having to be closed for an extended period. It is also the Assessors' experience, that the public tolerance of groundborne noise and vibrations has reduced in recent years and it is an increasing problem in the public perception. A new metro should therefore be constructed to give the lowest practical groundborne noise and vibrations, as the Applicant has committed to during the Oral Hearing with the reduction to a maximum level 35dBA for residential dwellings together with the commitment for a floating slab track through much of the city centre alignment section.

Two factors that significantly influence the impact from the construction, particularly from noise, are the permitted working hours and the restrictions placed on night time working, together with the overall duration of the noisy/vibration causing activities. The issues regarding working hours are addressed in Section 12 of this report, where the Assessors largely agree with the working hours proposed by the Applicant with some amendments. Further restrictions to the working hours and activities were requested by some Observers, however; further restrictions would inevitably prolong the construction period and extend the duration of the negative effect.

It is noted that the Applicant has stated that the overall construction period is approximately nine years, in the EIAR Appendix A5.2 Construction Programme, and has not provided detailed time schedules for the activities at each of the construction sites. Such detailed construction time schedules would most likely show that many of the noisy activities are limited in duration and may, at least to some extent, allay some concerns from nearby residents to the construction sites such as the Observers at Dartmouth Square. For example, for a typical deep station in Section AZ4, the most noisy activities will be associated with the diaphragm wall installation and secant piling works for the shallow structures, together with the demolition of the upper portion of the diaphragm walls to enable a capping beam and the top slab to be cast. Once the top slab is cast, excavation works will be carried out beneath the slab which will attenuate much of the noise from the excavation works.

The Applicant gave some clarification at the Oral Hearing (Mr. Moloney on 4th March 2024), in response to the submission/questioning by Kenneth Goodwin on behalf of the Charlemont and Dartmouth Community Group, giving a more detailed breakdown of the time schedule for the construction of Charlemont Station. This would be applicable for the other deep stations with the exception of Glasnevin which is significantly larger and more complex in nature. The Applicant stated that:

- Enabling works, first year.
- Piling operation and D-walling, 11 months, carried out in 3 phases.
- Roof slab, 1 year, carried out in 3 phases..
- Excavation below roof slab, 30 months.

- Bottom up construction within the station,1 year.
- Station structure finished within the first 5 years.
- Then other activities. Internal building works, MEP works, SCL works, TBM arrival – Years 6-7.
- MEP and finishing works. years 7-8.

Based on the Assessors' experience, the durations stated by the Applicant are reasonable.

The construction of Glasnevin Station is more complex and larger than for the other deep stations, however; the overall duration will be the same in order for the Applicant to meet the overall project time schedule. It will therefore be executed within the 9 year period identified by the Applicant. The Applicant provided in the EIAR, Appendix A5.5 *Glasnevin Construction Report,* a description of the methodology and sequencing of the construction works as the station will incorporate two existing commuter railways, the western commuter line and the south western commuter line. In the Assessors view, the overall time schedule will be achieved essentially with activities being overlapped and sequenced such that the overall time schedule of 9 years is achieved. This will for instance mean that piling and diaphragm walling works will most likely take 2 to 3 years which will overlap with the excavation and concreting works. Neighbours close to the site, such as at Dalcassian Downs, will therefore have a long duration of the noisier impacts such as the piling and diaphragm wall installation extending of several years.

The other area of significant noise impacts is the construction of the retained cut and cut & cover tunnel, for instance the section of cut and cover at Seatown West where there have been concerns raised by Observers regarding airborne noise. A detailed time schedule has not been provided by the Applicant for these works, however the Board questioned the Applicant on this issue on Day 4 of the Oral Hearing and the Applicant stated on Day 5 that the noise assessment modelled a 300m linear working area and that affected properties can expect to be exposed to the predicted noise levels for 6 months. Whilst this answer seems reasonable, the noisy works may not be executed continuously and there may be breaks in the noisy works depending on how the D&B Contractor sequences the works. Therefore the 6 month impact period is likely to be spread over a longer time period with the construction period for a 300m length of the works being likely to be longer than 6 months, probably more like 1 to 2 years.

It would therefore be likely that an individual property would have the most noisy works impacting them for approximately 1 to 2 years whilst the piling, excavation and concrete works are carried out. Outside of this noisy periods the impact from the project regarding airborne noise and vibration will be significantly less.

The character of the noise will also change as the different phases of construction proceed, with noise characteristics from the piling and diaphragm wall operations being different from those when the excavation commences and from the concreting operations.

13.1 Airborne Noise and vibration

Airborne noise is likely to be one of the largest impacts during construction and affects a large number of receptors along the alignment, particularly around the major construction sites, i.e. the deep stations, retained cut, cut & cover and the at-grade works and to a much lesser extent along the tunnel alignment. The issue was raised in a large number of submissions both during the Consultations and at the Oral Hearing.

The Applicant has addressed the airborne noise issues in the EIAR Chapter 13 Airborne Noise and Vibration with the following Appendices:

A13.1 Baseline Noise Monitoring Report

A13.2 Baseline Noise Monitoring Report – Appendices

A13.3 Baseline Vibration Monitoring Report

A13.4 Baseline Noise Monitoring NCH and Gate Theatre

A13.5 Baseline Vibration Monitoring at Trinity College Dublin

A13.7 Construction Phase modelling

A13.8 Operational Phase Modelling

These documents have been amended and updated during the Oral Hearing by a number of documents, including the following:

OH9 Schedule of Errata

OH12 Errata Appendix 10, Updated Appendix A13.7 Charlemont station

OH122 Errata Update Ch.13 Airborne Noise and Vibration, Table 13.64 Mater Station

OH168 Noise Control from Fixed Installations

OH181 Airborne Rail Noise Effects at Glasnevin during MetroLink Project

OH374 Final Schedule of Errata

OH375 Schedule of Updates

OH376 Final Schedule of Additional Environmental Commitments

13.1.1 Agreements with Local Authorities

The Applicant has reached agreement with the two relevant local authorities Dublin City Council (DCC) and Fingal County Council (FCC)

which were submitted during the Oral Hearing as OH76 and OH147. Only the agreement with FCC (OH147) contains any conditions regarding airborne noise and these (Condition 9) and this only relates to work outside of daytime hours.

The Applicant states in the EIAR Chp. 13 Section 3.2.5.1.2 that work outside of the defined working hours will be agreed with the Local Authorities. It is unclear what the Local Authorities roles are to ensure that the Applicant complies with its commitments regarding airborne noise.

The Assessors recommends that the Board considers how it will be ensured that the airborne noise and groundborne noise commitments made by the Applicant will be adhered to. This may require the Board placing additional conditions on the Applicant when granting the Railway Order.

13.1.2 Requirements for Airborne Noise during Construction

Before summarising the requirements for noise, which are normally defined in terms of amplitude or energy levels, it should be emphasised that it is not possible to fully quantify the grade of disturbance using only these measures. This is because the individual experience of noise and vibrations also depends on the frequency content, duration and background level, as well as on the personality of the individual being exposed and the environmental context. Examples of this are for instance at night, where residential properties are much more sensitive to airborne noise than during the day and when a short duration noise event may cause disturbance at night which during the day would not cause any disturbance.

In the absence of Irish standards or statutory limits for airborne noise, the Applicant has chosen to use the British Standard BS5228-1:2009+AS1:2014 – ‘ABC Method’, for managing the impact from airborne noise. The requirements are defined in Table 13.12 Chapter 13 of the EIAR and summarised in the Table 6 below together with other guidance used such as the relevant sections of the UK Design Manual for Roads and Bridges (DMRB).

Table 6 Summary of Airborne noise requirements EIAR Chp 13 Table 13.12

Assessment Category & Threshold Value Period (L_{Aeq})	Construction Noise Threshold (CNT) (dB)		
	Category A [A]	Category B [B]	Category C [C]
Daytime (07:00 – 19:00hrs) and Saturdays (07:00 – 13:00hrs)	65	70	75
Evenings & Weekends (19:00 – 23:00hrs weekdays) (13:00 - 23:00hrs Saturdays) (07:00 – 23:00hrs Sundays)	55	60	65
Night-time (23:00 to 07:00hrs)	45	50	55
Notes	Category A: threshold values to use when ambient noise levels (when rounded to the nearest 5dB) are less than these values	Category B: threshold values to use when ambient noise levels (when rounded to the nearest 5dB) are the same as category A values.	Category C: threshold values to use when ambient noise levels (when rounded to the nearest 5dB) are higher than category A values.
			If the ambient noise level exceeds the Category C threshold values given in the table (i.e. the ambient noise level is higher than the above values), then a potential significant effect is indicated if the total $L_{Aeq,T}$ noise level for the period increases by more than 3 dB due to site noise

As indicated in Table 6, the threshold values are related to the ambient noise level which is also referred to as the Baseline Noise Level, i.e. the current noise level at a given location without any construction work related to the MetroLink project ongoing. The advantage of this relative definition of the target level is that it includes the masking effect of noise not related to construction work and thus captures the experienced noise better than an absolute noise limit.

However, in order to be relevant and representative of the noise environment at a particular location, the Baseline Noise Levels (BNL) should be updated whenever there is a change in the neighbouring soundscape such as, for example, a change in road traffic speed limit or flow. Considering the importance of the Baseline Noise Levels for the construction noise, the method for determining these levels is particularly important.

An alternative approach, not dependent on the baseline, would be to use absolute targets as is used in many countries e.g. Sweden. In Sweden the threshold values coincide with the “Category A” of BS BS5228-1:2009+AS1:2014 values apart from the daytime level being further restricted to 60 dB(A). These thresholds apply no matter the background level. In addition, in Sweden there is also a limit for the maximum noise level during night set to 70 dB(A) which, considering the character of construction noise, severely restricts the possible activities during night.

Finally, the Applicant has also set a threshold value for noise from blasting with a maximum peak value of 125 dB as specified in Chp. 14, page 8 in the EIAR. Blasting has been addressed by the Assessors in Section 4.1.1 and is recommended that blasting is avoided in city centre locations and for the SCL works and that the Board places conditions on the Applicant to limit blasting.

13.1.3 Assessment Procedures

The assessment procedures used in the preparation of the EIAR are summarised in the EIAR Chp.13 Table 13.7. The procedures adopted essentially use the SoftNoise noise prediction software with the BS 5228-1 methodology and the predictions compared with the Baseline Noise Levels (BNL) and the Construction Noise Thresholds (CNTs).

The Applicant has defined the construction worksites and selected typical plant and equipment for representative stages of the work. The predictions of construction noise levels are then associated with the key work stages that were deemed representative of the likely worst-case scenarios for each work site using the expected plant types and numbers, and planned site layouts. The Sound power data for the plant to be used were sourced from BS 5228-1 (BSI 2009 +A1 2014a), from previous measurements and the experience of the Applicant's consultants.

The Applicant notes that the assessment has been carried out at an early stage of design maturity (i.e. Railway Order/EIAR phase) when not all details of the equipment and working methods can be defined and that the assessment will need to be updated during the Detailed Design phase where it is stated in the EIAR Chp 13 Section 13.2.5.1.3 that:

Should the project be approved, prior to the commencement of any construction works, a detailed noise assessment for each work site will be undertaken based on the most up to date information for each.construction worksite ……

This approach is consistent with BS5228-1, Section E.1 of which provides for further assessment of noise impacts, which will be used for defining the final noise mitigation measures and for the application of *the Noise and Vibration Mitigation Policy* (NMP) when the need for Noise Insulation (NI) or Temporary Rehousing (TRH) will be determined. This will be carried out after the Contractor has been appointed and detailed method statements and programme information are available. At this time the site specific CNVMPs will be developed by the Contractor based on his detailed planning, it is expected that these documents will be reviewed and approved by the Applicant. This is a normal approach on large projects and is considered acceptable to the Assessors and is discussed further below.

For each of the worksites or construction compounds the Applicant has determined a Construction Noise Level (CNL), calculated at each receiver

location. CNLs have been calculated at each floor height and for buildings with multiple calculation points at varying floor heights, the highest CNLs has been extracted for the impact assessment.

All results are expressed as LA_{eq}, T and have included a façade correction. For daytime weekday periods, the T (time) value has been expressed over a 12hr period (07:00 to 19:00hrs) and for Saturday morning periods over a 6 hour period (07:00 to 13:00hrs). Where evening and night-time calculations are made, these have been expressed over a 4 hour period (19:00 to 23:00hrs) and 8 hour period (23:00 to 07:00hrs) respectively.

The duration, nature and extent of construction activities associated with the construction phase of the proposed MetroLink project would categorise it within the high-risk category, in accordance with the DCC Good Practice Guide for Construction and Demolition, which states that the ABC Method detailed in Paragraph E.3.2 of BS 5228-1:2009 should be used to determine acceptable noise levels for day, evening and night time work.

It is noted that FCC does not use an equivalent noise risk assessment procedure, however the Applicant has proposed to use the DCC guidance across the full extent of the MetroLink Project and FCC has not raised any concern in relation to the approach taken.

The ABC guidance refers to BS 5228–1 and the DMRB Noise and Vibration (UKHA 2020) approach, in order to review and set appropriate construction noise significance ratings or significance thresholds. The ABC approach uses Assessment Categories (A, B or C) based on the existing ambient noise levels in the absence of construction noise. This then sets a threshold noise value that, if exceeded at this location, indicates that a potential significant noise impact is associated with the construction.

The Applicant has summarised the resulting CNLs in Chp.13 Table 13.12. The Applicant notes the extensive nature of the MetroLink project, the number of construction sites and sensitive receptors and anticipates that the CNTs will vary across the project on a site by site and receptor by receptor basis.

The Applicant acknowledges that due to the nature, scale and duration of the proposed Project, certain CNTs discussed in Table 13.12 will be exceeded during specified Construction Phases, particularly at NSLs which form the boundary with large work sites. This will be particularly so for areas with the lowest CNT (Category A), where it will not be possible to manage certain construction activities within these significance thresholds.

The Applicant has then used the DMRB Noise and Vibration (UKHA 2020), approach to determine whether the noise impact is a significant effect and to determine a Construction Noise Impact rating. The criteria for determining a significant effect and construction Noise impact Rating are defined in the EIAR Chp.13 Section 3.2.6.1.3 and Table 13.13.

The approach as described above and used by the Applicant is accepted by the Assessors, however it will require both the noise predictions and the noise Baseline measurements to be repeated during the Detailed Design period and prior to construction commencing with possibly several iterations being needed as the different phases of the project progress. Care needs to be taken that the predictions are made with representative plant and working methods and that the Baseline noise measurements are made in such a way that they are representative of the noise environment at the relevant locations, as Observers have raised questions regarding the EIAR stage Baseline monitoring, as detailed in Section 13.7 below.

13.1.4 Mitigation Measures

The Applicant has described the mitigation measures they intend to apply in the EIAR section 13.6 with the key principals being applied of:

- Noise control at source
- Noise control along the transmission pathway
- Noise Control at the receiver

Control at source includes selection of the quietest available plant and working methods, together with adopting the top-down construction sequence for the Deep Stations in AZ4, which will significantly reduce the noise impacts at these sites. Many of these Deep Station sites are located close to residential receptors or commercial buildings and are thus sensitive to airborne noise. It is noted however that for some working methods such as piling and diaphragm walling activities, there are limits to what can be done regarding silencing the equipment, as for instance there is significant “clanging” from the piling equipment even with the most modern equipment. This type of noise can be disturbing to neighbours and can only be mitigated by strict adherence to the defined working hours, pathway control and, ultimately, if these are insufficient, application of the Airborne Noise & Groundborne Noise Mitigation Policy (NMP). The NMP is contained in Appendix A14.6 of the EIAR and is discussed further in Section 13.1.5 below.

One of the main pathway control measures is for site hoardings with a height of 2.4m high applied as standard around the site boundaries and with taller hoardings at the more sensitive sites. The EIAR Chp.13 presents details of the hoarding heights at each of the sites in Table 13.85. The Applicant has committed in the EIAR Chp.13 section 13.6.1.2.4 to reviewing the hoarding height and details for each site prior to construction commencing as part of the development of the CNVMPs for each site.

The hoarding locations are shown on the site hoarding layout drawings in the EIAR Chp. 5 Figure 5.1 *Construction Compounds and Works Sites*. It is noted that there are practical limits to hoarding heights and it is often

difficult to screen upper floors of building without using tall hoardings, which can block access to light.

Control at the receiver is only applied when the noise impacts cannot be mitigated by either control at the source or along the pathway. The noise control at the Receiver would be managed with the Airborne Noise & Groundborne Noise Mitigation Policy (NMP) and would include Noise Insulation (NI) measures and Temporary Rehousing (TRH).

There are a number of particularly noisy activities some of which will run continuously during tunnelling operations or during diaphragm wall and piling works. One of these is at the Northwood portal, where the TBM operations will run 24/7 for an extended period. The Applicant has specified that a variable density TBM will be used, which will require a large bentonite cleaning plant. The Applicant has committed in the EIAR Chp.13 Section 13.6.1.2.4 to cover the “surface working area” with an enclosed building, giving a high level of noise attenuation. It is not clear if the area covered includes the bentonite cleaning plant and it is recommended that the Board includes a condition that the bentonite cleaning plant is contained within the acoustic building.

In a similar manner a bentonite cleaning plant will be needed at all the sites where diaphragm wall construction is to be carried out. It is recommended that the Board includes a condition that at the more sensitive deep stations locations the bentonite cleaning plant is enclosed within an acoustic building. Similar measures have been taken on other major projects such as the Copenhagen Metro and it is recommended that this requirement is applied at the following locations:

- Charlemont
- St. Stephens Green
- Mater
- Collins Avenue

The Applicant has also proposed acoustic enclosures for the SCL works at Charlemont and at Albert College Park. Such measures are good practice as the SCL works will run 24 hrs per day. The Assessors in their review of the working hours have recommended that the SCL works are not run 7 days per week and are stopped from Saturday afternoon to Monday morning. The Applicant’s proposals for mitigation measures are in accordance with good practice for such a large projects, are in line with adopted approach in BS5228 and are acceptable to the Assessors if the additional conditions set out in Appendix A are implemented.

13.1.5 Airborne Noise & Groundborne Noise Mitigation Policy

The Applicant has provided as part of the EIAR in Appendix A14.6, an Airborne Noise & Groundborne Noise Mitigation Policy (NMP), their

overarching policy regarding the mitigation impacts for noise and in this document they identify how situations where the Triggers Values defined in the EIAR are predicted to be exceeded will be mitigated. Additional measures stated in the Policy include hard and soft measures such as additional noise control measures like secondary glazing or temporary rehousing along with some “soft” intervention measures that may be offered to affected parties.

The Policy reflects normal practice on major projects and is fundamentally based on BS5228-1. It is considered to be acceptable by the Assessors except with regard to the statement made by the Applicant in Section 3.3 for Temporary Re-Housing where they state that: “*Where temporary re-housing arrangements are made, they will be for, in general, a maximum of 4 weeks. Any extensions to the 4 week rehousing programme will be addressed on a case by case basis*.”

From the Assessors review of the Applicant’s documents, it is likely that where the EIAR Trigger Values are likely to be exceeded, this will be for periods greater than 4 weeks and the period for temporary rehousing should be agreed based on the duration that the relevant construction activity is predicted to exceed the relevant trigger criteria and not an arbitrary 4 week period. The Assessors recommend that the Board include a condition in respect of this on the Applicant if they grant approval of the Railway Order to this effect.

13.1.6 Requirements for Airborne Noise during Operation

As the proposed MetroLink is routed mainly in tunnel or retained cut, the potential for noise during operation is reduced. However, there are open sections as well as stationary installations such as ventilation fans and electrical transformers that need to be considered. In addition, groundborne noise may be an issue for buildings closely located to the track.

Other issues that are relevant to the operational phase include the use of Public Address systems at the station locations which was raised by Observers interested in Charlemont Station. On metro systems the use of Public Address systems is limited and usually confined to periods of traffic disruption or emergencies and the impact on the surrounding environment will be limited, particularly given that at most locations they are confined with the station. The only exception to this is the at-grade stations in AZ1. The Applicant has addressed these issues in the EIAR Chp. 13 Section 3.5.3.2.4 Public Address (PA) Systems and has committed to minimising the impact from the PA systems.

What the Applicant is proposing is acceptable to the Assessors.

13.1.6.1 Rail Noise

The thresholds for noise from trains running in open sections of the alignment have been defined by the Applicant from reviewing other large scale urban rail projects such as Dublin Luas, Channel Tunnel Rail Link (London) and Cross Rail (London), as well as including recommendations from WHO Environmental Noise Guidelines 2018. They are summarised in Table 7 below. In summary, the thresholds are defined as equivalent sound levels below 55 and 45 dB(A) day and night respectively. It should be noted that there is no threshold set for the maximum sound level. This basically means that a few very noisy train passages could still be within the requirements, even though it could affect nearby residents ability to sleep during night. For this reason, the requirements set upon equivalent sound level is often complemented by thresholds for the maximum sound level during night hours, possibly with a limited number of events surpassing the limits to account for the somewhat stochastic character of the maximum sound level. On the MetrolLink this issue should not be problematic as only the MetroLink trains and maintenance trains will run on the tracks, there will be no potentially noisy freight trains for instance. As with construction noise impacts there may be non-standard receptors, such as e.g. theatres, museums and heritage buildings, that will need specific attention for the operational phase. These assessments should be carried during the Detailed Design phase when the track slab design is being developed, together with verification measurements being carried out to verify that the requirements can be met.

Table 7 Threshold values for operational rail noise from EIAR chapter 13, page 38.

Sensitive Locations	Receptor Sensitivity	Noise Criteria during Operational Phase
Locations that are highly sensitive during day and night-time periods ▪ All residential buildings; ▪ Health care facilities (hospitals, nursing homes) ▪ Hotels, student accommodation and hostels	High	Daytime: 55dB $L_{Aeq,16hr}$ (07:00 – 23:00hrs) Night-time: 45dB $L_{Aeq,8hr}$ (23:00 – 07:00hrs)
Locations that are only sensitive during daytime periods, and are sensitive to noise: ▪ Educational Establishments; ▪ Theatres ▪ Places of worship (churches & other religious buildings) ▪ Offices	High	Daytime: 55dB $L_{Aeq,16hr}$ (07:00 – 23:00hrs)
Locations that are only sensitive during day but are less sensitive to noise that the categories above: ▪ Commercial buildings ▪ Outdoor recreational areas ▪ Cinemas	Medium	Assessed on a case-by-case basis, depending on the sensitivity of the specific use, the level of sound insulation that may be afforded by the building & the prevailing noise environment
▪ Industrial Warehouses ▪ Indoor recreational areas ▪ Shopping centres/retail park	Low	

13.1.6.2 Stationary Sources

For noise from stationary sources that are related to the MetroLink such as, for example, the maintenance depot and ventilation shafts, the British standard BS 8233:2014 (BSI 2014c) for indoor noise levels in residential dwellings has been used to set the requirements. Note that these concern the total noise level, i.e., MetroLink related noise in addition to the Baseline Noise level and are defined in Table 8 below.

Table 8 Threshold values for indoor noise levels from stationary sources, baseline and MetroLink related noise, from EIAR chapter 13, page 42.

Activity	Location	Daytime	Night-time
Resting	Living room	35dB $L_{Aeq,\ 16hour}$	-
Dining	Dining room/area	40dB $L_{Aeq,\ 16hour}$	-
Sleeping (daytime resting)	Bedroom	35dB $L_{Aeq,\ 16hour}$	30dB $L_{Aeq,\ 8hour}$
Notes: Daytime assessment period – 07:00 to 23:00 hrs Night-time assessment period – 23:00 to 07:00 hrs			

In this case there are also requirements for the maximum sound level, $L_{AFMAX,Fast}$ not to exceed 45 dB(A) during nighttime. By assuming a building insulation in the case of a partially open window of 15 dB, these values can be transformed to yield the following thresholds for outdoor sound levels at residential properties.

- Daytime (07:00hrs to 23:00hrs): 50dB $L_{Aeq,\ 16hr}$;
- Night-time (23:00hrs to 07:00hrs): 45dB $L_{Aeq,\ 8hr}$; and
- Night-time (23:00hrs to 07:00hrs): 60dB L_{AFmax}.

In locations where the total noise level is higher than the above values, the British Standard BS 4142 (BSI 2014+A1 2019) has been used to estimate the impact of noise from the MetroLink by comparing with the Baseline Noise level. This means that if noise sources that form part of the Baseline are abated or eliminated, it may result in the MetroLink installation exceeding the threshold on its own. If instead the requirements are set upon the standalone noise from the MetroLink, then the efforts to achieve a less noisy Dublin in general are better supported.

It is well known that fans, in this case associated with the Albert College Park Ventilation Shaft, will have large ventilation fans installed, which often generate low frequency tonal noise that may propagate over long distances. To address this the Applicant proposed additional requirements to deal with this issue during the Oral Hearing in document "*Noise control from fixed installations for MetroLink*" (OH168). The Assessors accepts the measures put forward in this document, however we recommend these requirements are complemented by specific thresholds for the frequencies between 10 and 160 Hz according to the NANR34 assessment referred to in the British Standard BS4142.

13.2 Applicant's Approach and Assessors Comments Airborne Noise & Vibrations

Noise and vibrations can have significant environmental impacts both during construction and operation and need to be mitigated as far as reasonably possible and monitored, to ensure that the resulting noise and vibration impacts are within the predictions and to identify where additional measures need to be implemented.

A major issue with this monitoring will be to separate noise related to the MetroLink from the background results from other noisy activities in a large city like Dublin. In the case of measurements this is not straightforward, and this is why numerical simulations of the different sources of noise and to some extent vibrations are increasingly more common on major projects and is an approach used in countries such as Sweden, as opposed to the BS5228 approach that compares the impact with the Baseline Noise levels.

An advantage of using simulations compared to measurements is, in addition, the possibility to evaluate each source on its own merits together with source, pathway and receptor mitigation measures with increased spatial resolution. Even with an ambitious measurement program the recorded sound levels are restricted to a discrete set of locations and times.

The Applicant has chosen to use the UK approach as defined in BS5228-1. This is a commonly used methodology, which has been used on major recent projects in the UK such as Crossrail and HS2 and which is also used in Ireland on other projects. This approach is considered to be acceptable by the Assessors and valid for such a large infrastructure project provided the additional conditions as recommended by the Assessors are placed on the Applicant by the Board.

13.2.1 Baseline

To use the approach chosen by the Applicant (i.e. the BS5228-1 approach) and enable estimates of the impact of noise from the MetroLink activities to be made, the background noise levels in the surroundings are required. The Baseline Noise assessment is outlined in Chapter 13.3 and 13.4 of the EIAR. This Baseline Noise Level (BNL) is defined by the equivalent sound level and was determined by measurements at 126 locations distributed along the alignment either for longer time periods, typically a week, or by attended measurements during a single day from which a long-term equivalent level was estimated. The sound field in a given environment was defined by the strength and location of the dominant sound sources and the topography and absorption properties of the landscape. In an urban environment the shielding, and to some extent reflective properties of buildings also influence the resulting soundscape. For the Baseline to be useful, the location of the measurement points must be carefully chosen

with respect to these parameters and also to suit the locations relevant for construction and operational activities of the project.

It is noted that the Applicant chose to use as the basis to fulfil the requirements of the Environmental Noise Regulations (S.I. No 140/2006 and S.I. 549/2018) the noise maps published by the EPA at their geo portal for Noise Maps with the Round 3 2016 maps utilised.

As noted above, and as per the guidance contained in BS5228-1, the EIAR proposes more detailed construction stage assessments and management plans prior to construction, when detailed design has progressed. As part of this, they have committed to re-assessing the baseline noise prior to construction. As the Baseline Noise Level determines whether noise from MetroLink activities requires mitigation in a specific building or not, the 126 base line monitoring locations from Estuary to Charlemont are considered to be too few to accurately support these decisions for the more detailed CNVMPs that are to be prepared prior to construction commencing. Considering the time required for and the general uncertainty in outdoor noise measurements, it is recommended to perform an updated noise mapping of the MetroLink area prior to construction commencing and to use this as the Baseline for the Construction Stage noise assessments (CNVMP) and for the definition of the final mitigation measures. These measurements may need to be rerun at different stages as the project progress, particularly if there are major changes in the noise environment such as the traffic patterns during construction.

The measured data could also be used to calibrate numerical modelling which would provide a more consistent and more easily updated baseline by which the noise impact in each location can be more accurately and also transparently estimated and communicated to local residents and businesses.

Due to its nature, the background vibration level is in general negligible and this is why the baseline vibration investigation has been limited to 3 specific locations nearby the existing railways. The measured vibrations are presented both as vibration dose and peak level and thus gives sufficient data to determine the impact of the MetroLink activities at these locations

13.3 Groundborne Noise and Vibration

Groundborne noise and vibration are primarily an issue for the MetroLink operational phase as persistent noise and vibration arising from groundborne vibrations can be particularly problematic for residential properties above the tunnel, but may also be problematic for heritage buildings and some commercial office buildings. It is also the Assessors' experience that public awareness of these issues has increased and the tolerance to structure borne noise has decreased in recent years.

Groundborne noise and vibrations will also arise during the construction phase from the tunnelling operations, however this is of a relatively short duration as the TBM will be beneath a particular structure for only a short period and the TBM can be “heard” from a specific property for typically only a few days. The EIAR outlines that tunnelling is likely to cause a significant effect in terms of annoyance and sleep deprivation for a period of c.2 weeks, with a peak of 2-3 days when the TBM is closest, and with affected properties on or close to the line of the TBM most affected.

Groundborne noise and vibration from the other construction works such as diaphragm walls and piling works are limited and will not be problematic. The Applicant had proposed the use of blasting in the sections of SCL tunnels and at the deep stations. This issue is addressed in Section 4.1.1 of the report and the Applicant has committed to not use blasting for the Charlemont intervention tunnel whilst keeping the option open for the deep stations. The Assessors recommend that the Board places additional conditions regarding blasting on the applicant as discussed in Section 4.1.1

The Applicant has addressed the groundborne noise issues in the EIAR Chapter 14 Groundborne Noise and Vibration with the following Appendices

A14.1 Relevant guidance and standards

A14.2 Train Characteristics

A14.3 Track Support System Assumptions

A14.4 Groundborne Noise Numerical Modelling Method FINDWAVE

A14.5 Groundborne Noise and Vibration and Blasting Modelling Results

A14.6 Airborne Noise & Groundborne Noise Mitigation Policy

These documents have been amended and supplemented during the Oral Hearings by a number of documents, including the following:

OH11 Errata Appendix 5, Chapter 14 Groundborne Noise and Vibration Addendum

OH13 Errata Appendix 11, Updated A14.5 - Groundborne Noise and Vibration and Blasting Modelling Results

OH14 Errata Appendix 12, Updated and Additional GBNV - Figures1

OH68 MetroLink Regeneration Braking Technical Note

OH69 Metrolink – Figure 14.8 – EIAR proposed locations for Floating Slab Track drawings: DR-Y-40021 to DR-Y-40027

OH103 Floating Slab Track locations

OH104 MetroLink Floating Slab track (maps)

OH112 Prediction of Groundborne Noise from Groundborne Vibration

OH119 and OH119A Additional Groundborne Noise Vibration Commitments, Switches and Roughness. Presentation and TNO "*Additional Ground borne Noise and Vibration Commitments*"):Swing-nose switches at 5 locations

OH174 Additional Groundborne Noise Commitment

OH374 Final Schedule of Errata

OH375 Final Schedule of Updates

OH376 Final Schedule of Additional Environmental Commitments

13.3.1 Requirements for Groundborne Noise and Vibration during Operation

During operation, vibrations propagating from the tunnel into adjacent buildings result in a rumbling low frequency noise and is a known problem that requires special attention. The preferred choice to avoid this is to ensure a minimum distance between rail and building but in the current case, where this is not possible, measures have to be taken in the design of the railbed/trackform.

In the EIAR chapter 14, page 6-7 the proposed thresholds for residential as well as non-residential buildings for this groundborne noise are set out, as per Tables 9 and 10 below.

During the Oral Hearing, the Applicant committed to lower the upper threshold that they will not exceed and stated that:

"*TII will ensure that during the operation of the Metrolink passenger service, the operational groundborne noise levels in any lawfully occupied residential dwellings, measured near the centre of any noise-sensitive room, will be below 35dBLA$_{max}$,S".* Lowering it from 40 dB(A) in the EIAR to 35 dB(A). This is set out in the Applicant's TII document entitled "Additional ground borne noise commitment" submitted at the Oral Hearing on 5th March 2024 (Ref. OH174).

The Applicant made the change after questioning from the Board's Inspectors and the Assessors with the motivation mainly being to ensure that the disturbance caused by noise from the MetroLink operations during sleeping hours for residential buildings is comparable to typical in-house background levels, and to lower the groundborne noise levels for particularly sensitive commercial and heritage buildings. The Assessors were aware of the levels being discussed on new projects in the Nordic countries where the levels are lower than proposed by the Applicant in the EIAR. The Applicant also significantly extended during the Oral Hearing the sections of the alignment that would have a floating slab track in order to

enable this new commitment to be met, with the majority of the City Centre AZ4 section have floating slab track by the end of the Oral Hearing.

Table 9 Threshold values for ground borne noise in residential buildings (construction and operational phases), note that an upper limit of 35 dBA was proposed at the Oral Hearing for the operational phase.

Impact Magnitude	Groundborne Noise Level dB ($L_{Amax,s}$) (measured near the centre of any dwelling room on the ground floor)		Significance of Effect
	Activity except TBM	TBM advancement	
Low	35-39	40-44	Not significant
Medium	40-44	44-49	Significant effect
High	45-49	50-54	
Very High	>49	>54	

Table 10 Threshold values for effects of ground borne noise in non-residential buildings (construction and operational phases),

Building	Level/ Measure (Activity except TBM)	Level/ Measure (TBM advancement)	Commentary
Theatres	25 dB $L_{Amax,s}$	30 dB $L_{Amax,s}$	*Human Response:* Noticeable to all and disturbing to some during quiet performances.

Building	Level/ Measure (Activity except TBM)	Level/ Measure (TBM advancement)	Commentary
Large Auditoria/Concert Halls	25 dB $L_{Amax,s}$	30 dB $L_{Amax,s}$	*Human Response:* Noticeable to all and disturbing to some during quiet performances.
Studios	30 dB $L_{Amax,s}$	30 dB $L_{Amax,s}$	*Equipment:* Noticeable in recordings.
Churches	35 dB $L_{Amax,s}$	40 dB $L_{Amax,s}$	*Human Response:* Noticeable to all and disturbing to some
Courts, lecture theatres	35 dB $L_{Amax,s}$	40 dB $L_{Amax,s}$	*Human Response:* Noticeable to all and disturbing to some
Small Auditoria/halls	35 dB $L_{Amax,s}$	40 dB $L_{Amax,s}$	*Human Response:* Noticeable to all and disturbing to some
Schools Colleges	40 dB $L_{Amax,s}$	45 dB $L_{Amax,s}$	*Human Response:* Noticeable to all and disturbing to some.
Hospitals, laboratories	40 dB $L_{Amax,s}$	45 dB $L_{Amax,s}$	*Human Response:* Noticeable to all and disturbing to some.
Libraries	40 dB $L_{Amax,s}$	45 dB $L_{Amax,s}$	*Human Response:* Noticeable to all and disturbing to some.
Offices	40 dB $L_{Amax,s}$	45 dB $L_{Amax,s}$	*Human Response:* Noticeable to all and disturbing to some.
Commercial Buildings	45 dB $L_{Amax,s}$	50 dB $L_{Amax,s}$	*Human Response:* Noticeable to all and disturbing to some.

13.3.1.1 Vibration Impact on Buildings

In the case of buildings, the thresholds for vibration velocities in terms of peak particle velocity (PPV) are taken from the British Standard BS 5228-2 (BSI 2014b) and are summarised in Table 11 below.

Table 11 Threshold values for vibrations velocities in buildings due to construction work, from EIAR chapter 13, page 36.

Vibration Limits for Buildings (PPV) at the closest part of building to the source of vibration, at a frequency of 4Hz		
Building Type	**Transient Vibration**	**Continuous Vibration**
Reinforced or framed structures. Industrial and heavy commercial buildings	50mm/s	25mm/s
Unreinforced or light framed structures. Residential or light commercial-type buildings	15mm/s	7.5mm/s
Protected and Historic Buildings *Note 1	6mm/s – 15mm/s	3mm/s – 7mm/s
Identified Potentially Vulnerable Structures and Buildings with Low Vibration Threshold	3mm/s	

In the special case of blasting where the vibration is of impulse character the German Standard DIN 4150-3:2016 has been used to define the thresholds for buildings, as stated in Table 12 below.

Table 12 Threshold values for vibrations in buildings due to blasting during construction work, from EIAR chapter 14, page 8

Category of Building	Threshold PPV
Standard buildings	8mm/s
Listed or potentially vulnerable buildings	3mm/s

13.3.1.2 Vibration Impact on Equipment

Obviously, it is impossible to set general requirements for equipment as each piece of equipment may have different sensitivity to vibration, which is why each case has to be handled in agreement with the corresponding stakeholder. A possible guideline is given by ASHRAE, 2007 which is also referred to on page 11 in chapter 14 in the EIAR.

An exception to this is the Luas Light Rail System, where specific thresholds for the vibrations during construction were set according to Table 13.

Table 13 Threshold values for vibrations at the Luas Light Rail System during construction work, from EIAR chapter 13, page 37.

Frequency Range	Level 1	Level 2	Level 3
Above 50Hz	10mm/s	12mm/s	15mm/s
50Hz and below	10mm/s	10mm/s	10mm/s
Actions above trigger levels	Initiate review of techniques to reduce vibration magnitudes	Cease of associated works & propose alternative techniques to reduce to below Level 1	As level 2

13.3.1.3 Vibration Impact on Humans

The effect on humans is best captured using a time integrated measure such as the vibration dose value, i.e. the root mean square value for a given time period. The British Standard 6472-1:2008 and also experience from projects such as High Speed 2 in the UK provide threshold values for effects on humans, as given in Table 14 for different types of buildings.

Table 14 Threshold vales for significant effect on humans by vibrations

Examples	$VDV_{day}[m/s^{1.75}]$	$VDV_{night}[m/s^{1.75}]$
Dwellings	0.8	0.4

Examples	$VDV_{day}[m/s^{1.75}]$	$VDV_{night}[m/s^{1.75}]$
Hospital wards; and education dormitories Assisted living, nursing homes, homeless hubs	0.2	0.1
Offices; Schools; and Places of Worship	1.6	n/a
Workshops	3.2	n/a
Vibration sensitive research and manufacturing (e.g. computer chip manufacture); hospitals with vibration sensitive equipment / operations; universities with vibration sensitive research equipment / operations	Risk assessment will be undertaken based on the information currently available for the relevant equipment / process, or where information provided by the building owner or equipment manufacturer	

Table 15 Threshold values for vibrations during operation, from EIAR chapter 14, page 10.

Impact Magnitiude	In the Absence of Appreciable Existing Levels of Vibration		Appreciable Existing Levels of Vibration (1) (2)	Effect according to BS 6472	Significant?
	VDV ms-1.75 Daytime (07:00-23:00)	VDV ms-1.75 Night-time (23:00-07:00)	% Increase in VDV		
None	≤0.2	<0.1	<25	Adverse comment not expected	Not significant
Negligible	>0.2 – 0.4	>0.1 – 0.2	25 – 40%	Low probability of adverse comment	
Low	> 0.4 – 0.8	> 0.2 – 0.4	> 40 – 100%	Adverse comment possible	
Medium	> 0.8 – 1.6	> 0.4 – 0.8	> 100 –185%	Adverse comment probable	Significant
High	> 1.6	> 0.8	> 185%	Adverse comment very likely	

13.4 Summary Airborne Noise

Noise from construction activities has been estimated by the Applicant by numerical noise mapping software using the calculation package Soft Noise predictor which is based on the British Standard BS 5228-1 BSI (2009+A1 23014a). The results of the noise estimations are reported in the EIAR Appendix A13.7 for the construction works and A13.8 for operational noise.

Clearly, at this early stage in the project the construction activities are not yet detailed regarding equipment to be used and detailed time schedules, however the preliminary results reported in the EIAR Chp.13 and the Appendices serve to identify critical locations with respect to noise. It is stated in Chapter 13, page 18 that these calculations will be updated prior to construction presumably by the Design & Build Civil Works Contractor who will at that stage have defined the detailed time schedules and will have defined the specific equipment he intends to use.

In addition to noise from the construction work itself, there will be noise due to increased construction traffic. In chapter 13, page 20 there is a description of how this has been analysed by modelling the changed traffic flows and from this data an estimate of the noise level at 5 m from the road has been made. In cases where there is a significant change in traffic volume, the noise level at the nearest sensitive location is calculated and compared to Baseline Noise Level data. Even though this approach follows the British Standard, in the case of an existing noise map of the Baseline, as recommended above, this could straightforwardly be complemented to include changes in road traffic as well as construction work to give the overall noise levels.

It is also noted that the Applicants evaluation of the noise impact from traffic that is summarised in EIAR Chp. 13 Table 13.72 appears to only consider the impact on adjacent major roads where the impact is obviously limited. For instance at Charlemont, EIAR Chp. 13 Table 13.72 only considers Grand Parade when there are also traffic impacts on a short section of Dartmouth Road as the construction traffic leaves the site and flows towards either Dartmouth Place or Charlemont Street. This will need to be addressed in the Detailed Design stage when the CNVMPs are prepared.

As the major part of the MetroLink is underground, the airborne noise during operation is limited to open rail section in the northern part, Dardistown depot, tunnel and station ventilation and the Estuary Park and Ride. As for the construction phase there may also be changes in road traffic which will result in changed soundscape of the Dublin area. The airborne noise from operation is estimated using the same tool as for construction noise to generate illustrative noise maps and compare at specific locations to the baseline level and thresholds.

13.5 Summary - Groundborne Vibrations

To estimate the vibrations and resulting ground borne noise, numerical modelling by FINDWAVE and rules of thumb have been utilised as described in Chapter A14.4 of the EIAR. Even though a thorough analysis has been performed, one must be aware of the difficulties in such an analysis. In particular, the coupling between ground and building is often most difficult to model correctly, due to the lack of detailed knowledge of the ground structure adjacent to the building. In the current investigation the most widely used assumption is applied to transform the ground vibrations to in house (building)noise. This is elaborated in “*Prediction of Groundborne Noise From Groundborne Vibration*” presented at the Oral Hearing on the 28th of February (OH112).

On similar projects, such as the Copenhagen Metro, the actual propagation of vibrations and the coupling between the tunnel and ground and ground/buildings have been measured by placing a seismic vibrator in the

completed tunnel prior to trackbed construction, exciting the tunnel/ground and measuring noise and vibrations in the buildings. The tunnel may be excited at a range of relevant frequencies and the response at ground surface and selected buildings measured. This approach can be used to calibrate the models and removes the need for making assumptions regarding the propagation and coupling. It also allows confirmation that the selected trackbed solution will provide the required result in terms of groundborne vibrations during the operational phase. Such an approach is described by Talic et.al in *Prediction of ground-borne vibrations from Copenhagen Metro* published in the proceedings of BNAM 2021. The Assessors recommend that a similar approach to measurement of actual groundborne vibration propagation should be utilised in the MetrolLink project, and have recommended a condition accordingly.

The uncertainty of the analysis is also discussed in the EIAR and the importance of wheel/rail roughness for limiting the generation of vibrations and noise, is remarked and the need of regular maintenance during operation is emphasized in the EIAR Chapter 14.2.5.4.3.

13.6 Assessors Comments

It is clear that during construction, a project of the nature of the Dublin MetroLink will generate noise that cannot be fully mitigated to be within the noise thresholds at all locations and during all phases of work. This is due partly to the large scale of the works, large deep stations and the types of activities needed, i.e. diaphragm walls, piling, concrete works etc. It is also due to the prolonged period of these activities with significant noise impacts going on for four or five years.

During operation, on the other hand, we consider it is possible to fulfil the noise and vibration requirements provided engineering noise control is given full attention and correctly incorporated into the design.

Being of linear nature, most noise and vibration problems may be divided into source, pathway and receptor and in accordance, so are the various mitigation measures. For many construction noise and vibration sources such as TBM tunnelling and excavation, there are few methods to reduce the source strength. In the case of airborne noise, barriers, noise abated ventilation and secondary glazing on adjacent buildings are possible mitigation methods. For groundborne noise and vibration, however, corresponding measures will in most cases not be possible and the sole alternative is to restrict the working hours to periods where the disturbance is minimized, however the opportunities to change the working hours are limited as discussed in Section 12 .

For operational phase noise and vibration the picture is somewhat different, as mitigation at the source is possible, e.g. by the use of a floating track slab together with regular rail grinding and swing nose switches as

discussed in the document "*Additional Groundborne Noise and Vibration Commitments*" submitted during the Oral Hearing on 29th February 2024 (OH119). Also, the use of noise barriers in the at grade sections of the alignment and improved insulation of buildings primarily by double glazed windows.

The suggested mitigation measures during construction as well as operation are discussed in the EIAR Chapters 13 and 14 which have been supplemented in the Oral Hearing by notes OH321 and OH347, "*Summaries of the route wide mitigation and monitoring proposal*".

It is noted that there were many errata introduced during the Oral Hearing for noise and vibrations, such as OH122 and OH374.

The proposed modifications of the project with regard to noise and vibration compared to the original EIAR and commented in this document are summarised by the Applicant in the Oral Hearting note OH376 *"Final Schedule of Additional Environmental Commitments*".

13.6.1 Construction

Equivalent outdoor noise levels above 75 dB(A) during the construction phase are predicted. This is clearly noisy, considering as a reference that daily speech has a level of 65 dB(A) and a dynamic range of 30 dB. Critical construction sites are listed in Table 13.85 in Chapter 13. At these locations the standard 2.4 m high noise barrier will not be sufficient and instead 4 to 7 m high hoardings are proposed. At Northwood Portal, Albert College Park, Griffith Park, Matter and Charlemont further measures will be required, such as placing the bentonite separation plants and other noisy equipment in acoustic housings. A recommendation has been included in Appendix A to this effect. It should be emphasised that for barriers, as well as enclosures, the design must be completely sealed to avoid noise leakage. The modelling of mitigation measures such as screens and enclosures carried out by the Applicant estimates that the construction noise level can be reduced to be within the threshold in many, but most likely not in all, locations. To manage this, it is important to monitor the noise levels and keep a focus on minimising noise levels. The procedures for monitoring are discussed in "*Monitoring during construction*" (OH173), including handling of exceedances of trigger levels as well as the role of an Independent Monitoring Engineer (IME) and an Expert Panel (IE) to oversee the monitoring. However, this Note whilst covering the main aspects of the monitoring not provide any details of the noise monitoring. The Assessors have made recommendations for noise and vibrations monitoring in Section 14 .

It is recommended that the progress of work in general and noisy activities in specific must be communicated to nearby receptors weekly to create understanding of the cause of the disturbances among the public. This is discussed in the "*Stakeholder Communication Plan*" issued by the

Applicant and submitted during the Oral Hearing (OH3 and also OH124). A regularly updated noise map with estimated noise from construction activities along the MetroLink and accessible on an open website would be of assistance for this. This is addressed in the "*Risk Management Plan – Trigger Action Plan*" (OH175 and OH276).

To reduce the general disturbance and gain public acceptance, the construction activities must also, as indicated in the EIAR, be confined to the defined Working Hours. The exceptions from normal working hours are discussed in Section 12 .

In the case of vibrations during construction, problems are not equally severe in general but may arise at specific locations, which will have to be monitored. Unfortunately, there may not be an efficient mitigation technique for works such as the diaphragm walling and piling works and these works will inevitably cause some disturbance.

To ensure that the contractors put sufficient weight into the mitigation of noise and vibration during the construction works an ambitious and detailed "Construction Environmental Management Plan" was included in the EIAR, with an updated version issued at the Oral Hearing (OH320 and OH348). This is intended to be updated prior to construction by the D&B Contractor along with other documents and it is expected that the Applicant will review and approve such documents and ensure that the measures in the EIAR are complied with. In addition to the specification of various noise mitigation techniques, routines for monitoring and communication with stakeholders are outlined. The Contractors will be required to prepare a "*Construction Noise and Vibration Management Plan* (CNVMP)" for each site which will include a revision of the Baseline noise and vibration levels as well as detailed analysis of mitigation measures for each construction site and corresponding receptors. This is a more detailed continuation of the assessments contained in Chapter 13 and 14 of the EIAR and follows the approach required by BS5228-1.

13.6.2 Operation

Airborne noise during operation will result from the at grade section and the retained cut sections in the northern part of the alignment, the Dardistown depot, tunnel ventilation and at the Estuary Park and Ride. There will also be some noise from the stations, however this will be limited and is not considered likely to be problematic. All of these have been assessed by the Applicant, including suitable mitigation measures to reduce the residual noise impact. The general noise level is, in most cases, within the requirements. As noted above, restricting the thresholds to concern only equivalent levels may result in the disturbance of a limited number of quickly passing trains being missed however this is believed not to be problematic . Low frequency tonal noise from ventilation has also not been analysed in the EIAR but it should not be a problem to fulfil the

requirements in practice and has been addressed in the recommendations to the Board.

Further, due to the increased traffic and major works for the construction of the Glasnevin station there will be an increase in airborne noise at this location. Simulations were reported in Oral Hearing note OH181, and it was estimated to increase noise levels of the order of 3 dB at the nearby residential buildings, however this should still be within the thresholds for rail noise as given in the EIAR Chp.13. It may be noted that there are locations in the surroundings where an increase in level of as much as 7 dB was estimated which is quite a considerable increase and would need mitigation. As the threshold is defined in terms of equivalent level, the traffic intensity will affect the resulting noise level. In many cases, however, the impact of a given disturbance rather depends on the maximum level rather than the equivalent level which is why an analysis including also this could be useful.

Possible groundborne noise impacts have been identified at sections AZ1 and AZ4, according to Tables 14.53 and 14.54 in Chapter 14. To handle this a floating slab track design of the rail bed has been proposed by the Applicant, see Figure 14.8 in the EIAR given in the Oral Hearing note OH69 on the 22nd of February. During the hearing on the 28th February 2024 the Applicant proposed installing floating slab track at a number of additional locations in both sections AZ1 and AZ4, see Oral Hearing note OH103. Parts of these sections are mentioned also in OH74 presented on the 26th of February. Some areas where floating slab track was originally planned have been adjusted as the corresponding building is to be demolished, see Oral Hearing note OH104. In the analysis of floating slab track in this early stage of the project, a noise reduction of 15 dB is assumed according to the Applicant's experts during the Oral Hearing. This is not straightforwardly achieved and it should also be noted that floating slab track is generally not suited for frequencies below the hearing range. With the threshold level for groundborne noise further reduced to target the disturbance by trains passing below during night hours a more detailed analysis will be required at the Detailed Design stage together with an in tunnel source and measurement at the surface and existing buildings as recommended to the Board as a condition.

In reducing the groundborne noise impact during operations the applicant has restricted the revised criteria to residential dwellings and has not considered the impact on possibly sensitive commercial buildings and to the important heritage building between Tara Street station and St. Stephens Green where there are many important heritage buildings such as Leinster House. The Assessors recommend that the Board places a condition on the Applicant that the maximum groundborne noise criteria that has been defined for residential dwelling be also applied to commercial and heritage buildings. This condition is considered not to be overly onerous as the applicant has already committed to having a floating slab

track for the majority of the alignment in AZ4 where the majority of these buildings are located.

The tunnel alignment passes beneath Trinity College in section AZ4(g) beneath some sensitive laboratory facilities. Whilst it is noted that Trinity College have confirmed that their concerns have been addressed and that they support the project, this has required the commitment to install floating track slab in this section of the alignment to reduce groundborne vibrations during the MetroLink operations. During the Oral Hearing the Applicant submitted several versions of drawings defining the sections of alignment where floating slab track is to be installed, increasing the length of the floating slab track from revision to revision. This may be perceived as a good outcome for the observers who sought this, however floating slab track requires additional maintenance and it is usually avoided unless absolutely necessary.

13.7 Submissions

A large number of Submissions were made by Observers regarding noise and vibration and particularly airborne noise. A selection of the Submissions are addressed below, representing common themes regarding noise and vibration and submissions that were addressed at the Oral Hearing. Comments are made regarding the Submissions and the corresponding response from the Applicant. It should be noted that the more than 300 submissions are generally very much alike regarding noise and vibration. Most of the submissions express a general concern for airborne noise during the construction process. Possible methods for mitigation are discussed in a general manner in Chapter 13.6 in the EIAR and also in the Oral Hearing notes OH125, 321 and 320. As noted above noise and vibration assessments and the analysis of the effect of the various mitigation measures needs to be updated during the Detailed Design stage of the project and the Construction Noise and Vibration Management Plans (CNVMPs) developed. A number of non-residential buildings where specific noise and vibration problems has been identified are commented on in detail, see oral hearing note OH190 regarding *Trigger Action Plans*. Some of the issues identified below are addressed by the Applicant in the Oral Hearing note OH322 "*Working Draft Additional Environment Commitments*" and OH376 "*Final Schedule of Environmental Commitments*". The Applicant has also made further response to some of the submissions in the document *2nd Statutory Consultation Response to Submissions Received* that was prepared by the Applicant after the 2nd Consultation.

Area AZ1 (Northern Section)

S33. (Caitriona and Ciaran Byrne, Seatown)

From the Baseline the CNT is set to 75 dB(A) during daytime and as the CNL is estimated to be above 80 dB(A), at Seatown West a significant disturbance is expected from the construction work. To handle this, it is proposed to use 4 m high hoardings at the site. With the effect of such a screen reduced by distance to source and receiver, a more detailed analysis will be required in the CNVMP to verify that an acceptable attenuation of the airborne noise is achieved prior to construction.

S64. (Devonmill Ltd, Fosterstown)

The CNT is set to 70 dB(A) at the specific location of the Travelodge Hotel and the threshold is set at 75 dB which implies that the predicted noise at this location is not significant.

An updated/refined noise assessment will be undertaken within the Contractor prepared CNVMP and there is potential that the predicted noise levels will be reduced from their current predicted levels. It should be able to be satisfactorily addressed in the Construction stage CNVMP and with updated Baseline monitoring.

S89-90, (Estuary Court Residents Association) S277(Seatown Villas Residents).

Concerns were raised by the observers during the Oral Hearing regarding noise during construction activities (see OH46). This is also identified in the simulations by the Applicant and reported in Table 13.39 in the EIAR where noise levels up to 10 dB above the CNT are predicted from the various activities related to e.g. cut and cover at Estuary Courts and Seatown Villas. This is classified as a significant disturbance and considering the proximity between construction activities and buildings, not unexpected. It is proposed to use 4 m high noise barriers to handle this. In Table 13.86, mitigation measures are claimed to reduce the impacts to moderate. The Applicant's assumptions regarding the effectiveness of construction hoardings is consistent with advice contained within BS5228-1. The Applicant commits to further assessment of noise impacts prior to commencement of construction and further commits to further revisions of proposed construction hoardings, where necessary.

Area AZ2 (Airport Section)

No remaining submissions raised particular noise and vibration related issues relating to this section.

Area AZ3 (Dardistown Section)

No remaining submissions raise particular noise and vibration related issues relating to this section.

Area AZ4 (City Section)

S1: (ACRA and Ballymun Road North Residents)

There will be construction noise in particular from piling/diaphragm walls and excavation in this location. In Table 13.59 at page 89 in Chapter 13 noise levels exceeding the CNT by 10 -15 dB are estimated at Our Lady of Victories Church and at Albert College Court. It is stated on page 90 in Chapter 13 that mitigation measures will be required. In Appendix A13.7 of the EIAR, predicted noise levels resulting from mitigation by localised screening and enclosures are reported. In position 30 and 39 which is in front of the church and the court respectively, equivalent noise levels 77 and 82 dB pre mitigations are reported. In the presentation given at the hearings by the ACRA and Ballymun Road North Residents Association, note OH45, there were concerns regarding the effectiveness of the chosen mitigation measures. As has been outlined above, proposed mitigation measures are standard construction practice and TII's assumptions regarding effectiveness are in line with BS5228-1 advice. TII commits to further assessment of noise impacts prior to commencement of construction and further commits to further revisions of proposed construction hoardings, where necessary.

S111. (Hampstead Residents CLG)

The Hampstead Residents Group have raised a number of relevant issues regarding noise, see OH61. Firstly, they note that the Baseline reference point used to evaluate construction noise at Hampstead Avenue is AT27 which is located on the opposite side of Ballymun Road and quite a distance away from Hampstead Avenue. The better suited baseline reference point would be AT64 but that point seems to be missing in Appendix A13.7. Concerns are also raised regarding the usefulness of baseline reference points UT30 and 31 not being representative but in this case the discrepancy may be of minor importance. The Applicant will need to ensure that night time working is strictly controlled in accordance with the proposed Working Hours, together with the use of an acoustic building for the Albert College Park shaft site. These measures should provide an acceptable solution which needs to be documented in the CNVMP developed for the construction work at these sites.

The issue of ventilation noise during operation is also mentioned in the submission from the Hampstead residents. The stricter requirements on low frequency noise adopted during the Oral Hearing, see Section 13.1.6 above will be useful in this context and should result in an acceptable design solution for the ventilation system with respect to noise.

It should be noted that TII has addressed observer concerns at the Oral Hearing (OH148) where it is stated that monitoring of noise and vibration will be performed once the construction process starts.

S173. (Louise Boughton and Glenn Sharpe)

The construction noise threshold CNT has been set to 70 dBA at 114 Ballymun Road, which, following the British Standard BS 8228 given in

Table 13.12, implies a Baseline noise level in the order of 65 dBA. The closest Baseline survey location was AT64, as shown in Appendix A13.1 and the CNT value yields the estimated construction noise to have a “moderate to significant” impact.

It is expected that the issue can be satisfactorily be solved during Detailed Design as part of the CNVMP development.

S13: (Anne G Meehan)

The MetroLink will pass directly below 48 Prospect Avenue. There are no numerical values for ground borne noise reported at this location, the nearest is at Dalcassian Downs. In this location a ground borne level of 31 dBA is predicted. Assuming cylindrical spread of the vibration energy a ground borne noise level close to 40 dBA could be expected at 48 Prospect Avenue. Considering the thresholds for ground borne noise being revised during the hearing, see Section 13.3 further consideration will need to be given at the Detailed Design stage that will ensure this threshold is not exceeded.

S45. (Claire Dunne)

In the Oral Hearing note OH85 and OH233 general concerns are raised regarding construction noise at The Court in Glasnevin. The impact of noise at this location during construction work which is enclosed by a 3 m hoarding at the Glasnevin Station and adjacent rail interchange is estimated to be “significant to very significant” exceeding the CNT by more than 10 dB. Simulations of mitigation using an increased 4 m high noise barrier enclosing the site is reported in Appendix A13.7 showing no notable reduction in noise at the current address. This may not be surprising considering the size of the construction site which is difficult to mitigate. It will likely be necessary to use the *Airborne Noise and Groundborne Vibrations Mitigation Policy* (NVMP) and improve the acoustic properties of windows and ventilation to reduce indoor noise. Temporary re-housing as discussed in the Policy may also be necessary

S168. (Lesley Hewson)

The need for good communication between the MetroLink project and stakeholders regarding noise and vibration disturbances are highlighted in the Oral Hearing submission (OH81). This is in line with the Stakeholder Communication Plan presented at the hearings, note OH3.

S175. (Management Company on Behalf of The Court)

The concerns raised in hearing submission OH84 are similar to those of OH81 regarding the need for independent monitoring and frequent communication of the state regarding noise and vibration disturbances during construction.

S180. (Marie McMahon)

A ground borne noise level during operation of 36 dB(A) has been predicted which is above the revised threshold limit for residential buildings. The Applicant can be expected to deal with this issue during Detailed Design, due to the commitment regarding the upper threshold limit.

S209 (Nigel Mallen). S251 (Paul and Brian Connell)

A ground borne noise level during operation of 40 dB(A) has been predicted which is above the revised limit for residential buildings.

The Applicant can be expected to deal with this issue during Detailed Design due to the commitment regarding the upper threshold limit.

S278. (Shandon Mill Owners Management Company CLG)

Concerns were raised in the Oral Hearing submission (OH239) regarding construction noise by the Shandon Mills residents regarding the period of track alignment and lowering. The predictions for these works are reported in Table 13.63 in the EIAR. The prediction estimates noise levels between 66-75 dB(A) which, with a CNT of 55 dB(A) during night, is deemed as a “very significant to profound” impact. Modelling the effect of mitigation reported in Appendix A13.7 shows similar noise levels. Noise barriers may have limited effect considering the relative location of the building and barriers although this is not clear from the simulations by the Applicant reported in Appendix A13.7. It is likely that the noise cannot be significantly mitigated and it obviously needs to be carried out at night, it is noted by the Applicant that the duration of the impact is restricted to a few weeks and if not building insulation or rehousing according to the Airborne and Groundborne Noise Mitigation Policy in Appendix 14.6 of the EIAR could be implemented.

S6 (Amanda Hughes) S19 (Berkeley Road Services and Traders Association) & S25 (Breda Scully)

From the modelling results reported in Table 13.64 in the EIAR it is clear that there will be significant construction noise in the area of these Third Parties. More detailed modelling of possible mitigation methods to be installed at the start of the construction activities will need to be carried out at the Detailed Design stage as part of the preparation of the CNVMP. It is likely that the *Airborne and Groundborne Noise Mitigation Policy* will need to be applied at this location

Also good monitoring of noise levels and dialogue with stakeholders during the construction process is vital.

S247. (Owners of 1, 10, 11 Nelson Street)

Request for noise monitoring at Nelson Street was raised in Oral Hearing submission OH87 and also in OH242. Predictions of construction noise reported in Appendix A13.7 shows noise levels in most cases well below the CNT of 65 dB(A). The Baseline measurements in positions AT41 and

UT43 shows noise levels of 59 and 65 dB(A) respectively which goes in line with this being an urban environment even though Nelson Street is not a main traffic passage.

S317. (Wynn's Hotel)

In the Oral Hearing submission OH102 the problem of groundborne noise and vibrations during TBM passage under the Wynn´s Hotel was raised. During operation, the groundborne noise level is estimated by the Applicant to be below 35 dBA in the case without slab track. In the Oral Hearing submission, simulations performed by Arup for the case with slab track indicate groundborne noise levels as low as 20 dBA. This corresponds to an insertion loss of the slab track system of 15 dB which is plausible. This should be verified during Detailed Design when the trackslab design will be carried out.

S303. (Trinity College Dublin)

This case relates to Trinity College where there are both groundborne noise and vibration issues related to sensitive equipment. It is noted that an agreement has been reached between the Applicant and Trinity College and that the Applicant has amended the EIAR to include floating slab track through this section of the alignment.

Further analysis will be need during the Detailed Design and it is recommended that verification is carried with an in tunnel source as proposed in the recommendations to the Board.

S3: (Aidan Cyril Forde)

Concerns are raised regarding vibration and noise during passage of TBM. Vibration levels are estimated according to best practice to be below threshold values. Vibration will be monitored during construction. Regarding groundborne noise during passage of TBM there are no mitigation techniques but the duration of the disturbance is limited to a few days and thus should not be problematic.

S117. (Hines Real Estate Ireland Ltd)

Ground borne noise levels of 34 dB(A) during operation are estimated. As discussed above, it is recommended that measurements of the transmission of vibrations from tunnel floor to building after tunnel construction should be undertaken in order to assist in the design of the trackform.

S129. (Irish Life Assurance PLC)

A detailed technical report regarding noise and vibration issues for the Cadenza building was presented in the Oral Hearing submission (OH140). Firstly, it is noted that the Baseline Level is not determined in connection to the current building. Instead a measurement point closer to St. Stephens

Green is used, AT49. This may result in the threshold for construction noise, CNT being incorrect and thereby also the impact of noise, see Table 13.12 in the EIAR. A CNT reduced from 75 to 70 dBA is suggested and may very well be correct. No predictions have been carried out for construction noise levels at the Cadenza Building as it is not located near to a construction worksite.

A groundborne noise level during operation of 37 dB(A) has been predicted, which is above the revised maximum limit for residential buildings although the Applicant has not committed to this maximum limit for commercial buildings. The Assessors have recommended that the residential maximum limit is also applied to commercial buildings.

A more detailed analysis including measurements of vibration transmission after tunnel construction is recommended. This will verify the proposed design of track bed mitigation methods such as floating slab track provide the required maximum levels.

Concerns are finally raised regarding ventilation noise, this should not be a problem at this location as there are no nearby ventilation equipment.

The Assessors judge that the Observer's noise and vibration concerns have been satisfactorily responded to by the Applicant if the Assessors recommendations are placed on the Applicant.

S15 (Barry and Aileen Dempsey), S37 (Caroline Regan and family) & S40 (Charlemont and Dartmouth Community (Dartmouth Rd))

Clearly airborne noise is a problem at Charlemont and a more detailed study of the effect of various mitigation efforts on construction noise would probably increase the acceptance for the project and will need to be carried out at the Detailed Design stage as part of the CNVMP.

During the 2nd Consultation a number of observers (John Conway and Orlaith McCarthy, and CDCG) have made further comments relating to Airborne Noise & Vibration at Charlemont and the Applicant has responded to these comments in the 2nd Consultation response.

The Applicant had issued Errata Appendix 10 with an updated Appendix A13.7: Charlemont Station, which provided updated noise predictions for Charlemont. The Applicant responded to the Third Parties' individual points and referenced the relevant section of the EIAR (Section 13.6.1.2 of Chapter 13) where it describes the role of the CEMP and the CNVMP, which will provide the detailed planning of the measures and mitigations to be taken at each of the construction sites. This document will be developed by the D&B Civil Works Contractor prior to construction commencing.

The Assessors find that the Applicant's response is in line with normal practice and is acceptable, however a 7 m high hoarding may be required over part of the site. It is clear that noise and to some extent vibrations will

be a major issue at Charlemont station and the Applicant together with the D&B Contractor should place significant effort in good communications with the residents at this location.

In the Oral Hearing submission OH153, a noise specialist on behalf of CDCG has addressed a number of issues related to noise and vibration at Dartmouth Rd and surroundings. Firstly, it is pointed out that the Baseline noise measured at AT72 and AT73 are contaminated by construction noise (from the Hines Building Construction) which may affect the rating of the noise impacts and thereby possible mitigation measures. Further, it is noted that the unattended measurement point UT51 may not have been correctly located and may not have measured a representative noise level. Nevertheless, if UT51 still is used as the reference baseline position, a level of 61 dBA is recorded which would result in a CNT of 65 dBA, not 70 dBA as currently being used for Darthmouth Rd. This results in that the level of impact is judged less severe. A number of errors in the classification of impact at different locations has also been identified. It should also be noted that the height upon which the sound level is calculated is decisive in relation to the effects of noise barriers and hoarding. Concerns are also raised regarding whether the proposed steel clad acoustic building for the SCL will reach 24 dB in noise reduction. To obtain this attenuation careful design is required and will need to be analysed in detail to ensure the desired result.

The Assessors recommend to actually measure the noise insulation of the most critical buildings to better estimate the indoor noise levels.

It may be noted that there are multiple Oral Hearing submissions addressing noise and vibration problems during construction in the area around Dartmouth Rd, e.g. OH162 (submission 51), OH163 (submission 60), OH164 (submission (149) although these were later withdrawn.

A significant effort will need to be made a Charlemont by the Applicant and the D&B Contractor in the rerunning of the Baseline noise levels, the updated predictions, the choice of mitigation measures and the development of the CNVMP. Perhaps most importantly will be the communication with the local residents together with the D&B Contractor strictly adhering to all the requirements and working hours.

S153. CHARLEMONT

The requirements for ventilation noise were complemented with thresholds for lower frequencies during the hearing. The ventilation systems need to be designed to account for this. Conventional SEA type design of the HVAC system may not fulfil the targets, instead a wave based approach is recommended. Frequency resolved noise measurements with the ability to identify tones are required to control the result.

The Applicant is expected to deal with this issue during Detailed Design and as part of the development of the CNVMP.

13.8 Conclusions and Recommendation

The Applicant has performed a detailed and comprehensive study of the possible effects of noise and vibration due to the construction and operation of the MetroLink, which has followed the approach used in UK and described in BS5228-1 and the DMRB guidance, as there are no Irish statutory requirements for construction noise and vibrations. The approach used is also in agreement with the requirements from Dublin City Council (DCC). It is unavoidable that such a large infrastructure project in an urban area will cause disturbances due to noise and vibration during the construction phase. To minimise the negative impact, an approach where noise and vibration is continuously monitored, communicated and mitigated as far as possible, is required. This is what the Applicant has described in the EIAR which has been further described during the Oral Hearings with additional commitments made by the Applicant.

Provided mitigation measures such as noise barriers and floating slab track are implemented as committed to by the Applicant the MetroLink is likely to fulfil the requirements for noise and vibrations except in certain locations, where in particular the noise disturbance cannot be fully mitigated. It is noted that the Applicant has identified many of these locations in the EIAR and in the Oral Hearing documents. This may result in a need for the application of the *Noise & Vibration Mitigation Policy* (NVMP) which provides for the use of noise insulation at affected receptors or temporary re-housing in certain cases.

However there remains significant further work for the Applicant to undertake together with his D&B Contractor prior to construction commencing, including updated Baseline Noise surveys, updated noise predictions and mapping based on the actual plant equipment and methods the Contractor will use. This will include updating and further developing the CEMP and the *Noise and Vibration Management Plan* (CNVMP) for each site. This should provide the detailed planning of the measures and mitigations to be taken at each of the construction sites.

In particular the mitigation measures will need to be further developed.

The most important comments and recommendations from the Assessors regarding airborne and groundborne noise and vibration are listed below.

- The maximum level for groundborne noise from the MetroLink operations in residential dwellings has been reduced during the Oral Hearings from 40 dB(A) to 35 dB(A). This will require further analysis during the Detailed Design in order to select the correct type of floating slab track system.

This is a significant improvement for nearby residential dwellings and is seen as a very positive development for the MetroLink.
The Assessors recommend the same criteria is applied to selected commercial and heritage buildings in the alignment section AZ4 and that the Applicant involves the Expert Panel in determining which commercial and heritage buildings the reduced criteria is applied to.

- Threshold for low frequency noise from installations has been added which will require more detailed analysis and possibly additional mitigation measures to be developed during the Detailed Design.
- The Baseline Noise surveys are currently based on discrete measurements. Complementing this with noise maps developed by modelling of the various sound emitters as is carried out in many countries such as Sweden would increase the precision and the possibility to better evaluate various noise mitigation measures.
  Such noise maps should be used to assist communication with stakeholders and could be published by the project on a live web portal along with other information such as construction progress and monitoring results.
- Measurements of the actual vibration transmission properties from tunnel floor to nearest building during construction is recommended to obtain data for the design of slab track system.

With the above recommendations which are further detailed in Section 14 the Applicant's assessments and measures for noise and vibrations are deemed acceptable

14 Recommendations to the Board

The Assessment (this report) has identified a number of additional measures, mitigations and requirements that the Assessors recommend that the Board impose on the Applicant if it decides to grant the Railway Order. These are discussed and listed in the relevant sections of the report and summarised in Appendix A.

Appendix A Schedule of Recommendations to the Board for Additional Conditions

Reference	Requirement
3 Overall Scheme Design	1. That the Applicant during the development of the project and the Detailed Design shall not change the methods stated in the EIAR and in the submissions made by the Applicant during the Oral Hearing.
4 Geotechnical Issues	1. No blasting shall take place for the Sprayed Concrete Lined (SCL) works such as the construction of the Albert College Park shaft and intervention tunnels, the SCL pumping sumps, and SCL works at Dublin Airport in addition to the Applicant's commitment to not use blasting for the Charlemont Intervention tunnel construction. 2. Blasting shall not be carried out for the construction of the deep stations at: a. Charlemont b. St. Stephens Green c. Tara Street d. O'Connell St. Station e. Mater Station 3. At other locations, the Applicant shall ensure that the effects from blasting do not extend beyond the zone covered by the Property Owners Protection Scheme. 4. The Expert Panel shall review the scope of the additional Detailed Design geotechnical investigations and the adequacy of the interpretation of them at sensitive locations. This shall include the locations where SCL works are to be carried out and where buildings that require a Phase 3 Building Damage Assessment are located.

Reference	Requirement
5 Hydrogeological Issues	1. The Applicant shall take such measures that are necessary for controlling groundwater dewatering from the deep station construction that ensures that no groundwater lowering shall occur outside the station boxes as stated by the Applicant in OH189. This requirement shall be applied to all deep stations. 2. The Applicant shall take such measures that are necessary for controlling the groundwater dewatering from the Sprayed Concrete Lining works (e.g. Charlemont Intervention tunnel, Albert College Park intervention tunnel and Area AZ4 pumping sumps), to ensure that No groundwater lowering occurs as stated by the Applicant in OH189. 3. The definition of No Groundwater Lowering shall be that no groundwater lowering occurs outside the normal seasonal variation of groundwater levels as determined by at least 1 year of pre-excavation monitoring. 4. The Applicant's Expert Panel as described in OH26 document title 'Ground Movement Monitoring Information Paper' ML1-JAI-COM-ROUT_XX-PL-Z-00001| P03.1 dated 2024/02/12 shall review and approve the groundwater control measures to be adopted by the Applicant's Contractor prior to implementation. 5. The Expert Panel shall follow the execution and monitoring of the groundwater control works and shall have the power to instruct the Applicant to carry out any additional measures the Expert Panel requires to ensure that No Dewatering occurs outside the station boxes and SCL works. 6. The Applicant shall implement groundwater control measures to limit the abstraction at Dublin Airport Station and associated tunnels, caverns and shafts to a maximum of $32m^3$/day and implement the measures set out in the PFAS Management Strategy for Dublin Airport, submitted to the Board on the 31st January 2025.

Reference	Requirement
6 Building Damage & settlement	1. Damage shall not exceed Building Damage Category 1 and suitable measures shall be taken by the Applicant to prevent damage exceeding Category 1. 2. The Expert Panel shall review and sign off on Phase 3 assessments and the measures to be undertaken for sensitive locations of the alignment, these shall include: a) the area around Charlemont Station b) sensitive buildings with deep basements or settlement sensitive facades such as AerCap House and the Cadenza Building c) heritage buildings including buildings where the OPW is responsible and heritage buildings on the Trinity College estate. d) The Carrolls Building at Charlemont e) Buildings adjacent to tunnel break-in break-out zones from the station boxes. f) Special buildings and protected buildings as defined in the Phase 1 and Phase 2 Building Assessments
7 Monitoring	1. The Applicant shall carry out baseline monitoring of at least one year prior to piling or diaphragm wall construction commencing to establish Baseline movement of representative, heritage and special buildings and all buildings anticipated to require a Phase 3 Building Assessment 2. The Applicant shall engage the Expert Panel (EP) prior to starting the procurement of the Independent Monitoring Engineer (IME) and the Main Civil Works contracts and the EP shall verify the scope of the IME and the Contract requirements for building damage risk assessments 3. The Applicant shall ensure that the Expert Panel has a verifying and “sign off” role rather than the advisory role stated by the Applicant.

Reference	Requirement
	4. The Applicant shall put into place an InSAR monitoring of the alignment commencing at the start of the baseline monitoring period, continuing through construction and up to the completion of the close-out monitoring period. The InSAR data shall cover a zone approximately 100 m either side of the tunnel centre line.
8 Future Development Rights	1. The document “Outline Guidance for Developers” shall be developed further during the preparation of the procurement documents to clearly identify the level at which the allowable 75kN/m^2 load is applied and it shall be “signed off” by the Expert Panel prior to inclusion in the D&B tender. 2. Suitable provisions shall be included in the D&B tender documents to ensure the tunnel design has suitable robustness to cope with the anticipated loading from adjacent developments and not unduly constrain future development.
9 Station Design and Construction	1. If the Board decide to grant the Railway Order it is recommended that they impose suitable conditions to ensure that the Applicant is required to implement all mitigation measures and commitments made in the EIAR and during the Oral Hearings and impose conditions that do not allow the Applicant to make significant changes to the constructions methods and sequencing of the works that would materially change the impact from the construction.
10 Tunnel Design and Construction	1. The Applicant shall engage the Expert Panel (EP) prior to starting the procurement of the Independent Monitoring Engineer (IME) and the Main Civil Works contract and the EP shall verify the scope of the IME and the Contract requirements for building damage risk assessments. 2. The Applicant shall ensure that the Expert Panel has a verifying and “sign off” role rather than the advisory role stated by the Applicant.

Reference	Requirement
	3. The Applicant shall procure the Main Civil Works and implement the work to respect the commitment made in OH192 and OH376. 4. The Applicant shall include in the D&B Civil Works Contract additional requirements to those stated in the EIAR for the tunnel works as follows: a) A Plan for the Advancement of the Tunnel (PAT) shall be prepared for each section of tunnel in accordance with the methods as described in *"Mechanized Tunnelling in Urban Areas Design methodology and construction contro*l" by Guglielmetti et. al. and each PAT shall be reviewed and signed off by the IME and Expert Panel. b) The Applicant shall ensure that provisions are included in the D&B Main Civil Works contracts to ensure that the appropriate software and hardware are included in the TBM specifications to allow the Applicant and IME to have access to real time data from the tunnelling operations and that it is integrated with other monitoring such as settlement and displacement in real time. 5. The TBM type to be used to construct the ventilation and evacuation tunnels in Dublin Airport shall be a closed-face TBM.
11 Tunnel Outfitting	No additional requirements
12 Working Hours	1. It is recommended that the allowable working hours are amended to the working hours as defined in Table 5 Recommended Working Hours
13 Noise and Vibration	1. The Airborne Noise & Groundborne Noise Mitigation Policy shall be amended to remove reference to a 4 week maximum temporary re-housing period and it shall be replaced with criteria based on the duration of the activity or activities that are the cause of the Trigger Values being exceeded.

Reference	Requirement
	2. For noise control from fixed installations, in addition to the measures proposed by the Applicant in the document OH168, specific thresholds for the frequencies between 10 and 160 Hz shall be set in accordance with the NANR34 assessment referred to in the British Standard BS4142. 3. The Baseline noise surveys shall be re-run prior to construction commencing and the results used in updated noise assessments and in the updating and further development of the CEMP and the Construction Noise and Vibration Management Plan (CNVMP) 4. Noise modelling shall be carried out in to provide 3D “Predicted Noise Maps” which shall be used for the preparation of the CNVMP and as a basis shall use the specific noise emissions for the plant to be used and their location on site. 5. The noise modelling shall be used to communicate the noise impact from upcoming activities to affected receptors and shall be published by the Applicant through a suitable web portal. 6. The results of noise and vibrations monitoring shall be published on a daily basis by the Applicant on a suitable Web portal. 7. The actual groundborne vibration propagation and the coupling between the tunnel and ground and ground/buildings shall be determined by placing a seismic vibrator in the completed tunnel prior to trackbed construction. This shall be carried out at a number of representative locations along the alignment such as in the vicinity of Trinity College and the heritage buildings in AZ4 and Mater Hospital. The measurements shall use a range of relevant frequencies and the response at ground surface and selected buildings measured. This approach shall be used to calibrate the models used for the predictions of groundborne noise and vibrations and shall be used to confirm that the selected trackbed solution will provide the required result in terms of groundborne vibrations during the operational phase. It shall be carried out in similar manner to the approach described by Talic et.al in Prediction of ground-borne

Reference	Requirement
	vibrations from Copenhagen Metro published in the proceedings of BNAM 2021 for the Copenhagen Cityringen project. 8. The reduction of the groundborne noise and vibration limit during as proposed by the Applicant at the Oral Hearing on 5th March 2024 in document titled “Additional ground borne noise commitment (Ref. OH174) that during the operation of the Metrolink passenger service, the operational groundborne noise levels in any lawfully occupied residential dwellings, measured near the centre of any noise-sensitive room, will be below 35dBLAmax,S”. Lowering it from 40 dB(A) in the EIAR to 35 dB(A) shall also apply to selected heritage buildings and commercial buildings and that the Applicant agrees with the Expert Panel which buildings this will be applicable to.. 9. Noise and vibrations monitoring shall be carried out by the IME and overseen by the Expert Panel 10. Noise & Vibration monitoring data along with predicted noise maps shall published on an ongoing basis by the Applicant on a suitable Web portal. 11. The Board shall place a condition on the Applicant that a Trigger Action Plan (TAP) is developed for the Cadenza Building and that noise and vibration monitoring is put into place during the passage of the TBM beneath the building. 12. A similar condition to Condition 11 above regarding TAPs shall apply to other buildings that are sensitive to noise and vibration during passage of the TBM that do not currently have a commitment for a TAP to be produced and a commitment that noise and vibration monitoring will be carried out during the passage of the TBM. The Applicant shall agree with the Expert Panel regarding which buildings this is applicable to.