Greater Dublin Drainage

Alternative Sites Assessment and Route Selection Report (Phase 4):

Final Preferred Site and Routes

Appendix 8

Soils and Geology

June 2013

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Fingal County Council

Greater Dublin Drainage Scheme

Phase 1 Ground Investigation - Geotechnical Interpretative Report

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Contents

Appendix G

Saucerrstown to Southern Outfall - Site Plan and Logs

1 Introduction

A preliminary site investigation was carried out along the alignment of the proposed Greater Dublin Drainage Scheme. This was carried out by IGSL Ltd. between 23-01-2013 and 10-05-2013 and included a number of LCP (Light Cable Percussive Boreholes) with Rotary Follow-on (RF). The exact extent of the investigation was:

- 17 no. Trial Pits,
- 22 no. Cable Percussive Boreholes (BH)
- 16 no. Rotary Core (RC) follow on in selected cable percussive boreholes
- 8 no. standpipes within the rotary core boreholes
- Geophysical surveys in 3 no. areas including 2D resistivity and seismic surveys
- Laboratory testing of soils and rock.

The laboratory testing during the preliminary site investigation was included the following:

- Moisture Contents
- Atterberg Limits
- Particle Size Distribution
- MCV
- CBR
- OMC
- Sulfate Testing
- Point Load Tests
- UCS Testing

The Phase 2 Alternative Sites Assessment and Route Selection Report identified 3 emerging preferred sites for the proposed Waste Water Treatment Plant (WwTP), 2 possible outfall locations and the associated orbital sewers associated with these alternatives and this investigation focussed on emerging preferred sites and routes. As part of the Phase 2 assessment a risk register was developed and the preliminary investigation quantified the risks identified in the during the Phase 2 assessment (Alternative Sites Assessment Report – Phase 2, Site Assessment and Route Selection Report risk registers which were issued 07-02-2012).

The site investigation is split up into the following sections for interpretation:

- Proposed Wastewater Treatment Plant Locations
    - o Annsbrook
    - o Clonshagh (Clonshaugh)

    - Newtowncorduff
- Possible Outfalls
    - Northern Outfall
    - Southern Outfall

This site investigation was a preliminary investigation and as such does not include any offshore locations at the outfalls. Further investigation will be required to provide data for detailed design.

This report was prepared with reference to the Alternative Sites Assessment Report – Phase 2, Site Assessment and Route Selection Report issued 07-02-2012.This report carried out a review of publically and internally held information on the ground conditions across the proposed alignment of the Greater Dublin Drainage Scheme (GDDS).This report gave indicative ground conditions for each of the land packages and across the alignment.

For ease of reference, Figures 8.1 to 8.5 from the Phase 2 ASA report are reproduced in the figures section. These figures are;

- Figure 8.1 Soils Map
- Figure 8.2 Quaternary Map
- Figure 8.3 Geology Map
- Figure 8.4 Groundwater Vulnerability Map
- Figure 8.5 Constraints Map

This report presents the results and interpretation of the findings of the Preliminary Ground Investigation.

2 Proposed Wastewater Treatment Plants (WwTP)

2.1 Introduction

Three emerging preferred sites where the proposed WwTP could be located were investigated. These locations are as follows:

- Annsbrook
- Clonshagh (Clonshaugh)
- Newtowncorduff

Details of the ground investigations at each of the locations, the findings of these investigations and the interpretation of the findings of the ground investigation are presented in the following sections.

2.2 Annsbrook

2.2.1 Site Description

The Annsbrook site slopes gently from west to east and the topography ranges between approximately 25m to 35m OD.

The site is bounded to the north and south by streams which are tributaries of the nearby river and eventually discharge into the Rogerstown Estuary. The site has previously been used for agriculture and the western part of the site is classed as pasture land.

2.2.2 Ground Investigation

The site investigation at Annsbrook included the following:

- 6 no. trial pits to 2.9–3.3 m below ground level (BGL) (TP04–TP09)
- 2 no. cable percussive boreholes to 13.2–13.7 m BGL (BH05–06)
- 2 no. Rotary corehole follow on in the cable percussive boreholes BH05 and BH06 to 24.0 m BGL (RC05-06)
- 2 no. Standpipes in RC05 and RC06

These locations can be seen in Drawing No. G002 Rev. P3, which is presented in Appendix A.

2.2.3 Ground Conditions

A layer of topsoil was observed in all the trial pits throughout the site. This layer consisted of soft grey/brown silty clay. The topsoil was underlain by glacial deposits which are described as brown sandy gravelly clay with cobbles. These deposits are classified as soft to firm in the upper layers, which become stiff to very stiff with increasing depth. Water bearing gravel lenses were noted in BH05 (3.0 and 8.6 m BGL), along with a boulder lens which was noted at in BH06 (5.8 m BGL).

The particle size distribution for various samples recovered from trial pits and boreholes are shown in Figure A.1. The sandy gravelly clays correspond to well-graded glacial tills, while the gravel layer observed in BH05 is classified as a fine to coarse gravel. The ground conditions are summarised in Table 1.

Table 1 - Summary of Soil Profile at Annsbrook

Strata	**Depth to top of strata (m BGL)**	**Thickness (m)**
Topsoil	0.0	0.1 – 0.4
Soft to firm brown boulder clay	0.0 – 0.4	0.4 – 2.9
Firm to stiff brown boulder clay	0.6 – 4.0	4.1 – 4.6
Gravel lens	2.9 – 8.6	0.6 – 2.4
Stiff to very stiff brown boulder clay	8.2 – 9.2	9.8 – 14.8
Limestone bedrock	18.0 – 24.0	–

2.2.4 Bedrock Geology

Bedrock was encountered in RC06 between 18–22.15 m BGL, in the form of a highly fractured limestone. No recovery of bedrock occurred thereafter, with the driller recording returns of limestone and drilling was terminated at a depth of 24 m BGL. Coarse sand sized cubic pyrite was noted at 19.7 m BGL. BH05 refused at 13.2m BGL within a stiff to very stiff light brown sandy gravelly silty clay with a medium cobble and boulder content.

2.2.5 Groundwater

The groundwater level was measured using standpipes in RC05 and RC06, with response zones between 2.0–8.0 m BGL and 15.0–18.0 m BGL, respectively. Readings of groundwater level were taken over a two month period (27/03/13 to 24/04/13). The highest groundwater levels recorded over this period were 11.88 and 9.86 m BGL in RC05 and RC06, respectively. The pore water pressure corresponding to these levels is plotted against the bottom of their respective response zones in Figure A.2.

2.2.6 Characteristic Results

A series of index tests were conducted on the recovered soil samples to determine the Atterberg limits. The liquid limit is plotted against the plasticity index is Figure A.3, which indicates that the soil samples primarily consists of low to intermediate plasticity clays. It can also be seen that the plasticity index ranges from 13–27%, with an average of c. 20%.

The strength and stiffness characteristics of the soil profile at Annsbrook were determined by conducting a series of Standard Penetration Tests (SPT) at discrete depths in the cable percussive boreholes. The number of blows (N) to advance a cone 300 mm is plotted against depth (z) for BH05 and BH06 in Figure A.4. Stroud (1975) proposes correlation factors (f_1 and f_2), which are dependent upon plasticity index, to estimate the undrained shear strength (c_u) and modulus of compressibility (m_v) from N values:

$$c_u = f_1 N \ (kN/m^2)$$

$$m_v = \frac{1}{f_2 N} (m^2/MN)$$

Correlation factors f_1 = 5.5 and f_2 = 0.55 are adopted for the glacial deposits encountered at Annsbrook, based on an average plasticity index of 20%.An angle of internal friction (at large deformations) and an effective cohesion (c') for glacial tills in the Dublin region is reported as ϕ' = 36° and c' = 0 kPa by Long & Menkiti (2007), who conducted a series of triaxial tests.

It can be seen in Figure A.4 that N values generally increase with depth and reaches a limiting value of N = 50 at 14 m BGL. An adopted design profile is shown in Figure A.4 which allows the estimation of stiffness and strength parameters, as outlined in Table 2.

Table 2 - Summary of Strength and Stiffness Parameters at Annsbrook

Depth (m BGL)	N	c_u (kPa)	ϕ' (°)	c' (kPa)	m_v (m^2/MN)
0 – 6	3 – 30	16.5 – 165	36	0	0.61 – 0.061
6 – 10	30	165	36	0	0.061
10 – 14	30 – 50	165 – 275	36	0	0.061 – 0.036
14+	50	275	36	0	0.036

2.2.7 Engineering Options

Structural foundations

Lightly loaded structures can be supported on shallow pad foundations founded on the brown boulder clay. Preliminary calculations show square pad foundations constructed at a depth of 2m below existing ground level with an allowable working load of 110kN/m^2 will settle by approximately 25mm.

Heavier structural loads can be accommodated by excavating to a depth of 3.5 – 4m below ground level and back filling the excavation with lean mix concrete and constructing the pad foundation at a level closer to ground level. Preliminary calculations show square pad foundations constructed in this way with an allowable working load of 250kN/m^2 will settle by approximately 25mm.

The above loads and settlements are indicative only and will require further site investigation and assessment in conjunction with a structural engineer.

Higher structural loads will most likely require alternative foundation options, such as raft or piled foundations. These options should be developed further when the preliminary sizing of the structural foundations is progressed.

Deep Excavations

Details of deep excavations at the WWTP are not yet known. The temporary slope retention requirements during construction for any deep excavation will have to take into account the depth of the excavation and any surrounding constraints. Subject to detailed analysis, it is likely that excavations carried out in the middle of the site, away from any road ways (temporary or otherwise) may be excavated using steep slopes (45deg) within the brown boulder clay. Such excavation methods have been used successfully in many deep excavations in boulder clay and may be suitable here providing the deep gravel lenses are avoided. If these lenses are encountered, dewatering may be required and a shallower excavation angle will need to be adopted. If the location of any deep excavations coincide with the location of significant gravel lenses then it is possible that piled retaining walls would be required. This will have to be carefully assessed as the designs progress and should be addressed at detailed site investigation stage.

It is unlikely that sheet pile or driven pile retaining walls will be suitable here due to the difficulty of driving piles through stiff overburden deposits. Other possibilities such as kingpost systems with pre-boring for the installation of the posts may be suitable.

Roadways

Internal road ways will likely be constructed on the soft to firm brown clay. This material is weak and preliminary designs should assume a design CBR of not greater than 2% and it is likely that, subject to assessment of roadway alignment, the upper 0.5m may have to excavated to achieve a CBR of 2%

2.2.8 Conclusions

During initial site assessment, it was identified that there was the potential for made ground to be present on site. No made ground was encountered during the preliminary ground investigation.

Bedrock was found to be at a depth of 18mbgl, which is likely to lie beneath the lowest proposed dig level for the site.

At 9.86mbgl it appears that the groundwater level is lower for Annsbrook than at the other potential sites. Standpipes should be monitored for over time to allow the groundwater to recover from drilling and installation affects. It should be expected that in time groundwater levels may rise above those recorded to date.

Overall, based on the findings of the preliminary ground investigations, nothing has been identified that would prevent detailed civil and structural designs for the WwTP from being developed. It is envisioned that standard construction practices would be suitable for this site.

2.3 Clonshagh (Clonshaugh) site

2.3.1 Site Description

The topography of the Clonshagh (Clonshaugh) site is generally flat and slopes from west to east, with a topographic range between approximately 40m to 50 mOD. The Mayne River is parallel to the northern boundary of the site. The site is currently used for agriculture.

2.3.2 Ground Investigation

The site investigation at Clonshagh (Clonshaugh) included the following:

- 3 no. trial pits to 3.15–3.85 m BGL (TP01–TP03)
- 4 no. cable percussive boreholes to 10.0–14.8 m BGL (BH01–04)
- 2 no. Rotary corehole follow on in the cable percussive boreholes (BH01 and BH02) to 18.0 m BGL (RC01–02)
- 3 no. Standpipes in RC01, RC02 and BH04

These locations are shown in Drawing No. G003 Rev. P3, which is included in Appendix B.

2.3.3 Ground Conditions

A layer of topsoil was observed in all the trial pits throughout the site. This layer consisted of soft grey/brown silty clay. The topsoil was underlain by brown and black boulder clay. The brown boulder clay is classified as firm brown sandy gravelly clay with cobbles. This stratum is generally soft in the upper layers and becomes stiff with increasing depth. The black boulder clay is described as stiff to very stiff grey black sandy gravelly clay with cobbles.

Water bearing gravel lenses were noted within the glacial deposits in BH01 (7.3 m BGL) and BH03 (5.8 m BGL), along with a sand lens in BH02 (17.4 m BGL). The depth to bedrock was not confirmed as this was not encountered in RC01 or RC02, which were advanced to 18 m BGL.

The particle size distribution for various samples recovered from trial pits and boreholes are shown in Figure B.1. The sandy gravelly clays correspond to well-graded glacial tills, while the gravel layer observed in BH01 is classified as sandy gravel.

The ground conditions are summarised in Table 3.

Table 3 - Summary of soil profile at Clonshagh (Clonshaugh)

Strata	Depth to top of strata (m BGL)	Thickness (m)
Topsoil	0.0	0.4
Brown boulder clay	0.0 – 0.4	1.2 – 2.8
Black boulder clay	1.6 – 3.2	8.2 – 15.4
Gravel lens	5.8 – 7.3	0.3 – 1.5
Sand lens	17.4	0.4

2.3.4 Bedrock Geology

No bedrock was encountered on this site. All of the boreholes terminated at 18mbgl.

2.3.5 Groundwater

The groundwater level was measured using standpipes in RC01, RC02 and BH04, with response zones between 6.8–8.8 m BGL, 13.0–18.0 m BGL and 2.0–8.0 m BGL, respectively. Readings of groundwater level were taken over a two month period (25/02/13 to 24/04/13). The highest groundwater levels recorded over this period were 0.3, 5.78 and 1.03 m BGL in RC01, RC02 and BH04, respectively.

2.3.6 Characteristic Results

A series of index tests were conducted on the recovered soil samples to determine the Atterberg limits. The liquid limit is plotted against the plasticity index is Figure B.3, which indicates that the soil samples primarily consists of low to intermediate plasticity clays. It can also be seen that the plasticity index ranges from 13–20%, with an average of c. 17%.

The strength and stiffness characteristics of the soil profile at Clonshagh (Clonshaugh) were determined by conducting a series of Standard Penetration Tests (SPT) at discrete depths in the cable percussive boreholes. The number of blows (N) to advance a cone 300 mm is plotted against depth (z) for BH01–04 in Figure B.4. Stroud (1975) proposes correlation factors (f_1 and f_2), which are dependent upon plasticity index, to estimate the undrained shear strength (c_u) and modulus of compressibility (m_v) from N values:

$$c_u = f_1 N \ (kN/m^2)$$

$$m_v = \frac{1}{f_2 N} (m^2/MN)$$

Correlation factors f_1 = 5.5 and f_2 = 0.55 are adopted for the glacial deposits encountered at Clonshagh (Clonshaugh), based on an average plasticity index of 17%. An angle of internal friction (at large deformations) and an effective cohesion (c') for glacial tills in the Dublin region is reported as ϕ' = 36° and c' = 0 kPa by Long & Menkiti (2007), who conducted a series of triaxial tests.

It can be seen in Figure B.4 that N values generally increase with depth and reach a limiting value of 50 at 14 m BGL. An adopted design profile is shown in Figure B.4 which allows the estimation of stiffness and strength parameters, as outlined in Table 4.

Table 4 - Summary of strength and stiffness parameters at Clonshagh (Clonshaugh)

Depth (m BGL)	**N**	**c_u (kPa)**	**ϕ' (°)**	**c' (kPa)**	**m_v (m^2/MN)**
0 – 6	8 – 30	44 – 165	36	0	0.23 – 0.061
6 – 10	30	165	36	0	0.061
6 – 14	30 – 50	165 – 275	36	0	0.061 – 0.036
14+	50	275	36	0	0.036
Gravel lens	20	110	36	0	0.09

2.3.7 Engineering Options

Structural foundations

Lightly loaded structures can be supported on shallow pad foundations founded on the brown boulder clay. Preliminary calculations show square pad foundations constructed at a depth of 2m below existing ground level with an allowable working load of 120kN/m^2 will settle by approximately 25mm.

Heavier structural loads can be accommodated by excavating to a depth of 3.5 – 4m below ground level and back filling the excavation with lean mix concrete and constructing the pad foundation at a level closer to ground level. Preliminary calculations show square pad foundations constructed in this way with an allowable working load of 260kN/m2 will settle by approximately 25mm.

The above loads and settlements are indicative only and will require further site investigation and assessment in conjunction with a structural engineer.

Higher structural loads will most likely require alternative foundation options, such as raft or piled foundations. These options should be developed further when the preliminary sizing of the structural foundations is progressed.

Deep Excavations

Details of deep excavations at the WWTP are not yet known. The temporary slope retention requirements for any deep excavation will have to take into account the depth of the excavation and any surrounding constraints. Subject to detailed analysis, it is likely that excavations carried out in the middle of the site, away from any road ways (temporary or otherwise) may be excavated using steep slopes (45deg) within the brown boulder clay. Such excavation methods have been used successfully in many deep excavations in boulder clay and may be suitable here providing the deep gravel lenses are avoided. If these lenses are encountered, dewatering may be required and a shallower excavation angle will need to be adopted. If the location of any deep excavations coincide with the location of significant gravel lenses then it is possible that piled retaining walls would be required. This will have to be carefully assessed as the designs progress and should be addressed at detailed site investigation stage.

It is unlikely that sheet pile or driven pile retaining walls will be suitable here due to the difficulty of driving piles through stiff overburden deposits. Other possibilities such as kingpost systems with pre-boring for the installation of the posts may be suitable.

Roadways

Internal road ways will likely be constructed on the soft to firm brown clay. This material is weak and preliminary designs should assume a design CBR of not greater than 2% and it is likely that, subject to assessment of roadway alignment, the upper 0.5m may have to excavated to achieve a CBR of 2%

2.3.8 Conclusions

During initial site assessment and based on the findings of the ASA Phase 2 assessment, it was suspected that made ground was present on site. No made ground was noted during the preliminary ground investigation.

This site differs from Annsbrook in that there was no bedrock encountered on site.

The pore water pressure corresponding to the recorded groundwater levels is plotted against the bottom of the respective response zones in the boreholes in Figure B.2. It appears that pore water pressure profile which corresponds to a groundwater level at 1 m BGL agrees quite well with the measured data. However, it can be seen that the pore water pressure is much lower than the proposed hydrostatic profile for BH/RC02. Standpipes should be monitored over time to allow the groundwater to recover from drilling and installation affects. It should be expected that in time groundwater levels may rise above those recorded to date.

This may be explained as the response zone for the standpipe is located stiff boulder clay, which is characterised by low permeability and, consequently, reduces the inflow of water into the standpipe.

Overall, based on the findings of the preliminary ground investigations, nothing has been identified that would prevent detailed civil and structural designs for the WwTP from being developed. It is envisioned that standard construction practices would be suitable for this site.

2.4 Newtowncorduff site

2.4.1 Site Description

The southern boundary of the site is the confluence point of two streams and the topography of the site reflects this. The site is generally flat with a gentle slope to the south and a topographic range of 15 -25 mOD.

The site land use is classified as agricultural with the southern section specifically designated as pasture land.

2.4.2 Ground Investigation

The ground investigation at Newtowncorduff included the following:

- 4 no. trial pits to 2.3–3.2 m BGL (TP10–TP13)
- 3 no. cable percussive boreholes to 10.6–11.7 m BGL (BH07–09)
- 2 no. rotary follow-on coreholes in two of the cable percussive boreholes (BH07 and BH09) to 17.8–18.0 m BGL (RC07 and RC09)
- 2 no. Standpipes in RC07 and RC09.

These locations can be seen in Drawing No. G004, Rev P3 which is presented in Appendix C.

2.4.3 Ground Conditions

A layer of topsoil was observed in all the trial pits throughout the site. This layer consisted of soft grey/brown silty clay. The topsoil was underlain by glacial deposits which consisted of upper and lower, brown and black boulder clay. The upper brown boulder clay is generally classified as soft to firm brown sandy gravelly clay with cobbles, while the lower brown boulder clay is stiff to very stiff. The upper black boulder clay is described as firm to stiff black sandy gravelly clay with cobbles, while the lower black boulder clay is stiff to very stiff. Water bearing gravel lenses were noted within the glacial deposits in BH08 (9.8 m BGL) and BH09 (9.4 m BGL), along with sand lenses in TP13 (2.2 m BGL) and BH07 (12.0 m BGL), and a boulder lens in BH08 (7.8 m BGL).

Two of the trial pits encountered loose to medium dense sand, TP12 consisted entirely of moderately compact sand (0.0–2.3 m BGL) and TP 13 contained a 0.6 m thick uncompact sand lens (2.2–2.8 m BGL). These deposits are most likely associated with the streams present at the southern boundary of the site.

The particle size distribution for various samples recovered from trial pits and boreholes are shown in Figure C.1. The sandy gravelly clays correspond to well-graded glacial tills, while the sand layers observed in TP12 and boulder lens observed in BH08 are classified as ‘fine to coarse sand’ and ‘boulders with fine to coarse gravel’, respectively.

The ground conditions are summarised in Table 5.

Table 5 - Summary of the soil profile at Newtowncorduff

Strata	**Depth to top of strata (m BGL)**	**Thickness (m)**
Topsoil	0.0	0.1 – 0.5
Upper brown boulder clay	0.0 – 0.5	2.2 – 3.2
Sand	2.2 – 12.0	0.6 – 0.8
Upper black boulder clay	2.3 – 3.2	3.7 – 4.1
Boulder lens	7.8	2.0
Lower brown boulder clay	6.8 – 8.9	0.6 – 3.1
Lower black boulder clay	9.0 – 10.4	5.4
Gravel lens	9.4 – 9.8	0.2 – 0.6
Bedrock	13.5 - 15	–

2.4.4 Bedrock Geology

Bedrock was encountered at 13.5m and 15 m BGL in RC07 and RC09, respectively. This was described as limestone with bands of mudstone.

BH08 terminated at 12.6mBGL on a dense subangular to subrounded fine to coarse gravel.

2.4.5 Groundwater

The groundwater level was measured using standpipes in RC07 and RC09, with response zones between 11.5–13.0 m BGL and 10.0–12.0 m BGL, respectively.

On 24/04/13, the groundwater level was recorded at 3.02 and 2.68 m BGL in RC07 and RC09, respectively.

2.4.6 Characteristic Results

A series of index tests were conducted on the recovered soil samples to determine the Atterberg limits. The liquid limit is plotted against the plasticity index is Figure C.3, which indicates that the soil samples primarily consists of low to intermediate plasticity clays. It can also be seen that the plasticity index ranges from 14–21%, with an average of c. 18%.

The strength and stiffness characteristics of the soil profile at Newtowncorduff were determined by conducting a series of Standard Penetration Tests (SPT) at discrete depths in the cable percussive boreholes. The number of blows (N) to advance a cone 300 mm is plotted against depth (z) for BH01–04 in Figure C.4. Stroud (1975) proposes correlation factors (f_1 and f_2), which are dependent upon plasticity index, to estimate the undrained shear strength (c_u) and modulus of compressibility (m_v) from N values:

$$c_u = f_1 N \ (kN/m^2)$$

$$m_v = \frac{1}{f_2 N} (m^2/MN)$$

Correlation factors f_1 = 5.5 and f_2 = 0.55 are adopted for the glacial deposits encountered at Newtowncorduff, based on an average plasticity index of 18%. An angle of internal friction (at large deformations) and an effective cohesion (c') for glacial tills in the Dublin region is reported as ϕ' = 36° and c' = 0 kPa by Long & Menkiti (2007), who conducted a series of triaxial tests.

It can be seen in Figure C.4 that N values generally increase linearly with depth and reach a limiting value of 50 at 14 m BGL. An adopted design profile is shown in Figure B.4 which allows the estimation of stiffness and strength parameters, as outlined in Table 6.

Table 6 - Summary of strength and stiffness parameters at Newtowncorduff

Depth (m BGL)	**N**	**c_u (kPa)**	**ϕ' (°)**	**c' (kPa)**	**m_v (m^2/MN)**
0 – 13	9 – 50	50 - 275	36	0	0.2 – 0.036
13+	50	275	36	0	0.036
Gravel lens	36 – 50	198 - 275	36	0	0.05 – 0.036

2.4.7 Engineering Recommendations

Structural foundations

Lightly loaded structural can be supported on shallow pad foundations founded on the brown boulder clay. Preliminary calculations show square pad foundations constructed at a depth of 2m below existing ground level with an allowable working load of 130kN/m^2 will settle by approximately 25mm.

Heavier structural loads can be accommodated by excavating to a depth of 3.0 – 4m below ground level and back filling the excavation with lean mix concrete and constructing the pad foundation at a level closer to ground level. Preliminary calculations show square pad foundations constructed in this way with an allowable working load of 280kN/m^2 will settle by approximately 25mm.

The above loads and settlements are indicative only and will require further site investigation and assessment in conjunction with a structural engineer.

Higher structural loads will most likely require alternative foundation options, such as raft or piled foundations. These options should be developed further when the preliminary sizing of the structural foundations is progresses.

Deep Excavations

Details of deep excavations at the WWTP are not yet known. The temporary slope retention requirements for any deep excavation will have to take into account the depth of the excavation and any surrounding constraints. Subject to detailed analysis, it is likely that excavations carried out in the middle of the site, away from any road ways (temporary or otherwise) may be excavated using steep slopes (45deg) within the brown boulder clay. Such excavation methods have been used successfully in many deep excavations in boulder clay and may be suitable here providing the deep gravel lenses are avoided. If these lenses are encountered, dewatering may be required and a shallower excavation angle will need to be adopted. If the location of any deep excavations coincide with the location of significant gravel lenses then it is possible that piled retaining walls would be required. This will have to be carefully assessed as the designs progress and should be addressed at detailed site investigation stage.

It is unlikely that sheet pile or driven pile retaining walls will be suitable here due to the difficulty of driving piles through stiff overburden deposits. Other possibilities such as kingpost systems with pre-boring for the installation of the posts may be suitable.

Roadways

Internal road ways will likely be constructed on the soft to firm brown clay. This material is weak and preliminary designs should assume a design CBR of not greater than 2% and it is likely that, subject to assessment of roadway alignment, the upper 0.8 - 0.95m may have to excavated to achieve a CBR of 2%

2.4.8 Conclusions

During initial site assessment and based on the findings of the ASA Phase 2 assessment, it was suspected that there was made ground present on site. No made ground was noted during the preliminary ground investigation. Bedrock was found to be at a depth of 13.5mbgl to 15mbgl, which is likely to lie beneath the lowest proposed dig level for the site.

The pore water pressure corresponding to the recorded levels is plotted against the bottom of the respective response zones for the boreholes in Figure C.2. It appears that pore water pressure profile which corresponds to a groundwater level at 3 m BGL agrees well with the measured data.

Overall, based on the findings of the preliminary ground investigations, nothing has been identified that would prevent detailed civil and structural designs for the WwTP from being developed. It is envisioned that standard construction practices would be suitable for this site.

3 Outfall sites

3.1 Introduction

Two potential outfall sites have been located.

The first, known as the Northern Outfall Site is located near Loughshinny, with the Southern Outfall located near Portmarnock.

Each Outfall location will be dealt with separately below.

3.2 Northern Outfall

3.2.1 Site Description

Towards the north of the area there is pasture ground and agricultural land. The southern part of the headland is mainly described as isolated housing.

3.2.2 Ground Investigation

The site investigation at the location of the Northern Outfall included the following:

- 2 no. Trial pits to 3.3mbgl,
- 3 no. Cable percussive boreholes (BH 10, 11 & 12) to 4.7mbgl to 7.2mbgl,
- 2 no. Rotary coreholes (RC 11, 12) follow on in the cable percussive boreholes (BH11 & BH12) to 19.3mbgl and 24.8mbgl respectively.
- Geophysics, including Seismics and 2D Resistivity

These locations can be seen in Drawing No. G006 and Drawing No. G011 (BH 10) which are presented in Appendix D.

3.2.3 Ground Conditions

The two trial pits carried out were located in and around the location of the proposed Northern Outfall. These trial pits encountered differing ground conditions. TP14, which was located further in-land, encountered what appear to be firm brown boulder clays overlying dense sand from 1.1-3.1mbgl. TP15, which was within the catchment of the geophysical survey, encountered soft to firm brown boulder clay overlying stiff brown boulder clay from 3.0 to 3.3mbgl.

BH10, which is located inland along the proposed pipeline route, showed ground conditions consistent with the results received across the alignment to date, with boulder clays of increasing stiffness with depth.

BH11, located to the western edge of the catchment of the geophysical survey refused at a shallow depth (4.8mbgl). The deposits up to this point were recorded as soft to firm brown boulder clays.

BH12 which is located within the catchment of the geophysical survey also refused at a shallow depth (4.7mbgl). The deposits encountered were also described as soft to firm brown boulder clays.

No Made Ground was noted in any of the investigation locations.

Table 7 – Northern Outfall Ground Conditions

Strata	**Depth to top of strata**	**Thickness**
	(m BGL)	**(m)**
Topsoil	0.0	0.3
Upper Brown Boulder Clay	0.0	4.4
Sand	1.1	2.0
Upper Black Boulder Clay	3.0	1.7
Boulder lens	5.3	0.7
Lower Brown Boulder Clay	6.3	2.9
Weathered Rock	12.1	4.3
Bedrock	13.4	5.1
* - Bedrock geology in this area is very complex with faulting and erosional or faulted contacts present between the rock types		

3.2.4 Bedrock Geology

Two rotary corehole follow-ons were carried out in BH11 and BH12.

RC11 continued on from BH11 at 3.4mbgl, and encountered boulder clay and boulder beds down to 12.1mbgl. This was followed by weathered bedrock to 13.4mbgl. Intact limestone was then encountered but this material appeared to have undergone some karstification, with dissolution features noted within the core. The affected material continued down to approximately 16.1mbgl. Below this the core was described as an Argillaceous Limestone. This material most likely belongs to the Lane Formation.

RC12 continued on from where BH12 finished (4.7mbgl). Boulder clay and boulder beds were also encountered down to 13.2mbgl, upon which material described as possible weathered bedrock was encountered. It should be noted that this weathered bedrock was described within the logs as a brown sandy clay with SPT N values ranging from 21 to 38. The weathered bedrock continued down to 20.5mbgl. Competent Limestone was then encountered. However there was very poor recovery over the next 4.3m bgl, with non-intact angular to subangular limestone recovered. This material is thought to be part of the Lane Formation. It also could be influenced by the presence of a number of faults, trending NE SW nearby.

3.2.5 Groundwater

No groundwater installations were constructed and so no readings are presented in the Factual Report received from IGSL.

A water strike was encountered in RC12 at 14.8mbgl.

3.2.6 Characteristic Results

A series of index tests were conducted on the recovered soil samples to determine the Atterberg limits. The liquid limit is plotted against the plasticity index is Figure D.3, which indicates that the soil samples primarily consists of low to intermediate plasticity clays. It can also be seen that the plasticity index ranges from 11–23%, with an average of c. 16%.

The strength and stiffness characteristics of the soil profile at the Northern Outfall were determined by conducting a series of Standard Penetration Tests (SPT) at discrete depths in the cable percussive boreholes. The number of blows (N) to advance a cone 300 mm is plotted against depth (z) for BH10–12 in Figure D.4. Stroud (1975) proposes correlation factors (f1 and f2), which are dependent upon plasticity index, to estimate the undrained shear strength (cu) and modulus of compressibility (mv) from N values:

$$c_u = f_1 N \ (kN/m^2)$$

$$m_v = \frac{1}{f_2 N} (m^2/MN)$$

Correlation factors f1 = 5.5 and f2 = 0.55 are adopted for the glacial deposits encountered at the Northern Outfall, based on an average plasticity index of 16%. An angle of internal friction (at large deformations) and an effective cohesion (c') for glacial tills in the Dublin region is reported as ϕ' = 36° and c' = 0 kPa by Long & Menkiti (2007), who conducted a series of triaxial tests

It can be seen in Figure D.4 that N values generally increase with depth. An adopted design profile is shown in Figure D.4 which allows the estimation of stiffness and strength parameters, as outlined in Table 8.

Table 8 - Summary of strength and stiffness parameters at Northern Outfall

Depth (m BGL)	**N**	**c_u (kPa)**	**ϕ' (°)**	**c' (kPa)**	**m_v (m^2/MN)**
0 – 3	7-14	100	36	0	0.728
3-6.5	32-50	320	36	0	0.061

3.2.7 Engineering Options

Deep Excavations

Based on the preliminary designs developed to date it is understood that a deep shaft will be constructed at the outfall location. Details on the dimensions of this shaft, the final diameter of the outfall and the final invert level of the outfall are not available at this stage of the design.

It is theoretically possible that the excavation works for this shaft could be carried out in an open cut, however it is considered that this approach would be neither economically or environmentally preferable and is not considered further.

The construction of the shaft will require the use of a retaining wall to support the sides during excavation. This retaining wall may be a temporary structure (with the permanent structure constructed within) or the retaining wall may form the outer wall of the permanent structure itself.

Without knowledge of the final invert levels of the pipe it is difficult to predict the levels requiring excavation. It should be noted that karstified material described as a brown sandy clay was encountered in both RC11 and RC12. The depth to intact limestone increases as one moves eastward, going from 16.1mBGL (12.8mOD) in RC11 to 24.8mBGL (-9.35mOD) in RC12.

A highly fractured and brecciated layer of rock was encountered between 20.5 (-5.05mOD) and 24.8mBGL (-9.35mOD) in RC12. This may be associated with the fault which can be observed on the geological map trending NE SW.

Tunnelling

The overburden / bedrock interface is located at a depth of circa. 12m BGL. Tunnelling in mixed face conditions, with the tunnel axis close to the interface between rock and overburden should be avoided if at all possible. In mixed materials, the tunnel cutter will draw in more of the softer material (overburden) while cutting / progressing more slowly through the harder material, leading to problems with settlement and possibly collapse at the surface.

Given the possible presence of karst features in the bedrock in this area, voids or clay filled caverns of unknown size may be encountered. Karstification may have implications regarding the difficulty of tunnelling in this material such as those outlined above as well as sudden inflows of water due to the presence of water filled voids.

The brecciated area which was also observed may lead to local instability requiring some form of rock stabilisation to be employed. Both of these features need to be taken into account when assessing tunnelling methodologies.

Rock testing results include point load tests at 4 no. depths across core RC11, presented in Table 9. No intact rock was recovered from RC12. Sufficient intact core suitable for UCS testing was not recovered from either borehole. The point load tests show large variations over small areas but generally appear to suggest the rock would be conducive to easy tunnelling. However the added complications of faulting in the area along with the presence of karstified material down to 24.8m bgl may result in additional complications.

3.2.8 Conclusions

During initial site assessment, it was feared that there was the potential for made ground to be present on site. No made ground was noted during the preliminary ground investigation.

Bedrock was found to be at a depth of 18.3mbgl. The area is faulted with what appear to be brecciated deposits. The logs also contain evidence of karstification which has implications on the quality of the bedrock beneath the site.

Table 9 - Rock Testing Results

Borehole	Depth m	Point Load MN/m^2	Description
	14.5	1.66	Strong massively bedded light grey and brown calcisiltite LIMESTONE with significant brecciation coupled with penetrative brown discolouration and honeycomb dissolution features / pitting of core walls (up to 20mm). Weathering: Slight loss of core strength in areas displaying dissolution to medium strong occasionally weak Discontinuities 13.40-16.10m SET 1: 0-10° closely to medium spaced rough undulating occasionally smooth partly open, occasionally with brown fine sand on fracture surfaces. SET 2: Subvertical widely spaced rough undulating, open with yellow clay smearing on fracture surfaces
	14.6	3.26	
	18.3	0.2	Medium strong medium bedded light grey green fine grained argillaceous LIMESTONE with localised brecciation often loosely cemented. Weathering: Occasional loss of wall strength to weak at fractures. Penetrative (up to 5mm) orange brown discolouration noted on subvertical fracture surfaces Discontinuities 16.10-19.30m SET 1: 0-10° closely spaced rough undulating tight to partly open, clean. SET 2: 60-80° closely to medium spaced rough undulating, open often displaying orange brown discolouration, occasionally with light grey green sandy CLAY veneer on surfaces. Fracture set often associated with non intact angular to subrounded fine to medium gravel-sized fragments of light grey green limestone. 18.35-18.50m 10mm thick subvertical to undulating calcite vein
RC11	18.4	0.13	

3.3 Southern Outfall site

3.3.1 Site Description

The lands surrounding the Southern Outfall are mainly occupied by Portmarnock golf club as well as the estuary and sea areas. There is a beach used for bathing located on Velvet Strand on the east of the peninsula.

3.3.2 Ground Investigation

The site investigation at the Southern Outfall site included the following:

- 2 no. Trial pits to 3.0m bgl to 3.4mbgl,
- 2 no. Cable percussive boreholes to 13.0mbgl to 13.4mbgl, (BH 13 and BH14A)
- 2 no. Rotary corehole follow on in the cable percussive boreholes (BH13 and BH14A) to 22.7mbgl and 27.45mbgl. (RC 13 and RC 14A)
- Geophysics, including Seismics and 2D Resistivity

These locations can be seen in Drawing No. G005 which is presented in Appendix D.

3.3.3 Ground Conditions

Glacial tills were noted across the site in both trial pits, becoming stiffer with depth. BH13 which was located further inland also recorded glacial tills becoming stiffer with depth.

BH14 and BH14A were both located nearer the coast and showed Loose to medium sands and silts down to 11.7mbgl, with very stiff brown boulder clays below.

Table 10 Southern Outfall Ground Conditions

Strata	**Depth to top of strata (m BGL)**	**Thickness (m)**
Topsoil	0.0	0.175
Upper Brown Boulder Clay	0.0	2.45
Sand	0.0	3.675
Upper Black Boulder Clay	2.5	6.5
Silt	5.1	6.6
Lower Brown Boulder Clay	11.7	1.7
Gravel	13.4	0.1
Weathered Rock	13.5	5.35
Bedrock	15.4	5.575

3.3.4 Bedrock Geology

The depth to bedrock was proven by RC13 and RC14A, at 23.6m and 15.4m respectively. This weathered bedrock extended down to 24.5mbgl and 20.2mbgl in RC13 and RC14A.

The bedrock recovered appeared typical of the Malahide formation, i.e. an argillaceous bioclastic limestone with some shales. The desk study appears to suggest that there may be a fault in this area. However no evidence of this was noted. The area is known to be the site of a local anticline trending NE SW.

3.3.5 Groundwater

No installations were placed within the boreholes in this area.

3.3.6 Characteristic Results

A series of index tests were conducted on the recovered soil samples to determine the Atterberg limits. The liquid limit is plotted against the plasticity index is Figure E.2, which indicates that the soil samples primarily consists of low to intermediate plasticity clays. It can also be seen that the plasticity index ranges from 14–18%, with an average of c. 16%.

The strength and stiffness characteristics of the soil profile at the Southern Outfall were determined by conducting a series of Standard Penetration Tests (SPT) at discrete depths in the cable percussive boreholes. The number of blows (N) to advance a cone 300 mm is plotted against depth (z) for BH13–14 in Figure E.3. Stroud (1975) proposes correlation factors (f1 and f2), which are dependent upon plasticity index, to estimate the undrained shear strength (cu) and modulus of compressibility (mv) from N values:

$$c_u = f_1 N \ (kN/m^2)$$

$$m_v = \frac{1}{f_2 N} (m^2/MN)$$

Correlation factors f1 = 5.5 and f2 = 0.55 are adopted for the glacial deposits encountered at the Southern Outfall, based on an average plasticity index of 16%. An angle of internal friction (at large deformations) and an effective cohesion (c') for glacial tills in the Dublin region is reported as $\phi' = 36°$ and c' = 0 kPa by Long & Menkiti (2007), who conducted a series of triaxial tests.

It can be seen in Figure E.4 that N values generally increase with depth (z). An adopted design profile is shown in Figure E.4 which allows the estimation of stiffness and strength parameters, as outlined in Table 10.

Table 11 - Summary of Strength and Stiffness Parameters

Depth (m BGL)	**N**	**c_u (kPa)**	**ϕ' (°)**	**c' (kPa)**	**m_v (m^2/MN)**
0 – 2	7-10	100	36	0	0.364
2 - 14	22-50	225	36	0	0.061

3.3.7 Conclusions

No evidence of made ground was noted during the preliminary site investigation.

Bedrock was observed at 15.4m (BH14) and 23.6m (BH13) bgl.

No evidence of faulting was noted in the area. BH13 showed a large thickness of weathered bedrock.

No groundwater information is available for this area as no installations were constructed during the ground investigation.

3.3.8 Engineering Options

Deep Excavations

Based on the preliminary designs developed to date it is understood that a deep shaft will be constructed at the outfall location. A shaft of this depth in this area will pass through overburden consisting of generally cohesive materials with some layers of granular materials such as sands and gravels.

It is theoretically possible that the excavation works for this shaft may be carried out in an open cut, however it is considered that this approach would be neither economically or environmentally preferable and is not considered further.

The construction of the shaft will require the use of a retaining wall to support the sides during excavation. This retaining wall may be a temporary structure (with the permanent structure constructed within) or the retaining wall may form the outer wall of the permanent structure itself.

Bedrock was noted to occur at 20.2 and 24.5m bgl. The bedrock level may impact on the type of retaining wall constructed here, however this will have to be reviewed when further information on the alignment of the outfall tunnel and the shaft geometry are developed.

Tunnelling

Based on the preliminary ground investigation there are no particular geohazards expected over and above what would be considered normal or usual associated with tunnelling in overburden. The overburden was noted to extend down to 20.2 and 24.5mbgl.

Tunnelling in mixed face conditions, with the tunnel axis close to the interface between rock and overburden should be avoided if at all possible. In mixed materials, the tunnel cutter will draw in more of the softer material (overburden) while cutting / progressing more slowly through the harder material, leading to problems with settlement and possibly collapse at the surface.

The rock recovered from RC13 (at 24.5mbgl) and RC14 (at 20.2mbgl) was intact competent rock.

Based on the rock testing results (See Table 12) the rock in these areas would be classed as easy tunnelling. There is no evidence of karstification or faults in the rock core recovered, however bedrock mapping indicates fold axis passes through the area. This will be further investigated during EIA studies.

Table 12 – Rock Testing

Borehole	Depth m	Point Load MN/m^2	UCS MPa	Description
RC13	25.4	1.06		Medium strong to very strong, medium to thinly bedded, grey/pale greym fine-grained, LIMESTONE (locally plastically sheared), fresh to slightly weathered. Discontinuities are medium to closely spaced, rough, irregular. Apertures are tight to moderately open, locally clay-smeared, commonly moderately iron-oxide stained, locally calcite-veined (1-8mm thick). Dips are 45° & sub-vertical.
	25.9	1.27		
	26.1	1.43		
	27.1	0.61		
RC14	21.3	2.16		Medium strong to very strong, medium to thinly bedded, grey/pale greym fine-grained, LIMESTONE (locally plastically sheared, predominantly calci-siltite but grading into argillaceous limestone approx every 1.00m), fresh to moderately weathered (at 20.80-20.91m). Discontinuities are medium to closely spaced, rough, planar. Apertures are tight to open, locally clay-smeared, locally slightly iron-oxide stained, locally calcite-veined (1-30mm thick). Dips are 45-60°.
	21.3-21.5		57.09	
	21.7	2.33		
	22.3	1.72		
	22.4	2.13		

4 Pipeline Alignment

A number of locations were investigated along the proposed alignment of the GDDS. These included a number of LCP (Light Cable Percussive Boreholes) with Rotary Follow-on (RF).

These boreholes are dealt with in the following sections:

- Chapelmidway to Northern Outfall (BH15/17/19/20)
- Saucerstown to Southern Outfall (BH24/25/26)

4.1 Chapelmidway to Northern Outfall site

A number of boreholes were carried out along the pipeline route, from Chapelmidway to the Northern Outfall. The site investigation along the route consisted of:

- 4 no. Cable percussive boreholes to 12.8mbgl, (BH15/17/19/20)
- 4 no. Rotary corehole follow on in the cable percussive boreholes to a maximum of 30mbgl(RC15/17/19/20)

These locations can be seen in Drawing Nos. G007 to G0011 which are presented in Appendix F.

Glacial Tills were noted across the site in all locations, becoming stiffer with depth. Gravel and sand beds were noted in BH17 (<4.5mbgl) and BH20 (7.4-7.7mbgl).

The depth to bedrock along the alignment was variable but appeared to increase as one travelled towards the Northern Outfall. Depth to bedrock started at 3.4mbgl in BH15, increasing to 4.5mbgl for weathered bedrock in BH17, to not encountering bedrock in BH19, even though BH19 reached a depth of 20.0mbgl.

The bedrock encountered in BH15 was described as a dark grey black fine grained argillaceous Limestone, consistent with either the Rush or Tober Colleen Formations, based on the Bedrock map. Some cubic pyrite was noted within the bedrock at 15.45mbgl.

BH17 encountered a fine grained argillaceous Limestone, with very thin weak Mudstone beds. This would be considered consistent with the Lucan Formation, as shown on the bedrock map.

BH20 encountered weathered bedrock at 16.1mbgl, and intact bedrock was observed at 17mbgl. The borehole terminated at a depth of 21.2mbgl. This rock was described as an argillaceous Limestone. This material would be consistent with the Walshestown Formation, as shown on the bedrock map.

Table 13 – Chapelmidway to Northern Outfall

Strata	Top	Thickness	SPT N Value
Upper Brown Boulder Clay	0	3.4-7.4	23
Upper Black Boulder Clay	6.7-7.7	8.15	50
Lower Brown Boulder Clay	12.8-17.9	1.2-2.1	49
Weathered Bedrock	4.5-16.1	0.9-8.5	N/A
Bedrock	3.4-17	N/A	N/A

4.2 Saucerstown to Southern Outfall site

Three boreholes were carried out along the pipeline route, from Saucerstown to the Southern Outfall. The site investigation along the route consisted of:

- 3 no. Cable percussive boreholes to 10.0mbgl, (BH24/25/26)
- A Rotary corehole follow on in the cable percussive borehole BH24 to a depth of 10.1mbgl. (RC 24)

These locations can be seen in Drawing Nos. G012 and G0013 which are presented in Appendix G.

Boulder clays were noted across the site in all locations comprising of glacial tills, becoming stiffer with depth. A gravel bed was noted in BH25 (6.8 – 7.3mbgl).

Bedrock was only encountered in BH24. The cable percussive borehole terminated at 5.0mbgl, with rotary core follow on from that depth encountering fine grained argillaceous limestone which appears to be a member of the Malahide Formation.

Table 14 – Saucerstown to Southern Outfall Ground Conditions

Strata	Top	Thickness	SPT N Value
Upper Brown Boulder Clay	0	2.1-10	21
Upper Black Boulder Clay	2.1-2.9	1.9-4.0	27
Lower Brown Boulder Clay	6.9	3.1	46
Bedrock	5.0	N/A	N/A

4.3 Conclusion

Based on the ground investigation carried out to date, there are no major risks identified in relation to ground conditions which could prevent the construction of the orbital sewer. Further site investigation will be required in order to progress the detailed design of the pipeline.

5 Conclusion

Based on the ground investigation carried out to date, there are no major risks identified in relation to ground conditions which could prevent the project progressing.

No made ground was identified at any of the proposed WWTP sites, which was identified in the Phase 2 Alternative Site Assessment report as a potential risk. Overall, based on the findings of the preliminary ground investigations, nothing has been identified on any of the emerging preferred sites that would prevent detailed civil and structural designs for the WwTP from being developed. It is envisioned that standard construction practices would be suitable for each of the sites.

During initial site assessment of the Northern Outfall location, it was feared that there was the potential for made ground to be present on site. No made ground was noted during the preliminary ground investigation. The area is faulted with what appear to be brecciated deposits. The logs also contain evidence of karstification which has implications on the quality of the bedrock beneath the site, which may increase the complexity of design and the cost of tunnelling, in this area.

No evidence of made ground was noted during the preliminary site investigation of the Southern Outfall location.Bedrock mapping indicates a fold axis passes through the area however no evidence of faulting was noted in the area during the investigations. The presence of bedrock folding (i.e. an anticline) near the Southern Outfall may have cost implications for the construction of any deep excavations for shafts in this area and should be further investigatied.

Based on the ground investigation carried out to date, there are no major risks identified in relation to ground conditions which could prevent the construction of the orbital sewer.

Further site investigation will be required in order to progress the detailed design of the pipeline. This site investigation will need to take into account the proposed outfall and WwTP location, and will require further intrusive investigations and may include marine site investigation to look at the design of the outfall.

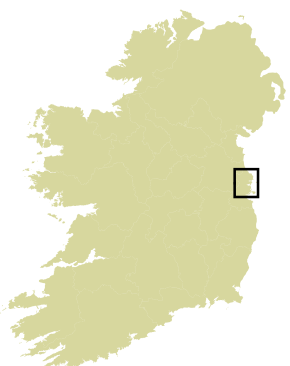
Figures

Greater Dublin Drainage

Drawing Title

ASA: PHASE TWO
SITES ASSESSMENT AND ROUTE SELECTION REPORT

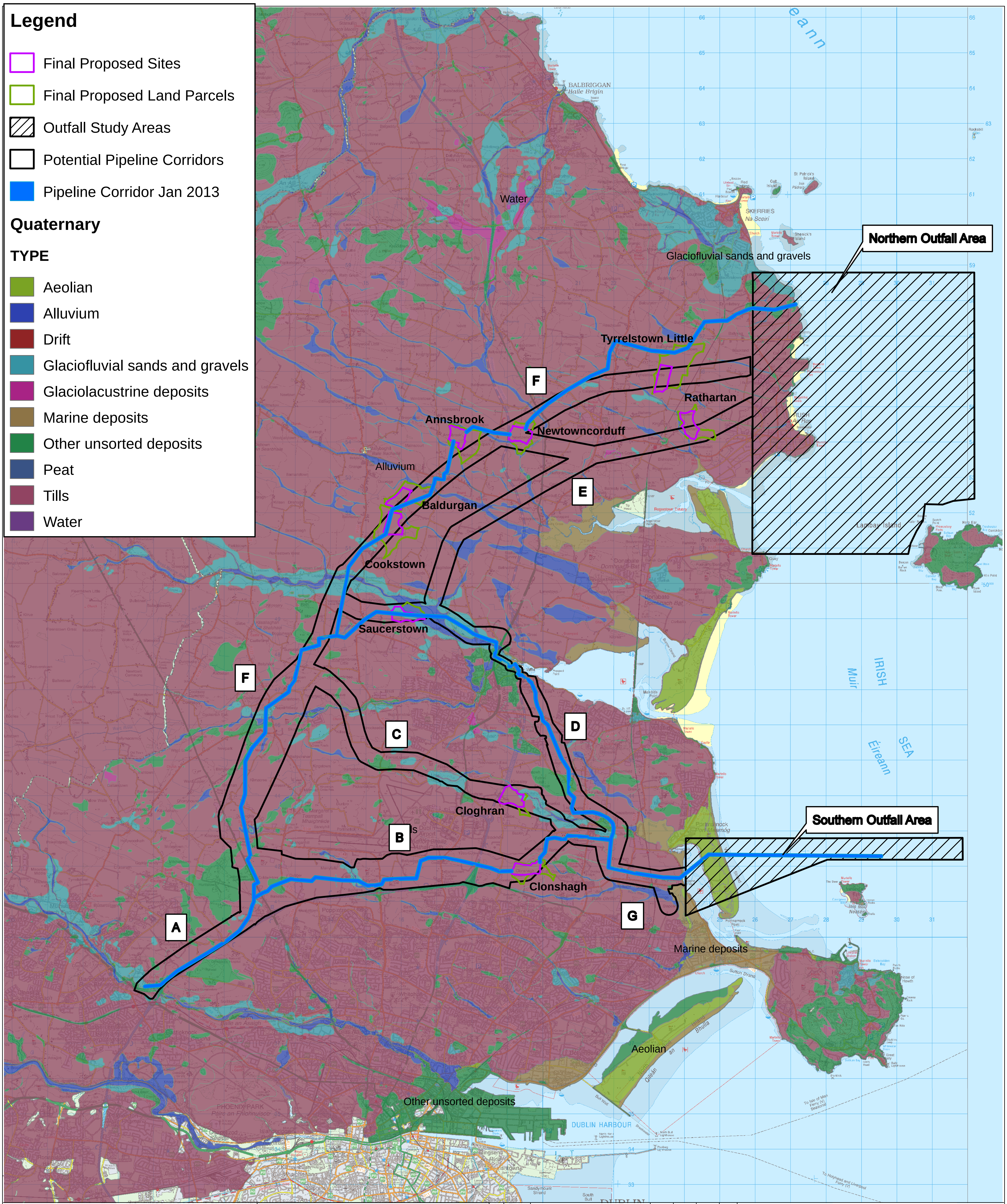
SOILS MAP

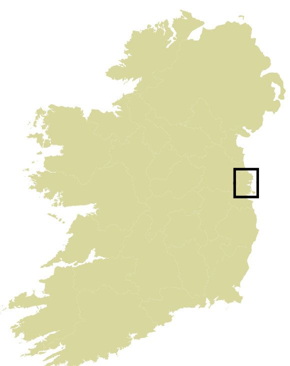


Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
D02	17/04/13	DRAFT	MF			
D01	26/01/12	DRAFT	BL			

JACOBS TOBIN ARUP

Drawing Status	DRAFT
Scale @ A3	1:100,000 — DO NOT SCALE
Job No.	218525-00
Drawing No.	FIGURE 8.1





Greater Dublin Drainage

Drawing Title

ASA: PHASE TWO
SITES ASSESSMENT AND ROUTE SELECTION
REPORT

QUARTERNARY MAP

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
D02	17/04/13	DRAFT	MF			
D01	03/03/12	DRAFT	BL			

N W E S

0 1 2 3

Kilometres

Drawing Status: DRAFT

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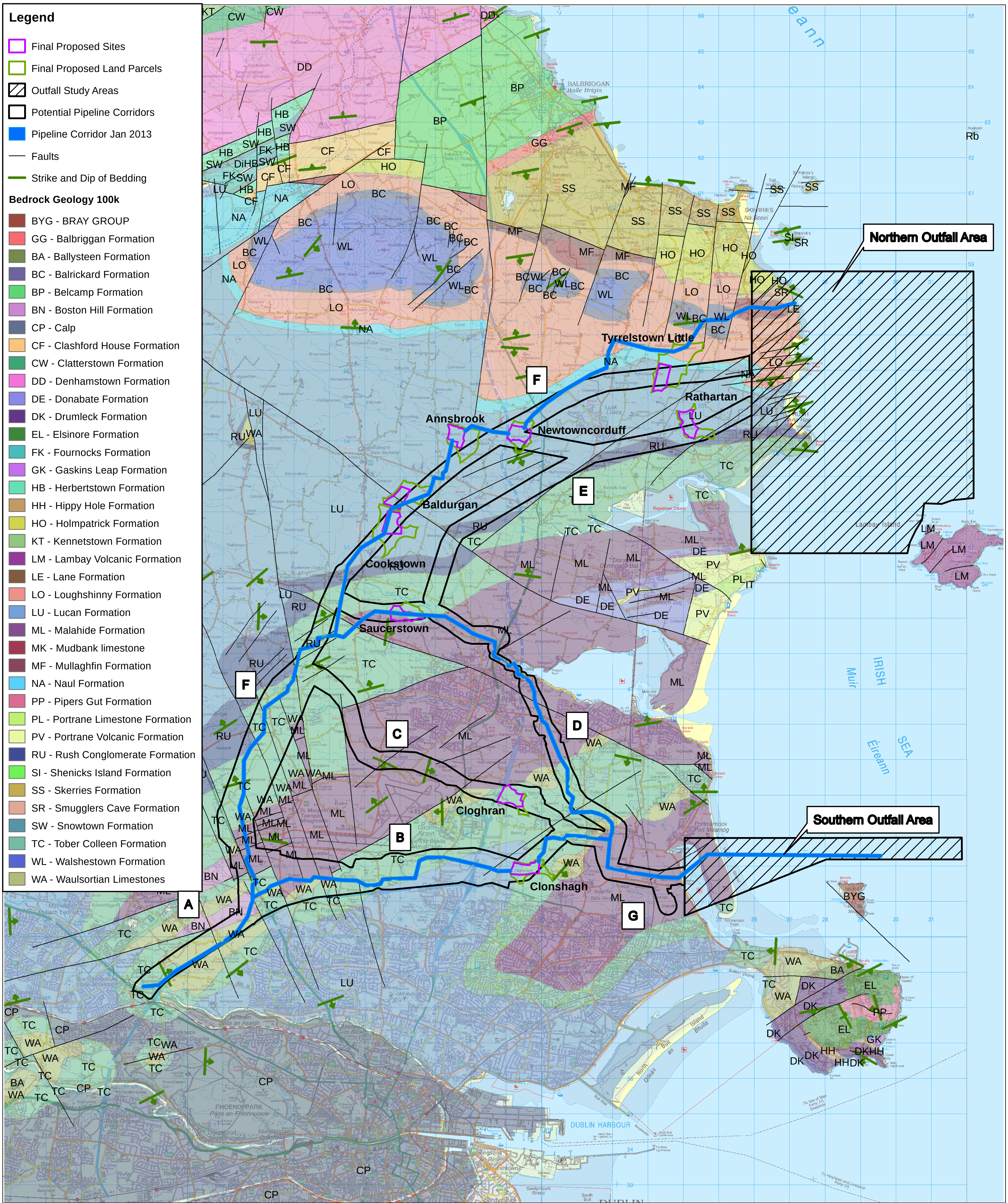
Job No. 218525-00

Drawing No. FIGURE 8.2



Greater Dublin Drainage

Drawing Title

ASA: PHASE TWO
SITES ASSESSMENT AND ROUTE SELECTION REPORT

GEOLOGY MAP

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
D02	17/04/13	DRAFT	MF			
D01	26/01/12	DRAFT	BL			

N W E S

0 1 2 3
Kilometres

JACOBS TOBIN ARUP

Drawing Status: DRAFT
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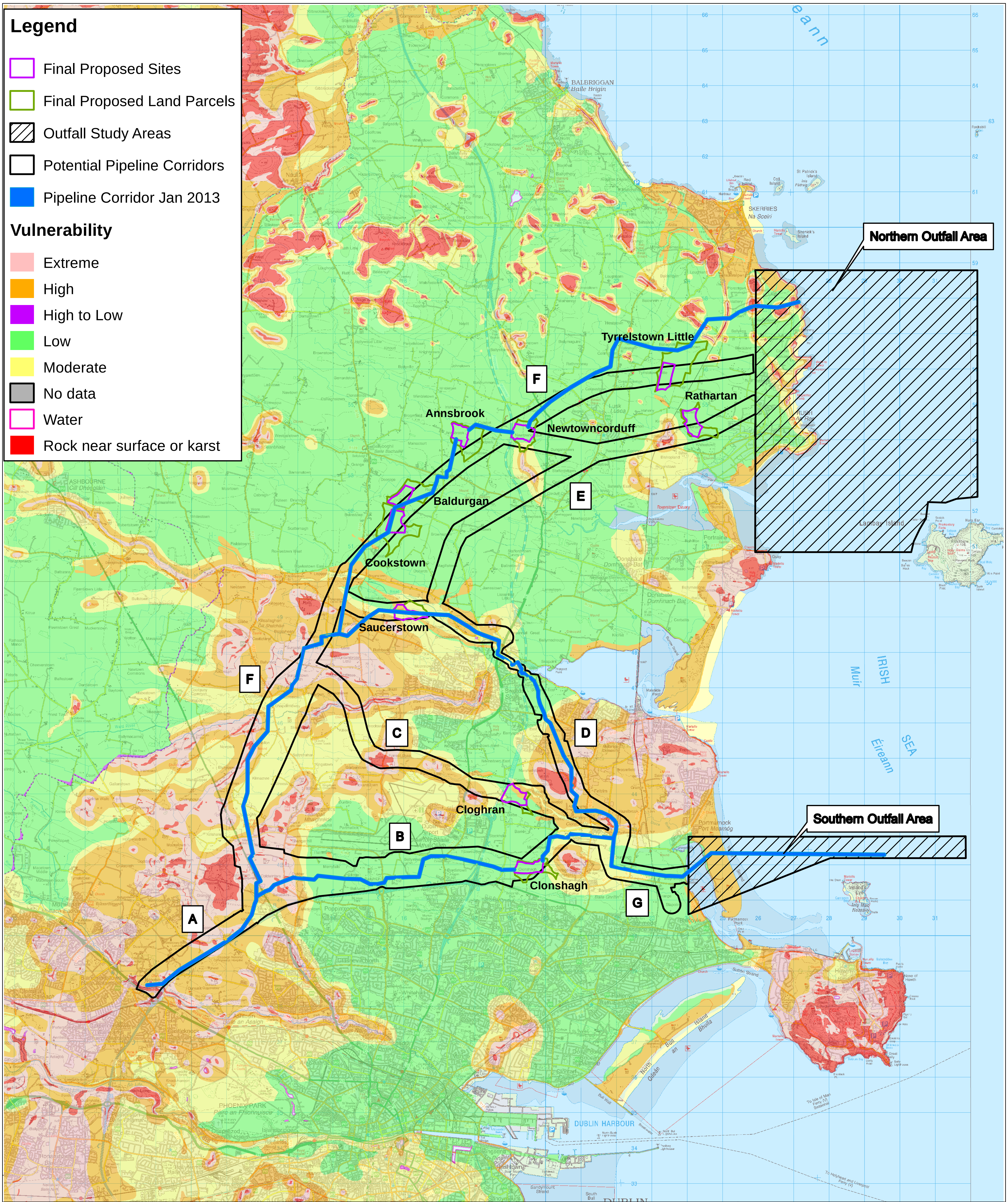

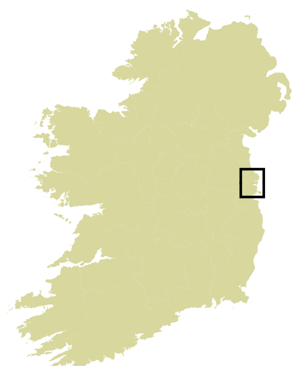

Drawing Title

ASA: PHASE TWO
SITES ASSESSMENT AND ROUTE SELECTION REPORT

GROUNDWATER VULNERABILITY MAP

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
D03	17/04/13	Draft - update Pipeline Corridor	MF			
D02	29/03/12	Updated format	BL			
D01	26/01/12	DRAFT	BL			

N W E S

0 1 2 3
Kilometres

Drawing Status: DRAFT
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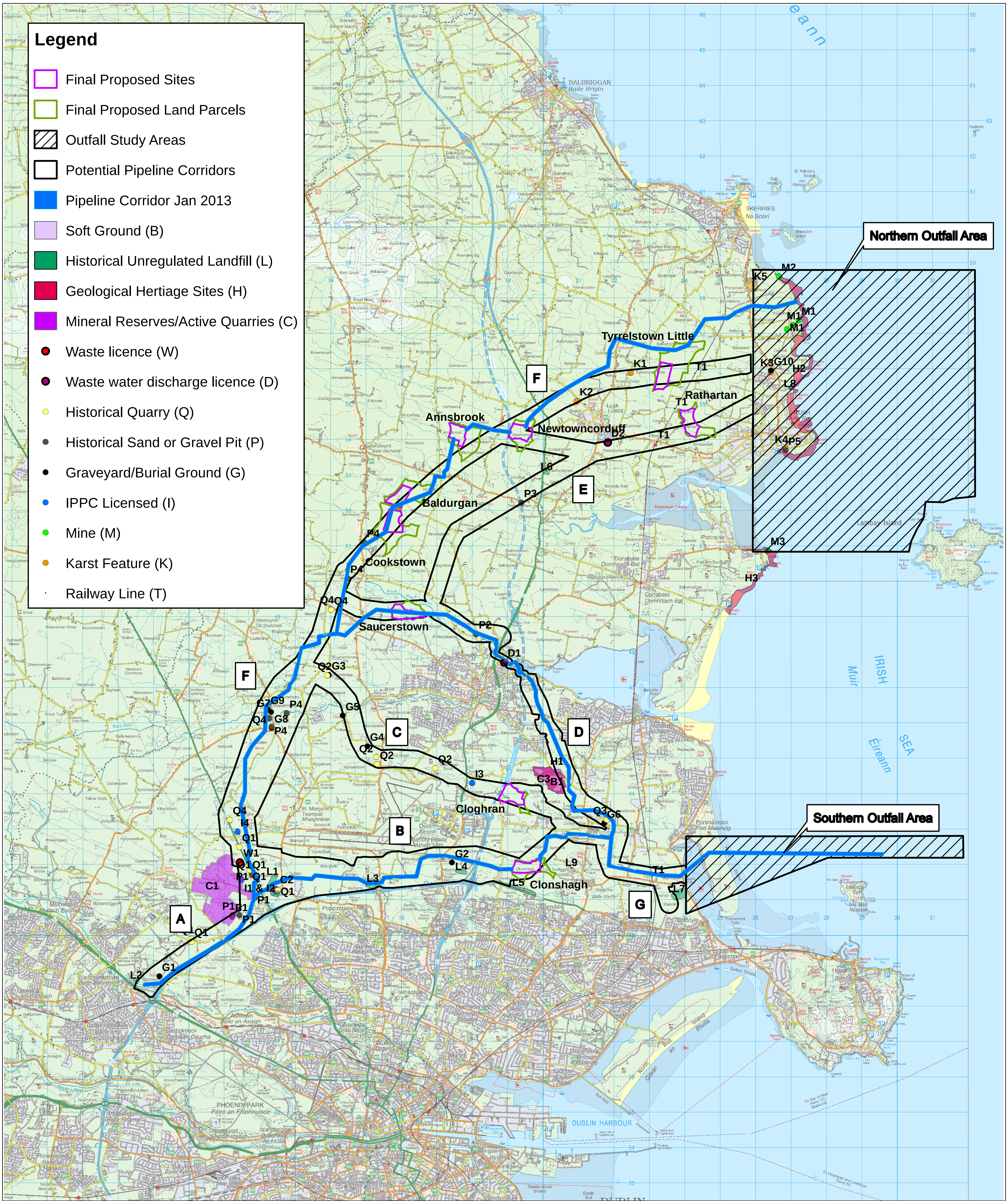
Job No. 218525-00
Drawing No. FIGURE 8.4



Greater Dublin Drainage

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
D04	17/04/13	Revised Pipeline Corridor Added	MF			
D03	29/03/12	Constraints updated	BL			
D02	26/01/12	Inclusion of new proposed site boundaries	BL			
D01	23/11/11	DRAFT	BL			

Kilometres 0 1 2 3

JACOBS TOBIN ARUP

Drawing Title

ASA: PHASE TWO
SITES ASSESSMENT AND ROUTE SELECTION REPORT

CONSTRAINTS MAP

Drawing Status: DRAFT

Scale @ A3: 1:100,000 | DO NOT SCALE

Job No.: 218525-00

Drawing No.: FIGURE 8.5

Legend

- Sites
- Boreholes & Slit Trenches
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

Issue	Date	By	Chkd	Appd
P1	12-04-12	DF	BA	SM

Metres
0 1,000 2,000 4,000

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Client
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Job Title
Dublin Greater Drainage Scheme

Location of Boreholes along Pipeline route

Scale at A3
1:75,000

Job No	Drawing Status
218525-00	**For Information**

Drawing No	Issue
G-001	**P1**

A3

Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

Issue	Date	By	Chkd	Appd
P1	12-04-12	DF	BA	SM

Metres
0 140 280 560

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Client
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Job Title
Dublin Greater Drainage Scheme

Location of Boreholes at Annsbrook

Scale at A3
1:10,000

Job No
218525-00

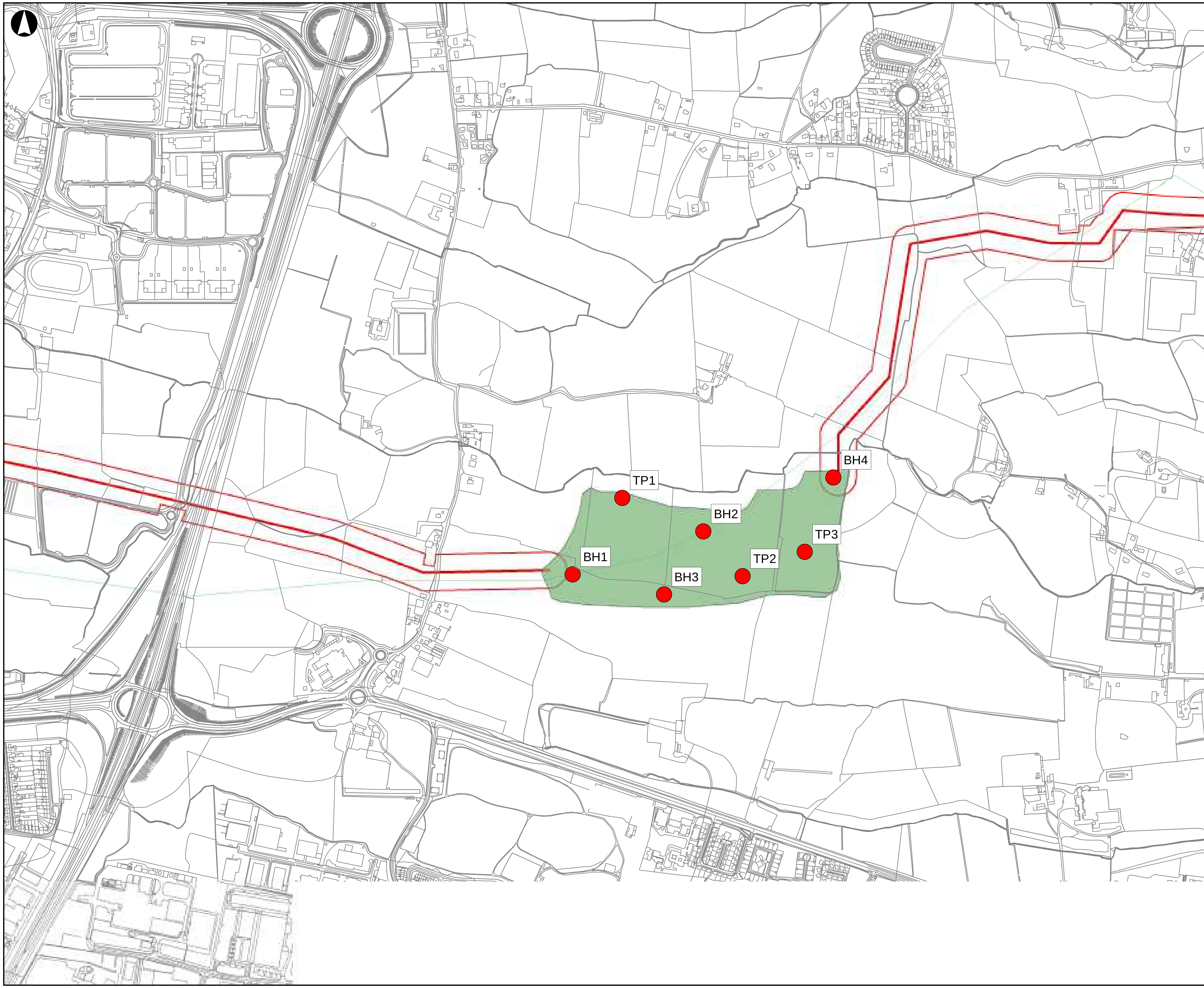
Drawing Status
For Information

Drawing No
G-002

Issue
P1

MXD Location

A3



Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

Issue	Date	By	Chkd	Appd
P1	12-04-12	DF	BA	SM

Metres
0 140 280 560

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Job Title
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Location of Boreholes at Clonsagh

Scale at A3
1:10,000

Job No
218525-00

Drawing Status
For Information

Drawing No
G-003

Issue
P1

MXD Location

A3

Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

P1	12-04-12	DF	BA	SM
Issue	Date	By	Chkd	Appd

Metres
0 140 280 560

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Job Title
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Location of Boreholes at Newtowncorduff

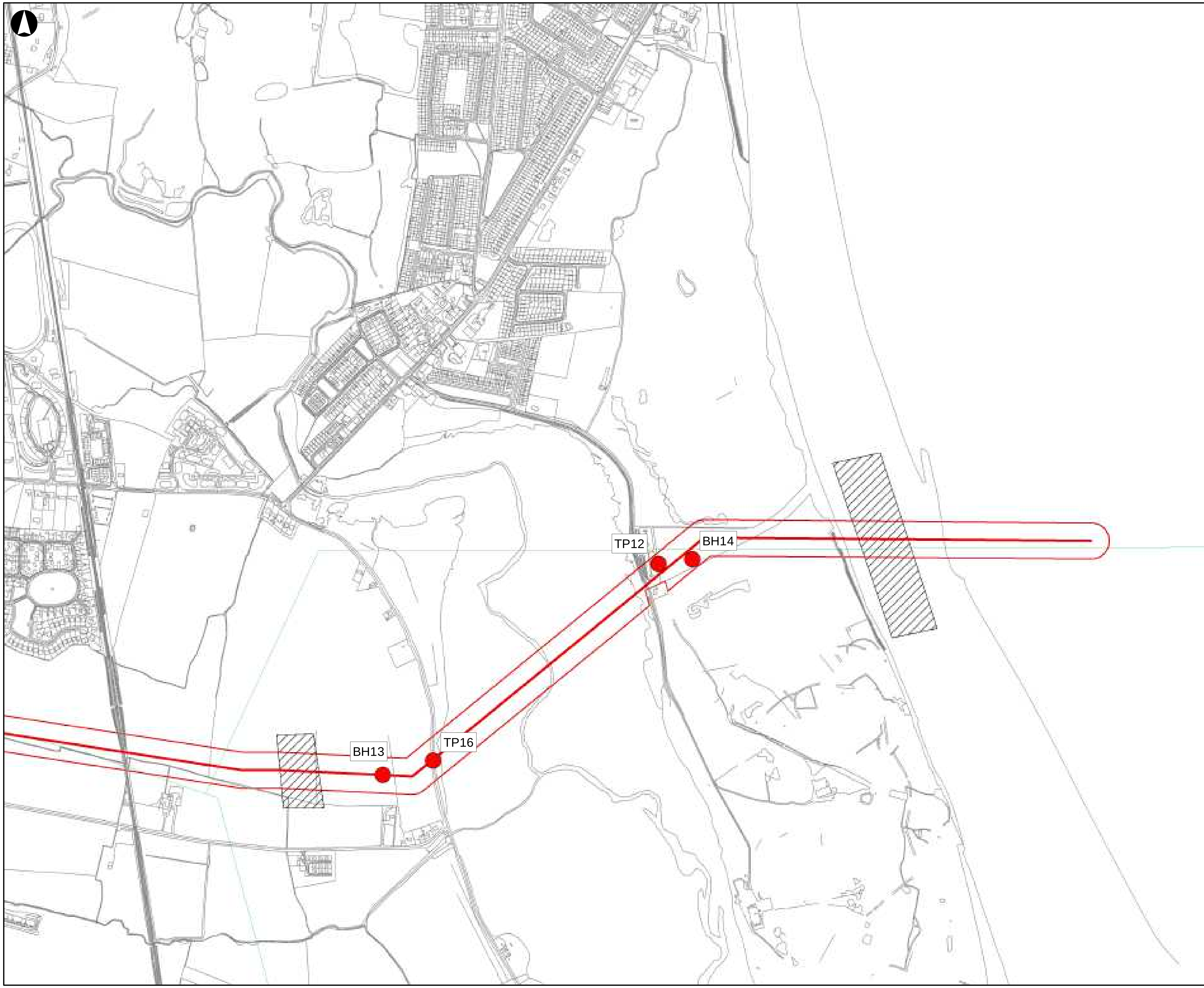
Scale at A3
1:10,000

Job No	Drawing Status
218525-00	**For Information**

Drawing No	Issue
G-004	**P1**

MXD Location

A3



Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

Issue	Date	By	Chkd	Appd
P1	12-04-12	DF	BA	SM

Metres
0 137.5 275 550

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Location of Boreholes at Southern Outfall

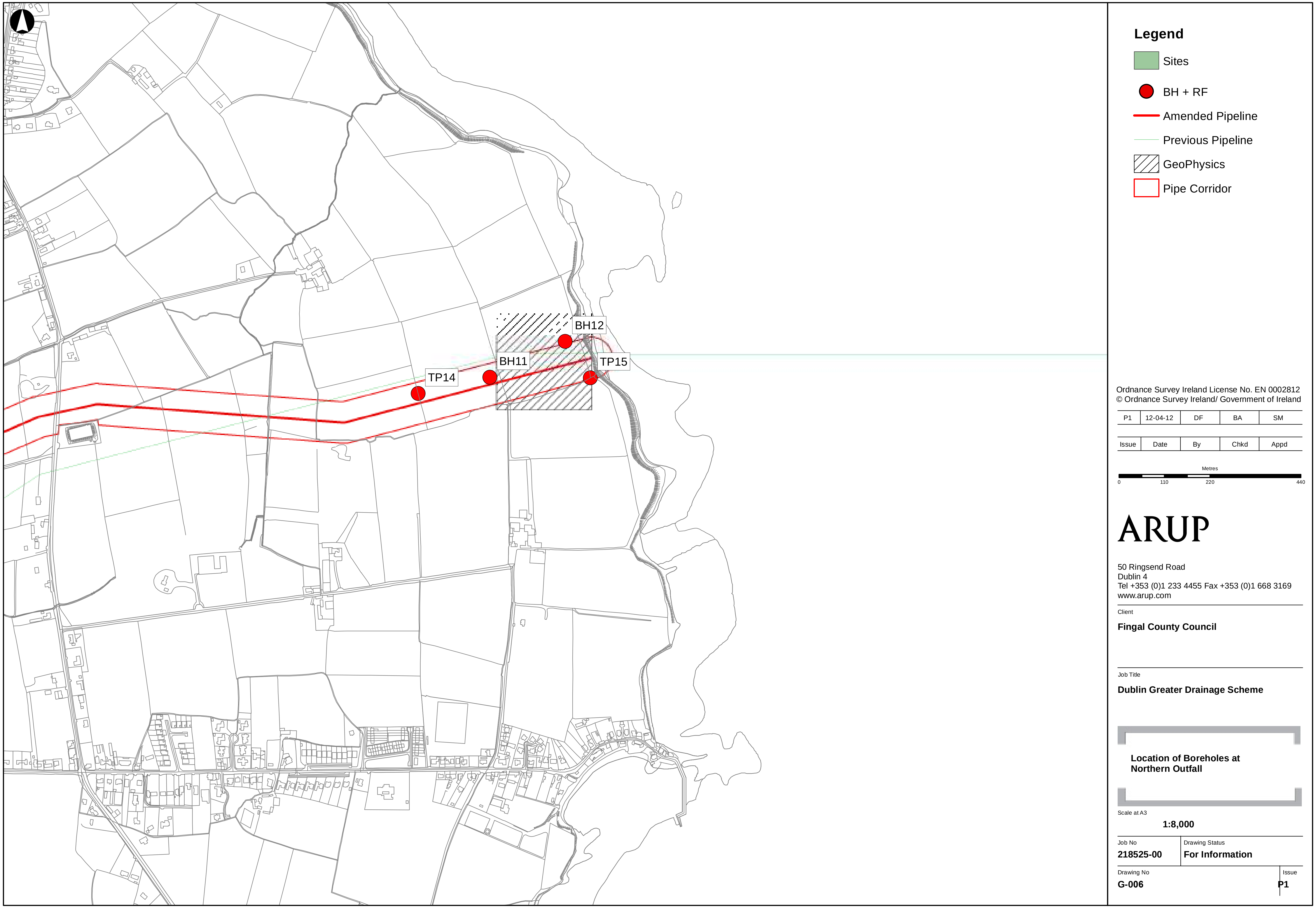
Scale at A3
1:10,000

Job No	Drawing Status
218525-00	**For Information**

Drawing No	Issue
G-005	**P1**

MXD Location

A3



Issue	Date	By	Chkd	Appd
P1	12-04-12	DF	BA	SM

Metres
0 110 220 440

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Job Title
Dublin Greater Drainage Scheme

Location of Boreholes at Northern Outfall

Scale at A3
1:8,000

Job No
218525-00

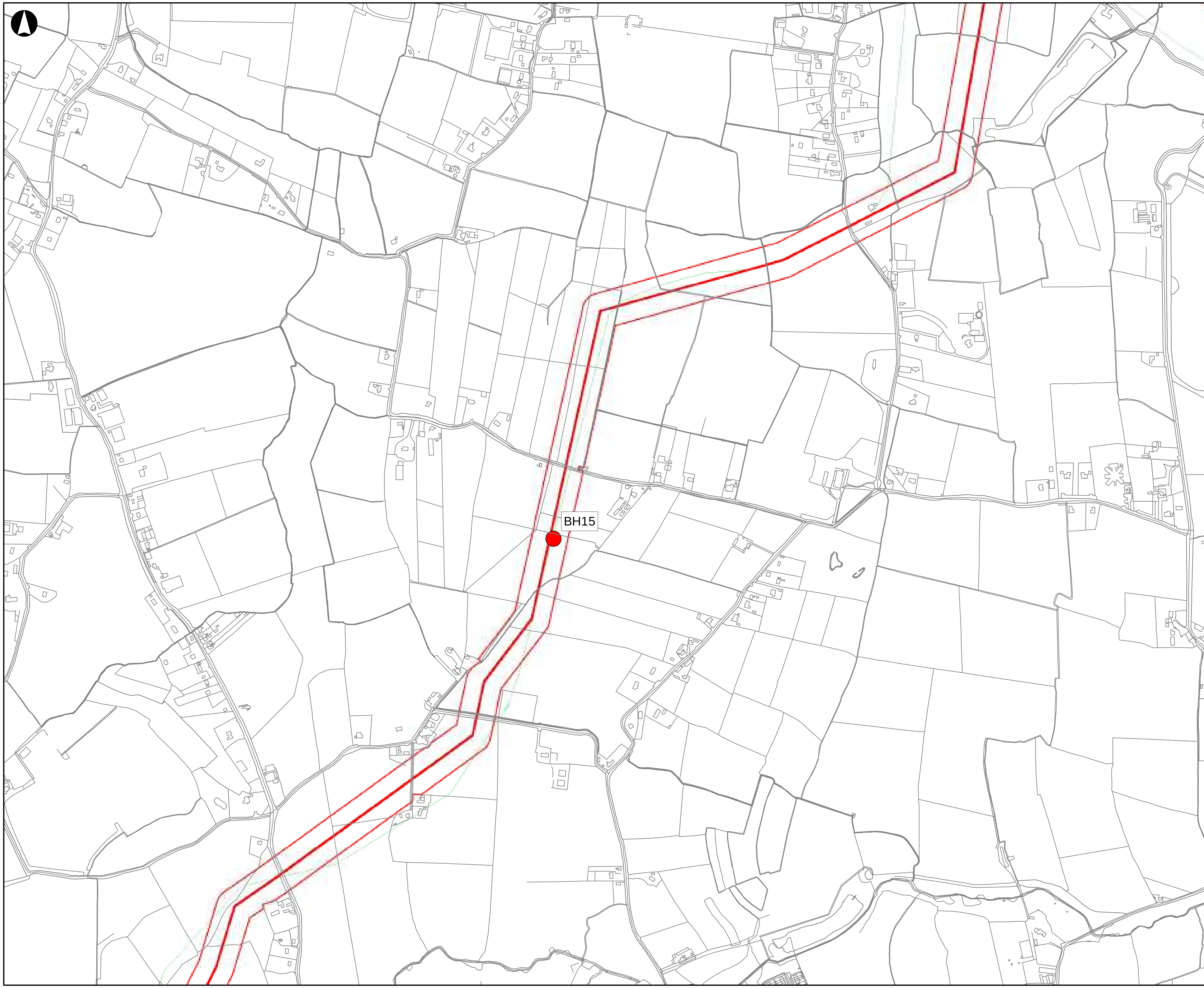
Drawing Status
For Information

Drawing No
G-006

Issue
P1

MXD Location

A3



Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

P1	12-04-12	DF	BA	SM
Issue	Date	By	Chkd	Appd

Metres
0 140 280 560

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Job Title
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Location of Borehole 15

Scale at A3
1:10,000

Job No	Drawing Status
218525-00	**For Information**

Drawing No	Issue
G-007	**P1**

MXD Location

A3

Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

P1	12-04-12	DF	BA	SM
Issue	Date	By	Chkd	Appd

Metres
0 140 280 560

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Job Title
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Location of Borehole 16

Scale at A3
1:10,000

Job No	Drawing Status
218525-00	**For Information**

Drawing No	Issue
G-008	**P1**

MXD Location

A3

Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

Issue	Date	By	Chkd	Appd
P1	12-04-12	DF	BA	SM

Metres
0 140 280 560

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Client
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Job Title
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Location of Boreholes 17 & 18

Scale at A3
1:10,000

Job No
218525-00

Drawing Status
For Information

Drawing No
G-009

Issue
P1

MXD Location

A3

Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

Issue	Date	By	Chkd	Appd
P1	12-04-12	DF	BA	SM

Metres
0 140 280 560

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Client
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Job Title
Dublin Greater Drainage Scheme

Location of Borehole 19

Scale at A3
1:10,000

Job No
218525-00

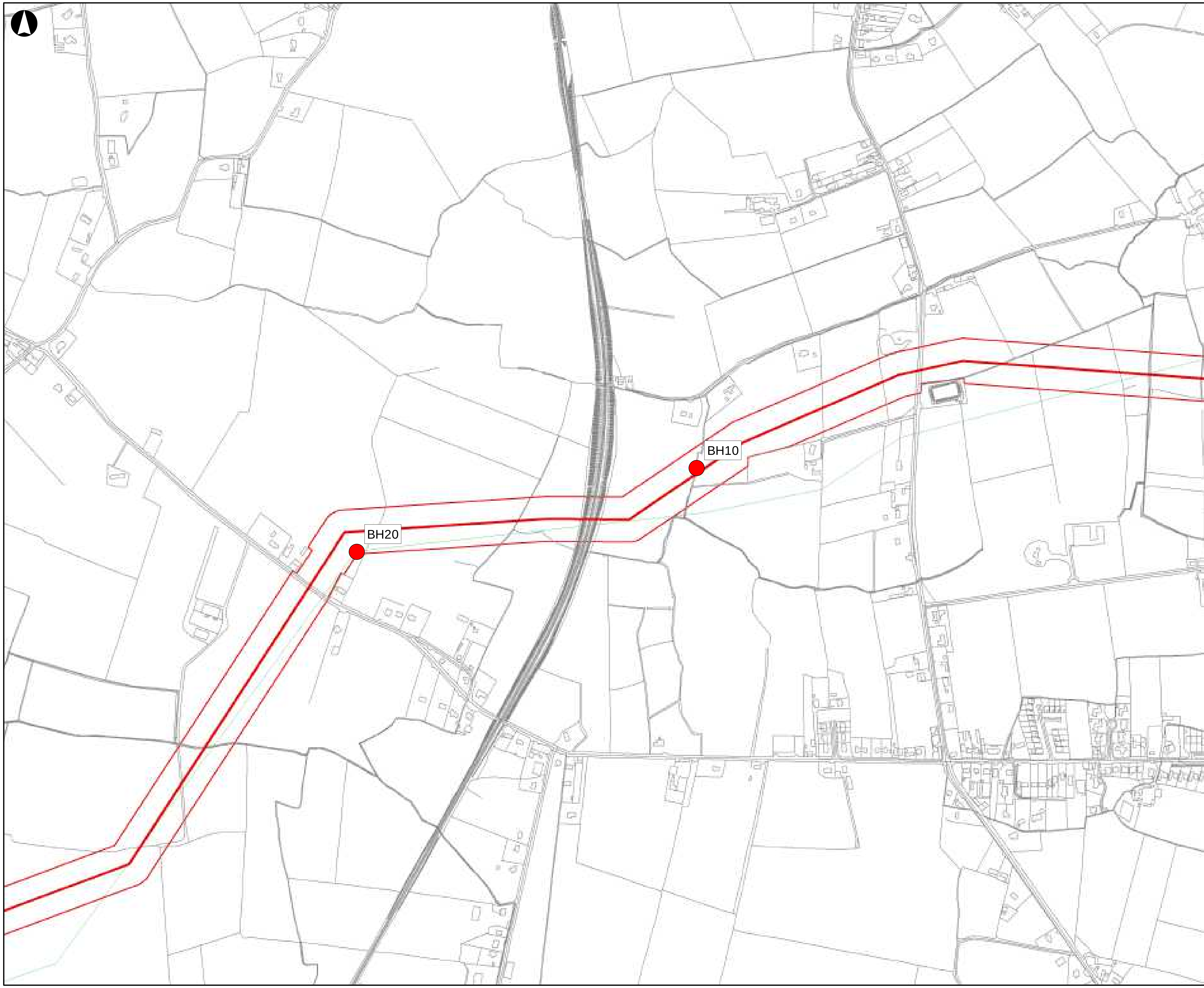
Drawing Status
For Information

Drawing No
G-010

Issue
P1

MXD Location

A3



Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

Issue	Date	By	Chkd	Appd
P1	12-04-12	DF	BA	SM

Metres

0 110 220 440

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Job Title

Dublin Greater Drainage Scheme

Location of Boreholes 10 & 20

Scale at A3

1:8,000

Job No	Drawing Status
218525-00	**For Information**

Drawing No	Issue
G-011	**P1**

MXD Location

A3

Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

Issue	Date	By	Chkd	Appd
P1	12-04-12	DF	BA	SM

Metres
0 140 280 560

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Client
Fingal County Council

Job Title
Dublin Greater Drainage Scheme

Location of Borehole 24

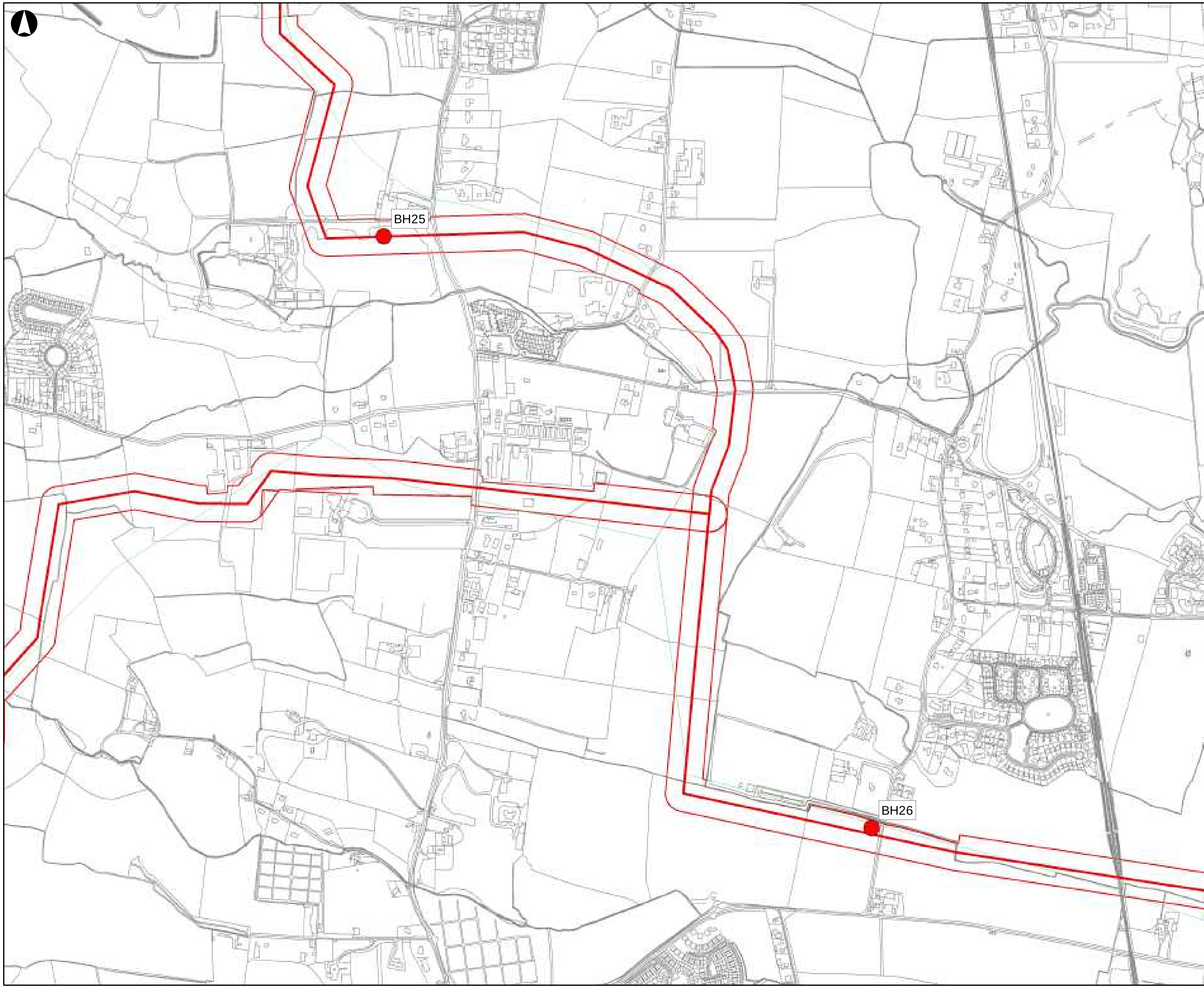
Scale at A3
1:10,000

Job No	Drawing Status
218525-00	**For Information**

Drawing No	Issue
G-012	**P1**

MXD Location

A3



Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

Issue	Date	By	Chkd	Appd
P1	12-04-12	DF	BA	SM

Metres
0 140 280 560

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Job Title
Dublin Greater Drainage Scheme

Location of Boreholes 25 & 26

Scale at A3
1:10,000

Job No
218525-00

Drawing Status
For Information

Drawing No
G-013

Issue
P1

MXD Location

RC Hole	Depth	Is	UCS	Description
	19	2.78		
	19.6	4.69		Medium strong thinly bedded grey fine grained agrillaceous LIMESTONE with occasional medium to widely spaced medium strong to weak very thin black MUDSTONE. Weathering: Negligable Discontinuities 18.0-22.15m 0-10° very closely to medium spaced smooth planar tight to partly open, clean. Occasional extremely closely spaced fractures in mudstone 18.0-18.12m fracture 90° smooth planar 18.60-18.86m Fracture 90° smooth planar
	21.4	4.04		19.70m Coarse sand-sized disseminated cubic pyrite Medium strong thinly bedded grey fine grained agrillaceous LIMESTONE with occasional medium to widely spaced medium strong to weak very thin black MUDSTONE. Weathering: Negligable Discontinuities 18.0-22.15m 0-10° very closely to medium spaced smooth planar tight to partly open, clean. Occasional extremely closely spaced fractures in mudstone (continued) 21.26-21.30m Soft to firm black CLAY with some subangular gravel-sized fragments of very weak mudstone
RC06	21.6	2.59		
	15.6	3.35		Medium strong thinly to medium bedded dark grey fine to medium grained argillaceous LIMESTONE with medium to widely spaced very thin medium strong black MUDSTONE bands. Weathering: Loss of wall strength to very weak in extremely closely fractured / laminated mudstone. (16.40 - 16.48m) Discontinuities 15.0-17.80m 0-10° extremely closely to medium predominantly closely spaced smooth planar tight, clean. 15.45-15.48m Non intact angular to subangular gravel-sized fragments of argillaceous limestone wiith some black clay 15.92-16.32m Fracture 80° to subvertical smooth undulating with thin (1-2mm thick) brwon CLAY veneer 17.34-17.43m Fracture 60° smooth planar with brown non-penetrative discolouration
RC07	15.8	3.83		
	15.1	2.74		Medium strong thinly to medium bedded dark grey fine to medium grained argillaceous LIMESTONE with medium to widely spaced very thin medium strong black MUDSTONE bands. Weathering: Loss of wall strength to very weak in extremely closely fractured / laminated mudstone. (16.40 - 16.48m) Discontinuities 15.0-17.80m 0-10° extremely closely to medium predominantly closely spaced smooth planar tight, clean. 15.45-15.48m Non intact angular to subangular gravel-sized fragments of argillaceous limestone wiith some black clay 15.92-16.32m Fracture 80° to subvertical smooth undulating with thin (1-2mm thick) brwon CLAY veneer 17.34-17.43m Fracture 60° smooth planar with brown non-penetrative discolouration
	15.9	2.87		
	16.0-16.4		58.2	
RC09	16.3	2.74		
	14.5	1.66		Strong massively bedded light grey and brown calcisiltite LIMESTONE with significant brecciation coupled with penetrative brown discolouration and honeycomb dissolution features / pitting of core walls (up to 20mm). Weathering: Slight loss of core strength in areas displaying dissolution to medium strong occasionally weak Discontinuities 13.40-16.10m SET 1: 0-10° closely to medium spaced rough undulating occasionally smooth partly open, occasionally with brown fine sand on fracture surfaces. SET 2: Subvertical widely spaced rough undulating, open with yellow clay smearing on fracture surfaces
	14.6	3.26		
	18.3	0.2		Medium strong medium bedded light grey green fine grained argillaceous LIMESTONE with localised brecciation often loosely cemented. Weathering: Occasional loss of wall strength to weak at fractures. Penetrative (up to 5mm) orange brown discolouration noted on subvertical fracture surfaces Discontinuities 16.10-19.30m SET 1: 0-10° closely spaced rough undulating tight to partly open, clean. SET 2: 60-80° closely to medium spaced rough undulating, open often displaying orange brown discolouration, occasionally with light grey green sandy CLAY veneer on surfaces. Fracture set often associated with non intact angular to subrounded fine to medium gravel-sized fragments of light grey green limestone. 18.35-18.50m 10mm thick subvertical to undulating calcite vein
RC11	18.4	0.13		
	25.4	1.06		Medium strong to very strong, medium to thinly bedded, grey/pale greym fine-grained, LIMESTONE (locally plastically sheared), fresh to slightly weathered. Discontinuities are medium to closely spaced, rough, irregular. Apertures are tight to moderately open, locally clay-smeared, commonly moderately iron-oxide stained, locally calcite-veined (1-8mm thick). Dips are 45° & sub-vertical.
	25.9	1.27		
	26.1	1.43		
RC13	27.1	0.61		
	21.3	2.16		Medium strong to very strong, medium to thinly bedded, grey/pale greym fine-grained, LIMESTONE (locally plastically sheared, predominantely calci-siltite but grading into argillaceous limestone approx every 1.00m), fresh to moderately weathered (at 20.80-20.91m). Discontinuities are medium to closely spaced, rough, planar. Apertures are tight to open, locally clay-smeared, locally slightly iron-oxide stained, locally calcite-veined (1-30mm thick). Dips are 45-60°.
	21.3-21.5		57.09	
	21.7	2.33		
	22.3	1.72		
RC14	22.4	2.13		
	6.55	0.73		Medium strong to strong medium to thinly bedded grey and dark grey black fine grained argillaceous LIMESTONE with occasional widely spaced medium thickness band of calcisiltite LIMESTONE (3.70-3.90m, 7.50-7.70m, 8.80-9.11m, 28.95-29.90m) and occasional medium to widely spaced very thin calcite vein (rarely showing plastic shearing at 12.80-13.0m) Weathering: Slight brown and yellow brown non-penetrative staining on fracture surfaces (3.40-4.55m). Otherwise Negligable. Discontinuities 3.40-8.25m SET 1: 0-10° closely spaced smooth planar tight, clean with rare yellow brown non-penetrative discolouration. SET 2: Subvertical widey spaced smooth planar to undulating partly open with occasional very thin calcite (~1mm) veneer on exposed surfaces - possible failed calcite vein 7.45-7.70m Incipient subvertical fracture with brown staining along fracture Discontinuities 8.25-29.80m SET 1: 0-10° closely to widely spaced predominantly medium spaced tight, clean. SET 2: 45-60° medium to widely spaced smooth planar occasionally undulating tight clean
	7.65	0.34		
	7.7-7.9		63.46	
	7.95	1.15		
	14	1.3		Medium strong to strong medium to thinly bedded grey and dark grey black fine grained argillaceous LIMESTONE with occasional widely spaced medium thickness band of calcisiltite LIMESTONE (3.70-3.90m, 7.50-7.70m, 8.80-9.11m, 28.95-29.90m) and occasional medium to widely spaced very thin calcite vein (rarely showing plastic shearing at 12.80-13.0m) Weathering: Slight brown and yellow brown non-penetrative staining on fracture surfaces (3.40-4.55m). Otherwise Negligable. Discontinuities 3.40-8.25m SET 1: 0-10° closely spaced smooth planar tight, clean with rare yellow brown non-penetrative discolouration. SET 2: Subvertical widey spaced smooth planar to undulating partly open with occasional very thin calcite (~1mm) veneer on exposed surfaces - possible failed calcite vein (continued) 13.70-13.95m Incipient fracture 70° partly open 15.45m Cluster of cubic pyrite along incipient subvertical fracture tight 15.50-15.80m 75° fracture smooth stepped 16.35-16.70m Incipient subvertical fracture tight 19.60-19.70m 45° fracture smooth planar with non-penetrative yellow brown discolouration
	14.1-14.3		14.3	
	14.35	1.76		
	14.7	0.93		
	22.9	4.3		As above - 21.60-22.0m 70-80° fracture smooth undulating with orange brown non-penetrative discolouration on fracture surfaces 22.40-22.50m 50° fracture smooth undulating with orange brown non-penetrative discolouration on fracture surfaces 23.40-24.80m Strong matrix-supported fossiliferous mud-rich wackestone LIMESTONE (clasts up to 45mm) 24.0-25.0m Possible Limestone boulder 25.0-25.10m Thin calcite (10mm) veinfill reduced to weak wall strength 25.67-25.68 Soft grey CLAY veneer on non-intact angular medium to coarse gravel fragments 29.70-29.80m Non-intact angular medium to coarse
	23-23.4		46.37	
	23.5	3.23		
	23.9	3.99		
	27.7	0.3		
	27.8-28		26.64	
RC15	28.1	3.25		
	13.6	1.85		Medium strong dark grey and black very thin to thinly bedded fine grained argillaceous LIMESTONE with closely to medium spaced very thin weak MUDSTONE bands and occasional firm black clay often associated with brecciated limestone material (13.10-13.26, 13.45-13.61m & 14.44-14.75m). Weathering: Mudstone bands display occasional loss of wall strength to very weak. Discontinuities 13.0-15.0m 0-10° very closely to closely spaced smooth planar occasionally associated with angular non intact gravel-sized fragments of argillaceous limestone and mudstone, partly open, with occasional black clay smear (<2mm)
RC17	14.2	0.88		
	5.5	2.34		Strong grey and dark grey thin to medium bedded slightly fossiliferous fine grained argillaceous LIMESTONE with occasional thin calcite veins (<1mm) and rarely plastically sheared matrix. Weathering: Negligable Discontinuities 5.0-10.10m 5-20° closely to widely spaced predominantly medium spaced smooth undulating, tight to moderately open, clean
	6.35	2.39		
	6.3-6.6		34.86	
	6.7	3.1		
	8.85	2.8		
	9.65	1.14		
	9.75-9.95		94.21	
RC24	10	2.82		

Appendix A

Annsbrook - Site Plan, Graphs and Logs

A1

A3

Legend

- Sites
- BH + RF
- Amended Pipeline
- Previous Pipeline
- GeoPhysics
- Pipe Corridor

Issue	Date	By	Chkd	Appd
P1	12-04-12	DF	BA	SM

Metres
0 140 280 560

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Client
Fingal County Council

Job Title
Dublin Greater Drainage Scheme

Location of Boreholes at Annsbrook

Scale at A3
1:10,000

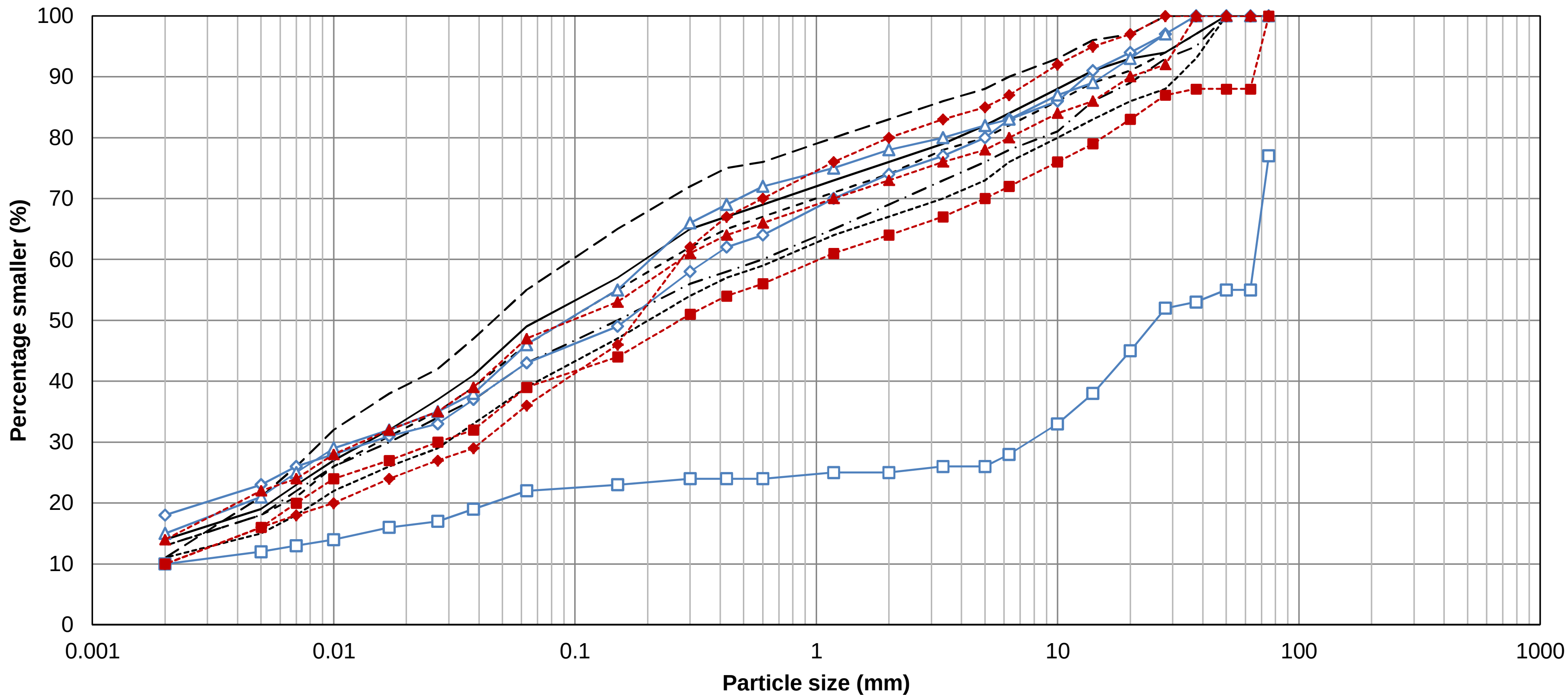
Job No
218525-00

Drawing Status
For Information

Drawing No
G-002

Issue
P1

MXD Location



Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles	Boulders
	Silt			Sand			Gravel				

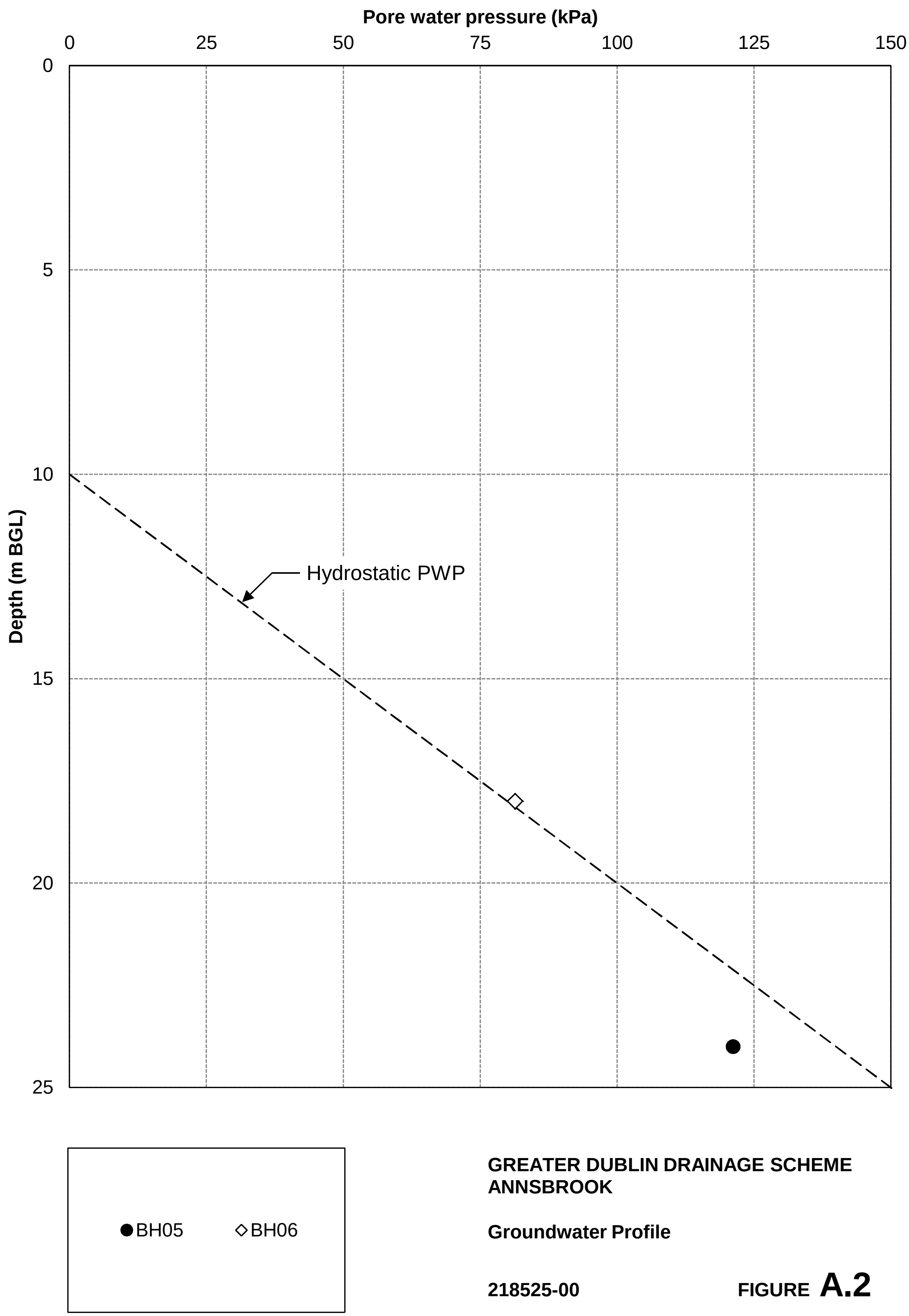
TP04 (0.6 m)
TP06 (0.9 m)
TP07 (1.1 m)
TP07 (1.7 m)
TP09 (1.0 m)
BH05 (3.0 m)
BH05 (4.0 m)
BH05 (11.0 m)
BH06 (2.0 m)
BH06 (6.5 m)
BH06 (9.5 m)

GREATER DUBLIN DRAINAGE SCHEME
ANNSBROOK

Particle Size Distribution

218525-00

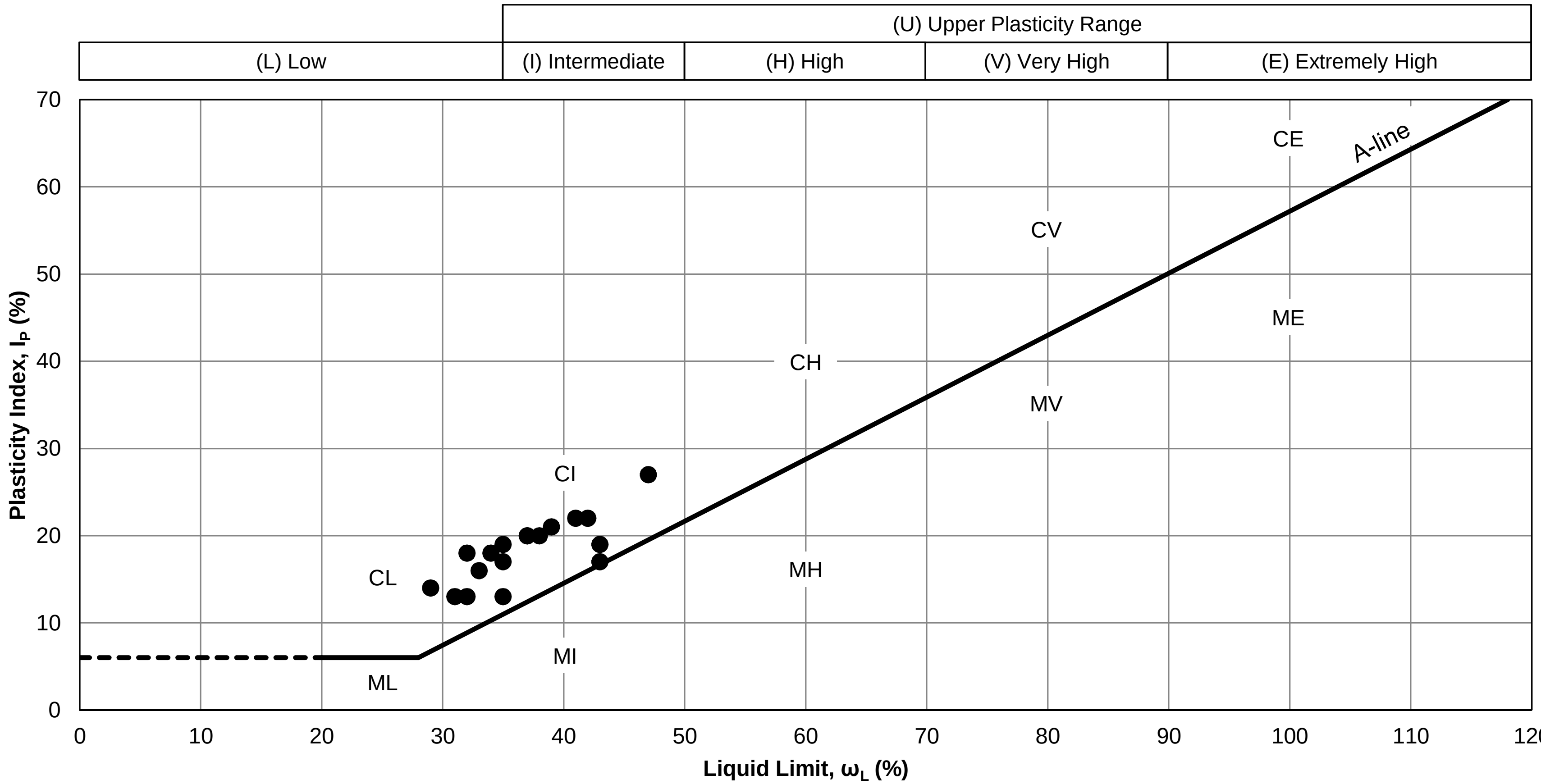
FIGURE A.1



GREATER DUBLIN DRAINAGE SCHEME
ANNSBROOK

Groundwater Profile

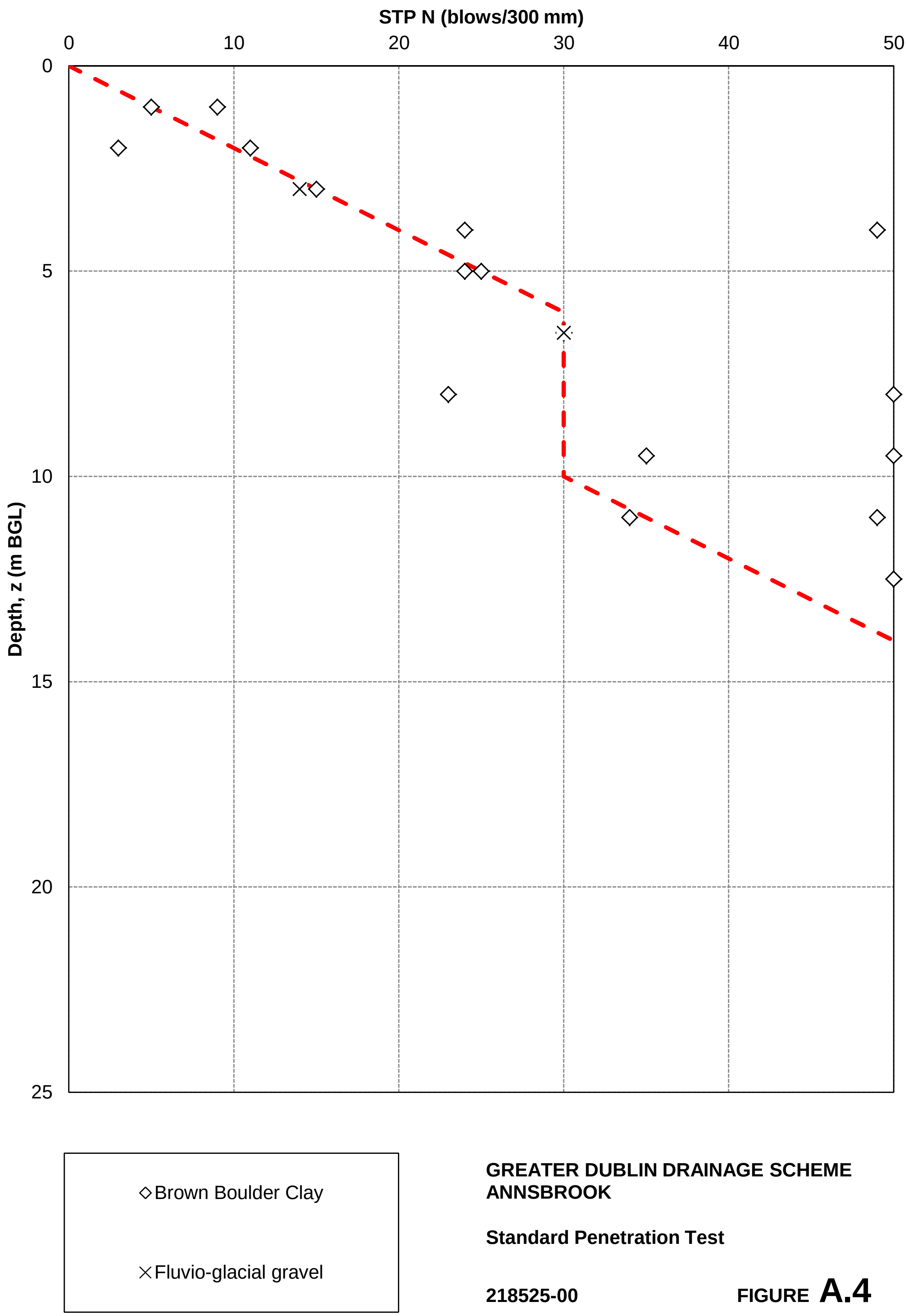
218525-00 **FIGURE A.2**



GREATER DUBLIN DRAINAGE SCHEME
ANNSBROOK

Particle Size Distribution

218525-00 **FIGURE A.3**



GREATER DUBLIN DRAINAGE SCHEME
ANNSBROOK

Standard Penetration Test

218525-00 **FIGURE A.4**