APPENDIX 23

AGL CONSULTING ENGINEERS REPORT
18-200 FINAL DRAFT REV.2
PRELIMINARY TECHNICAL PROPOSAL FOR THE PROPOSED CAPPING LAYER
FOR AN HISTORIC LANDFILL AT BARNAGEERAGH COVE, SKERRIES, CO. DUBLIN
(30/01/2019)

DRAFT – FOR REVIEW AND DISCUSSION

Preliminary Technical Proposal for the Proposed Capping Layer for an Historic Landfill at Barnageeragh Cove, Skerries, Co. Dublin

1.0 Introduction

This technical proposal sets out the conceptual design and construction requirements for the proposed capping system for a historic landfill on the site of a residential development in Barnageeragh Cove in Skerries, Co. Dublin. Based on the environmental risk assessment carried out by Mulroy Environmental on behalf of the developer, Winsac Ltd., it is proposed to cap the landfill with a 1.0 mm thick LLDPE geomembrane liner ($k < 1x10^{-9}$m/s), an overlying geocomposite drainage layer ($k > 1x10^{-4}$ m/s) and 1.0 m of cover soil comprised of 0.85 m of subsoil and 0.15 m of topsoil. The primary purpose of the liner is to prevent leachate being generated due to infiltration of surface water through the underlying landfill waste.

This report sets out the primary requirements for the earthworks design of the landfill capping system, including the following criteria:

- Geometry of the landfill and capping system
- Specification for the LLDPE liner and geocomposite drainage layer
- Earthworks design and specification for the cover soil and topsoil layer
- Material sourcing and stockpiling
- Quality control during construction

The final geometry of the landfill will be designed to promote clean surface runoff to a perimeter drainage system with a controlled outfall to the existing surface water drainage network. We understand that that the drainage system will be designed by others. However, schematic details are included in this report.

Details of the extent, depth and characteristics of the waste body are presented in the following report by Mulroy Environmental: "*Winsac Ltd., Residential Development, Barnageeragh Cove, Skerries – Phase II Site Investigation/DQRA & Landfill Gas Survey*", Final Report, Mulroy Environmental, Ref. No. 309-01, dated 31/8/18.

The results of the DQRA are presented in the following report prepared by Peter Conroy on behalf of Mulroy Environmental/Winsac: "*Detailed Quantitative Risk Assessment of Barnageeragh Cove Landfill, Rev. D – Response to Queries Plus Preferred Cap Design*", dated January 2019.

2.0 Geometry and Profile of the Landfill and Capping System:

The final geometry of the landfill and the landfill capping details have been designed to comply with the relevant requirements of the following Landfill Manuals from the Environmental Protection Agency:

- *Landfill Restoration and Aftercare*, EPA 1999
- *Landfill Site Design*, EPA 2000

Figure No.1 shows a profile of the proposed capping system which complies with the recommendations for non-hazardous waste landfill capping systems in Figure 10.1 of the EPA Landfill Site Design Manual. In this case a gas collection layer is not required below the LLDPE liner.

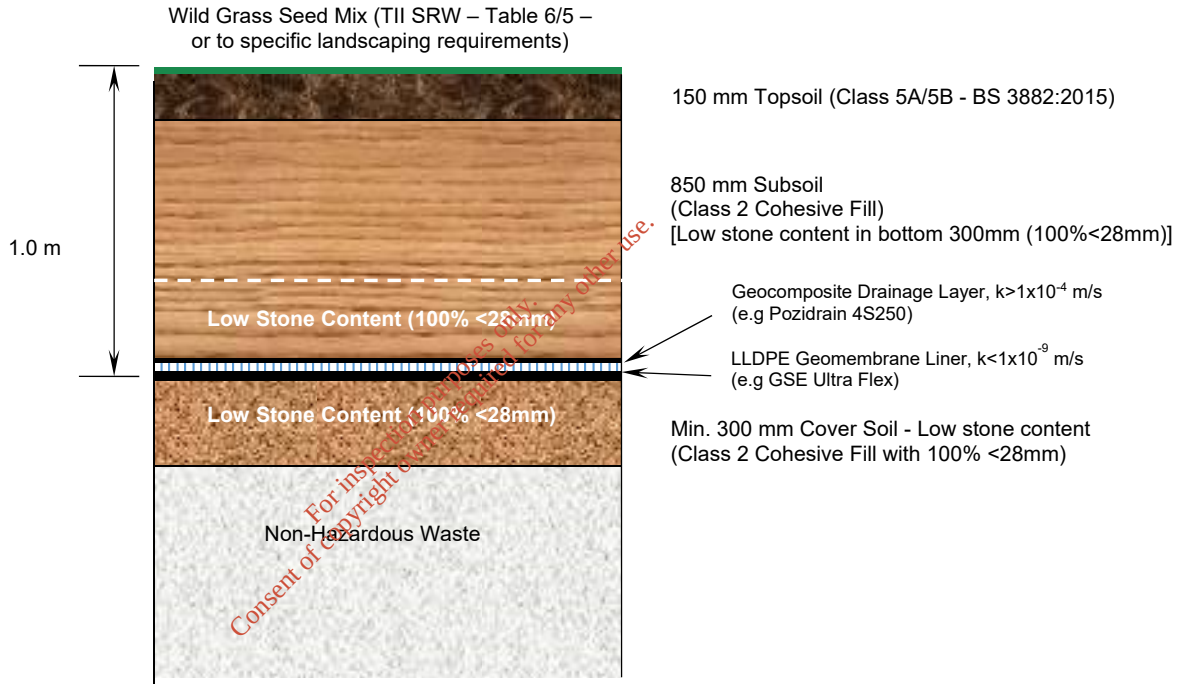


Figure No.1 – Proposed Capping and Soil Cover Details for Non-Hazardous Waste

The primary components of the landfill capping system are as follows:

- A min. 300 mm thick cover layer of Class 2 cohesive subsoil with low stone content to regulate the surface of the non-hazardous waste. To protect the liner from puncture a maximum particle size of 28 mm will be specified for this material.
- A 1.0 mm thick LLDPE (Linear Low-Density Polyethylene) geomembrane with a permeability, $k < 1 \times 10^{-9}$m/s (e.g. GSE Ultra-Flex or equivalent). The smooth liner will be used across the crest of the landfill, whereas the textured liner with higher interface frictional resistance will be used on the perimeter side slopes.
- A geo-composite drainage layer with a permeability, $k < 1 \times 10^{-9}$m/s (e.g. Pozidrain 4S250 or equivalent – 4mm thickness) to intercept groundwater infiltration through the overlying topsoil and subsoil layers, and to prevent a build-up of groundwater over the LLDPE liner, which can contribute to shallow slope instability.

- An 850 mm thick layer of Class 2 cohesive subsoil as a protective and anchoring layer for the LLDPE liner. To protect the liner and drainage layer from puncture or damage, a maximum particle size of 28 mm will be specified for the material within 300 mm of the base of this layer.
- A 150 mm thick layer of Class 5A/5B Topsoil to create a vegetated surface to the landfill. The topsoil shall be seeded with a typical wild grass seed (e.g. Table 6/5 of the TII Specification for Roadworks), or as otherwise specified in the landscape design.

Figure No.2 shows the outline of the historic landfill from the environmental report by Mulroy Environmental. A recent topographical survey of the landfill is included in Appendix A (Drawing No. D16076-F2D by Land Surveys, dated 2/1/2019). Photo No.1 shows a recent aerial photograph of the site.

Photo No.1 – Recent aerial photograph of the landfill site (looking from west to east)

Figure No.3 shows the extent of the landfill where it is proposed to cover the waste with the LLDPE liner. The DQRA has determined that the liner is not required outside this area. There is also a bio-window around gas vents GV-1 to GV-1 (BH-4, BH-9 & BH-10) where the landfill liner will be omitted and a Class 1 granular cover soil will be placed below the topsoil to allow a localised concentration of landfill gas to dissipate into the atmosphere.

Figure No.4 shows the extent of the landfill capping system on a recent aerial photograph with a schematic outline of the perimeter drainage system.

Figure No.5 shows a schematic North-South profile through the landfill showing typical details of the proposed landfill geometry, capping system and perimeter drainage.

The main details of the proposed geometry of the landfill and capping system are as follows:

- Where there is an existing embankment slope on the north and east sides of the landfill the existing slope shall be trimmed back to a maximum gradient of **1V:3H** leaving a **2.0 m** wide setback from the site boundary at the base of the slope for the perimeter drain.

- The crest of the landfill shall be re-shaped and mounded to promote surface runoff to the perimeter drain at a uniform minimum gradient of **1V:30H,** ensuring that there are no low spots over the surface of the landfill where surface water can pond.
- The waste body shall be covered with a minimum 0.3 m thick layer of suitable inert site-won Class 2A cohesive fill with a low stone content (100% <28mm), as defined in Series 600 (Earthworks) of the TII Specification for Works (TII Publication No. CC-SPW-0600). The material shall be placed and compacted as Class 4 landscape fill to provide a firm working surface with a minimum **subgrade CBR of 2%** for the construction of the overlying LLDPE liner, geocomposite drainage layer and subsoil/topsoil layers that make up the capping system. The existing site-won material that has already been placed on the landfill can be used for this purpose where it satisfies the requirements for the construction of the liner and capping layers after landscaping to the design profile and proof rolling (i.e. firm with a subgrade CBR of 2% and no soft spots).
- As stated previously, the total thickness of the capping layer shall be 1.0 m and comprised of the following layers
    - A 1.0 mm thick **LLDPE geomembrane liner** with a permeability, **k <1 x 10^{-9} m/s** (e.g. GSE Ultraflex)
    - A **geocomposite drainage layer** with a permeability, **k >1 x 10^{-4} m/s** (e.g. Pozidrain 4S250 – 4mm thickness)
    - An **850 mm thick subsoil layer of suitable inert site-won Class 2 cohesive fill**, as defined in Series 600 of the TII Specification. The lower 300 mm of this layer shall be comprised of Class 2A cohesive fill with a low stone content (100% <28mm).
    - A **150 mm thick layer of Class 5A/5B topsoil** seeded or planted in accordance with the landscape design to prevent erosion from surface runoff.
- An interceptor drain shall be constructed at the base of the slopes around the perimeter of the landfill to collect the clean surface runoff and discharge it to the existing surface drainage system on the east side of the site. The drain shall be constructed outside the footprint of the waste body. It is currently proposed to construct the perimeter drain as a standard filter drain, as shown on Figure No.4. However, it can also be constructed as a shallow open swale (typ. <0.5 m deep) if required.
- A lined interceptor drain will be used to locally divert clean surface runoff away from the bio-window around gas vents GV-1 to GV-1 into the perimeter drain.

3.0 Specification for the LLDPE Geomembrane Liner & Geocomposite Drainage Layer:

- The geomembrane liner shall be comprised of a 1.0 mm thick linear low-density polyethylene (LLDPE) Liner such as the **GSE Ultraflex Geomembrane**, or equivalent. Copies of the manufacturer's technical data sheets and product specifications are included in Appendix B.
- The LLDPE geomembrane is preferred over the HDPE liner in this case because of its increased flexibility to accommodate future deformation due to long-term settlements of the capped landfill without rupture. It will also be better-suited to conform to the irregular profile of the landfill.
- The Ultraflex Smooth Geomembrane will be used on the relatively flat surfaces on the top of the landfill.
- The Ultraflex Textured Geomembrane will be used on the steeper perimeter slopes up to 1V:3H due to the increased frictional resistance on the surface, which will reduce the risk of sliding along the interface with the underlying soil and overlying geocomposite drainage layer. Anchor trenches will also be used to support the geomembrane at the crest of the slopes.
- The liner will be installed in accordance with the manufacturer's recommendations to form a continuous impermeable liner across the surface of the landfill. A copy of the manufacturer's installation quality assurance manual is included in Appendix B.
- Seaming shall be performed using automatic fusion welding equipment and techniques to form a double welded (dual track) seam. Extrusion welding will only be used where fusion welding is not possible such as at patches, repairs and short seam runs.
- The Geocomposite Drainage Layer shall be comprised of the ABG Pozidrain 4S250, or equivalent. It is comprised of a high strength flexible polyethylene cuspated core with a non-woven geotextile bonded to the top. The geotextile acts as a filter between the drain and the overlying Class 2 subsoil allowing groundwater to percolate into the core while supporting the backfill material. A copy of the product catalogue and the manufacturer's installation guidelines is included in Appendix C.
- The ABG Pozidrain 4S250 has a total thickness of 4mm and a permeability, $k > 1 \times 10^{-4}$ m/s.
- The drains are rolled out downslope across the landfill. Adjacent rolls are laid with the polythene core layers butting against each other along the sides without welding but with the geotextile layer overlapping across the seams. No welding is required.
- The geocomposite drain is fixed in the anchor trenches at the top of the steeper perimeter slopes and they are extended down into the perimeter drain so that the clean groundwater that infiltrates down to the drainage layer is collected in the surface water drainage system.
- The total estimated area of <u>each</u> of the LLDPE liner and geocomposite drainage layers is approximately **7,210 m^3** based on the plan area of the landfill cap (Google Earth) and allowing for additional surface area on the perimeter side slopes. A contingency of **10%** should be allowed at preliminary design stage to allow for some variations at detailed design and for some wastage due to trimming during construction. This gives a total estimated area of approximately **7,930 m^3** for each layer.

4.0 Earthworks Specification for the Class 2 Subsoil/Cover Soil Layers and Class 5 Topsoil:

- The earthworks shall be carried out in accordance with Series 600 (Earthworks) of the TII Specification for Works (TII Publication No. CC-SPW-00600, dated June 2013).
- The 300 mm thick cover soil below the LLDPE liner and the 850 mm thick subsoil layer above the liner shall be comprised of acceptable **Class 2A or Class 2C1/2C2 cohesive fill**, as defined in the TII Specification. Excerpts from Table 6/1 (Acceptable Earthworks Materials) and Table 6/2 (Grading Requirements) from the specification are presented below as Tables 4a & 4b, respectively.
- Typically firm gravelly North Dublin Boulder Clay would be classified as Class 2C1/2C2 stony cohesive fill, depending on the fines content. Firm clay with a lower gravel content would normally be classified as Class 2A wet cohesive fill.
- Acceptable Class 2 cohesive fill shall be Firm (c_u = 40-75 kPa) with an MCV between 8 and 15 to ensure that it is traffickable by conventional earthmoving equipment.
- The material shall be placed and compacted as Class 4 landscape fill in accordance with Clause 620 of the TII Specification i.e. the material shall be placed in maximum **300 mm thick lifts** and compacted by tracking across the surface with a bulldozer or tracked excavator so that the degree of compaction is sufficient to remove large voids and to produce a coherent mass whilst preventing over-compaction and any build-up of excess pore pressures.
- To ensure that the compaction can be achieved for the capping layer, the subgrade on the cover soil at the underside of the capping layer shall have a minimum CBR of 2% on dry Firm Boulder Clay or Gravel.
- Prior to placing the capping layer all soft or deleterious material at subgrade level shall be removed and incorporated elsewhere within the landfill under a suitable depth of cover soil. The surface of the cover soil shall be trimmed to the required profile and proof rolled by 2 No. passes of a vibratory roller with a mass >5000 kg per meter width of roll.
- The layer of subsoil over the landfill liner and geocomposite drainage layer shall be covered with 150 mm of Class 5A (site-won) or Class 5B (imported) topsoil, as defined in the TII Specification and BS 3882 – British Standard Specification for topsoil and requirements for use. The specification for the topsoil shall also comply with the landscaping requirements.

Tables Nos.4a and 4b: Excerpts from the TII Series 600 Specification (Earthworks) for Class 2C1 Cohesive Fill

Table 6/1 (Continued): Acceptable Earthworks Materials: Classification and Compaction Requirements (See footnotes)

Class				General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601 and Appendix 6/1)	Material Properties Required for Acceptability (In Addition to Requirements on Use of Fill Materials in Clause 601 and Testing in Clause 631)				Compaction Requirements in Clause 612	Class		
							Property (See Exceptions in Previous Column)	Defined and Tested in Accordance with:	Acceptable Limits Within:					
									Lower	Upper				
GENERAL COHESIVE FILL	2	A	-	Wet cohesive material	General Fill	Any material, or combination of materials.	(i) grading	BS 1377: Part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 1 except; for materials with liquid limit greater than 50, determined by BS 1377 : Part 2, only tamping or grid rollers shall be used.	2	A	-
							(ii) plastic limit (PL)	BS 1377: Part 2	-	-				
							(iii) mc	BS 1377: Part 2	PL -3%	App 6/1				
							(iv) MCV	Clause 632	App 6/1	App 6/1				
							(v) undrained shear strength of remoulded material	Clause 633	App 6/1	App 6/1				
							(vi) effective angle of internal friction (Ø') and effective cohesion (c')	Clause 636	App 6/1	App 6/1				
ESIVE FILL	2	C	1	Stony cohesive material (High Fines Content)	General Fill	Any material or combination of materials.	(i) grading	BS 1377: Part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 2	2	C	1
							(ii) mc	BS 1377: Part 2	App 6/1	App 6/1				
							(iii) MCV	Clause 632	App 6/1	App 6/1				
							(iv) Undrained shear strength of remoulded material	Clause 633	App 6/1	-				
							(v) effective angle of internal friction (Ø') and effective cohesion (c')	Clause 636	App 6/1	App 6/1				
GENERAL COHESIVE FILL	2	C	2	Stony cohesive material (Low Fines Content)	General Fill	Any material or combination of materials.	(i) grading	BS 1377: Part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 2	2	C	2
							(ii) mc	BS 1377: Part 2	App 6/1	App 6/1				
							(iii) MCV	Clause 632	App 6/1	App 6/1				
							(iv) Undrained shear strength of remoulded material	Clause 633	App 6/1	-				
							(v) effective angle of internal friction (Ø') and effective cohesion (c')	Clause 636	App 6/1	App 6/1				

Volume 1
Specification for Road Works

Series 600
Earthworks

Table 6/2: Grading Requirements for Acceptable Earthworks Materials

Class	Size (mm)		Percentage by Mass Passing the Size Shown: Size (mm) BS Series													Size (microns) BS Series				Size (microns)	Class
	500	300	125	100	75	37.5	28	20	14	10	6.3	5	3.35	2	1.18	600	300	150	63	2	
1A		100	100																0-15		1A
1B			100																0-15		1B
1C	100		10-95													0-25			0-15		1C
2A & 2B			100											80-100					15-100		2A & 2B
2C1			100											35-80					35-80		2C1
2C2			100											15-80					15-35		2C2

5.0 Quality Assurance/Quality Control (QA/QC):

- AGL will develop a project-specific quality assurance and quality control plan for the landfill capping system, liner, and earthworks operations at detailed design stage, which will include the frequency of sampling and testing. The following is an outline of the sampling and testing that will be carried out.
- **Landfill LLDPE Liner:** At least 2 weeks prior to construction of the capping layer the Contractor shall submit details of the proposed liner and specialist lining sub-contractor for approval. The liner shall be transported, stored, handled and installed in accordance with the manufacturer's instructions in Appendix B. During construction the following quality assurance tests shall be carried out to evaluate the seals and welds along the seams of the impermeable liner:
    - **Pre-qualification test seams** will be carried out daily to verify that the welding equipment is set correctly and that the seaming conditions are acceptable. The test seams will be tested by peal and shear testing to confirm that the required properties are achieved.
    - **Field Seam Non-Destructive Testing:** All field seams shall be non-destructively tested over the full length of the seams in accordance with the recognised industry standards. All double fusion welded seams shall be tested using the air pressure method. All extrusion fillet welds shall be tested using the vacuum box test method. Welds shall only be spark tested where it is not possible to test welds using the vacuum box test method. The tests shall be carried out by experienced technicians over the progress of the works and before the seams are covered.
    - **Destructive Field Seam Testing:** Destructive testing shall be carried out on samples of field seams sampled at a frequency of 1 sample per 200 m^2. The destructive sample size shall be 300 mm wide by 1.0 m long with the seam centred lengthwise. The trial seam shall be peal and shear tested in accordance with GRI GM19 to verify the specified minimum strength parameters.
    - **Visual Inspection:** All panels and seals shall be inspected by the specialist lining sub-contractor and by the Employer's Representative on site during and after panel deployment to identify all defects, including holes, blisters, undispersed raw materials and signs of contamination by foreign matter.

  Any defects that are identified over the course of the testing and inspections shall be rectified and repaired by the specialist sub-contractor. All repaired seams shall be re-tested to confirm compliance with the liner specification. The location of all destructive field tests shall be recorded by GPS for inclusion in the site records for the QA/QC testing.
- **Geocomposite Drainage Layer:** At least 2 weeks prior to construction of the landfill capping the Contractor shall submit details of the proposed geocomposite drainage layer and specialist installation sub-contractor for approval. The geocomposite drainage layer shall be transported, stored, handled and installed in accordance with the manufacturer's instructions in Appendix C. All panels and seam overlaps shall be inspected by the specialist lining sub-contractor and by the Employer's Representative on site during and after panel deployment to identify all defects, including holes, blisters, undispersed raw materials and signs of contamination by foreign matter. Any defects that are identified shall be rectified and repaired by the specialist sub-contractor.
- **Sourcing of Acceptable Cohesive Fill Material (Cover Soil/Subsoil)**: At least 2 weeks prior to construction of the capping layer the following tests shall be carried out to confirm that the source material for the cover layer below the liner and for the subsoil within the landfill capping layer complies with the specification for acceptable Class 2 cohesive fill:

  - **Soil Classification tests:** water content, Atterberg Limits, particle size distribution (gradings) – wet sieve and hydrometer.
  - **Earthworks tests:** Moisture Condition Value (MCV).

- **Earthworks Testing during Construction:** The following QA/QC testing shall be carried out during construction of the capping layer:
  - **Plate Load Tests:** In-situ plate load tests to verify minimum subgrade CBR of 2% at underside of capping;
  - **MCV tests** on Class 2 fill at the point of deposition prior to compaction to confirm material acceptability;

  In addition, the following tests will continue to be carried out at the specified frequency to monitor compliance of the material with the specification for Class 2 fill:
  - **Soil Classification tests:** water content, Atterberg Limits, particle size distribution (gradings) – wet sieve and hydrometer.
- **Field Supervision:** Periodic site visits will be carried out by a Chartered Geotechnical Engineer from AGL Consulting to ensure that the works are being carried out in accordance with the Specification.
- **Construction Quality Assurance Validation Report (CQAVR):** On completion of the fieldwork, AGL will prepare a CQAVR to confirm that the works have been completed in accordance with the Specification and design requirements. The report will include the results of all of the relevant field and laboratory testing.

6.0 Material Sourcing and Handling

- Based on preliminary estimates, the plan area of the historic landfill within the area that needs to be capped, as shown on Figure No.2, is approximately **7,210 m^2** (Google Earth)**.**
- Allowing for the additional surface area on the side slopes and on the gently graded slopes on the crest of the landfill (i.e. area of sloping ground versus plan area), the total estimated volume of **compacted Class 2 fill** that will be required for the 0.85 m thick subsoil layer within the landfill cap is approximately **6,300 m^3**. At this stage, for sourcing material, we would recommend allowing for an additional 15% to account for regulating the layer over the surface of the LLDPE liner, or wastage due to spoil during construction. This would increase the required **source volume** of Class 2 fill to **7,245 m^3**. This would be equivalent to the in-situ volume of undisturbed material at the borrow source – i.e. prior to bulking by excavation.
- Allowing for **35% bulking** for excavated material, the equivalent **stockpile volume** would be approximately **9,780 m^3** (≈ 62.5 x 62.5 x 2.5m), of which approximately **3,450m^3 (≈35%)** needs to have a low stone content (100% < 28mm).
- A suitable material shall be identified from an appropriate borrow source within the site boundary, if possible, at least 2 weeks in advance of constructing the capping layer.
- Trial pits within the proposed borrow area shall be inspected and logged by a suitably qualified geotechnical engineer to make an initial visual assessment of whether there is a sufficient volume of inert material that consistently meets the specified material requirements within the borrow pit.
- Bulk samples of suitable material shall be collected from the trial pits for laboratory testing to confirm that the material meets the specified requirements for Class 2 fill (e.g. Firm Boulder Clay, 8 ≤ MCV ≤ 15, & 100% <28mm for low-stone content fill within 300 mm of LLDPE liner)
- Preferably, to avoid contamination or degradation, the material shall be left undisturbed in place at the borrow source until construction is started on the capping layer.
- If necessary due to operational reasons, the material can be excavated and stockpiled on site provided that:
    - Only material from approved borrow sources are excavated and stockpiled;
    - Sufficient direction and supervision is maintained at the borrow area to ensure that only suitable materials are excavated;
    - Material from different borrow areas are stockpiled separately;
    - The material is only excavated and stockpiled during dry weather;
    - The stockpiles are shaped to promote rapid surface runoff, and sealed by nominal compaction to prevent infiltration of surface water; and
    - The stockpiles are maintained outside the boundary of the historic landfill to avoid contamination.
- **Topsoil:**
    - The total estimated volume of the 150 mm thick layer of topsoil is approximately **1,115 m^3**. Suitable **Class 5A** topsoil shall be identified on the site at least 2 weeks prior to constructing the landfill capping layers. Where topsoil is stored on site the stockpiles shall not exceed 2 m in height and topsoil shall not be stored for greater than 6 months.
    - Where there is a deficit of topsoil, acceptable **Class 5B** topsoil shall be imported to the site from an approved source so that it complies with the landscaping requirements.

Figure No.2 – Extent of Historic Landfill (Mulroy Environmental, 2018)

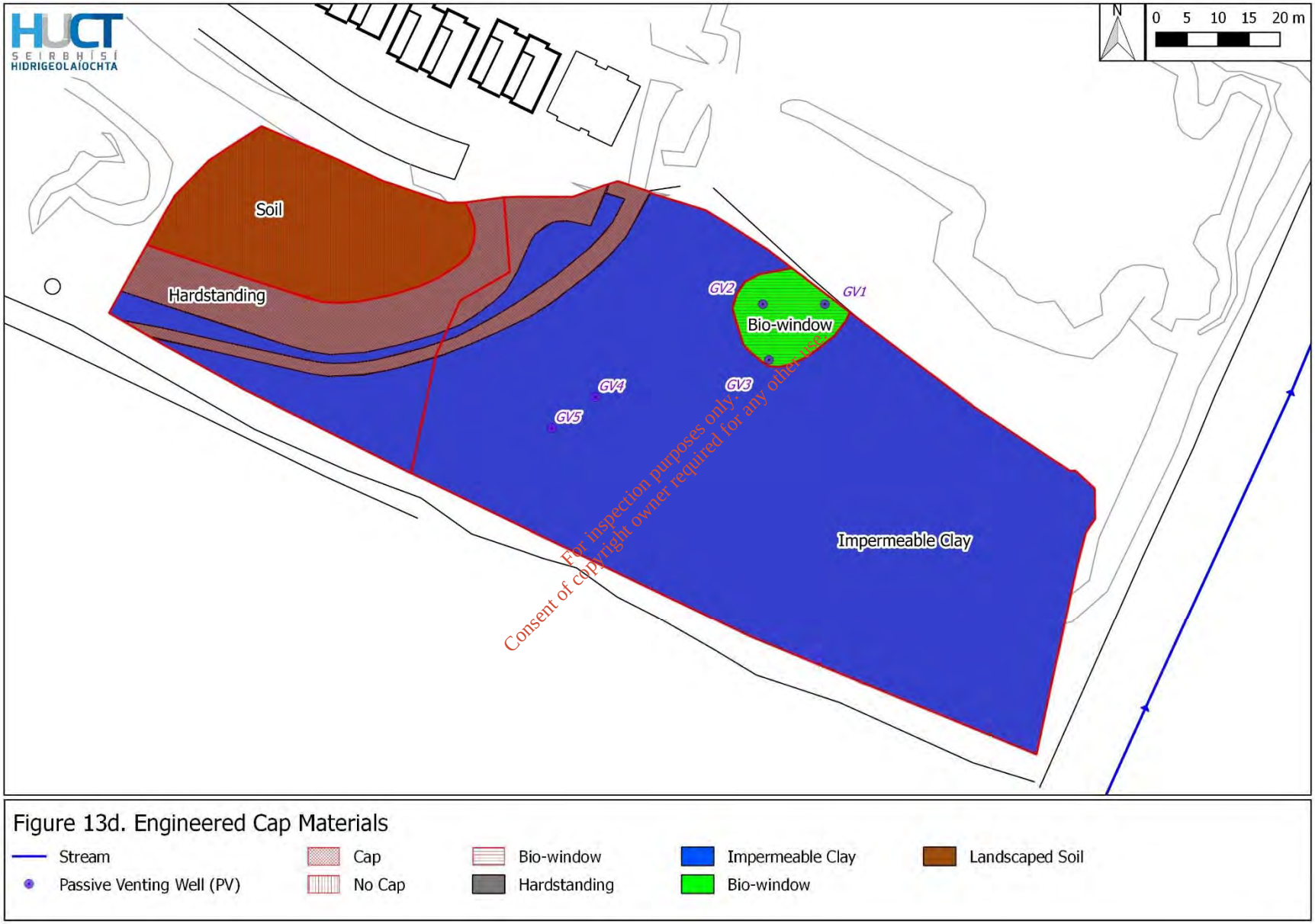


Figure No.3 – Extent of Impermeable Liner & Bio Window from DQRA (Conroy, 2019)
[Note: LLDPE Geomembrane to be used in lieu of Impermeable Clay Liner]

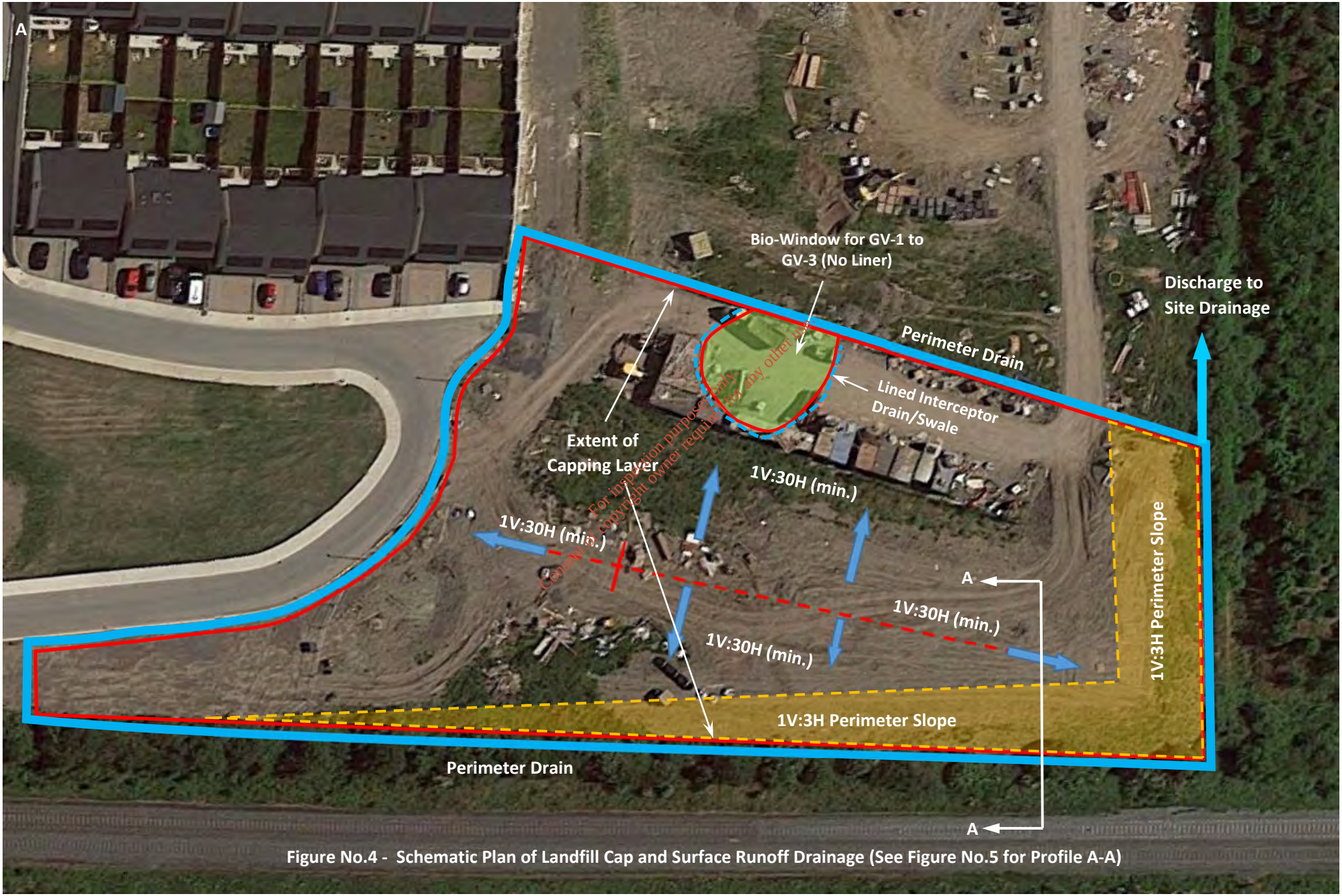
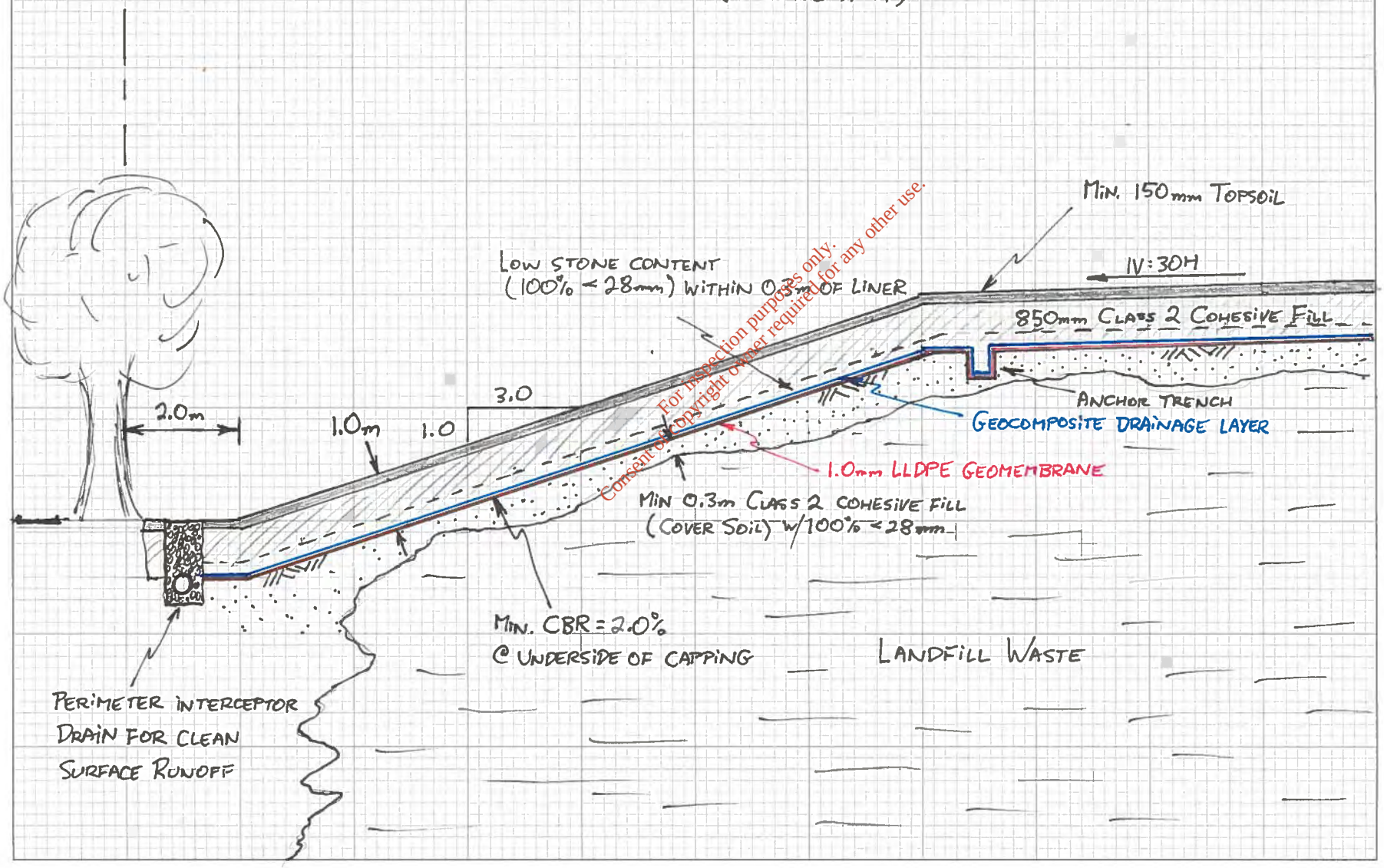


Figure No.4 - Schematic Plan of Landfill Cap and Surface Runoff Drainage (See Figure No.5 for Profile A-A)

FIGURE No. 5 TYPICAL PROFILE OF LANDFILL CAPPING & PERIMETER DRAIN (PROFILE A-A)



AGL CONSULTING
GEOTECHNICAL ENGINEERS

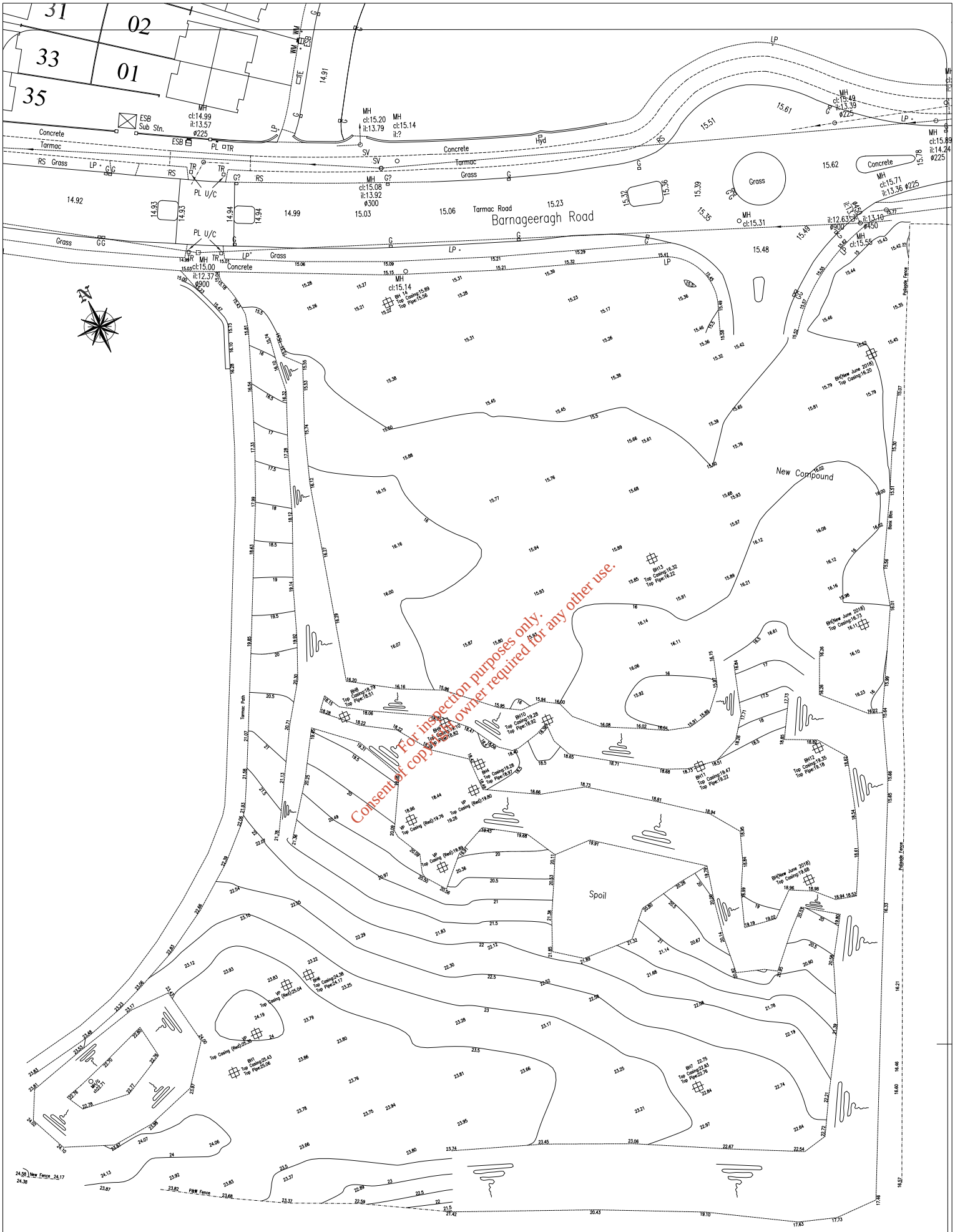
CALCULATION SHEET

JOB TITLE: CAPPING FOR HISTORIC LANDFILL - TECHNICAL PROPOSAL
BARNAGEERAGH COVE, SKERRIES, CO. DUBLIN

MADE BY: CO'D
CHK'D BY:
DATE: 30/1/2019
JOB NO:
PAGE: 1 OF: 1

Appendix A

Site Survey



Note: Road Frontage taken from Previous Taking-in-Charge Survey.

LAND SURVEYS
22 Mellifont Avenue, Dun Laoghaire, Co. Dublin.
Ph: 2805212 Fax: 2302535 info@landsurveys.ie

Site at: Barnageeragh Cove, Skerries

Client: Winsac Ltd.

Scale:	1:250 (A1)
Contour:	0.5m Interval
Datum:	OS Malin Head
Issued:	02.01.2019
Ref:	D16076-F2D

Appendix B

LLDPE Geomembrane Liner
Technical Specification and Installation/QC Guidelines

PRODUCT DATA SHEET

GSE UltraFlex Smooth Geomembrane

GSE UltraFlex is a smooth linear low density polyethylene (LLDPE) geomembrane manufactured with the highest quality resin specifically formulated for flexible geomembranes. This product is used in applications that require increased flexibility and elongation properties where differential or localized subgrade settlements may occur such as in a landfill closure application.

AT THE CORE:

An LLDPE geomembrane that is used in applications requiring increased flexibility and elongation properties, such as landfill closures, and mining applications.

Product Specifications

Tested Property	Unit	Test Method	Values(*)					
Thickness [a]	mm	DIN EN ISO 9863-1	0.5	0.75	1.0	1.5	2.0	2.5
Density	g/cm³	DIN EN ISO 1183-1/A	≤ 0.939	≤ 0.939	≤ 0.939	≤ 0.939	≤ 0.939	≤ 0.939
Tensile Properties (each Direction) Stress at Break Elongation at Break	 MPa %	DIN EN ISO 527-3 (Type 5; 100 mm/min; lo = 50 mm)	 33 (26) 850 (700)	 33 (26) 850 (700)	 33 (26) 900 (750)	 33 (26) 900 (750)	 33 (26) 900 (750)	 33 (26) 900 (750)
Tear Resistance	N	DIN ISO 34-1/B(a)	50 (45)	85 (80)	115 (110)	175 (165)	230 (220)	285 (275)
Puncture Resistance	N	DIN EN ISO 12236	1,150 (900)	1,750 (1,450)	2,250 (2,000)	3,500 (3,100)	4,600 (4,100)	5,700 (5,100)
Carbon Black Content	%	ASTM D 4218	2.0 – 3.0	2.0 – 3.0	2.0 – 3.0	2.0 – 3.0	2.0 – 3.0	2.0 – 3.0
Carbon Black Dispersion	Category	ASTM D 5596	1/2 [b]	1/2 [b]	1/2 [b]	1/2 [b]	1/2 [b]	1/2 [b]
Dimensional Stability (each Direction)	%	DIN 53377 (100°C/1 h)	± 2	± 2	± 2	± 2	± 2	± 2
Melt Flow Index [c]	g/10 min	DIN EN ISO 1133 (190°C / 5.0 kg) (190°C / 2.16 kg)	≤ 3.0 ≤ 1.0	≤ 3.0 ≤ 1.0	≤ 3.0 ≤ 1.0	≤ 3.0 ≤ 1.0	≤ 3.0 ≤ 1.0	≤ 3.0 ≤ 1.0
Oxidative Induction Time (OIT)	min	ASTM D 3895 (200°C; Pure O_2; 1 atm)	≥ 100	≥ 100	≥ 100	≥ 100	≥ 100	≥ 100
Reference Property								
Multiaxial Elongation at Break	%	similar to ASTM D 5617; Ø = 500 mm	≥ 30	≥ 30	≥ 30	≥ 30	≥ 30	≥ 30
Low Temperature Brittleness	°C	ASTM D 746	- 77	- 77	- 77	- 77	- 77	- 77
UV Resistance [d] HP-OIT retained after 1,600 hours [e]	 %	ASTM D 7238 ASTM D 5885	 ≥ 35	 ≥ 35	 ≥ 35	 ≥ 35	 ≥ 35	 ≥ 35
Roll Width (approx.) [f]	m	---	7.0	6.95	6.95/7.5			7.5
Surface	---	---	double-sided smooth					

NOTES:

(*): All values - unless otherwise noted - are nominal values. Values in brackets are minimum values within the 95% confidence interval.
(a): Tolerance ± 10% for the lowest individual reading. - Special thickness available upon request.
(b): Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be category 1 or 2. No more than 1 view from category 3.
(c): Standard test conditions: 190°C / 5.0 kg.
(d): Test-Conditions: 20 hours UV cycle at 75°C followed by 4 hours condensation at 60°C.
(e): UV Resistance is based on percent retained value regardless of the original High Pressure - OIT value.
(f): Roll widths and lengths have a tolerance of ± 1%.

GSE is a leading manufacturer and marketer of geosynthetic lining products and services. We've built a reputation of reliability through our dedication to providing consistency of product, price and protection to our global customers.

Our commitment to innovation, our focus on quality and our industry expertise allow us the flexibility to collaborate with our clients to develop a custom, purpose-fit solution.

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PRODUCT DATA SHEET

GSE UltraFlex Textured Geomembrane

GSE UltraFlex Textured is a co-extruded linear low density polythylene (LLDPE) geomembrane available on one or both sides. It is manufactured from the highest quality resin specifically formulated for flexible geomembranes. This product is used in applications that require increased frictional resistance, flexibility and elongation properties where differential or localized subgrade settlements may occur such as in landfill closure application.

AT THE CORE:

An LLDPE geomembrane that is used in applications requiring increased frictional resistance, flexibility, and elongation properties, such as landsfills, and mining applications.

Product Specifications

Tested Property	Unit	Test Method	Values		
Thickness [a] (Core Thickness)	mm	ASTM D 5994	1.0	1.5	2.0
Density	g/cm³	DIN EN ISO 1183-1/A	≤ 0.939	≤ 0.939	≤ 0.939
Tensile Properties (each Direction) (Minimum Average) Stress at Break Elongation at Break	 MPa %	DIN EN ISO 527-3 (Type 5; 100 mm/min; lo = 50 mm)	 12 250	 12 250	 12 250
Tear Resistance (Minimum Average)	N	DIN ISO 34-1/B (a)	110	165	220
Puncture Resistance (Minimum Average)	N	DIN EN ISO 12236	1,350	2,050	2,750
Carbon Black Content	%	ASTM D 4218	2.0 – 3.0	2.0 – 3.0	2.0 – 3.0
Carbon Black Dispersion	Category	ASTM D 5596	1/2 [b]	1/2 [b]	1/2 [b]
Dimensional Stability (each Direction)	%	DIN 53377 (100°C/1 h)	± 2	± 2	± 2
Melt Flow Index [c]	g/10 min	DIN EN ISO 1133 (190°C / 5.0 kg) (190°C / 2.16 kg)	 ≤ 3.0 ≤ 1.0	 ≤ 3.0 ≤ 1.0	 ≤ 3.0 ≤ 1.0
Oxidative Induction Time (OIT)	min	ASTM D 3895 (200°C, Pure O_2; 1 atm)	≥ 100	≥ 100	≥ 100
Reference Property					
Multiaxial Elongation at Break	%	similar to ASTM D 5617 ; Ø = 500 mm	≥ 30	≥ 30	≥ 30
Low Temperature Brittleness	°C	ASTM D 746	- 77	- 77	- 77
UV Resistance [d] HP-OIT retained after 1,600 hours [e]	 %	ASTM D 7238 ASTM D 5885	 ≥ 35	 ≥ 35	 ≥ 35
Roll Width (approx.) [f]	m	-	6.95		
Surface	---	---	single-sided or double-sided coextruded textured		

NOTES:
(a): Minimum average: - 5%, lowest individual for 8 out of 10: - 10%, lowest individual: - 15% - Special thickness available upon request.
(b): Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be category 1 or 2. No more than 1 view from category 3.
(c): Standard test conditions: 190°C / 5.0 kg.
(d): Test conditions: 20 hours UV cycle at 75°C followed by 4 hours condensation at 60°C.
(e): UV Resistance is based on percent retained value regardless of the original High Pressure - OIT value.
(f): Roll widths and lengths have a tolerance of ± 1%.

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GEOMEMBRANE PRODUCTS
INSTALLATION QUALITY ASSURANCE MANUAL

Contents

Geomembrane Products

1.0 INTRODUCTION

This manual provides an overview of the GSE Installation Quality Assurance procedures consistent with industry accepted practices to ensure that the geomembrane products installed will perform for its intended purpose. In addition, all installation work will be performed in strict accordance per the customer's specifications. Please read the procedures below completely before you begin. If you need further clarification, contact GSE Engineering Support Staff for assistance. Remember safety first and use safe practices always on every project.

2.0 STANDARD TEST METHODS

ASTM D 6392: Standard Test Methods For Determining The Integrity Of Non-Reinforced Geomembrane Seams Produced Using Thermo Fusion Methods

ASTM D 5820: Standard Practice For Pressurized Air Channel Evaluation of Dual Seamed Geomembranes

ASTM D 5641: Standard Practice For Geomembrane Seam Evaluation By Vacuum Chamber

ASTM D 6497: Standard Guide For Mechanical Attachment of Geomembrane to Penetrations or Structures

ASTM D 7007 - 09 "Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials"

ASTM D 7240: Standard Practice for Leak Location using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique (Conductive Geomembrane Spark Test)

GRI Standard GM13: Test Methods, Test Properties, and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes

GRI Standard GM14: Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes

GRI Standard GM 17: Test Properties, Testing Frequency, and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes

GRI Standard GM19: Standard Specification for Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes

3.0 ADDITIONAL REFERENCES

GSI White Paper 26: Need for Justification of Quality Management Systems for Successful Geosynthetic Performance

GRI GM14: Standard Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes

GRI GM20: Standard Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts

Liner Integrity Survey: General Guide published by TRI Environmental

4.0 MATERIAL DELIVERY

A. Upon arrival on site, the QA personnel will inventory all materials on the job site.

B. Roll numbers of geomembrane will be logged on the Inventory Check List (Appendix A) and crossreferenced with the Bill of Lading for materials supplied by GSE.

C. Copies of the Inventory Check List and signed Bill of Lading should be sent to the appropriate parties (CQA Management and Engineer of Record) while the QA personnel retains the original copies.

D. Any visible damage to roll materials should be noted on the roll and Inventory Check List.

5.0 EARTHWORK

A. The general contractor is responsible for preparing and maintaining the subgrade. The subgrade should be prepared and maintained per the job specifications.

B. The site manager shall be responsible for assuring that the subgrade surface has been properly prepared for deployment of geosynthetics. After each day's deployment the Subgrade Surface Acceptance form (Appendix B) will be signed by all parties.

6.0 PANEL PLACEMENT

A. Each panel will be assigned a number as described below.

1. When there is one layer, panels may be designated with only a number, i.e...1, 2, 3, 4 etc.
2. When two or more layers are required, use a letter and number, i.e....

   Primary Liner P1, P2, P3, P4 etc...

   Secondary Liner S1, S2, S3, S4 etc...

   Tertiary Liner T1, T2, T3, T4 etc...

B. This numbering system should be used whenever possible. Agreement to a panel numbering system should be made at the pre-construction meeting. However, it is essential that the installer, the owner representative and third party QA inspector agree.

C. Panel numbers shall be written in large block letters in the center of each deployed panel. The roll number, date of deployment and length (gross) should be noted below the panel number. All notes should be made, so that they are easily visible from a distance. On long panels it is beneficial to write information on both ends. Spray painting is appropriate for roll labeling.

D. Panel numbers shall be logged on the Panel Placement Log (Appendix C) along with the roll number and other information neccessary to complete the form.

E. If there is a partial roll left after deployment, it is important to write the last four digits of the roll number in several locations on the roll along with the estimated length for future identification.

F. Deployment of geomembrane panels shall be performed in a manner that will comply with the following guidelines:

1. Unroll geomembrane using methods that will not damage geomembrane and will protect underlying surface from damage. GSE Leak Location should be installed with Conductive layer facing down.
2. Place temporary ballast, such as sangbags, on geomembrane that will not damage the geomembrane and to prevent wind uplift.
3. Personnel walking on geomembrane shall not engage in activities or wear shoes that could damage it. Smoking is not permitted on the geomembrane.
4. Do not allow heavy vehicular traffic directly on geomembrane. Rubber tired and tracked ATV's and equipment are acceptable if contact pressure is less than 8 psi.
   a. Protect geomembrane in areas of heavy traffic by placing protective cover over the geomembrane.
   b. Prior to driving on any geomembrane layer, please check for sharp edges, embedded rocks, or other foreign objects that may protrude in the tires and tracks.

c. Path driven on geomembranes shall be as straight as possible with no sharp turns, sudden stops or quick starts.

d. Areas where driving occurs shall be continuously and thoroughly inspected throughout the deployment process by the contractor and the third party CQA.

G. In the past, it has been a common practice to turn to leak surveys once the project has been constructed and the barrier system performance has been found unsatisfactory. A current state-of-the-practice geosynthetic installation would plan ahead for both post-installation/exposed, pre-cover soil placement survey (commonly done utilizing ASTM D 7240 or ASTM D 7002) AND a post soil cover survey (commonly done utilizing ASTM D 7007). Proper execution of these surveys and protocols are best applied before installation. State-of-the-art welding techniques, proper isolation of sections for testing, and other details can be simply and inexpensively addressed during installation, but may be expensive and complicated to recreate if a leak is discovered after the facility has been placed into service. See the reference LINER INTEGRITY SURVEY: GENERAL GUIDE published by TRI Environmental.

7.0 TRIAL WELDS

A. Seaming apparatus shall be allowed to warm up a minimum of 10 minutes before performing trial welds.

B. Each seaming apparatus along with a welding technician will pass a trial weld prior to use. Trial welds to be performed in the morning and afternoon, as a minimum, as well as whenever there is a power shutdown.

C. Fusion or wedge welds will always be performed or conducted on samples at least 6.0 ft long. Extrusion welds will be done on samples at least 3.0 ft long.

Note: Always perform trial welds in the same conditions that exist on the job. Run the trial welds on the ground, not the installed liner. Do not use a wind break unless you are using one on the job.

D. Operating temperatures should be monitored while welding. The welding technician should verify that the equipment is capable of maintaining temperature while welding.

E. Sampling Procedure

1. Cut five 1.0 in wide specimens from the trial weld sample. Specimens will always be cut using a 1.0 in die cutter, so the peel values may be used for qualitative analysis.
2. When cutting coupons from the trial weld samples, the inside and outside tracks on the coupon should be identified to assist in troubleshooting problems in case the weld fails. The outside track will be defined as the track, which would be peeled if pulling the overlap exposed in a typical installation, or the seam that is closest to the edge of the top sheet. The inside track is the seam closest to the edge of the bottom sheet.

F. Cutter

1. Only cut one sample at a time to avoid damaging the die cutter.
2. Samples should be free of sand and grit prior to cutting sample.
3. Inspect the die edge weekly for nicks, dents or signs of dullness. Dullness of the cutting edge may damage the units.
4. Remove die when edge has been dulled and lightly reshape it with a medium hand file. When wear is excessive return it for a replacement die.
5. When the cutting board becomes deeply scored and/or interferes with coupon cutting it should be replaced.
6. To adjust the depth of the die cut into the cutting board, after replacing the cutting board or sharpening the die, 0.015 in washer shims can be added or removed between the cutting ram and the ram extension. Only add shims when cutting is difficult due to lack of depth of cut.

G. Trial Weld Testing

1. Allow coupons to cool prior to testing. Avoid separating the coupons while hot as failure of the sheet may be initiated and false readings indicated.
2. In extreme heat the coupons may need to be cooled, using water or an insulated cooler prior to peel testing. Lab conditions specify 70 degrees (plus or minus 4 degrees) Fahrenheit. Coupon temperatures greater than 70 degrees may result in lowered strengths.
3. Visually inspect the coupons for squeeze-out, footprint, pressure and general appearance.
4. Each of the five coupons will be tested in peel on the field tensiometer at a separation rate of 2 in per minute (for HDPE). Shear tests, in addition to the peel tests, will be performed.

H. Pass/Fail Criteria

1. Criteria for passing trial welds will be as follows:
   a. Seam must exhibit film tear bond (FTB). Trial welds should have no incursion into the weld.
   b. Peel and shear values shall meet or exceed the values as listed in Appendix D, Table 1 for HDPE smooth or textured sheet (@ 2 in/min).
   c. Peel and shear values shall meet or exceed the values as listed in Appendix D, Table 2 for LLDPE smooth or textured sheet (@ 20 in/min).
   d. Both tracks of fusion welded samples must pass for the trial weld to be considered acceptable. If any of the five coupons fail due to seam incursion (no FTB) or low strength values, the trial weld must be performed again.
   e. The QA personnel will give approval to proceed with welding after observing and recording all trial welds.
2. All trial weld data will be logged on the Trial Weld Log (Appendix E).
3. When logging fusion welded peel values on the Trial Weld Log indicate the values. for the outside track first, followed by the inside track.
4. Speed and temperature settings will be recorded for each machine trial weld as appropriate.

8.0 GEOMEMBRANE FIELD SEAMING

A. The seam number takes the identity of the panels on each side. The seam between panels 1 & 2 becomes seam 1/2.

B. Welding technicians will record their initials, machine number, date and time at the start of every seam and on the Seam Log (Appendix F). The technician should also periodically mark temperatures along the seam and at the end of the seam.

C. Approved processes for field seaming and repairing are fusion welding and extrusion welding. All welding equipment shall have accurate temperature monitoring devices installed and working to ensure proper measurement.

D. Fusion welding shall be used for seaming panels together and is not used for patching or detail work. The site manager shall verify that:

1. The equipment used is functioning properly.
2. All work is performed on clean surfaces and done in a professional manner. No seaming will be performed in adverse weather conditions. (GRI Test Method GM9: Standard Practice for Cold Weather Seaming of Geomembranes

E. Extrusion welding shall be used primarily for repairs, patching and special detail fabricating and may be used for seaming. The site manager shall verify that:

1. Equipment used is functioning properly.
2. Welding personnel are purging the extrusion welders of heat degraded extrudate prior to actual use.
3. All work is performed on clean surfaces and done in a professional manner. No seaming will be performed in adverse weather conditions.

F. For seam preparation, the welding technician shall verify that:

1. Prior to seaming, the seaming area is free of moisture, dust, dirt, sand or debris of any nature.
2. The seam is overlapped properly for fusion welding.
3. The seam is overlapped or extended beyond damaged areas at least 4.0 in when extrusion welding.
4. The seam is properly heat tacked and abraded prior to extrusion welding.
5. Seams are welded with fewest number of unmatched wrinkles or "fishmouths".

G. No seaming will be performed in ambient air temperatures or adverse weather conditions that would jeopardize the integrity of the liner installation.

9.0 FIELD DESTRUCTIVE TESTING

The process and protocol of obtaining destructive samples is damaging to the geosynthetic systems, and even when done properly, it may result in a geosynthetic system that is weaker and less effective. Clearly destructive samples are necessary; they are a key step in verifying the effectiveness of the welding process. However the frequency of sampling should reward "good welding" and penalize "poor welding." Of more importance is the location of the destructive samples. Everything that can be done to remove destructive sample locations from within the geosynthetic system should be done: taking samples from runouts, anchor trenches, and practice pads. Within the body of the installation, sample locations should be removed from critical areas: the toe of sloped areas, near panel connections, adjacent to penetrations, etc. Ideally the destructive samples will be taken at as low a frequency as possible, within flat areas of the installation where the impact of a hole in the liner can be minimized.

A. Destructive seam tests shall be performed to evaluate bonded seam strength. The frequency of sample removal shall be one sample per 500 ft of seam, unless site specifications differ. Location of the destructive samples will be selected and marked by the QA technician or third party QA inspector. Field testing should take place as soon as possible after seam is completed.

B. Samples should be labeled in numerical order, i.e. DS-1, DS-2 etc....This should carry through any layer and/or multiple ponds; do not start numbering from 1 again. The size of samples and distribution should be approximately 12 in x 39 in (Size may vary depending on job requirements) and distributed as follows:

1. 12 in x 12 in piece given to QA technician for field testing.
2. 12 in x 12 in piece sent to the GSE's corporate headquarters for testing, if required.
3. 12 in x 12 in piece given to third party for independent testing or to archive.

NOTE: All samples will be labeled showing test number, seam number, machine number, job number, date welded and welding tech number.

C. The sample given to the QA technician in the field shall have ten coupons cut and be tested with a tensiometer adjusted to a pull rate as shown below. The strength of four out of five specimens should meet or exceed the values below, and the fifth specimen must meet or exceed 80% of the value below.

1. Seam must exhibit film tear bond (FTB). Welds should have < 25% incursion into the weld.
2. Peel and shear values shall meet or exceed the values as listed in Appendix D, Table 1 for HDPE smooth or textured sheet (@ 2 in/min).

3. Peel and shear values shall meet or exceed the values as listed in Appendix D, Table 2 for LLDPE smooth or textured sheet (@ 20 in/min).

D. All weld destructive test data will be logged on the Destructive Test Log (Appendix G).

E. When logging fusion welded peel values on the Destructive Test Log, indicate the values for the outside track first, followed by the inside track.

F. Test results will be noted in the Destructive Test Log as Pass (P) or Fail (F).

G. If a test fails, additional samples will be cut, approximately 10 ft on each side of the failed test, and retested. These will be labeled A (After) & B (Before). This procedure will repeat itself until a sample passes. Then the area of failed seam between the two tests that pass will be capped or reconstructed.

10.0 NON-DESTRUCTIVE TESTING

A. All seams shall be non-destructively tested over their full length using an air pressure or vacuum test. The purpose of this test is to check the continuity of the seam.

B. For air pressure testing, the following procedures are applicable to those seams welded with a double seam fusion welder.

1. The equipment used shall consist of an air tank or pump capable of producing a minimum 35 psi and a sharp needle with a pressure gauge attached to insert into the air chamber.
2. Seal both ends of the seam by heating and squeezing them together. Insert the needle with the gauge into the air channel. Pressurize the air channel to 30 psi. Note time test starts and wait a minimum of 5 minutes to check. If pressure after five minutes has dropped less than 2 psi then the test is successful (Thickness of material may cause variance).
3. Cut opposite seam end and listen for pressure release to verify full seam has been tested.
4. If the test fails, follow these procedures.
    a. While channel is under pressure, walk the length of the seam listening for a leak.
    b. While channel is under pressure, apply a soapy solution to the seam edge and look for bubbles formed by air escaping.
    c. Re-test the seam in smaller increments until the leak is found.
5. Once the leak is found using one of the procedures above, cut out the area and retest the portions of the seams between the leak areas per 4a to 4b above. Continue this procedure until all sections of the seam pass the pressure test.
6. Repair the leak with a patch and vacuum test.

C. For vacuum testing, the following procedures are applicable to those seams welded with an extrusion welder.

1. The equipment used shall consist of a vacuum pumping device, a vacuum box and a foaming agent in solution.
2. Wet a section with the foaming agent, place vacuum box over wetted area. Evacuate air from the vacuum box to a pressure suitable to affect a seal between the box and geomembrane. Observe the seam through the viewing window for the presence of soap bubbles emitting from the seam.
3. If no bubbles are observed, move box to the next area for testing. If bubbles are observed, mark the area of the leak for repair per section 11.0 and re-test per section 9.0.

NOTE: If vacuum testing fusion welded seams, the overlap flap must be cut off to perform the tests

4. All non-destructive tests will be noted in the Non-Destructive Logs (Appendixes H-I).

D. For spark testing GSE Leak Location geomembranes, ASTM D 7240 will be the procedure, unless otherwise instructed by the engineer client.

11.0 DEFECTS & REPAIRS

A. All seams and non-seam areas of the geomembrane lining system shall be examined for defects.

B. Identification of the defect should be made using the following procedures:

1. For any defect in the seam or sheet that is an actual breach (hole) in the liner, installation personnel shall circle the defect and mark with the letter P along side the circle. The letter P indicates a patch is required.
2. For any defect that is not an actual hole, installation personnel shall circle the defect indicating that the repair method may be only an extruded bead and that a patch is not required.
3. Each suspect area that has been identified as repair shall be repaired in accordance with section 11.0 and in the non-destructively testing per section 9.0. After all work is completed, the site manager will conduct a final walk-through to confirm all repairs have been completed and debris removed. Only after this final evaluation by the site manager, the owner, and the agent shall any material be placed over the installed liner.

12.0 REPAIR PROCEDURES

A. Any portion of the geomembrane lining system exhibiting a defect that has been marked for repair may be repaired with any one or combination of the following procedures:

1. Patching - used to repair holes, tears, undispersed raw materials in the sheet.
2. Grind and Reweld - used to repair small sections of extrusion welded seams.
3. Spot Welding - Used to repair small minor, localized flaws.
4. Flap Welding - Used to extrusion weld the flap of a fusion weld in lieu of a full cap.
5. Capping - Used to repair failed seams.

B. The following conditions shall apply to the above methods:

1. Surfaces of the geomembrane which are to be repaired shall be prepared according to this section.
2. All surfaces must be clean and dry at the time of the repair.
3. All seaming equipment used in repairing procedures shall be qualified.
4. All patches and caps shall extend at least 4 in beyond the edge of the defect, and all patches must have rounded corners.
5. All cut out holes in liner must have rounded corners of 3.0 in minimum radius.

C. Patches should be labeled in numerical order, i.e. RP-1, RP-2, etc... This should carry through any layer and/or multiple ponds, and do not start with the number 1 again.

13.0 AS-BUILT DRAWINGS

The installer shall provide the following:

A. As-built drawings will be provided at the completion of the project.

B. As-built drawings will include geomembrane panels and panel numbers with the last four digits of the roll number.

C. Panel numbers and the full roll numbers will correspond with the Panel Placement Log(Appendix C).

D. All destructive testing and repair locations will be placed on the as-built drawings.

APPENDIX A

Inventory Check List

Project: _____ Site Manager: _____ Date: _____

Project # _____ QA Technician: _____ Page: _____ of _____

Material	Roll #	Used	Material	Roll #	Used	Material	Roll #	Used	Material	Roll #	Used

Subgrade Surface Acceptance

Date: _____

Project: _____ Site Manager:_____

Project #: _____

Location:_____ Partial: _____

Final: _____

This document only applies to the acceptability of surface conditions for installation of geosynthetic products. GSE does not accept responsibility

for compaction, elevation or moisture content, nor for the surface maintenance during deployment. Structural integrity of the subgrade and maintenance of these conditions are the responsibility of the owner or earthwork contractor.

_____

_____

_____

_____

_____

Geosynthetic Installer :

_____

_____

For Owner / Contractor:

_____

_____

Acceptance Number:_____ Area Accepted: _____ s.f Total Area Accepted to date: _____ s.f.

APPENDIX C

Panel Placement Log

Project Name: _____
Location: _____ Site Supervisor: _____
Job Number: _____ Type of Materials: _____
Q.A. Tech.: _____ Sheet Thickness: _____

Panel Number	Roll Number	Deployment Date	Width (Feet)	Length (Feet)	Squar Feet	Squar Feet (Cumulative)	A/T 1	A/T 2

APPENDIX D

TABLE 1. HDPE Seam Strength Properties

Material (Mil)	Shear Strength (PPI)	Fusion Peel (PPI)	Extrusion Peel (PPI)
40	80	60	52
60	120	91	78
80	160	121	104
100	200	151	130

TABLE 1. LLDPE Seam Strength Properties

Material (Mil)	Shear Strength (PPI)	Fusion Peel (PPI)	Extrusion Peel (PPI)
40	60	50	44
60	90	75	66
80	120	100	88
100	150	125	114

Trial Weld Log

Project Name: ____________
Location: ____________
Job Number: ____________
Q.A.: ____________

Site Supervisor: ____________
Type of Material: ____________
Sheet Thickness: ____________

Fusion (ppi)
Min. Peel ______
Min. Sheer ______

Extrusion (ppi)
Min. Peel ______
Min. Sheer ______

Trial No.	Date of Trial	Time of Trial	Technicians ID Number	Ambient Temp.	Welder Type	Wedge Mass	Speed Preheat	Peel ppi	Peel ppi	Peel ppi	Peel ppi	Peel ppi	Shear ppi	Shear ppi	Shear ppi	Shear ppi	Shear ppi	Pass Fail

APPENDIX F

Seam Log

Project Name: _____
Location: _____ Site Supervisor: _____
Job Number: _____ Type of Materials: _____
Q.A. Tech.: _____ Sheet Thickness: _____

Seam Number	Time of Weld	Date of Weld	Type of Weld	Length of Seam	Machine Number	Technician ID Number

Destructive Test Log

Project Name: ______________________________
Location: ______________________________
Job Number: ______________________________
Q.A.: ______________________________

Site Supervisor: ____________________
Type of Material: ____________________
Sheet Thickness: ____________________

Fusion (ppi) Extrusion (ppi)
Min. Peel ______ Min. Peel______
Min. Sheer ______ Min. Sheer______

Sample Number	Date Welded	Seam Number	Technicians ID Number	Machine Type & No.	Location	Testing Frequency	Peel ppi	Peel ppi	Peel ppi	Peel ppi	Peel ppi	Shear ppi	Shear ppi	Shear ppi	Shear ppi	Shear ppi	Pass Fail

APPENDIX H

Repair Log - Vacuum Test

Project Name: _____
Location: _____ Site Supervisor: _____
Job Number: _____ Type of Materials: _____
Q.A. Tech.: _____ Sheet Thickness: _____

Repair Number	Weld Date	Machine Number	Tech ID	Location	Test Date	Tech ID	Pass/Fail

APPENDIX I

Non-Destructive Log - Air Test

Project Name: _____
Location: _____ Site Supervisor: _____
Job Number: _____ Type of Materials: _____
Q.A. Tech.: _____ Sheet Thickness: _____

Seam Number	Test Date	Technician ID Number	Air Pressure Test		Test Result (P or F)	Location
			psi start	psi finish		

APPENDIX J

Non-Destructive Log - Air Test/Leak Location Liner Seam Isolation Test

Project Name: _____
Location: _____ Site Supervisor: _____
Job Number: _____ Type of Materials: _____
Q.A. Tech.: _____ Sheet Thickness: _____

Seam Number	Test Date	Technician ID Number	Air Pressure Test		Test Result (P or F)	Seam Isolation Test (M ohms)		Test Result (P or F)
			psi start	psi finish		S1	S2	

APPENDIX K

Liner Integrity Survey Log

Project Name: _____
Location: _____ Site Supervisor: _____
Job Number: _____ Type of Materials: _____
Q.A. Tech.: _____ Sheet Thickness: _____
ASTM Liner Integrity Protocol Used: _____

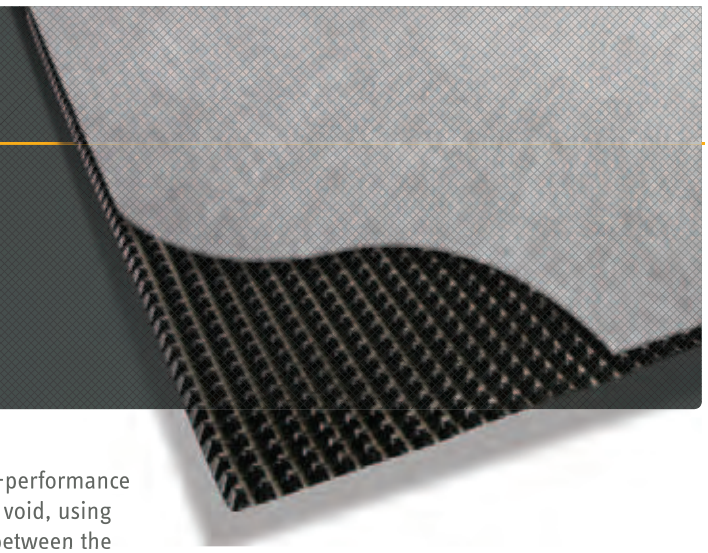
Panel Number	Date of Test	Time of Test	Technician ID Number	Spark Tester ID	Pass/Fail	Location of Repairs

Appendix C

Geocomposite Drainage Layer
Technical Specification and Installation Guidelines

Pozidrain

Pozidrain is the original wide width drainage and gas venting layer and offers a sustainable, environmentally friendly alternative to traditional drainage using filter stone



Pozidrain consists a high strength flexible polyethylene cuspated core with a non-woven geotextile bonded to either one or both sides.

The geotextile filters a wide range of materials and is bonded to the core to ensure that it does not deform into the drainage passages under the load of the backfill material. It allows fluids and gases to percolate into the core whilst supporting the backfill material. The collected fluids are then transported along the core to a discharge point.

The single cuspated HDPE core forms a high-performance free draining void, using the spacing between the cuspates. This unique core design offers clear passageways which allows flow in all directions, even in the event of damage or a blockage occurring.

Impressive compressive strength and creep resistance properties ensure that the core maintains drainage capacity under a wide range of compressive loadings.

Pozidrain is durable and sufficiently robust to resist the mechanical stresses imposed during installation and throughout the design life.

Use of Pozidrain may eliminate the requirement for secondary protection of the geomembrane liners; thick Terrex NW geotextiles may be used in the manufacture of Pozidrain to create a very substantial protection and drainage layer with just one installation cost.

When compared with aggregate drainage, Pozidrain offers superior flow characteristics in a much thinner layer. This reduces the required thickness of the capping and base lining system and results in extra void space and savings.

Wide width Pozidrain composites are especially suited for rapid installation on large landfill and restoration projects.

Pozidrain Applications

- A strong, robust drainage layer for collecting leachate or ground water in landfill containments.
- Drainage layer between soil cover and geomembrane of a landfill cap.
- A system of venting methane and other gases from the perimeter of landfills and below the capping layer.
- Leakage detection layer within the landfill base lining. Cut-off trenches.
- Embankment drainage and reinforcement.
- Capillary break layer in the restoration of contaminated land.

Chemical resistance

Pozidrain has excellent resistance to petrol, oils, acid, alkalis, leachate and all common chemicals.

Supply

Pozidrain is available in 4.4, 2.2 or 1.1 metre wide rolls, 50 or 100 metre in length, manufactured in 4mm, 6mm, 7mm, 12mm & 25mm thickness and a wide range of compressive strengths.

Installation

Pozidrain is easy to handle and is rapidly installed without the need for specialist plant. The 4.4m wide rolls are ideal for coverage of large areas.

Health, Safety & Environment

All components of Pozidrain are inert and do not present a hazard to health.

Pozidrain Benefits

- Sustainable recyclable resource.
- Creates more landfill void.
- Allows use of lower specification backfill materials.
- Reduced excavation and backfill.
- Technically defined filter properties and extremely high impact and crush strength.
- Long life performance and high flow capacity.
- Compatible with geomembrane systems. Acts as the protection layer to geomembrane liners.
- Ease and speed of installation.
- Massively reduced traffic volumes compared to drainage stone.

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Waste Management

Landfill Capping

To guarantee effective cover, landfill caps should incorporate a drainage layer above and a gas collection layer below the lining system. Pozidrain has the properties to provide these functions and offers improved performance with lower costs than using conventional crushed stone filter/drainage layers

Pozidrain is designed to be compatible with all common lining systems and provides optimum performance over the whole-life of the cap. It enhances the performance of GCL or HDPE liners by providing an additional barrier that prevents the majority of the water or gas from reaching the liner. Pozidrain geocomposite drainage layer has a proven track record in landfill capping and has been used on many projects globally.

Landfill Cap Drainage

Pozidrain installed over a geomembrane, within the geosynthetic landfill cap, will collect and drain rainwater from the soil cover. This prevents saturation ensuring the capping soil remains stable.

Gas collection & dispersal

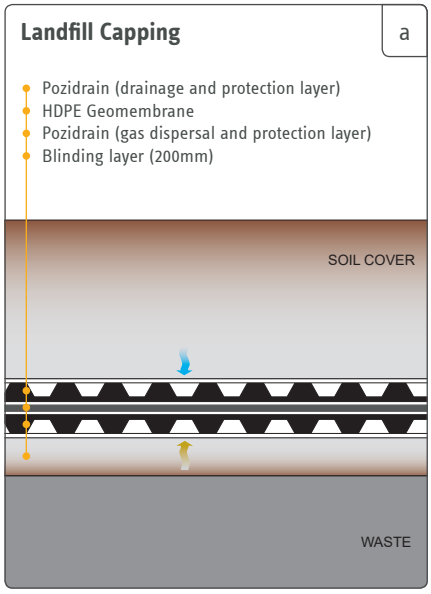
Pozidrain below a capping geomembrane forms the basis of a highly-efficient gas collection and dispersal system by creating a free draining void across the cap area.

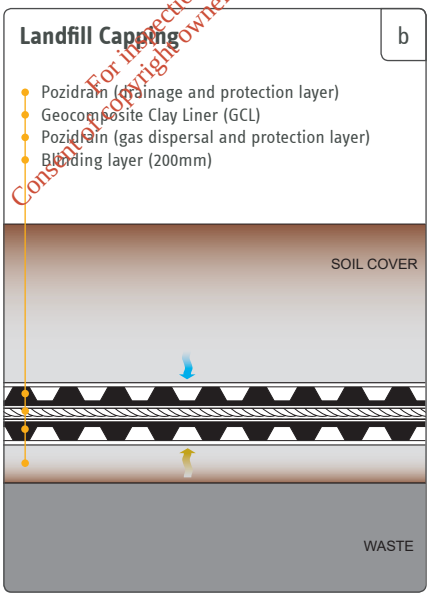
Installed with the flat face of the core against the liner and dimpled face against the waste, Pozidrain also affords a high level of protection to the lining system.

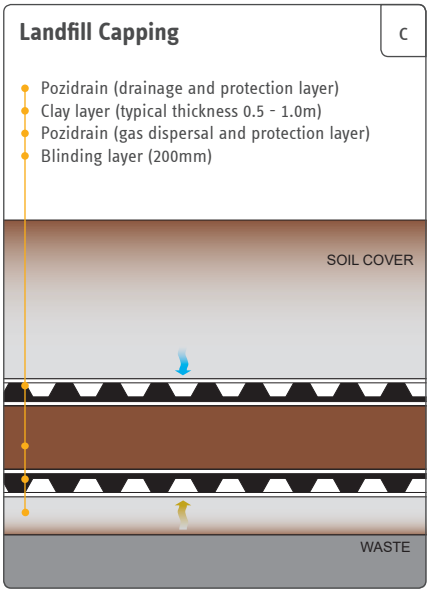
Geomembrane protection

Pozidrain has a smooth flat core that has the optimum design to reduce the contact stress on the geomembrane.

The high CBR puncture resistance of Pozidrain cushions the geomembrane from sharp material in the landfill waste. Site specific protection efficiency tests are readily undertaken.







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Pozidrain 4S250/NW8

POZIDRAIN 4S250/NW8 is a geocomposite drainage layer comprising a high performance second generation single cuspated HDPE (High Density Polyethylene) core with a geotextile filter thermally bonded on one side. The textile filter has a flap extending beyond the core on one edge. The major application is its use instead of stone drainage layers in landfill containment systems.

Data Sheet

Geocomposite Properties						
Thickness at 2kPa	(mm)	4.6			±10%	EN ISO 9863-1
Mass per unit area	(g/m²)	590			approx	EN ISO 9864
Tensile strength MD / CMD	(kN/m)	14 / 9.5			-10%	EN ISO 10319
Elongation at peak MD / CMD	(%)	45 / 45			nominal	EN ISO 10319
CBR puncture resistance	(N)	2 150			-20%	EN ISO 12236
Perpendicular Water Inflow	(dimple side only)					
Water flow at 50mm head	(l/m²·s)	103			±30%	EN ISO 11058
At 2kPa permeability *(coefficient)*	(m/s)	2.5×10^{-3}			±30%	EN ISO 11058
Breakthrough head	(mm)	0			nominal	
In-plane water flow MD [2]		HG = 1.0		HG = 0.1		Hydraulic gradient
at 20kPa confining pressure	(l/m·s)	0.85	±0.15	0.25	±0.07	EN ISO 12958
at 100kPa confining pressure	(l/m·s)	0.65	±0.15	0.20	±0.05	EN ISO 12958
at 200kPa confining pressure	(l/m·s)	0.55	±0.10	0.15	±0.05	EN ISO 12958
with **soft foam** contact surfaces to simulate textile intrusion into the core due to soil pressure						
Resistance to weathering		To be covered in 14 days				EN 12224
Resistance to chemicals		Excellent				EN 14030
Design life		120 years (manufacturer's declaration)				
Geotextile Properties						
Thickness at 2kPa	(mm)	1.2			±20%	EN ISO 9863-1
Tensile strength MD/CMD	(kN/m)	9.5 / 9.5			-13%	EN ISO 10319
Pore size O_{90}	(µm)	120			±30%	EN ISO 12956
CBR puncture resistance	(N)	1600			-20%	EN ISO 12236
Dynamic perforation cone drop	(mm)	32			+20%	EN ISO 13433
Type and material	Non-woven needle-punched and heat-treated long staple fibre polypropylene					
Product Dimensions						
Standard roll dimensions	4.4 x 125 m. Other sizes on request.					

Notes

1. The values given are indicative and correspond to nominal results obtained in our laboratories and testing institutes. In line with our policy of continuous improvement the right is reserved to make changes without notice at any time.
2. CMD flow is typically 80% of the value in the MD.
3. The tolerance on roll length is ±1.5% and on roll width is ±1.0%; in multi-core products this may manifest itself between core elements.
4. Guidance on interface shear strength, creep and certain other parameters is available. Site specific tests are strongly recommended.
5. Final determination of the suitability of any information is the sole responsibility of the user. ABG will be pleased to discuss the use of this or any other product but responsibility for selection of a material and its application in any specific project remains with the user.

CE

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Pozidrain

abg creative geosynthetic engineering

Installation Guide

General Advice

These instruc s should be read in conjun on with the contract spe n and drawings. They are intended to provide guidance in normal insta situ ns and are addressed to the installer on site. If there are any ques s related to the design, unusual insta challenges, or any doubt, consult ABG for further advice. In all situ ns, responsibility for insta remains with the Installer.

Descrip on

Pozidrain is a thin, preformed surface water drainage or gas vent geocomposite consis of a HDPE cuspated core laminated to a geotex e er on one or on both sides (Fig. 1). Typical applic ns are land containment and capping, cut-o trenches, capillary breaks, gas vents, highway embankments, drainage at the rear of reinforced earth walls, etc.

Supply

Pozidrain is supplied in rolls typically 4.4m or 5.5m long, 0.8m diameter and may weigh up to 500 kg.

Equipment Required

- Appropriate PPE.
- Sharp knife.
- Sand bags or erial for ballas

Setting out

Step 1

Pozidrain is supplied in rolls wrapped for pro on against UV light. Do not remove the wrapper un ready to install. Single use slings are provided for the safe o -loading of rolls. These slings are designed for single use to remove the rolls from the delivery vehicle to an appropriate site storage lo . Store on a rm base and do not stack more than six rolls high. Inspect all rolls for damage/defects during o ding and immediately report to **ABG**.

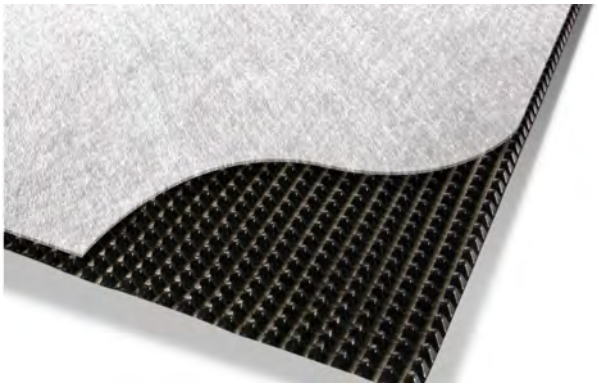

Fig. 1: Pozidrain

Fig. 2: Rolling out Pozidrain

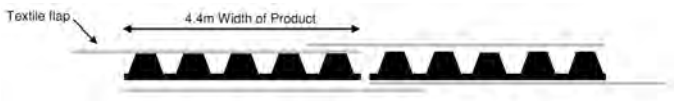

Fig. 3: Double te le Pozidrain — cores bu ed

Fig. 4: Sandbags holding edges of Pozidrain in place

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Pozidrain

Step 2

Roll or carry the **Pozidrain** rolls to the place of work, using suitable ing equipment that does not damage the product. Do not drag the rolls as this could cause damage to the geote e covering and avoid contact with machine buckets. L e rolls with a boom or pole & frame through the centre tube or by means of ing straps around the roll.

Step 3

The form n on which **Pozidrain** is to be laid should be rm, free of roots and sharp objects and be graded smooth so that there are no ruts or ridges greater than 50mm high. **Pozidrain** will bend to follow stepped or benched ground pro s.

Step 4

In choosing the commencing point and dire on of laying, consider the ou ll pos ons, the prevailing wind dire on, site slope and access point for materials. **Pozidrain** is designed to be laid so that the major w of water is longitudinally along the roll length[2].

Installa n

Step 1

Unroll the rst roll of **Pozidrain** into pos on (Fig. 2) (allowing enough material to fold into the anchor trench if required)[4].

Step 2

The next roll should be placed such that the black drainage cores bu together along the edge (Fig. 3). In all situ ns the geotex e edge ap overlaps onto the le of the adjacent roll. The aps may be held down by sandbags, sewing, adhesive, join tape, or (if lining opera s permit), staples[6](Fig. 4).

Step 3

On steep slopes, it is easiest to commence laying the **Pozidrain** from the top of the slope and allow the material to unroll gently down the slope (Fig. 5).

Fig. 5: Pozidrain being rolled downhill

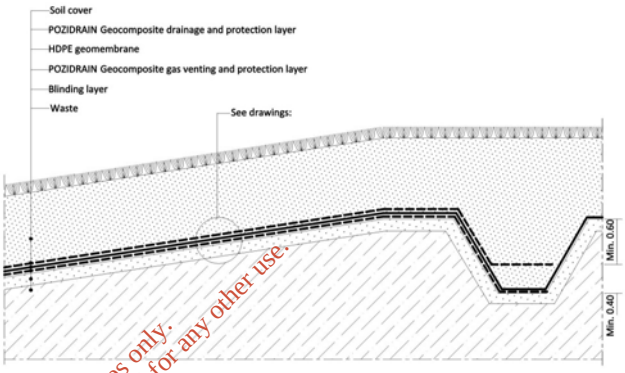

Fig. 6: Pozidrain Laid in anchor trench

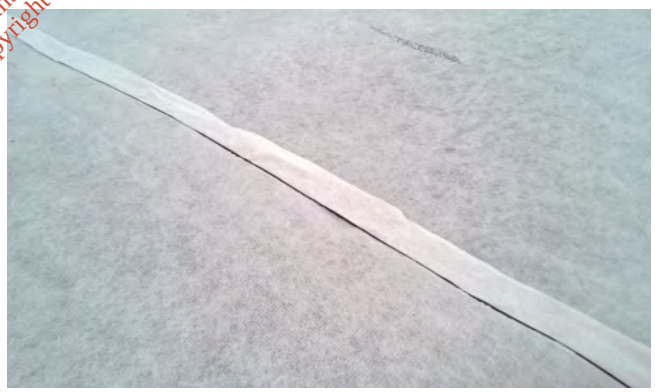

Fig. 7: Pozidrain bu ed together

Fig. 8: First layer of covering

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Pozidrain

Step 4

Con e to lay rolls to create a con ous layer. Subject to site safety procedures, rolls can be cut to length using a sharp knife or disc saw.

Step 5

A trapezoidal anchor trench will be required at the top of steep slopes to securely locate the **Pozidrain** (Fig. 6). Long steep slopes are constructed with intermediate berms and anchor trenches. Such details are normally provided in the contract drawings. On steep slopes the rolls must be con ous from top to bo om - there must be no joints on the slope between berms.

Step 8

Before back make sure there are no gaps in the geotex e cover where soil or clay could enter into the drainage core (Fig. 7). Ensure that water/gas can exit freely from the **Pozidrain**.

Step 9

To prevent damage, mechanical plant must not operate directly on **Pozidrain**. st layer of back hould be at least 150 mm thick or twice the maximum par le dimension and be spread by tracked plant (Fig. 8). Fill material should be ped on the advancing layer, not directly onto the **Pozidrain**, and the ll should be compacted closely behind the spreading opera .

Step 10

A minimum cover of 450 mm of acceptable ll is recommended over **Pozidrain** before general use by site tra Heavy plant must not be used on steep slopes. lling must always commence from the bo om of the slope upwards unless a geogrid has been designed and installed for the forces.

Step 11

In the event that the **Pozidrain** geo le cover is damaged either before or er insta , small areas can be repaired using a patch of similar le at least 300 mm larger than the damaged area. If the dimpled drainage core has been damaged, this should be cut out carefully and a new piece of **Pozidrain** inserted along with an over-size patch of geotex e.

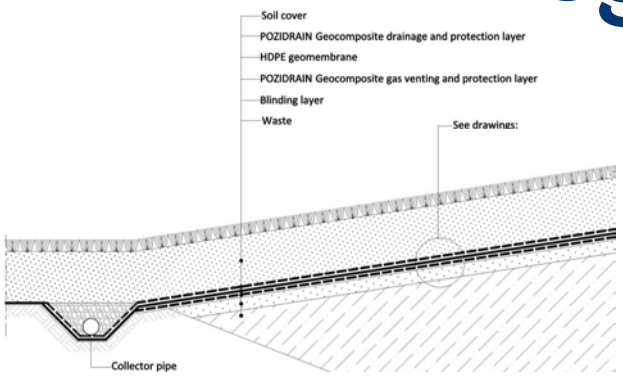

Fig. 9: Toe trench detail

Notes

1. There are no known COSHH hazards associated with the insta of **Pozidrain** but read the MSDS and care should be taken when cu g.
2. Plan only to lay as much **Pozidrain** as can be lled over that day, to avoid up in strong winds and the risk of inund n by silt-laden runo . Unused rolls may be used as ballast on at areas. **Pozidrain** can be secured temporarily by means of sandbags or small piles of ll material..
3. On steeply sloping sites the rolls of **Pozidrain** must be laid up and down the slope, not across the slope and suitable anchor trenches or run-out lengths must be used.
4. When applicable, the ends of the rolls should be overlapped at least 300 mm onto the next roll "roof e" fashion such that the water or gas can ow out of the end of the top roll and onto the drainage side of the next roll.
5. Altern vely, the **Pozidrain** can be unrolled progressively up a steep slope with the rolls held in place on the slope using large wooden chocks or wedges.
6. Ou lls for the water or gas collected by **Pozidrain** may consist of a perforated pipe laid in a gravel / stone trench. For water drainage the **Pozidrain** may discharge to a toe ditch (Fig. 9).

Terms and Condi ons

Site spe engineering design should be carried out site inves a has provided all the necessary informa n.

The assessment of suitable safety factors in re to each par ular project must always remain the responsibility of the design engineer.

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