CITY OF YELLOWKNIFE

INTERIM CLOSURE AND RECLAMATION PLAN

Version 4

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DOCUMENT CONTROL

Significant changes have been made to this document, refer to the revision table below.

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1. INTRODUCTION

1.1. Background

The Yellowknife Solid Waste Facility (SWF) is operated by the City of Yellowknife (City) and is used in the collection and disposal of many types of waste from the residents and the Industrial, Commercial, and Institutional (ICI) sector of Yellowknife. The facility has been in operation since the early 1970's and will continue to operate well into the future; however, there are areas of the SWF that are approaching their capacity. The City is preparing to close out the areas nearing capacity and return them to a certain condition of endpoint. The purpose of this plan is to take an overall look at the facility and discuss the procedures that are necessary to prepare all areas of the facility so that they can eventually be closed out and returned to certain condition of endpoint. The plan also includes monitoring requirements associated with the closure and post-closure of the SWF. This plan was developed with reference to the Environment and Climate Change Canada (ECCC) Solid Waste Management for Northern and Remote Communities Planning and Technical Guidance Document (ECCC, 2017)

1.2. Interim Closure and Reclamation Plan

As a requirement of the City's Water Licence, the City is required to submit an Interim Closure and Reclamation Plan (ICRP) prior to closure of the SWF.

The original waste disposal cell, the old landfill cell, is estimated to reach capacity by 2030 and the City intends to close this cell out once it can no longer accept waste. The actual timeline for reaching capacity will be dependent on annual waste quantities received and operational changes at the SWF. The ICRP was submitted so that this process could commence, and closure activities could take place where necessary; however, there are several other areas of the SWF that are not near closure and will remain active for years to come. The ICRP will discuss these areas in general terms, but as they are not intended to be closed out for years, specific details are unavailable at this time. The ICRP is intended to be a working document that will be updated, improved and provide greater clarity to the closure processes of the different areas of the SWF. The ICRP is reviewed on an annual basis and revised as necessary. As more information is gathered and new closure processes are incorporated, the document will undergo several iterations and will be submitted to the Mackenzie Valley Land and Water Board (MVLWB) periodically for review when changes occur. The ICRP will provide a guideline for closure and reclamation of the landfill that includes leachate prevention with the associated design of final cover systems for specific areas of the SWF, contaminated sites remediation if required, leachate/surface water/groundwater monitoring requirements during and post closure, and landfill gas monitoring.

2. SITE DESCRIPTION

2.1. Site Location

The SWF is located at the corner of Highway 3 and the old Highway 4 at Lot 1 Block 313 in Yellowknife, Northwest Territories (see Figure 2-1). The entire property is approximately 108 ha (1,080,000 m^2) and currently encompasses the SWF and the adjacent quarries.

Figure 2-1: Solid Waste Facility Location

The original landfill cell, also known as the "old landfill cell", is located near the middle of the property with the new cell area, known as Cell A and B, being located on the north side of the original lease area where quarry activities have already occurred (see Figure 2-2). Most of the quarry areas are on City owned land (red outline in Figure 2-1), with a small section of quarry area still on leased land. Cells will continue to be designed in this area as additional space becomes needed for waste disposal. As quarry operations move further toward the west side of the property, more room will become available for future disposal cells in the area left behind by the quarrying activities. As quarry excavations are completed, the excavation provides a footprint where a cell can be constructed with the installation of a liner system and leachate collection system, when necessary. In 2015, the boundaries of the SWF were expanded to include the adjacent RTL Construction, NWT Construction, and Tli Cho Landtran quarries, extending the boundaries further north to the current existing boundary shown on Figure 2-1. The purpose of obtaining land rights to the quarry areas north of the existing SWF was to claim/reserve the area for future landfills cells to keep providing waste management services to Yellowknife well into the future. Landfilling activities have not commenced in the area, there are no activities planned for the area in the immediate future, and no timeline for using this area has been established.

2.2. Historical Information

The SWF opened in 1974 and for the first 16 years of operation it was used as a non-licensed, unmonitored dump with uncontrolled burning. In 1989, Stanley Associates Engineering Ltd. (Stanley) was retained to develop a solid waste management master plan. In 1990, it began operating as a modified landfill and in 1993, the baling facility was constructed and went into operation. In 1993, the City also assumed the responsibility of a recycling program that was previously initiated by Ecology North. Since that time, other alterations to the site have occurred including amongst others:

- Implementation of the weigh scale (1998)
- Construction of the Contaminated Soil and Water Treatment Facility (2006, with operations beginning in 2007)
- Installation of a new baler (2008)
- Introduction of the composting pilot project (2009)
- Construction of a new weigh scale and gate house (2009)
- Introduction of the three-cell system (2010)
- A pilot project to test capping materials (2010)
- Construction of landfill Cell A (2011)
- Construction of Centralized Compost Facility (2014-2017)
- Decommissioning of Contaminated Soil and Water Treatment Facility (2016)
- Construction of landfill Cell B (2016)
- Decommissioning of the three-cell system (2020)
- Introduction of the Public Drop-Off area (2020)
- Introduction of a CAT816K Compactor (2020).

Since the opening of Cell A in 2011, the old landfill cell has not accepted any more household waste as this material is all brought to the new cell areas. The old landfill cell still operates, accepting construction and demolition waste in areas where space is available to bring the cell up to final design grade and contouring.

2.3. Current Site Uses/Areas

The SWF is used for several different waste collection activities and as such, has several different collection areas located throughout the property. Figure 2-2 shows the locations of the main operational areas of the landfill. A more complete picture of the activities that take place throughout the SWF, including safety precautions and processes, can be found in the City's SWF Operations & Maintenance Manual (City, 2021a). The most current version of this manual along with the City's annual reports can be found on the MVLWB's online public registry.

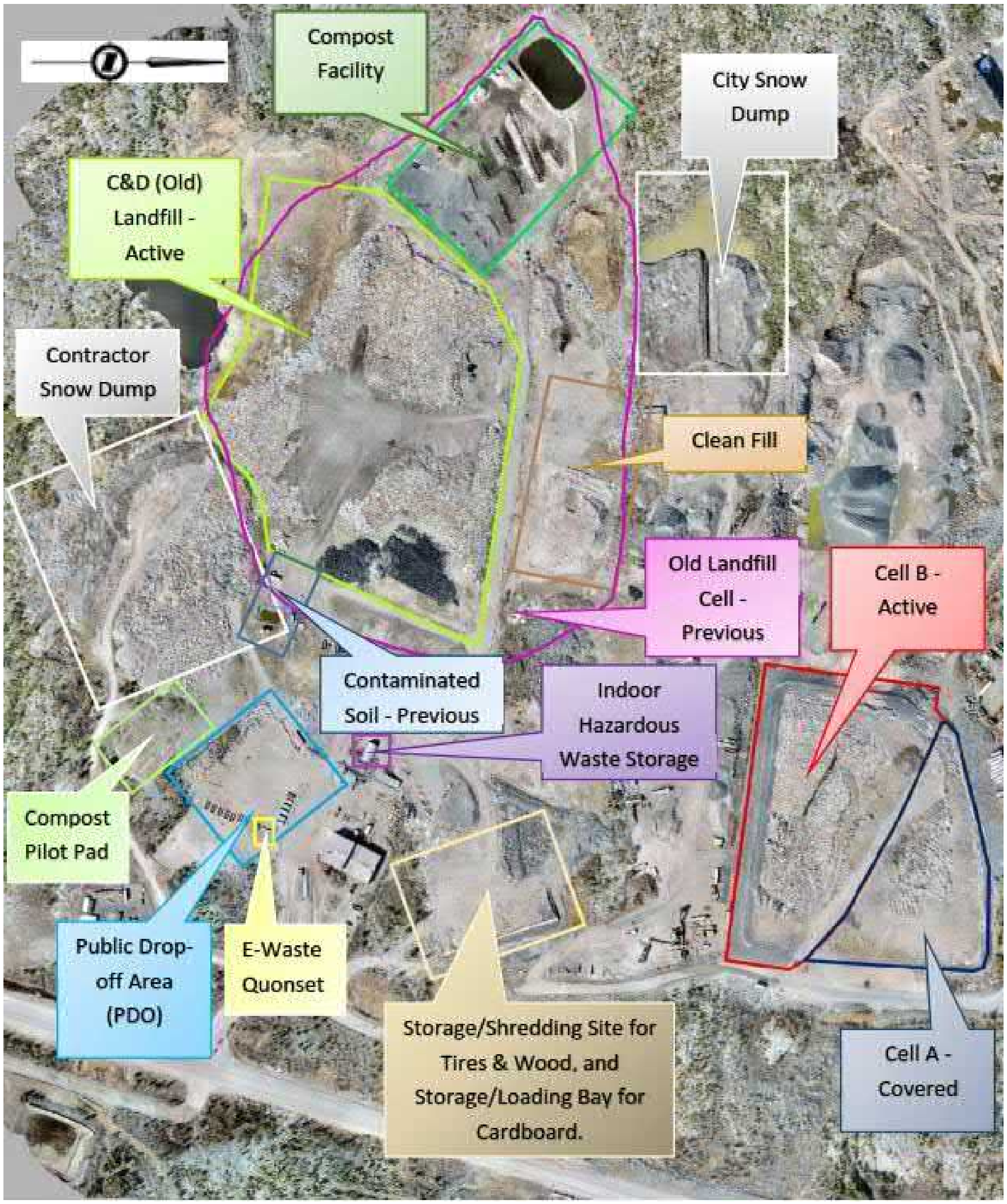

Figure 2-2: Current Site Uses

2.4. Surface Water Management

On March 8, 2012, the City submitted a Landfill Drainage Study (LDS) to the MVLWB which included information on the water patterns in and around the SWF. The topographic investigation that was a part of this study determined catchment areas of the SWF (see Appendix A) and the discharge locations. In general, water from the SWF flows to the south and the east eventually entering Jackfish Lake, Great Slave Lake, or Fault Lake. The intended capping of a large area of the SWF should not have a significant impact on this drainage. It is anticipated that the water will still discharge into these three nearby lakes throughout the closure process and after it is completed. Capping of areas within the SWF may cause minor detours in the flow paths, but no major flow patterns will be altered. Further evaluation of the site drainage will be completed as cap designs are finalized. The water that is draining from the area of the SWF will be monitored to ensure that it falls within the environmental guidelines that are required. The current monitoring requirements can be found in the City's Water Licence, and more information on future water monitoring activities associated with the SWF closure can be found in Section 6 of this plan.

2.5. Future Uses

For the most part, the different areas of the SWF will continue to be used for their current purpose or will be closed out as shown in Figure 2-3 and returned to a certain condition of endpoint with no activities taking place on them. The one major exception is the Centralized Compost Facility (CF) and its access road. A brief description of the activities currently taking place in the different areas of the SWF and any future plans are summarized in this section.

2.5.1. Centralized Compost Facility

The CF was approved for construction as a modification to the City's Water Licence by the MVLWB on February 27, 2014. The CF was subsequently approved for operations to commence by the MVLWB on February 4, 2015. The CF began receiving organic material in 2015 and is currently receiving all of the organic material that is collected under the City's composting program. Additionally, the City uses yard waste, paper waste and woodchips in the composting procedure. More information on the operations that occur at the CF can be found in the City's Compost Facility Operations & Maintenance Manual (City, 2021b). As shown in Figures 2-2 and 2-3, the CF is located at the western extents of the SWF property and worker vehicles will need to travel across a portion of the area intended to be capped to reach it. The capping system used on both the CF itself and the access road will tie directly into the capping system for the remainder of the intended close out area. A more complete description of the capping system can be found in Section 5 of this plan.

Figure 2-3: Initial Area to be Capped

2.5.2. Areas Continuing Current Operations

The areas of the SWF that will continue to be used in their current capacity for the foreseeable future are as follows:

i. Entrance and gatehouse: A weigh-in/weigh-out system is planned for implementation at the gatehouse, including an additional scale at the exit. This system is planned at the same location as the previous gatehouse and scale. Operationally, it will be very similar. The one difference is that vehicles will be required to pass over a scale on the way out of the SWF as well as when they enter the facility.

ii. Offices and baling facility: There are no plans to move any of the buildings from their current locations at the SWF.

iii. Transfer station/hazardous waste collection areas: These areas will remain where they are currently located. Some improvements to the collection areas or changes to the acceptable waste may be made based on operational capabilities, but the general layout and locations will remain constant.

iv. Snow dump areas: The two (2) snow dump areas at the SWF will remain in their current locations.

v. Scrap steel recycling area: The scrap steel recycling area will continue to operate in a similar fashion.

For more information on the operations in these areas, please refer to the City's SWF Operations & Maintenance Manual (City, 2021a).

2.5.3. Areas Changing Operations

The areas of the SWF are intended to cease operating in their current capacity in the near future include the following locations:

i. Contaminated soil and water treatment facility: This facility has ceased operations in 2016 and will be removed in the future. All contaminated water and soil at the facility was treated and has been removed from site. After the operations of the facility ceased, the facility was utilized as a holding area for vehicles before the liquids in the vehicles were drained and the vehicles processed and removed from site. Currently, the area is no longer utilized as a holding area for vehicles.

ii. Compost pilot project pad: The new compost pad is now operational and is accepting all compostable material that is delivered to site. The original pad that was used with the pilot project is no longer in operation and is vacant at this time. Future uses for this site have not been determined at this time.

iii. E-waste Quonset: Now that the GNWT's electronics recycling program has been implemented, the City is no longer accepting any electronics that fall under this program at the SWF. Currently, the E-waste Quonset is utilized by SWF staff to consolidate hazardous wastes.

2.6. Landfill Cells A & B

Cell A was originally opened in 2011 and was projected to have a five (5) year lifespan. Cell B was constructed in the summer of 2016**.** Cell B is designed to tie in with Cell A and allow for the maximum height of Cell A to be increased, thereby increasing the capacity of both Cell A and Cell B. As a result, additional waste will eventually be added to Cell A prolonging its life. Once areas of Cell A and Cell B (and any future cells) reach their final design elevations, the City will look to close them out in a similar method to how the old landfill cell is intended to be closed out. As technology is constantly advancing, specific details on the closure systems for future cells will likely be slightly different than the method utilized for the old landfill cell. More details on the specifics of how these cells will be closed out will be provided in future versions of the ICRP when the cells are closer to the closure stage.

At this point, the intent is for cells that have reached their final elevation to be closed out with an impermeable cap and covered with native grasses returning the area to a certain condition or endpoint, which would be approved via this plan. This cycle will continue for future cells in the area with typical cells having a five (5) to ten (10) year operational lifespan depending on available area, design, and how they tie into the previous cells. The long-term intent is to continue the expansion of the landfill into the quarry area through the design and development of these connected cells. This method will allow small areas to be developed, used, and returned to a certain condition or endpoint, which would be approved via this plan, while being able to maintain the collection and operational activities of the SWF in a centralized location.

Since the construction of Cell B, the City has implemented an intermediate cover on Cell A to promote run-off and reduce exposure to solid waste. Utilizing an intermediate cover is a typical operation for the landfill, as is continuing to clear the area of snow to limit spring run-off. 300 mm to 450 mm of intermediate cover is placed as waste is compacted in 3 m lifts. The frequency of the installation of intermediate cover is dependent on the amount of waste material received. Clean fill material from the City's Water & Sewer Infrastructure Replacement Program and the Road Reconstruction – Paving Program are typically utilized for intermediate cover. The leachate collection system and sump for Cells A and B are monitored. If the City notices an increase in leachate at these cells in the future, the City will examine additional ways to minimize water infiltration into the waste.

3. REGULATORY OBJECTIVES

Pursuant to the Water Act and Regulations, the City operates its collection of water and disposal of waste in compliance with current Water Licence issued by the MVLWB. With regards to the SWF, the main objective of the Water Licence is to ensure that no harmful contaminants are leaving the area and entering the receiving environment. This will be achieved by continuing to ensure that well managed, safe practices are incorporated into the design, maintenance, and operations of the facility as well as monitoring of the surrounding area. As landfill cells reach their design top of waste elevation, the cells will be progressively capped to reduce leachate generation and limit exposure risks to waste.

3.1. Current Regulations

Part F of the City's Water Licence deals with conditions applying to closure and reclamation of any waste disposal facilities. Included in this is section F.1 which states:

F1. The Licensee shall submit to the Board for approval an Interim Closure and Reclamation Plan for the Solid Waste Disposal Facilities at least 6 months prior to closure of the current solid waste disposal cell. The Plan shall include, but not be limited to, the information as set out in Schedule 3, Item 1, included in this Licence.

The board later clarified this item in a letter sent to the City on November 6, 2014 which states that: "*closure begins when a facility stops being used for its original purpose".* Furthermore, Schedule 3, Item 1 of the Licence states:

"The Closure and Reclamation Plan shall include, but not be limited, to the following:

a) Contaminated site remediation;
b) Leachate prevention;
c) An implementation schedule;
d) Maps delineating all disturbed areas, borrow material locations, and site facilities;
e) Consideration of altered drainage patterns;
f) Type and source of cover materials;
g) Future area use;
h) Hazardous Wastes;
i) Reclamation of the existing Solid Waste Disposal Facilities cell;
j) Preliminary/conceptual information for the new Solid Waste Disposal Facilities cell;
k) Details of how leachate, surface, and subsurface runoff will be monitored and modeled during and after closure;
l) Leachate Modeling and Monitoring Plan and annual reporting details;
m) Landfill Gas Monitoring Plan; and
n) Annual reporting of the findings of the Landfill Gas Monitoring Plan."

The old landfill cell is still currently accommodating more construction waste into the cell and is expected to reach capacity by approximately 2030. The City, the MVLWB, and other interested parties have been working together to produce an ICRP that meets the requirements listed above; however, it must be noted that Schedule 3 lists the items for a Closure and Reclamation Plan and since this is an interim plan, some of the final details are unknown at this time. This plan addresses all of the required items in Schedule 3 to the highest level of detail that is currently known. The ICRP is intended to be updated throughout the closure process as more details on the different aspects are finalized and closure processes become clearer. The City will submit these updated versions of the ICRP to the MVLWB as changes occur and more information becomes available. Construction plans and record drawings will be submitted in accordance with the Water Licence conditions.

3.2. Future Goals & Objectives

The long-term goal of the closure plan for the SWF is to minimize impacts on the surrounding environment due to the operations of the SWF and return the site to a certain condition or endpoint, which would be approved via this plan, when activities cease in each area. This will be accomplished through continued environmental monitoring and maintenance of the site and by looking at the complete lifecycle when planning for new areas to be opened up and used. Regular inspections of the cap and monitoring systems will be critical to meeting the long-term objectives. Inspections will assist in identifying if the integrity of the cap or monitoring systems has been compromised and therefore requires remedial measures to address any issues.

At the current time, there is no long-term plan for any uses in this area other than as a SWF. The intent is for any areas that complete their useful life as landfill cells to be capped off and then returned to a certain condition of endpoint and covered with native flora. This will limit exposure risks associated with the waste as well as reduce the generation of leachate that can potentially impact the environment.

3.3. Contaminated Sites Remediation

At the time of closure of the SWF, an Environmental Site Assessment (ESA) will be completed to identify the nature and extent of contaminants at site areas, outside of the landfill cells footprint, where there is potential for contamination due to operation of the SWF and areas where contamination is observed. Soil, surface water, and groundwater samples will be collected and tested by an accredited laboratory. The laboratory results will be interpreted to determine if any parameters exceed the applicable environmental guidelines. The City will propose guidelines or endpoints to be met through final closure. These proposed guidelines or endpoints will be submitted for approval through this plan. If there are exceedances of the environmental guidelines and it is confirmed that an area is contaminated, remedial measures will be implemented to clean up the area and prevent migration of contamination off-site. Confirmatory soil, surface water, and/or groundwater sampling and testing will be completed to ensure that the contaminated material in the area(s) are properly remediated. ESA, soil sampling and testing, and remedial measures will be completed in accordance with the Environmental Guideline for Contaminated Site Remediation (GNWT, 2003).

The ESA may consist of the following phases:

- Phase I: Site Information Assessment – Identify actual and potential site contamination in accordance with Canadian Standards Association (CSA) Standard Z768-01. This involves a review of historical and current information to develop a field testing program, if necessary. Information reviewed includes, but is not limited to, facility characteristics, contaminant characteristics, and physical site characteristics.
- Phase II: Reconnaissance Testing Program – Confirm presence and characterize substances of concern at the site in accordance with CSA Standard Z869-00. Characterization of contamination and site conditions is necessary to develop a remedial action plan or identify the need for more specific Phase III investigations. It may also include risk assessment to public health, safety, and the environment.
- Phase III: Detailed Testing Program – Phase III is dependant on the results of the Phase II investigation. If sufficient information is obtained during Phase II to characterize the site and/or risks, then a Phase III may not need to be completed and a remedial action plan will be developed, if necessary. If the Phase II indicates remediation is required due to extensive contamination, the additional investigation will address outstanding issues/data gaps to formulate a remedial action plan.

The ESA, analytical results, and remedial measures completed will be summarized in the annual report for the year that the work was completed. This will serve as a record of contaminated sites remediation and shall be completed by a qualified environmental professional.

Some typical mitigation and remedial options to handle contamination and contaminant migration issues include, but are not limited to, the following:

- Follow best management practices
- Follow Spill Contingency Plan (City, 2021c)
- Proper design of landfill cells
- Regular monitoring of groundwater
- Dig out and remove the contaminated material to a location which can accept it
- Installation of a pump and treat system for groundwater contamination.

3.4. Additional Information

While there is very little in terms of precedent and legislation in the Northwest Territories regarding landfill closures, information can be gathered from other jurisdictions. Several useful links and documents were received from the MVLWB in an email on December 15, 2014 and this information can be found on the MVLWB's public registry. Useful information can be found in the Environment and Climate Change Canada (ECCC) guidance document as well as the Government of Northwest Territories Contaminated Site Guidance Document. The City reviewed legislation and closure plans from a variety of sources across Canada including British Columbia (B.C.), Alberta, and Ontario, and incorporated the information into this ICRP. Some of the more informative sources are included in the reference section of the ICRP. The City will endeavor to become familiar with any new developments and technology used in landfill closure throughout the country and, if applicable, will incorporate this information into future closure activities where possible.

4. LANDFILL GAS

Landfill gas is typically composed of approximately 50% carbon dioxide and 50% methane gas that is generated through decomposition of organic material under anaerobic conditions. Landfill gas can be hazardous at concentrations between 5% (the lower explosive limit (LEL) and 15% of methane by volume in the air, where it can become explosive. According to the B.C. Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills, if the concentrations of methane are less than 25% of the LEL in the facility structures, and the concentration does not exceed the LEL at the property boundary, then hazardous conditions are not present at the landfill.

A second hazard associated with landfill gas is due to the carbon dioxide that is present. Since carbon dioxide is heavier than air, it can displace oxygen in confined spaces which can make for safety risks at nearby buildings. Many of the health and safety risks associated with landfill gas can be mitigated through proper staff training, work practices, and landfill gas system design and operation.

4.1. History of Landfill Gas at the Solid Waste Facility

From 2004-06 landfill gas assessments were conducted at the SWF by Jacques Whitford Limited (Jacques Whitford) and reports of the findings were completed in 2005 and 2006. These studies are available on the public registry on the MVLWB website. These assessments included ten (10) sampling wells located throughout the original landfill cell and sampling events at each of the wells. After the 2004 sampling period, landfill gas monitoring well MW3 was buried with waste and is no longer available for sampling, reducing the number of monitoring wells to nine (9). Five (5) wells were sampled in December 2004 and all nine (9) remaining wells were sampled in July 2005 and again in October 2006.

It was noted that measured methane concentrations exceeding the LEL were measured once in five (5) of the ten (10) wells; however, none of the methane levels measured were over the LEL more than once. It also should be noted that these monitoring wells were located throughout the middle of landfill cell and not at the property boundary and as such, methane levels would be expected to be much greater where the measurements were taken. It was also noted in the study that the methane concentrations in the on-site building were significantly lower than the hazardous level. While the limits for hazardous levels in buildings in the B.C. guidelines are 12,500 ppm (25% of the LEL), the maximum methane levels detected in the building at the SWF were 0.5 ppm for an eight (8) hour test and 1.6 ppm for a 24 hour test.

The City enlisted the services of Dillon Consulting Limited (Dillon) to complete a Landfill Gas Monitoring Plan and make recommendations on future measures to be implemented at the SWF. This plan is included in Appendix B.

4.2. Landfill Gas Management

While landfill gas may not pose an imminent threat to the safety of the SWF at this point in time, it is an issue that may need to be monitored as closure activities take place and/or after areas of the SWF have been closed out and capped. It is important to the health and safety of the SWF workers and the general public that visit the site and as such, it will remain an important part of the landfill management throughout its operation and closure.

4.2.1. Current Safety Measures

The safety measure that provides the most widespread protection at the SWF from the dangers of landfill gas is awareness and monitoring by staff as part of their workplace safety plan. As Dillon noted in their recommendation letter and landfill gas study, the presence of landfill gas can be detected through odour, hissing noises on top of an existing cell, or surface bubbling of any ponded water. Staff at the SWF are briefed on this during safety training sessions and any such instances are to be recorded and reported. No such reports have been received to date which suggests that landfill gases are not present at levels warranting any immediate action at the SWF. City staff are required to look for stressed vegetation as an indication of landfill gas as part of their daily work activities. The City is currently investigating the purchase of a portable landfill gas detection instrument.

A second form of gas monitoring that is available at the baling facility is an Armstrong Monitoring AMC-1400 Gas Monitor (see specifications in Appendix C). This monitor is installed at the baling facility and set up to monitor levels of methane, carbon monoxide and hydrogen sulfide. Alarms have been set to lower levels. If alarms sound, procedure is to evacuate the area. Investigation into the cause of the alarm to be completed in a safe manner and remedial measures to be undertaken.

4.2.2. Future Landfill Gas Monitoring Plan

The City had a Landfill Gas Study done in 2015 and the resulting report was received in early 2016. The report recommended a variety of potential monitoring methods and the City is working on implementing these recommendations. Some of the recommendations have been implemented (the operation of the AMC-1400 Gas Monitor), while some of the recommendations will only be required when capping of the landfill occurs (installation of monitoring wells). The implementation of the recommendations is summarized in Table 1 and following sections.

Table 1: Landfill Gas Monitoring Recommendations Summary

Recommendation	Implemented	Comment
Source/Surface Monitoring	No	Passive Landfill Gas Collection System to be installed when the old landfill cell is capped (estimated 2030) and as the newer cells are progressively capped. The City is investigating the procurement of a portable hand-held instrument for point sampling of vents/clean-outs (estimated 2021).
Meteorological Monitoring	Yes	Accessed online.
Atmospheric Pressure Monitoring	No	To be completed following capping of the old landfill cell (estimated 2030).
Lateral Emission Monitoring	No	Perimeter monitoring network to be installed following capping of the old landfill cell (estimated 2030).
Structure Monitoring	Yes	Armstrong Monitoring AMC-1400 Gas Monitor installed at baling facility.
Odour Monitoring	Yes	Complaints to be logged, followed-up, and investigated.

4.2.1.1 Source/Surface Monitoring

The City will use source monitoring to characterize the quantity and quality of LFG in a section of the landfill, to determine the composition and some physical parameters of the gas. This will be done using handheld instruments. Dillon recommended a calibrated LANDTEC Gem 5000 (or equivalent). Visual indications of LFG escaping the landfill cover include stressed vegetation; LFG can replace oxygen in the root zone leading to stress and potential death of the surface vegetation. Rather than complete regular surveys, landfill staff are informed of this indicator and are on the lookout for stressed vegetation throughout their daily work activities.

4.2.1.2 Meteorological Monitoring

The City will use meteorological data obtained from the Yellowknife Airport, as it is located within close proximity to the SWF. This data (atmospheric pressure, temperature, precipitation, and wind speed/direction) will be used to monitor conditions that could affect landfill gas generation and migration.

4.2.1.3 Passive Collection System

As stated in Dillon's report, "Passive systems use the variation in the pressure within the landfill to vent the LFG into the atmosphere." Vertical vents (or extraction wells) will be installed in the landfill. These will be installed at various depths, depending on the specific location of the vent, typically between 50 and 90 percent of the waste depth. Passive LFG vents are typically spaced at 60 m. The finalized locations of these vents have yet to be determined but proposed locations are provided in the Landfill Gas Monitoring Plan included in Appendix B. During the design of the next area for progressive capping, the locations of the passive LFG vents will be evaluated.

To measure potential horizontal movement of LFG within the waste mass, LFG probes will be installed between the landfill and potential receptors. This will be completed following final cover installation**.** The finalized locations of these probes have yet to be determined but proposed locations for the LFG probes are provided in Landfill Gas Monitoring Plan included in Appendix B. The locations of the LFG probes will be evaluated once progressive capping has commenced. These will be located based on site infrastructure, soil types, property boundaries and groundwater/water bodies.

Lateral emissions will be monitored using handheld gas monitoring probes outside the perimeter of the landfill on a regular basis.

4.2.1.4 Structure Monitoring

As previously mentioned, there is currently an Armstrong Monitoring AMC-1400 Gas Monitor set up in the Baling Facility to detect for LFG. Further to that, passive LFG vents will be set up adjacent to the facility to determine if there is any LFG in the vicinity.

4.2.1.5 Odour

An indicator of LFG is the odours that can accompany its presence. As such, during the operation of the landfill, odour complaints may occur. Odour complaints will be documented by SWF staff. A response will be made to the complainant on the same day confirming receipt and nature of the complaint, if possible. If the complaint is made after hours, the SWF staff will respond the next working day. An investigation into the complaint shall be completed and remedial measures undertaken. The investigation, remedial measures, timelines, and correspondence shall be recorded and kept on file. A follow-up will be provided to the complainant. Complaint records shall include, but not limited to, the following:

- Date and time of day that the complaint was received
- Date and time of day the complaint incident occurred
- Complainant's name, address, phone number, and location of incident
- Nature of complaint
- Method of receipt of complaint
- Operational data at the time of the incident
- Nature and result of any investigation or follow-up
- Weather conditions and meteorological measurements at the time of the complaint
- Any correspondence related to the complaint.

4.2.2 Monitoring Frequencies

The City will undertake site monitoring during the operational, closure, and post-closure phases of the landfill once the monitoring equipment for the parameter has been installed as presented in Table 2. Frequency of monitoring during the post-closure period may potentially be modified based on the results of the monitoring. This monitoring will continue until such a time that the landfill is deemed no longer likely to cause a hazard to the environment as defined in Section 6.3(c)(ii) and Table 5.5 in the Standards for Landfills in Alberta (Government of Alberta, 2010).

Table 2: Landfill Gas Monitoring Frequencies

Monitoring Location and/or Type	Frequency While Operational	Frequency After Closure	Parameters to be Monitored
Current Monitoring			
Structures	Monthly	Semi-annually	CH_4, CO_2, O_2, H_2S, atmospheric pressure, differential pressure, temperature, meteorological
Odour Complaint	As received	As received	-
Future Monitoring			
Monitoring Probes	Monthly	Semi-annually	CH_4, CO_2, O_2, H_2S, atmospheric pressure, differential pressure, temperature, meteorological
Surface emissions	Annually	Annually	General surface conditions, CH_4, vegetation stress, atmospheric pressure, temperature, meteorological
Source vent/wells	Monthly	Semi-annually	CH_4, CO_2, O_2, H_2S, atmospheric pressure, differential pressure, temperature, meteorological
Meteorological	Daily	As required	Temperature, precipitation, wind speed, wind direction, atmospheric pressure

The future monitoring will be implemented once the old landfill cell is capped.

5. FINAL CLOSURE COVER SYSTEM

As mentioned in section 2.5, closure of the facility will be a phased approach as some areas may be ready for closure immediately while others are intended to operate in their current capacity for the foreseeable future. The different areas will require different methods of closure depending on what they have been used for and what they will be used for moving forward. For areas that are intended to remain open for years to come no final closure system has been developed yet. Technological advances may make any current materials obsolete by the time closure occurs in these areas and therefore no closure systems will be designed until a timetable for their closure is known. The MVLWB will be notified at the time of planned closure. Specific materials that will be utilized to cap the landfill cells will be laboratory tested to ensure suitability of use for the cap. Typically, caps require a barrier layer with a maximum hydraulic conductivity of 1 x 10-7 meters per second as per various standards and guidelines across Canada (ie., the Standards for Landfills in Alberta, BC Landfill Criteria for Municipal Solid Waste, etc.). This will prevent precipitation from draining into waste material and generating leachate. The area under the CF has been fully cap.

An area that does have a timetable for capping, is the remainder of the area of the old landfill cell as indicated in Figure 2-3. The area will have an impermeable cap to prevent precipitation from entering the cell. By preventing the infiltration of water, the creation of leachate will be minimized and water flow from this area to downstream waterbodies will remain as free of contaminants as possible. In the Landfill Drainage Study (LDS), the benefits of the liner system were described as follows:

> *"This liner system will also serve as a risk mitigative measure, by suppressing several transport mechanisms and exposure pathways associated with surface soil contamination. Currently leachate is generated on-site via infiltration of precipitation into the waste mass. Implementation of an engineered capping system will significantly reduce infiltration of surface water into the waste mass, thus significantly decreasing the amount of leachate generated. Exposure of human health and environmental receptors should be generally limited given the proposed capping program and limited evidence of off-site migration of contaminated groundwater and no evidence of potable wells in the area."*

The capping method for both areas of the old landfill cell (CF and non-CF areas) are very similar to one another, the difference being that the cap for the CF provides more support as this area needs to accommodate equipment working on it. A description of both capping methods is provided in the following sections and specifications on the liner materials can be found in Appendix D. For the purpose of maintaining an impermeable cap, the key layer of both areas is the Linear Low-Density Polyethylene (LLDPE) liner. This liner provides a high strength impermeable layer to prevent water from entering the waste area while also providing some flexibility to allow for any minor settling that may occur over time. The cap will be graded to promote drainage away from the landfill cells and prevent ponding on the cap. Typically, the slopes of caps should not exceed 3H:1V for slope stability, to minimize risks of erosion, and allow for safe operation of equipment (Government of Canada, 2017). Slope stability is dependent on the type of waste disposed in landfills.

Following completion of capping, regular inspections will be completed. Inspections of the final cover will continue post-closure of the SWF. The typical post-closure period ranges between 25 and 30 years. Inspections will include monitoring the cap/final cover for stability, erosion, settlement, vegetative growth, and integrity. If any issues are noticed during the inspections, a plan will be developed and implemented to remediate the issue. Records of the inspections and any remedial actions will be kept and retained throughout the operation, closure, and post-closure period of the SWF.

5.1. Old Landfill Cell Cap (Non-Compost Area)

The intention for the majority of the old landfill cell is that there will be no future activities taking place on top of it. A layer of cover material followed by a layer of sand will be placed over the waste. The source of the cover material has not yet been determined, however, it is planned that material used will be native and clean fill found within the boundaries of Yellowknife. A three (3) layered liner system will be placed on top of this to provide the impermeable layer. This will be followed by a layer of native granular material; a layer of topsoil and then native grasses and plants will be allowed to grow on the surface. This configuration has already been placed on the outside slopes of the CF that have been constructed and a cross-section of this is shown in Figure 5-1. Figure 5-2 shows the future capping system for non-CF areas.

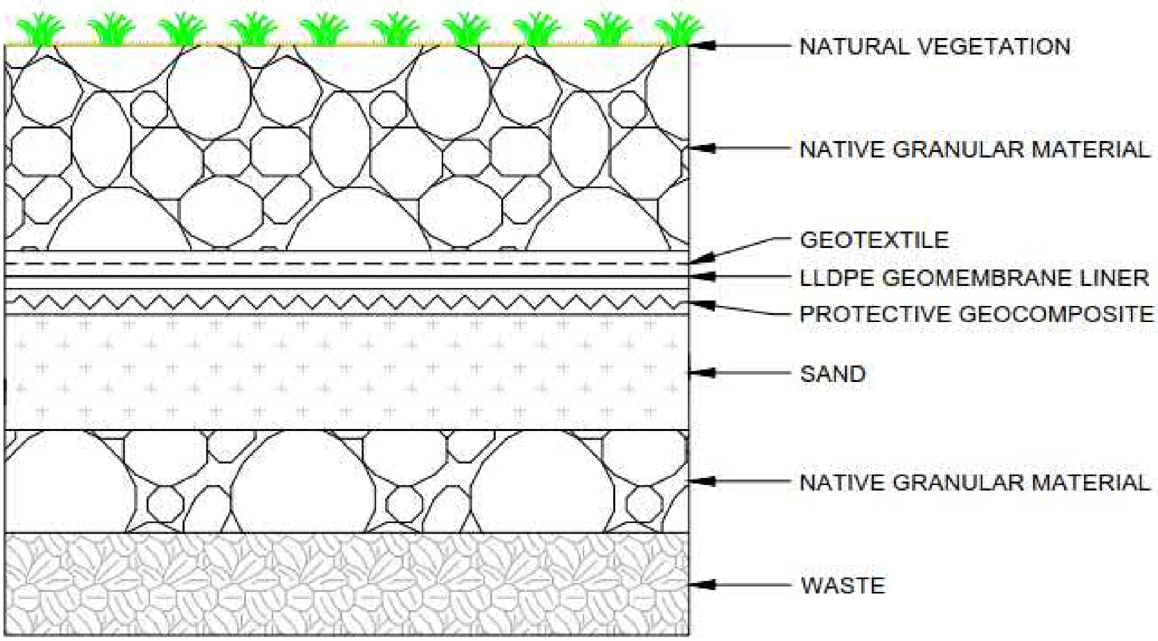

Figure 5-1: Existing Capping System for Non-CF Areas

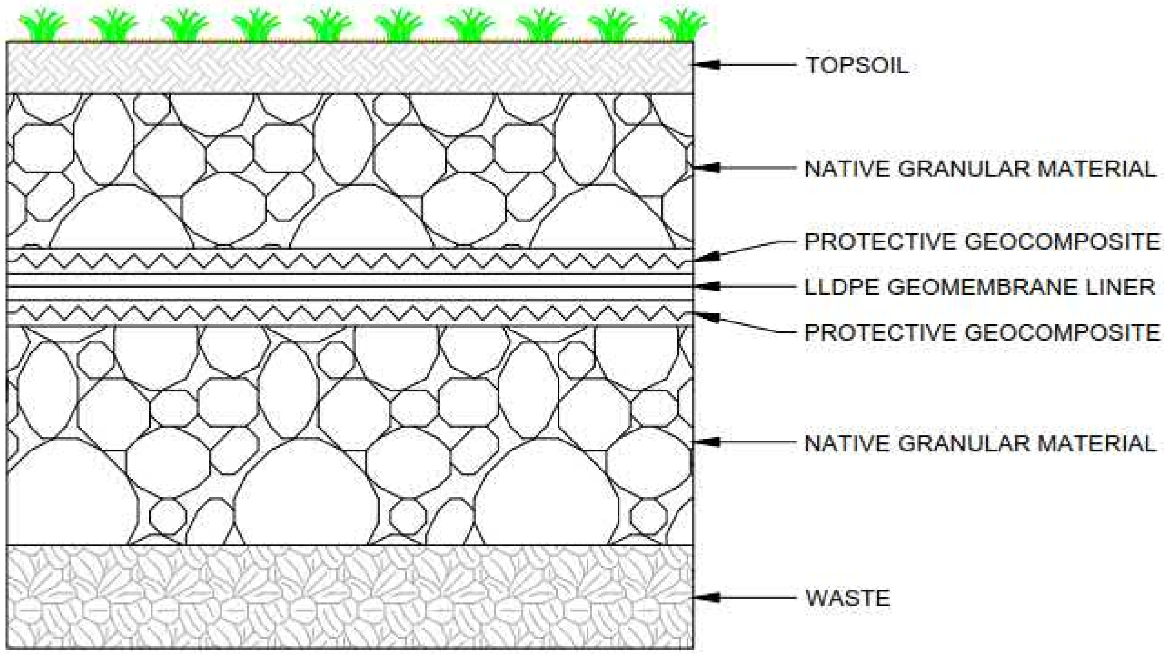

Figure 5-2: Future Capping System for Non-CF Areas

5.2. Centralized Compost Facility Cap

The cap that was constructed beneath the CF provides a few additional layers of protection and support due to the fact that there is traffic on top of this area. This additional protection will also be used underneath the road that will lead across the old landfill cell cap to the CF. Below the liner layer, the capping material remains consistent with other areas with a layer of granular material followed by a layer of sand. The three (3) layer liner system varies slightly from the cap for the old landfill cell area as it included a stronger geogrid layer as opposed to the geotextile liner. This geogrid offers more strength and support and can accommodate the expected traffic in this area. On top of the liner system, there is a second sand layer and then a geotextile covering. This geotextile will prevent any of the granular material located above it from working down through the sand layer and damaging the liner. The final two layers will be 50 mm aggregate and then 20 mm aggregate. This provides the surface of the CF on which any traffic will travel. Figure 5-3 shows the capping system that was used in construction of the CF and will be used when the road to the facility is fully built. Figure 5-4 shows the future capping system for the road area leading across the old landfill cell cap to the CF.

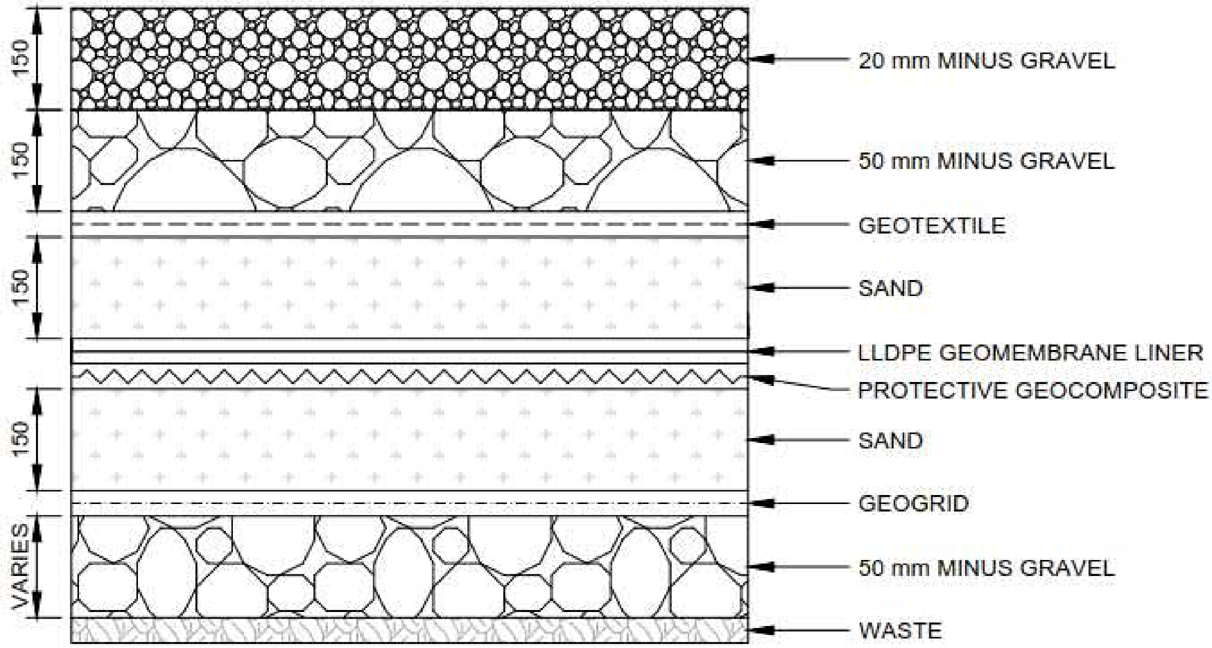

Figure 5-3: Existing Capping System for Centralized Compost Facility

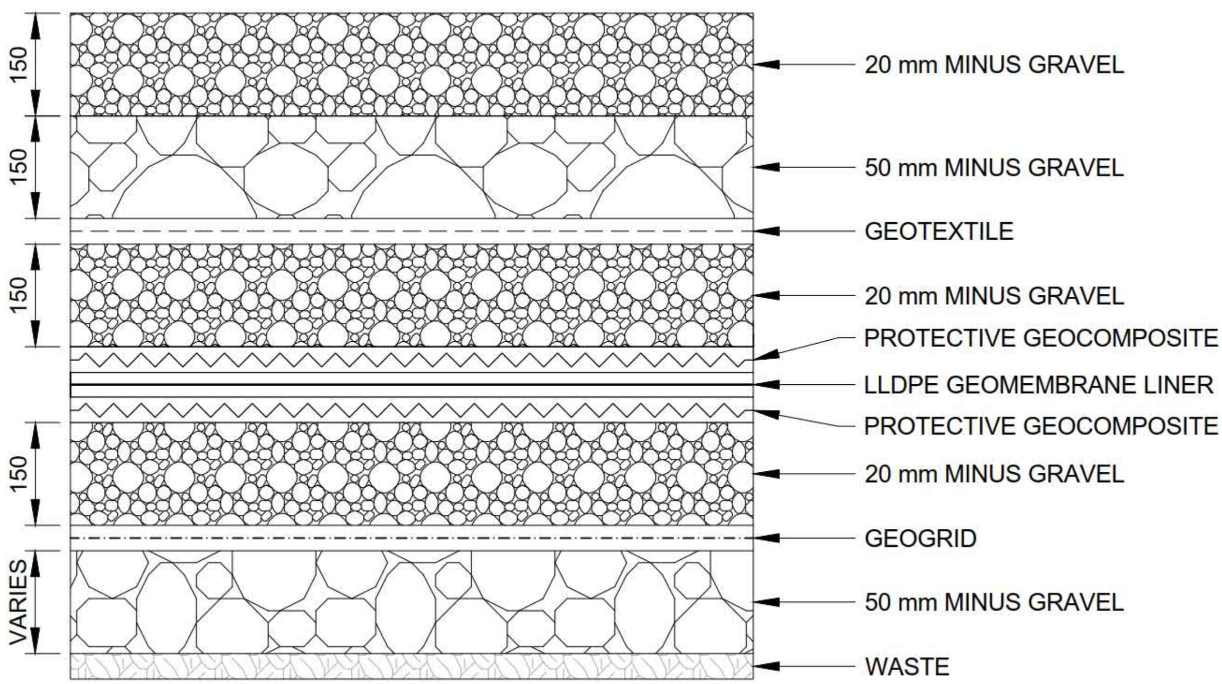

Figure 5-4: Future Capping System for Road System to Centralized Compost Facility

6. ENVIRONMENTAL MANAGEMENT

There are several aspects to consider in the environmental management of the site now and moving forward. As set forth in the requirements for the ICRP in the City's Water Licence, the main aspects that need to be monitored at the SWF are leachate, surface water and groundwater, and landfill gas.

Environmental monitoring will be completed during the operation, closure, and post-closure period (typically 25 to 30 years). This includes monitoring of leachate, surface water, groundwater, and landfill gas as well as inspections completed by the City in accordance with the frequency of the Water Licence conditions. Samples of leachate, surface water, and groundwater will be collected and sent to an International Organization of Standardization (ISO)/International Electrotechnical Commission (IEC) 170125 accredited laboratory that is accredited to analyze for the water quality parameters identified in the Water Licence. If any issues are noticed during the inspections, the issue will be analyzed, and a plan will be developed and implemented to remediate the issue. For additional details, refer to the SWF Operations & Maintenance Manual (City, 2021a) and Interim Groundwater Monitoring Plan (City, 2021d).

Monitoring systems and infrastructure will be regularly inspected and maintained during the operation, closure, and post-closure of the SWF. This is completed to ensure that the systems and infrastructure are working properly and effectively for its purpose.

6.1. Surface and Groundwater Monitoring

The intent of the water monitoring program is to determine if any contaminants are being transported away from the site to surrounding water bodies and if so, what level of threat these pose. To accomplish this, monitoring of surface water and groundwater around the site will be done now and into the future in accordance with the Licence Surveillance Network Program (SNP) requirements. The LDS addresses these issues and makes recommendations for monitoring of the site moving forward. The study recommends "[a] long term monitoring program (completed annually at minimum) to assess changes in surface water and groundwater quality at the SWF". Currently, there are no guidelines in the NWT for groundwater. The City has committed to collecting three (3) years of data as a baseline to determine criteria for future assessment.

6.1.1. Surface Water Monitoring

The City currently monitors the surface water that flows away from the SWF through the SNP. Historically, five (5) sampling stations have been included in this program and these stations are sampled twice annually, in June and September for the parameters listed in the City's Water License. In 2015 the City added two (2) additional sampling points to the plan to capture results from a wider area. The City intends to monitor all seven (7) points twice annually moving forward for the foreseeable future. A figure with the locations of the SNP is included in Appendix A.

6.1.2. Groundwater Monitoring

For information on subsurface water monitoring, please refer to the latest version of the Interim Groundwater Monitoring Plan (City, 2021d) found on the MVLWB registry website.

6.1.3. Leachate Monitoring

There are currently two (2) leachate management sumps at the SWF, one (1) in Cell A and one (1) in Cell B. The sumps are used to collect and remove leachate from the cells and any future cells that are designed and built will also have this provision. The City is considering implementing evaporation cannons to recirculate leachate to the active area(s) of the landfill and reduce leachate. If disposal of the leachate at an off-site location is required, the City will sample and test the leachate for the parameters listed in the City's Water License. A vac truck will be utilized to dispose of the leachate at an appropriate disposal facility approved to handle the leachate. The old landfill cell does not have a sump for collection of leachate, but the monitoring of surface water and groundwater will allow the City to monitor and minimize any off-site migration of contaminants. Additionally, the capping of this cell will further reduce its ability to produce any leachate. For additional information regarding leachate, refer to the SWF Operations & Maintenance Plan.

Leachate collection and removal infrastructure will be maintained and/or repaired to ensure proper operations of the system during operation, closure, and post-closure period. Regular inspections during these periods will be conducted to evaluate the effectiveness of the system and determine whether remedial measures are required.

6.2. Landfill Gas Monitoring & Studies

As detailed in section 4, there is no formal gas monitoring program in place at this time at the SWF; however, informal monitoring does occur on a regular basis and a more accurate monitoring of gas levels within the baling facility is measured with an Armstrong Monitoring AMC-1400 Gas Monitor since it is the most low lying area near the old landfill cell where landfill gas is likely to accumulate. The City had a Landfill Gas Study completed during 2015 and the results were received in 2016. The proposed landfill gas monitoring plan is found in section 4. The City is currently investigating implementation of a gas monitoring plan.

6.3. Hazardous Materials

As the SWF is used for collection and disposal of some hazardous materials, there is the potential for spills to occur on site. The Hazardous Waste Management Plan addresses the ways in which these hazardous materials are managed on site. A Spill Contingency Plan (City, 2021c) has been developed to address how spills are managed along with reporting requirements. The Spill Contingency Plan (City, 2021c) should be utilized along with applicable Safety Data Sheets (SDS) for handling spills in accordance with the applicable rules and regulations to ensure that no off-site water bodies are contaminated. Additionally, any areas that are used, or have been used in the past, to store, transfer, or contain hazardous materials will be thoroughly tested (soils testing) before they are closed out to ensure that no contamination remains at that time. If contamination is found, remedial measures will be undertaken to handle the contamination and prevent impacts migrating off-site. Soils testing and remedial measures will be completed in accordance with the Environmental Guideline for Contaminated Site Remediation (GNWT, 2003). As there are presently no plans to close out any of these areas, the specific nature of this testing is unknown at this time.

6.4. Reporting Summary

The City reports the results of the SNP to the MVLWB on a regular basis in the applicable Quarterly Report and again in the Annual Report. The City will notify the MVLWB in advance of any closures. Reporting of testing done under the ICRP will be submitted with the City's Annual Report in accordance with the Water Licence conditions. Test results will be interpreted and compared with applicable environmental guidelines and previous testing to determine if there are potential issues that require further investigation and measures. A summary of all hazardous waste received and disposed of at the SWF is included in the Annual Report and any spills or incidents involving hazardous materials are reported immediately as per the governing rules and regulations. As this ICRP is intended to be updated as required, a review of it will take place at least once a year and an updated version will be submitted with when necessary.

Annual reporting will continue to be composed and submitted to the MVLWB during the closure and post-closure period in accordance with the current Water Licence conditions. The annual reports will include a summary of the environmental monitoring, interpretation of results, inspections of the final cover and leachate collection infrastructure, any issues observed, and remedial actions undertaken.

7. IMPLEMENTATION SCHEDULE

Some activities have already begun that will eventually help facilitate the closure of the old landfill cell at the SWF. The old landfill cell is still in operation and accepting construction waste to bring the cell up to its final design grade and contouring. Capping of the footprint of the CF and subsequent construction of the CF was completed in 2017. An overview of previous activities completed and the expected timeline for upcoming major closure activities at the SWF is provided in Appendix E. Several of the activities will be dependent on budget availability and City Council priorities and, as with the rest of this ICRP, updates will be made to the timeline when they become available.

Long-term, as the growth of the SWF progresses, the City intends to have a similar timeline for additional new landfill cells. The MVLWB will be informed of plans for the SWF. Typically, design and construction of a new cell will begin two (2) years before the previous cell is scheduled to be filled, the cell will then be opened and operational for five (5) to ten (10) years, followed by a two (2) to five (5) year period to tie it in to the next cell and close out the old cell. This timeframe will vary slightly depending on the available space, the designed capacity of the future cells, and quantity of waste received on an annual basis. Closure activities that arise at other areas within the SWF will be added to the schedule when they are needed and when more details on them become available.

The entire ICRP will be reviewed on a yearly basis and updates will be submitted to the MVLWB when changes occur. The City intends for the current SWF to be operational for many years to come and that the ICRP will adapt and progress as needed along with the SWF itself.

REFERENCES

Alberta Government. Code of Practice for Landfills. Edmonton, AB: Alberta Queen's Printer.

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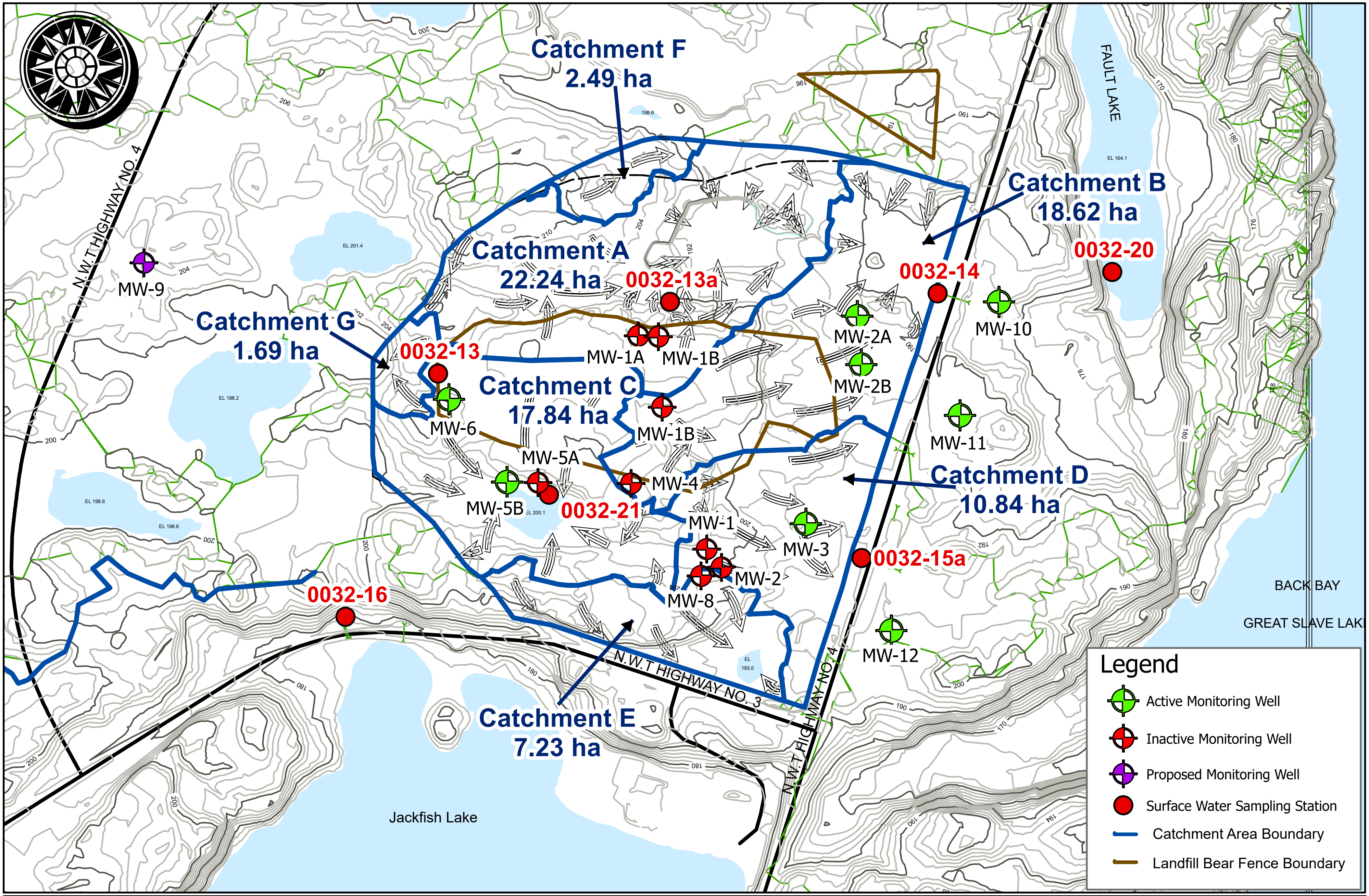
APPENDIX A

Figures



City Of Yellowknife

Public Works & Engineering

PROJECT: Solid Waste Facility O&M Manual	SCALE: 1:9,696
	CREATED BY: *KD*
	FILE: *20_SWF_O&M_SNP_Station_Locations*
TITLE: Figure 1 - SNP Stations and Groundwater Monitoring Locations	DATE: *November 04, 2020*

APPENDIX B

Landfill Gas Monitoring Plan

January 22, 2015

DILLON CONSULTING

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City of Yellowknife
4807 – 52nd Street
Yellowknife, NT X1A 2N4

Attention: Alison Ryan, Public Works

City of Yellowknife – Landfill Cell B – Landfill Gas

Dear Ms. Ryan;

The City of Yellowknife requested Dillon Consulting Limited (Dillon) to review the concerns raised by the Mackenzie Land and Water Board with respect to the closure operations of the City's old landfill cell. Specifically these questions were raised in the Board's communication dated November 6, 2014, and are quoted below.

1. *"Explain how proper venting of landfill gas is being incorporated into the design of all phases of the landfill cell closure given that construction of the compost pad and landfill cap is scheduled to be nearly complete prior to completion of the Landfill Gas Study and finalization of a gas venting system.*
2. *Confirm that potential landfill gas management measures, including vertical gas vent pipes, could be installed following completion of the compost pad and landfill capping, in the event that the Landfill Gas Study determines that measures are required.*
3. *Provide information on the stages at which a registered professional with specific expertise in landfill gas has or will be involved in:*
    a. *the design and construction of the compost pad and landfill cap; and*
    b. *the development and implementation of the Landfill Gas Monitoring*

Additionally, the Board requests the City to substantiate their assertion that landfill gas generation is not a concern and that monitoring is not needed currently."

Mr. Chris Shortall, P. Eng. (NS) and Mr. Gary Strong, P. Eng. completed the review of the above issues. Their CVs are attached. Dillon's involvement in the City's landfill operation dates back a number of years. Recently, Dillon was involved in the pilot scale capping work completed in 2011 and 2012 on the old cell, as well as the development of the groundwater monitoring wells at the facility. Dillon was the engineer of record for the detailed design and construction administration of the current landfill cell (Cell A). Both Mr. Shortall and Mr. Strong were involved in those previous projects, and are currently involved in the development of the design for the expansion of the landfill (Cell B). Our comments are based on our knowledge of the site, and our experience with similar facilities throughout Canada.

Gas Venting Design and installation

Gas venting systems can be installed, based on the anticipated generated landfill gas, prior to capping, during capping, or after the capping is complete. Each of these approaches is used depending on the site logistics. There are both advantages and disadvantages to each of the approaches. When progressive reclamation is being used, as is the case with the City of Yellowknife closure, then installing the gas vents after the capping system is installed has certain advantages. The design and installation of the venting system can proceed in concert with the progressive reclamation and closure activities.

Below is a brief description of how a vertical venting system is installed through the capped cell and the consideration of taking this approach.

- Equipment is mobilized to the drilling site. With the use of tracked drilling equipment (most common in YK) the equipment can travel over the closed cell without the need for access roads. Where rubber tired drilling equipment is required, additional care must to take to prevent damage to the liner system for the closed cell. The proposed compost facility will have an access road to the area, therefore either tracked, or rubber tired drilling equipment can be used.
- The liner system is cut to allow the installation of the vertical piping. Typically a drill rig is used to auger a 450 mm or larger diameter hole, and to install the vertical pipe, however a backhoe / excavator can also be used.
- The slotted vertical pipe is installed.
- The liner system is sealed around the pipe, and the liner covered and the areas returned to the required grade.

Substantiation that landfill gas generation is not currently a concern.

The presence of landfill gas LFG (primarily methane) can be detected in a number of ways.

- Commonly the presence of LFG is detected and reported because of odour issues associated with the landfill. Residence next to the landfill will register complaints of the odour (e.g. rotten eggs - hydrogen sulfide) . Similarly, users of the landfill or site operation staff would notice and record the ordour issue. Neither of these has occurred at the Yellowknife landfill. It should be stated that there are no residences adjacent to the landfill, so the likelihood of receiving an odour complaint from a City resident is low. However, the site is open to the public, and the have been no complaints related to odour reported by the public.

- Site operations staff may also note the sound of "hissing" when walking on the closed cell. Or if there is ponded water, they may note that there is bubbling in the water. Neither of these has been noted by operations staff.
- When sampling groundwater monitoring wells, there will be the presence of landfill gas smell coming from the groundwater monitoring well. Both Dillon and the City have been involved in the installation and sampling of the groundwater monitoring wells on site. To date there has been no report of landfill gas odours from the groundwater monitoring wells.

Summary

The design and installation of LFG systems during a progressive reclamation operation is typical in the industry. In this case, there are no constraints to the development of a gas venting system being created by the development of the compost facility.

There are no indications that LFG is present based on the lack of reported incidents of ordour concerns. The presence of LFG should be continued to be monitored as described above. Increased effort in monitoring can be achieved through the use of portable gas detectors. The likely locations that LFG can be monitored would be the existing monitoring wells, and within any proximate building. The two buildings at site that could be monitored are the E-Waste facility and the bailing facility.

Should you have any question's please do not hesitate to contact me at 867-920-4555, ext. 4111.

Yours sincerely,
DILLON CONSULTING LIMITED

REGISTERED PROFESSIONAL ENGINEER
G. STRONG
01/21/15
N.W.T.

Gary Strong, P.Eng.
Project Manager

Christopher Shortall, P. Eng (NS)
Design Engineer, P. Eng. (NS)

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 010
DILLON CONSULTING LIMITED
01/21/15

GS:jma

Encl.

DILLON CONSULTING

CITY OF YELLOWINIFE

Landfill Gas Monitoring Plan

January 2016 – 14-9696

January 20, 2015

City of Yellowknife
P.O. Box 580
Yellowknife NT
X1A 2N4

Attention: Chris Greencorn, Director, Public Works and Engineering

Landfill Gas Monitoring Plan

Dear Mr. Greencorn:

Dillon Consulting Limited (Dillon) is pleased to submit the draft landfill gas (LFG) monitoring plan to address the requirements of the Water License Schedule 3, Item 1.m. The intent of this report is to document our engineering review of the LFG needs and requirements of the City of Yellowknife Landfill.

Yours sincerely,

DILLON CONSULTING LIMITED

Gary Strong, P.Eng
Project Manager, Partner

GS:adc

Our file: 14-9696-1000

Table of Contents

DILLON CONSULTING

1.0 Background

The Yellowknife Solid Waste Facility SWF is located on the Ingraham Trail, approximately 2 km north of the city centre. The new second generation landfill is located approximately 430 meters from the existing landfill site.

Residents of Yellowknife have been using the current SWF site since the early seventies. The original disposal site consisted simply of a valley in the topography where the community dumped their waste. The facility was not licensed and, consistent with typical operations in the North at the time, operated without an attendant or monitoring program (Dillon, 2005). As a result, all types of wastes were dumped at the site including scrap vehicles and metals, household waste, construction and demolition waste, waste from surrounding mines, honey bags and other undocumented hazardous and non-hazardous wastes.

In 1990, the SWF stopped burning waste for volume reduction and conversion of the site to a more typical sanitary SWF operation began (Dillon, 2006). The SWF, in its current form, began operations in 1993 when buildings were erected and the SWF was re-organized to house a new baler to commence baling operations (Dillon, 2006). All collected residential waste is deposited at the baling facility to be baled. Construction and demolition waste, and waste from commercial collection bins that are not compatible with baling operations were deposited directly in the disposal site and compacted with a dozer. Other wastes including white goods, tires, oil drums, old paint and batteries which are segregated away from the general waste stream are stockpiled to be processed.

In 2011, a second generation landfill cell was constructed in a quarry adjacent to the existing disposal site and the disposal site stopped accepting waste. Figure No. 1 identifies the current configuration of the SWF.

1.1 Landfill Gas

Assessment of landfill gas (LFG) and monitoring was conducted at the original SWF in 2004 and 2005 by Jacques Whitford. The results of this assessment confirmed the presence of methane in soil at concentrations exceeding the Lower Explosive Limit (LEL) of 50,000 parts per million by volume. The concentration of methane measured in the monitoring wells did not directly correlate to ambient methane concentrations; however, the concentrations measured indicate that there is generation of LFG at the existing landfill.

Since the previous cell was closed at the site, landfill gas concentrations have been periodically monitored and intervention applied when necessary to prevent landfill fires.

FIGURE 1: LEASE BOUNDRY LIMIT OF THE YELLOWKNIFE SOLID WASTE FACILITY

2.0 2.0 Waste Composition

Municipal solid waste is currently delivered to the baling facility, baled, and then placed in the landfill. Construction and demolition and commercial collection waste bins that are not compatible with baling operations are dumped at the landfill and compacted with a dozer. Other wastes includes: white goods, tires, oil drums, old paint and batteries, which are segregated from the general waste stream and stockpiled to be processed. Table No. 1 presents the typical composition of waste by percentage and tonnage. The percentage column is based on the results of the 2007 waste composition study, while the tonnage is extrapolated from the 2006 annual waste disposed for each waste sector.

For the purpose of this report this waste composition is considered to be representative of the waste that has been placed since the site became operational.

TABLE 1: TYPICAL WASTE COMPOSITION

Material	Small Commercial/ Multi-Family Units	Large Commercial	Single Family Units	Estimated Disposal (Tonnes)	Waste Stream Composition (%)
Paper Products	2,132	841	367	3,341	37.1
Organics	1,233	419	702	2,353	26.1
Plastic	616	224	280	1,120	12.4
Household Hygiene	230	40	186	455	5.1
Wood Waste	256	47	3	306	3.4
Textiles	244	9	30	284	3.2
Ferrous Metal	188	17	56	261	2.9
Bulky Items	193	4	23	220	2.4
Glass	134	24	47	206	2.3
Composites	130	9	26	165	1.8
Other Unspecified	45	20	6	71	0.8
Inorganic (soils)	29	16	11	57	0.6
Aluminum	35	3	8	46	0.5
Fines	32	8	4	44	0.5
Special Care Waste	31	8	1	41	0.5
Renovation Waste	25	-	1	25	0.3
Rubber	3	4	-	7	0.1
Tires	-	-	-	-	0.0
Totals	5,556	1,693	1,752	9,001	100.0

Source: *City of Yellowknife Solid Waste Composition Study and Waste Reduction Recommendations, Gartner Lee Limited 2007*

3.0 Regulatory Requirements

3.1 Pertinent Regulations/Guidelines

The Northwest Territories currently has no regulations for landfill gas monitoring. However, the City of Yellowknife is following the “Standards for Landfills in Alberta” (http://environment.gov.ab.ca/info/library/7316.pdf). In section 5.11 Subsurface Landfill Gas Monitoring Program it states:

a) The Subsurface Landfill Gas Monitoring Program shall include, at a minimum, all of the following:
   (i) a description of the subsurface landfill gas monitoring sites and their locations;
   (ii) the methods to be used for measurement and detection of the lateral migration of subsurface landfill gas;
   (iii) the frequency for measurement of subsurface landfill gas; and
   (iv) a Subsurface Landfill Gas Contingency Plan for the mitigation of subsurface landfill gas migration.

b) The subsurface landfill gas monitoring data shall be interpreted by a professional registered with APEGGA, or other professional authorized in writing by the Director, to determine the potential impacts from the subsurface migration of landfill gas.

4.0 The Composition of Landfill Gas

LFG is generally produced as organic compounds breakdown in anaerobic conditions. While the LFG consists of a mixture of different gases, typically it contains (by volume) 45% to 60% methane and 40% to 60% carbon dioxide. There are also trace amounts of nitrogen, oxygen, ammonia, sulfides, hydrogen, carbon monoxide, and non-methane organic compounds (NMOCs).

Methane is an odourless, flammable gas, with a density of 0.68 kg/m3 @ 15^{o}C making methane lighter than air which has a density of 1.20 kg/m^3@ 15^{o}C. Methane is widely distributed and the atmosphere naturally contains approximately 0.0002% (by volume). Additionally, it is explosive in concentrations between 5% and 15% (by volume). These values (limits) are identified as the lower explosive limit (LEL) and upper explosive limits (UEL). Carbon Dioxide is an odourless, non-flammable gas, with a density of 1.84 kg/m^3 @ 15^{o}C, making it heavier than air, and is normally present in the atmosphere in concentrations of 0.04% (by volume).

4.1 The Phases of Landfill Gas Generation

When municipal solid waste is placed in a landfill it begins to decompose aerobically (with oxygen). As additional waste is placed in the landfill the older waste is covered and the availability of oxygen decreases, resulting in anaerobic (without oxygen) conditions. As landfills operate over a number of years the placed wastes (vertically and horizontally) in the landfill are decomposing at different phases. The bacteria (aerobic and anaerobic) in the landfill decompose landfill waste in four phases and the composition of the LFG produced changes with each of the four phases.

Phase I

During the first phase of decomposition, aerobic bacteria consume oxygen while breaking down long molecular chains of complex carbohydrates, proteins, and lipids that comprise organic waste. Nitrogen content is high at the beginning of this phase, with the primary byproduct of this phase being carbon dioxide. This phase continues until available oxygen is depleted and can last for days or months, depending on how much oxygen is present when the waste is disposed of in the landfill.

Phase II

Phase II decomposition starts after the oxygen in the landfill has been used up. In an anaerobic process bacteria convert compounds created by aerobic bacteria into acetic, lactic, and formic acids and alcohols such as methanol and ethanol. This causes the landfill to become acidic. As the acids mix with available moisture (leachate) they cause certain nutrients to dissolve, making nitrogen and phosphorus available to the increasingly diverse species of bacteria in the landfill. The gaseous byproducts of these processes are carbon dioxide and hydrogen.

If the area where waste has been placed is disturbed or if oxygen is somehow introduced into the landfill, the waste in that area will return to Phase I.

Phase III

Phase III decomposition starts when some of the anaerobic bacteria consume the acids produced in Phase II and form acetate, an organic acid. This process causes the landfill to become a more neutral environment where methane-producing bacteria begin to form. Methane and acid producing bacteria have a mutually beneficial relationship. Acid-producing bacteria create compounds for the methanogenic bacteria to consume. At the same time methanogenic bacteria consume the carbon dioxide and acetate, too much of which would be toxic to the acid-producing bacteria.

Phase IV

Phase IV decomposition begins when both the composition and production rates of LFG remain relatively constant. Here the LFG is approximately 45% to 60% methane (by volume), 40% to 60% carbon dioxide, and 2% to 9% other gases. LFG is produced at a stable rate in Phase IV, typically for about 20 years; however, gas will continue to be emitted for 50 or more years after the waste is placed in the landfill (Crawford and Smith 1985). Gas production might last longer, for example, if greater amounts of organics are present in the waste, such as at a landfill receiving higher than average amounts of domestic animal waste. Figure No. 2 depicts the phases of LFG generation.

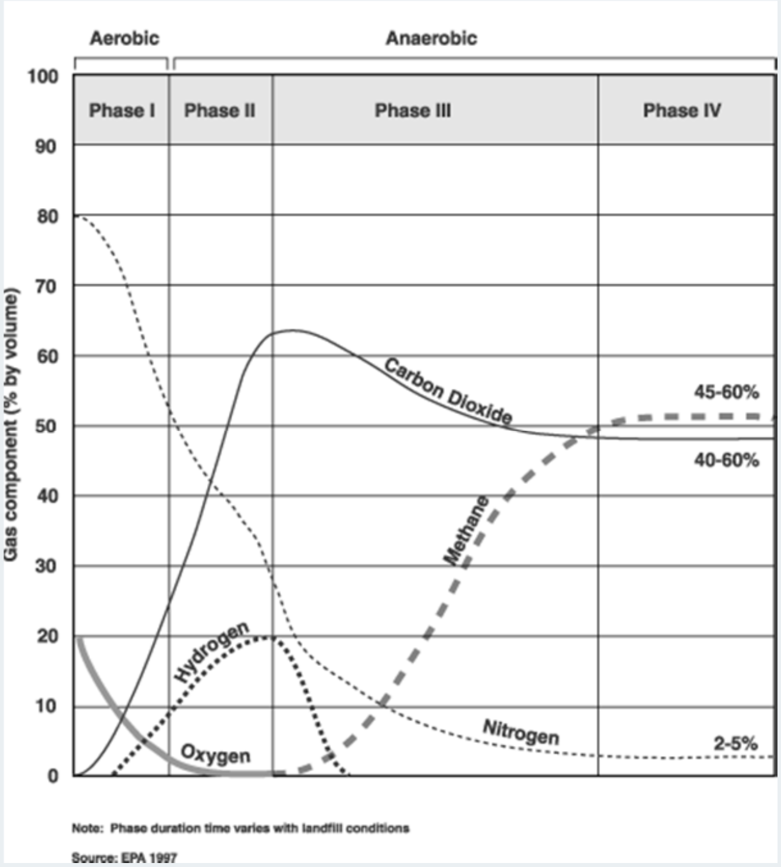

FIGURE 2: PHASES OF LANDFILL GAS GENERATION

LFG can also be formed by:

- Volatilization. Landfill gases can be created when certain wastes, particularly organic compounds, change from a liquid or a solid into a vapor. This process is known as volatilization. Non-methane organic compounds (NMOCs such as household cleaning products, materials coated with or containing paints and adhesive) in landfill gas may be the result of volatilization of certain chemicals disposed of in the landfill.
- Chemical reactions. Landfill gas, including NMOCs, can be created by the reactions of certain chemicals present in waste. For example, if chlorine bleach and ammonia come in contact with each other within the landfill.

4.2 Factors Affecting Landfill Gas Generation

The rate and volume of landfill gas produced depends on the characteristics of the waste and environmental factors, such as:

- Waste composition. The more organic waste in the landfill, the more LFG gas is produced by the bacteria during decomposition. The more chemicals in the landfill, the more likely NMOCs and other gases will be produced either through volatilization or chemical reactions.
- Age of refuse. Landfills usually produce appreciable amounts of gas within 1 to 3 years; with peak gas production usually occurs from 5 to 7 years after the waste is buried. Generally, waste buried less than 10 years produces more landfill gas through bacterial decomposition, volatilization, and chemical reactions than waste buried more than 10 years.
- Temperature. As the landfill's temperature rises, bacterial activity increases, resulting in increased gas production. Increased temperature may also increase rates of volatilization and chemical reactions. Bacterial activity releases heat, typically stabilizing the temperature of a landfill between 25° C and 45° C. Colder temperatures obstruct bacterial activity and bacterial activity drops off dramatically below 10° C. Weather changes have a far greater effect on gas production in shallow landfills as the bacteria are not insulated against temperature changes.
- Presence of oxygen in the landfill. Methane is produced only when oxygen is no longer present in the landfill.
- Moisture content. The presence of moisture in a landfill increases gas production because it encourages bacterial decomposition and transports nutrients and bacteria to all areas within a landfill. Moisture may also promote chemical reactions that produce gases. Moisture content of 40% or higher, based on the wet weight of waste, promotes maximum gas production.
- Waste compaction slows gas production because it increases the density of the landfill contents, decreasing the rate at which water can infiltrate the waste.

4.3 Landfill Gas Movement

As LFG is produced it expands and fills the available space and moves through the pore spaces within the waste and cover soils. As methane is lighter than air and some other LFG gases are typically lighter than air they have a tendency to move upward, usually through the landfill surface. The upward movement of landfill gas can be slowed by densely compacted waste, daily soil cover and covers.

When upward movement is slowed, the LFG tends to move horizontally to other areas within the landfill or to areas outside the landfill, where it can resume its upward path. Basically, the gases follow the path of least resistance. Three factors that influence the migration of landfill gases are:

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- Permeability. Gases will move according to where the paths of least resistance occur. Sandy soils are highly permeable, while moist clay tends to be much less permeable. Gases also move through areas of high permeability (e.g., sand or gravel) rather than through areas of low permeability (e.g., clay or silt). Landfill covers are often made of low-permeability soils, such as clay.
- Pressure. Gases accumulating in a landfill create areas of high pressure in which gas movement is restricted by compacted refuse or soil covers and areas of low pressure in which gas movement is unrestricted. The variation in pressure throughout the landfill results in gases moving from areas of high pressure to areas of low pressure. Movement of gases from areas of high pressure to areas of lower pressure is known as convection. As more gases are generated, the pressure in the landfill increases, usually causing sub-surface pressures in the landfill to be higher than either the atmospheric pressure or indoor air pressure. When pressure in the landfill is higher, gases tend to move to ambient or indoor air.
- Diffusion (concentration). Diffusion describes a gas's natural tendency to reach a uniform concentration in a given space. Gases in a landfill typically move from areas of high gas concentrations to areas with lower gas concentrations. Because gas concentrations are generally higher in the landfill than in the surrounding areas, landfill gases diffuse out of the landfill to the surrounding areas with lower gas concentrations.
- Landfill cover type. If the landfill cover consists of relatively permeable material, such as gravel or sand, then gas will likely migrate up through the landfill cover. If the landfill cover consists of silts and clays, it is not very permeable; gas will then tend to migrate horizontally underground. If one area of the landfill is more permeable than the rest, gas will migrate through that area.
- Natural and man-made pathways. Drains, trenches, and buried utility corridors (such as tunnels and pipelines) can act as conduits for gas movement. The natural geology often provides underground pathways, such as fractured rock, porous soil, and buried stream channels, where the gas can migrate.
- Wind speed and direction. Landfill gas naturally vented into the air at the landfill surface is carried by the wind. The wind dilutes the gas with fresh air as it moves it to areas beyond the landfill. Wind speed and direction determine the gas's concentration in the air, which can vary greatly from day to day, even hour by hour. In the early morning, for example, winds tend to be gentle and provide the least dilution and dispersion of the gas to other areas.
- Moisture. Wet surface soil conditions may prevent landfill gas from migrating through the top of the landfill into the air above. Rain and moisture may also seep into the pore spaces in the landfill and "push out" gases in these spaces.
- Groundwater levels. Gas movement is influenced by variations in the groundwater table. If the water table is rising into an area, it will force the landfill gas upward.

- Temperature. Increases in temperature stimulate gas particle movement, tending also to increase gas diffusion, so that landfill gas might spread more quickly in warmer conditions. Although the landfill itself generally maintains a stable temperature, freezing and thawing cycles can cause the soil's surface to crack, causing landfill gas to migrate upward or horizontally. Frozen soil over the landfill may provide a physical barrier to upward landfill gas migration, causing the gas to migrate further from the landfill horizontally through soil.
- Atmospheric and soil gas pressure. The difference between the soil gas pressure and atmospheric pressure allows gas to move either vertically or laterally, depending on whether the atmospheric pressure is higher or lower than the soil gas pressure. When atmospheric pressure is falling, landfill gas will tend to migrate out of the landfill into surrounding areas. As atmospheric pressure rises, gas may be retained in the landfill temporarily as new pressure balances are established.

4.4 Landfill Gas Modeling

LFG modeling is primarily undertaken to forecast the potential LFG generation rates such that decisions can be made relating to capital expenditures, and risk and performance evaluation.

Capital Expenditures can be developed based on the probable LFG generation rates so that collection wells or vents, transportation piping and processing plant and flare can be sized for present and future requirements.

Risk associated with the placement of waste can be assessed according to near term migration of odours and greenhouse gas contributions along with the pathways and receptors. Lateral migration could occur, where monitoring could be used to provide presence or absence of migrating LFG.

Performance Evaluation provides a benchmark against which field measurements for extraction rates can be compared. The caution is that modeling is inexact.

Landfill Gas Modeling

LFG is generated from decomposing biological waste material in an anaerobic environment. Each type of waste placed in the landfill (e.g. bones, fruit, paper wrapping) has the potential to contribute to the generation of LFG based on the nature of the waste. Generally, the higher the organic content the higher the potential to contribute to the generation of LFG.

There are a number of models that can be used to predict the generation of LFG based on the following inputs:

- Annual waste tonnages;

- Landfill specific waste composition;
- Moisture content;
- Waste decomposition rate

The model that is commonly used, and has been accepted by Environment Canada, is the Microsoft Excel Landfill Gas Emission Model (LandGEM), which has been adopted by the U.S. EPA as part of its New Source Performance Standards (NSPS) for MSW landfills.

LandGEM is a first-order decomposition rate equation for quantifying emissions from decomposing waste in municipal solid waste landfills. The model should be considered as a screening tool where better input data provided better estimates of potential LFG generation. The model has the following user input parameters:

- Annual waste tonnages
- Landfill gas composition
- Methane generation rate ($year^{-1}$) - k
- Potential methane generation capacity (m^3/tonne) - L_o

It assumes that the gas production rate is at its peak upon initial waste placement, after a short lag time during which anaerobic conditions are established in the landfill. The gas production rate is then assumed to decrease exponentially (i.e., first order decay) as the organic fraction of the landfill refuse decreases.

The model equation is as follows:

$$Q = \sum_{i=l}^{n} 2kL_0M_i\left(e^{-kt}\right)$$

Where,

$$Q = Methane\ generation\ rate\ from\ the\ landfill\ in\ the\ i^{th}\ year, \frac{cf}{yr}$$

$$k = Methane\ generation\ rate\ constant, \frac{1}{yr}$$

$$L_0 = Methane\ generation\ potential, \frac{m3}{tonne}$$

$$M_i = Mass\ of\ refuse\ in\ the\ i^{th}\ section, tonne$$

$$t_i = Age\ of\ the\ i^{th}\ section, yrs$$

$$i = Section\ number$$

The methane generation rate constant, k, determines the rate of methane generation for the waste in the landfill. The higher the value of k, the faster the methane generation rate increases and then decreases over time. The value of k is a function of the following four factors:

- moisture content of the waste
- available nutrients for the bacteria to produce methane and carbon dioxide
- pH
- temperature.

The potential methane generation capacity of refuse, Lo, depends on the composition and type of waste (e.g., residential, commercial, construction and demolition) placed in the landfill. The higher the cellulose (e.g., wood, paper) content in the waste, the higher the value of the potential methane generation capacity. If the landfill conditions (e.g., moisture content, pH, temperature) are not favorable to the growth of anaerobic bacteria and the associated four phases the potential methane generation capacity of the waste may never be reached.

Environment Canada (EC) is responsible for preparing a National Inventory Report of Greenhouse Gas Sources and Sinks in Canada as part of Canada's signing of the United Nations Framework Convention on Climate Change. Part 1, Section 8.2 Solid Waste Disposal on Land of the 1990-2012 Inventory addresses emissions from landfills and provided typical values for k and L_o for each Province and Territory. For the Northwest Territories the following values are recommended for municipal solid waste:

- k – 0.003 year $^{-1}$
- L_o – 62.36 kg Ch_4/tonne of waste
    - LandGEM requires L_o to be in units of m^3 CH_4/tonne. Based on a density of 0.68 kg/m^3 at 15^oC for CH_4 for an equivalent value of a L_o of 91.7 m^3 CH_4/tonne.

The disposal site was operational from the seventies to 2010 and until 1990 burning was used as a means of reducing volume. Also, it is our understanding that early disposal records are not available. LandGEM requires an estimated annual tonnage for each year a disposal site is operational to be able to prepare an estimate of the potential generated LFG. To provide an approximation of a potential waste tonnage placed in the disposal site the following methodology was used:

- Census population data from Statistics Canada for Yellowknife for the years 1971, 1981 and 1991
- Population for the non-census years was interpolated from the census data
- Census population data from the Northwest Territories Bureau of Statistics for the years 1996 to 2010
- From the 2005 Landfill Volume Assessment (Dillon, 2005) the disposed tonnage in 2004 was obtained at 13,393 tonnes.

- An estimated disposal tonnage per person was calculated in 2004 as 13,393 tonnes/19,622 persons = 0.68 tonnes/person.

- An approximation of a potential waste tonnage placed in the disposal site was determined based on the population and disposal tonnage per person

The LandGEM model run for municipal solid waste is presented in Appendix B, with Figure No. 3 graphically presenting the results.

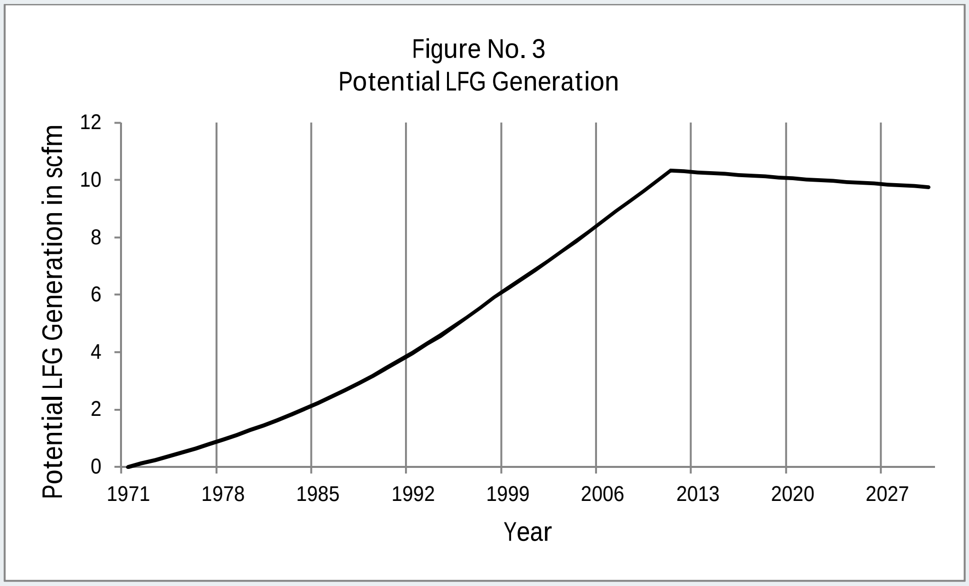

FIGURE 3: POTENTIAL LFG GENERATION

Model Limitations

Limitations exist with any modeling. Record keeping requirements have changed over time relating to accurate tonnage and waste received. The option of the proposed generation rates are based on the assumptions presented in this report. Changes in waste composition, tonnages, temperature, precipitation, landfill operations, daily and final cover affect the generation of landfill gas. Dillon does not guarantee the quality and quantity of the landfill gas that may potentially be generated.

5.0 Landfill Gas Collection/Monitoring

The results of the LFG modeling indicate that an active collection, transmission and treatment system is not required. While there is not sufficient LFG for active collection a passive system is recommended to allow for LFG to be released in a controlled manner to minimize the subsurface migration of LFG. Similar to active collection systems, passive systems are required to handle the anticipated potential LFG generation rates over the projected active and closed life of the landfill.

Passive Collection System

Passive systems use the variation in the pressure within the landfill to vent the LFG into the atmosphere. Similar to an active collection system, vertical vents or extraction well are installed in the landfill to depths typically between 50 to 90% of the waste depth. They can be installed during active waste placement or after closure. The efficiency of the passive collection system is influencing by atmospheric pressure and pressure within the landfill and how well the LFG is contained (e.g., engineered liner system, soil based daily cover, engineered cover). A high atmospheric pressure will "push" air into the landfill, where a low internal landfill pressure is not sufficient to "push" the LFG to an extraction well.

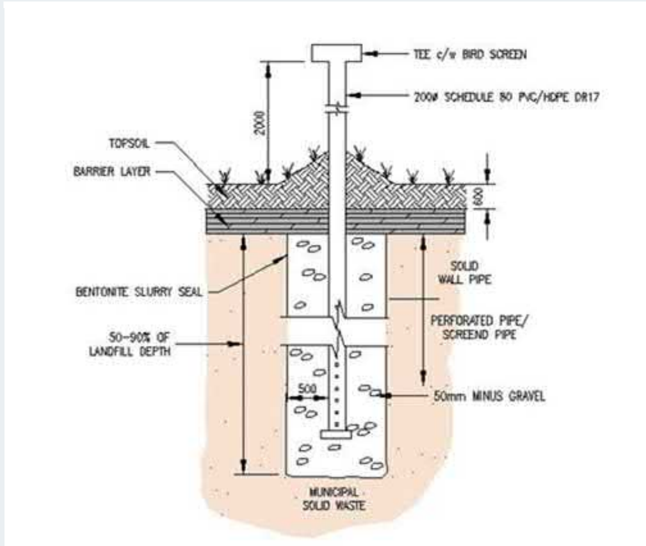

FIGURE 5: PASSIVE LFG VENT INSTALLED UNDER THE COVER

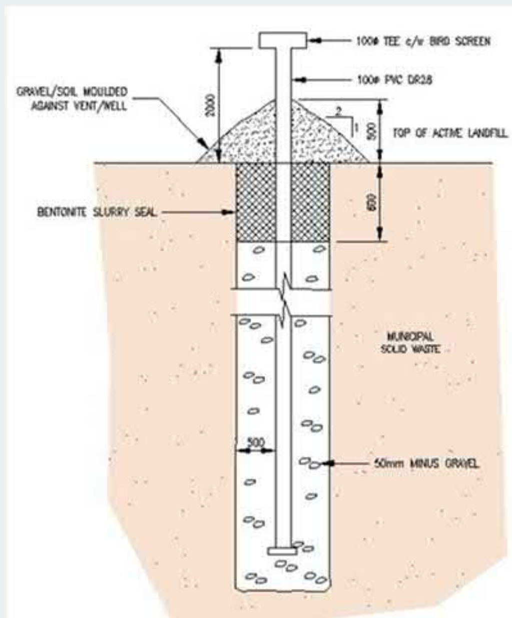

FIGURE 6: PASSIVE VENT INSTALLED DURING LANDFILLING

The spacing of the extraction wells within the landfill is based on the wells being able, over the active and closed life of the landfill, to be able to collect LFG from a defined area of the landfill. Typically, passive extraction wells are spaced at 60 m and at high elevations within the landfill. Additional wells are placed if perimeter monitoring probes indicate levels of LFG (e.g., methane exceeding regulatory limits). Figure No. 4 presented in Appendix A identifies the proposed passive extraction well system. With Figure No. 5 and 6 depicting the proposed LFG vents/wells.

Perimeter Monitoring Network

As presented previously LFG tends to migrate in the landfill following the path of least resistance or from high to low areas of concentration. With methane lighter than air the tendency is for LFG to move vertically until the atmosphere or a barrier (e.g., final cover, cover soils, dense waste) is reached. When this occurs the LFG tends to move horizontally in or outside the landfill. As the LFG wants to move vertically the depth of monitoring probes are typically at or just below the lowest elevation of waste in the landfill or an impermeable layer.

The horizontal distance is difficult to predict and is a function of atmospheric pressure, soil and bedrock permeability, frozen ground, site infrastructure (e,g., ditching, structures, basements, elevation location).

To monitor the potential horizontal movement LFG probes are installed between the landfill and a potential receptor. The locations proposed for this landfill are based on the site infrastructure, installed liners, soil types, property boundaries and groundwater/water bodies. The proposed probe locations are presented on Figure No. 7 in Appendix A and a typical probe is presented in Figure No. 8

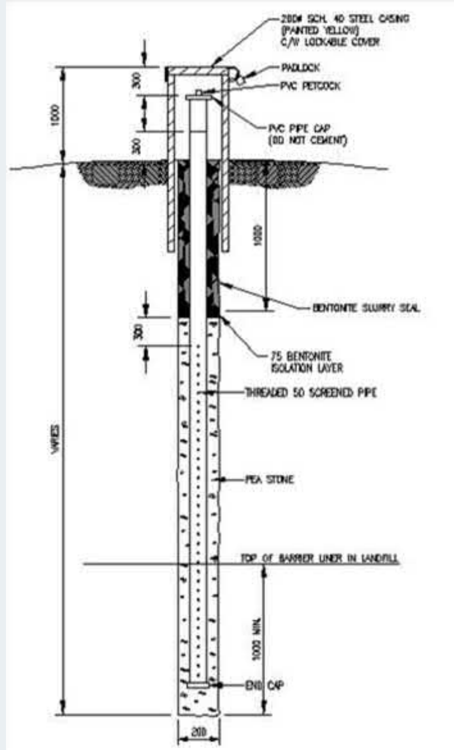

FIGURE 8: TYPICAL MONITORING PROBE

Methane Concentrations

There is a risk of explosion when the concentration of methane in the atmosphere is between its lower explosive limit (LEL) and upper explosive limit (UEL) and there is an ignition source. The concentration LEL limit for methane is 5% by volume in air and the UEL is 15% by volume in air. There also exists the potential for an explosion when the concentration is higher than the UEL. As previous mentioned the two major components of LFG is methane, which is lighter than air, and carbon dioxide, which is heavier than air. This means that LFG can be lighter or heavier than air and can sink and be present in pipe trenches or rise and be under manhole or well covers.

6.0 Landfill Gas Monitoring Plan

While LandGEM predicts low LFG generation rates the LFG assessment reports prepared by Jacques Whitford indicate that LFG is present in the monitoring wells. As such, a LFG Monitoring Plan (Plan) is required. The Plan provides the structure for the management of LFG based on the waste composition, LFG characteristics, and the LFG collection system and site specific conditions and is a live document and should be periodically reviewed and updated as conditions at the landfill changes. The objectives of the Plan are to set out the methods of implementing site-specific gas management systems to:

- prevent the migration of and control release of landfill gas
- minimize the risk of accidents
- prevent harm to human health
- minimize the impact on local air quality
- control the release of odorants

Source/Surface Monitoring

Source monitoring characterizes the quantity and quality of LFG in a section of the landfill, to determine the composition and some physical parameters of the gas using portable hand-held instruments. Passive vents/wells and leachate clean-out piping can be utilized for this purpose. The monitoring is also used to determine the condition of the cover system that may affect the performance of the landfill. Point sampling of vents and clean-outs can be completed by using a portable hand-held instrument such as a calibrated LANDTEC Gem 5000 or equivalent. Stressed vegetation can be an indication that escaping methane has replaced oxygen in the root zone resulting in stress and death.

Meteorological Monitoring

Meteorological data should be collected using an on-site weather station with an automated logging capability.

Atmospheric Pressure Monitoring

Atmospheric pressure is measured to aid understanding of gas pressure readings in the landfill. Drops in atmospheric pressure can result in the pressure of landfill gas being above that of ambient atmospheric pressure, resulting in possible migration. The monitoring of pressures in the landfill will give an indication of the likelihood of gas migration occurring.

Lateral Emission Monitoring

The monitoring of lateral emissions is by using gas monitoring probes outside the perimeter of the landfill. The probes should be sealed and locked to avoid the dilution of landfill gas with air. Typically the background concentrations for methane and carbon dioxide are established in consultation with the regulator before landfilling begins with defined details of these levels and the appropriate action/trigger levels. If the results of monitoring are at or above the appropriate trigger levels, the regulator must be informed immediately and remedial action implemented within an appropriately defined time.

Before sampling using a portable instrument (e.g., Gem 5000) or other techniques, atmospheric pressure and probe pressure should be measured. If the pressure differential is large, it is an indication that gas is likely to be moving under advective pressure (i.e., from a high pressure area to a low pressure area). If LFG is detected in a monitoring probe, it should be assumed that landfill gas has moved beyond the monitoring point. The lack of a positive pressure reading (relative to atmospheric pressure) when landfill gas is present in the monitoring probe may indicate that landfill gas is migrating off-site through diffusive flow (i.e., from a are of high concentration to a low concentration area).

Structure Monitoring

Monitoring of building and pads located on the property are recommended. Buildings should be measured where below ground utilities enter the building, at the floor, ceiling/attic, utility spaces, small confined areas such as closets, bathrooms, etc. Other potential locations to be measured include sumps, oil water separators, manholes, probes, wells, scales, septic tanks, confined spaces and locations where there is a potential for LFG to be confined at low or high elevations. Figure No. 9 illustrates a passive LFG that can be installed at a structures/building to intercept and vent intercepted LFG.

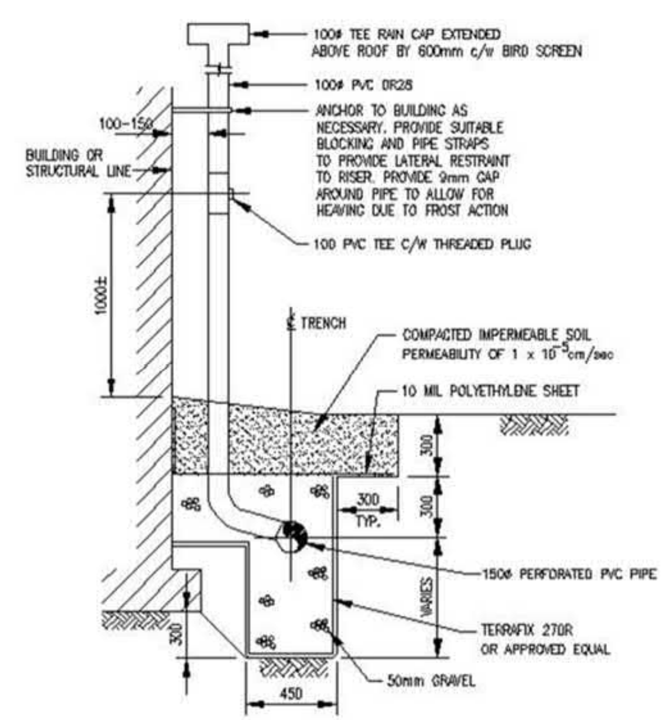

FIGURE 9: TYPICAL PASSIVE LFG VENT AT STRUCTURE

Odour Monitoring

The offensiveness of an odour is highly subjective, with the offensiveness dependent upon factors such as gender, age, occupation, health and previous history of odour experiences. The perceptibility of an odour depends on the concentration of that substance or mixture of substances in the atmosphere and, for each pure substance, there is a limiting concentration in air below which the odour is not perceptible. Mixtures of more than one substance such as landfill gas are more complex as the gases can interact. Resulting in a mixture is that is less than, greater than or equal to the sum of the gases individual intensities.

During the operation of the landfill odour complaints may occur. Received complaints will be directed to the landfill manager for resolution. The telephone number for complaints will be made available for the public and will be posted on a sign at the site entrance. The complaint will be recorded in a Complaint Log. A response will be made to the complainant on the same day confirming the receipt and nature of the complaint, and to give results of any follow-up. If a complaint cannot be resolved within a reasonable time period, the complainant will be notified of what action will be taken and when it will be taken. Any complaints received after hours will be recorded using an answering machine or answering service.

A complaint forms will be completed when a complaint is received. This will be done for all complaints, whether received verbally or by correspondence. This form will be kept on file, along with copies of any correspondence or records of discussions with the complainant. The form will indicate the following information:

- Date and time of day that the complaint was received.
- Date and time of day the complaint incident occurred.
- Complainant's name, address, telephone number, and location of incident.
- Nature of complaint (noise, dust, odour, etc.).
- Method of receipt of complaint (phone, letter, site visit, personal communication).
- Operational data at the time of the incident.
- Nature and result of any investigation or follow-up.
- Weather conditions and meteorological measurements at the time of the complaint.

Weather conditions at the time of a complaint should be noted.

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Monitoring Frequencies

The Landfill Directive and Regulations require the operator of a site to undertake site monitoring during the operational phase of a landfill site. They also require the operator to undertake monitoring during the closure and aftercare period of the site until the regulator deems the landfill no longer likely to cause a hazard to the environment. Table No. 2 summarizes typical frequencies for monitoring.

TABLE 2: MONITORING FREQUENCIES

Monitoring	Frequency while Operational	Frequency after Closure	Parameters to be Monitored
Source vent/well	Monthly	Bi-annually	CH_4, CO_2, O_2, H_2S atmospheric pressure, differential pressure, temperature, meteorological
Meteorological	Daily	As-required	Temperature, precipitation, wind speed, wind direction, atmospheric pressure
Surface Emissions	Annually	Annually	General surface conditions, CH_4, vegetation stress, atmospheric pressure, temperature, meteorological
Monitoring Probes	Monthly	Bi-annually	CH_4, CO_2, O_2 , H_2S atmospheric pressure, differential pressure, temperature, meteorological
Structures	Monthly	Bi-annually	CH_4, CO_2, O_2 , H_2S atmospheric pressure, differential pressure, temperature, meteorological
Odour Complaint	As received	As received	-

7.0 Contingency

If methane readings are:

- equal to or greater than the 50% of LEL in any probe the immediate actions are to be implemented. Notify landfill manager.
- equal to or greater than the 20% of LEL in any on-site structure or adjacent to a structure the immediate actions are to be implemented. Notify landfill manager.
- equal to or greater than the 1% of LEL in any off-site structure or adjacent to a structure the immediate actions are to be implemented. Notify landfill manager.

If Hydrogen Sulfide H_2S readings are:

- 10 ppm (threshold limit) on a direct reading H_2S meter, cease work and move to a safe area. Notify landfill manager.

Immediate Action

The landfill manager shall take the following actions to protect human health and safety:

- Determine potential receptors in the area where the exceedances occurred.
- Safely, check the LEL concentration in structures and at other receptors.
- If warranted by the intensity of the readings (e.g., >25% LEL), evaluate the area.
- Notify emergency services.
- Notify immediate supervisor.
- Investigate the potential sources and possible LFG migration pathways that may be the source(s).
- Identify if additional probes are required to help delineate the extent of the LFG issue.
- Install additional LFG probes, if required.
- As required, take corrective action to control the LFG levels in site structures and buildings.
- Document actions undertaken.

Documentation and Reporting

Provide documentation of actions taken and the next steps to be taken to protect human health and safety. Include the nature and extent of the issue and proposed future actions to address/remediate the issue.

Remediation Plan

If the issue changes to a prolonged issue and LFG concentrations remain high, the landfill manager shall prepare and implement a Remediation Plan to address the movement of LFG on and off-site.

Appendix A

Figures

Passive LFG Vent/Well Locations

Conditions of Use

Verify elevations and/or dimensions on drawing prior to use. Report any discrepancies to Dillon Consulting Limited.

Do not scale dimensions from drawing.

Do not modify drawing, re-use it, or use it for purposes other than those intended at the time of its preparation without prior written permission from Dillon Consulting Limited.

0 20 40 60 80 100m

Legend

- Passive LFG Vent/Well
- Boundary

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No.	ISSUED FOR	DATE	BY

DESIGN CRS	REVIEWED BY
DRAWN HEB	CHECKED BY
DATE JANUARY 2016	
SCALE -	

LANDFILL CELL B DESIGN & CONSTRUCTION

PASSIVE LFG VENT/WELL LOCATIONS

PROJECT NO. 14-9696

SHEET NO. 1

FILENAME: C:\PROJECTWISE\WORKING DIRECTORY\ACTIVE\50HEB\D0191550\149696-00-GEN-SITE PLAN.DWG PLOTTED BY: BALLEINE, HEATHER
PLOT DATE: 2016-01-20 @ 12:02:46 PM PLOT SCALE: 1:2 PLOT STYLE: DILLON-STANDARD.CTB

Monitoring Probe Location Plan

Conditions of Use

Verify elevations and/or dimensions on drawing prior to use. Report any discrepancies to Dillon Consulting Limited.

Do not scale dimensions from drawing.

Do not modify drawing, re-use it, or use it for purposes other than those intended at the time of its preparation without prior written permission from Dillon Consulting Limited.

0 20 40 60 80 100m

Legend

- LFG Monitoring Probe
- Boundary

DILLON CONSULTING

No.	ISSUED FOR	DATE	BY

DESIGN: CRS
REVIEWED BY:
DRAWN: HEB
CHECKED BY:
DATE: JANUARY 2016
SCALE: -

LANDFILL CELL B DESIGN & CONSTRUCTION

LFG MONITORING PROBE LOCATIONS

PROJECT NO. 14-9696

SHEET NO. 2

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PLOT DATE: 2016-01-20 @ 12:01:46 PM PLOT SCALE: 1:2 PLOT STYLE: DILLON-STANDARD.CTB

Appendix B

Tables

LandGEM Potential LFG Recovery

Year	Population	Approximation of Potential Waste Tonnage	Potential LFG Recovery
		tonnes	scfm
1971	6,122	4,179	0.0
1972	6,458	4,408	0.1
1973	6,794	4,637	0.2
1974	7,130	4,867	0.4
1975	7,466	5,096	0.5
1976	7,803	5,326	0.6
1977	8,139	5,555	0.8
1978	8,475	5,784	1.0
1979	8,811	6,014	1.1
1980	9,147	6,243	1.3
1981	9,483	6,473	1.5
1982	10,053	6,861	1.6
1983	10,622	7,250	1.8
1984	11,192	7,639	2.0
1985	11,761	8,028	2.2
1986	12,331	8,417	2.4
1987	12,901	8,805	2.7
1988	13,470	9,194	2.9
1989	14,040	9,583	3.2
1990	14,609	9,972	3.4
1991	15,179	10,360	3.7
1992	15,794	10,780	4.0
1993	16,410	11,201	4.3
1994	17,025	11,621	4.6
1995	17,641	12,041	4.9
1996	18,256	12,461	5.2
1997	19,307	13,178	5.5

LandGEM Potential LFG Recovery

1998	17,664	12,057	5.9
1999	17,469	11,923	6.2
2000	17,414	11,886	6.5
2001	17,772	12,130	6.9
2002	18,409	12,565	7.2
2003	19,210	13,112	7.5
2004	19,622	13,393	7.9
2005	19,644	13,408	8.2
2006	19,522	13,325	8.6
2007	19,727	13,465	8.9
2008	19,929	13,603	9.3
2009	19,874	13,565	9.6
2010	19,978	13,636	10.0
2011			10.3
2012			10.3
2013			10.3
2014			10.2
2015			10.2
2016			10.2
2017			10.1
2018			10.1
2019			10.1
2020			10.1
2021			10.0
2022			10.0
2023			10.0
2024			9.9
2025			9.9
2026			9.9
2027			9.8
2028			9.8
2029			9.8

LandGEM Potential LFG Recovery

2030			9.8

Note:

1	6112 - Census data from Statictics Canada
2	18256 - Census data from NWT Beaurea of Statistics
3	13,393 tonnage from 2005 Landfill Volume Assessment

APPENDIX C

Gas Monitor Specifications

AMC-1400

Four Channel Gas Monitor

A compact system for up to four sensor/transmitters, the AMC-1400 monitoring panel provides features normally found in much larger, more expensive packages.

An easy to read vacuum fluorescent display provides continuous gas concentration and alarm indication for each of four sensors. Housed in a fiberglass enforced polyester enclosure, the fully programmable AMC-1400 is designed to permit the user to configure relays, alarms and timers to their specific application.

Engineering units are selectable from an internal memory library, including PPM, PPB, %L.E.L, and % volume.

The versatile AMC-1400 can be used with any of Armstrong's wide array of hazardous gas sensor/transmitters.

SPECIFICATIONS

Inputs: Up to 4 x 4-20 mA or MultiDrop Inputs
Outputs: 4-20 mA per Channel
Enclosure: Nema 4x Fiberglass Reinforced Polyester
Supply Voltage: 110 VAC, 60 Hz
Relay Contacts: Up to 16 SPDT 6A @ 250 VAC Res.
max relays, max 4 per channel
Dimensions: 27cm W x 35cm H x 19cm D
(10.5" x 14" x 7.5")
Operating Temperature: -20°C to 40°C (-4°F to 104°F)
Storage Temperature: -20°C to 65°C (-40°F to 149°F)
Monitor Warranty: Two years
Keypad: Internal – Optional Nema 4x External
Alarm Thresholds: Up to 3 + Fail per Channel
Indicators: VFD Concentration
LED Status per Channel

Features

- 4-20 mA Outputs can be tied back to variable drives and fan motors for significant energy savings over traditional "all or nothing" ventilation strategies

User Programmable:

- Activation Delays
- Minimum Run Timers
- Alarm Thresholds

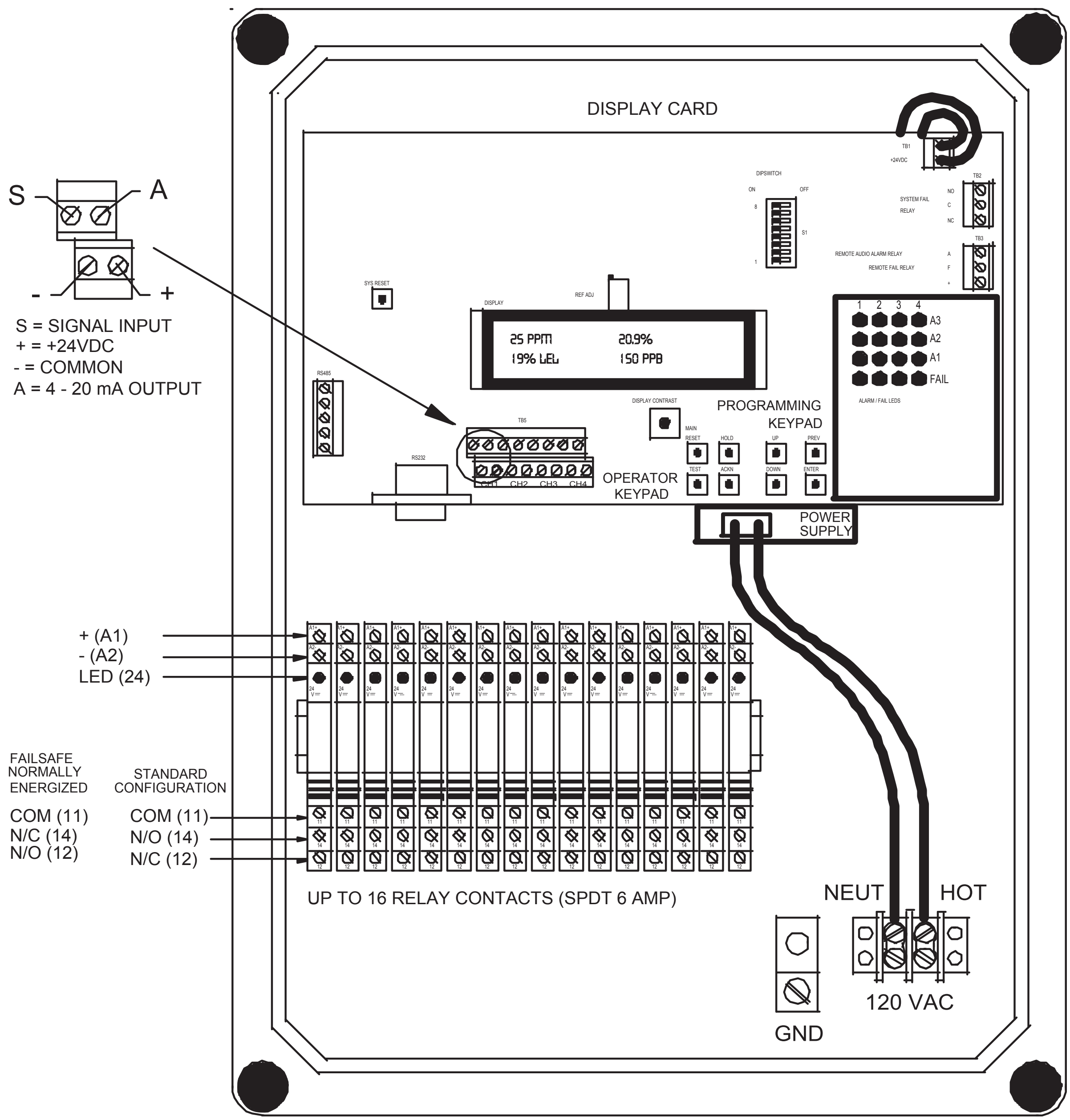
Accessories

External Nema 4x Keypad - AMC-EK4
Integral Strobe – AMC-AB110
External Nema 4x Sonalarm – AMC-1400-SA

BUILT WITH 100% GREEN ELECTRICITY

215 Colonnade Road South Ottawa, Ontario K2E 7K3 CANADA
Toll Free: 800.465.5777 gas@armstrongmonitoring.com www.armstrongmonitoring.com

AMC-1400 INTERNAL VIEW



APPENDIX D

Landfill Liner Specifications

Product Specifications

TBX11 Biaxial Geogrid

Polypropylene – single layer of extruded biaxial geogrid

Terrafix TBX11 is a Polypropylene Single Layer Extruded Biaxial Geogrid. Used as an effective base reinforcement and subgrade improvement. Terrafix TBX11 Biaxial Geogrid is inert to biological degradation and resists naturally encountered chemicals, alkalis, and acids. Polypropylene is stable within a pH range of 2 to 13.

Property	ASTM Test Method	Machine Direction Strength (MD)	Cross Machine Direction Strength (XMD)
Mechanical Properties			
• Ultimate Tensile Strength(2)	D 6637	12.4 kN/m	19.0 kN/m
• Junction Efficiency		96 %	94 %
• Tensile Strength @ 2% Strain(2)	D 6637	4.1 kN/m	6.6 kN/m
• Tensile Strength @ 5% Strain(2)	D 6637	8.5 kN/m	13.4 kN/m
• Flexural Stiffness/Rigidity	D 7748	710,000 mg-cm	278,000 mg-cm
• Aperture Stability(1)		0.75 m-N/deg @ 20kg-cm torque	
Roll Properties			
• Aperture Size(2)	--	25 mm (±1 mm)	33 mm (±1 mm)
• Rib Thickness(2)	--	1.15 mm	.88 mm
• Roll Size	--	50 m	3.95 m
Typical Geogrid Properties			
• Carbon Black Content	D 4218	2%	
• Resistance to UV Degradation	D 4355	100%	

(1) In-plane torsional rigidity measured by applying a moment to the central junction of a 225mm x 225mm specimen restrained at its perimeter in accordance with U.S. Army Corps of Engineers Methodology for measurement of Torsional Rigidity (Kinney, T.C. Aperture Stability Modulus ref 3, 3.1.2000)
(2) Values shown are MARV as per GRI

The information contained herein has been compiled by Terrafix Geosynthetics Inc. and is, to the best of our knowledge, true and accurate. Terrafix TBX11 - Version 2.3
This information is provided for reference purposes only and is not intended as a warranty or guarantee. Terrafix Geosynthetics Inc. assumes no liability in connection with the use of this information. 10/02/14

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Geotextile Product Description Sheet
Skaps GT - 180
8 oz Nonwoven Geotextiles

SKAPS **GT-180** is a needle-punched nonwoven geotextile made of 100% polypropylene staple fibers, which are formed into a random network for dimensional stability. SKAPS GT-180 resists ultraviolet deterioration, rotting, biological degradation, naturally encountered basics and acids. Polypropylene is stable within a pH range of 2 to 13. SKAPS GT-180 conforms to the physical values listed below:

PROPERTY	TEST METHOD	UNIT	M.A.R.V. (Minimum Average Roll Value)
Weight (Typical)	ASTM D5261	oz/sy (g/sm)	8.0 (271)
Grab Tensile	ASTM D4632	lbs (kN)	205 (.911)
Grab Elongation	ASTM D4632	%	50
Trapezoid Tear Strength	ASTM D4533	lbs (kN)	85 (.378)
Puncture Resistance	ASTM D4833	lbs (kN)	130 (.578)
Mullen Burst	ASTM D3786	psi (kPa)	400 (2756)
Permittivity*	ASTM D4491	I/sec	1.4
Water Flow*	ASTM D4491	gpm/sf (I/min/sm)	90 (3657)
A.O.S.*	ASTM D4751	U.S. Sieve (mm)	80 (.180)
U.V. Resistance	ASTM D4355	%/hrs	70/500

* At the time of manufacturing. Handling, storage, and shipping may change these properties.

PACKAGING	
Roll Dimension (W x L) - Ft	12.5 x 360 / 15 x 300
Square Yards per Roll	500
Estimated Roll Weight - lbs	250

* At the time of manufacturing. Handling may change these properties.

This information is provided for reference purposes only and is not intended as a warranty or guarantee. SKAPS assumes no liability in connection with the use of this information.

Engineered Synthetic Products, Inc.
405 Hood Road - Lilburn, Georgia - 30047
Office: 770-564-1857; Fax: 770-564-1818
www.espgeosynthetics.com

July 24, 2014
A&A Technical Services
327 Old Airport Road
Yelloknife, , X1A 2R2

Ref. : City of Yellowknife Compost Facility, NT
Customer P.O. # 14-0233
Product : TN 220-2-8

We certify that the TN 220-2-8 drainage geocomposite, meets the project requirements as stated in the specifications. The properties listed in this section are:

Property	Test Method	Unit	Required Value	Qualifier
Geonet[4]				
Mass per Unit Area	ASTM D 5261	lbs/ft^2	0.162	MAV[7]
Thickness	ASTM D 5199	mil	220 +/- 20	Range
Carbon Black	ASTM D 4218	%	2.0 - 3.0	Range
Tensile Strength	ASTM D 5035	lbs/in	45	MAV
Melt Flow	ASTM D 1238[3]	g/10 min	1.0	Maximum
Density	ASTM D 1505	g/cm^3	0.94	Minimum
Transmissivity[1]	ASTM D 4716	m^2/sec	2.0×10^{-3}	MAV
Composite				
Ply Adhesion	ASTM D 7005	lb/in	1.0	MAV
Transmissivity[2]	ASTM D 4716	m^2/sec	1.0×10^{-4}	MAV
Geotextile[4 & 5]				
Fabric Weight	ASTM D 5261	oz/yd^2	8.0	MARV[6]
Grab Strength	ASTM D 4632	lbs	225	MARV
Grab Elongation	ASTM D 4632	%	50	MARV
Tear Strength	ASTM D 4533	lbs	90	MARV
CBR Puncture	ASTM D 6241	lbs	650	MARV
Water Flow Rate	ASTM D 4491	gpm/ft^2	100	MARV
Permittivity	ASTM D 4491	sec^{-1}	1.26	MARV
Permeability	ASTM D 4491	cm/sec	0.30	MARV
AOS	ASTM D 4751	US Sieve	80	MARV
UV Resistance	ASTM D 4355	%/hrs	70/500	MARV

Notes:

1 Transmissivity measured using water at 21 $\pm$ 2 ^{o}C (70 $\pm$ 4 ^{o}F) with a gradient of 0.1 and a confining pressure of 10,000 psf between steel plates after 15 minutes.

2 Transmissivity measured using water at 21 $\pm$ 2 ^{o}C (70 $\pm$ 4 ^{o}F) with a gradient of 0.1 and a confining pressure of 10,000 psf between steel plates after 15 minutes.

3 Condition 190/2.16

4 Geotextile and Geonet properties are prior to lamination.

5 Geotextile data is provided by the supplier.

6 MARV is statistically defined as mean minus two standard deviations and it is the value which is exceeded by 97.5% of all the test data.

7 Minimum average value.

Sincerely,

Nilay Patel

Nilay Patel
QA Manager

APPROVED 5 QA

TECHNICAL DATA SHEET

Geomembrane LLDPE Textured DS

Solmax, 2801 Boul. Marie-Victorin, Varennes, Qc, Canada, J3X 1P7
Tel.: (450) 929-1234 Fax: (450) 929-2550 www.solmax.com

PROPERTY	TEST METHOD	FREQUENCY (1)	UNIT Metric	Solmax 660T-9000
SPECIFICATIONS				
Thickness (min. avg.)	ASTM D-5994	Every roll	mm	1.43
Asperity Height (min. avg.) (3)	ASTM D-7466	Every roll	mm	0.38
HPOIT - High Pressure (avg)	ASTM D-5885	Per formulation	min	2000
Tensile Properties (min. avg) (2)	ASTM D-638	Every 2 rolls		
Strength at Break			kN/m	16
Elongation at Break			%	250
Tear Resistance (min. avg.)	ASTM D-1004	Every 6 rolls	N	150
Puncture Resistance (min. avg.)	ASTM D-4833	Every 6 rolls	N	290
Dimensional Stability	ASTM D-1204	Per formulation	%	± 1.5
UV Resistance	ASTM D-4329	Certification		
Strength retained after 30,000 hr			%	90
SUPPLY SPECIFICATIONS (Roll dimensions may vary ±1%)				
Roll Dimension - Width	-		m	8.00
Roll Dimension - Length	-		m	140
Area (Surface/Roll)	-		m^2	1120

NOTES

1. Testing frequency based on standard roll dimensions and one batch is approximately 180,000 lbs (or one railcar).
2. Enviromax meets or exceeds the GRI-GM17.
3. Of 10 readings; 8 out of 10 must be >7 mils (0.18 mm), and lowest individual reading must be >5 mils (0.13 mm). ASTM D7466 is identical to GRI-GM12.

* All values are nominal test results, except when specified as minimum or maximum.
* The information contained herein is provided for reference purposes only and is not intended as a warranty of guarantee. Final determination of suitability for use contemplated is the sole responsability of the user. SOLMAX assumes no liability in connection with the use of this information.

APPENDIX E

Implementation Schedule

2015 (completed):

- Construction of Phase 2 of the CF
- Installation of wildlife fence around Phase 1 of the CF
- Landfill Gas Study completed
- Continued shaping of areas of the old landfill cell with construction waste
- Closure of the contaminated soil/water treatment facility
- Design of Cell B

2016 (completed):

- Construction of Phase 3 of the CF
- Installation of trash and bear fence around Phase 2 of the CF
- Grading of the concrete dump area and processing of this material
- Continued remediation of the contaminated soil/water treatment facility and surrounding area
- Activation of Gas Monitor in baling facility and monitoring of results
- Survey of old landfill cell elevations and completion of final design elevations for this cell
- Construction of Cell B

2017 (completed):

- Construction of Phase 4 of the Centralized Compost Facility
- Grading work on the remaining areas of the old landfill cell
- Composition, review, and approval of the Interim Groundwater Monitoring Plan

2018 (completed):

- Completion of trash and bear fence around the CF
- Extended power lines to the CF area
- Installation of additional groundwater monitoring wells as per Interim Groundwater Monitoring plan
- Monitoring programs to continue

2019

- Nothing to note

2020 (completed)

- Decommissioning of three cell system
- Commissioning of PDO area
- Baling facility converted to processing only recyclables
- Implementation of use of CAT816K Compactor at active landfilling areas
- New processing area for special waste (tires, wood, etc.)

- Separate area for contractors
- Tire shredding
- Begin long-term assessment of landfill site use

2021 and Beyond

- Continue long-term assessment of landfill site use (2021)
- Utilization of evaporation cannons for recirculation of leachate (tentatively 2021)
- New weigh out scale (2021)
- Gatehouse replacement (2021)
- Progressive capping of landfill cells as they reach the design elevation
- Design and construction of Cell C (2024)
- Capping work on the rest of the old landfill cell, tying into the liner of the CF once the old landfill cell has reached capacity (approximately 2030)
- Installation of Landfill Gas Monitoring wells on old landfill cell (included in capping activities; approximately 2030)