RPA has a significant agreement with Dublin City Council, with specific details agreed in relation to St. Stephen's Green. RPA has also entered into a number of agreements with property owners in the immediate vicinity of St. Stephen's Green. Each of the agreements is applicable solely to the parties involved. Through written submissions to the Board and oral submissions to the Hearing RPA and a number of other observers in the St. Stephen's Green area have been able to provide the Board of understanding in relation to a wide range of concerns. The Oral Hearing also afforded the applicant and DoEHLG the opportunity to address subjects of concern in a public forum to clearly understand where there is agreement in the construction and operational approaches and where remaining difficulties lie.

For the benefit of the Board I consider it appropriate to outline the details of these agreements and understandings. Such agreements and understandings provide the grounding for tolerable conditions for those most affected by the works in particular, both at the enabling and main works phases.

Agreement with Dublin City Council

As has been alluded to earlier, this agreement was presented to the Board on 22nd April, 2009. This agreement was added to by details provided to the Oral Hearing on 30th November, 2009.

The original agreement makes provisions in relation to:

- Architecture and planning affecting public realm infrastructure, the make-up of InfraCo’s architectural team, masterplanning for St. Stephen’s Green station, escalator entrances and a wide range of other plant;
- Specific details directly applicable to St. Stephen’s Green Stop, notably design, station access from the street, materials, storage of street furniture and paving, and the proposed new shared surface between Dawson Street and St. Stephen’s Green West;
- An archaeological strategy to be adopted for the Green and the application of a methodology to deal with Fustier’s Arch;
- Works affecting the local authority’s utilities;
- Landscape protection and planning for public parklands; and
- Traffic management.

The addendum to the agreement arises after the local authority’s response to the applicant’s further information submission. A wide range of details are considered. In relation to specific issues affecting the environs of the Green, this related to the submission on the impacts on the Fitzwilliam Hotel. This document clarified matters on monitoring, traffic flows, and relocation of bus stops.

I note that the planning authority and the applicant both foresee the St. Stephen’s Green Stop as being a major city centre interchange facility and expect the architectural design to reflect this. The station hall is to be designed as a grand central station hall and to present itself as a unique piece of architecture. Such considerations should adequately address the principal concerns raised by observers such as Justin Marden.

The Board should note again that, subject to this agreement, the local authority does not request any further conditions be attached to any decision to grant the Railway Order.

Agreement with Iarnród Éireann/CIE

RPA has an agreement with Iarnród Éireann / Córas Iompair Éireann in relation to St. Stephen's Green, extracts of which were submitted to the Oral Hearing on 3rd December 2009. Those extracts made available to the Hearing relate solely to the traffic management plan. It is agreed that the STMP will take due cognisance of the requirements of CIE/IE in relation to traffic management for the duration of the Metro North works.

Agreement with Ampleforth Ltd.

RPA has a detailed agreement with Ampleforth Ltd., owners of the Fitzwilliam Hotel on St. Stephen’s Green West. The Observer made a very detailed submission in writing to the Board following the receipt by the Board of the application. By the time submissions were due to be given by the Observer at the Oral Hearing in December 2009 agreement had been reached and a copy of this agreement was forwarded to the Board at the Hearing on 3rd December, 2009.
METRO NORTH
ORAL HEARING

PROOF OF EVIDENCE
DESCRIPTION OF
ARCHITECTURAL DESIGN

Dr. John Smith
Tuesday April 7th 2009
Metro North Oral Hearing
Proof of Evidence
Description of Architectural Design
Dr John Smith
1. INTRODUCTION

1.1. My name is John Smith I studied architecture at University College London and obtained a doctorate at the Royal College of Art for research into 17th Century Parisian architecture. I have 24 years of professional experience, including 18 years of designing railway stations. As well as working on the design of Metro North, I have also worked on the Jubilee Line Extension, CrossRail and the East London Line. In Asia I worked on the Singapore Marina line, the Bangkok Transit System and the Hong Kong MTR. My other clients have included Iarnród Éireann, Metronet, Tubelines and the Kowloon Canton Railway Corporation.

2. METRO NORTH ARCHITECTURAL INTRODUCTION

2.1. These are all familiar images to any Dubliner but you may be wondering why I’m showing them to you now. The reason is because they all have one important thing in common...they are all within a 10 minute walk of one of the proposed Metro North Stops.

2.1.1. 
- Image of Fusiliers’ Arch
- Image of St Stephen’s Green Park
- Image of Royal College of Surgeons
- Image of St Patrick’s Cathedral
- Image of Bank of Ireland
- Image of Trinity College
- Image of Dublin Castle
- Image of Government Building
- Image of Ha’penny Bridge
- Image of Custom House
- Image of O’Connell Street
- Image of GPO
- Image of The King’s Inn

2.2. Dublin is one of the great European cities and I’m showing these pictures to suggest the profound impact Metro North will have on its future development.

2.3. All great cities need to be regularly renewed; to be re-shaped in response to the demands and aspirations of a new era. Dublin is gradually being renewed to meet the urban requirements of the 21st Century. Each era makes its own contribution to the historical regeneration of a city with the construction of infrastructure, housing and public buildings.

2.4. In the 21st Century, great cities invariably have high quality transport systems. Metro North will be the key component in the re-shaping of Dublin’s transport infrastructure. It will link the Luas Green and Red Lines. It will directly link Irish Rail’s Maynooth Line into the city’s urban railway system. It will provide, via the Red Line, connection between Heuston Station and the airport.

2.5. The new metro will provide a North South spine for the city:

2.5.1. It will bring people from Swords directly into the centre of the city.
- Image of Fingal Council building

2.5.2. It will take patients, staff and visitors to the Mater and Rotunda hospitals
- Image of Rotunda Hospital

2.5.3. It will bring students to Dublin City University and Trinity College.
- Image of Trinity College Library
2.5.4. It will bring art-lovers to the Hugh Lane Dublin City Gallery, The National Museum and the National Gallery, as well as the Gate and the Gaiety Theatres.

- Image of Hugh Lane Dublin City Gallery
- Image of National Museum
- Image of The National Gallery
- Image of The Gate Theatre
- Image of The Gaiety Theatre

2.5.5. And it will bring sports fans to Croke Park.

- Image of Croke Park Stadium

2.6. Metro North’s impact on urban development can happen in a wide variety of ways:

2.6.1. By significantly improving the speed and ease of travel between people’s homes and their places of work, it will begin to affect where people choose to live and where they’re able to work. This, in turn, will affect where we decide to build future housing, offices and places of work for many years to come. Also, the areas around stations and transport hubs have the potential for greater density of development.

2.6.2. Bringing more people quickly and comfortably to theatres, museums and galleries can have an impact on the cultural life of the city. Improvements to transport, will help to make Dublin a more liveable place for residents, tourists and other visitors and it will have a major positive effect on the primacy and viability of the city centre.

- Image of people in the city

2.6.3. At various points along the line, developments are being planned that will benefit greatly from their proximity to a Metro North stop. Examples include:

- The expansion of the Mater and Rotunda public hospitals.
  - Image of proposed Mater Hospital development

- The enhancement of Parnell Square as an important cultural quarter for the city.
  - Image of Dublin’s Writers Museum

- The development of Dublin City University and the creation of knowledge-based industries by all of the city’s universities.
  - Image of DCU

- The regeneration of Ballymun.
  - Image of Ballymun

- Terminal 2 represents a very significant development for Dublin Airport. Metro North will be the other key element in the creation of an international hub for the city. The provision of a modern, integrated, transport system, including a fast link from the airport to the city centre, will play a valuable role in promoting Dublin as a destination for overseas business investment.
  - Image of T2

  And

- Also, new Metro North stops will facilitate the planned expansion of the city to the north – in Swords and on other land designated for development within Fingal.
  - Image of Swords development

All of these developments will be supported by the connectivity provided by a modern urban transport system.

- Image of modern urban transportation system – Luas tram on bridge
3. ARCHITECTURAL VISION

3.1. As Architects, the design of Metro North is both a major challenge and a major opportunity to significantly benefit Dublin’s urban development. The city will see a series of fine new public buildings in the form of the stops themselves. So, what will the new Metro North stops be like?

*Animation of Metro North stops*

3.2. Our architectural vision is to create a single coherent project. The modern clean lines and understated elegance of Luas will be continued and improved in Metro North. Wherever passengers find themselves, they will experience a consistency of style, materials and detail.

*Image of Dardistown Stop - in rural location*

3.3. To the north, in suburban and rural areas, the metro will have a discrete, modern presence in the form of a series of modestly scaled, ground level stops.

3.4. As we move south towards the city centre, the line goes underground in order to minimise disruption to the existing urban fabric and to preserve the city’s historic core. Although the major part of these stops will be constructed below the surface, they will be bright open and spacious. Stops on the edge of the city centre will have entrances and ticket halls in elegant, glazed, pavilions at ground level, for example:

- At DCU
  *Image of DCU Stop entrances*

3.5. Stops in central historic locations will be constructed almost entirely below ground. They will have the most minimal presence at street level so as to preserve the integrity of their settings, for example:

- At St Stephen’s Green
  *Image of St Stephen’s Green Stop entrance*

3.6. Metro North stops will provide passengers with a high-quality, modern environment. They are designed to be accessible and comfortable to use. I would like to describe the architectural approach we have taken to the design of the stops. These computer-generated images of the new stops, as well as photographs from Luas and actual examples of similar projects illustrate the quality of design that the project seeks to achieve.

*Image of a stop in Porto*

4. URBAN DESIGN

4.1. The selection of Metro North’s alignment has been shaped by a broad range of considerations:

- Local development plans
  *Image of Ballymun Stop*
- Integration of existing and proposed transport infrastructure
- Areas of development and regeneration
- Stakeholder consultation
  And
- Environmental and engineering constraints.

4.2. These considerations have also impacted on the location of stops. In addition, there are particular local issues that have helped to shape the position and design of each stop.

*Image of Griffith Avenue Stop entrance*
4.3. While all stops will have common features to give a consistent identity the design of each Metro North stop – particularly those in the city centre - has been developed in response to the unique characteristics of each location.

4.4. Given these many, varied constraints, the aim has been to create civic architecture that will complement, enhance and integrate with its local urban environment.

5. TRANSPORT INTERCHANGE

5.1. The integration of Metro North with other transport systems is a key feature of the new line and of the Government’s transport strategy, Transport 21. Metro North will link together existing services and future projects. Stops have been designed to allow easy transfer to other rail lines, such as the Luas Green Line at St Stephen’s Green, the Luas Red Line at O’Connell Bridge and the Maynooth Line at Drumcondra.

5.2. The future Metro West project would interchange with Metro North at Dardistown. Irish Rail are also planning the Dart underground, which would be fully integrated with the Metro North stop at St Stephen’s Green.

5.3. At other city centre locations, Metro North stops cater primarily for pedestrians and bus passengers.

5.4. At suburban stops, dedicated provision has also been made for interchange with cars, taxis and bicycles. Park and ride facilities are provided at: Dardistown, Fosterstown and Belinstown.

5.5. Inclusive design is a priority for Metro North, and the aim is that the mobility impaired can move conveniently between modes of transport. Where necessary, additional pedestrian facilities such as signal controlled crossings will be provided.

6. STATION SIZING

6.1. To aid the specification and architectural design of stops, a stop sizing assessment was carried out to ensure that peak pedestrian flows could be comfortably catered for at projected levels of usage in the year 2040. The capacity assessments covered all key areas of stops including:

- Platform widths.  
  Image of Swords Stop platform
- Number of escalators.  
  Image of escalators that would typically be installed
- Widths of stairways.  
  Image of Ballymun Stop stair way
- Number of lifts  
  Image of O’Connell Bridge Stop lifts and escalators
- Widths of passageways (including over bridges and subways).  
  Image of Ballymun Stop passageway
- Number of ticket gates.  
  Image of Ballymun Stop ticket gateline

And
6.2. The stop assessments employed the station quantification procedures of London Underground to ensure that the designs provide for efficient movement of passengers in all areas of the stops.

6.3. For each stop the Central Case demand forecast for 2040 was calculated by the RPA. The forecasts took into account other transport services that are being planned, such as Metro West, Dart Underground and new Luas lines.

6.4. Application of the London Underground station planning calculations determined the requirements for facilities at each stop. These were compared with the standard design criteria applied at each stop and the specific stop designs, especially in relation to underground stops. Advice was provided to the architects, including advice on integration with Irish Rail at St Stephen’s Green (Dart Underground) and Drumcondra. Further iterations of the designs were assessed and some micro-simulation assessments of selected underground stops was undertaken. These studies addressed key stop planning issues such as ensuring adequate separation of escalators to minimise crowding and delays.

6.5. The latest designs were concluded to provide sufficient capacity to accommodate the Central Case morning peak hour demands forecast for 2040.

6.6. At Drumcondra the stop will need to cope with event traffic from Croke Park stadium. The design accommodates 20% of stadium capacity passing through the station in 1 hour, with 20% of passengers using Irish Rail Services. The stop will be provided with appropriate gates in the arcade passageway to provide for crowd control.

7. STOP ENTRANCES AND URBAN CONTEXT

7.1. The way that stops are integrated into their surroundings will be important. In historic locations, entrances will be restrained in scale and will blend in discreetly with their urban context. Where appropriate, new materials will be selected that respect the materials that already exist in the area. Other members of the RPA design team will describe in more detail the approach to the conservation of historic structures, sculpture and landscape.

7.2. In other locations, Metro North entrances will have a bright, modern design and will form a series of distinctive new structures across the city.

7.3. The project will include local streetscape improvements such as pedestrianisation, road realignments and kerb adjustments to provide better footpath widths. Hard landscaping and features such as seating, lighting, signage and planting will enhance the local environment.

7.4. In some locations entrances will be carefully integrated with new developments:
   - The entrance at Mater will be incorporated into the new hospital extension.
   - At Ballymun, the entrances will be integrated with the local regeneration proposals.
   - At the Airport, the stop is integrated with the Terminal 2 Project now moving towards completion.
8. SURFACE STOP PLANNING

8.1. The planning of surface stops is relatively simple and direct, so that passengers are able to get on and off platforms as quickly and safely as possible.

8.2. They have generally been designed with a central island platform or two side platforms.

*Image of Swords Stop island platform*
*Image of Belinstown Stop side platforms*

8.3. There will be a consistency of style and design across all the surface stops. They will form a series of elegant structures running north from Northwood to Belinstown (although Airport will be underground). High-quality, well-detailed materials, such as glass and stainless steel, will give Metro North a sleek, modern appearance.

8.4. While the height of platforms in relation to street level is dependant on site characteristics, they all provide for step-free access. To cater for pedestrian movement from street level to platform level, ramps are provided at the end of platforms. Marked pedestrian crossings are provided at the base of platform ramps to enable passengers to cross between platforms. Special consideration for the mobility impaired includes features such as handrails and tactile paving.

*Image of Dardistown Stop*

8.5. Stops have been designed to integrate conveniently and safely with adjacent roads and with other modes of transport. Dedicated provision has been made for pedestrian crossings, bus stops, car drop-off bays and bicycle parking.

9. UNDERGROUND STOP PLANNING

9.1. The planning of underground stops is far more complicated than surface stops, particularly those in or near the city centre. Although the stops vary greatly in their design scale and planning, we have followed a number of common principles.

*Image of St Stephen’s Green ticket hall*

9.2. Although underground stops are, by necessity, large and complex, they are designed to be bright, open and safe. Public areas are planned to be clearly legible to passengers, ensuring they can find their way around with confidence. Stop planning follows instinctive wayfinding principles: Passengers will be able to clearly understand where they should be going; there will be a logical progression between street and platform; there will be good visibility and orientation.

10. ENTRANCES AND TICKET HALL

10.1. Wherever possible, entrances to underground stops are located so they are easily visible and accessible.

10.2. While the specific urban context of each entrance dictates many design features, a level of consistency has been sought to provide familiarity for users. Given any local constraints, the aim is to bring people directly to ticket halls without lengthy passageways or many changes of direction.

10.3. Once we move underground, passengers will find bright, open concourses. Areas used by the public will be spacious and the design seeks to incorporate natural light which will flood through roof lights into ticket halls and even down onto platforms.

*Image of Drumcondra light to ticket hall level*
*Image of Drumcondra light to mezzanine and platform level*
10.4. The ticket hall level can be broadly divided into the paid and unpaid sides, which are separated by the ticket gate line. On the unpaid side of the gate line, passenger facilities such as ticket vending machines, help-points and local area information have been provided. Image of ticket gate line at Drumcondra Stop

10.5. Stop control rooms - which will be staffed during operational hours - will have a view of the ticket hall, ensuring adequate monitoring and enabling staff to provide assistance to those seeking help. Monitored CCTV will give full coverage of all public areas. Image of stop control room at O’Connell Bridge Stop

11. PLATFORMS

11.1. All Metro North platforms are 94m in length, which is sufficient for two joined metro vehicles. Platform widths vary in accordance with the number of people expected to use the stop. Platforms also have to incorporate lifts, escalators and other structures that ensure maximum accessibility without impacting on the minimum areas required for safe, comfortable passenger circulation. Image of platform level at Drumcondra Stop

12. ACCESSIBILITY

12.1. The design of Metro North has been guided by inclusive design principles to enable everyone, including the mobility impaired, convenient access and use of metro services, premises and information. The aim is that all passengers can find their way through the stop instinctively, without over-reliance on signage. Image of lift

12.2. The Metro Accessibility Group will discuss and agree actions to optimise the overall accessibility of the system. The Metro Accessibility Group will include the RPA, and relevant passenger representatives such as the National Council for the Blind of Ireland, the Irish Wheelchair Association, the Association for the Deaf, and the National Council on Ageing and Older People. They will provide ongoing advice and guidance about how to make the stops suitable for all groups within society.

13. ESCALATORS AND LIFTS

13.1. Access between street level, ticket hall and platforms will be by escalators and lifts. Given the depth of Metro North stops, escalators will provide the primary means of vertical circulation. Image of escalators at St Stephen’s Green Stop

13.2. Lifts provide vertical access within all underground stops, ensuring step free access to all public areas. There will be a minimum of two lifts from street level to platform level, each to hold a minimum capacity of 17 persons. Image of lifts and escalators at O’Connell Bridge Stop

14. EMERGENCY ESCAPE

14.1. Passenger safety is paramount and this has been reflected in the design of all Metro North stops. Emergency means of escape are provided from every level. Escape cores have been carefully designed to ensure that maximum predicted passenger numbers in 2040 can be catered for.

14.2. Primary means of escape will be via staircases which connect all levels (including maintenance areas and plant rooms) to street level, where further emergency evacuation
procedures will be in place. In addition, lifts will be provided for the use of emergency services personnel. Emergency lifts will be capable of providing space for two personnel carrying a stretcher. Our fire engineer, Tom Keeper, will give a more detailed explanation of fire safety provisions.

15. MATERIALS AND AMBIANCE

15.1. The materials selected for Metro North stops have been chosen to provide public environments that are both aesthetically pleasing and functional. A consistent approach to the use of materials and finishes will ensure a familiarity between stops and help with the recognition of stops at street level. The choice of materials and finishes will be based on several criteria, including:

- Durability
- Environment
  Image of Luas canopy detail
- Ease of cleaning & maintenance
- Slip resistance of paving
  Image of slip resistance paving and tactile paving
- Metro branding
- Meeting the needs of people with disabilities or visual impairment.

15.2. Materials and finishes will generally be modern, bright and hard-wearing, including:

- Toughened glass
  Image of glass detail
- Stainless steel
  Image of stainless steel handrail detail
- Natural stone

16. ART

16.1. An art budget will be allocated for many stops. This budget will allow the inclusion of art works from artists with the aim of enhancing Metro North.

17. PASSENGER INFORMATION AND FACILITIES

17.1. A comprehensive approach to the provision of passenger information and facilities has been taken in the design of all stops:

18. PASSENGER INFORMATION

18.1. Information regarding services, safety and other matters will be displayed at convenient and suitable locations throughout stops. Information provision includes:

- Passenger Information Displays above gate lines and on all platforms
  Image of O’Connell Bridge Stop signage
  Image of Swords Stop information and facilities
- Variable message displays at stop entrances and ticket gate lines.
- Directional signage
  Image of Airport Stop
- Local area information
- Operator information
- Network maps
And
  • Public address systems

19. PASSENGER FACILITIES

19.1. The provision of facilities such as emergency help points, passenger help points, ticket vending machines, ticket validation points and gates, shelter, seating, waste bins and clocks will help to ensure a comfortable, safe and convenient experience for passengers.

*Image of O’Connell Bridge Stop gate lines and ticket machines*

20. ADVERTISING

20.1. To help the financial viability of metro, advertising will be used to generate revenue. However the amount of advertising will be controlled and only displayed in locations where it will not detract from the passenger experience or cause visual clutter.

*Image of Drumcondra Stop advertising*

20.2. Digital advertising sites will be located at ticket concourse, mezzanine, circulation areas and on tunnel walls opposite island platforms.

*Image of O’Connell Bridge Stop advertising*

20.3. Surface stops will have advertising displays at locations along the platform.

*Image of Luas advertising displays*

*Image of Swords Stop advertising on platforms*

21. DETAILED DESCRIPITIONS OF UNDERGROUND STOPS

21.1. I will now go through the design of each underground stop in some detail. I will start with St Stephen’s Green and move northwards.
22. AREA 107: ST STEPHEN’S GREEN STOP

22.1. Site location

The proposed location of St Stephen’s Green Metro North stop is at the junction of St Stephen’s Green and the southern end of Grafton Street.

22.1.1. The surroundings consist of a wide variety of different uses including many retail and commercial properties. There are important government and cultural buildings nearby, as well as many bars and restaurants. The Luas Green Line, numerous bus routes and the proposed Dart Underground means that this stop will become an important transport interchange.

22.1.2. Significant local buildings include the Royal College of Surgeons, The Dáil, The Gaiety Theatre and several five star hotels.

22.1.3. St Stephen’s Green park is one of the City’s most historic green spaces, the current layout of which dates from the 1880s. The park, and all the associated buildings, features and statues, has recently become a National Monument. St Stephen’s Green will be restored to its original Victorian park layout after construction works are complete.

22.1.4. The plaza around the North West corner of St Stephen’s Green will be pedestrianized. The whole area will be subject to an integrated landscape design to incorporate the new metro north structures. Good quality materials such as natural stone will be used throughout the scheme and historic features such as railings and street furniture will be conserved and reinstated at the end of the works.

22.2. Stop box

St Stephen’s Green stop will form part of a major interchange station with the proposed Dart Underground. The Dart underground station will be located largely under the northern boundary of St Stephen’s Green and will share the Metro North ticket concourse.

22.2.1. The stop is located next to the existing Luas Green Line. There are also plans to extend Luas Green Line to connect to the existing Red Line.

22.2.2. The ticket hall will be constructed under the road at the junction of Grafton Street and South King Street. The main stop box is largely built in the location of the pond in St Stephen’s Green park; the box is approximately 120m long, 34m wide and 21m deep. Below the Metro North platforms, another level will be constructed to accommodate part of the Dart Underground station.

22.2.3. The architectural design of St Stephen’s Green Stop reflects its status as a major city centre interchange station, with spacious ticket hall and platform areas. However, despite its large scale the design minimises the visual impact on its historic context and the surface expression of the stop is very limited in its scale and its extent.

22.3. Ground Level

Entrances to the stop are designed to respect the character of St Stephen’s Green. An understated approach has been used to reduce the visual impact of the
entrances. For this reason, there are no canopies over the entrances. The two escalator entrances are simply enclosed by low walls.

22.3.2. One entrance is located at St Stephen’s Green West, close to the Luas Green Line stop and provides easy access between the two systems.

22.3.3. Another entrance is located at St Stephen’s Green North.

22.3.4. Other ground level structures associated with the stop are located within the park. These include escape stairs, fireman’s lifts and vent shafts. There are three sets of escape stairs and lifts, and as far as possible, these have been located to have the least impact in St Stephen’s Green. The top of escape stairs stop flush with ground level and have fail-safe opening hatches.

22.3.5. One fireman’s lift and escape stair is located between the footpath and the railings on St Stephen’s Green west and another in a similar position on St Stephen’s Green north. The third is at the southern end of the pond. Heavy planting of foliage and trees will help to conceal these structures.

22.3.6. Low level vent shafts and a roof light are located within the reconstructed island in the pond. These structures will be carefully hidden behind reinstated ‘Pulham’ rock, trees and planting. Given the limited scale of ground level structures at this location and the means to screen and integrate them into the park environment, their impact in visual terms will not be significant.

22.4. **Ticket hall level**

*Image of ticket hall level plan*

22.4.1. Pedestrian access between street level and the unpaid side of the ticket hall will be provided by two banks of three escalators and by two passenger lifts. The open, clear layout allows passengers to locate the route to Metro North and Dart Underground.

22.4.2. From the gate lines, passengers have a choice between escalators down to Metro North platform level or Dart platform level. Two glazed passenger lifts will serve both Metro North and Dart platforms.

22.4.3. There is a very large area of mechanical and electrical plant rooms at this level. In addition, ESB require a high voltage substation to serve the whole of the Metro North line. This dedicated substation is located below street level, behind the escalators of St Stephen’s Green north.

22.4.4. The ticket hall will be spacious and flooded with natural light from roof lights in St Stephen’s Green.

*Image of computer model ticket hall level*

22.5. **Platform level**

*Image of platform level*

22.5.1. The platform is 20m wide. This width is required to accommodate large passenger numbers, two banks of two escalators, lifts at the platform ends and stairs down to the Dart Underground platforms.

22.5.2. Natural light is channelled down from the island roof light to emphasise the clean lines and bright internal finishes of the platform area.

*Image of computer model platform level*
22.6. Changes to Railway Order drawings

*Image of changes to Railway Order ground level*

22.6.1. We have continued to discuss the proposals with the local authority and other interested parties and a number of improvements have been made to the design. These include:

- The main entrances on both St Stephen’s Green west and St Stephen’s Green north have been revised in order to locate them nearer to the end of Grafton Street. This change produces a number of improvements:
  - A shorter walk between the entrances and Grafton Street.
  - A reduction in the size of the box construction.
  - Improved access to buildings and streets during construction.
  - And it allows the Luas platform to be extended in the future.

- Passenger lifts have been moved further away from the top of Grafton Street to the western edge of St Stephen’s Green Park. This will benefit the design in a number of ways:
  - The north west corner of St Stephen’s Green will be kept uncluttered and will become an important civic space, with an uninterrupted view of Fusilier’s Arch.
  - One lift will be a shared emergency fireman’s lift, thereby reducing the size of one of the escape cores within the park.
  - Passenger circulation is improved within the ticket hall.

- Metro North and Dart Underground escape stairs at St Stephen’s Green North have been combined in order to reduce their impact on the park.

- The size of escape hatches has been reduced thereby minimising impact on the park.

- An additional escalator has been introduced between the ticket hall and Dart Underground.

*Image of changes to Railway Order ticket hall level*
23. AREA 107: O’CONNELL BRIDGE STOP

23.1. Site location

Image of site location

23.1.1. O’Connell Bridge stop is located under the River Liffey, with entrances on O’Connell Street Lower and Westmoreland Street.

23.1.2. The surroundings predominately consist of shops and offices, with a number of other uses including pubs, restaurants and hotels. The Westmoreland Street entrance is next to Temple Bar.

23.1.3. The Abbey Street Stop on the Red Luas Line, and the proposed extension of the Green Luas Line (Line BX) will ensure that this stop becomes an important transport interchange.

23.1.4. Significant buildings in the surrounding area include the GPO, Trinity College and the Bank of Ireland. There are also some important statues such as Daniel O’Connell. Conservation issues will be dealt with in later evidence.

23.1.5. In July 2001 O’Connell Street was designated an architectural conservation area.

23.2. Stop box

Image of O’Connell Bridge Stop long section

23.2.1. The platforms are approximately 28m below street level and directly under O’Connell Bridge. The entrance box at O’Connell Street is approximately 28m deep x 81m long x 24m wide. The entrance box at Westmoreland Street is approximately 28m deep x 81m long x 17m wide.

23.3. South Box ground level (Westmoreland Street)

Image of O’Connell Bridge Stop - Westmoreland Street ground level

23.3.1. A bank of three escalators and two lifts on the western side of Westmorland Street will provide access to a sub-surface ticket hall. A low stone wall will surround the escalator entrance, and lifts will be glazed.

23.3.2. Escape stair exits are covered by low level hatches to reduce their visual impact.

23.4. South Box ticket hall level (Westmoreland Street)

Image of O’Connell Bridge Stop Westmorland Street ticket hall level

23.4.1. Escalators from landing level and lifts from ground level provide access to the unpaid side of the ticket hall. Once through the gate line, passengers can use escalators or lifts to get down to platform level.

23.4.2. Double helix stairwells at the southern end of the concourse level provide means of escape.

23.5. North Box ground level (O’Connell Street)

Image of O’Connell Bridge Stop - O’Connell Street ground level

23.5.1. A pair of escalators and a lift on both sides of O’Connell Street provide access to a sub-surface ticket hall. The escalator entrances will be enclosed by low natural stone
walls and will have no canopies in order to minimise their visual impact on this historic area. For the same reason passenger lifts will be glazed and escape stair exits are covered by hatches.

23.6. **North Box ticket hall level (O’Connell Street)**

*Image of O’Connell Bridge Stop - O’Connell Street ticket hall level*

23.6.1. Passengers reach the unpaid side of the ticket hall by escalators and lifts from both sides of O’Connell Street. Once through the gate line, passengers descend to platform level by escalators or can access two lifts via an open walkway.

23.6.2. The quality of these public spaces will be greatly enhanced by a combination of roof lights and open plan design. Glazed areas on O’Connell Street allow light to filter down to ticket hall level.

*Image of computer model ticket hall level*

23.7. **Platform level**

*Image of O’Connell Bridge platform level*

23.7.1. A bank of three escalators and two passenger lifts lead down from both the O’Connell Street and Westmoreland Street entrances to a broad, open central concourse at platform level.

23.7.2. The central concourse is 10.5 m wide and six passageways lead through to each 4.3m wide platform, giving good distribution of passengers along the length of the trains.

*Image of computer model platform level central concourse Image of computer model platform*

23.7.3. Escape stairs, fire fighting lifts and plant rooms are located at each end of the central concourse.
24. AREA 107: PARNELL SQUARE STOP

23.1 Site location
*Image of site location*

24.1.1. Parnell Square stop will be located on Parnell Square East. The surrounding area is a mixture of tourist destinations, commercial properties and hotels. There are a number of significant cultural buildings nearby, including the Gate Theatre, the Hugh Lane Dublin City Gallery and the Dublin Writers Museum.

24.2. Stop box
*Image of Parnell Stop long section*

24.2.1. The stop box is approximately 130m long x 24-38m wide and is between 24-28m deep. It is situated mainly under the road and partly under the grounds of the Rotunda Hospital.

24.3. Ground level
*Image of Parnell stop ground level*

24.3.1. Parnell Square is one of the city’s most historic spaces and the aim has been to reduce the visual impact of the stop at ground level. For this reason, there are no canopies over the escalator entrances, which will be enclosed by low natural stone walls. Two pairs of escalators and two glazed passenger lifts are located on Parnell Square East. A glazed roof light flush with the pavement will bring light into the ticket hall below.

24.3.2. In order to reduce visual impact, escape stairs are covered by low level hatches and the lifts are glazed.

24.4. Ticket hall level
*Image of Parnell Stop ticket hall level*

24.4.1. Passengers will pass through ticket gates to the paid side from where lifts and escalators will bring them down to platform level via an intermediary mezzanine level.

24.4.2. A glazed roof light will bring natural light into the ticket hall.

24.4.3. There are a considerable number of plant rooms at this level.

24.5. Platform level
*Image of Parnell Stop platform level*

24.5.1. The platform is 9.7m wide with a passenger lift at both ends.

24.5.2. There is limited space for plant rooms at the platform ends. Additional space for plant rooms is provided in an area to the south of the main box.

24.6. Changes to Railway Order drawings
*Image of changes to Rail Order ground level*
*Image of changes to Rail Order section*
24.6.1. We have continued to discuss the proposals with the local authority, and amongst others, the Rotunda Hospital. Various improvements have been made to the design. These include:

- Surface penetrations have been laid out to better suit future development in the area.

- The fireman’s lifts have been combined with passenger lifts to reduce the number of lifts.

- Lifts have been relocated, which removes visually intrusive structures from the public space on Parnell Square East.

- As a result of this replanning there is now an uninterrupted view of Findlater’s Church.

- The size of escape hatches has been reduced, minimising their impact on the pavement on Parnell Square East.

- The smoke vents have been rationalised. Two vents are hidden within the gates structure for the Garden of Remembrance. Two more are in a temporary position which allows for their relocation as part of a future development.

- Passenger lifts between concourse level and platform level are in a central location for clear, direct access.

- Escalator locations have been rationalised at platform level.
25. AREA 106: MATER STOP

25.1. Site location

The Mater stop is located on the site of the Mater Misericordiae Hospital between Eccles Street, North Circular Road, Leo Street and Berkeley Road.

25.1.1. The Mater stop is located on the site of the Mater Misericordiae Hospital between Eccles Street, North Circular Road, Leo Street and Berkeley Road.

25.1.2. As well as the main hospital complex, there is also the Mater Private Hospital on Eccles Street. Dorset St Lower has pubs, shops, restaurants and offices. Otherwise the area is predominantly residential.

25.1.3. The redevelopment of the hospital site will include a new adult hospital and the phased implementation of a new children’s hospital on Eccles Street. Access into the hospital site has been reconfigured to provide a dedicated ambulance lane from the North Circular Road.

25.2. Stop box

The stop box is approximately 22m deep, 167m long x 23-47m wide situated below the hospital car park, directly behind the Victorian terraced housing on Leo Street.

25.3. Ground level

The main stop entrance is located on North Circular Road next to the proposed hospital service vehicle route and will be integrated into the hospital development.

The glazed entrance has been kept small in area to minimise the impact on the hospital’s development. Escalators and lifts will take passengers down to concourse level. Provision will be made for future access from the adult Mater Hospital directly to the unpaid side of the ticket hall.

Two buildings will facilitate the ventilation and escape cores to the north and south of the box. The scale of both these buildings will match the existing houses on Leo Street.

25.4. Concourse level

At concourse level passengers transfer to separate sets of lifts and escalators to access platform level. Lifts between concourse and platform level are positioned to the north end.

Plant rooms and escape cores are located at both ends of concourse level.

Ground level constraints, such as the service access road, restrict the position where escape stairs arrive at ground level. Escape from platform level requires the escape routes to divert to the east side of the stop at either end of Leo Street.

25.5. Platform level

The platform is 9m wide with two passenger lifts.
25.5.2. Plant rooms and escape cores are located at each end of the platform. Additional plant rooms are located at trackside which is accessed from mezzanine level.

25.6. Changes to Railway Order drawings

Image of changes to Railway Order ground level
Image of changes to Railway Order section

25.6.1. We have continued to discuss the proposals with the local authority and the Mater Adult Hospital and improvements have been made to some aspects of the design. These include:

- The ground level entrance has been set back to match the proposed Mater development building line.
- The entrance has been rationalised to give better pedestrian access to escalators and lifts.
- The ticket hall has been moved from ground level down to concourse level.
- A roof light has been introduced to allow natural light down into the lower levels.
- The fireman’s lift has been combined into one structure with the Mater Hospital security booth in the ambulance lane median – this lift has direct access to the platforms level below.
- The overall height of the stop box has been reduced and the number of floor levels reduced from three to two.
26. AREA 106: DRUMCONDRA STOP

26.1. Site location

*Image of site location*

26.1.1. Drumcondra Stop will be located on Lower Drumcondra Road, between the junctions of St Alphonsus Road and St Anne’s Road North. The stop has been designed to integrate with the existing Irish Rail station and will provide it with a new entrance and ticket hall.

26.1.2. The surrounding land-use is predominately residential, with some retail outlets and pubs located nearby. The wider area has a number of important buildings most notably Croke Park Stadium and the palace of the Roman Catholic Archbishop of Dublin. Holy Cross College is one of a number of educational institutes in the area.

26.2. Stop box

*Image of Drumcondra Stop long section*

26.2.1. The main stop box is approximately 25m wide, 107m long and 25m deep. It is to be constructed on land between the Lower Drumcondra Road and St Joseph’s Avenue.

26.2.2. Site constraints have severely limited the available space for the underground stop box, which has resulted in the need to locate a number of plant rooms at ground level.

26.3. Ground level

*Image of Drumcondra Stop ground level plan*

*Image of computer model towards Metro North escalator*

26.3.1. From the main entrance on Lower Drumcondra Road, pedestrians will walk along a retail arcade to the main interchange plaza.

26.3.2. From this plaza, escalators and lifts will provide access down to the Metro North ticket hall and up to the Irish Rail Station.

26.3.3. High level roof lights will bring natural light down to the plaza giving passengers a sense of orientation and openness as they enter the stop.

26.3.4. Plant rooms and the southern escape core are next to St Joseph’s Avenue.

26.3.5. The northern escape core and ventilation plant will be located at the junction of St Alphonsus Avenue and St Joseph’s Avenue.

26.3.6. As a result of the construction works there will be an unused area of land within the site boundary providing an opportunity for future development.

26.3.7. Streetscape improvements will be made in the area including increasing the footpath width outside the stop entrance. There will also be a controlled pedestrian crossing over Lower Drumcondra Road and landscaping of the median reserve.

26.4. Irish Rail ticket hall level

*Image of Drumcondra Stop Irish Rail ticket hall level*

*Image of computer model view to Irish Rail*
26.4.1. From the interchange plaza, escalators and lifts bring passengers up to the Irish Rail ticket hall and platform level approximately 8m above ground level.

26.4.2. An Irish Rail ticket office and other facilities are provided at this level. After passing through the ticket barriers, passengers will have direct access to the northern platform, with stairs and lifts giving access to the southern platform via an overbridge.

26.5. **Metro North ticket hall level**

*Image of Drumcondra Stop ticket hall level*
*Image of computer model ticket hall*

26.5.1. From the ground level plaza, a bank of four escalators lead down to the Metro North ticket hall. Above the escalator landing there is a roof light bringing natural light into the stop.

26.5.2. Once through the ticket barriers, two glazed lifts will provide direct access to the platform level, while escalators will provide access via an intermediary mezzanine level.

26.5.3. Roof lights will allow natural light to flood down into this level above the escalators and ticket gates.

26.5.4. The north part of the box contains escape stairs, plant rooms and ventilation ducts.

26.6. **Platform level**

*Image of Drumcondra Stop platform level*

26.6.1. Two glazed lifts and two pairs of escalators give access to the platform.
*Image of computer model view to mezzanine and platform level*

26.6.2. The platform is 12m wide with escape cores at both ends.
*Image of computer model platform level*

26.7. **Changes to Railway Order drawings**

*Image of changes to Railway Order ground level*
*Image of changes to Railway Order section*

26.7.1. We have continued to discuss the proposals with the local authority and to make improvements to some aspects of the design. These drawings show the changes that have been made:

- Re-planning of the stop allows for the future possibility of an underpass to connect St Anne’s Road North.

- The bridge over Irish Rail tracks have been reduced in scale and height.

- Views down Clonliffe Road have been improved at ground level and at Irish Rail level.

- The space available for retail use has been rationalised and improved.

- The building line on St Joseph’s Avenue has been set back from the street to allow for a widened footpath on the east side of the street and to allow for landscaping. The façade of this building is being redesigned to be more sympathetic to the existing housing.
Passenger circulation has been rationalised. In particular vertical circulation has been re-arranged to give better pedestrian movement between metro and the Irish Rail station. Space within the stop is now more efficiently used.
27. AREA 106: GRIFFITH AVENUE STOP

27.1. Site location

Image of Griffith Avenue Stop site location

27.1.1. Griffith Avenue stop is situated directly north of the junction between Griffith Avenue and Griffith Lawns. Griffith Avenue has mainly 1930’s housing and is lined by fine rows of trees. DCU has plans to develop its lands around the stop.

27.2. Stop box

Image of Griffith Avenue Stop long section

27.2.1. The stop box is approximately 28m wide by 148m long and between 20-25m deep and is largely constructed under a green field site currently owned by Dublin City University.

27.3. Ground level

Image of Griffith Avenue Stop ground level

27.3.1. Passengers will access the stop from Griffith Avenue, passing through a forecourt into a glazed ticket hall. The ticket hall has a clear layout and passengers will proceed directly through the gate line to the paid side, where a bank of three escalators and two lifts will provide access to the lower levels. A control room, plant rooms, emergency escape stairs and fire access lift are ranged along the east side of the ticket hall. The emergency escape core opens directly onto a service road which provides access for maintenance staff as well as emergency personnel.

Image of computer model entrance

27.3.2. To minimise the visual impact of the stop, only essential structures are located at ground level, including the northern escape core and emergency tunnel exhaust vents. Trees and landscaping will help blend the buildings into the surrounding area.

27.4. Concourse level

Image of Griffith Avenue Stop concourse level

27.4.1. Passengers proceed down to concourse level from where they reach two lifts and four escalators giving access to the lower levels of the stop. Roof lights bring daylight down into this area.

27.4.2. Provision has been made for a possible secondary entrance at this level from the future University development to the east. A large number of plant rooms and vent shafts are located at the north and south ends of concourse level.

27.5. Platform level

Image of Griffith Avenue Stop platform level

27.5.1. Passengers arrive at the 12 m wide platform level by centrally located escalators and lifts.

27.5.2. Plant rooms and escape cores are located at both ends of the platforms.

27.5.3. A roof light above the glazed double lift shafts allows some natural light to filter down to this level.

Image of Griffith Avenue Stop cross section
28. AREA 105: DCU

28.1. Site location

*Image of DCU Stop site location*

28.1.1. Dublin City University (DCU) stop will be located along the east of Ballymun Road, between Albert College Drive and Albert College Lawn. The site is positioned just north of the main entrance to Dublin City University campus and Albert College Park, and to the south of Our Lady of Victories Church. The surrounding area is mainly residential, with a number of local retail outlets at the corner of St Pappin Road and Ballymun Road. Signalised pedestrian crossings will cater for the large residential area on the west side of Ballymun Road.

28.2. Stop box

*Image of DCU long section*

28.2.1. The stop box is approximately 234m long x 18m wide and 12m deep. The stop has two main levels, the first being ground level ticket halls and the second is platform level.

28.3. Ground level

*Image of DCU Stop ground level*

28.3.1. Access to the existing Scout Hall will be maintained by a private vehicle and pedestrian access gate from Ballymun Road, next to the north entrance.

28.3.2. Access to residential areas including Albert College Grove, Albert College Crescent and Albert College Lawn will be maintained as part of the proposal. Semi-mature trees will be planted along the eastern boundary of the site to screen these areas from the stop.

28.3.3. The design of the stop includes roof lights over the main platform areas, which also serve as ventilation outlets for smoke in the event of a fire. Solar panels are located on the roof of both entrance pavilions.

28.3.4. Tunnel vents will be located at both ends of the stop and these will be surrounded by planting to minimise their visual impact.

28.3.5. Two glazed entrance pavilions will be located on Ballymun Road approximately 90m apart.

28.3.6. The southern entrance will accommodate the stop control room, staff facilities, ticket vending machines and a gate line. The ticket hall has a simple clear layout and passengers will proceed directly through the gate line to the paid side, where a staircase and a lift will provide access to platform level.

28.3.7. The northern entrance pavilion will contain ticket machines, a gate line, a lift and stairs only.

*Image of computer model entrance*

28.3.8. There are no escalators at this stop because of the shallow platform level.

28.4. Platform level

*Image of DCU Stop platform level*
28.4.1. A stair and a lift give access to each end of an 8m wide platform. These stairs will also provide means of escape and the lift will serve as emergency services access. Due to the shallow depth of the stop, dedicated fire escape stairs and emergency services lift are not required.

28.4.2. Roof lights bring natural light down to the platform.

28.4.3. Plant rooms are located at both ends of the platform.
29. AREA 105: BALLYMUN STOP

29.1. Site location

*Image of Ballymun Stop site location*

**29.1.1.** Ballymun Stop will be located on Ballymun Main Street between Balbutcher Lane South and Silloge Road, adjacent to the proposed Ballymun Civic Plaza to the east. The surrounding area is predominately residential, with some retail outlets, a community art centre and a hotel nearby. An extensive new shopping centre and residential development is planned to the west of the stop.

29.2. Stop box

*Image of Ballymun Stop long section*

**29.2.1.** The stop box is approximately 188m long by 31m wide and between 10-12m deep and will be constructed under the Ballymun Main Street

**29.2.2.** It has two main levels, the first being a mezzanine ticket hall level and the second being platform level, 10m below ground.

29.3. Ground level

*Image of Ballymun Stop ground level*  
*Image of computer model entrance*

**29.3.1.** An entrance to the east of Ballymun Main Street will be accessed from a sunken civic plaza. A lift and stairs will provide access down to this plaza.

**29.3.2.** Two staircase entrances will be located on the west side of Ballymun Main Street between Balbutcher Lane South and Silloge Road. A further lift is provided at the Silloge Road entrance.

**29.3.3.** There are no escalators at this stop because of the shallow platform level.

**29.3.4.** Ground level roof lights in the central reserve allow natural light to filter down to the platform, with openings for ventilation.

**29.3.5.** Tunnel vents will be located on Shangan Road and Ballymun Main Street central median. Escape stairs from the plant rooms have been designed to blend in with the proposed landscaping.

29.4. Mezzanine level

*Image of Ballymun Stop mezzanine level*

**29.4.1.** The northern entrances open into a ticket hall at mezzanine level. Two separate gate lines lead into the same paid area which is overlooked by a control room. At the civic plaza entrance glazing will allow natural light into the ticket hall.

**29.4.2.** Once passengers have passed through the ticket barriers, they will access the platforms below by stairs or lifts.

**29.4.3.** The southern entrance has ticket vending machines and a separate gate line. There are stairs leading directly down to the platforms. There is a gallery walkway which leads to the northern ticket hall and gives access to lifts down to the platforms. Glass walls allow views down to platform level. Provision is made for a future connection between the stop entrances and Ballymun shopping centre to the west.
29.4.4. There are plant rooms and tunnel vent fans at both ends.
*Image of Ballymun Stop ticket hall at mezzanine level*

29.5. **Platform level**
*Image of Ballymun Stop platform level*

29.5.1. The two side platforms are 3.6m wide, but increase to 7m at the ends to accommodate stairs and lifts. The access stairs per platform will also serve as the means of escape. Each platform will have one emergency lift direct to ground level.

29.5.2. Roof lights located in the Ballymun Main Street central median allow some natural light to filter down to this level.

29.5.3. Due to the shallow depth, there is no requirement for dedicated fire escape stairs and fireman’s lifts. Two minor escape stairs are located in the vicinity of the emergency smoke vents to allow escape from the plant rooms at each end of the stop.*Image of Ballymun Stop cross section*

29.5.4. Plant rooms are located at the ends of each platform.*Image of computer model platform level*
30. AREA 103: AIRPORT STOP

30.1. Site location

Image of Airport Stop site location

30.1.1. The stop is located in the centre of the airport to the north east of the existing Terminal 1 building.

30.1.2. Dublin Airport Authority has an extensive development programme that includes a masterplan to incorporate the new metro stop, the construction of Terminal 2 and major improvements to the existing terminal.

30.1.3. The phased development of a ground transportation centre is proposed which will incorporate the southern stop entrance. There are plans for a new access road and a multi storey car park to the east of the metro site. Covered pedestrian links from the stop to each terminal will be provided as part of the master plan. The number of ground level structures associated with the stop has been kept to a minimum to enable future development of the airport.

30.2. Stop box

Image of Airport Stop long section

30.2.1. The underground stop box is approximately 140m long by 31m wide and 22m deep, it will be largely constructed under what is currently a car park.

30.3. Ground level

Image of Airport Stop ground level

Image of computer model entrance

30.3.1. Entrances to the stop are designed to complement the airport’s new developments, including Terminal 2. The southern entrance will be within a glazed pavilion, with two public lifts and a bank of four escalators. The southern escape core with escape stairs, a fireman’s lift, plant rooms and ventilation shafts are next to the entrance.

30.3.2. Provision for a second entrance to the north has been allowed and this location takes into account planned airport developments. The northern entrance will be similar to the southern entrance, with a glazed structure over public escalators and lifts.

30.3.3. There will be a landscaped plaza between the north and south entrances. Roof lights will bring daylight into the public spaces below.

30.4. Ticket hall level

Image of Airport Stop ticket hall level

30.4.1. At the southern entrance, passenger access between street level and the unpaid side of the ticket hall will be provided by a bank of four escalators and by two passenger lifts.

30.4.2. The ticket hall has a relatively simple, clear layout that gives easy access to ticket vending machines and the gate line. Two wide gates are provided for passengers with large items of luggage.

30.4.3. Once through to the paid side, passengers have a choice of six escalators and four to access platform level.
30.4.4. Roof lights provide natural light to public areas. Voids around the escalators allow light to filter down to lower levels of the stop.

30.4.5. Plant rooms and escape cores are located at both ends of ticket hall level. 

*Image of computer model ticket hall*

30.5. **Platform level**

*Image of Airport Stop platform plan*

30.5.1. The platform is 14m wide ensuring ample space for passenger circulation.

30.5.2. Means of escape are provided at both ends.

*Image of computer model platform*
CONCLUSION

At various points in Dublin’s history, there have been important periods of urban renewal and Metro North will be a key component in the re-shaping of the city for the 21st century. It will link the city centre to the Airport, to Swords and beyond. Together with the Luas Green Line, it develops a north-south spine through the city. With the Luas Red Line, and later, Dart Underground and Metro West, it will link the city centre to the West.

Overall, Metro North will provide a significant unifying element for the city and will have a major positive impact on future urban development.

The architectural contribution which Luas has made to the city is extended and improved by Metro North. Great care has been taken to design restrained, yet elegant, modern buildings which I believe will in future years become admired features of Dublin’s urban landscape.
Expert’s Report for An Board Pleanála on Environmental Impact Statement for Metro North

Assessment of the Environmental Impacts in Relation to Ground Vibrations and Ground-borne Noise, Geotechnical, Hydrogeological and Related Issues

July 2010

By K. Rainer Massarsch

Ferievägen 25, SE 168 41 BROMMA, Sweden
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1 Executive Summary
This report presents the results of my evaluation of the Environmental Impact Statement submitted to An Bord Pleanála for the proposed construction of the Metro North Scheme.

1.1 Brief
I have been contracted by An Bord Pleanála to respond to the following questions:

1. Following a review of the documentation submitted with the application in relation to vibration and settlement, advise on the adequacy of the application details and Environmental Impact Statement in relation to predicted vibration and geotechnical impacts (inclusive of settlement), both for the construction and operational phases of the scheme.

2. Advise on the vibration and other geotechnical impacts (inclusive of settlement) of the vertical alignment option selected for the routing through Ballymun, i.e. cut and cover as opposed to elevated, at-grade, in retained open cut, and in bored tunnel.

3. Specifically, to advise on the construction and operational vibration and geotechnical impacts (including hydrogeology) of the proposed development on specific sensitive receptors.

4. Advise on the adequacy of the applicant’s methodology in assessing vibration and geotechnical impacts and on mitigation measures proposed.

1.2 Scope of Review
I have assessed the information presented in the EIS and submissions by RPA, further information presented in October 2009, and reviewed the observations and submissions made prior to and during in the Oral Hearing. I have attended the entire Oral Hearing. According to the Brief by An Bord Pleanála, my work has focused on environmental impact related to vibrations and groundborne noise, geology, soils and groundwater. I have also reviewed construction methods to be used for the Scheme, as these are of significance when assessing the above technical disciplines. In addition, I have reviewed and commented upon the concepts and methods used by RPA to prepare the Environmental Impact Statement (EIS) and the methodology for implementing the Environmental Impact Assessment (EIA) process.

1.3 Information Obtained in the EIS and at the Oral Hearing
The initially presented information in the EIS and supporting documents were reviewed. Presentations and submissions during the Oral Hearing and response to questioning during the first part of the Oral Hearing in April and May 2009 provided additional input. In response to this request, RPA prepared a comprehensive set of documents which was submitted prior to reconvening of the Oral Hearing on 30th November 2009. The Oral Hearings were suspended 20th January 2010 and were reconvened on 1st March 2010. The Oral Hearings ended on 10th March 2010.
Clarification was requested from RPA on a number of specific topics in the Further Information Request. RPAs response contained useful documents which have shed light on several technical issues and provided additional background material.

The subsequent phase of the Oral Hearing from November 2009 through March 2010 was beneficial as it enabled further information eventually to be obtained for the Board’s consideration. The information provided by RPA and the presentations and submissions by experts were comprehensive and generally of high technical standard.

During the period of the Oral Hearing, RPA conducted negotiations with a number of observers with the aim of finding compromise solutions to eliminate environmental concerns. These resulted in a number of agreements. Therefore, submissions made prior to and/or during the Oral Hearing, which were resolved by agreements are not discussed in this report.

1.4 Summary of Main Issues
This report documents the results of my review and evaluation of the EIS, of submissions by different parties as well as of the information gained during the period of the Oral Hearing. Herewith, I do submit for your consideration the following summary of conclusions and recommendations, which are presented and discussed in detail in this report:

1.4.1 Environmental Impact Statement
The scope of the EIS and methodology used to assess environmental impacts are adequate for evaluating the environmental impacts of the proposed Scheme. RPA have made considerable efforts to disseminate information to those potentially affected by the Scheme.

1.4.2 Environmental Impact Assessment Process
The Metro North project is proposed to be constructed, passing through highly sensitive urban environment, beneath and close to buildings of important heritage. Tunnels are to be constructed for a significant part of the alignment in challenging ground conditions which include coarse- and fine-grained glacial soils, mixed face tunnelling conditions and in some locations high water pressure. Due to the nature of the Metro North project and the still limited extent of information about geological and geohydrological conditions as well as lack of knowledge about actual construction procedures to be use, attention must be paid to unforeseen conditions and construction scenarios.

Although design and construction of the Metro North project is challenging, tunnelling projects have been carried out successfully under similar geotechnical and geological conditions without resulting in unacceptable environmental impacts. The main factor for successful implementation of tunnelling projects is the introduction and implementation of risk management. Careful planning, design and field monitoring shall be an essential part of this project. RPA have given assurances during the Oral Hearing that they intend to require the contractor(s) to implement and enforce a comprehensive risk management program which also focuses on environmental impacts.
During the Oral Hearing, RPA confirmed that risk management procedures are already being implemented. RPA shall remain responsible for overseeing, updating and enforcing environmental risk management. Risk management shall be a key condition when RPA negotiate with contractors.

I am satisfied with the information and concepts provided by RPA regarding procedures and methodologies for environmental impact assessment.

1.4.3 Vertical Tunnel Alignment

**Mater to St. Stephen’s Green**

Between Mater and St. Stephen’s Green, the vertical alignment of tunnels is still tentative and may deviate within the distances permitted by the EIA. At this stage of the project, sufficiently detailed geotechnical and geological information is still not available and the Reference Design is thus tentative. Based on a more detailed evaluation of subsoil and rock formation, changes of the vertical alignment may be required in order to reduce construction risks. This aspect is of particular relevance in sections where the bored tunnel passes through the interface between rockhead and overlying soil layers.

**Ballymun Area**

RPA propose a shallow tunnel and shallow stations in the Ballymun area, to be constructed by the cut and cover method. In response to the Further Information Request, RPA have presented a detailed evaluation of different alignment options. With respect to environmental considerations, the cut and cover option is slightly more favourable than the bored tunnel option. The deeper bored tunnel will require larger depth and size of the stops at DCU and Ballymun. However, construction of a bored tunnel could also have significant environmental benefits especially during the construction period (relocation of access shaft to less restricted area, transportation of excavated material below ground with reduced truck traffic etc.) and should not be ruled out as a viable option.

While the EIA has been prepared on the assumption of a shallow cut and cover tunnel, the contractor for the construction of the scheme may consider a bored tunnel solution within the limits of deviation feasible.

The overall evaluation of different options is clearly in favour of a shallow cut and cover tunnel. Based on the comprehensive study presented by RPA, I do endorse a shallow tunnel through Ballymun by cut and cover. However, I recommended that once more detailed geotechnical and geological information becomes available (which can affect the depth of tunnel alignment and size of stations), the contractor shall present detailed solutions for the cut and cover option and the bored tunnel option. The objective is to validate the assumptions of large tunnel depth and stop box size on which the evaluation by RPA in the EIS has been based.
1.4.4 Hydrogeological Impact
Information regarding geology and groundwater was given in the EIS and supporting documents. Additional information and explanation regarding specific questions was given in RPAs response to the Further Information Request. Valuable evidence was also presented during the Oral Hearing and in response to questions. The submission on groundwater was also the subject of a Peer Review. As part of the environmental risk management scheme and according to the observational method, groundwater levels will be monitored prior to, during and after completion of the Metro scheme.

If the proposed mitigation measures are implemented and construction is monitored carefully, residual environmental impact on groundwater will be acceptable in all areas during the construction period and the operational phases.

1.4.5 Geotechnical Impact
Interpretation of ground conditions based on the available geotechnical data for soils, rocks and groundwater was used to infer geological profiles along the alignment. In my view the geotechnical and geological investigations carried out as part of the EIS and the additional information provided by RPA are sufficient for a robust Reference Design.

Based on response to questions and complementary information provided during the Oral Hearing, I am satisfied that the risks associated with variable ground conditions are fully appreciated. Potentially problematic areas will be included in the geotechnical risk register and appropriate mitigation measures be implemented.

The Property Owners’ Protection Scheme envisages an initial survey prior to start of construction work and after completion of work (within a distance of approximately 100 m from the respective property). However, it is conceivable that damage is noticed when construction work is still in progress. In such a case, inspection of affected buildings should be carried out without delay. When noticeable damage (exceeding Damage Category 2) is observed the contractor should be notified and an intermediate building survey should be carried without delay.

The following comments and conclusions are presented with respect to geotechnical impact and the Property Owners’ Protection Scheme:

1. **Geological and geotechnical conditions**: these are complex in some areas along the project alignment (especially in the City centre). Construction work will be carried out in areas with sensitive buildings and other structures. This aspect has been recognized by RPA in the Reference Design.

2. **Geotechnical risk management**: RPA intend to implement a comprehensive risk management scheme, assuring that unacceptable environmental impacts will be avoided. The Observational method is central in planning, project execution and monitoring of the Scheme.
3. **Full-scale trials**: in critical areas, prior to – or in connection with the start-up of construction work – full scale field tests, supported by extensive field monitoring, should be foreseen and carried out to optimize different types of construction procedures (tunnelling, wall construction, excavation etc.) in order to keep environmental impacts to acceptable levels.

4. **Reference Design**: information about geotechnical conditions is sufficient for a robust Reference Design, on which the EIS is based. However, comprehensive geotechnical, geological and hydrogeological investigations will be required for the detailed design. Consequently, new information may become available which could affect the construction methods and techniques assumed in the Reference Design.

5. **Construction methods**: the proposed methods for construction of tunnels and deep excavations have been used successfully in similar geological settings and geotechnical conditions elsewhere. However, it is important that the contractor has documented and verifiable experience from the use of such methods under similar geotechnical conditions.

6. **Geotechnical impacts**: assessment of geotechnical impacts – and in particular the risk of building damage – shall be carried out in three stages. This methodology is in accordance with modern risk assessment concepts and suitable for the project.

7. **Geotechnical risk management**: the proposed management concept of geotechnical and hydrogeological risks as presented by RPA in the response to the Further Information Request will be an efficient tool to minimize and mitigate environmental risks.

8. **Building damage classification**: damage classification is based on ease of repair. The approach demonstrated by RPA experts is consistent with high international requirements.

9. **Trigger level**: exceeding of damage category 2 should be used as the trigger level for the contractor to adjust construction procedures. When damage category 2 is observed at any stage of the project, building surveys should be carried immediately to document the extent of damage. Also, the contractor shall be required to modify immediately the construction method in order to eliminate further damage to occur.

10. **Responsibility for POP Scheme**: the Scheme should remain the responsibility of RPA during the entire period of Metro construction, although some practical tasks of its implementation could be transferred to the contractor.

11. **Scope of Property Owners’ Protections Scheme**: the Scheme should not be limited to ground settlement due to tunnelling work and construction of underground stations but also cover other types of construction work, such as deep excavation, soil compaction or pile driving. The Scheme should also cover temporary works and enabling works (utilities).
1.4.6 Impact of Vibrations and Groundborne Noise

Modelling and Prediction

Information provided as part of the initial EIS was considered insufficient for evaluation of environmental impacts from vibration and groundborne noise. RPA submitted additional information in their response to the Further Information Request. Clarification was also obtained during the Oral Hearing and in response to questions. The following comments are made regarding modelling and prediction of ground vibrations and groundborne noise:

1. Prediction of construction-induced vibrations is a challenging task and in spite of the use of sophisticated numerical modelling methods, the presented results must be considered to be only indicative in nature. Therefore, emphasis shall be on the verification of predictions by full-scale vibration monitoring in critical areas prior to and/or during the initial phase of construction. Such information shall be used to calibrate the predictions and to gradually update the impact assessment.

2. Based on field trials, the effect of different operational modes on ground vibrations (especially in the case of TBM operation) shall be investigated. The contractor should produce method statements for construction work in critical areas substantiated by such field trials.

Impact Assessment

Vibrations in the EIS are assessed based on the German Standard DIN 4150. However, the impact magnitude concept is not supported by DIN 4150. It is recommended that the DIN guideline values for damage to structures are applied as outlined in the standard. Type of affected structure, vibration frequency, position of sensor (ground level or upper building floors) measurement direction etc. should be used for risk assessment and damage evaluation.

The levels of groundborne noise proposed for the construction period appear to be acceptable, provided that the proposed mitigation measures are implemented. The contractor should be encouraged to find agreement and practical arrangements with residents in order to carry out the temporary work in an efficient manner.

With regard to limits on groundborne noise during the operational phase, more restrictive levels appear to be appropriate than those proposed in the EIS. Groundborne noise will have permanent impact on residents living above and in the vicinity of the proposed Metro North Scheme. The lasting impression of the project will be influenced to a high degree on how residents and the general public experience groundborne noise. Groundborne noise usually increases during the lifetime of a railway scheme, in spite of maintenance and other mitigation efforts.

Review of standards in Europe and the United States and practice applied on recent railway projects in Scandinavia suggests that in residential areas, groundborne noise at night time
should not exceed 35 dB $L_{\text{Amax,S}}$. Groundborne noise levels applied at the Metro North should not fall short of the environmental requirements which are applied in countries with comparable geological conditions and similar environmental ambitions. It is recommended that an effort is made by RPA to meet groundborne noise criteria of 35 dB $L_{\text{Amax,S}}$ during the operational phase in all populated areas along the alignment.

1.4.7 Sensitive Receptors

I have reviewed the environmental impact on the following sensitive receptors. The most important aspect of protecting sensitive receptors is by implementation of the above suggested measures regarding risk management, application of the observational method and of the mitigation measures proposed in the EIS. Details are given in Appendix 1 to this report. In summary, I do offer the following conclusions:

**Corpus Christi Girls National School**

The impact during the construction phase will be noticeable but if the proposed mitigation measures are implemented, construction activities should not cause unacceptable residual impact. There is no danger to the building and its occupants from ground vibrations or settlements. Should settlements occur, these will be limited and building damage can be readily repaired.

**Mater and Mater Private Hospitals**

Prediction of ground vibrations and groundborne noise have identified as potential environmental risks, which could arise during the construction phase.

Agreement has been reached between RPA and the Mater and Mater Private Hospital how geotechnical and ground vibration impacts can be mitigated. It is the responsibility of RPA to fulfil the requirements set out in the agreement.

**Mater Hospital/Mater Private Hospital/Private Rotunda Hospital and HARI Clinic**

Prediction of ground vibrations and groundborne noise and assessment of geotechnical risks (settlement) has identified unacceptable environmental risks, which could arise during the construction phase. Following extensive discussions, agreements have been reached between RPA and the respective hospitals how to mitigate these effects.

**Parnell Square Ambassador/Gate Theatre**

During the construction phase, the theatres will experience limited impact from vibrations and groundborne noise. RPA have proposed methods to meet to a large extent the requirements by the property owners. I am thus satisfied that the mitigation measures will be sufficient to limit effects to acceptable levels.

**South King Street**

During the construction phase, owners of private property will be protected by the Property Owners’ Protection Scheme. The mitigation measures proposed in the EIS appear to be
sufficient to protect owners from unacceptable environmental impacts with regard to settlement and ground vibration.

The area will benefit from the proposed lowering of groundborne noise levels to 35 dBA.

**The Fitzwilliam Hotel**
The mitigation measures proposed in the EIS appear to be sufficient to protect owners from unacceptable environmental impacts with regard to settlement and ground vibration.

The area will benefit from the proposed lowering of groundborne noise levels to 35 dBA.

**St. Stephen’s Green West**
During the construction phase, owners of private property will be protected by the Property Owners’ Protection Scheme. The mitigation measures proposed in the EIS appear to be sufficient to protect owners from unacceptable environmental impacts with regard to settlement and ground vibration.

The area will benefit from the proposed lowering of groundborne noise levels to 35 dBA.

### 2 Recommendations
Based on the above conclusions, I do offer the following recommendations:

- Railway projects including tunnels and stations of similar size and in comparable geological settings have been constructed successfully and with limited environmental impact in many European cities. The construction methods proposed in the EIS are considered suitable for the Metro North Scheme.

- The Environmental Impact Statement – supplemented with information presented during the Oral Hearing and in documents in response to the Further Information Request - is in principle adequate for the Railway Order Application.

- The Metro North Scheme shall be planned and implemented according to environmental risk assessment procedures accepted by the tunnelling industry.

- Risk assessment is a mechanism which ensures that the requirements stated in the Railway Order Application are met during the construction phase and thereafter. Also, environmental risk from “unlikely” events - but of significant impact - shall be considered in the risk assessment process.

- The staged assessment of geotechnical risks (settlements) is suitable for the project and assures that construction can be carried out even in environmentally sensitive urban settings with important historic buildings and archaeological structures. Extensive field monitoring will be required in sensitive areas, according to the Observational Method.

- In the EIS, damage categorization of buildings is based on ease of repair of buildings. However, it is recommended that if damage corresponding to category 2 is noticed, construction work be stopped and construction methods and/or equipment be modified in order to avoid further damage.
• The POP scheme should foresee intermediate building inspection/survey when damage corresponding to category 2 is noticed.

• Predictions of vibrations and groundborne noise due to construction activities is complex and associated with significant uncertainties as construction methods and tunnelling equipment to be used are yet unknown. Therefore, extensive field trials should be planned and carried out in critical areas (as part of the risk management process), especially during the initial phase of the project. Results of such trials and evaluation of field monitoring should be used to optimise construction procedures and to control environmental impact due to settlement, vibration and groundborne noise.

• The proposed groundborne noise level during the operational phase of the project of 40dB is considered too high and should be limited to 35dB during night-time in all residential areas.

• Environmental impact assessment of vibration is based on the widely accepted German standard DIN 4150. Vibration impact magnitudes were used to identify environmental risks. However, when assessing the effect of vibrations on buildings and occupants of buildings, it is necessary to use clearly defined and verifiable values. Therefore, the guideline values stated in DIN 4150 (Part 2 and Part 3) should be applied according to concepts and measurement procedures stated in the German standard.

• RPAs choice of cut and cover tunnel in the Ballymun area is largely based on the assumption that a bored tunnel requires larger and deeper stations. However, bored tunnel has potentially significant environmental advantages. The evaluation by RPA of different tunnelling options is based on limited geotechnical and geological information, which influences the assumed depth of tunnel and size of stations. It is recommended that as part of the detailed design, the RPA is required to re-evaluate the environmental benefits of the two options (with potentially reduced depth of bored tunnel and reduced stations size).

• Finally, it is acknowledged that during the Oral Hearing, RPA have commendable efforts and reached agreements how to mitigate residual environmental impacts, with all hospitals and several observers which submitted observations.
3 Introduction

3.1 Background
Metro North is a light rail system which is intended to connect Belinstown in north County Dublin to Dublin city centre. The route corridor has a length of 18 km which includes underground tunnels for a length of approximately 8 km. The proposed development would comprise a metro system running on a segregated alignment between St. Stephen’s Green and Fosterstown stops, and at grade, in underpasses or on elevated sections between Fosterstown and Belinstown, north of Swords. The Metro North would run in a mix of bored and cut and cover tunnels beneath the city and beneath Dublin Airport.

The applicants are the Railway Procurement Agency (RPA) which has submitted the Environmental Impact Statement (EIS) as part of Metro North Railway Order application.

3.2 Brief
An Bord Pleanála (ABP) has appointed an in-house Inspector to examine and report on this application.

By letter dated 17th December 2008, I have been appointed by ABP to provide consulting services in relation to evaluation of the proposed construction, operation and maintenance of the Metro North Scheme. My task has been to assist the Inspector with review of submission related to vibrations and geotechnical issues and to participate in the Oral Hearings. The scope of my brief was extended by letter dated 10th February 2009 to also include the issue of hydrogeology.

3.3 Tasks of Consultant
According to instructions by ABP, the consultant shall assist the Inspector in a specialist capacity, covering the subject areas: geotechnical engineering (e.g. issues related to settlement, tunnelling and excavation etc.), hydrogeology (groundwater flow, groundwater lowering etc.), ground vibrations (including groundborne noise). In broad outline, the nature of the advice sought by ABP is as follows:

1. Following a review of the documentation submitted with the application in relation to vibration and settlement, advise on the adequacy of the application details and Environmental Impact Statement in relation to predicted vibration and geotechnical impacts (inclusive of settlement), both for the construction and operational phases of the scheme.

2. Advise on the vibration and other geotechnical impacts (inclusive of settlement) of the vertical alignment option selected for the routing through Ballymun, i.e. cut and cover as opposed to elevated, at-grade, in retained open cut, and in bored tunnel.
3. Specifically, to advise on the construction and operational vibration and geotechnical impacts (including hydrogeology) of the proposed development on the following sensitive receptors:

- Corpus Christi Girls National School,
- Drumcondra Mater and Mater Private Hospitals
- Rotunda Hospital and HARI Clinic,
- Parnell Square Ambassador/Gate Theatre,
- Parnell Square
- The Gaeity Theatre,
- South King Street
- The Fitzwilliam Hotel,
- St. Stephen’s Green West.

4. Advise on the adequacy of the applicant’s methodology in assessing vibration and geotechnical impacts and on mitigation measures proposed.

Note 1: Considerations on vibration and geotechnical impacts to include settlement and effects on structural integrity of buildings, application of rock blasting, sensitivity of specialist equipment, impact on piled foundations (such as at Mater Private Hospital), proposed allowable deviations of tunnelling, tunnel stability, dewatering, and treatment of contaminated soils.

Note 2: The specified list of sensitive receptors is a preliminary schedule of properties and may be revised in consultation with the in-house Inspector.

Note 3: This Brief covers the broad areas on which the Board is seeking independent advice. On the appointment of the independent consultant, the reporting Inspector would contact him/her with a view to finalizing the brief and oral hearing arrangements.

3.4 **Acceptance of Appointment**

I have accepted to advise the Inspector on this project, based on the following grounds:

I have more than forty years of experience in geotechnical engineering, soil dynamics and earthquake engineering. Having worked in different parts of the world in a variety of capacities, such as an academic and researcher, consultant and specialist foundation contractor, I became involved in large infrastructure construction projects. I have been retained on major projects as consultant and expert advisor to governmental organizations and planning authorities.

In particular, I have worked on tunnelling and foundation projects in regions with similar geological, hydrogeological and geotechnical conditions as exist in Dublin, for instance in
southern Sweden, Denmark, Austria and Germany. I have also been responsible for setting up risk management systems with tunnelling projects. As external examiner for a doctoral thesis at Trinity College, Dublin, I have also had the opportunity to review geotechnical and vibration aspects associated with the construction of the Dublin Port Tunnel. I feel therefore competent to advise the Board of ABP on the project in consideration.

As independent expert for this challenging project, I am aware of my responsibilities and the requirement for balanced and constructive assessment of the EIS. In my opinion, high international standards should be applied for such an important and complex project, to be constructed in a metropolitan area with many sensitive receptors.

3.5 Definition of Subject Areas
The subject areas to be covered by my report have been divided into the following categories:

Geotechnical engineering: ground distortion (heave or settlement, lateral displacement) caused by construction activities (earthworks, tunnelling, ground improvement, retaining structures) and their effects on buildings and other structures. Geotechnical problems are often influenced by other factors such as engineering geology, rock mechanics and hydrogeology which need to be considered.

Hydrogeology: settlements due to change of groundwater conditions, flow of groundwater, lowering (or rise) of ground water level and consequences on the environment, including contamination.

Vibrations: ground vibrations and groundborne noise caused by construction activities, boring and drilling, including mining of tunnels, ground excavation, soil compaction as well as traffic-induced vibrations during construction and the operational phase.

Risk Assessment: concepts used to assess environmental risks related to tunnelling projects, with reference to settlement, ground vibration and groundborne noise as well as geotechnical and groundwater conditions.

Environmental Impact Assessment: the evaluation process of environmental impacts covering the construction period, but also the operational phase of the project. Also, enabling and preparatory works or temporary works including utilities diversion work need to be considered as part of the projects, as these may create environmental risks.

Interaction with other disciplines: in some cases, the above subject areas are closely linked to other technical disciplines, such as noise and traffic, rock mechanics, mechanical engineering, surface water and flooding, land planning etc.

3.6 Scope and Structure of the Report
As required in the Brief, the objective of this report is to advise the Board on issues related to geotechnical, hydrogeological and vibration aspects of environmental impact. The main
report is intended to provide a synthesis of the EIS, with comments on specific issues in the
text and recommendations at the end of subject areas for consideration by the Inspector. 
Background information regarding environmental impact assessment for areas along the
Metro alignment is given in Appendix 1. Background information for justification of
recommendations given in this report on critical issues (risks, vibrations and groundborne
noise) are presented in Appendix 2 and 3 to this report.

General project information regarding the EIS, administrative matters and procedural issues
will be addressed in the Inspector’s report and is not repeated in this report unless of direct
relevance for specific issues. I have not intended to reiterate or respond extensively to
documentary and oral evidence presented at the Oral Hearing. Issues where agreement has
been reached between the RPA and observers during the Oral Hearing will be commented
upon without repeating the discussions which have led to the respective agreements.

My report interprets the body of information as it was available at the end of the Oral
Hearing, taking into consideration oral presentations, response to questioning, review of
supporting documents and submissions relevant for the subject area. In order to verify the
relevance of statements and conclusions made in the EIS and Oral Hearing, I have also
reviewed information from similar tunnelling projects and compared the environmental
requirements with those set out in the EIS. This review included visits to tunnelling projects
and discussion with experts in the respective subject areas.

This report with appendices reviews the information submitted by RPA to ABP as part of the
EIS, submissions by RPA presented during the Oral Hearing, submissions by observers and
information provided during response to questions. The report is divided into the following
chapters:

Chapter 1 is the Executive Summary of the Report.

Chapter 3 gives an introduction with Brief from APB as well as background information
about the project.

Chapter 4 describes the structure and contents of the Environmental Impact
Statement as well as relevant background information.

Chapter 5 reviews the Environmental Impact Assessment.

Chapter 6 discusses construction methods and alignment issue.

Chapter 7 Error! Reference source not found.addresses environmental impact with
respect to hydrogeology.

Chapter 8 deals with geotechnical impact.

Chapter 8.6 comments on the Property Owner’s Protection Scheme.
Chapter 9 deals with impact from vibration and groundborne noise.

In Chapter 5 through 9, comments have been added in the running text, addressing specific points of relevance for the EIS. At the end of each chapter, the respective findings and conclusions are given.

Background information is provided in appendices for reference and detailed background.

Appendix 1 – Description of and Comments on MN101-MN107: describes the project alignment, divided into the seven segments MN101 through MN107:

- Area description
  - Human beings – vibrations
  - Soil and geology
  - Groundwater.

In each of the areas, mitigation measures as proposed in the EIS are discussed. Recommendations regarding environmental impacts and mitigation measures are presented.

Appendix 2 – Management of Environmental Risks: discusses environmental risk management concepts.

Appendix 3 – Background Information on Vibrations and Noise: gives a background regarding vibrations and groundborne noise standards.

3.7 Contractual Aspects of Project
The Metro North Scheme is a Public Private Partnership (PPP) which will be carried out on the basis of a design, build, finance and maintain contract having a term of the construction period plus 25 years from the commencement of passenger services. The project will also include an operations contract which will be effective from the commencement of passenger services. The competitive procurement process requires a level of flexibility in the design as the contractor shall be able to choose among alternative construction methods and choosing innovative solutions. Therefore, the design on which the EIS is based (“Reference Design”) is tentative as not all technical and contractual information is yet available. This is an important aspect which needs to be kept in mind when evaluating the EIS and formulating the Environmental Impact Assessment (EIA) process. However, the contractor will be obligated to comply with the Environmental Impact Statement (EIS), and the Metro North Construction and Maintenance Requirements (C&MRs).

3.8 Availability of Information
An extensive body of information was presented as part of the EIS and in the form of submissions during the Oral Hearing, resulting in a large amount of data, text, plans, maps etc. Numerous consultants, advisors and experts have prepared and contributed with, and presented information on behalf of the RPA. In addition to the information which formed
part of the initial EIS submitted by the RPA, a considerable body of new information was presented at the Oral Hearing by the applicant and observers:

* Proof of Evidence submitted by RPA to the Oral Hearing, including accompanying documentation (drawings, reports and other documents),
* response by RPA to the Further Information Request by ABP,
* orally presented observations and written submissions by Prescribed Bodies, residents (resident organisations) and other organisations and companies,
* response by RPA and experts representing RPA to questions by observers and the Inspector,
* agreements (parts of agreements relevant to the EIS) between RPA and observers (organisations and companies).

Information made available after submission of the EIS and presented during the Oral Hearing (technical and administrative information, legal agreements etc.) has in several key aspects altered the initial EIS, or qualified its content. Documents submitted by observers and prescribed bodies, including observations and submissions with supporting information were obtained in print at the Oral Hearings, some of these also in electronic format.

The Oral Hearing were documented by ABP in the form of stenographic notes and made available to myself.

3.9 Suspension of Oral Hearing and Further Information Request
The information provided as part of the initial EIS and documentation presented during the initial phase of the Oral Hearing was considered insufficient for a fair evaluation of the environmental impact of the Scheme. On 26th June 2009, An Bord Pleanála requested RPA to provide further information which was considered necessary to evaluate the application and validity of the EIS. In response to this request, RPA prepared a comprehensive set of documents which was submitted prior to reconvening of the Oral Hearing on 30th November 2009. The documents and related background information was made available in print and/or were accessible from the Metro North web site. The Oral Hearings were suspended 20th January 2010 and were reconvened on 1st March 2010. The Oral Hearings ended on 10th March 2010.

I have been in attendance during the entire period of the Oral Hearing with the exception of four days when issues not relevant for my subject area were dealt with. I have listened to and critically reviewed all information presented by different parties during the Oral Hearing and asked questions to representatives of the RPA and others. The format and quality of presentations at the Oral Hearing was generally excellent and gave valuable background information for this report.
4 Environmental Impact Statement

4.1 General
As part of the Metro North Railway Order application process, RPA have submitted to ABP the application documents on 17th of September 2008. The EIS which forms part of the EIA process, and information presented in connection with the Oral Hearing, are the subject of this report. Sections of the EIS which are of direct relevance for this report will be cited and discussed in detail. Otherwise, the reader is referred to the documentation provided by RPA and presented during the Oral Hearings.

The project alignment covered by the EIS has been divided into seven areas, numbered Area MN101 through Area MN107 from Belinstown in north County Dublin to St Stephen’s Green:

- MN101: Belinstown to Swords Stop
- MN102: Swords Stop to Airport North Portal
- MN103: Dublin Airport
- MN104: Dublin Airport South Portal to Santry Avenue
- MN105: Santry Avenue to Albert College Park
- MN106: Albert College Park to Mater Stop

4.2 Structure and Contents of EIS
The EIS comprises three separate Volumes:

**Volume 1** contains an introduction to the scheme and a description of the receiving environment and is set out in 25 Chapters.

**Volume 2** presents the environmental impact of the proposed scheme, comprises seven books which collectively make up Volume 2 of this EIS. These books describe the environmental impact along the alignment (Areas MN101 through Area MN107). Each book is divided into 18 Chapters. Chapters of direct relevance for this report are:

- Chapter 1: Introduction to Areas MN101 - MN107
- Chapter 4: Human Beings: Noise
- Chapter 5: Human Beings: Vibration
- Chapter 9: Soils and Geology
- Chapter 10: Groundwater

**Volume 3** contains 2 books.
**Book 1** includes maps describing baseline information and impact assessment maps. The following parts of Book 1 are of direct relevance for this report:

- **Part 4 - Baseline Vibration**
  - Baseline Vibration Sheet 1 of 4 Batter Lane to Carlton Court
  - Baseline Vibration Sheet 2 of 4 Ashley Avenue to Dardistown
  - Baseline Vibration Sheet 3 of 4 Perimeter Road to Hardiman Road
  - Baseline Vibration Sheet 4 of 4 Bantry Road to St Stephen's Green

- **Part 7 - Baseline Soils & Geology**
  - Baseline Soils & Geology Sheet 1 of 4 Batter Lane to Carlton Court
  - Baseline Soils & Geology Sheet 2 of 4 Ashley Avenue to Dardistown
  - Baseline Soils & Geology Sheet 3 of 4 Perimeter Road to Hardiman Road
  - Baseline Soils & Geology Sheet 4 of 4 Bantry Road to St Stephen's Green

- **Part 8 - Baseline Surface Water & Ground Water**
  - Baseline Surface Water & Ground Water Sheet 1 of 4 Batter Lane to Carlton Court
  - Baseline Surface Water & Ground Water Sheet 2 of 4 Ashley Avenue to Dardistown
  - Baseline Surface Water & Ground Water Sheet 3 of 4 Perimeter Road to Hardiman Road
  - Baseline Surface Water & Ground Water Sheet 4 of 4 Bantry Road to St Stephen's Green

**Book 2** contains Annexes to the EIS including technical reports. Annex E Metro North contains:

- Information supporting the groundwater chapters
- Estimated groundwater levels
- GSI well card data.

The methodology used in this EIS involved the following steps:

- Definition of the study area;
- Data collection and description;
- Baseline description and evaluation;
Identification of potential environmental impacts and the potential areas to be affected;
Description and evaluation of the impacts;
Derivation of mitigation measures to minimise the impact;
Description of the residual impacts of the scheme.

4.3 Contributors to EIS
The following contributors were responsible for the contents of chapters in the initial EIS which are of relevance for this report:

<table>
<thead>
<tr>
<th>Input</th>
<th>Contributor</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIS management and compilation</td>
<td>ERM and RPA</td>
</tr>
<tr>
<td>Human Beings:</td>
<td>Noise ERM</td>
</tr>
<tr>
<td>Human Beings:</td>
<td>Vibration Rupert Taylor F.I.O.A and ERM</td>
</tr>
<tr>
<td>Human Beings: Traffic</td>
<td>MVA Consulting</td>
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<tr>
<td>Soil and Geology</td>
<td>ERM and Jacobs Engineering Ireland Ltd.</td>
</tr>
<tr>
<td>Groundwater</td>
<td>AWN Consulting</td>
</tr>
<tr>
<td>Surface Water</td>
<td>AWN Consulting</td>
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<tr>
<td>Material Assets: Archaeology, Architectural Heritage</td>
<td>CRDS Ltd.</td>
</tr>
<tr>
<td>Interrelationships, Interactions and Cumulative Impacts</td>
<td>ERM</td>
</tr>
</tbody>
</table>

During the period of the Oral Hearings, RPA called in new expert witnesses which made oral presentation, submissions and responded to questions.

4.4 Deviations from EIS
Because of the early stage of the project at which the Reference Design was made, and due to the procurement process (PPP), it is necessary to allow deviations from the initial EIS. Such deviations from the proposed Railway Order design may occur in order to facilitate on-site construction or maintenance and to allow a limited degree of flexibility to react to on-site circumstances which are unforeseeable at this stage, provided that these have no significant adverse environmental effect.

The EIS assumes that lateral deviations of up to 2.5m are permitted where the works are situated in a public road, 10m where the works form part of an underground tunnel or stop and 5m elsewhere. Vertical deviations of up to 1m upwards or downwards are permitted where the works are situated in a public road; up to 5m upwards and 10m downwards where the works form part of an underground tunnel or stop and up to 2m upwards or downwards elsewhere. Longitudinal deviations are permitted up to 20m. In addition, the internal layout of underground stops may be amended provided that such amendments do
not reduce the accessibility or amenity of the publicly accessible areas of the stop, and single or interlacing tracks may be laid where double tracks are shown.

### 4.5 Independent Engineering Experts Report

A team of Independent Engineering Experts was commissioned in August 2008 by RPA in order to respond to concerns raised by residents’ groups and associations and other non-commercial stakeholders affected by the Metro North scheme. The terms of reference for the Independent Engineering Expert team were developed by the RPA in partnership with residents’ representatives, who also participated in the selection process. Information was intended to be available to residents and others as a resource to assist them in their consideration of the Railway Order application for Metro North, and by participation in the consultation process. Following a series of meetings with residents’ groups and other interested parties in August and September 2008, a draft report for comment and discussion was issued on 8th October 2008. The final report which was issued in March 2009 takes account of the comments received from residents and the RPA. The report comprises 3 volumes:

- **Volume I** provides an introduction to environmental impact assessment and the design process, together with a review of selected sections of the Environmental Impact Statement and other Railway Order documentation;
- **Volume II** provides a summary of the particular concerns and questions of residents and other interested parties, cross references to sources of further information and brief comments where appropriate;
- **Volume III** includes four supporting appendices for Volumes I and II.

The Independent Engineering Experts Report covers environmental impacts, several of which are of relevance also for this report:

- Airborne noise from construction works and railway operation
- Vibration and groundborne noise from Metro construction and operation
- Influence of proposed works on surface water
- Influence of proposed works and
- Settlement of ground around tunnels and excavations.

### 5 Review of Environmental Impact Assessment

Construction of the Metro North Scheme will result in environmental impacts. Two types of geotechnical impact can occur as a result of construction work in the ground: temporary and permanent impacts.

**Temporary impacts**

Temporary impacts are typically associated with the construction phase of the scheme. These impacts are short-term in nature and are required to facilitate the start-up and the
execution of the actual construction work. These impacts will not continue after the construction phase has been completed. Impacts of this type include activities such as tunnel excavation, installation of walls, ground anchors, piles, excavation and disposal of soils, contaminated materials and bedrock, temporary paving or compaction of soils, temporary construction of roads, traffic management procedures and dewatering works. In some cases, only minor disturbance occurs.

**Permanent impacts**
Permanent impacts are longer term in nature and are expected to persist for the lifetime of the scheme and its operation. Permanent structural impacts occur where the soil or geology has been permanently altered to allow for the construction of the parts of the scheme e.g. tunnels, box stops, shafts, sealing of surfaces by paving and also impacts associated with the installation of the railway, new traffic systems or roadways, drainage and conduit channels, car park facilities, ancillary buildings and ground movement and/or settlement. Permanent operational impacts occur where the general day to day operation of the scheme impacts on soil and geology and in the form of groundborne noise and vibration. Potential impacts of this type can arise due to maintenance works (including track cleaning) and activities which could potentially lead to groundwater contamination.

### 5.1 Consideration of Environmental Impact
Environmental considerations are becoming increasingly important when evaluating the benefits and negative consequences of major infrastructure projects and more stringent environmental requirements have been adopted on recent projects in many countries. The Metro North Scheme is intended to meet high international standards and therefore, modern and strict environmental requirements which are used on similar projects elsewhere should also be applied in the planning, design, execution and operation of this project.

The EIS was prepared at an early stage of the project, based on inherently incomplete information (assumptions made in the Reference Design) and submitted prior to the Oral Hearing. Additional information has become available during the period of the Oral Hearing. However, the EIS is part of a process (EIA) with the aim to protect humans and the living environment, covering preparatory works, the actual construction of the Metro North but also including the subsequent operation of the scheme. Such a process must be flexible to accommodate changes in project conditions, introduction of new information etc. which may become available and could deviate from the initial assumptions made in the EIS.

The present report aims at formulating such a mechanism (Environmental Risk Assessment, cf. below) which takes account of such requirements. This approach is widely used in connection with major infrastructure projects and risk management concepts have been developed by the construction industry. Risk assessment is of particular relevance when dealing with problems related to vibrations, groundborne noise, geological and hydrogeological aspects of environmental impact.
Section 39(2)(b) of the Railway Infrastructure Act, 2001 specifies that an environmental impact statement must contain a description of the aspects of the environment that are likely to be significantly affected by the proposed scheme. With regard to the requirement of likely events to be considered in the EIS, RPA in their closing submission by Mr. Connolly remarked:

“When one actually looks at Annex IV of the EIA Directive it becomes clear that the EIS is not intended to address every conceivable issue. It requires only a description of the aspects of the environment likely to be significantly affected by the project and a description of the likely significant effects. In other words, a description of unlikely and insignificant effects is not required.”

The statement is of importance and deserves clarification, as the quoted text is not consistent with risk assessment concepts. There is an important distinction between “likely effects” and “likely events”. The EIS shall assess the consequences of unlikely events, which can have a significant effect as even events of low likelihood can be of high environmental significance (high risk) and shall not be ignored. Many failures and accidents which have occurred recently during major tunnelling works were considered to be “unlikely events”.

The insurance industry has recognised this important aspect in connection with tunnelling works by introducing risk management schemes. On many major infrastructure projects, environmental risk assessment (ERA) procedures are used to identify environmental impacts. This aspect is discussed in the following section.

5.2 Assessment of Environmental Risks

When preparing the EIS, different types of environmental impact were identified through scoping procedures. Consultation with stakeholders, interested parties and the public were carried out on an ongoing basis. According to RPA, each individual specialist reviewed the engineering plans and identified the potential impacts based on their technical experience and expertise. As an EIS has to be carried out at an early stage of the planning process of a project, this must inherently be based on incomplete information.

An important observation when reviewing the EIS, initially submitted by the RPA, was the inability by observers to evaluate confidently the future impacts of the proposed Scheme, in spite of the efforts by RPA to inform those potentially affected. In addition to the complexity of the issues, a contributing factor was that information provided by RPA was at times fragmented, making evaluation of individual and combined environmental impacts difficult.

Also the Independent Engineering Experts expressed some specific reservations about the breadth of coverage and/or the way in which the results of the environmental assessment have been communicated for some topic areas. However, overall, they were satisfied that no major subject for concern has been overlooked in the EIS. They also express the view

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1 Underlined by author of this report.
that, in some respects, the initially submitted EIS “goes beyond what is statutorily required to be covered in an EIS”. This statement is somewhat surprising.

Risk management concepts are widely used for assessment of environmental impacts as these apply a well-defined procedure to identify hazards, to assess the likelihood of hazards to occur and to evaluate and quantify their consequences (potential risks). Environmental Risk Assessment (ERA) is a systematic and transparent approach of identifying environmental impacts, based on uncertainties.

In order to assure that the environmental goals set out for the Metro North Scheme are actually achieved during the different stages of the project, it is crucial that a mechanism is put in place which on a continuous basis verifies that environmental requirements are actually met.

Implementation of risk assessment according to an ERA procedure provides planners, designers, contractors and decision makers with information about critical activities (events) and environmental consequences of their action. Such an approach considers both likely and unlikely events.

5.3 RPA Risk Management Concept
It is understood that RPA have applied elements of risk management concepts during the preparation of the EIS; however, this information was not made available in the EIS. Therefore, RPA were asked in the Further Information Request to describe in detail their concept and procedures for assessment and management of environmental risk.

In response, RPA presented a comprehensive report outlining the methodology of designers risk assessment. In accordance with “A Code of Practice for Risk Management of Tunnel Works” prepared by The International Tunnelling Insurance Group, the risk register will be managed throughout the project. As the project moves forward through different stages, the Technical and Environmental Risk Register develops from the Pre-Contract Risk Register to the Tender Risk Register and ultimately the Construction Stage Risk Register.

The risk register enclosed in the RPA report (Appendix A) is based on the process adopted on a number of large tunnelling projects in recent years. The following factors are assessed (bold text indicates factors of relevance for environmental issues):

- **Likelihood of risk occurring**
- Impact on Cost
- Impact on Programme
- **Impact on Safety**
- Impact on Environmental

Appendix B presents the above information in the format of a risk matrix. The resulting risk score and categorisation of risk (Low, Medium or High) is the probability of the risk being
realised multiplied by the highest assessed cost, programme, safety or environmental impact. It is appreciated that the risk assessment procedure used by RPA is still at an early stage of evolution. Several aspects of the risk assessment procedure are not fully transparent as several factors belonging to different risk categories are combined, some of which are not related to environmental hazards (such as cost, programme).

5.4 Comments - Environmental Impact Assessment
The Metro North Scheme is proposed to be constructed passing through highly sensitive urban environment, beneath and close to important urban heritage. Irreparable or extensive damage to buildings and historic monuments is unacceptable. Tunnels are to be constructed for a significant part of the alignment in challenging ground conditions which include coarse- and fine-grained glacial soils, mixed face tunnelling conditions and in some locations high water pressure. Due to the nature of the project and the still limited extent of information about geological and geohydrological conditions as well as lack of knowledge about actual construction procedures to be used, attention must be paid to unforeseen conditions and construction scenarios, also considering unlikely events. Major problems associated with tunnelling projects usually occur when “unlikely scenarios” are encountered.

Although design and construction of the Metro North Scheme is challenging, tunnelling projects have been carried out successfully under similar geotechnical and geological conditions without resulting in unacceptable environmental impacts. The main factor for successful implementation of tunnelling projects in urban areas is the introduction and implementation of environmental risk management concepts. Careful planning, design and field monitoring should be an essential part of this project. Insufficient emphasis has yet been placed on this aspect in the EIS.

During the Oral Hearing, RPA confirmed that risk management procedures are being implemented and that they intend to require the contractor(s) to apply a comprehensive risk management program which focuses on environmental impacts. This responsibility should not be transferred to the contractor(s). RPA shall remain responsible for overseeing, updating and enforcing environmental risk management. Risk management shall be a key condition when RPA negotiate with contractors.

It is recommended that RPA use a computer-based risk management system.

Provided that the assurances given by RPA during the Oral Hearing are implemented, I am satisfied with the procedures and concepts for environmental impact assessment.

In Appendix 2 – Management of Environmental Risks of this report, information of relevance for the implementation of an environmental risk management program and application of the Observational Method are presented for consideration.
6 Construction of Metro North Scheme

6.1.1 Main Construction Methods
Significant environmental risks are associated with the construction of structures which are constructed as part of the Metro North Scheme. The principal structures to be constructed are:

* Approximately 2300m route length of twin bored running tunnel beneath Dublin Airport.
* Approximately 5200m route length of bored running tunnel from Albert College Park to St. Stephen’s Green.
* Approximately 2700m route length of cut and cover running tunnels.
* Eight cross passages in the bored airport tunnels and 14 in the bored city tunnels.
* Eight cut and cover running tunnel cross passages.
* Two underground emergency crossovers.
* One emergency shaft in the grounds of St. Patrick’s College.
* St. Stephen’s Green vehicle turns back facility.
* Westbound Iarnród Éireann Interconnector tunnel crossing of Metro North running tunnels.
* Nine below grade stops.

The following construction methods are to be employed at the Metro North Scheme:

**Mined Tunnels** will be constructed at St. Stephen’s Green to form the turnaround loop tunnels, for the crossover caverns situated just north of St. Stephen’s Green and St Patricks College and for cross passage excavation between the running tunnels.

**Cut and cover Tunnels** will be constructed between DCU and Ballymun Stop and from here to the Northwood Portal from Northwood to Albert College Park, and in areas along the Swords Road beneath the Malahide Roundabout and across the R132 at Fosterstown.

**Stop Boxes** will be constructed to form the Stations at the Airport, Ballymun, Dublin City University, Griffith Avenue, Drumcondra, Mater Hospital, Parnell, O’Connell Bridge and St. Stephen’s Green, there is also an intervention shaft to be constructed at St. Patricks College.

**Bored tunnels** will be constructed beneath the Airport and from Albert College Park to St. Stephen’s Green, will be constructed using tunnel boring machines tailored to the specific ground that they will encounter.

The construction methods will be chosen by the contractor, considering geological, geotechnical and hydrogeological conditions. Decisions are also influence by site constraints, efficiency and performance of respective method as well as by commercial and financial considerations.
An important consideration when assessing risks associated with construction work is past experience and competence of the contractor in using particular construction techniques. The contractor (or subcontractor) should have documented experience from work with these methods under similar geological and geotechnical conditions (Dublin boulder clay, limestone etc.).

6.1.2 Execution of Construction Work

Excavation Work
Most of the excavation work will be carried out with hydraulic excavators coupled with various techniques to break the rock to allow it to be excavated. To provide support to the excavation, different methods or combination of methods could be used. Many factors need to be considered by the contractor when deciding on particular methods of excavation within the project.

Mined Tunnels
Drill and blast techniques will be used to break the rock over suitable lengths in the order of 1 to 1.5 m advance per blast. Holes are first drilled into the rock and then charged with explosives and primed with detonators. By reducing the length of the blast the amount of explosive per blast is reduced. Following the blast the tunnel will be ventilated to remove gases produced by the explosives by diluting the atmosphere with clean air pumped in from the surface.

Rock excavation by drill and blast method can potentially cause major environmental impact. The amount of explosive depends on several factors including the depth/length of excavation required per blast, the in-situ strength of the rock, the structural pattern of the rock mass and environmental constraints at the surface. When the explosive contained in the borehole is detonated, high pressure gases are formed expanding in the drill holes and fracturing and shattering the rock. The broken rock can then be excavated and removed from the tunnel or work place using by mechanical excavators and dump trucks.

Temporary support in the form of sprayed concrete, and rock bolts will be applied. The excavation and support cycle will be repeated until the tunnel is complete. A waterproof lining will then be applied to the profile of the tunnel and a permanent concrete lining cast using shutter to obtain the final shape of the tunnel.

Walls and Excavation Support
Diaphragm walls, secant walls or contiguous piled walls can be used to provide rigid retaining walls. Their primary purpose is lateral ground support and which is placed into the ground prior to the commencement of bulk excavation.

The movement of excavation and construction equipment on site can also result in negative environmental impact, especially when operating in the close vicinity of sensitive receptors.
Vibration and groundborne noise can be generated when the excavation tool encounters stiff soil formations, boulders or rock.

**Diaphragm walls** consist of overlapping concrete panels which can be installed using different types of equipment. Efficient rock cutting equipment (of type “hydromill” or “hydrofraise”) is preferred when working in environmentally sensitive environments as the excavation method can be controlled in great detail.

**Secant (bored) or contiguous pile walls** can be constructed using different types of piling methods (boring/drilling/augering).

**Support structures**, either as permanent or temporary support, are required to ensure excavations remain open and safe and their choice depends primarily on the local geological conditions, space constraints and environmental considerations such as settlement and dewatering.

**Cut and Cover Technique**
Cut and cover tunnels will be constructed in ground which is a mixture of made ground and Dublin boulder clay. This type of soil is suitable for excavation with hydraulic excavating equipment. The method most suitable for Metro North is known as bottom up construction and consists of firstly installing a rigid retaining wall into the ground, probably in the form of secant piles. The ground is then excavated between these retaining walls with temporary propping or anchoring to the walls being installed as required. Once the excavation has reached the required depth a steel reinforced concrete base slab will be cast, followed by the side walls and the roof slab. The ground above the roof slab will then be backfilled and the surface re-instated.

An alternative method to bottom up is top-down construction. This is achieved by constructing the permanent underground structure in stages as the excavation between the temporary retaining walls proceeds to depth. The retaining walls are installed prior to excavation as previously described.

**Bored Tunnels – TBM**
The majority of the bored tunnel will be constructed within mainly good limestone rock but between Mater and O’Connell Bridge a section of the tunnels will be constructed within variable, poorer soil conditions and the machine selected by the contractor will have to be able to adapt to these ground conditions. The bored (and mined) sections of the running tunnels fall into two principal ground categories:

* Soft ground tunnelling conditions that consist of mainly glacial till (boulder clays) or fluvial glacial materials (clay, silts, sands and gravels).
* Hard ground tunnelling conditions which consist of rock (mainly limestone). For design purposes all tunnels with at least one tunnel diameter of rock cover have been designed as hard rock tunnels. All other tunnels have been designed for soft ground conditions.
The design of the bored tunnels requires a careful review of the anticipated geology, groundwater regime and alignment to enable the magnitude and distribution of loads applied to the tunnel support system to be determined.

Tunnel Boring Machines (TBMs) shall be used to excavate tunnels with a circular cross section through a broad range of materials from hard rock to sand. For Metro North the proposed TBM has approximately 7 meters diameter. TBMs are suitable for use in heavily urbanized areas where settlement must be kept to a minimum.

TBMs typically consist of one or two shields, which are basically large cylinders, in conjunction with trailing support mechanisms. At the front end of the shield is a rotating cutting wheel often referred to as the “cutting head”.

In poor ground it is important to minimise overexcavation or face loss which leads to settlement on the surface, which in turn can lead to damage to buildings and structures. Reducing face loss is achieved by the introduction of positive face control to maintain soil pressure. Two types of machine are commonly used.

* Earth Pressure Balance (EPB) machine,
* Bentonite Slurry (BS) machine.

Both EPB and BS machines could possibly be used on Metro North and would be the preferred methods over open face tunnelling in these areas of poor ground conditions. The functions of the TBM can be continuously monitored by a data logger and all measured parameters are important to the contractor’s management in terms of controlling the effect that the TBM has on the environment.

Dr. Alastair Biggart was retained by RPA to make a presentation with regard to closed face tunnelling (17th December 2009). He emphasised that the ground conditions on this project are mixed. Some lengths of the tunnel are 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. This aspect is a complicating factor when the contractor shall select the type of TBM – which necessarily will be a compromise between different geotechnical requirements (hard rock, mixed face, soft ground).

6.2 Comments - Construction Work

Environmental problems including damage to structures and installations in or on the ground are usually caused by “unforeseen events”, poor workmanship and lack of quality control. These factors include unexpected geological conditions, work delays or lack of supervision, deviation of drill hole direction and length, malfunctioning of detonation equipment (blasting) etc. Therefore, a strict quality management and control system should be set up and implemented. This aspect was discussed in section 5.3. The following comments are offered with respect to the use of above mentioned construction methods.
6.2.1 Soil and Rock Excavation
Excavation of rock and stiff soil can cause environmental impacts in the form of groundborne noise (TBM or hydromill/hydrofraise operation) and/or vibration (blasting, chiselling, drilling etc.). Execution of all such work must be planned that these comply with environmental impact requirements, and considering the restrictions (limiting values) set out in the EIS.

6.2.2 Drill and Blast
Test blasting will be required to assess the environmental impact (for instance ground vibrations) in different geological settings.

6.2.3 Retaining Structures for Deep Excavations
Settlement and lateral ground movement can occur during construction/excavation of vertical wall elements (decompression of soil and/or ground loss). Also during the subsequent excavation inside the walls, lateral ground movement can take place if lateral support is not sufficient.

Settlement and lateral displacement adjacent to deep excavations can be kept under control by careful design based on realistically assumed soil parameters and competent execution of excavation and ground support. In addition, buildings and structures adjacent must be monitored using the observational method.

6.2.4 Bored Tunnels - TBM Operation
The decision which type of TBM machine to be used is critical in the case of varying ground conditions. It will be a challenge for the contractor to find a compromise (EPB or BS) machine for variable ground conditions.

The contractor shall have demonstrated experience from work in similar ground conditions (mixed face, boulder clay).

Proper construction management is a key element for successful tunnelling work, including accurate measurement of excavated spoil. A detailed monitoring scheme must be implemented, combining machine performance parameters and ground response measurements.

The main area of concern regarding settlement is when the tunnel is in a mixed face of bedrock and either glacial sands or glacial till. In such ground conditions the volume loss is estimated to be approximately 1.5%. Mixed face tunnelling requires extra care in measuring critical parameters, apply additional pressure to reduce ground loss but also avoid heave. Available thrust may be needed, giving additional support to tunnel face; cutters must be in good conditions.

6.2.5 Cut and Cover vs. Bored Tunnel
Both construction methods can be used for tunnel construction and the choice of method depends on site-specific conditions and environmental considerations and requirements.
**Bored Tunnel**

Bored tunnels constructed by TBM can be installed in a variety of ground conditions, ranging from soft soils to hard rock. Construction is less affected by the depth of the tunnel. Excavation in soft ground does not cause noticeable vibrations or groundborne noise. However, when boring in rock, groundborne noise can affect buildings founded below or on the ground surface and disturb inhabitants of buildings.

The excavated material is moved below ground to the access/exit shaft, from where it can be transported to the deposition site. Thus, most environmental effects will be in the vicinity of access/exit shafts. Construction risks depend on the extent of ground investigations available prior to start of the project. The type of TBM must also be suitable for the geotechnical conditions and ground water situation.

The most important advantage is that the tunnel can be constructed without affecting the ground surface (with exception of the construction compound and access shaft).

**Cut and Cover Method**

The cut and cover method is suited for relatively shallow tunnels in ground which can be removed by conventional excavation methods. Tunnelling becomes more difficult and costly when deep tunnels are to be constructed in soft soils, and with increasing stiffness of the subsoil (when boulders and/or rock are encountered). Also, ground water conditions can influence the execution of tunnel construction. Cut and cover construction is carried out in phases, requiring the installation of vertical wall elements (or piles), propping and/or anchoring of the wall prior to excavation. Lateral and vertical ground movements can occur due to installation of the retaining walls and lateral movement of the retaining walls during excavation or base heave within the excavation. A larger soil volume must be excavated than corresponding to the actual tunnel volume, compared to a bored tunnel. Consequently, transportation of excavated material by heavy trucks from the site will negatively affect traffic during the construction period. Construction noise can be disturbing due to movement of heavy equipment and vibrations can be generated when stiff rock or boulders have to be excavated (chiselling or grinding).

A significant disadvantage of the cut and cover method compared to bored tunnelling is that a larger surface area will be needed during the construction period.

**6.2.6 Alignment Option through Ballymun**

RPA advocate a shallow tunnel between DCU Stop and Ballymun Stop. The tunnel starts at DCU Stop under the median of Ballymun Road, passes through Ballymun, crossing under Collins Avenue and Santry Avenue. The DCU Stop and the Ballymun Stop will be shallow underground stops, with platforms approximately 10 to 12m below ground level.

Although, the contractor will be entitled to evaluate the cut and cover and the bored tunnel options, the alternative preferred by RPA is the cut and cover method.
In their response to the Further Information Request, RPA have presented a detailed analysis of alignment options. For this report, only issues related to the vertical alignment will be addressed, comparing cut and cover and bored construction alternatives. Table 1 summarizes the evaluation by RPA of different tunnelling alternatives in relation to environmental impact.

According to RPA, Options D and E perform best from the perspective of long-term environmental impacts. The main difference relates to the potential for long-term socioeconomic impacts on business in Ballymun Town Centre associated with the much longer construction programme associated with Option E.

Table 1. Summary of comparative evaluation in relation to environmental impact according to RPA.

<table>
<thead>
<tr>
<th>Option Criterion</th>
<th>Option A Elevated</th>
<th>Option B Surface</th>
<th>Option C Open cut</th>
<th>Option D Cut &amp; cover</th>
<th>Option E Bored tunnel</th>
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<tbody>
<tr>
<td>Land-use: Land-take</td>
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<td>Archaeology and heritage</td>
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Table 2 gives the overall comparison of the five options (A through E). Option E, the bored tunnel option, performs worse in the evaluation than Option D. While Option E appears to have significant advantages associated with boring tunnels rather than constructing them by cut and cover, in the opinion of RP these advantages are considered short term and more than outweighed by the need to construct significantly larger and deeper stop boxes at DCU and Ballymun.

Table 2. Table 4.13: Overall comparative evaluation of options.
While the EIA has been prepared on the assumption that the tunnels in Ballymun would be cut and cover tunnels, it is not RPAs intention to dictate construction methodologies to the tenderers for the construction of the scheme. Thus, if the contractor considers it feasible, it would not be precluded from suggesting a bored tunnel methodology within the above limits of deviation.

The overall evaluation of different options is clearly in favour of a shallow cut and cover tunnel. Based on the comprehensive study presented by RPA, I do endorse a shallow tunnel through Ballymun by cut and cover. However, it is recommended that based on more detailed geotechnical and geological information, the contractor shall present a comparison of the cut and cover option and the bored tunnel option. The objective is to validate the assumptions of large tunnel depth and stop box size on which the evaluation by RPA is based.

7 Hydrogeological Impact

7.1 General
The area affected by hydrological impact has been assumed to comprise 500m to either side of the proposed alignment to which potential impacts of the construction and operation of the scheme will most likely be restricted to. Groundwater conditions are addressed in Volume 1 of the EIS. Chapter 18 describes and evaluates the existing groundwater environment in the project area.
Chapter 10 of Volume 2 describes the potential impact on groundwater, which may arise due to activities associated with the construction and operation of the proposed scheme in areas MN101 through MN107. For details, reference is made to Error! Reference source not found..

The proposed scheme passes over, under and near a number of surface water bodies. Tunnelled sections of the alignment penetrate the ground and therefore have the potential to have an influence on the groundwater situation. Relevant administrative bodies and Government bodies have defined policies that aim to protect the hydrogeological environment and aquatic resources by controlling development in such areas. These guidelines broadly state that all groundwater resources are important and should be protected and that adverse impacts on regionally or locally important aquifers, in particular, need to be avoided because of their potential use as a water supply. There is also justifiable concern in relation to the potential impact of groundwater drawdown, ingress, settlement and pollution.

7.2 Hydrogeology of Project Area

The EIS shows that there are two main sources of groundwater along the Metro North alignment:

* shallow groundwater associated with fluvioglacial and alluvial/estuarine granular deposits; and
* deeper groundwater associated with the Carboniferous Limestone bedrock.

The EIS states further that the extent of shallow groundwater within the superficial deposits is dependent on the extent of the sand and gravel deposits: sands and gravels close to water courses are expected to be in hydraulic contact with them. Fluvioglacial sands and gravels within the glacial till are generally of limited extent, whereas, more extensive deposits of sands and gravels are likely to be in hydraulic continuity with adjacent water courses. The glacial till generally has a low permeability and protects and restricts recharge of, or confines, the underlying bedrock. The low permeability of the clay within the glacial till often hides the existence of a high groundwater table, based on the apparent dryness of even deep excavations. Only localised flow of groundwater occurs within the glacial till where this is confined to layers and lenses of granular material.

Where made ground overlies soils of lower permeability, perching of the groundwater can occur. Perched groundwater tables are vulnerable to significant variation in level, both on a seasonal basis and over short periods of time, due to the fluctuation in the level of adjacent watercourses, or due to rainstorm infiltration.

Close to the River Liffey the groundwater level is generally at about 0m OD and not significantly affected by tidal variations. The annual fluctuation of the groundwater table is generally likely to be less than 5m, except where the limestone and gravel aquifers are more elevated.
Groundwater flow in the bedrock is controlled by fissure permeability. The limestone, where this consists of fine grained and argillaceous limestones and shales, is characterised by its low permeability and is generally unproductive. Higher yields can be obtained in fault disturbed zones. The limestones are generally recorded to be tight and dry, although experience suggests that individual fracture systems can give flows of between 5 and 20 litres/second.

According to the EIS, deposits of glaciomarine silts, alluvial silts, sands and gravels act as conduits for groundwater flow from the study area towards the Irish Sea. Topography is considered to be the main factor governing the groundwater regime in this area and groundwater typically flows from high areas to low areas.

7.3 Hydrogeological Risks
Metro North involves the construction of three broad types of permanent underground structure, namely:

* bored and mined tunnels
* stop boxes and cut and cover tunnels (constructed in open excavation from the surface, or possibly top-down) and
* cuttings.

Chapters 10, Volume 2 describe the potential impacts of these structures on groundwater, which may arise due to activities associated with the construction and operation of the proposed scheme in each area MN101 through MN107. The potential risks are discussed in the following section.

7.3.1 Belinstown Stop to Lissenhall Stop

**Groundwater flow**

The Dublin Limestone aquifer is highly sensitive to small-scale changes in recharge rates, which can have significant impacts on the artesian heads in the surrounding area. The hydraulic conductivity of the Dublin Limestone Aquifer is due to fracture permeability and ranges from $3.6 \times 10^{-6}$ to $6.95 \times 10^{-7}$ m/s. However, the connection of the limestone aquifer to more hydraulically transmissive units (such as sands, gravels and silts) also plays an important role in the hydro-geological regime in the area.

**Groundwater vulnerability**

According to the GSI Eastern Interim Vulnerability Map, the proposed alignment crosses an area where the groundwater vulnerability ranges from high to low. The precise vulnerability of the groundwater in this area has not yet been determined because the GSI has only carried out an interim study to date.
7.3.2 Lissenhall Stop to Dublin Airport Stop

**Groundwater flow**
In general, the groundwater in this area is expected to flow in an easterly direction towards the lower lying coastal areas. The glacial deposits encountered in this area typically act as conduits for groundwater flow from the project area towards the Irish Sea. The Ward River, which flows in a north-easterly direction through Swords, and the Broad Meadow River, which flows in an easterly direction through Swords, are likely to influence the direction of groundwater flow in the vicinity of Swords. The Mayne River, which flows in an easterly direction towards Dublin Bay from the east of Dublin Airport, is likely to influence the direction of groundwater flow in this localised area.

**Groundwater vulnerability**
The EIS indicates that the section of the proposed alignment, which extends from Lissenhall Stop to the Dublin Airport Stop, crosses an area where the groundwater vulnerability ranges from high to low. The precise vulnerability of the groundwater in this area has not yet been determined because the GSI has only carried out an interim study to date. A review of information available for this area was used to define the groundwater vulnerability, ranging from high to extreme (the subsoil consists of low permeability glacial tills and the groundwater is encountered within 3-5m of the surface).

7.3.3 Dublin Airport Stop to DCU Stop

**Groundwater flow**
The general direction of groundwater flow in this area is expected to be in a south easterly direction towards the lower lying coastal areas. This flow is likely to be facilitated by the presence of glacial deposits that have the potential to act as conduits for groundwater flow towards the Tolka River and the Irish Sea.

**Groundwater vulnerability**
Reference to the GSI Eastern Interim Vulnerability Map indicates that the section of the proposed scheme, which extends from Dublin Airport to DCU, crosses an area where the groundwater vulnerability ranges from high to low. As previously discussed, the GSI has only carried out an interim study to date. Thus, the precise vulnerability of the groundwater in this area has not yet been determined. The information available for this area was used to define the groundwater vulnerability as high (the subsoil consists of low permeability glacial tills and the groundwater is encountered within 5m of the surface).

7.3.4 DCU Stop to St. Stephen’s Green Stop

**Groundwater flow**
According to the EIS, the deposits of glaciomarine and alluvial silts, sands and gravels act as conduits for groundwater flow towards the Irish Sea. Historic infilling, which has taken place between DCU and St. Stephen’s Green, could act as a further conduit for groundwater flow towards the Irish Sea. The topography of this area is also expected to influence groundwater
flow in a south easterly direction towards the Irish Sea. The River Tolka, which flows in a south-easterly direction towards the harbour, is likely to influence the direction of groundwater flow in the Drumcondra area. The River Liffey, which flows in an easterly direction towards the harbour, is likely to influence the direction of groundwater flow in the city centre area.

**Groundwater vulnerability**

The GSI has not identified any Source Protection Zones in this area. Reference to the GSI Eastern Interim Vulnerability Map indicates that the section of the proposed scheme, which extends from DCU to St. Stephen's Green, crosses an area where the groundwater vulnerability ranges from high to low. The precise vulnerability of the groundwater in this area has not yet been determined because the GSI has only carried out an interim study to date. The information available for this area was used to define the groundwater vulnerability as high (the subsoil consists of low permeability glacial tills and the groundwater is encountered within 5m of the surface).

### 7.4 RPA Response to Further Information Request Regarding Groundwater and Hydrogeology

#### 7.4.1 General Response

The EIS documentation and Oral Submissions did not produce fully convincing information with respect to the vulnerability of specific areas and the risks associated with negative impact on groundwater. After hearing evidence from RPA in support of its application, ABP requested RPA to provide further information relating to groundwater and hydrogeology, addressing four issues:

- **a)** Groundwater lowering and recharging
- **b)** Field monitoring and verification tests
- **c)** Effect of cut-off walls and stop on groundwater flow
- **d)** Lowering of groundwater affecting areas with compressible soils.

#### 7.4.2 RPAs responded to the request with a comprehensive report and supporting documents

RPA emphasised that the detailed design of permanent and necessary temporary works is the responsibility of the contractor, who is obligated to comply with the Environmental Impact Statement (EIS), and the Metro North Construction and Maintenance Requirements (C&MRs). Groundwater lowering is only permitted by the Metro North C&MRs if the contractor can demonstrate that there will be no detrimental impact to buildings, infrastructure or the environment.

The Reference Design and associated construction planning satisfies the requirements of the EIS and the C&MRs in the following way:
* Groundwater cut-off to stop boxes is achieved by diaphragm walls or bored piles supported by ground treatment as required.
* Ground treatment of the base of excavations as required.
* Fissure grouting of the limestone bedrock as required - both for stop and tunnel excavation.
* Ground treatment of tunnel excavations in soft ground where required.
* Construction of the twin bored running tunnels using a tunnel boring machine (TBM) to install a watertight segmental tunnel lining with the ability to pressurise the tunnel face above the natural hydrostatic pressure of the ground, where required, to prevent significant groundwater inflows that could potentially result in groundwater lowering.

An assessment of the potential for groundwater lowering associated with the construction of Metro North underground structures, based on the Reference Design, has been made. A summary of the envisaged construction methods and dewatering requirements, the ground profile, the approximate depth to groundwater and likely mitigation measures have been analysed for critical structures.

7.5 Detailed Response on Specific Topics

7.5.1 Lowering of Groundwater

More compressible soils, comprising made ground and/or alluvial/estuarine deposits, occur only locally along the route. Although these localised soils are more compressible than the predominant glacial till and glacial sands and gravels, they are not necessarily "soft". The areas where more compressible soils have been identified, and, therefore, theoretically have the potential, if subjected to groundwater lowering, to consolidate are: O’Connell Bridge, identified former river courses, River Tolka, Ferguson Road, Drumcondra, Airport Stop.

The primary area where more compressible soils are present (identified by the Metro North Reference Ground Conditions Report for Information, May 2008, issued to An Bord Pleanála) that could potentially be subjected to groundwater lowering is at the O’Connell Bridge Stop where made ground and alluvial/estuarine deposits associated with the River Liffey are present. The depth to the base of the alluvial/estuarine deposits (which are predominantly granular in nature) is typically 6m below ground level. It is most likely that these compressible soils will already have experienced full drawdown, and as a result of this slight overconsolidation, significant additional settlement would not be anticipated.

Similarly, the fluvioglacial sands and gravels beneath the alluvial / estuarine deposits are medium dense to dense and, therefore, settlement resulting from full groundwater drawdown (if it was allowed to occur) is expected to be of the order of 10mm. However based on the provision made by the Reference Design and associated construction planning to prevent groundwater inflows, consolidation settlement is predicted to be in the region of 1mm.
Permanent groundwater lowering
The Metro North C&MRs require that all permanent underground structures are designed as undrained, watertight structures; therefore, underground structures will have no significant long-term impact on groundwater levels.

Temporary groundwater lowering
Details and locations of planned temporary groundwater lowering are dependent upon the Contractor’s temporary works proposals. Where excavations for underground stop boxes, cut and cover tunnels, mined tunnels and shafts are planned and temporary groundwater lowering is necessary within the excavation, it is possible that groundwater levels may be lowered during construction outside the excavation in the temporary condition. However, as stated above, the extent of any such groundwater lowering will not be permitted to exceed the allowable impact specified by the EIS and the C&MRs.

7.5.2 Bored and Mined Tunnels
Tunnel boring methods and the expected ground conditions are such that general groundwater levels should remain substantially unaffected during construction. The glacial till has a very low permeability while the limestone in most cases will be predominantly dry. In the case of the bored running tunnels to be excavated by TBM, where significant inflows of water can be anticipated the TBM, will be operated in closed face mode at a pressure above that of the natural groundwater pressure to prevent significant groundwater inflows in to the tunnel during construction.

The construction of the O’Connell Bridge Stop mined platform tunnels beneath the River Liffey is considered to represent a significant challenge, particularly with respect to the control of groundwater inflow. The relatively high permeability of the superficial soils overlying rockhead at this location will provide little attenuation of flow from the River Liffey, and therefore steady state conditions could be assumed as credible worst case conditions for flow calculations. If this scenario is valid, although groundwater drawdown may occur in the roof rock as a result of the relatively small storage capacity, it is unlikely that significant groundwater drawdown will occur in the overlying superficial soils. Inflows during mined tunnelling will generally be dictated by the permeability of the rock mass, which in turn is likely to be significantly influenced by the presence of joints. Such joints are likely to have permeability values of one or possibly two orders of magnitude higher than the typical rock mass. It is considered likely that the mined tunnels will intersect such features over some part of their length. Limitation of inflows to acceptable levels via systematic ground treatment to achieve hydraulic isolation will be required to allow safe and efficient construction of the tunnels.

7.5.3 Stop Boxes and Cut and Cover Tunnels
Short-term lowering of the groundwater table within the supported excavation may sometimes be required in connection with the construction of the cut and cover tunnels and stop boxes in open excavations from the surface (or top-down). This may be needed to
prevent the excavation from flooding, and/or to maintain the stability of the base of the excavation, battered slopes and possibly retaining walls that are less well supported during construction than in their permanent condition.

7.5.4 Effect of Permanent Underground Structures

The effect of permanent structures, which can interfere with the flow of groundwater, is potentially most significant in permeable granular strata. It is self-evident that strata of low permeability will have no significant effect on groundwater flow. Retained cut, and cut and cover tunnel sections are wholly located in the relatively impermeable, predominantly cohesive glacial till (i.e. north of Swords Stop, south of Fosterstown Stop and from Northwood Stop to DCU Stop). As groundwater flow is insignificant and attenuation is high within the glacial till, the impact of underground structures on a macro/regional hydrogeology scale will be negligible. This scenario applies equally to stop boxes at the Airport, Ballymun, DCU, Griffith Avenue and Drumcondra.

The stop boxes at Mater, Parnell Square, O’Connell Bridge and St. Stephen’s Green are located in more permeable and extensive granular strata. The underground structures are typically in the region of 25m deep by 30m wide by up to 165m long, with the exception of O’Connell Bridge where 30m deep by 30m wide (north access) and 17m wide (south access) boxes, each in the region of 70m long, are located either side of the River Liffey. The dimensions of the boxes are considered to be insignificant when compared with the scale of the hydro-geological regime and groundwater flow patterns within which they are located. Additionally, the stop boxes are generally aligned north-south, which is similar to the regional scale pattern of groundwater flow towards the River Liffey and, therefore, will not act as a significant barrier to groundwater flow.

In order to demonstrate that the flow of groundwater in the vicinity of cut-off walls and stops has negligible permanent consequences, a numerical hydro-geological model of the Parnell Square Stop and the River Liffey basin was created and calibrated using the computer software programme MODFLOW (see Appendix B – Parnell Square: Hydro-geological Modelling). The Parnell Square Stop was selected for analysis as it is the stop with the most significant (i.e. deepest) granular layer. Analysis of the Parnell Square Stop has the added advantage that good calibration / validation data are available. The objective of the modelling was to estimate and assess the effects of the stop box on the existing groundwater regime.

The flow and particle-tracking model shows that the proposed Parnell Square Stop will not have a significant effect on the local groundwater regime. Taking into account the modelling limitations, the accuracy of the calibrated models and the sensitivity analysis, the long term effect of the proposed Stop is assessed to be less than the seasonal fluctuation of groundwater levels in the area. Therefore, the impact of the permanent structure on groundwater flows is predicted to be negligible.
7.6 Comments - Impact on Hydrogeology
Information regarding geology and groundwater was given in the EIS and supporting documents. Additional information and explanation regarding specific questions was included in RPAs response to the Further Information Request. Valuable evidence was also presented during the Oral Hearing and in response to questions. As part of the environmental risk management scheme and according to the observational method, groundwater levels will be monitored prior to, during and after completion of the Metro scheme.

The submission on groundwater was also the subject of a Peer Review, which was carried out by Professor. Professor Powrie has fully endorsed the work carried out by RPA with regard to groundwater control as presented in this submission.

I am now satisfied that, based on the predictions detailed in the Groundwater chapters of this EIS (Volume 2, Chapters 10), no significant impacts arising from changes in groundwater are expected to occur during the operational or construction phases of the proposed scheme.

8 Geotechnical Impact
Construction and operation of the proposed scheme may cause environmental impacts due to soils and geology. The following elements of the scheme can potentially affect the environment:

* Stops, track, substations, ventilation shafts, landscaping bunds, ancillary roads and access ways and tunnel portals,
* earthworks, cuttings and embankments,
* spoil storage areas and disposal sites,
* construction compounds and
* track maintenance and drainage operations which may lead to contamination of soil.

Volume 2, Chapter 9 of the EIS describes the potential impacts on soils and geology, which may arise due to activities associated with the construction and operation of the proposed scheme in Area MN101 through MN107.

8.1 Study Area and Geotechnical Investigations
The study area for assessment of geotechnical parameters is set out in Table 9.1. The assessment area has been defined with reference to the potential for impact from the scheme and the availability of relevant information.
### Table 9.1 Study area

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Width of study area (on both sides of the alignment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geology</td>
<td>50m</td>
</tr>
<tr>
<td>Landuse</td>
<td>50m</td>
</tr>
<tr>
<td>Subsoils</td>
<td>50m</td>
</tr>
<tr>
<td>Ecology</td>
<td>50m</td>
</tr>
<tr>
<td>Preliminary Ground Investigation</td>
<td>1km approx.</td>
</tr>
<tr>
<td>Construction compounds</td>
<td>All areas within 50m of construction site boundary</td>
</tr>
<tr>
<td>Constructed generated</td>
<td>Tunnels - The greater of 30m horizontal distance from the tunnel centreline or the position of the predicted 2mm settlement contour line.</td>
</tr>
<tr>
<td>ground movements</td>
<td>Cut and cover structures - The greater of the distance equating to the depth of the excavation measured from the face of the cut and cover excavation, or the position of the predicted 2mm settlement contour line.</td>
</tr>
</tbody>
</table>

The baseline assessment of soil and geology included a desktop study and a review of the findings of the main ground investigation carried out by RPA. The geotechnical conditions of the project area were evaluated based on information obtained from the Metro North ground investigation programme and other sources containing geotechnical data. The numbers and types of exploratory holes undertaken have been reported and brief descriptions of the in situ field and laboratory testing and the instrumentation installed were provided. The phased ground investigation programme included the preparation of various geotechnical reports. Inferred geological sections were described. In addition, extensive background information and other relevant geotechnical reports were made available during the Oral Hearing.

An overview was given of the work undertaken to derive the interpretation of geotechnical parameters. A summary of the inferred ground and groundwater conditions along the proposed route of Metro North and highlights of key geotechnical features relevant to the scheme was given. The need for additional, comprehensive ground investigation on which the detailed design following contract award can be based, was also discussed and acknowledged by RPA.

#### 8.2 Geotechnical Situation

Baseline soils identified include boulder clay, sands and gravels, silts and sandy clays from river deposits and made ground including rubble and waste materials. Bedrock geology consists predominantly of limestones with shales. The baseline conditions are not presented in this report and only significant aspects are discussed. The general stratification of the ground along the route of Metro North consists of the following formations: made ground; alluvial/estuarine deposits; fluvio-glacial deposits (glacial sands and gravels); glacial till and bedrock (Carboniferous limestone).
Made Ground
Locally, extensive areas of made ground are present along the route. The composition of made ground varies widely and generally consists of a mixture of waste materials including, for example, domestic refuse, clinker and demolition rubble. In the city centre, the thickness is generally between 1m and 4m, but locally deeper, and in general reduces to between 1m and 2m to the north of Mater Stop.

Alluvial deposits
Alluvial deposits, of generally limited extent, are present locally in the vicinity of the River Liffey, River Tolka and Broadmeadow River. Alluvial deposits, of limited extent, are also likely to be present in areas associated with existing and former stream courses. The alluvial deposits generally consist of loose to medium dense, interbedded, organic silts, sands, gravels and cobbles. Bands of peat have been encountered locally within the alluvial deposits in the area of the River Liffey.

Estuarine deposits
Estuarine deposits are present in the vicinity of the River Liffey. The glacial sands and gravels comprise sands and gravels with cobbles and occasional boulders. The glacial sands and gravels generally occur as layers or lenses within the predominantly clayey glacial till. However, in the area of the preglacial channel to the north of the River Liffey (and also to a lesser extent between the River Liffey and St. Stephen’s Green) significant thicknesses are present. The geology of the pre-glacial channel area is complex with glacial tills occurring within glacial gravels and vice-versa and likely reflects the complexity of the variations and different stages of ice sheet advance and withdrawal. Artesian and/or sub-artesian groundwater conditions have been encountered within the glacial sands and gravels in the O’Connell Street and Parnell Square areas.

Alluvium
Soft silts and clays are likely to be present in the areas of the River Liffey, Tolka River and Broadmeadow River and other smaller streams and former river courses. Bands of peat were encountered locally within alluvial deposits in the vicinity of the River Liffey. The selected construction methods will need to address the potential for ground stability issues and excessive settlement associated with construction over and within these materials.

Glacial Till
The glacial till consists of a heterogeneous mixture of clay, silt, sand and gravel with cobbles and boulders. It is locally known as Dublin brown or black boulder clay. The till contains discrete, and in places extensive, layers, lenses and pockets of sand and gravel.

Glacial till is generally considered to be a good material for tunnel construction. However, lenses and layers of sand and gravel are present within the predominantly clay matrix that can contain groundwater under high pressure.
The presence of boulders within the glacial till has the potential to disrupt bored tunnelling construction and also the construction of deep foundations. Previous experience indicates that boulders with maximum dimensions of greater than 0.5m are rarely encountered during construction works in Dublin.

**Granular Materials within Glacial Till**

Pockets, lenses and layers of granular material, of varying extent, exist within the glacial till, while extensive glacial gravel deposits are present to the north of the River Liffey. Therefore, engineering solutions will need to be capable of dealing with the potential risk of encountering groundwater in localised areas within the till; inflows have the potential to be sudden and variable, with the volume of inflow being dependent on the volume of granular material, interconnectivity with other gravel deposits and groundwater pressure.

Saturated gravels with sub-artesian pressures are expected north of the Liffey and other areas; blowing sands and gravels have been encountered in a number of exploratory holes during ground investigation works. The presence of sandy or gravelly soils within cut slopes can potentially lead to rapid dissipation of excavation induced negative pore water pressures and can lead to slope failures. The presence of such materials can also have adverse effects on deep foundation and shaft construction.

**Weathered and Rafted Rockhead**

The occurrence of weathered rockhead is variable across the site. Where encountered, the engineering properties are likely to be poorer and can potentially cause problems in achieving an adequate cut-off for retaining walls. Design and construction solutions will need to consider the impact on foundation construction and make provision to achieve an adequate cut-off for retaining walls.

**Karst**

Karst features could be encountered within the Waulsortian formation, which is present in the vicinity of Dublin airport. The existence of water and clay filled voids in the form of an elongated vertical pipe has previously been reported in this area.

**Bedrock**

In Dublin city centre the bedrock consists of carboniferous limestone interbedded with mudstone and shale (Calp limestone), whereas locally at the airport, the limestone consists of massive limestone and mudstone (Waulsortian limestone). The Waulsortian limestone is more susceptible to the development of karst features. The bedrock has been faulted and partly folded and uplifted.

**Groundwater**

The groundwater level is typically between 2m and 4m below ground level in the city centre area and may be deeper where ground levels are more elevated. Subartesian groundwater pressure and/or running sands and gravels have been encountered in several areas, particularly associated with the pre-glacial buried channel to the north of the River Liffey.
The hydrogeological aspects have been discussed in Chapter 6 and are not repeated here.

8.3 Comments - Geotechnical Conditions
Within the glacial till, lenses of sands and gravels with high water pressure may be encountered; these materials are most likely dense. Even when compressible layers undergo drainage these will not experience significant consolidation. This applies also to the glacial sands and gravels which are dense by nature.

It is noted that RPA’s Metro North CMRs require that an assessment be made of the effects of construction on all structures within the zone of influence of the works. The zone of influence for excavations from the surface is defined as the distance equating to twice the depth of the excavation originating from the sides of the excavation or the position of the predicted 1mm settlement contour line, whichever is the greater. This requirement is not necessarily in agreement with the definition of the study area given in Table 9.1.

Key geological features, which may have a negative impact on the design and construction of Metro North, have been identified in the EIS and require particular consideration in the selection of appropriate design solutions and construction methods.

During the Oral Hearing, RPA confirmed that further detailed ground investigation data will be required for the detailed design and especially in critical areas, in order to address specific construction method related aspects (TBM passing through soil-rock interface, construction of walls and deep excavations etc.).

Interpretation of ground conditions based on the available geotechnical data for soils, rocks and groundwater was used to infer geological profiles along the alignment. In my view the geotechnical and geological investigations carried out as part of the EIS and the additional information provided by RPA are sufficient for a robust Reference Design.

8.4 Geotechnical Impact Assessment
Ground investigation data and other relevant records have been made available to tenderers in accordance with the International Tunnelling Insurance Group’s Code of Practice for Risk Management of Tunnelling Works. The objective of this Code is to promote and secure best practice for the minimisation and management of risks associated with the design and construction of tunnels, caverns, shafts and associated underground structures. The successful contractor will be required to follow the requirements of this code.

Ground movements generated by construction work have a high potential to impact on property overlying or adjacent to sites where such works are being undertaken:

- TBM bored tunnels,
- cut and cover tunnels,
- retained cuttings,
- mined tunnels,
shafts,
stop boxes and
portal structures.
It is noted that the risk of damage, which also exists during enabling works is not addressed extensively in the EIS.

In response to the Further Information Request on geotechnical and geological aspects, RPA submitted additional comprehensive written documentation. During the Oral Hearing, presentations were made which addressed the assessment of building damage.

8.4.1 Geotechnical Impact Assessment Methodology
The assessment of geotechnical impacts – and in particular the risk of building damage – is carried out in three stages:

Stage 1 Preliminary ‘Greenfield’ Settlement Analysis: This stage involves the prediction of ground movements generated by underground excavation and construction of TBM bored tunnels, cut and cover tunnels, retained cuttings, mined tunnels, shafts, stop boxes and portal structures and the identification of property at potential risk of damage. Settlement predictions take account of likely construction methods, ground conditions and comparable projects (in terms of ground conditions and construction methods). The predictions have been undertaken using empirical, finite element and discrete element computer analysis and validated against case studies.

Stage 2A Initial Response Assessment: This stage involves the assessment of the response of buildings and infrastructure (identified during Stage 1) to predicted ground movements, and where appropriate, the consideration of possible mitigation measures. All buildings carried through from the Stage 1 Assessment are individually assessed using a limiting tensile strain approach. Buildings are modelled and assumed to follow the greenfield settlement profile of the ground.

Stage 2B Review of 2A Initial Response Assessment: Stage 2B provides for a review and update of the Stage 1 and 2A assessments taking account of the detailed design and actual construction methods to be used.

Stage 3 Detailed Response Assessment: This stage involves a detailed assessment of all buildings, utilities and infrastructure carried over from Stage 2B, and the design and implementation of protection measures as appropriate. All buildings that fall into the moderate, severe and very severe categories will be assessed in detail taking account of information collected from detailed structure and sub-structure surveys. The method, extent and detail of the analysis will be determined on a case by case basis, however factors that would be taken account of include, three dimensional effects, construction and excavation methods and sequencing, structural continuity of the building, foundation and
structural details, building condition, orientation of the building, soil/structure interaction, settlement predictions at depth and previous movements.

8.4.2 Building Damage Classification

The criteria used to assess the impact of construction-generated ground movements on overlying and adjacent buildings was undertaken in accordance with the building damage classification system set out by the Building Research Establishment 251 (1990) using a limiting tensile strain approach. Table 9.3 of the EIS introduces five categories of damage based on limiting tensile strain. The type of typical damage is also described.

<table>
<thead>
<tr>
<th>Category of damage</th>
<th>Normal degree of severity</th>
<th>Limiting Tensile Strain (%)</th>
<th>Description of typical damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Negligible</td>
<td>0 – 0.05</td>
<td>Hairline cracks less than about 0.1 mm</td>
</tr>
<tr>
<td>1</td>
<td>Very Slight</td>
<td>0.05 – 0.075</td>
<td>Fine cracks not greater than 1 mm which are easily treated during normal decoration.</td>
</tr>
<tr>
<td>2</td>
<td>Slight</td>
<td>0.075 – 0.15</td>
<td>Cracks less than 5mm, Cracks filled. Re-decoration probably required. Recurrent cracks can be masked by suitable linings.</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>0.15 – 0.30</td>
<td>Cracks 5-15mm, or number of cracks &gt;3mm. The cracks require some opening up and can be patched by a mason. Re-pointing of external brickwork and possibly a small amount of brickwork to be replaced.</td>
</tr>
<tr>
<td>4</td>
<td>Severe</td>
<td>&gt;0.3</td>
<td>Cracks 15-25mm. Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows.</td>
</tr>
<tr>
<td>5</td>
<td>Very Severe</td>
<td>&gt;0.3</td>
<td>Cracks &gt;25mm. This requires a major repair job involving partial or complete rebuilding.</td>
</tr>
</tbody>
</table>

8.4.3 Impact of Ground Movements on Buildings

Proof of evidence was given by Prof. Burland during the Oral Hearings, which described the engineering studies carried out prior to and during the Oral Hearings to predict effects of ground settlement on buildings and utilities resulting from the proposed tunnelling and excavation works. The proof of evidence addressed the following issues:

* Method of predicting ground movements above tunnels and adjacent to deep excavations.
* Causes of building damage and its classification. Effects on buildings of the ground movements are predicted.
* Protective and remedial measures which can be used to mitigate these ground movement effects.
8.4.4 Construction Monitoring - Observational Method
All buildings potentially at risk due to settlement shall be monitored. Monitoring will be carried out over a time scale commencing prior to the tunnelling and excavation works. Monitoring will also be used to check that the behaviour of each building or structure is within acceptable limits as determined in the detailed settlement analysis.

The "Observational Method" was introduced as part of the EIS during the Oral Hearing. This concept will be used to observe the response of the ground and of structures. Detailed monitoring permits the early identification of unexpected behaviour. This proactive approach requires, however, that contingency measures are prepared in advance to deal with unexpected developments during the construction work.

8.5 Comments - Geotechnical Impact Assessment
The following comments are offered with regard to geotechnical impact assessment.

8.5.1 Tunnelling Work in Central Dublin
Tunnelling and deep excavation in central areas of Dublin will be carried out below or in the close vicinity of historic monuments and sensitive Georgian building. Some of these buildings, for instance near Parnell Square, have irreplaceable interior cornices, plaster ceilings and other architecturally important elements. It is appropriate that the threshold "at risk" category will be reduced from "moderate" to "slight". Thus, any impacts due to ground movement shall be "very slight" (Category 1). These buildings will automatically be progressed to the Stage 3 assessment by the contractor.

8.5.2 Problematic Ground Conditions
The problem of potentially loose, water-saturated soils was identified by RPA as problematic, cf. Chapter 8.3. The question regarding variable ground conditions is not limited to layers of loose sand and gravel but refers in particular to problems associated with tunnelling across the rock-soil interface. This is a potentially problematic situation for TBM operation.

Tunnelling protective measures are often cost-effective in order to reduce excessive ground loss. Therefore, it is recommended that extensive field monitoring procedures are applied during the initial phase of tunnelling work in critical areas. The topic was also discussed during the Oral Hearing by geotechnical and tunnelling experts.

Based on response to questions and complementary information provided, I am satisfied that the risks associated with variable ground conditions are fully appreciated. Potentially problematic areas will be included in the geotechnical risk register and appropriate mitigation measures be implemented.

8.5.3 Geotechnical and Geological Risks
RPA confirmed that it has implemented a risk management concept for the Metro North project, and has, and continues to follow and adopt the guidance provided by “A Code of Practice for Risk Management of Tunnel Works” prepared by The International Tunnelling
the following aspects:

* Ground conditions/geotechnical
* Groundwater lowering
* Ground movement, building response and monitoring
* Construction

General comments on the structure of environmental risk assessment and risk management
are given in Chapter 5.3 and a detailed discussion is given in Appendix 2 – Management of
Environmental Risks. RPA confirmed during the Oral Hearing that a more sophisticated risk
management system will be gradually introduced, with emphasis on environmental aspects.

It is important that all parties involved in the Metro scheme (project owner, designer,
contractor, surveyors, supervisors etc.) will be required to adhere to the risk management
concept. RPA assured that it will set up an organisation which is able to enforce its
implementation.

I am now satisfied with the risk management approach presented by RPA with respect to
geological, geotechnical and hydrogeological impacts.

8.5.4 Assessment of Ground Movements
Prediction of ground movements is a complex task and predictions should be interpreted
with caution. An even more complicated task is to predict the effects of ground movements
on buildings and other structures on or below the ground.

The three stage approach of ground movements and building damage evaluation is in
agreement with the concepts of environmental risk assessment, cf. Chapter 5.2, Assessment
of Environmental Risks.

During the Oral Hearing, RPA and its experts presented maps with predicted ground
settlement contours (settlement troughs) which are used to categorize buildings and other
structures which potentially could be affected.

Prof. Burland also presented several examples of detailed building response analyses (Stage
3) which demonstrate the practical application of ground distortion analysis.

I am convinced that the proposed approach is appropriate for predicting settlements which
potentially can cause damage to buildings.

8.5.5 Building Damage Evaluation
The classification of building damage is a key issue. Table 9.3 is based on ease of repair of
visible damage. This is a modern and consistent approach. In his submission during the Oral
Hearing, Prof. Burland pointed out that an important dividing line is between damage
category 2 and 3. If damage exceeds category 2, this is usually associated with ground
movement and easier to identify. This aspect will be address in chapter 8.6.3, Comments on POP Scheme. When damage category 2 according to Table 9.3 is reached in a structure, the extent of field measurements should be intensified. It is important that the contractor is also informed about the extent of damage and required to modify or adjust the excavation or tunnelling method.

Professor Burland gave proof of evidence regarding the consequences of settlement and their impact on buildings. He also provided clarifications regarding building damage categorisation. This information is valuable as building damage due to tunnelling and other construction work is one of the critical issues when discussing geotechnical risks with residents in the vicinity of Metro North.

Mr David Slattery who is the RPA appointed Conservation Architect for Metro North has reviewed the expert evidence presented by Prof. Burland. In his view the detailed assessment outlined by Prof. Burland takes account of the sensitive nature of historic buildings. He considers that the classification of visible damage described by Prof. Burlands is considered detailed and measurable in the context of fragile features contained in 18th century buildings such as delicate plaster ceilings, covings etc.

The parameters to be employed within the 3 Stage Analysis will be conducted by Prof. Burland in close cooperation with Mr. Slattery. Mr. Slattery's long experience dealing with sensitive historic buildings of this nature will be a significant element of this evaluation process.

The assurances given by Mr. Slattery are of importance when establishing the protection scheme for historically important buildings. Involvement of an expert with experience in protection of buildings and structures of historical and architectural significance is crucial for safe execution of tunnelling and excavation work in sensitive areas. The contractor should be required to involve experts with the task to develop a comprehensive monitoring scheme. Special attention should be paid to the protection and monitoring of buildings with ornate plaster ceilings.

I do endorse the proposed method of assessing risk in relation to historic buildings. However, in my opinion, special monitoring and supervision methods (instrumentation) should be used to detect noticeable changes at an early construction stage (when work is started in the vicinity, or tunnelling work is approaching).

Based on the above considerations, I find the proposed method of monitoring the risk of building damage acceptable for the proposed scheme.

**8.5.6 Monitoring and Observational Method**
Field monitoring should be an integral part of construction work where geotechnical risks are high. In addition, it is recommended to carry out full-scale field trials during critical phases of the project. The contractor shall be obliged to carry out such trials, for which a
A detailed monitoring program should be worked out, cf. Appendix 2 – Management of Environmental Risks.

An important aspect of limiting building damage is field monitoring, in order to adapt/modify construction methods to prevailing ground conditions. Field trials can provide valuable information for studying the effect of different working procedures on ground response. Based on analytical studies, critical parameters shall be identified. Measurement of these parameters and interpretation of ground response should be compared with predictions in order to verify the accuracy of design assumptions.

The Observational Method is an integral element of geotechnical risk management. The geotechnical risk analysis should identify trigger (threshold) values for each of the parameters to be monitored. Should trigger values be exceeded, a plan of action can be initiated, requiring the contractor to modify the construction procedure.

8.6 Property Owners' Protection Scheme

8.6.1 Objectives
RPA is aware that residents are concerned about the impact of construction on their properties. In order to address these concerns, RPA set up in January 2009 the Property Owners’ Protection (POP) Scheme. Participation in the Scheme is voluntary and is in addition to - and does not impede - normal legal rights. The POP Scheme applies to private residential property. It will remain in place for 12 months after completion of the underground works.

8.6.2 Implementation of POP Scheme
It is envisaged that the main contractor takes over the POP Scheme, and will carry out regular monitoring of surface levels and vibrations.

All residential properties that lie within 30 metres of the edge of the tunnels or 50 metres of the underground stations can sign up to the Scheme. Owners of property within this area are entitled to participate in the Scheme.

RPA will establish a panel of three independent firms of building surveyors. These firms will carry out an initial condition survey report with an initial survey report. After construction, a final condition survey will be carried out and a second survey report will be prepared.

An assessment will be carried out by the building surveyor, resulting in an interim survey report. If the interim survey and report recommends repairs to rectify the damage caused by the Metro North works, and those repairs cost up to € 30,000, the recommendations will be implemented.

In case of a dispute, the case will be referred to an independent expert, selected from a panel established by the Institution of Engineers of Ireland.
8.6.3 Comments on POP Scheme
The proposed POP scheme is an important step in taking account of the concerns by owners of private property which potentially could be affected by the Metro North scheme. However, the following comments are offered regarding the scope and implementation of the Scheme:

Responsibility
The POP Scheme was initiated and set up by RPA and its implementation should remain the responsibility of RPA throughout the entire period of Metro construction. It is, of course, acceptable to require the contractor to assume certain responsibilities (such as monitoring etc.) but the Scheme should not be transferred to the contractor.

Scope of Scheme
The Scheme should not be limited to settlement caused by to tunnelling work and construction of underground stations. It is recommended to cover ground distortion (settlement and heave, lateral soil movement) from all types of underground construction work (i.e. excavation of soil and rock, compaction, pile driving etc.).

The Scheme should also include temporary works and enabling works (utilities).

Observational Method
RPA has assured that the Observational Method will be applied throughout the construction of the Metro North Scheme. As has been discussed above, risk assessment procedures should be implemented, including extensive monitoring by different methods (in addition to settlement and vibration measurement).

For monitoring of historic buildings, special observation systems (for instance crack monitoring in wall and ceilings) should be introduced.

Role of Building Surveyor
The settlement damage assessment methodology proposed by Prof. Burland shall be the basis for building survey. As this concept is novel and its application requires experience. Those overseeing and implementing the POP Scheme (building surveyors) need to be trained in the practical application of damage assessment.

8.6.3.1 Intermediate Building Survey
The POP Scheme envisages an initial survey prior to start of construction work and after completion of work (within a distance of approximately 100 m from the respective property). However, it is conceivable that damage is noticed when construction work is still in progress. In such a case, inspection of affected buildings should be carried out without delay.

When noticeable damage (exceeding Damage Category 2) is observed the contractor should be notified and an intermediate building survey should be carried without delay.
Modification of Construction Process
If damage exceeding Category 2 is observed, the contractor should be required to change construction method(s) and/or equipment in order to avoid further damage to occur.

Commercial Buildings
The POP covers only private property. However, it is recommended that a similar scheme of risk assessment, building survey and monitoring is implemented also for commercial buildings.

8.7 Comments – Geotechnical Impact and POP Scheme
The following comments and conclusions are presented with respect to geotechnical impacts and the POP Scheme:

1. **Geological and geotechnical conditions**: these are complex in some areas along the project alignment (especially in the City centre). Construction work will be carried out in areas with sensitive buildings and other structures. This aspect has been recognized by RPA in the Reference Design.

2. **Geotechnical risk management**: RPA intend to implement a comprehensive risk management scheme, assuring that unacceptable environmental impacts will be avoided. The Observational method is central in planning, project execution and monitoring of the Scheme.

3. **Full-scale trials**: in critical areas, prior to – or in connection with the start-up of construction work – full scale field tests, supported by extensive field monitoring, should be foreseen and carried out to optimize different types of construction procedures (tunnelling, wall construction, excavation etc.) in order to keep environmental impacts to acceptable levels.

4. **Reference Design**: information about geotechnical conditions is sufficient for a robust Reference Design, on which the EIS is based. However, comprehensive geotechnical, geological and hydrogeological investigations will be required for the detailed design. Consequently, new information may become available which could affect the construction methods and techniques assumed in the Reference Design.

5. **Construction methods**: the proposed methods for construction of tunnels and deep excavations have been used successfully in similar geological settings and geotechnical conditions elsewhere. However, it is important that the contractor has documented and verifiable experience from the use of such methods under similar geotechnical conditions.

6. **Geotechnical impacts**: assessment of geotechnical impacts – and in particular the risk of building damage – shall be carried out in three stages. This methodology is in accordance with modern risk assessment concepts and suitable for the project.

7. **Geotechnical risk management**: the proposed management concept of geotechnical and hydrogeological risks as presented by RPA in the response to the Further Information Request will be an efficient tool to minimize and mitigate environmental risks.
8. **Building damage classification**: damage classification is based on ease of repair. The approach demonstrated by RPA experts is consistent with high international requirements.

9. **Trigger level**: exceeding of damage category 2 should be used as the trigger level for the contractor to adjust construction procedures. When damage category 2 is observed at any stage of the project, building surveys should be carried immediately to document the extent of damage. Also, the contractor shall be required to modify immediately the construction method in order to eliminate further damage to occur.

10. **Responsibility for POP Scheme**: the Scheme should remain the responsibility of RPA during the entire period of Metro construction, although some practical tasks of its implementation could be transferred to the contractor.

11. **Scope of Property Owners’ Protections Scheme**: the Scheme should not be limited to ground settlement due to tunnelling work and construction of underground stations but also cover other types of construction work, such as deep excavation, soil compaction or pile driving. The Scheme should also cover temporary works and enabling works (utilities).

9  **Impact - Vibration and Groundborne Noise**
Vibrations and groundborne noise are major sources of potential environmental impact, which can occur during construction but also as a result of operation of the scheme.

9.1  **Construction Phase**
Construction methods which potentially can cause ground vibrations and groundborne noise are discussed in Chapter 6.1.2. The most important source of vibration and groundborne noise during the construction phase is rock excavation by TBM operation. Each of the two TBMs is expected to advance at the rate of about 75m per week, operating 5 days per week. The fact that the TBM will only be heard in each tunnel for the short period of its passage means that higher impact thresholds can be applied than for the operational phase of the proposed scheme. In locations between the two tunnels, this experience will be repeated with a delay of the order of two months between the two tunnel drives. Because of the finite duration of this effect, the night-time impact thresholds have been set slightly higher than those for the operation of the proposed scheme.

Another potentially critical construction activity is rock excavation by blasting. Some underground construction within the limestone bedrock, for example the excavation of cross-passage, may be carried out by the use of drill and blast techniques.

Operation of normal civil engineering plant includes machines for bored and driven piling, diaphragm walling, rock breakers and jackhammers. Vibration sources from construction plant operating on worksites are not likely to generate high vibration and perception will decrease with distance. Potentially critical activities are excavation of wall elements, driven and/or bored piling and ground compaction by vibratory rollers.
9.2 **Operational Phase**
The main source of vibration and groundborne noise during the operation of the scheme is the wheel/rail interaction during the movement of light metro vehicles.

9.3 **Ground Investigations**
A major ground investigation programme has been carried out for Metro North, involving a large number of boreholes. In addition to conventional geotechnical investigations, surface geophysical surveys were carried out at as well as seismic refraction profiling, multichannel analysis of surface wave profiling and microgravity surveys. The results of these surveys were used to assess the principal dynamic ground properties such as density, shear wave speed and compression wave speed (through which shear modulus, compressive modulus are determined). Material damping in the soil (loss factor) was not measured by ground investigations but conservative assumptions can be based on theoretical considerations and experience published in literature.

9.4 **Modelling of Ground Vibration**
The same theoretical models are applied for ground vibrations and groundborne noise. The distinction between ground vibrations and groundborne noise is how impact levels are expressed in vibration terms (dB, ppv etc.). However, there is a significant difference how ground vibrations affect buildings and how groundborne noise is experienced by humans/residents in buildings. This chapter discusses modelling of ground vibrations.

9.4.1 **Modelling of Vibration from Construction**
Theoretical models are not sufficiently reliable to predict vibration propagation from different sources of construction activities through geological formations. Therefore, predictions of vibrations and groundborne noise presented in the EIS are preliminary in nature and must be verified by field vibration measurements. Prediction models need to be calibrated against and updated based on field trials.

**TBM Operation**
One principal sources of vibration is tunnel boring and in particular the cutting action of the shield. Vibration and groundborne noise were analysed using the finite difference program FINDWAVE. In order to model the vibration source at the tunnel face, results of this model have been back-fitted to the groundborne noise and vibrations results that were measured when the Dublin Port Tunnel was constructed. The program predicts in the time domain the three dimensional components of vibration (particle) velocity in the ground. The initial model did not incorporate a free (ground) surface in the model. Cross-sectional plots of vectored vibration velocity were obtained. The model encompassed an area of approximately 30 m to either side of the proposed alignment. The output of the modelling exercise provided an indication of likely levels of ground vibration and associated groundborne noise at various depths and assuming different geological conditions. Also, a prediction of the decay of vibration and groundborne noise with distance, both laterally and ahead and behind the TBM, was obtained.
Drilling and Blasting

The principal source of vibration from drilling and blasting is the detonation of explosive charges underground. Vibration is a well known effect of blasting and empirical techniques for predicting the magnitude based on measurements in comparable lithology are well established. Vibrations caused by blasting can be predicted using empirical relationships between the effective (contributing charge) weight of explosive, the distance from the source and the ground in which vibrations are generated and propagated. It is common practice to establish site-specific correlations for modelling of vibrations based on measurements during test blasting. The intensity of vibration depends also on the relative location (position) between the source of vibration and the location of affected buildings (blasting below a building will generate different types/frequencies of vibrations than blasting at some lateral distance from the source).

Wall construction and other construction activities

It is generally difficult to predict vibrations and groundborne noise caused by wall construction (impact, chiselling, grinding or drilling). Therefore, it is necessary to monitor ground vibrations during the initial phase of construction and to develop site-specific correlations for modelling and prediction of ground vibrations.

Prior to construction of piles or diaphragm wall panels close to vibration-sensitive structures or installations, a detailed work schedule needs to be prepared by the contractor. Prediction of ground vibrations shall be made and verified by field monitoring and control (to avoid exceeding vibration thresholds).

Vibrations from other construction activities such as pile driving and soil compaction are also difficult to predict and are usually assessed empirically by field monitored, applying the observational method.

9.4.2 Modelling of Vibration during Operation

Vibration and groundborne noise can arise from the operation of railway vehicles. Modelling of the likely intensity of vibration and groundborne noise from the operation of vehicles has been carried out using likely design and operational parameters for vehicles expected to be offered by prospective operators. The most important parameters are wheel/rail roughness, bogie unsprung mass, suspension stiffness and speed.

A particular feature of the operation of a newly designed railway is that the incorporation of resilient rail support and the use of welded rail have the result that significant effects due to vibration and groundborne noise are completely avoided provided that the appropriate form of track support is selected, and an adequate maintenance regime is followed.

The assessment of vibration and groundborne noise from a new railway therefore consists to a large degree on consideration of the likely nature of incorporated mitigation in the design and operation (including maintenance) of the system.
Prediction of ground vibrations and groundborne noise is a challenging task. Therefore, it is recommended to carry out vibration tests in critical areas to verify that the limiting values of vibrations and groundborne noise are not exceeded.

9.5 Further Information Request on Ground Vibration and Groundborne Noise

The information which was submitted as part of the EIS, supporting documents and evidence presented during the Oral Hearing did not clarify all the questions with regard to impact assessment of vibrations and groundborne noise. The Further Information Request dealt with the following topics:

* Free-field prediction of construction-induced vibrations and groundborne noise.
* Free-field prediction of vibrations and groundborne noise due to train operation.
* Verification of FDTD computer program.
* Calibration of FDTD program against Dublin Port Tunnel measurements.
* Dynamic soil and rock properties.
* Soil-structure interaction.
* Dynamic characteristics of buildings.
* Effect of vibrations on underground structures.
* Effects of construction-induced vibrations.
* Field verification of vibration predictions.
* Dynamic performance of tunnel.

9.5.1 Response to Further Information Request provided by RPA

Since completion of the EIS more detailed information has become available and it has been possible to refine the numerical predictions.

RPA submitted a comprehensive response to the Further Information Request, addressing the raised questions. Additional clarification was obtained during the Oral Hearing and in response to questions. In the following, comments are made on the information submitted by RPA.

Free-field prediction of construction-induced vibrations and groundborne noise

RPA have not predicted ground vibrations from different types of construction activities. Instead, emphasis will be placed on construction monitoring and application of the observational method.

Vibrations from blasting shall be controlled by blasting tests and establishment of site-specific vibration attenuation relationships.
Free-field prediction of vibrations and groundborne noise due to train operation

Contours have been generated using the formula in DIN4150-1, calculated in third-octave bands from 1Hz to 315Hz. This information is useful for prediction of vibration and groundborne noise during the operational phase. However, prediction of ground vibrations in geological formations and the response of buildings in/on the ground is highly complex. Therefore, simplifications have to be made which introduce sources of uncertainty and the results of the analyses must be considered to be indicative only. Therefore, it is necessary to verify vibration predictions in critical areas with field trials.

Verification of FDTD computer program

The analysis of controlled vibration signals confirms that FINDWAVE with sufficient accuracy predicts wave propagation in geologic formations.

Calibration of FDTD program against Dublin Port Tunnel measurements

Although reference is made to vibration measurements from the Dublin Port Tunnel project, which have been used to calibrate vibration predictions for this project, such information or references have not been given in the response. Publicly available vibration data from the Dublin Port tunnel are generally of limited quality and not sufficient for calibration of the theoretical model, for application at the Metro North Scheme.

It is also unlikely that the type of TBM which was used at the Dublin Port Tunnel project is comparable to the TBM (yet unknown) which may be chosen for the Metro North Scheme, cf. Chapter 6.2.4. Also, the geological formations through which the TBM will pass, are likely to be different to those along the Dublin Port Tunnel alignment. Therefore, calibration against measurements from the Dublin Port tunnel can at best be approximate.

It is recommended to perform full-scale vibration monitoring in areas where vibration prediction has been made in order to verify and calibrate the predictions. Accumulated knowledge from vibration monitoring and comparison with predictions should be the basis for an updated assessment of ground vibrations from TBM operation.

Dynamic soil and rock properties

The geological and dynamic soil properties used in the analyses are representative for Dublin subsoil conditions. However, the actual stratification of soil and rock layers is significantly more complex along the tunnel alignment than assumed in the analyses.

Soil-structure interaction - Dynamic characteristics of buildings

The analysis of a soil structure interaction presented is for the Victoria Theatre in London. However, a soil-structure interaction for a structure of the Metro North Scheme has not been available during the Oral Hearing (e.g. vibration response of Mater Hospital, a case which was modelled by others).
**Effect of vibrations on underground structures**
According to RPA, this aspect of vibration modelling is the responsibility of the contractor. No problems are expected, even when blasting is carried out adjacent to existing tunnels or caverns. However, in the case of blasting, underground structures, water and/or gas mains etc. could be affected. This aspect should be included in the vibration risk analysis.

**Effects of construction-induced vibrations**
According to RPA, the contractor will be required to ensure, by selection of appropriate construction methods, monitoring and control, that unacceptable environmental effects do not occur. Groundborne noise from certain construction activities (drilling in rock, construction of slurry wall panels, soil compaction, driving of piles or sheet piles) can potentially give rise to environmental impacts. A detailed risk analysis should be worked out and incorporated in the vibration monitoring scheme.

**Field verification of vibration predictions**
RPA recognises that in certain instances field vibration tests are needed. These tests will be carried out by the contractor at an appropriate time, prior to excavation, such that the effects of resonance frequencies of soil layers and buildings at this critical location may be used to update prediction modelling.

In order to carry out the proposed construction works, it is important that predictions of ground vibrations and groundborne noise are verified in a consistent way by field tests. The effect of different operational modes on ground vibrations (especially in the case of TBM operation) should be investigated. The contractor should be required to produce method statements for construction work in critical areas based on field trials. The field trials should be supervised by experts in the respective technical disciplines.

**Dynamic performance of tunnel – operational phase**
Prediction of groundborne noise during operation of railway vehicles is complicated and must be based extensively on empirical data. Therefore, it is common to use field vibration tests after tunnel construction to study the dynamic response of the tunnel and of buildings on the ground.

Vibration model tests have been carried out successfully as part of the design and construction of the Copenhagen and Malmö Metro (as well as several other tunnel projects).

9.6 **Impact Assessment of Vibration and Groundborne Noise**
The impact of vibration and groundborne noise arising from the construction and operation of the proposed scheme within Area MN101 through MN107 is described in Volume 2, Chapter 5 of the EIS. The methodology of defining impact magnitudes on humans and buildings was based on the German standard, DIN 4150, which separates criteria for operational and construction vibration. DIN 4150 uses five categories of guideline values according to the location of the building. It has guideline value for vibration due to road traffic, rail traffic, short-term vibration (e.g. blasting) and construction. For rail traffic,
separate guideline values are given for underground rail traffic, surface urban transportation and surface traffic other than urban transportation.

With regard to groundborne noise, impact has been assessed based primarily on experience from railway projects, mainly in the United Kingdom (for instance from Crossrail project).

9.6.1 Definition of Vibration
The impact of vibrations propagating in the ground depends on several parameters which are used to define their impact on humans and structures. The most important parameters are:

* vibration amplitude (velocity or acceleration, for instance peak particle velocity, or rms value),
* vibration frequency (frequency spectrum and/or dominant frequency) and
* duration of vibration (number of vibration cycles).

Vibration signals can be processed (for instance filtered) for instance in order to take into account human perception (disturbance) or response of buildings and structures with different dynamic characteristics. Different vibration parameters are used in standards and regulations to establish limiting (guideline) values.

The EIS introduces the term “Impact Magnitude”, which ranges from “very low” to “very high” (five levels) in order to assess the impact of vibrations on people and on buildings. This concept avoids the use of specific limiting values which could be more readily monitored and enforced. Therefore, standards avoid subjective definitions of potential negative effects of vibrations on humans in buildings and on buildings.

9.6.2 EIS Study Area
The study area for assessment of vibrations and groundborne noise is set out in Table 5.1. Table 5.1 does not clearly state from where of the structures to be constructed, the distance shall be measured. It would be appropriate that the lateral distance should be determined from the outside edge of any structure, wall of deep excavation or tunnel, including a distance of possible deviation to that determined by the Reference Design.
9.7 Impact Magnitude – Vibration
Assessment of vibration effects in the EIS is based on DIN 4150-2 (*Effects on humans in buildings*) and on DIN 4150-3 (*Effects on structures*) for day-time and night-time periods, respectively. The assessment of groundborne noise is dealt with in Chapter 9.8, Impact Magnitude – Groundborne Noise. Different vibration criteria are used for assessing impacts during the construction phase and the operational phase, respectively. A detailed discussion of DIN 4150 and of other vibration standards is given in Error! Reference source not found..

**Construction Phase**
The criteria used in the EIA to define impact magnitude during the construction phase are shown in Table 5.2.

### Table 5.1 Study area

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Width of study area (on both sides of the alignment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Groundborne Noise – human perception</td>
<td>50m</td>
</tr>
<tr>
<td>Construction Groundborne Noise – effects on sensitive facilities</td>
<td>100m</td>
</tr>
<tr>
<td>Construction Vibration – building damage</td>
<td>50m</td>
</tr>
<tr>
<td>Construction Vibration – human perception</td>
<td>80m</td>
</tr>
<tr>
<td>Construction Vibration – effect on sensitive equipment</td>
<td>1,000m</td>
</tr>
<tr>
<td>Operational Vibration – human perception</td>
<td>50m</td>
</tr>
<tr>
<td>Operational Vibration – effect on sensitive equipment</td>
<td>100m</td>
</tr>
<tr>
<td>Operational Groundborne Noise – human perception</td>
<td>50m</td>
</tr>
<tr>
<td>Operational Groundborne Noise – effects on sensitive facilities</td>
<td>100m</td>
</tr>
</tbody>
</table>
Table 5.2 Criteria for assessment of impact magnitude during construction

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Impact magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration effect on people</td>
<td></td>
</tr>
<tr>
<td>Night $A_u &gt; 0.2, A_o &gt; 0.4, A_r &gt; 0.1$</td>
<td>very high</td>
</tr>
<tr>
<td>Day $A_u &gt; 1.6, A_o &gt; 5, A_r &gt; 1.2$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u \leq 0.2, A_o \leq 0.4, A_r \leq 0.1$</td>
<td>high</td>
</tr>
<tr>
<td>Day $A_u \leq 1.6, A_o \leq 5, A_r \leq 1.2$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u \leq 0.15, A_o \leq 0.3, A_r \leq 0.07$</td>
<td>medium</td>
</tr>
<tr>
<td>Day $A_u \leq 1.2, A_o \leq 5, A_r \leq 0.8$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u \leq 0.1, A_o \leq 0.2, A_r \leq 0.05$</td>
<td>low</td>
</tr>
<tr>
<td>Day $A_u \leq 0.8, A_o \leq 5, A_r \leq 0.4$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u \leq 0.1, A_o \leq 0.15, A_r \leq 0.05$</td>
<td>very low</td>
</tr>
<tr>
<td>Day $A_u \leq 0.4, A_o \leq 3, A_r \leq 0.2$</td>
<td></td>
</tr>
<tr>
<td>Vibration – building damage</td>
<td></td>
</tr>
<tr>
<td>&gt;50 mm/s ppv</td>
<td>very high</td>
</tr>
<tr>
<td>≤50 mm/s ppv</td>
<td>high</td>
</tr>
<tr>
<td>≤12 mm/s ppv</td>
<td>medium</td>
</tr>
<tr>
<td>≤5 mm/s ppv</td>
<td>low</td>
</tr>
<tr>
<td>≤3 mm/s ppv</td>
<td>very low</td>
</tr>
</tbody>
</table>

The table is divided into two groups: a) Vibration effects on people and b) Vibration effects on buildings. It should be noted that different definitions of vibration intensity are used for human impact ($A_u$, $A_o$ and $A_r$) and for building damage (peak particle velocity, ppv).

9.7.1 Comments - Vibration Impact During Construction Phase

The EIS omits several important assumptions on which the DIN 4150 is based. Some of the major deviations of the EIS from the DIN 4150 are:

* DIN 4150 uses quantitative values of vibration intensity. The EIS is based on an “impact magnitude” scale which is a subjective interpretation of DIN 4150, but which is not found in DIN 4150.

* Guideline values in DIN 4150-3 differentiate between types of structures and their locations. This information has been omitted in the EIS.

* No information is given in the EIS or supporting documents concerning the measurement (direction, position of sensors etc.) of vibrations in buildings. DIN 4150-3 uses different guideline values when vibrations are measured at the foundation of the building compared to measurements on upper floors.

* According to DIN 4150, vibrations shall be measured in three orthogonal directions (vertical, and two perpendicular horizontal components – the largest of the measured values shall be applied).

* An important parameter of vibration impact on buildings is vibration frequency. Guideline values for building damage are based on vibration frequency, a parameter which is not included in the EIS.
It can be concluded that the methodology of impact assessment applied in the EIS deviates substantially from the assumptions on which DIN 4150 guideline values are based.

**Operational Phase**
The criteria used to define vibration impacts associated with the operation of the proposed scheme are shown in Table 5.3. The proposed impact magnitudes are based on DIN 4150-2 which states that the guideline values $A_u$ and $A_r$ shall be applied for vibrations from railway traffic and in particular for railways in tunnels.

Comparison of the values in Table 5.3 with DIN 4150-2 shows reveals deviations, the reason for these have not been stated.

9.7.2 Comments - Vibration Impact During Operational Phase
As stated above, the DIN standard uses quantitative guideline values and does not use impact magnitudes, which is a subjective interpretation made in the EIS. The following comments can be made regarding the proposed vibration impact during the operational phase:

* DIN 4150-2, Table 1 suggests guideline values of vibration immission in residential areas for five specified building categories (1. industrial buildings; 2. industrial estates; 3. mixed residential and industrial areas; 4. mainly or only residential buildings; 5. especially sensitive areas such as hospitals, health clinics in specially assigned areas). This important distinction is not made in Table 5.3.

* It is noted that for night time vibrations, the level for “very high” impact magnitude used in Table 5.3 is slightly lower than in DIN 4150 (0.3 - 0.6 - 0.15). In contrast, the level for “low” impact magnitude is slightly higher than in DIN 4150 (0.10).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Impact magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration</td>
<td></td>
</tr>
<tr>
<td>Night $A_u = 0.2, A_r = 0.4, A_i = 0.1$</td>
<td>very high</td>
</tr>
<tr>
<td>Day $A_u = 0.4, A_r = 6, A_i = 0.2$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u = 0.2, A_r = 0.4, A_i = 0.1$</td>
<td>high</td>
</tr>
<tr>
<td>Day $A_u = 0.3, A_r = 6, A_i = 0.15$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u = 0.15, A_r = 0.3, A_i = According to DIN 4150-2: 0.10</td>
<td>medium</td>
</tr>
<tr>
<td>Day $A_u = 0.2, A_r = 5, A_i = 0.15$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u = 0.15, A_r = 0.2, A_i = 0.05$</td>
<td>low</td>
</tr>
<tr>
<td>Day $A_u = 0.15, A_r = 3, A_i = 0.07$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u = 0.1, A_r = 0.15, A_i = 0.05$</td>
<td>very low</td>
</tr>
<tr>
<td>Day $A_u = 0.1, A_r = 3, A_i = 0.05$</td>
<td></td>
</tr>
</tbody>
</table>

9.8 Impact Magnitude – Groundborne Noise

9.8.1 Definition of Groundborne Noise
Groundborne noise is experienced as sound as a result of structural vibrations (caused by walls or other structural elements). The metric which is widely used for the assessment of
Groundborne noise is the maximum A-weighted sound level using 'slow' time response, \( L_{A_{\text{max},S}} \). The symbol 'L' indicates a value expressed in decibels (abbreviated dB). A standard reference level (0 dB = 20 \( \cdot \) Pa of root mean square sound pressure) is used so that the dB scale can measure absolute levels as well as relative levels. The symbol 'A' signifies that the measured sound pressure has been subjected to frequency weighting using the standard 'A-weighting scale', to approximate the frequency response of the human ear—relatively insensitive at low frequencies and very high frequencies.

The symbol 'S' specifies a method of averaging the oscillating sound pressure, by exponential averaging as defined in IEC 61672 (2002), using the standard 'slow' time constant of one second—the alternative being the 'F' or 'fast' time constant of 1/8 second. 'S' has a greater smoothing effect on sound that varies in level. The symbol 'max' means the highest averaged value reached during an event such as the passage of a train. Different criteria for groundborne noise are used for assessing impacts during the construction phase and the operational phase, respectively.

**Construction Phase**

The groundborne noise criteria used in the EIA to define impact magnitude during the construction phase are shown in Table 5.2. Separate day-time thresholds have been used which are 5 dB above the night-time thresholds.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Impact magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dwellings, Offices, Hotels, Schools, Colleges, Hospital Wards, Libraries</strong></td>
<td></td>
</tr>
<tr>
<td>Groundborne noise (TBM)</td>
<td></td>
</tr>
<tr>
<td>Night ( L_{A_{\text{max},S}} \geq 50\text{dB} )</td>
<td>very high</td>
</tr>
<tr>
<td>Day ( L_{A_{\text{max},S}} \geq 55\text{dB} )</td>
<td></td>
</tr>
<tr>
<td>Night ( 45\text{dB} &gt; L_{A_{\text{max},S}} \leq 50\text{dB} )</td>
<td>high</td>
</tr>
<tr>
<td>Day ( 50\text{dB} &gt; L_{A_{\text{max},S}} \leq 55\text{dB} )</td>
<td></td>
</tr>
<tr>
<td>Night ( 40\text{dB} &gt; L_{A_{\text{max},S}} \leq 45\text{dB} )</td>
<td>medium</td>
</tr>
<tr>
<td>Day ( 45\text{dB} &gt; L_{A_{\text{max},S}} \leq 50\text{dB} )</td>
<td></td>
</tr>
<tr>
<td>Night ( 35\text{dB} &gt; L_{A_{\text{max},S}} \leq 40\text{dB} )</td>
<td>low</td>
</tr>
<tr>
<td>Day ( 40\text{dB} &gt; L_{A_{\text{max},S}} \leq 45\text{dB} )</td>
<td></td>
</tr>
<tr>
<td>Night ( L_{A_{\text{max},S}} \leq 35\text{dB} )</td>
<td>very low</td>
</tr>
<tr>
<td>Day ( L_{A_{\text{max},S}} \leq 40\text{dB} )</td>
<td></td>
</tr>
</tbody>
</table>

| Groundborne noise (TBM) | |
| \( L_{A_{\text{max},S}} \geq 55\text{dB} \) | very high |
| 50dB > \( L_{A_{\text{max},S}} \leq 55\text{dB} \) | high |
| 45dB > \( L_{A_{\text{max},S}} \leq 50\text{dB} \) | medium |
| 40dB > \( L_{A_{\text{max},S}} \leq 45\text{dB} \) | low |
| \( L_{A_{\text{max},S}} \leq 40\text{dB} \) | very low |
**Operational Phase**

RPA have proposed to apply criteria of groundborne noise during the operational phase as shown in Table 5.3

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Impact magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwellings, Offices, Hotels, Schools, Colleges, Hospital Wards, Libraries</td>
<td></td>
</tr>
<tr>
<td>Groundborne noise</td>
<td></td>
</tr>
<tr>
<td>$L_{Amax,S} &gt; 45$ dB</td>
<td>very high</td>
</tr>
<tr>
<td>$40$ dB $&gt; L_{Amax,S} \leq 45$ dB</td>
<td>high</td>
</tr>
<tr>
<td>$35$ dB $&gt; L_{Amax,S} \leq 40$ dB</td>
<td>medium</td>
</tr>
<tr>
<td>$30$ dB $&gt; L_{Amax,S} \leq 35$ dB</td>
<td>low</td>
</tr>
<tr>
<td>$L_{Amax,S} \leq 30$ dB</td>
<td>very low</td>
</tr>
</tbody>
</table>

| Places of meeting for religious worship, courts, lecture theatres, small auditoria – Sensitive During Daytime Only | |
| Groundborne noise | |
| $L_{Amax,S} > 40$ dB | very high |
| $35$ dB $> L_{Amax,S} \leq 40$ dB | high |
| $30$ dB $> L_{Amax,S} \leq 35$ dB | medium |
| $25$ dB $> L_{Amax,S} \leq 30$ dB | low |
| $L_{Amax,S} \leq 25$ dB | very low |

According to the EIS, the above criteria are proposed to be applied along Metro North as follows:

* To ensure that noise disturbance during operation of Metro North is minimised, the maximum permissible level of groundborne noise that may be generated during operation does not exceed $40$ dB $L_{Amax,S}$ determined near the centre of any occupied sensitive room of an inhabited building.

* Between Parnell Street and Albert College Park the maximum permissible groundborne noise that may be generated during operation does not exceed $25$ dB $L_{Amax,S}$ determined near the centre of any occupied sensitive room of an inhabited building.

During the Oral Hearing it was stated by RPA experts that the guideline values shown in Table 5.3 are based on international practice.

**9.8.2 Comments - Groundborne Noise Impact During Construction Phase**

Levels of groundborne noise proposed in Table 5.2 appear to be reasonable from a construction viewpoint but can potentially give rise to complaints from residents. RPA have indicated that the contractor will make efforts to find agreements with residents in areas where levels of groundborne noise are likely to be high or impact magnitudes exceeded. Temporary relocation of residents or other forms of compensation could be explored in discussions with residents.
9.8.3 Comments - Groundborne Noise Impact During Operational Phase
In order to verify which levels of groundborne noise that are applied on similar tunnelling projects in Europe and the USA, a survey standards and national regulations has been performed. In addition, the requirements for similar railway tunnel projects in several Scandinavian countries were reviewed, cf. Appendix 3 – Background Information on Vibrations and Noise.

International Standards and Regulations
The limiting values of groundborne noise suggested by RPA are allegedly based on similar projects in other countries (primarily UK). In order to verify the level of groundborne noise applied in other countries with similar geological conditions and comparable, environmental ambitions and standard of living, regulations and guideline values have been compiled in Appendix 3 – Background Information on Vibrations and Noise.

Information obtained from hearings in connection with the Crossrail project as well as regulations and national standards is summarized below:

Crossrail Project
RPA have on several occasions referred to the groundborne noise levels to be applied at the Crossrail project in London and reference was made to information presented during the Oral Hearing. Inspection of the final Version 4 of the document: "D10 – Groundborne Noise and Vibration", dated 03/04/08 shows new considerations which were not known at the time of the Oral Hearing. In the introduction of the final Version 4 the following note is made:

"An Information Paper on groundborne noise and vibration (IP D10) was published in January 2006 (Version 1). This revised Information Paper sets out an updated version of IP D10, reflecting discussions held with the London Borough of Camden, the lead local authority on the generic issue of groundborne noise and vibration, since January 2006, and replaces earlier versions."

The following additional comment has been added to the initial document, which expresses the requests by local authorities to apply more rigorous levels of groundborne noise for residential dwellings:

"2.13 In recognition of the local authorities’ preference for groundborne noise levels within residential dwellings which are not greater than 35 dB $L_{A_{max,S}}$ during the operation of Crossrail, the nominated undertaker will provide the information identified in paragraph 4.2 to the relevant local authority where any residential property is predicted through modelling as being likely to experience noise levels exceeding 35 dB $L_{A_{max}}$.”

Local authorities requested the application of a limiting value of 35 dB $L_{A_{max,S}}$ for residential dwellings.

Regulations by the US Department of Transportation
The below table summarizes the recommendations with regard to groundborne noise for different types of land use, to be used for railway projects in the USA.
The recommendation is that for residences and buildings where people normally sleep, groundborne noise should not exceed 35 dB $L_{A_{max,S}}$.

**Standards and Regulations in European Countries**

In Appendix 3 – Background Information on Vibrations and Noise, a survey of guideline values for railway projects applied in Denmark, Norway, Sweden and Switzerland for groundborne noise shows that for inhabited buildings and residential areas, ground borne noise should not exceed 35 dB $L_{A_{max,S}}$.

**Inventory of Recent Railway Projects in Scandinavia**

An inventory of railway projects recently constructed in Scandinavia suggests that reference values for residential areas are not allowed to exceed 35 dB $L_{A_{max,S}}$.

Because of the importance of this aspect of the EIS, which will influence the living environment of many people during the lifetime of the proposed scheme, and considering the increasing awareness of the public with regard to environmental impact, it is appropriate not to permit levels of groundborne noise which will be experienced as unacceptable.

**9.9 Recommendation - Groundborne Noise**

The levels of groundborne noise proposed for the construction period appear to be acceptable. The contractor should be encouraged to find agreement with resident in order to carry out the temporary work in an efficient manner.

With regard to limits on groundborne noise during the operational phase, more restrictive levels appear to be appropriate. Groundborne noise will have permanent impact on residents living above and in the vicinity of the proposed Metro North Scheme. The lasting impression of the project will to a high degree depend on how residents and the public experience groundborne noise. Groundborne noise usually increases during the lifetime of a railway scheme, in spite of maintenance and other mitigation efforts.
Review of standards in Europe and the United States and practice applied on recent railway projects in Scandinavia suggests that for residential areas, groundborne noise at night time should not exceed $35 \text{ dB } L_{\text{Amax,S}}$.

Therefore, groundborne noise levels applied at the Metro North Scheme should not fall short of the environmental requirements which are applied in countries with comparable geological conditions and similar environmental ambitions.
Appendix 1

Description of and Comments on MN101– MN 107

Geotechnical and Hydrogeological Mitigation Measures including Ground Vibrations and Groundborne Noise

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Description of and Comments on MN101–MN 107

Geotechnical and Hydrogeological Mitigation Measures including Ground Vibrations and Groundborne Noise

Metro North Scheme Environmental Impact Evaluation

This Appendix serves as background documentation of the information obtained during the Oral Hearing, submissions by observers and RPA response. For each of the seven project areas (MN101 through MN107), the following information is provided:

1. Area Description
2. Impact on Human Beings – Vibrations
3. Soil and Geology
4. Groundwater

Comments regarding environmental impact during the construction and operational phase are given. Also, a list of submission, observations for the respective area with comments is added for reference. All submissions are listed although only a limited number of which are related to hydrogeology, settlement and vibration.

The following information was used as reference documentation for preparation of the Environmental Impact Assessment Report.
1 Area MN101 - Belinstown to Swords Stop

1.1 Area Description
Area MN101 begins at Belinstown which is located approximately 1.6km to the north of Swords, adjacent to and directly west of the M1 motorway, on land that is currently used for agriculture. The maintenance and stabling facilities for the proposed scheme are located at the depot in this area. A 110kV substation serving the scheme is to be located in this area. The northern terminus stop of the scheme, Belington, lies immediately southwest of the depot. A Park & Ride facility with 2,000 parking spaces, designed as a multi-storey car park, is planned adjacent to the stop. From Belinstown, the proposed route passes southwards, across green field land at surface level, to a provisional stop at Lissenhall. This stop is located in a green field site to the west of the interchange between the M1 and R132 in an area of potential development proposed by Fingal County Council. The route continues southwards and crosses the Broad Meadow River and the Ward River and then runs at surface level along the western verge of the R132 to a second provisional stop at Estuary. The route then rises up onto an elevated section of track which crosses over the Estuary Roundabout, travels along the median of the R132 and over the Seatown Roundabout before descending to reach the next at grade stop, at Seatown. The Seatown Stop is located in the central median of the R132. The Estuary and Seatown Roundabouts are to be converted to signal controlled junctions. After Seatown Stop, the route proceeds southward son the surface along the central median of the R132 and then descends to pass under the Malahide Roundabout. To the south of the roundabout, the route emerges from the underpass and rises to the surface in the median of the R132 to the Swords Stop which is located opposite the Pavilions Shopping Centre. Initially, access to this stop is by pedestrian crossings of the R132. However, provision is made to allow this stop to be accessed from a possible future east-west bridge over the R132. Swords Stop marks the end of Area MN101.

1.2 Human Beings Vibrations

1.2.1 Assessment of residual impacts

1.2.1.1 Construction Phase
For this part of the proposed scheme, vibration sources during the construction phase will be limited to construction plant operating on worksites. Most construction plant is not likely to generate vibration that will be perceptible at offsite locations. Therefore, vibration impacts have been considered from the particular plant items that have the potential to generate perceptible levels of vibration. The activities that are most likely to fall into this category are bored piling and the use of vibratory rollers. These activities are unlikely to take place outside of daytime working hours.
1.2.1.2 **Operational Phase**
The main source of vibration and groundborne noise during the operation of the scheme is the wheel/rail interaction during the movement of light metro vehicles.

1.2.2 **Summary of residual impacts**
The potential noise and vibration effects from construction and operation of the proposed scheme have been assessed. An assessment of the requirements for mitigation has been undertaken. A summary of the residual impacts associated with the proposed scheme is provided in Table 5.4.

<table>
<thead>
<tr>
<th>Construction phase</th>
<th>Magnitude of impact taking into account mitigation</th>
<th>Functional value of area affected</th>
<th>Significance of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration affecting humans</td>
<td>low</td>
<td>very high</td>
<td>Not Significant</td>
</tr>
<tr>
<td>Vibration affecting buildings</td>
<td>low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment</td>
<td>low</td>
<td>Very high</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operational phase</th>
<th>Magnitude of impact taking into account mitigation</th>
<th>Functional value of area affected</th>
<th>Significance of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration affecting humans</td>
<td>very low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment</td>
<td>very low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

1.3 **Soil and Geology**
The only underground structure in Area MN101 is the Malahide Roundabout underpass. No significant settlement impacts are anticipated.

1.3.1 **Assessment of residual impacts**

1.3.1.1 **Excavation**
Excavation of soil will occur along the track line in Area MN101 and for the underpass at Malahide Roundabout. The magnitude of the impact associated with this activity (i.e. excavating an area during construction) is high as soil disturbance has a high impact on soil function. The majority of the excavated areas are located in areas of medium functional value so the impacts will have moderate significance. However, areas of made-ground and existing paving such as those along the R132 and the Malahide Roundabout have lower functional value and the significance of impact is reduced to Low and Very low respectively.

1.3.1.2 **Summary of residual impacts**
A summary of the residual impacts associated with the scheme and affecting this area is provided in Table 9.3.
1.4 Groundwater
This section of the route is mainly at-grade but some excavations will extend to approximately 7m below ground level.

1.4.1 Assessment of residual impacts

1.4.1.1 Construction phase
All of the impacts identified for the construction phase of the proposed scheme for this section of the route were found to be of Low significance.

1.4.1.2 Operational phase
All of the impacts identified for the operational phase of the proposed scheme for this section of the route were found to be of Low significance. It is likely that discharge of groundwater will be required. Unless they are suitably controlled, such activities have the potential to temporarily cause minor reductions in the level of the water table. No significant long-term lowering of the water table is expected as a consequence of building the proposed scheme. Lowering of the water table will be limited to 1m depths during construction. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is Low and the impact affects an area of Medium functional value. Therefore, the impact is considered to be of Low significance.

1.5 Comments on Environmental Impact - MN101
Low impact from construction vibration is predicted in this area, (see the Vibration chapters of this EIS (Volume 2, Chapter 5)). No impact on Human Health is therefore predicted. Modelling predicts no significant effect from the operational phase either in terms of groundborne noise, vibration effect in humans and vibration affecting sensitive equipment. Based on this no adverse effect on human health is predicted.

1.6 Submissions and Observations with Comments

<table>
<thead>
<tr>
<th>OBSERVER</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barry &amp; Sally Hare – Balheary, Belinstown</td>
<td>Agreement reached with RPA.</td>
</tr>
<tr>
<td>Brian &amp; Ailbhe Doyle – Belinstown</td>
<td></td>
</tr>
<tr>
<td>Fingallians GAA – Estuary</td>
<td></td>
</tr>
<tr>
<td>Ger Dwyer &amp; Others – Belinstown</td>
<td></td>
</tr>
<tr>
<td>James &amp; Siobhan Flynn – Belinstown</td>
<td></td>
</tr>
<tr>
<td>James and William Flynn Lands in support of</td>
<td></td>
</tr>
</tbody>
</table>
Metro North. Flynn farm needs access to property. Rural road to be constructed. Landscaping mound at MN depot

James & William Flynn – Belinstown
John & Ann Graham – Belinstown
John Fleming – Belinstown
Kevin & Mary Fox – Balheary, Belinstown
Mary & Des Rainey – Belinstown
Mary & John Bond – Belinstown
Matt & Linda Graham – Belinstown
Michael & Tom Bailey (Bovale Developments Ltd.) (Barrysparks, Swords)
Michael & Tom Bailey (Bovale Developments Ltd.) (Lissenhall)
Michael Jones – Magillistown
MKN Property Group – Seatown, Swords
Padraig Flynn – Belinstown
Percy Nominees Ltd. – Seatown
Salix Trust Ltd. (Swords) – MN 101
Sean & Noel Brangan – Belinstown
Siemens Healthcare Diagnostics Manufacturing Ltd. – Swords
Stephen & Heather Joynt – Belinstown
Sylvia Jones & Thomas Guy – Swords
Teba Ltd. – Pavillion, Swords Stop
Tempore Ltd. – Swords

Total Produce Ltd. – Swords
Una Donnelly – Batter Lane, Belinstown

Agreement between RPA and Tempore Ltd (redacted): Amendment to RPA and Tempore Ltd.
2 Area MN102 - Swords Stop to Dublin Airport north portal

2.1 Area Description
South of the Swords Stop, the route rises up onto an elevated section of track to cross over Pinnock Hill Roundabout and continues south to an at grade stop at Fosterstown. This stop is located north of the Airside Retail Park on the east side of the R132. An at grade Park & Ride car park with 300 spaces is to be provided to the east of this stop. The route then continues southwards along the east side of the R132 and then descends to cross under the R132 just south of the junction at Airside and Boroimhe. The route emerges from the underpass, passes under a new accommodation bridge serving a local business at Fosterstown to rise to the surface and onto embankments through a greenfield area. A turnback facility is provided in this area to the north of the airport to allow some Metro services to reverse at the airport in the future. An agricultural underpass is located beneath the turnback facility. The turnback facility marks the end of Area MN102.

2.2 Human Beings Vibrations

2.2.1 Assessment of residual impacts

2.2.1.1 Construction Phase
For this part of the railway, vibration sources during the construction phase will be limited to construction plant operating on worksites. Most construction plant is not likely to generate vibration that will be perceptible at off-site locations. Therefore, vibration impacts have been considered from the particular plant items that have the potential to generate perceptible levels of vibration. The activities that are most likely to fall into this category are bored piling and the use of vibratory rollers. These activities are unlikely to take place outside of daytime working hours.

2.2.1.2 Operational Phase
The main source of vibration and groundborne noise during the operation of proposed scheme is the wheel/rail interaction during the movement of trams.

2.2.2 Summary of residual impacts
The potential groundborne noise and vibration effects from construction and operation of the proposed scheme in Area MN102 have been assessed. An assessment of the requirements for mitigation has been undertaken. A summary of the residual impacts associated with the scheme is provided in Table 5.4.
Table 5.4 Summary of residual impacts

<table>
<thead>
<tr>
<th></th>
<th>Magnitude of impact taking into account mitigation</th>
<th>Functional value of area affected</th>
<th>Significance of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibration affecting humans</td>
<td>low at most locations; very high, briefly at one location</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting buildings</td>
<td>low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment</td>
<td>low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Operational phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibration affecting humans</td>
<td>very low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment</td>
<td>very low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

2.3 Soil and Geology
To assess the impact of ground movements on section MN102 a Stage 1 Preliminary Ground Movement Assessment and Stage 2A Preliminary Building Response Assessment have been undertaken.

2.3.1 Assessment of residual impacts

2.3.1.1 Construction Phase
Where the Fosterstown Underpass runs alongside and traverses the Dublin Road in Area MN102, the road is predicted to settle in the region of 5mm close to the face of the excavation, with a corresponding maximum settlement slope of 1:1333 predicted. Based on experience of highway maintenance, settlements of up to 50mm are considered permissible for carriageways and can be managed for temporary situations provided ground slope is not greater than 1:500 which is the case for Area MN102.

Compaction
Compacted areas will occur during the construction phase in Area MN102. These will include parts of the track, the stops, the Park & Ride facility at the Fosterstown Stop, the underpass at R132, access roadways, roads, footpaths and the construction compounds. The magnitude of the impact associated with the compacting of an area during construction is high as the soil is compressed and disturbed.

Excavation
Excavation of soil will occur along the track line in Area MN102 and at the underpass of the R132. The magnitude of the impact associated with this activity (i.e. excavating an area during construction) is high as soil disturbance has a high impact on soil function. The majority of the excavated areas are located in areas of medium functional value so the impacts will have Medium significance.
Settlement
For Section MN102 the residual impact is a maximum predicted settlement in the region of 5mm for the Fosterstown Underpass. The significance of this impact is Very low.

2.3.1.2 Operational Phase
During the operational phase the Fosterstown Underpass will not generate further ground movement. The structure is designed to prevent long-term ground movements resulting from groundwater lowering occurring.

2.3.2 Summary of residual impacts

<table>
<thead>
<tr>
<th>Location</th>
<th>Area of land-take (m²)</th>
<th>Type of impact</th>
<th>Significance of Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>MN 102</td>
<td>37,000</td>
<td>Paved</td>
<td>medium to very low</td>
</tr>
<tr>
<td>MN 102</td>
<td>54,000</td>
<td>Potentially Disturbed Ground</td>
<td>medium to very low</td>
</tr>
</tbody>
</table>

2.4 Groundwater

2.4.1 Assessment of residual impacts

2.4.1.1 Construction phase
Groundwater encountered in excavations may be hydraulically connected to the underlying aquifer. Alternatively shallow groundwater encountered in excavations may indicate perched water, which is not hydraulically connected to the underlying aquifer but located instead above a low permeability clay layer. The accidental release at the surface of potential contaminants such as oils or solvents into groundwater encountered in excavations has the potential to contaminate the underlying aquifer, in the event that it is hydraulically connected to the aquifer. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of medium functional value. Therefore, the overall impact is considered to be of Low significance. This section of the route is mainly at-grade or elevated but some excavations will extend to approximately 7m below ground level (bgl).

2.4.1.2 Operational phase
With the mitigation measures set out in Section 10.4.2, the magnitude of this impact is low and the impact affects an area of medium functional value. Therefore, the impact is considered to be of Low significance.

2.5 Comments on Environmental Impact - MN102
Low impact from construction vibration is predicted in this area, (see the Vibration chapters of this EIS (Volume 2, Chapter 5)). No impact on Human Health is therefore predicted. Modelling predicts no significant effect from the operational phase either in terms of groundborne noise, vibration effect in humans and vibration affecting sensitive equipment. Based on this no adverse effect on human health is predicted.
<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>David Daly</td>
<td>Airside</td>
<td>Concern about business.</td>
</tr>
<tr>
<td>Irish Property Unit Trust &amp;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irish Life Investment</td>
<td>Managers – Fosterstown</td>
<td></td>
</tr>
<tr>
<td>Juliana &amp; Joseph Boland</td>
<td>Nevinstown</td>
<td>Environmental concerns regarding noise and vibration. Acquisition of land.</td>
</tr>
<tr>
<td>Nethercross Holdings Ltd.,</td>
<td>Fosterstown</td>
<td></td>
</tr>
<tr>
<td>Residents of Carlton Court</td>
<td>Pinnock Hill</td>
<td></td>
</tr>
<tr>
<td>Tadgh &amp; Maureen O'Scannaill</td>
<td>Pinnock Hill</td>
<td>Traffic impact</td>
</tr>
</tbody>
</table>
3 Area MN103 - Dublin Airport

3.1 Area Description
The route enters two bored tunnels (one for northbound services and one for southbound) to the north of Dublin Airport. A tunnel portal and ventilation building is located in this area. The route traverses the airport in a southerly direction passing under the Airport South Perimeter Road (Collinstown Lane) which marks the end of Area MN103. An underground stop, Airport, is located on this tunnelled section close to the existing airport terminal on the site of the proposed airport Ground Transportation Centre.

3.2 Human Beings Vibrations

3.2.1 Assessment of residual impacts

Construction Phase
Two principal methods of mitigation are available for tunnel boring. The first is to limit hours of operation to avoid the more sensitive night period. The second method is optimisation of TBM characteristics including face pressure and selection of cutters and teeth.

The following incorporated mitigation measures have been assumed:

Work may only be carried out between 07h00 and 23h00, Monday to Saturday but excluding bank holidays (‘core permitted underground working hours’) except that work may be carried out at times outside the core permitted underground working hours in the following cases:

i) groundborne noise levels are not in excess of 40dB LA_{max,s} \text{, where LA}_{max,s} \text{ is as defined in IEC 61672, 2002} as measured near the centre of any occupied sensitive room of an inhabited building.

or

ii) groundborne noise levels are in excess of 40dB LA_{max,s} \text{, where LA}_{max,s} \text{ is as defined in IEC 61672, 2002} as measured near the centre of any occupied sensitive room of an inhabited building provided that that work does not cause noise disturbance, where noise disturbance is defined as any complaint made by any person who is the occupant of a sensitive room in an inhabited building

or

iii) the full extent of the tunnel drives under the airport as well as for the Airport Stop where working hours of 24 hours per day seven days per week will be permitted without restriction.

Operational Phase
It is assumed that the following specification will be imposed:
To ensure that noise disturbance during operation of the proposed scheme is minimised, InfraCo shall ensure that the maximum permissible level of groundborne noise that may be generated during operation does not exceed 40dB $L_{A,max,S}$ determined near the centre of any occupied sensitive room of an inhabited building, except at the following locations:

(b) An inhabited building is a building which is in whole or in part lawfully used either temporarily or permanently as a dwelling, hospital, hostel or hotel. An occupied sensitive room is a room in an inhabited building that is a hospital ward, living room, or bedroom which is not a kitchen, bathroom, WC or circulation space that is in use as a living room or bedroom at the time the works are being carried out.

### 3.2.2 Summary of residual impacts

The potential noise and vibration effects from construction and operation of the proposed scheme have been assessed. An assessment of the requirements for mitigation has been undertaken. A summary of the residual impacts associated with the scheme is provided in Table 5.4.

<table>
<thead>
<tr>
<th>Table 5.4 Summary of residual impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction phase</strong></td>
</tr>
<tr>
<td>Groundborne noise</td>
</tr>
<tr>
<td>Vibration affecting humans</td>
</tr>
<tr>
<td>Vibration affecting buildings</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment</td>
</tr>
<tr>
<td><strong>Operational phase</strong></td>
</tr>
<tr>
<td>Groundborne noise</td>
</tr>
<tr>
<td>Vibration affecting humans</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment</td>
</tr>
</tbody>
</table>

### 3.3 Soil and Geology

This chapter of the EIS describes the potential impacts on soils and geology, which may arise due to activities associated with the construction and operation of the proposed scheme in Area MN103. In addition this chapter also considers the impact of ground movements generated by construction of the bored and mined tunnels and Airport Stop cut and cover structure on overlying and adjacent property.
3.3.1 Assessment of residual impacts

**Construction Phase**

**Compaction**
Compacted areas will occur during the construction phase in Area MN103. These will include parts of the track, the tunnel portal, the tunnel and the Airport Stop. The magnitude of the impact associated with compaction of an area during construction is high as the soil is compressed and disturbed and this has a detrimental effect on its ability to perform its natural functions. The compacted areas at the tunnel portal will be constructed predominantly in areas of high functional value so the magnitude and significance of this impact is high. When the mitigation measures are taken into consideration, the magnitude and significance of this impact remains the same but the footprint of the area impacted upon decreases.

There are also areas of natural soil, made-ground and paved areas such as areas to the north of the tunnel portal and at the halting site. These have lower functional value and the significance of impacts in these areas decreases to Medium, Low and Very low respectively. The locations of paved areas are illustrated on the Landscape Insertion Plans in the Landscape and Visual chapter of this EIS (Volume 2, Chapter 13).

**Excavation**
Excavation of soil will occur at the tunnel portal and the Airport Stop. The magnitude of impact associated with this excavation activity is high as the soil has been disturbed. Excavation associated with the tunnel portal is to occur in areas of high functional value so the impact is of High significance. There are also areas of made-ground and paved areas such as the halting site in this area. These areas are of lower functional value with respect to soil and the impact is of Low to Very low significance.

Excavation associated with the Airport Stop occurs in an area of very low functional value, so the impact is of Very low significance. The locations of paved areas are illustrated on the Landscape Insertion Plans in the Landscape and Visual chapter of this EIS (Volume 2, Chapter 13).

**Settlement**
For Area MN103 the residual impact is a maximum predicted settlement of 15mm. The significance of the impact is Very low.

**Operational Phase**
During the operational phase Metro North infrastructure will not generate further ground movement. The underground structures are designed as undrained (watertight) and therefore long-term ground movements beyond the construction phase are not expected to occur.
3.3.2 Summary of residual impacts
A summary of the residual impacts associated with the scheme and affecting this area is provided in Table 9.4.

Table 9.4 Summary of residual impacts

<table>
<thead>
<tr>
<th>Location</th>
<th>Area of land-take (m²)</th>
<th>Type of impact</th>
<th>Significance of Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>MN103</td>
<td>52,000</td>
<td>Paved</td>
<td>Predominantly Low to Very low. Medium to High in the area of the Northern Airport Tunnel Portal</td>
</tr>
<tr>
<td>MN103</td>
<td>12,000</td>
<td>Potentially Disturbed Ground</td>
<td>Predominantly Low to Very low. Medium to High in the area of the Northern Airport Tunnel Portal</td>
</tr>
</tbody>
</table>

3.4 Groundwater

3.4.1 Assessment of residual impacts

Construction phase
During the construction phase of this section of the route, there is the minor potential for localized alteration of groundwater flow around the tunnel. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of low functional value. Therefore, the impact is considered to be of Low significance. There is the potential for cumulative adverse impacts on groundwater along this section of the route during dewatering activities that may be required during the construction of Dublin Airport Terminal 2. However, the implementation of the mitigation measures recommended in Chapter 11 (Soils, Geology and Groundwater) of the EIS for Dublin Airport – Terminal 2 (Ove Arup and Partners International Ltd., 2006) for the Dublin Airport Authority will help ensure that such impacts are of Low significance.

Operational phase
During the operational phase of this section of the route, there is potential for localized alteration of groundwater flow around the tunnel. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of low functional value. Therefore, the impact is considered to be of Low significance.

3.5 Comments on Environmental Impact - MN103
Low impact from construction vibration is predicted in this area, (see the Vibration chapters of this EIS (Volume 2, Chapter 5)). No impact on Human Health is therefore predicted. Modelling predicts no significant effect from the operational phase either in terms of groundborne noise, vibration effect in humans and vibration affecting sensitive equipment. Based on this no adverse effect on human health is predicted.
3.6 Submissions and Observations with Comments

McComish Ltd. – Cloghran, Fosterstown
Shaun McComish – Cloghran, Fosterstown

4 Area MN104 – Dublin Airport south portal to Santry Avenue

4.1 Area Description
South of the Airport Perimeter Road, the route emerges from tunnel and rises to surface level. A tunnel portal and ventilation building is located in this area. The route then turns south-west to cross agricultural lands between Dublin Airport and the M50 motorway. Dardistown Stop is located in this area on a greenfield site to the north of the M50. An at grade Park & Ride facility with 300 parking spaces is proposed for this location, to the north of the stop. Space provision is made at this stop for a future operational link to the proposed Metro West line. A 110kV substation is to be located in this area. Continuing south, the route crosses the M50, associated slip roads, and Old Ballymun Road on bridges. South of these bridges the route passes over the culverted Santry River, and proceeds south descending to surface level at the next stop, Northwood, which is an at grade stop located near Santry Lodge, south of the M50. South of Northwood Stop, the route descends into a cut and cover tunnel along the median of the R108 (Ballymun Road). This tunnel passes under Santry Avenue. This area is also marked by the boundary between the Fingal County Council and Dublin City Council.

4.2 Human Beings Vibrations
This chapter of the EIS evaluates the potential vibration impacts arising from the construction and operation of the proposed scheme within Area MN104.

4.2.1 Assessment of residual impacts

Construction Phase
South of Northwood Stop, the route descends into a cut and cover tunnel along the median of the R108 (Ballymun Road) passing 21m from the nearest house in Coultry Road. Low vibration impacts are likely from the excavation of the cut-and-cover tunnel unless boulders are encountered requiring percussive or explosive techniques to remove them. This is not likely, and therefore is not assumed in this assessment.

Operational Phase
In any case where either a Medium, High or Very high significant impacts for groundborne noise are identified in this way, or where ‘not to exceed’ limits for sensitive equipment would be exceeded, incorporated mitigation in the form of floating slab track is assumed. South of Northwood Stop, the route descends into a cut and cover tunnel along the median of the R108 (Ballymun Road) passing 21m from the nearest house in Coultry Road. Low vibration or groundborne noise impacts are likely with standard resilient rail support.
4.2.2 Summary of residual impacts
The potential noise and vibration effects from construction and operation of the scheme have been assessed. An assessment of the requirements for mitigation has been undertaken. A summary of the residual impacts associated with the proposed scheme is provided in Table 5.4.

Table 5.4 Summary of residual impacts

<table>
<thead>
<tr>
<th>Construction phase</th>
<th>Magnitude of impact taking into account mitigation</th>
<th>Functional value of area affected</th>
<th>Significance of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundborne noise</td>
<td>low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting humans</td>
<td>low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting buildings</td>
<td>low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment</td>
<td>low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operational phase</th>
<th>Magnitude of impact taking into account mitigation</th>
<th>Functional value of area affected</th>
<th>Significance of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundborne noise</td>
<td>low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting humans</td>
<td>very low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment</td>
<td>very low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

4.3 Soil and Geology

4.3.1 Assessment of residual impacts

Construction Phase

Compaction
Compacted areas will occur during the construction phase in Area MN104. These compacted areas will include the tunnel boring launch site, the tunnel portal, the cut and cover section at R108, parts of the track, embankments, electricity substations, bridge over M50, the stops, the Park & Ride facility, access roadways, bridges, roads and footpaths and the construction compounds. The magnitude of the impact associated with the compacting of an area during construction is high as the soil is compressed and disturbed. The compacted areas will be constructed in areas of medium functional value so the impacts will have Medium significance. When the mitigation measures are taken into consideration, the magnitude and significance of this impact remains the same but the footprint of the area impacted upon decreases. There are two areas of high functional value, a section of the hedgerows along the access road to the DOE test centre and an area around Santry Lodge. The track will cross through this area and compaction will occur. This impact will have High significance.
There are also areas of made-ground and existing paved areas such as those along the M50 and R108. These areas are of lower functional values and therefore the significance of impact is reduced to Low and Very low respectively.

**Excavation**
Excavation of soil will occur at the tunnel boring launch site, the tunnel portal, cuttings and the cut and cover section at R108. The magnitude of the impact associated with this activity (i.e. excavating an area during construction) is high as soil disturbance has a High impact on soil function. The excavated area will be constructed in an area of medium functional value so the impacts will have Medium significance.

**Settlement**
For Area MN104 the residual impact is a maximum predicted settlement of 15mm. The significance of the impact is Very low.

**Operational Phase**
During the operational phase the proposed scheme infrastructure will not generate further ground movement. The underground structures are designed as undrained (watertight) and therefore long term ground movements beyond the construction phase are not expected to occur.

### 4.3.2 Summary of residual impacts
A summary of the residual impacts associated with the scheme and affecting this area is provided in Table 9.3.

<table>
<thead>
<tr>
<th>Area</th>
<th>Chainage From</th>
<th>Chainage To</th>
<th>Maximum Settlement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northwood to South of Ballymun</td>
<td>10+780 m</td>
<td>12+170 m</td>
<td>5mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Area of land-take (m²)</th>
<th>Type of Impact</th>
<th>Significance of Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>MN104</td>
<td>77,000</td>
<td>Paved</td>
<td>Predominantly Low to Very low. Medium to High in the area of the Northern Airport Tunnel Portal (in Area MN104)</td>
</tr>
<tr>
<td>MN104</td>
<td>208,000</td>
<td>Potentially Disturbed Ground</td>
<td>Predominantly Low to Very low. Medium to High in the area of the Northern Airport Tunnel Portal (in Area MN104)</td>
</tr>
</tbody>
</table>
4.4 Groundwater

4.4.1 Assessment of residual impacts

Construction phase
This section of the route will include a cut and cover tunnel. According to the baseline Groundwater chapter of this EIS (Volume 1, Chapter 18), groundwater has been encountered within 1m below ground level (bgl) along this section of the route. Therefore, it is likely that dewatering activities will be required. Unless they are suitably controlled, dewatering activities have the potential to temporarily cause minor reductions in the level of the water table. No significant long-term lowering of the water table is expected as a consequence of building the proposed scheme. Lowering of the water table will be limited to 1m depths during construction. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of medium functional value. Therefore, the impact is considered to be of Low significance.

Operational phase
During the operational phase of the proposed scheme, there is a slight potential for localised alteration of groundwater flow around the underground structures (piles) for the bridges and the cut and cover tunnel. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of medium functional value. Therefore, the impact is considered to be of Low significance.

With the mitigation measures set out in Section 10.4.2, the magnitude of this impact is low and the impact affects an area of medium functional value. Therefore, the impact is considered to be of Low significance.

4.5 Comments on Environmental Impact - MN104
Low impact from construction vibration is predicted in this area, (see the Vibration chapters of this EIS (Volume 2, Chapter 5)). No impact on Human Health is therefore predicted. Modelling predicts no significant effect from the operational phase either in terms of groundborne noise, vibration effect in humans and vibration affecting sensitive equipment. Based on this no adverse effect on human health is predicted.

4.6 Submissions and Observations with Comments

<table>
<thead>
<tr>
<th>OBSERVER</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosgrave Developments – Northwood Stop</td>
<td></td>
</tr>
<tr>
<td>Dunlix Investments (Ireland) Ltd. – Northwood</td>
<td></td>
</tr>
<tr>
<td>Hainvale Ltd. – Dardistown</td>
<td></td>
</tr>
<tr>
<td>Hugo Byrne – Ballymun</td>
<td></td>
</tr>
<tr>
<td>Irish Food Processors – Dardistown</td>
<td>Agreement reached with RPA</td>
</tr>
<tr>
<td>Stephen McEvoy, Santry</td>
<td></td>
</tr>
<tr>
<td>Tesco Ireland Ltd. – Ballymun Rd.</td>
<td>Traffic concerns,</td>
</tr>
<tr>
<td>The Byrne Family – MetroPark</td>
<td>Agreement reached with RPA</td>
</tr>
<tr>
<td>Whitehall Rangers – Dardistown</td>
<td></td>
</tr>
</tbody>
</table>
5 Area MN105 – Santry Avenue to Albert College Park.

5.1 Area Description
The route runs in a cut and cover tunnel beneath Ballymun Road, to a shallow underground stop at Ballymun, adjacent to the new civic plaza. Continuing south in a cut and cover tunnel along the Ballymun Road, crossing under Collins Avenue, the next stop is DCU. This is a shallow underground stop on the east side of Ballymun Road beside Albert College housing estate. Area 105 ends on the DCU access road, just south of the DCU Stop.

5.2 Human Beings Vibrations

5.2.1 Assessment of residual impacts

Construction Phase
For each group of receptors the potential impact with no mitigation has been predicted. The extent of committed mitigation is described and the resultant residual impact expected with that mitigation adopted is reported. The depth of the tunnel may reduce somewhat due to the proposed limits of deviation. In each case, this is not expected to change the predicted impact categories. The route runs in a cut and cover tunnel beneath the Ballymun Road, to a shallow underground stop at Ballymun, then passing 20m from the nearest house in Gateway View. The route continues along the Ballymun Road, crossing under Collins Avenue, passing approximately 5m from the nearest house in Ballymun Road, then southwards to the DCU Stop where the nearest house, 2 Albert College Lawn is approximately 2.5m from the tunnel.

The use of piling equipment here is expected to produce vibration levels ($K_{B_{F_{max}}}$) of approximately 0.5mm/s, resulting in a Medium impact. There are likely to be Medium vibration and groundborne noise impacts from the excavation of the cut-and-cover tunnel because of the short distances. Mitigation will involve selection of low-vibration methods of work, liaison with residents and monitoring.

Operational Phase
For the standard case of resilient rail support, three generic models have been created, one for the case of the tunnel in limestone with glacial till (boulder clay) above, one for the case of the tunnel in the clay above the limestone and one for cut-and-cover tunnel sections. The basic models are unbounded, and a further model was created including a ground surface to determine the effect of multiple reflections between the ground surface and the limestone rockhead. This was found to increase dB(A) levels by an average of 5dB(A), and this has been added to the unbounded results. The results are speed dependent at the rate of approximately 1dB per 8% change in speed. It is noted that the highest levels are not directly above the tunnel.
In any case where either a Medium, High or Very high significant impacts for groundborne noise are identified in this way, or where ‘not to exceed’ limits for sensitive equipment would be exceeded, incorporated mitigation in the form of floating slab track is assumed. The route runs in a cut and cover tunnel beneath the Ballymun Road, passing 24m from the nearest house in Gateway View and 4m from the nearest house in Ballymun Road. At the DCU Stop the nearest house, 2 Albert College Lawn, is 2m from the near rail. There are likely to be Medium vibration and groundborne noise impacts with standard resilient rail support. The specification of floating slab track in the vicinity of the DCU Stop will result in no significant groundborne noise or vibration impacts.

5.2.1 Summary of residual impacts
The potential noise and vibration effects from construction and operation of the proposed scheme have been assessed. An assessment of the requirements for mitigation has been undertaken. A summary of the residual impacts associated with the proposed scheme is provided in Table 5.4.

<table>
<thead>
<tr>
<th>Magnitude of impact taking into account mitigation</th>
<th>Functional value of area affected</th>
<th>Significance of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundborne noise</td>
<td>medium</td>
<td>very high</td>
</tr>
<tr>
<td>Vibration affecting humans</td>
<td>medium</td>
<td>very high</td>
</tr>
<tr>
<td>Vibration affecting buildings</td>
<td>low</td>
<td>very high</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment</td>
<td>low</td>
<td>very high</td>
</tr>
<tr>
<td><strong>Operational phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundborne noise</td>
<td>low</td>
<td>very high</td>
</tr>
<tr>
<td>Vibration affecting humans</td>
<td>very low</td>
<td>very high</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment</td>
<td>very low</td>
<td>very high</td>
</tr>
</tbody>
</table>

5.3 Soil and Geology
To assess the impact of ground movements in Area MN105, a Stage 1 Preliminary Ground Movement Assessment and Stage 2A Preliminary Building Response Assessment have been undertaken. Assessment of residual impacts

**Construction Phase**
Temporary impacts are typically associated with the construction phase of the proposed scheme. These impacts are typically short-term in nature and are required to facilitate the construction of the proposed scheme. The impacts will not continue after the construction phase has been completed. Impacts of this type include those associated with activities such as the movement, excavation and disposal of soils, contaminated materials and bedrock,
temporary paving or compaction of soils, temporary construction of roads, traffic management procedures and dewatering works. In some cases, only minor disturbance of soils occurs. An example of this is areas on construction compounds used for temporary administration structures or ground disturbed during construction but not subject to compaction.

**Compaction**

Compacted areas will occur during the construction of the cut and cover tunnel and stops in Area MN105. The magnitude of the impact associated with the compacting of an area during construction is high as the soil is compressed and disturbed. The compacted areas are to be constructed in areas of very low functional value so the impacts are of Very low significance. However, areas of made ground along the R108 have a higher functional value and the significance of impact is increased to Low. When the mitigation measures are taken into consideration, the magnitude and significance of this impact remains the same but the footprint of the area impacted upon decreases.

**Excavation**

Excavation of soil will occur as part of the cut and cover method of construction. The magnitude of the impact associated with this activity (i.e. excavating an area during construction) is high as soil disturbance has a high impact on soil function. The excavated area is to be constructed in areas of low to very low functional value so the impacts are of Low to Very low significance.

**Operational Phase**

**Highways**

The roads identified within Area MN105 are predicted to settle in the region of 5mm. Based on experience of highway maintenance, settlements of up to 50mm are considered permissible for carriageways and can be managed for temporary situations provided ground slope is not greater than 1:500, which is the case for Area MN105. Resurfacing may be required on the cessation of ground movements over short lengths of road and footpaths.

**Buildings**

For Area MN105 the Stage 1 Assessment identified only two buildings for further investigation at Stage 2A, and this was a result of the buildings condition. Both buildings, Albert Scout Hall and 31 Albert College Grove are located adjacent to the proposed DCU Stop on the east side. The conclusion of the Stage 2A assessment was that although the assessment demonstrated that the predicted damage category for the Albert Scout Hall was 1, and for 31 Albert College Grove 0, both buildings are to be taken forward for a detailed Stage 3 Assessment due to their potential susceptibility to ground movements as a result of their condition. While the Stage 2A assessment did not identify any other buildings to be taken forward for detailed assessment, it is possible that future surveys may identify further buildings whose condition might make them susceptible to movement.
5.2.2 Summary of residual impacts

For Area MN105 the residual impact is a predicted settlement in the region of 5mm. The significance of the impact is Very low. During the operational phase the proposed scheme infrastructure will not generate further ground movement. The underground structures are designed as undrained (watertight) and therefore long term ground movements beyond the construction phase are not expected to occur.

A summary of the residual impacts associated with the proposed scheme and affecting this area is provided in Table 9.4.

<table>
<thead>
<tr>
<th>Location</th>
<th>Area of land-take (m²)</th>
<th>Type of impact</th>
<th>Significance of Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>MN105</td>
<td>65,000</td>
<td>Paved</td>
<td>Low to Very low</td>
</tr>
<tr>
<td>MN105</td>
<td>7,000</td>
<td>Potentially Disturbed Ground</td>
<td>Low to Very low</td>
</tr>
</tbody>
</table>

5.4 Groundwater

5.4.1 Assessment of residual impacts

Construction phase
Potential impacts on the groundwater environment during the operational phase would be expected to include localised alteration of the groundwater flow along sections of the proposed route where tunnels and bridges exist. The replacement of greenfield areas along sections of the route with areas of hard standing areas (stops, rail depots, in addition to Park & Ride facilities) can reduce to some extent the recharge rate into the underlying aquifer. The construction of a tunnel within an aquifer can result in a localised depression of the water table due to the construction of sumps within the tunnel.

Operational phase
During the operational phase of the project, there is the potential for the migration of surface contaminants (arising from chemical storage areas at depots, wastewater discharge and runoff from car parks, for example) towards the underlying groundwater sources. Due to the fact that the tunnelled sections of the route will comprise sealed structures and all underground pipe work will include appropriate containment measures, the potential for contamination from underground sections of the route is considered to be low.

All of the impacts identified for the operational phase of the proposed scheme for this section of the route were found to be of Low significance. The following good housekeeping practices will be implemented in order to ensure protection of the surrounding groundwater sources. The substation located to the west of Ballymun Road will be regularly checked and maintained to minimise the potential for leakage of oil and will be located on areas of hard standing and bunded. The substations at Ballymun and DCU Stops will be located underground.
5.5 Comments on Environmental Impact - MN105

There are likely to be medium vibration and groundborne noise impacts from the excavation of the cut-and-cover tunnel during the construction phase in a few houses closest to the proposed scheme. These are identified in the Vibration chapters of this EIS (Volume 2, Chapter 5). However given the relatively short duration of the works no significant human health impacts are predicted. Modelling predicts no significant effect from the operational phase either in terms of groundborne noise, vibration effect in humans and vibration affecting sensitive equipment. Based on this no adverse effect on human health is predicted.

5.6 Submissions and Observations with Comments

<table>
<thead>
<tr>
<th>OBSERVER</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albert College, Ballymun Road &amp; Greenfield Park Residents Association</td>
<td>Utilities, groundwater, surface water</td>
</tr>
<tr>
<td>(Community Org. Netw.)</td>
<td></td>
</tr>
<tr>
<td>Ballymun Regeneration Ltd. – Northwood Stn</td>
<td>Utilities diversion work</td>
</tr>
<tr>
<td>Ballymun Shopping Centre Ltd.</td>
<td></td>
</tr>
<tr>
<td>Donal &amp; Linda O’Sullivan – Albert College</td>
<td></td>
</tr>
<tr>
<td>Na Fianna CLG – Albert College Park</td>
<td></td>
</tr>
<tr>
<td>Peter Tintari – Ballymun/DCU</td>
<td></td>
</tr>
<tr>
<td>Vera Hunt – Ballymun Road</td>
<td></td>
</tr>
</tbody>
</table>
6 Area MN106 - Albert College Park to Mater Stop.

6.1 Area Description
The proposed scheme runs in a cut and cover tunnel across Albert College Park, entering bored tunnel near the southern boundary of the park. The route remains underground in the bored tunnel until its termination at St. Stephen's Green. Continuing south in a bored tunnel from Albert College Park, the next stop is Griffith Avenue. This stop is located in the southwest corner of the agricultural lands on the north side of Griffith Avenue. Proceeding in a south-easterly direction, the route continues in tunnel under St. Patrick's College playing fields. An emergency access and ventilation shaft is located in the southwest corner of the college playing fields. The route continues in tunnel under the Tolka River to Drumcondra Stop. This stop is located to the west of Lower Drumcondra Road and adjacent to St. Joseph’s Avenue. An interchange with Iarnród Éireann’s suburban rail services to Maynooth is provided at this stop. The route turns in a south-westerly direction passing under a second mainline railway and the Royal Canal, to the Mater Stop, located under the Mater Hospital’s existing surface car park. Area MN106 ends 100m further south where the tunnels pass under St. Joseph’s Parade.

6.2 Human Beings Vibrations

6.2.1 Assessment of residual impacts

Construction Phase
Baseline monitoring at Griffith Avenue/Walnut rise junction was in the high category and in the very low category near the proposed stop on Drumcondra.

The bored tunnel begins at Albert College Park, and passes in the glacial till (boulder clay) above the limestone beneath the park entering the limestone at Hampstead Avenue. South of Griffith Avenue is a residential area and the Corpus Christi Girls National School (not occupied at night) having a basement directly above the tunnel with approximately 21m of ground cover to the school basement. During the passage of the TBM, the groundborne noise level is likely to be 46dB LA\text{max,5} (slightly higher in the school basement). This will cause a High impact in the residential area if tunnelling takes place at night and a Medium impact if tunnelling does not occur at night. Vibration is likely to be less than 0.08 KBFTr. This will cause a High impact at night, and a Very low impact by day.

There is a proposed cross passage to the east of The Rise, which has approximately 15m of ground cover (78m slant distance to the nearest residential buildings). The likely PPV will be 6mm/s, KB\text{f, max} = 3, at the nearest residential building, in the Low impact category for people in the building. There is a proposed cross passage near Bantry Road, which has approximately 19m of ground cover (33m slant distance to the nearest residential buildings).
The likely PPV will be 24mm/s, $K_{B_{F_{max}}} = 12$, at the nearest residential building, in excess of the building damage threshold and in the Very high impact category for people in the building. The Low impact threshold of $K_{B_{F_{max}}} = 3$ will be exceeded within a radius of 75m and the building damage threshold of 12mm/s will be exceeded within a radius of 45m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.4g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 1.4 to 1.8kg depending on the final tunnel alignment.

Rock breaking will be required for the construction of Griffith Avenue Stop, and assuming this is done using a hydraulic rock breaker, groundborne noise levels of approximately 44dB(A), assuming four breakers in simultaneous operation, are likely in buildings above the stop, with vibration less than 0.2 KBFTR, resulting in Low impact by day, Medium impact by night.

There is a proposed cross passage at Home Farm Road, which has approximately 22m of ground cover (27m slant distance to Corpus Christi School and 23m slant distance to the nearest residential buildings). The likely PPV will be 32mm/s $K_{B_{F_{max}}} = 16$, at the school and 42mm/s, $K_{B_{F_{max}}} = 21$, at the nearest residential building, in excess of the building damage threshold and in the Very high impact category for people in the building. The Low impact threshold of $K_{B_{F_{max}}} = 3$ will be exceeded within a radius of 74m and the building damage threshold of 12mm/s will be exceeded within a radius of 45m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.6g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 0.7 to 0.9kg depending on the final tunnel alignment.

There is a proposed cross passage to the east of Ferguson Road, which has approximately 27m of ground cover (38 slant distance to the nearest residential buildings). The likely PPV will be 19mm/ s $K_{B_{F_{max}}} = 10$, in excess of the building damage threshold and in the Very high impact category for people in the building.

The Low impact threshold of $K_{B_{F_{max}}} = 3$ will be exceeded within a radius of 72m and the building damage threshold of 12mm/s will be exceeded within a radius of 42m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.3g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 2.0 to 2.3kg depending on the final tunnel alignment.

Under the Sports Ground of St. Patrick’s College there is a proposed crossover with 28m of ground cover, and the nearest house is 24m to the west. The crossover tunnel is proposed just to the south of the Ferguson Road cross passage, and similar PPVs and, $K_{B_{F_{max}}}$ values will occur if the crossover tunnel is excavated by drill and blast. i.e. to limit the PPV to the Low
impact category for daytime the charge weight per delay would have to be restricted to 1.0 to 1.7kg depending on the final tunnel alignment. During the passage of the TBM, the groundborne noise level in this area is likely to be 44dB L_{A_{max,S}}, Medium impact if tunnelling takes place at night, Low impact if tunnelling does not occur at night.

The tunnels pass below the St. Patrick’s Boys National School in Millbourne Avenue and Drumcondra Library, and to the east of Chapelgate. There is approximately 28m of ground cover above the tunnel at Drumcondra Stop. Rock breaking will be required for the construction of Drumcondra Stop, and assuming this is done using a hydraulic rock breaker, groundborne noise levels of approximately 45dB(A), assuming four breakers in simultaneous operation, are likely in buildings above the stop, with vibration less than 0.2 KBFTR, resulting in Medium impact by day, High impact at night. During the passage of the TBM, the groundborne noise level in this area is likely to be 49dB L_{A_{max,S}}, High impact if tunnelling takes place at night, Medium impact if tunnelling does not occur at night. Vibration is likely to be 0.1 KBFTr, causing High impact at night, Very low impact by day.

There is a proposed cross passage near Woodvale Road directly below residential buildings, which has approximately 25m of ground cover. The likely PPV will be 37mm/s, KB_{F_{max}} = 19, in excess of the building damage threshold and in the Very high impact category for people in the building. The Low impact threshold of KB_{F_{max}} = 3 will be exceeded within a radius of 73m and the building damage threshold of 12mm/s will be exceeded within a radius of 47m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.6g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 0.8 to 1.0 kg depending on the final tunnel alignment.

During the passage of the TBM in this area, the groundborne noise level is likely to be 47dB L_{A_{max,S}}.

High impact if tunnelling takes place at night, Medium impact if tunnelling does not occur at night. Vibration is likely to be 0.08 KBFTr High impact at night, Very low impact by day. There is a proposed cross passage near Carlingford Road directly below residential buildings, which has approximately 27m of ground cover. The likely PPV will be 32mm/s, KB_{F_{max}} = 16, in excess of the building damage threshold and in the Very high impact category for people in the building. The Low impact threshold of KB_{F_{max}} = 3 will be exceeded within a radius of 72m and the building damage threshold of 12mm/s will be exceeded within a radius of 47m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.5g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 1.2kg.

South of Drumcondra Stop the tunnels pass beneath mixed uses including residential buildings, and rise out of the limestone into the glacial till some 140m north of Mater Stop.
There is a proposed cross passage under the Royal Canal, approximately 25m slant distance from the nearest residential buildings in St. Ignatius Road. The likely PPV will be 38mm/s, \( KB_{F_{\text{max}}} = 19 \), in excess of the building damage threshold and in the Very high impact category for people in the building. The Low impact threshold of \( KB_{F_{\text{max}}} = 3 \) will be exceeded within a radius of 73m and the building damage threshold of 12mm/s will be exceeded within a radius of 47m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.5g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 0.7 to 1.0kg depending on the final tunnel alignment.

There is a proposed cross passage near Kenmare Parade directly below residential buildings, which has approximately 19m of ground cover. The likely PPV will be 58mm/s, \( KB_{F_{\text{max}}} = 29 \), in excess of the building damage threshold and in the Very high impact category for people in the building. The Low impact threshold of \( KB_{F_{\text{max}}} = 3 \) will be exceeded within a radius of 74m and the building damage threshold of 12mm/s will be exceeded within a radius of 45m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.75g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 0.5 to 0.7kg depending on the final tunnel alignment.

During the passage of the TBM in this area, the groundborne noise level is likely to be 49dB \( L_{A_{\text{max}},S} \), High impact if tunnelling takes place at night, Medium impact if tunnelling does not occur at night. Vibration is likely to be 0.1 KBFTr High impact at night, Very low impact by day.

**Operational Phase**

The bored tunnel begins at Albert College Park, and passes in the glacial till (boulder clay) above the limestone beneath Albert College Park entering the limestone at Hampstead Avenue. South of Griffith Avenue is a residential area and the Corpus Christi Girls’ National school directly above the tunnel with approximately 26m of ground cover. LMV speeds reach up to 70 km/h. With resiliently supported rail the \( L_{A_{\text{max}},S} \) would be approximately 30dB with two LMVs passing at Corpus Christi, which is not significant. Under the Sports Ground of St. Patrick’s College there is a crossover, and the nearest house is 22m to the west with 32m of ground cover so that there will be no significant effect-

The tunnels pass below the St. Patrick’s Boys’ National School in Millbourne Avenue and Drumcondra Library, and to the east of Chapelgate. There is approximately 16m of ground cover above the tunnel at Drumcondra.

South of Drumcondra the tunnels pass beneath mixed uses including residential buildings, and rise out of the limestone into the glacial till some 140m north of Mater Stop. Baseline monitoring at Griffith Avenue/Walnut Rise junction was in the high category and at
Drumcondra was in the Very low category. Very low vibration or groundborne noise impacts are likely with standard resilient rail support.

### 6.2.2 Summary of residual impacts

The potential noise and vibration effects from construction and operation of the proposed scheme have been assessed. An assessment of the requirements for mitigation has been undertaken. A summary of the residual impacts associated with the proposed scheme is provided in Table 5.4.

#### Table 5.4 Summary of residual impacts

<table>
<thead>
<tr>
<th></th>
<th>Magnitude of impact taking into account mitigation</th>
<th>Functional value of area affected</th>
<th>Significance of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction phase</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundborne noise (TBM)</td>
<td>medium by day high by night</td>
<td>very high</td>
<td>Significant</td>
</tr>
<tr>
<td>Vibration affecting humans (TBM)</td>
<td>very low by day high by night</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting buildings (TBM)</td>
<td>very low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment (TBM)</td>
<td>low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting humans (drill and blast)</td>
<td>very High</td>
<td>very high</td>
<td>Significant</td>
</tr>
<tr>
<td>Vibration affecting buildings (drill and blast)</td>
<td>high</td>
<td>very high</td>
<td>Significant</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment (drill and blast)</td>
<td>high</td>
<td>very high</td>
<td>Significant</td>
</tr>
<tr>
<td><strong>Operational phase</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundborne noise</td>
<td>low or very low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting humans</td>
<td>very low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
<tr>
<td>Vibration affecting sensitive equipment</td>
<td>very low</td>
<td>very high</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

### 6.3 Soil and Geology

To assess the impact of ground movements on Area MN106, a Stage 1 Preliminary Ground Movement Assessment and a Stage 2A Preliminary Building Response Assessment have been undertaken. From these assessments the following impacts have been determined:

#### Highways

The assessment of highways has been undertaken in two stages:

1. An assessment of the impact of ground movements on serviceability criteria, measured in terms of poor performance due to excessive change in gradient, cross fall and / or road drainage inefficiency. These criteria are more critical and onerous in determining the performance of a highway than risk of structural damage.
2. For highways identified as exceeding serviceability limiting criteria, or highways deemed to be particularly sensitive to ground movements, a risk based approach has then been adopted to consider particular features of the highway such as surfacing material, condition and traffic levels / usage.

The risk assessment has been completed considering likelihood of ‘ponding’ occurring, and requirement for temporary and permanent repair. An assessment of the temporary and permanent situations has also been undertaken for walkways.

There are numerous roads located along this section of the alignment. However with the exception of those roads affected by the construction of Griffith Avenue, Drumcondra and Mater Stops, predicted maximum settlement for affected roads ranges from 10mm between Albert College Park and Griffith Avenue Stop, reducing to 2mm between Home Farm Road and Drumcondra Stop before increasing to 5mm south of Drumcondra Stop to Mater Stop. Corresponding predicted settlement slopes are gentle. It is possible some minor localised resurfacing may be required on the cessation of ground movements over short lengths of road and pathway to restore the highways to their original condition prior to Metro North construction.

In the vicinity of the stops where the combination of ground movements resulting from stop cut and cover construction, and tunnelling are cumulative; predicted settlements along Griffith Avenue are 60mm, 15mm over very localised areas along St Josephs Avenue adjacent to Drumcondra Stop, and increasing from 10mm in St Ignatius Road to 35mm on the North Circular Road immediately south of Mater Stop. Leo Street to the east of Mater Stop is predicted to experience settlements of 20mm. Immediately south of Mater Stop predicted settlements on Eccles Street and St Josephs Parade are in the region of 40mm. For all these aforementioned roads corresponding ground slopes are greater than 1/500. Based on experience of highway maintenance, settlements of up to 50mm are considered permissible for carriageways and can be managed for temporary situations provided ground slope is not greater than 1:500. It is therefore possible that during Metro North construction provision may need to be made for planned road maintenance, in particular Griffith Avenue, North Circular Road and Eccles Street which are heavily trafficked roads, in addition to the resurfacing of roads on the cessation of ground movements.

Buildings
For Area MN106 the buildings are predominantly residential. Between DCU and Griffith Avenue Stops there a number of discrete structures. From Griffith Avenue to St Patrick’s shaft the overlying buildings are relatively low density residential buildings.

Moving towards Drumcondra the buildings remain mainly residential but start to increase in density as the alignment moves closer to the city centre. Of the 165 buildings identified by the Stage 1 Assessment for further consideration, 27 have been identified to be subject of a detailed Stage 3 Assessment. None of the buildings are predicted to exceed a predicted
damage category of 2, with the exception of the Mater Private Hospital that has a predicted damage category of 3 in accordance with Table 9. The remaining buildings selected for a Stage 3 Detailed Assessment are a result of surveys that have identified these buildings may be susceptible to ground movements due to their condition, with the exception of Chapelgate building located along St Joseph’s Avenue that is recommended for a detailed assessment due to its prestigious nature. While the Stage 2A assessment did not identify any other buildings to be taken forward for detailed assessment, it is possible that future surveys may identify further buildings whose condition might make them susceptible to movement.

Railways
The Metro North tunnel alignment for Area MN106 crosses railway tracks (heavy rail) at two locations. Almost immediately south of Drumcondra Stop the bored tunnels pass beneath a retained embankment upon which twin railway tracks run. The railway and embankment will be potentially affected by bored tunnelling and construction of Drumcondra Stop. The embankment itself is predicted to settle approximately 7mm placing it in the negligible damage category (superficial damage unlikely). Further south between Drumcondra and Mater Stops the bored tunnels pass beneath a twin track railway line contained within a retained cutting that also runs alongside the Royal Canal. The masonry wall that forms the retained cutting is predicted to settle in the region of 10mm, resulting in a corresponding damage category of negligible (low risk of superficial damage). The tunnel crossing is at the shallowest point in terms of the depth of the railway and canal, thereby minimising the impact of ground movements.

At both locations, in accordance with limiting track geometry criteria provided by Irish Rail, it is predicted that the deformation of the rails are within acceptable limits and that operation of the railway will not be compromised during construction of Metro North. This conclusion would be supported by a detailed condition survey prior to construction.

Waterways
The alignment passes beneath the River Tolka within Griffith Park. No major structures are in the vicinity of the crossing other than the retaining walls which flank the riversides, and St Patrick’s Footbridge. Walls and bridge are predicted to settle in the region of 3mm and therefore are not expected to suffer damage. Metro North twin bored running tunnels pass beneath the Royal Canal, that includes construction of a cross passage resulting in a predicted settlement of 10mm. It is envisaged that the puddle clay or glacial till (Dublin boulder clay) lining to the canal would accommodate the predicted movement of 10mm without the lining to the canal incurring damage. The horizontal alignment is in the optimum location between the lock structures, and as a result these structures do not fall within the settlement zone of influence.

Bridges
The alignment passes beneath several bridges, St Josephs Avenue railway bridge, Drumcondra Road railway bridge (both immediately south of Drumcondra Stop) and St
Patrick’s Footbridge within Griffith Park (see waterways above). St Josephs Avenue railway bridge and Drumcondra Railway bridge are subject to 7mm and 2mm settlement respectively and is not expected to result in damage to these structures. These bridges will be the subject of detailed Stage 3 Assessment to take account of individual bridge components such as bearings.

6.3.1 Assessment of residual impacts

Construction Phase

Compaction
Compacted areas will occur during the construction of the cut and cover tunnel and the tunnel boring launch site in Albert College Park, Griffith Avenue Stop, Mater Stop and access routes, the ventilation shaft and Drumcondra Stop in Area MN106. The magnitude of the impact associated with the compacting of an area during construction is high as the soil is compressed and disturbed.

The compacted areas are to be constructed in areas of medium functional value so the impacts are of Medium significance. When the mitigation measures are taken into consideration, the magnitude and significance of this impact remains the same but the footprint of the area impacted upon decreases.

The locations of paved areas are illustrated on the Landscape Insertion Plans in the Landscape and Visual chapter of this EIS (Volume 2, Chapter 13).

Excavation
Excavation of soil will occur during the construction of the cut and cover tunnel and the tunnel boring launch site in Albert College Park, Griffith Avenue Stop, Mater Stop and access routes, the ventilation shaft and Drumcondra Stop in Area MN106. The magnitude of the impact associated with this activity (i.e. excavating an area during construction) is high as soil disturbance has a High impact on soil function. The excavated area will be constructed in an area of medium functional value so the impacts are of Medium significance.

Settlement
For Area MN106 the settlement residual impact is summarised by Table 9.4 below. These are maximum settlements associated with the localised construction of the Stops. For the sections of the tunnel alignment between the stops, maximum predicted settlement ranges between 10mm between Albert College Park and Griffith Avenue Stop, reducing to 2mm between Home Farm Road and Drumcondra Stop and increasing to 5mm south of Drumcondra Stop to Mater Stop.

Operational Phase
During the operational phase, Metro North infrastructure will not generate further ground movement. The underground structures are designed as undrained (watertight) and
therefore long term ground movements beyond the construction phase are not expected to occur.

### 6.3.2 Summary of residual impacts

A summary of the residual impacts associated with the proposed scheme and affecting this area is provided in Table 9.4.

<table>
<thead>
<tr>
<th>Area</th>
<th>Maximum Settlement</th>
</tr>
</thead>
<tbody>
<tr>
<td>South of DCU to South of Griffith Avenue</td>
<td>60mm</td>
</tr>
<tr>
<td>South of Griffith Avenue</td>
<td>40mm</td>
</tr>
<tr>
<td>South of Drumcondra to South of Mater</td>
<td>60mm</td>
</tr>
<tr>
<td>South of Mater to O’Connell Bridge</td>
<td>50mm</td>
</tr>
</tbody>
</table>

### 6.4 Groundwater

#### 6.4.1 Assessment of residual impacts

**Construction phase**

During the construction phase of this section of the route, there is potential for localised alteration of groundwater flow around the tunnel. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of medium functional value. Therefore, the impact is considered to be of Low significance. The Groundwater Chapter of this EIS (Volume 1, Chapter 18) indicates that the levels of a range of contaminants in groundwater are either non-detectable or present at low concentrations along this section of the route with the exception of electrical conductivity, sulphate and total coliforms, which exceeded the criteria contained in Table 3.1 Interim Guideline Values for Characterisation of List of Parameters (IGV) in the document ‘Towards Setting Guideline Values for the Protection of Groundwater in Ireland, Interim Report by the EPA’ (EPA, 2003). In general, the concentration of the contaminants in the groundwater along this section of the route is below the surface water quality criteria in the EPA publication ‘Parameters of Water Quality, Interpretation and Standards’ (2001). Therefore, there is the possibility that groundwater generated from construction along this section of the route can be discharged into a surface water body/drain but this would be subject to approval by the relevant Local Authority and treatment of the water to remove...
microbial contaminants. The construction of the bored tunnel sections will not require continuous significant dewatering operations but will require the removal of groundwater seepage into the tunnel by means of a sump, pump and rising main arrangement.

The construction phase for this section of the route will also involve activities at the surface stop box compounds and the TBM launch site with the potential to adversely impact the underlying groundwater quality.

Tunnel boring operations will result in the generation of spoil that has the potential to be contaminated with oil, lubricants or conditioning agents. The storage of stockpiles of potentially contaminated spoil from boring operations could result in the generation of contaminated leachate, if suitable mitigation measures (such as the immediate removal of spoil) are not implemented. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of medium functional value. Therefore, the impact is considered to be of Low significance. As previously mentioned, tunnelling operations are not expected to result in dewatering of significant volumes of groundwater. No significant long-term lowering of the water is expected as a consequence of building the proposed scheme. Lowering of the water table will be limited to 1m. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of medium functional value. Therefore, the impact is considered to be of Low significance.

Operational phase
During the operational phase of the proposed scheme, there is a slight potential for localised alteration of groundwater flow around the tunnel. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of medium functional value. Therefore, the impact is considered to be of Low significance. Infiltration into the bored tunnel sections of the route will be collected at the stops and vent shaft, filtered and where possible recharged into the water table during the operational phase. If the quality of this drainage water is not controlled, it can impact the quality of the surrounding aquifer. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of medium functional value. Therefore, the impact is considered to be of Low significance.

6.5 Comments on Environmental Impact - MN106

Construction Phase
The predicted vibration exposures are contained in the Vibration chapter of this EIS (Volume 2, Chapter 5). During the construction phase at Corpus Christi school (not occupied at night) during the passage of the tunnel boring machine, the groundborne noise level is likely to be 46dB L$_{Aeq,5}$. This is just around the level which would have the potential to interfere with
education, (see Section 8.6.3) but given the relatively short duration a significant effect on education is not predicted. South of Griffith Avenue a high impact is predicted in the residential area if tunnelling takes place at night, medium impact if tunnelling does not occur at night and so not affecting sleep. However given the relatively short duration of exposure a significant effect on human health is not predicted. Near Bantry Road, a very high impact category is predicted for people in some buildings. Mitigation measures to limit the effect are suggested. However given the relatively short duration of exposure a significant effect on human health is not predicted. Rock breaking will be required for the construction of Griffith Avenue Stop resulting in low impact by day, medium impact by night with the potential to affect sleep. Given the relatively short duration of exposure a significant effect on human health is not predicted. There is a proposed cross passage at Home Farm Road which could result if unmitigated in a very high impact to Corpus Christi School and to the nearest residential buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted. A proposed cross passage to the east of Ferguson Road could result, if unmitigated in a very high impact for people in adjacent buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect on human health is predicted. Under the Sports Ground of St Patrick’s College there is a proposed crossover and during the passage of the tunnel boring machine, the groundborne noise level in this area is likely to be 44dB $L_{An,5}$, medium impact if tunnelling takes place at night, low impact if tunnelling does not occur at night. Given the relatively short duration of exposure a significant effect on human health is not predicted. In the area of St Patrick’s Schools in Millbourne Avenue and Drumcondra Library, and to the east of Chapelgate during the passage of the tunnel boring machine, the groundborne noise level in this area is likely to be up to 49dB $L_{An,5}$. This is just around the level which would have the potential to interfere with education, (see Section 8.6.3) but given the relatively short duration a significant effect on education is not predicted. With regard to the residential properties groundborne noise, high impact is predicted if tunnelling takes place at night with the potential to affect sleep, medium impact if tunnelling does not occur at night. Vibration is likely to be 0.1 KB$F_{Tr}$, causing high impact at night, very low impact by day. Given the relatively short duration of exposure a significant effect on human health is not predicted. The proposed cross passage near Woodvale Road could result (if unmitigated) in very high groundborne noise and vibration impacts for people in adjacent buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted. The proposed cross passage near Carlingford Road could result (if unmitigated) in very high impacts for people in adjacent buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted. The proposed cross passage under the Royal Canal could result (if unmitigated) in very high impacts for people in adjacent buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted. The proposed cross passage near Kenmare Parade could result (if unmitigated) in very high impacts for people in adjacent buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted.
Construction vibration impacts on the Mater Hospital and the neighbouring Mater Private Hospital will arise both from the construction of the Metro stop box and from the construction of the Adult Hospital. It is predicted that the limit for sensitive equipment in the Mater and Mater Private Hospitals will be significantly exceeded for a period of around 10 weeks. Unless alternative tunnelling methods are found to be possible for some 400m, temporary alternative arrangements will be required for the most sensitive equipment in the hospital. Unmitigated this has the potential for a significant detrimental effect on human health. Rock breaking may be required for the construction of Mater Stop and this too could result in limits for sensitive equipment being exceeded. Unmitigated this has the potential for a significant detrimental effect on human health. Blasting for the Kenmare Parade cross-passage could also interfere with the operation of sensitive equipment at the Mater site and mitigation in the form of liaison between the site and the hospital will be required to ensure that blasts and critical use of the equipment do not occur simultaneously.

**Operational phase**

Modelling predicts no significant effect from the operational phase either in terms of groundborne noise, vibration effect in humans or vibration affecting sensitive equipment. Based on this no adverse effect on human health is predicted. It is noteworthy that a specific detailed study was carried out to assess vibration sensitive equipment in the Mater Misericordiae Hospital, Mater Private Hospital, Rotunda Hospital and the HARI clinic and no residual effect after mitigation is predicted.

### 6.6 Submissions and Observations with Comments

<table>
<thead>
<tr>
<th>Observer</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aidan &amp; Barbara Hynes</td>
<td>St. Ignatius Rd., Dublin 7</td>
</tr>
<tr>
<td>Alan &amp; Catherine Beirne</td>
<td>Bantry Road, Drumcondra</td>
</tr>
<tr>
<td>All Hallows Area Residents Association</td>
<td>Upper Drumcondra</td>
</tr>
<tr>
<td>Angela &amp; Carmel Morgan</td>
<td>Ferguson Rd., Drumcondra</td>
</tr>
<tr>
<td>Bernadette &amp; Karen Donnelly</td>
<td>Griffith Ave.</td>
</tr>
<tr>
<td>Breda &amp; John Walsh</td>
<td>Botanic Ave., Drumcondra</td>
</tr>
<tr>
<td>Brendan Bonass &amp; Others</td>
<td></td>
</tr>
<tr>
<td>Brendan Gaffney &amp; Valerie Smith</td>
<td>Griffith Ave.</td>
</tr>
<tr>
<td>Christy McCormack</td>
<td>St. Alphonsus Rd., Drumcondra</td>
</tr>
<tr>
<td>Cormac Corley</td>
<td>Griffith Ave.</td>
</tr>
<tr>
<td>Damien Coleman</td>
<td>Lwr. Drumcondra Road</td>
</tr>
<tr>
<td>Dawn Mulligan and Ken Lacey</td>
<td>St. Alphonsus Ave., Drumcondra</td>
</tr>
<tr>
<td>Donal O'Brochtein</td>
<td>Griffith Avenue</td>
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<tr>
<td>Donal O'Donoghue</td>
<td>Griffith Ave., Drumcondra</td>
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<tr>
<td>Elizabeth Hollywood</td>
<td>Charles Earley, Botanic Avenue</td>
</tr>
<tr>
<td>Emer &amp; Frank Lawlor</td>
<td>Valentia Rd., Drumcondra</td>
</tr>
<tr>
<td>Francis Doherty &amp; Shane Cryan</td>
<td>Homefarm Rd.,</td>
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Drumcondra
Frank & Mary McCormack – Valentia Rd, Drumcondra
Georgina Doyle & Others – Botanic Ave., Glasnevin
Griffith Avenue & District Residents’ Association
Iona & District Residents Association – Drumcondra
James Grant – Ferguson Road, Drumcondra
James Hunt – St. Joseph’s Ave., Drumcondra
Jean McLeod & Others – Ferguson Rd., Drumcondra
Jim & Rita Maguinness – Gratton Parade, Drumcondra
John & Eva McDermott – Alphansus Rd, Drumcondra
John A. Baushel – Bantry Rd., Drumcondra
John Daly – Whitworth Road, Drumcondra
Karen Griffin – St. Joseph’s Ave., Drumcondra
Kieran Carolan – St. Joseph’s Ave., Drumcondra
Leo Residents Association
Leonard Carty & Others – Homefarm Road, Drumcondra
Liam O’Doherty – Whitworth Rd., Drumcondra
Margaret & Victor Barry – Griffith Ave.
Marie Daly – Whitworth Rd., Drumcondra
Mary Flanagan – Ferguson Rd., Drumcondra
Mary McLaughlin – Ferguson Rd., Drumcondra
Mater Campus Hospital Development Ltd.
Mater Private Hospital
Matthew & Aideen Kelly – St. Joseph’s Ave., Drumcondra
Maureen Kennedy – Whitworth Rd., Drumcondra
Michael Casey – Millbourne Ave., Drumcondra
Michael Walsh – Bantry Road, Drumcondra
National Paediatric Hospital Development Board
Patricia & Diarmuid Doyle – Ferguson Rd., Drumcondra
Patricia O’Donoghue – Griffith Ave.
Patrick & Kathleen Hassett & Others – Ferguson Rd.,

Impact from airborne and groundborne noise, vibration, increase of tunnel depth.

Only three options were discussed with residents – need to be verify this with residents. Other issue regarding testing and proximity of the works. Settlement and vibrations a concern to residents. Property damage scheme not sufficient. Opposition of residents to relocation of metro. Construction noise: levels and durations excessive.

Agreement Reached with RPA:
Letter from RPA to Mater Private Hospital 13th January 2010,
11 Drawings attached to the above letter 13th January 2010,
Appendix 3 (Extract from Mater Private Hospital Agreement).
<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Comment</th>
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</thead>
<tbody>
<tr>
<td>Pauline Walsh</td>
<td>Bantry Road, Drumcondra</td>
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<tr>
<td>Peter Sweetman</td>
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<td></td>
</tr>
<tr>
<td>Philip Reilly</td>
<td>The Rise/Hollybank Rd., Drumcondra</td>
<td></td>
</tr>
<tr>
<td>Quinn's Public House</td>
<td>Drumcondra</td>
<td></td>
</tr>
<tr>
<td>Residents for Realignment Ltd.</td>
<td>Drumcondra</td>
<td>Construction sequence (crossover tunnel), ventilation shaft, tunnel boring at night, maintenance of track</td>
</tr>
<tr>
<td>Residents of Hampstead Avenue &amp; The Rise</td>
<td>Glasnevin</td>
<td></td>
</tr>
<tr>
<td>Residents Opposed to Option B (R.O.T.O.)</td>
<td>Drumcondra/Griffith Ave.</td>
<td></td>
</tr>
<tr>
<td>Rita Hurson</td>
<td>St. Alphonsus Ave., Drumcondra</td>
<td></td>
</tr>
<tr>
<td>Roisin Ni Ceallaigh</td>
<td>Ferguson Rd., Drumcondra</td>
<td></td>
</tr>
<tr>
<td>Ruadhan MacEoin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shane McGeary &amp; Orla Canavan</td>
<td>St. Alphonsus Ave., Drumcondra</td>
<td>Water management due to tunnelling, traffic.</td>
</tr>
<tr>
<td>Sheila Burke</td>
<td>St. Alphonsus Rd., Drumcondra</td>
<td></td>
</tr>
<tr>
<td>St. Patrick's College Drumcondra</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Susan Taylor</td>
<td>Valentia Rd., Drumcondra</td>
<td></td>
</tr>
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</table>
7 Area MN107 - Mater Stop to St. Stephen’s Green

7.1 Area Description
On leaving the Mater Hospital the route turns south easterly under the Dorset Street/ North Frederick Street junction and on to Parnell Square East where a cut and cover stop, Parnell Square, will be constructed. To the south of Parnell Square, the route proceeds in tunnel under O'Connell Street to O'Connell Bridge Stop. This stop is located under the River Liffey and access to this stop is provided to the north and the south of O'Connell Bridge. Entrances to the north of the River Liffey will facilitate interchange with the Luas Red Line. From O'Connell Bridge the route proceeds beneath Westmoreland Street and College Green and under buildings between Clarendon Street and Grafton Street. The terminus stop, St. Stephen’s Green, is located in the north west corner of the Green. Entrances to this stop are outside the Green on St. Stephen’s Green North and St. Stephen’s Green West. This stop will permit interchange with the Luas Green Line services and the proposed Iarnród Éireann Interconnector. Turnback of Metro vehicles is via a tunnel loop under St. Stephen’s Green.

7.2 Human Beings Vibrations

7.2.1 Assessment of residual impacts

Construction Phase
For each group of receptors the potential impact with no mitigation has been predicted. The extent of committed mitigation is described and the resultant residual impact expected with that mitigation adopted is reported. The depth of the tunnel may reduce somewhat due to the proposed limits of deviation. In each case, this is not expected to change the predicted impact categories. At Mater Stop the bored tunnels are in the glacial till (boulder clay) overlying the limestone, and the stop box is founded on the limestone which is at a depth of about 20m. The existing Mater Private Hospital has piled foundations. The proposed future Mater Adult Hospital will have a raft foundation. The depth of the tunnel here is dependent on the choice of two options for the Mater Stop. During construction, the nearest operational part of the Mater Misericordiae University Hospital will be approximately 75m to the west of the stop box. Vibration transmission from the stop site would be through the made ground which is a layer approximately 10m thick above a layer of about 15m of boulder clay above the limestone. The base of the stop box is in the limestone. The proposed future extension to the Adult Hospital will be partially supported from the structure of the Mater Stop. For this reason the Mater Stop box is expected to be constructed as advance works, and at this time construction vibration impacts on the neighbouring Mater Private Hospital will arise both from the construction of the Metro stop box and from the construction of the Adult Hospital. The advanced works involved will consist of the insertion of a contiguous/secant bored pile retaining wall, the insertion of diaphragm walls for the stop box, the excavation of soil and rock between the walls and the concreting of the floor.
and roof slabs to the box. The principal potential cause of significant vibration would be the excavation of bedrock at the base of the stop box. For this reason, a slightly raised vertical alignment is under consideration that will minimise the need for rock excavation. There is no equivalent construction activity involved in the Adult Hospital construction, and the cumulative effect of the co-existence of the two construction projects is therefore no greater than the effect of the construction of the stop box.

The Mater Private Hospital will be in normal use during the construction of the Mater Stop and the tunnel drive. The southern headwall of the stop is proposed at approximately 2m from the Mater Private Hospital. Vibration will be transmitted into the foundations from the excavation of the limestone at the base of the stop box, from concreting of the headwall which may include breaking out a soft eye in the headwall to admit the TBM. Vibration from the passage of the TBM will be transmitted through the ground to the hospital foundations. Vibration, once it has entered the hospital structure, will decay only slightly with distance, although it would require on-site tests to establish the effect of distance within the structure. The limit for sensitive equipment in the Mater Hospitals of 12 µm/s will be significantly exceeded in the Private Hospital, by a factor of the order of 25, during the passage of the TBM, and the limit will not be achieved until the TBM is of the order of 350-400m from the hospital. This amounts to some 10 weeks for each tunnel at a progress rate of 75m per week, although in the overburden the progress rate may be faster. Unless alternative tunnelling methods are found to be possible for some 400m, temporary alternative arrangements will be required for the most sensitive equipment in the hospital. The existing Mater Adult Hospital also lies within this distance. Depending on the vertical alignment, rock breaking may be required for the construction of Mater Stop, and assuming this is done using a hydraulic rock breaker, groundborne noise levels of approximately 49dB(A), assuming four breakers in simultaneous operation, are likely in buildings above the stop, with vibration at 0.2 KBFTR, resulting in Medium impact on humans by day, High impact by night, but some 17 times the sensitive equipment limit of 12 µm/s. There are no cross-passages in the vicinity of Mater Stop, the nearest being at St. Joseph’s Place 380m to the south at the bottom of the glacial sands and gravels and the top of the limestone, and Kenmare Parade 190m to the north, in the limestone.

Blasting for the Kenmare Parade cross-passage will occur about 280m from the Mater Private Hospital. This would interfere with the operation of sensitive equipment, and mitigation in the form of liaison between the site and the hospital will be required to ensure that blasts and critical use of the equipment do not occur simultaneously. The equivalent value of KB_{Fmax} = 0.4 is in the Very low category for day; High for night.

There are residential buildings immediately above the cross-passage at St. Joseph’s Place where there is approximately 25m of ground cover. It is likely that the PPV be of the order of 37mm/s, KB_{Fmax} = 19, will exceed the building damage threshold of 12mm/s, and be in the
Very high impact category for human response. The Low impact threshold of $KB_{F_{\text{max}}} = 3$ will be exceeded within a radius of 73m and the building damage threshold of 12mm/s will be exceeded within a radius of 44m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.6g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 0.8 to 1.0kg depending on the final tunnel alignment.

During the passage of the TBM in this area, the groundborne noise level is likely to be 47dB $LA_{\text{max},S}$, High impact if tunnelling takes place at night, Medium impact if tunnelling does not occur at night. Vibration is likely to be 0.09 KBFTr High impact at night, Very low impact by day.

South of Mater Stop, the bored tunnels enter the limestone at approximately St. Joseph’s Parade and pass under residential areas north of Parnell Square. The educational, institutional and community facilities in the area are sensitive to structure-radiated noise and vibration. There are various protected monuments and structures included throughout the area, mainly Georgian buildings. The area also includes the Rotunda Hospital including the HARI Clinic, Ambassador Theatre, the Temple Theatre and the Gate Theatre in Cavendish Row. The depth of the tunnel at Parnell Square is approximately 22m. During the passage of the TBM in this area, the groundborne noise level is likely to be 48dB $LA_{\text{max},S}$, High impact if tunnelling takes place at night, Medium impact if tunnelling does not occur at night. Vibration is likely to be 0.09 KBFTr High impact at night, Very low impact by day. The effect of 48dB $LA_{\text{max},S}$ in the theatres will depend on the nature of the production. During quiet moments in a production, this will be clearly audible and intrusive. The main mitigation possible is liaison with the theatre managements, with as much advance warning as practicable. Reduction in face pressure and/or cutter speed may be an option although the effect on ground settlement must also be taken into account.

There is a planned cross passage opposite Hardwicke Street, just south of Telecom Eireann. Ground cover is approximately 26m and a PPV of some 35mm/s, $KB_{F_{\text{max}}} = 18$, can be expected. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.5g, in excess of the damage threshold for computer equipment. This cross passage is approximately 300m from the HARI clinic to give a PPV of 0.7mm/s at the clinic. This would be close to the limit advised for the operation of sensitive equipment at the Rotunda Hospital/HARI clinic, and mitigation in the form of liaison between the site and the hospital together with vibration monitoring will be required to ensure that use of the equipment is not adversely affected. The Low impact threshold of $KB_{F_{\text{max}}} = 3$ will be exceeded by blasting in the Hardwicke Street cross-passage within a radius of 72m and the building damage threshold of 12mm/s will be exceeded within a radius of 43m.
The HARI/Rotunda vibration threshold for sensitive equipment of 6µm displacement at 15Hz is equivalent to a velocity of 565µm/s. Based on the modelling carried out for the Mater Private Hospital, it is not likely that vibration from the passage of the TBMs will exceed this threshold. The groundborne noise level is likely to be 48dB $L_{A_{max,5}}$ high impact if tunnelling takes place at night, Medium impact if tunnelling does not occur at night. Vibration is likely to be 0.09 KBFTR High impact at night, Very low impact by day. Groundborne noise at 48dB $L_{A_{max,5}}$ is likely to have a High impact in the Gate Theatre during performances. Baseline monitoring showed vibration less than the limit for sensitive equipment for the Mater and Rotunda Hospitals. Rock breaking will be required for the construction of Parnell Square Stop, and assuming this is done using a hydraulic rock breaker, groundborne noise levels of approximately 39dB(A), assuming four breakers in simultaneous operation, are likely in buildings above the stop, with vibration less than 0.16 KBFTR, resulting in Low impact by night, Very low impact by day.

There is a proposed cross-passage below O’Connell Street Upper which is approximately 170m from the HARI clinic to give a PPV of 1.7mm/s at the clinic. This would interfere with the operation of sensitive equipment, and mitigation in the form of liaison between the site and the hospital will be required to ensure that blasts and critical use of the equipment do not occur simultaneously.

From Parnell Square to O’Connell Street the tunnel is in glacial sands and gravels, re-entering the limestone for the remainder of the route. From Parnell Street to O’Connell Bridge the sensitive receptors are the hotels in O’Connell Street. The proposed cross-passage below O’Connell Street Upper with approximately 21m of ground cover (26m slant distance to the nearest building). The likely PPV will be 34mm/s, $K_{B_{\text{frmax}}} = 17$, in excess of the building damage threshold and in the Very high impact category for people in the building. The Low impact threshold of 3mm/s will be exceeded within a radius of 74m and the building damage threshold of 12mm/s will be exceeded within a radius of 45m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.5g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 1.1kg.

Drill and Blast may be necessary for the construction of O’Connell Bridge Stop beneath the Liffey. The likely PPV will be 48mm/s, $K_{B_{\text{frmax}}} = 24$, in excess of the building damage threshold and in the Very high impact category for people in the building. The Low impact threshold of 3mm/s will be exceeded within a radius of 74m and the building damage threshold of 12mm/s will be exceeded within a radius of 45m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.75g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 0.75kg.

During the passage of the TBM in this area, the groundborne noise level is likely to be 48dB $L_{A_{max,5}}$. High impact if tunnelling takes place at night, Medium impact if tunnelling does not
occur at night. Vibration is likely to be 0.09 KBFTr High impact at night, Very low impact by day. There is a proposed cross passage near Princes Street North, which has approximately 23m of ground cover (25m slant distance to the nearest building). The likely PPV will be 37mm/s, $KB_{F_{max}} = 19$, in excess of the building damage threshold and in the Very high impact category for people in the building. The Low impact threshold of $KB_{F_{max}} = 3$ will be exceeded within a radius of 73m and the building damage threshold of 12mm/s will be exceeded within a radius of 44m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.6g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 0.6 to 1.0kg depending on the final tunnel alignment.

From O’Connell Street to St. Stephens Green there are buildings with residential use and the academic buildings in Trinity College. There is a proposed cross passage near College Green, which has approximately 23m of ground cover (27m slant distance to the nearest building). The likely PPV will be 32mm/s, $KB_{F_{max}} = 16$, in excess of the building damage threshold and in the Very high impact category for people in the building. The Low impact threshold of $KB_{F_{max}} = 3$ will be exceeded within a radius of 73m and the building damage threshold of 12mm/s will be exceeded within a radius of 44m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.4g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 0.75 to 1.5kg depending on the final tunnel alignment.

The cross passage is close to the northern end of the crossover step-plate junction in which drill and blast may also be used. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.4g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 0.75 to 1.5kg depending on the final tunnel alignment.

During the passage of the TBM in this area, the groundborne noise level in the nearest buildings of Trinity College is likely to be 45dB $L_{A_{max,S}}$. High impact if tunnelling takes place at night Medium impact if tunnelling does not occur at night. The noise will be clearly audible in Trinity College and intrusive in quiet rooms occupied by people engaged in activities requiring concentration or relaxation. Vibration is likely to be 0.07mm/s KBFTr Medium impact at night, Very low impact by day.

There is a proposed cross passage near Wicklow Street, which has approximately 24m of ground cover. The likely PPV will be 39mm/s, $KB_{F_{max}} = 20$, in excess of the building damage threshold and in the Very high impact category for people in the building. The Low impact threshold of $KB_{F_{max}} = 3$ will be exceeded within a radius of 73m and the building damage threshold of 12mm/s will be exceeded within a radius of 44m. With a dominant frequency of 25Hz, this would be equivalent to approximately 0.6g, in excess of the damage threshold for computer equipment. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 1.0kg. During the passage of the TBM in this area, the groundborne noise level is likely to be 47dB $L_{A_{max,S}}$. High impact if tunnelling takes place at
night, Medium impact if tunnelling does not occur at night. Vibration is likely to be 0.09 KBFTr High impact at night, Very low impact by day.

The Gaiety Theatre is in King Street South and Groundborne noise at 47dB $L_{A_{max}}$ will cause a High impact during performances. The effect of 47dB $L_{A_{max}}$ in the theatre will depend on the nature of the production. During quiet moments in a production, this will be clearly audible and intrusive. The main mitigation possible is liaison with the theatre managements, with as much advance warning as practicable. Reduction in face pressure and/or cutter speed may be an option although the effect on ground settlement must also be taken into account.

At St. Stephen’s Green, blasting is likely to be used for the excavation of the turnback loop. There is approximately 17m of ground cover, and the shortest slant distance to the nearest property is 50m. The PPV is likely to be 13mm/s, KB$F_{max} = 7$, at the limit of the building damage threshold and in the High impact category for people in the building. The Low impact threshold of KB$F_{max} = 3$ will be exceeded within a radius of 74m. To limit the PPV to the Low impact category for daytime the charge weight per delay would have to be restricted to 3 to 4kg depending on the final tunnel alignment.

The nearest residential properties to the north of the proposed Bailey bridge over the Liffey, 15-17 Eden Quay, lie within 24m of driven piling plant. Vibration levels (KB$F_{max}$) of approximately 4.4mm/s are expected here, resulting in a Very high impact. The nearest vibration sensitive property to the south of the proposed Bailey bridge is the Corn Exchange, which lies at a distance of 23m. Vibration levels due to driven piling (KB$F_{max}$) of 4.5mm/s are expected here, resulting in a Very high impact.

The north and south banks of the Liffey lie within approximately 2m of the nearest driven pile from the proposed Bailey bridge. Vibration levels (ppv) of 19mm/s are expected. Assessing these levels according to the criteria set out for building damage due to vibration, gives a High impact. The Abbey Theatre and Peacock Theatre lie within approximately 50m of the proposed Bailey bridge piling. Groundborne noise may be audible at times as a result of driven piling. If this occurs at audible levels, it will be mitigated. Possible mitigation measures include pre-drilling, using reduced energy piling plant and avoiding noise sensitive times.

**Operational Phase**

For the purposes of this assessment the vibration performance of the track and vehicles have been assessed by numerical modelling, in two ways. For the most demanding cases, namely the achievement of the limits for sensitive equipment at the Mater hospitals, detailed numerical models of the stops, tunnels and the hospital buildings have been created, and the results have shown that with the use of floating slab track the vibration limits can be achieved. These vibration limits are equivalent to levels of groundborne noise below the most stringent Very low impact magnitudes in Table 5.2, and it follows that in any
location where mitigation better than resilient rail support is required, floating slab track will provide mitigation sufficient for the most demanding case.

For track laid without rail joints (except at switches and crossings) and with modern standards of rail alignment, groundborne noise is the determining impact, and tactile vibration is normally at levels below the threshold of human perception. Vibration only requires special consideration in the case of highly sensitive equipment as further explained below. For the standard case of resilient rail support, three generic models have been created, one for the case of the tunnel in limestone with glacial till (boulder clay) above, one for the case of the tunnel in the clay above the limestone and one for cut-and-cover tunnel sections. The basic models are unbounded, and a further model was created including a ground surface to determine the effect of multiple reflections between the ground surface and the limestone rockhead. This was found to increase dB(A) levels by an average of 5dB(A), and this has been added to the unbounded results. The results are speed dependent at the rate of approximately 1dB per 8% change in speed. It is noted that the highest levels are not directly above the tunnel. Because it will be for the appointed contractor to select the track form at a future stage in the programme, and the procurement process for the vehicles will take place after the writing of this Environmental Impact Statement, it is not possible to model the performance of the actual track and vehicles. The approach that has been taken is to model the rail support dynamic stiffnesses for resiliently supported rail as 13MN/m per metre run of rail, to yield the likely significant effect of the scheme. The vehicle characteristics used have been those for the vehicle with the highest unsprung mass among those likely to be offered by the contractor, and an allowance of 5dB(A) for vehicle and rail support stiffness uncertainty has been added to the results. The results of the modelling are shown in Figure 5.1 to Figure 5.3. These figures illustrate that generally the groundborne noise will reduce for higher depths of ground cover. They also show that the groundborne noise is dependent on transverse distance from the tunnel, and that it does not follow a simple linear decay. In any case where either a Medium, High or Very high significant impacts for groundborne noise are identified in this way, or where 'not to exceed' limits for sensitive equipment would be exceeded, incorporated mitigation in the form of floating slab track is assumed. The results of this assessment are as follows:

At Mater Stop the bored tunnels are in the glacial till (boulder clay) overlying the limestone, and the stop box is founded on the limestone which is at a depth of about 20m. The existing Mater Private Hospital has piled foundations. The proposed future Mater Adult Hospital will have a raft foundation. The depth of the tunnel here is dependent on the choice of two options for the Mater Stop. Because of the presence of scientific equipment of very high sensitivity to vibration at Mater Misericordiae University Hospital and the Mater Private Hospital a detailed study has been carried out which indicates that the installation of floating slab track will be required through the Mater Stop and the bored tunnels past the Mater Private Hospital. The extent of the floating slab track is likely to extend beyond the end of each hospital building.
South of Mater Stop, the bored tunnels enter the limestone at approximately St. Joseph’s Place and pass under residential areas north of Parnell Square. The educational, institutional and community facilities in the area are also sensitive to structure-radiated noise and vibration. There are various protected monuments and structures included throughout the area, mainly Georgian buildings, the Rotunda Hospital including the HARI Clinic, Ambassador Theatre, the Temple Theatre and the Gate Theatre in Cavendish Row. The depth of the tunnel at Parnell Square is approximately 22m, and the presence of these receptors will require the installation of floating slab track as far as Parnell Street in order to avoid a significant groundborne noise or vibration effect.

From Parnell Square to O’Connell Street the tunnel is in glacial sands and gravels, re-entering the limestone for the remainder of the route. From Parnell Street to O’Connell Bridge the sensitive receptors are the hotels in O’Connell Street. The depth of the tunnel is approximately 24m and resiliently supported rail will provide adequate mitigation to avoid a significant effect, giving an $L_{A_{max,S}}$ value of up to 30dB. Very low vibration or groundborne noise impacts are likely with standard resilient rail support. From O’Connell Street to St. Stephen’s Green there are buildings with residential use and the academic buildings in Trinity College. There is a crossover proposed close to Trinity College, and the added effect of the passage of wheels over the frogs in the switches will potentially increase the level of groundborne noise above the threshold of High impact for the uses of the spaces within Trinity College. The recommended mitigation measures will either be the use of swing-nose points or the installation of floating slab track, which will be sufficient to avoid significant noise or vibration impacts.

The Gaiety Theatre is in King Street South. The tunnel depth is approximately 25m (increasing towards St. Stephen’s Green). Resiliently supported rail will provide adequate mitigation to avoid a significant effect, giving an $L_{A_{max,S}}$ value of up to 30dB. A detailed study will be required to establish whether the predicted $L_{A_{max,S}}$ would have fallen to no more than 20dB at the Gaiety Theatre, the threshold above which floating track slab would be required. If floating track slab is necessary it will ensure that no significant impacts occur. Baseline monitoring showed vibration less than the limit for sensitive equipment for the Mater and Rotunda Hospitals.

7.2.2 Summary of residual impacts
The potential noise and vibration effects from construction and operation of Metro North have been assessed. An assessment of the requirements for mitigation has been undertaken. A summary of the residual impacts associated with the scheme is provided in Table 5.4.
7.2.3 COMMENTS

7.3 Soil and Geology

To assess the impact of ground movements on Area MN107, a Stage 1 Preliminary Ground Movement Assessment and a Stage 2A Preliminary Building Response Assessment have been undertaken. From these assessments the following impacts have been determined:

Highways

The assessment of highways has been undertaken in two stages:

1. An assessment of the impact of ground movements on serviceability criteria, measured in terms of poor performance due to excessive change in gradient, cross fall and / or road drainage inefficiency. These criteria are more critical and onerous in determining the performance of a highway than risk of structural damage.

2. For highways identified as exceeding serviceability limiting criteria, or highways deemed to be particularly sensitive to ground movements, a risk based approach has then been adopted to consider particular features of the highway such as surfacing material, condition and traffic levels / usage. The risk assessment has been completed considering likelihood of ‘ponding’ occurring, and requirement for temporary and permanent repair. An assessment of the temporary and permanent situations has also been undertaken for walkways.
From St. Joseph’s Parade to just north of the Dublin Spire, ground movements are predicted to be in the region of 40mm, increasing to 45mm above the cross passage locations. Predicted ground slopes are in the range of 1:200 to 1:800. At the interface of the running tunnels with the Parnell Square Stop box, settlements are expected to increase in excess of 60mm due to the cumulative effects of tunnelling and cut and cover box construction, and the transition from bored tunnel construction to cut and cover construction. These predicted settlements reflect the ground conditions (glacial sands and gravels). For all these aforementioned roads corresponding ground slopes are greater than 1/500. Based on experience of highway maintenance, settlements of up to 50mm are considered permissible for carriageways and can be managed for temporary situations provided ground slope is not greater than 1:500. It is therefore possible that during construction provision may need to be made for planned road maintenance along this section of the proposed scheme in Area MN107.

Approximately at the location of the Spire the tunnels pass into the limestone bedrock, and predicted settlements reduce to less than 5mm. At O’Connell Bridge Stop settlement is predicted to peak at around 30mm along the Bachelors Walk / Eden Quay, while within Westmoreland Street due to the south box construction settlements are estimated to be in the region of 10-15mm. Therefore some resurfacing of the highway and paths may be necessary on the cessation of ground movements.

Beyond O’Connell Bridge Stop until just north of St. Stephen’s Green the running tunnels are predicted to generate settlement of less than 5mm, with the exception of College Green where settlement of up to 10mm is predicted to be generated by construction of the mined emergency crossover. Based on these predictions remedial work to highways is generally not envisaged with the exception of a localised area in the vicinity of the emergency crossover.

At St. Stephen’s Green the settlements are expected to be in the region of 60mm at the north end of Grafton Street where the caverns will be constructed to accommodate the crossing of the Eastbound Interconnector railway tunnel beneath the Metro North running tunnels and therefore localised reinstatement may be required. Along St. Stephen’s Green West and North, settlements from box construction within the park may result in the need for some resurfacing of the roads and pathways.

**Buildings**

From St. Joseph’s Parade, building use continues to change from residential to a mix of residential, commercial and offices. The tunnel passes along Frederick Street North that has major buildings on both sides. There are a large number of medium sized hotels, and Findlaters Church, a prominent and prestigious structure. The tunnel drive between St Joseph’s Parade and Parnell Square Stop will traverse ground that has a complex mix of glacial till with sands and gravels resulting in predicted settlements in the region of up to 45mm. None of the buildings assessed along this section of the alignment are predicted to
exceed Damage category 2 in accordance with Table 9.3, however surveys have identified 12 buildings in poor condition, the Telecom Eireann Building that is a piled structure, and Findlaters Church, a prestigious structure. All will be assessed further as part of the Stage 3 Detailed Assessment.

Immediately to the east side of the proposed Parnell Square Stop there is a prestigious Georgian style terrace. The combination of being located immediately adjacent to the stop cut and cover box, and construction being undertaken in the glacial sands and gravels means all these buildings will be the subject of a detailed Stage 3 Assessment.

Likewise the same applies to the Gate Theatre and Ambassador Cinema which are subject to predicted settlements in the region of 45mm due to the tunnel rising into Parnell Square Stop and being located in the glacial sands and gravels. These structures are also considered sensitive structures taking account of their use.

From south of Parnell Square Stop to Bachelors Walk / Eden Quay no buildings are predicted to exceed damage category 2 as a result of predicted building settlements not exceeding 20mm with corresponding gentle settlement slopes. However 11 buildings have been identified to be taken forward to the Stage 3 Detailed Assessment Stage either due to their surveyed condition, identified as a piled structure (No. 9 Cavendish Row), or significant historical interest (The General Post Office).

From O'Connell Bridge the tunnel will be constructed completely in the limestone bedrock. Overlying structures are mainly commercial, but also include, O'Connell Bridge, Trinity College Gate House, The Bank of Ireland Building, Brown Thomas Department Store, St. Teresa's Church, Gaiety Theatre and the Westbury Hotel. The settlements generated by construction of O'Connell Bridge Stop on the north side of the River Liffey are less than 20mm, while along Westmoreland Street they are expected to be of a magnitude of 15 to 20mm. Three buildings on the north side of O'Connell Street Lower are to be the subject of a detailed Stage 3 Assessment due to their existing condition suggesting they may be susceptible to ground movements. Along Westmoreland Street no buildings are predicted to exceed the damage category 2 in accordance with Table 9.3, but due to being founded on piles (No.’s 18-19, 20-21, 23-25, 35-39, 40-41) they will be moved forward to Stage 3 for a detailed assessment.

From College Green to St. Stephen's Green the settlements are small as a result of the tunnels being constructed in limestone bedrock. Settlements are predicted to be in the
region of 5mm or less with exception of a localised area at the emergency crossover located between College Green and Suffolk Street where buildings within the zone of influence are predicted to settle up to 18mm. As a result only prominent structures such as Bank of Ireland, Regent House, St Teresa’s Church and the Gaiety Theatre on King Street South (understood to be founded on piles) have been identified as requiring further detailed assessment at Stage 3.

In addition buildings that fall within the zone of influence of the cavern structures that will accommodate the crossing of the Interconnector Eastbound tunnel beneath the Metro North running tunnels will be considered for a detailed Stage 3 Assessment.

Many of the buildings selected for a Stage 3 Detailed Assessment are a result of surveys that have identified these buildings may be susceptible to damage from ground movements due to their condition. It is therefore possible that future surveys may identify further buildings whose condition might make them susceptible to movement and therefore the response of these buildings to ground movements would also be investigated further at the Detailed Stage 3 Assessment Stage.

**River Liffey**

From preliminary inspection the masonry quay walls to the River Liffey at O’Connell Bridge are in good condition and are predicted to be subject to 30mm settlement over a 30m length, with a maximum predicted settlement slope of 1/1000. This corresponds to a ‘slight’ damage category (superficial damage unlikely). However given the significance of these walls as supporting structures to Bachelors Walk, Eden Quay, Aston Quay, Burgh Quay and O’Connell Bridge they will be the subject of a detailed Stage 3 Assessment based on information collected from structural and condition surveys, and detailed design and construction proposals for O’Connell Bridge Stop. O’Connell Bridge platform and concourse tunnels will be constructed beneath the River Liffey. Settlement of the river bed is predicted to be in the region of 30mm and is not expected to detrimentally affect the river bed.

**O’Connell Bridge**

O’Connell Bridge is predicted to be subject to settlement in the region of 30mm. The response of O’Connell Bridge to ground movements generated by tunnelling and cut and cover construction will be assessed taking account of the results of a Principal Bridge Inspection. This assessment shall also determine what mitigation and/or protection measures should be implemented to prevent this prominent structure from suffering unacceptable damage.

**Monuments**

A total of 14 monuments have been identified along this section of the alignment that could potentially be affected by construction generated ground movements. All the monuments have been categorised as being within the negligible damage category (superficial damage unlikely) with the exception of the fountain and water trough on Cavendish Row, and the
Charles Stewart Parnell monument that may be subject to some superficial damage. The monuments in this area close to Parnell Square will be given particular attention due to the ground conditions and resulting predicted settlements. The Sir John Gray, William Smith O’Brien, and Daniel O’Connell monuments will be temporarily removed to facilitate the construction of O’Connell Bridge Stop. Similarly the Fusiliers Arch in St. Stephen’s Green will be temporarily relocated to allow construction of St. Stephen’s Green Stop.

The 120m tall steel Spire is located on O’Connell Street at the junction with Henry Street and North Earl Street. Taking account of the General Post Office (GPO) Building canopy structure in the close vicinity of the Spire, a track separation of 23.4m with the Spire located centrally between the tracks results in a predicted settlement of the Spire of 3.9mm, and the GPO canopy of 2mm. This magnitude of settlement is not expected to place these structures at risk of damage from tunnelling.

7.3.1 Assessment of residual impacts

Construction Phase

Compaction
Compacted areas will occur at the construction compounds. The magnitude of the impact associated with the compacting of an area during construction is high as the soil is compressed and disturbed. The compacted areas are to be constructed in areas of low to very low functional value so the impacts will be Low to Very low.

When the mitigation measures are taken into consideration, the magnitude and significance of this impact remains the same but the footprint of the area impacted upon decreases.

Excavation
Excavation of soil will occur at the construction compounds and stops. The magnitude of the impact associated with this activity (i.e. excavating an area during construction) is high as soil disturbance has a High impact on soil function. The excavated area will be constructed in an area of low to very low functional value so the impacts will be Medium to Low.

Settlement
Between St. Joseph’s Parade and the Spire settlements of up to 45mm are predicted as a result of construction being undertaken in the glacial sands and gravels. These settlement predictions may increase further slightly immediately adjacent to Parnell Square Stop. At approximately the Spire the TBM constructed running tunnels enter the limestone bedrock and predicted settlement reduces to less than 5mm generally between here and St. Stephen’s Green Stop with the exception of those areas identified below.

At O’Connell Bridge Stop, ground movements generated by cut and cover construction of the vertical access boxes in O’Connell and Westmoreland Streets, and mining of the platform tunnels using SEM techniques is predicted to generate 30mm settlement.
The mined emergency crossover is predicted to generate peak settlements over a localised area between College Green and Suffolk Street of less than 20mm, while the caverns at the north end of Grafton Street to accommodate the crossing of the eastbound Interconnector tunnel beneath the Metro North running tunnels is expected to generate peak settlement in the region of 60mm. Peak settlements in St. Stephen’s Green Park resulting from the construction of the stop box, and loop arrangement immediately south of the box are expected to be approximately 40mm. During the operational phase Metro North infrastructure will not generate further ground movement. The underground structures are designed as undrained (watertight) and therefore long-term ground movements beyond the construction phase are not expected to occur.

**Operational Phase**

During the operational phase Metro North infrastructure will not generate further ground movement. The underground structures are designed as undrained (watertight) and therefore long-term ground movements beyond the construction phase are not expected to occur.

### 7.3.2 Summary of residual impacts

A summary of the residual impacts associated with the scheme and affecting this area is provided in Table 9.4.

<table>
<thead>
<tr>
<th>Location</th>
<th>Area of land-take (hectares)</th>
<th>Type of impact</th>
<th>Significance of Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>MN107</td>
<td>0.2</td>
<td>Paved</td>
<td>Medium to Very low</td>
</tr>
<tr>
<td>MN107</td>
<td>19.5</td>
<td>Potentially Disturbed Ground</td>
<td>Medium to Very low</td>
</tr>
</tbody>
</table>

### 7.4 Groundwater

#### 7.4.1 Assessment of residual impacts

**Construction phase**

During the construction phase of this section of the route, there is the minor potential for localised alteration of groundwater flow around the tunnel. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of low functional value. Therefore, the impact is considered to be of Low significance. The Groundwater Baseline Assessment indicates that the levels of a range of contaminants in groundwater are either non-detectable or present at low concentrations along this section of the route with the exception of Total Petroleum Hydrocarbons (TPH), which exceeded the criteria contained in Table 3.1 Interim Guideline Values for Characterisation of List of Parameters (IGV) in the document. ‘Towards Setting
Guideline Values for the Protection of Groundwater in Ireland, Interim Report by the EPA (EPA, 2003). In general, the concentration of the contaminants in the groundwater along this section of the route is below the surface water quality criteria in the EPA publication ‘Parameters of Water Quality, Interpretation and Standards’ (EPA, 2001).

Therefore, there is the possibility that groundwater generated from construction along this section of the route can be discharged into a surface water body/drain but this would be subject to approval by the relevant Local Authority and the use of oil interceptors due to the presence of TPH in the groundwater. It is understood that the construction of the bored sections of the tunnel will not require continuous significant dewatering operations but will require the removal of groundwater seepage into the tunnel by means of a sump, pump and rising main arrangement. Dewatering is likely to be required at the cut and cover stop at Parnell Square.

Tunnel boring operations will result in the generation of spoil that has the potential to be contaminated with oil, lubricants or conditioning agents. The storage of stockpiles of potentially contaminated spoil from boring operations could result in the generation of contaminated leachate, if suitable mitigation measures (such as the immediate removal of spoil) are not implemented. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of low functional value. Therefore, the impact is considered to be of Low significance. According to the Groundwater Baseline Assessment, groundwater has been encountered within 1.0m below ground level along this section of the route and would be largely expected to be hydraulically connected to the River Liffey. Therefore, the tunnel, which extends to depths in the range of 26m bgl will be located within the underlying aquifer and well below the River Liffey. The tunnelling operations are not expected to result in dewatering of significant volumes of groundwater. However, dewatering operations are likely to be required for the cut and cover sections of the route. Unless they are suitably controlled, dewatering activities have the potential to temporarily lower the water table to the extent that the water supply in nearby wells is affected. No significant long-term lowering of the water is expected as a consequence of building the scheme. Lowering of the water table will be limited to 1m. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of low functional value. Therefore, the impact is considered to be of Low significance. It should be noted that the application of the above mitigation measures will ensure that the magnitude of the impact on groundwater quality and its regime in the St. Stephen’s Green area will be low during the construction of the proposed scheme.

Due to the long history of urban development in the St. Stephen’s Green area and the fact that the groundwater would not be considered suitable (due to contamination and the potential for saline intrusion due to the proximity to the coast) for abstraction for water
supply purposes, the area has a low functional value. Therefore, the impact of the construction of the proposed scheme on groundwater in the St. Stephen’s Green area is considered to be of Low significance.

**Operational phase**
During the operational phase of this section of the route, there is a slight potential for localised alteration of groundwater flow around the tunnel. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of low functional value. Therefore, the impact is considered to be of Low significance. Infiltration into the bored tunnel sections of the route will be collected at the stops, filtered and where possible recharged into the water table during the operational phase. If the quality of this drainage water is not controlled, it can impact the quality of the surrounding aquifer. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of low functional value. Therefore, the impact is considered to be of Low significance. Potential sources of groundwater contamination within the tunnel during the operational phase would be expected to include inappropriate disposal of domestic effluent from stops along the route and fire water from the tunnel. In addition, there is the potential for leakage from oils used in substations at each stop, in addition to storage areas for waste, cleaning agents and chemicals (oils, lubricants and solvents for example) required for stop equipment. The tunnel will be a sealed structure and the potential for the release of contaminants into the surrounding groundwater is low. The hydrostatic pressure at the depth of the tunnel would be expected to minimise the potential for the release of contaminants from the tunnel into the surrounding aquifer. Provided that the mitigation measures detailed in Section 10.4.2 are put in place, the magnitude of this impact is low and the impact affects an area of low functional value. Therefore, the impact is considered to be of Low significance.

It should be noted that the application of the above mitigation measures will ensure that the magnitude of the impact on groundwater quality and its regime in the St. Stephen’s Green area will be low during the operational phase of the proposed scheme.

Due to the long history of urban development in the St. Stephen’s Green area and the fact that the groundwater would not be considered suitable (due to contamination and the potential for saline intrusion due to the proximity to the coast) for abstraction for water supply purposes, the area has a low functional value. Therefore, the impact of the operation of the proposed scheme on groundwater in the St. Stephen’s Green area is considered to be of Low significance.

**7.5 Comments on Environmental Impact - MN107**

**Construction phase**
There are residential buildings immediately above the cross-passage at St. Joseph’s Place and tunnelling could result if unmitigated in very high impact category for people in adjacent
building. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted. For the area south of Mater Stop including St. Joseph’s Parade residential areas north of Parnell the Rotunda Hospital including the HARI Clinic, Ambassador Theatre, the Temple Theatre and the Gate Theatre in Cavendish Row significant effects are predicted. For example during quiet moments in a production in the Gate Theatre the noise from tunnelling will be clearly audible and intrusive. The main mitigation possible is liaison with the theatre managements, with as much advance warning as practicable. However no human health impacts are predicted from this. For most of the tunnelling it is predicted that during construction vibration would be close to, but not exceed the limit advised for the operation of sensitive equipment at the Rotunda Hospital/HARI clinic, and mitigation in the form of liaison between the site and the hospital together with vibration monitoring will be required to ensure that use of the equipment is not adversely affected. Provided this is done no significant effect on human health is predicted. However during the construction of the proposed cross-passage below O’Connell Street Upper this limit for sensitive equipment may be exceeded. Mitigation in the form of liaison between the site and the hospital will be required to ensure that blasts and critical use of the equipment do not occur simultaneously. Provided this is done no significant effect is predicted. From Parnell Street to O’Connell Bridge sensitive receptors include hotels in O’Connell Street which could result (if unmitigated) in very high impacts for people in adjacent buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted. Drill and Blast techniques may be necessary for the construction of O’Connell Bridge Stop beneath the River Liffey which could result (if unmitigated) in very high impacts for people in adjacent buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted. The proposed cross passage near Princes Street North could result (if unmitigated) in very high impacts for people in adjacent buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted. From O’Connell Street to St. Stephens Green there are residential and academic buildings (including Trinity College) which could result (if unmitigated) in very high impacts for people in adjacent buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted. The passage of the tunnel boring machine in this area, the groundborne noise level in the nearest buildings of Trinity College is likely to be 45dB L_Aeq. This is just around the level which would have the potential to interfere with education, (see Section 8.6.3) but given the relatively short duration a significant effect on education is not predicted. The proposed cross passage near Wicklow Street could result (if unmitigated) in very high impacts for people in adjacent buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted. During quiet moments in a production in the Gaiety Theatre the noise from tunnelling will be clearly audible and intrusive. The main mitigation possible is liaison with the theatre managements, with as much advance warning as practicable. However no human health impacts are predicted from this. At St. Stephens Green, blasting techniques are likely to be used for the excavation of the turnback loop which could result (if unmitigated) in very high impacts for
people in adjacent buildings. Mitigation is suggested limiting the charge weight. Assuming this is done no significant effect is predicted.

**Operational phase**

Modelling predicts no significant effect from the operational phase either in terms of groundborne noise, vibration effect in humans or vibration affecting sensitive equipment. Based on this no adverse effect on human health is predicted. It is noteworthy that a specific detailed study was carried out to assess vibration sensitive equipment in the Mater Misericordiae Hospital, Mater Private Hospital, Rotunda Hospital and the HARI clinic and no residual effect after mitigation is predicted.

<table>
<thead>
<tr>
<th>Company</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbey Presbyterian Church</td>
<td>Concerns about ground movement, settlement and vibrations due to proximity, lack of geotechnical information, discussions with RPA experts and building assessment carried out which led to agreement with RPA. Tunnel alignment will be located within the limestone bedrock. RPA will prepare detailed method statement. Agreement reached with RPA.</td>
</tr>
<tr>
<td>Ampleforth Ltd. – Fitzwilliams hotel, St. Stephen’s Green</td>
<td>Agreement reached with RPA.</td>
</tr>
<tr>
<td>Appleby Jewellers – Johnson’s Court</td>
<td>Vibration and settlement concern</td>
</tr>
<tr>
<td>Arnotts Ltd. – Henry Street</td>
<td>Similar concerns as Hibernian club – cf. response by RPA.</td>
</tr>
<tr>
<td>Blend Resident’ Committee – Blessington, Eccles, Nelson, Dorset Street</td>
<td>Metro North Scheme will have positive impact on land development.</td>
</tr>
<tr>
<td>Brown Thomas &amp; BT – Grafton St</td>
<td>In support of Metro North Scheme</td>
</tr>
<tr>
<td>Brown Thomas Ltd.</td>
<td>Vibration and settlement concerns, mitigation measures will be implemented, vibrations from blasting will be controlled by charge weight and monitoring. Risk register is being implemented. Contractor will be required to have third party insurance to cover claims.</td>
</tr>
<tr>
<td>Carrigwood Developments Ltd. – 13/13A St.</td>
<td>Stated requirements regarding effects of Metro North Scheme, alternative bus service?</td>
</tr>
<tr>
<td>Stephen’s Green and 24 Dawson St.</td>
<td></td>
</tr>
<tr>
<td>Carrolls Irish Gift Stores – Westmoreland/O’Connell Sts.</td>
<td></td>
</tr>
<tr>
<td>Castle Hotel – Parnell Square</td>
<td></td>
</tr>
<tr>
<td>Chartered Land Ltd. – Ilac Centre</td>
<td></td>
</tr>
<tr>
<td>Chartered Land Ltd. – O’Connell Street Upper, Henry St., Moore St.</td>
<td></td>
</tr>
<tr>
<td>Clery &amp; Co. PLC – O’Connell St</td>
<td></td>
</tr>
<tr>
<td>David, Joanne &amp; Paul Daly – Grafton St</td>
<td></td>
</tr>
<tr>
<td>Dixon Hempenstall Ltd. – Suffolk St.</td>
<td></td>
</tr>
<tr>
<td>Dublin Chamber of Commerce</td>
<td></td>
</tr>
<tr>
<td>Dublin City Centre Business Association Ltd.</td>
<td></td>
</tr>
</tbody>
</table>
Dublin Cycling Campaign – St. Stephen's Green  
Sufficient space and standard of bicycle stands.

Eason & Son Ltd. – O'Connell Street  
Concern about vibrations and noise, but following discussions with RPA experts are no longer concerned.

Edmund Ross Studios – Grafton Street

Fitzers Holdings Ltd. – Chatham/Dawson Streets

Fliver Investments Ltd. – Aston Quay

Gaelscoil Colaiste Muire

Gate Theatre

Gaiety Theatre

Highbury Lane Properties Ltd. – O'Connell Street

Hotel St. George – Parnell Sq

Industrial Development Authority Ireland

Irish Life & Permanent – O'Connell St.

Irish Life Investment Managers & Royal College of Surgeons in Ireland – St. Stephen’s Green

Irish Property Unit Trust – Suffolk/Grafton Street

Justin Marden – St. Stephen’s Green

K.S.K. Enterprises Ltd. – Westmoreland St.

Kildare Street and University Club – St. Stephen’s Green

L'Occitane (Olive Tree Lifestyle) – Wicklow/Upper Liffey Sts.

Landlords of 124/127 St. Stephen’s Green

Lisney – St. Stephen’s Green

Millennium Theatre Company

National Taxi Drivers Union

O'Brien's Sandwich Bar Ltd. – Bachelor's Walk

Park Rite Ltd.

Percy Nominees Ltd. – Grafton/Henry/O’Connell St.

Quinn Insurance Ltd. – O’Connell Street

Rehab Group – Westmoreland St.

Salix Trust Ltd. – Grafton St.

Salix Trust Ltd. – St. Stephen’s Green

Schuh Ltd – O’Connell St.

Stanberry Investments Ltd.

Sunday River Ltd. (Il Posto) – St. Stephen’s Green

The National Concert Hall – Earlsfort Terrace

The Rotunda Hospital

The St. Stephens Green Hibernian Club

Agreement reached with RPA:  
Extract from Rotunda Agreement (Clauses 5.7 and 10.8),  
Rotunda Agreement (redacted).

Utilities diversion work of concern, concerns about settlement and vibrations; RPA have carried out building characterisation and basement survey. RPA accept that building is vulnerable and architectural conservation survey will be undertaken.

Settlement assessment Stage 2A have been
<table>
<thead>
<tr>
<th>Company/Location</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomas Lenehan &amp; Co. – Capel Street</td>
<td>Further ground investigations have been carried out. Building damage will be limited to category 1 according to EIS. DART Interconnector work will go on approx. at same time, cumulative effects, baseline vibration measurements?</td>
</tr>
<tr>
<td>Thomas Patrick of Grafton Street 77</td>
<td>Vibration and settlement could impact on buildings have poor foundations, tunnel depth approx. 27 m, buildings on Grafton street have been surveyed by RPA. Low impact expected but minor repair may be required. Is DIN most appropriate standard? POP Scheme useful, cost for independent professional advice.</td>
</tr>
<tr>
<td>Trinity Street Car Park Ltd. Q-Park Ireland Ltd.</td>
<td>Traffic concern, loss of business</td>
</tr>
<tr>
<td>Warren Whitney – St. Stephen’s Green</td>
<td></td>
</tr>
<tr>
<td>Weir &amp; Sons – Grafton Street</td>
<td></td>
</tr>
<tr>
<td>West Hotel Trading Company Ltd. – Grafton St. (Westbury hotel)</td>
<td>Accessibility will not be restricted, concerns regarding groundborne noise and vibration. EIS states limits, extensive monitoring will be required during construction. Environmental risk management plan is required by contractor.</td>
</tr>
<tr>
<td>Westin Hotel Trading Company</td>
<td>Concerns about traffic management, public transport gate, access will be maintained.</td>
</tr>
<tr>
<td>Wynn’s Hotel – Abbey St.</td>
<td></td>
</tr>
</tbody>
</table>
### 8 Miscellaneous

#### 8.1 Submissions from Prescribed Bodies

<table>
<thead>
<tr>
<th>Organization</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coras Iompair Eireann/Iarnrod Eireann</td>
<td>Agreement reached regarding Drumcondra Station and St. Stephen's Green</td>
</tr>
<tr>
<td>Department of the Environment, Heritage &amp; Local Government</td>
<td>Only responsible for monuments and buildings (not churches). Monuments: Option 3 preferred.</td>
</tr>
<tr>
<td></td>
<td>Option for St. Stephen's Green proposed. Ongoing investigations to be continued.</td>
</tr>
<tr>
<td>Dublin Airport Authority</td>
<td>Supportive of Metro North Scheme</td>
</tr>
<tr>
<td>Dublin Bus</td>
<td>Amendments needed, modification required</td>
</tr>
<tr>
<td>Dublin City Council</td>
<td>DCC are in support of Metro North project which fit into strategies of DCC.</td>
</tr>
<tr>
<td>Dublin Transportation Office</td>
<td></td>
</tr>
<tr>
<td>Fingal County Council</td>
<td>FCC is in favour of the application by RPA.</td>
</tr>
<tr>
<td>National Roads Authority</td>
<td></td>
</tr>
<tr>
<td>National Trust for Ireland (An Taisce)</td>
<td></td>
</tr>
<tr>
<td>Dublin Business Centre</td>
<td>No agreement reached</td>
</tr>
</tbody>
</table>
Appendix 2

Considerations Regarding Management of Environmental Risks

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Considerations Regarding Management of Environmental Risks

1 Introduction

"I have made my greatest engineering contributions not by solving difficult problems but by avoiding them", Conlon 1989.

The main objective of environmental risk management for tunnelling projects is to identify risks at an early stage of the project, which makes it possible to avoid future problems. During the construction phase or thereafter it is often difficult and time-consuming to resolve such problems, which can result in negative environmental effects, project delays and increased costs. Environmental risk management shall therefore be an integral part of environmental impact assessment.

Risk management is widely adopted to control risks in construction projects, especially when assessing environmental aspects of a project, safety of workers and the public and financial and other project risks. Codes and technical guidance documents have been published on safety in tunnelling and risk management of tunnel works, for example the Code of Practice by the ITIG (2006).

The most important aspect of environmental risk management and the observational method is the identification of hazards and associated risks and the preparation of remedial and/or mitigation measures.

2 Identification of Environmental Risks

A multi-disciplinary approach shall be used to update the identification of the initial risks and to keep under control the residual risks by:

- Collecting, analysing, and processing the monitoring data relating to the previously excavated section, (TBM data, retaining wall movements).
- Collecting, analysing, and processing new data that can affect the local geological / hydrogeological reference model.
- Collecting, analysing and processing the piezometric data.
- Collecting, analysing and processing data related to noise and vibration monitoring.
Reviewing the results of recent condition surveys of buildings and pre-existing information on buildings and their foundations.

Reviewing the results of the building assessments including the sensitivity to potential variations.

Defining mitigation and contingency measures.

Reviewing the need for monitoring instruments or the frequency of the readings, and reviewing the requirements in terms of the ongoing construction works.

3 Implementation of Environmental Risk Management

The contractor in cooperation with RPA shall manage the risks during construction of the tunnels and underground works and operation of the scheme in compliance with the requirements given and ensure that the residual environmental risks associated with these works after the application of any mitigation measures shall comply with the Environmental Impact Assessment (EIA). The environmental risk management process, to be managed by RPA and implemented by the contractor, should include the following activities:

* Implement an integrated organisation to manage environmental movement risks, including ground movements, ground water flow, vibrations and groundborne noise.

* Implement a database and geographic information system (GIS) to provide a common means of storing, accessing and interpreting the all relevant information, including buildings, tunnel construction and monitoring data.

* Carry out building/structural surveys as required for any buildings/structures that may be affected by the works.

* Carry out predictions of settlement/movement from the works.

* Carry out predictions of vibrations and groundborne noise from the works.

* Assess the initial risks induced by the predicted settlement/movement and assess the vulnerability of buildings and other structures to damage.

* Identify buildings and other structures at risk and requiring extended monitoring and/or protection or other mitigation measures.

* Design the appropriate mitigation measures to ensure that building damage as defined under the terms of the EIA will not occur.

* Reassess the impact to buildings and other structures as well as installations in the ground, taking into account mitigation measures to be implemented.
* Document that damage as defined under the terms of the EIA will not occur.
* Design and implement appropriate monitoring systems.
* Develop secondary mitigation measures to be implemented if movement thresholds are reached.

### 3.1 Contractual Requirements

The contractor shall integrate the real time monitoring with other project information so that the works are tightly controlled, any behaviour outside the predicted range is immediately observed and the appropriate remedial measures are taken. The sensitivity of ground movement estimates and the consequent structural damage assessments shall be considered as part of the building assessments. The assessments shall take into account potential variations in the ground conditions together with a range of parameters for the soil and for the volume loss from the tunnelling. These assessments shall incorporate sensitivity analyses covering the "worst credible" parameters together with the "most likely" parameters.

### 3.2 Building Conditions Survey

The information obtained during the building condition surveys including, drawings, building construction and condition, photographs foundation information and building assessment reports shall be entered into the database system and be accessible via the GIS system. The assessment process shall include a detailed documentation, indicating that damage will not occur, taking into account both the mitigation measures to be implemented, and the “worst credible” parameters. During the execution of the works the building assessments shall be updated in accordance with the experience gained and amended as necessary. In that respect, trigger levels shall be identified which indicate that critical conditions (which may lead to potential damage) are reached.

### 3.3 Control of Residual Risks

The basic concepts and objectives employed by environmental risk management are in close agreement with the objectives of the observational method of geotechnical design and monitoring of the construction process, (CIRIA, 1989). When applying the Observational Method, emphasis is placed on prototype testing, field monitoring and ongoing analysis of obtained information regarding the construction process and ground response, (EN 1997-1, 2004).

The contractor shall for each station and shaft and for each section of the tunnel drives (between adjacent stations or shafts) and for each underground structure through application of the Observational Method ("active design") collect all relevant information for that part of the works.
3.4 Full-scale Test

Full-scale tests are an important part of any design based on the Observational Method and should be specified in the construction process. Full-scale tests shall be employed to determine geotechnical and other construction risks as well as risks related to vibrations and groundborne noise. Such full-scale tests shall be carried out at the initial phase of sensitive works and carefully monitored (e.g. ground movements, groundwater, vibrations and groundborne noise etc.). Based on the results of initial construction monitoring or information obtained from ground and building response measurements, the construction method and equipment to be employed may have to be altered or adapted to the prevailing environmental conditions in order to control and minimise residual environmental risks.

4 References


Appendix 3
Inventory of Vibration and Groundborne Noise Guidelines and Standards for Railway Tunnels

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4 Inventory of Reference Values for Groundborne Noise – Scandinavian Tunnelling
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1 Introduction
Vibrations and groundborne noise are two important factors which affect the environment during construction and operation of the Metro North Scheme. This Appendix reviews national standards and regulations as well as internationally applied practice in relation to construction and operation of railway tunnel projects in Europe and the United States. Differences between the EIS and relevant standards, in particular in respect to the German DIN standard (4150) are highlighted.

2 Vibrations - Inventory of Standards, Regulations and Reference Values
This chapter reviews standards and generally accepted guidelines regarding vibrations from traffic in Germany, Sweden and Denmark.

2.1 Germany
The EIS vibration impact is based on German vibration standard DIN 4150, which is reviewed in detail with respect to

- Vibrations in buildings (effects on persons).
- Effects on structures.


Measurements
The standard states that vibration measurements shall be carried out in the vertical and two horizontal directions.

Vibrations Cause by Railway Traffic, Section 6.5.3
DIN 4150-2 gives guideline values (A) for the evaluation of vibrations in buildings which are classified according to different building categories, Section 6.3. Below 0 does not give a sensitivity scale on which the impact magnitude in the EIS could be based (Impact magnitude ranging from very low to very high).

Reference value A for the Assessment of Vibration Immission in residential areas and similarly used locations, DIN 4150-2, Table 1.

<table>
<thead>
<tr>
<th>Row</th>
<th>Building Category</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$A_u$</td>
<td>$A_o$</td>
</tr>
<tr>
<td>1</td>
<td>Industrial buildings</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$A_r$</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Areas with mainly industrial buildings (Industrial estates)</td>
<td>0.3</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>Mixed residential and industrial areas</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>4</td>
<td>Mainly or only residential buildings</td>
<td>0.15</td>
<td>0.07</td>
</tr>
<tr>
<td>5</td>
<td>Especially sensitive areas such as hospitals, health clinics in specially assigned areas</td>
<td>0.1</td>
<td>0.05</td>
</tr>
</tbody>
</table>

*) Values are not in agreement with EIS.

2 Refers to section number in DIN 4150-2.
The DIN Standard states that the guideline values should be applied with judgement and taking into consideration the specific circumstances of a project. The Standard states that the guideline values $A_u$ and $A_r$ in 0 are directly applicable to vibrations caused by railway traffic and in particular railway traffic in tunnels (6.5.3.2).

**Comment on EIS: Chapters 05 - Human Beings: Vibrations**

In the EIS, reference is made to DIN 4150-2 when establishing criteria for impact magnitude during the operational phase which is shown in Tables 5.3. However, the EIS does not state how the values for impact magnitudes “very high” and “low” in Table 5.3 below were determined from DIN 4150-2 0 above.

**Table 5.3 Criteria for assessment of impact magnitude during operation**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Impact magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration</td>
<td></td>
</tr>
<tr>
<td>Day $A_u = 0.4, A_o = 6, A_r = 0.2$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u = 0.2, A_o = 0.4, A_r = 0.1$</td>
<td>high</td>
</tr>
<tr>
<td>Day $A_u = 0.3, A_o = 6, A_r = 0.15$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u = 0.15, A_o = 0.3, A_r = 0.1$</td>
<td>medium</td>
</tr>
<tr>
<td>Day $A_u = 0.2, A_o = 6, A_r = 0.1$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u = 0.15, A_o = 0.2, A_r = 0.05$</td>
<td>low</td>
</tr>
<tr>
<td>Day $A_u = 0.15, A_o = 3, A_r = 0.07$</td>
<td></td>
</tr>
<tr>
<td>Night $A_u = 0.1, A_o = 0.15, A_r = 0.05$</td>
<td>very low</td>
</tr>
<tr>
<td>Day $A_u = 0.1, A_o = 3, A_r = 0.05$</td>
<td></td>
</tr>
</tbody>
</table>

**Vibrations Caused by Construction Activities, Section 6.5.4**

In DIN4150-2, the same evaluation concept is applied to construction activities as to railway-induced vibrations. For day-time work lasting no longer than 78 days (actual working days), the guideline values given in 0 below shall be applied. For night-time work, the guideline values given in 0 shall be applied. Three different levels are proposed (I, II and III). Below Level I, annoyance is unlikely to occur. If Level II is not exceeded, significant annoyance is unlikely to occur. Exceeding Level III will result in unreasonable exposure to vibrations.

**Reference Value A for the Assessment of Vibration Imission from Construction Work Except Blasting.**

<table>
<thead>
<tr>
<th>Level</th>
<th>$D &lt; 1$ Day</th>
<th>6 Days $&lt; D &lt; 26$ Days</th>
<th>26 Days $&lt; D &lt; 78$ Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$A_u$</td>
<td>$A_u^\prime$</td>
<td>$A_r$</td>
</tr>
<tr>
<td>I</td>
<td>0.8</td>
<td>5</td>
<td>0.4</td>
</tr>
<tr>
<td>II</td>
<td>1.2</td>
<td>5</td>
<td>0.8</td>
</tr>
<tr>
<td>III</td>
<td>1.6</td>
<td>5</td>
<td>1.2</td>
</tr>
</tbody>
</table>

<sup>1</sup> For commercial and industrial estates $A_o = 6$. 

**According to DIN 4150-2:** 0.10
2.1.2 DIN 4150-3 Vibration in Buildings – Part 2: Effects on Structures

**Effects of Short-term Vibrations**

DIN Standard 4150-3 suggests guideline values for the assessment and evaluation of vibrations affecting structures, 0. If the guideline values are not exceeded it is unlikely that the value of the property will be negatively affected. It should be noted that the DIN Standard introduces different types of buildings and structures and gives guideline values which should not be exceeded. The largest value (maximum value) of three measured components, x, y and z shall be used in the assessment. Note that for most buildings, the frequency range 10 – 50 Hz is applicable.

Reference values of the vibration velocity for the assessment of short-term vibrations on buildings, Table 1 of DIN 4150-3.

<table>
<thead>
<tr>
<th>Row</th>
<th>Type of Structure</th>
<th>Guideline Values$^\dagger$ of Vibration Velocity in mm/s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Foundation</td>
</tr>
<tr>
<td>1</td>
<td>Buildings used for industrial purposes, industrial buildings and buildings of similar design</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Dwellings and buildings of similar design and/or use</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Structures that, because of their particular sensitivity to vibration, do not correspond to those listed in rows 1 and 2, and are of great intrinsic value (e.g. buildings that are under a preservation order)</td>
<td>3</td>
</tr>
</tbody>
</table>

$^\dagger$ Reference values shall be interpolated between the upper and lower boundary of a frequency range.

**Effects of Long-term Vibrations**

In DIN 4150-3, guideline values are also given for the effect of long-term vibrations on buildings, 0.

Reference values of the vibration velocity for the assessment of long-term vibrations on buildings, Table 3 of DIN 4150-3.

<table>
<thead>
<tr>
<th>Row</th>
<th>Type of Structure/building</th>
<th>Guideline Values of Vibration Velocity in mm/s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Upper floor, horizontal, all frequencies</td>
</tr>
<tr>
<td>1</td>
<td>Buildings used for industrial purposes, industrial buildings and buildings of similar design</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Dwellings and buildings of similar design and/or use</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Structures that, because of their particular sensitivity to vibration, do not correspond to those listed in rows 1 and 2, and are of great intrinsic value (e.g. buildings that are under a preservation order)</td>
<td>2.5</td>
</tr>
</tbody>
</table>

2.2 Sweden

The Swedish parliament has stated that for the development of enhanced environmental regulations, called: “Good build environment” (god byggd miljö), the aim is to reduce noise by 5% by 2010, compared to the year 1998.
The Swedish Environmental Protection Agency (Naturvårdsverket) in cooperation with the Swedish Transport Administration (previously Banverket), has published guidelines regarding noise and vibrations from railway traffic: "Buller- och vibrationer från spårburen linjetrafik – riktvärden och tillämpningar" (Noise and vibrations from railway traffic – Guidelines and applications), issued 2006. The following guideline values are applied for construction of new railway lines. The given values refer to permanent housing and health care facilities, 0. The given values are rms values, slow with frequency weighing according to ISO 8041 within the frequency range of 1 – 80 Hz).

Reference values for construction of new railway line adjacent to buildings – comfort in buildings.

<table>
<thead>
<tr>
<th>Vibration level RMS (1 – 80 Hz)</th>
<th>Velocity, mm/s</th>
<th>Acceleration, mm/s²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.4</td>
<td>14</td>
</tr>
</tbody>
</table>

2.3 Denmark

2.3.1 Cityringen Metro, Copenhagen

Protection of Structures

The maximum vibration velocity ($v_{peak}$) shall not exceed the levels shown in Table 3-A measured according DIN 4150-3 at neighbour buildings to the work areas.

Table 1. General standard limits for vibrations harmful to buildings, $v_{peak}$ according DIN 4150-3.

<table>
<thead>
<tr>
<th>Application of buildings</th>
<th>Peak Vibration Velocity, $v_{peak}$ mm/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structures like industrial plants or infrastructure</td>
<td>20</td>
</tr>
<tr>
<td>Normal building structures; like residential housing, offices, institutions etc.</td>
<td>5</td>
</tr>
<tr>
<td>Vulnerable building structures; like preserved and listed buildings and buildings classified as preservation-worthy.</td>
<td>3</td>
</tr>
</tbody>
</table>

Vibration Comfort Limits

Guideline standard limits are shown in the following Table 3-B.

Table 3-B General standard limits for vibration comfort

<table>
<thead>
<tr>
<th>Application</th>
<th>Weighted acceleration level, $L_{aw}$ in dB (KBweighted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential areas (day and night), Residential buildings in mixed residential/business areas 6 p.m. – 7 a.m., Institutions for children etc.</td>
<td>75</td>
</tr>
<tr>
<td>Residential buildings in mixed residential/business areas 7 a.m. - 6 p.m. Offices and educational facilities and similar</td>
<td>80</td>
</tr>
<tr>
<td>Business and industry areas</td>
<td>85</td>
</tr>
</tbody>
</table>
The comfort vibration limits apply for long-duration work only.

3Groundborne Noise - Inventory of Standards, Regulations and Reference Values
The standards and guidance values applied in different countries have been compiled based on Banverket (2006). Also, an inventory of recommended and applied criteria for groundborne noise from projects with similar geological and geotechnical conditions (Malmö, Copenhagen) as Dublin has been prepared.

3.1 Austria
The Austrian Standard ÖNORM S-9012 gives guideline values for "sufficient" and “good standard” with reference to groundborne noise for residential buildings and areas with noise-sensitive activities. Buildings are divided into 5 categories with values for day, evening and night time, 0. When measuring groundborne noise, at least 10 train passages shall be measured and at least three of each train type. In addition, the standard requires that groundborne noise from railway traffic may not exceed background noise by 10 dB. Daytime is defined from 06.00 – 18.00, evening from 18.00 – 22.00 and night time from 22.00 – 06.00.

Good standard for groundborne noise according to ÖNORM S-9012.

<table>
<thead>
<tr>
<th>Good noise standard</th>
<th>Criteria for $L_{PAmx}$ [dBA], Slow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Good standard</td>
</tr>
<tr>
<td></td>
<td>Type of area</td>
</tr>
<tr>
<td></td>
<td>Day</td>
</tr>
<tr>
<td>1 Recreational area, healthcare, hospital area</td>
<td>35</td>
</tr>
<tr>
<td>2 Residential suburban area, countryside, schools</td>
<td>40</td>
</tr>
<tr>
<td>3 Residential urbanized area, farming areas with housing areas</td>
<td>40</td>
</tr>
<tr>
<td>4 Densely populated areas, industrial area without noise emission</td>
<td>45</td>
</tr>
<tr>
<td>5 Industrial areas with low noise emission</td>
<td>45</td>
</tr>
</tbody>
</table>

3.2 Denmark
The following low frequency noise limits are used for tunnelling projects, 0. These noise limits follow the guidelines from the Danish Environmental protection Agency: Miljøstyrelsens orierentering nr. 9/1997.

General standard limits for low frequency noise, Table 3-C.

<table>
<thead>
<tr>
<th>Application</th>
<th>Low frequency noise (A-weighted noise level (10 - 160 Hz), $d_B L_{eq,10min}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential building facilities</td>
<td>$L_{PAmx}$, 20</td>
</tr>
<tr>
<td>Evening/night</td>
<td>6 p.m. - 7 a.m.</td>
</tr>
<tr>
<td>Day</td>
<td>25</td>
</tr>
<tr>
<td>7 a.m. - 6 p.m.</td>
<td></td>
</tr>
<tr>
<td>Offices, education facilities</td>
<td>35</td>
</tr>
<tr>
<td>Other noise vulnerable facilities</td>
<td></td>
</tr>
<tr>
<td>Other facilities in industry and business</td>
<td>30</td>
</tr>
</tbody>
</table>
3.3 United Kingdom

3.3.1 General Guidelines
Many tunnelling projects in the United Kingdom, such as Channel Tunnel Rail Link, Crossrail and Thames link 2000 use the following guideline values, 0.

Operational Groundborne Noise Criteria Applicable to Dwellings.

<table>
<thead>
<tr>
<th>Impact classification</th>
<th>Ground borne noise level dB, L\text{PA_{max,slow}} measured near the centre of any dwelling room on the ground floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>35-39</td>
</tr>
<tr>
<td>Medium</td>
<td>40-44</td>
</tr>
<tr>
<td>High</td>
<td>45-49</td>
</tr>
<tr>
<td>Very High</td>
<td>&gt;49</td>
</tr>
</tbody>
</table>

Operational groundborne noise criteria applicable to non-residential receptors.

<table>
<thead>
<tr>
<th>Building</th>
<th>Level/Measure L\text{PA_{max,slow}}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theatres</td>
<td>25 dBA</td>
</tr>
<tr>
<td>Large Auditoria/Concert Halls</td>
<td>25 dBA</td>
</tr>
<tr>
<td>Studios</td>
<td>30 dBA</td>
</tr>
<tr>
<td>Churches</td>
<td>35 dBA</td>
</tr>
<tr>
<td>Courts, lecture theatres</td>
<td>35 dBA</td>
</tr>
<tr>
<td>Small Auditoria/halls</td>
<td>35 dBA</td>
</tr>
<tr>
<td>Schools Colleges</td>
<td>40 dBA</td>
</tr>
<tr>
<td>Hospitals, laboratories</td>
<td>40 dBA</td>
</tr>
<tr>
<td>Libraries</td>
<td>40 dBA</td>
</tr>
</tbody>
</table>

3.3.2 Crossrail Project
The Crossrail project has been used as reference on several occasions to support the choice of groundborne noise values. The final Version 4 of the document: D10 – Groundborne Noise and Vibration, dated 03/04/08. In the introduction of the final Version 4 the following note is made:

"An Information Paper on groundborne noise and vibration (IP D10) was published in January 2006 (Version 1). This revised Information Paper sets out an updated version of IP D10, reflecting discussions held with the London Borough of Camden, the lead local authority on the generic issue of groundborne noise and vibration, since January 2006, and replaces earlier versions."

The thresholds of significance used to assess the groundborne noise impacts of Crossrail are presented in Table 1 below.

\(^3\) Numbering: Table 1 according to D10 Document.
The following additional requirements have been added to the document, which state stringent restrictions:

2.10 The nominated undertaker will put in place measures that will ensure that at no point during the operational life of the Crossrail passenger service will the combined power spectral density of the wheel and rail roughness amplitudes be worse than 30 dB re 1 micron in the 1/3 octave centred on a wavelength of 2m, decreasing by 15 dB per tenfold reduction in wavelength.

2.11 Prior to opening, the nominated undertaker will ensure that the rails of the underground sections of Crossrail are conditioned by grinding, or other suitable means, and are appropriately maintained thereafter. The nominated undertaker will be required, as part of the final track design development, to provide details to the local authorities addressing the frequency of routine maintenance regimes, and the criteria under which maintenance activities such as wheel turning and rail grinding will be triggered, to demonstrate that Best Practicable Means will be adopted in respect to those matters so far as relevant for the purpose of maintaining the system to achieve the performance levels set out in Table 1 above.

2.13 In recognition of the local authorities’ preference for groundborne noise levels within residential dwellings which are no greater than 35dB L_{A,ref,5} during the operation of Crossrail, the nominated undertaker will provide the information identified in paragraph 4.2 to the relevant local authority where any residential property is predicted through modelling as being likely to experience noise levels exceeding 35dB L_{A,ref,5}.

2.14 Further as paragraph 1.5 of the Environmental Minimum Requirements explains, the nominated undertaker will use reasonable endeavours to adopt mitigation measures that will further reduce any adverse environmental impacts caused by Crossrail, insofar as these mitigation measures do not add unreasonable costs to the project or unreasonable delays to the construction programme. This requirement will be applied to any residential property in which the level of groundborne noise arising from the operation of the Crossrail passenger service near the centre of any noise-sensitive room is predicted to equal or exceed 35dB L_{A,ref,5}.

<table>
<thead>
<tr>
<th>Building</th>
<th>Level/Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential buildings</td>
<td>40dB L_{A,ref,5}</td>
</tr>
<tr>
<td>Offices</td>
<td>40dB L_{A,ref,5}</td>
</tr>
<tr>
<td>Hotels</td>
<td>40dB L_{A,ref,5}</td>
</tr>
<tr>
<td>Theatres</td>
<td>25dB L_{A,ref,5}</td>
</tr>
<tr>
<td>Large Auditoria/Concert Halls</td>
<td>25dB L_{A,ref,5}</td>
</tr>
<tr>
<td>Sound recording studios</td>
<td>30dB L_{A,ref,5}</td>
</tr>
<tr>
<td>Places of meeting for religious worship</td>
<td>35dB L_{A,ref,5}</td>
</tr>
<tr>
<td>Courts, lecture theatres</td>
<td>35dB L_{A,ref,5}</td>
</tr>
<tr>
<td>Small Auditoria/halls</td>
<td>35dB L_{A,ref,5}</td>
</tr>
<tr>
<td>Schools Colleges</td>
<td>40dB L_{A,ref,5}</td>
</tr>
<tr>
<td>Hospitals, laboratories</td>
<td>40dB L_{A,ref,5}</td>
</tr>
<tr>
<td>Libraries</td>
<td>40dB L_{A,ref,5}</td>
</tr>
</tbody>
</table>
3.4 United States of America
Reference values for groundborne noise according to US Department of Transportation – Federal Transit Administration; Transit Noise and Vibration Impact Assessment, (1995). The time constant (slow or fast) is not indicated in Table 10.


<table>
<thead>
<tr>
<th>Land Use Category / Type of Building or Room</th>
<th>Ground-Borne Noise Impact Levels (re 20 micro Pascals)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequent events</td>
</tr>
<tr>
<td>Residences and buildings where people normally sleep</td>
<td>35 dBA</td>
</tr>
<tr>
<td>Institutional land uses with primarily daytime use</td>
<td>40 dBA</td>
</tr>
<tr>
<td>Concert Halls</td>
<td>25 dBA</td>
</tr>
<tr>
<td>TV Studios</td>
<td>25 dBA</td>
</tr>
<tr>
<td>Recording Studios</td>
<td>30 dBA</td>
</tr>
<tr>
<td>Auditoriums</td>
<td>35 dBA</td>
</tr>
<tr>
<td>Theatres</td>
<td>35 dBA</td>
</tr>
</tbody>
</table>

Notes:

“Frequent Events” is defined as more than 70 vibration events per day.

“Infrequent Events” is defined as fewer than 70 vibration events per day.

4. Inventory of Reference Values for Groundborne Noise – Scandinavian Tunnelling Projects

4.1 General
During the past 10 years, an increasing number of major transportation infrastructure projects, many of these including railway tunnels, have been planned and constructed in Scandinavian countries. Awareness for environmental consideration has been increasing and new guidelines and regulations have been introduced on a national and/or regional scale. This chapter summarizes the guidelines with respect to groundborne noise from a large number of projects.

4.2 Scandinavian Projects Summary
0 summarizes guideline values from recent tunnelling projects in Sweden and Norway, Banverket (2006).

Summary of guideline values for groundborne noise (stomljud) for recent Swedish projects.

<table>
<thead>
<tr>
<th>Tunnelling Project</th>
<th>Reference Value</th>
<th>Premises</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citytunneln - Malmö</td>
<td>30 dBA</td>
<td>Residential buildings, healthcare, churches, courts of law, Offices and schools Malmö music theatre</td>
<td>Maximum value, slow,</td>
</tr>
<tr>
<td></td>
<td>38 dBA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25-30 dBA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Citybanan - Stockholm</td>
<td>30 dBA</td>
<td>Residential buildings</td>
<td>Maximum value, slow,</td>
</tr>
<tr>
<td>Botniabanan - Örnsköldsvik</td>
<td>30 dBA</td>
<td>Residential buildings</td>
<td>Maximum value, slow,</td>
</tr>
<tr>
<td>Tågtunnel Varberg - Hamra</td>
<td>30-35 dBA</td>
<td>Residential buildings</td>
<td>Maximum value,</td>
</tr>
</tbody>
</table>
fast corresponds to 28-34 dBA, slow.

Chalmerstunneln – Göteborg railway
30 dBA
Residential buildings, healthcare institutions
Maximum value, slow. 35 dBA can be discussed.

Railway tunnel Falkenberg - Tröingeberg
35 dBA
Residential buildings
Maximum value, fast correspond to 33-34 dBA, slow.

NÄL-tunnel, railway line Trollhättan - Öxnered
35 dBA/50 dBC
30 dBA/47 dBC
28(30) dBA
45(47) dBC
Residential buildings (Limiting values)
Healthcare
Hospital
Reference value (limit)
Maximum value, slow

<table>
<thead>
<tr>
<th>Region</th>
<th>Reference Value</th>
<th>Premises</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental program Malmö City (2003 – 2008)</td>
<td>30 dBA</td>
<td>Residential buildings, healthcare, hotels, teaching facilities and equivalent</td>
<td>Maximum value, fast corresponds to 28-29 dBA, slow</td>
</tr>
<tr>
<td>Stockholm City Environmental program 2000</td>
<td>30 dBA</td>
<td>Residential buildings</td>
<td>Maximum value, slow</td>
</tr>
</tbody>
</table>

Reference values with time constant “fast” give ca. 1 – 2 dB higher values compared to time constant “slow” (ISO/DIN 14 837 – 1.2:2004)

4.4 Västlänken, Gothenburg
For the Västlänken project in Gothenburg, a railway tunnel which passes below central areas of the city, applies the guideline values by the Swedish Environmental Protection Agency, BRVT 2006:03:10, 2006-02-09.

Project-specific guidance values for structural noise from railway traffic in operational phase.

<table>
<thead>
<tr>
<th>Type of Premises</th>
<th>Structural noise level, LpA,max,slow</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV studios, studios for sound recording, concert halls, opera</td>
<td>25-30 dBA</td>
</tr>
<tr>
<td>Residential buildings, healthcare facilities, hotels</td>
<td>30 dBA</td>
</tr>
<tr>
<td>Museums, theatres, schools, day-care centres, places of worship, libraries, conference centres</td>
<td>35 dBA</td>
</tr>
<tr>
<td>Offices and similar business during day-time</td>
<td>40 dBA</td>
</tr>
</tbody>
</table>

5 References


Citytunneln Malmö (2002). Miljökonsekvensbeskrivning (Environmental impact assessment),


