Guidance Notes

The Assessment of Surface and Sub-surface Developments in the Vicinity of the Dublin Port Tunnel

Document No. XT0155/R/126/41862/R04

Issue	Date	Description	Produced by	Reviewed by	Authorised by
01	28th February 2009	Draft Issue	S Morgan	D Lawrence	N/A
02	11th March 2009	Amended Issue	S Morgan	P Jewell / R Allen	N/A
03	12th March 2009	Amended Issue	S Morgan	P Jewell	D Lawrence
04	16th March 2009	Final Issue	S Morgan	D Lawrence	D Lawrence

GUIDANCE NOTES
MARCH 2009

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1 Introduction

Kellogg Brown and Root (KBR) and its sub-consultant on the Dublin Port Tunnel Project (DPT), London Bridge Associates Ltd (LBA), have been requested by the National Roads Authority (NRA) to provide guidance notes for the assessment of the impact on the DPT of the construction of future developments above and in the vicinity of the operating tunnel. Such assessments will form the basis of requirements at the planning and construction stages of the developments.

This document, in conjunction with supporting information contained in Appendix 2, forms the requested guidance.

2 Overview

Within the world's major cities, as populations increase and spread-out and tunnels become more common solutions for transport and utility infrastructure, the impact of the construction of buildings and infrastructure above and in the vicinity of tunnels has increasingly become an issue.

Where a tunnel already exists and a new development is proposed, there is a requirement to determine the influence of the proposed development on the tunnel. The interacting effect between the development and the tunnel can take the following forms:

1. The development may impose additional loading on the tunnel during construction and at completion.
2. Subsoil overburden may be removed (e.g. by basement construction) inducing stress in the tunnel lining from the removal or redistribution of surcharge loads.
3. There may be a combination of 1 & 2 at completion with differing extents of each effect during construction.
4. Short or long term changes to the hydro-geological regime around the tunnel.

The extent to which the above effects impose an influence on the tunnel not only depends on the size and mass of the building or development to be constructed but also the sequence and method of construction, the depth of the tunnel and the prevailing geological conditions both above and at the tunnel horizon. Any engineering or environmental assessment has to take these into consideration and should be undertaken at the planning stage of the development by the building designer. It is preferable for this designer to have, or have access to, experience in the design of tunnels and foundations. Access to specific experience in hydro-geology and ground-structure interaction is also recommended.

This document has been written specifically for the DPT and is limited for use for that particular infrastructure. It is not intended to give in-depth design information in the form of design methods and calculation parameters but seeks to supply the reader with the information required to ascertain whether a design submission, for the purpose of demonstrating the effects of future developments on the tunnel, is appropriate, complete

and conclusive. Furthermore, the reader is supplied with information to advise the developer or its designer on the appropriate requirements if the above criteria are not met. A flow chart has been produced to assist the NRA in the decision making process (Appendix 1).

NOTE: It is acknowledged that a developer or its designer will possibly require guidance on the NRA requirements. To assist the NRA in this issue, the information contained in Appendix 2 includes a précised and tailored version of this document which it is suggested is submitted to the developer.

A Design Certificate template has been adapted from the DMRB (Volume 1, Section 1, Part 1A NRA BD 2/01) for certification of the design of a development with respect to its influence on the Dublin Port Tunnel and has been included in Appendix 3. For the purpose of standardisation and clarity, it is suggested that this is submitted to the developer and subsequently used for any design assessment.

3 Dublin Port Tunnel

The Dublin Port Tunnel was commissioned in December 2006. The alignment of the tunnel extends from the Santry interchange in the north of the scheme to an area west of the Port of Dublin.

The tunnel project employed a base reference, zero chainage, point 600m from the northern portals on the M1 road alignment. This nomenclature is used consistently through this document.

The northern extent was constructed using the cut and cover method from the northern portals at project Ch. 0+600[m] to an area roughly opposite Whitehall Church (Ch. 1+900). This portion of the tunnel is entirely overlain by the N1 national road from the church to the north tunnel portals at the Santry interchange.

From Ch. 1+900 to Ch. 4+537 at Fairview Park, the tunnel was constructed as twin bored tunnels and is overlain by green-field sites and densely populated housing/retail development. These tunnels were driven by tunnel boring machines (TBMs) from a 56m diameter shaft, centred at Ch. 2+250 which was subsequently backfilled.

Within Fairview Park, the tunnel was constructed using cut and cover methods which continued on the south side of the railway where the southern portals are located north of the Tolka river (Ch. 5+100).

Taking the above into consideration and for the purpose of this document, the alignment has been divided into areas of potential future surface development. In addition, these areas have been further subdivided, where applicable, on the basis of the prevailing geological conditions and the structure of the tunnel lining.

It is anticipated that future developments in the vicinity of the tunnel will take place in three main geographical areas notably:

A. From Ch. 2+000 to Ch. 2+170 – Currently designated and used as the church car park.
B. From Ch. 2+210 to Ch. 4+537 – "Green-field" land from Collins Avenue to Griffith Avenue and the housing/retail areas of Marino and Fairview.
C. From Ch. 4+950 to Ch. 5+000 – Approximate area between the railway wayleave and Alfie Byrne Road.

Area (B) has been sub-divided as follows:

i) Ch. 2+210 to Ch. 2+400 – Area above bored tunnel constructed within soils
ii) Ch. 2+227 to Ch. 2+283 – Area above Vehicular Cross Passage 2 (VCP 2)
iii) Ch. 2+400 to Ch. 3+330 – Area above bored tunnel constructed within rock with low rock cover
iv) Ch. 2+950 to Ch. 3+050 – Area above VCP 3
v) Ch. 3+330 to Ch. 4+430 – Area above bored tunnel constructed within rock with high rock cover
vi) Ch. 4+100 to Ch. 4+200 – Area above VCP 4
vii) Ch. 4+430 to Ch. 4+537 – Area above bored tunnel constructed partly within soils and partly within rock

The above sub-division takes into consideration the variable nature of the ground along the tunnel and the special geometry associated with the large VCPs.

4 Assessment Criteria

4.1 Location

It is suggested that the NRA employ the following diagrams to decide on the **initial** requirement for an assessment by the developer or its designer:

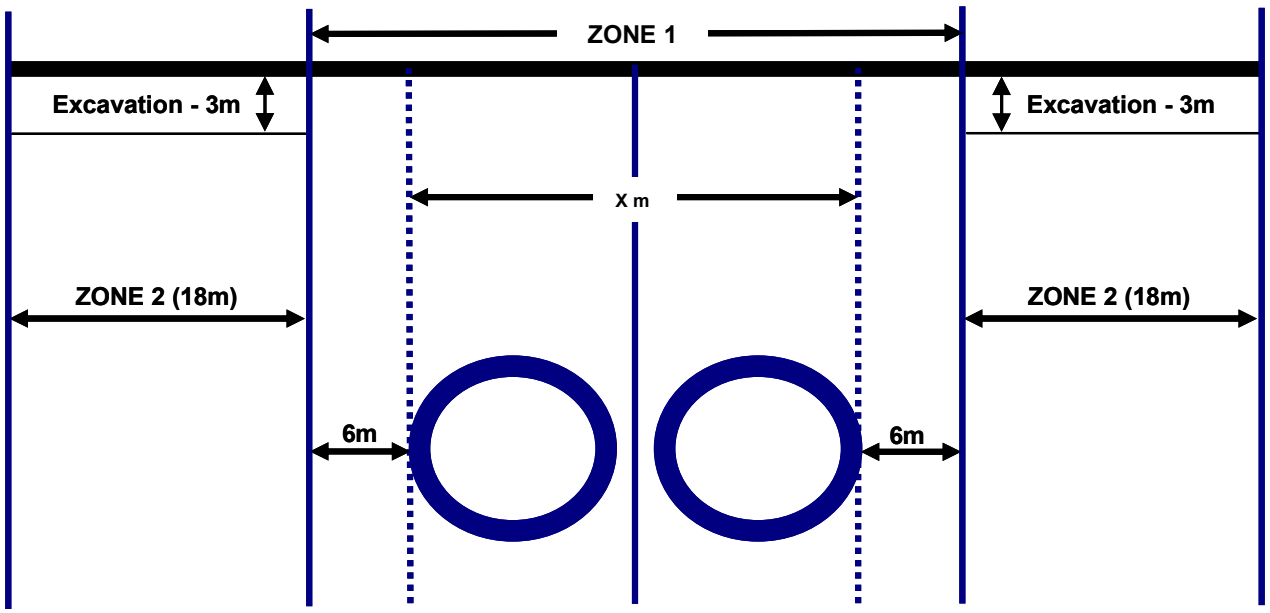


Figure 1: Bored Tunnel – Areas A & B [1]

Not to scale – Depth of Tunnel varies

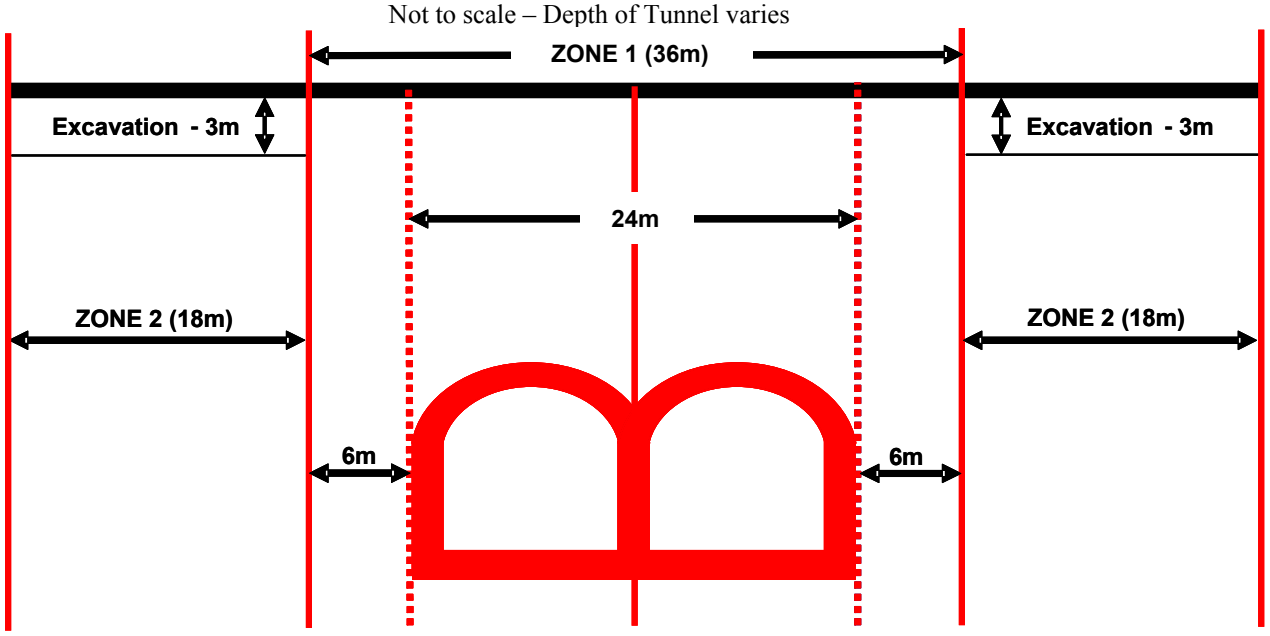


Figure 2: Cut & Cover Tunnel – Area C [1]

Not to scale – Depth of Tunnel varies

[1] Adapted from; Nye, Ted (2005). *Building around Tunnels – Case Histories,* AGS AUCTA Mini-Symposium: Geotechnical Aspects of Tunnelling for Infrastructure Projects

It is recommended that:

- NRA requires all developments within **ZONE 1** to be assessed by a qualified and experienced engineer.

- NRA requires any development within **ZONE 2** which requires a basement excavation of greater than or equal to 3m depth and/or requires piles or ground anchors for building foundations to be assessed by a qualified and experienced tunnelling engineer.

- Where a proposed development is sited over both Zones 1 and 2 or extends outside of Zone 2, NRA requires that an assessment is undertaken by a qualified and experienced tunnelling engineer for the maximum requirement over the whole footprint of the development.

Not withstanding Figures 1 & 2, the following is also recommended:

- NRA requires any development sited in the vicinity of the tunnel which has the potential to affect the groundwater regime e.g. through extraction, to be assessed by a qualified and experienced engineer with particular experience in groundwater hydrogeology and underground structures.

4.2 Surcharge Loading

The DPT has been designed to sustain surcharge loading of 22.5kNm^{-2} and remain within limits for the SLS (Serviceability Limit State).

Volume 2, Part 3, Clause 3.16.8.5 (iv) of the DPT Employer's Requirements states:
"For underground structures influenced by loads imposed from an existing or proposed buildings, the self weight of the existing or proposed building with appropriate allowance for live load in accordance with BS 6399 shall be applied as a surcharge at the foundation level of the building. Where the effect of this load is less than the surcharge load of 22.5 KN/m2, the surcharge load shall govern the design and no additional live load needs to be applied."

It is recommended that:

- NRA requires the developer or its designer to demonstrate that a development does not incur a surcharge loading on the tunnel in excess of **22.5kNm^{-2}** either during construction or at completion.

It should be noted that this surcharge loading may not necessarily be applied at the surface. For example, rock anchors or piles will redistribute loads with resultant increase stresses at depth.

4.3 Unloading

Developments that require excavations for basements will result in the unloading of the ground. The consequent redistribution of ground stress gives potential for the deformation of the tunnel lining.

Generally these effects can be mitigated and managed by design during construction by appropriate construction sequencing and surcharge compensation.

It is recommended that:

- NRA requires the developer or its designer to demonstrate that the method and sequencing of construction of the development minimises or eliminates the potential for tunnel deformation.

4.4 Assessment Variables

It is recommended that the NRA ensures that the developer or its designer considers a number of variables in the analysis. The basic information required for assessment with respect to the DPT is, but not limited to:

- Depth and lateral location of the tunnel relative to the surface development
- Depth and breadth of the building excavations
- Sequencing of excavations

- Distribution and magnitude of the building loads
- Geological model of the site
- Groundwater levels and any changes that may arise in the short or long term
- Tunnel lining type and profile
- Geotechnical properties of the ground
- Positioning of any ground reinforcement or piles relative to the tunnel
- Direction of all stressing loads at all stages of the works

A suite of electronic copies of the DPT documents is supplied in Appendix 2 for transmittal to the developer or its designer to satisfy part of the above listed informational requirements. It should be noted however that, in the case of geological information, it is expected that the developer will undertake specific site investigations for its project.

It is recommended that:

- In the case of geological information, the NRA requires the DPT geology model supplied by the NRA to be augmented by site investigation data gathered by the developer.

4.5 DPT Information

The following information is available for transmittal to the developer. The documents are primarily in Portable Document Format (pdf files), augmented by several CAD and MS Excel files and are included on CD-ROM at Appendix 2:

- Site investigation profiles and interpretation; Long sections and plans (5 files)
- Geological logs – Additional boreholes (18 files)
- As-built tunnel geology (11 files)
- DPT Employer's Requirements – Relevant clauses (2 files)
- Bored Tunnel Alignment - as-built drawings (20 files)
- Bored Tunnel Primary Lining – calculations (2 files)
- Bored Tunnel Primary Lining – as-built drawings (7 files)

- Bored Tunnel Niches/ Cross-Passages - as-built drawings (6 files)
- Vehicular Cross-Passages (VCPs) 2, 3 & 4 – as-built drawings (17 files)
- Bored Tunnel VCPs - Design statement (1 file)
- Cut & Cover Horseshoe Structure – calculations (1 file)
- Cut & Cover Horseshoe Structure – as-built drawings (34 files)
- Mainline Alignment – setting-out data (1 file)
- Mainline Alignment – as-built wriggle data (4 files)
- Mainline Alignment – as-built drawings CAD format (14 files)
- NRA Specification for Road Works – Series 600 – Earthworks (1 file)
- Topographical Surveys - Local to National Grid conversion (2 files)

5 Location Specific Requirements

As noted in Section 3, the bored tunnel has been divided and sub-divided based upon location, geology and structure.

It is recommended that:

- All developer/designer assessments in these areas include analysis based upon the variables listed above and the recommendations included in this report.

However, it is recognised that the NRA does not wish to delay any planning approval process nor be seen to be acting in an over-zealous manner with its requirements. To expedite the process, it is possible to reduce the analysis requirements for certain areas.

Development above the bored tunnel in Area **B(v)** is highly unlikely to cause any unloading problems as the tunnel is deep within the rock with high cover. It is also unlikely that loading will increase significantly at the tunnel horizon due to the depth and the load redistribution through the soil and rock mass. This is obviously caveated by the size of the development and the nature of any proposed underground intrusions (basements; piles; etc.). It is therefore suggested that a simple load calculation to demonstrate compliance with the $22.5kNm^{-2}$ requirement would suffice in this area. The same approach could be used for Area **B(vi)**; however caution should be observed due to the specific structural geology of this area (faulting) and the relative size and complexity of the underground structure.

The above approach is also possible for areas of low rock cover such as Area **B(iii)** but caution is advised as the nature of the rock/soil interface has not been proven to a sufficient degree to assume competent rock above the tunnel horizon. If the developer's own site investigation can demonstrate this competency then the above approach should be considered. Area **B(iv)** is not included in this advice as the rock/soil interface is known to be very close to the structure at this location.

All other areas should be subjected to the full assessment and analysis as recommended. Particular attention should be made to the groundwater and hydro-

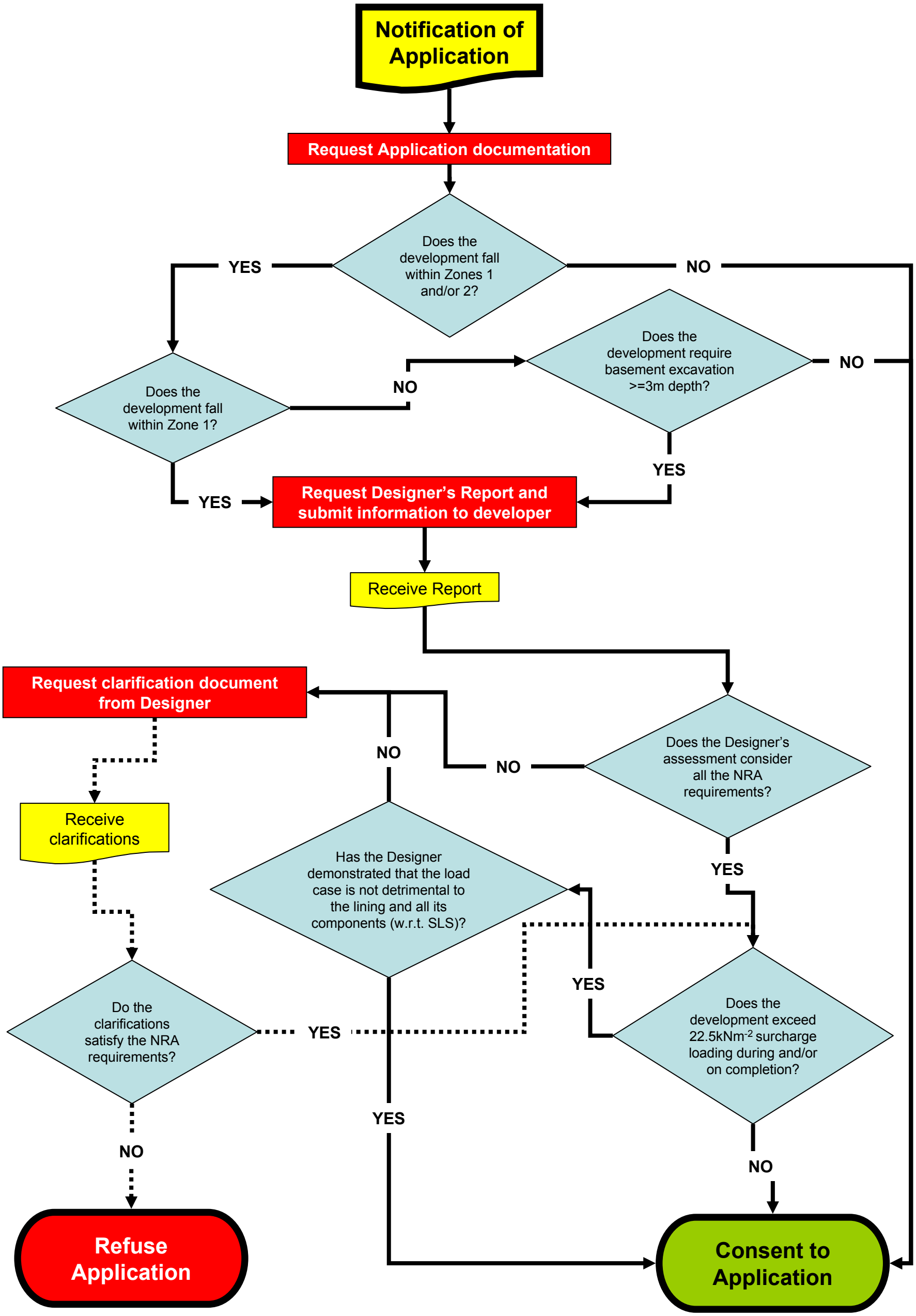
geological conditions that prevail in Area **C.** This area is one which has a relatively complex geology and groundwater regime as well as having low cover above the tunnel.

Special attention should be made to Area **B(ii)** not only due to the nature of the underlying structure (VCP 2) but also because of the condition of the overlying ground. In this location, from the VCP structure to the surface, the geology is categorised as made-ground (backfill of the shaft). The majority of the backfill is of type 2C material and complies with the NRA Specification for Road Works, Series 600. Cognisance of this material should be noted by the designer.

It has been suggested that a method of compensating for load could be used during assessments. In this case, if a designer cannot demonstrate a surcharge load at the tunnel horizon of less than or equal to **22.5kNm^{-2}**, then any ground excavated for the purpose of the development could be used to offset this surcharge load. This is a relatively simplistic approach to apply to a variable and complex geological environment and may lead to complications with unloading considerations. It is therefore not advised, however if the designer can demonstrate that the excess surcharge is not detrimental to the lining (with respect to its SLS) and all its other components, then planning consent should be granted, all other things considered.

Appendix 1

Flowchart



Appendix 1 - Flowchart

Appendix 2

Dublin Port Tunnel Information

Guidance Notes for Developers

The assessment of surface and sub-surface developments in the vicinity of the Dublin Port Tunnel

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MARCH 2009

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1 Dublin Port Tunnel

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2 Assessment Criteria

2.1 Location

The NRA will employ the following diagrams to decide on the **initial** requirement for an assessment by the developer:

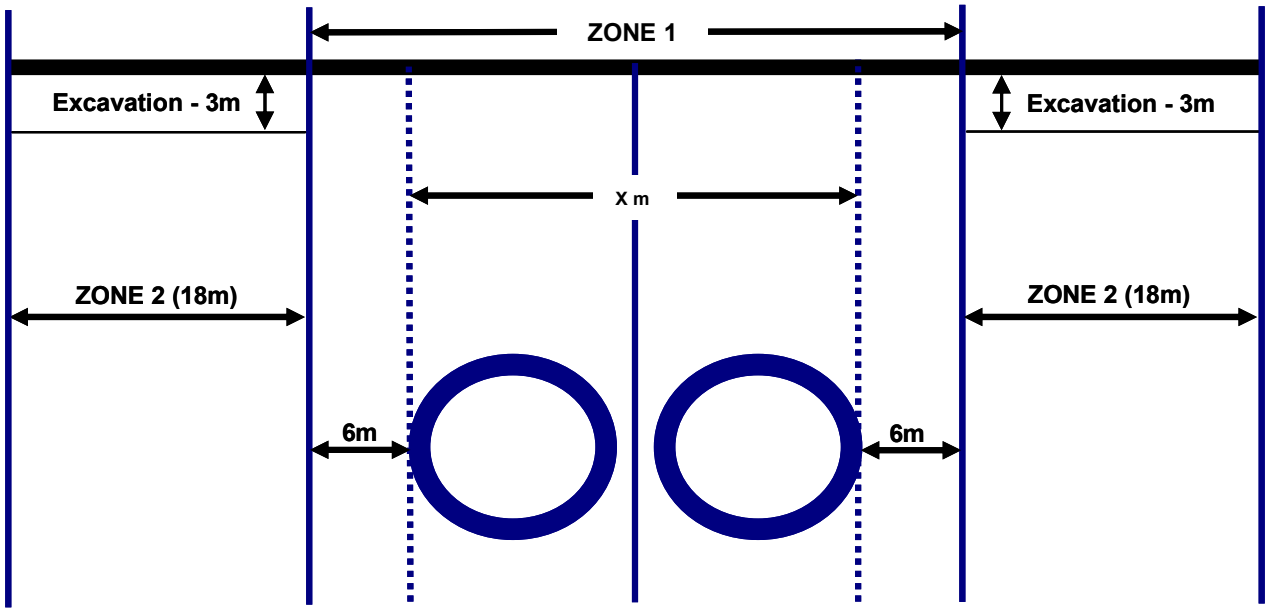

Figure 1: Bored Tunnel – Areas A&B [1]

Not to scale – Depth of Tunnel varies

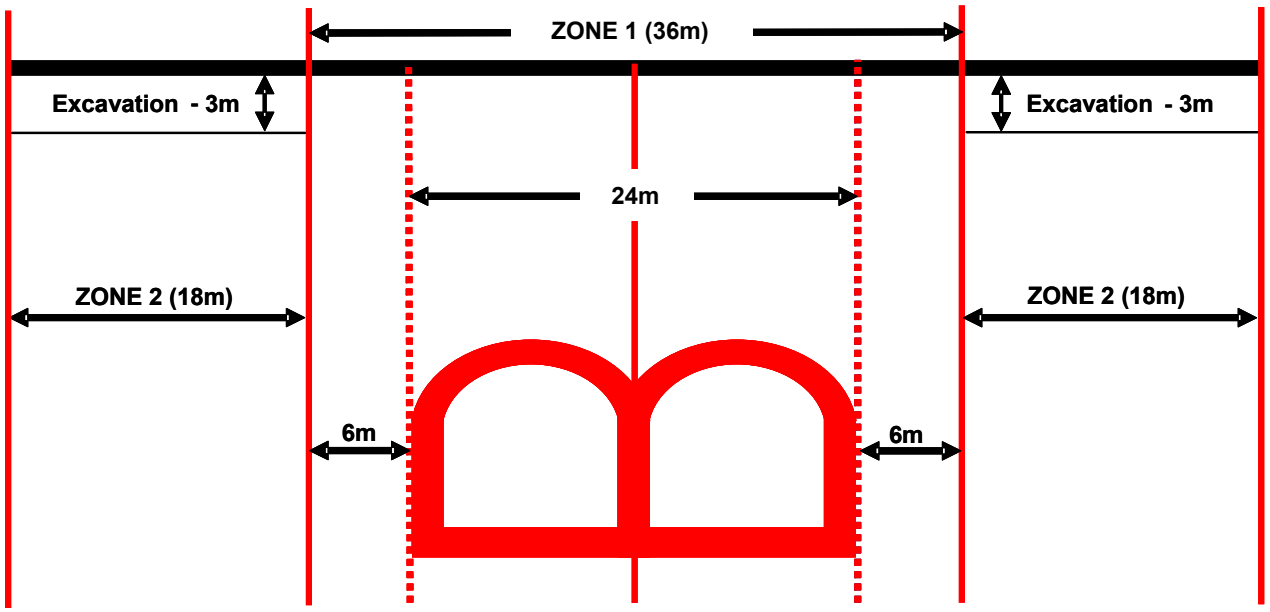

Figure 2: Cut & Cover Tunnel – Area C [1]

Not to scale – Depth of Tunnel varies

[1] Adapted from; Nye, Ted (2005). *Building around Tunnels – Case Histories,* AGS AUCTA Mini-Symposium: Geotechnical Aspects of Tunnelling for Infrastructure Projects

The following assessments are required by the NRA:

- All developments within **ZONE 1** are to be assessed by a qualified and experienced tunnelling engineer.

- Any development within **ZONE 2** which requires a basement excavation of greater than or equal to 3m depth and/or requires piles or ground anchors for building foundations is to be assessed by a qualified and experienced tunnelling engineer.

- Where a proposed development is sited over both Zones 1 and 2 or extends outside of Zone 2, an assessment is to be undertaken by a qualified and experienced tunnelling engineer for the maximum requirement over the whole footprint of the development.

Not withstanding Figures 1 & 2, the following is also required:

- Any development sited in the vicinity of the tunnel which has the potential to affect the groundwater regime e.g. through extraction, is to be assessed by a qualified and experienced engineer with particular experience in groundwater hydrogeology and underground structures.

2.2 Surcharge Loading

The DPT has been designed to sustain surcharge loading of 22.5kNm^{-2} and remain within limits for the SLS (Serviceability Limit State).

The NRA requires:

- The developer to demonstrate that a development does not incur a surcharge loading on the tunnel in excess of **22.5kNm^{-2}** either during construction or at completion. Cognisance must be taken of any surcharge loading at depth due to anchors or piles.

2.3 Unloading

The NRA requires:

- The developer to demonstrate that the method and sequencing of construction of the development minimises or eliminates the potential for tunnel deformation.

2.4 Assessment Variables

The NRA requires:

- The DPT geology model, supplied by the NRA, to be augmented by site investigation data gathered by the developer where applicable.

The NRA requires the developer to consider the following variables in its analysis:

- Depth and lateral location of the tunnel relative to the surface development
- Depth and breadth of the building excavations
- Sequencing of excavations
- Distribution and magnitude of the building loads
- Geological model of the site
- Groundwater levels and any changes that may arise in the short or long term
- Tunnel lining type and profile
- Geotechnical properties of the ground
- Positioning of any ground reinforcement or piles relative to the tunnel
- Direction of all stressing loads at all stages of the works

2.5 Location Specific Requirements

As noted in Section 1, the bored tunnel has been divided and sub-divided based upon location, geology and structure.

The NRA requires:

- All assessments in these areas include analysis based upon the variables listed above and the NRA requirements included in this document.

However, the NRA does not wish to cause delay to the planning approval process. It is possible to reduce the analysis requirements for certain areas.

The NRA will accept:

- A simple load calculation to demonstrate compliance with the $22.5kNm^{-2}$ requirement in Area **B(v)**.

- A simple load calculation to demonstrate compliance with the $22.5kNm^{-2}$ requirement in Area **B(vi)**; however cognisance of the specific structural geology of this area and the relative size and complexity of the underground structure must be demonstrated.

- A simple load calculation to demonstrate compliance with the $22.5kNm^{-2}$ requirement in Area **B(iii)** but **ONLY** if the developer's site investigation can demonstrate competent rock above the area.

Acceptance of the above is dependent on the size of the development and the nature of any ground intrusions e.g. piles. The developer is to make its own assessment on the suitability of availing itself of the reduced requirements. Acceptance of the above is not guaranteed by the NRA.

All other areas must be subjected to the full assessment and analysis as required by the NRA.

In addition to the above, the NRA also requires the developer to demonstrate that:

- Particular attention has been made to the groundwater and hydro-geological conditions that prevail in Area **C.**

- Special attention has been made to Area **B(ii)** not only due to the nature of the underlying structure (VCP 2) but also because of the condition of the overlying ground. In this location, from the VCP structure to the surface, the geology is categorised as made-ground (backfill of the shaft). The majority of the backfill is of type 2C material and complies with the NRA Specification for Road Works, Series 600. Cognisance of this material should be noted by the designer.

The NRA will consider:

- A comprehensive submission from the developer which demonstrates that surcharge loads, during construction and on completion, exceeding 22.5kNm^{-2} are not detrimental to the lining and its components with respect to the Ultimate Limit and Serviceability Limit States.

Appendix 3

Design Certificate

Design Assessment Certificate
Structures above and in the vicinity of the Dublin Port Tunnel

Scheme: _____

Designer: _____

Designer's Reference: _____

NRA Reference: _____

1.0 Undertaking

1.1 *We certify that reasonable professional skill and care has been used in the preparation of the design assessment of the capacity of the Dublin Port Tunnel to withstand the changes in loading and stress induced by development of the scheme and that:-*

1.1.1 *It has been assessed in accordance with the Developer's proposals for the structures of the scheme and the construction programme;*

1.1.2 *It has been checked for compliance with the relevant Standards as listed in* _____

1.1.3 *The design assessment has been based upon the contract drawings, specification and bar schedules as listed in* _____

Signed _____

Position *Team Leader – Design*

Date _____

Signed _____

Position *Principal Officer or Director – Designer*

Date _____

2.0 Acceptance of Certificate

The National Roads Authority accepts this certificate.

Signed _____

Position *Senior Project Manager – Structures, NRA*

Date _____