Feasibility Study and Development of Procurement Document for Upgrading, Extension, Reconditioning / Rehabilitation and Closure of MSWDS in Philipsburg, Sint Maarten

Analysis and Selection of Alternatives for MSWDS development

National Recovery Program Bureau

20 March 2025

Project	Feasibility Study and Development of Procurement Document for Upgrading, Extension, Reconditioning / Rehabilitation and Closure of MSWDS in Philipsburg, Sint Maarten
Client	National Recovery Program Bureau
Document	Analysis and Selection of Alternatives for MSWDS development
Status	Final version D01
Date	20 March 2025
Reference	25-006.096
Project code	144046
Project manager	Johan Lijftogt
Project director	Peter Tienhooven
Author(s)	Johan Lijftogt
Checked by	Peter Tienhooven
Approved by	Johan Lijftogt
Initials	
Address	Witteveen+Bos Raadgevende ingenieurs B.V. Leeuwenbrug 8 P.O. Box 233 7400 AE Deventer The Netherlands +31 570 69 79 11 www.witteveenbos.com CoC 38020751

The Quality management system of Witteveen+Bos has been approved based on ISO 9001.

TABLE OF CONTENTS

APPENDICES

Number of pages

1

EXECUTIVE SUMMARY

In order to facilitate a decision on the selection of the alternative to be further elaboration into a Concept Design as basis for the preparation of the Feasibility Study Report and Procurement Documents, an analysis has been prepared for the site Layout alternatives of the existing situation and two options for a horizontal extension. The analysis of the site Layout alternatives is based on a single engineering concept for improvement of the Environmental, Health and Safety conditions which has been uniformly applied for the current situation at the MSWDS within its existing boundaries as well as two site Layout alternatives for horizontal extension at the Pondfill, consisting of: (I) Horizontal Extension at the Resettlement Area, and (II) Horizontal Extension at the VROMI Yard.

Figure 1.1 Visualization of Horizontal Extension at Resettlement Area (L) and VROMI Yard (R)

Given the fact that the engineering concept for improvement of the Environmental, Health and Safety conditions which is uniformly applied and has been elaborated based on previously established Feasibility Criteria and Boundary Conditions. Based on an analysis of the alternatives against the criteria contained therein for Technical Feasibility, Socio-Economic Feasibility and Environmental, Health and Safety Feasibility, the alternative in which the existing boundaries of the MSWDS are maintained performance the best against all criteria.

It is to be noted that a separate analysis of the alternatives has been made against two main distinctive criteria included in the Feasibility Criteria and Boundary Conditions: (I) Landfill Capacity and Associated Life-Span for Waste Disposal, and (II) Capital Expenditure Costs for Construction. The summary of the results of the analysis of alternatives for these distinctive criterial is presented in the tables hereafter.

Table 1.1 Summary of Indicative Life-Span for Analysis of Alternatives

No	Alternative	Capacity (thousand m3)	Life Span	Life-Span (diversification scenario)
1	Existing Boundary - IDS Crest at 10m	70	Middle 2025	Middle 2025
2	Existing Boundary - IDS Crest at 25m	360	End 2027	End 2028
3	Resettlement Area - IDS Crest at 10m	900	Middle 2033	Middle 2039
4	Resettlement Area - IDS Crest at 25m	1.190	End 2035	After 2040
5	VROMI Yard - IDS Crest at 10m	319	Middle 2027	Beginning 2028
6	VROMI Yard - IDS Crest at 25m	609	End 2030	End 2030

Table 1.2 Summary of the Capital Expenditure for Construction for Analysis of Alternatives

No	Alternative	Itemized Direct (million USD)	Total Direct & Indirect (million USD)	Total Investment (million USD)
1	Existing Boundary - IDS Crest at 10m	35.4	59.5	70.4
2	Existing Boundary - IDS Crest at 25m	34.9	58.6	69.4
3	Resettlement Area - IDS Crest at 10m	40.0	67.3	79.6
4	Resettlement Area - IDS Crest at 25m	39.5	66.4	78.6
5	VROMI Yard - IDS Crest at 10m	41.5	69.7	82.5
6	VROMI Yard - IDS Crest at 25m	41.0	68.9	81.5

Table 1.3 Cost Breakdown Itemized Direct Costs for selection of alternatives (in million USD)

Cost Breakdown	Alternative 2. Existing Boundary IDS Crest at 25m	Alternative 4. Resettlement Area IDS Crest at 25m
Total	$ 34.88 (100%)	$ 39.50 (100%)
IDS Total	*$ 9.38 (27%)*	*$ 9.38 (24%)*
Reprofiling & Ring dike (incl. Service Road Landside Toe)	*$ 1.08 (3%)*	*$ 1.08 (3%)*
Closure Cover Layer	*$ 8.03 (24%)*	*$ 8.03 (21%)*
SWDS Total	*$ 25.50 (73%)*	*$ 30.12 (76%)*
Reprofiling & Ring Dike (incl. Service Road Landside Toe with Fencing)	*$ 5.50 (16%)*	*$ 5.18 (13%*
Closure Cover Layer	*$ 20.00 (57%)*	*$22.48 (57%)*
Costs for Extension	--	*$ 2.46 (6%)*

2

INTRODUCTION

2.1 Project Background

Sint Maarten struggles with a weak municipal solid waste management system. The responsible Ministry of Public Housing, Spatial Planning, Environment and Infrastructure (VROMI) is operating a poor and unsanitary waste management and disposal system, while a related framework for the financial and governance setup is lacking. Since the start of its operation in the seventies, the Solid Waste Disposal Site (SWDS), and later the Irma Disposal Site (IDS), both situated at Pond Island in Philipsburg and collectively referred as the Municipal Solid Waste Disposal Sites (MSWDS), operate without a legal and regulatory framework and serves as an open dumpsite for the whole country with limited supervision, operational workflows, waste measures and controls.

In response to the Irma hurricane destruction in 2017, the Government of Sint Maarten initiated the National Recovery and Reconstruction Program, known as "Building Back Better". This program aims to facilitate the island's large-scale recovery and reconstruction efforts. Since January 2018, the World Bank has been providing assistance to the Government of Sint Maarten in implementing this program. A significant portion of the funding is provided through a Trust Fund established by the Netherlands in collaboration with the World Bank. The projects funded by this Trust Fund are managed by the National Recovery Program Bureau (NRPB), which serves as the Project Implementation Unit (PIU) for Trust Fund projects.

One of the projects supported by the Trust Fund is the Emergency Debris Management Project (EDMP). This project aims to effectively manage debris resulting from the hurricane and reconstruction activities, as well as improve the organization, rehabilitation, and upgrading of debris storage and municipal disposal sites.

As part of the EDMP a project was developed by the NRPB for conducting a Feasibility Study and Development of Procurement Document for the Upgrading, Extension, Reconditioning/Rehabilitation and Closure of Municipal Solid Waste Disposal Site (MSWDS) in Philipsburg, Sint Maarten. The aim of this project assigned to the consortium of Witteveen+Bos and TAUW is to develop a sustainable solution, including a Concept Design and associated Procurement Documents for implementation, for the SWDS and IDS with an acceptable level of Environmental, Health and Safety impacts and to establish sufficient landfill disposal capacity during a transition period to a non-disposal Integrated Solid Waste Management System.

2.2 Document Purpose and Scope

The situation at the current MSWDS is considered not to be acceptable due to the unsafe condition of the geotechnical slope stability. This results in the risk that the current steep slopes (mainly at the boundary with the Great Salt Pond) will collapse, resulting in major environmental impacts with large volumes of disposed waste sliding into the water. Thus, a reprofiling of these slopes to ensure the geotechnical stability to prevent the risk of collapsing is therefore assessed to require an immediate intervention.

In addition, the disposal at the existing MSWDS also results in an environmental impact, especially on the water quality of the Great Salt Pond. Infiltrated stormwater passing through the waste results in biologically and (to a lesser extend) chemically contaminated leachate, which due to the uncontrolled conditions at the MSWDS seeps through the subsurface into the Great Salt Pond. An intervention for this environmental impact is ultimately also considered to be required. As such a continuation of the current operations at the landfill, with the steep slopes and lack of leachate control is not considered to be a feasible option.

The purpose of this document is to define and analyse the alternatives for the improvement, extension and (ultimate) closure of the MSWDS, in order to facilitate a decision by NRPB of the alternative to be selected for further elaboration into a Concept Design as basis for the preparation of the Feasibility Study Report and the Procurement Documents.

This analysis and selection of alternatives report is the final deliverable under the Project Task 2 “Evaluating of Alternatives for the MSWDS in Sint Maarten”. Other deliverables under this Task previously submitted and for which their findings have been applied in the subject analysis and selection of alternatives consists of: Environmental Field Study Report [Ref. 1], Geotechnical and Geographical Survey Report [Ref. 2], Methane Gas Model Calculations Note, Feasibility Criteria and Boundary Conditions Report [Ref. 4], and the Waste Generation, Composition and Disposal Note [Ref. 5].

2.3 Abbreviations and Reference Documents

2.3.1 Abbreviations

The abbreviations, as well as specific terms and definitions used in this report are specified in the table below.

Table 2.1 Specific Terms, Definitions and Abbreviations

Specific Term, Definition, Abbreviation	
AACE	Association for the Advancement of Cost Engineering
ALARA	As Low As Reasonable Achievable
CAPEX	Capital Expenditures
EHS	Environmental, Health and Safety
EUR	Euro
EuroCode 7	European Standard on Geotechnical Engineering, issued by the European Commission
IDS	Irma Disposal Site
EDMP	Emergency Debris Management Project
GHG	Greenhouse Gas
GSP	Great Salt Pond
ha	Hectare (10,000m2)
HDPE	High-Density Poly Ethylene
IPCC	Intergovernmental Panel on Climate Change
LLDPE	Linear Low Density Poly Ethylene
NGO	Non-Governmental Organisations
NRPB	National Recovery Program Bureau
OPEX	Operational Expenditures

Specific Term, Definition, Abbreviation	
Resettlement Area	Area south of existing SWDS bordering Soualiga road
MSWDS	Municipal Solid Waste Disposal Sites (consisting of IDS and SWDS)
SF	Safety Factor as per Eurocode 7
SWDS	Solid Waste Disposal Site
SXM	Sint Maarten
USD	United State Dollar
VROMI	Ministry of Public Housing, Spatial Planning, Environment and Infrastructure Sint Maarten
VROMI Yard	Area south of existing SWDS bordering the GSP currently used by VROMI as storage facility
WB	WordBank

2.3.2 Reference Documents

An overview of previous work performed and referenced in this report are specified in the table below.

Table 2.2 Reference Documents

No.	Document
[1}	Environmental Field Study Report (R002-1293149ABR-V03-mvg-NL, November 28, 2024)
[2]	Geotechnical and Geographical Survey Report (R003-1293149GMC-V01-mvg-NL, January 10, 2025)
[3]	Methane Gas Model Calculations for MSWDS, Philipsburg, Sint Maarten (N003-1293149ABR-rlk-V01-NL, January 15, 2025)
[4]	Feasibility Criteria and Boundary Conditions (R004-1293149IKR-V01-mvg-NL, February 21, 2025)
[5]	Waste Generation, Composition and Disposal Note (144046/TN/25-002, April 7., 2025)
[6]	Sint Maarten National Ordinance on Environmental Protection (Landsverordening Milieu, 1995)
[7]	Eindrapport Milieunormen Nederlandse Antillen, Lucht en Geluid, Water en Afvalwater, Afval (Werkgroep Milieunormering Nederlandse Antillen, June, 2007

3

DEFINITION OF ALTERNATIVES

3.1 General

During the process of the definition of alternatives various discussions have been held with NRPB, WB and VROMI on the site Layout to be applied as boundary conditions for the project. These meetings have been supported with an overview of various options and the estimated theoretical maximum landfill capacity and associated lifespan extension for disposal operations that could be achieved. Necessary measures to comply with the feasibility criteria and boundary conditions [Ref. 4] were not yet considered at that stage. During these meetings, no decision was made with respect to the site Layout to be applied as boundary condition for the project.

Without clear boundary conditions, the initial approach of defining two technical alternatives for the improvement and closure of the MSWDS within a given boundary condition for site-Layout was no longer possible. An adjusted approach has therefore been applied whereby in addition to the current site boundaries of the MSWDS, two alternatives for horizontal extension on the Pondfill have been defined.

In addition, a uniform Engineering Concept with the minimum interventions to be taken to ensure an acceptable minimal level of (potential) EHS impacts has been developed. This uniform Engineering Concept has been applied for the analysis of the current situation as well as for two options with respect to the site-layout of a horizontal extension: (I) Horizontal Extension at the Resettlement Area, and (II) Horizontal Extension at the VROMI yard.

3.2 Environmental, Health and Safety Engineering Concept

3.2.1 General

The EHS Engineering Concept has been developed based on the findings and assessment presented in the Field Survey Report [Ref. 1], the Geotechnical and Geographical Survey Report [Ref. 2] and the Landfill Gas Note [Ref. 3]. Various engineering solutions have been considered and screened to ensure that an acceptable level of (potential) EHS impacts of the MSWDS is achieved through cost-effective and robust measures.

In developing the engineering solutions for the upgrade of the MSWDS priority has been given to their robustness. Due to its location, special equipment and spare parts for repairs and maintenance are in general not readily available resulting in relatively high costs and substantial downtime in case of repair and maintenance. This is to be avoided by prioritizing robust engineering solutions preventing frequent repair and maintenance and thereby minimize downtime of proposed engineering solutions.

The suggested engineering solutions to be applied for the various elements for the development of the EHS Engineering Concept have been discussed with and further clarified to NRPB, WB and VROMI, to achieve prior alignment for the alternatives to be analysed.

The engineering solutions for the various elements as applied for the development of the EHS Engineering Concept are elaborated hereafter.

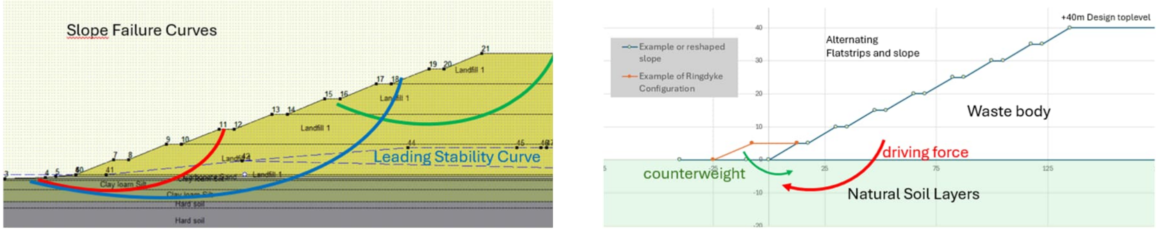
3.2.2 Geotechnical Stability

General

The Geotechnical Survey [Ref. 2] and associated assessment indicates that both the IDS and the SWDS currently have an instability on both macro and micro slope scales. This instability is primarily attributed to the poor geotechnical strength of the geological base, in combination with the steep slopes and the considerable weight of accumulated waste. As such this results in a risk of sliding of the slopes.

In addition, there is a significant risk of macro-scale failure in the landfill in the event of an earthquake, stemming from the unstable basal structures. Completely eliminating the risk of geotechnical failure in the event of an earthquake would necessitate either a very long toe or substantial subsurface strengthening, which are not considered feasible due to spatial constraints and neither considered cost efficient. The potential for macro slope failure under earthquake conditions with associated seismic loading is therefore considered unavoidable. However, the engineering solution with respect to geotechnical stability shall ensure that no risk exists on geotechnical failure under normal conditions. This will also reduce but not prevent the risk on potential slope failure under earthquake conditions with associated seismic loading.

Figure 3.1 Slope Failure Curves and Forces



Slope Stability

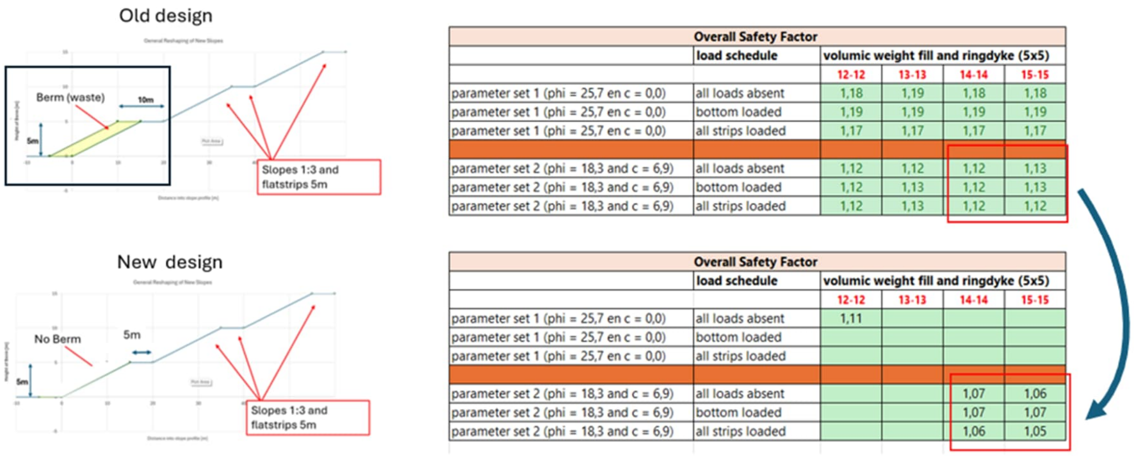
The geotechnical stability has been assessed as per the EuroCode 7 requiring a Safety Factor (SF) > 1.0 to ensure the geotechnical stability of the engineering design. The SF has been calculated for different slopes and configurations, using Geo-3D Software. The input data on the geotechnical design parameters of the underground and phreatic lines within the waste mass have been derived from the geotechnical survey report [Ref. 2]. As per EuroCode the lowest density obtained from the trial pits and included in the field survey report [Ref. 1] has been applied for the geotechnical assessment.

Due to the extremely poor geotechnical conditions of the subsurface, calculations showed that a minimum slope of 1:2 was to be achieved. However, this would require that a ring-dike with a width of 25m wide and 5m high would be required around the full boundaries of SWDS and IDS to prevent sliding. This would have a substantial impact on the GSP, which according to the set boundary conditions for the design [Ref. 4] is not acceptable. Reducing the slope to 1:3 in a plateau structure (slopes 1:3 with a height of 5m in combination with 5m interim flat crest) would reduce the dimensions of the ring-dike to 5m width and 5m height.

This height of the ring-dike to be applied around the full boundaries of the SWDS and IDS is not considered acceptable due to the large volumes of (soil) material required and the impact of the slopes which will extend an additional 15m into the GSP.

Therefore, calculations have been performed for a configuration of the top cover layer in which a slope reinforcement by means of a geocell (300mm HDPE Hexagon or Wave Shape) has been applied. Due to the application of this geocell as slope reinforcement, the ring-dike which is required in any case for accessibility during operation, construction of top cover layer and monitoring and maintenance after closure does not need to be elevated above ground level. This has therefore been applied for the engineering concept for the full boundaries of both the SWDS and IDS and potential horizontal extensions.

Figure 3.2 Slope Safety Factors for situation without and with geotechnical reinforcement (to reduce ring-dike dimensions)



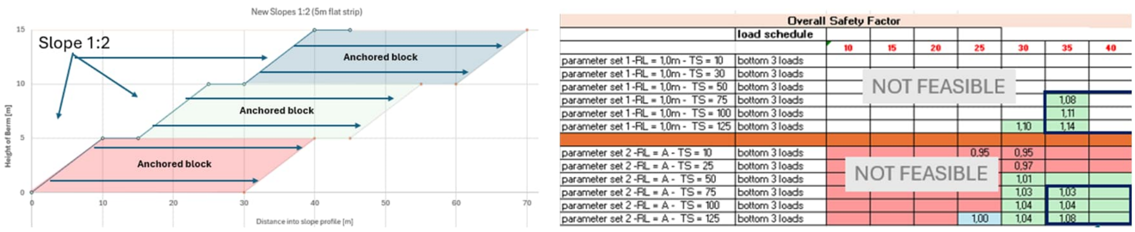
Overall Safety Factor					
	load schedule	volumic weight fill and ringdyke (5x5)			
		12-12	13-13	14-14	15-15
parameter set 1 (phi = 25,7 en c = 0,0)	all loads absent	1,18	1,19	1,18	1,18
parameter set 1 (phi = 25,7 en c = 0,0)	bottom loaded	1,19	1,19	1,19	1,19
parameter set 1 (phi = 25,7 en c = 0,0)	all strips loaded	1,17	1,17	1,17	1,17
parameter set 2 (phi = 18,3 and c = 6,9)	all loads absent	1,12	1,12	1,12	1,13
parameter set 2 (phi = 18,3 and c = 6,9)	bottom loaded	1,12	1,13	1,12	1,13
parameter set 2 (phi = 18,3 and c = 6,9)	all strips loaded	1,12	1,13	1,12	1,12

Overall Safety Factor					
	load schedule	volumic weight fill and ringdyke (5x5)			
		12-12	13-13	14-14	15-15
parameter set 1 (phi = 25,7 en c = 0,0)	all loads absent	1,11			
parameter set 1 (phi = 25,7 en c = 0,0)	bottom loaded				
parameter set 1 (phi = 25,7 en c = 0,0)	all strips loaded				
parameter set 2 (phi = 18,3 and c = 6,9)	all loads absent			1,07	1,06
parameter set 2 (phi = 18,3 and c = 6,9)	bottom loaded			1,07	1,07
parameter set 2 (phi = 18,3 and c = 6,9)	all strips loaded			1,06	1,05

Improved Slope Stability for Landfill Extension

Based on a suggestion from NRPB, an additional geotechnical stability assessment has been made on the feasibility to apply a slope of 1:2 (considered to be the max slope feasible for the construction of the top cover layer for closure of the landfill) at the extension of the landfill in order to create additional landfill capacity by applying a horizontal reinforcement using a geogrid as interim reinforcement layer(s) during the operation of the landfill. Calculations showed that to ensure geotechnical stability, horizontal high-tensile geogrid / HDPE geomembrane reinforcement must be applied over a width of 35m with 1m height intervals. This is not deemed feasible as part of the ongoing landfill disposal operations. In addition, it is to be noted that every horizontal reinforcement needs to be anchored by means of soil cover, thereby reducing the capacity for waste disposal and negatively impact the additional waste disposal capacity achieved through the steeper slopes.

Figure 3.3 Slope Safety Factors for situation with horizontal geotechnical reinforcement to increased slope ratio



Overall Safety Factor								
	load schedule							
		10	15	20	25	30	35	40
parameter set 1 -RL = 1,0m - TS = 10	bottom 3 loads							
parameter set 1 -RL = 1,0m - TS = 30	bottom 3 loads							
parameter set 1 -RL = 1,0m - TS = 50	bottom 3 loads			NOT FEASIBLE				
parameter set 1 -RL = 1,0m - TS = 75	bottom 3 loads						1,08	
parameter set 1 -RL = 1,0m - TS = 100	bottom 3 loads						1,11	
parameter set 1 -RL = 1,0m - TS = 125	bottom 3 loads					1,10	1,14	
parameter set 2 -RL = A - TS = 10	bottom 3 loads				0,95	0,95		
parameter set 2 -RL = A - TS = 25	bottom 3 loads					0,97		
parameter set 2 -RL = A - TS = 50	bottom 3 loads			NOT FEASIBLE		1,01		
parameter set 2 -RL = A - TS = 75	bottom 3 loads					1,03	1,03	
parameter set 2 -RL = A - TS = 100	bottom 3 loads					1,04	1,04	
parameter set 2 -RL = A - TS = 125	bottom 3 loads				1,00	1,04	1,08	

Crest Reinforcement IDS

Even though not recommended due to reasons of visual impact and accessibility, VROMI intends to develop the IDS after closure as an area for waste processing and/or treatment. As a result, heavy transport loads need to be considered at the crest of the IDS after closure, which will increase the risk of uneven settlement and associated damage to the permeability barrier included in the closure cover layer. Therefore, a high-tensile biaxial geogrid reinforcement is included in the engineering concept to reduce the risk of uneven settlement because of transport loads, thereby preventing damage to the permeability barriers.

Figure 3.4 Visualisation of Geotechnical Slope Reinforcement (SWDS&IDS) and Crest Reinforcement (IDS)

Summary of Assessment Justifying the Design Solution

An overview of Safety Factor resulting from the Stability Assessment based on EuroCode - 7 is presented in the table hereafter. It is to be noted that based on EuroCode - 7, a Safety Factor > 1 should be achieved to ensure the Geotechnical Stability of the Design Solution. However, given some uncertainties in soil conditions, a Safety Factor of 1.1 has been applied in the assessment to verify Geotechnical Stability.

Table 3.1 Safety Factor for Slope Ratio's based on EuroCode- 7 Methodology and evaluated for Safety Factor > 1.1

Slope Ratio	Safety Factor Range	Conclusion and Comment
1 : 2	0.92 (0.99 - 0.95)	Not stable under feasible design conditions (requiring additional horizontal geogrid (high tensile strength >125kN/m) at 1m intervals over a horizontal distance > 35m)
1 : 2.5	0.99 (0.95 - 1.04)	Not stable under feasible design conditions (only a ring dike with a height of 5m and 25m width results in a Safety Factor > 1 but below 1.1 used for evaluation)
1 : 3	1.15 (1.12 - 1.18)	Stable for 5m high 1:3 slopes with 5m wide flat intervals and geotechnical slope reinforcement, with a 5m wide Ring Dike at Ground Level

It is to be noted that the Design Solution for ensuring geotechnical stability is an integrated set of mitigating measures consisting of the slope ratio to be applied, the width of the flat intervals and the ring dike, as illustrated in the table above. As such, no clear relative contributions for ensuring geotechnical stability can be assigned to an individual mitigating measure. The set of mitigating measures has been determined based on achieving the highest overall slope ratio with a minimum necessary extension into the GSP.

Furthermore, it is to be noted that due to the fact that the subsoil beneath the Pondfill is similar to the subsoil at the GSP, the engineering design to ensure geotechnical stability is to be uniformly applied on all slopes of both the IDS and the SWDS and both those slopes bordering the GSP as well as the slopes facing inward.

3.2.3 Leachate Management

General

The leachate from and shallow groundwater at the MSWDS are contaminated with heavy metals, and to a lesser extent, with aromatic hydrocarbons, polycyclic aromatic hydrocarbons, and total petroleum hydrocarbons. Elevated concentrations of several per- and polyfluoroalkyl substances, Total Coliform, and E. Coli are also present in the leachate and groundwater. Whereas no horizontal break-outs of leachate or signs thereof have been observed during the field survey, the highly permeable beach sands at the base of the MSWDS facilitate a strong interchange between the leachate/groundwater and the GSP, while thick clay layers at greater depths limit the further vertical migration of the contaminated leachate.

Due to the permeable beach sands and the thick clay layer at greater depths, an effective leachate collection system at the toe of the landfill is not considered to be feasible. Any intervention at the toe of the landfill for leachate collection will result in substantial volumes of surface water from the GSP being collected instead of actual leachate and/or contaminated shallow groundwater.

The engineering solution with respect to leachate management is based on the human health risks associated of contamination of the GSP with leachate and local conditions, in combination with the regulatory standards at SXM for discharge of contaminated water.

Due to local conditions like the high salt content of the GSP and the lack of direct exposure, the human health risks associated with contamination of the GSP with leachate are very limited. Furthermore, the legal and regulatory framework for environmental protection at SXM [Ref. 6] does not set any norms or limitations to the (uncontrolled) discharge of leachate from the MSWDS into the GSP. However, a Working Group for Environmental Norms at the Netherlands Antilles, in their final report [Ref. 7] does suggest discharge limit values for household wastewater to surface water. No norms are provided in this final report for wastewater discharge for companies but does prescribe the ALARA-principle (As Low As Reasonably Achievable) and Stand-Still principle for wastewater discharges of companies. Despite the fact that this report was prepared for the Netherlands Antilles as predecessor of SXM, this report is still expected to serve as a guideline for regulatory norms to be established and will thus be applied as guidance for the engineering solutions to be applied with respect to leachate management.

Engineering solutions have thus been developed in order to comply with the ALARA and Stand-Still principles with respect to the (uncontrolled) discharge of leachate from the MSWDS into the GSP, based on a combination of: (I) reduction of leachate generation from existing SWDS and IDS upon closure, in combination with (II) collection and treatment of leachate from the landfill extension.

Reduction of Leachate Generation

The most important element for long-term management of the leachate, is the reduction of leachate generation. Therefore, it is common practice to include a permeability barrier in the cover layer upon closure of both sanitary landfills as well as dumpsites similar to the MSWDS.

The permeability barrier can be constructed by means of a mineral layer, synthetic layer or a combination thereof. Based on the local weather conditions, with short and heavy rainfall events mainly resulting in stormwater run-off thereby reducing the infiltration, a combination of a mineral and synthetic permeability barrier is not considered to be cost-effective. As such, the engineering solution for the reduction of leachate generation is thus to be achieved by either a mineral or a synthetic permeability barrier to be incorporated in the cover layer upon closure of the MSWDS.

Figure 3.5 Permeability Barrier for Landfill Closure (Synthetic vs Mineral Barriers)

Even though a mineral layer would result in a semi-permeable barrier, the permeability would be substantially reduced. There is no functional loss in the performance of the mineral semi-permeable barrier, thereby ensuring a durable reduction of leachate generation, whereas a synthetic permeability barrier would be impermeable upon installation but would gradually loose its functionality because of degradation. The life-time of a synthetic permeability barrier depends on the specific local conditions, but it is commonly considered that substantial functionality loss occurs after 30-100 years.

Different types of materials can be applied for the mineral layers as permeability barrier at landfills. Common materials include clay, sand-bentonite as well as sand-bentonite-polymer, which can reduce the permeability below 20mm/yr. However, for reasons of material availability and costs, also alternatives such as a bitumen-spray can be applied even though no evidence has been found that the application of bitumen-spray at a landfill would be able to reduce the permeability below 20mm/yr.

NRPB, WB and VROMI have expressed a preference for a synthetic permeability barrier over a mineral permeability barrier as initially suggested to reduce leachate generation, despite the functional loss of a synthetic permeability barrier over time. This preference is based on the possible risk of uneven settlements and cracks, which would potentially damage the mineral permeability barrier. Whereas the risks for uneven settlements and cracks cannot be included, it is to be noted that a mineral permeability barrier (especially sand-bentonite-polymer) has also a flexibility preventing damage in case of (minor) uneven settlements and cracks and that a synthetic is also vulnerable to (major) uneven settlements and cracks. The preference for a synthetic permeability is therefore considered arbitrary.

An engineering solution for the synthetic permeability barrier, consisting of a LLDPE liner (2 mm) as synthetic permeability barrier. The selection of a LLDPE liner is based on its higher flexibility and lower puncture risk in comparison to a HDPE liner.

In order to install the LLDPE liner the waste mass is to be covered by a support sand layer (0.3m). A geotextile is to be installed between the support layer and the LLDPE liner to reduce the risk of damage of the liner. In order to collect and discharge infiltrated storm water accumulated by the permeability barrier, a drainage system is to be installed above the LLDPE liner (see section 3.2.6).

The strokes of LLDPE liner need to be welded together using special equipment by qualified personnel and tested for strength after installation to ensure the functionality of the synthetic permeability barrier.

Anchoring of the LLDPE liner by means of a soil cover at the toe of the MSWDS is anticipated underneath the service road and integrated within the ring-dike structure surrounding the full boundary of the MSWDS.

Figure 3.6 Special Welding Equipment for Synthetic Permeability Barrier

Leachate Collection

Stormwater infiltrating through the waste at the extension of the SWDS will be collected to avoid further migration of the generated leachate to the groundwater and/or GSP. The engineering solution consists of the creation of a permeability barrier in combination with a drainage layer for collection and transport of the leachate.

Similar considerations have been made with respect to the engineering solution for the permeability barrier of the leachate collection system as for the permeability barrier to reduce leachate generation. However, as the extension of the SWDS is to be newly developed, providing easier working conditions for construction of the permeability barrier in combination with the fact that this area will maintain uncovered for a longer period, a combination of a mineral and synthetic permeability barrier is applied as engineering solution.

In order to install the permeability barrier, a sand/gravel support layer (0.3m) is required as base layer. The mineral permeability barrier is constructed on top of this base layer.

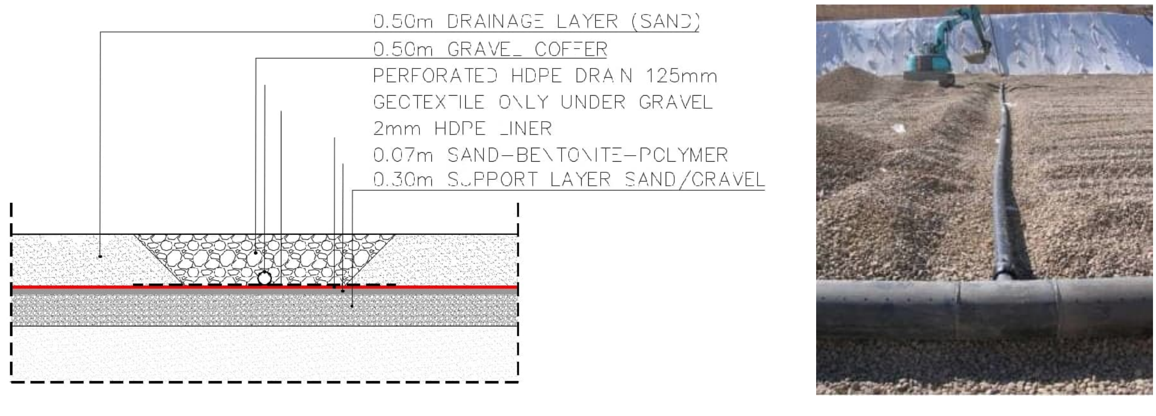
Given the fact that none of the materials commonly used as permeability barrier for leachate collection at landfills can be locally sourced, sand-bentonite-polymer is applied as this will substantially reduce the volume of material to be transported due to the required thickness (0.5m clay and sand-bentonite vs. 0.07m sand-bentonite-polymer) to achieve the maximum permeability of 20mm/yr. The material for the sand-bentonite-polymer, is to be produced at a batch plant at site for mixing sand with a bentonite-polymer mixture. Because of its salt-content sea-sand cannot be used or shall be washed to reduce its salt content. The mixture is then spread on the support layer and compacted.

Figure 3.7 Visualization of Mineral Permeability Barrier based on Sand-Bentonite-Polymer

The synthetic permeability barrier is constructed on top of the mineral permeability barrier. Contrary to the LLDPE liner applied for leachate generation prevention, a HDPE liner (2mm) has been selected for the engineering solution. Given the low risks for uneven settlements and punctuation, a HDPE liner is considered to be more suitable due to its higher resistance against deterioration by leachate and is thus expected to remain its functionality for a longer period as compared to LLDPE.

A drainage layer is required to collect and transport the accumulated leachate above the synthetic permeability barrier. Since the disposed waste on top of the drainage layer will result in a substantial load, drainage mats as applied in the engineering solution to reduce leachate generation cannot be applied under these circumstances. As such a traditional drainage system has been selected as engineering solution, consisting of a sand drainage layer (0.5m), with perforated HDPE drains (125mm) embedded in a gravel coffer to be installed with an interval of 15m between the HDPE drains. In order to protect the HDPE liner against damage caused by the perforated drains and gravel, a geotextile is foreseen between the gravel material and the HDPE liner.

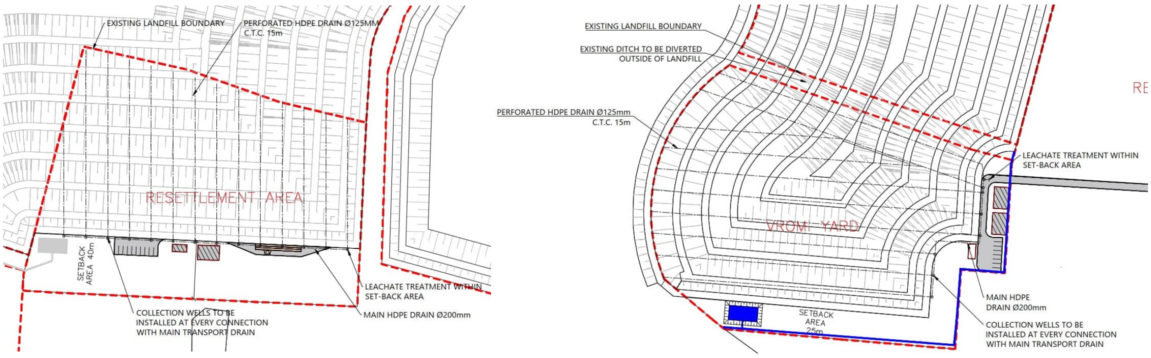
Figure 3.8 Visualization Overall Leachate Collection Engineering Concept and Example of Leachate Drainage



The perforated HDPE leachate drains incorporated in the drainage layer are connected to a main gravity HDPE drain (200mm) to transport collected leachate for leachate treatment. In order to allow for inspection and maintenance of the drainage system, collection wells will be installed at every connection of the perforated drains with the leachate transport drain.

The top of the layer is foreseen to be equal to the existing ground level. As such, prior excavation of the extension area up to a depth of 0.87m is required.

Figure 3.9 Leachate Drainage for Resettlement Area and VROMI Yard alternatives



Leachate Treatment

As previously stated, SXM does not have a regulatory standard for the quality of the leachate to be discharged into the GSP. As such, the engineering solution is based on selecting a leachate treatment system compliant with an ALARA-principle, prioritising the robustness of the system.

The capacity of the leachate treatment is based on the precipitation levels observed during the wettest month of the year. The wettest month shows an average precipitation of 180 mm, resulting in a total precipitation volume of the extension area of the SWDS of approximately 145 m3 / day (not considering evaporation and run-off). However, circumstances can exist where collected leachate will exceed the design capacity of the treatment system and even though a leachate buffer storage is included, resulting in the discharge of contaminated leachate into the GSP by-passing the treatment system.

The chemical-analytical assessment of leachate quality relies on groundwater monitoring wells located at the toe of the landfill. Consequently, the measured concentrations reflect a mixture of leachate, groundwater, and water from the adjacent Great Salt Pond. At the landfill extension pure leachate will be collected, which is likely to contain higher level of contaminants compared to the concentrations previously determined. This has been considered when developing the engineering concept for leachate treatment.

Leachate treatment options have been identified, mainly focusing on the reduction of the biological contamination of the leachate and heavy metal content being the main contaminants. Two main types of leachate treatment systems have been considered for the engineering solution: (I) Helophyte Treatment System, and (II) Nitrifying/Denitrifying Sand Filter.

Helophyte treatment systems are based on the natural ability of vegetation to remove contaminants from the influent and can achieve the following performance standards:

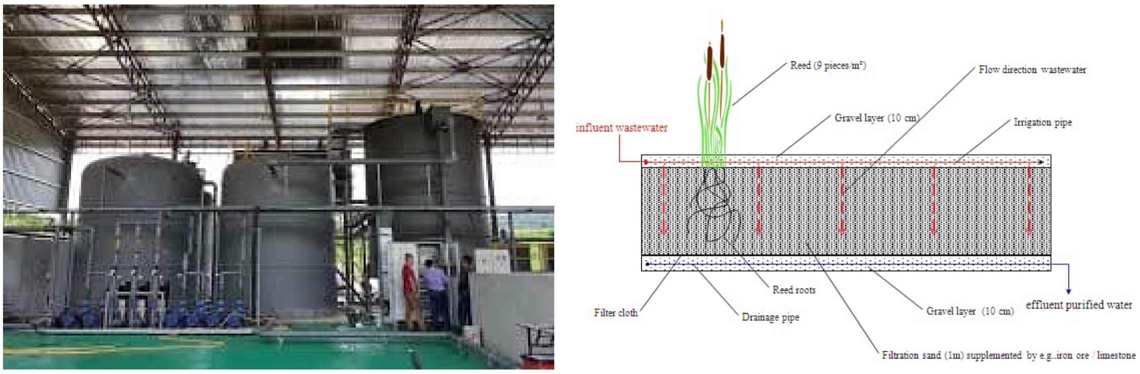
- > 90% removal of Suspended Solids
- 80 – 100% NH_4 removal
- 40 – 60% N-total removal
- 40 - 60% P-removal
- Log 2 – log 5 – E.coli removal
- 20 – 100% Heavy metal removal

Helophyte treatment systems typically consist of consist of an influent (leachate) buffer with an overflow on to a sand and gravel bed, with a natural vegetation (normally reed). The influent infiltrates through the sand/gravel bed where the vegetation roots as well as natural soil processes remove the contaminants form the influent. After passing the sand/gravel bed, the effluent is collected in a gravel layer and can be discharged. Given the simplicity of the system, the CAPEX for a helophyte treatment system is limited. Based on the defined design leachate treatment capacity of 145 m3/day, a sand/gravel bed (excluding buffer) with a surface area of approximately 1,500 m2 is required.

Due to the fact a helophyte treatment system is a natural process, it is considered to be extremely robust (requiring no special equipment or chemicals and limited maintenance). As such, the OPEX for a helophyte treatment system is also limited. This robustness in combination with the fact that the performance efficiency of helophyte treatment systems improves at higher (ambient) temperatures, it is considered to be highly suitable to be applied in the specific conditions at SXM.

Leachate treatment by means of a nitrifying and denitrifying sand filter, is a proven technology with improved performance standards in comparison to a helophyte filter. However, this is a highly advanced technology requiring special equipment, chemicals and knowledge to be operated and maintained. This results in substantially higher CAPEX and OPEX for this technology in comparison to a helophyte system. In addition, the required special equipment, chemicals and knowledge to operate and maintain the system can result in substantial downtime in the context of the situation in SXM with long-lead times for repairs.

Figure 3.10 Leachate Treatment Systems (examples of Nitrification/Denitrification System vs Helophyte Filer)



Based on the considerations made the selected engineering solution is based on leachate treatment by means of a helophyte system. This selection is deemed acceptable given the robustness of the system and associated CAPEX and OPEX in comparison to the nitrifying and denitrifying sand filter, as well as the fact that the advanced level of the latter might result in additional downtime and additional discharges of contaminated leachate into the GSP thereby reducing its overall performance standards.

In addition, it is to be noted that the GSP appears to be not extremely vulnerable to N discharges. Existing studies (Gallagher and Bassett – Baseline Environmental Site Assessment Blue Box Zone – January 13, 2020) show that, in the current situation Nitrogen concentrations are below limit values and as such N is not a major factor in the environmental status of the GSP. In the new situation, the N load from the leachate from the existing landfill will be reduced by prevention/reduction of leachate generation through the permeability barrier as part of the cover layer upon closure, in combination with the reduction of 40-60% reduction achieved through the treatment collected at the extension of the SWDS by the helophyte system. As such, the overall situation is expected to improve in comparison to current (uncontrolled) discharges from the MSWDS.

The helophyte system for leachate treatment, including the leachate buffer is foreseen to be located within the zone established through the defined set-back distance (see Section 3.2.5).

3.2.4 Landfill Gas Management

General

The theoretical methane generation as part of the landfill gas (LFG) produced through the decomposition of organic carbon in disposed waste, has been assessed in accordance with the Guidelines for National Greenhouse Gas Inventories of the Intergovernmental Panel on Climate Change (IPCC). Local conditions for SXM have been applied as input for the IPPC model calculations.

Based on the performed assessment [Ref. 3], the current (2024) theoretical annual methane production of the existing MSWDS (considered as a single entity without a division into IDS and SWDS) is around 1,453 tonnes per year is expected to increase to a peak generation of 1,593 tonnes per year in 2027. Continued landfill disposal is expected to add additional 389 tonnes as theoretical peak generation of methane (to occur one year after closure).

The recovery efficiencies of generated methane are estimated to be 30% during disposal through early gas control, and 70-90% after the installation of the synthetic (LLDPE) permeability barrier upon closure; in case of a mineral permeability barrier a recovery efficiency of 70% is assumed [Ref.3].

Given the specific conditions at the MSWDS, methane generation is not only affected by the climatic conditions at SXM and other input data for the IPCC Model, but also by the volume of waste located in the saturated liquid layer as well as the frequent fires that have occurred. As such it is very difficult to establish a reliable forecasted methane generation and potential recovery curve for a justified position on the feasibility of a gas-engine for electricity production from recovered methane despite the attractive current electricity deficit and price level. A reliable technical and economic assessment of the feasibility on a gas-engine for electricity production from the recovered methane, can under the subject conditions only be made after obtaining actual data on recovered gas.

IDS

Given the size of the IDS, a relatively low volume of methane generation is expected. However, since the synthetic (LLDPE) permeability barrier applied as Base-Case (see Section 3.2.3) is also impermeable for LFG, an accumulation of LFG can occur beneath the permeability barrier. In order to avoid damage to this synthetic permeability barrier due to the accumulated LFG, as a minimum a passive extraction of LFG is required. Such a passive extraction is also deemed suitable in case the IDS is raised to a height of 25m, despite the increased volume of waste material deposited there.

The selected engineering solution consists of a horizontal gas drainage incorporated in the support layer underneath the synthetic permeability barrier. A network of perforated HDPE gas drains (200mm) will be trenched into the support layer for gas relieve to prevent accumulation. The network of perforated HDPE drains will be connected to a single gas main (HDPE 200mm) that will pass through the entire built-up of the cover layer on the crest of the IDS.

The relieved gas collected through the passive horizontal drainage can in principle be vented into the atmosphere since SXM has no regulatory standards nor target values for methane emissions and universally established international target values for methane emissions specifically from landfill sites neither exist. However, an engineering solution is developed for further treatment of the LFG to reduce the emission of GHG into the atmosphere as part of the global effort. The design capacity for the treatment of the relieved gas is based on expert judgement of the estimated LFG generation at the IDS which is expected not to exceed a volume of 100m3/d. Whereas commonly, a gas flare is applied for the LFG treatment to combat emissions of GHG, this is less suitable for the subject situation given the fact that a passive extraction will be applied resulting in varying volumes of gas relieved and methane content. Therefore, under these specific conditions a cost-efficient engineering solution has been selected to mitigate the emission of methane by passing the relieved LFG through a biofilter filled with compost material. Compost materials in general provide a high oxidation capacity for the methane oxidation thereby reducing the GHG emission. The biofilter should be designed for a volume of 100m3/d of methane and an oxidation rate of at least 60%.

Figure 3.11 Visualization Biofilter

SWDS

The SWDS and its foreseen extension is substantially larger in size compared to the IDS, As such, the potential LFG generation is also substantially larger, resulting in higher GHG emissions but also offering an improved potential for the technical and economic feasibility of electricity generation from recovered methane by a gas-engine.

Installation of a passive gas extraction, as applied as engineering solution for the IDS is not suitable to allow for potential (future) use of the LFG for electricity generation. In addition, passive systems with treatment by means of a biofilter result in higher GHG emissions compared to an active system, in combination with either a flare or a gas-engine for electricity generation. As such an active LFG extraction system upon closure of the SWDS has been selected as engineering solution. Active extraction systems consist of a network of vertical gas extraction wells.

Traditionally large gas extraction wells with a wide gas extraction radius are applied as active gas extraction system, which require re-excavation of the waste for their installation. In addition, these wells can be vulnerable to damage caused by the thermal and chemical conditions and settlements occurring within the waste mass. Recent developments have resulted in a proven technology for an improved LFG extraction by means of a dense grid (4m x 4m) of small diameter flexible extraction wells at the crest and flat areas of the landfill, resulting in a higher LFG recovery, which has therefore been selected as engineering solutions.

Working on the levelled waste, each vertical well is forced instead of excavated into the landfill site. Following installation of the vertical flexible wells, the horizontal collection wells are fitted. These are connected together and also collect the gas from the waste environment before transporting it via grooved collector tubes to the manifold(s). The drains are then covered with the support layer underneath the permeability layer.

Figure 3.12 Visualization of installation of dense grid flexible landfill gas extraction system

Since no reliable estimate can be made on the technical and feasibility of a gas engine due to the lack of data on actual LFG production and methane recovery, at this stage an engineering solution has been selected whereby the extracted gas is treated by means of a gas flare to eliminate the GHG emissions. Design capacity of the gas flare for the SWDS (incl. foreseen extension) has been set at 400m3/d of methane based on expert judgement. The installation of the gas flare is foreseen within the zone established as set-back distance (See Section 3.2.5).

SWDS Extension

In order to reduce the emission of GHG during the operational period of the extension of the SWDS, it is foreseen that horizontal gas drainage will be applied at this extension area. The horizontal gas drainage will be incorporate in the intermediate cover layers, with extracted gas being transported to the gas-flare anticipated for gas treatment from the SWDS upon closure.

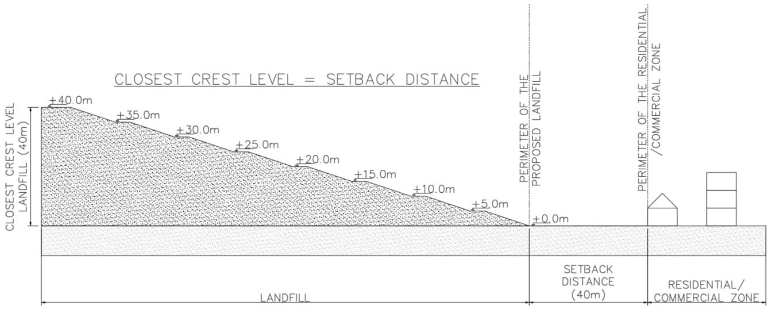
3.2.5 Set-Back Distance

The setback distance is the required distance between residential developments and the perimeter of the proposed landfill cell to minimize potential health and environmental risks, particularly the migration of underground gaseous emissions. The nearest residential area to the landfill is located along Pendant Cactus Road, approximately 200 meters to the northeast of the Integrated Disposal Site (IDS). To the south of the landfill, there is an area designated as mixed residential and commercial area centrally situated on Pond Island which is currently mainly used for low-profile commercial and storage rather than residential purposes. No other residential zones are present to the south, as this area is predominantly utilized for commercial and storage purposes.

The current MSWDS configuration has the advantage that most of its mass is situated above the saturated liquid level, which minimizes landfill gas generation and the underground migration of gaseous emissions. In addition, whereas it is not possible to completely eliminate risks associated with odorous nuisances (including odours, vectors, and smoke) or contaminant migration, the engineering solutions and operational performance are expected to further reduce these risks.

Underground landfill gas migration is therefore considered to be negligible under the local circumstances (low gas generation and existing saturated liquid layer). This is also substantiated by the fact that existing studies (Gallagher and Bassett – Baseline Environmental Site Assessment Blue Box Zone – January 13, 2020) did not indicate the presence of landfill gas outside of the MSWDS. As such underground landfill gas migration has not been applied as criteria for the set-back distance. Nuisance has neither been applied as criteria for determining the set-back distance, due to the already existing nuisance level from the existing landfill in combination with the anticipated improved operations and the fact that no permanent occupation at the mixed Residential and Commercial Zone south of the SWDS exists. However, it is essential that the set-back distance does ensure a safe distance to the mixed Residential and Commercial Zone for geotechnical failures during earthquake events. Therefore, a set-back distance has been applied being equal to the closest crest level of the SWDS to ensure a safe distance for geotechnical failures during earthquake events.

Figure 3.13 Principle of Set-Back Distance



3.2.6 Stormwater Management

General

Pond Island is currently flooded during heavy rainfall events, despite the stormwater drainage channel located south of the SWDS. Therefore, engineering solutions are proposed to ensure that stormwater from the MSWDS is reduced or separately collected and discharged to avoid that this results in an additional volume to be discharged through the existing stormwater drainage channel for Pond Island.

Stormwater Run-Off

The selected engineering solution consists of a separate collection of stormwater runoff from the MSWDS through the construction of open gutters consisting of (pre-fab) concrete U profiles along the toe of the MSWDS boundary at the land side. Stormwater collected in this open gutter will be transported under gravity to a stormwater storage basin with a discharge overflow into the GSP. The stormwater from the storage basin can be used during dry periods as reduce dust emissions from the landfill (excessive watering should however be prevented to prevent additional leachate generation). Stormwater run-off at the MSWDS boundary with the GSP will not be separately collected and be allowed to flow across the ring-dike into the GSP.

Figure 3.14 Visualisation Concrete U-Profile Gutter

Infiltrated Stormwater

After closure, the stormwater infiltrated through the soil of the cover layer will accumulate above the permeability barrier layer. This infiltrated stormwater will be collected by means of so-called “drainage mats” (drainage core connected to nonwoven filters) installed on top of the permeability barrier layer.

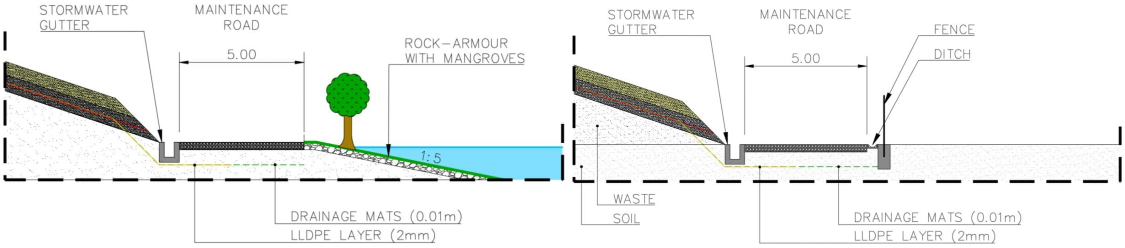
This engineering solution has been selected instead of a sand drainage layer to reduce the volume of natural resources and its flexibility for settlements potentially to occur during the early stages after landfill closure. The infiltrated stormwater collected by the drainage mats will be transported to the toe of the slope. At the landside, the drainage mats will be extended underneath the open gutter for stormwater run-off and the service area to discharge into an open ditch. At the area of the MSWDS bordering the GSP, the drainage mats will be extended to the slope of the ring-dike.

Erosion Protection

Erosion damage at the slopes is prevented due to the foreseen vegetation (grass) as part of the cover layer, in combination with the relatively shallow (1:3) and short slopes (plateau shaped profile with intermediate (flat) crest with a width of 5m at 5m height intervals). As such no specific erosion protection for the slopes is included.

Since no gutters are foreseen for collection and discharge of the stormwater run-off for the areas of the MSWDS bordering the GSP, there is a potential risk of erosion. However, the gravel pavement applied as top layer for the ring-dike (see section 3.2.7) will prevent that the erosion damages on the top of the ring-dike. The slopes of the ring-dikes will also require erosion protection to avoid excessive damage. Whereas normally this slope protection would be achieved through a rock armour protection layer, in this specific situation a combination with a natural alternative has been applied as engineering solution consisting of mangrove vegetation. It is foreseen that the existing rock-armour will be re-used and (cultivated) juvenile mangroves suitable for the salt conditions of the GSP (Red Mangrove - Avicennia Marina) will be planted along the slopes of the ring-dike. Rock-armour should be placed in such a manner that planting holes (e.g. 0.5m diameter) will remain free of rock-armour. No further adjustment in the rock-armour is required to facilitate the application of mangroves as combined erosion protection. The benefit of applying the mangrove vegetation as additional erosion protection at the slopes of the ring-dike is that it will also compensate for the loss of existing mangrove vegetation due to the construction of the ring-dike.

Figure 3.15 Visualization Stormwater Management and Ring Dike and Maintenance Road



VROMI Yard Alternative

Furthermore, it is to be noted that the routing of the existing stormwater drainage channel creates a conflict in case of the VROMI Yard alternative. Therefore, a re-routing of the existing stormwater drainage channel is accounted for in the VROMI Yard alternative, by means of creating an open gutter consisting of (pre-fab) concrete U profiles located just outside of the boundary of this VROMI Yard.

3.2.7 Accessibility, Fire Safety, Fencing

In order to ensure sufficient workspace for the construction of the construction works related to the upgrade and extension of the MSWDS, as well as for maintenance, inspection and monitoring purposes during the operational phase and after closure of the MSWDS, their accessibility along the entire boundary is required.

Accessibility is achieved through the 5m wide ring-dike to be constructed along the boundary with the GSP as part of the engineering solution for the geological stability, in combination with a 5m wide service area is foreseen at the landside of the MSWDS. Both the ring-dike and the service area will have a gravel pavement (0.3m top layer).

Whereas Fire Safety is primarily to be achieved by proper landfill operations with sufficient compaction of disposed waste and intermediate cover layers, it is considered important that the MSWDS is fully accessible from all sites for firefighting purposes if necessary. The engineering solution of the ring-dike along the boundary with the GSP and the service area along the landside boundary, will also ensure the accessibility for firefighting purposes around the full boundary of the MSWDS.

Furthermore a 1.8m high mesh wired (max mesh 0.1m), including supporting poles and a manually operated sliding access gate at the entrance road, is foreseen at the landside of the SWDS and its extension to prevent uncontrolled and/or unauthorised access during its operational phase. The installation of a fence at the IDS to prevent trespassers is no longer needed as operations will have ceased and is therefore not included.

3.2.8 Operational Amenities and Buildings

In order to further improve the operational performance, control and management of the landfill, a number of operational amenities and buildings are foreseen in the developed EHS Engineering Concept. These amenities and buildings are elaborated hereafter.

Weighing Bridge, including Control Unit

The weighing bridge and associated control unit, as per the recent NRPB project currently implemented, is foreseen to be applied. However, due to the relocation of the access when implementing the Resettlement Alternative for site Layout, the relocation of these facilities to the zone defined as set-back distance has been this incorporated in the analysis of this site Layout alternative.

Office and Sanitary Building

The existing facilities at site are foreseen to be removed and replaced by a new office and sanitary building in order to improve the working conditions of landfill operators and managers. A new office and sanitary building, incl. electricity supply, lighting, airco, internet-cable connection and wastewater collection and discharge is foreseen to be relocated within the zone defined by the set-back distance. The foreseen dimensions are 10x15m, including 2 office rooms for 2 persons each, sanitary facilities for 4 persons, a canteen with double water tap (hot-cold) for 10 persons and a Change & Shower area for 6 persons. The new office and sanitary building will be located within the zone established as set-back area.

Storage and Maintenance Building

The construction of a new storage and maintenance building is foreseen with dimensions of 10x15m is foreseen. This is foreseen to be a farm shed type with open and enclosed bay on concrete floor, incl. electricity supply, lighting, and wastewater drain collection with oil-sand separator. The storage and maintenance building will be located within the zone established as set-back area.

Figure 3.16 Visualization Storage and Maintenance Building

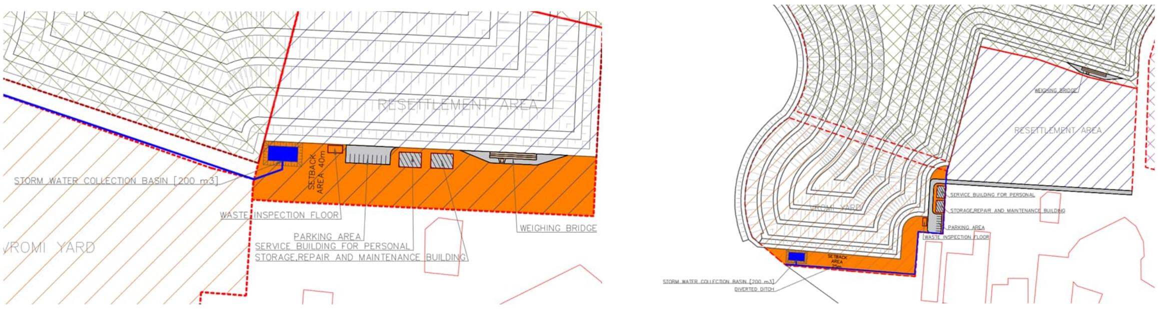
Waste Inspection Floor:

In order to allow for inspection of incoming waste, the construction of a (covered) inspection floor is foreseen with a dimension of 10x5m. This is foreseen to be an open farm shed type construction installed on a concrete floor, incl. drain for water/leachate collection with oil-sand separator. The waste inspection floor will be located within the zone established as set-back area.

Location of Buildings and Amenities

The location of the various Buildings and Amenities as well as the leachate treatment is visualised hereafter. The access road will consist of an asphalt pavement, whereas all other internal transport routes and open areas within the set-back area will consist of 0.3m gravel.

Figure 3.17 Visualization of Indicative Location for Buildings and Amenities for Resettlement Area and VROMI Yard Alternatives



3.2.9 Summary of Cover Layer Upon Closure

A summary of the built-up of the cover layer for landfill closure incorporating the selected engineering solutions as per the base-case with a synthetic permeability barrier is presented hereafter. As different engineering solutions have been applied for the crest and slopes of the MSWDS and for the SWDS and IDS, these are separately summarized.

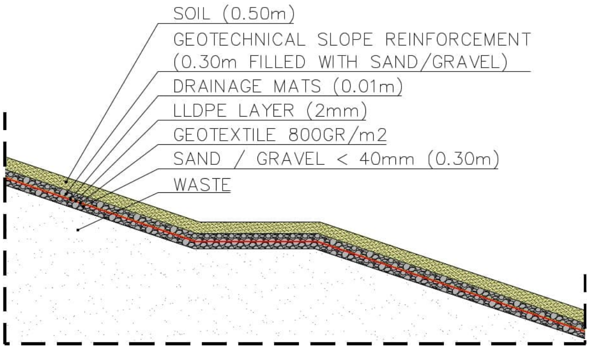
Furthermore, a summary of the built-up of the cover layer for landfill closure is also presented for the sensitivity case based on a mineral permeability layer.

Cover Layer at Slopes

A uniform engineering solution is applied for the cover layer at the slopes upon closure of the SWDS, SWDS Extension and IDS. Based on the base-case where a synthetic permeability barrier is foreseen, the cover layer consists of the following elements (top down):

- Top Soil with grass vegetation (0.5)
- Geotechnical Reinforcement Structure (0.3m) filled with sand/gravel (0-40mm)
- Drainage Mat
- Synthetic Permeability Barrier (2mm LLDPE)
- Protective Geotextile (800g/m2)
- Support Layer (0.3m sand/gravel, 0-40mm), with high-dense vertical gas extraction incorporated at flat areas of slopes at SWDS and SWDS Extension)
- Profiled Waste Material

Figure 3.18 Total Overview Engineering Concept for Slope Cover Layer

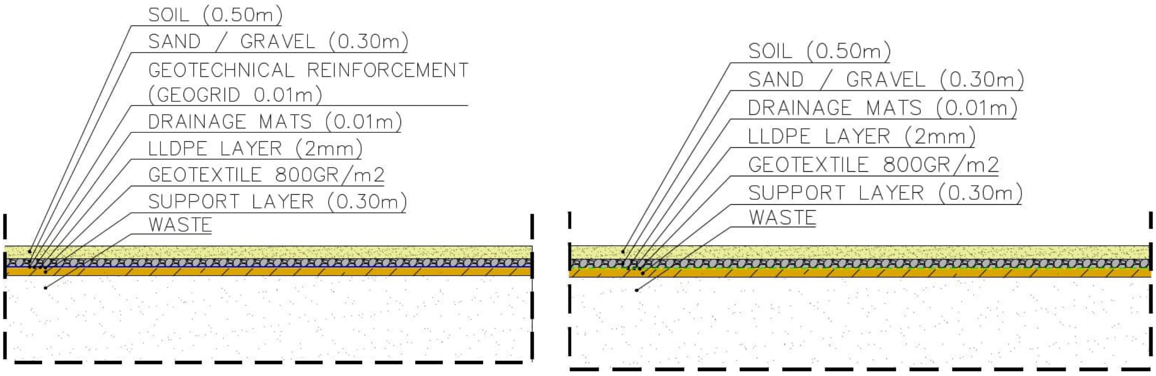


Cover Layer at Crest

The engineering solution of the cover layer to be constructed upon closure for the base-case with a synthetic permeability barrier, solely differs for the IDS and the SWDS and SWDS Extension in the fact that for the IDS an additional geogrid is included for load distribution of (heavy) transport at this crest as part of future development of this area. This results in a cover layer consisting of the following elements (top down):

- Top Soil with grass vegetation (0.5)
- Sand/Gravel (0-40mm)
- *Geogrid (only applied at IDS, not foreseen at SWDS and SWDS Extension)*
- Drainage Mat
- Synthetic Permeability Barrier (2mm LLDPE)
- Protective Geotextile (800g/m2)
- Support Layer (0.3m sand/gravel, 0-40mm), with gas drainage incorporated (horizontal passive extraction system at IDS, vertical active high-dense extraction system at SWDS and SWDS Extension)
- Profiled Waste Material

Figure 3.19 Total Overview Engineering Concept for Crest Base Case Cover Layer - IDS and SWDS



3.3 Site Layout of Current MSWDS and Alternatives for Extension

3.3.1 General

Land availability at the Pondfill, as everywhere at SXM, is extremely scarce. However, the possibility for a vertical extension within the existing boundaries of the MSWDS is limited since a maximum height of 40m is established as boundary condition [Ref. 4]. Apart from the visual impact resulting from increasing the maximum height of 40m set as boundary condition, this will also result in major operational constraints for waste disposal in terms of access to and manoeuvrability at the operational waste front.

The possibility for a horizontal extension of the MSWDS is also limited, given the fact that the hydrological (buffer) capacity of the GSP for stormwater discharges is a major component of the flood management system for Philipsburg. A boundary condition has therefore been established that any horizontal expansion into the GSP is limited to necessary supporting structure only and not for waste disposal [Ref. 4].

Given the established and agreed boundary conditions, a horizontal extension of the MSWDS at the Pondfill; is the sole remaining possibility. Adjacent to the MSWDS the only available parcels for horizontal extension consist of the “Resettlement Area” and the “VROMI Yard” south of the SWDS. Both available parcels have approximately the same size: 3.3 ha for the Resettlement Zone and 3.6 ha for the VROMI Yard. At the IDS, a further horizontal extension at the Pondfill is not feasible due to the presence of the Baseball Stadium.

As part of the overall plan for an improved Integrated Waste Management System, waste processing and recycling initiatives are intended to be started at the Pondfill as well. Therefore, a restriction has been established that either the Resettlement Area or the VROMI Yard can be considered as an alternative for the extension of the SWDS whereas the other parcel should remain available for other (waste related) developments.

The parcel adjacent to the west of the existing IDS, is leased by a private party for storage and processing of waste metal materials. Adjacent to the north of the IDS, is the pre-Irma landfill. This entire area including adjacent parcels is jointly referred to as the IDS.

Figure 3.20 Pondfill Parcels and Possibilities for Horizontal Extension

3.3.2 IDS

A further horizontal extension of the IDS has not been considered due to land constraints resulting from existing infrastructure. However, in order to verify the impact on the net remaining capacity for waste disposal, a vertical extension has been considered in the analysis. Therefore, a Base Case has been defined whereby a maximum Crest Level of 10m for the IDS would be applied, as well as a Sensitivity Case whereby the maximum Crest Level would be increased to 25m.

An identical Site Layout of the IDS for the Base Case and the Sensitivity Case situations have been applied for the analysis of the Resettlement Area and the VROMI Yard alternatives under Base Case and Sensitivity Case conditions.

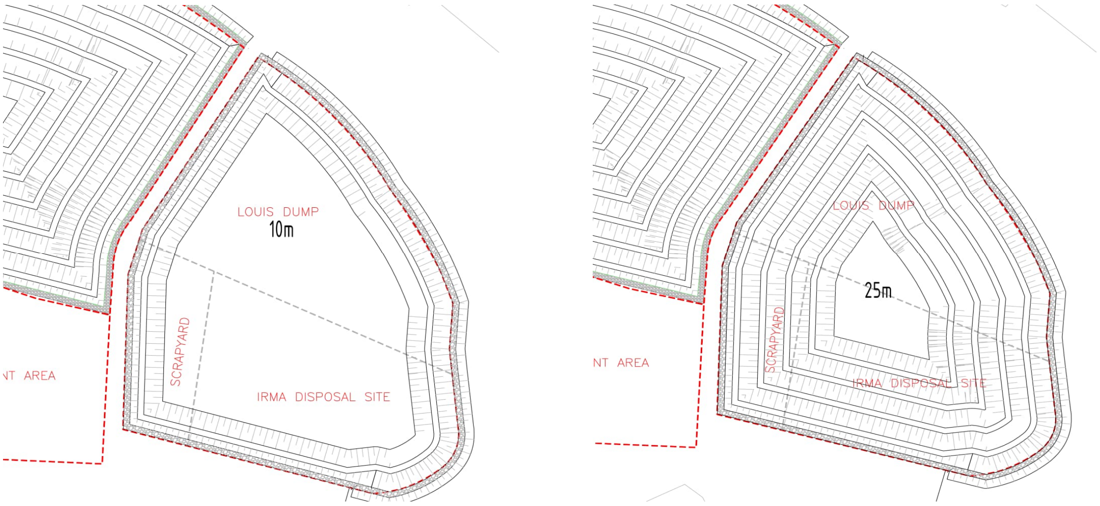
Base Case

In the Base Case situation, no further waste disposal at the IDS is foreseen. The existing waste mass will be reprofiled for stable slopes (see Section 3.2.2) and levelled to a height of 10m. Based on the topographic survey from August 2024 [Ref. 2], there is a limited positive net-balance of approximately 116 thousand m^3 between the volumes for slope reprofiling and levelling at 10m. This capacity has probably already been further reduced due to continued disposal operations after the topographic survey of August 2024. As such, the net-balance is that limited, that no major further disposal operations are foreseen at the IDS as part of the reprofiling of slopes and the levelling at a height of 10m. This request of VROMI is driven by the desire to close the IDS on short term and the intention to make this area available for future development of waste management initiatives.

Sensitivity Case

In order to maximise the disposal capacity without a horizontal extension at the Pondfill, a Sensitivity Case has been defined in which the IDS would be vertically extended to a maximum crest level of 25m. This increased maximum crest level generates an addition capacity of approximately 290 thousand m^3, resulting in a total net-capacity after reprofiling of approximately 406 thousand m^3 at the IDS for the Sensitivity Case situation.

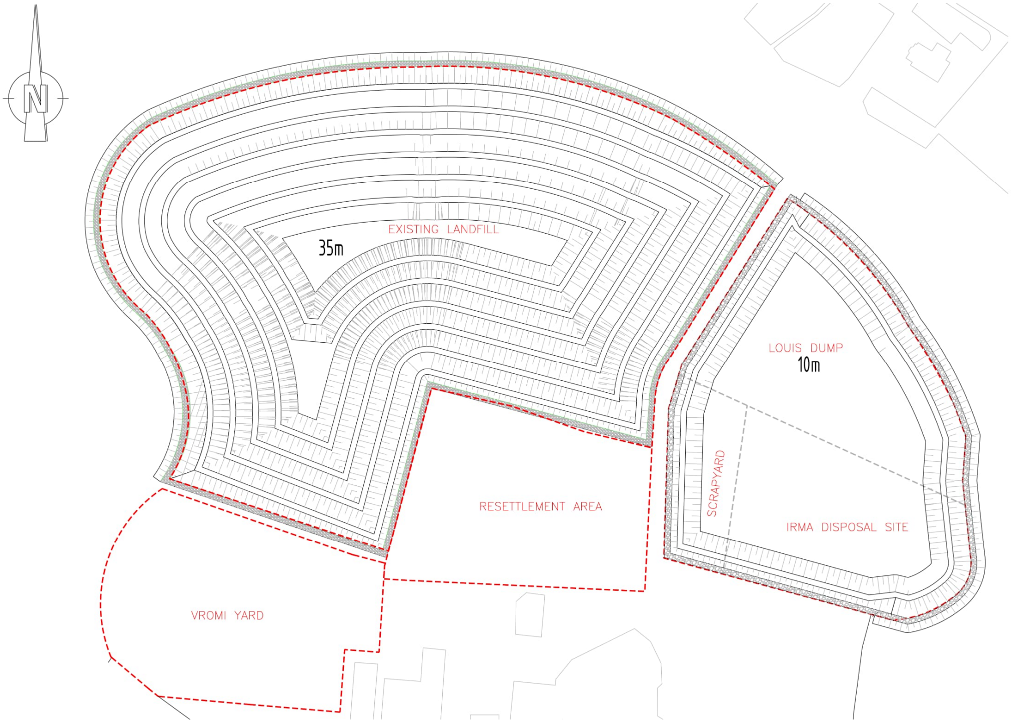
Figure 3.21 Visualization of IDS Site Layout for Base Case and Sensitivity Case



3.3.3 SWDS - Existing Horizontal Boundaries

Based on the topographic Survey performed in August 2024 [Ref. 2], when considering the necessary reprofiling of the steep slopes, the existing SWDS within its existing boundaries already has a net deficit capacity of 46 thousand m3. As a result, excavated material for the necessary reprofiling already must be redistributed at the IDS. In that respect, it is to be noted that new buildings and amenities are therefore no longer anticipated and have thus also not been included as part of the analysis.

Figure 3.22 MSWDS Site Layout - Existing Boundary (no horizontal extension) for IDS Base Case



Combined Capacity SWDS and IDS (Base Case - IDS Crest at 10m)

The combined net capacity remaining for disposal at the SWDS and IDS within their existing boundaries for the Base Case amounts to approximately 70 thousand m^3 as per September 2024.

Combined Capacity SWDS and IDS (Sensitivity Case - IDS Crest at 25m)

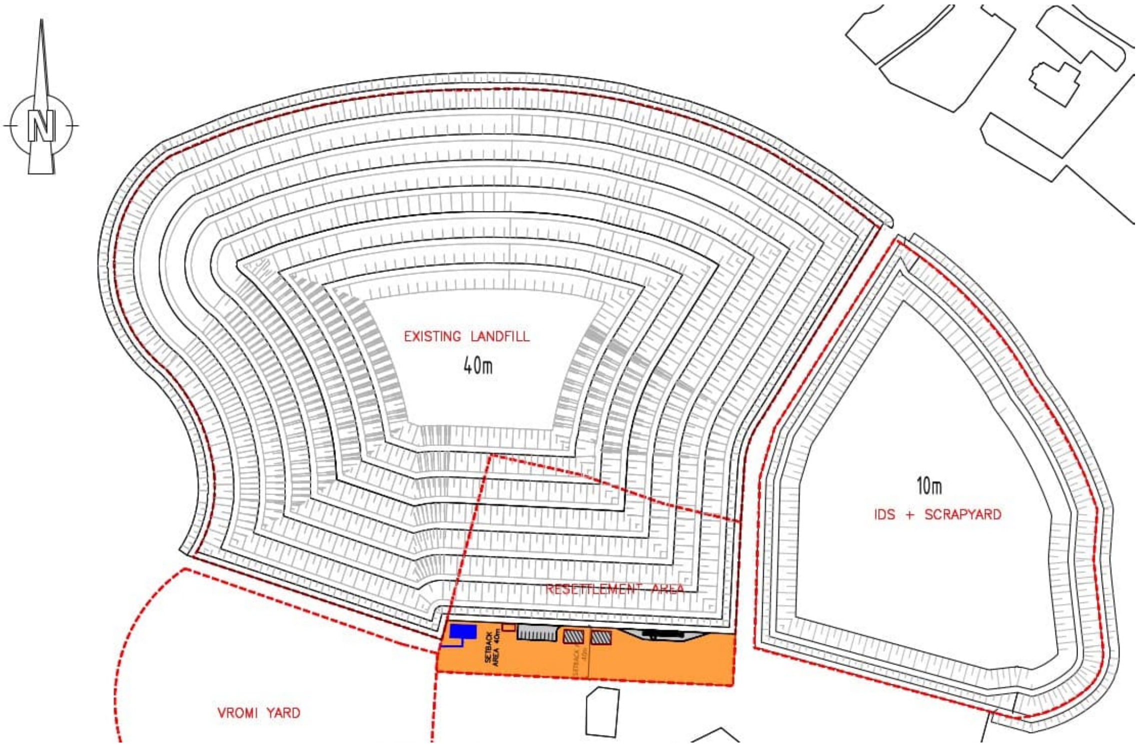
The combined net capacity remaining for disposal at the SWDS and IDS within their existing boundaries for the Base Case amounts to approximately 360 thousand m^3 as per September 2024. It is anticipated that this combined net capacity is to be stablished at the SWDS by redistributing the maximum volume of excavated material from the reprofiling of the slopes on the IDS until reaching its maximum capacity.

3.3.4 SWDS with Horizontal Extension - Resettlement Area Alternative

The Resettlement Area previously was used for informal housing and commercial activities which have all been removed under a Resettlement Plan implemented by the NRPB. The Resettlement Area, with a size of 3.3 ha, borders to the existing SWDS at its north and west, the Soualiga Road at the East and an area officially designated as mixed residential and commercial area although primarily serving as commercial area to the south. The Pondifll Drainage Channel is also partly located adjacent to the south of Resettlement Area and extends till the southern boundary of the existing SWDS.

The site Layout for the extension of the SWDS with the Resettlement Area at its final height (top crest of disposed waste at 40m) is visualized hereafter. This visualization incorporates all relevant elements of the EHS Engineering Concept, such as the maximum slope profile, the ring dike, the service road as well as the set-back zone.

Figure 3.23 MSWDS Site Layout - Horizontal Extension at Resettlement Area for IDS Base Case



The site Layout visualization shows that the currently existing location of the access road cannot be maintained for the Resettlement alternative. It is therefore foreseen that a new access to the (extended) SWDS will be created at the road south of the Resettlement area. The (new) weighing bridge and inspection unit will thus have to be relocated to the set-back zone at the south of the Resettlement area. The existing container units are foreseen to be removed and replaced by new buildings and amenities to improve the operational performance and working conditions at the landfill. These new buildings and amenities are also foreseen to be located in the set-back zone.

Combined Capacity SWDS with Resettlement Area Extension and IDS (Base Case - IDS Crest at 10m)

The combined remaining net capacity of the MSWDS consisting of the SWDS with a horizontal extension at the Resettlement Area and the IDS for the Base Case situation, amounts to approximately 900 thousand m^3 as per September 2024.

Combined Capacity SWDS with Resettlement Area Extension and IDS (Sensitivity Case - IDS Crest at 25m)

The combined remaining net capacity of the MSWDS consisting of the SWDS with a horizontal extension at the Resettlement Area and the IDS for the Sensitivity Case situation with the IDS Crest at 25m, amounts to approximately 1.190 thousand m^3 as per September 2024.

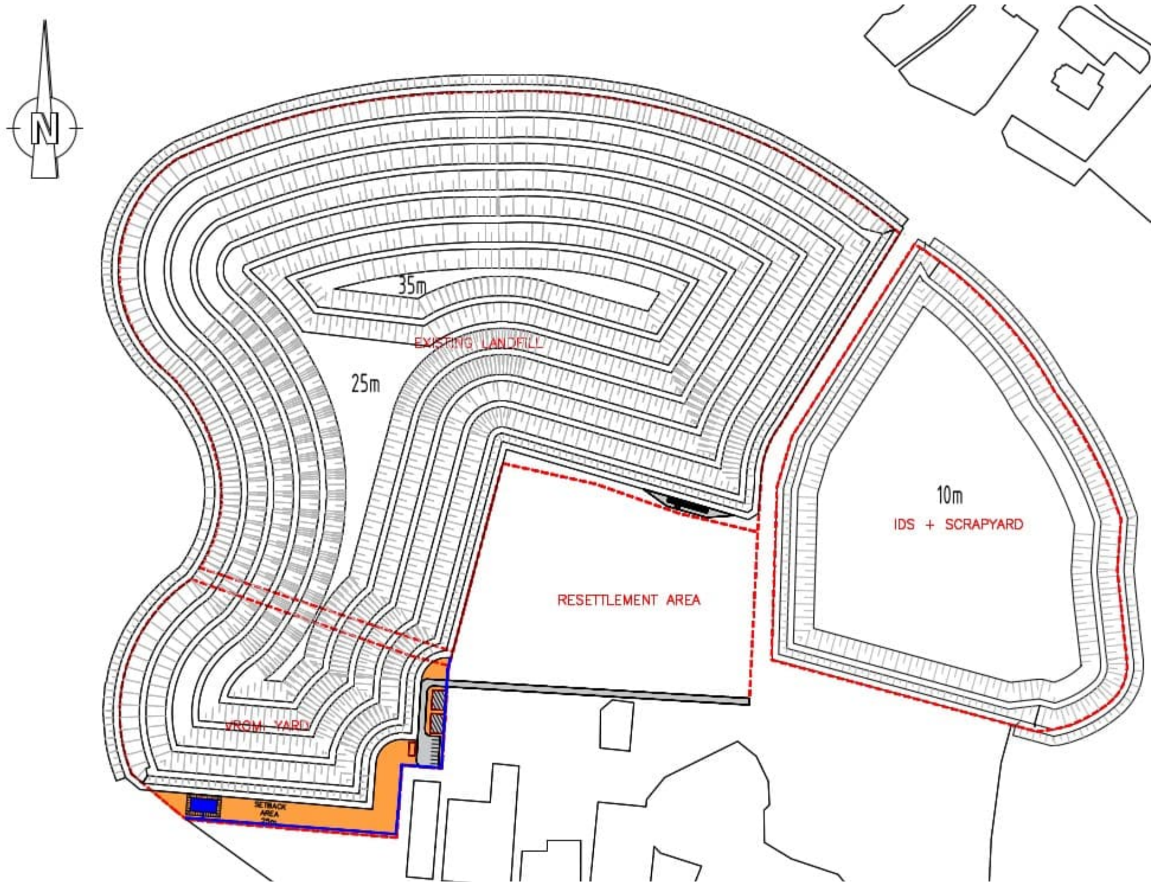
3.3.5 SWDS with Horizontal Extension - VROMI Yard Alternative

The VROMI Yard is currently used for storage purposes. The area, with a size of approximately 3.6 ha, is located south of the SWDS at the other side of the open stormwater drainage channel of the Pondfill and border the GSP to its west and to the previously mentioned area officially designated as mixed residential and commercial area although primarily serving as commercial area to its west. The area to the south of the VROMI yard is currently undeveloped.

The site Layout for the extension of the SWDS with the VROMI Yard area is visualized hereafter. This visualization incorporates all relevant elements of the EHS Engineering Concept, such as the maximum slope profile, the ring dike, the service road as well as the set-back zone.

Due to the relatively narrow width at the south achieved by the VROMI Yard extension, the maximum height at this extension is 25m due to the profile of the slopes. In addition, the maximum height that can be achieved at the existing SWDS is 35m due to the decreased length of the SWDS in comparison to the Resettlement Area alternative for extension.

Figure 3.24 MSWDS Site Layout - Horizontal Extension at VROMI Yard for IDS Base Case



The site Layout visualization shows that the existing Pondfill stormwater open drainage channel cannot be maintained for the VROMI Yard alternative. It is therefore foreseen that this open drainage channel is rerouted along the east and southern border of the VROMI Yard to discharge into the GSP. A prefabricated concrete U-profile is foreseen for this rerouting of the Pondfill stormwater drainage channel.

The existing access road with the (new) weighing bridge and inspection unit can be maintained in the VROMI Yarde alternative. However, similar as to the Resettlement Area alternative, the existing container units are foreseen to be removed and replaced by new buildings and amenities to improve the operational performance and working conditions at the landfill. These new buildings and amenities are either foreseen to be located nearby the existing entrance road and/or in the set-back zone.

Combined Capacity SWDS with VROMI Yard Extension and IDS (Base Case - IDS Crest at 10m)

The combined remaining net capacity of the MSWDS consisting of the SWDS with a horizontal extension at the VROMI Yard and the IDS for the Base Case situation, amounts to approximately 319 thousand m^3 as per September 2024.

Combined Capacity SWDS with VROMI Yard Extension and IDS (Sensitivity Case - IDS Crest at 25m)

The combined remaining net capacity of the MSWDS consisting of the SWDS with a horizontal extension at the VROMI Yard and the IDS for the Sensitivity Case situation with the IDS Crest at 25m, amounts to approximately 609 thousand m^3 as per September 2024.

4

ANALYSIS OF ALTERNATIVES

4.1 General

The analysis of alternatives is intended to facilitate a decision by NRPB on the selection of the alternative to be further elaboration into a Concept Design as basis for the preparation of the Feasibility Study Report and Procurement Documents. Since an approach has been applied whereby the EHS Engineering Concept is uniformly applied on all alternatives for the Site Layout, the differences with respect to many of the established Feasibility Criteria [Ref. 4] are limited but will nevertheless be evaluated hereafter. Special attention will however be given to the two most distinctive feasibility criteria consisting of an assessment of the landfill capacity and associated life-span and the cost estimates, which are elaborated in separate paragraphs. The analysis will be performed for the Site Layout alternatives consisting of maintaining the existing boundaries as well and a horizontal extension at either the Resettlement Area or the VROMI Yard.

4.2 Feasibility Criteria Analysis

4.2.1 Introduction

The feasibility criteria encompass individual elements with respect to the technical feasibility, socio-economic viability, and health, safety and environmental criteria. impact, and health and safety considerations [Ref. 4]. The alternatives are ranked against the established different individual elements based on the established definition of the scoring [Ref. 4] consisting of “Very Poor”, “Poor”, “Moderate”, “Good”, or “Very Good”, please refer to the Feasibility Criteria and Boundary Conditions Report for a description of every class of all the criteria.

4.2.2 Technical Feasibility

The technical feasibility qualitatively assesses the practicality of implementing the proposed alternatives for the upgrade, extension, and closure of the MSWDS, including robustness, accessibility of materials, constructability, and level of confidence.

Robustness

In developing the Environmental, Health, and Safety (EHS) engineering concept for the upgrade of the Municipal Solid Waste Disposal System (MSWDS), special emphasis has been placed on ensuring robustness. Given the site's location, access to specialized equipment and spare parts for repairs and maintenance is generally limited, leading to relatively high costs and significant downtime during repair and maintenance activities.

In terms of robustness, the main difference between the alternatives is related to the leachate collection and treatment system which is solely foreseen for the two alternatives that include a horizontal extension. Due to the necessity for ongoing maintenance of the leachate collection and treatment system despite that the form of treatment has been selected for its robustness, the alternatives with a horizontal extension are therefore considered to be less robust (moderate) in comparison to the alternative based on the existing boundaries (good).

Accessibility of Materials

The majority of the required materials are similar for all alternatives and will primarily need to be sourced from regional and international suppliers, as local availability. Even though re-use of Construction & Demolition waste from the existing landfills will be considered as design optimization as part of the development of the Concept Design for the selected alternative, the accessibility of materials is therefore to be considered to be poor for all alternatives as it solely varies between the proposed alternatives in terms of the volumes materials required.

Constructability

The EHS engineering concept is considered to be straightforward in terms of constructability with respect to the required construction techniques and their practicality. The constructability is therefore classified as Good to Very Good and does not significantly vary between the proposed alternatives.

Level of Confidence

Overall, the EHS Engineering Concept is supported with strong evidence supporting the techniques effectiveness, and as such is classified as Good, which does not significantly vary between the proposed alternatives.

Conclusion Technical Feasibility Evaluation

An overview of the evaluation for Technical Feasibility is presented in the table hereafter.

Table 4.1 Overview Evaluation and Ranking Alternatives for Technical Feasibility Criteria

Criteria	Existing Boundaries	Resettlement Area	VROMI Yard
Robustness	Good	Moderate	Moderate
Accessibility of Materials	Poor	Poor	Poor
Constructability	Good / Very Good	Good / Very Good	Good / Very Good
Level of Confidence	Good	Good	Good

4.2.3 Socio- Economic Feasibility

It is to be noted that the Capital Expenditures as well as the Waste Disposal Capacity have been included as criteria for the Socio-Economic Feasibility. However, since these are separately evaluated based on a quantitative assessment, they will not be considered here as part of the evaluation of the alternatives for their Socio-Economic Viability.

Operational Expenditures (OPEX)

The OPEX for the different alternatives are more or less identical, given the uniform application of the same Environmental, Health and Safety (EHS) Engineering Concept across all options. OPEX are expected to remain more or less at the level compared with the existing costs for OPEX and are therefore ranked as being moderate.

Indirect Economic Costs and Benefits

The economic effects of all the alternatives are balanced, with both positive and negative impacts that largely offset each other but differ between the alternatives. For example, a rapid closure of the landfill will have an impact on the employment of the landfill but will on the other hand create additional economic opportunities for the required waste diversification. The alternatives that anticipate an extension will maintain current employment for landfill operations, but the benefits of the job retention may be offset by the perceptions of the landfill negatively affecting tourism. Overall, the indirect economic costs and benefits for all alternatives have therefore been ranked as moderate.

Implementation Duration

Based on the current established Trust Fund framework, the landfill upgrade must be fully completed by June 2028. For the alternative maintaining the existing boundaries, the landfill is projected to reach full capacity within 3 to 5 years after which its final closure can be executed, which is more or less consecutive to the prior works for the landfill upgrade like the reprofiling of existing waste and partial closure of IDS. As such the completion date as per the existing Trust Fund framework cannot be achieved, ranking this alternative as poor. However, when considering the alternatives anticipating an extension the completion date for final closure is even further delayed resulting in a ranking of these alternatives as being Very Poor.

Viability of Procurement Process

This analysis qualitatively assesses how the alternatives align with contractor capabilities and preferences, particularly in the context of the competitive international market for knowledge, resources, and expertise. For the alternative maintaining the existing boundaries, the ultimate outcome will be the closure of the landfill, which represents a more clearly defined assignment compared to the alternatives anticipating an extension in which the landfill continues to operate. As such, the alternative maintaining the existing boundaries is ranked as good, whereas the other alternatives are ranked as moderate.

Resettlement

All alternatives anticipate a relocation of the existing Scrap Yard operated by Steel Shredders B.V. as well as the termination of the operation of the Waste Crusher at the existing landfill by Windwards Roads. It is anticipated that a relocation to either the VROMI Yard or the Resettlement Area is feasible. Consequently, the Resettlement Criteria will be classified as Moderate for all alternatives. It is important to note that no formal decision has yet been made regarding the relocation.

Aesthetic Value

Enhancing the site's appearance improves the social aesthetic acceptance among residents and tourists. In this context, the EHS engineering concept includes re-vegetation of the landfill after its final closure and planting of mangroves at the toe of the landfill; this final situation will be earlier with the alternative maintaining the existing boundaries which has thus been ranked as good. The extensions of the wastes will reduce the social acceptance of the landfill aesthetic value due to the continued disposal operations and as such have been ranked as moderate.

Conclusion Socio-Economic Feasibility Evaluation

An overview of the evaluation for the Socio-Economic Feasibility is presented in the table hereafter.

Table 4.2 Overview Evaluation and Ranking Alternatives for Socio-Economic Feasibility Criteria

Criteria	Existing Boundaries	Resettlement Area	VROMI Yard
Operational Expenditure	Moderate	Moderate	Moderate
Indirect Economic Cost and Benefit	Moderate	Moderate	Moderate
Implementation Period	Poor	Very Poor	Very poor
Procurement Process	Good	Moderate	Moderate
Resettlement	Good	Good	Good
Aesthetic Value	Good	Moderate	Moderate

4.2.4 Health, Safety and Environmental Feasibility

The evaluation of the alternatives against the criteria for its Health, Safety and Environmental Feasibility is primarily based on a qualitative assessment which is for some criteria complimented with rudimentary calculations.

Set-Back Distance

This criterion assesses the distance between residential developments and the perimeter of the proposed landfill extension to mitigate potential health and safety risks. Based on site studies, a minimum setback distance of 30 meters has been established as part of the Boundary Conditions and Evaluation Criteria [Ref. (4)].

Table 4.3 Set-Back Distance and Evaluation Ranking

Alternative	Set-Back Distance	Ranking
Existing Boundary	68	Moderate
Extension Resettlement Area	40	Moderate
Extension VROMI Yard	25	Poor

Air Quality

Two types of Air Quality impact have been considered: Landfill Gas, and Air Pollution caused by construction.

Landfill gas treatment is proposed for all alternatives in accordance with the EHS Engineering Concept. The proposed landfill gas system collects and processes the landfill gas thereby reducing the emission of greenhouse gas thereby as a minimum classifying as good. However, in case of the alternatives that are based on an extension, the increased waste accumulation in the landfill will ultimately also lead to higher emissions of greenhouse gases in comparison to the alternative in which the existing boundaries are maintained.

The reprofiling of the landfill and its closure as well as the transport of construction material, will cause an emission of various air pollutants. This variation in air pollutant emissions will differ among the alternatives, due to the volume of construction material to be transported as well as the surface area that will be closed. As a result, the extension alternatives result in higher air pollution compared to the alternative in which the existing boundaries is maintained.

Table 4.4 Air Pollution Evaluation and Ranking

Alternative	Evaluation	Ranking
Existing Boundary	Lowest Landfill Gas production / Lowest volume of material transport & handling	Very Good
Extension Resettlement Area	Extended Landfill Gas production / Increased volume of material transport & handling	Good
Extension VROMI Yard	Extended Landfill Gas production / Increased volume of material transport & handling	Good

Landfill Fires

Landfill fire management has been significantly improved since 2019, by compaction of the wastes and installation of intermediate covering with soil. Fire safety will be primarily addressed through proper landfill operations, ensuring sufficient compaction of disposed waste and the use of intermediate cover layers. The ring-dike and service area will also provide full accessibility for firefighting operations around the entire boundary of the MSWDS. The proposed fire management strategies can be considered good, ensuring a safe operational environment.

Reduction of Toxicity, Mobility or Volume of Leachate Migration into GSP

The effectiveness of measures implemented in the landfill upgrade to reduce the toxicity, mobility, and overall volume of leachate migrating into the GSP and the surrounding groundwater is an important environmental criterion. The EHS engineering solution for leachate management is guided by the applicable human health risks and regulatory standards. To manage leachate generation, a permeability barrier will be incorporated into the landfill cover upon closure. For the extension into the Resettlement Area or VROMI Yard, a leachate collection system will be implemented to prevent further contamination of groundwater and the GSP. This will involve a permeability barrier combined with a drainage layer to capture leachate. For leachate treatment, the preferred method is a helophyte treatment system, which utilizes natural vegetation for contaminant removal and has proven robust performance. Overall, the helophyte treatment system is expected to improve the environmental situation of the GSP by significantly reducing nitrogen loads and enhancing leachate quality; however, considering that this will be solely implemented at the extension, the overall load of chemicals will increase at these alternatives due to their later closure of the existing landfill compared to the alternative maintaining existing boundaries.

Table 4.5 Toxicity, Mobility or Volume of Leachate Migration Evaluation and Ranking

Alternative	Evaluation	Ranking
Existing Boundary	Substantial reduction within limited period of time (3-5 years)	Good
Extension Resettlement Area	Existing migration maintained until closure	Moderate
Extension VROMI Yard	Existing migration maintained until closure	Moderate

Odour and Noise

This criterion evaluates the potential effects of the proposed alternatives on odour and noise nuisance during and after the construction and operational phases of the landfill upgrade. The most important sources of odour and noise are the General Landfill Operations, the Reprofiling of MSWDS and the transport and handling of the construction material for the MSWDS closure.

For determining noise exceedance levels in the evaluation of alternatives, all noise sources have been assessed as individual sound sources, utilizing rudimentary calculations. In practice, noise levels may vary slightly due to the presence of barriers and the amplification effects of different sources. Additionally, no detailed assessment of potential dust generation during the construction and operational phases was conducted as part of this report. Finally, it is to be noted that the exact number of receptors remains uncertain due to a lack of data, especially with respect to the commercial-residential area south of the SWDS. This entire area is now seen as a residential area, while likely less housing will be present, which might also be located further away of the proposed activities.

Studies indicate that individuals living at least 2 kilometres away from a landfill may still experience health and environmental effects compared to those residing farther away[1]. The negative impact, including odour and noise, are further amplified during the reprofiling of the wastes. The predominant wind direction is towards the West, resulting that the receptor in this direction are more affected by the construction and operational activities.

---

[1] Njoku, Edokpayi, and Odiyo (2019) Health and Environmental Risks of Residents Living Close to a Landfill: A Case Study of Thohoyandou Landfill, Limpopo Province, South Africa, Environmental Research and Public Health, 15 June 2019, Volume 16, Issue 12.

Considering that the MSWDS is situated in a valley, odour and noise will remain within the boundaries of the ridges of the surrounding hills. Alternatives containing an extension are anticipated to cause more odour and noise hinder considering that the activities will take place nearer to the commercial, office, and residential receptors.

With respect to noise, the transportation of substantial volumes of soil is anticipated from the Port of Sint Maarten to MSWDS. Based on the assumption that the traffic is increased with 60 dumper trucks per hour, the noise level will be 67 dB directly next to road at the period of peak traffic, instead of 62 dB(A). The dumper trucks result in an increase of noise pressure exceeding the noise level of 55 dB in a proximity of 45 meters. The alternative maintaining the existing boundaries will require less soil; however, this benefit is off set by the fact that transport needs to be performed in a shorter period of time.

All alternatives will lead to odour and noise disturbances, and none include specific measures to mitigate these issues, such as noise barriers. Distinctions can be made between the alternatives: in the case of those involving an extension, waste processing activities and uncovered waste will be present for an extended period, and operations will occur closer to the residential-commercial area. Additionally, these alternatives will require more soil, geotextile, and other materials for operations and final waste cover, leading to increased traffic to the landfill, which may exacerbate odour and noise issues. The table hereafter summarizes the evaluation and ranking of the odour and noise impacts associated with each alternative.

Table 4.6 Odour and Noise Evaluation and Ranking

Alternative	Evaluation	Ranking
Existing Boundary	Acceptable levels of odour and noise (occasional discomfort)	Moderate
Extension Resettlement Area	Noticeable odour and noise problems (disruptive but manageable)	Poor
Extension VROMI Yard	Noticeable odour and noise problems (disruptive but manageable)	Poor

Impact on Bird Nesting and GSP Flood Capacity

An ecological assessment was not included in the scope of the study. As such it is difficult to verify whether any protected species may be affected by the planned activities and to what extent. Therefore, the impact on bird nesting has been determined based on the lost surface area of their (potential) habitat at the existing ring- dike.

The impact on bird nesting as well as the flood capacity of the GSP varies among the proposed alternatives due to differences in the amount of fringing vegetation and flood capacity that will be lost because of structures such as the ring dike. The alternative maintaining existing boundaries and the alternative with an extension at the Resettlement have the same impact on flood capacity of GSP and bird nesting. In contrast, the alternative with an extension at the VROMI Yard leads to a greater loss of vegetation for bird nesting and a higher loss of flood capacity of the GSP. However, in the situation of all alternatives, mangroves will be replanted or restored.

Table 4.7 Evaluation and Ranking of Impact on Bird Nesting and GSP Flood Capacity

Alternative	Evaluation	Ranking
Existing Boundary	Impact on GSP flood capacity as well as (temporarily) disrupted bird nesting is minimized.	Moderate
Extension Resettlement Area	Impact on GSP flood capacity as well as (temporarily) disrupted bird nesting is minimized.	Moderate
Extension VROMI Yard	Increased impact on GSP flood capacity as well as (temporarily) disrupted bird nesting	Poor

Land-Use Efficiency

In the context of waste management in Sint Maarten, optimizing land use is crucial due to the limited availability of land for disposal purposes. The MSWDS encounter significant challenges regarding land availability. While potential horizontal extensions at the Resettlement Area and VROMI Yard may offer additional disposal capacity, they further exacerbate the issue of land scarcity on the island.

Table 4.8 Land-Use Efficiency Evaluation and Ranking

Alternative	Evaluation	Ranking
Existing Boundary	Waste Capacity per Area: 11.75 m^3 per m^2	Very Good
Extension Resettlement Area	Waste Capacity per Area: 10.60 m^3 per m^2	Good
Extension VROMI Yard	Waste Capacity per Area: 10.42 m^3 per m^2	Moderate

Sustainable Resources and Raw Materials

The recycling or re-use of waste is considered beneficial by the different stakeholder, as such, the design should include the sustainability of these resources, including their origin and availability to minimize environmental impact. While efforts have been made to incorporate as much as possible locally sourced materials, a significant portion of the materials still needs to be imported. Additionally, while the recycling of inert aggregates will be encouraged its feasibility is yet to be determined during the development of the Concept Design. Consequently, all alternatives are currently classified as poor, but this ranking can be improved through optimization as part of the preparation of the Concept Design.

Conclusion Health, Safety and Environmental Feasibility Evaluation

An overview of the evaluation of the alternatives against the criteria for Health, Safety and Environmental Feasibility is presented in the table hereafter.

Table 4.9 Overview Evaluation and Ranking Alternatives for Technical Feasibility Criteria

Criteria	Existing Boundary	Resettlement Area	VROMI Yard
Set-Back Distance	Moderate	Moderate	Poor
Air Quality	Very Good	Good	Good
Landfill Fires	Good	Good	Good
Toxicity, Mobility or Volume of Leachate Migration	Good	Moderate	Moderate
Odour and Noise	Moderate	Poor	Poor
Impact on Bird Nesting and GSP Flood Capacity	Moderate	Moderate	Poor
Land-Use Efficiency	Very Good	Good	Moderate
Sustainable Resources and Raw Materials	Poor	Poor	Poor

4.2.5 Conclusion Evaluation Feasibility Criteria

In conclusion, among the alternatives, the alternative maintaining the existing boundaries scores the highest for technical feasibility, requiring lower maintenance and less imported materials. However, the differences of technical feasibility are slim as one uniform EHS Engineering Concept is applied to all alternatives. Also, in terms of socio-economic considerations, the alternative maintaining the existing boundaries scores the highest, particularly in terms of the viability of the Procurement Process and the Aesthetic Value. For health, safety, and environmental criteria, the alternative maintaining existing boundaries also performs best, particularly in air quality management and land use efficiency. Maintaining the existing boundaries result in a moderate setback distance from residential areas, minimizing health risks and enhancing overall environmental sustainability.

4.3 Landfill Capacity and Associated Life-Span for Waste Disposal

4.3.1 General

The analysis of the Landfill Capacity and Associated Life-Span for waste disposal is based on the previously prepared Waste Generation and Disposal forecast up to the year 2040 [Ref. 5]. It is to be noted that the Waste Generation and Disposal Forecast [Ref. 5] is based on an extensive survey on waste generation rates performed in 2009, which has been reviewed and verified for assumptions like waste increased due to population growth and accordingly updated. Nevertheless, the forecast should not be interpreted as exact figures on actual and future waste production and composition. As such the presented disposal forecast as well as the resulting life-span for disposal at the different alternatives shall be considered to be indicative but realistic.

Forecasting Waste Production and Composition is not an exact science. Foreseen developments in for example population and tourism growth are likely to show deviations to the forecast, whereas unforeseen developments like for example a hurricane event will have an even larger impact of any forecast. As such, any forecast will have an indicative character with respect to waste generation and composition. Whereas further analysis of the current Waste Generation Rates including a break-down of sources of generation (e.g. Tourism) and composition, might have an added value for defining and implementing a Waste Diversification Strategy, this will result in major deviations with respect to the current forecast applied for the Analysis of Alternatives.

The disposal forecast applied for the Analysis of Alternatives is furthermore based on a continuation of the existing system of disposal of all generated waste. Waste diversification by means of recycling or processing is largely non-existent at the moment and a clear implementation strategy to achieve this has neither been established yet.

Nevertheless, an additional waste disposal forecast has been prepared for a situation in which a waste diversification scenario is actually established at SXM. The indicative waste disposal forecast for the waste diversification scenario is prepared based on a Diversification Strategy of short and medium-term measures and suggestions for implementation as presented in the Waste Generation and Disposal Forecast [Ref. 5]. This strategy is based on preliminary considerations with respect to the technical and economic conditions for waste diversification at SXM. Given the required institutional; legal and regulatory developments and necessary educational and public awareness efforts as well as necessary waste infrastructure developments, the financial and economic consequences of, and the associated political commitment for implementing the waste diversification scenario, it is considered justified that the current situation of disposal of all generated waste is applied as main scenario to analyse the indicative life-span of the landfill capacity. For comparison, the indicative life-span for waste disposal will also be analysed for a situation whereby the waste diversification scenario is actually successfully implemented.

The corresponding volume of the waste disposal forecast is based on the weight of the waste and an average density of disposed waste of 1.74 tonne/m3 as per the results of the field survey performed [Ref. 1]. Even though the applied density of disposed waste is extremely high for municipal solid waste, this is considered to be justified due to the large percentages of C&D waste being disposed, which is likely also the reason for the extremely high tonnes of forecasted waste generation.

Since the remaining volume capacity of the MSWDS for continued disposal of waste is determined against the situation identified during the Topographical Survey performed on 31 August 2024 [Ref. 2], only the last quarter of 2024 has been considered for the forecasted waste disposal volume. Finally, 30% of additional volume has been considered to the forecasted waste disposal volume to account for the (intermediate) covering of the waste as part of the landfill operations. The results of the forecasted waste disposal volume as per September 2024 onward is presented in the table hereafter.

Table 4.10 Waste and Overall Disposal Forecast for Base Case and Waste Diversification Scenario as per September 2024.

Year	Base Case			Waste Diversification Scenario		
	Annual (t/yr)	Cumulative (ton)	Cumulative (gross m3)	Annual (t/yr)	Cumulative (ton)	Cumulative (gross m3)
2024	32.862	32.862	24.552	32.862	32.862	24.552
2025	132.791	165.653	123.764	125.487	158.349	118.307
2026	134.247	299.900	224.063	119.480	277.829	207.573
2027	135.703	435.603	325.450	113.312	391.141	292.232
2028	137.159	572.762	427.925	106.984	498.125	372.162
2029	138.615	711.377	531.488	100.496	598.621	447.246
2030	140.071	851.448	636.139	93.848	692.469	517.362
2031	140.622	992.070	741.202	85.076	777.545	580.924
2032	141.174	1.133.244	846.676	76.234	853.779	637.881
2033	141.725	1.274.969	952.563	67.319	921.098	688.177
2034	142.277	1.417.246	1.058.862	58.334	979.432	731.759
2035	142.828	1.560.074	1.165.572	57.131	1.036.563	774.444
2036	144.332	1.704.406	1.273.407	56.289	1.092.852	816.499
2037	145.836	1.850.242	1.382.365	55.418	1.148.270	857.903
2038	147.339	1.997.581	1.492.445	54.515	1.202.786	898.633
2039	148.843	2.146.424	1.603.650	53.583	1.256.369	938.667
2040	150.347	2.296.771	1.715.978	52.621	1.308.990	977.981

Life-Span extension through Waste Mining (removal of specific types of waste for re-use, e.g. processing of disposed C&D Waste excavated during the reprofiling in order to be re-used as sand/gravel layer) has not been considered at this stage, but will be reviewed as part of the Feasibility Study as next phase of the project as potential optimisation opportunity.

4.3.2 Site Layout Alternative - Existing MSWDS Boundary

Base Case - IDS Crest at 10m

In the Base Case situation with the IDS Crest of max 10m, the net remaining capacity of the MSWDS within its existing boundary, amounts to approximately 70 thousand m3. This corresponds to an indicative disposal life-span until the middle of 2025. Immediate interventions with respect to Waste Diversification will not make a difference on this indicative life-span and an immediate emergency situation would occur due to the lack of final treatment or disposal opportunities for the generated waste.

Sensitivity Case - IDS Crest at 25m

In the Sensitivity Case situation with the IDS Crest of max 10m, the net remaining capacity of the MSWDS within its existing boundary, amounts to approximately 360 thousand m3. This corresponds to an indicative disposal life-span until the end of 2027. Immediate interventions with respect to Waste Diversification will solely have a slight positive impact on life-span extension up to indicatively the end or 2028 as waste diversification is a gradual process.

4.3.3 Site Layout Alternative - MSWDS Extension at Resettlement Area

Base Case - IDS Crest at 10m

In the Base Case situation with the IDS Crest of max 10m, the net remaining capacity of the MSWDS with a horizontal extension at the Resettlement Area amounts to approximately 900 thousand m3. This corresponds to a Life-Span for continuation of the existing disposal operations with all collected waste being disposed at the MSWDS until approximately the middle of 2033.

In case of an immediate start and successful implementation of a waste diversification strategy, the site Layout with a horizontal extension at the resettlement area would indicatively result in a Life-Span for disposal operations until approximately the middle of 2039.

Sensitivity Case - IDS Crest at 25m

In the Sensitivity Case situation with the IDS Crest of max 25m, the net remaining capacity of the MSWDS with a horizontal extension at the Resettlement Area, amounts to approximately 1,190 thousand m3. This corresponds to an overall Life-Span extension for a continuation of the existing practice of disposal of all collected waste until approximately the end of 2035, which will be further extended till after 2040 in case of an immediate start and successful implementation of a waste diversification strategy.

4.3.4 Site Layout Alternative - MSWDS Extension at VROMI Yard

Base Case - IDS Crest at 10m

In the Base Case situation with the IDS Crest of max 10m, the net remaining capacity of the MSWDS with a horizontal extension at the VROMI Yard amounts to approximately 319 thousand m3. This corresponds to a Life-Span for continuation of the existing disposal operations with all collected waste being disposed at the MSWDS until approximately the middle of 2027.

In case of an immediate start and successful implementation of a waste diversification strategy, the site Layout with a horizontal extension at the VROMI Yard would indicatively result in a Life-Span for disposal operations until approximately the beginning of 2028.

Sensitivity Case - IDS Crest at 25m

In the Sensitivity Case situation with the IDS Crest of max 25m, the net remaining capacity of the MSWDS with a horizontal extension at the VROMI Yard, amounts to approximately 609 thousand m3. This corresponds to an indicative Life-Span for a continuation of the existing practice of disposal of all collected waste until approximately the end of 2030, which will be further extended until the end of 2032 in case of an immediate start and successful implementation of a waste diversification strategy.

4.3.5 Summary of Life-Span Analysis of Alternatives

A summary of the life-span analysis of the different alternatives is presented in the table below. Based on the results, only the alternative with a horizontal extension of the MSWDS at the Resettlement Area is realistically to result in a Life-Span for disposal exceeding 10 years as highly ambitious transition period towards full waste diversification

Table 4.11 Summary of Indicative Life-Span Analysis of Alternatives

No	Alternative	Capacity (thousand m3)	Life Span	Life-Span (diversification scenario)
1	Existing Boundary - IDS Crest at 10m	70	Middle 2025	Middle 2025
2	Existing Boundary - IDS Crest at 25m	360	End 2027	End 2028
3	Resettlement Area - IDS Crest at 10m	900	Middle 2033	Middle 2039
4	Resettlement Area - IDS Crest at 25m	1.190	End 2035	After 2040
5	VROMI Yard - IDS Crest at 10m	319	Middle 2027	Beginning 2028
6	VROMI Yard - IDS Crest at 25m	609	End 2030	End 2030

4.4 Estimate of Capital Expenditures for Construction

4.4.1 General

The analysis of cost estimate for the site Layout alternatives for horizontal extension is based on an assessment of the Capital Expenditures (CAPEX) for their construction. Operational Expenditures (OPEX) have not been considered for the analysis at this stage for the site Layout alternatives as OPEX for both alternatives are identical due to the uniform EHS Engineering Concept applied and as such is not a distinctive criterion for the analysis. OPEX will however, be incorporated in the Cost Estimate for the selected alternative as part of the Feasibility Study Report during the next phase of the project.

Accuracy and AACE Class of Estimate

The Cost Estimate at this phase of the project has an estimated range of accuracy of -20% to -50% on the low side, and +30% to +100% on the high side (i.e. the calculated degree of deviation from the average of the investment costs due to dispersions in prices and quantities, uncertainties and risks). This is in compliance with the standards for an AACE International Class 5 Cost Estimate, which is commonly applied at the Stage of Concept Select.

It is to be noted that as part of the Feasibility Study Report as the next phase of the project a more accurate cost estimate will be prepared based on the Concept Design of the selected alternative, corresponding to a AACE Class 4 Cost Estimate with a range of accuracy of -15% to -30% on the low side, and +20% to +50% on the high side.

General Starting Points & Assumptions

The following general starting points and assumptions have been applied for the cost estimate:
the price level of the estimate is the 1st of January 2025 based on the current state of affairs and laws and regulations. Changes to this are not included.

- the estimate has been drawn up entirely from a business point of view (market forces have not been taken into account).
- the price information used in the estimates is based on TAUW's cost database, dated the 1st of January 2025. Furthermore, percentages under the indirect construction costs are based on knowledge and experience from previously completed projects. Percentages included for knowledge uncertainties are also based on similar projects as well as knowledge and experience.
- costs for Contractor engineering and Client Supervision have been included and estimated as a percentage of 20% of the total construction costs.
- all costs included in this estimate are expressed in US Dollars, based on the current daily exchange rate of March 28, 2025, with EUR 1,00 = USD 1,0821.

Cost Exclusions

No VAT has been included on any of the cost items in the estimate. In addition, it is assumed that all land is already in the possession of the client or will be made available. Therefore, real estate costs are not included in this estimate.

Itemized Direct Construction Costs

Itemized Direct Construction Costs have been estimated based on all construction objects and activities included in the design as per a Bill of Quantity prepared for the different alternatives. These so-called Itemized Direct Costs, also include the supply and transport of required material and their installation, as well as the costs for the necessary (mobile and stationary) equipment and personnel for the construction.

Construction Costs - To Be Detailed

Construction Costs - To Be Detailed is a surcharge as a contingency for parts of the design or the adopted implementation method that are provided for but not yet explicitly elaborated. The percentage of the surcharge varies depending on the level of elaboration of the design. At this stage of the project (Concept Select) a preliminary surcharge of 15% is applied.

Indirect Construction Costs

The indirect construction costs are the costs that must be incurred by the executing party to be able to properly conduct the work that falls under the 'direct costs'. Indirect costs have no direct relationship with the quantities. For indirect costs, a total preliminary surcharge of 32.8% has been applied at this stage of the project (Concept Select), covering amongst others: Construction Site Costs, Project Management Costs, Implementation Costs, General Costs and Profit&Risk.

Miscellaneous Additional Costs

The Miscellaneous Additional Costs have a number of fixed costs as well as a surcharge for specific items. Represented as surcharge these Miscellaneous Additional Costs amount to approximately 18%. Following costs are amongst included as miscellaneous additional costs:

- Engineering and Supervision Costs
- Fees and Charges for Permits
- Insurance Costs
- Installation of new cables and piping for connection to public utility means
- Various investigations (a.o. sampling and assessment costs released materials)

Risks

Object risks are risks that have a direct link to the work (the so-called objects). If a certain activity is not done, the risk also disappears. In addition, there are risks that transcend the object and cannot be assigned to specific objects. Within both these risks, a distinction can be made between 'named' and 'unnamed' risks. Because many activities involve several 'standard' risks, they are rarely specifically named.

Because no risk file is available for this work, and therefore no risks have been identified, only a non-named object risk item has been included in the estimate. Based on other expected risks, an unnamed object risk as well as transcends objects risk as cover for the project uncertainties of 10% has been included in the construction costs.

4.4.2 Summary of Alternative Analysis for Capital Expenditure

General

The capital expenditure for construction have been estimated for all identified alternatives, based on the methodology described in paragraph 4.4.1. As indicated in that paragraph, the main and most reliable cost component of the Total Investment Costs are the Direct Itemized Costs. These Direct Itemized Costs are based on the Bill of Quantity with a detailed breakdown and associated unit prices. All other cost components of the Total Investment Costs are primarily based on surcharges that will be further narrowed down based on the Concept Design in the AACE Class 4 Cost Estimate to be prepared as part of the

Feasibility Study Report during the next phase of the project. As such, it is recommended that a ranking of the alternatives to facilitate a decision on the preferred alternative is primarily based on the estimated Direct Itemized Costs.

Summary of Capital Expenditure

The summary of the Capital Expenditure, broken down into Direct Itemized Costs, Total Direct and Indirect Costs and Total Investment Costs for all 6 identified alternatives is presented in the table hereafter.

Table 4.12 Summary of the Capital Expenditure for Construction of identified alternatives

No	Alternative	Itemized Direct (million USD)	Total Direct & Indirect (million USD)	Total Investment (million USD)
1	Existing Boundary - IDS Crest at 10m	35.4	59.5	70.4
2	Existing Boundary - IDS Crest at 25m	34.9	58.6	69.4
3	Resettlement Area - IDS Crest at 10m	40.0	67.3	79.6
4	Resettlement Area - IDS Crest at 25m	39.5	66.4	78.6
5	VROMI Yard - IDS Crest at 10m	41.5	69.7	82.5
6	VROMI Yard - IDS Crest at 25m	41.0	68.9	81.5

Summary of Breakdown for Direct Itemized Cost for selected Alternatives

A breakdown of the Direct Itemized Costs has been prepared for two of the Alternatives: (I) Alternative 2 - MSWDS within the existing boundary with IDS at 25m, and (II) Alternative 4 - MSWDS with Extension at the Resettlement Area with IDS at 25m. A full breakdown of the cost estimate for both alternatives have also been included in the annexes to this Alternative Analysis Report.

The Direct Itemized Costs have been presented in the table hereafter, with a Breakdown into the costs for the IDS and the costs with the SWDS and its extension if applicable. A sub-breakdown is also provided for costs associated with the Steep Slopes (Reprofiling, Ring Dike), the Cover Layer upon Closure and the Extension.

Based on the comparison of the Direct Itemized Costs between the two selected Alternatives, it can be concluded that an extension of the MSWDS at the Resettlement Area as included in Alternative 4 including all associated cost components (e.g. relocation of weighing bridge, leachate treatment, larger area for closure), will increase the estimated project costs with approximately 13% compared to Alternative 2 which is based on maintaining the existing boundary of the MSWDS.

Table 4.13 Cost Breakdown Itemized Direct Costs for selection of alternatives (in million USD)

Cost Breakdown	Alternative 2. Existing Boundary IDS Crest at 25m	Alternative 4. Resettlement Area IDS Crest at 25m
Total	$ 34.88 (100%)	$ 39.50 (100%)
IDS Total	*$ 9.38 (27%)*	*$ 9.38 (24%)*
Reprofiling & Ring dike (incl. Service Road Landside Toe)	*$ 1.08 (3%)*	*$ 1.08 (3%)*
Closure Cover Layer	*$ 8.03 (24%)*	*$ 8.03 (21%)*
SWDS Total	*$ 25.50 (73%)*	*$ 30.12 (76%)*
Reprofiling & Ring Dike (incl. Service Road Landside Toe with Fencing)	*$ 5.50 (16%)*	*$ 5.18 (13%*
Closure Cover Layer	*$ 20.00 (57%)*	*$22.48 (57%)*
Costs for Extension	--	*$ 2.46 (6%)*

5

DISCUSSION

5.1 Life-Span for Waste Disposal

Independent on the extension to be considered, the assessment of the Life-Span for waste disposal at the Pondifll shows the need for immediate actions with respect to the development and implementation of a waste diversification strategy at SXM. This cannot be solely achieved by establishing a Waste Authority and the introduction of a Gate-Fee for waste disposal at the MSWDS, but requires a comprehensive set of actions with respect to institutional; legal and regulatory developments and necessary educational and public awareness efforts (see [Ref. 5]) and associated waste management infrastructure development. Furthermore, given the anticipated financial and economic consequences, a strong political commitment towards a waste diversification strategy is a key requirement.

Even an increase in the Life-Span for waste disposal through a vertical extension of the IDS to a height of 25m or 30m does not influence the previously indicated need for immediate actions with respect to the development and implementation of a waste diversification strategy.

Furthermore, the assessment made it obvious that maintaining the MSWDS at its current site boundary as well as horizontal extension at the VROMI Yard, would result in an improvement and a rapid closure of the MSWDS. Although this might be welcomed by a large number of citizens and organisations, this would solely provide a feasible solution in case of immediate actions for the development of a new (sanitary) landfill and/or (temporary) waste storage or transshipment facility at an alternative location as part of the waste diversification strategy. Disposed or stored waste can be processed for volume reduction and recycling either at SXM or off-island, thereby growing towards a zero-disposal situation.

As indicated, the prediction of the presented life-span is not an exact science but reflects an indicative though justified base. Optimization of the life-span can amongst others also be achieved through waste mining which is currently not accounted for. However, given the large volumes of C&D waste at the landfill these can potentially be separately excavated for re-use in the anticipated construction works associated with the planned intervention. This optimisation (incl. guaranteed volumes of suitable C&D waste that can be made available to the construction contractor) will be further investigated during the preparation of the Feasibility Study Report in the next phase of the project based on a further elaborated Concept Design.

5.2 Capital Expenditure for Construction

It is to be noted that the costs of the Direct Itemized Costs are primarily driven by the extreme high costs for sand, gravel, and soil. Given the scarcity of these materials, these materials are likely to be imported resulting in substantial transport costs. This is not unique for SXM but is common to other similar islands in the Caribbean Region as well based on previous experience. Nevertheless, during the preparation of the Feasibility Study Report in the next phase of the project, further optimisations will be considered for alternative sourcing of these materials (e.g. waste mining, dredging sand).

Other cost optimisation opportunities will also be considered as part of the preparation of the Feasibility Study Report during the next phase of the project. These cost optimisation opportunities might be related to:

- Alternative development of the IDS after its closure (e.g. installation of solar energy park), preventing heavy traffic and (stationary) loads and thus the need for the horizontal geotechnical reinforcement for load distribution
- Installation of a single (mineral) permeability barrier at the horizontal extension for leachate collection, instead of the foreseen combination of synthetic and mineral permeability barrier
- Exclude the active gas extraction system at the SWDS and/or the horizontal extension and apply a passive gas extraction in combination with a biofilter.

Appendices

I

APPENDIX: COST ESTIMATE FOR ALTERNATIVE 2 - MSWDS WITHIN EXISTING SITE BOUNDARY AND IDS AT 25 METER

144046 - Landfill Sint Maarten
Alternative - Existing Boundary & IDS at 25m

Location 1 Pre-Irma/IDS	Number	Unit	Unit Cost	Total Cost
01 Reprofiling				
Excavation, relocation and compacting waste	48.050	m3	$9,69	$465.662
02 Ringdike (assumed water depth - 1.5m below Ground Level)				
Ringdike towards Pond (Ground Level, 5m wide, Slope (into pond) 1:5) - Soil	6.431	m3	$66,78	$429.482
Slope Protection (0.3m top layer) - top till toe) - Re-use Existing Graded Rock Amour	1.124	m3	$20,41	$22.936
Mangrove vegetation over full slope (1 per 8m2) - Red Mangrove	3.748	m2	$1,62	$6.054
Gravel Pavement (0.3m top layer) - Crushed C&D Waste	735	m3	$40,88	$30.043
03 Cover Layer on top of profiled waste mass (bottom to top)				
Support Layer (0.30 m), sand / gravel < 40 mm grain size	20.973	m3	$66,78	$1.400.643
Reprofiling of existing topcover (0,30m)	69.910	m2	$1,21	$84.313
Synthetic Isolation Layer (0.002 m) - LLDPE 2mm	69.910	m2	$14,80	$1.034.335
Geotextile - PP non-woven 800 gr/m2	69.910	m2	$6,29	$439.630
Drainage Layer (0.01m) - Drainage Mats (drain core with non-woven textile on both sic	76.108	m2	$7,67	$583.506
Landfill Gas Collection (horizontal system below future topcover) - HDPE 100mm	1	pcs	$39.000,00	$39.000
Biofilter	1	pcs	$47.000,00	$47.000
Sand/gravel layer (0.3 m)	20.973	m3	$66,78	$1.400.643
Slope Stability Reinforcement - 300mm HDPE type of Hegaxon or Wave Shape Geocel	63.800	m2	$11,25	$717.913
Crest Reinforcement - High-Tensile Bi-Aaxial Geogrid Reinforcement	6.110	m2	$31,26	$190.996
Soil Cover (0.5m)	34.955	m3	$66,78	$2.334.405
Vegatation (e.g. grass)	69.910	m2	$0,39	$27.100
04 Stormwater Drainage Land Side				
Stormwater Drainage (landside toe) - pre-cast U shape concrete - 0.5x0.5m	550	m	$169,28	$93.106
05 Additional Facilities				
Gravel Pavement for Service Road (0.3m top layer) - Crushed C&D Waste	825	m3	$40,88	$33.722
Location 2 Existing SWMDS				
01 Reprofiling (Staged slopes: Slope1:3 with height of 5m and 5m wide flat strip)				
Excavation, relocation and compacting waste	434.500	m3	$9,69	$4.210.826
02 Ringdike (assumed water depth - 1.5m below Ground Level)				
Ringdike towards Pond (Ground Level, 5m wide, Slope (into pond) 1:5) - Soil	12.469	m3	$66,78	$832.719
Slope Protection (0.3m top layer) - top till toe) - Re-use Existing Graded Rock Amour	2.180	m3	$21,63	$47.156
Mangrove vegetation over full slope (1 per 8m2) - Red Mangrove	7.266	m2	$1,35	$9.780
Gravel Pavement (0.3m top layer) - Crushed C&D Waste	1.425	m3	$40,88	$58.247
03 Cover Layer on top of profiled waste mass (bottom to top)				
Support Layer (0.30 m), sand / gravel < 40 mm grain size	50.751	m3	$66,78	$3.389.311
Reprofiling of existing topcover (0,30m)	169.170	m2	$0,79	$132.978
Synthetic Isolation Layer (0.002 m) - LLDPE 2mm	169.170	m2	$14,77	$2.499.266
Geotextile - PP non-woven 800 gr/m2	169.170	m2	$6,29	$1.063.828
Drainage Layer (0.01m) - Drainage Mats (drain core with non-woven textile on both sic	169.170	m2	$7,67	$1.296.995
Landfill Gas Collection (high-density vertical system) - Multriwell	43.670	m2	$14,00	$611.310
Gas Flare 250 m3/hr on concrete base	1	pcs	$67.000,00	$67.000
Sand/gravel layer (0.3 m)	50.751	m3	$66,78	$3.389.311
Slope Stability Reinforcement - 300mm HDPE type of Hegaxon or Wave Shape Geocel	162.940	m2	$11,24	$1.831.738
Soil Cover (0.5m)	84.585	m3	$66,78	$5.648.852
Vegatation (e.g. grass)	169.170	m2	$0,39	$65.578
04 Stormwater Drainage Land Side				
Stormwater Drainage (0.45m wide at landside toe of the landfill - flow towards pond)	830	m	$169,28	$140.505
05 Facilities				
New Asphalt Pavement	1.150	m2	$47,81	$54.982
Fencing around total facility (land side), exisiting and extended area	830	m	$161,52	$134.062
Sliding (Manual) Acces Gate - steel access gate 10m wide, 2m high	1	pcs	$12.921,60	$12.922

Itemized direct contractor costs				*$34.877.854*
Surcharge	15,0%	of	$34.877.854	$5.231.678
Total Direct Contractor Costs				$40.109.532
Surcharge	32,8%	of	$40.109.532	$13.155.927
Indirect contractor costs				*$13.155.927*
Total Forseen Direct and Indirect Contractor Costs				$53.275.486
Unforseen	10%	of	$53.275.485,94	$5.327.549
Unforseen Direct and Indirect Costs				*$5.327.549*
Total Forseen and Unforseen Direct and Indirect Contractor Costs				$58.603.035
Miscellaneous Additional Costs (Incl. Supervision)				$10.777.861
TOTAL INVESTMENT COSTS, EXCLUDING VAT				$69.380.895

II

APPENDIX: COST ESTIMATE FOR ALTERNATIVE 4 - MSWDS WITH EXTENSION AT RESETTLEMENT AREA AND IDS AT 25 METER

144046 - Landfill Sint Maarten

Alternative - Extension at Resettlement Area & IDS at 25m

Location 1 Pre-Irma/IDS	Number	Unit	Unit Cost	Total Cost
01 Reprofiling				
Excavation, relocation and compacting waste	48.050	m3	$9,69	$465.662
02 Ringdike (assumed water depth - 1.5m below Ground Level)				
Ringdike towards Pond (Ground Level, 5m wide, Slope (into pond) 1:5) - Soil	6.431	m3	$66,78	$429.482
Slope Protection (0.3m top layer) - top till toe) - Re-use Existing Graded Rock Amour	1.124	m3	$20,41	$22.936
Mangrove vegetation over full slope (1 per 8m2) - Red Mangrove	3.748	m2	$1,62	$6.054
Gravel Pavement (0.3m top layer) - Crushed C&D Waste	735	m3	$40,88	$30.043
03 Cover Layer on top of profiled waste mass (bottom to top)				
Support Layer (0.30 m), sand / gravel < 40 mm grain size	20.973	m3	$66,78	$1.400.643
Reprofiling of existing topcover (0,30m)	69.910	m2	$1,21	$84.313
Synthetic Isolation Layer (0.002 m) - LLDPE 2mm	69.910	m2	$14,80	$1.034.335
Geotextile - PP non-woven 800 gr/m2	69.910	m2	$6,29	$439.630
Drainage Layer (0.01m) - Drainage Mats (drain core with non-woven textile on both si	76.108	m2	$7,67	$583.506
Landfill Gas Collection (horizontal system below future topcover) - HDPE 100mm	1	pcs	$39.000,00	$39.000
Biofilter	1	pcs	$47.000,00	$47.000
Sand/gravel layer (0.3 m)	20.973	m3	$66,78	$1.400.643
Slope Stability Reinforcement - 300mm HDPE type of Hegaxon or Wave Shape Geocel	63.800	m2	$11,25	$717.913
Crest Reinforcement - High-Tensile Bi-Aaxial Geogrid Reinforcement	6.110	m2	$31,26	$190.996
Soil Cover (0.5m)	34.955	m3	$66,78	$2.334.405
Vegatation (e.g. grass)	69.910	m2	$0,39	$27.100
04 Stormwater Drainage Land Side				
Stormwater Drainage (landside toe) - pre-cast U shape concrete - 0.5x0.5m	550	m	$169,28	$93.106
05 Additional Facilities				
Gravel Pavement for Service Road (0.3m top layer) - Crushed C&D Waste	825	m3	$40,88	$33.722
Location 2 Existing SWDS				
01 Reprofiling (Staged slopes: Slope1:3 with height of 5m and 5m wide flat strip)				
Excavation, relocation and compacting waste	400.880	m3	$9,69	$3.885.008
02 Ringdike (assumed water depth - 1.5m below Ground Level)				
Ringdike towards Pond (Ground Level, 5m wide, Slope (into pond) 1:5) - Soil	12.469	m3	$66,78	$832.719
Slope Protection (0.3m top layer) - top till toe) - Re-use Existing Graded Rock Amour	2.180	m3	$21,63	$47.156
Mangrove vegetation over full slope (1 per 8m2) - Red Mangrove	7.266	m2	$1,35	$9.780
Gravel Pavement (0.3m top layer) - Crushed C&D Waste	1.425	m3	$40,88	$58.247
03 Cover Layer on top of profiled waste mass (bottom to top)				
Support Layer (0.30 m), sand / gravel < 40 mm grain size	57.300	m3	$66,78	$3.826.674
Reprofiling of existing topcover (0,30m)	191.000	m2	$0,79	$150.138
Synthetic Isolation Layer (0.002 m) - LLDPE 2mm	191.000	m2	$14,77	$2.821.776
Geotextile - PP non-woven 800 gr/m2	191.000	m2	$6,29	$1.201.106
Drainage Layer (0.01m) - Drainage Mats (drain core with non-woven textile on both si	191.000	m2	$7,67	$1.464.362
Landfill Gas Collection (high-density vertical system) - Multriwell	49.733	m2	$14,00	$696.182
Gas Flare 250 m3/hr on concrete base	1	pcs	$67.000,00	$67.000
Sand/gravel layer (0.3 m)	57.300	m3	$66,78	$3.826.674
Slope Stability Reinforcement - 300mm HDPE type of Hegaxon or Wave Shape Geocel	175.910	m2	$11,24	$1.977.544
Soil Cover (0.5m)	95.500	m3	$66,78	$6.377.789
Vegatation (e.g. grass)	191.000	m2	$0,39	$74.041
04 Stormwater Drainage Land Side				
Stormwater Drainage (0.45m wide at landside toe of the landfill - flow towards pond)	800	m	$169,28	$135.427
Storm Water Storage Basin (liner basin)	200	m2	$9,80	$1.960
05 SWDS Extension Resettlement Area				
05.01 Site Preparation				

Site Clearance	1	pcs	$10.000,00	$10.000
Excavation, relocation and compacting of material at Landfill extension (0.7m deep)	16.212	m3	$3,27	$53.070
Excavation, relocation and compacting of material at Service Area (0.3m deep)	2.736	m3	$4,03	$11.019
05.02 Bottom Layer				
Foundation Layer (0.30 m) - sand / gravel < 40 mm grain size	6.948	m3	$66,78	$464.009
Mineral Isolation Layer (0.10 m) - Sand-Benotine-Polymer (Trisoplast or similar)	1.621	m2	$45,55	$73.843
Synthetic Isolation Layer (0.002 m) - HDPE 2mm	23.160	m2	$14,80	$342.658
Drainage Layer (0.50 m) - Drainage Sand	11.580	m3	$66,78	$773.349
Drainage Coffer (Gravel)	213	m3	$32,33	$6.885
Geotextile - PP Non-Woven 500gr/m2	2.550	m2	$5,00	$12.741
Leachate Drainage Pipes - Perforated HDPE Drains 160mm	1.500	m	$36,09	$54.142
Leachate Collection Pipes - HDPE 200mm	200	m	$158,59	$31.718
Leachate Collection Wells - HDPE 1.000 mm with cover	15	pcs	$3.600,00	$54.000
06 Facilities				
Fill in of Service Area (Soil)	2.736	m3	$66,78	$182.719
New Asphalt Pavement (internal transport 0.1m)	1.600	m2	$47,81	$76.496
Fencing around total facility (land side), exisiting and extended area	830	m	$161,52	$134.062
Sliding (Manual) Acces Gate - steel access gate 10m wide, 2m high	1	LS	$12.921,60	$12.922
Relocation Weighing Bridge and Control Unit	1	LS	$47.500,00	$47.500
Office&Service Building	1	LS	$195.000,00	$195.000
Waste Inspection Floor	1	LS	$27.500,00	$27.500
Storage, Repair and Maintenance Building	1	LS	$63.500,00	$63.500
Helophyte Filter	1	LS	$35.000,00	$35.000
Itemized direct contractor costs				*$39.496.202*
Surcharge	15,0%	of	$39.496.202	$5.924.430
Total Direct Contractor Costs				$45.420.632
Surcharge	32,8%	of	$45.420.632	$14.897.967
Indirect contractor costs				*$14.897.967*
Total Forseen Direct and Indirect Contractor Costs				$60.318.599
Surcharge	10,0%	of	$60.318.599	$6.031.860
Unforseen Direct and Indirect Contractor Costs				*$6.031.860*
Total Forseen and Unforseen Direct and Indirect Contract Costs				$66.350.459
Miscellaneous Additional Costs (Incl. Supervision)				$12.263.436
TOTAL INVESTMENT COSTS (EXCL. VAT)				$78.613.896

www.witteveenbos.com