AAHANGSEL II

WATERGEHALTEVERANDERLIKES WAT VEREIS WORD VIR AGTERGRONDMONITERING EN ONDERSOEKINGSMONITERING : VOORWAARDES 6.2 EN 6.4

Alkaliniteit
Kalsium
Chroom (Totaal)
Chroom (heksavalent)
Chemiese suurstof eis (CSE)
Sianied
Lood
Nitraat (as N)
Fenol verbindings
Kalium
Totale opgeloste vaste stowwe
Vrye- & gebonde ammoniak (as N)
Boor
Magnesium
Kadmium
Chloriede
Kwik
pH
Natrium
Elektriese geleidingsvermoë
Sulfaat

AANHANGSEL III

WATERGEHALTEVERANDERLIKES WAT VEREIS WORD VIR WAARNEMINGS MONITERING: VOORWAARDE 6.3

(a) Alkaliniteit
Chemiese suurstof eis
pH
Totale opgeloste vastestowwe
Chloriede
Nitrate
Kalium

(b) Jaarliks vir elektriese geleidingsvermoeë, kalsium, magnesium, natrium, sulfaat en fluoriedes.

AANHANGSEL IV

INLIGTING WAT JAARLIKS VERSKAF MOET WORD: VOORWAARDE 6.6

NAAM VAN TERREIN:______________________ DATUM VAN VERSLAG [J J J J M M D D]

Geregistreerde eienaar(s) van eiendom waarop stortterrein geleë is:

Naam...

Posadres.......................... Telefoonkode & No ....

.... Fakskode & No ....

.... Poskode .... Teleks No ....

2. Naam van Operateur in beheer van stortterrein:

....

Telefoonkode & nommer .... Na-ure ....

Identiteitsnommer..

Opvoedkundige kwalifikasies (*).

st 6	☐	diploma	☐
st 8	☐	hoër diploma	☐
matriek	☐	graad	☐

ander (spesifiseer)....................

3. (a) Nuutste geskatte lewensduur van stortterrein .... jaar

(b) Dui die toepaslike tipe afval en hoeveelhede wat gedurende die jaar gestort is aan:

Tipe afval	Hoeveelheid (m^3 per jaar)	Gekompakteer(G)	Ongekompakteer(O)
Nie-gevaarlike afval			
Huishoudelike afval	....	☐	☐
Tuinafval	....	☐	☐
Bourommel	....	☐	☐
Industriële afval (nie gevaarlik)	....	☐	☐
- (spesifiseer)......	....	☐	☐
-	....	☐	☐
TOTAAL	....		
Gevaarlike afval			
- Ontvlambare vloeistowwe	....	☐	☐
- Ontvlambare vastestowwe	....	☐	☐
- Oksideermiddels	....	☐	☐
- Giftige stowwe	....	☐	☐
- Bytende stowwe	....	☐	☐
- Hospitaal afval en smetstowwe	....	☐	☐
- (spesifiseer).....	....	☐	☐
-	....	☐	☐
TOTAAL	....		

* Dui aan met 'n X

4.(a) Dui die metode van afvalstorting aan (*). Landopbouing ☐ Landvulling ☐

(b) Dui die huidige afmetings van die terrein aan in meter.

Hoogte/diepte	....
Lengte	....
Breedte	....

5.Dui die afvaltipes en hoeveelhede aan wat gedurende die jaar herwin is. (*)

Geen herwinning is onderneem nie ☐

Tipe	Hoeveelheid(m^3)	Tipe	Hoeveelheid(m^3)
☐ Papier/houtvesel	....	☐ Rubber	....
☐ Plastiek	....	☐ Tekstiele	....
☐ Glas	....	☐ Yster	....
☐ Koper	....	☐ Aluminium	....
☐ Sink	....	☐ Lood	....
☐ Fosfogips	....	☐ Poeierkoolas	....
☐ Afval vir kompostering	....	☐ Voedselreste	....
☐ Brandbare gasse	....	Ander	....
Ander	....	Ander	....
Ander	....	Ander	....

6.Dui die tipes, bronne en beraamde hoeveelhede beskikbare bedekkingsmateriaal aan (*).

Tipe	Bronne	Hoevelheid (m^3)
☐ Grond	....	....
☐ Sand	....	....
☐ As	....	....
☐ Gruis	....	....
☐ Klei	....	....
☐ Bourommel	....	....
Ander (spesifiseer)	....	....
....	....	....
....	....	....
....	....	....

* Dui aan met 'n X

Handtekening ....

Hoedanigheid ....

Plek .... Datum ....

AANHANGSEL V: VORM OM CHEMIESE INLIGTING TE RAPPORTEER: VOORWAARDES 6 en 8

Naam van terrein: ____________ Boorgat naam/nommer ____________

Datum van monster [ ] Tyd [h] Monster-metode: Skep (S) [ ] Pomp (P) [ ]

Tyd na aansit van pomp [h] Monsterdiepte [.]

Datum van Analise [ ] Laboratorium [ ]

Fisiese parameters

pH [.] EG [.] TOS [ ] Temp [.] S.G. [.]

Makro chemie (mg/l)

Ca [ ] Mg [ ] Na [ ] K [.] Si [.] P Alk [ ] M Alk [ ]

M Suur [ ] P Suur [ ] Cl [ ] SO_4 [ ] $N(NO_3)$ [.] F [.]

Mikro chemie (mg/l)

Al [.] As [.] B [.] Cd [.] CN [.] Cr [.]

[.] Fe [.] Mn [.] Pb [.] Sr [.] Zn [.]

Kommentaar [ ]

Besoedelingschemie

Kleur [ ] mg/l Pt Reuk [ ] TON Opgeloste suurstof [ ] mg/l

CSB [ ] mg/l Smaak [ ] TTN Turbiditeit [.] NTU

N(Ammoniak) [ ] mg/l $N(NO_2)$ [.] mg/l N (Kjeldahl) [.] mg/l

Fenole [.] mg/l PO_4 [.] mg/l H_2S [.] mg/l

Olie [.] mg/l Seep [.] mg/l *E. coli* [ ] /100ml

Br [.] mg/l

Chloor (Vrye reste) [.] mg/l Totale organiese koolstof [.] mg/l

Sulfied [.] mg/l Metileenblou aktiewe stowwe [.] LAS

Kommentaar [ ]

Ander mikro elemente (mg/l)

Ag [.] Au [.] Ba [.] Be [.] Bi [.] Br [.]

Cs [.] Co [.] Hg [.] I [.] Li [.] Mo [.]

Ni [.] Sb [.] Se [.] Te [.] Ti [.] Tl [.]

U [.] V [.] W [.]

Kommentaar [ ]

Appendix D: Feasibility Engineering Package (FEP) for the Stormwater and Leachate Management of Charlie 1 Landfill

June 2015

SASOL CHEMICAL INDUSTRIES (PTY) LIMITED

Feasibility Engineering Package (FEP) for Stormwater and Leachate Management, Landfill Development and Overall Landfill Configuration for Charlie 1 Landfill

Submitted to:
Sasol Chemical Industries (Pty) Limited
Private Bag X 1000
Secunda
2302

REPORT

Report Number: 1418079-13574-1

Distribution:

1 x copy Sasol Chemical Industries (Pty) Limited
1 x electronic copy project folder
1 x electronic copy GAA Library

Golder Associates

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTODUCTION

Sasol Synfuels (Sasol) commissioned Golder Associates Africa (PTY) Ltd. (Golder) to assess the feasibility of the expansion of the Charlie 1 Landfill in February 2015. This work follows on from the prefeasibility work conducted by Golder during 2013.

This Feasibility Engineering Package (FEP) covers the remaining airspace for waste deposition, taking into account the relevant permit conditions. Within this context a development plan for the landfill as well as feasibility engineering designs for the stormwater and leachate management systems were conducted. The stormwater and leachate management measures/systems as well as the initial rehabilitation operations were costed.

2.0 BACKGROUND

The Sasol Charlie 1 Landfill Site was authorised in 1993 as a Class 2 Site (permit number 33/2/310/28/P51) in terms of the Environmental Conservation Act (ECA), (Act 73 of 1989), under Section 20(1) of ECA. Recent legislation changes such as the National Environmental Management: Waste Act, 2008 (Act 59 of 2008) that was enacted in July 2009, and the new Waste Management and Classification Regulations have implications for the management of waste disposal sites. In order to be pro-active, complying with the expected requirements from the authorities, Sasol prepared an updated Operating Plan for this site.

The Charlie 1 Landfill Site has been in operation since 1993, receiving domestic waste, office waste and plant waste of a non-hazardous nature. The site has been operated by Inter-waste since September 2009. Currently, the operations are orderly with cell operation and cover. However, it is evident that historically the site has not always been operated well.

A site inspection by the Department of Environmental Affairs (DEA) Environmental Management Inspectorate (EMI) during March 2008 indicated water management on the landfill site is not in accordance with permit requirements. The EMI instructed that the necessary measures as required by the landfill permit be implemented.

Extensive work has since taken place at Charlie 1, including a geo-hydrological study undertaken by the Institute for Groundwater Studies (IGS) during 2008, as well as a subsequent remediation-based investigation by SRK Consulting (2009). In addition, Golder assisted with the development of an operational plan (report no. 11616412-10857-1, dated November 2011) by recommending appropriate on-site handling of stormwater and shallow contaminated seepage arising from the site in a practical manner that will address the identified shortcomings. Further to this, Golder completed pre-feasibility engineering for the proposed stormwater and leachate management systems as well as airspace modelling (Report No. 12614891-12400-1, dated October 2013).

2.1 Overview of the current operation

Since the early nineties the Charlie 1 Landfill Site has been receiving General Waste from the Sasol Synfuels plant. The waste streams currently received are scrap rubber, office waste, beverage tins, plastics, cardboard, wood, scrap metal, cables, building rubble, soil, insulation waste, spent catalyst, garden waste, general household and canteen waste. The average waste volume per month is about 16 000 m³. No waste generated outside the Sasol boundary is disposed at the landfill.

A contractor, Inter-waste, operates the site with a staff complement of 6 on-site, including a gate clerk, 3 spotters, plant operators and 1 supervisor (*ad-hoc*).

The waste volumes are not large and therefore the waste is tipped into cells, pushed by bulldozer into the end of the cell, and covered with soil or rubble. The landfill site receives comparatively large volumes of builder's rubble and excavated soils from ongoing trenching and building works on the Sasol plant. The soil and rubble is stockpiled upslope of the cells, while the waste is pushed to the back of the cell at a lower level. At the end of the day, the bulldozer is used to push some building rubble as cover material over the placed waste. This system is suitable for the current size of the operation.

The handling of the reclaimable waste streams is less satisfactory. Wooden pallets and rubber conveyor belts are spread out over a large area, apparently without any system of managing this situation.

However, the more formalised plastic and tins recycling area is an excellent example of how recycling should be done, and it has created genuine empowerment opportunities. All of the recycling is managed by Nondaba projects (contracted), who has a staff of approximately 14 people.

2.2 Landfill classification

The *Minimum Requirements* (DWAF, 1998) classified waste in two different categories, namely General (G) or Hazardous (H). More recently however, the GN R.636 of 23 August 2013 classifies waste into five different “Types” as indicated in Figure 1.

Waste Type	Landfill Disposal Requirements
Type 0 Waste	The disposal of Type 0 waste to landfill is **not allowed**. The waste must be treated and re-assessed in terms of the *Norms and Standards for Assessment of Waste for Landfill Disposal*.
Type 1 Waste	Type 1 waste may only be disposed of at a **Class A** landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a **Hh / HH landfill** as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., Department of Water Affairs and Forestry, 1998).
Type 2 Waste	Type 2 waste may only be disposed of at a **Class B** landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a **GLB+ landfill** as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).
Type 3 Waste	Type 3 waste may only be disposed of at a **Class C** landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a **GLB+ landfill** as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).
Type 4 Waste	Type 4 waste may only be disposed of at a **Class D** landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a **GLB- landfill** as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).

Figure 1: Landfill Disposal Requirements (GN R.636) of 2013

Although not formally classified, given that only domestic, non-hazardous waste is disposed at the Charlie 1 Landfill, a Class B landfill would be required. Previously, in accordance with the *Minimum Requirements* series, the site would have been classified as a G:M:B^- (medium-sized landfill which does not have potential to produce significant leachate). As Charlie 1 Landfill Site was issued with a permit in 1993, prior to the publication of the *Minimum Requirements* series and GN R.636, it is still classified as a Class 2 landfill for general waste.

2.3 Permit conditions

The Permit, number **B33/2/310/28/P51** is attached in APPENDIX B. Some highlighted conditions from the permit are:

- The boundary is defined as that on drawing 45052-R11-A1-0531 which is included in APPENDIX C;
- Prior to disposal on any new portion of the site, the Regional Director must be notified;
- No asbestos besides asbestos-cement products, no medical waste or scheduled medicines may be disposed of on the site;
- Upslope stormwater runoff to be diverted away from the working face;
- All contaminated runoff and leachate are to be contained in a lined sump and only released or re-used in manner agreed by the Regional Director, and at a water quality agreed by the Director;
- The Director should be notified within 24 hours of any incident that occurred on the site that could cause water contamination or other environmental pollution, a health risk or nuisance, or that has caused any of the aforementioned. The Permit Holder then has 14 days within which to provide a solution to mitigate the incident or risk; and
- Monitoring and reporting requirements.

An application to lower the boundary fence from 1.8 m to 1.2 m in height was approved on 26 July 1993. This amendment is also attached in APPENDIX D. The amendment requires:

- The site should be fenced by at least a 1,2 m high fence and gates at entrance points of the same height to prevent uncontrolled access; and
- The prevention of windblown paper and plastic.

2.4 Landfill site and surroundings

2.4.1 Size and location

The footprint area of the landfill is approximately 31 ha, within the about 1 611 ha owned by Sasol that is predominantly zoned as industrial. The Sasol plant area is located within the jurisdiction of the Govan Mbeki Local Municipality, Mpumalanga Province.

The approximate co-ordinates of site are:

- Latitude: 26° 31' 11"; and
- Longitude: 29° 10' 15".

2.4.2 Site description

The site was originally a dolerite borrow area, presumably for aggregate required during the building of the plant and road network. Some informal disposal of rubble and coarse ash began as a means of filling the pits. In 1991 a formal permit application process for a disposal site was initiated. A Class II permit was issued in 1993. This description is based on the site investigations that were carried out at that time, and other information gathered during the desktop study.

Sasol Synfuels is situated on the Remainder Portion of the Farm Driehoek 275 JS. Charlie 1 Landfill Site is located 1.3 km north of the Sasol Synfuels main plant area. It is located within the secondary security fence of the plant, approximately 450 m west of the Charlie 1 security gate. Figure 1 shows the landfill boundary outlined in yellow. The Charlie 1 Security Entrance is immediately east of the landfill, with the main plant access road on the east and south. A secondary road runs east-west on the northern edge of the site, along the main plant security fence. All waste delivery vehicles approach the site on this road, from the west. Entrance to the site is midway along the northern boundary.

To the west and south, the site is surrounded by open fields. To the north, beyond the road and fence lies a buffer zone of open veld and beyond that is a light aircraft landing strip.

This is approximately 200 m from the waste disposal area which would not have complied with the Minimum Requirement 4.4, had the site been identified post 1998, which states that no landfill may be developed in an area with a Fatal Flaw which may be, amongst others, “3 000 m from the end of any airport runway or landing strip in the direct line of the flight path and within 500 m of an airport or airfield boundary”.

To the east of the landfill is an open area previously quarried for aggregate during the construction of the plant, and partially filled with building rubble and soil stockpiles. Subsequently, this area has been rehabilitated for future use. The resulting landform is uneven with areas of ponded water, and has been re-vegetated with veld grasses, reeds and weeds.

Figure 2: Charlie 1 Landfill boundary

3.0 PROJECT OBJECTIVE

The overall project objective is to refine/improve the pre-feasibility engineering designs in a manner to assess the feasibility of the project to a greater resolution. More specifically, the feasibility of the project was assessed in terms of the following:

- Optimize the remaining airspace volume to maximize the life of the site, taking account of the outcomes of a dedicated view shed analysis and within the bounds of the existing Landfill Permit requirements/conditions;
- Compile life of landfill development plan until site closure taking account of the above; and
- Develop the contaminated groundwater interception system and stormwater management system to serve both the current site as well as any extension thereof within the permit boundaries, ensuring that the systems are within the applicable legislation, guidelines, regulations and standards.

4.0 DESIGN OVERVIEW

4.1 Leachate and stormwater management

The overall design concept has been largely based on and in keeping with the prefeasibility work by Golder in October 2013 (Report No. 12614891-12400-1: Pre-feasibility Assessment for Site Extension and Storm Water Management for Charlie 1 Landfill).

Contaminated stormwater from the landfill site is captured in perimeter drains along the northern, western and southern boundary. This water gravitates via a silt trap to the Contaminated Stormwater Pond. Upslope clean stormwater is diverted away from the site by a berm located along the eastern boundary. It is noted that the stormwater routing design also allows for the “disposal” of clean runoff from the portions of the landfill as these are concurrently rehabilitated into the receiving environment.

Contaminated shallow seepage, or leachate, is captured in a subsoil “curtain” interception drain, located along the south-western and northern boundaries of the site. This is gravity fed via a collection pipe located approximately 3 m below the ground to a sump located in the north-western corner of the site. From this sump, leachate is pumped into a standalone Leachate Pond.

The suitably lined contaminated stormwater and leachate ponds are located immediately adjacent to the north-west corner of the landfill, outside the permitted site boundary. Enhanced evaporation systems on each of the ponds allow for a significant reduction in the required pond sizes (holding capacity).

4.2 Deposition plan

The deposition plan is premised on an approach and sequence for waste deposition on the landfill to ensure maximum airspace utilisation while limiting the generation of contaminated stormwater and leachate. In terms of this approach the landfill is split into operational and non-operational areas.

The deposition plan is not only aligned with the leachate and stormwater management designs but is integral to these designs to ensure their overall viability/integrity.

5.0 COMPARISON OF FEASIBILITY ASSESSMENTS

From site visits, client interaction and a review of available information, the key pre-feasibility and feasibility aspects that were considered are listed in Table 1. Specific assessments of the respective aspects are addressed in the sections that follow.

Table 1: Feasibility assessment aspects

Component/Focus area	Pre-feasibility considerations	Feasibility considerations
Pond locations	Pond (combination of stormwater and leachate) was located in north-west corner, outside of landfill permitted area. No option analysis.	Separate stormwater and leachate ponds considered. Pond location options analysis conducted. Pre-feasibility location confirmed.
Ponds sizing	Combined pond of 16 000 m^3 capacity with leachate cell included. Concurrent landfill rehabilitation to obtain optimal pond size/capacity was taken into account. Alignment to the previously submitted Charlie 1 Landfill Operating Plan (Golder, 2012).	Dedicated test pitting conducted on the site. Given elevated leachate flows expected, leachate pond was separated from stormwater pond. Dedicated numerical modelling conducted to size ponds: ■ Leachate Pond = 1 500 m^3; and ■ Stormwater Pond = 15 000 m^3. Aligned to development/deposition plan.

Component/Focus area	Pre-feasibility considerations	Feasibility considerations
Leachate management	Limited leachate was expected, but feasibility test pitting proved otherwise. In the absence of test pitting, allowance was made for a 2 phased approach. This allowed for the extension of the leachate interception along the full site boundary as the 2^{nd} phase (also including eastern boundary).	Leachate interception, collection and handling introduced with separate leachate pond. Leachate interception drain design refined and only along the northern, western and south western boundaries. Gravity flow to main sump, from which leachate is pumped to the pond.
Stormwater management	Stormwater network was developed to ensure compliance with permit conditions and functional routing of contaminated runoff to the stormwater pond.	Stormwater network design refined and pond size confirmed, separate from leachate pond.
Enhanced evaporation	Concept proposed in design.	Refinement of design to include details, first flush system and pumping requirements.
Abstraction from ponds	Not considered.	Detailed modelling indicated that direct abstraction is required to obtain appropriate pond sizes. Abstracted leachate/stormwater to be disposed into sewage network in controlled manner.
Power requirements	Pumps for leachate interception drain sized. Small pumping requirements (3 kW x 0.37 kW for leachate sump pumps + 2 kW x 0.37 kW for evaporation recirculation). Lighting for the site recommended.	One pump needed for leachate sump (gravity flow to this point). Pumping required for evaporation systems as well. Total requirement approximately 25 kW, with additional standby included.
Leachate quality and barrier/liner requirements	Not analysed.	Leachate samples tested – classified as Type 3 waste. Class A barrier system for leachate due to increased concentration due to evaporation. Although not tested, contaminated stormwater barrier is equivalent Class B for similar reasons.
Landfill height, side slope and aesthetics	Height study conducted, but final height not confirmed by Sasol. 1:4 side slopes recommended due to best practice guidelines. Basic view shed analysis was conducted which provided key information on the height of Charlie 1 for visual assessment and hence the likely final height.	View shed analysis conducted, with overall landfill height currently agreed with Sasol as 15 m. Side slopes of 1:4 adopted from pre-feasibility recommendation.
Deposition plan and landfill life	Only footprint and overall height considered in pre-feasibility.	Detailed development plan with operational and non-operational areas as the landfill develops to full height of 15 m. Clean/dirty stormwater diversion as well as concurrent rehabilitation also considered.

Component/Focus area	Pre-feasibility considerations	Feasibility considerations
Additional site maintenance	Not analysed.	Additional site maintenance addressed due to design and development plan considerations.
Concurrent rehabilitation	Concurrent rehabilitation proposed as good practice to ensure “optimally” sized stormwater pond.	Concurrent rehabilitation details refined and rehabilitation ratio from prefeasibility of 40% adopted.
Construction schedule	Not analysed.	Construction schedule proposes 12 to 15 months from start of basic design to completion of construction.
Overall costing	High level costing conducted to compare continued use of existing site (R 27 – 40 million) vs. closure of existing site and construction of new site (R 130 – 195 million).	Updated feasibility costs are R 39 million. Costs include vegetative screening to reduce visual impact as well as the initial preparation and shaping as required by the development plan. These additional costs were not included in the prefeasibility work.

6.0 LOCATIONS OF PONDS

The prefeasibility report (Golder, 2013) stipulated that the ponds be situated immediately north-west of the permitted landfill area of Charlie 1 (refer to Option 1 in Table 2). As part of the feasibility work, that included a site selection analysis, the locations of the ponds were confirmed. The various site options analysed are summarised in Table 2.

The site selection analysis addressed the following:

- Relevant and likely regulatory considerations;
- Basic technical considerations for site; and
- Advantages and disadvantages for the various sites considered.

The options were analysed at a high level with potential for optimisation during the subsequent engineering design stage. It is noted that no dedicated geotechnical investigations were performed at these locations to inform the analysis, especially in terms of constructability.

The full technical memorandum on the outcomes of this analysis is attached as APPENDIX E.

Table 2: Site selection options for ponds

Option	Description	Location illustration
Option 1	The location of the ponds in Option 1 is outside the property of the landfill site, immediately adjacent to the north western boundary. The pre-feasibility designs (Golder, October 2013) were based on this location.	

Option	Description	Location illustration
Option 2	The location of the ponds in Option 2 is within the property boundary of the Charlie 1 Landfill. The ponds are located in the north western corner of the landfill area. A large part of this location has already been landfilled, with some small structures also existing.	
Option 3	The location of the ponds in Option 3 is in the south east corner of the Charlie 1 Landfill Site, inside the landfill property. A large part of this location has already been landfilled, although a section of the eastern extent is currently open.	
Option 4	The location of the ponds in Option 4 is in the north east corner of the site, within the boundary of the landfill property. A section of the ponds covers a currently landfilled area.	
Option 5	Option 5 involves the pumping of surface water and leachate to Sasol's sewage treatment plant. This is located approximately 2.5 km south west of the facility and would include a pipeline with a minimum of two road crossings and a river crossing.	
Option 6	Option 6 is essentially a combination of Options 1 and 5. It includes a leachate sump, located at an appropriate location along the lower western boundary of the site, which will collect leachate. The leachate will then be pumped from this sump to the sewage treatment plant as in Option 5. The leachate will add a small additional waste load to the large sewage stream at the sewage treatment plant. A dedicated stormwater pond will collect the relatively clean run-off from the site, which will be located outside the property boundary, in the north-western corner, as in Option 1.	

The assessment of the five ponds location options and the one option related to a stormwater pond indicated that Option 1 is the favoured location from an engineering perspective mainly due to the following:

- It is located at the lowest point topographically, allowing for simpler and cost effective implementation of the ponds by minimising pumping and earthworks requirements; and
- Allows the opportunity to develop the landfill to its full footprint potential as authorised, notably increasing the available airspace and hence remaining operational life.

The only potentially significant disadvantage concerning this option is the rezoning which could be required, adding to the authorisation period.

7.0 POND SIZING

Two separate ponds were modelled for the storage of stormwater runoff and leachate respectively. Although the pre-feasibility work assumed the construction of a single pond with a leachate cell, further work in terms of the feasibility work concluded that the volume of leachate expected would require and justify a separate pond.

To determine the required storage capacities to ensure acceptable spillage frequencies, a hydrological simulation model of the facility and the two ponds was developed.

7.1 Climate Data

7.1.1 Rainfall

Rainfall data for the study area was sourced through the Design Rainfall Estimation Program (Smithers and Schulze, 2002) and the Daily Rainfall Data Extraction Utility (Kunz, 2004). Station 0412875W (Goedgevonden) was selected for use in the study. The rainfall gauge metadata is presented in Table 3. The selection is based on the station being the closest station to the site with a reasonably long and reliable record.

Table 3: Metadata for the Goedgevonden rain gauge

Station Name	Station No	Distance	Latitude	Longitude	Record	Reliable	MAP	Altitude
		(km)	(°)(')	(°)(')	(Years)	(%)	(mm)	(mamsl)
Goedgevonden	0412875W	10.5	27°00'	29°09'	103	59	605	1 542

The cumulative distribution function of annual rainfall is presented in Figure 3. The analysis of annual rainfall shows that:

- The Mean Annual Precipitation (MAP) for the selected portion of data is 630 mm/annum. 50% of the years receive between 545 mm/annum and 720 mm/annum; and
- The annual rainfall on record varies significantly year to year. The annual rainfall varies between 343 mm/annum and 1 139 mm/annum. A dry year (defined as the 5^{th} percentile) will receive 427 mm/annum. A wet year (defined as the 95^{th} percentile) can receive 920 mm/annum.

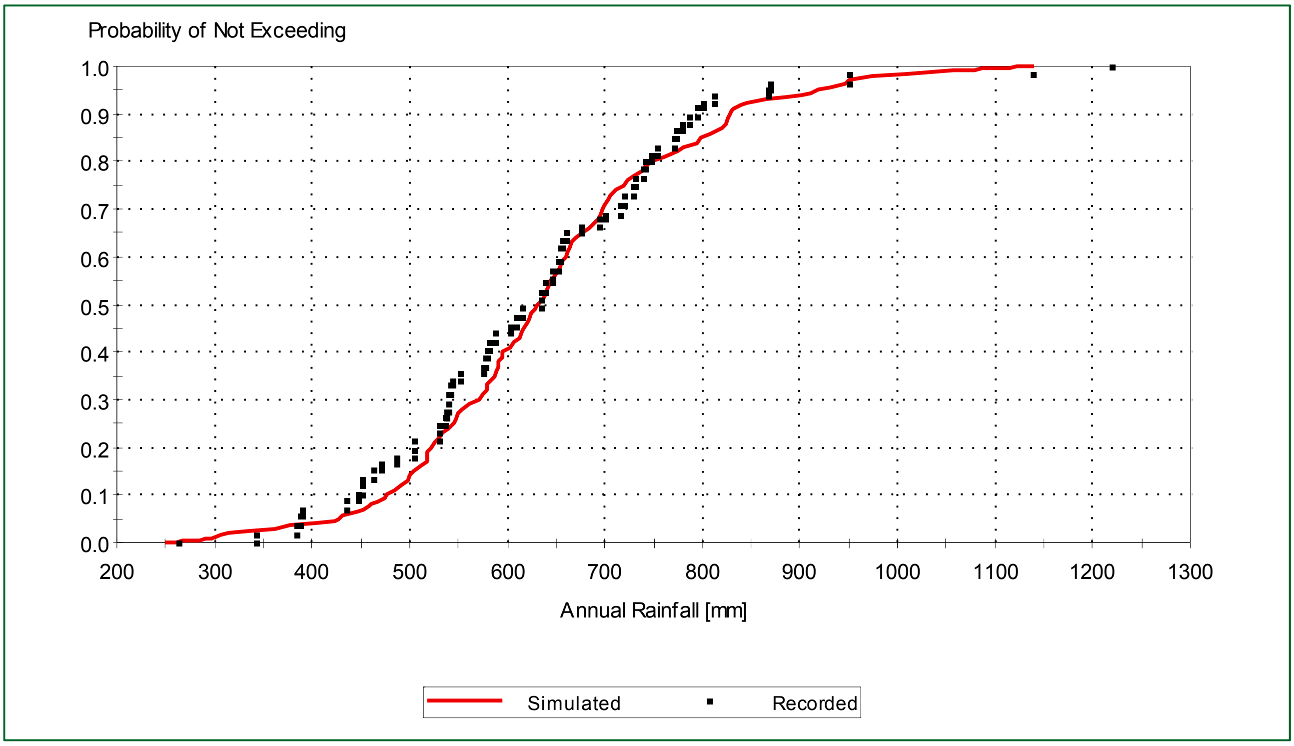

Figure 3: Cumulative distribution function of annual rainfall recorded at Station 0412875W

7.1.2 Evaporation

The study area has a Mean Annual Symons S-Pan evaporation of 1 360 mm/year and a corresponding average potential lake evaporation of 1 140 mm/year. The average monthly evaporation rates are indicated in Figure 4.

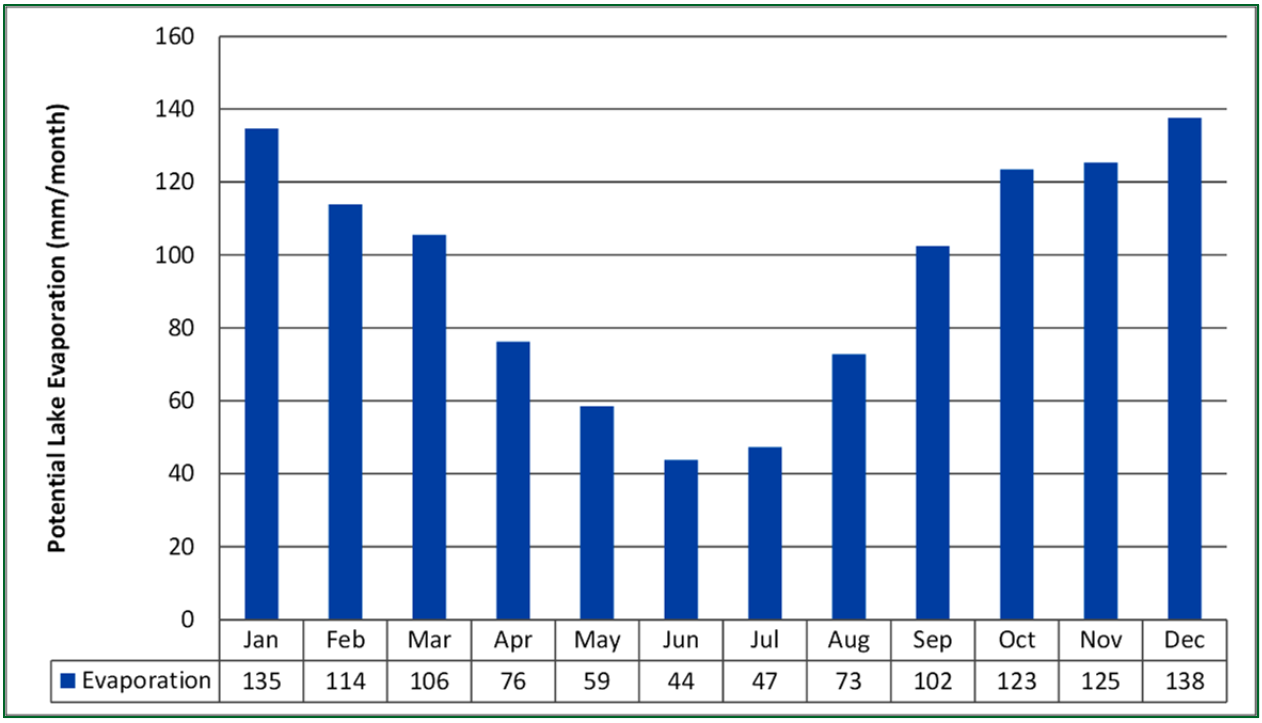

Figure 4: Mean monthly potential lake evaporation for the site

7.2 Basis of design for model

The hydrological model is based on the following assumptions:

- Facility footprint (catchment area) = 0.3 km^2;
- Two ponds with fringe widths of 12.5 m were modelled. Any water stored in the ponds will be sprayed onto the fringe to increase the evaporation rate (evaporation is estimated to increase by a factor of 1.3 over the fringe (Golder, 2011)), all rainfall landing on the fringe will be directed away from the pond through a first flush system (refer to section 10.3);
- No seepage from the ponds was included in the model due to the installation of liner systems;
- No stage-storage curve data was available and thus the ponds' surface areas do not increase with height;
- The ponds needs to be sized to comply with GN 704, thus both achieving a maximum spillage frequency of once in 50 years;
- Leachate pond design:
  - Only leachate from the landfill will be directed to the pond, no other stormwater will be collected here (other than direct precipitation on the pond);
  - The average seepage discharging to the pond over an average rainfall year is 12 m^3/d (refer to section 8.3);
  - Base flow recession constants were analysed and ranged between 0.2 to 0.01 per day;
  - Abstraction from pond: (other than to fringe):
    - Initially only the enhanced evaporation (water to the fringe) was abstracted at a rate equal to the estimated evaporation rate (mm/d x fringe area);
    - An additional take-off was added and quantified to assess what would be required to reduce the pond size but still comply with Regulation 704. This take-off was modelled as follows:
      - Pumps switch on when the pond goes above 80% full; and
      - Pumps switch off when volume drops below 20%.
- Stormwater runoff pond design:
  - Runoff calculations based on the SCS method incorporated the inputs in Table 4.

Table 4: Inputs to SCS runoff calculations

	Grassed	Gravel
Area (m^2)	88,840*	30,000
Curve Number	75	88

*40% of total footprint and subtracted the gravel covered area

  - In addition to the fringe water abstraction another artificial take-off was added and quantified to reduce the required pond size but still comply with Regulation 704. A number of abstraction activation rules were analysed to determine to most acceptable strategy with regards to minimising additional take-off required.

7.3 Analysis

7.3.1 Methodology

A daily dynamic continuous probabilistic model representing the facility and two ponds was constructed using GoldSim simulation software. The proposed water management strategy needs to be assessed under different rainfall sequences. A stochastic rainfall generator allows different sequences of daily rainfall to be generated within the model to determine the expected runoff and seepage volumes as well as the probability of spills for a particular water management strategy.

The stochastic rainfall generator should be able to reproduce key statistical characteristics of historic records at not only a daily level but also monthly levels. A daily time step stochastic rainfall generator (Boughton, 1999) was included in the model. The parameters of the stochastic model were determined by fitting the model to a measured daily rainfall record considered to be representative of the area (section 7.1).

Two different scenarios were analysed for the Leachate Pond:

- **Scenario LP1:** To analyses the sensitivity of the results to the unknown recession constant a number of varying recession constants were applied and the required pond size analysed, assuming that the average seepage remains constant at 12 m^3/d over time; and
- **Scenario LP2:** A base flow recession constant of 0.01/d was assumed along with a reduction in seepage from an average of 12 m^3/d to 6 m^3/d over a 10 year period. This recession is associated with the required improved operation of the site to reduce leachate generation over time.

Two pond sizes (12,000 m^3 and 15,000 m^3) were considered for the Stormwater Pond and the associated required additional take-off activation rules were assessed. (**Scenarios SP1 and SP2**)

7.4 Results

7.4.1 Scenario LP1

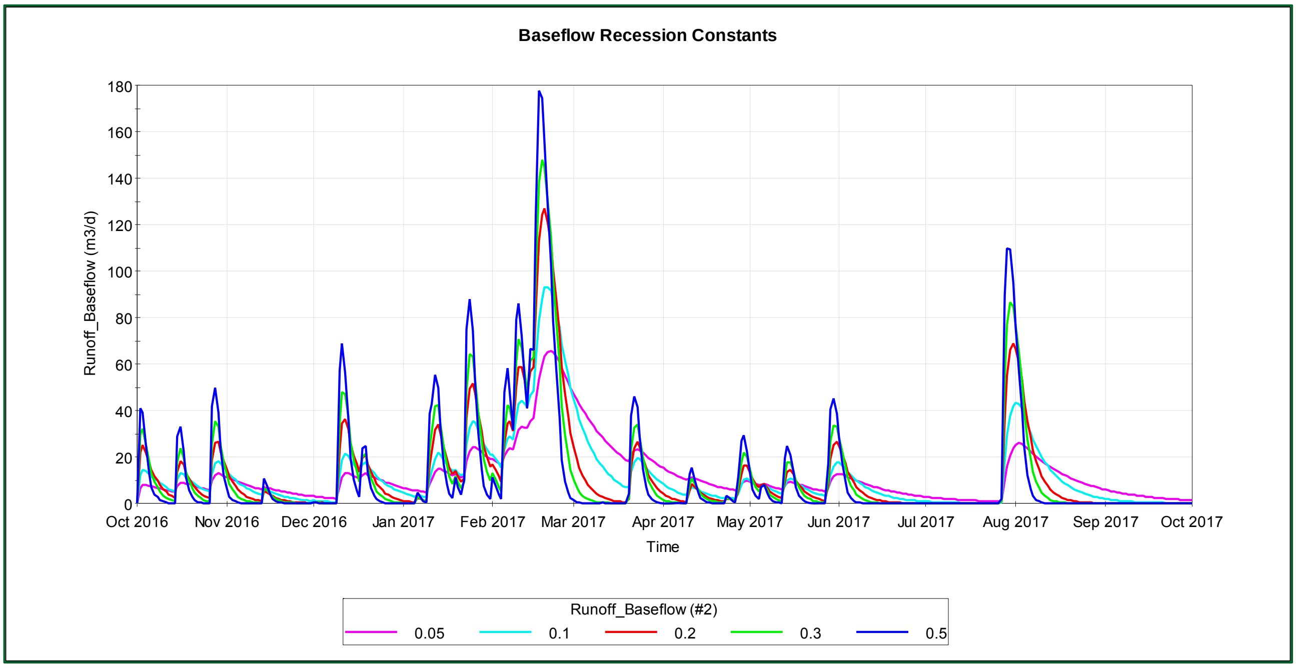

Figure 5: Varying base flow recession constant over a typical rainfall year

The combinations of pond capacities and take-off rates that resulted in ponds with a spillage frequency of less than once in 50 years are indicated in Table 5.

Table 5: Varying base flow recession constants

Base flow recession constant (1/d)	Required pond volume (m^3)	Take-off above 80% capacity (m^3/d)
0.2	5 000	0
0.2	2 000	75
0.05	4 500	0
0.05	3 000	25
0.05	1 500	50
0.02	1 500	30
0.02	1 000	32
0.01	1 000	22
0.01	1 500	20

7.4.2 Scenario LP2:

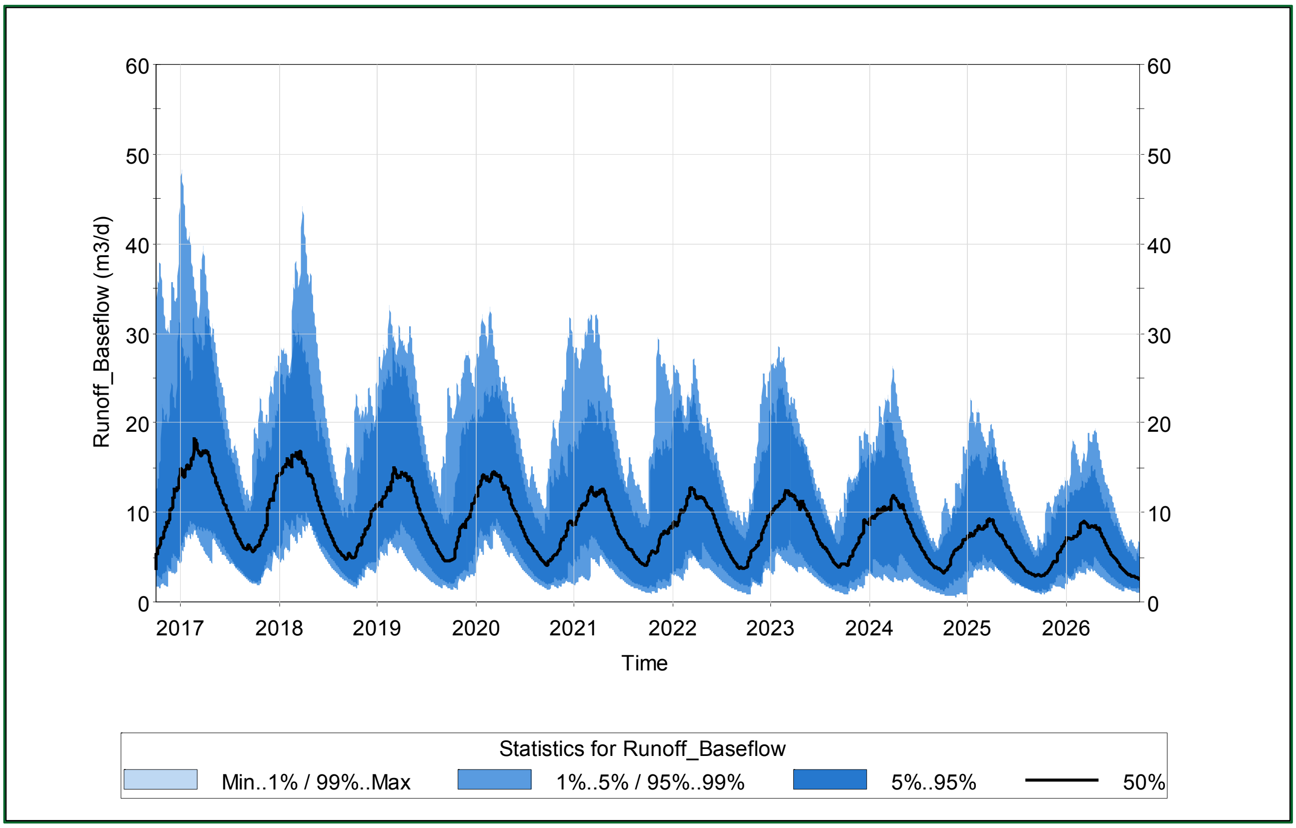

Figure 6: Reduction of seepage over time

The resultant required combination of pond capacity and additional take-off rate (from when pond capacity is above 80% until it reaches 20%) was simulated to be:

- For a 1,500 m^3 pond: 16 m^3/d; and
- For a 1,000 m^3 pond: 18 m^3/d.

The abstraction rates were further modelled and refined to reduce the frequency of abstraction required over a 12 month period by adjusting volume and duration. These results are presented in section 11.0 of this report.

7.4.3 Scenario SP1

A number of operating procedures related to the activation and deactivation rules of various additional take-offs were analysed given a 15,000 m^3 pond. The combinations resulting in acceptable simulated spillage frequencies are presented in Table 6 below. Each one of the combinations result in a different expected frequency and duration of take-off required. The product of these two aspects indicates the average number of days annually that the additional take-off will be required.

Table 6: Acceptable operating procedure for a 15 000 m^3 pond

Pond capacity (m^3)	Additional take-off			Spill frequency (1 in X years)	Additional take-off average results			Average additional take-off (days/year)
	Rate (m^3/d)	On (%)	Off (%)		Occurrences (per year)	(1 in X years)	Avg duration (days)	
15 000	300	90	65	56	0.07	15	5.86	0.40
15 000	100	80	70	50	0.12	8	13.79	1.63
15 000	50	80	50	50	0.08	12	46.43	3.81

7.4.4 Scenario SP2:

A number of operating procedures related to the activation and deactivation rules of various additional take-offs were analysed given a 12,000 m^3 pond. The combinations resulting in acceptable simulated spillage frequencies are presented in Table 7 below. Each one of the combinations result in a different expected frequency and duration of take-off required. The product of these two aspects indicates the average number of days annually that the additional take-off will be required.

Table 7: Acceptable operating procedures for a 12,000m^3 pond

Pond capacity (m^3)	Additional take-off			Spill frequency (1 in X years)	Additional take-off average results			Average additional take-off (days/year)
	Rate (m^3/d)	On (%)	Off (%)		Occurrences (per year)	(1 in X years)	Avg duration (days)	
12 000	300	60	45	50	0.32	3	9.70	3.12
12 000	100	50	30	56	0.35	3	44.96	15.92

7.5 Recommended ponds sizes

Taking the outcomes of the above analysis into consideration, the recommended pond sizes are as follows:

- Leachate pond = 1 500 m^3; and
- Contaminated Stormwater Pond = 15 000 m^3.

The subsequent feasibility designs and modelling have been based on the above pond sizes.

8.0 LEACHATE MANAGEMENT

Leachate is the highly contaminated water which has seeped through the waste.

With the testing pitting conducted on the site as part of this feasibility work, leachate inflows were observed into the test pits excavated along the western and southern boundaries.

In addition, leachate ponding along the toe of the landfill was also observed. The two eastern most test pits along the southern boundary indicated no leachate.

As the Charlie 1 Landfill was not equipped with a bottom liner system, effort must be made to intercept, collect and handle this leachate as effectively as possible to limit the potential contamination of local shallow groundwater. A dedicated leachate interception system was conceptualised that comprises the construction of interception "curtain" drains along the downslope boundaries of the site (refer to Figure 7).

Given the above, the following deviations from the prefeasibility work are noted:

- Leachate quantity is greater than initially expected, necessitating the design and construction of a separate leachate pond (as opposed to containing it in a cell within the stormwater pond); and
- Given the uncertainty on leachate production, the prefeasibility work allowed for a phased approach to leachate interception. Phase 1 included cut-off trenches along the northern, western and southern boundaries of the landfill while Phase 2 allowed for trench along the eastern and south-eastern boundaries. Phase 2 development is currently not recommended as no surface leachate was observed along these boundaries and no seepage was encountered in the two eastern-most test pits. In the event that leachate generation becomes an issue along the eastern boundary of the site during later development of the eastern portion of the landfill, Phase 2 development may be considered.

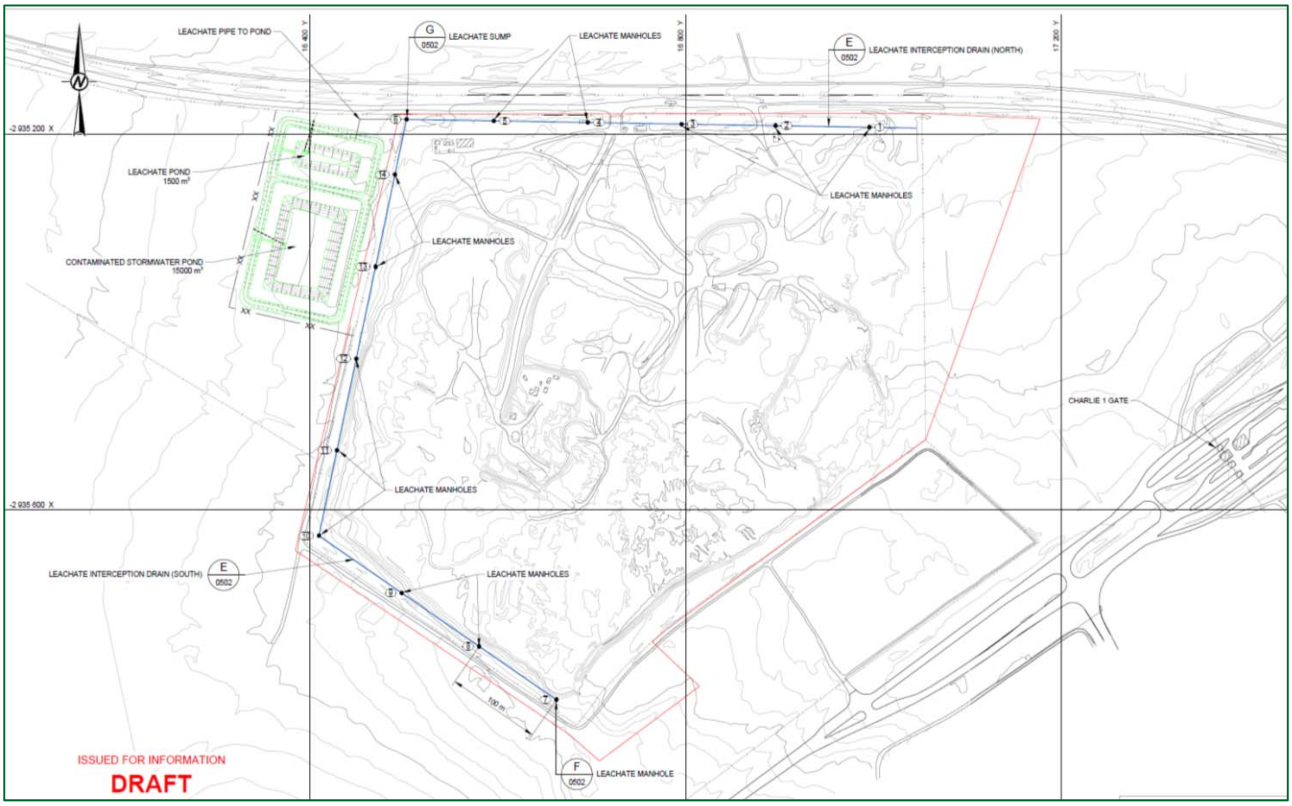

Figure 7: Leachate system general arrangement (Drawing 0301)

8.1 Shallow geology

8.1.1 Test pitting

The shallow geology information presented here is based on observations during the feasibility test pitting. A total of 9 test pits were excavated at various points along the southern and western (downslope) boundaries of the landfill.