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FIRST REPORT OF THE INDEPENDENT ENGINEERING EXPERT PANEL, DUBLIN METRO NORTH:

A REVIEW OF THE ENVIRONMENTAL IMPACT STATEMENT AND OTHER ELEMENTS OF THE RAILWAY ORDER APPLICATION FOR DUBLIN METRO NORTH

FOR

RESIDENTS' GROUPS AND OTHER INTERESTED PARTIES
&
RAILWAY PROCUREMENT AGENCY

VOLUME I
(OF 3)

REVIEW OF THE ENVIRONMENTAL IMPACT STATEMENT AND OTHER RAILWAY ORDER DOCUMENTATION

MARCH 2009

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Appendix 4 Document entitled: *"RfR Tunnelling questions for Independent Expert (Jan 2009)". (Minor amendments since first issued on 13th February 2009 to correct some factual information and qualify some comments as the opinions of the experts).*

FIRST INDEPENDENT ENGINEERING EXPERTS' REPORT:

A REVIEW OF THE RAILWAY ORDER APPLICATION FOR DUBLIN METRO NORTH AND CONSIDERATION OF THE CONCERNS OF RESIDENTS AND OTHER INTERESTED PARTIES

EXECUTIVE SUMMARY

This report reviews the Railway Order Application (especially the Environmental Impact Statement) for Dublin Metro North. It is the first formal output of a team of Independent Engineering Experts commissioned in August 2008 by RPA, on behalf of residents' groups and associations and other non-commercial stakeholders with interests in the effects of 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.

It is 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 in participating in the consultation process (including, as appropriate, making written and oral submissions to An Bord Pleanála). Following a series of meetings with residents' groups and other interested parties in August and September, a draft report for comment and discussion was issued on 8th October 2008. Meetings were held during the week commencing 20th October 2008 to present the report and allow discussion and feedback. This final report takes account of the comments received from residents and the RPA.

The report is presented in 3 volumes:

- Following this executive summary, **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** (based on Section 5 of the October draft) 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; and
- **Volume III** includes supporting appendices for Volumes I and II.

VOLUME I

Volume I of our report is based on a review of the Environmental Impact Statement (EIS), backed up by reference to the plans showing details of the proposed railway works. All of these documents (comprising the Railway Order Application for Dublin Metro North) may be found at www.dublinmetronorth.ie/. Our review has considered the adequacy and clarity of each of the elements of the EIS for topics of particular interest and concern to residents (see Volume II). We have also attempted to identify gaps or unanswered questions that arise from the Railway Order Application (especially the EIS and the drawings describing the scheme).

We have 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, we are satisfied that no major subject for concern has been overlooked in the EIS and we note that, in some respects, it goes beyond what is statutorily required to be covered in an EIS. The EIS is of limited usefulness to a non-technical readership without some additional guidance. Volume I of our report attempts to bridge this gap by presenting the findings of our review in three main sections following the introduction:

Section 2 includes an introduction to the EIS, and explains its structure and purpose.

Section 3 includes background sections that are intended to set the scene for residents to help them appreciate the stage that the engineering design of the scheme has reached and how it will be refined between now and the construction phase, as well as providing a non-technical introduction to tunnelling and associated works, such as station and shaft construction.

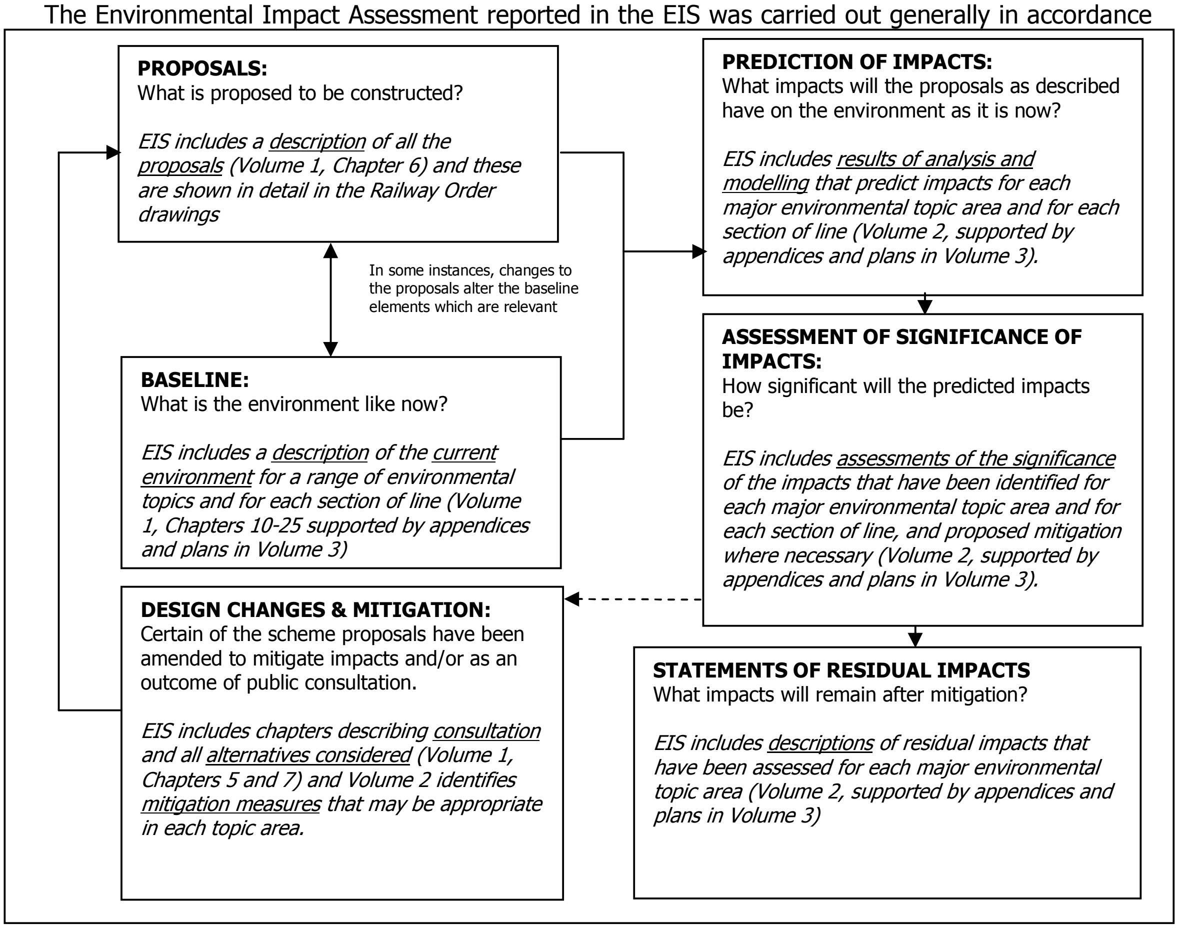
In **Section 4** key environmental impacts relevant to the project are described:

2. THE ENVIRONMENTAL IMPACT STATEMENT

Environmental Resources Management (Ireland) Ltd. (ERM) has co-ordinated the work of some 20 environmental experts to undertake an Environmental Impact Assessment. The findings of this assessment are reported in a 3-volume Environmental Impact Statement (EIS) for the Metro North scheme.

The objective of the EIS is to consider the likely impact that the proposed scheme described in the Railway Order application may have on the people who live close to it and their surroundings, and to describe the mitigating measures that can be taken to avoid (and, if not avoid, to reduce and constrain) hazards and disturbances to the local population, its resources and the natural environment. The EIS is a central part of the Railway Order documentation and records various conclusions reached by the ERM team. The EIS does not set out in full the basis upon which those conclusions; behind it there are many other investigations and analyses that the ERM team used to support its work.

The Environmental Impact Assessment reported in the EIS was carried out generally in accordance with the standard methodology indicated in the sketch below (larger version at Figure 1, Volume I).



In response to comments on the discussion draft from members of the public regarding the accessibility of the EIS, given its specialist vocabulary, we have included a section (2.2) that aims to assist readers by putting into context some of the specialist vocabulary used in the main parts of the EIS (baseline studies, impact prediction and impact assessment). The way in which the ***baseline environment*** is categorised by allocating ***functional values*** to selected areas is described. Functional values are determined by reference to the ***importance*** and ***sensitivity*** of the area and the ***receptors*** within it as well as the presence of ***existing adverse effects***. Some examples are given.

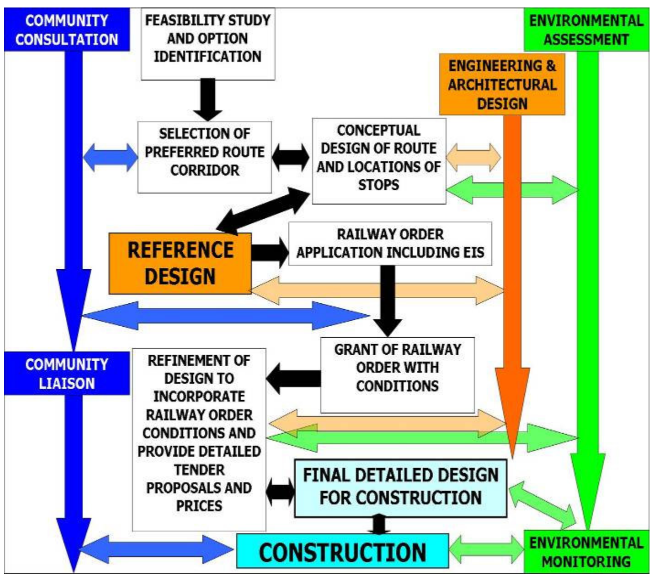
The methodology for ***impact prediction and assessment*** is then described in terms of the way in which ***impact magnitude*** is predicted. ***Impact significance*** is determined on the basis of the expected ***magnitude*** of the impact and the ***functional value*** of the receptor. Each of the assessment chapters in the EIS ends with a summary of ***residual impacts*** of the scheme taking into account ***mitigation*** (a residual impact is the degree of environmental change that will occur after the proposed mitigation measures have taken effect.

3. BACKGROUND SECTIONS

The design process for construction works

This section (3.1) provides a non-technical explanation of the way in which the design process evolves and the stage that it has currently reached, by reference to the diagram below (larger version at Figure 2, Volume I), under the headings:

- Evolution of the detailed design of the works
- Ground conditions (geology)
- Limits of deviation
- Instrumentation and monitoring
- Public consultation and liaison



How tunnels and underground stations are constructed

This section (3.2) provides a non-technical introduction to the construction of bored running tunnels, mined crossover passages and shaft and station box construction (also relevant to cut and cover tunnel construction).

4. CONSIDERATION OF KEY ENVIRONMENTAL IMPACTS RELEVANT TO THE PROJECT

In accordance with the scope of the tender and our commission, we have concentrated our detailed review of environmental impacts relevant to the project (and deployed relevant expertise) in the following topic areas:

- Airborne noise from construction works and railway operation (also referred to as "environmental noise");
- Vibration and groundborne noise from metro construction and operation;
- Influence of proposed works on surface water;
- Influence of proposed works on ground water; and
- Settlement of ground around tunnels and excavations.

Each of the sections is structured as follows:

(i) Introduction to the subject - important concepts and terminology;

(ii) Description of the assumptions made in the Metro North assessments and the methodology used;
(iii) Reference to relevant sections of the EIS;
(iv) Summary of findings of the EIS;
(v) Comment from the Independent Engineering Experts on the adequacy and clarity of the EIA (and other Railway Order documentation) in relation to the impact under consideration and identification of gaps and/or un-answered questions.

The summaries that follow focus on the 'summary of findings of the EIS' and 'comment' sections in Section 4 of the report.

Airborne noise from surface construction works and railway operation (Section 4.2)
The EIS identifies a number of locations where the threshold criteria for airborne noise assessment set out[1] will be exceeded during the construction and operational phase, based on the assumptions that underlie the assessment, even after mitigation is taken into account. However, the RPA's comments (Volume III, Appendix 3) provide reassurance that the contractor will be under an obligation to limit emissions of airborne noise so that the thresholds criteria upon which the environmental assessment is based are not exceeded. It will therefore be for the contractor to incorporate in the final detailed design and programming of the works measures to ensure that the airborne noise criteria will not be breached. In effect, the EIS draws to the contractor's attention locations where mitigation measures additional to those that have been assumed may be needed to achieve this (*e.g.* by programming the construction works to avoid the cumulative effects assumed in the EIS, by selecting different (quieter) construction plant, by adding barriers to reduce construction or operational noise, or by changing track design to reduce operational noise).

The threshold criteria for construction noise during the day and evening (75dB and 65dB) have each been set 5dB higher than those in the relevant National Roads Authority guidance (*"Guidelines for the Treatment of Noise and Vibration in National Road Schemes")* and the reasons for this are stated in the EIS[2]. We have made some observations in paragraphs 4.2.26 to 4.2.31 in relation to these limits. Our opinion is that, even if the rationale for the 5dB over NRA guidelines is accepted, they ought to be lower where construction works continue for significant periods and/or where they take place in 'urban' areas where pre-existing noise levels are low. We further consider that planning conditions referring to airborne noise should specify a period of less than 12 hours to which L_{Aeq} noise levels will relate and that it would also be reasonable to impose a maximum noise level not to be exceeded in any event (and a time limit on the maximum).

Vibration and groundborne noise from metro construction and operation (Section 4.3)
The RPA has responded to questions relating to the amount of vibration that will be experienced, particularly during the construction phase as follows: *"Vibration limits have been chosen to avoid structural damage. Where any damage does occur, repairs will be made under the Property Owners' Protection scheme. This does not affect owners' statutory rights"* and *"Groundborne noise and vibration limits are set out in Volume 2 Chapter 5 of the EIS"* . However, we note that no limits have actually been proposed in the EIS (Volume 2, Chapter 5) for vibration and groundborne noise during the construction period, although impact magnitudes have been defined (very low, low, medium, high, and very high).

The description of residual impacts (*i.e.* those that are expected to arise after mitigation) includes some that are identified as having high and very high impact magnitudes, giving rise to significant construction phase impacts. Given the RPA's assurance that "vibration limits have been chosen to avoid structural damage", it appears that the contractor will be expected to introduce more mitigation than is assumed in the assessments in order to reduce these impacts. It is implied in the EIS that the 'Low' impact thresholds may be those that are intended to provide upper vibration (and groundborne noise) limits, but this needs to be clarified as currently the limits are not stated in the EIS.

During the operational phase, we confirm that 25dB $L_{Amax,S}$ (the proposed limit for operational phase groundborne noise between Parnell Street and Albert College Park) is a very low limit for

1 Tables 4.1 and 4.3 in Chapter 4 of each of the seven books comprising Volume 2 of the EIS
2 Volume 2, Books 1-7, Chapter 4, paragraph 4.3.2.1

groundborne noise in residential properties; so low that people in these properties are very unlikely to hear a train passing beneath. Elsewhere, the proposed limit on groundborne noise inside residential property is 40dB $L_{Amax\ S}$, which is a low level of groundborne noise. If there are locations that are deemed particularly sensitive to groundborne noise and where it is appropriate to impose a lower limit than 40dB $L_{Amax\ S}$, the use of FST rather than resilient rail support would reduce the groundborne noise impacts to ≤25dB $L_{Amax,S}$.

Vibration from blasting (not the TBM) could, in some circumstances, cause structural damage. RPA is well advanced with developing a Property Protection Scheme, and has already undertaken structural surveys at a representative sample of buildings (different types, ages, styles, materials, construction techniques etc) to establish their characteristics and potential vulnerability to damage caused by vibration (and settlement). Later stages of this scheme will involve detailed condition surveys of all properties within a pre-defined zone above and either side of the proposed bored tunnels and adjacent to underground stations and other deep excavations.

Influence of proposed works on surface water (Section 4.4)

Functional values relating to surface water are described as having been assessed by consideration of water quality as well as flood status. The water quality criteria are quantitative (based on Q-values), but it is not clear as to how flood risk has been taken into account either in defining functional values or in terms of assessing impact magnitudes. It would have been better in our view to have assigned functional values and assessed impact magnitudes separately for surface water quality and for the risk and consequences of flooding. The functional values that have been assigned to the various watercourses assessed appear to us to be reasonable in relation to water quality but do not highlight areas where flooding may occur and its impacts.

For most of the proposed alignment, impact on flood risk within the surface water catchments is likely to be negligible. This is because the 'footprint' of the works within the various catchments is relatively small, and because the amount of water to be discharged from the construction sites (and the finished metro facilities) into surface water courses is expected to be very small (and therefore will have a very small impact on flood flows in streams and rivers into which that water may be discharged).

However, the very large depot site at Belinstown is within an area where residents report that flooding that affects local roads and houses occurs fairly frequently (likely to be as a result of 'backing up' of flood waters in the drainage system). The potential for flood risk associated with the Belinstown Depot site has been recognised in the EIS and the following is stated in Volume 2, Book 1, Chapter 11, Section 11.4.2.2: *"The performance of the drainage system will also be assessed for extreme rainfall events (in excess of the design rainfall) to identify areas at risk of flooding. Adequate measures will be put in place to safely manage the flood water and reduce the risk of damage to lives and properties".* To achieve this, a more comprehensive baseline survey will be needed in this area and a flood risk assessment will need to be carried out. This is an area where it may be possible to improve upon the current situation.

We consider that it would be appropriate for a condition to be imposed on the Railway Order requiring flood risk assessments to be carried out for the catchments to be affected by building on agricultural land (as at Belinstown) or discharge of storm water or groundwater to existing water courses, before construction proceeds. Such flood risk assessments may indicate the need for modifications to the significant land raising suggested in the flood plain of the Broad Meadow River, off site improvement works to drainage structures and receiving watercourses to mitigate flood risk, and possibly the deployment of tunnel spoil to provide flood defences in areas that are already vulnerable to flooding. They may also indicate the need for design modifications to culverts and bridges that are needed where the alignment crosses watercourses and flood plains.

Several watercourses are known to have been culverted or flow in tunnels or pipes beneath urban areas in North Dublin; where these will be intersected in cut and cover tunnels or station boxes, they will require temporary or permanent diversion to allow the works to proceed and maintain the flow in the watercourse. Intersection of such watercourses gives rise to the potential for contamination of the water flowing within them and also for changes to flow capacities. The detailed design will need to ensure that diverted tunnels or culverts have sufficient capacity to prevent backing up of water and flooding upstream. Where such watercourses are not actually intersected but cross the alignment of bored tunnels, they are potentially susceptible to settlement disrupting culvert or tunnel linings, giving rise to leakage. It will be important to identify all such 'underground' watercourses and monitor their condition before and after the works, providing for repairs to be carried out if settlement causes damage. Whilst this has not been recognised in the EIS, we have confirmed that RPA is aware of such streams and has made provision in its design to date for appropriate engineering measures to safeguard, replace or divert these structures where they cross the tunnel alignment.

Influence of proposed works on groundwater (Section 4.5)

Functional Values for groundwater, defined in the baseline study, are assessed to be either Low (II) or Medium (III). Impact magnitudes are assessed to be low (or in one case medium) and the impacts identified will affect areas of medium (III) or low (II) functional value. Therefore the assessment concludes that residual impacts will be of 'Low Significance' providing the mitigation measures described in this section are implemented.

The operational scenarios considered are necessarily somewhat generalised at this stage given the status of the design and associated ground investigations but they encompass all likely impacts on groundwater. The mitigation measures that are proposed are comprehensive and are appropriate to the construction and operational scenarios considered and the potential impacts identified.

Settlement of ground around tunnels and excavations (Section 4.6)

The 4 stage assessment process that is underway, which will eventually incorporating monitoring, should allow the identification of buildings where damage is expected to fall into the 'Moderate' category or worse and specific protective/mitigation measures can then be designed and implemented. Where possible, it appears that the design objectives will be to restrict building damage to the 'Slight' category or below. This level of damage would be rectified under the Property Protection Scheme.

Where there will be rock above the top of the tunnel, the predicted settlement is significantly smaller than for lengths of tunnel where the top of the tunnel will be in sediments overlying the rock (for estimated thicknesses of rock above the top of the tunnel, see Volume III, Appendix 2.

The prediction of settlement on a location-specific basis requires detailed knowledge of the geology, the groundwater and the interaction of these with the tunnel (or other) excavation. Not until the construction phase is underway will detailed information be available from monitoring at the surface, monitoring of the geology and hydrogeology at the tunnel face and forward drilling. Using this information, property specific predictions of settlement can be made and, where necessary, adjustments to the tunnelling operation made to reduce settlement effects to a minimum.

The success of the responsive approach to predicting and minimising settlement described in Section 4.6 in Volume I depends on a carefully designed monitoring scheme and a robust process for using the data which arises from it.

The 4 stage assessment process described in the EIS in relation to ground movements and their effects on buildings and infrastructure is logical and represents established good practice. Stages 2B and 3 are based on the detailed design and actual construction methods to be used and therefore this assessment process is ongoing (and will logically continue into the detailed design and construction phases).

The 4 stage assessment process, eventually incorporating monitoring, should allow the identification of buildings where damage is expected to fall into the 'Moderate' category or above and specific protective/mitigation measures can then be designed and implemented. Where possible, it appears that the design objectives will be to restrict building damage to the 'Slight' category or below. This level of damage would be rectified under the Property Protection Scheme.

The EIS reports maximum settlements to be expected at various locations along the alignment with no explanation of how those values have been derived, and what they mean or the expected distribution of ground movements (relevant to an assessment of differential settlement as described above). Similarly, the EIS does not discuss the anticipated time over which ground movements will develop where they occur.

VOLUME II

Volume II of the report summarises the general and specific issues raised by members of the public during meetings and correspondence with the Independent Engineering Experts during the period August to November 2008. It is an expanded version of Section 5 of the draft report issued by the Independent Engineering Expert team on 8th October 2008.

For each topic covered, the main objectives of this volume of the report are to:

- Provide cross references to information in Volume I of this report and the Railway Order Application that is relevant to the questions and concerns that have been raised with us to date (and which address the comments and feedback we have received on the October draft);
- Navigate the Railway Order Application documents (especially the EIS) so as to find information relevant to each issue considered below;
- Provide an update (where relevant) on the current status of ongoing discussions between residents' groups and RPA and on progress with important schemes for property protection and monitoring; and
- Provide assistance to residents and others in framing their questions, concerns and requests for information, whether made directly to RPA or at an oral hearing (or both).

In Section 2 we make some general comments relevant to the status of the design in the Railway Order Application. In Section 3 we summarise issues that we have found to be of general concern, and in Section 4 we record location-specific issues that have been raised with us. For each area of concern (both general and location-specific), we provide a summary of the nature of that concern (often through a series of questions) and reference to the relevant paragraphs in Volume I of this report and/or the EIS. In some cases, we provide a note of our understanding of the current status of ongoing discussions with the RPA and/or a summary of our opinions or observations on the subject being addressed.

VOLUME III

The report is supported by appendices in Volume III as follows:

- **Appendix 1** Schedule of groups of residents and other interested parties with which the experts have worked to date and a record of meetings held.
- **Appendix 2** Table summarising proposed and minimum depths from ground surface to the bored tunnel and inferred depths to rockhead.
- **Appendix 3** RPA comments on GWP draft report for comment issued in October 2008 (Version 3 (RJS/GFE))
- **Appendix 4** Document entitled: *"RfR Tunnelling questions for Independent Expert (Jan 2009)"*. (First issued and circulated to residents, RPA and other interested parties February 2009).

We anticipate that our report (together with any future addenda required to cover further topic areas and our continued assistance) will provide a useful resource for residents in ongoing discussions and negotiations with RPA and during the Oral Hearing. In the future, it may be useful as a source of reference during the construction phase.

FIRST INDEPENDENT ENGINEERING EXPERTS' REPORT:

A REVIEW OF THE RAILWAY ORDER APPLICATION FOR DUBLIN METRO NORTH AND CONSIDERATION OF THE CONCERNS OF RESIDENTS AND OTHER INTERESTED PARTIES

VOLUME I: REVIEW OF THE ENVIRONMENTAL IMPACT STATEMENT AND OTHER RAILWAY ORDER DOCUMENTATION

1. INTRODUCTION

1.1 The authors of the report

1.1.1 This report has been prepared by a team of independent engineering experts commissioned (in August 2008) by the Railway Procurement Agency (RPA) on behalf of residents' groups and associations, and other stakeholders with interests in the effects of the Metro North scheme for Dublin. The team is managed and co-ordinated by GWP Consultants LLP and currently comprises the following experts:

Ruth Allington	**(GWP)** Project Manager, responsible for ensuring that the expert team's work is effectively communicated to residents and for ensuring a continued dialogue with, and flow of information between, the RPA and residents' groups.
Dr Michael DeFreitas	**(First Steps Ltd)** Lead expert, and expert on hydrogeology and ground response to tunnelling. Responsible for co-ordinating the work of the engineering experts.
Dr Alan Cobb	**(GWP and Blast Log Ltd)** Vibration expert.
Dr Paul Cockcroft	**(WBM)** Noise and groundborne noise expert.
David Donaldson	**(Donaldson Associates)** Tunnelling expert.

1.1.2 The range of expertise reflects the requirements set out in the terms of reference for the Independent Engineering Expert team. These were developed by the RPA in partnership with residents' representatives, who also participated in the selection process.

1.2 Purpose of the report

1.2.1 This report is the first formal output of the independent expert team and is intended to be available to residents as a resource to assist them in their consideration of the Railway Order application for Metro North, and in participating in the consultation process (including, as appropriate, making written and oral submissions to An Bord Pleanála).

1.2.2 The Railway Order application, which was submitted to An Bord Pleanála on 17th September 2008, comprises the following elements:

- a draft of the proposed Railway Order;
- plans showing details of the proposed railway works;
- a 'book of reference' to the plan indicating the identity of the owners and occupiers of the lands described in the plan; and

- a statement of the likely effects on the environment (an "Environmental Impact Statement") of the proposed railway works.

1.2.3 Interested parties had until 29th October 2008 to make submissions to An Bord Pleanála. A draft of our report was issued for comment and discussion on 8th October 2008, followed up by open public meetings, meetings with the RPA engineering and environmental teams and meetings with groups of residents and others during the week commencing 20th October 2008. The draft report aimed to provide information and technical background to assist interested parties in framing their submissions and to record their concerns, questions and objections (communicated to us in meetings and in correspondence during August and September 2008). The meetings held during the week commencing 20th October 2008 allowed the experts to explain in more detail some of the matters covered in the report and to identify further questions, matters of concern, and objections from interested parties that should be covered in the final report. In addition, these meetings and associated correspondence provided an opportunity to receive feedback (comments, clarification, further points requiring consideration and suggestions as to amendments) from RPA and interested parties. A schedule of meetings held and attended by the Independent Experts is included at Appendix 1.

1.2.4 The comments and feedback on the 8th October draft resulted in an amended and expanded version of the report. A final draft report was issued on 20th December 2008, intended to incorporate the comments and feedback received on the draft and to bring up to date the schedule of interested parties' concerns, questions and objections (originally Section 5 in the October 2008 draft, now Volume II of this Report). This is a final version of our report incorporating feedback on the December 2008 final draft. The principal differences are as follows:

- **Volume I** Update of Section 1 to reflect changes in other parts of the document. Later sections left unchanged except for insertion of reference to the new Appendix 4.
- **Volume II** Expansion of some sections and addition of sections to reflect omissions in the final draft (drawn to our attention by several residents' groups), feedback from RPA on the final draft of Volume II and requests to express their concerns more clearly from some parties.
- **Volume III** Schedule of meetings extended to include meetings held in January 2009. Additional appendix (Appendix 4) added: *Document entitled "RfR tunnelling questions and answers for Independent Expert (Jan 2009)".*

1.2.5 To assist readers, we have made available marked up versions of elements of the report that have been amended and/or extended since the December final draft.

1.3 Scope and structure of the report

1.3.1 Our report is in three volumes:

- Volume I (this volume) provides an introduction to environmental impact assessment and the design process, together with a review of selected sections of the Environmental Impact Statement;
- Volume II (based on Section 5 of the October draft) provides a summary with comments and cross references of the particular concerns and questions of residents and other interested parties; and
- Volume III includes supporting appendices for Volumes I and II.

Volume I

1.3.2 Volume I of our report is based on a review of the Environmental Impact Statement (EIS), backed up by reference to the plans showing details of the proposed railway works. All of these documents (comprising the Railway Order Application for Dublin Metro North) may be found at www.dublinmetronorth.ie/. We have also had access to unpublished technical data and reports generated by and for the RPA design and environmental teams, but these have not been reviewed in detail. Our review has considered the adequacy and clarity of each of the elements of the EIS depicted in the sketch after paragraph 2.2.3, for topics of particular interest and concern to residents (see Volume II). We have also attempted to identify gaps or unanswered questions that arise from the Railway Order Application (especially the EIS and the drawings describing the scheme).

1.3.3 We have 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, we are satisfied that no major subject for concern has been overlooked in the EIS and we note that, in some respects, it goes beyond what is statutorily required to be covered in an EIS. The EIS is of limited usefulness to a non-technical readership without some additional guidance. Volume I of our report attempts to bridge this gap by presenting the findings of our review in three main sections following this introductory section as follows:

Section 2 – an introduction to the EIS, its structure and purpose.

Section 3 – background sections covering:

- How the final detailed design will be developed, and how it will be monitored and controlled; and
- How tunnels and underground stations are constructed.

1.3.4 Section 3 is intended to set the scene for residents to help them appreciate the stage that the engineering design of the scheme has reached and how it will be refined between now and the construction phase, as well as providing a non-technical introduction to tunnelling and associated works, such as station and shaft construction.

Section 4 – Consideration of key environmental impacts relevant to the project[3]:

- Airborne noise from construction works and railway operation (also referred to as "environmental noise");
- Vibration and groundborne noise from metro construction and operation;
- Influence of proposed works on surface water;
- Influence of proposed works on groundwater; and

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3 Some of the issues of particular interest to residents concern topic areas that were not anticipated in the original brief for our appointment (particularly for sections of the line that do not involve tunnelling). Particular examples are traffic and flood risk. Although we have included a section covering surface water (including flood risk) in Section 4 in this report (drawing on expertise and experience available within the team), other matters of concern that have been raised with us (notably traffic impacts and the feasibility of design changes to elevated and 'at grade' surface track to reduce impacts) are not covered in this report (although they are recorded as concerns in Volume II and comment is made where appropriate). We anticipate addressing these additional areas if appropriate in an addendum report drawing, where appropriate, on expertise within the expert team members' organisations (or elsewhere if necessary).

- Settlement of ground around tunnels and excavations.

1.3.5 Each of the scientific sections in Section 4 is structured as follows:

(i) Introduction to the subject - important concepts and terminology;
(ii) Reference to relevant sections of the EIS;
(iii) Description of the assumptions made in the Metro North assessments and the methodology used;
(iv) Summary of the results of the assessment; and
(v) Comment from the Independent Engineering Experts on the adequacy and clarity of the EIA (and other Railway Order documentation) in relation to the impact under consideration and identification of gaps and/or un-answered questions.

Volume II

1.3.6 Volume II records the concerns expressed and issues raised during meetings with, and in correspondence from, residents and other interested parties. Where possible, we have provided cross references to Volume I of this report and the Railway Order documentation (especially the EIS). We have also included our own comments and observations where appropriate and have recorded feedback from RPA as well as details of any further developments on specific issues since we issued our draft report for comment and discussion in October 2008 and since the final draft in December 2008.

Volume III

1.3.7 The report is supported by appendices in Volume III as follows:

- **Appendix 1** Schedule of groups of residents and other interested parties with which the experts have worked to date and a record of meetings held.
- **Appendix 2** Table summarising proposed and minimum depths from ground surface to the bored tunnel and inferred depths to rockhead.
- **Appendix 3** RPA comments on GWP draft report for comment issued in October 2008 (Version 3 (RJS/GFE))
- **Appendix 4** Document entitled: "RfR Tunnelling questions for Independent Expert (Jan 2009)". (First issued and circulated to residents, RPA and other interested parties February 2009).

1.3.8 We anticipate that our report (together with any future addenda required to cover further topic areas and our continued assistance) will provide a useful resource for residents in ongoing discussions and negotiations with RPA and during the Oral Hearing. In the future, it may be useful as a source of reference during the construction phase.

2. THE ENVIRONMENTAL IMPACT STATEMENT

2.1.1 Environmental Resources Management (Ireland) Ltd. (ERM) has co-ordinated the work of some 20 environmental experts to undertake an Environmental Impact Assessment. The findings of this assessment are reported in a 3-volume Environmental Impact Statement (EIS) for the Metro North scheme.

2.1.2 The objective of the EIS is to consider the likely impact that the proposed scheme described in the Railway Order application may have on the people who live close to it and their surroundings, and to describe the mitigating measures that can be taken to avoid (and, if not avoid, to reduce and constrain) hazards and disturbances to the local population, its resources and the natural environment. The EIS is a central part of the Railway Order documentation and records various conclusions reached by the ERM team. The EIS does not set out in full the basis upon which those conclusions were reached and it is therefore important to appreciate that behind it there are many other investigations and analyses that the ERM team used to support its work. We have had access to some of the supporting data and reports relevant to key topic areas, and also to the experts who prepared certain chapters to discuss details of their approach and methodology.

2.1.3 The Environmental Impact Assessment reported in the EIS was carried out generally in accordance with the standard methodology indicated in the sketch at Figure 1 below (after paragraph 2.2.3). Figure 1 provides references to the EIS volumes where relevant aspects of the environmental impact assessment are reported and more detailed guidance to navigating the EIS is provided for the specific environmental topics covered in Section 4 of this report.

2.1.4 In response to comments on the discussion draft from members of the public regarding the accessibility of the EIS, given its specialist vocabulary, we have added the following additional section in this report introducing important terms and concepts used in the EIS.

2.2 Important terms and concepts used in the EIS

2.2.1 This section identifies some of the specialist vocabulary and concepts that are used in the main parts of the EIS (describing baseline studies, impact prediction and impact assessment) to assist readers in navigating through the document and interpreting its findings. There is a helpful glossary of terms included at the end of each of the books and volumes comprising the EIS; this section aims to assist readers by putting into context some of the terms therein.

2.2.2 Environmental impact assessment is based on a simple source-pathway-receptor model where the "source" is the origin of the impact, the "pathway" is the transmission route of the impact to areas outside the source and the "receptor" is the natural and built environment, most notably people and the structures they occupy and use. In applying this model, the ***source*** of each impact arising from the scheme is identified (*e.g.* a train moving along the track at surface giving rise to noise and visual impact or a tunnel boring machine working at depth, giving rise to vibration and ground-borne noise). The location and magnitude of the source is also assessed (*e.g.* sound power level of particular equipment, numbers of vehicles on a particular stretch of road, amount of water to be discharged at a particular point *etc*) and the time for which it will be operating in a particular location.

2.2.3 In order for a source of impact to cause a detectable change (or effect) at any other location (*e.g.* noise or vibration generated at point A (the source) to be heard or felt at point B (the receptor)), there must be a ***pathway*** linking them together (*e.g.* noise is propagated through the air, vibration is propagated through the ground, the pathway for visual impact is a line of sight *etc*).

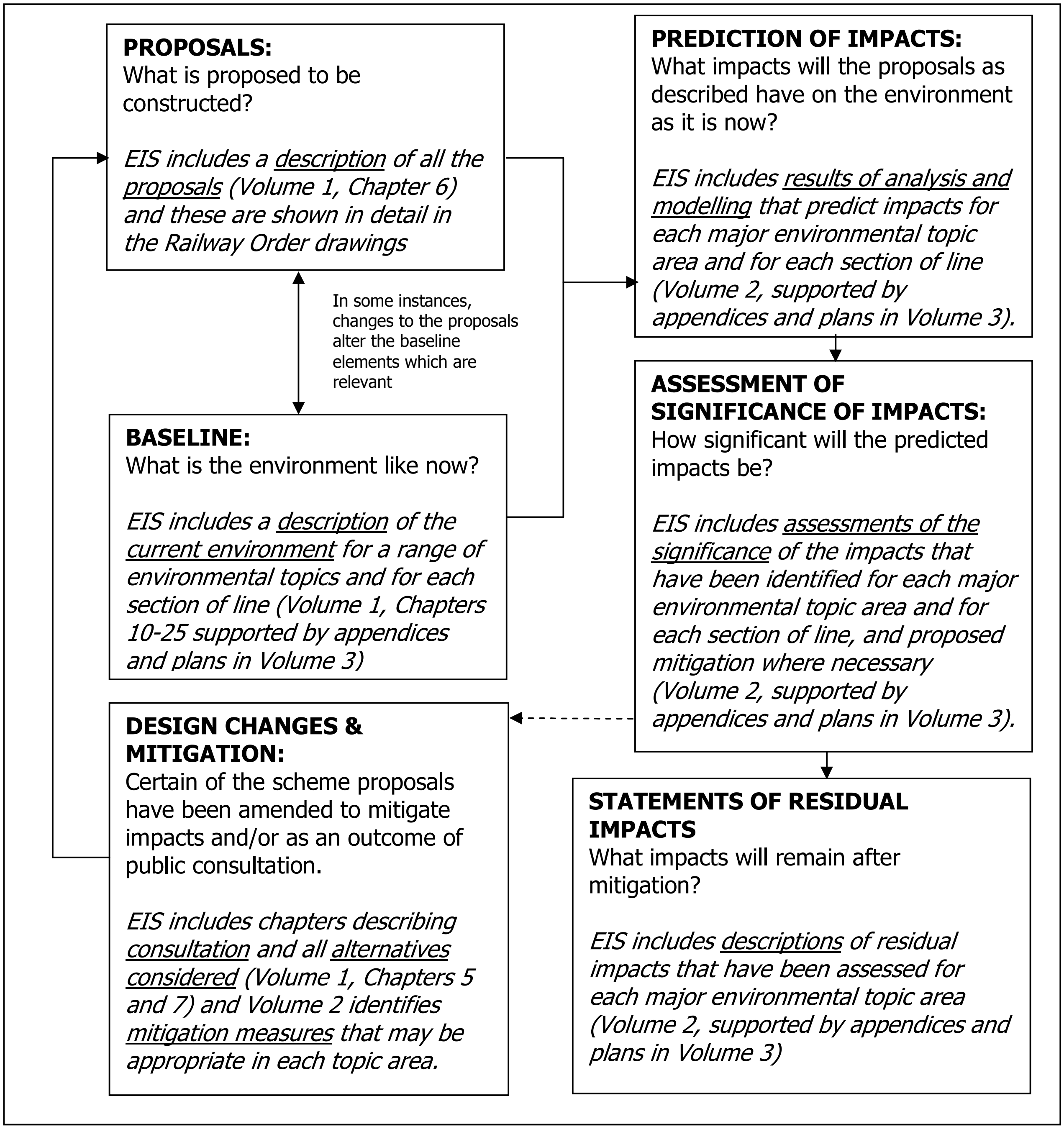

Figure 1: Environmental Impact Assessment methodology

2.2.4 People, sensitive environments and structures which may be affected by the impact of 'sources' of environmental change transmitted *via* 'pathways' are referred to as ***receptors***. Examples of receptors are: people who live close enough to a source of noise or vibration to hear it or feel it; structures that are within a zone where settlement could occur; landscapes that might be changed as a result of the structures to be constructed within them; or air quality that may be affected by increased traffic volumes. For each relevant environmental topic area, 'receptors' are identified that are linked to 'sources' *via* 'pathways'. The magnitude and significance of predicted effects on receptors is assessed taking account of the magnitude of the source, the nature of the pathway and the sensitivity of the particular receptor to the effect under consideration.

Baseline studies

2.2.5 As is indicated in Figure 1 above, description of the 'baseline' environment for each relevant environmental topic area, together with a description of the proposals, is an essential pre-requisite for predicting the magnitude and importance of impacts and assessing their significance. In Volume 1 of the EIS, each of the Chapters 10-25 describes the baseline environment for the range of environmental topics considered by the environmental assessment team. Each of these chapters is structured identically as follows:

Study area:	The study area is defined and the important considerations in that definition are set out. For example, in Chapter 12 (which is concerned with airborne noise) the study area has been defined based on examination of a corridor 500m either side of the proposed alignment. Within this corridor, sensitive receptors have been identified and some have been selected for baseline monitoring based on their proximity to the alignment (the source of noise). Similarly, in Chapter 17 (soil and geology) a corridor 500m wide has been defined as the study area within which to establish the baseline environment for soils, geology, landuse and ecology.
Baseline data:	This is generally provided as a table listing the information required for the baseline study and the sources of that information used by the environmental assessment team.
Baseline categorisation criteria:	The baseline environment is categorised by allocating ***functional values*** to selected areas within the study area; the areas selected are those which are likely to contain receptors of particular environmental effects. A 'functional value' for a particular element or area of the baseline environment is evaluated by reference to the ***importance*** and ***sensitivity*** of the area and the receptors within it, as well as the presence of ***existing adverse effects***. Importance is considered in relation to national or international statutory designations, best practice and regulations. Sensitivity considers the sensitivity of receptors to the particular environmental matter under consideration. For example, places of worship and educational facilities are considered to be highly sensitive noise receptors, whilst industrial premises are considered to be of low sensitivity. Existing adverse effects (such as existing high levels of noise) are also taken into account. Functional values are defined on a qualitative scale ranging from Very Low (I) to Very High (V). These are presented in each of the baseline chapters in Volume 1 in a table describing the criteria that have been used for categorisation and allocating a functional value in relation to the topic under consideration. For example, in relation to noise, 'locations that are highly sensitive during both day and night' are defined and given a functional value of Very High (V), whilst 'Locations that are only sensitive during the day and where the activities that are carried out can be carried out in the presence of some noise, but not high levels of noise' are given a functional value of Medium (III).
Description and categorisation of the baseline environment:	Using the terminology and methodology described above, the baseline environment is described and categorised for each element of the proposed line and its associated structures and activities (generally by reference to the numbered lengths of line MN101, MN102 *etc*).

Impact prediction and assessment

2.2.6 Volume 2 of the EIS comprises 7 books, one for each of the Metro North areas (MN101, 102 *etc*). Each book is structured identically and comprises 17 chapters considering each of the environmental subjects covered in the EIS, and an 18th chapter on interrelationships and cumulative effects. After a short introduction and a description of the study area (generally consistent with the study area descriptions in Volume 1), each of the 17 environmental topic chapters has the same basic structure as outlined below:

Impact assessment methodology	The impact assessment methodology is described in terms of the way in which impact ***magnitude*** is predicted. The assessment of magnitude of impacts takes into account the quality, type and range of impact that will occur when the project is implemented (construction and operational phase), as well as its duration (*i.e.* elapsed time and time of day or night) over which the impact will occur. For many topics, the assessment criteria are entirely descriptive (*e.g.* landscape and visual amenity criteria in tables 13.1 and 13.2, which are expressed in sentences such as 'Major changes in view….' or 'Clearly perceptible changes in views….'), whilst others have quantitative (numerical) criteria (*e.g.* noise criteria listed in table 4.1 are expressed in dB). Whether the criteria are expressed in a descriptive or quantitative manner, they are used to develop an impact magnitude scale from 'very low' to 'very high'. For example, where there will be a 'major change of view', the magnitude of the change in visual amenity is described as 'very high' (table 13.2). Where actual noise predicted at a receptor exceeds the relevant noise assessment criterion (table 4.1) by less than 1dB, the magnitude rating is given as 'very low'.
Impact assessment	Impact ***significance*** is determined on the basis of the expected ***magnitude*** of the impact and the ***functional value*** (see paragraph 2.2.5 above) of the receptor. Significance is expressed slightly differently in different chapters, but is generally expressed according to a scale: 'Not significant', 'Low significance', 'Medium significance' and 'High significance'. Impacts are assessed separately for the construction phase of the project and for the operation of the metro when complete. Mitigation measures are described and there is a section (and usually a summary table) at the end of each chapter summarising the ***residual impacts taking into account mitigation***. A residual impact is the degree of environmental change that will occur after the proposed mitigation measures have taken effect.

2.2.7 Within this basic structure, each chapter varies significantly in the way it is laid out and the background information that is provided (in Volume 3). This reflects the wide variation in topics considered, the fact that the investigation and analysis behind each chapter was undertaken by different specialist teams, and the way that each particular topic is assessed.

3. BACKGROUND SECTIONS

3.1 The design process for construction works

Evolution of the detailed design of the works

3.1.1 The scheme for construction and operation of Dublin Metro North described in the Railway Order application, currently the subject of public consultation, is extremely detailed and may appear to be beyond change, a *fait accompli*. This is not true, as we will explain in this section; the current proposals are an important but nevertheless intermediate stage in an overall design process.

3.1.2 The design process for an engineering project such as this is directed towards designing and implementing a scheme that meets its overall objectives whilst being acceptable financially, technically and politically. The design process for major schemes such as this (and this is a large scheme on the scale of engineering works) progresses in stages, starting with a simple idea, which, through a process of iteration and incorporation of decisions and additional data, is progressively fleshed out until a detailed design is complete and implemented. The 'generic' stages in the design process for the Dublin Metro North project are illustrated schematically in Figure 2 below. The double headed arrows signify iteration and feedback in the process, rather than progression from one element to the next.

3.1.3 The current design is known as a "***Reference Design***". It is sufficiently detailed to allow meaningful Environmental Impact Assessment and to be the basis for a Railway Order application (which, when granted, amounts to a detailed planning permission for the works). Whilst the proposed outcomes of the project are set out in detail in the Railway Order Application, there is less detailed information as to *how it will be done*; the development of programmes and detailed plans for the construction itself will be matters for the contractor (within the requirements of the contract between the contractor and RPA and compliant with legal obligations set in place by the granting of the Railway Order).

3.1.4 The Reference Design permits variations within defined limits to allow the selected contractor to vary certain aspects to achieve technical, financial, operational or environmental performance or to accommodate variations in actual conditions experienced during the works. In addition to variations that the contractor may make within these defined limits, the works are also subject to the Railway Order planning process that will give rise to environmental and other conditions being applied (which will have to be incorporated into the final design, such that it may differ from the Reference Design). Limits of deviation are further described and discussed at paragraph 3.1.11 below). In addition to the limited permitted variations built into the Reference Design, it is possible that, in the course of consultation on and determination of the Railway Order, amendments to the reference design may be made (either as a result of negotiation and agreement between RPA and interested parties or as a result of requirements by An Bord Pleanála as part of its determination of the application). Such changes could give rise to significant differences between the Reference Design and the Final Design but would, of course, be subject to environmental assessment and public consultation and scrutiny.

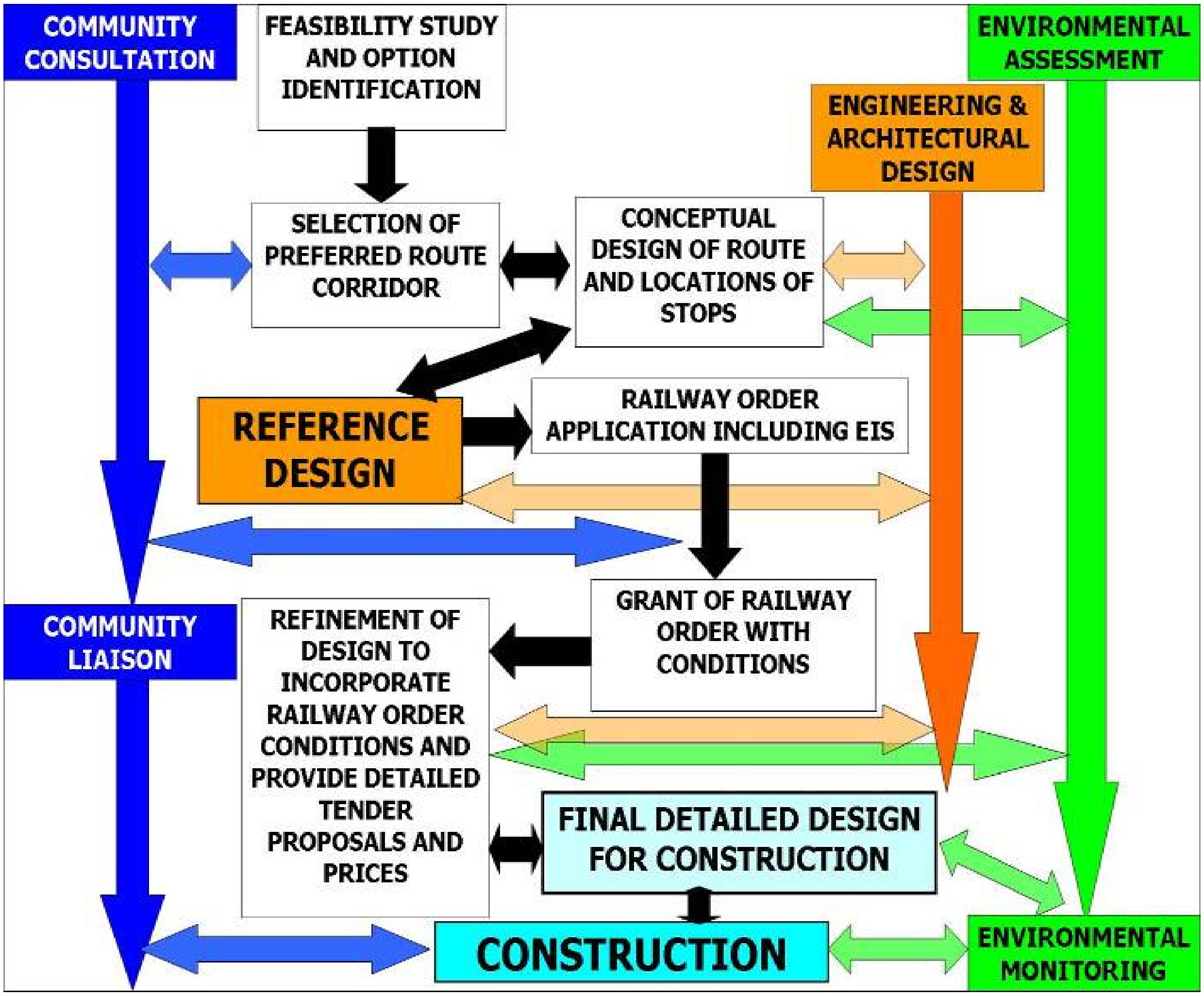

Figure 2: Evolution of the final design for construction and its relationship to the Railway Order process, environmental assessment and community consultation and liaison

Ground conditions (geology)

3.1.5 The design of engineering work on, in and with the ground starts with the application of broad principles that are known to govern work of this kind, *e.g.* the excavation of holes for stations, the formation of foundations for structures, the excavation of tunnels and shafts, the disposal of spoil and control of ground water. To start the process, all these are assumed to behave as they "normally do", where knowledge of this expected behaviour comes from a considerable body of experience gained in practice from such work around the world. It is available to all engineers through the technical publications they can access and conferences and meetings they attend. Case histories underpin our knowledge of the ground and how it works; if the theories do not agree with case history it is the theory that changes over time as the knowledge gained from case histories is incorporated into engineering practice.

3.1.6 The next stage checks that what exists at this site can be described by the conditions expected from this body of knowledge, *i.e.* that the soils are like those in the case histories and that the water and rock are like those encountered elsewhere, for example in Dublin Port Tunnel. The Dublin Port Tunnel case history is very important for the design of the bored tunnels for Metro North because it involved creating tunnels in similar geological strata, not very far away. In order to check whether what exists at the site is 'as expected' and to identify site specific details, the ground must be investigated. Records are consulted, (*e.g.* those produced by the Irish Geological Survey), and archives visited, (*e.g.* for archaeological and other historical uses of the ground). Shortcomings in this knowledge are rectified by drilling holes into the ground where necessary and taking samples for testing. All this builds up a body of knowledge that is based on experience and calibrated against local on-site conditions, so as to allow a Reference Design, and ultimately a Final Design to be completed.

3.1.7 As far as the ground is concerned, neither the Reference Design nor the Final Design presumes to know what is under every piece of ground – that is something a ground engineer only knows once it has been excavated. Excavation under these circumstances is made possible by (i) the ability of contracts to accommodate changing and unexpected conditions (which by this time are expected to be small and local changes of conditions from those expected), and (ii) the ability of the construction process to respond to the changing ground conditions so that conditions in the ground (and the effects at the surface to which they give rise) can be controlled.

3.1.8 The gathering, testing and incorporation of information on ground conditions is an essential and integral part of the design process described in Figure 2. It is generally phased so that, as the design evolves and requires more reliable information, investigations can be targeted appropriately. An effective ground investigation at the reference design stage aims to provide sufficient knowledge for construction to be priced and detailed construction processes to be defined. It also aims to be sufficiently detailed for the risks that actual conditions are different from those assumed to be identified and evaluated. If risks arising from uncertainty with respect to ground conditions are considered to be too high (or significant departures from the Reference Design are being contemplated), then further ground investigation may be indicated, even at a late stage in the detailed design process, or sometimes during the course of construction.

3.1.9 The Dublin Metro North scheme has now reached the stage where contractors who are able to take on such projects have been invited to bid for the work. They have been given access to all the data acquired so far about the ground by the team working on the Reference Design, the Reference Design itself, and details of the restrictions that will be imposed for environmental and other reasons. It is the contractors who will decide what particular machines and methods they will use to satisfy these requirements and they who will make assessments of ground related risk and build into their costings and work plans requirements for further data collection either before or during the construction work. This is the way such projects are commonly done around the world; the contractors considered for this sort of contract will have international experience. It is the successful contractor who will produce the Detailed Design; in other words, much of the work that has been done by the RPA will be done again by the contractor but this time with knowledge of the machinery, and men, and processes that they plan to deploy to achieve the work, as well as with the benefit of the EIS and the work that underlies it.

3.1.10 The relationship between the ground investigation and the Reference Design is described in more detail in paragraphs 3.2.1 and 3.2.2 below.

Limits of deviation

3.1.11 The Reference Design will be refined as described above in the light of further information about the ground, the engineering solutions proposed by the contractor, and to comply with conditions imposed in the Railway Order when granted. However, the Reference Design is also the design that has been submitted with the Railway Order which, when granted, will amount to a detailed planning permission. If the Reference Design is absolutely prescriptive in every detail, planning permission will be granted for a scheme that must be constructed exactly as described and therefore gives no scope to a contractor to propose an alternative solution that meets the client's objective whilst reducing engineering risks and project costs. Similarly, a prescriptive scheme at this stage would not allow for sensible adjustments to be made in the light of additional ground investigation information or more detailed analysis of that which has already been assembled. To give the contractor room to innovate and improve the scheme, and also to adjust appropriately to the ground conditions actually encountered (because ground conditions can never be perfectly known in advance, as described above), 'limits of deviation' are set for a project such as this. The following excerpts from the Draft Railway Order, Part 2, Article 6 describe the limits of deviation proposed for the Dublin Metro North Reference Design:

6 Deviation

In executing any of the authorised works the Agency may —

(a) where those works are situated in a public road —

(i) deviate laterally by any distance not exceeding 2.5 metres from the lines or situations shown on the plan,

(ii) deviate vertically by any distance not exceeding 1 metre upwards from the levels shown on the plan,

(iii) deviate vertically by any distance not exceeding 1 metre downwards from the levels shown on the plan,

(iv) deviate longitudinally by any distance not exceeding 20 metres,

(b) where those works form part of an underground stop other than such parts as are situated in a public road, amend the internal layout of the stop provided that such amendments do not reduce the accessibility or amenity of the publicly accessible areas within the stop;

(c) where those works form part of an underground tunnel or stop —

(i) deviate laterally by any distance not exceeding 10 metres from the lines or situations shown on the plan,

(ii) deviate vertically by any distance not exceeding 5 metres upwards from the levels shown on the plan,

(iii) deviate vertically by any distance not exceeding 10 metres downwards from the levels shown on the plan,

(iv) deviate longitudinally by any distance not exceeding 20 metres,

(d) in respect of all other works —

(i) deviate laterally by any distance not exceeding 5 metres from the lines or situations shown on the plan,

(ii) deviate vertically by any distance not exceeding 2 metres upwards from the levels shown on the plan,

(iii) deviate vertically by any distance not exceeding 2 metres downwards from the levels shown on the plan,

(iv) deviate longitudinally by any distance not exceeding 20 metres.

3.1.12 There are certain locations where the amounts of allowable deviation (particularly in relation to the minimum depths of bored tunnels beneath properties and the proximity of surface structures to residential properties) set out in Article 6 have been reduced; there are no circumstances where they have been increased. Rather than setting these out on a complex schedule, the Railway Order Drawings show the limit of surface and sub-surface lands to be acquired in order to construct the scheme. It will be a legal and contractual requirement for the contractor to remain within the limits of land that has been acquired and therefore these limits coincide with the allowable deviation at any point.

3.1.13 In Appendix 2, we provide a schedule of the proposed depths to the track level in the bored tunnel beneath every road that crosses it between St Stephen's Green and Albert College Park (also referred to in the application as 'Hampstead Park'). In Appendix 2, we also provide an estimated depth to the top of the Reference Design tunnels (based on the expected diameter of the tunnels) and the minimum depth to the tunnel if the contractor were to construct it at the upper limit of the subsurface lands to be acquired.

Instrumentation and monitoring

3.1.14 As indicated in paragraph 3.1.7 above, a ground investigation cannot provide perfect knowledge of the ground conditions that will actually be encountered or of the behaviour of the ground when disturbed. It is therefore essential, during the work, for contractors to have "ears" and "eyes" in the ground that can detect changes which are significant for managing ground response to ground engineering and managing the (related) environmental impacts caused by the work. These "eyes" and "ears" are provided by the installation of instrumentation and the results of ongoing monitoring of the instruments are used to identify the need to adjust details of the working methods and to establish whether those changes have had the desired effect. The following example scenarios demonstrate how this works in practice:

- Monitoring of vibration caused by the progress of the tunnel boring machine at a sensitive surface location as the tunnel approaches demonstrates that the amount of vibration is close to the maximum value allowed, and is expected to increase as the tunnel advances closer to that location. The results of monitoring at this and other comparable locations are used to re-calibrate the predictive model for the propagation of vibration through the ground and the rate of progress of the tunnel boring machine is revised and/or adjustments made to the set up of the machine to reduce the vibrations experienced. Further monitoring of the instruments as the tunnel approaches, passes beneath and moves away from the subject location demonstrates that the adjustments have had the desired effect and/or provide the contractor with the information needed to make further adjustments.
- Noise monitoring (and complaints) demonstrate that contractors working at one of the surface sites have exceeded noise limits required in the contract and the Railway Order at the subject properties. The work is reviewed to establish the scope for: re-programming of noisy activities to reduce cumulative effects; replacing some items of plant with less noisy alternatives; and introducing additional screening. The effect of remedial action taken is monitored and any necessary further adjustments or controls implemented.

3.1.15 This method of working is seen by engineers as a normal part of the efficient and sensitive excavation and construction of ground works. It provides a constructive framework for public liaison and feedback, and ensures that the impacts of the scheme are monitored and appropriate actions taken to reduce them to a minimum.

3.1.16 Instrumentation and monitoring are so important to this scheme that the contractor may be instructed by the RPA to pass responsibility for it to an independent body. The task for such an independent body would be to ensure that the instrumentation system is functioning and monitored as required, that the output from the monitoring is stored and interpreted, and that this information is available to all who need it in appropriate formats as feedback for: verifying design assumptions; monitoring compliance with environmental conditions and making any necessary reports to regulatory authorities; regulating construction progress; and informing residents and other stakeholders affected by the ground works (see below).

Public consultation and liaison

3.1.17 In Figure 2, we make a distinction between 'public consultation' and 'public liaison'. Public consultation and public liaison are essential elements of the design evolution process.

3.1.18 ***Public consultation*** in this context is interaction with the public that influences the design process (*e.g.* the consultation exercises that took place for Metro North during the route selection phase and public input to the Railway Order process that is underway now). As the design becomes more detailed and the range of options more limited (culminating in a Railway Order and final design for implementation), the extent to which public consultation can influence the outcome decreases.

3.1.19 ***Public liaison*** involves exchange of information between the public, the contractor and the RPA about the project during its implementation that, through a process of negotiation or mediation, may bring about improvements in performance or changes in methods (*e.g.* if complaints and/or monitoring indicate that a particular aspect of the project is causing an unacceptable impact on members of the public, through a process of negotiation, a change can be agreed to the way the job is done to mitigate the effects – see paragraph 3.1.14 above).

3.1.20 Figure 2 shows 'consultation' occurring up to the granting of the Railway Order and 'liaison' continuing throughout the final detailed design and construction phases. These activities advance in stages from general acceptance of the need and benefits of such a scheme up to the details of where, when and how the proposal is to come to reality and how its effects are to be limited during the implementation phase. In fact, there is no clean break between 'consultation' and 'liaison', rather a transition from one to the other.

3.1.21 In some respects planning and deciding what to do in a project of this size have similarities to planning and deciding an important family event; perhaps a wedding, an anniversary, or a holiday. For such an event, the plans evolve over time, accommodating opinions and sensitivities of a range of people involved, as well as financial constraints *etc*, through a process of consultation. Inevitably, some decisions can only be made "on the day" as events unfold; a degree of flexibility is always necessary and this requires liaison between key individuals to make sure the right decisions are made.

3.2 How tunnels and underground stations are constructed

Bored Running Tunnels

3.2.1 The bored running tunnels for the sections of the Dublin Metro North scheme between St Stephen's Green and Albert Park and beneath Dublin Airport will comprise twin circular tunnels with an excavated diameter of approximately 6.4 metres, with the tunnel crown approximately 4.8m above track level[4]. These will be constructed by mechanised excavation using Tunnel Boring Machines (TBMs). The TBMs which are envisaged to be used on the project are, in effect, mobile linear production lines where excavation of the ground, erection of the lining support and stabilisation of the excavated surfaces take place simultaneously. Tunnel engineers will always seek to match the excavation and support capabilities of their TBMs to the ground conditions which are anticipated to be excavated along the tunnel route. To achieve this, ground investigations comprising borehole surveys are undertaken (as described above). These surveys include *in situ* and laboratory testing to determine soil and rock mass characteristics and also testing to establish the groundwater regime of the soils and rocks through which the tunnels will be driven.

3.2.2 The engineers who have developed the Reference Design of the project have undertaken a significant ground investigation which includes specific borehole surveys along the route and study of relevant ground investigation data from other projects (as described above). Comprehensive review of all of the factual data obtained has enabled the engineers to establish the types of ground which will be encountered by the TBMs during construction (this will include sediments (sand, clay, silt and gravel) deposited by glaciers that covered the area during the Ice Ages as well as the Carboniferous Limestone bedrock upon which these were laid). This review has also allowed the engineers to infer the likely depth to the interface between rock and sediment interface (a boundary known as "rockhead"). Tunnellers need to know which lengths of tunnel are expected to be in rock (*i.e.* below rockhead) and which will be above rockhead in sediment (which is referred to by engineers in a short-hand way as "soil"), and along which lengths the tunnel may pass from one to the other or straddle the boundary. As is described in paragraph 4.6.4 below, there is likely to be a transitional zone where broken limestone is mixed with soil materials at rockhead; in areas such as North Dublin that have been glaciated in the geological past and where the bedrock is soluble, rockhead is rarely a single, clearly defined, surface. The ground investigation will have collected relevant information with which to establish the character of the rockhead (particularly the nature of the materials in the transitional zone and the width of that zone between intact rock and overlying sediments). This information is available to the tenderers now and will be available to the appointed contractor (supplemented if necessary by additional information that they may collect in further ground investigations). Using the ground investigation information, contractors will make their own assessment of the ground conditions at and around the rock/sediment interface, where that is relevant to the tunnel alignment that is proposed in the final design (*i.e.* where the tunnels pass through, straddle or run close to this zone). At the Reference Design stage, it is important to know, with reasonable confidence, where the rockhead is so that alternative vertical alignments for the tunnels can be evaluated in relation to the engineering challenges that they are likely to present and their practical and economic advantages and disadvantages. On the summary geological drawings that

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4 Taken from a draft drawing provided by RPA: *"Typical running tunnel cross section showing equipment arrangement"*, Drawing No. TU-0201-B01

we have seen[5], the inferred rockhead surface is depicted as a single surface with question marks along it to indicate that it is inferred at this stage; this is what we would expect to see at this stage of the design/ground investigation process. It is the depth to this surface as shown on the RPA's geological profile drawings which is given in Appendix 2.

3.2.3 It is known that the strata at the tunnel horizon will, for the most part, comprise limestone bedrock overlain by glacial till (mixtures of gravels, sands, silts and clays). In strata that is predominantly stiff clay, the ground conditions are considered to be stable and there is little likelihood of surface settlement caused by consolidation of the clay overlying rockhead, due to drawdown of groundwater into the tunnels.

3.2.4 In the schedule at Appendix 2 (Volume III), we have measured from the RPA's summary ground investigation drawings the depth to the inferred rockhead horizon beneath every road that crosses the bored tunnel between St Stephen's Green and Albert College Park and provided an estimate of the thickness of limestone between the top of the tunnel and rockhead. These measurements may change as further information becomes available from the ground investigation. Even so, it is evident that the vertical alignment of the Reference Design will pass through two zones along the route where the tunnels are likely to be constructed on the rock/ sediment interface or entirely in sediment, which is identified as comprising glacial sands and gravels. Glacial sands and gravels are saturated strata which have limited ability to bind their particles together and where, without special provisions on the TBMs, ground movement and groundwater ingress at the tunnel face will create surface settlement (see Section 4.6 below).

3.2.5 The first such location is at or close to the TBM launch site in Albert College Park (also referred to in the documents as Hampstead Park). The geological long section produced for the Reference Design shows glacial sands and gravels within the glacial till at this location. The boundaries of the sand and gravel deposits are not defined and it is anticipated that further site investigation will be required, as their presence would impact negatively on the TBM launch activity. It is probable that improvement of the ground by way of consolidation grouting will be necessary to ensure successful launch of the TBMs. Consolidation grouting injects a milky suspension of either clay or clay and cement or lime, to permeate the pores of the ground so providing the ground with strength, because it now has fewer voids and its particles are bound together by the grout between them. It also reduces the ability of the ground to transmit groundwater because its voids have been either filled or blocked. The use of the term "consolidation" in relation to grouting means strengthening and solidifying – it is not the "consolidation" that is associated with settlement and referred to in Section 4.6 of this report. In any event, if surface movement does occur in this location there will be no impact upon the residences adjacent to the working site in Hampstead Park, because the tunnels will be entirely below rockhead by the time they cross Hampstead Avenue. The inferred geological long section shows that, after launch, where the tunnels cross Hampstead Avenue at approximate chainage 13740 metres, the tunnel face will comprise limestone bedrock overlain by boulder clay with rock cover to the TBMs increasing rapidly as the tunnels are driven south towards the Griffith Avenue stop (see Appendix 2).

3.2.6 The second location where the bored running tunnels are likely to be excavated either on the bedrock/sediment interface or entirely in deposits comprising sands and gravels,

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5 Jacobs Drawings: *"Exploratory hole location plan and inferred geological section (incl. MGI data) (sheets 10-14 of 14)"* Contract No. B0307000, Drawing No. B-MN-0000-GE-230-234 (rev A01)

extends over a length of approximately 1000 metres and encompasses both the Mater and Parnell Square stops. It is understood that the primary driver for the tunnel level shown on the Railway Order drawings along this length is the architectural design of the stations. In particular, the architects' key objective has been to limit to a minimum the depth of underground stations to ensure maximum accessibility for the travelling public. This is the reason why the Reference Design shows the tunnel horizon in this position, which is highly unfavourable from the point of view of tunnelling. Special engineering measures will therefore be required to ensure that the tunnelling process (that is excavation and the installation of concrete lining to support the excavated surfaces) does not cause ground movements and settlements which will damage property or cause disruption at the surface. In the light of the inevitable uncertainty at this stage regarding the precise level of the top of the intact limestone and the characteristics of the mixed ground immediately above it (as described in paragraph 4.6.4 below), design and implementation of these special engineering measures will have to be associated with further site investigation aimed at providing adequate information about the ground conditions. An alternative approach would be to re-design the tunnel alignment at a lower level so as to avoid the engineering challenges associated with tunnelling with a mixed face at rockhead. It remains to be seen whether tenderers for the construction contract will propose this during the detailed design phase.

3.2.7 The project designers have recognised that tunnelling on the rock/sediment interface or wholly in the sands and gravels is not without the potential for problems and sensibly they have stated that closed face TBMs will be required. The EIS in Volume 2, Chapter 9 (Soils and Geology), paragraph 9.4.2 (Mitigation Measures) states:

"The running tunnels will be constructed using a TBM with the capability to pressurise and support the tunnel face to minimise ground loss. Probing ahead of the tunnel face to determine problematic ground conditions in advance, such as water bearing sand lenses in the glacial till, rockhead profile uncertainty and mixed face conditions will be undertaken as necessary".

3.2.8 The designers are therefore setting down the requirement for TBMs used on the project to be either Earth Pressure Balance Machines (EPBMs) or Slurry Shields. Both types serve the same purpose of balancing the earth/groundwater pressure at the tunnel face by pressurising the excavated material to control the stability of the tunnel face (EPBM) or by mixing pressurised bentonite slurry with excavated material to achieve the same result (slurry shield). In both cases the excavated material is pressurised and mixed in the cutterhead chamber in front of a pressure bulkhead, thereby creating a balance with the earth/groundwater pressure in the non-cohesive saturated soils through which the tunnels are being driven. The significant difference between EPBMs and slurry shields is the mechanism by which the pressurised excavated material is removed from the cutterhead chamber, safely reduced to atmospheric pressure within the TBM and transported from the tunnel.

3.2.9 These tunnelling machines are sophisticated, and despite being rugged, heavy civil engineering plant, they are capable of a high degree of control. Properly used they are effective in minimising ground movements which lead to surface settlements. There is much precedent experience of the successful use of such TBMs in extremely adverse conditions. There are of course pluses and minuses for each type of TBM, dependent upon the ground conditions which are anticipated to be encountered. Selection of the right machine will be a function of the skill and experience of the tunnelling contractor engaged to undertake the Works as well as his assessment of the ground conditions. That said, informed observers will be aware that collapses and major settlements at surface level have occurred on tunnelling projects. Ongoing monitoring and instrumentation schemes, when properly designed and implemented, will ensure 'early warning' and positive feedback as described in Section 3.1 above, so avoiding such troubles.

Single Shield TBMs are a suitable choice for brittle or soft rock. In shield tunnelling the tunnel is lined with concrete segments. To tunnel forward, the hydraulic thrust cylinders of the Single Shield TBM push against the last installed lining ring.

Mined Crossover Tunnel and Cross Passages

3.2.10 It is proposed to construct a crossover tunnel and numerous cross passages between the running tunnels. The crossover tunnel is located underneath the school sports ground (St Patrick's College) adjacent to Ferguson Road and the cross passages are proposed at maximum 250 metre spacing along the tunnel route. The crossover tunnel is required to provide the facility to switch trains from one running tunnel to the other and the cross passages are required for safe access/egress during operation and maintenance of the tunnels, and especially for use during emergencies. These are normal facilities, to be found on metro systems worldwide.

3.2.11 The geological sections summarising the interpretation of ground investigation data used for the reference design[6] shows that the crossover tunnel will be constructed at about 35 metres below ground level with around 20 metres of limestone bedrock cover overlain by boulder clay and some lenses of sand and gravel. The designers have indicated that the tunnel will be excavated by mechanical means and/or drill and blast. Mechanical excavation will be dependent upon the rock mass characteristics *i.e.* strength, fracture spacing *etc* and the availability of suitable road header tunnelling machines to undertake this work. If drill and blast methods are used, the use of explosives will be carefully controlled, commencing with trial blasts using small charges to provide the basis for the design of production blasts that will comply with conditions attached to the Railway Order

6 Jacobs Drawing: *"Exploratory hole location plan and inferred geological section (incl. MGI data) (sheet 11 of 14)"* Contract No. B0307000, Drawing No. B-MN-0000-GE-231 (rev A01)

in relation to blast vibrations and ground-borne noise. Main blasts during construction of the tunnel will be monitored on adjacent surface properties to ensure that vibration limits are not exceeded and to provide further information to feed back into the design of subsequent blasts (to reduce vibration to a minimum and ensure efficient use of explosives). There is precedent experience of blasting in the limestone bedrock and boulder clay of Dublin to create new tunnel systems (Grand Canal Drainage Tunnel, 5km x 4 metres diameter, circa 1973 – 1975), where no significant adverse effects at ground level were suffered.

3.2.12 The cross passages are short tunnels set at right angles to the main running tunnels and making direct connections between them. These are located for the most part in the limestone bedrock or the boulder clay and the construction methodology will be similar to that of the crossover tunnel. Where cross passages are located in areas of sands and gravels or soft ground, or where significant water ingress is present, localised ground treatment, by way of consolidation grouting and/or fissure grouting will be required. In both the crossover tunnel and the cross passages, the tunnel advance will be staged to allow immediate installation of primary support to excavated surfaces. Support of the excavated faces will be provided using a combination of sprayed concrete, lattice arch girders and rock bolts, dependent upon the specific requirement at each tunnel face.

Shaft and Station Box Construction

3.2.13 The Reference Design for underground stations and shafts allows for robust and internationally proven construction methods to ensure that no significant movement occurs in the sediments overlying rockhead. The residents and other interested parties with whom we have been working to date, are affected by shaft and station box construction between Ballymun and Parnell Square Stops. The design engineers have scheduled applicable excavation and support techniques for this length of line as detailed below:

Ballymun and DCU Stops	The stop structures will be constructed using cut and cover method of construction using diaphragm[7] walls as primary support.
St Patrick's Shaft	Secant[8] piles will provide support to upper soft ground strata. Rock excavation will be by mechanical methods and or drill and blast.
Griffith Avenue Stop	Stop structure will be construction using cut and cover form of construction. Contiguous pile walls in the glacial till (boulder clay) to rockhead.
Drumcondra Stop	Stop structure will be constructed using cut and over with contiguous pile walls in the glacial till to rockhead.
Mater Stop	Stop structure will be constructed using rigid diaphragm walls to formation level.
Parnell Square Stop	Stop structure will be constructed using rigid diaphragm walls to formation level.

7 **A diaphragm wall** is a wall that is constructed in the ground prior to excavation so that it supports the sides of the excavation once the material inside the wall is excavated. The wall is constructed by excavating down in narrow slots, to form panels that join to create the wall required, replacing the *in situ* material removed as excavation is undertaken with bentonite (clay) slurry to support the slot and then replacing the bentonite slurry with reinforced concrete.

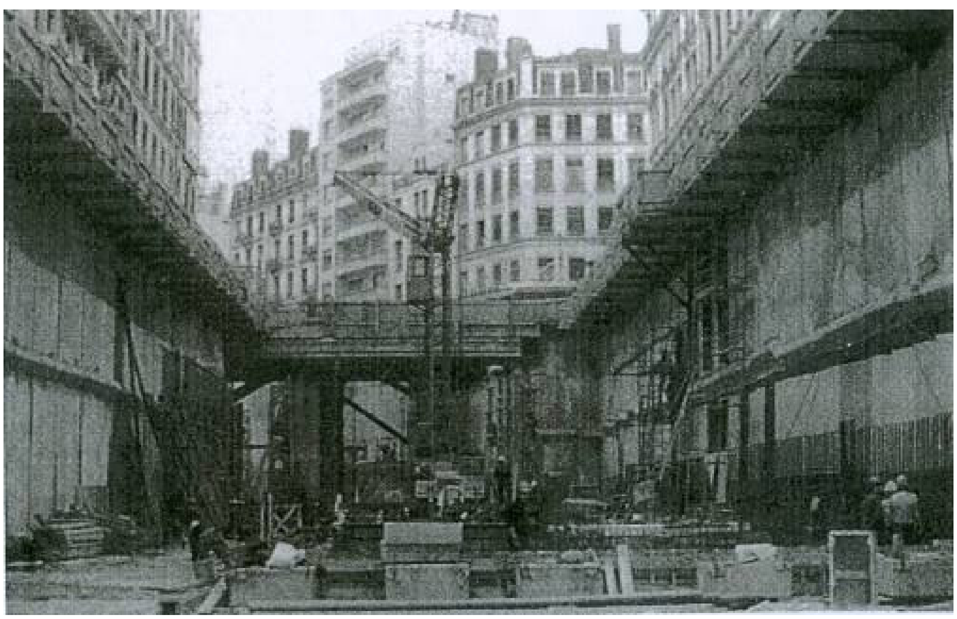
8 **Creating a secant wall** is similar to forming a diaphragm wall but is achieved through drilling a line of partially intersecting large diameter boreholes within which the replacement of *in situ* ground with reinforced concrete takes place.

3.2.14 All of the foregoing methods scheduled by the designers are considered appropriate methodology to provide support to the sediments overlying rock and to prevent ground movement. There are several case histories for deep basement construction in Dublin, similar to those proposed for station construction, which have been successfully completed without incidence of ground movement.

3.2.15 The most significant issue will be disruption and nuisance caused by the construction process which will necessarily affect the lives of those people who live and work in the community around these structures. Experience of similar construction processes in London has shown that much can be done to reduce or even eradicate such disruption and nuisance. The erection of acoustic barriers and canopies can reduce noise from construction sites to less than normal background levels and implementation of a strict regime of cleaning, wheel washing *etc* can ensure that the necessarily dirty excavation and construction processes are not carried outside the worksite compound. Such measures are now commonplace on major construction sites, and their implementation on the Dublin Metro North project should be a foregone conclusion.

3.2.16 Cut and cover tunnel construction is undertaken in a similar manner to station box construction and uses the same range of techniques (especially construction of diaphragm and secant walls).

3.2.17 Further information on tunnelling and related topics can be found in Appendix 4, in which a number of specific questions referred to us by the group Residents for Realignment have been addressed.



Lyon Metro, Saxe-Gambetta station: completed station excavation showing precast diaphragm walls

4. CONSIDERATION OF KEY ENVIRONMENTAL IMPACTS RELEVANT TO THE PROJECT

4.1.1 In accordance with the scope of the tender and our commission, we have concentrated our detailed review of environmental impacts relevant to the project (and deployed relevant expertise) in the following topic areas:

- Airborne noise from construction works and railway operation (also referred to as "environmental noise");
- Vibration and groundborne noise from metro construction and operation;
- Influence of proposed works on surface water;
- Influence of proposed works on ground water; and
- Settlement of ground around tunnels and associated civil engineering works.

4.1.2 Each of the following sections is structured as follows:

(i) Introduction to the subject - important concepts and terminology;
(ii) Description of the assumptions made in the Metro North assessments and the methodology used;
(iii) Reference to relevant sections of the EIS;
(iv) Summary of findings of the EIS;
(v) Comment from the Independent Engineering Experts on the adequacy and clarity of the EIA (and other Railway Order documentation) in relation to the impact under consideration and identification of gaps and/or un-answered questions.

4.2 Airborne noise from surface construction works and railway operation

Introduction to airborne noise – important concepts and terminology

4.2.1 Airborne (or environmental noise) is the noise that is transmitted through the air and therefore might be heard outside or within a building. For this project, the sources of airborne noise include:

- construction works that are at or above ground level or open to the atmosphere. These will include construction of: 'at grade' and elevated track, station boxes, surface infrastructure at stations, cut and cover tunnels; and all construction activities at and around the Belinstown depot, park and ride and station site;
- construction traffic;
- emergency ventilation fans; and
- light metro vehicles (LMVs) operating at the surface or on elevated track.

4.2.2 Noise from construction sites (and moving LMVs or road vehicles) is constantly varying because very few of the items of plant and machinery (sources of noise) operates continuously in the same place; they move about relative to an individual (static) receptor. In addition, the amount of noise actually emitted from each individual item may vary depending on what it is doing (*e.g.* more noise is emitted by a truck travelling up a slope in a low gear than when stationary with the engine running). An example noise signal is depicted in Figure 3.

4.2.3 Noise perceptible to humans is measured in decibels (symbol dB(A)). The "(A)" after "dB" signifies that a noise measurement (or prediction) has been "A-weighted" to approximate the frequency range of a human ear, which is relatively insensitive at low frequencies and very high frequencies. The objective of environmental noise measurements is to quantify the level of noise experienced from a human perspective (hence the need for applying a weighting to measurements made using a monitoring device that can detect the full range of frequencies to convert them into units that reflect human experience). There is an explanation of the units used to describe noise in Figure 4. Figures 3 and 4 were originally PowerPoint slides presented by the Independent Experts at public meetings in Dublin held during the week commencing 20th October 2008.

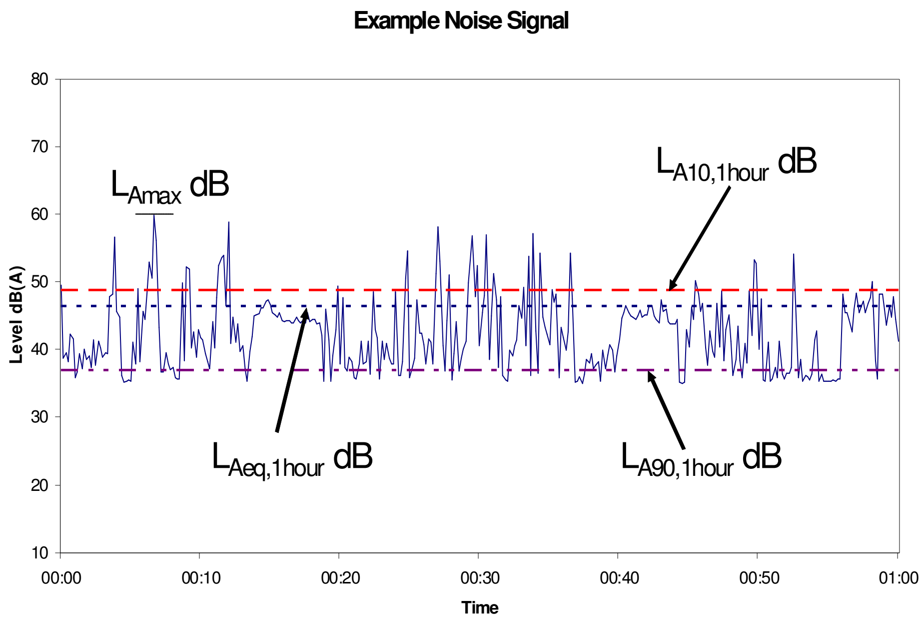


Figure 3 Example noise signal

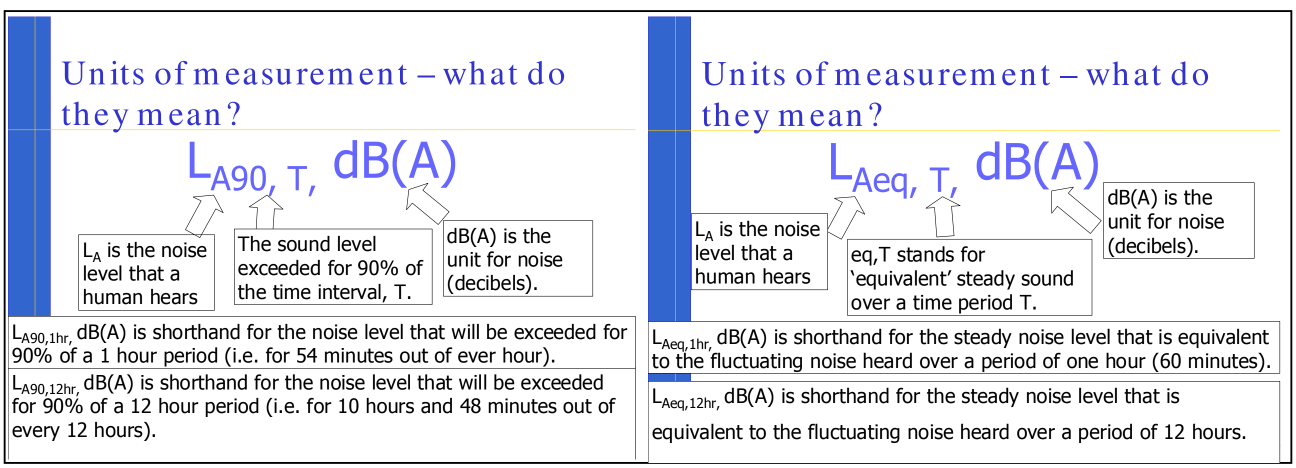


Figure 4 Explanation of noise measurement units

4.2.4 $LA_{90,T}$ is the normal measure used to describe the level of background noise (*i.e.* noise which exists in the environment before the noise being assessed is added). $LA_{eq,T}$ can be used to describe the ambient noise or overall noise level of an existing noise climate. $LA_{eq,T}$ is the way in which predicted and measured site noise levels are generally described. When comparing noise levels (*e.g.* actual or predicted against background), it is important to compare noise levels relating to the same time period (T value).

4.2.5 The following excerpt from the EIS (Volume 3, Book 2, Annex B, Page 1) is a table describing what given ranges of noise in dB(A) might sound like, in comparison to commonly experienced noise environments.

$L_{Aeq,T}$, dB(A)	Example
0	Absolute silence
25	Very quiet room
35 - 40	Quiet rural area during night with no wind
55	Day-time, flat to undulating topography, busy roadway 0.5km away
70	Busy restaurant
85	Very Busy pub, voice has to be raised to be heard
100	Disco or rock concert
120	Large chipping hammer. Uncomfortably loud and conversation impossible
140	Four propeller aircraft. Noise causes pain to the ears

*Adapted from EPA Guidance Note for Noise in Relation to Scheduled Activities (2nd Edition), 2006

4.2.6 Each source of noise can be ascribed a 'sound power level' – the amount of noise that is emitted from an item of plant or a collection of activities going on in one place. Noise levels reduce (attenuate) with distance from a noise source. For a given noise source, reductions over and above the attenuation that takes place by virtue of the distance between source and receptor can be achieved by introducing barriers between the source and the receptor. The influence of the roughness and topography of the intervening ground can also be important. Options for noise mitigation therefore include reducing noise levels at the source and the introduction of barriers between sources and receptors.

4.2.7 For complex noise sources (such as construction sites), where noise is constantly varying as described above, noise assessment criteria (against which the significance of the impact of additional noise is assessed) are either expressed as a 'threshold' in dB(A) ($L_{Aeq,period}$), or in relation to the background or ambient noise levels. It is common to assess noise outside buildings, generally 1m from the façade or, in the free field, more than 3.5m from the façade of buildings.

4.2.8 For static items of plant that will operate during the operational phase (*e.g.* exhaust vents for fans), 'Noise Criteria' (NC) curves are used to specify sound levels that are acceptable in particular circumstances; these provide an indication of the noise that will be experienced inside buildings. There is no direct conversion from NC to dB(A) but a rough rule of thumb is dB(A) = NC + 5 and therefore NC25 is approximately 30 dB(A), although this could vary considerably depending on the spectrum shape of fan noise (*i.e.* whether it is broad band noise or contains tonal noise). NC25 is regarded by the noise assessment team who contributed to the EIS to be the appropriate level of noise from fixed plant experienced inside residential properties at night (to avoid sleep disturbance)[9].

9 The last paragraph of Section 4.3.2.2 in Volume 2, Chapter 4 (all Books) states: *"Noise from fixed plant is considered in the same manner; however it has been assumed insignificant if noise is less than NC25 inside neighbouring buildings at night (to avoid sleep disturbance) or to not exceed the existing L_{A90} background noise".*

4.2.9 Residual impacts, in terms of noise, are those impacts which exceed the assessment criteria but cannot be mitigated further (based on the mitigation assumed in the assessment).

Reference to relevant sections of the EIS

4.2.10 **Description of the noise baseline.** In Volume 1 Book 1, the noise baseline is described in Chapter 12. Chapter 12 is supported by 4 Noise Baseline Maps in Volume 3 Book 1 and a Baseline Noise Monitoring Report in Annex B of Book 2 of Volume 3. The maps and report in Volume 3 provide details of thirty-one baseline Noise Monitoring Locations in the vicinity of the proposed route of Metro North and report the results of baseline noise monitoring at each of these locations. Daytime readings were made at all locations with evening or night time readings made at most but not all of the locations. The Baseline Noise Maps also show areas with given Functional Values within the study area for airborne noise.

4.2.11 **Evaluation of the potential noise impacts arising from the scheme.** In each of the seven books making up Volume 2, Chapter 4 relates to noise impacts. These chapters are in 4 main sections as follows:

- 4.1 Introduction
- 4.2 Study area
- 4.3 Assessment methodology
- 4.4 Impact assessment

4.2.12 Annex C in Volume 3, Book 2 provides "*details of the noise modelling methods and results, including predicted levels of noise without mitigation for both the construction and operational phases.*"[10] The locations at which predictions have been made are shown on the 4 Noise Impact Maps in Volume 3, Book 1 (these maps also show the baseline monitoring locations).

4.2.13 Residual impacts are discussed at section 4.4.3 and summarised in Table 4.5 (Books 3, 6 and 7), Table 4.6 (Books 2, 4 and 5) and Table 4.8 (Book 1), all entitled "*Summary of residual impacts*".

Assumptions and methodology applied in the EIS

4.2.14 The general methodology that has been applied in the EIS to the assessment of environmental impacts and their significance is described in Section 2 of this report and is not repeated in detail here.

4.2.15 The criteria for baseline categorisation (in terms of functional value) are listed in Table 12.3 (page 224) of Volume 1 of the EIS and shown on the baseline maps in Volume 3. Baseline noise monitoring was carried out during both day and night periods, with attended sample noise monitoring exercises almost exclusively on weekdays between December 2006 and October 2007.

4.2.16 The sources of airborne noise are described in general terms in section 4.4.1 of each Chapter 4. Construction noise impacts have been assessed by assuming that the plant operating at the various surface construction sites along the route will be as listed in the

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10 From introductory text to sections 4.3 in the 7 noise chapters included in Volume 2

construction plant inventories at tables 7.6 to 7.23 in Volume 3, Book 2, Annex C. These inventories list the types of plant, their sound power levels (*i.e.* the amount of noise that they will emit), the number of units assumed to be operating, and the percentage of time for which they are assumed to be operating. Using this information an 'effective sound power level' is derived for the particular site (or category of site, *e.g.* stops generally are covered by Table 7.13). We understand from the RPA that a general assumption has been made that, where receptors are likely to be affected by more than one source of noise, all relevant noise sources will be assumed to be in operation concurrently (with the effective sound power levels detailed in tables 7.6 to 7.23 in Annex C).

4.2.17 The noise assessment team has specified noise criteria as noise thresholds in dB(A) $L_{Aeq,period}$, and not by reference to the anticipated change from background noise levels. The noise assessment criteria for the construction and operational phases of the Metro North project are set out in Tables 4.1 and 4.3 in each of the books comprising Volume 2 (reproduced below):

Table 4.1 Noise criteria during the construction phase (at 1m from the façade)

Period over which criterion applies	Noise Impact Criterion ($L_{Aeq, period}$)
- Monday to Friday:	
Urban areas or near main roads; Day: 07.00 to 19.00	75 dB
Rural areas away from main roads Day: 07.00 to 19.00	70 dB
- Monday to Friday: Evening: 19.00 to 22.00	65 dB
- Monday to Friday: Night: 22.00 to 07.00	The higher of 45 dB or the ambient level.
- Saturday: Day: 08.00 to 16.30 (work outside these hours will be subject to Monday to Friday night time noise levels i.e. the higher of 45dB or the ambient level)	65 dB
- Sundays and Bank Holidays: Day: 08.00 to 16.30 (work outside these hours will be subject to Monday to Friday night time noise levels i.e. the higher of 45dB or the ambient level)	60 dB

Table 4.3 Threshold criteria for assessment of impacts during the operational phase

Area description	Functional value	Noise impact threshold during operation
Locations that are highly sensitive during both night and day: - Residential areas, medical facilities (hospitals, nursing homes etc)	very high	Daytime: 55 dB L_{Aeq} Night-time: 45 dB L_{Aeq}
Locations that are only sensitive during the day, where the activities that are carried out require an acceptable noise environment: - Educational/Institutional uses, theatres and religious buildings.	high	Daytime: 55 dB L_{Aeq} Night-time: Not applicable: Locations are not sensitive at night
Locations that are only sensitive during the day and where the activities that are carried out can be carried out in the presence of some noise, but not high levels of noise: - Outdoor recreational areas. - Cinemas. - Offices.	medium	Assessed on a case by case basis, depending on the sensitivity of the specific use and the level of protection that may be afforded by the building.

4.2.18 In addition to the criteria set out in Table 4.1, an assessment criterion of 65dB(A) is applied to schools for construction noise.

4.2.19 Having established the functional value of receptors (through analysis of the baseline as described above), predicted the amount of construction or operational noise that will be experienced at receptors, and defined the assessment criteria, the next step is to assess the significance of the impact on the receptors (by considering magnitude and functional value as described in paragraphs 2.2.6 and 2.2.7 above). In the Metro North noise assessment, the assumption made is that areas with a functional value of < medium are not sensitive to noise. The way in which the magnitude of noise impacts is defined is set out in Table 4.2 and reproduced below:

Table 4.2 Definition of noise magnitude ratings

Extent of Noise Impact (Exceedance of Assessment Criteria)	Noise Impact Magnitude	Magnitude Rating
>10dB	Severe	very high
5 to 10dB	Substantial	high
3 to 5dB	Moderate	medium
1 to 3dB	Slight	low
<1dB	No Impact	very low

4.2.20 For fixed plant (exhaust fans), NC25 has been set as the assessment criterion. The EIS (*e.g.* section 4.3.2.2, Volume 2, book 6) states that, *"Since all fixed plant is being designed to meet these standards, it has not been necessary to define magnitudes of impact since no significant residual effects are expected".* In other words, through design of the installations and selection of machinery it will be possible to meet this standard at all sensitive receptors.

4.2.21 Residual impacts are summarised in a final table at the end of Chapter 4 in each of the books comprising Volume 2; these are presented as 'taking into account mitigation'. There is no supporting appendix document indicating precisely what mitigation has been assumed as background to the assessments of significance in these summaries, although there is a list of mitigation measures in each of the Chapter 4s at sections 4.4.2.1 and 4.4.2.2, and an expressed commitment to 'best practical means' to be applied to reducing noise.

Summary of EIS findings on airborne noise

4.2.22 In respect of airborne noise impacts during the construction phase, there are a number of locations where the relevant summary tables indicate that, using the equipment inventories assumed, the assessment criteria defined and the functional values assessed, construction will give rise to residual impacts with magnitude described as 'high', or 'very high' on receptors of high or very high functional value (*i.e.* significant residual airborne noise impacts after mitigation).

4.2.23 With the exception of the depot and park and ride at Belinstown, six properties on Seatown Terrace (NM101-19) and six houses to the east of the R132/M1 junction (all in area MN101), for every section of the proposed metro, the residual noise impacts during the operational phase are assessed to have a magnitude of 'low or very low' and a significance of 'not significant'. To achieve this for noise from LMVs, further mitigation in the form of modified trackway and/or barriers has been identified as being required at specific locations in areas MN102, MN103 and MN104, where the track will be at grade or elevated (see Table 4.5 in Volume 2, Books 2, 3 and 4).

4.2.24 In area MN101, impacts of the operation of the depot and changed traffic patterns at and around the Belinstown site are described as having magnitude 'low' or 'medium' and expected to give rise to 'potentially significant' and 'significant' residual impacts respectively. At Seatown Terrace, an impact magnitude of 'moderate' (3.4dB) has been assessed but is not considered to be 'significant'.

4.2.25 The standard 'NC25' will be met inside buildings that may be affected by noise from the emergency exhaust fan installations, because all fixed plant is being designed to meet these standards.

Comments

4.2.26 There has been discussion and correspondence between the noise expert on the Independent Engineering Expert Team (Dr Paul Cockcroft) and the noise assessment team at ERM to clarify certain technical matters that were not initially completely clear to him. We are now happy that, with one exception (see paragraph 4.2.30 below) we understand what has been done and the assumptions upon which it has been based.

4.2.27 The information in the noise chapters in the EIS is generally clearly presented and supported by relevant information in the appendices. However, we consider that the definition of noise magnitude ratings (Table 4.2) is potentially confusing without further explanation. In Table 4.2 (which is the same in each of the seven books comprising Volume 2), an exceedance of assessment criteria of <1dB is described as 'No Impact' and is ascribed a noise magnitude rating of 'Very Low'. These words, when used (in the text of the EIS) to describe the magnitude of the noise impacts predicted at particular receptors, could easily be misconstrued by a reader as meaning that the works proposed in the Railway Order application are not expected to have any impact on that receptor (*i.e.* that, even with construction activity taking place, it will be no more noisy at that location than it is at present). In fact, they mean that, although the noise criterion appropriate to that receptor will be exceeded, it will be exceeded by a negligible amount. In other words, where the existing noise level at a particular receptor is currently below the relevant noise criterion, an assessed noise impact described as 'no impact' could indicate that it will be much more noisy at that location than it is now.

4.2.28 For each of the seven areas, the EIS reports predicted residual airborne noise impacts during the construction and operational phases (*i.e.* after mitigation) that exceed the assessment criteria in areas of medium or high functional value and are therefore described as 'significant'. We have discussed this with RPA and have been reassured to hear that the assessment criteria are considered by them to represent maximum allowable noise limits to be binding on the contractor. This is not stated in the EIS, which gives the impression that there will be nothing further that can be done at locations where airborne noise has been predicted in the environmental assessment to exceed these thresholds. The EIS will clearly be an essential reference document for contractors in identifying locations where more will be required in terms of mitigation to reduce construction related airborne noise to below the criteria set out (or imposed in conditions by An Bord Pleanála). There is, of course, scope for the contractors to vary the plant inventories from those assumed in the EIS noise assessments; significant reductions in source noise can be achieved through careful programming of the works.

4.2.29 The assessment criteria applied in the noise assessments for construction noise in urban areas or near main roads (75dB for daytime and 65dB in the evening) are higher than those proposed in the National Roads Authority document "*Guidelines for the Treatment of Noise & Vibration in National Road Schemes*" (where, at paragraph 2.3.2 and Table 4.1 under the heading *Construction Noise*, levels of 70dB ($L_{Aeq,1hour}$) during the day and 60dB ($L_{Aeq,1hour}$) during the evening are deemed to be acceptable). The EIS explains[11] that the daytime criteria given in the NRA document may be appropriate for the interurban situation "*but are not necessarily appropriate for the urban situation through which the majority of the proposed scheme is to be constructed. For the urban area, or near to main roads, the 75dB value is used, taken directly from the UK guidance and common practice".* We make the following observations on the assessment criteria set:

- There is a note in the relevant section of the NRA document explaining that *"it may be appropriate to apply more stringent limits in areas where pre-existing noise levels are low".* We note that some areas that have been assumed to be 'urban' in the assessment have rather low background noise levels. Consideration of more stringent limits may therefore be appropriate in certain 'urban' locations.
- For each relevant period (days and times) the NRA document provides guidance criteria comprising an $L_{Aeq,1hour}$ limit (*i.e.* noise 'averaged' over a one hour period) together with a maximum noise level that must not be exceeded. The EIS assessments reported in Volume 3, Book 2, Annex C, Table 7.24-7.30 list predicted noise levels expressed as $L_{Aeq,\ T}$, but the time period 'T' is not defined. The predicted noise levels in these tables are inferred to be $L_{Aeq,\ 12\ hour}$ for daytime noise, *i.e.* noise averaged over a 12 hour period between 07.00 to 19.00[12]. These are compared with the appropriate assessment criteria to give 'exceedence' (if any) and to derive impact ratings. If the daytime limits set for contractors were to be based on $L_{Aeq,\ 12\ hour}$ and no maximum noise level were to be set, this raises the possibility that very noisy construction activities could take place for one or two hours but that the construction noise measured over a 12 hour period could be within the limits. This factor (and the pre-existing noise levels) should be an important consideration in setting noise limits for the contractor, designing monitoring schemes and setting noise limits in planning conditions.
- Clearly, given that noise sources move about relative to an individual receptor (see paragraph 4.2.2 above) it is very unlikely that the highest predicted construction noise levels at an individual receiver would be generated consistently over a four year period, more likely for a few weeks or perhaps months. However, if there were a noise source generating a fairly steady noise at a particular location for more than a few months, then the assessment criteria (limits to apply to the contractor) should be lower at that location than those set out in the EIS.

4.2.30 There is a description of construction activities to be carried out at the depot site (Belinstown, MN101) in Volume 2, Book 1, Chapter 4, Section 4.4.3.1. In Volume 3, Book

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11 Volume 2, Books 1-7, Chapter 4, paragraph 4.3.2.1

12 Noise impact criteria in Volume 2, Books 1-7, Chapter 4, Table 4.1 are described as being $L_{Aeq,\ period}$ and the periods over which they apply are specified. In Annex C, at the end of Section 6 (*Unmitigated construction noise impacts*) the following is stated: "*Noise levels (LAeq,T) are presented for the relevant period when works are in progress, usually* [this will] *be the day time period (0700 to 1900), although some night-time and evening works are also expected".*

2, Annex C, Tables 7.6 and 7.7 relate specifically to construction plant assumed in the assessments to be used at the depot site (for top soil strip and substructures respectively). We cannot see, either in the description in Chapter 4 nor in the relevant tables in Annex C, any reference to airborne noise that will be generated by the ongoing construction of the substantial landscaped mound along the southern boundary of the depot/park and ride site. This mound is intended to accept surplus spoil from the tunnelling operations and its construction will therefore take place over a substantial period. We understand that it is to be compacted so as to be suitable to support a road or related structures in the future. Although there are construction plant inventories for surface stops and structures generally in Annex C, we do not see any specific reference in the airborne noise assessment to the construction of the proposed multi-storey car park at the Belinstown stop; this structure is very close to residential properties along Batter Lane.

4.2.31 It will clearly be for the contractor to create a final design for the works in the Belinstown area (and elsewhere along the alignment) to ensure that noise does not exceed absolute limits set in conditions to the Railway Order and included in the contract. As discussed in paragraph 4.2.29 above, it is entirely possible, given the rural location (low pre-existing noise environment) and the duration of the works at this site, that noise limits imposed will be lower than the assessment criteria defined in the EIS. There is, at present, insufficient information upon which to base an evaluation of whether even the EIS assessment criteria are likely to be achievable at this location, given the proximity of the proposed multi-storey car park to houses and the length of time over which the mound will be under construction.

4.2.32 The criteria for operational noise appear reasonable, but the EIS does not provide sufficient information upon which to judge whether they are achievable at all locations even with the mitigation measures considered.

4.3 Vibration and groundborne noise from and metro construction and operation

Introduction to vibration and groundborne noise - important concepts and terminology

4.3.1 Construction and transport activities impart energy to the surrounding ground, which causes the ground to vibrate. The magnitude of oscillations is very small; much less than a tenth of a millimetre. Vibration is transmitted outward from its source, and reduces in strength (attenuates) with distance between source and receptor. This is due to the wave front lengthening and hence spreading out the available energy and also to frictional resistance to movement. A vibration underground may be experienced at the surface as vibration or as sound (known as groundborne noise). Groundborne noise occurs when the vibration of a surface or structure radiates into the air, which causes sound (noise) to be experienced by a the human ear (or a microphone). Groundborne noise is more closely related to vibration (having the same source) than it is to airborne noise (for which the pathway from source to receptor is oscillation of the air as described in the previous section).

4.3.2 For this project, sources of vibration and groundborne noise include:

- TBMs forming the bored tunnels;
- Blasting to form cross passages, shafts, station boxes and crossover tunnels where rock has to be excavated;

- Construction plant on work sites (*e.g.* bored piling and the use of vibratory rollers); and
- Wheel/rail interaction during the movement of LMVs in tunnels, at surface or on elevated track.

4.3.3 The primary effect of ground vibration is disturbance: of people, of animals or of sensitive equipment. When very severe, it can give rise to building damage and, more frequently, the fear of building damage. The criteria relevant to the assessment of vibration effects on people differ from those relevant to building damage and the effect of vibration on sensitive equipment as described below. Groundborne noise is relevant to human perception (and interference with sound recording equipment).

4.3.4 **The magnitude of vibration** is expressed in terms of Peak Particle Velocity (PPV) in millimetres per second (mm/s).

4.3.5 The following paragraphs, taken from the National Roads Authority document "*Guidelines for the Treatment of Noise & Vibration in National Road Schemes*", section 2.3.4 (*Construction vibration*), provide an accessible introduction to the subject of construction vibration.

> *There is no published Irish guidance relating to vibration during construction activities. Common practice in Ireland has been to use guidance from internationally recognised standards.*
>
> *In the case of nominally continuous sources of vibration such as traffic, vibration is perceptible at around 0.5mm/s and may become disturbing or annoying at higher magnitudes. However, higher levels of vibration are typically tolerated for single events or events of short duration. For example, blasting and piling, two of the primary sources of vibration during construction, are typically tolerated at vibration levels up to 12mm/s and 2.5mm/s respectively. This guidance is applicable to the day-time only; it is unreasonable to expect people to be tolerant of such activities during the night-time.*
>
> *Guidance relevant to acceptable vibration at the foundation of buildings is contained within BS 7385 (1993): Evaluation and measurement for vibration in buildings Part 2: Guide to damage levels from ground-borne vibration. This states that that there should typically be no cosmetic damage if transient vibration does not exceed 15mm/s at low frequencies rising to 20mm/s at 15Hz and 50mm/s at 40Hz and above. These guidelines relate to relatively modern buildings. Therefore, the guideline values should be reduced to 50% or less for more critical buildings. Critical buildings would include premises with machinery that is highly sensitive to vibration or historic buildings that may be in poor repair, including residential properties.*
>
> *The German standard DIN4150 provides limits below which it is very unlikely that there will be any cosmetic damage to buildings. For structures that are of great intrinsic value and are particularly sensitive to vibration, transient vibration should not exceed 3mm/s at low frequencies. Allowable levels increase to 8mm/s at 50Hz and 10mm/s at 100Hz and above.*

4.3.6 **Groundborne Noise** is measured in dB(A) (the same unit as airborne noise). Current common practice in measuring and setting limits for structure-borne noise is to use the maximum A-weighted level and 'slow response' ($L_{Amax,slow}$).

4.3.7 The level of groundborne noise and/or vibration at a receptor depends on the amount and nature of the vibration at the source, the distance between the source and the receptor (in this case usually the depth of a tunnel beneath a building) and the nature of the ground through which the vibration passes. By far the most important of these is magnitude and nature of the vibration at source (*e.g.* the vibration caused by the TBM or the vibration of LMVs running on the track).

4.3.8 For this project, vibration and groundborne noise will emanate from known single sources, such as LMVs and the TBMs, and will create impacts on people, structures and sensitive equipment which are, in the main, not currently affected by vibration or groundborne noise. Therefore linking cause and effect in the course of monitoring is more straightforward than it is for some other environmental impacts.

4.3.9 In relation to airborne noise, a range of mitigation measures can be available including reducing the noise emitted at source, introducing barriers between the source and the receptor and adapting the receptor to make it less sensitive. In contrast, for vibration and groundborne noise, any mitigation required to reduce impacts on receptors generally has to take place at the source (as installing barriers or modifying buildings to reduce impacts at the receptor are normally impractical). It is therefore common practice for vibration and groundborne noise to set absolute criteria for maximum levels at certain receptors and to use these criteria as a basis for 'designing to comply'. During the construction phase the rate of TBM progress and the way in which it is operated can be varied to reduce vibration transmitted to the ground if monitoring shows that vibration or groundborne noise limits are being approached and may be exceeded (see section 3.1.14 above). Similarly, carefully monitored trial blasts and incorporation of monitoring information during production blasts will enable the tunnellers to refine blast designs so as to comply with the vibration limits in their contract and planning conditions.

4.3.10 In the EIS the assessment criteria for vibration effects on people are guideline values for evaluating human exposure to vibration in dwellings and similar spaces, taken from DIN4150-2. The German DIN standard is generally considered to be one of the most stringent. The criteria used to define impact magnitudes reflect duration and frequency of vibration, as well as the magnitude of that vibration. They are defined by reference to sets of criteria A_u (lower limit), A_o (upper limit) and A_r (value for comparison with KB_{FTr} values, where KB_{FTr} is 'evaluation vibration severity'). KB_{FTr} is the standard deviation[13] of all KB values recorded in all of the short time periods during the evaluation time frame. The KB_{FTr} values are then compared against A_o, A_u and A_r to establish whether the vibrations are at an acceptable level or not. For blasting vibration effects on people, only A_o (upper limit) is relevant. These values do not relate directly to PPV levels but PPV levels are approximately 2 x KB_{max}.

Reference to relevant sections of the EIS

4.3.11 **Description of the vibration and groundborne noise baseline.** In Volume 1 Book 1, the vibration and groundborne noise baseline is described in Chapter 13. Chapter 13 is supported by four Vibration Baseline Maps in Volume 3 Book 1. There is no supporting baseline report presented as an annex in Book 2 of Volume 3. However we have been provided with a copy of a baseline vibration report[14] that was prepared in February 2008. This report describes an investigation of baseline vibration levels at a sample number of

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13 Standard Deviation (SD) is a measure of the scatter of a collection of numbers (the vibration level results). The SD is defined as the root-square-mean (RMS) deviation of the numbers from the mean of the sum of the numbers

14 *Baseline vibration monitoring for Metro North,* Prepared by ERM and Rupert Taylor. (Final, February 2008)

areas along the proposed alignment, which was carried out in order to determine whether significant vibration already exists in any areas. Given the findings of the investigation as reported (*i.e.* that there are no pre-existing significant sources of vibration) and the fact that vibration impacts are usually assessed by means of comparison with absolute criteria, we understand that it was not considered to be necessary to include this report in the EIS. The maps in Volume 3, Book 1 show areas with given Functional Values (using the definitions in Volume 1, Book 1, Chapter 13) within the study area for vibration and groundborne noise.

4.3.12 **Evaluation of the potential vibration and groundborne noise impacts arising from the scheme.** In each of the seven books making up Volume 2, Chapter 5 relates to vibration and groundborne noise impacts. These chapters are in 4 main sections as follows:

- 5.1 Introduction
- 5.2 Study area
- 5.3 Impact assessment methodology
- 5.4 Impact assessment

4.3.13 Residual impacts are discussed at section 5.4.4 and summarised in Table5.4 in Volume 2, Books 1-7, Chapter 4, entitled "Summary of residual impacts".

Assumptions and methodology applied in the EIS

4.3.14 The general methodology that has been applied in the EIS to the assessment of environmental impacts and their significance is described in Section 2 of this report and is not repeated in detail here.

4.3.15 The criteria for baseline categorisation (in terms of functional value) are listed in Table 13.3 (page 234) of Volume 1, Chapter 13 of the EIS and shown on the baseline maps in Volume 3. Three categories are defined in this table: Very Low (I), Medium (III) and Very High (V). Facilities with vibration sensitive equipment, areas where people are sleeping and concert halls and theatres are all included in the Very High (V) category.

4.3.16 The assessment criteria are set out in Table 5.2 for construction impacts and Table 5.3 for operational impacts. Each of the construction period tables (5.2) has separate sets of criteria for the following (where relevant to that section of the alignment):

- Groundborne noise (TBM);
- Vibration effect on people (TBM and construction plant);
- Vibration effect on people (blasting);
- Vibration – building damage; and
- Vibration effects on sensitive equipment.

4.3.17 These are grouped in terms of types of receptors to which the criteria relate.

4.3.18 For operational noise, the sets of criteria relate simply to groundborne noise and vibration (from trains) and there is a list of known sensitive equipment with absolute limits on vibration for each.

4.3.19 The sources of vibration and groundborne noise during the construction phase and the operational phase are described in detail in section 5.4.1 of each Chapter 5. Section 5.4.2

describes the mitigation measures that will be put in place for any adverse impacts that are deemed to be of medium or greater significance prior to mitigation. Residual impacts are considered in section 5.4.3.

4.3.20 If prescribed limits on vibration are exceeded (as revealed by monitoring), the principal mitigation measure during the construction phase will relate to controlling drilling and blasting so as to reduce vibration effects. It is noted in the chapters that it may be possible to use road headers as an alternative to blasting if rock conditions are suitable; road headers give rise to significantly less vibration than blasting. Mitigation measures to prevent exceedance by the TBM of groundborne noise impact criteria are likely to involve reducing its rate of advance or stopping it altogether for a period (*e.g.* at night). Obviously, these methods of control would have an impact extending construction times and spreading the disturbance over a longer time period. These effects would need to be weighed against the reduction of groundborne noise magnitude.

Summary of the results of the assessment

4.3.21 In respect of vibration and groundborne noise impacts during the construction phase, there are a number of locations where, using the assessment criteria defined and the functional values assessed, construction will give rise to residual impacts with magnitude described as 'high', or 'very high' on receptors of very high functional value (*i.e.* significant residual vibration and/or groundborne noise impacts after mitigation).

4.3.22 Absolute limits on vibration and groundborne noise are not specified in the text of the EIS; vibration impacts are ascribed impact magnitudes ranging from very low to very high in 5 classes.

4.3.23 For the operational period, the maximum permissible groundborne noise between Parnell Street and Albert College Park will be 25dB $L_{Amax,S}$. Elsewhere, the maximum permissible groundborne noise will be 40 dB$L_{Amax,S}$. The 25 dB $L_{Amax,S}$ limit cannot be achieved by varying the depth of the tunnels; only by utilising floating slab track (FST) to limit to a minimum the level of vibration emanating from the source. *"FST achieves greater isolation of vibration and groundborne noise, largely because the mass of the concrete slab enables a lower natural frequency to be achieved without excessive dynamic deflection. Some of the vibration is also stored and dissipated in the slab and components above the slab"*[15]. Setting the 25 dB $L_{Amax,S}$ limit between Parnell Street and Albert College Park therefore amounts to ensuring that this type of track is used in the final design.

Comment

4.3.24 There has been discussion between the groundborne noise expert on the Independent Engineering Expert Team (Dr Paul Cockcroft) and Rupert Taylor (who was responsible for the vibration and groundborne noise chapters in the EIS) to clarify certain technical matters that were not initially completely clear to him. Rupert Taylor also attended part of an open meeting of residents on Wednesday 22nd October 2008 and made a presentation about vibration and groundborne noise and also answered questions from the public.

4.3.25 The presentation in October was very helpful in bringing out the main findings of the assessment, particularly the significance of the proposed Floating Slab Track (FST) in the bored tunnel between Parnell Street and Albert College Park.

15 Final paragraph of 5.4.2.2 in EIS Volume2, Books 1-7, Chapter 4

4.3.26 With the exception of section 5.3.1.1 (*Magnitude*), which is highly technical and therefore less accessible to the general reader, the information in the vibration and groundborne noise chapters in the EIS is generally clearly presented.

4.3.27 The RPA has made the following observations in response to questions posed on vibration and groundborne noise (see Appendix 3 in Volume III)

Will vibration cause damage to houses?	Vibration limits have been chosen to avoid structural damage. Where any damage does occur, repairs will be made under the Property Owners' Protection scheme. This does not affect owners' statutory rights.
What limits have been set for vibration and groundborne noise?	Groundborne noise and vibration limits are set out in Volume 2 Chapter 5 of the EIS.

4.3.28 As noted above, no limits have actually been proposed in Chapter 5 for vibration and groundborne noise during the construction period, although impact magnitudes have been defined (very low, low, medium, high, and very high). The description of residual impacts (*i.e.* those that are expected to arise <u>after</u> mitigation) includes high and very high impact magnitudes giving rise to significant construction phase impacts. Given the RPA's assurance that "vibration limits have been chosen to avoid structural damage", it appears that the contractor will be expected to introduce more mitigation (through alternative methods of working or reduced charge weights) than is assumed in the assessments in order to reduce these impacts. It is implied in the EIS that the 'Low' impact thresholds may be those that are intended to provide upper vibration (and groundborne noise) limits, but this needs to be clarified as currently the limits are not stated in the EIS. The following extract from Volume 2, Book 6, Chapter 5, Section 5.4.3.1 is an example of how we have reached this view (underlining highlights the material passage:

"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_{fmax} = 19, in excess of the building damage threshold and in the Very High impact category for people in the building………<u>To limit the PPV to the Low impact category</u> for daytime the charge weight per delay would have to be restricted to 0.8 to 1.0kg depending on the final tunnel alignment."

4.3.29 During the operational phase, we confirm that 25dB $L_{Amax,S}$ (the proposed limit for operational phase groundborne noise between Parnell Street and Albert College Park) is a very low limit for groundborne noise in residential properties; so low that people in these properties are very unlikely to hear a train passing beneath. Elsewhere, the proposed limit on groundborne noise inside residential property is 40dB $L_{Amax\ S}$, which is a low level of groundborne noise. If there are locations that are deemed particularly sensitive to groundborne noise and where it is appropriate to impose a lower limit than 40dB $L_{Amax\ S}$, the use of FST rather than resilient rail support would reduce the groundborne noise impacts to ≤25dB $L_{Amax,S}$.

4.4 Influence of proposed works on surface water

Introduction to surface water - important concepts and terminology

4.4.1 Surface water is water in lakes, ponds, rivers, streams, and ditches (including streams and rivers that may run underground in culverts or tunnels). For this project, potential surface water related environmental impacts include:

- Potential for contamination of surface water courses or changes in water quality;
- Potential for increasing flood risk in water courses receiving discharge of runoff water from the works or water pumped from tunnels; and
- Potential for increasing flood risk in water courses by changing drainage patterns and landforms within river catchments.

4.4.2 Water falling as rain (or other precipitation) on an area of land will either:

- Evaporate directly;
- Be taken up by plants (and evaporate indirectly through transpiration);
- Infiltrate (soak in) and be added to groundwater; or
- Run off and flow towards a watercourse or water body.

4.4.3 The area within which surface runoff contributes to the flow in a stream or river and its tributaries is called its catchment. When it rains, the amount of water flowing in the watercourses within a catchment increases. There is a time lag between the onset of rainfall and peak flow in the watercourses, because it takes time for runoff to reach each tributary water course and then time for the flood peak to travel down that water course to join the main stream or river. Similarly, there is a time lag between the cessation of rainfall and the reduction of flows in the watercourses to 'normal' levels.

4.4.4 Construction works alter the topography and nature of the ground surface within surface water catchments and so affect the proportions of incident rainfall in each of the categories listed above. In particular, the replacement of farm or park land with buildings or impermeable surfaces (*e.g.* clay from which vegetation and soil have been stripped, bare rock, concrete or asphalt) decreases the amount of infiltration that takes place and therefore increases the amount of direct runoff and the speed with which it reaches a receiving water course during or after a rain storm event. The combination of more direct runoff and the reduction in the time for it to reach a water course can cause or exacerbate flooding in watercourses as a result of increases in flood flows. In order to prevent or mitigate this effect, it is important to control surface water discharge from construction and operational sites to avoid causing or exacerbating flooding of receiving watercourse. This can be done by incorporating adequate short term storage capacity within temporary drainage works during the construction phase of an engineering project and permanent drainage works during the operational phase to delay the introduction of additional flood water to the receiving watercourse such that flooding is not caused or made worse. Alternatively (or in addition), it may be possible to improve the receiving watercourse to allow it to accept the additional runoff during extreme events. Mitigation measures relating to flood risk are designed in the context of a detailed understanding of the capacity of a catchment system to accept additional runoff and modelling of the permanent or temporary changes that will occur as a result of the proposed construction works. This is commonly referred to as a flood risk assessment. In some circumstances, new construction works can provide an opportunity to reduce flood risk.

4.4.5 Infrastructure construction works such as Dublin Metro North may have an impact on surface drainage when it crosses streams and rivers and their flood plains; bridges or culverts need to be designed to avoid impeding flows, which could give rise to flooding upstream of the alignment and/or flooding of the alignment itself (and related structures).

4.4.6 The reduction of infiltration that can be caused by construction works can have an adverse impact on groundwater by reducing a source of recharge to the groundwater system – this is considered in the groundwater chapters of the EIS.

4.4.7 For any surface construction works, there is the possibility of contaminating surface water as a result of discharge of contaminated water from the site into watercourses (both direct discharge and seepage of contaminated water in the near surface layers of soil and sediment towards rivers and streams). Water quality can also be adversely effected by increasing total suspended solids in watercourses (silt and clay in suspension) and by introducing pumped groundwater into surface watercourses (if that water is of a different chemistry and/or contaminated).

4.4.8 Several watercourses are known to have been culverted or flow in tunnels or pipes beneath urban areas in North Dublin; where these will be intersected in cut and cover tunnels or station boxes, they will require temporary or permanent diversion to allow the works to proceed and maintain the flow in the watercourse. Intersection of such watercourses gives rise to the potential for contamination and also for changes to flow capacities. The detailed design will need to ensure that diverted tunnels or culverts have sufficient capacity to prevent backing up of water and flooding upstream. Where such watercourses are not actually intersected but cross the alignment of bored tunnels, they are potentially susceptible to settlement disrupting culvert or tunnel linings, giving rise to leakage. It will be important to identify all such 'underground' watercourses and monitor their condition before and after the works, providing for repairs to be carried out if settlement causes damage.

Reference to relevant sections of the EIS

4.4.9 **Description of the surface water baseline.** In Volume 1, Book 1, the surface water baseline is described in Chapter 19. Chapter 19 is supported by the 4 Baseline surface water and groundwater maps in Volume 3, Book 1. This shows the following seven named rivers and one canal, each of which is labelled with its assessed functional values:

- Broad Meadow River (MN101)
- Ward River (MN101)
- Sluice River (MN102/MN103)
- River Mayne (MN103)
- Santry River (MN104)
- River Tolka (MN106)
- Royal Canal (MN106)
- River Liffey (MN107)

4.4.10 In Volume 3, Book 2 Annex F is information supporting the surface water chapters. This includes results of chemical water sampling of surface water bodies; emission limit values for surface water discharges (and references to relevant regulations, directives *etc*); and relevant surface water legislation. The results of surface water sampling relate to the watercourses listed above.

4.4.11 **Evaluation of potential effects on surface water arising from the scheme.** In each of the seven books making up Volume 2, Chapter 11 relates to surface water. These chapters are in four main sections as follows:

11.1 Introduction

11.2 Study area

11.3 Impact assessment methodology

11.4 Impact assessment.

4.4.12 Section 11.4.4 in each of the surface water chapters in Volume 2 provides a summary of residual surface water impacts (*i.e.* impacts after mitigation).

Assumptions and methodology applied in the EIS

4.4.13 The general methodology that has been applied in the EIS to the assessment of environmental impacts and their significance is described in Section 2 of this report and is not repeated in detail here.

4.4.14 The study area is stated (Volume 1, Chapter 19, section 19.2.2) to comprise *"any watercourses and floodplains that are intersected by the alignment or lands five hundred metres to either side of the central line of the proposed alignment."* [16] Baseline characterisation is based on identification of features of the existing environment that are both relevant and can be assigned a functional value. The criteria for baseline categorisation are set out in Table 19.2:

[16] The study area in Chapter 18 (and in chapter 10 in each of the seven books comprising Volume 2) is said to be 500m either side of the alignment, whereas it is shown only 50m either side of the alignment on the maps in Volume 3, Book 1.

Table 19.2 Criteria for baseline categorisation

Criteria	Functional value
- Areas of watercourses with Q-values of Q5 and/or Q4-5 or Q4, which are classified by the EPA as 'Class A - Unpolluted' - Watercourses with flood plains that have significant storage capacity for potential floodwaters	Very high (V)
- Areas of watercourses with Q-values of Q3-4, which are classified by the EPA as 'Class B -Slightly Polluted' - Watercourses with flood plains that have significant storage capacity for potential floodwaters	High (IV)
- Areas of watercourses with Q-values of Q3 or Q2-3, which are classified by the EPA as 'Class C - Moderately Polluted' - Watercourses with flood plains that have significant storage capacity for potential floodwaters	Medium (III)
- Watercourses with Q-values of Q2 or Q1-2 or Q1, which are classified by the EPA as 'Class D - Seriously Polluted' - Watercourses with flood plains that have no storage capacity for potential floodwaters	Low (II)
- Not applicable	Very low (I)

4.4.15 The Q-values in Table 19.2 describe the biological status of the watercourse; the higher the pollution level in a watercourse, the lower the Q-value.

4.4.16 In each of the seven books comprising Volume 2, Chapter 11 identifies potential construction phase and operational phase impacts at section 11.4.1. Table 11.2 describes criteria for assessment of impact magnitude:

Table 11.2 Criteria for assessment of impact magnitude

Criteria	Impact magnitude
Long-term to permanent change to a designated conservation site or designated salmonid river Medium-term to permanent contamination of surface water over entire surface water catchment Medium-term to permanent changes in drainage patterns over entire catchment	very high
Medium term change to a designated conservation site or a designated salmonid river Temporary to short-term contamination of surface water over entire surface water catchment Temporary to short-term changes in drainage patterns over entire catchment	high
Temporary to short-term change to a designated conservation site or a designated salmonid river Medium to long-term contamination of local surface water Medium to long-term changes in local drainage patterns	medium
Short-term contamination of local surface water Short term changes in local drainage patterns	low
Temporary contamination of local surface water Temporary changes in local drainage patterns	very low

The duration of impacts (as detailed in Table 11.2) are defined as shown in Table 11.3 as per EPA Guidance (EPA, 2002).

4.4.17 These are grouped together according to their duration in 5 classes where permanent impacts (defined as being impacts lasting over sixty years) are ascribed 'Very High' impact magnitude. Long-term impacts (15-60 years) have 'High' impact magnitude; Medium-term impacts (7-15 years) have 'Medium' impact magnitude; Short-term impacts (1-7 years) have 'Low' impact magnitude; and Temporary impacts (≤1 year) have 'Very Low' impact magnitude (see Table 11.3).

4.4.18 Consideration of impact magnitude together with functional value has been used to define significance of the impacts on Surface water of construction and operation of Dublin Metro North (section 11.4.1), mitigation measures are described at section 11.4.2 and residual impacts are described at section 11.4.3. The assessments in sections 11.4.1, 11.4.2 and 11.4.3 are entirely descriptive without any summary tables.

Summary of the results of the surface water assessment

4.4.19 Functional values for the watercourses studied in the assessment are set out, with a summary description, for each watercourse in Table 19.5 in Volume 1, Book 1, Chapter

19. The Santry River is assessed as having Low functional value (II). The other five rivers are all assessed as having Medium functional value (III). The Royal Canal is considered to have High functional value (IV).

4.4.20 For all of the watercourses considered, providing the mitigation measures stipulated are implemented, the significance of residual impacts on these watercourses is assessed to be Low.

Comment

4.4.21 The chapters describing the surface water baseline and potential impacts on surface water are generally clear and well laid out. It is apparent that a significant amount of information has been assimilated and taken into account in the baseline study and the descriptions in Chapter 19 of Volume 1, Book 1 are very detailed for the watercourses that have been reviewed. Mitigation measures proposed are comprehensive and appear deliverable.

4.4.22 The maps in Volume 3, Book 1 appear incomplete in terms of surface water. Although the study area is defined in Volume 1, Chapter 19 as including both watercourses and floodplains that are intersected by the alignment (or lie within lands 500m on either side of the alignment), no floodplains are shown on these maps. In addition, there are watercourses that fall within the study area as defined in the text that are not shown on the maps; in particular, the extensive drainage ditch network draining the area north of the Broad Meadow River (including the depot site at Belinstown) and a number of culverted rivers and streams which cross the alignment in Areas MN105-MN107.

4.4.23 There appears to be an error on the maps in that the edge of the study area is drawn 50m from the alignment, whereas the study area indicated in the text is defined as being 500m either side of the alignment.

4.4.24 Functional values are described as having been assessed by consideration of water quality as well as flood status. The water quality criteria are quantitative (based on Q-values), but it is not clear as to how flood risk has been taken into account either in defining functional values or in terms of assessing impact magnitudes. It would have been better in our view to have assigned functional values and assessed impact magnitudes separately for surface water quality and for the risk and consequences of flooding. The functional values that have been assigned to the various watercourses assessed appear to us to be reasonable in relation to water quality but do not highlight areas where flooding may occur and its impacts.

4.4.25 For most of the proposed alignment, impact on flood risk within the surface water catchments is likely to be negligible. This is because the 'footprint' of the works within the various catchments is relatively small, and because the amount of water to be discharged from the construction sites (and the finished metro facilities) into surface water courses is expected to be very small (and therefore will have a very small impact on flood flows in streams and rivers into which that water may be discharged).

4.4.26 However, the very large depot site at Belinstown is within an area where residents report that flooding that affects local roads and houses occurs fairly frequently (likely to be as a result of 'backing up' of flood waters in the drainage system). The potential for flood risk associated with the Belinstown Depot site has been recognised in the EIS and the following is stated in Volume 2, Book 1, Chapter 11, Section 11.4.2.2: "*The performance of the drainage system will also be assessed for extreme rainfall events (in excess of the design rainfall) to identify areas at risk of flooding. Adequate measures will be put in* *place to safely manage the flood water and reduce the risk of damage to lives and properties".* To achieve this, a more comprehensive baseline survey will be needed in this area and a flood risk assessment will need to be carried out. This is an area where it may be possible to improve upon the current situation.

4.4.27 We consider that it would be appropriate for a condition to be imposed on the Railway Order requiring flood risk assessments to be carried out for the catchments to be affected by building on agricultural land (as at Belinstown) or discharge of storm water or groundwater to existing water courses, before construction proceeds. Such flood risk assessments may indicate the need for modifications to the significant land raising suggested in the flood plain of the Broad Meadow River, off site improvement works to drainage structures and receiving watercourses to mitigate flood risk, and possibly the deployment of tunnel spoil to provide flood defences in areas that are already vulnerable to flooding.

4.5 Influence of proposed works on ground water

Introduction to ground water - important concepts and terminology

4.5.1 Groundwater is water that exists in the ground in pores and fissures in rocks and in the spaces between particles in sediments. Soils and rocks within which water can flow and be stored are known as aquifers. Examples of aquifers are sand and gravel (where water exists and flows within and between spaces between the particles) and jointed rocks (where water exists and flows within joints and fissures within the rock). Rocks such as mudstone or shale and sediments such as clay and silt may contain water 'locked up' within them but they have very limited pore space within which water can be stored and flow. These rocks impede the flow of water and are sometimes referred to as 'aquicludes'. It is clear that the great majority of the works to be conducted below ground level will also be below groundwater levels or within aquifers.

4.5.2 For this project, groundwater related environmental impacts of concern include:

- The potential for changes in groundwater levels affecting the yield of water abstraction wells within the zone of influence of dewatering;
- The potential for contamination of groundwater;
- The potential for changes at the surface to alter the amount of incident rainfall infiltrating through the ground and adding to groundwater (recharge);
- The potential for dewatering of excavations or ingress of water into tunnels to alter groundwater pressures in the ground leading to settlement; and
- The potential for changes to groundwater flow patterns caused by the works.

4.5.3 Groundwater is one of the most difficult parameters to define because it changes with time and circumstances. Groundwater levels in aquifers vary naturally, depending on the season of the year (which affects the amount of rainfall and runoff that infiltrates and is added to the groundwater – a process known as recharge) and the amount of water that is being pumped from wells in the aquifer. If construction works reduce the amount of rainfall and runoff that is available to recharge an aquifer (*e.g.* by introducing impermeable surfaces where there was previously open ground), if water is pumped out of excavations, or if the works form barriers or obstacles to groundwater flows, the works can have a temporary or permanent effect on groundwater levels. Changes in groundwater levels (or groundwater flow patterns) may have an adverse impact on the yield of water supply wells, or on groundwater dependent ecosystems (wetlands fed by springs or in low lying areas that intersect the water table in an aquifer) or may cause settlement as described in Section 4.6 below.

4.5.4 Groundwater contamination can occur where construction works intersect aquifers (*i.e.* contaminants can come into contact with groundwater directly) or where contaminants are transported to aquifers by water infiltrating through the ground overlying the aquifer (*e.g.* a surface spill soaks into the ground and is carried towards the aquifer by infiltrating rainfall).

4.5.5 Data on groundwater (depth from the ground surface to water and the quality of that water) has to be collected from discrete points of measurement, mainly boreholes, and it is assumed that such data can be extrapolated between boreholes and treated as a continuum. This is akin to sampling the air in the kitchen, the living room and the bedroom of a house and grading the values measured in one room to those in the next; that might be correct if the doors are open but if the kitchen door is shut the quality there may differ considerably from elsewhere in the house. So it is with groundwater; if geology partitions the ground, groundwater becomes much more difficult to interpret from data gathered separate sampling points. It is therefore important, in understanding groundwater and how it may be affected by construction works, to understand the geology of the subject area in some detail.

4.5.6 In construction works that are to take place below the water table, there is a range of well tried and tested measures to protect ground water by reducing to a minimum (or avoiding entirely) changes to groundwater levels caused by the works and by taking all practical steps to prevent the escape of contaminants from the works.

4.5.7 Tunnelling and station construction works are of two kinds; those that exclude ground water and those that do not. An example of the former is a tunnel boring machine that prevents ground water from freely entering its cavity. At the moment the contractor's method of working is not known and so it is prudent to consider the situation in which water will be able to enter the excavations, both at the face of the tunnel and at the stations. The ease with which water can travel through this ground is not great and high flows are not expected in anything other than local areas. Some ground treatment can be expected, taking the form of injecting suspensions of clay and cement into water bearing voids and fissures (probably *via* surface boreholes), but these are unlikely to stop water flows entirely and more likely to be used to reduce inflows to levels that produce acceptable conditions for working underground.

4.5.8 It is unlikely that such inflows will either affect water supplies or have much impact on the quantity of water in the ground, as the ground water in the limestone below Dublin mainly flows in laterally from the surrounding countryside, some distance outside the area of construction. However, some of the works will divert the local direction of flow from its present path, which is unknown in detail but probably towards the sea in general and locally towards the local watercourses. The current flow pattern will tend to re-establish itself after construction, possibly within a year. The changes in direction of ground water flow, the amount of ground water flow and the quality of ground water are unlikely to be matters for serious concern, but water levels and water quality should be monitored during the contract to ensure that is so; this is referred to again in the Section 4.6 in relation to settlement.

4.5.9 Of greater concern is drainage to the tunnels and station excavations as this has the potential to promote settlement by allowing any compressible sediment that lies above the bedrock to consolidate. This is considered further in Section 4.6 below.

4.5.10 To know how ground water responds to engineering works it is necessary to observe it using instruments placed in the ground. These should be read at regular intervals and the values they provide used to build a model of what is happening in the ground. This model can then be used to help construction progress with greatest efficiency whilst at the same time providing the means for detecting the initiation of situations that should not be permitted to develop in an uncontrolled way. The following should be monitored:

a) ground water levels, in a way that permits settlement to be quantified and groundwater flow during excavation to be interpreted and represented as a model, and
b) ground water quality, in a way that permits emissions of contaminants into the groundwater to be detected and appropriate action taken to remedy the occurrence.
c) Given the linear nature of the scheme this implies that observation stations should be established at regular distances along the route, to be defined by the engineers as being suitable for satisfying (a) and (b) above.

Reference to relevant sections of the EIS

4.5.11 **Description of the groundwater baseline.** In volume 1, Book 1, the groundwater baseline is described in Chapter 18. Chapter 18 is supported by 4 Baseline Surface water and Groundwater Maps in Volume 3, Book 1 and by Annex E of Volume 3, Book 2. The maps in Volume 3, Book 1 show the Functional Values for groundwater in each area (MN101 to MN107); they are shown by means of coloured outlining of lengths of the study area, the boundary of which is depicted on the maps at a distance of approximately 50m on either side of the alignment. Annex E of Volume 3, Book 2 comprises two tables. Table 1.1 gives estimated groundwater levels along the alignment, and Tables 1.2 to 1.5 provide details of wells held by the GSI within a 5km radius of Dublin Airport, Dublin City University, St Stephen's Green and Lissenhall Bridge. The wells for which data is provided in Tables 1.2 to 1.5 are not shown on the baseline maps, and the groundwater levels summarised in Table 1.1 are not indicated on the maps.

4.5.12 **Evaluation of potential effects on groundwater arising from the scheme.** In each of the seven books making up Volume 2, Chapter 10 relates to groundwater impacts. These chapters are in 4 main sections as follows:

- Introduction
- Study area
- Impact assessment methodology
- Impact assessment

4.5.13 Residual impacts are discussed at section 10.4.3; there are no tables summarising these.

Assumptions and methodology applied in the EIS

4.5.14 The general methodology that has been applied in the EIS to the assessment of environmental impacts and their significance is described in Section 2 of this report and is not repeated in detail here.

4.5.15 The raw data for the ground water baseline comes from a range of published data sources as well as from the ground investigations that have been undertaken for Dublin Metro North. Reference is also made to groundwater flow modelling relating to the Dublin Port

Tunnel. The data referred to in the assessment is listed at Volume 1, Chapter 18, Table 18.1. Baseline information is listed in the following categories:

- Aquifer characteristics: Groundwater depth; regional direction of groundwater flow; aquifer hydraulic conductivity; water-bearing stratum; and nature and thickness of overlying strata.
- Aquifer importance: Aquifer classification; and aquifer productivity.
- Groundwater quality: Potential for groundwater contamination from historic activities; and potential for groundwater contamination from current activities.
- Aquifer sensitivity: Aquifer vulnerability; source protection zones; depth of groundwater; nature of subsoils overlying the aquifer; and groundwater quality.

4.5.16 Using this information, functional values have been determined with reference to aquifer importance, aquifer sensitivity and existing adverse effects. The criteria for baseline categorisation (in terms of functional value) are listed in Table 18.3 (page 322) of Volume 1 of the EIS. The results of the desktop review of all the hydrogeological data currently available and applicable to the study area are set out in section 18.3.1, which considers geology, aquifer type, groundwater depth, groundwater flow, groundwater vulnerability, and potential contamination for the entire alignment in the following sections (which do not coincide with areas MN101-MN107):

- Belinstown Stop to Lissenhall Stop (18.3.1.1);
- Lissenhall Stop to Dublin Airport Stop (18.3.1.2);
- Dublin Airport Stop to DCU Stop (18.3.1.3);
- DCU Stop to St Stephen's Green Stop (18.3.1.4).

4.5.17 The functional values ascribed to each area (MN101 – MN107) along the route as a result of this exercise are summarised in Table 18.4 and are shown on the baseline maps in Volume 3, Book 1[17].

4.5.18 In each of the seven books comprising Volume 2, Chapter 10 identifies potential construction phase and operational phase impacts at section 10.4.1. Table 10.2 describes criteria for assessment of impact magnitude defined according to the following impact categories:

- Alteration of the direction of groundwater flow;
- Depletion of groundwater sources due to dewatering activities;
- Deterioration of groundwater quality (if left untreated); and
- Impact relating to the recharge of the underlying groundwater sources.

4.5.19 These are grouped together according to their duration in 5 classes where permanent impacts (defined as being impacts lasting over sixty years) are ascribed 'Very High' impact magnitude. Long-term impacts (15-60 years) have 'High' impact magnitude; Medium-term impacts (7-15 years) have 'Medium' impact magnitude; Short-term impacts (1-7

17 The study area in Chapter 18 (and in chapter 10 in each of the seven books comprising Volume 2) is said to be 500m either side of the alignment, whereas it is shown only 50m either side of the alignment on the maps in Volume 3, Book 1.

years) have 'Low' impact magnitude; and Temporary impacts (≤1 year) have 'Very Low' impact magnitude (see Table 10.3).

4.5.20 Consideration of impact magnitude together with functional value has been used to define significance of the impacts of construction and operation of Dublin Metro North (section 10.4.1), mitigation measures are described at section 10.4.2 and residual impacts are described at section 10.4.3. The assessments in sections 10.4.1, 10.4.2 and 10.4.3 are entirely descriptive without any summary tables.

Summary of the results of the groundwater assessment

4.5.21 Functional Values for groundwater, defined in the baseline study, are assessed to be either Low (II) or Medium (III) as summarised in Table 18.4 (Volume 1, Book 1, Chapter 18, pages 331-332). This is reproduced at the end of Section 4.5.

4.5.22 The result of the assessment of residual impacts is recorded, in each of the seven books comprising Volume 2, at Section 10.4.3. Impact magnitudes are assessed to be low (or in one case medium) and the impacts identified will affect areas of medium (III) or low (II) functional value. Therefore the assessment concludes that residual impacts will be of 'Low Significance' providing the mitigation measures described in this section are implemented.

Comment

4.5.23 The chapters describing the groundwater baseline and potential impacts on groundwater are generally clear and well laid out. It is apparent that a significant amount of information has been assimilated and taken into account in the baseline study and the descriptions in Chapter 18 of Volume 1, Book 1 are very detailed. The maps in Volume 3, Book 1 and the tables in Volume 3, Book 2 do not add much to the text. There appears to be an error on the maps in that the edge of the study area is drawn 50m from the alignment, whereas the study area indicated in the text is defined as being 500m either side of the alignment.

4.5.24 The operational scenarios considered are necessarily somewhat generalised at this stage given the status of the design and associated ground investigations (Reference Design - see Section 3.1 above) but they encompass all likely impacts on groundwater. The mitigation measures that are proposed are comprehensive and are appropriate to the construction and operational scenarios considered and the potential impacts identified.

Table 18.4 Baseline categorisation

Area	Name	Summary Description	Functional Value
MN101	Lissenhall to Nevinstown	- No Groundwater Source Protection Zones are present; - Locally Important Aquifer present with moderate groundwater yields; - Aquifer of extreme vulnerability (groundwater encountered within 3m from the ground level and overlain by low permeability glacial tills); - Groundwater quality impacted to some extent by long term urban activity and agricultural practices.	(III)
MN102	Nevinstown to Fosterstown South	- No Groundwater Source Protection Zones are present; - Locally Important Aquifer present with moderate groundwater yields; - Aquifer of extreme vulnerability (groundwater encountered within 3m from the ground level and overlain by low permeability glacial tills); - Groundwater quality impacted to some extent by long term urban activity and agricultural practices.	(III)
MN103	Fosterstown South to Dardistown	- No Groundwater Source Protection Zones present; - Poor Aquifer with poor groundwater yields; - Aquifer of moderate to high vulnerability; - Groundwater quality is likely to be impacted to some extent by development in the area; - This section of the route is largely located underground in tunnel.	(II)
MN104	Dardistown to Northwood	- No Groundwater Source Protection Zones are present; - Locally Important Aquifer present with moderate groundwater yields; - Aquifer of extreme vulnerability (groundwater encountered within 3m from the ground level and overlain by low permeability glacial tills); - Groundwater quality impacted to some extent by long term urban activity.	(III)

Area	Name	Summary Description	Functional Value
MN105	Northwood to DCU	- No Groundwater Source Protection Zones are present; - Locally Important Aquifer present with moderate groundwater yields; - Aquifer of extreme vulnerability (groundwater encountered within 3m from the ground level and overlain by low permeability glacial tills); - Groundwater quality impacted to some extent by long term urban activity.	(III)
MN106	DCU to Mater	- No Groundwater Source Protection Zones are present; - Locally Important Aquifer present with moderate groundwater yields; - Aquifer of high vulnerability (groundwater encountered within 5m from the ground level and overlain by low permeability glacial tills); - Groundwater quality impacted to some extent by long term urban activity; - Tunnelled section of route.	(II)
MN107	Mater to St. Stephen's Green	- No Groundwater Source Protection Zones are present; - Locally Important Aquifer present with moderate groundwater yields; - Aquifer of high vulnerability (groundwater encountered within 5m from the ground level and overlain by low permeability glacial tills); - Groundwater quality impacted to some extent by long term urban activity; - Tunnelled section of route.	(II)

4.6 Settlement of ground around tunnels and excavations

Introduction to settlement - important concepts and terminology

4.6.1 Settlement is not the same as "collapse", where a void opens suddenly at ground level. It is generalised lowering of the ground surface as a result of changes in the volume of the sub-strata. Its significance for structures and services at and near the ground surface where different parts of such structures are subject to a different amounts of settlement (known as "differential settlement") is illustrated in the following sketch.

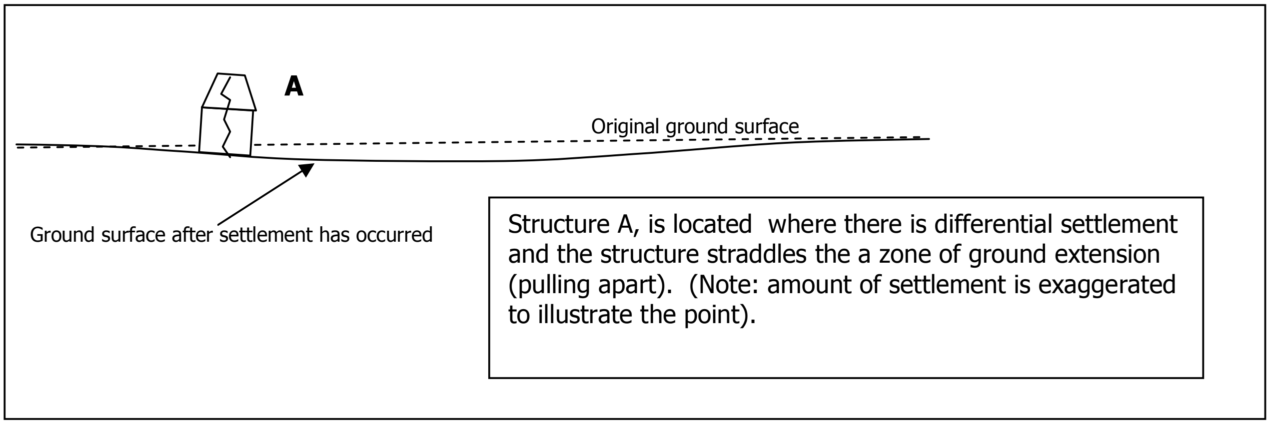

Figure 5 Sketch illustrating settlement effects on structures

4.6.2 Settlement of the ground surface and near surface can be caused in several ways:

- By collapse of a void at depth, where the void is sufficiently deep that it cannot migrate up to the surface but does permit the ground above it to sag a little, and ground level to settle;
- Through closure of a void at depth leading to generalised lowering of the ground immediately above and around the location of the void; or
- Through withdrawal of water from sediments or weak rocks causing them to compress (*i.e.* consolidate) and reduce in volume.
- Through lateral movements of the ground into an open excavation, leading to volume changes in the ground adjacent to the excavation and ground level lowering (settlement).

4.6.3 It is possible to envisage circumstances that could give rise to any one of these mechanisms for settlement in association with the proposed tunnelling. However, the techniques to be used for tunnelling in this project will be designed to avoid the first two; there is no reason for the works to result in collapse if engineering is applied that is appropriate to the known ground conditions. The second two mechanisms are more likely to occur in certain circumstances, and can give rise to small movements at the surface, where "small" means a few millimetres.

4.6.4 The bedrock is limestone and this is a rock that can dissolve more readily than many others in water. That can result in karst (the name given to a range of solution features in limestone and other soluble rocks) and features typical of karst are expected to be encountered in the limestone along the line of the tunnel. The limestone is overlain by significant thicknesses of sediments (sand, silt and clay). The recent geological history of the area makes it unlikely that large open voids of the sort that could give rise to collapse are present, and no cavities of this sort were seen in the strata through which the Dublin Port Tunnel passes. Ground investigations can be used to assess the likelihood of solution cavities being present and steps can be taken to prevent them developing. However, the solution of the top of the intact limestone where it is in contact with overlying sediments is likely to be highly irregular, giving rise to pockets of clay and sand materials extending down into the top of the overall limestone surface. There is also likely to be a zone within which there is a mixture of sediments and broken limestone immediately above the top of the intact rock ("rockhead"). The anticipated irregularity of the junction between the limestone bedrock and its overlying sediments can create difficulties for construction when the tunnel is positioned so that its floor is in rock and its roof is in sediment and may give rise to inflow of water from sediments to the tunnel, leading to consolidation settlement as described above. The tunnels have been designed so that passenger access is as effortless as possible, so limiting the depth of stations, and this has caused the tunnel to be placed in places where both rock and sediment may have to be excavated at the same time (what tunnellers describe as a "mixed face"). In these circumstances it may be necessary to treat the ground to ensure that it can be excavated with the minimum of settlement, and in sensitive areas, with no settlement. This may require work from ground level as drills are needed to penetrate the ground and inject strengthening fluids to solidify the ground ahead of the tunnelling machine. Water inflow to the tunnel can also be prevented or reduced through utilising air pressure or slurry at the face as described in Section 3.2 above.

4.6.5 As there is no settlement at present, the baseline values relevant to its monitoring and assessment are (a) present day ground level and (b) the elevation and condition of structures founded on or below it. None of these data could be gathered before the route of the works had been decided, however as the route is now known, base line conditions along its length can be established through ground levelling and a precondition survey of structures. More detailed geological and geotechnical information will also be important to allow identification of sediments that are vulnerable to settlement and the related groundwater conditions in these areas. As described in paragraphs 3.1.5 to 3.1.10 above, this will be collected in any event in the course of refining the design and the associated ground model and during the works themselves.

4.6.6 As described above, settlement associated with underground works comes from two sources: (1) ground that should be on the outside the limit of excavation moving into the excavation and being removed – there are a number of reasons why this happens, as explained below, and (2) consolidation of compressible strata above and around the excavation as a result of the excavation lowering water pressures in the surrounding ground. Assumptions have to be made, based on a very considerable body of evidence from tunnels excavated in similar ground, in order to complete calculations of predicted settlement and they can be constrained using evidence from the boreholes drilled along the line of the route. Despite this, settlement predictions are associated with a level of uncertainty because the magnitude of settlement depends on the interaction of the tunnelling machine (or open excavation) with the ground at each location and the time between the ground being excavated at that location and permanent support being erected and sealed. In other words, settlement does not depend just on the ground but on the interaction of the works with the ground. Thus it is conventional on contracts of this size for the accuracy of these calculations to be checked by careful and continuous monitoring settlement along the length of the works, and for the results of this monitoring to be used for refining predictions as the work progresses. Damage to buildings and other structures caused by settlement depends not only on the magnitude of the settlement that occurs but also on the type and condition of structures affected by it. There is a considerable body of case study knowledge and experience relating to the response of different types, ages and conditions of structures to ground movements but, as with the amount of ground movement that will occur, this is not wholly predictable. Therefore it is necessary to survey structures and assess their vulnerability to settlement (and their condition) before work commences and then monitor building response during the works.

4.6.7 Settlement takes time to happen; maximum settlements could occur over many months if left uncontrolled. These will be greater in the immediate vicinity of the excavation, *e.g.* above the tunnel and adjacent to the stations, and decrease with distance away from the structures; ground engineers talk in terms of a "settlement trough" (see Figure 5). In other words, settlement will not be the same everywhere; some places could have more than others. This is called "differential settlement" and that is the settlement that can cause damage when the differential becomes too great for a structure that straddles it to sustain without cracking. The settlement likely to happen first is that from "over excavation" and construction techniques can be used to avoid this; *e.g.* it is proposed that retaining walls will be installed for the cut and cover sections of the works, before any earth is removed ("diaphragm" and "secant" walls as described in Section 3.2 above), so that over excavation is prevented. Likewise the tunnel will be excavated using a machine that supports the hole it makes and has a design at its front that enables the tunnel face to be supported and controls how much ground comes into the machine. Measurement of the movement that occurs around a tunnel is an important indicator to the appropriateness of the calculations made to predict ground movement and so ground engineers like to see their structures and surrounding ground instrumented to observe ground-structure interaction.

4.6.8 Pre-contract surveys and in-contract monitoring are essential in a project such as this, as follows.

a) Structures along the route should be inspected and their condition recorded before any work commences.
b) Precise levels should be established along the route that can become the basis for measuring settlement during the works.
c) The instrumentation advised in Section 4.5 for studying ground water should be accompanied by instrumentation for measuring ground movements around tunnels and adjacent to retaining walls.
d) Records from the observation points along the line should be available for display to the public, in an acceptable format, within 24hours of collection.
e) A technical response to questions of vertical and horizontal ground movements should be available to residents on a daily basis whilst underground excavation is in progress.

Reference to relevant sections of the EIS

4.6.9 **Description of the settlement baseline.** There is no baseline information relevant to settlement in Volume 1 of the EIS or supporting information in Volume 3 because, as explained in paragraph 4.6.5, there is no settlement at present. However, the preliminary identification of structures susceptible to settlement (and of significant public interest) described as Stage 1 in the assessment of settlement impacts in Chapter 9 of the relevant books of Volume 2 is, in effect, part of a baseline assessment.

4.6.10 **Evaluation of potential settlement impacts arising from the scheme.** Potential settlement impacts are assessed for areas where tunnelling and cut and cover excavations are proposed in Volume 2, Books 2, 3, 4, 5, 6, and 7, Chapter 9. Residual impacts relating to settlement are described at the end of section 9.4.3.1 (construction phase) and 9.4.3.2 (operational phase).

Assumptions and methodology applied in the EIS

4.6.11 In section 9.3 of the relevant books in Volume 2 of the EIS, the impact assessment methodology is described in relation to settlement. The assessment of the impact of ground movements and the response of buildings and infrastructure to excavation induced ground movements has not followed the same structure as the other impacts considered in this report (*i.e.* definition of functional values for the baseline environment, identification of potential impacts and their magnitude, and assessment of the significance of the impacts). Instead, a four stage assessment process has been adopted:

Stage 1: Preliminary 'Greenfield' settlement analysis. Settlement predictions are made using computer modelling techniques and the results validated against case studies. The assumptions underlying the settlement predictions include likely construction methods, ground conditions as they are currently understood and reference to other projects (where methods and ground conditions are comparable). The 'green field' represents the simplest of situations, where the ground does not have to interact with foundations within it and upon it. The magnitudes of settlement so calculated indicate the sorts of structures that would be adversely influenced by such movements. Thus, at this stage, buildings and structures can be identified that are deemed to be particularly susceptible or are of significant public interest and therefore warrant close inspection.

Stage 2A. Initial response assessment. The purpose of this stage is to assess the response of the buildings and infrastructure identified during stage 1 to the ground movements predicted during stage 1. At this stage there is also consideration of possible mitigation measures.

Stage 2B. Review of 2A initial response assessment. Here, the findings of Stage 2A are reviewed and interpreted in the light 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.

4.6.12 A building damage classification system is presented at Table 9.3, ranging from 'Negligible' to 'Very Severe' in 6 categories (numbered 0-5). Buildings have been identified for protective measures when predicted damage falls into the 'Moderate' category or above. The rationale for not providing protective measures for the 'Slight' damage category or below is that such damage (which amounts to small cracks of the type commonly encountered in properties built on ground that shrinks and swells) presents a very low risk of structural damage and may generally be easily and cost effectively repaired. For this type of damage, the measures required to prevent it can, themselves, be disruptive to the function and occupiers of buildings. For buildings where the degree of ground movement damage is likely to be "Moderate" or worse, protective/mitigation measures will be considered with the aim of restricting damage to the "Slight" category or less.

4.6.13 A range of settlement related mitigation and protection measures which have been implemented (or will be implemented in the course of the ongoing design process) are listed in Section 9.4.2 as follows:

a) Ground investigation (to enable adequate design of ground support measures needed and accurate prediction of ground movements);

b) Sub-structure surveys and assessment of building records (to identify building type and condition and determine likely impacts);

c) Alignment design (design of tunnel separation and vertical alignment to reduce settlement potential where possible);

d) Internal measures (selection of tunnelling equipment and methods of excavation and support);

e) Instrumentation and monitoring to allow verification of predicted settlement, assessment of actual building damage and communication of results back into detailed design to allow modification of methods and/or protection and mitigation measures);

f) Action and contingency plans (pre-determined plans of action in response to monitoring results to avoid damage occurring);

g) Particular mitigation measures (specific measures to be taken for locations and structures identified as at particular risk); and

h) Property Protection Scheme (covering properties within 30m of the tunnel centrelines or the face of a cut and cover structure and allowing damage occurring as a result of the underground works below a ceiling of €30,000 to be rectified promptly with as little disruption to the property owner as possible).

Summary of the results of the settlement assessment

4.6.14 In each of the relevant books of Volume 2, Chapter 9, a statement of predicted residual settlement impacts is included at the end of section 9.4.3.1 in terms of the maximum predicted settlement (in millimetres) in that area, and the construction works that will potentially give rise to that settlement. The expected points at which the maximum predicted settlement is anticipated to occur are not specified and there are no plans showing predicted settlement contours.

4.6.15 The 4 stage assessment process that is underway, which will eventually incorporating monitoring, should allow the identification of buildings where damage is expected to fall into the 'Moderate' category or worse and specific protective/mitigation measures can then be designed and implemented. Where possible, it appears that the design objectives will be to restrict building damage to the 'Slight' category or below. This level of damage would be rectified under the Property Protection Scheme.

4.6.16 Where there will be rock above the top of the tunnel, the predicted settlement is significantly smaller than for lengths of tunnel where the top of the tunnel will be in sediments overlying the rock (for estimated thicknesses of rock above the top of the tunnel, see Volume III, Appendix 2.

Comment

4.6.17 The 4 stage assessment process described in the EIS in relation to ground movements and their effects on buildings and infrastructure is logical and represents established good practice. Stages 2B and 3 are based on the detailed design and actual construction methods to be used and therefore this assessment process is ongoing and further assessment will logically continue into the detailed design and construction phases.

4.6.18 The EIS reports maximum settlements to be expected at various locations along the alignment with no explanation of how those values have been derived, and what they mean or the expected distribution of ground movements (relevant to an assessment of differential settlement as described above). Similarly, the EIS does not discuss the anticipated time over which ground movements will develop where they occur.

Nevertheless, detailed reports of these calculations and assessments exist and have been seen (but not reviewed) by the experts.

4.6.19 In making the assessments in the EIS it has been assumed that the method of tunnelling chosen will prevent excessive and uncontrolled settlement and that ground treatment can remedy settlement that is detected as developing. Complex structures such as the Houses of Parliament in London and the tower of Big Ben were protected in this way from ground movement associated with the recent, and very large, excavations for the London Underground. It will have been assumed that settlement which might occur will be controlled by that branch of ground engineering called "ground-structure interaction"; a specialist area of study. We confirm that these assumptions are entirely reasonable and conform to international best practice with projects of this nature.

4.6.20 Of greater potential concern therefore are ground responses to the movement of water and change in its pressure, especially where all or part of the bored tunnel is in sediments. These can be felt some distance in front of the tunnel face and to the side of tunnels and station excavations. Retaining walls limit the influence of ground water change but that associated with tunnelling can require more sophisticated techniques involving intervention from ground level (drilling rigs injecting water stopping fluids into the ground) and from the tunnel itself (by drilling from underground around and ahead of the tunnel). The EIS indicates that a tunnelling machine will be chosen that prevents water from freely draining into the tunnel (see for example Volume 2, Book 7, paragraph 9.4.2 (d)).

4.6.21 Settlement is very difficult to predict with precision as ground conditions can never be perfectly known. The warning of ground movements and water level changes can only come from instrumentation placed in the ground before work commences. This instrumentation has to be monitored regularly and the results analysed by the engineers for the ground response to be known. The values from this instrumentation can be used to regulate progress and performance of the works, especially by taking steps to control groundwater. Providing groundwater control with instrumentation and monitoring is undertaken, whilst differing amounts of settlement will occur at different locations, it is likely that most of it not be noticeable without recourse to instrumentation.

Dublin Metro North Independent Expert Panel
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