Banniskirk Hub Site

Earthworks Strategy

Prepared for

J. Murphy & Sons Ltd.; Scottish & Southern Electricity Networks (SSEN)

Document no: BANN4-LT407-JMS-EWKS-XX-PLN-G-0002
Revision: P03
Date: 14/06/2024

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Document Issue Record

Project:	Banniskirk Hub Site
Report Title:	Earthworks Strategy
Client:	J. Murphy & Sons Ltd.; Scottish & Southern Electricity Networks (SSEN)
Document No:	BANN4-LT407-JMS-EWKS-XX-PLN-G-0002
Revision:	P03
Status	S5 – Suitable for review and authorisation
Date:	14/06/2024
Filename:	BANN4-LT407-JMS-EWKS-XX-PLN-G-0002

Rev	Date	Description and Purpose of Issue	Prepared	Reviewed	Approved
P01	09/04/24	First Issue	TK	AF	TCC
P02	21/05/24	Re-issue following SSEN comment	TK	AF	TCC
P03	14/06/24	Full Earthworks Strategy	TK	AF	TCC

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1. Introduction

Tony Gee and Partners LLP (TG) have been appointed by Scottish & Southern Electricity (SSEN) to undertake the detailed design of the earthwork platform and foundations to support the proposed 400kV Banniskirk Substation located in the north of Scotland, adjacent to the A9 trunk road, north of Spittal. The proposed substation is to facilitate connections for new and renewable onshore and offshore electricity generation.

This report is intended to supersede the Earthworks Strategy produced by Jacobs in 31st January 2023 and the Earthworks Strategy Addendum produced by TG and most recently issued in May 2024.

2. Ground Investigation

2.1. Available Ground Investigation Information

A site-specific Ground Investigation (GI), scoped by Jacobs on behalf of SSEN, was undertaken by Raeburn Drilling and Geotechnical Ltd in July/August 2023. The findings of the investigation are contained in the following report:

SSEN LT407 SPITTAL SUBSTATION REPORT ON GROUND INVESTIGATION, Raeburn Drilling and Geotechnical Ltd, Contract number: 26470, Date of Issue: 18 December 2023, Report Issue: Final.

An extract of the exploratory hole locations is shown in Figure 1 and a summary of the GI undertaken is included in Figure 2.

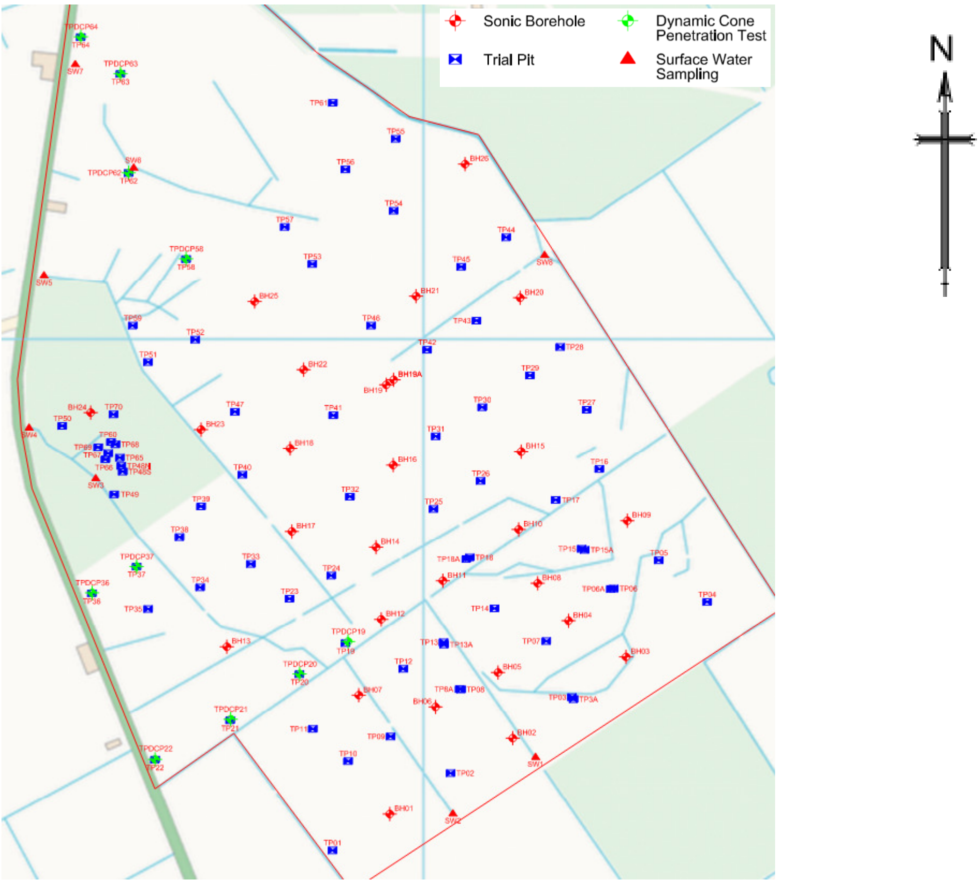

Figure 1. GI plan (extract taken from GI Factual Report. Contract No. 26470)

Type of fieldwork		Number undertaken
Exploratory Hole Method	Boreholes (sonic cored)	27
	Trial Pits	70
In-Situ Testing	SPTs	17
	Thermal Resistivity tests	7
	DCPs	11
	Soakaway	7
Groundwater Monitoring	Standpipe	19

Figure 2. GI Summary

2.2. Summary of Ground Conditions

A GIR, produced by Jacobs, published 23rd January 2024 (Document No. B2413738-JAC-ZZ-XX-RP-GE-0001. Revision: 01) covers the ground conditions at the site. A summary of the ground is included below.

2.2.1. Topsoil

Topsoil was encountered across the site and often described as peaty topsoil. Topsoil was encountered to a maximum depth of 0.50m bgl but typically 0.3m thick.

2.2.2. Made Ground

General Made Ground is noted across the site to a maximum depth of 1.50m bgl. The material is typically described as slightly silty sandy gravel with low cobble content.

Quarried Made Ground is also reported on site. This material is located near the disused quarry and is found to a maximum depth of 2.20m bgl.

2.2.3. Peat

Peat is encountered within localised areas of the site and is found to a depth of 0.65m bgl.

2.2.4. Cohesive Glacial Deposits

Cohesive Glacial Deposits were encountered across most of the site and were found to typically comprise slightly gravelly to gravelly slightly sandy clay with cobbles and boulders.

The deposits are typically described as very soft to stiff mottled brown, grey and orange slightly gravelly to gravelly slightly sandy to sandy CLAY or SILT with low to medium cobble content or soft to firm locally stiff blueish grey slightly gravelly to gravelly slightly sandy to sandy CLAY or SILT of low plasticity with medium cobble content.

These deposits were found from a depth of 0.05m bgl to 4.30m bgl.

2.2.5. Granular Glacial Deposits

Granular Glacial Deposits are present as localised sand and gravel throughout the site and are more prevalent in the north of the site. The granular deposits are encountered between 0.10m and 3.00m bgl.

They are typically described as light brown to brownish grey, occasionally mottled orange, slightly gravelly to very gravelly, silty to very silty or clayey fine to coarse SAND with low cobble content.

2.2.6. Weathered Bedrock

Weathered bedrock as residual soil was not extensively encountered and occurs as localised areas beneath the Glacial Deposits throughout the site. Weathered rock encompasses weathered sandstone, siltstone and mudstone typically recovered as orangish brown/grey or greyish brown silty to very silty slightly sandy to very sandy fine to coarse angular GRAVEL.

The Weathered Bedrock was encountered between 0.50m bgl and 5.70m bgl.

2.2.7. Siltstone Bedrock

Siltstone was encountered within all boreholes and most of the trial pits across the site. Within the boreholes, bedrock was encountered between 0.75m and 5.70m bgl.

The Siltstone was typically described as medium strong to very strong, locally weak, thinly laminated grey and orangish brown slightly sandy SILTSTONE with occasional planar white calcite veins (up to 10mm thick). Slight to moderately weathered evident, particularly in the upper strata, as frequent surface and penetrative orangish brown iron staining on fracture surfaces (up to 10mm), high fracture density, frequently non-intact and rare silt infill on fracture surfaces (up to 5mm thick); Occasionally the core was described as fresh with no weathering.

2.2.8. Mudstone Bedrock

Mudstone is interbedded with siltstone between 2.70m and 7.80mbgl and is typically described as extremely weak to moderately weak dark grey and brownish grey shaley MUDSTONE recovered as fine to coarse angular gravel or slightly gravelly sandy clay with lithorelics.

2.2.9. Groundwater

Gas and groundwater monitoring instrumentation was installed in selected boreholes across the site to provide groundwater level and gas concentration data. The groundwater monitoring undertaken to date indicates that the recorded groundwater level is at shallow level across most of the site. The shallowest recorded groundwater levels vary from marginally below ground level in BH17 (0.10mbgl) to 1.52mbgl within BH24 in the immediate vicinity of the disused quarry.

3. Re-use of as-dug materials

The requirements of SP-NET-CIV-501 and SHW Series 600 govern the acceptability of excavated material for re-use and additionally takes cognisance of the GI and associated laboratory testing. The acceptable material properties are summarised in Table 6/1 of SHW Series 600, with some acceptability criteria being defined in the table and others being defined by the designer in a Specification Appendix.

For the values that the designer will ultimately specify, engineering judgement has been applied based on general practice in the UK and the available laboratory testing data. Such values for the superficial deposits are summarised below as a guide to acceptability for earthworks fill.

- Moisture content generally ±2% of Optimum Moisture Content (OMC).
- Moisture Condition Value (MCV) should be in the range 8 to 15.
- Undrained shear strength of remoulded material should be >75kN/m^2

Consideration has also been given to the use of the superficial deposits as landscape fill. In this case a wider range of acceptability can be used, the primary requirement being the ability to place and traffic the material as opposed to a need to attain specific engineering performance. For landscaping the lower limit of MCV could reasonably be reduced to 6.

3.1. Topsoil / Peat

Excavated topsoil/peat should be separated from other materials excavated on site and stockpiled in accordance with SHW Series 600 Clause 602. Where peat deposits can be sensibly separated from the topsoil, they should be recovered and stored separately.

Topsoil will be suitable for re-use in landscaping areas only as a Class 5 material in in accordance SHW Series 600.

Minor occurrences of peat were recorded as localised thin deposits on site. In practice peat may be difficult to separate from topsoil, given that some of the topsoil is described as peaty. An environmental specialist should give consideration as to whether a Peat Management Plan is required for the site.

3.2. Superficial Deposits

The superficial materials are considered unlikely to be acceptable for reuse as engineered fills in their as-excavated condition. This is due to the elevated moisture content of the materials, which significantly exceeds the optimum moisture content required to achieve efficient compaction. When considering particle size distribution analysis of the materials, there is significant overlap between the Granular and Cohesive Glacial Deposits with both having a high fines content in excess of 15%. These deposits will therefore be particularly moisture susceptible and challenging to place to an engineering standard without controlling the moisture content. Accordingly, these deposits are likely to classify as Class U1A in accordance with SHW Series 600 in their excavated state.

Notwithstanding the above, with appropriate drying, the superficial deposits are likely to meet the requirements of Class 2C material (General Cohesive Fill - Stony Cohesive material) in accordance with SHW Series 600. Drying of the material could be achieved through air drying (evaporative dewatering) or conditioning with lime or cement. Mixing the superficial deposits with other materials (processed rock) may also be possible, albeit, this is unlikely to prove economically viable.

With appropriate drying of the superficial deposits, it is reasonable that somewhere between 50% and 75% of the excavated material could be rendered suitable for earthworks. However, it is understood that processing of the superficial to render the material suitable is not considered feasible.

Unacceptable superficial deposits could potentially be used for landscaping (Class 4 Fill to landscape areas) where the range of acceptability can be widened subject to the practical aspects of material handling (i.e., placement and trafficking during construction). With appropriate specification, processing and handling the unsuitable material could meet the requirements of Class 4 material.

3.3. Bedrock

Excavated bedrock, with appropriate processing, has potential to meet the requirements of Classes 1 or 6 in accordance with the SHW Series 600. This material is considered to represent the best material on site for engineering re-use. Some allowance should be made for losses/wastage in processing; however, such losses should be relatively low with in excess of 90% of the excavated material being suitable for re-use.

Aggregate tests including Los Angeles Abrasion Value, Magnesium Sulphate Soundness, Water Absorption and Slake Durability were carried out on the siltstone bedrock as part of the GI. The test results, which are summarised in the GIR, indicate that the aggregate properties of the bedrock are within the acceptable limits defined in Appendix A of the SSEN Specification for Earthworks for the platform materials (Class 6F2, Type 3 and single-sized aggregate).

Although the siltstone bedrock is technically an argillaceous material, and argillaceous materials are precluded by Appendix A of the SSEN Specification for Earthworks for Class 6N granular fill. The aggregate testing undertaken as part of the GI has demonstrated the competency and durability of the material. As an aside it is noted that the same bedrock formation is quarried just to the south of the site for high-quality flagstone paving and use in aggregate production. Accordingly, it is considered reasonable that the excavated bedrock can be processed to meet the requirements of Class 6N fill material, albeit this will require appropriate adjustment to the permitted constituents and material acceptance properties in the Earthworks Specification.

4. Earthworks Balance Information

The earthworks balance has been undertaken based on the latest site arrangement provided by J. Murphy & Sons Ltd. HV Plant Design Team (BAAN4-LT407-JMS-MPD-INT-GA-M-0001 - Phase2B Submission Frozen Layout, Rev. P01.5, provided on 14/03/2024).

For the determining the earthworks material volumes, the following assumptions have been made:

- Ground level profile is based on an aerial LiDAR survey provided by SSEN (Cyberhawk Datasets, provided on 12/02/2024). Further topographical survey is required prior to detailed design to ensure sufficient coverage across the full site extents.
- A 3D ground model has been produced based on factual information provided in GI report (Contract No.: 26470) and simplified into three soil layers; Topsoil, superficial material and rock.
- A uniform thickness of topsoil equal to 300 mm has been assumed.
- The separate two platform areas for the DC and AC facilities are to be broadly level over the full extent of each platform, with a level difference of up to 3 m between the DC and AC platforms considered in the modelling.
- Allowance has been made for the platforms to be excavated to rockhead and backfilled to platform level with granular material at the location of Syncom buildings, given their more sensitive nature. The settlement limit at these structures needs confirmation from the supplier and appropriate foundations detailed at detailed design to cater for the loading conditions.
- No allowance has been made for foundations in either the AC or DC platforms that may reduce the requirement for processed platform materials.
- Laydown areas are based on assumed areas indicated by SSEN, from other similar works, to be of appropriate size. The size of these areas is consistent with the Jacob's Earthworks Strategy.
- Allowance has been made for all compound/laydown areas to be stripped of topsoil and a 300 mm crushed rock platform constructed. An initial import of 3,000 m^3 has been allowed to provide an initial compound area to allow earthworks to get underway, with other laydown platforms material being sourced from site excavations.
- No allowance has been made for the levelling of compound/laydown areas. It is assumed that following topsoil strip, the construction of the laydown areas will follow the existing topographical surface.
- Bulking factors have been taken as 1.0 for topsoil and superficial deposits. For bedrock, assuming processed as granular material, a bulking factor of 1.3 is considered appropriate. This is based on an assumed in situ density of 2.7 Mg/m^3 and a placed (compacted) density of 2.1 Mg/m^3.
- As discussed in Section 3, 90% of rock excavated from the ground will be suitable for re-use as a granular fill following crushing. This value allows for some wastage / loss of material during the process.
- Also as discussed in Section 3, superficial deposits excavated from the ground are not considered suitable for re-use and methods that could render the material suitable are understood to not be desirable nor feasible options.

- No allowance has been made for haul routes or tracks or wastage of material through multiple usage (i.e. material placed in haul route which may degrade or become contaminated with other materials).
- No additional excavation and replacement allowance has been made to render sub-formation suitable for fill. It is also assumed that the Made Ground associated with the disused quarry is left in-situ.
- Minor excavations associated with drainage, cable routes and the like are not included in the volume assessments.
- A 1:500 fall (not currently modelled) is assumed on the top of the formation to meet drainage requirements for groundwater flows. This is to be reviewed at later design stages. For further details refer to Drainage Impact Assessment (reference: BANN4-LT407-JMS-DRAI-XX-RPT-C-0004).

A single optimised proposed level for each platform (AC and DC) has been determined. These levels have been carried through from the earthworks calculations undertaken at Phase 2b, which was intended to provide an optimum balance between excavation of the existing site and reuse of the excavated material, minimising the import and export required. During Phase 2c, the earthworks calculations have been refined to include cut and fill quantities for the basins, overhead tower platform earthwork requirements and access roads.

AC level: 80.5mAOD

DC level: 83.5mAOD

The earthworks balance calculations for these levels are shown in Appendix A. A relatively substantial net fill (rock import) is indicated, which is heavily dictated by the platform requirements for the temporary laydown areas. Once the size of the laydown areas is confirmed, further optimisation of the platform level will be undertaken with the aim of reducing the import requirements.

NOTE: the above levels are the optimised levels and differ from the 'worst-case' higher levels (81.5mAOD) shown on the Planning drawings. The levels shown for planning allow for opportunities for further optimisation at subsequent design stages.

5. Preliminary Slope Stability Analysis

A high-level review of the slope stability has been conducted to establish the typical safe slope angles both during construction and in the long term for each strata encountered.

Excavated slopes are proposed to be formed at 1(v):2(h) through superficial deposits and rock. This will be developed further at detailed design (superficial slopes may need to be shallower and rock slopes may need to go steeper) and consideration made to incorporate an interface berm between the superficial deposits and rock to intercept groundwater and ease construction. However, the impact on volumes from this optimisation compared to the assumed gradient is considered minimal.

Engineered fill slopes (granular) are to be formed at a gradient of 1(v):2(h).

Landscaped fill slopes are to be formed at a gradient of 1(v):4(h).

Table 1. Typical safe slope angles both during long term and during construction.

Material Type	Safe Cutting Slope Angle
Superficial Deposits	1V : 2H
Bedrock	1V : 2H – 1V : 1H

6. Access and Maintenance Strategy

Slope gradients of 1V:2H are proposed within the new fill build-up below the platform. It is envisaged that these will require minimal maintenance; typically limited to management of vegetation, depending on the coverage of planting that is included on the slopes (noting that the biodiversity net gain of the substation proposals is being reviewed ERM).

In most instances it is thought that any maintenance would involve clearing vegetation from the slope crest (to ensure that the platform operation is not obstructed), with little to no maintenance of the vegetation on the slope itself, promoting greater biodiversity. Installation of barriers at the slope crest are to be considered by the maintainer to provide edge restraint during these works.

Where access directly onto the slope is required for maintenance, roped access is considered necessary, although it is anticipated that this will be an infrequent requirement. It is noted that to provide a slope that does not require roped access, the slope gradient would have to be significantly reduced (to less than ~1V:4H), which is not considered economically viable.

A detailed access and maintenance strategy is to be developed at detailed design in conjunction with the Client’s specific requirements.

7. Drainage

In addition to the construction of the substation platform, improved drainage has been incorporated into the design to combat the risk of shallow groundwater.

A subsequent drainage impact assessment report (Doc No. BANN4-LT407-JMS-DRAI-XX-RPT-C-0004) has been developed by Tony Gee and should be read in conjunction with this Earthwork Assessment Report.

8. Design Specifics

8.1. Slope Stability

It is recommended that during excavation, the slopes are examined by a suitably qualified geotechnical engineer to assess the stability and advise the contractor accordingly as the excavation proceeds.

Safe slope angles (or shallower slope angles) identified within Table 2 must be abided by throughout the scheme's development.

8.2. Drainage

The substation platform will be constructed of free draining granular material, primarily the top layer of the platform, to ensure the platform is well drained and inhibiting groundwater from accumulating beneath the platform. In order to ascertain such properties, a void ratio will be specified within the detailed design of the drainage that achieves the appropriate infiltration rate.

9. Conclusions and Recommendations

An Earthworks Strategy has been produced which assesses the AC and DC platform levels for the site. Finished levels of 80.5mAOD for the AC platform and 83.5mAOD for the DC platform were proposed as these are considered to provide the optimum earthworks balance.

It is recommended that the detailed designer for the project liaise closely with the proposed Contractor to manage and develop the identified risks contained within Geotechnical Risk Register.

Appendix A – Earthworks Balance Calculations

Tony Gee

BANNISKIRK AC SUBSTATION - CUT / FILL BALANCE CALCULATIONS Rev: 2 Date: 21/05/2024

PLATFORM FINISHED LEVEL - AC =	80.5	mAOD
PLATFORM FINISHED LEVEL - DC =	83.5	

EXCAVATION VOLUMES

Item	Length (m)	Width (m)	Area (m2)	Depth (m)	Volume (m3)
Laydown areas and roads					
Laydown area, wellfare and parking - AC	N/A	N/A	39300	0.3	11790
Laydown area, wellfare and parking - DC	N/A	N/A	14500	0.3	4350
Optional laydown area	N/A	N/A	25400	0.3	7620
Basins					
Basin 01	Assessed in CAD		5164	0.30	1549
Basin 01	Assessed in CAD		5164	1.38	7131
Basin 02 Access Road	Assessed in CAD		850	0.13	111
Basin 02	Assessed in CAD		4330	0.30	1299
Basin 02	Assessed in CAD		4330	0.41	1775
Overhead Towers					
OHT Platform 2 Access	Assessed in CAD		2313	0.07	165
OHT Platform 2	Assessed in CAD		5958	0.07	397
OHT Platform Top Access	Assessed in CAD		8120	0.07	579
OHT Platform Top	Assessed in CAD		5943	0.24	1454
Access					
Access Road 1	Assessed in CAD		4640.00	0.11	492
Access Road 2	Assessed in CAD		4291	0.30	1287
Access Road 2	Assessed in CAD		4291	0.32	1383
Acess Road 2A	Assessed in CAD		5022	0.10	496
HVDC East Access	Assessed in CAD		1025	0.30	308
HVDC East Access	Assessed in CAD		1025	1.20	1234
Pond Access Road 1	Assessed in CAD		1106	0.30	332
Pond Access Road 1	Assessed in CAD		1106	0.54	600
Temporary Access Top	Assessed in CAD		3534	0.19	688
AC / DC Site					
Topsoil	Assessed in CAD				108065
Superficial Material	Assessed in CAD				275813
Rock	Assessed in CAD				442730
Exc of Superficial below (2No.) syncom buildings down to rock	100	50	10000	1	10000

EXCAVATION TOTAL =	881646.618
EXCAVATION BREAKDOWN BY TYPE:	
TOPSOIL =	141077
SUPERFICIAL =	297840
ROCK =	442730
ASSUME ROCK CAN BE RE-USED FOR 6N1, 6F2, TYPE 3 AND SINGLE SIZE AGGREGATE	
EXCAVATED ROCK, TRUE VOLUME =	442730
BULK FACTOR FOR ROCK =	1.3
BULKED ROCK VOLUME =	575548
EXCAVATED GRANULAR SUPERFICIAL MATERIAL, TRUE VOLUME =	297840
ASSUMED RE-USABILITY =	0%
BULK FACTOR FOR SUPERFICIALS =	1.0
BULKED GRANULAR SUPERFICIAL MATERIAL FOR RE-USE =	0.0

FILL VOLUMES

Item	Length (m)	Width (m)	Area (m2)	Depth (m)	Volume (m3)
Site Set-Up					
Laydown Area, Welfare & Parking (*)	100	100	10000	0.3	3000
Welfare and parking - AC	N/A	N/A	39300	0.3	11790
Laydown area, wellfare and parking - DC	N/A	N/A	14500	0.3	4350
Optional laydown area	N/A	N/A	25400	0.3	7620
Basins					
Basin 01	Assessed in CAD		5164		152
Basin 02 Access Road	Assessed in CAD		850		7
Basin 02	Assessed in CAD		4330		472
Overhead Towers					
OHT Platform 2 Access	Assessed in CAD		2313		726
OHT Platform 2	Assessed in CAD		5958		1903
OHT Platform Top Access	Assessed in CAD		8120		3897
OHT Platform Top	Assessed in CAD		5943		484
Access					
Access Road 1	Assessed in CAD		4640.00		2341
Access Road 2	Assessed in CAD		4291		36
Acess Road 2A	Assessed in CAD		5022		4187
HVDC East Access	Assessed in CAD		1025		11
Pond Access Road 1	Assessed in CAD		1106		111
Temporary Access Top	Assessed in CAD		3534		769
AC / DC Site					
Platform Layer 1 - Single Size Aggregate (75mm)	Assessed in CAD				21362.68
Platform Layer 2 - Type 3	Assessed in CAD				57137.39
Platform Layer 3 - 6F2	Assessed in CAD				320062.56
Capping (subformation to platform, 6N1)	Assessed in CAD				134434.81
Fill back up with granular fill below syncom building	100	50	10000	1	10000.00

FILL TOTAL =	584853.44
FILL BREAKDOWN BY TYPE:	
INITIAL FILL IMPORT FOR COMPOUND =	3000
STONE FILL =	581853.44
NET CUT/FILL (ROCK IMPORT (+VE), ROCK EXPORT (-VE)) (^) =	6305
TOTAL SURPLUS SUPERFICIAL AND TOPSOIL =	438917

Bulking Factors:

	As Dug Den	Placed Den	Bulk Factor
Class 1 / 6N1	2.7	2.1	1.286
Class 6F2	2.7	2.1	1.286
Type 3	2.7	2	1.350
75mm single	2.7	1.7	1.588

Notes:
(*) = taken from SSE Standard Welfare/Car Park and Laydown Area drawing