Appendix 3E
Soils and Geology

N5 SCRAMOGE TO BALLAGHADERREEN

ROUTE CORRIDOR SELECTION

SOILS AND GEOLOGY

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1 Introduction

1.1 Work brief

Hydro Environmental Ltd was commissioned by the Roscommon National Roads Design Office (NRDO) on behalf of Roscommon County Council to carry out a geological assessment for the N5 Scramoge to Ballaghaderreen Route Corridor Selection Study.

This report section was prepared in accordance with the National Roads Authority (NRA) publication '*Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes*'.

The proposed scheme relates to upgrading 35.7km of the existing N5 National Primary Road between Teevnacreeva (6.2km east of Ballaghaderreen) and Scramoge (4.7km east of Strokestown).

1.2 Route corridor options

Based on information obtained during the Constraints Study Report (Roscommon County Council, 2006) a total of seven feasible route corridors were developed taking into account all physical, planning and environmental constraints that were identified.

The following sections provide a general route description, subdivided into discrete sections based on recognisable features in the landscape. For each section an existing environment summary of the topography, surface water features, subsoil geology, bedrock geology, aquifers, karst features and groundwater vulnerability is given.

1.2.1 Corridor 1

This corridor option is approximately 33.7 km long. It is located north of the existing N5 along its entire length. The option passes just north of Frenchpark where it crosses the R361 (Boyle) Regional Road. It remains north of Bellanagare and Tulsk, crossing the N61 (Athlone to Boyle) road near Shankill Cross Roads. It then continues north of the existing N5 and north of Clooncullaan Lough before crossing the R368 (Elphin to Strokestown) at Lugboy Townland and veering south to bypass Strokestown on the north and east.

1.2.1.1 Western Tie-in to R361 (Boyle) Road (approximately 6.3 km)

Topography is relatively flat with a slight overall fall from west (90 maOD) to east (80 maOD). No main surface water features are present. The subsoil is classified predominantly as sandstone and shale till. The underlying bedrock is classified as Undifferentiated Visean Limestone. This bedrock is a Regionally Important Karstified Aquifer, with conduit permeability. Two springs are located at the eastern tie-in in Keelbanada, one (Luggadill Spring Well) begin approximately 60 m to the west of the corridor. The only other mapped karst feature is an enclosed depression on the southern corridor boundary at Portaghard. Groundwater has an extreme vulnerability rating for most of this section apart from small areas with a high rating at both ends and a small pocket rated as medium at the western tie-in.

1.2.1.2 R361 (Boyle) Road to Owennaforeesha River (approximately 3.2 km)

The corridor runs along the southern edge of Cloonshanville Bog a NHA and SAC designated site. It crosses the Carricknabraher and Owennaforeesha Rivers in Ballynahowna Townland. EPA water quality monitoring data is available immediately down stream towards Loughbally Bridge. A small tributary of the Owennaforeesha River flows from Mantua through the middle of the corridor for approximately 3 km. Most of

the section is characterised by flat boggy / peaty ground with a slight fall towards the rivers. The subsoil is predominantly classified as fen peat. The western half of the section is underlain by Undifferentiated Visean Limestone. These rocks are classified as a Regionally Important Karstified Aquifer, with conduit permeability. The eastern half is underlain by the Boyle Sandstone Formation that is classified as a Locally Important Aquifer where the bedrock is generally productive only in local zones. No known karst features are mapped in the section. The groundwater vulnerability in the western half of the section is predominantly rated as extreme to the south and high to the north, and the eastern half is predominantly low rated corresponding to the boggy ground, with small areas of medium, and a finger of extreme vulnerability on higher ground at Ballynahowna.

1.2.1.3 Owennaforeesha River to Brackloon Road (approximately 3.0 km)

The corridor passes through a section of forestry and bog followed by marginal / peaty land before rising slightly, from 70 maOD at the River to 80 maOD at Brackloon Road. Subsoil is predominantly classified as fen peat with a small section of sandstone and shale near the LP1215road. Apart from the western edge of the section next to the river that is still within the Boyle Sandstone, the remaining section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features are mapped in the section. Groundwater vulnerability mapping along this section is predominantly rated as low with a small area of medium vulnerability just before the Brackloon Road in the east.

1.2.1.4 Brackloon Road to R369 (Bellanagare to Elphin) Road (approximately 4.5 km)

A small tributary of the Owenur River flows eastwards through the corridor from Cloonyeffer. The landscape is mainly pasturelands interspersed with small pockets of forestry. Topography is relatively flat (approximately 80 maOD). Subsoils are predominantly classified as sandstone and shale till with small areas of fen peat near the R369 to the east. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features are mapped in the section, although a swallow hole is located approximately 20m from the southern corridor boundary at Clogher More. Groundwater vulnerability for this section has a medium rating apart from the eastern fifth that has a high vulnerability and a very small pocket of extreme rating at the R369 at Cartronagor.

1.2.1.5 R369 (Bellanagare to Elphin) Road to N61 National Secondary Road (approximately 2.3 km)

The Owenur tributary flows along the southern edge of the corridor for 1.2 km. Continuing to run through primarily pastureland interspersed with occasional small pockets of forestry the topography is relatively flat but includes a number of small drumlins. Subsoil is classified as sandstone and shale till in the western part and limestone till along the eastern part of this section. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features are mapped in the section. Groundwater in this section has a high vulnerability rating.

1.2.1.6 N61 National Secondary Road to R368 (Elphin to Strokestown) Road (approximately 5.0 km)

The corridor crosses the Owenur River near Ballyoughter Bridge on the LP1412 road the location being monitored for water quality by the EPA. It also crosses as a small tributary to the west of this road. Ballyoughter Lough, a small lake is located within the corridor west of the LP1412. The corridor passes 100 m south of Lough O'Moran and just north of the 'Clooncullaan Loughs' system trimming the northern periphery of Clooncullaan Lough. The ground is relatively flat at around 60 maOD, apart from near the lake where it drops to approximately 50 maOD. Subsoils are predominantly limestone till with interspersed fingers of fen peat associated with the lakes. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features are mapped in the section. The western and eastern thirds of the section are mapped as having a high vulnerability rating with the central third just north of Clooncullaan Loughs predominantly low rated. A small pocket of extreme vulnerability with rock outcrop at or close to ground surface as located on the southern side of the corridor at Killeen East.

1.2.1.7 R368 (Elphin to Strokestown) Road to LP1405 (Kilmore) Road (approximately 5.4 km)

The corridor runs along the sides of Cregga, Cuilrevagh (Greywood Hill) and Kiltrustan hills which rise to the east of the section. The topography undulates between approximately 60 and 130 maOD with a fall off to the west and the SAC / NHA designated Lough Annaghmore located approximately 0.8 km west of the corridor. The land is predominantly pastureland. Subsoil is predominantly limestone till with significant areas of rock outcrop and several karstic features mapped in the area. A large quarry operation (Largan Quarries) is located on the eastern side of Cuilrevagh Hill. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features are mapped in the section. A spring (Lettreen Well) is located approximately 100 m upgradient of the corridor in Lettreen. Groundwater vulnerability along the whole section length has an extreme rating with widespread pockets of rock outcrop or subcrop close to surface.

1.2.1.8 LP1405 (Kilmore) Road to Eastern Tie-in (approximately 4.0 km)

Topography falls gradually from 70 maOD at the LP1405 to 50 maOD at a small tributary of the Mountain River that cuts across the corridor section, remaining relatively flat through pastureland and then into low-lying marshy ground with pockets of bog and forestry particularly in the vicinity of the tributary, and on to the Scramoge River and existing N5. EPA water quality monitoring is carried out east of Strokestown on the Mountain River tributary within the corridor, and at Scramoge Bridge on the N5 for the Scramoge River. The Mountain River tributary source located at Cloonslanor is identified next to the Strokestown Group Water Supply. Subsoils are predominantly limestone till interspersed with fingers of fen peat and lacustrine deposits associated with the Scramoge River. Some sandstone and shale till is present at the tie-in. The section is predominantly underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. A fault line runs southwest – northeast passing through Treanaceeve and Scramoge approximately 500 m east of the Scramoge Bridge. The bedrock to the east of this is identified as Dinantian Sandstones (Fearnaght Formation) and classified as a Locally Important Aquifer where the bedrock is generally moderately productive. No known karst features are mapped in the section, although Bumlin Spring is approximately 40 m southwest of the corridor boundary. Overall the groundwater vulnerability along this section has an extreme rating with some pockets of rock outcrop or close to surface apart from a section of high vulnerability on higher ground east of Vesnoy, a pocket north of Bumlin and an area south of Scramoge Bridge.

1.2.2 Corridor 1A

This corridor option is approximately 34.2 km long. It commences south of the existing N5 but, just west of Bellanagare, crossing to the northern side of the N5 and follows the same route as Option 1. The option passes just south of Frenchpark where it crosses the R361 (Boyle) Regional Road. It crosses the N5 at Cashel Townland west of Bellanagare. It proceeds north of Bellanagare where it follows the same route as Option 1 from Corry West Townland eastwards.

1.2.2.1 Western Tie-in to R361 (Castlerea) Road (approximately 5.8 km)

Topography is relatively flat with an overall slight fall in gradient from 90 to 80 maOD across the section, apart from a gradual rise from the south-western boundary of the corridor towards Fairymount Hill. No main surface water features are present. West of Turlaghnamaddy Townland the subsoil is predominantly sandstone and shale till with fen peat to the east. The land is mainly pastureland west of Turlaghnamaddy Townland and a mixture of peat and forestry to the east. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. Two springs are located at the eastern tie-in in Keelbanada, one (Luggadill Spring Well) begin approximately 60 m to the west of the corridor. The only other mapped karst feature is an enclosed depression in Portaghard. Groundwater has an extreme vulnerability rating for most of this section apart from small areas with a high and medium rating at the tie-in.

1.2.2.2 R361 (Castlerea) Road to Existing N5 Road (approximately 2.6 km)

The corridor crosses the Carricknabraher River at the western end of this section and a small tributary of it near the N5 road that drains from the Leitrim area on the northern part of the SAC, SPA and NHA designated Bellanagare Bog. Numerous small drainage channels flow off the northern part of the bog across the corridor discharging into a number of karst swallow holes (including Pollnagran Cave) in Leggatinty. Other karst features in the area include enclosed depressions and a second cave 40 m north of the corridor boundary. Topography rises slightly towards the east away from the river. The ground is mainly boggy with some forestry at the western end of the section. Bellanagare Bog is located approximately 400 m to the south. Subsoil is classified as predominantly peat. The western two thirds of the section is underlain by Undifferentiated Visean Limestone. These rocks are classified as a Regionally Important Karstified Aquifer, with conduit permeability. Underground flow through the limestone has been traced between Pollnagran Caven and Cloonshanville Spirng to the northeast. The eastern third is underlain by the Boyle Sandstone Formation that is classified as a Locally Important Aquifer where the bedrock is generally productive only in local zones. The north western half of this section is predominantly mapped as having an extreme groundwater vulnerability rating, bordered by thin strips of high and medium in the central part. The south eastern half is predominantly low rated relating to soft boggy ground with some areas of medium, high and extreme towards the north of this portion.

1.2.2.3 Existing N5 Road to Owennaforeesha River (approximately 1.7 km)

The Owennaforeesha River is traversed in this section of corridor at the Cashel and Drummin Townland boundary. The landscape falls gently from west to east towards the river. Subsoil is primarily sandstone and shale till west of the Local Secondary Road LS5641 and fen peat to the east. The majority of the section is underlain by the Boyle Sandstone Formation that is classified as a Locally Important Aquifer where the bedrock is generally productive only in local zones. The eastern 200 m up to the Owennaforeesha River is underlain by Undifferentiated Visean Limestone that is classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features are mapped in the section. Groundwater vulnerability is mixed along the length of the section moving from approximately equal areas of high to extreme to low vulnerability.

1.2.2.4 Owennaforeesha River to Brackloon Road (LP1215) Road (approximately 3.0 km)

Two small tributaries of the Owennaforeesha River are traversed in this section. The western 2 km of the corridor is borderline between pastureland and boggy ground, with forestry along the eastern 1 km. The topography rises slightly from the river at 70 maOD towards the LP1215 road at 80 maOD. The subsoils are classified as predominantly sandstone and shale till with some dispersed pockets of fen peat. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features are mapped in the section. The western three fifths of the section have a low groundwater vulnerability rating and the remaining two fifths being mapped as having a medium rating.

1.2.2.5 Brackloon Road (LP1215) Road to R369 (Bellangare to Elphin) Road (approximately 4.4 km)

A small tributary of the Owenur River flows eastwards from Cloonyeffer through the corridor. This section is predominantly pastureland with some pockets of forestry especially along the western 0.5 km portion. Topography is relatively flat at approximately 80 maOD. The subsoils are predominantly sandstone and shale till with small areas of fen peat near the R369. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. Numerous karst features are mapped within the corridor in Kilvoy just south of the R369 comprising five swallow holes (one identified as Polloweneen Swallow Hole) and four enclosed depressions. Another swallow hole is located in Clogher More. Groundwater vulnerability for this section has a medium rating apart from the eastern fifth that has a high vulnerability and a very small pocket of extreme rating at the R369 at Cartronagor.

1.2.2.6 R369 (Bellanagare to Elphin) Road to N61 National Secondary Road (approximately 2.3 km)

As per Option 1.

1.2.2.7 N61 National Secondary Road to R368 (Elphin to Strokestown) Road (approximately 5.0 km)

As per Option 1.

1.2.2.8 R368 (Elphin to Strokestown) Road to LP1405 (Kilmore) Road (approximately 5.4 km)

As per Option 1.

1.2.2.9 LP1405 (Kilmore) Road to Eastern Tie-in (approximately 4.0 km)

As per Option 1.

1.2.3 Corridor 2

This corridor option is approximately 34.6km long. It weaves north and south of the existing N5. The corridor follows substantially the same path as option 1A from the western tie-in to Tonaknick (north of Bellanagare). It crosses the R369 (Bellanagare to Elphin) Road at Kilvoy Townland, the N61 at Castleland Townland and continues along the existing N5 between Ardkeenagh (Plunkett) Townland and Ardakillin Townland from where it veers south to bypass Strokestown.

1.2.3.1 Western Tie-in to R361 (Castlerea) Road (approximately 5.8 km)

As per Option 1A.

1.2.3.2 R361 (Castlerea) Road to Existing N5 Road (approximately 2.6 km)

As per Option 1A.

1.2.3.3 Existing N5 Road to Owennaforeesha River (approximately 1.7 km)

As per Option 1A.

1.2.3.4 Owennaforeesha River to R369 (Bellanagare to Elphin) Road (approximately 3.3 km)

Two small tributaries of the Owennaforeesha River are traversed at the start of this section. Topography rises slightly from the river at 70 maOD to 80 maOD. Subsoil is classified as predominantly sandstone and shale till with some dispersed pockets of fen peat. The eastern third of the section is in forestry with the remaining section bordering between pasture and bog. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features are mapped in the section. The western half of this section has a low groundwater vulnerability rating with a medium rating in the eastern half.

1.2.3.5 R369 (Bellanagare to Elphin) Road to Local Primary Road LP1419 (approximately 4.5 km)

A small tributary of the Owenur River flows eastwards across the corridor at Flaskagh Beg. The landscape is predominantly pastureland apart from the initial 0.5 km which is forestry. The 'Rathcroghan Plateau' rises gently, approximately perpendicular to the line of the corridor in a south-westerly direction. Topography is relatively flat with a gentle rise from the R369 at 80 maOD to approximately 90 maOD in the Townland of Catron before falling again towards the LP1419 at Flaskagh apart from a small hillock. The subsoil is classified as sandstone and shale till in the western half, and limestone till in the eastern half. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. Numerous karst features are located within this section, in particular around the Townland of Kilvoy. A total of eight swallow holes, five springs (including Toberowen Spring), two enclosed depressions and one dry valley have been mapped. Further springs are located just south of the corridor in Grallagh. A small area of medium rated groundwater vulnerability extends east from the R369, moving into a high rating for the majority of the rest of the section, apart from fingers of extreme rating with occasional rock outcrop or subcrop running along the southern boundary of the corridor.

1.2.3.6 Local Primary Road LP1419 to the Existing N5 at Ardkeenagh (Plunkett) (approximately 5.2 km)

The corridor crosses a small tributary of the Ogulla River between Cammoge and Attiballa, and the main Ogulla channel on the eastern border of Castleland. It passes through part of Corbally Lough just south of the existing N5, a pNHA designated site. Topography varies between undulating pastureland at either end of the section and a significant section of low-lying boggy ground centred around the N61. The topography of the western part skirts along the eastern slopes of Camoge Hill (70 to90 maOD) before dropping to the boggy areas at the N61 (60 maOD) and then rising to approximately 65 maOD at Corbally Lough. Subsoil is predominantly limestone till at both ends of the section with the middle section classified as fen peat. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. Known karst features along this section comprise two springs, one of with has been identified as the source for the Ardkennagh and Cloonart Group Schemes, and Corbally Lough turlough. Further springs are located between 150 and 180 m towards the south near Tulsk, including the Tobernakicky Spring. Groundwater vulnerability is mapped as having a predominantly high rating with a pocket of medium vulnerability at the southern part just north of the N5. A small area along the N5 that borders Corbally Lough is mapped as an extreme rating with bedrock at or close to surface.

1.2.3.7 Along the existing N5 at Ardkeenagh (Plunkett) to Ardakillin (approximately 3.8 km)

A tributary of the Scramoge River is crossed in Kilcooley and again between Clooncullaan and Ardakillin, where it flows through a small lake located on the southern edge of the corridor. The eastern part of this section passes 150 m north of the pNHA designated Ardakillin Lough. Topography falls gently from approximately 65 to 60 maOD at the LP1422 and then lies relatively flat along boggy ground fro the remainder of the section. Subsoils are primarily limestone till with a finger of fen peat crossing the corridor west of the LP1422. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features have been mapped along this section. Groundwater vulnerability mapping is varied moving from a high rating in the western part of this section to medium and then a large portion from Clooncullaan to Ardakillin mapped as an extreme rating.

1.2.3.8 Existing N5 at Ardakillin to R368 (Strokestown to Roscommon) Road (approximately 4.5 km)

A small drainage channel flows from the centre of the corridor south westwards into Ardakillin Lough. The topography is predominantly flat apart from a small hillock in the Townland of Lisnahirka. The corridor passes along the northern slopes of this hillock before passing between Cloonfree Lough (to the north) and Fin Louth (to the south) which are linked by a small channel. The corridor cuts through the southern part of Cloonfree Lough before crossing the channel flowing out of the lake in the vicinity of Cloonfinlough Bridge, which is a tributary of the Scramoge River. The EPA monitors water quality 650 m downstream from the corridor at Cloonconny Bridge. Land use is predominantly pastureland apart from boggy ground between the lakes and around the R368. The ground between the two lakes (approximately 0.5 km) which is traversed by the corridor is subject to flooding and appears to be poorly drained. The topography is generally flat at around 60 maOD apart from 66 maOD at the hillock in Lisnahirka and the area around the R368 where it drops gently to approximately 50 maOD. The subsoils are classified as predominantly limestone till with significant areas of fen peat between the two lakes and surrounding the watercourse serving Ardakillin Lough and an area centred on the R368. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features have been mapped along this section. Groundwater vulnerability is mapped as a high rating with a small pocket of medium vulnerability located between the Cloonfee and Fin Loughs.

1.2.3.9 R368 (Strokestown to Roscommon) Road to Eastern Tie-in (approximately 3.2 km)

The Scramoge River tributary flowing from Cloonfree Lough is crossed again, as well as the main Scramoge channel. The topography through this section rises gently from 50 to 60 maOD at the N5 in Farnbeg. It then falls gently to 50 maOD at the junction with the LP1425 road. The remaining section is relatively flat. The subsoils are classified as ranging from limestone till in the western part to sandstone and shale till in the east, including an area of lacustrine deposits in between. The section is predominantly underlain by

Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. A fault line runs southwest – northeast passing through Treanaceeve and Scramoge approximately 500 m east of the Scramoge Bridge. The bedrock to the east of this is identified as Dinantian Sandstones (Fearnaght Formation) and classified as a Locally Important Aquifer where the bedrock is generally moderately productive. Only one karst feature, Bumlin Spring has been identified in this section. Groundwater vulnerability is mapped as high along the western third of the section, extreme along the middle part following the tributary of the Scramoge River from Carrowclogher to the N5 at Bumlin, and then high further east.

1.2.4 Corridor 2A

This corridor option is approximately 35.0 km long. It is similar to Option 2 except that it veers further south between its western tie-in and the R361 crossing south of Frenchpark.

1.2.4.1 Western Tie-in to R361 (Castlerea) Road (approximately 5.8 km)

The topography rises from the N5 (90 maOD) up to the lower reaches of Fairymount Hill to approximately 105 maOD before falling gradually back to 80 maOD at the R361 road. No main surface water features are present. The subsoils west of the LS5629 are classified as predominantly sandstone and shale till changing to fen peat east of this road towards the R361. Land usage is mainly pastureland in the western part overlying the till with peat and forestry in the eastern section. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. Two springs are located at the eastern tie-in in Keelbanada, one (Luggadill Spring Well) begin approximately 60 m to the west of the corridor. The only other mapped karst features are two enclosed depressions located in Portaghard. Groundwater has an extreme vulnerability rating for most of this section apart from small areas with a high and medium rating at the western tie-in.

1.2.4.2 R361 (Castlerea) Road to Existing N5 Road (approximately 2.6 km)

As per Option 1A.

1.2.4.3 Existing N5 Road to Owennaforeesha River (approximately 1.7 km)

As per Option 1A.

1.2.4.4 Owennaforeesha River to R369 (Bellanagare to Elphin) Road (approximately 3.3 km)

As per Option 2.

1.2.4.5 R369 (Bellanagare to Elphin) Road to Local Primary Road LP1419 (approximately 4.5 km)

As per Option 2.

1.2.4.6 Local Primary Road LP1419 to the Existing N5 at Ardkeenagh (Plunkett) (approximately 5.2 km)

As per Option 2.

1.2.4.7 Along the existing N5 at Ardkeenagh (Plunkett) to Ardakillin (approximately 3.8 km)

As per Option 2.

1.2.4.8 Existing N5 at Ardakillin to R368 (Strokestown to Roscommon) Road (approximately 4.5 km)

As per Option 2.

1.2.4.9 R368 (Strokestown to Roscommon) Road to Eastern Tie-in (approximately 3.2 km)

As per Option 2.

1.2.5 Corridor 2B

This corridor option is approximately 34.5 km long. It is similar to Option 2 except that between the crossing point of the N61 at Castleland Townland and the crossing point of the N5 at Ardakillin, the route is north of and parallel to the existing N5 as opposed to along it.

1.2.5.1 Western Tie-in to R361 (Castlerea) Road (approximately 5.8 km)

As per Option 1A.

1.2.5.2 R361 (Castlerea) Road to Existing N5 Road (approximately 2.6 km)

As per Option 1A.

1.2.5.3 Existing N5 Road to Owennaforeesha River (approximately 1.7 km)

As per Option 1A.

1.2.5.4 Owennaforeesha River to R369 (Bellanagare to Elphin) Road (approximately 3.3 km)

As per Option 2.

1.2.5.5 R369 (Bellanagare to Elphin) Road to Local Primary Road LP1419 (approximately 4.5 km)

As per Option 2.

1.2.5.6 Local Primary Road LP1419 to the Existing N61 (approximately 3.1 km)

The corridor crosses two small tributaries of the Ogulla River between Cammoge and Attiballa. It passes through part of Corbally Lough just south of the existing N5, a pNHA designated site. Topography varies from undulating pastureland on the higher ground along the eastern slopes of Camoge Hill (70 to 90 maOD) before descending to low-lying boggy land approaching the N61. Subsoil is divided along the section with limestone till on the higher north western part and fen peat on the south eastern portion. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. Only one known karst feature has been mapped in this section, a spring at Cloonyquin. Groundwater vulnerability has been mapped as having a high rating apart from a small finger of extreme with rock outcrop or subcrop in Cloonyquin.

1.2.5.7 Existing N61 to Ardakillin (approximately 5.9 km)

The corridor crosses the Ogulla River just east of the N61. A small tributary of this river flows along the south of the corridor westwards for approximately 2 km from Corrabeg back towards the river and N61. Lough Caudagh a small lake southeast of Carton is located in the centre of the corridor, with a channel flowing eastwards for 1.2 km through the corridor to connect with a tributary of the Scramoge River. Topography along this section is initially undulating pastureland to Steill, where it falls to low-lying peaty / boggy ground. It gradually climbs up onto more pastureland at Derryquirk Hillock (approximately 70 maOD) before falling back down to boggy land on the eastern side of the hillock (approximately 55 maOD). The ground begins to rise again to Correagh Hillock (approximately 65 maOD) and again falling on the far side of the hillock to peaty land (approximately 55 maOD). The subsoils are classified as limestone till on the higher ground and fen peat along the low ground. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features have been mapped along this section. Groundwater vulnerability is predominantly rated as high, with two large pockets of medium rating in the centre of the section. A small area of extreme rated ground is located close to the N5 in the east, with a few other very small pockets near the middle of the section.

1.2.5.8 Existing N5 at Ardakillin to R368 (Strokestown to Roscommon) Road (approximately 4.5 km)

As per Option 2.

1.2.5.9 R368 (Strokestown to Roscommon) Road to Eastern Tie-in (approximately 3.2 km)

As per Option 2.

1.2.6 Corridor 3

This corridor option is approximately 35.7 km long. It represents an online upgrade of the existing N5 route.

1.2.6.1 Western Tie-in to Frenchpark (approximately 6.3 km)

There are no watercourses crossing this section of the existing N5. Land usage is mainly pastureland. Subsoils are classified as predominately sandstone and shale till, with a skirting area of fen pet from Turlaghnamaddy eastwards to the R361. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features have been mapped along this section. There are two springs (including Luggadill Spring Well) just northwest of the western tie-in. Pollnagolum Cave, a swallow hole and two enclosed depressions are located approximately 80 m south of the section in Frenchpark, along the R361. Groundwater is predominantly mapped as having an extreme vulnerability rating for most of this section apart from small areas with a high and medium rating at the western tie-in, and a high rating for the eastern 1.2 km up to Frenchpark.

1.2.6.2 Frenchpark to Bellanagare (approximately 4.1 km)

The N5 crosses the Carricknabraher River approximately 0.9 km south of Frenchpark at Cloonshanville Bridge. The OPW maintain a staff gauge at this location and the EPA monitor water quality. The route crosses an underground channel that has been mapped by the GSI flowing from a swallow hole (Pollnagran Cave) in Leggatinty to the Cloonshanville Spring, a short distance south of the river. A further 1.5 km from the Cloonshanville Bridge the route crosses a tributary of the Carricknabraher River that drains from the Leitrim area on the northern part of the SAC, SPA and NHA designated Bellanagare Bog. The Owennaforeesha River crosses the route just east of Bellanagare, at a reach monitored by the EPA for water quality. Land usage is mainly pastureland. Subsoils are predominantly sandstone and shale till. The western third of the section is underlain by Undifferentiated Visean Limestone. These rocks are classified as a Regionally Important Karstified Aquifer, with conduit permeability. The eastern two thirds is underlain by the Boyle Sandstone Formation that is classified as a Locally Important Aquifer where the bedrock is generally productive only in local zones. Apart from the underground conduit mentioned above, the only other karst feature along the section is a dry valley at Leggatinty, just south of the N5. The initial two thirds of this section from Frenchpark has an extreme groundwater vulnerability rating, with the remaining third a mix of medium, high and extreme.

1.2.6.3 Bellanagare to Tulsk (approximately 11.9 km)

The route crosses the Ogulla River in Tulsk. The land is primarily pastureland. Subsoils are classified as predominantly sandstone till along the western third of this section followed by limestone till along the eastern two thirds. A superimposed drumlin listed as a site of geological heritage (IGH7) borders the corridor to the northwest of Tulsk. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. This section passes through very karstified areas with numerous mapped features. Two swallow holes and an enclosed depression have been mapped on the corridor in Rathnallog / Carrowreagh. Approximately 3 km southeast of Tulsk in the Townland of Carrowreagh there is a large area approximately 1 km in length running parallel to the N5 and 150 m to the north that is heavily karstified with at least twenty three enclosed depressions and sixteen swallow holes mapped. A short distance further east and about 300 m south of the N5 at Moneylea another similar area comprises at least forty two enclosed depressions, thirteen swallow holes and one dry valley. Two enclosed depression are located within the corridor at Ballyconboy, and two springs, Tobar na Spunoige Spring at Carrowntoosan and another at Knockavurrea are also within the corridor. Groundwater vulnerability along the north western quarter of this section has a predominantly low rating, with the central half extreme and the south eastern quarter a high rating.

1.2.6.4 Tulsk to Strokestown (approximately 10.5 km)

The route runs adjacent to the pNHA designated Corbally Lough. A tributary of the Scramoge River is crossed in Kilcooley and again 1.7 km downstream, west of Ardakillin. Another tributary of the same river is crossed between Ardakillin and Cloonfree. The main channel flowing into the Scramoge River is crossed at Cloonfree Bridge that is monitored for water quality by the EPA, and is 700 m upstream of Cloonfree Lough. Land use is mainly pastureland. Subsoils are classified as predominantly sandstone till. A superimposed drumlin listed as a site of geological heritage (IGH7) borders the corridor to the northwest of Tulsk. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. Three springs (including Tobernakicky Spring) are located just north of Tulsk. The only other karst feature mapped along the section is Corbally Lough. Groundwater vulnerability various along the section from equal portions of high and medium ratings apart from a small pocket of extreme vulnerability next to Corbally Lough and a 1.5 km stretch at Ardakillin.

1.2.6.5 Strokestown to Eastern Tie-in (approximately 2.9 km)

The Mountain River tributary that flows from the near the source of Strokestown Group Water Supply located at Cloonslanor is traversed in Strokestown at Farnbeg. The EPA monitors water quality at the location. The final river crossing is Scramoge Bridge over the Scramoge River between Bumlin and Treanaceeve, also an EPA monitoring location. Land usage is a mixture of pastureland, forestry and poorly drained / boggy agricultural land. The subsoil is predominantly sandstone till. The section is predominantly underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. The only karst feature that has been mapped along the section is Bumlin Spring. A fault line runs southwest – northeast passing through Treanaceeve and Scramoge approximately 500 m east of the Scramoge Bridge. The bedrock to the east of this is identified as Dinantian Sandstones (Fearnaght Formation) and classified as a Locally Important Aquifer where the bedrock is generally moderately productive. The initial half of this section from Strokestown has a high groundwater vulnerability rating, with the remaining half mapped as an extreme rating, including a small pocket of high at the Scramoge Bridge.

1.2.7 Corridor 4

This corridor option is approximately 38.0 km long. It is located south of the existing N5 along its entire length. This option follows the approximate line of Options 1, 2 and 2B as far as the crossing of the R361 south of Frenchpark. From here it veers further south crossing the R367 (Ballintober to Tulsk) road at Mullygollan Townland and the N61 at Sheegeeragh Townland. The route then veers north-eastwards towards the existing N5 at Lissaphuca Townland and follows a similar route as Options 2, 2A and 2B to bypass Strokestown on the southern side.

1.2.7.1 Western Tie-in to R361 (Castlerea) Road (approximately 5.8 km)

As per Option 1A.

1.2.7.2 R361 (Castlerea) Road to Owennaforeesha River (approximately 4.2 km)

The corridor crosses the Carricknabraher River at the western end of this section and a small tributary of it near the N5 road that drains from the Leitrim area on the northern part of the SAC, SPA and NHA designated Bellanagare Bog. Numerous small drainage channels flow off the northern part of the bog across the corridor discharging into swallow holes (including Pollnagran Cave) in Leggatinty, 110 m north of the corridor. It crosses the Owennaforeesha River southwest of Bellanagare in Ballincool. Topography is relatively flat across the initial boggy ground, rising eastwards away from the Carricknabraher River (80 maOD) up a rise to Bellanagare Bog peaking at Knockroe hillock (110 maOD) before falling back towards the Owennaforeesha River at 80 maOD. Subsoils are predominantly fen peat apart from a finger of sandstone till between Knockroe and the LP1221 at the river. The western third of the section is underlain by Undifferentiated Visean Limestone. These rocks are classified as a Regionally Important Karstified Aquifer, with conduit permeability. Karst features have been mapped at Leggatinty, with tow enclosed depressions and two swallow holes located within the corridor. Similar features are mapped at this location within 180 m of the corridor including the Pollnagran Cave and swallow hole that has been linked to the Clonnshanville Spring

further northeast. The eastern two thirds of the section is underlain by the Boyle Sandstone Formation that is classified as a Locally Important Aquifer where the bedrock is generally productive only in local zones. Groundwater vulnerability is predominantly mapped as having an extreme rating along with a low rating on the soft ground north of the bog area and approaching the Owennaforeesha River.

1.2.7.3 Owennaforeesha River to LP1219 (approximately 5.8 km)

A small tributary of the Owennaforeesha River flows northwards through the corridor for approximately 1.3 km from Killaster to Kilcorkey. Two small tributaries of the Termon River rise in the centre of the corridor within forestry north of Rathmoyle, joining the main channel 670 m west of the corridor. The topography shows a general and gentle rise in elevation away from the Owennaforeesha River (80 maOD) to the peak of Rathmoyle Hill (140 maOD) and then gradually falls to approximately 130 maOD at the LP1219. Land usage varies from pastureland in the vicinity of the roads to boggy lands at the western section in Mountdruid and Killaster Townlands. There are also large areas of forestry along the slopes of Ballyglass / Rathkineely Hill. Subsoils are predominantly fen peat on the northern portion with a finger of sandstone till along the LP1220, and predominantly sandstone till along the south-eastern portion. The initial 500 m of this section next to the Owennaforeesha River is underlain by the Boyle Sandstone Formation that is classified as a Locally Important Aquifer where the bedrock is generally productive only in local zones. The remainder of the section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. A spring is located in Mountdruid within the corridor, and further southeast an area of karst features has been mapped in Ballyglass, 170 m east of the corridor that includes at least twelve enclosed depressions and fifteen swallow holes. The initial quarter of the section from the Owennaforeesha River has a low groundwater vulnerability rating with the remaining portion predominantly split between a high rating to the north and an extreme rating to the south on the higher ground.

1.2.7.4 LP1219 to R367 (Tulsk to Castleplunkett) Road (approximately 4.0 km)

No main surface water channels are traversed along this section. The SAC and pNHA designated Mullygollan Turlough is located 600 m northeast and downgradient (89 maOD) of the end of the section, on the northern side of the R367. Castleplunkett Turlough listed as a pNHA site is located 800 m southwest and downgradient of the corridor, on the southern side of the R367. The topography is relatively level at between 125 and 130 maOD, with a gradual fall in the south east to approximately 110 maOD at the R367. Land usage is mainly pastureland with isolated pockets of forestry. The subsoil is classified as predominantly sandstone till throughout the section. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features have been mapped within the section, although St Elvia's Spring and another adjacent spring are located in Toberelva approximately 45 and 95 m south of the corridor. Groundwater has been tracer to flow to this location from a swallow hole in Knockalegan East, 2.8 km to the southwest. Groundwater has an extreme vulnerability rating along this section.

1.2.7.5 R367 (Tulsk to Castleplunkett) Road to N61 (Boyle to Athlone) National Secondary Route (approximately 5.5 km)

The corridor runs through the pNHA designated Brierfield Lough, with the northern part of the lake and an approximately 1.8 km length of possible floodplain within the corridor. Topography is relatively flat along the first third at approximately 100 maOD, before rising slightly across the Carnfree 'Plateau' at approximately 120 maOD. It fails back then to 75 maOD at the N61 in Manor Townland. Land usage is mainly pastureland. Subsoils are classified as predominantly sandstone till throughout. St Elvia's Spring emerges at Toberelva 600 m southwest of the corridor. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. The only known karst feature present along this section is Brierlough Turlough that extends in flooding from the south across the mid-point of the section. The associated swallow hole if located 120 m south of the corridor. Approximately one third of the section, to the west and around Dooneen is mapped as having a high groundwater vulnerability rating. The remainder has an extreme rating with numerous pockets of bedrock outcrop or subcrop.

1.2.7.6 N61 (Boyle to Athlone) National Secondary Route to existing N5 at Ardakillin (approximately 5.0 km)

The corridor crosses a small tributary of the Scramoge River at Ballydaly that flows into the pNHA designed Ardakillin Lough 1 km to the east. Further tributaries run along the middle of the corridor between Clooncullaan and the N5, including a small lake within the corridor. Topography falls gradually from the N61 to Ballydaly and then remains relatively flat. The land is mostly pastureland becoming increasingly poorly drained and boggy on the approach to the N5 as it crosses the river channels. Apart from sandstone till near the N61 the subsoil is predominantly fen peat. The section is underlain by Undifferentiated Visean Limestone, classified as a Regionally Important Karstified Aquifer, with conduit permeability. No known karst features have been mapped along the section. Groundwater has an extreme vulnerability rating for the initial 600 m east of the N61 followed by a high rating to Clooncullaan with the remainder mapped as extreme including some bedrock outcrop or subcrop along the N5.

1.2.7.7 Existing N5 at Ardakillin to R368 (Strokestown to Roscommon) Road (approximately 4.5 km)

As per Route Option 2.

1.2.7.8 R368 (Strokestown to Roscommon) Road to Eastern Tie-in (approximately 3.2 km)

As per Route Option 2.

1.3 Geological objective

This section of the Route Corridor Report seeks to assess and evaluate the route corridor options in relation to soils and geology. Considering the environmental aspects summarised in the previous section, the main criteria that have been used are:

- Percentage of each route corridor underlain by peat, moderated by the depth of peat;
- Percentage of each route corridor underlain by subsoil unlikely to be suitable for re-use as engineering fill, primarily gley soils;
- Earthworks analysis for each route corridor;
- Impact on designated sites – considering the geological characteristics of each site within the study area and proximity to the individual route corridors; and
- General impact implications road schemes have on the geological environment.

The report has been prepared by expanding the desk study work carried out for the Constraints Study to look at all available data specifically relating to the selected route corridor options. It includes an assessment of aerial photography reviewing possible ground surface karst features. The desk study details have been verified on the ground by a drive-by survey along each route corridor.

Any areas that have been highlighted as being of potential geological significance were targeted for walkover surveys in order to assess the significance of any likely environmental impacts on them.

2 Methodology

2.1 Data sources

The following list of data sources were the main information sources reviewed as part of this route corridor selection report:

Roscommon National Roads Design Office (NRDO)

- N5 Strategic Corridor Constraints Report, December 2006
- Feasible Route Corridors overlaid on Ordnance Survey (OSi) background mapping
- Digital Ground Model Contours overlaid on OSi background mapping
- N5 Strategic Corridor Draft Route Corridor Selection Report, December 2007
- Calculations on areas of soft and unsuitable ground

Ordnance Survey

- Discovery Series Mapping (1:50,000)
- Six Inch Raster Maps (1:10,560)

Geological Survey of Ireland (GSI)

- Bedrock Geology Mapping
- Aquifer Mapping
- Groundwater Vulnerability Mapping
- Groundwater Source Protection Mapping
- Teagasc Subsoil Classification Mapping
- Well Database
- Karst Features and Tracer Test Database
- Geology of Longford and Roscommon: A geological description of Roscommon, Longford, Westmeath, and adjoining parts of Cavan, Leitrim and Galway, to accompany the bedrock geology 1:100,000 scale map series, sheet 12, Longford - Roscommon. GSI 2003
- Geology of Longford – Roscommon Sheet 12. GSI, 1999

Environmental Protection Agency (EPA)

- Teagasc Subsoil Cover Classification Mapping
- Teagasc Subsoil Classification Mapping

Roscommon County Council

- Planning Register
- Roscommon County Development Plan (2002 – 2009)

Other Sources

- Site Investigation Report, Glover Site Investigations Limited

2.2 Consultation with regulatory and other bodies

Consultation was made with various departments of Roscommon County Council as well as the GSI. The Irish Peatland Conservation Council (IPCC) was also contacted regarding Cloonshanville and Bellanagare Bogs.

2.3 Site investigations and field surveys

Areas of soft ground were identified from an aerial fly-over survey and site visits were carried out by the design team. A total of thirty three areas of potentially soft ground were selected dispersed along each of the route corridor options.

Preliminary site investigation works comprising ground probing was carried out by Glover Site Investigations in January and February 2007 to determine the extent and depth of soft ground at each location. A total of 411 dynamic probes were carried out.

A field survey was carried out to look briefly at any karst and outcrop features that were identified during the desk study and review of the aerial photography. Key areas including the section of ground east of Frenchpark between Cloonshanville and Bellanagare Bogs were assessed and ground elevations surveyed in more detail to obtain a better understanding of the geological regime in particular reference to the flow of groundwater through the underlying karstified aquifer at that location.

2.4 Impact assessment

In order to assess the relative merits of each of the identified route corridors, an assessment of the likely impact each route will have on the geological attributes along each route has been made. Consideration has been given to both the importance of the attributes and the predicted scale and duration of the likely impacts.

As only very limited engineering design details and site specific data is available at this stage, much of the preliminary impact assessment is of a qualitative rather than a quantitative nature. A significant degree of professional judgement has therefore been used in identifying and rating the likely impacts. For each route corridor a summary of these associated impacts has been presented in a tabular format.

In relation to likely significant impacts on soils and geology, each route corridor option has been assessed and rated on the following attributes:

- Geological heritage sites along each route
- Subsoil classification;
- Bedrock classification;
- Karst features; and
- Aquifer vulnerability

2.5 Comparison of route corridors

A comparison of route corridors has been made based on the number and degree of likely impacts and along each corridor. This has established an order of preference from a soils and geological perspective.

Where a similar number of likely impacts have been identified then the route corridor which affects the least number of high value attributes has been given preference.

2.6 Limitations and gaps in available data

Limitations for this stage of reporting exist in the lack of field and site investigation data in relation to bedrock geology and more specifically karst features. Most of the conclusions and recommendations have been arrived at through desk study research and basic site walkovers. Until the final alignment is known it will not

be possible to make detailed appraisals regarding how any cut or fill sections will impact on the geological environs.

Once the preferred route has been selected it is recommended that any areas within the corridor that have known karst features be surveyed in detail, including geophysical investigation. This should include the key area in Leggatinty where the Pollangran Cave system is located.

3 Soil & Bedrock Classification

3.1 Subsoil geology

Geological maps from the GSI and Teagasc were reviewed to obtain details on the soil cover and subsoil type within the study area, and more specifically underlying each corridor. The classification into Great Soil Groups has categorised a number of main soil types within the study area, the most dominant being the Gleys. These are generally underlain by Till subsoils.

3.1.1 General soil cover descriptions

3.1.1.1 Gleys

Gleys are soils in which the effects of drainage impedance dominate and that have developed under the influence of permanent or intermittent waterlogging. The impedance may be due to a high groundwater table, a perched groundwater table caused by the impervious nature of the soil material, or to seepage or runoff from slopes. Most Gleys have poor physical conditions, which makes them unsuitable for cultivation or intensive grassland farming. There are three types of Gley soil material:

- Surface Water Gleys – Deep poorly drained mineral soils, derived from mainly either non-calcareous or calcareous parent materials. Most of the deposits that have been mapped in the flat to undulating ground are Surface Water Gleys, and they are waterlogged close to the ground surface due to the presence of a low permeable layer.

- Groundwater Gleys – Deep poorly drained mineral soils, derived from mainly either non-calcareous or calcareous parent materials. They occur mostly on the higher and hilly ground where the drainage is poor as the groundwater table is high.

- Peaty Gleys – Poorly drained mineral soils with peaty topsoil, derived from mainly non-calcareous parent materials.

3.1.1.2 Grey Brown Podzolics / Brown Earths

These are deep well drained mineral soils, derived from mainly calcareous parent materials.

- Grey Brown Podzolics – The parent material is mostly glacial limestone till that tends to exhibit higher free carbonate content and exhibit varied drainage characteristics. The calcareous nature counteracts the effects of leaching, resulting in the podzolisation process being restricted, with the principal materials translocated down the soil profile being the clay particles themselves. The lighter texture types are good all-purpose soils while the heavier textured types are highly suited to pasture production. They are associated with drumlin features.

- Brown Earths – These are relatively mature soils possessing a rather uniform profile that has not been extensively leached or degraded. Most occur on lime-deficient parent materials and are therefore acidic in nature (Acid Brown Earths). They generally possess medium texture (sandy loam, loam, sandy clay loam) and are friable, resulting in them being extensively cultivated.

3.1.1.3 Basin Peats / Blanket Peats

Peats are characterised by high (>30%) organic matter content and are at least 0.3 m deep. The soil classifications are identified as Cutaway / Cutover Peat. A description of the types is presented in the following subsoil section.

3.1.1.4 Rendzinas / Lithosols

These deposits are shallow (less than 0.5 m deep) well drained mineral soils, derived from mainly (>40%) calcareous parent materials.

- Rendzinas – The surface horizon is very dark in colour, with a strong structure and a neutral or alkaline reaction. The shallow depth limits the potential use of the soil and they are most suited to extensive grazing, however where sufficiently deep they can also be excellent tillage soils.

- Lithosols – These are skeletal stony soils, usually overlying solid or shattered bedrock. They are often associated with Podzols at higher elevations. Generally there is rock outcrop at frequent intervals in such soil areas and steep slopes may be present. Usage is usually limited to rough grazing.

3.1.1.5 Variable

Deposits within this great soil group include:

- Mineral Alluvium – Associated with river deposits.

- Lacustrine-Type Soils – Associated with deposition around lakes.

3.1.2 General subsoil descriptions

3.1.2.1 Till

The most widespread subsoil in County Roscommon is Till, often referred to as boulder clay or drift. It is a diverse material that is largely deposited sub-glacially and has a wide range of characteristics due to the variety of parent materials and different processes of deposition. Tills are often tightly packed, unsorted, unbedded, and have many different particle and stone sizes and types, which are often angular or subangular. Some of the tills in the county have been formed into elongated hills, or drumlins, which are thought to provide an indication of ice flow direction (GSI, 2003b).

There are four types of till mapped across the study area. From west to east the deposits are grouped into distinct bands based on age and parent material:

- Sandstone Till (Devonian) – Covers approximately one quarter of the study area (with large tracts of peat throughout and along the eastern part of this section).

- Sandstone Till (Devonian / Carboniferous) – Covers approximately one quarter of the study area (with large tracts of peat along the western part of this section).

- Limestone Till (Carboniferous) – Covers most of the eastern half of the study area, apart from the far east (with numerous pockets of peat associated with the small lakes on the low-lying ground and areas of bedrock outcrop on the higher ground towards the centre of the area).

- Sandstone and Shale Till (Lower Palaeozoic) – Covers the eastern 2 km of the study area (with pockets of peat and lacustrine deposits)

The type of parent material plays a critical role in providing the particles that create different subsoil permeability with sandstones giving rise to a high proportion of sand sized grains in the till matrix, clean limestones providing a relatively high proportion of silt, while shales, shaly limestones and mudstones break down to the finer clay sized particles (GSI, 2003b).

3.1.2.2 Peat

Deposition of peat occurred in post-glacial periods associated with the start of warmer and wetter climatic conditions. Peat is an unconsolidated brown to black organic material comprising a mixture of decomposed and undecomposed plant matter that accumulated in a waterlogged environment. Peat has an extremely high water content averaging over 90% by volume (GSI, 2003b).

There are three main types of peat deposits:

- Blanket Bog – Comprising a carpet of flat, sloped or undulating peat over a large area of land that is recharged by rainfall (in areas with >1,200 mm annually). The type is subdivided into lowland blanket bogs (below 200 m aOD) and mountain blanket bogs (above 200 m aOD). Soil is acidic (approximate pH of 4.2) and is usually between 2 to 6 m deep.

- Raised Bog – Comprising dome shaped bogs that have developed in former lake basins (on top of fens), and recharged by rainfall (in areas with an annual rainfall usually between 800 and 900 mm). Soil is acidic (approximate pH of 3.5) and is usually up to 12 m deep. Most notable areas within the study area include Cloonshanville Bog and Bellanagare Bog (which also contains some features characteristic of blanket bogs).

- Fens – Comprising flat bogs that are found around lake margins and in waterlogged areas where there is a supply of mineral rich groundwater. They develop into raised bogs when the supply of mineral rich water is cut off. Soil is alkaline (approximate pH of 7 to 8) and is usually up to 2 m deep.

3.1.2.3 Alluvium

Alluvial sediments have been deposited by rivers and include unconsolidated materials of all grain sizes, from coarse gravel down to finer silts and clays, and may contain organic detritus. The deposits are usually bedded, consisting of many complex strata of waterlain material. Most of the alluvium deposits in the County comprise sand, silt and clay, with occasional gravel (GSI, 2003b).

3.1.2.4 Lake deposits

Lake or lacustrine deposits were formed in the quiet waters of lakes formed by the melting glacier waters. They typically consist of silty and clayey material, similar to the finer type of alluvium (GSI, 2003b). Only a few small areas of these deposits are mapped within the County.

3.1.2.5 Sands and gravels

Deposition of sands and gravel takes place mainly when glaciers are melting, which gives rise to large volumes of meltwater with great erosive and transporting power. The subsoils deposited in this environment are primarily well rounded gravel and sand, with the finer fractions of clay and silt washed out (GSI, 2003b). County Roscommon has few extensive deposits and most of the larger areas are usually widely quarried. The presence of sand and gravel deposits is reflected in the topography with the following common features:

- Outwash deposits – These take the form of fans of stream debris dropped at the glacier front via drainage channels. Hummocks (kames) and hollows (kettle holes) are present.

- Deltaic deposits – These are similar to the outwash ones, but are formed where drainage channels discharge into a standing body of water.

- Esker deposits – Deposits that remain in the drainage channels, forming straight or meandering ridges depending on the associated river feature, after the ice has retreated.

3.1.2.6 Made Ground

Made Ground is present associated with the urban centres throughout the study area.

3.2 Subsoils in route corridors

3.2.1 Corridor 1

From the western tie in to the R361 soils are classified as wet Gleys described as deep poorly drained mineral soils derived from mainly con-calcareous parent materials. These are underlain by sandstone and shale till. Due to the high water content in the Gley material it would require special engineering treatment to render them acceptable as general earthwork fill.

The corridor runs eastwards from the R361 along the southern edge of Cloonshanville Bog a NHA and SAC designated site to the Owennaforeesha River. The subsoil is predominantly classified as fen peat. The peat would require excavating and replacing with suitable fill or other special measures depending on the depth encountered.

Continuing east from the Owennaforeesha River the subsoil is predominantly classified as fen peat with a small section of sandstone and shale near the LP1215 road. The peat areas would require removal and the Gley soil overlying the till would require special treatment prior to reuse.

From the LP1215 road to the R369 subsoils are predominantly classified as sandstone and shale till with small areas of fen peat near the R369 to the east. The soils would require special engineering treatment to render them acceptable as general earthwork fill due to their high water content.

Between the R369 and the N61 the sandstone and shale till continues through the western half with limestone till mapped in the eastern half. Based on the wet nature of the Gley soils present, special engineering treatment would be required to render them acceptable as general earthwork fill.

The limestone till material continues east to the R368 at Lugboy, interspersed fingers of fen peat associated with the lakes south of the corridor. Based on the wet nature of the Gley soils present, special engineering treatment would be required to render them acceptable as general earthwork fill.

Turning southeast to the LP1405 the corridor remains on the limestone till however numerous pockets, some significant in area of rock outcrop are present including several karstic features that have mapped in the area. The Grey Brown Podzolics mapped along this section would have a higher acceptance for reuse as general fill.

The remainder of the corridor is underlain by predominantly limestone till interspersed with fingers of fen peat and lacustrine deposits associated with the Scramoge River. Some sandstone and shale till is present at the tie-in. The Gley material derived from sandstone till is drier and the material would be generally acceptable for general fill.

3.2.2 Corridor 1A

From the western tie-in to Turlaghnamaddy Townland the subsoil is predominantly sandstone and shale till with fen peat to the east of this and the R361. Based on the wet nature of the Gley soils present overlying the tills, special engineering treatment would be required to render them acceptable as general earthwork fill. Areas of peat would require excavation and removal.

East of the R361 the subsoil is classified as peat, associated with Bellanagare Bog. The peat material would require excavating and replacing with suitable fill or other special measures depending on the depth encountered.

From the existing N5 north of Bellanagare the subsoil is primarily sandstone and shale till west of the Local Secondary Road LS5641 and fen peat to the east of this minor road. Treatment measures on the Gleys overlying the till subsoil and excavation of the peat would be required to render the area suitable for development.

The section of corridor between the Owennaforeesha River and the LP1215 road is underlain by sandstone and shale till with some dispersed pockets of fen peat. The wet Gleys overlying the till and areas of peat would need to be treated and / or removed prior to development.

Similar sandstone and shale till with small areas of fen peat continues to the east and the R369. As for the previous sections any Gley material on the tills would be unsuitable for reuse and would require special treatment, and the areas of peat would need to be excavated and other fill imported.

The remainder of the corridor is the same as Option 1.

3.2.3 Corridor 2

Between the western tie-in and the Owennaforeesha River the subsoils within the corridor are the same as Option 1A.

From the Owennaforeesha River to the R369 the subsoils are classified predominantly sandstone and shale till with some dispersed pockets of fen peat.

Continuing to the southeast and the LP1419 the subsoil is classified as sandstone and shale till in the western half, and limestone till in the eastern half.

Subsoil between the LP1419 in Flaskagh Beg and the existing N5 at Ardkeenagh is predominantly limestone till at both ends of the section with the middle section around the N61 classified as fen peat.

The limestone till extends to the east along the existing N5 to Ardakillin, and includes a small finger of fen peat that crossed the corridor west of the LP1422.

From Ardakillin to the R368 in Strokestown the corridor is underlain by limestone till with significant areas of fen peat between Cloonfree Lough (to the north) and Fin Louth (to the south) and surrounding the watercourse serving Ardakillin Lough and an area centred on the R368.

The remaining section to the eastern tie-in is classified as ranging from limestone till in the western part to sandstone and shale till in the east, including an area of lacustrine deposits in between.

Throughout the corridor, wet Gleys are present overlying the till and these would require special treatment to render them suitable, and the areas of peat would require excavation and backfilling with more suitable fill material.

3.2.4 Corridor 2A

From the western tie-in to the R361 the subsoils are classified as predominantly sandstone and shale to the west of the LS5629 and fen peat east of this road.

Between the R361 and the Owennaforeesha River the subsoils are the same as Option 1A.

Between the Owennaforeesha River and the eastern tie-in the subsoils are the same as Option 2.

Any wet Gleys that are present overlying the till along the corridor would require special treatment to render them suitable, and the areas of peat would require excavation and backfilling with more suitable fill material.

3.2.5 Corridor 2B

From the western tie-in to the Owennaforeesha River the subsoils are the same as Option 1A.

Between the Owennaforeesha River and the LP1419 at Flaskagh Beg the subsoils are the same as Option 2.

Heading south from the LP1419 to the N61 the subsoil is divided along the section with limestone till on the higher north western part and fen peat on the lower south eastern portion.

From the N61 to the existing N5 at Ardakillin the subsoils are classified as limestone till on the higher ground and fen peat along the low ground.

The remaining section from Ardakillin to the eastern tie-in is the same as Option 2.

Any wet Gleys that are present overlying the till along the corridor would require special treatment to render them suitable, and the areas of peat would require excavation and backfilling with more suitable fill material.

3.2.6 Corridor 3

The section of the existing N5 from the western tie-in to Frenckpark is underlain by sandstone and shale till, with a skirting area of fen pet from Turlaghnamaddy eastwards to the R361.

Between Frenchpark and Bellanagare the subsoil is predominantly sandstone and shale till.

The western two thirds of the section between Bellanagare and Tulsk is mapped as sandstone till, followed by limestone till along the eastern two thirds. A superimposed drumlin listed as a site of geological heritage (IGH7) borders the corridor to the northwest of Tulsk. Any excavation work in this area would offer an opportunity for the geological profession to examine and study the stratigraphy of such features.

Continuing east from Tulsk to Strokestown the subsoils are classified as predominantly sandstone till. Another superimposed drumlin is located just south of Strokestown.

The final section of this corridor option is on sandstone till.

Any wet Gleys that are present overlying the till along the corridor would require special treatment to render them suitable, and the areas of peat would require excavation and backfilling with more suitable fill material.

3.2.7 Corridor 4

From the western tie-in to Turlaghnamaddy Townland the subsoil is predominantly sandstone and shale till with fen peat to the east of this and the R361.

Between the R361 and the Owennaforeesha River the subsoils are predominantly fen peat apart from a finger of sandstone till between Knockroe and the LP1221 at the river.

Continuing towards the east from the Owennaforeesha River to the LP1219 the ground is mostly fen peat on the northern portion with a finger of sandstone till along the LP1220, and predominantly sandstone till along the south-eastern portion.

From the LP1219 to the R367 the subsoil is classified as predominantly sandstone till throughout the section.

The sandstone till unit continues to the N61 and for a short distance further northeast.

A mixture of sandstone till and fen peat associated with surface water streams and small lakes is mapped between the N61 and the N5 at Ardakillin.

The remainder of the section to the eastern tie-in is the same as Option 2.

Any wet Gleys that are present overlying the till along the corridor would require special treatment to render them suitable, and the areas of peat would require excavation and backfilling with more suitable fill material. The drier Grey Brown Podzolic soils overlying the limestone till associated with the southwest section of the corridor would generally be acceptable for earthworks.

3.3 Occurrence of peat

Road alignments that cross areas of peat can represent significant constraints including:

- Issues related to ecology;
- Difficult / expensive construction methods
- Issues relating to the disposal of excavated peaty material; and
- Issues relating to health and safety during construction.

It is therefore preferable to have the route traversing as little peat as possible, particularly where the depth of the peat increases.

The occurrence of peat deposits within each corridor option has been assessed using the Teagasc subsoil maps for the area, to calculate the centreline length of each route that traverses peat. An average depth of peat has been estimated based on the preliminary site investigation probing data. Table 3.1 summarises the results as calculated by the Roscommon NRDO.

Route	1	1A	2	2A	2B	3	4
Length (m)	7,832	7,983	8,917	8,533	8,505	896	10,422
Depth (m)	8.69	5.46	7.62	7.60	6.15	7.56	4.71
Volume of peat (m3)	68,062	43,605	68,015	64,891	52,366	6,777	49,060
Order of preference	7th	2nd	6th	5th	4th	1st	3rd

Table 3.1: *Estimation of volume of peat underlying each centreline alignment in each route corridor*

It must be noted that at this stage of Route Corridor Selection each corridor has a wide width which will potentially allow for lateral movement of the alignment later on to avoid potential soft ground conditions. It is also noted that the order of preference can only be used for general guidance as the various corridors vary greatly in width and cannot therefore be accurately compared to each other.

3.4 Bedrock geology

3.4.1 Overview of bedrock geology

Geological maps from the GSI were reviewed to obtain details on the bedrock geology within the study area, and more specifically underlying each corridor. Three main units have been identified: Undifferentiated Visean Limestones; the Boyle Sandstone Formation; and the Fearnaght Formation.

3.4.1.1 Undifferentiated Visean Limestones

The bedrock geology in the study area is predominantly (approximately 90.32%) Lower Carboniferous (Dinantian) Pure Bedded Limestone comprising Undifferentiated Visean Limestones.

These limestones are categorised as undifferentiated due to lack of exposure and drilling information. In the study area they are likely to be a combination of clean and muddy limestones equivalent to the Oakport Limestones. Karst features are abundant and widespread in the Visean rocks.

Within the limestones there is a diagenetic lithology of oolitic limestone formation centred around Ballymurray and Cartron. The area extends northwards to the R369, south to Glenballythomas, west to Ballyconboy and east to Flaskagh More.

The formation is classified as a regionally important karst aquifer. The degree of karstification limits the potential to develop groundwater. The rocks have a high 'flashy' throughout, with a large proportion of flow concentrated in conduits. Storage is also low.

The Woodbrook Fault marks the boundary of this unit with the Boyle Sandstone Formation, and the Strokestown Fault the boundary with the Fearnaght Formation.

3.4.1.2 Boyle Sandstone Formation

A lens averaging 2.5 km wide running northwards through the study area (approximately 8.98%) in a line between Castlerea and Bellanagare is classified as Lower Carboniferous (Courceyan) Sandstones comprising the Boyle Sandstone Formation.

This formation rests uncomformably on the Lower(?) Devonian Keadew Formation, and consists of poorly-bedded conglomerates, associated with purple pebbly coarse-grained sandstones at its base. It then grades upwards into a cyclic sequence with pale grey, sometimes pink coloured, sandstones capped by intervals of red, green and grey mudrocks with caliche carbonate nodules. These are overlain by laminated black pyretic mudstones with thin shelly laminae and gypsum beds, interbedded with bioturbated and ripped sandstone. The top of the formation consist of pale grey bioturbated sandstone overlain by a calcareous sandstone with shelly fragments. The shell fragments mark the initiation of the marine transgression which led to the deposition of the overlying Kilbryan Formation.

The Boyle Formation is classified as a locally important aquifer, which is moderately productive in local zones. Possible faults and fractures in the sandstones may lead to reasonable permeability, with muddier rocks likely to be less permeable. The basal and upper beds comprise reasonably competent sandstones, which suggests that faults and fractures will remain relatively open and be able to transmit significant quantities of groundwater.

3.4.1.3 Fearnaght Formation

In the extreme east around Scramoge of the study area (approximately 0.70%) the underlying bedrock is classified as Lower Carboniferous (Courceyan) Sandstones comprising the Fearnaght Formation.

This formation is composed of two very distinct lithofacies associations, normally occurring separately. One is a very widely exposed sequence of yellowish-white quartz pebble conglomerate and subarkose, interpreted as a sequence of braided river deposits. It is composed principally of rounded quartz and quartzite pebbles, with minor amounts of igneous, jasper and chert clasts, in a medium-grained feldspathic sandstone matrix. It

is generally massive, although it locally defines graded units, up to 1m thick, into pebbly and bedded sandstone / subarkose. Lenticular and tabular megaripple cross-bedding is very common in the subarkose and generally indicates a transport direction towards the south or southwest.

The second lithofacies is an areally very restricted, inferred alluvial fan "ORS" facies sequence of dark reddish-brown coloured conglomerate and sandstone. These rocks are massive, non-bedded conglomerates that are very distinctive, being composed almost entirely of reddened greywacke clasts in a medium-grained sandstone matrix.

The Fearnaght Formation is classified as a locally important aquifer, which is generally moderately productive. Groundwater flow is expected to be concentrated in fractures and weathered zones and in the vicinity of fault zones.

3.4.1.4 Oakport and Kilbryan Formations

The extreme western corner of the study area is associated with the Oakport Formation and Kilbryan Formation however the corridor options do not extend onto these units.

The Kilbryan Formation is composed of dark grey, irregular-bedded and nodular-bedded, fine-grained bioclastic limestones, interbedded with dark calcareous fossiliferous shales and minor argillaceous micrites and calcisiltites. Birdseye micrite is developed in the basal beds and gypsum nodules and rosettes in the middle part of the formation. The upper beds are more massive and dolomitised, and contain vugs filled with calcite and possible gypsum. Some beds have chert nodules present. Various fossil macrofauna are also present including corals and brachiopods. The formation is classified as a locally important aquifer, which is moderately productive in local zones. High clay content and shale layers in the formation are likely to restrict groundwater circulation, however where faults are present the permeability is likely to increase, especially in the cleaner limestone beds.

The Oakport Formation is divided into three units. The basal unit is composed of thickly-bedded to massive, pale grey, clean crinoidal calcarenites with occasional dark fine-grained argillaceous limestones. This is overlain by a variable unit of fine- and coarse-grained pelleted and coated 'oolitic' limestones, fenestral and 'cryptalgal' micrites and rare thin shales, with brachiopod bands common near the base. The upper unit is composed of shale-free, massive, pale grey, fine- to medium-grained calcarenites with occasional chert nodules. The formation is classified as a regionally important karst aquifer. The degree of karstification limits the potential to develop groundwater. The rocks have a high 'flashy' throughout, with a large proportion of flow concentrated in conduits. Storage is also low.

3.4.2 Bedrock geology within each route corridor

The bedrock maps published on the GSI website have been used to assess the proportion of the route corridors overlying each type of bedrock. As the mapped unit boundaries need to be confirmed on the ground the calculated percentages are given as approximate.

3.4.2.1 Corridor 1

The corridor starts off on from the western tie-in at Teevnacreeva on Undifferentiated Visean Limestones. Between the Townlands of Cloonshanville and Carrigeenynaghtan it crosses the Boyle Sandstone Formation. The remaining section is predominantly on Undifferentiated Visean Limestones, with small portion along the southern boundary between Mantua and Runnsruag classified as oolitic limestone. The most easterly section from Treanaceeve to the eastern tie-in is on the Fearnaght Formation.

3.4.2.2 Corridor 1A

The corridor starts off in the west on the Undifferentiated Visean Limestones. Between the Townlands of Derreen and Drummin it crosses the Boyle Sandstone Formation. The remaining section is predominantly on

the Undifferentiated Visean Limestones, with small portion along the southern boundary between Mantua and Runnsruag classified as oolitic limestone. The most easterly section from Treanaceeve to the eastern tie-in is on the Fearnaght Formation.

3.4.2.3 Corridor 2

The corridor starts off in the west on the Undifferentiated Visean Limestones. Between the Townlands of Derreen and Drummin it crosses the Boyle Sandstone Formation. The remaining section is predominantly on the Undifferentiated Visean Limestones with small portion of it classified as oolitic limestone between Kilvoy and Flaskagh More. The most easterly section from Treanaceeve to the eastern tie-in is on the Fearnaght Formation.

3.4.2.4 Corridor 2A

The bedrock traversed is similar to Option 2.

3.4.2.5 Corridor 2B

The bedrock traversed is similar to Option 2.

3.4.2.6 Corridor 3

The corridor starts off in the west on the Undifferentiated Visean Limestones. Between the Townlands of Derreen / Keanspark and approximately 0.5 km east of Bellanagare it crosses the Boyle Sandstone Formation. The remaining section is predominantly on the Undifferentiated Visean Limestones with small portion of it classified as oolitic limestone between Moneylea and 1 km south of Rathcroghan Cross Roads. The most easterly section from Treanaceeve to the eastern tie-in is on the Fearnaght Formation.

3.4.2.7 Corridor 4

The bedrock traversed is similar to Option 2 apart from the Boyle Sandstone Formation extending from Derreen to Kilcorkey, rather than Drummin, and no occurrence of oolitic limestone.

3.4.2.8 Bedrock summary

Table 3.2 gives a summary of the relative percentage of three types of bedrock underlying each of the route corridors.

Bedrock Type	1	1A	2	2A	2B	3	4
Undifferentiated Visean Limestones	93.57	88.80	91.96	95.15	91.99	91.12	92.77
Boyle Sandstone Formation	0.81	6.10	0.80	0.40	0.62	0.72	0.72
Fearnaght Formation	5.61	5.06	7.23	4.45	7.39	8.16	6.51

Table 3.2: Summary of p*ercentage of bedrock type traversed by each corridor*

4 Ground Conditions and Karst Features

4.1 Ground conditions

4.1.1 Engineering and geotechnical aspects

4.1.1.1 Unsuitable subsoil material

The major geotechnical challenge for the study area is to deal with soft areas (bogs and wetlands), wet glacial tills / Gleys, deep cuts and high embankment fills if any. Specific engineering actions will be required to ensure complete stability of the infrastructure. The glacial till in the study area is described as wet mineral soils and the behaviour of this material in road earthworks depends critically upon its water content, particularly the relationship with plastic limit (PL) at the time of placement. Tills with high water content would be difficult to transport. High water content would also produce unacceptable pore water pressure in clay tills, which would threaten embankment stability.

Therefore most of the glacial till in the study area would either be unacceptable or require special treatment (drying) to render the material acceptable. It is likely however that a large proportion of the Gley material overlying the glacial tills will be excavated and disposed of during the construction works. This will have potential negative environmental and economic effects in relation to the proposed development.

Using a centreline method for area coverage estimation, the length of each route traversing areas characterised as having Gley subsoils has been calculated by the Roscommon NRDO. The corridor with the shortest length traversing this type of material is considered to be the most preferably (Table 4.1).

Route	1	1A	2	2A	2B	3	4
Length in Gley material (m)	19,374	23,324	29,035	29,222	28,769	21,981	30,133
Order of preference	1st	3rd	5th	6th	4th	2nd	7th

Table 4.1: *Estimation of length of Gley material along the centreline alignment for each corridor*

It must be noted that at this stage of Route Corridor Selection each corridor has a wide width which will potentially allow for lateral movement of the alignment later on to avoid potential unacceptable and unusable subsoil material. It is also noted that the order of preference can only be used for general guidance as the various corridors vary greatly in width and cannot therefore be accurately compared to each other.

Once the preferred route corridor has been selected and a likely alignment available it will be necessary to examine in depth the geotechnical properties of the underlying subsoil.

4.1.1.2 Earthworks analysis

Anticipated earthworks quantities for each route corridor have been estimated by the Roscommon NRDO. The analysis is based on the indicative alignments of the different options, with side slopes designed at a common slope of 2H / 1V. The results are guideline only.

Data was collated from the following sources:

- The depth to bedrock as indicated in the GSI borehole database;
- The depth of soft material as indicated on the Glover Site Investigations probing logs;
- Trial pit logs submitted to the Local Authority as part of planning applications; and

- Guidelines from Teagasc on the methodology for subsoil mapping.

Table 4.2 presents the results as calculated by the Roscommon NRDO.

Route	1	1A	2	2A	2B	3	4
Assumed Rock	677,576	655,527	147,101	331,154	165,380	38,388	47,922
Assumed Suitable	356,831	573,908	857,705	743,853	554,948	485,368	451,927
Total Suitable	1,034,407	1,229,435	1,004,806	1,075,007	720,328	523,756	499,849
Fill Requirement	1,553,875	1,218,330	1,367,487	1,364,750	1,008,093	742,584	979,449
Percentage F/C	66.6%	100.9%	73.5%	78.8%	71.4%	70.5%	51.0%
Import	519,468	-11,105	362,681	289,743	287,765	218,828	479,600
Import x 4	2,077,872	-44,420	1,450,724	1,158,972	1,151,060	875,312	1,918,400
Suitable + Import	3,112,279	1,185,015	2,455,530	2,233,979	1,871,388	1,399,068	2,418,219
Ranking	7th	1st	6th	4th	3rd	2nd	5th

Table 4.2: *Estimation of anticipated earthworks analysis for each corridor*

4.1.2 Topography and land use

4.1.2.1 Corridor 1

The topography along the initial section from the western tie in to the R361 is relatively flat with a slight overall fall from west (90 maOD) to east (80 maOD). Land use is predominantly pasture with some non-irrigated areas and discontinuous urban fabric along the R361.

From the R361 the corridor runs along the southern edge of Cloonshanville Bog a NHA and SAC designated site. Most of the section is characterised by flat boggy / peaty ground with a slight fall towards the Carricknabraher and Owennaforeesha Rivers.

From the Owennaforeesha River the corridor passes through a section of forestry (transitional woodland scrub) and peat bog followed by marginal / peaty pastureland before rising slightly, from 70 maOD at the River to 80 maOD at Brackloon Road.

Eastwards to the R369 the landscape is mainly pastureland interspersed with small pockets of forestry (transitional woodland scrub) in particular at Raheen. Topography is relatively flat (approximately 80 maOD).

The corridor continues through primarily pastureland interspersed with occasional small pockets of forestry to the N61. The topography is relatively flat but includes a number of small drumlins.

From the N61 to R369 the ground is relatively flat at around 60 maOD, apart from near Clooncullaan Lough where it drops to approximately 50 maOD. The area is dominated by pastureland with marshes present northwards from the lake.

Heading southeast from the R368 at Lugboy to the LP1405 (Kilmore Road) the corridor runs along the sides of Cregga, Cuilrevagh (Greywood Hill) and Kiltrustan hills which rise to the east of the section. The topography undulates between approximately 60 and 130 maOD with a fall off to the west and the SAC / NHA designated Lough Annaghmore located approximately 0.8 km west of the corridor. The land is predominantly pastureland, with some natural grassland identified at Dunmurraghoe and non-irrigated land at Lettreen.

The remaining section to the eastern tie-in falls gradually from 70 maOD at the LP1405 to 50 maOD at a small tributary of the Mountain River that cuts across the corridor section. The topography remains relatively flat through pastureland and then into low-lying marshy ground with pockets of bog and forestry particularly in the vicinity of the tributary, and on to the Scramoge River and existing N5. Land principally occupied by agriculture with areas of natural vegetation has been identified between Bumlin and Treanaceeve.

4.1.3 Corridor 1A

The topography along the initial section from the western tie in to the R361 is relatively flat with an overall slight fall in gradient from 90 to 80 maOD across the section, apart from a gradual rise from the south-western boundary of the corridor towards Fairymount Hill. The land is mainly pastureland west of Turlaghnamaddy Townland and a mixture of brad-leaved and coniferous forestry to the east.

From the R361 to the existing N5 the ground is mainly boggy with large areas of coniferous and broad-leaved forestry. The western end of this section is pastureland. Bellanagare Bog is located approximately 400 m to the south, with actively worked areas along the northern boundary.

East from the N5 to the Owennaforeesha River the ground falls gently, crossing pastureland, with transitional woodland scrub near the river.

The topography rises slightly from the Owennaforeesha River at 70 maOD towards the LP1215 road at 80 maOD. The western two thirds of this section is borderline between pastureland and boggy ground, with forestry along the eastern third.

Heading east to the R369 the section is predominantly pastureland with some pockets of transitional woodland scrub.

The remainder of this corridor from the R369 at Cartronagor is the same as Option 1.

4.1.4 Corridor 2

The initial part of this corridor from the western tie-in to the Owennaforeesha River is the same as Option 1A.

From the river the topography rises slightly from 70 maOD to 80 maOD to the R369. Land use is predominantly pastureland with some transitional woodland scrub along the R369.

To the east the landscape is predominantly pastureland apart from the initial 0.5 km which is forestry, and some areas of non-irrigated land. The 'Rathcrohan Plateau' rises gently, approximately perpendicular to the line of the corridor in a south-westerly direction. Topography is relatively flat with a gentle rise from the R369 at 80 maOD to approximately 90 maOD in the Townland of Catron before falling again towards the LP1419 at Flaskagh apart from a small hillock.

From the LP1419 to the existing N5 at Ardkeenagh the topography varies between undulating pastureland at either end of the section and a significant section of low-lying boggy ground (land principally occupied by agriculture with areas of natural vegetation) centred around the N61. The topography of the western part skirts along the eastern slopes of Camoge Hill (70 to90 maOD) before dropping to the boggy areas at the N61 (60 maOD) and then rising to approximately 65 maOD at Corbally Lough. Marshland is associated with this turlough.

The corridor follows the exsiting N5 from Ardkeenagh to Ardakillin falling gently from approximately 65 to 60 maOD at the LP1422 and then remaining relatively flat along boggy ground for the remainder of the section.

Land is mainly pasture with some non-irrigated land around Cloonfree and marshland is associated with Ardakillin Lough to the south.

From the N5 at Ardakillin to the R368 south of Strokestown, the topography is predominantly flat apart from a small hillock in the Townland of Lisnahirka with some transitional woodland scrub to the west. The corridor passes along the northern slopes of this hillock before passing between Cloonfree Lough (to the north) and Fin Louth (to the south) which are linked by a small channel. Land use is predominantly pastureland apart from boggy ground between the lakes identified as marsh and around the R368. The marshy ground between the two lakes (approximately 0.5 km) which is traversed by the corridor is subject to flooding and appears to be poorly drained. The topography is generally flat at around 60 maOD apart from 66 maOD at the hillock in Lisnahirka and the area around the R368 where it drops gently to approximately 50 maOD.

The ground in the remaining section of the corridor rises gently from 50 to 60 maOD at the N5 in Farnbeg and then falls gently back to 50 maOD at the junction with the LP1425 road. The last part to the eastern tie-in is relatively flat. The area is mainly pastureland with some land principally occupied by agriculture with areas of natural vegetation located around Castlenode.

4.1.5 Corridor 2A

From the western tie-in to the R361, the topography rises from 90 maOD up to the lower reaches of Fairymount Hill at approximately 105 maOD before falling gradually back to 80 maOD at the R361 road. Land usage is mainly pastureland in the western part and forestry in the eastern section.

From the R361 to the eastern tie-in the corridor is the same as Option 1A.

4.1.6 Corridor 2B

From the western tie-in to the LP1419 at Flaskagh Beg the corridor is the same as Option 1A.

South of Flaskagh Beg the topography varies from undulating pastureland on the higher ground along the eastern slopes of Camoge Hill (70 to 90 maOD) before descending to low-lying boggy land approaching the N61.

From the N61 to Ardakillin the topography is initially undulating pastureland to Steill, where it falls to low-lying peaty / boggy ground. It gradually climbs up onto more pastureland at Derryquirk Hillock (approximately 70 maOD) before falling back down to boggy land on the eastern side of the hillock (approximately 55 maOD). Natural grassland is identified between Derryquirk and Corragarve. The ground begins to rise again to Correagh Hillock (approximately 65 maOD) and again falling on the far side of the hillock to peaty land around Bloomfield (approximately 55 maOD).

The remainder of the corridor from the N5 northeast of Ardakillin to the eastern tie-in is the same as Option 2.

4.1.7 Corridor 3

Topography along the existing N5 rises gradually eastwards to higher ground between Gortnagoyne and Carrowntoosan. The eastern half falls gradually towards the eastern tie-in, traversing a low-lying landscape of low drumlins and small lakes. Superimposed drumlins listed as a site of geological heritage are located at Tulsk and Strokestown.

The corridor runs through mostly pastureland with areas of discontinuous urban fabric associated with the towns of Frenchpark, Bellanagare, Tulsk and Strokestown. A small pocket of marshland is associated with Corbally Lough, and there are some isolated areas of forestry. The eastern part of the corridor from Strokestown is poorly drained with the section between Bumlin and Treanaceeve identified as land principally occupied by agriculture with areas of natural vegetation.

4.1.8 Corridor 4

The initial section of the corridor from the western tie-in to the R361 is the same as Option 1A.

From the R361 to the Owennaforeesha River the topography is relatively flat across the initial boggy ground, rising eastwards away from the Carricknabraher (80 maOD) up a rise to Bellanagare Bog peaking at Knockroe hillock (110 maOD) before falling back towards the Owennaforeesha River at 80 maOD. There are large areas of coniferous and broad-leaved forestry present with the western end of this section in pastureland.

From the Owennaforeesha River the topography shows a general and gentle rise in elevation away from the river (80 maOD) to the peak of Rathmoyle Hill (140 maOD) and then gradually falls to approximately 130 maOD at the LP1219. Land usage varies from pastureland in the vicinity of the roads to boggy lands at the western section in Mountdruid and Killaster Townlands. There are also large areas of forestry along the slopes of Ballyglass / Rathkineely Hill.

South from the LP1219 the topography is relatively level at between 125 and 130 maOD, with a gradual fall in the south east to approximately 110 maOD at the R367. At the south eastern part of this section before the R367, the ground falls away from the corridor towards the SAC and pNHA designated Mullygollan Turlough and similarly to the south towards the pNHA Castleplunkett Turlough. Land usage is mainly pastureland with isolated pockets of forestry

The corridor runs southeast from the R367 through the pNHA designated Brierfield Lough, with the northern part of the lake and an approximately 1.8 km length of possible floodplain within the corridor. Topography is relatively flat along the first third at approximately 100 maOD, before rising slightly across the Carnfree 'Plateau' at approximately 120 maOD. It fails back then to 75 maOD at the N61 in Manor Townland. Land usage is mainly pastureland with coniferous forestry at Slevin east of the R367, some non-irrigated land between Lismurtagh, Ballaghabawmore and Dooneen, as well as natural grassland around Brierfield Lough.

Topography falls gradually from the N61 to Ballydaly and then remains relatively flat. The land is mostly pastureland becoming increasingly poorly drained and boggy on the approach to the N5 as it crosses the river channels present in the area. The section through Ballydaly is identified as land principally occupied by agriculture with areas of natural vegetation.

From the existing N5 at Ardakillin to the eastern tie-in the corridor is the same as Option 2.

4.2 Karst

4.2.1 Karst landscape

Karst is a term used to describe the distinctive landforms that develop on rock types that are readily dissolved by water. In Ireland, limestone (composed of calcium carbonate) and to a lesser extent dolomite (calcium and magnesium carbonate) are by far the most widespread rocks that show karst features. Typically, karst regions lack rivers and other surface waters because the rain is swallowed up by fissures and conduits in the rock and then flows as underground streams in caves. Eventually the waters return to the land surface, often as large springs. Karst areas are indicated by a general absence of permanent surface streams and the presence of swallow holes and enclosed depressions. The water is usually all underground in solutionally enlarged channels, some of which are big enough to be termed caves (GSI, 2002).

Thus a mature karst landscape is devoid of surface water, and the surface may be pitted with deep hollows, conical or saucer shaped, and sometimes hundreds of metres deep and several kilometres in diameter.

These dolines (small to medium sized enclosed depressions) act as funnels, collecting rainwater and leading it underground into cave systems.

4.2.2 Formation of karst features

Rain water, slightly acidic (carbonic acid) readily dissolves limestone rock. As it infiltrates through soil material it becomes more acidic increasing the capability to dissolve a greater quantity of rock. The water trickles down through cracks in the limestone, progressively enlarging them, which allows a greater quantity of water to enter forming fissures. In time, the fissures are sufficiently enlarged to engulf all rainwater within moments of its falling. In some areas, rivers which rise on non-limestone rocks flow on to the limestone and sink underground in swallow holes. Underground, the waters from fissures unite to form small streams and these in turn join and excavate correspondingly large conduits. Conduits accessible to humans are termed caves. At some point the underground waters return to the surface as springs, except where local geological conditions may cause the waters to emerge from the sea bed some distance off-shore. Caves and karst fissures are common at shallow depths beneath the ground surface but they are also known to exist at great depths (GSI, 2002).

4.2.3 Implications for road schemes

Karst regions may provide particular problems for engineering works associated with major road and bridge construction. These problems mainly arise from the unpredictable occurrence, extent and depth of underground cavities which may lead to subsequent road subsidence and inadequate foundation support for bridge structures.

An important feature of karst areas is the absence of surface water which often leads to groundwater being the main source of supply (GSI, 2002). The presence of private well supplies in the vicinity of the road development is therefore important regarding potential impacts to water quantity and in particular to the quality of the water that has an increased vulnerability to contamination.

4.2.4 Karst in study area

Karstification is widespread in the Undifferentiated Visean Limestones. Current records of karst features are considered to represent only a fraction of existing features. Higher topographic areas are frequently devoid of surface water streams, as water is drained through karst features, including numerous areas of large clusters of features. Several seasonal lakes / turloughs are noted especially in the south of the area resulting from the up-welling of groundwater through springs and estavelles as the groundwater table rises in winter.

Apart from the scattered occurrences of features present in particular enclosed depressions, swallow holes and springs, there are eight cluster areas that are of relevance to the locations of the route corridor options. The most important one for this study is the area located in the Undifferentiated Visean Limestones south of Frenchpark in Leggatinty, to the west of the Boyle Sandstone Formation.

4.2.4.1 Leggatinty

This area is of particular interest in that all route corridor options apart from Option 1 pass through it. The designated Bellangare Bog is located to the southwest with surface water drainage from the bog flowing through a number of small channels across the route corridors and discharging underground into karst features in Leggatinty. Mapped features comprise five enclosed depressions, five swallow holes, two caves (Pollnagran Cave (grid reference 173520, 289698) and Pollbaun Cave (grid reference 173450, 289700)), one spring (Cloonshanville Spring (grid reference 174008, 290285)) and one dry valley. A review of aerial photography indicates that there are likely to be further features present.

A large proportion of surface water runoff and seepage from the nearby area of the bog and the ground underneath the corridor footprints appears to flow into Pollnagran Cave and to a lesser extent into Pollbaun Cave. The stream flowing into Pollnagran Cave has not been known to dry out despite its very limited

catchment area of afforested bogland, and the stream flowing into Pollbaun is active in all but drought conditions. Tracer tests carried out in this area by the GSI in September 2004 found a link between the two Caves and Cloonshanville Spring 780 m to the northeast, with a flow rate of 110 m/hr measured during dry conditions.

During site visits by Hydro Environmental Ltd on the 25th of August and 16th of September, 2009 the water discharging from the spring was noted to be very peaty and brown, being similar to the surface water run-off in the channels draining from Bellangare Bog.

A detailed report of the caves in the area has been published (Hickey & Drew, 2003). This report details the cave system that has been explored from the cave entrance to the spring, with a summary as given below.

The system is entered through Pollnagran Cave. After about 10 m a passage from the west (left) is encountered. This can be followed for 25 m upstream to a junction where the Pollbaun inlet flows into the passageway from the east (right). This passage is blocked by stone after 4 m but the flow has been traced to the inlet 100 m away. The main passage at the junction (right) proceeds to the south underneath the route corridors in this area and is blocked after 15 m. The source of water within it is unknown but is understood not to originate from the two other swallow holes present in the area to the west. The cave system is therefore likely to extend further south under the corridor section and beneath Bellanagare Bog.

Returning to the main cave section that runs for approximately 50 m due north the passage enlarges to 2 m wide by 0.8 m in height. Thereafter it runs northeast to the emergence with a cross section that is predominantly a vadose (unsaturated zone) trench about 2.4 m in height with an enlarged bedding plane varying from 3 to 4 m wide at floor level, forming an inverted 'T' or a 'L' depending on the location of the vadose trench. The trench is relatively straight over the length of the cave system whereas the bedding plane meanders sharply over much of the length. Dry ox-bows are also present and sections of roof breakdown. Before the emergence at Cloonshanville Spring a small passageway (1 by 0.6 m) enters from the southeast (right). The water in this was heavily contaminated by sewage and the passage was not explored further than 5 m.

The collapse zones identified in the system seem to be related to shallow dolines / enclosed depressions on the landscape, and it is therefore thought that along its course the cave can be no more than a few metres below ground surface.

The cave system is developed in the undifferentiated Visean limestone which is generally clean, medium to coarse grained and well bedded. Chert is evident in the passage walls in the northern reaches of the system. The bedrock dips slightly to the north by 2 to 3 degrees with the cave following a single bedding plane along the dip and to a lesser extent along the strike eastwards. The vadose trench is developed mainly in the north northeast to south southwest joint set and to a lesser degree in the east to west joint set.

Scalloping along the lower metre of the passage wall is common, with the average scallop diameter varying from 3 to 4 cm, which indicates fast flowing water. Further northwards the scallop size appears to decrease, suggesting an increase in flow velocity.

The cave has had a complex history, and although flow initially occurred along the bedding plane, the dominant conduit development took place through the vadose trench, until the bedding plane was enlarged along the floor of the passageway.

The cave has been largely filled with cobbles of sandstone and limestone, presumably reworked till. Flowstone deposits and sand and silt infilling is common towards the northern end of the system. During the investigation of the cave system in 2003, the stream following into the Pollnagran Cave was seen to be

eroding the infill within the main passageway indicating a sufficient capacity to move the coarse bed load. The smaller passageways near the entrance to the cave still retained intact infill indicating lower flows.

The lack of allogenic streams sinking at the contact with limestone has limited the potential for the development of active stream caves, and in this respect Pollnagran is an exception (Hickey & Drew, 2003).

4.2.4.2 Frenchpark

Karst features comprising the Pollnagollum Cave (grid reference 173030, 291120), two enclosed depressions and a swallow hole are located in Corskeagh, just southwest of Frenckpark. These are located south of Corridor Option 3.

Pollnagollum Cave and associated doline / enclosed depression are located approximately 150 m south of the existing N5, behind the primary school. The doline is a large collapse feature with vertical bedrock walls 4 to 5 m deep. It is approximately 7 m long by 4.5 m wide. A number of small rifts are located at the base of the southern side. These are too small to enter however the main cave approximately 2 m above the floor of the collapsed area has been explored (Hickey & Drew, 2003).

A small stream emerges from the cave entrance and flows into the base of the collapsed feature before disappearing underground through one of the smaller rifts. This stream was noted to be heavily contaminated with sewage.

The entrance to the cave is small, approximately 1 m high by 0.3 m wide through a vertical joint. The passage extends for 2 m westwards and then turns to the north (right), possibly back on itself after another 1 m. Further investigation was not possible as a large flowstone blocked the passage.

4.2.4.3 Carrowreagh and Moneylea

There are two locations on either side of Option 3 between Bellangare and Tulsk that are significant for the number of features present. In Carrowreagh to the north of the N5 there are at least twenty three enclosed depressions and sixteen swallow holes mapped in a corridor approximately 1km long running parallel to the road. And in Moneylea in a corridor approximately 800 m long to the south of the N5 there are at least forty two enclosed depressions, thirteen swallow holes and one dry valley mapped. This whole area is likely to be a main recharge zone for the aquifer.

Oweynagat Cave is located further south from these areas in Glenballythomas. This is off more importance archaeologically and of ancient legendary significance rather than to karstic interest. It is located approximately 850 m southwest of Option 3.

4.2.4.4 Ballymurry to Carrowntoosan and Tulsk to Cloonquin

There is a north – south line of at least fourteen springs mapped between Ballymurray and Carrowntoosan. Further springs to the east along the N61 between Tulsk and Cloonyquin are also present. It is possible that groundwater collected from the higher ground to the west is discharging to these springs and on to the numerous surface water channels and lakes further east.

4.2.4.5 Kilvoy

The Townland of Kilvoy has a large number of mapped karst features present including at least ten enclosed depressions, twelve swallow holes, two springs and one dry valley. These are of relevance to Options 1A, 2, 2A and 2B.

4.2.4.6 Ballyglass

A cluster of at least ten enclosed depressions and thirteen swallow holes has been mapped in Ballyglass, 3.7 km south of Bellanagare. The area is between 60 and 700 m east of Option 4. Recharged groundwater is likely to flow westwards towards the Owennaforeesha River and northwards towards two springs in Mountdruid and Gortmagoyne.

4.2.4.7 Lissalway

Karst mapping undertaken by the GSI in 2000 identified an unusually large number of features east of Castlerea. The mapping particularly highlighted the density of dolines and swallow holes and the alignment of these features, i.e. two lines of densely packed dolines and swallow holes were noted trending northwest to southeast. This cluster of features extends a short distance into the study area at Lissalway, with at least twenty two enclosed depressions, two swallow holes and one area of superficial solution feature at this location.

Tracer tests by the GSI have established underground flow paths away from this part of study area to the south west, flowing from Lissalway Swallow Hole (grid reference 173970, 279560) to Silver Island Spring, Corans Spring and Poolnacurragh Spring.

4.2.4.8 Knockalegan East

Further east in Knockalegan East tracer tests have established links from the Knockalegan East Swallow Hole (grid reference 175730, 278050) to St. Elvia's Spring and St. Luke's Well both to the northeast and just west of Option 4.

4.2.5 Summary of karst features within route corridors

Table 4.3 provides a summary of the occurrences of karst features listed on the GSI karst database within the route corridor options. Features just outside the corridor boundaries have not been included at this stage but should be investigated once the preferred corridor has been selected and the alignment known.

Route	1	1A	2	2A	2B	3	4
Springs	1	1	10	10	8	3	4
Swallow Holes	0	10	13	13	13	2	1
Enclosed Depressions	0	8	5	7	7	3	2
Caves	0	0	0	0	0	0	0
Turloughs	0	0	1	1	0	1	1
Dry Valleys	0	0	1	1	1	1	0
Superficial Solution Features	0	0	0	0	0	0	0
Total number of features	1	19	30	32	29	10	8
Order of preference	1st	4th	6th	7th	5th	3rd	2nd

Table 4.3: *Number of karst features within each route corridor*

It is important to note that there are likely to be further unmapped features present on the ground, as well as underground features. The order of preference listed above is guideline only as major features that are either immediately upgradient or downgradient of the corridor may be impacted subject to whatever alignment is taken through the corridor.

5 Historical Land Use

5.1 General land use within study area

The Corine Landuse database was queried for land use throughout the study area. Information was available for the years 1990, 2000 and 2006. The majority of the area has been classified as 'pastures' with isolated areas of 'peat bogs' and 'transitional woodland scrub'. The peripheral parts of Bellanagare Bog have been historically cut and are still actively worked.

Between 1990 and 2000 the only noticeable land use changes were the increased areas of broad-leaved and coniferous forestry. Between 2000 and 2006 further forestry changes occurred and Tulsk expanded its urban fabric.

6 Economic Geology

6.1 Overview

The GSI Quarry Database and the Quarry Registers for Counties Roscommon, Mayo and Longford were reviewed to identify productive quarries within a reasonable distance of the study area. There were sixteen known operations within 20 km of the study area and a further nine within 30 km of the area. The principal mineral quarried in the region is limestone.

6.2 Economic geology along route corridors

Only one active operation is located within the study area, quarrying limestone. This is Largan Quarries located on the eastern side of Cuilrevagh Hill, to the east of Options 1 and 1A.

7 Geological Heritage

7.1 Natural Heritage

Under European and Irish law, the Department of the Environment, Heritage and Local Government is responsible for the designation of conservation sites in Ireland. The three main types of designation are: Special Area of Conservation (SAC); Special Protection Area (SPA); and Natural Heritage Area (NHA). Sites not fully listed are known as candidate SACs (cSAC) and proposed NHAs (pNHA). A full description of each type has been presented in the Hydrogeological Report for this study.

There are two ecological designated sites within the study area that are relevant to subsoil geology, Cloonshanville and Bellanagare Bogs. The following summary descriptions for each site have been collated from descriptions presented in the NPWS datasheets available from their website and from the Habitats Directive Article 6 Assessment for the Shannon iRBD which covers SACs.

7.1.1 Bellanagare Bog

Bellanagare Bog (site code 000592) is a raised bog that is a priority habitat listed on Annex I of the EU Habitat Directive and is listed as a NHA, cSAC and SPA. It is located 6 km northeast of Castlerea and 2 km south of Frenchpark (grid reference to central area 171400, 286700) and extends approximately 6 km north-south and 2.5 km east-west at the central point. Covering an approximate area of 1207.6 hectares, approximately 52% is identified as 'degraded raised bog still capable of natural regeneration' (habitat code 7110), 9% as 'active raised bog' (habitat code 7110), and 1% of depressions on peat substrates of the Rhynchosporion (habitat code 7150).

The bog is underlain by muddy Carboniferous limestone with a low permeability, and the subsoil is identified as predominantly clayey limestone till. It lies in an upland area at the top of a surface catchment divide. The surface is undulating with the peat concentrated on ridges and flushes occurring in between these. Flush types include an in-filling lake, an extensive Purple Moor-grass (*Molinia caerulea*) flush with a high diversity of plant species, a large swallow-hole flush and flushes associated with springs, rises and streams. One flush is coincident with a bog burst. Well developed hummocks and several quaking areas occur in some sections.

A number of streams including the Frances River rise on the site. The area is vulnerable to water loss through the extensive drain network in its northern half and from turf cutting, which occurs in places all around the site. Because it is also quite a dry bog it is very vulnerable to burning. A large section of the site is in state ownership, and the area is traversed by several tracks used by private owners still engaged in active turf cutting.

The bog is unusual in that it supports plant species typically found on raised bogs as well as species more usually found on blanket bogs. For this reason it is classified as a western, or intermediate raised bog. It is also notable for its range of standing water habitats which include an in-filling lake, an extensive Purple Moor Grass area with a high diversity of plant species, a large swallow hole, springs, rises and streams. Among the other habitat types present are cutaway bog, small areas of heath, scrub, wet grassland and several small conifer plantations. The site provides habitat for a relatively large population of Red Grouse.

The Habitats Directive Article 6 Assessment for the Shannon iRBD gives the qualifying feature on this site as an 'active raised bog' (also for supporting a population of Red Grouse). The key environmental conditions to support site integrity are to maintain the Annex I habitats for which the cSAC has been selected at favourable conservation status. The main threats and impacts on the site are peat cutting; drainage and burning;

afforestation; invasive species; grazing; dumping; fertilisation; restructuring agricultural land; communication routes; cultivation; mowing / cutting; modification of inland water structures; and sand and gravel extraction.

7.1.2 Cloonshanville Bog

Cloonshanville Bog (site code 000614) is a raised bog that is a priority habitat listed on Annex I of the EU Habitat Directive and is listed as a NHA and cSAC. It is located approximately 2 km east of Frenchpark bounded along the east by the Breedoge River and the south by the Frenchpark / Elphin road (grid reference to central area 175250, 291500) and extends approximately 1.7 km north-south and 1.6 km east-west at the central point. Covering an approximate area of 225.8 hectares, approximately 63% is identified as 'degraded raised bog still capable of natural regeneration' (habitat code 7110), 21% as 'active raised bog' (habitat code 7110), 6% as 'bog woodland' (habitat code 91D0) and 1% of depressions on peat substrates of the Rhynchosporion (habitat code 7150).

The bog is underlain by low-permeability clayey limestones, and has developed in a shallow basin within a groundwater discharge zone. The regional groundwater table has been lowered, but evidence of groundwater inputs are seen on and around the high bog. Hummock / pool systems have developed in the wettest areas and a large flush area is present in the centre of the bog dome. The main body of the flush supports an extensive area of extremely rare Irish bog woodland. Three areas of coniferous plantation have been included within the site for hydrological reasons.

The Habitats Directive Article 6 Assessment for the Shannon iRBD gives the qualifying feature on this site as 'bog woodland'. The key environmental conditions to support site integrity are to maintain the Annex I habitats for which the cSAC has been selected at favourable conservation status. The main threats and impacts on the site are peat cutting; drainage and burning; afforestation; invasive species; grazing; dumping; fertilisation; restructuring agricultural land; communication routes; cultivation; mowing / cutting; modification of inland water structures; and sand and gravel extraction.

Restoration of the site has taken place as part of the 'Restoring Raised Bog in Ireland", which included the installation of twelve Walrags used to monitor groundwater level fluctuations prior to the work. Groundwater levels were found to be up to 0.5 m below the surface of the bog and adjacent plantations during the summer months. After trees were removed and drains unblocked as part of the restoration, there was a rise in the groundwater table within the plantations and on the high bog, with the levels remaining close to the bog surface throughout most of the year (Derwin, 2008).

7.2 Geological Heritage Programme

The GSI Geological Heritage Programme is in the process of compiling a list of geological / geomorphological sites in need of protection within Ireland. The list of karst and early fossil sites has been completed to date. It is anticipated that some of these would then receive a NHA designation.

To date the GSI has identified twenty potential Geological Heritage sites within County Roscommon, one of which is relevant to the study area. Four superimposed drumlins (IGH7- Quaternary) are located around the Tulsk area. Four superimposed drumlins are located at Tulsk, Strokestown, Lisboy and Cloonbony. The former two locations are within Corridor 3. The GSI has noted that any cut sections through these features will have a positive impact in that it will present a vertical subsoil profile for studying which will enhance the geological understanding of this type of feature.

7.3 Assessment of designated areas

A total of eight designated areas have been identified within the study area, as detailed in the Hydrogeological Report for this study. Most would be primarily assessed from an ecological point of view in relation to the potential impact the route corridors would have on them.

In relation this Soils and Geology Report it is considered that all of the sites still need to be assessed as they rely on the various interactions between the ecological, hydrological, hydrogeological and geological environs.

To assess the potential impact that the route corridor options would have on these designated sites the distance from each corridor to the site has been measured and an accumulative total used to assign an order of preference (Table 7.1). This can only be used for guidance only.

Designated Site	Category			Route Corridors & Distance (km) from Designated Site						
				1	1A	2	2A	2B	3	4
Cloonshanville Bog	NHA	cSAC		0.00	1.87	1.87	1.87	1.87	0.89	1.95
Bellanagare Bog	NHA	cSAC	SPA	0.50	0.50	0.50	0.50	0.50	0.66	0.00
Annaghmore Lough	pNHA	cSAC		0.90	0.90	2.30	2.36	2.36	1.20	2.36
Castleplunkett Turlough	pNHA			10.08	9.60	7.08	7.08	7.24	5.34	1.02
Mullygollan Turlough	pNHA	cSAC		8.20	8.20	4.43	4.43	4.60	3.05	0.60
Brierfield	pNHA			8.96	8.96	4.39	4.39	4.81	3.46	0.00
Corbally Lough	pNHA			6.27	6.27	0.00	0.00	1.00	0.00	1.65
Ardakillin Lough	pNHA			5.80	5.80	0.44	0.44	0.50	0.59	0.44
Total distance (km)				41.43	42.10	21.01	21.07	22.88	15.19	8.02
Corridor rank of preference				2nd	1st	5th	4th	3rd	6th	7th

Notes: Distances have been sourced from data provided by Roscommon NRDO

Table 7.1: *Designated areas within study area and distance to each route corridor*

The superimposed drumlins are not included in the above assessment as they offer positive impacts in that any cut sections through them will provide an opportunity to study them in cross-section.

8 Impact Assessment

8.1 Description of geological impacts

Road projects given their scale and nature have significant potential for causing impact to the soil and geology environment both during their construction and on-going operation and consequently require careful planning and detailed assessment to ensure the best solution is attained.

The attributes and impacts that are assessed for each route corridor include the following:

- Geological heritage site along each route corridor;
- Landfills, backfilled quarries or former industrial sites along each route corridor and the potential risk of encountering contaminated ground;
- The quality, drainage characteristics and range of agricultural uses of soil along each route corridor;
- Pits, quarries or mines in the vicinity of each route corridor, the potential implications (if any) for existing activities and future extractable reserves; and
- The extent of peat and soft ground along each route corridor and the potential requirement to excavate it and remove it off-site as waste for disposal or recovery.

Regarding the assessment of designated geological heritage sites, it is important to note that the management issues usually differ considerably from ecological sites in that some road schemes offer the opportunity to study the substrata exposed in cut sections.

8.2 Assessment criteria

Estimation of the importance of geological attributes is based on criteria for rating site attributes as outlined in the NRA publication '*Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes*', and presented in Table 8.1.

Importance	Criteria
Very High	Attribute has a high quality, significance or value on a regional or national scale Degree or extent of soil contamination is significant on a national or regional scale Volume of peat and / or soft organic soil underlying route is significant on a national or regional scale*
High	Attribute has a high quality, significance or value on a local scale Degree or extent of soil contamination is significant on a local scale Volume of peat and / or soft organic soil underlying route is significant on a local scale*
Medium	Attribute has a medium quality, significance or value on a local scale Degree or extent of soil contamination is moderate on a local scale Volume of peat and / or soft organic soil underlying route is moderate on a local scale*
Low	Attribute has a low quality, significance or value on a local scale

	Degree or extent of soil contamination is minor on a local scale Volume of peat and / or soft organic soil underlying route is small on a local scale*

* relative to the total volume of inert soil disposed of and / or recovered.

Table 8.1: *Criteria for rating site attributes*

The guidelines also define the impact significance level relative to the attribute importance (Table 8.2).

Impact Level	Attribute Importance				
	Extremely High	**Very High**	**High**	**Medium**	**Low**
Profound	Any permanent impact on attribute	Permanent impact on significant proportion of attribute			
Significant	Temporary impact on significant proportion of attribute	Permanent impact on small proportion of attribute	Permanent impact on significant proportion of attribute		
Moderate	Temporary impact on small proportion of attribute	Temporary impact on significant proportion of attribute	Permanent impact on small proportion of attribute	Permanent impact on significant proportion of attribute	
Slight		Temporary impact on small proportion of attribute	Temporary impact on significant proportion of attribute	Permanent impact on small proportion of attribute	Permanent impact on significant proportion of attribute
Imperceptible			Temporary impact on small proportion of attribute	Temporary impact on significant proportion of attribute	Permanent impact on small proportion of attribute

Table 8.2: *Criteria for rating impact significance*

8.3 Impacts associated with each route corridor

8.3.1 Corridor 1

Table 8.3 gives a summary of the key soil and geological attributes that have been identified along the route corridor and their importance within the environment. A description and level of potential impacts that the road scheme would have on the attribute is also given.

Attribute	Attribute Importance	Impact	Level of Impact
Clonshanville Bog	Very high	Partial loss of soil and subsoil material on a cSAC & pNHA site, impacting the reliant ecosystem	Profound
Limestone Bedrock – Cregga	High	Possible partial loss of proven economically extractable mineral resource (close to existing quarry operation), if cut section is required	Moderate
Peat – entire route	Low	Permanent loss of bogland habitats	Imperceptible

where present			
Gley Soils – entire route where present	Low	Possible permanent loss of poorly drained soil if any cut sections are required	Imperceptible

Table 8.3: *Preliminary assessment of geological impacts for Route Corridor 1*

8.3.2 Corridor 1A

Table 8.4 gives a summary of the key geological attributes that have been identified along the route corridor and their importance within the environment. A description and level of potential impacts that the road scheme would have on the attribute is also given.

Attribute	Attribute Importance	Impact	Level of Impact
Limestone Bedrock – Cregga	High	Possible partial loss of proven economically extractable mineral resource (close to existing quarry operation), if cut section is required	Moderate
Pollnagran Cave System	High	Potential collapse and blockage of a unique geological feature in the county	Moderate
Peat – entire route where present	Low	Permanent loss of bogland habitats	Imperceptible
Gley Soils – entire route where present	Low	Possible permanent loss of poorly drained soil if any cut sections are required	Imperceptible

Table 8.4: *Preliminary assessment of geological impacts for Route Corridor 1A*

8.3.3 Corridor 2

Table 8.5 gives a summary of the key geological attributes that have been identified along the route corridor and their importance within the environment. A description and level of potential impacts that the road scheme would have on the attribute is also given.

Attribute	Attribute Importance	Impact	Level of Impact
Pollnagran Cave System	High	Potential collapse and blockage of a unique geological feature in the county	Moderate
Grey Brown Podzolics Soils – Tulsk to Ardakillin	Medium	Possible permanent loss of well drained soil in a karstified area if any cut sections are required	Slight
Peat – entire route where present	Low	Permanent loss of bogland habitats	Imperceptible
Gley Soils – entire route where present	Low	Possible permanent loss of poorly drained soil if any cut sections are required	Imperceptible

Table 8.5: *Preliminary assessment of geological impacts for Route Corridor 2*

8.3.4 Corridor 2A

Table 8.6 gives a summary of the key geological attributes that have been identified along the route corridor and their importance within the environment. A description and level of potential impacts that the road scheme would have on the attribute is also given.

Attribute	Attribute Importance	Impact	Level of Impact

Pollnagran Cave System	High	Potential collapse and blockage of a unique geological feature in the county	Moderate
Grey Brown Podzolics Soils – Tulsk to Ardakillin	Medium	Possible permanent loss of well drained soil in a karstified area if any cut sections are required	Slight
Peat – entire route where present	Low	Permanent loss of bogland habitats	Imperceptible
Gley Soils – entire route where present	Low	Possible permanent loss of poorly drained soil if any cut sections are required	Imperceptible

Table 8.6: *Preliminary assessment of geological impacts for Route Corridor 2A*

8.3.5 Corridor 2B

Table 8.7 gives a summary of the key geological attributes that have been identified along the route corridor and their importance within the environment. A description and level of potential impacts that the road scheme would have on the attribute is also given.

Attribute	Attribute Importance	Impact	Level of Impact
Pollnagran Cave System	High	Potential collapse and blockage of a unique geological feature in the county	Moderate
Grey Brown Podzolics Soils – N61 to N5	Medium	Possible permanent loss of well drained soil in a karstified area if any cut sections are required	Slight
Peat – entire route where present	Low	Permanent loss of bogland habitats	Imperceptible
Gley Soils – entire route where present	Low	Possible permanent loss of poorly drained soil if any cut sections are required	Imperceptible

Table 8.7: *Preliminary assessment of geological impacts for Route Corridor 2B*

8.3.6 Corridor 3

Table 8.8 gives a summary of the key hydrogeological attributes that have been identified along the route corridor and their importance within the environment. A description and level of potential impacts that the road scheme would have on the attribute is also given.

Attribute	Attribute Importance	Impact	Level of Impact
Pollnagran Cave System	High	Potential collapse and blockage of a unique geological feature in the county	Moderate
Grey Brown Podzolics Soils – Tulsk to Ardakillin	Medium	Possible permanent loss of well drained soil in a karstified area if any cut sections required in the existing alignment	Slight
Peat – entire route where present	Low	Permanent loss of bogland habitats	Imperceptible
Gley Soils – entire route where present	Low	Possible permanent loss of poorly drained soil if any cut sections are required	Imperceptible

Table 8.8: *Preliminary assessment of geological impacts for Route Corridor 3*

8.3.7 Corridor 4

Table 8.9 gives a summary of the key geological attributes that have been identified along the route corridor and their importance within the environment. A description and level of potential impacts that the road scheme would have on the attribute is also given.

Attribute	Attribute Importance	Impact	Level of Impact
Bellanagare Bog	Very high	Partial loss of soil and subsoil material on a cSAC & pNHA site, impacting the reliant ecosystem	Significant
Grey Brown Podzolics Soils – R367 to N5 Ardakillin	Medium	Possible permanent loss of well drained soil in a karstified area if section in cut alignment	Slight
Peat – entire route where present	Low	Permanent loss of bogland habitats	Imperceptible
Gley Soils – entire route where present	Low	Possible permanent loss of poorly drained soil if any cut sections are required	Imperceptible

Table 8.9: *Preliminary assessment of geological impacts for Route Corridor 4*

8.4 Environmental mitigation measures

The following generalised mitigation measures should be considered in detail at the Environmental Impact Statement phase of the scheme.

8.4.1 Baseline investigation

Once an EPR Corridor has been selected and an idea known regarding the lateral and vertical alignments, it is recommended that baseline field investigations be carried out in sensitive areas such as designated sites and concentrations of karst features that would be potentially impacted by the route. This work would be necessary for collating baseline data required by the subsequent EIS phase of reporting, to obtain a better understanding of the existing hydrological and hydrogeological interactions prior to any works.

If the EPR Corridor is likely to be one other than Option 1 then it is recommended that a detailed baseline investigation be carried out in Leggatinty to consider if any potential changes to the surface water and groundwater interactions between the northern part of the designated Bellanagare Bog, the Pollnagran Cave system and Clonshanville Spring could have an impact on the underlying geology, in particular the Pollagran Cave system where changes to flow rates throught the passageways could alter the dimensions of the cave, flush out lodged sediments and cause collapse. A profile of water level monitoring should be established linking water levels in the:

- Bellanagare Bog;
- Surface water channels draining north westwards off the bog;
- Discharge points to groundwater at the Leggatinty swallow holes and cave;
- Emergence point at Cloonshanville Spring; and
- Clonshanville River.

This would comprise the installation of staff gauges at the selected locations. The installation of a number of groundwater monitoring piezometers should also be considered. Monitoring work should be carried out over an extended period to obtain seasonal dry weather flows and winter high water levels. Basic water quality testing for field parameters such as pH and conductivity can be included to assess the variations between the acidic surface water and alkaline groundwater, and responses to rainfall events. An option of further tracer tests could be considered possibly in conjunction with the GSI, as well as further exploration of the cave

system to see if any changes have occurred since the last survey in 2003. Possible site access routes during the construction phase should be considered and planed accordingly to avoid heavy traffic over the cave system that would potential cause collapse.

As not all karst features have mapped by the GSI, it is recommended that a detailed survey be carried out on the ground surface to identify all features present that could be impacted or have an impact on the proposed road alignment. A geophysical survey would be recommended to identify any underground features and should at least be carried out in Leggatinty and any of the other highly karstified areas close to the EPR Corridor.

8.4.2 Construction phase

As an impact reduction strategy good environmental practices should be implemented during the construction of the development and including all ancillary areas, such as site compounds. These good environmental practices should be implemented by means of an environmental management plan and the implementation of a pollution incident control plan during construction to ensure that any incidents are dealt with should they occur. It is recommended that no ancillary areas be located within any sensitive areas e.g. where karst features are present at ground surface or near to designated sites, and no refuelling be allowed to reduce potential impacts.

During the design of the final alignment it is recommended that adequate drainage systems be incorporated into any sensitive areas e.g. the karstified area in Leggatinty if a corridor other than Option 1 is chosen, to ensure that the water balance regime associated with the underground cave system is not impacted. The drainage system along the length of road passing any identified karst features should be sealed to capture surface runoff and direct it to suitable discharge points. In the Leggatinty area this could involve channelling it northwards towards the Carricknabraher River rather than allowing it to infiltrate into the nearby groundwater system.

Provision should be made for the protection of exposed soil surfaces from rainfall erosion which would potentially influence groundwater vulnerability by removing the protective layer. Stockpiles and spoil heaps should be located well away from drainage ditches and watercourses.

It is essential to ensure that the use of cement and wet concrete in or close to any of the watercourses or karst features is carefully controlled. Any spillages of hydrocarbons should be immediately contained on site with suitable materials and the contaminated soil / material removed for appropriate disposal.

A large section of the alignment in this area is likely to require fill material to be imported. To reduce impacts on the hydrogeological environment it should be ensured that no contaminants are introduced within the fill. Where soft peaty subsoil is present it may be required to remove it and import fill material, however as the route may pass close to the one of the designated Bellanagare and Cloonshanville Bogs, removal of large volumes of peat may impact on the local water balance and consideration should therefore be given to alternatives such as piling to bedrock.

8.4.3 Operational phase

Appropriate measures should be in place to prevent any surface runoff eroding the adjacent subsoils.

Surface runoff from roads can adversely affect the chemistry of any receiving soils as a result of routine road drainage discharges and accidental spillages. Of particular concern is the impact of the “First Flush” runoff, where accumulated road waste material is washed off from the road surface and drainage system in relatively high concentrations, particularly when this coincides with dry weather flows in nearby streams. High

concentrations of suspended solids could potentially rapidly infiltrate via karst features to the underlying aquifer blocking the conduit flow paths. Properly designed treatment measures can mitigate such water quality impacts.

Accidental spillages are predominantly a function of traffic flows and pavement area draining to the nearest water body. Mitigation measures to prevent serious impact to the surrounding soils can comprise a combination of oil interceptors, storage areas and outlet facilities that can be shut off to capture harmful substances prior to discharge.

9 Comparison of Route Corridors

9.1 Summary of key hydrogeological attributes

A review of the existing environment with regards to geology has been made to select a preferable order of route selection that will minimise the impact on the environment as well as reducing the likely cost implications from mitigation requirements.

Table 9.1 indicates the order of preference for each order based on the most significant geological categories.

Geological Attribute Category	Route Corridor Preferences						
	1	1A	2	2A	2B	3	4
% of peat	7th	2nd	6th	5th	4th	1st	3rd
% of unsuitable material for reuse	1st	3rd	5th	6th	4th	2nd	7th
Earthworks analysis	7th	1st	6th	4th	3rd	2nd	5th
Proximity to designated sites	2nd	1st	5th	4th	3rd	6th	7th
Abundance of known karst features	1st	4th	6th	7th	5th	3rd	2nd
Total Score	18	11	28	26	19	14	24
Order of preference	3rd	1st	7th	6th	4th	2nd	5th

Table 9.1: *Route corridor preferences relevant to geological attributes*

9.2 Summary of geological impacts

As outlined in Section 8.3 an assessment has been made of the likely impact each route will have on the various key geological attribute categories. Table 9.2 gives an order of preference based on the number of occurrences of impact level.

Impact Level	Route Corridors						
	1	1A	2	2A	2B	3	4
Profound	1	0	0	0	0	0	0
Significant	0	0	0	0	0	0	1
Moderate	1	2	1	1	1	1	0
Slight	0	0	1	1	1	1	1
Imperceptible	2	2	2	2	2	2	2
Order of Preference	7th	5th	1st	1st	1st	1st	6th

Table 9.2: *Summary of geological impacts for route corridors*

There is no difference between corridors 2, 2A, 2B and 3. Options 1A and 4 also have a similar impact rating. Options 1 is the least favourable as it traverses part of Cloonshanville Bog.

9.3 Order of geological preference

Considering the number of geological attributes that are located within each corridor (Table 9.1) and the likely level of impact that a route would have on the attribute (Table 9.2) the following order of preference has been derived (Table 9.3) for the proposed routes.

Order of Preference	Corridor Option
1	Route 3
2	Route 1A
3	Route2B
4	Route 2A
5	Route 2
6	Route 4
7	Route 1

Table 9.3: *Geological route corridor preference order*

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11 Glossary

Aquifer: Any stratum or combination of strata that stores or transmits groundwater (Local Government (Water Pollution) Act, 1990). *More commonly:* A permeable geological stratum or formation that stores and transmits water in significant quantities.

Confined Aquifer: An aquifer in which the groundwater is overlain by impermeable geological strata; confined groundwater is generally subject to pressure greater than atmosphere.

Unconfined Aquifer: An aquifer where the water table is exposed to the atmosphere through openings in the overlying material.

Granular Aquifer: An aquifer composed of discrete grains of material (usually sand and/or gravel) in which groundwater flows through the spaces (pores) between the grains (intergranular flow). Such an aquifer is said to have a *primary* porosity and permeability, as contrasted with secondary porosity and permeability which results from fracturing, etc. Flow through a granular aquifer is said to be *intergranular flow.*

Poor Aquifer: An aquifer which is normally capable of yielding only sufficient water from wells or springs to supply single houses, small farms or small group water schemes. These can be sub divided into: Bedrock aquifers which are generally unproductive except for local zones (Pl) and Bedrock aquifers which are generally unproductive (Pu).

Locally Important Aquifer: An aquifer which is moderately productive, i.e. capable of yielding enough water to boreholes or springs to supply villages, small towns or factories. These are divided into: Sand/gravel aquifers (Lg); Bedrock aquifers which are generally moderately productive (Lm); and Bedrock aquifers which are moderately productive only in local zones (Ll).

Regionally Important Aquifer: An aquifer which is sufficiently productive to be able to yield enough water to boreholes or springs to supply major regional water schemes. These are divided into: extensive sand/gravel aquifers (Rg); karst aquifers (Rk); and fissured aquifers (Rf).

Attenuation: The process of diminishing contaminant concentrations in groundwater, due to filtration, biodegradation, dilution, sorption, volatilisation and other processes. The breakdown or dilution of a contaminant in water.

Baseflow: That part of the flow in a stream which is not attributable to direct runoff from precipitation or snowmelt, usually sustained by groundwater discharge. That part of a stream discharge derived from groundwater seeping into the stream.

Calcareous: Composed of, or containing, calcium carbonate.

Catchment: That area determined by topographic features within which falling rain will contribute to run-off at a particular point under consideration.

Cave: A naturally occurring cavity large enough for human access.

Conduit Flow: A characterisation of some types of Karst aquifers, in which flow is concentrated in conduits created by the dissolution of the limestone bedrock.

Contaminant Loading: The amount (volume and concentration) of a contaminant discharged to soil or groundwater.

Contaminant Transport: The transport of a contaminant through topsoil, subsoil or bedrock.

Carboniferous: The geological time period from 355 to 290 million years ago when most limestones were deposited.

Diffuse Flow: A characterisation of some types of Karst aquifers, in which flow is distributed relatively evenly throughout the rock.

Dissolution: A form of chemical weathering in which water molecules, sometimes in combination with acid or another compound in the environment dissolve parts of a mineral or rock.

Doline / Enclosed Depression: A small to medium sized closed depression, a few metres to a few hundred metres in diameter and depth. Dolines are formed by slow, concentrated solutional removal of rock in an area, from the surface downwards, or by the collapse of overlying rock into a cave or chamber beneath (collapse doline). Dolines function as funnels, allowing point recharge of the karstic aquifer.

Downgradient: The direction in which groundwater or surface water flows (also referred to as down-slope). Opposite of upgradient.

Drumlin: A long, egg-shaped hill that develops when pressure from an overriding glacier reshapes a moraine. Drumlins range in height from 5 to 50 meters and in length from 400 to 2000 meters. They slope down in the direction of the ice flow.

Effective Rainfall: The amount of rainfall that will be able to reach the underlying aquifer. It is determined as the actual rainfall, less evapotranspiration and soil moisture deficit.

Ecology: The study of the relationships among organisms and the relationship between them and their physical environment.

Estevelle: A karst feature that can function as a spring or as a swallow hole depending on underground water levels.

Evapotranspiration: Evaporation from a surface covered by vegetation (usually grass). It depends on both meteorological conditions and on the type of vegetation and is also influenced by the soil moisture status. The term evapotranspiration is used to indicate the combined amount of water evaporated from the soil surface and transpired from the soil moisture storage through vegetation.

Fault: A fracture in rock along which there has been relative displacement of the two sides.

Fissure: Natural crack in rock which allows rapid water movement.

Groundwater: That part of the subsurface water that is in the saturated zone, i.e. below the water table.

Groundwater Protection Response: Control measures, conditions or precautions recommended as a response to the acceptability of an activity within a groundwater protection zone.

Groundwater Protection Scheme: A scheme comprising two main components: a land surface zoning map which encompass the hydrogeological elements of risk and a groundwater protection response for different activities.

Groundwater Protection Zone: Zones delineated by integrating aquifer categories or source protection areas and associated vulnerability ratings. The zones are shown on a map, each zone being identified by a code e.g. SO/H (outer source area with a high vulnerability) or Rk/E (regionally important aquifer with an extreme vulnerability). Groundwater protection responses are assigned to these zones for different potentially polluting activities.

Groundwater Source: A source of water supply which depends on groundwater, usually a well (dug well or borehole) or a spring, occasionally an infiltration gallery.

Groundwater Table: The uppermost level of saturation in an aquifer at which the pressure is atmospheric.

Karst: An area of limestone or other highly soluble rock, in which the landforms are of dominantly solutional origin, and in which the drainage is usually underground in solutionally enlarged fissures and conduits.

Karst Feature: Landscape feature which results from karstification (solution of limestone) such as a turlough, swallow hole, cave, etc.

Lacusterine: Pertaining to a lake.

Limestone: A sedimentary rock composed primarily of calcium carbonate. Some 10% to 15% of all sedimentary rocks are limestones. Limestone is usually organic, but it may also be inorganic.

Limestone Pavement: Bare limestone surface from which soil and loose rocks have been stripped – usually by relatively recent ice erosion during a glacial period.

Mudstone: Argillaceous or clay-bearing sedimentary rock which is non-plastic and has a massive non-foliated appearance.

Perched Groundwater Table: When impermeable strata or lenses are present in the subsurface, the volume immediately above the impermeable unit can become saturated as the water is unable to percolate further down into the aquifer. The convex surface that this creates is a perched groundwater table.

Permeability: The ability of a medium to transmit fluids under a potential gradient (units = $L^3/t/L^2$ or L/t). Measure of a soil or rock's capacity to transmit water.

Piezometric Surface: (Potentiometric Surface) The surface representative of the level to which water will rise in a well cased to the impermeable layer above a confined aquifer. In unconfined aquifers, this surface corresponds with the groundwater table.

Potential Evapotranspiration (PE): The term used to describe the process under conditions of unrestricted availability of water at the vegetation surface. In drier conditions, actual evapotranspiration is usually less than

PE. The term potential evapotranspiration (PE) is used when the water supply available to the plant is not limited. If the water supply in the soil is limited, the actual evapotranspiration (AE) will be less than the potential value.

Point (Pollution) Source: Any discernible, confined, or discrete conveyance from which pollutants are or may be discharged, including (but not limited to) pipes, ditches, channels, tunnels, conduits, wells, containers, slatted sheds and animal rearing sheds.

Porosity: The total of all void spaces present within a rock, but not all these spaces will be interconnected and thus able to contain and transmit fluids.

Precipitation: Any form of water, such as rain, snow, sleet, or hail, that falls to the earth's surface.

Recharge: The addition of water to the zone of saturation; also, the amount of water added.

Sandstone: A clastic rock composed of particles that range in diameter from 1/16 millimetre to 2 millimetres in diameter. Sandstones make up about 25% of all sedimentary rocks.

Saturated Zone: The zone below the water table in which all pores and fissures are full of water.

Shale: A rock formed from fine-grained clay-size sediment.

Siltstone: A typically layered and flaggy rock composed of two thirds silt-sized particles.

Source Protection Area (SPA): The catchment area around a groundwater source which contributes water to that source (Zone of Contribution), divided into two areas; the Inner Protection Area (SI) and the Outer Protection Area (SO).

The **SI** is designed to protect the source against the effects of human activities that may have an immediate effect on the source, in particular in relation to microbiological pollution. It is defined by a 100-day time of travel (TOT) from any point below the water table to the source.

The **SO** covers the remainder of the zone of contribution of the groundwater source.

Spring: A flow of water that occurs where the groundwater table intercepts the ground surface.

Storage: The volume of water held within a certain volume of saturated aquifer.

Subsoil: The material between the topsoil and the bedrock.

Swallow Hole: A small steep depression caused in karst topography by the dissolution and collapse of subterranean caverns in carbonate formations.

Till: A glacial sediment composed of rounded rock fragments in a clay rich matrix.

Time of Travel (TOT): The time required for a contaminant to move in the saturated zone from a specific point to a well. It is the average linear velocity of flowing groundwater using Darcy's Law: $V = k/ne \cdot dh/dx$, where: ne = effective porosity; k = permeability; dh/dx = groundwater gradient

Turlough: Seasonal lakes found in the lowland karsts of western Ireland. They often fill and empty via estavelles.

Unsaturated Zone: The zone between the land surface and the water table, in which pores and fissures are only partially filled with water. Also known as the vadose zone.

Vulnerability: A term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities.

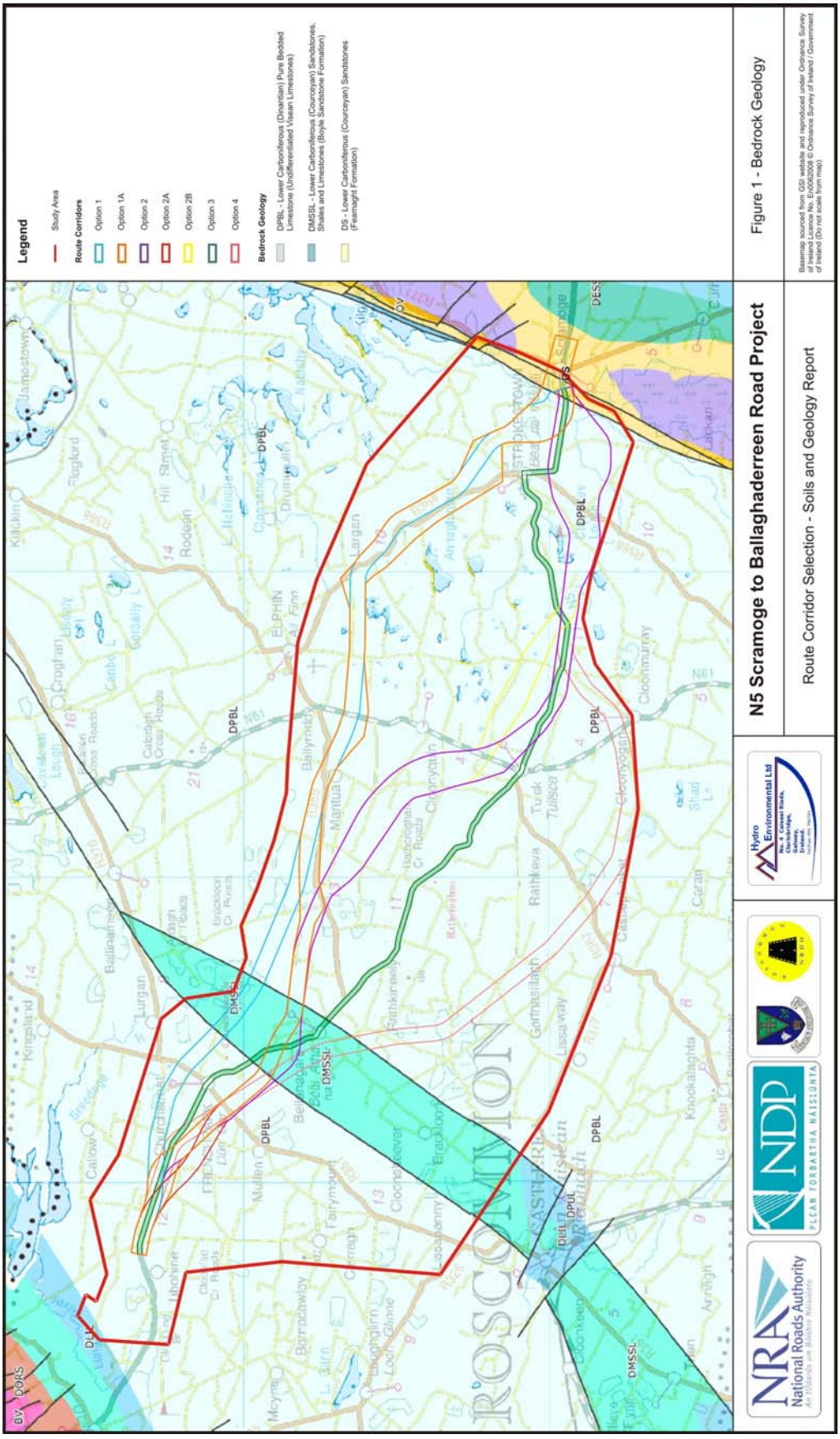
Zone of Contribution (ZOC): The area surrounding a pumped well that encompasses all areas or features that supply groundwater recharge to the well. It is defined as the area required to support an abstraction from long-term groundwater recharge.

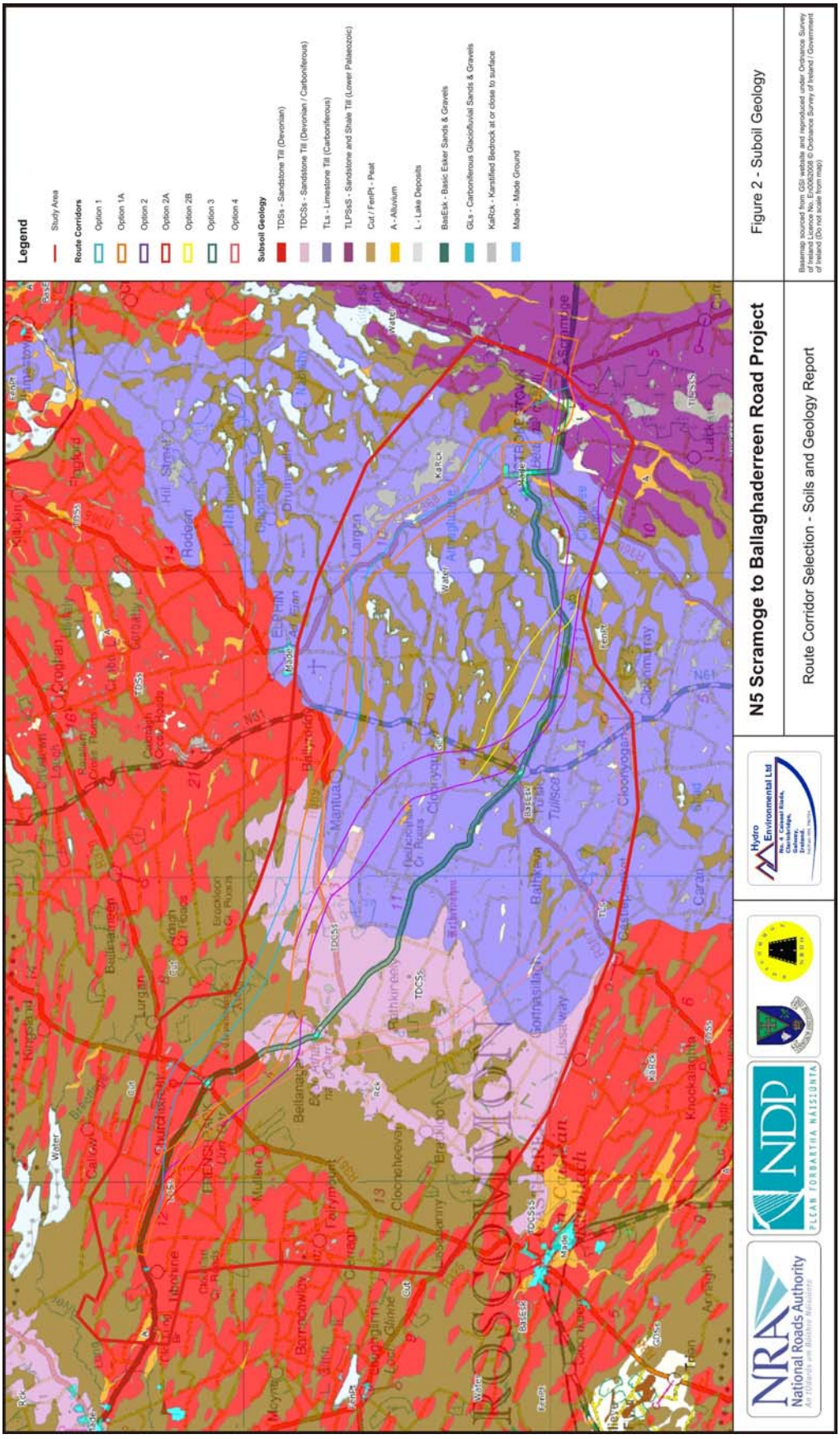
Figures

Figure 1: Bedrock Geology

Figure 2: Subsoil Geology

Figure 3: Soil Features – soft ground, geological resources, heritage features, karst features, and contaminated land


Legend
Study Area
Route Corridors
Option 1
Option 1A
Option 2
Option 2A
Option 2B
Option 3
Option 4
Bedrock Geology
DPBL - Lower Carboniferous (Dinantian) Pure Bedded Limestone (Undifferentiated Visean Limestones)
DMSSL - Lower Carboniferous (Courceyan) Sandstones, Shales and Limestones (Boyle Sandstone Formation)
DS - Lower Carboniferous (Courceyan) Sandstones (Fearnaght Formation)
DPBL
DMSSL
DS
DPUL
DUL
ROSCOMMON
N5 Scramoge to Ballaghaderreen Road Project
Route Corridor Selection - Soils and Geology Report
Figure 1 - Bedrock Geology
Hydro Environmental Ltd
NRA National Roads Authority
NDP


Legend
Study Area
Route Corridors
Option 1
Option 1A
Option 2
Option 2A
Option 2B
Option 3
Option 4
Subsoil Geology
TDSs - Sandstone Till (Devonian)
TDCSs - Sandstone Till (Devonian / Carboniferous)
TLs - Limestone Till (Carboniferous)
TLPSsS - Sandstone and Shale Till (Lower Palaeozoic)
Cut / FenPt - Peat
A - Alluvium
L - Lake Deposits
BasEsk - Basic Esker Sands & Gravels
GLs - Carboniferous Glaciofluvial Sands & Gravels
KaRck - Karstified Bedrock at or close to surface
Made - Made Ground
Figure 2 - Suboil Geology
N5 Scramoge to Ballaghaderreen Road Project
Route Corridor Selection - Soils and Geology Report
Hydro Environmental Ltd
NRA National Roads Authority
NDP
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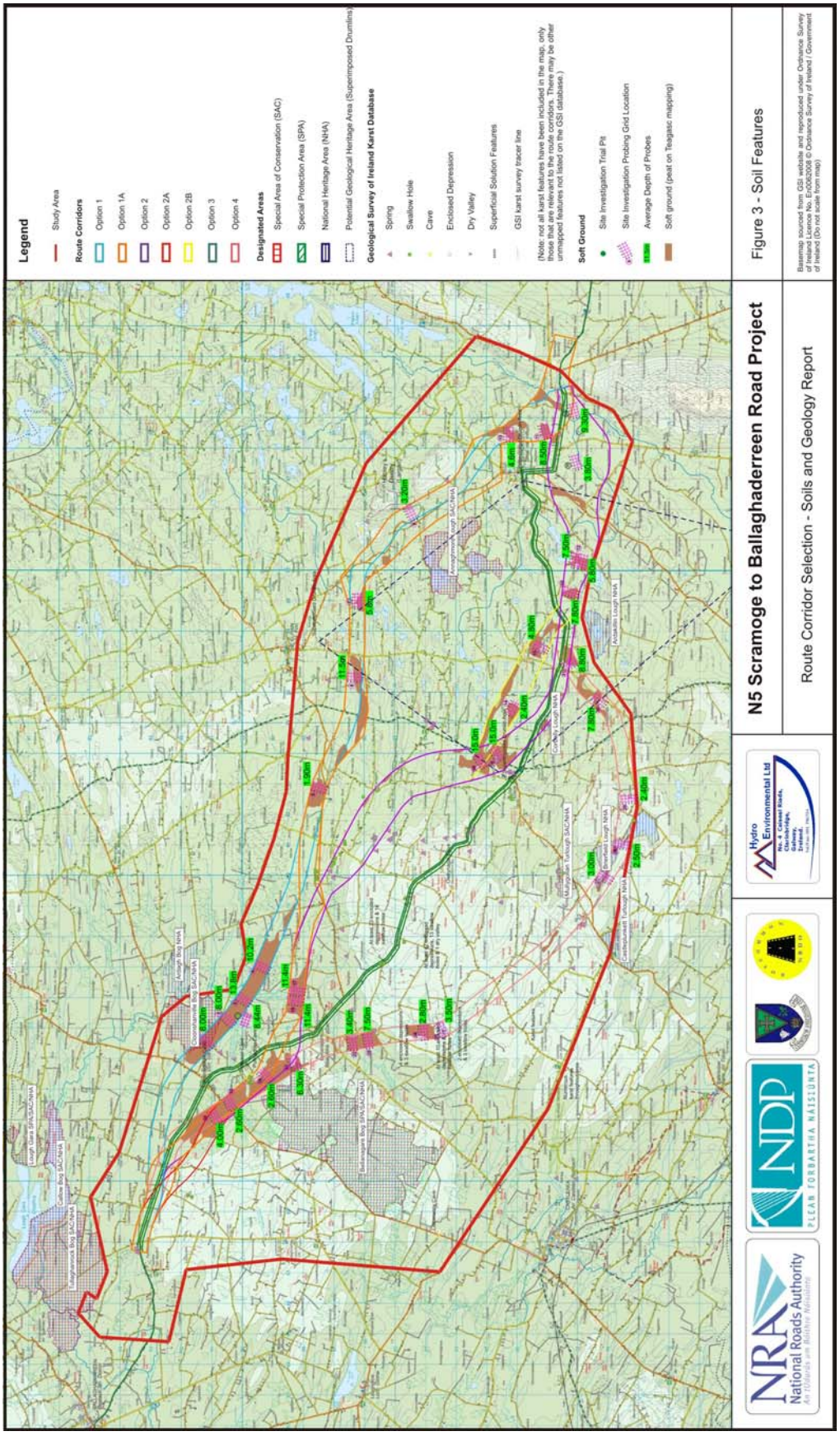
Legend
Study Area
Route Corridors
Option 1
Option 1A
Option 2
Option 2A
Option 2B
Option 3
Option 4
Designated Areas
Special Area of Conservation (SAC)
Special Protection Area (SPA)
National Heritage Area (NHA)
Potential Geological Heritage Area (Superimposed Drumlins)
Geological Survey of Ireland Karst Database
Spring
Swallow Hole
Cave
Enclosed Depression
Dry Valley
Superficial Solution Features
GSI karst survey tracer line
(Note: not all karst features have been included in the map, only those that are relevant to the route corridors. There may be other unmapped features not listed on the GSI database.)
Soft Ground
Site Investigation Trial Pit
Site Investigation Probing Grid Location
Average Depth of Probes
Soft ground (peat on Teagasc mapping)
N5 Scramoge to Ballaghaderreen Road Project
Route Corridor Selection - Soils and Geology Report
Figure 3 - Soil Features
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PLEAN FORBARTHA NAISIÚNTA