



**METRO NORTH  
ORAL HEARING**

**PROOF OF EVIDENCE**

**Stuart Cowan**

**Geology**

**Thursday 23rd April 2009**



**Metro North Oral Hearing**

**Proof of Evidence**

**Geology**

**Stuart Cowan**

## 1. INTRODUCTION

The purpose of this evidence is to provide an overview of the geology and groundwater conditions along the entire route of Metro North and to highlight areas which are considered to represent higher risk in relation to underground construction. The geology and hydrogeology will be described with the aid of inferred geological sections from Belinstown Depot in the north to St. Stephen's Green in the south.

The Main Ground Investigation (MGI) factual reports were issued to RPA between January and April 2008. As a result, an assessment of the MGI data is not included in the Geotechnical Data Report and Reference Ground Conditions Report for Information. These reports were prepared by RPA and issued to tenderers as part of the Invitation to Negotiate in May 2008. Tenderers were, therefore, required to include an assessment of the MGI data in their Tenderers Reference Ground Conditions Report, and to submit inferred geological sections which include interpretation of the MGI data.

Descriptions of the scope and contents of the Geotechnical Data Report and the Reference Ground Conditions Report for Information were included in the Geotechnical Proof of Evidence, which I presented to the Oral Hearing on Friday 3<sup>rd</sup> April.

The Reference Ground Conditions Report for Information includes inferred geological sections along the alignment, which are based on the Preliminary Ground Investigation (PGI) and historical ground investigation data. RPA subsequently prepared a separate set of inferred geological sections, which included preliminary rockhead level data from the MGI. It is these sections which will be used to describe the geology and hydrogeology along the route. The sections also show the maximum groundwater levels based on monitoring data obtained from both the PGI and the MGI.

## 2. SUMMARY OF GEOLOGICAL PROFILE

The general stratification of the ground along the route of Metro North consists of the following:

- Made Ground;
- Localised deposits of Alluvial / Estuarine soils;
- Fluvioglacial deposits (Glacial Sands and Gravels);
- Glacial Till; and
- Carboniferous Limestone Bedrock.

Descriptions of the strata were presented to the Oral Hearing on 3<sup>rd</sup> April in the Geotechnical Proof of Evidence.

## 3. SUMMARY OF GROUNDWATER CONDITIONS

There are two main sources of groundwater along the Metro North alignment: shallow groundwater associated with fluvioglacial and alluvial / estuarine granular deposits; and deeper groundwater associated with the Carboniferous Limestone bedrock. The extent of shallow groundwater within the superficial deposits is dependent on the extent of the sand and gravel deposits: sands and gravels close to

watercourses are expected to be in hydraulic continuity with them. Fluvioglacial sands and gravels within the glacial till are generally of limited extent, whereas, more extensive deposits of sands and gravels are likely to be in hydraulic continuity with adjacent water courses.

The glacial till generally has a low permeability and protects and restricts recharge of, or confines, the underlying bedrock. The low permeability of the clay within the glacial till often betrays the existence of a high groundwater table, based on the apparent dryness of even deep excavations. Where made ground overlies soils of lower permeability, perching of the groundwater can occur. Perched groundwater tables are vulnerable to significant variation in level, both on a seasonal basis and over short periods of time, due to the fluctuation in the level of adjacent watercourses, or due to rainstorm infiltration.

Close to the River Liffey the groundwater level is generally at about 0mOD and, reportedly, is not significantly affected by tidal variations. Experience suggests that tidal variations are likely to dissipate rapidly away from the Liffey, although conditions are somewhat dependent on the effectiveness of the cut-off provided by the retaining walls to the river.

The annual fluctuation of the groundwater table is generally likely to be less than 5m, except where the limestone and gravel aquifers are more elevated.

Groundwater flow in the bedrock is controlled by fissure permeability. The limestone, where this consists of fine grained and argillaceous limestones and shales, is characterised by its low permeability and is generally unproductive. Higher yields can be obtained in fault disturbed zones. The limestones are generally recorded to be tight and dry, although experience suggests that individual fracture systems can give flows of between 5 and 20 litres/second.

The Geological Survey of Ireland draft bedrock aquifer map classifies the majority of the bedrock along the Metro North alignment as locally important aquifer, where bedrock is moderately productive only in local zones. The area of Waulsortian Limestone at Dublin Airport is similarly classified. Two areas are classified as poor aquifers, where bedrock is generally unproductive except for local zones. These areas occur along the section of alignment between the M50 and Dublin Airport and also at the Belinstown Depot area, and are consistent with the extent of the Tober Colleen Limestone Formation.

#### **4. INFERRED GEOLOGICAL SECTIONS**

It is noted that the ground profile and groundwater conditions shown in the inferred geological sections were prepared based on fieldwork and monitoring undertaken at discrete locations. The intervening ground and groundwater conditions between discrete fieldwork locations can only be inferred, and, therefore, the actual sub-surface conditions may vary from those shown. It should be noted that the inferred geological sections present a simplification of the expected complexity of the glacial till formation, in terms of the inherent variability of grading, and stratification, of such materials.

##### **4.1 Belinstown Depot to north of Broadmeadow River**

The exploratory hole location plan is shown at the top with the inferred geological section below. The most recent MGI exploratory holes are indicated by the green

symbols. The thick dashed line on the section represents the vertical alignment and the thin black line is the ground level. The bedrock is shown in grey, glacial till in blue, glacial sand and gravel in brown, alluvial deposits in yellow and made ground is shown cross hatched. The maximum recorded groundwater levels in boreholes and monitoring wells are indicated by a red arrow. In subsequent slides the letters 'S' and 'R' denote groundwater levels in soil and rock, respectively.

The geological sections from Belinstown Depot to DCU Stop do not show the superficial soil profile (with the exception of limited areas at the Broadmeadow River and the Airport Stop), as at the time of their preparation in April 2008, there was insufficient MGI information to permit interpretation. However, following a subsequent review of the MGI data, it was established that the superficial soils from Belinstown Depot to DCU Stop consist of glacial till, with the exception of a few isolated occurrences of alluvial materials associated with minor watercourses.

Belinstown and Lissenhall Stops are located in this section of the alignment, which is generally at grade. The ground conditions consist of glacial till, which is between 3m and 12m thick, overlying relatively shallow bedrock of the Tober Colleen and Malahide Formations. The glacial till along this section is typical of much of the route in that it consists of low permeability, stiff to hard predominantly cohesive till with occasional layers and lenses of granular materials.

The depth to groundwater is generally between 0 and 2m below ground level, which reflects the low lying nature of the topography.

#### **4.2 Broadmeadow River to north of Seatown Stop**

Estuary Stop is located in this section of the alignment, which is at grade to the north of Estuary and elevated to the south. The ground conditions consist of stiff to hard, cohesive glacial till, which is between 3 and 8m thick, overlying relatively shallow bedrock of the Malahide Formation. Alluvial / estuarine deposits, between 2 and 3m thick and generally granular in nature, are present locally at the Broadmeadow River. Layers and lenses of sands and gravels, of limited extent, are present within the cohesive glacial till. Made ground is also present locally along the alignment.

Groundwater is generally encountered at depths of between 1 and 4m below ground level.

#### **4.3 Seatown Stop to Swords Stop**

The Seatown and Swords Stops are located in this section of the alignment, which is elevated to the north of Seatown, at grade at the Seatown and Swords Stops and in both cut and cover and retained cut between the Stops.

The ground conditions consist of stiff to hard, predominantly cohesive glacial till, which is between 2 and 20m thick, overlying bedrock of the Malahide Formation. Layers and lenses of sands and gravels, of limited extent, are present within the cohesive glacial till. Made ground is also present locally along the alignment.

Groundwater is generally encountered at depths of between 0 and 7m below ground level, with the shallowest groundwater levels generally recorded to the south, where ground levels are lower.

#### **4.4 Swords Stop to south of Fosterstown Stop**

The Fosterstown Stop is located in this section of the alignment, which is elevated to the north of Fosterstown, at grade at the Stop and in a combination of cut and cover, retained cut, and cutting to the south of the Stop.

The ground conditions consist of stiff to hard, predominantly cohesive glacial till, which is between 6 and 28m thick, overlying bedrock of the Malahide Formation. Layers and lenses of sands and gravels, of limited extent, are present within the cohesive glacial till. Made ground is also present locally along the alignment.

Groundwater is generally encountered at depths of between 1 and 11m below ground level.

#### **4.5 South of Fosterstown Stop to north of Airport Stop**

The northern Airport tunnel portal is located in this section of the alignment. The alignment requires relatively shallow cut and fill to the north of the proposed portal location. To the south of the portal the alignment runs in bored tunnels.

The ground conditions consist of stiff to hard, predominantly cohesive glacial till, which is between 14 and 30m thick, overlying bedrock of the Malahide and Waulsortian Formations. The boundary between the rock formations is defined by a fault lying to the north of the Airport Stop. Layers and lenses of sands and gravels, of limited extent, are present within the cohesive glacial till. Made ground is also present locally along the alignment.

Groundwater is generally at depths of between 1 and 12m below ground level. Artesian groundwater was encountered locally in the low lying stream course to the north of the tunnel portal.

#### **4.6 Airport Stop to Airport southern boundary**

The alignment runs in bored tunnels through this section, which includes the Airport Stop. The ground conditions at the Stop box consist of made ground between 1 and 4m thick and stiff to hard, predominantly cohesive glacial till between 0 and 15m thick overlying Waulsortian Limestone. Layers and lenses of sands and gravels, of limited extent, are present within the cohesive glacial till. The Waulsortian limestone is noted to be more susceptible to the development of karst features than the other bedrock formations encountered along the alignment. Groundwater at the Stop is generally at depths of between 1m and 3m below ground level.

The tunnels will be bored through bedrock then glacial till. Mixed face tunnelling conditions consisting of glacial till and bedrock will be encountered to the south of the Airport Stop.

The ground conditions to the south of the Stop consist of made ground between 0 and 5m thick, stiff to hard, predominantly cohesive glacial till between 2 and 34m thick, overlying bedrock of the Waulsortian and Tober Colleen Formations. Layers and lenses of sands and gravels, of limited extent, are present within the cohesive glacial till. Made ground is present locally.

To the south of the Airport Stop, groundwater is generally at depths of between 2 and 10m below ground level in the superficial deposits. Groundwater monitoring data in the rock was obtained from vibrating wire piezometers, which were installed to allow

remote readings to be taken airside. The groundwater levels recorded in the rock are between 13 and 18m lower than those recorded in the superficial deposits and likely reflect the relatively impermeable nature of the Tober Colleen Formation and the lack of joints and fissures over the short response zones of these instruments.

#### **4.7 Airport southern boundary to M50 viaduct**

The southern Airport tunnel portal is located in this section of the alignment. The alignment continues in bored tunnels to the Airport southern boundary before emerging at the portal. The alignment then continues generally at grade, or in shallow cut or embankment, as far as the M50 viaduct. The Dardistown Stop is located to the south of the tunnel portal and is at grade.

The ground conditions in this section consist of stiff to hard, predominantly cohesive glacial till, which is between 16 and 34m thick, overlying bedrock of the Tober Colleen and Lucan (Calp) Formations. Layers and lenses of sands and gravels, of limited extent, are present within the cohesive glacial till. Made ground is also present locally along the alignment. Groundwater is generally at depths of between 0 and 10m below ground level.

#### **4.8 M50 viaduct to north of Ballymun Stop**

The alignment crosses the M50 on viaduct and then continues on shallow embankment to the Northwood Stop which is at grade. The alignment then continues to the south towards Ballymun in cut and cover.

The ground conditions consist of stiff to hard, predominantly cohesive glacial till, which is between 12 and 22m thick, overlying bedrock of the Lucan (Calp) Formation. Layers and lenses of sands and gravels, of limited extent, are present within the cohesive glacial till. Made ground is present locally along the alignment.

Groundwater is generally encountered at depths of between 0 and 8m below ground level. Groundwater levels in the bedrock were observed to be 5m lower than in the glacial till, where measured in two monitoring locations with installations in both soil and rock.

#### **4.9 Ballymun Stop to DCU Stop**

The alignment continues in cut and cover throughout this section, which includes the Ballymun and DCU Stops. The ground conditions consist of stiff to hard, predominantly cohesive glacial till, which is between 19 and 28m thick, overlying bedrock of the Lucan (Calp) Formation. Layers and lenses of sands and gravels, of limited extent, are present within the cohesive glacial till. Made ground is present locally along the alignment.

As noted earlier, and also as a result of the greater density of exploratory holes from the DCU Stop southwards, the geological sections show the superficial soil profile including the inferred extent of glacial sand and gravel layers and lenses. Although it is acknowledged that the interpretation shown may not be fully representative of the actual in situ conditions, it helps to illustrate the frequency of occurrence, thickness and possible connectivity between the glacial sand and gravel deposits.

Groundwater levels within the shallow superficial deposits typically range from 0 to 7m below ground level. Where installations contain more than one monitoring point,

in the superficial deposits, the lower installation shows a lower groundwater level than the upper installation, indicating the existence of non-hydrostatic conditions. This is thought to be related to the occurrence of granular layers within the glacial till, the preferential drainage paths that they create and the resultant variable recharge conditions.

#### **4.10 South of DCU Stop to St. Patrick's Shaft**

The alignment continues in cut and cover to just south of the DCU Stop, where the bored tunnels commence. The tunnels will commence in glacial till before encountering bedrock to the north of the Griffith Avenue Stop.

The ground conditions over this section of the alignment consist of stiff to hard predominantly cohesive glacial till, which is between 11 and 28m thick, overlying bedrock of the Lucan (Calp) Formation. Layers and lenses of sands and gravels, of limited extent, are present within the cohesive glacial till. Made ground, between 1m and 2m thick, is present along the majority of this section of the alignment.

The Griffith Avenue Stop box will be formed partly in glacial till, which locally contain glacial sands and gravels, and partly in bedrock.

Groundwater is generally encountered at depths of between 0 and 12m below ground level. Groundwater levels in the bedrock are relatively consistent with groundwater levels in the superficial deposits.

#### **4.11 St. Patrick's Shaft to north of Mater Stop**

The alignment continues in bored tunnels in bedrock throughout this section, which includes the Drumcondra Stop. The tunnels pass beneath the River Tolka to the south of St. Patrick's College and the Royal Canal to the south of Drumcondra Stop.

The ground conditions consist of stiff to hard, predominantly cohesive glacial till, which is between 6 and 17m thick, overlying bedrock of the Lucan (Calp) Formation. Layers and lenses of sands and gravels, of limited extent, are present within the cohesive glacial till. Made ground, between 1m and 3m thick, is present along this section of the alignment. The locations of former sand and gravel pits are indicated on historic maps in the vicinity of St. Patrick's Shaft and Ferguson Road. These pits are likely to have been backfilled with made ground.

The Drumcondra Stop box will be formed partly in glacial till, which locally contain glacial sands and gravels, and partly in bedrock.

Groundwater is generally encountered at depths of between 1 and 7m below ground level. Groundwater levels in the bedrock are relatively consistent with groundwater levels in the superficial deposits.

#### **4.12 Mater Stop to north of O'Connell Bridge Stop**

This section of the alignment includes the Mater and Parnell Square Stops. The proposed invert levels of the bored tunnels lie close to the glacial till / bedrock interface along the majority of this section of the alignment, presenting technically challenging tunnelling conditions.

This section is characterised by the presence of the pre-glacial buried channel. The geology of the pre-glacial channel area is complex with glacial tills occurring within glacial sands and gravels and vice-versa and likely reflects the complexity of the variations and different stages of ice-sheet advance and withdrawal.

The ground conditions consist of made ground between 1 and 4m thick, glacial till, which is between 8 and 28m thick, overlying bedrock of the Lucan (Calp) Formation at depths of between 10m and 30m. Extensive glacial sand and gravel deposits are present in this section. It is anticipated that the actual ground conditions along this section of the alignment will be more complex than indicated on the geological section.

The Mater Stop will be formed partly in stiff to hard, cohesive glacial till, containing extensive dense to very dense glacial sands and gravels, and partly in bedrock. The glacial gravels have a maximum thickness of around 12m with cohesive glacial till typically encountered both above and below the sands and gravels. The groundwater level in the superficial deposits at the Mater Stop is generally encountered at depths of between 0 and 2m below ground level. The groundwater level in the bedrock was encountered at a depth of 12m below ground level and is markedly lower, indicating the existence of non-hydrostatic conditions. This is thought to be related to the presence of granular layers within the glacial till, the preferential drainage paths that they create and the resultant variable recharge conditions.

At the Parnell Stop, stiff to hard, predominantly cohesive glacial till with thickness ranging from 4 to 8m, is present overlying dense to very dense glacial sands and gravels, which have a maximum thickness of around 19m and, therefore, the Stop box will be formed predominantly in glacial sands and gravels and partly in cohesive glacial till and bedrock. Saturated gravels with sub-artesian pressures are expected in the Parnell area; blowing sands and gravels were encountered in a number of exploratory holes in this area. Construction methods for tunnels and foundations in these materials require careful consideration. The groundwater level in both the superficial deposits and the bedrock was encountered at depths of between 4m and 13m below ground level and is in hydraulic continuity. The sub-artesian conditions and blowing sands and gravels are likely to be a result of the confinement provided by the cohesive glacial till overlying the glacial sands and gravels.

As the alignment approaches the River Liffey, the ground level falls to 4 to 5m above Ordnance Datum. The rockhead level also rises towards the River Liffey resulting in the thickness of the predominantly granular glacial till reducing to approximately 8m. The maximum recorded groundwater levels in this area are generally between 3m and 5m below ground level with both the superficial deposits and bedrock in hydraulic continuity with the River Liffey.

#### **4.13 O'Connell Bridge Stop to St. Stephen's Green Stop**

This section includes the O'Connell Bridge and St. Stephen's Green Stops. The tunnels will be bored through bedrock throughout this section.

The ground conditions consist of made ground between 1 and 5m thick and glacial till, which is between 2 and 11m thick, overlying bedrock of the Lucan (Calp) Formation at depths of between 6m and 12m below ground level. Alluvial / estuarine deposits, between 1 and 2m thick are present locally in the vicinity of the River Liffey. The glacial till consists predominantly of dense to very dense glacial sands and

gravels (between 2m and 8m thick), with only isolated layers of stiff to hard, cohesive glacial till in the northern and central section. As the alignment approaches St. Stephen's Green, cohesive glacial till (between 1 and 6m thick) is encountered above the sand and gravel deposits.

At the O'Connell Bridge Stop, which will be constructed as a mined cavern within the bedrock beneath the bridge, the ground conditions consist of 3 to 4m of made ground overlying alluvial / estuarine deposits, which in turn overly glacial sands and gravels, which are between 2 and 6m thick. Bedrock is present at depths of between 8 and 11m below ground level. Previous boreholes located either side of the River Liffey had indicated bedrock levels at 7 to 8m below ground level, whereas the recent MGI boreholes indicate that the bedrock is somewhat deeper on the north side of the Liffey.

The maximum recorded groundwater levels in this area are generally between 3m and 5m below ground level with both the superficial deposits and bedrock in hydraulic continuity with the River Liffey.

The depth to rockhead, its variation and the depth of weathering require careful consideration in relation to the depth of roof rock cover required to support the mined cavern. Extensive grouting is likely to be required to minimise groundwater inflows into the cavern during construction.

Experience indicates that dewatering in the city centre has generally not caused significant settlements and this lack of ground movement due to dewatering is probably due to the limited extent and thickness of the alluvial and estuarine deposits as well as the short duration of the drawdown. However, the presence of alluvial deposits associated with the River Liffey means that particular care will be required to ensure dewatering settlements are maintained within acceptable limits.

The St. Stephen's Green Stop will be formed in made ground, stiff to hard, predominantly cohesive glacial till, glacial sands and gravels and bedrock. The groundwater level in both the superficial deposits and bedrock was encountered at depths of between 1 and 5m below ground level.

Railway Procurement Agency  
Ghníomhaireacht um Fháil Iamróid  
Parkgate Business Centre,  
Parkgate Street, Dublin 8, Ireland  
Phone +353 1 646 3400  
Fax +353 1 646 3401  
[www.rpa.ie](http://www.rpa.ie)

Responsible for

LUAS METRO

Integrated  
Ticketing  
System

With funding and  
support from

**transport21**  
progress in motion

