Zwejra Non Hazardous Waste Landfill

Landfill Final Cover Design Report

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1.0 INTRODUCTION

1.1 Scope of Work

WasteServ Malta Limited (WasteServ) has commissioned Design and Technical Resources Limited (DTR) to prepare a number of studies in relation to the closure of the Zwejra non Hazardous landfill. The studies requested by WasteServ include:

1. A topographic plan showing the final elevation contours of the landfill and surface water diversion and drainage controls;
2. Design of the final cover including the thickness and permeability of barrier layers and drainage layers, and information on topsoil, vegetative cover and erosion prevention controls;
3. Rodent and nuisance wildlife control procedures;
4. Proposed end use of the property after closure;
5. A plan for monitoring groundwater, surface water and landfill gas, erosion and settlement post-closure;
6. A plan for operation of any required pollution abatement engineering works such as leachate collection and treatment systems post-closure;
7. An estimated cost, updated annually, to carry out closure and post-closure activities, assuming a period of 25 years post-closure; and
8. Cut-Fill analysis.

DTR has asked SLR Consulting Limited (SLR) to support on a number of the studies. This report provides information in relation to Item 2 the design of the final waste cover layer.

1.2 Site Background

Zwejra Landfill Site is part of a large integrated waste management facility close to the village of Maghtab (referred to by WasteServ as the Maghtab complex). The overall site includes the following:

- The old and closed Maghtab Landfill;
- Zwejra Landfill Site; and
- Ghalllis integrated waste management facility (Ghallis non-hazardous landfill, Malta North MBT facility, biological treatment plant and associated infrastructure).

The Maghtab Landfill was closed in 2005 as a condition of Malta's accession to the European Union. At this time the Ghallis integrated waste management facility was authorised following submittal of an Environmental Impact Assessment. The Ghallis facility included a range of proposed waste management infrastructure including a new fully engineered non-hazardous landfill. The landfill was to be created by the extraction of in-situ limestone deposits but creation of the void took 2 years to develop. In the interim period between the closure of Maghtab (2005) and the opening of Ghallis (2007/08), WasteServ developed a small landfill located close to the old site entrance of the overall facility called Zwejra. This landfill comprised a number of fully engineered landfill cells and was used for the deposition of non-hazardous waste up to the opening of Ghallis non-hazardous landfill.

WasteServ have operated the site under an IPPC Permit IP0001/05/B issued by the Malta Environmental and Planning Authority.

Drawing No. 1 shows the site location and Drawing No. 2 shows a general layout of the Maghtab complex and the location of Zwejra Landfill Site within this complex.

2.0 EXISTING SITUATION

With reference to Drawing No. 2 Zwejra Landfill Site lies in the south of the Maghtab complex and is bound around the entire perimeter by formalised access roads (virtually all tarmacked). To the north lies the landfill gas management plant, Maghtab Landfill, the biological treatment plant and the hazardous waste landfill. To the west and east of the landfill lie agricultural land and at the southern tip of the landfill is the old entrance to the waste management complex (now replaced by the new access directly off the main coast road).

Zwejra Landfill has been developed on the principals of containment with a composite lining system installed across the base and perimeter slopes of the landfill, providing an impermeable barrier to prevent leachate seeping into the underlying groundwater regime. A leachate collection system, comprising a granular drainage blanket and associated pipework lies above the composite liner allowing leachate to be collected and removed, via pumping. Currently the leachate is recirculated within Zwejra to accelerate decomposition and the stabilisation of the waste mass. However, in the future it is intended that leachate from Zwejra will be extracted and treated/disposed of along with leachate from Ghallis Landfill. In summary from bottom to top the lining and leachate collection system comprises the following:

- Regulation layer to provide a level surface for the lining system installed over the excavated limestone formation;
- 500 mm thick mineral liner;
- Geosynthetic clay liner (GCL);
- 2mm thick high density polyethylene (HDPE) geomembrane;
- Geotextile protector;
- 300mm thick leachate drainage material; and
- Leachate extraction pipework.

A current topographical survey of the site is presented on Drawing No. 3.

SLR has been provided with a drawing which we understand is defined as the approved restoration profile. This drawing is referenced 165ZW04_00 and is stated as being the top of the waste. We also understand this drawing has been issued to the Malta Environment and Planning Authority (MEPA) which has subsequently restructured and is now the Environment and Resources Authority (ERA). This 'approved' restoration profile is reproduced as Drawing No. 4. The landform rises in a series of benches to a maximum elevation of 76maOD, at the northern end with a ridge running centrally to another peak in the south at 57maOD. Benches are 4m wide and spaced at approximately 5m vertical intervals, with a maximum inter-bench slope of 1 vertical in 2.25 horizontal, giving an overall slope of 1V in 3H. The benches are intended to provide both access over the whole of the landfill for future maintenance and to allow surface water to drain in a controlled manner to the toe of the landfill where it will discharge to the existing drainage system.

Drawing No. 5 presents an isopachyte of the difference in level between the approved and existing landforms. This shows the areas where the existing levels are above the approved restoration profile (areas of excavation/cut) and the areas where the existing levels are below the approved restoration profile (areas requiring additional fill). The drawing also indicates the following volumes required as detailed below:

- Excavation 34,928m^3
- Fill 79,408m^3

To achieve the approved profile the current waste profile will require excavation / re-profiling (approx. 35,000m^3), plus filling with an additional 44,480m^3 of waste to achieve the restoration levels.

The cut/fill isopachyte drawing can be used as a guide to indicate the work required prior to installation of the overlying capping and restoration system.

3.0 DESIGN PHILOSOPHY

3.1 End Use

The Zwejra landfill forms part of the active Maghtab waste management complex and it is highly unlikely that this shall be returned to free access in the foreseeable future. Furthermore, its proximity to active, long-term, waste management facilities would certainly discourage public use. In all likelihood the Zwejra mound shall, once rehabilitated, form a landscaped hillock within the territory owned by WastServ, which territory is, for all intents and purposes, considered private.

The orientation of the mound is general North-South on its longer (425 metre) axis with about 130 metres presented to the south and 240 metres to the north. Whilst it may seem tempting to use the lower slopes on the south face to harvest solar energy, the south-facing area is rather small and probably offers much less than 1000 square metres of usable space. Furthermore, any such installation would be highly visible from the vantage point of high ground to the south, south east and southwest and this would be impossible to screen considering the difference in altitude. It is therefore likely that such a proposal would be deemed undesirable by the Planning Authority and economically unviable.

In view of the above, it is proposed that the rehabilitated Zwejra landfill is allocated no practical use, shall be “returned to nature” and shall be made to fit into the landscape as much as this is possible.

3.2 Final Cover System

The final cover forms the final component in the construction of a containment landfill and comprises the engineered cap and the restoration layer. The principle objectives of the final cover are to:

- Contain the waste;
- Manage leachate production by controlling the ingress of rain and surface water into the underlying waste;
- Prevent uncontrolled escape of landfill gas or the entry of air into the waste;
- Accommodate the environmental control measures; and
- Provide a physical separation between the waste and overlying restoration layer and ultimately the wider environment.

To achieve the above objectives the proposed final cover design shall comprise the following (from top down):

- **Restoration Soils:** A layer of soils and or soil-forming materials shall be sourced from onsite stockpiles, manufactured using a host soils and ameliorants, or imported to site, to provide a growth medium to establish vegetation. The thickness of the drainage layer will be dependent upon the drainage layer used in order to provide 1000mm cover to the geomembrane cap.
- **Drainage Layer:** The drainage layer lies beneath the restoration soils and above the artificial sealing and/or mineral layer. The objective of the layer is to facilitate the drainage of rainwater and surface water that percolate through the restoration layer. Draining the water away from the base of the restoration soils not only reduces the infiltration of water through the engineered cap but also improves stability. The drainage layer may be formed from either a 300mm thick layer of permeable granular material installed above a geotextile protector or a geocomposite drainage layer (GDL). Water collected in the drainage layer above the capping layer will naturally flow

to the toe of the waste slope. At this point the water shall be collected in a perforated pipe which will control discharge to the existing drains in the perimeter road.

- **Capping Layer:** The capping layer provides a low permeability barrier controlling both the generation of leachate by minimising the infiltration of water and uncontrolled release of landfill gases. In the absence of suitable low permeability soils the capping layer over the waste will be formed by a geomembrane, manufactured from Linear Low Density Polyethylene (LLDPE). LLDPE is considered to be the most appropriate material for capping as it is more flexible than a High Density Polyethylene (HDPE) and can therefore withstand the anticipated settlement of the underlying waste as it decomposes. The geomembrane cap will tie into the basal geomembrane liner around the perimeter of the landfill.
- **Waste Regulating Layer:** A minimum 250mm thick layer of soils will be placed to provide a firm even surface over the waste fill upon which to install the barrier layer. The regulating layer will comprise soils excavated from onsite sources or stockpiles of imported soils.

Details of the proposed final cover design is presented on either Drawing No. 6a (granular drainage option) or Drawing No. 6b (GDL option). Around the perimeter of the landfill the capping geomembrane shall be welded to the basal liner to form an airtight seal. However, the construction detail for this tie-in will differ around the perimeter of the landfill, due to the topography and the need to control surface water discharging from the restored landfill, as indicated on Drawing No. 6a and 6b.

On the western side of the landfill, where the existing anchor trench to the basal liner is at the level of the perimeter access road, a rock faced bund will be constructed raising edge of the edge of the landfill to form a wide flat ditch. Along the eastern and southern sides of the landfill the edges have already been raised and the anchor trench for the basal liner is installed at this higher level. Along the northern edge of the landfill, adjacent to the landfill gas plant, the basal liner anchor trench is at the base of an existing wall and the cap will tie in at this level, with the ditch formed in the valley between the toe of the waste slope and the wall.

3.3 Surface Water Management System

The purpose of the surface water management scheme is to control the discharge of water off of the restored profile, to ensure that water discharges to the existing drainage system and to minimise erosion. Details of the surface water management system are presented on Drawing Nos. 7 and 8.

The proposed system utilises the benches within the approved restoration profile to act as drains along which water flows during a storm event. The water is directed to the perimeter of the landfill either along the benches or by diverting the water off the benches and then down spillway channels. To minimise erosion the spill way channels are protected with riprap.

At the perimeter toe of the landfill a bund is to be formed to provide space for a surface water ditch. The bund varies in height around the perimeter, but in general is 2m high with a rock facing to ensure stability. The riprap lined ditch is formed by the waste slope abutting a 1m high wall constructed on top of the bund. This ditch discharges to the existing drains in the surrounding perimeter road at12 locations, nominally at 50m spacings. At each discharge point a 1.5m long section of the wall is to be lowered by 400mm such that it lies beneath the level of the ditch. To prevent erosion of fill material behind the rock facing to the bund a layer of “Concrete Canvas” is to be installed.

4.0 STABILITY ANALYSIS

The proposed final waste slopes at Zwejra are considered to be stable. A visual inspection of the existing slopes indicated that whilst much of the existing waste surface is steeper than the proposed final levels, there are no signs of failure or pre-failure deformations. However, the installation of the capping system introduces a potential slip plane on the surface of the waste slope, above which a thin veneer of soil is to be placed. Hence, it is important to consider the stability of the veneer of soils and the underlying geosynthetic materials.

The capping stability review has been undertaken using the methods proposed by Jones and Dixon[1] and Jones and Pine[2]. The equations developed by these authors are input into Microsoft Excel spreadsheets for processing.

The selection of appropriate factors of safety used in this review is based on the recommendation contained within the United Kingdom Environment Agency R&D Technical Report P-385[3], volumes TR1 and TR2 (and, while not representing official Environment Agency Guidance, is from here on referred to as the Guidance). A minimum factor of safety of 1.3 is considered appropriate and has been adopted where peak shear strength conditions are applied for the pre-settlement slopes. A factor of safety greater than unity (1.0) is considered appropriate where residual or post peak shear strengths are applied.

The restoration soils to be used at Zwejra comprised 700mm of site won restoration soils. In the absence of specific test data conservative parameters, representing a variable restoration soil placed under low normal stresses have been used in the analyses, as presented in 1, below.

Table 1 Analysis Parameters

Material / Interface	Bulk Density (kNm^{-3})	Effective Cohesion, c' (kPa)	Angle of Shearing Resistance (o)	Peak		Residual	
				Apparent Cohesion c' (kPa)	Angle of Shearing Resistance (°)	Apparent Cohesion c' (kPa)	Angle of Shearing Resistance (°)
Restoration Soils	16 (Dry) 18 (Wet)	0	33	-	-	0	30
Restoration Soils / Geotextile (Geocomposite)	-	-	-	0	33	0	30
Geotextile(Geocomposite) / Textured LLDPE	-	-	-	6.9	25.8	3.6	13.1
Textured LLDPE / Regulation Layer	-	-	-	0	33	0	30

[1] Jones, D.R.V. & Dixon, N, 'The stability of geosynthetic landfill lining systems' Geotechnical Engineering of Landfills, Thomas Telford, London, 1998.

[2] Jones, D.R.V. & Pine, R.J., 'Design of inclined geosynthetic lining systems for vertical landfill expansion' Proc. 8th Int. waste Management and Landfill Symposium, 2001.

[3] Environment Agency R&D Technical Report P1-385/ TR1 and TR2, 'Stability of Landfill Lining Systems', February 2003.

The analyses undertaken considered a slope of 5m high with a gradient of 1 in 2.25, which is the worst case scenario, based on the approved restoration contours. Three different capping systems were considered, namely:

- Capping system without drainage comprising from top down 700mm soils, geotextile protector, geomembrane and waste regulating layer.
- Capping system with drainage comprising from top down 700mm soils, 300mm granular drainage layer, geotextile protector, geomembrane and waste regulating layer.
- Capping system with drainage comprising from top down 700mm soils, geocomposite drainage layer, geomembrane and waste regulating layer.

In considering the stability of the restoration soils overlying the geosynthetics of the capping system, the influence of possible partial saturation of the soil has been investigated. The analysis models the saturation of the soils overlying the lining system by adopting a Parallel Submerged Ratio (PSR) as defined by Jones and Dixon[1]. In the analysis the soils are assumed to be placed in a uniform layer over the slope and the phreatic surface of the water within the soil is assumed to be parallel to the slope. Within the model the PSR has been modelled to from 0 to 0.4.

The analysis has been undertaken following the guidance in TR2[3] and is presented as Table 1-1 in Appendix A and summarised below in Table 2. Figure 1(Appendix A) gives guidance on the forces and parameters used in the analysis.

Table 2 Summary of Closed Form Capping Stability Analysis

Case		Slope Height (m)	Soil Thickness (m)	PSR	Critical Interface				
					Friction Angle (°)	Cohesion (kPa)	FoS	Tension	Interface
1	No Drainage / Peak	5	0.7	0	33	1	1.64	No	Restoration Soils / Geotextile
1	No Drainage / Peak	5	0.7	0.40	33	1	1.26	No	Restoration Soils / Geotextile
1	No Drainage / Residual	5	0.7	0.40	33	1	1.12	No	Restoration Soils / Geotextile
2	Granular Drainage / Peak	5	0.7	0	33	1	1.72	No	Restoration Soils / Geotextile
2	Granular Drainage / Residual	5	0.7	0	33	0	1.53	No	Restoration Soils / Geotextile
3	Geocomposite Drainage / Peak	5	0.7	0	33	0	1.64	No	Restoration Soils / Geocomposite
3	Geocomposite Drainage / Residual	5	0.7	0	33	0	1.46	Yes	Restoration Soils / Geocomposite

In Case 1, where there is no drainage layer, it can be seen that when the soils are dry the factor of safety is adequate at 1.64. However, an increase in the pore water pressures at the

interface between the soils and the underlying geotextile reduces the factor of safety to an unacceptable level, i.e. less than 1.3. The inclusion of a drainage layer eliminates the possibility of pore water pressures at the interface with the geotextile, hence maintaining an adequate factor of safety. This demonstrates the importance of the drainage layer above geomembrane cap, as the provision of a free draining layer prevents the build-up of pore water pressures at the critical interface.

The difference in the calculated factor of safety between the granular drainage layer (1.72 peak, 1.53 residual) and the geocomposite (1.64 peak, 1.46 residual) is due to the increased thickness of soils above the geotextile. The method of analysis calculates the driving forces of a wedge of soils on the slope (active wedge) and resisting forces of a wedge of soils at the toe of the slope (passive wedge). A thicker layer of the soils increases the resistance provided by the passive wedge more than it increases the driving forces of the active wedge, as the active wedge is affected by frictional forces on the slope.

The effect of assuming peak and residual values reduces the factor of safety in all cases, however, due to the granular nature of the soils this reduction generally does not significantly impact the stability.

Prior to the approval of any materials within the works the it will be necessary to provide laboratory test data to demonstrate that the combination of materials they propose are stable at the maximum gradient anticipated on site, i.e.1V in 2.25 (24°).

5.0 MATERIAL SPECIFICATIONS

The primary function of the capping system is to provide an impermeable barrier to prevent the ingress of water into the waste mass. The system includes:

Option 1 - Granular Drainage Layer

- 250mm regulation layer
- 1mm thick LLDPE Geomembrane Cap (textured on both sides) with welded seams
- Geotextile Protector
- 300mm thick Granular Drainage Layer
- 700mm thick restoration soils.

Option 2 – Geocomposite Drainage layer

- 250mm regulation layer
- 1mm thick LLDPE Geomembrane Cap (textured on both sides) with welded seams
- Geocomposite Drainage Layer
- 150mm thick Soil Protection Layer
- 850mm thick restoration soils.

The following provides an overview of the specification and purpose of each of the elements of the capping system, a copy of the Specification is presented in Appendix B.

5.1 Regulating Layer

The regulating layer shall be placed to a minimum thickness of 250mm and compacted to ensure that an even surface has been achieved, free of abnormalities that could result in ponding. The regulating layer should be free of any objects that may puncture the overlying geomembrane. The maximum particle size (in a material with a broad particle size distribution) in contact with the membrane will be no greater than 10mm if angular material and 20mm if rounded particles. The maximum particle size in the regulating layer (not in contact with the geomembrane or within 100mm of the geomembrane) shall be 150mm (in a material with a broad particle size distribution). Any stone that protrudes above the level of the surface of the regulating layer should be stone picked and any indentations remaining should be filled and compacted with suitable material.

5.2 Geomembrane Cap

The welded geomembrane cap shall consist of an un-laminated 1mm thick double textured Linear Low Density Polyethylene (LLDPE) geomembrane. The specification requires the material to meet the requirements of GRI-GM17, which is an industry standard specification for the manufacturing of geomembranes published by the Geosynthetic Research Institute.

The specification sets out a how the geomembrane is to be handled, stored, deployed, welded, tested and repaired, to ensure that it provides an impermeable barrier over the final waste profile.

5.3 Drainage Layer

5.3.1 Granular Drainage Layer Option

The granular drainage system shall comprise a 300mm thick layer of free draining clean aggregate, nominally 10-20mm in size, as presented on Drawing No. 6a. To protect the underlying geomembrane from the puncturing during the installation of the granular material a geotextile protector will be required immediately above the geomembrane. To prevent fines from entering the granular drainage layer a separation geotextile shall be installed over the top of the granular drainage layer. Performance criteria for the geotextile separator and protector are set out within the Specification (see Appendix B).

The granular material shall be placed in such a manner to ensure that it does not damage the underlying geosynthetic materials either by puncturing or tearing. A minimum 1m thick of vertical separation between construction plant and the geosynthetic materials shall be maintained along the haul routes. Only low ground pressure construction plant shall be allowed to traffic on the 250mm thick drainage layer and no construction plant may access directly on the geosynthetic materials. Granular materials shall be placed from the toe of the slope up, to ensure stability during construction.

5.3.2 Geocomposite Drainage Layer Option

The Geocomposite Drainage Layer (GDL) shall be installed immediately above the geomembrane cap, as presented on Drawing No. 6b. The GDL provides both a free draining layer at the base of the restoration soils to improve stability by drainage water seeping through the restoration soils and protection to the geomembrane from the overlying restoration soils. The drainage composite shall comprise an upper and lower geotextiles, between which a drainage core is sandwiched. Performance criteria for the geocomposite drainage layer are set out within the Specification (see Appendix B).

5.4 Restoration Soils

The restoration soils shall be obtained from a suitable on site source, or imported to site, and shall be free from any deleterious materials, which should be removed and disposed of on an area of the site not already capped.

The maximum particle size shall not exceed 50 mm within 300mm of the underlying geosynthetic material, to ensure they are not damaged.

No unsuitable material shall be incorporated within the subsoil or topsoil layers. Unsuitable materials shall include but not be limited to the following:

- Materials susceptible to spontaneous combustion;
- Domestic, commercial or industrial waste;
- Frozen matter;
- Materials in contact with the Protective Geotextile with dimensions greater than 50mm; and
- Any material with the potential to damage the Protective Geotextile.

The restoration soils shall be placed in such a manner to ensure that it does not damage the underlying geosynthetic materials either by puncturing or tearing. A minimum 1m thick of vertical separation between construction plant and the geosynthetic materials shall be maintained along the haul routes. Soils shall be spread using low ground pressure construction plant to prevent over compaction of the soils. Soils shall be placed from the toe of the slope up, to ensure stability during construction.

5.5 Planting and Seeding

Restoration soils placed over the capped landfill shall consist of a suitably-augmented growing medium that would, on its own, accelerate the process by which natural plant growth would take place, this as nature reclaims this mound. To further accelerate the process, but mostly to secure the stability of the soil, all slopes shall be seeded and planted with low-laying shrubs, to a density of 1 per 1.5 square metre. This vegetation shall be compliant with the Planning Authority's list of approved species with a further requirement that such plants should not be of a man-edible, fruit-bearing variety.

To facilitate rapid rooting, an irrigation system shall be installed that shall be sufficient to provide each species with the daily water uptake it requires. This system shall be removed when vegetation has taken hold, which is assumed to be after three years.

5.6 Construction Quality Assurance

The construction of the final cover will be subject to full time construction quality assurance, to ensure that the installation of each element of the works meet the contractual and regulatory requirements as set out in the specification. The CQA activities shall include the following:

Waste Regulating Layer

- Assessment and acceptance of material placed;

LLDPE Geomembrane Cap

- Checking delivered material and inventory recording;
- Observation of geomembrane panel deployment;
- Observation and evaluation of trial seams;
- Inspection of field seams and seaming operations;
- Identification of defects and monitoring;
- documentation of repairs;
- Non-destructive seam continuity testing observations;
- Programming and assessing independent laboratory of geomembrane; and
- seam destructive testing and evaluation of results.

Drainage Layer – Granular

- Checking delivered geotextile materials and inventory recording;
- Observation of geotextile panel deployment;
- Inspection of seaming and repair operations;
- Programming and assessing independent laboratory of geotextile materials;
- Programming and assessing independent laboratory of drainage stone;
- Observe placement of drainage layer;
- Identification of areas of damage to underlying geomembrane and observing their repair; and
- Observe installation of pipework at toe of slope.

Drainage Layer – Geocomposite

- Checking delivered geocomposite drainage layer (GDL) material and inventory recording;
- Programming and assessing independent laboratory of GDL;
- Observation of GDL panel deployment;
- Inspection of seaming and repair operations;
- Identification of areas of damage to underlying geomembrane and observing their repair; and
- Observe installation of pipework at toe of slope.

Restoration Soils

- Observe placement of restoration soils; and

- Identification of areas of damage to underlying geosynthetic materials and observing their repair.

Surface water Management System

- Approve Observe construction of riprap lined ditches and spill ways; and
- Observe construction of rock faced bund and perimeter wall;

6.0 CLOSURE

This report has been prepared by SLR Consulting Limited with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of WasteServ Malta Limited; no warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

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APPENDIX B

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