August 19, 2019

Email: [redacted]

Dear [redacted]

Re: Request for Access to Information under Part II of the Access to Information and Protection Privacy Act (the ATIPP Act, 2015)

On July 24, 2019, the City of St. John's received your request for access to the following information:

Copies of all studies, correspondence, position papers, Q&As related to the nuisance odor issue at Robin Hood Bay Landfill Facility since 2008 and the amounts of capital expended at the facility to correct the issue.

Enclosed is the information you requested. Please be advised that you may ask the Information and Privacy Commissioner to review the processing of your access request, as set out in Section 42 of the ATIPP Act. A request to the Commissioner must be made in writing within 15 business days of the date of this letter or within a longer period that may be allowed by the Commissioner:

Office of the Information and Privacy Commissioner
2 Canada Drive; P. O. Box 13004, Stn. A, St. John's, NL. A1B 3V8
Telephone: (709) 729-6309; Facsimile: (709) 729-6500

You may also appeal directly to the Supreme Court Trial Division within 15 business days after you receive the decision of the public body, pursuant to Section 52 of the Act.

If you have any further questions, please feel free to contact me by telephone at 576-8429 or by e-mail at kcutler@stjohns.ca.

Yours truly,

Kenessa Cutler

Kenessa Cutler
ATIPP Coordinator

ST. JOHN'S

LANDFILL GAS MANAGEMENT PLAN - ROBIN HOOD BAY REGIONAL WASTE MANAGEMENT FACILITY

THE CITY OF ST. JOHN'S

March 15, 2018

COMCOR
ENVIRONMENTAL LIMITED
Consulting Engineers and Landfill Gas Specialists

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LANDFILL GAS MANAGEMENT PLAN
ROBIN HOOD BAY REGIONAL WASTE MANAGEMENT FACILITY

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LANDFILL GAS MANAGEMENT PLAN
ROBIN HOOD BAY REGIONAL WASTE MANAGEMENT FACILITY

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1.0 INTRODUCTION

Comcor Environmental Limited (Comcor) was retained by the City of St. John's (City) to prepare a landfill gas management plan (LGMP) for the Robin Hood Bay (RHB) Regional Waste Management Facility. The work undertaken includes:

- Preparation of a conceptual model for a complete landfill gas collection system (LGCS) over the entire site;
- Modelling of the recoverable landfill gas over the lifespan of the site;
- Preparation of a waste filling sequence plan to compliment the LGCS; and,
- Recommendations for immediate expansion of the LGCS.

As part of the scope of work, the City also requested that a review of available landfill gas management software packages be conducted together with a recommendation for implementing such packages at the RHB Facility.

For the purposes of this LGMP, Comcor worked together with AECOM and Kendall Engineering Ltd. (KEL) to prepare a comprehensive plan that meets the City's goals moving forward. Preparation of this plan was iterative and completed with input from the City. This LGMP has been broken down into the following Sections:

- Section 2.0 – Background;
- Section 3.0 – 2017 Expansion of the Existing LGCS;
- Section 4.0 – Landfill gas collection/recovery modelling;
- Section 5.0 – Waste Fill Sequencing Plan;
- Section 6.0 – Future Landfill Gas Collection System Infrastructure;
- Section 7.0 – Summary and Recommendations.

The review of available landfill gas management software packages and associated recommendations has been provided under separate cover.

2.0 BACKGROUND

The RHB Regional Waste Management Facility is owned and operated by the City of St. John's and accepts municipal solid waste (MSW) and institutional, commercial and industrial (ICI) waste from the eastern region of the island of Newfoundland. In 2016, the landfill accepted approximately 223,000 tons of waste and that number is expected to be maintained or slightly increase in future years. At the beginning of this project, the estimated remaining lifespan of the landfill was approximately 30 to 35 years.

Comcor has been involved with landfill gas management at the RHB Facility since 2003 when the firm was retained through AECOM (formerly Gartner Lee Ltd.) to perform a landfill gas pump test in order to quantify the sustainable landfill gas collection rate at the site. In the fall of 2007, Comcor, through KEL, was retained to design and oversee construction of a full-scale LGCS on the southern part of the landfill. In 2010, Comcor was retained to design a wellfield expansion in order to increase landfill gas collection and reduce odours. In 2011, Comcor designed and prepared technical specifications for a permanent enclosed flare and containerized blower skid (replacing a temporary candlestick flare system) that was commissioned during 2012.

3.0 2017 EXPANSION OF LANDFILL GAS COLLECTION SYSTEM

The City awarded the LGMP work to Comcor during May 2017 and indicated an interest in expanding the existing LGCS so the construction work could occur during Summer/Fall 2017. Comcor was tasked to put forth a recommendation for an expansion that would provide for landfill gas collection in the northeast uncapped area of the site and would also complement/conform with the future LGMP. Comcor and KEL considered this and recommended that the existing landfill gas header pipe be extended to complete the “ring” and that five (5) additional landfill gas extraction wells be drilled and connected to the existing extraction system. Figure 1 shows the extent of the 2017 LGCS expansion. The City retained Comcor to complete the detailed design and tender documents for the expansion as this was outside of the scope of the LGMP work. Construction was initiated during Fall 2017 and was substantially complete by January 2018.

4.0 LANDFILL GAS COLLECTION/RECOVERY MODELLING

As part of the landfill gas management plan work, Comcor updated landfill gas production modelling for the site based on updated tonnage information provided by the City. The City provided Comcor with a summary of the total waste landfilled from 2003 to 2016. In consultation with the City, Comcor assumed that the site would be open until 2058 and would accept on the order of 15,000,000 total tonnes of waste. As of 2017, it is estimated that there is 5,800,000 tonnes of waste currently in place.

4.1 Landfill Gas Generation Factors

There are many factors which affect landfill gas generation. These factors include refuse moisture content, water movement (infiltration), temperature, pH, refuse composition, refuse age, nutrient availability and other various factors. There are no exact scientific formulations relating all these parameters, such that their exact cumulative effect on landfill gas generation can be determined. Experience in dealing with landfill gas systems and gas production can help determine or characterize the importance of these parameters for gas production.

Refuse Type, Mass and Age

In general, the greater the refuse mass, the greater the potential amount of landfill gas generated in a municipal waste landfill. The type of refuse and age of refuse also determines the amount of gas produced and the length of time gas will be generated. Organic wastes (i.e. food scraps and paper) are readily degradable and produce gas at high rates compared to moderately degradable wastes (i.e. textiles and wood), which produce gas at lower rates. However, moderately degradable wastes produce gas over a longer period of time than readily degradable wastes. Therefore, the mix of waste materials determines both the rate of gas production as well as the length of time gas is produced at any municipal landfill. The waste in a typical North American municipal landfill is composed of on the order of 30 to 40 percent readily decomposable waste by volume.

Moisture Content and Movement

Moisture content is the most critical environmental factor for landfill gas production. If the waste is too dry, a site may never reach a steady methane producing state. To ensure the start of and continuation of landfill gas production on a steady basis, the waste moisture content should be at a minimum of 20 percent (wet basis). The optimum in-situ moisture content should be in the range of 30 to 40 percent (wet basis) in order to ensure that the anaerobic methanogenic steady phase of waste decomposition is achieved and maintained.

Moisture movement (infiltration) through the waste is also important in ensuring good steady landfill gas production. Water movement helps to solubilize the decomposable portion of the waste, making it easier for the bacteria to degrade it. Water movement also helps distribute bacteria and nutrients throughout the refuse thereby encouraging and sustaining waste degradation.

pH Level

The anaerobic degradation process has an optimum pH level of close to neutral (i.e. 6.7 to 7.6). Below a pH of 6 and above a pH of 8, methanogenesis is curtailed, since the anaerobic bacteria find these pH levels inhibiting. Therefore, the pH of the refuse and leachate can significantly influence the biological degradation process.

4.2 Landfill Gas Production and Recovery Estimate

Based on a review of historical waste tonnage and composition data provided by the City, landfill gas production curves were prepared using the U.S. Environmental Protection Agency (USEPA) Scholl Canyon first order decay model. A waste filling schedule is summarized as Table 1.

The Scholl Canyon model uses two parameters, including L_o (methane production potential, m^3 CH_4/tonne waste) and k (gas production coefficient, 1/yr). Typical L_o values range between 100 – 300 m^3/tonne, and k typically ranges from 0 – 0.2/yr. The Ontario Ministry of the Environment and Climate Change (MOECC) default values for L_o and k are 125 m^3/tonne and 0.04/yr, respectively, while the USEPA default values for L_o and k are 170 m^3/tonne and 0.05/yr, respectively.

Comcor prepared curves using both default values to determine a range of anticipated landfill gas production. The resulting landfill gas production curve is presented in Figure 2 with the corresponding data summarized on Table 2. The Scholl Canyon curve presented in Figure 2 (using the MOECC default values) indicates that the peak landfill gas production rate at the RHB Facility will be on the order of 5,760 m^3/hr (3,390 cfm) occurring one (1) year following site closure in 2059 and that the current landfill gas production rate is on the order of 3,550 m^3/hr (2,090 cfm).

The amount of landfill gas that can be collected is less than the amount of landfill gas produced due to inefficiencies in the landfill gas collection system and landfill site characteristics. Experience at other landfills of similar size suggests that a collection efficiency on the order of 60% to 70% may be attainable (assuming sufficient cover is placed in the area of the landfill gas collection system).

The landfill gas collection and flaring system at the RHB Facility is currently collecting on the order of 850 m^3/hr (500 cfm) of landfill gas, suggesting a landfill gas collection efficiency of only 25%. This is due to the fact that landfill gas collection infrastructure does not cover the entire waste mass area and that final cover has not been applied to large areas of the site. Based on collection efficiencies of 25% and 60%, a landfill gas recovery curve is presented in Figure 3 with the corresponding data summarized in Table 3. In the future, it is estimated that the maximum landfill gas recovery potential at the site may be on the order of 3,460 m^3/hr (2,030 cfm) assuming a 60% collection efficiency.

Landfill gas will continue to be produced long after the RHB Facility is anticipated to close in 2058. The curves estimate that in the year 2118, 135 to 325 m^3/hr (80 to 190 cfm) of landfill gas could be recovered, assuming a collection efficiency between 25% and 60%. A lower capacity flare would need to replace the existing enclosed flare in order for it to successfully operate at such low landfill gas flow rates.

5.0 WASTE FILL SEQUENCING PLAN

5.1 Site Life and Final Contour Design

In 2007, the City had a study completed that recommended a top landfill elevation of 104.5 masl to balance desired landfill capacity with operational issues. A fill plan completed during 2011 increased the cap elevation to 106 masl to try and increase the landfill useful life. As part of preparing the waste fill sequencing plan (WFSP) for the purposes of the landfill gas management plan, the City requested that Comcor evaluate the final cap elevation and make recommendations as to modifications to further increase the landfill useful life. After reviewing a number of options with the City, it was ultimately recommended that the City proceed with a modified final contour plan, taking the maximum landfill height to an elevation of 110 masl. Based on the May 2017 topographic survey of existing conditions for the Site, the fully developed landfill cap was updated to consider the following:

- Maximum fill elevation at center line: 110 masl
- From center line cap slopes:
  - 4% to project south to meet a 4:1 exterior side slope
  - 5% to project north to meet a 4:1 exterior side slope

The updated final contours resulted in a total of 12,080,123 m^3 of remaining space for waste, daily cover and final cover. Assuming that the City consumes 300,000 m^3 per year as waste and cover material, there will be approximately 40 years of additional space remaining. The waste fill sequencing plan generated was based on the final contours as shown in Figure 4.

5.2 Waste Fill Sequencing Design

A WFSP was developed that complements the implementation of the landfill gas collection infrastructure as well as other landfill operational considerations. The purpose of the fill plan is to provide guidance for the placement of waste in several sequenced phases between the existing and final waste contours.

The sequencing of the landfill development has been split into seven (7) sequence blocks and numbered 1 through 7, as illustrated in Figures 5 through 11. Sequence 1 generally follows the 2012 established fill plan maintaining the present approach of filling the cells from south to north completely across the landfill. The sequence will be filled to the new landfill elevation of 110 masl. This will provide the desired screening berm for all future filling.

Other than Sequence 1, the fill limits of each sequence were determined by the following criteria:

- The Sequence Plan provides for the filling of the south side of the landfill first.
- The sequencing splits the landfill into a north section and a south section.
- The dividing line for the north, south sections is at the landfill cap peak elevation of 110 masl.
- Filling the south side of the landfill first means that any modifications to existing gas wells in the north section of the landfill is delayed, and allows for the protection and maintaining of the existing GCL capped portion of the landfill in the north east quadrant. This approach also allows for the orderly development of the landfill gas system by allowing landfill gas wells to be installed as each sequence reaches the maximum fill elevation.

The plan view figures of each sequence also outline the total airspace available in each sequence for waste and cover material. An approximate lifespan of each sequence has been calculated based on a consumption rate of 300,000 m^3/year for waste and cover material and is summarized on the Figures.

The following modifications to the established fill plan have been made for Sequence 1:

- The east toe has been established to provide adequate clearance and avoid any potential conflict with existing landfill gas wells, specifically Well 2017-4,
- The east slope has been finished at a 3:1 slope rather than the previous “stepped” approach. This allows for the easier placement of intermediate fill on the north east section which will be left for an extended time until Sequence 4 is completed.

The north side of Sequence 2 will be finished at a 2.5:1 slope. This is required to avoid conflict with Well 2017-5. The east side slope for Sequence 2 will be finished with the cells stepped and using a 3:1 finished side slope.

5.3 Sequences 1 and 2 Cell Design

Figures 12 and 13 show the sections located on the plan view figures. Sections 1 and 2 provide details on the landfill cell divisions for Sequence 1. The cell numbering for Sequence 1 continues on from the numbering system used in the 2012 established fill plan. Cell width and cell height remain generally unchanged from the 2012 established fill plan. The approximate cell width is 45 m with a height of 4 m. However the width of some cells in Sequence 1 will be slightly smaller or larger than 45 m as the east slope is to be finished at a 3:1 slope, rather than stepped and this sequence has filling of cells from south to north completely across the landfill.

6.0 FUTURE LANDFILL GAS COLLECTION SYSTEM INFRASTRUCTURE

6.1 Landfill Gas Collection System Design

As described in Section 5.0, the waste fill sequences have been designed in conjunction with the future landfill gas collection system infrastructure, as well as to minimize disturbance to the existing LGCS for as long as possible. With the completion of the 400 mm (16”) ring header in 2017, all future LGCS infrastructure will be expanded sequence by sequence with minimal disturbance to finished ground surrounding the perimeter of the fill area. The final contours have been designed such that no additional fill will be placed over top of the ring header, ensuring that the header piping will remain accessible for future LGCS infrastructure connections.

Sequence 1 continues with the established plan of filling from south to north until the final elevation is met along the entire west side of the site to create a screening berm. Since the long edge of Sequence 1 runs parallel to the west ring header, each extraction well will be connected directly to the header with 100 mm piping, rather than running lateral piping across the length of the entire Sequence. The narrow width of Sequence 1 will preserve the five (5) extraction wells and associated collection piping installed in 2017. The LGCS infrastructure for Sequence 1 consists of five (5) extraction wells and is presented in Figure 14.

The size and shape of each subsequent sequence has been designed to allow for considerable LGCS expansions spaced over appropriate time frames. In other words, expansions will not be limited to a mere few wells; while at the same time, there will not be long periods of time where finished areas of the Site will be without landfill gas control. When compared to the previous filling plan, this will allow a portion of the site to get to final grade in roughly half the time, and a GCL cover and LGCS infrastructure can be installed sooner, reducing surface water infiltration and improving odour control.

Sequences 2 through 4 fill the south half of the site, up to the 110 masl cap centreline, and progress from west to east. In Sequences 2 and 3, three (3) laterals will be installed from the header along the southern edge of the fill area and run up the 4:1 side slope and 4% top slope and terminate at the 110 masl cap centreline. A fourth lateral will be installed up the eastern 4:1 side slope to connect additional wells in Sequence 4. This lateral may tie into the header at the existing PDT1 and FC1, provided that this infrastructure is still in working condition. As with the existing LGCS, 100 mm sublaterals will connect each extraction well to its corresponding lateral. The LGCS infrastructure for Sequences 2 through 4 is presented in Figures 15 through 17, respectively.

Sequences 5 through 7 are essentially mirror images of Sequences 2 through 4 on the north end of the Site. In Sequences 5 and 6, the three (3) existing laterals will be extended down the northern slope of the Site and connected to the ring header. Two (2) additional laterals will be installed up the 4:1 north eastern side slope to connect additional wells in Sequence 7. As in Sequence 4, one of the laterals may tie into the header at existing PDT3 and FC3. The LGCS infrastructure for Sequences 5 through 7 is presented in Figures 18 through 20, respectively. After the completion of Sequence 7, the overall LGCS buildout will consist of fifty-six (56) vertical extraction wells connected to six (6) laterals.

Flow control assemblies will be installed where each lateral meets the ring header. This will provide for operational flexibility by allowing sections of piping to be isolated and gas to be diverted through alternate piping routes in the unlikely event that piping is damaged or flooded.

Since all sublateral and lateral piping slopes from the extraction wells down the side slope to the ring header, no drain traps will be required for future LGCS infrastructure expansions. Condensate that drops out of the gas in the collection piping will ultimately flow to the existing pump drain traps on the ring header.

Consistent with the 2017 LGCS expansion, all landfill gas collection piping will be installed with compressed air and forcemain piping running in parallel. Compressed air and forcemain piping will terminate above grade at each extraction well to allow for a dual purpose well conversion in the event that high leachate levels are restricting landfill gas collection.

6.2 Extraction Well Design

As with the existing LGCS, a radius of influence (ROI) of 50 metres was used for spacing of the future extraction wells. A 50 metre ROI design has proven effective at adequately capturing landfill gas from existing Laterals 1 through 3 under the capped GCL area.

In the past, drilling contractors have experienced great difficulty when trying to install vertical landfill gas extraction wells at the Site. Large rock boulders, creosote timbers, and nylons are just some of the materials that have caused equipment breakdowns, wells to be installed at shorter than anticipated depths or have resulted in complete well refusal and relocation. As a result of these difficulties, the City could consider backfilling cylinders of gravel as waste filling progresses. After each waste cell is completed, an excavator could remove the waste from the predetermined well locations and backfill with a granular material. This process would be repeated with each successive cell until an uninterrupted cylinder of known granular material is present at each location when it comes time to drill the well.

6.3 Sequencing of LCGS Infrastructure Installation

Based on the sequence volumes provided in Figures 5 through 11, and an airspace consumption rate of 300,000 m^3/year, it is estimated that the site will be open until 2058. Table 4 provides a summary of the estimated timelines for the seven (7) sequences. Sequences 2 through 7 will take on the order of 4 to 8 years to fill. Installation of the LGCS infrastructure can commence immediately following the completion of the sequence and in coordination with final cover activities. Table 5 provides a summary of the infrastructure quantities the anticipated year of installation for the seven (7) LGCS sequences.

6.4 Decommissioning of Existing LGCS Infrastructure

As filling progresses beyond Sequence 1, existing LGCS infrastructure will eventually be covered with new waste. It is possible to extend the service life of an extraction well by raising the wellhead each time a cell is installed. However, the well riser must be constructed of solid PVC pipe to avoid drawing in atmospheric oxygen, so gas from the new waste will not be easily collected. Furthermore, the raised well becomes an obstacle to operations equipment and commercial drop off vehicles at the tipping face, and will likely be inadvertently damaged anyway.

If an extraction well is still producing good quality landfill gas, an alternative to raising the well is to convert it into a below ground manifold connection. Before a new cell is developed over the well, the wellhead assembly and flex hose are removed and replaced with rigid piping to connect the vertical PVC extraction well to the 100 mm HDPE sub-lateral riser. The only downside to this conversion is losing the gate valve at each manifold. So the only means to control the flow rate of gas from the manifolds is from downstream flow control assemblies. A manifold renovation detail is provided in Figure 21.

Decommissioning of other infrastructure such as pump drain traps within the waste filling area can include salvaging any reusable parts and backfilling the chambers with granular material to minimize the chance of piping being damaged, leading to leaks in the gas collection, compressed air and/or forcemain lines. If existing laterals are taken offline completely, the flow control assembly can either be closed if still functional, or removed and replaced with a blind flange.

7.0 SUMMARY AND RECOMMENDATIONS

Comcor was retained by the City to prepare a landfill gas management plan for the Robin Hood Bay Regional Waste Management Facility. Comcor worked with AECOM and Kendall Engineering Ltd. to design the future landfill gas collection system infrastructure in conjunction with the waste fill sequencing plan and to recommend an immediate expansion to the LGCS. During the design of the LGMP, Comcor and KEL designed and provided contract administration and construction supervision of LGCS expansion. Construction of the expansion was initiated during Fall 2017 and was substantially complete by January 2018.

After reviewing a number of final contour options, it was recommended that the maximum elevation be increased from 106 to 110 masl to increase the site's useful life. The updated final contours resulted in a total of 12,080,123 m^3 of remaining airspace. Based on an airspace consumption rate of 300,000 m^3/year for waste and cover material, it is estimated that the site will be open until 2058. Sequence 1 generally follows the established fill plan and creates a screening berm at the west end of the site. Sequences 2 through 4 fill the south side of the landfill first, to the 110 masl cap centreline. The remaining Sequences 5 through 7 fill the north half of the site, moving from west to east. Cell design for Sequences 1 and 2 remained generally unchanged from the 2012 established fill plan, with an approximate width and height of 45 m by 4 m, respectively.

The LGCS infrastructure was designed to be installed after the completion of each waste fill sequence. In general, lateral gas collection piping runs up the south side slope of the landfill to the 100 masl cap centreline, and down the other side after the north sequences are completed. The consistent slope of the final contour design allows all future LGCS infrastructure to be installed without any new condensate pump drain traps. However, compressed air and forcemain lines will still be installed in parallel with all landfill gas collection piping to allow for a dual purpose well conversion in the event that high leachate levels are restricting landfill gas collection.

All of which is respectfully submitted,
COMCOR ENVIRONMENTAL LIMITED

Jonathan Petsch, P.Eng.
Project Engineer

Denise Burgess, P.Eng.
Manager – Engineering

Table 1
Filling Schedule
Landfill Gas Management Plan
Robin Hood Bay Regional Waste Management Facility, St. John's, NL

Year	Annual Tonnage (tonnes)	Cumulative Tonnage (tonnes)
1963	23,300	23,300
1964	24,580	47,880
1965	25,930	73,810
1966	27,360	101,170
1967	28,860	130,040
1968	30,450	160,490
1969	32,130	192,620
1970	33,890	226,510
1971	35,760	262,270
1972	37,720	300,000
1973	39,800	339,800
1974	41,990	381,780
1975	44,300	426,080
1976	46,730	472,820
1977	49,300	522,120
1978	52,020	574,140
1979	54,880	629,020
1980	57,900	686,910
1981	61,080	747,990
1982	64,440	812,430
1983	67,980	880,420
1984	71,720	952,140
1985	75,670	1,027,810
1986	79,830	1,107,640
1987	84,220	1,191,860
1988	88,850	1,280,710
1989	93,740	1,374,450
1990	98,890	1,473,340
1991	124,240	1,597,580
1992	141,450	1,739,030
1993	138,360	1,877,390
1994	115,960	1,993,350
1995	111,670	2,105,020
1996	110,970	2,215,990
1997	127,850	2,343,840
1998	137,370	2,481,210
1999	89,350	2,570,560
2000	143,800	2,714,350
2001	174,410	2,888,760
2002	186,470	3,075,240
2003	142,850	3,218,090
2004	142,400	3,360,490
2005	153,280	3,513,770
2006	154,760	3,668,530
2007	163,710	3,832,250
2008	173,600	4,005,840
2009	159,990	4,165,840
2010	172,250	4,338,090
2011	194,840	4,532,930
2012	200,130	4,733,060
2013	209,330	4,942,390
2014	221,750	5,164,140
2015	215,670	5,379,810
2016	223,350	5,603,160
2017	225,000	5,828,160
2018	225,000	6,053,160
2019	225,000	6,278,160
2020	225,000	6,503,160
2021	225,000	6,728,160
2022	225,000	6,953,160
2023	225,000	7,178,160
2024	225,000	7,403,160
2025	225,000	7,628,160
2026	225,000	7,853,160
2027	225,000	8,078,160
2028	225,000	8,303,160
2029	225,000	8,528,160
2030	225,000	8,753,160
2031	225,000	8,978,160
2032	225,000	9,203,160
2033	225,000	9,428,160
2034	225,000	9,653,160
2035	225,000	9,878,160
2036	225,000	10,103,160
2037	225,000	10,328,160
2038	225,000	10,553,160
2039	225,000	10,778,160
2040	225,000	11,003,160
2041	225,000	11,228,160
2042	225,000	11,453,160
2043	225,000	11,678,160
2044	225,000	11,903,160
2045	225,000	12,128,160
2046	225,000	12,353,160
2047	225,000	12,578,160
2048	225,000	12,803,160
2049	225,000	13,028,160
2050	225,000	13,253,160
2051	225,000	13,478,160
2052	225,000	13,703,160
2053	225,000	13,928,160
2054	225,000	14,153,160
2055	225,000	14,378,160
2056	225,000	14,603,160
2057	225,000	14,828,160
2058	225,000	15,053,160

Table 2
Landfill Gas Production Estimate
Landfill Gas Management Plan
Robin Hood Bay Regional Waste Management Facility, St. John's, NL

Year	Landfill Gas Production MOE Default Values	
	m^3/hr	cfm
2010	2,690	1,580
2011	2,770	1,630
2012	2,870	1,690
2013	2,980	1,750
2014	3,090	1,820
2015	3,220	1,890
2016	3,330	1,960
2017	3,440	2,030
2018	**3,550**	**2,090**
2019	3,660	2,150
2020	3,760	2,220
2021	3,860	2,270
2022	3,960	2,330
2023	4,050	2,380
2024	4,140	2,440
2025	4,220	2,490
2026	4,300	2,530
2027	4,380	2,580
2028	4,460	2,620
2029	4,530	2,670
2030	4,600	2,710
2031	4,660	2,750
2032	4,730	2,780
2033	4,790	2,820
2034	4,850	2,850
2035	4,910	2,890
2036	4,960	2,920
2037	5,010	2,950
2038	5,060	2,980
2039	5,110	3,010
2040	5,160	3,040
2041	5,200	3,060
2042	5,240	3,090
2043	5,290	3,110
2044	5,320	3,130
2045	5,360	3,160
2046	5,400	3,180
2047	5,430	3,200
2048	5,470	3,220
2049	5,500	3,240

Year	Landfill Gas Production MOE Default Values	
	m^3/hr	cfm
2050	5,530	3,260
2051	5,560	3,270
2052	5,590	3,290
2053	5,620	3,310
2054	5,640	3,320
2055	5,670	3,340
2056	5,690	3,350
2057	5,720	3,370
2058	5,740	3,380
2059	**5,760**	**3,390**
2060	5,540	3,260
2061	5,320	3,130
2062	5,110	3,010
2063	4,910	2,890
2064	4,720	2,780
2065	4,530	2,670
2066	4,350	2,560
2067	4,180	2,460
2068	4,020	2,370
2069	3,860	2,270
2070	3,710	2,180
2071	3,570	2,100
2072	3,430	2,020
2073	3,290	1,940
2074	3,160	1,860
2075	3,040	1,790
2076	2,920	1,720
2077	2,800	1,650
2078	2,690	1,590
2079	2,590	1,520
2080	2,490	1,460
2081	2,390	1,410
2082	2,300	1,350
2083	2,210	1,300
2084	2,120	1,250
2085	2,040	1,200
2086	1,960	1,150
2087	1,880	1,110
2088	1,810	1,060
2089	1,740	1,020

Notes: MOE default parameters:
$L_o = 125\ m^3/tonne$, $k = 0.04\ yr^{-1}$

Table 3
Landfill Gas Recovery Estimate
Landfill Gas Management Plan
Robin Hood Bay Regional Waste Management Facility, St. John's, NL

Year	25% Recovery		60% Recovery	
	m^3/hr	cfm	m^3/hr	cfm
2010	670	400	1,610	950
2011	690	410	1,660	980
2012	720	420	1,720	1,020
2013	750	440	1,790	1,050
2014	770	460	1,860	1,090
2015	800	470	1,930	1,140
2016	830	490	2,000	1,170
2017	860	510	2,060	1,220
2018	**890**	**520**	**2,130**	**1,250**
2019	920	540	2,200	1,290
2020	940	550	2,260	1,330
2021	970	570	2,320	1,360
2022	990	580	2,370	1,400
2023	1,010	600	2,430	1,430
2024	1,030	610	2,480	1,460
2025	1,060	620	2,530	1,490
2026	1,080	630	2,580	1,520
2027	1,100	640	2,630	1,550
2028	1,110	660	2,670	1,570
2029	1,130	670	2,720	1,600
2030	1,150	680	2,760	1,620
2031	1,170	690	2,800	1,650
2032	1,180	700	2,840	1,670
2033	1,200	700	2,870	1,690
2034	1,210	710	2,910	1,710
2035	1,230	720	2,940	1,730
2036	1,240	730	2,980	1,750
2037	1,250	740	3,010	1,770
2038	1,270	740	3,040	1,790
2039	1,280	750	3,070	1,800
2040	1,290	760	3,090	1,820
2041	1,300	770	3,120	1,840
2042	1,310	770	3,150	1,850
2043	1,320	780	3,170	1,870
2044	1,330	780	3,190	1,880
2045	1,340	790	3,220	1,890
2046	1,350	790	3,240	1,910
2047	1,360	800	3,260	1,920
2048	1,370	800	3,280	1,930
2049	1,380	810	3,300	1,940

Year	25% Recovery		60% Recovery	
	m^3/hr	cfm	m^3/hr	cfm
2050	1,380	810	3,320	1,950
2051	1,390	820	3,340	1,960
2052	1,400	820	3,350	1,970
2053	1,400	830	3,370	1,980
2054	1,410	830	3,390	1,990
2055	1,420	830	3,400	2,000
2056	1,420	840	3,420	2,010
2057	1,430	840	3,430	2,020
2058	1,440	840	3,440	2,030
2059	**1,440**	**850**	**3,460**	**2,030**
2060	1,380	810	3,320	1,960
2061	1,330	780	3,190	1,880
2062	1,280	750	3,070	1,800
2063	1,230	720	2,950	1,730
2064	1,180	690	2,830	1,670
2065	1,130	670	2,720	1,600
2066	1,090	640	2,610	1,540
2067	1,050	620	2,510	1,480
2068	1,000	590	2,410	1,420
2069	970	570	2,320	1,360
2070	930	550	2,230	1,310
2071	890	520	2,140	1,260
2072	860	500	2,060	1,210
2073	820	480	1,970	1,160
2074	790	470	1,900	1,120
2075	760	450	1,820	1,070
2076	730	430	1,750	1,030
2077	700	410	1,680	990
2078	670	400	1,620	950
2079	650	380	1,550	910
2080	620	370	1,490	880
2081	600	350	1,430	840
2082	570	340	1,380	810
2083	550	320	1,320	780
2084	530	310	1,270	750
2085	510	300	1,220	720
2086	490	290	1,170	690
2087	470	280	1,130	660
2088	450	270	1,080	640
2089	430	260	1,040	610

Notes: Recovery based on MOE default parameters for landfill gas production as shown in Table 2

Table 4
Estimated Sequencing Timeline
Landfill Gas Management Plan
Robin Hood Bay Regional Waste Management Facility, St. John's, NL

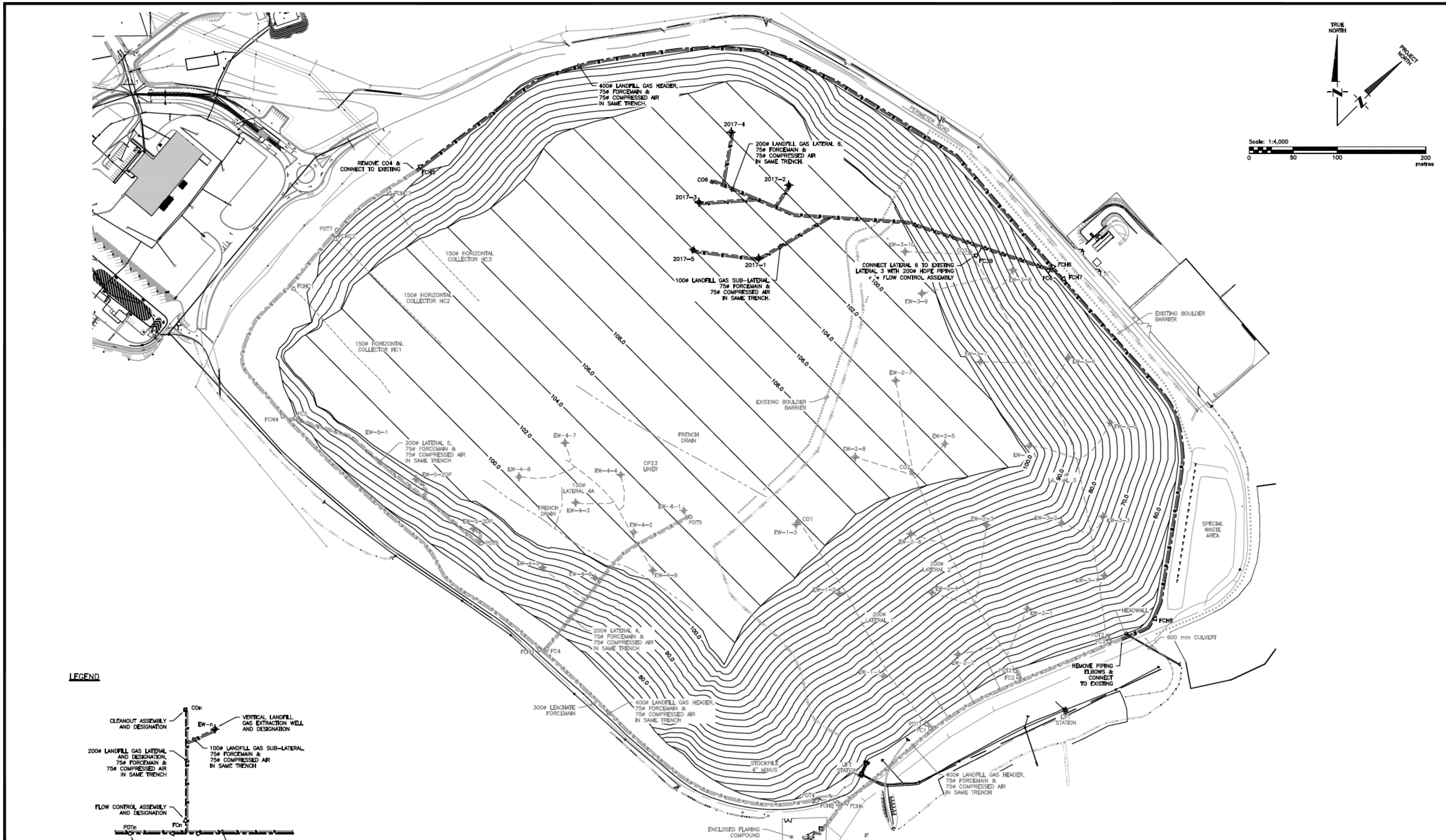
Sequence	Sequence Volume (m^3)	Cumulative Volume (m^3)	Start Date	End Date	Duration (Years)
1	572,176	572,176	January 2018	November 2019	1.9
2	2,335,075	2,907,251	November 2019	September 2027	7.8
3	2,431,350	5,338,601	September 2027	October 2035	8.1
4	2,038,807	7,377,408	October 2035	July 2042	6.8
5	1,204,391	8,581,799	July 2042	August 2046	4.0
6	1,431,343	10,013,142	August 2046	May 2051	4.8
7	2,066,981	12,080,123	May 2051	March 2058	6.9
				TOTAL:	40

Notes:

1. Sequence volumes taken from AECOM's Proposed Fill Sequence figures.
2. Start and end dates are based on an airspace consumption rate of 300,000 m^3/year.
3. The total duration refers to the number of years the site will be open after January 2018.

Table 5
Landfill Gas Collection System Sequence Summary
Landfill Gas Management Plan
Robin Hood Bay Regional Waste Management Facility, St. John's, NL

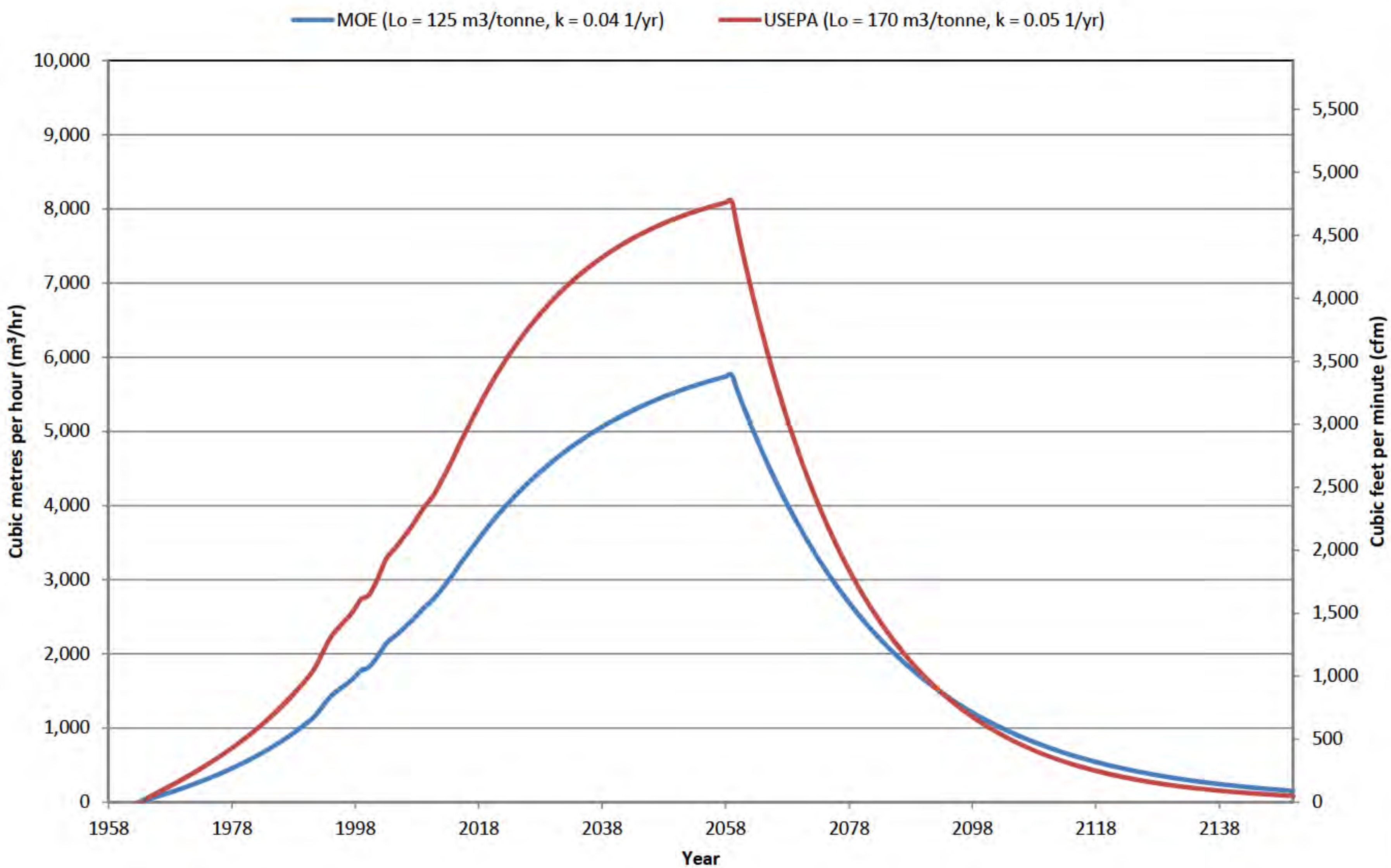
Sequence	Installation Year	Extraction Wells	Sublateral Length (m)	Lateral Length (m)	Flow Controls
1	2020	5	508	0	0
2	2028	11	408	773	2
3	2036	6	285	366	1
4	2042	8	552	185	0
5	2046	9	335	660	2
6	2051	6	288	355	1
7	2058	11	632	416	1
	TOTAL:	56	3,008	2,755	7



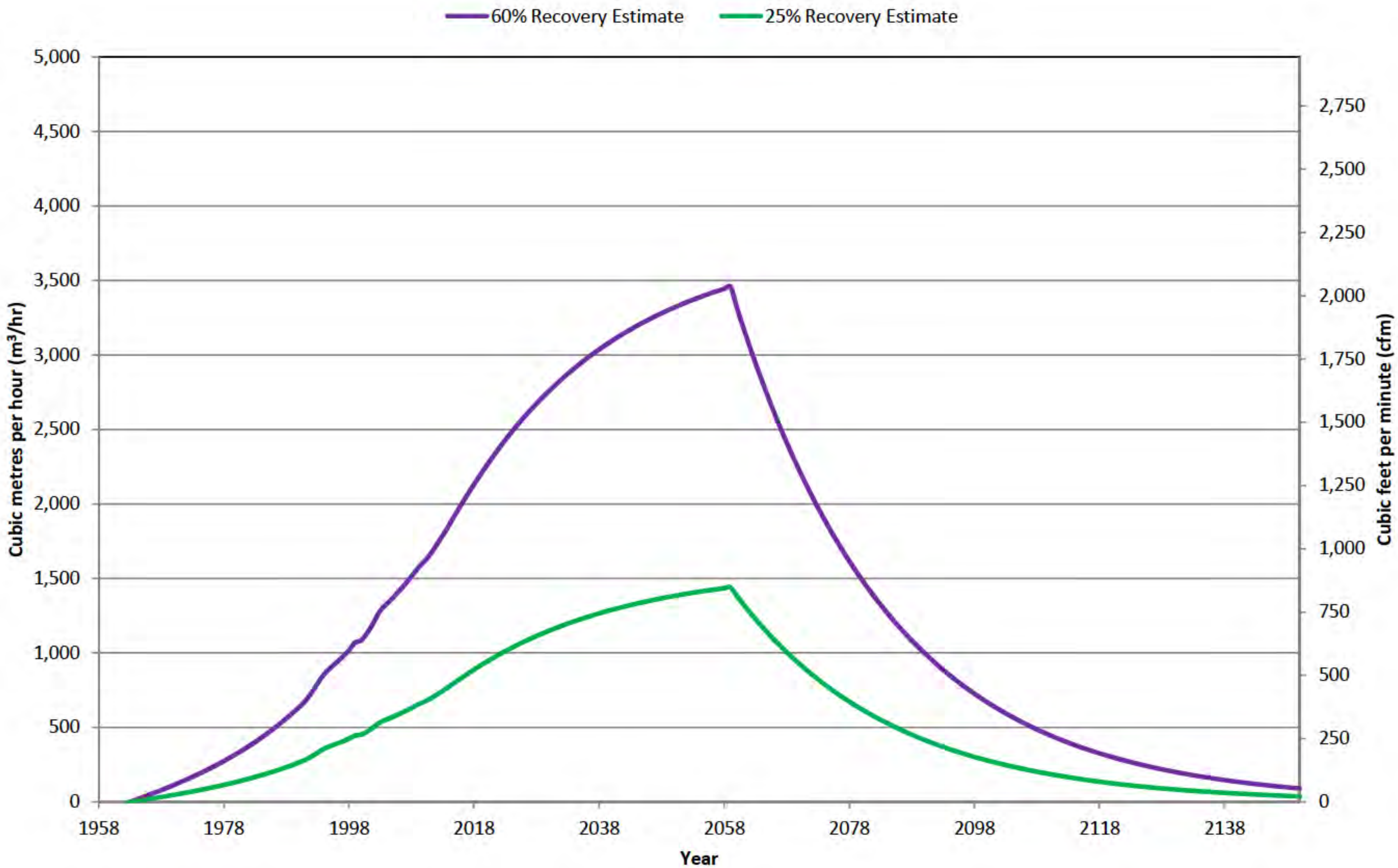
COMCOR ENVIRONMENTAL LIMITED
Consulting Engineers and Landfill Gas Specialists

ST. JOHN'S
ROBIN HOOD BAY WASTE MANAGEMENT FACILITY

Figure 1
2017 LANDFILL GAS COLLECTION SYSTEM EXPANSION

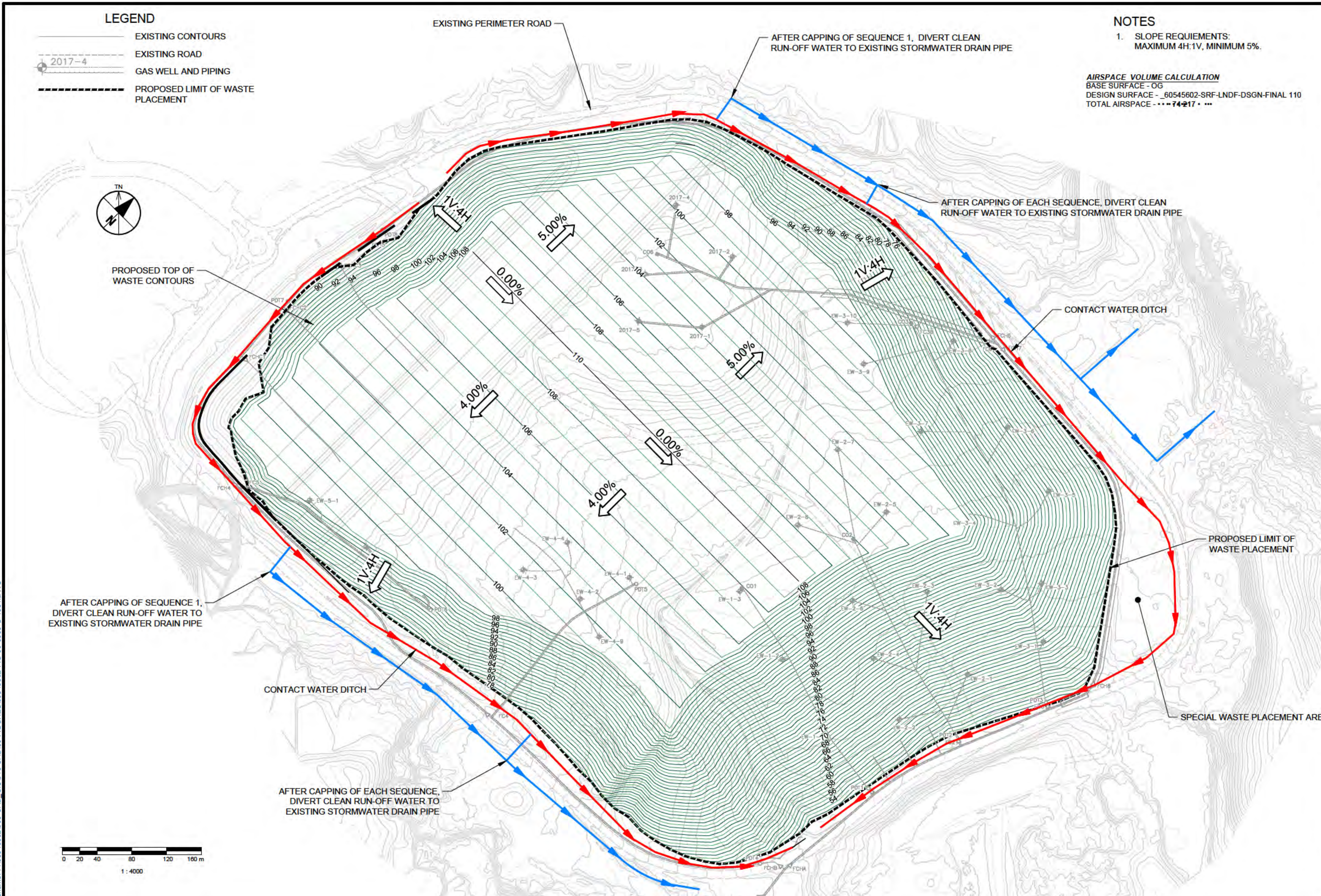


COMCOR ENVIRONMENTAL LIMITED Consulting Engineers and Landfill Gas Specialists	ST. JOHN'S ROBIN HOOD BAY WASTE MANAGEMENT FACILITY	Figure 2 LANDFILL GAS PRODUCTION ESTIMATE



Notes: Recovery based on MOE default parameters for landfill gas production as shown in Table 2

COMCOR ENVIRONMENTAL LIMITED Consulting Engineers and Landfill Gas Specialists	ST. JOHN'S ROBIN HOOD BAY WASTE MANAGEMENT FACILITY	Figure 3 LANDFILL GAS RECOVERY ESTIMATE



Project Management Initials: Designer: DS Checked: JC Approved: MW ANSI B 279.4mm x 431.8mm

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Filename: P:\60545602\900-CAD_GIS\910-CAD\30-FIGURES\60545602-FIG-00-0000-C-1004.DWG

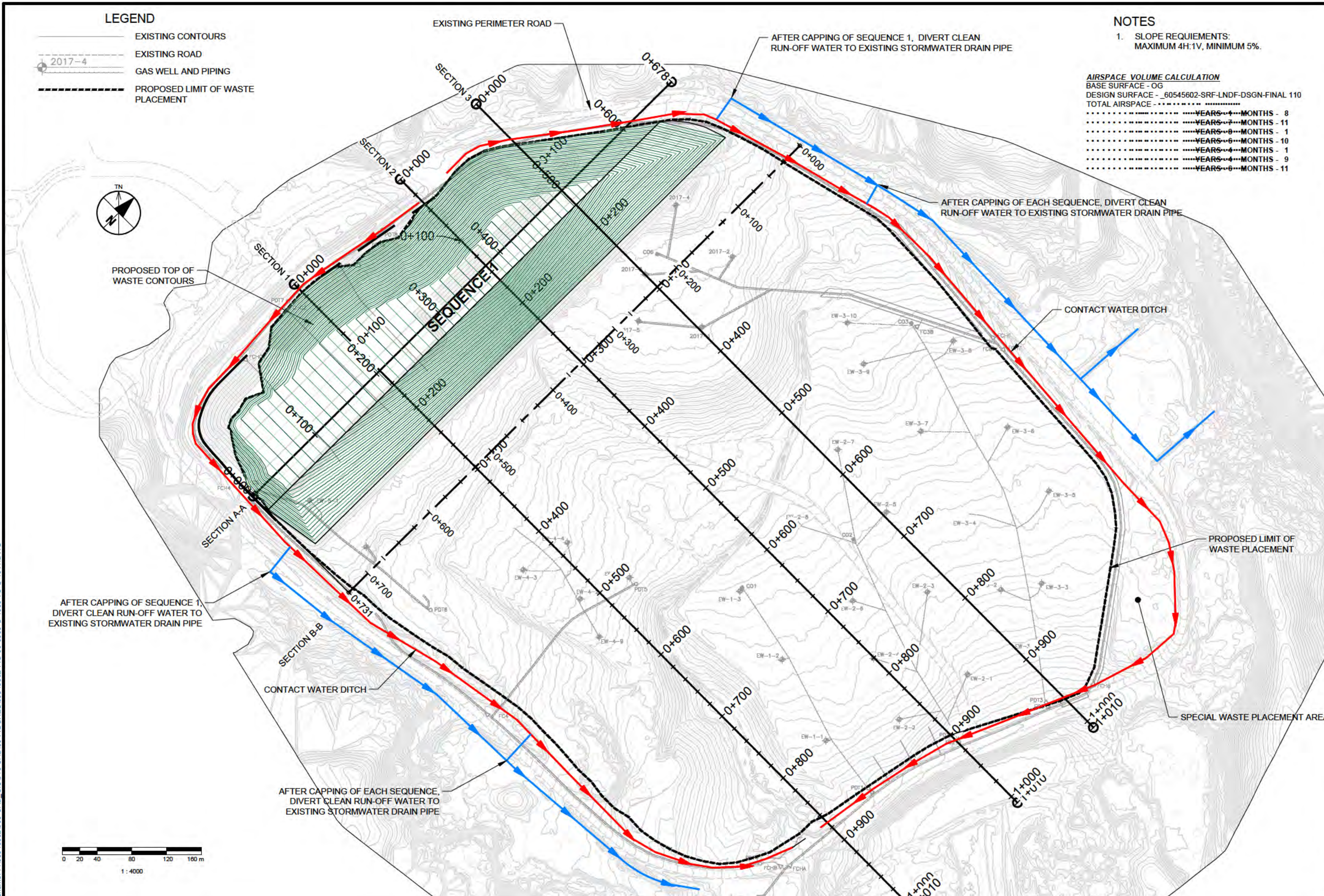
AECOM

Figure: 4

PROPOSED FINAL CONTOURS

ROBIN HOOD BAY LANDFILL
GAS COLLECTION SYSTEM DESIGN

Project No.: 60545602 Date: MARCH, 2018



Project Management Initials: Designer: DS Checked: JC Approved: MW ANSI B 279.4mm x 431.8mm

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Filename: P:\60545602\900-CAD_GIS\910-CAD\30-FIGURES\60545602-FIG-00-0000-C-1005 TO C-1011.DWG

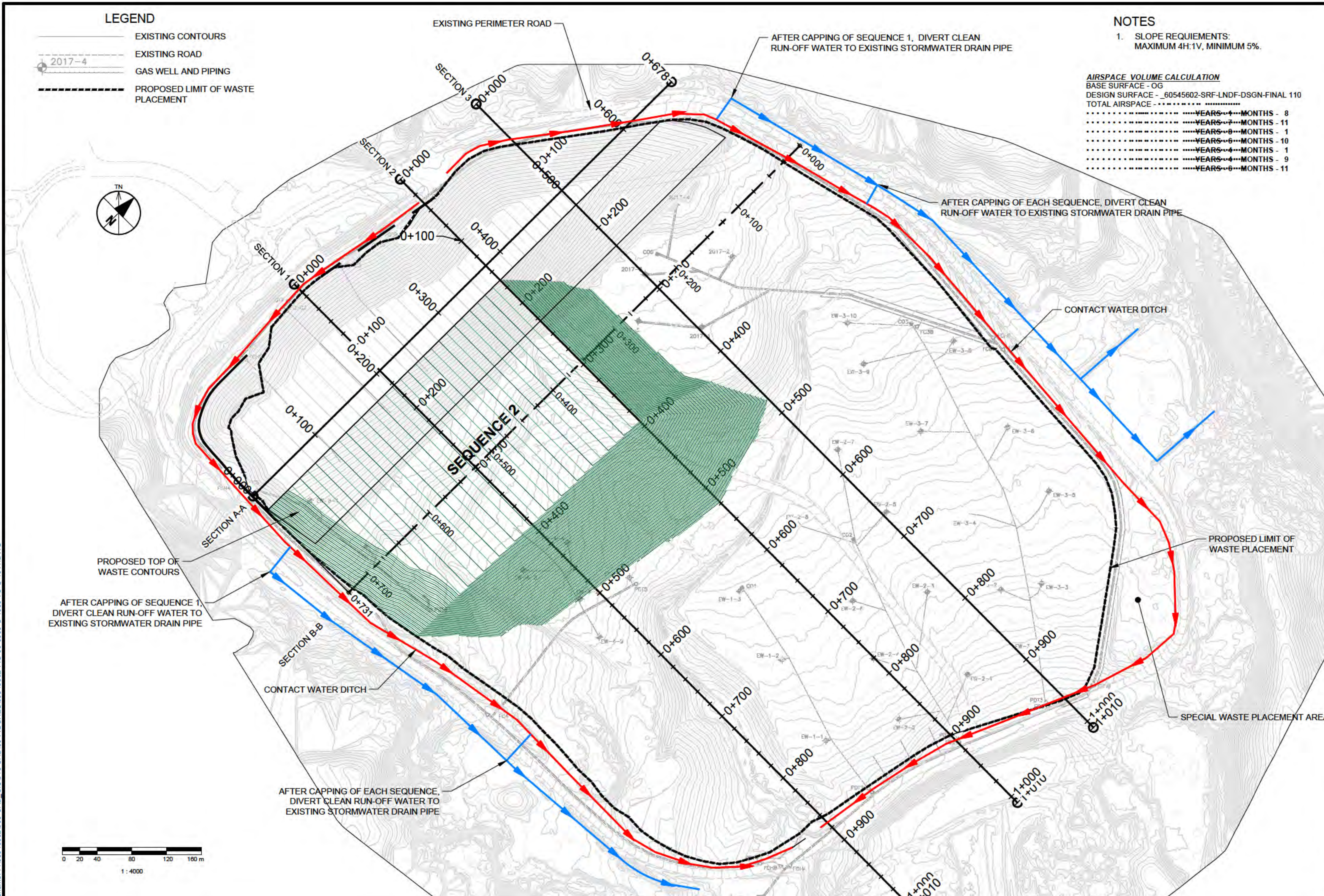
AECOM

Figure: 5

PROPOSED FILL SEQUENCE
SEQUENCE 1

ROBIN HOOD BAY LANDFILL
GAS COLLECTION SYSTEM DESIGN

Project No.: 60545602 Date: MARCH, 2018



ANSI B 279.4mm x 431.8mm

Approved: MW Checked: JC Designer: DS Project Management Initials:

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Filename: P:\60545602\900-CAD_GIS\910-CAD\30-FIGURES\60545602-FIG-00-0000-C-1005 TO C-1011.DWG

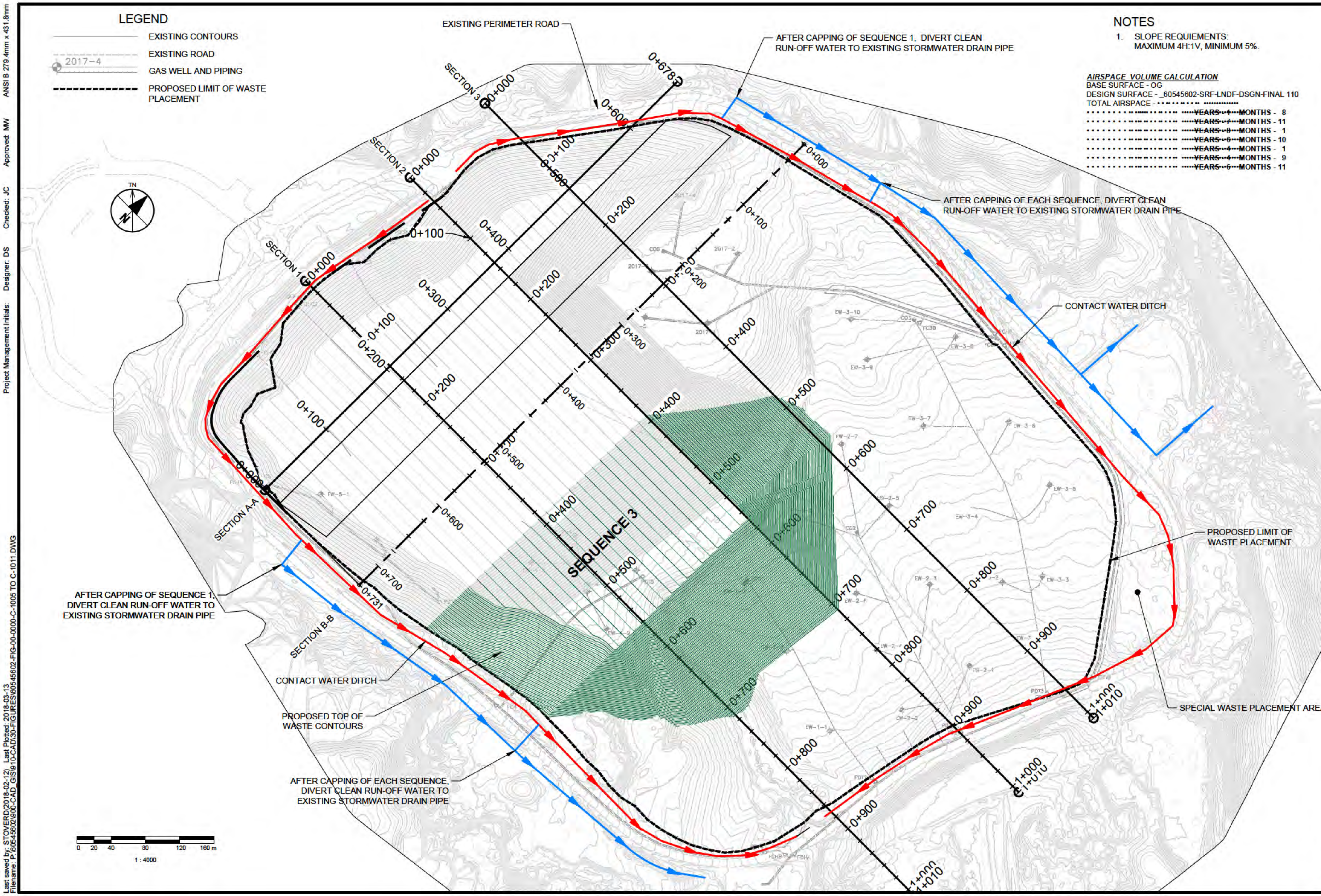
AECOM

Figure: 6

PROPOSED FILL SEQUENCE
SEQUENCE 2

ROBIN HOOD BAY LANDFILL
GAS COLLECTION SYSTEM DESIGN

Project No.: 60545602 Date: MARCH, 2018



ANSI B 279.4mm x 431.8mm Approved: MW Checked: JC Designer: DS Project Management Initials:

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Filename: P:\60545602\900-CAD_GIS\910-CAD\30-FIGURES\60545602-FIG-00-0000-C-1005 TO C-1011.DWG

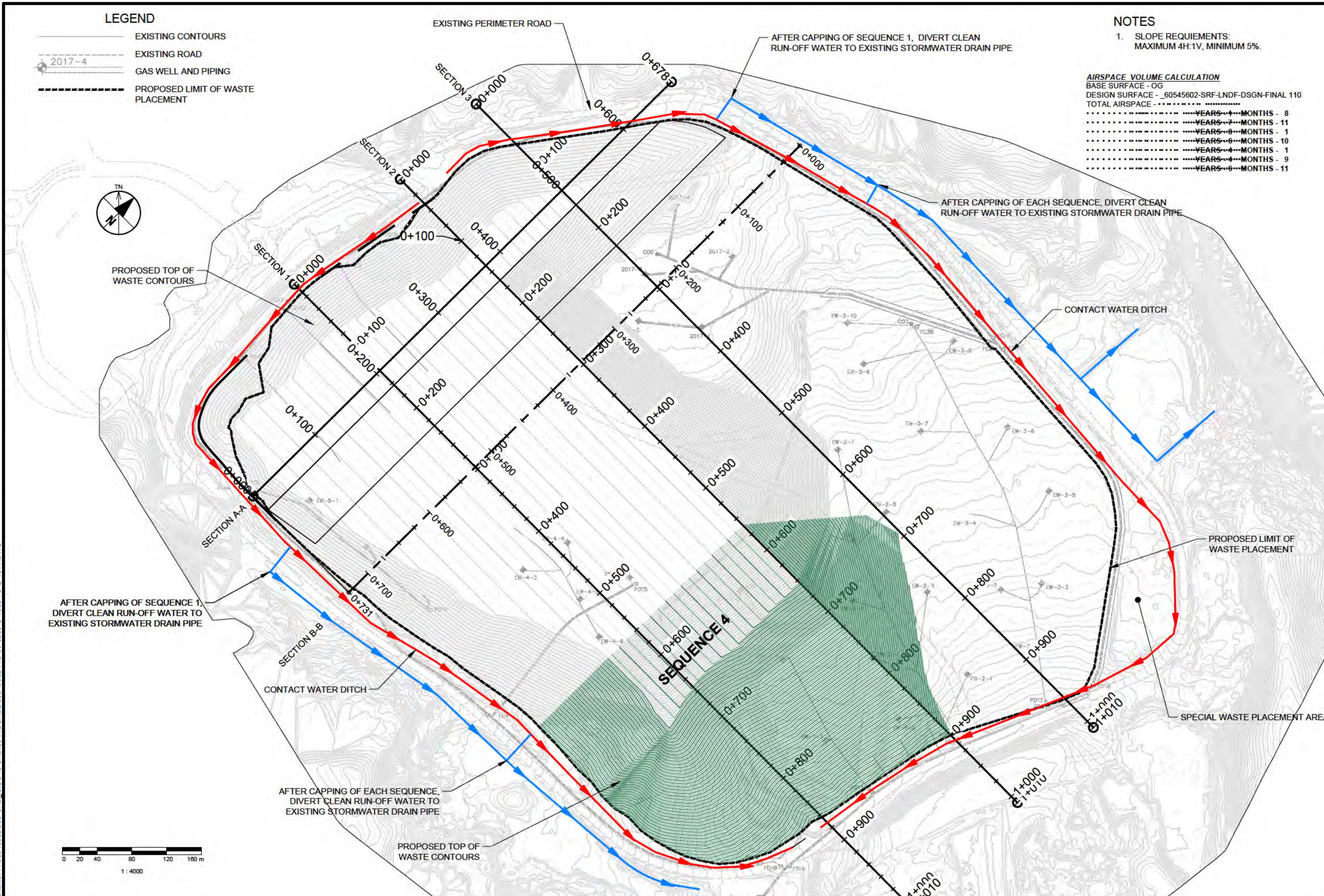
AECOM

Figure: 7

PROPOSED FILL SEQUENCE
SEQUENCE 3

ROBIN HOOD BAY LANDFILL
GAS COLLECTION SYSTEM DESIGN

Project No.: 60545602 Date: MARCH, 2018



AECOM

Figure: 8

PROPOSED FILL SEQUENCE
SEQUENCE 4

ROBIN HOOD BAY LANDFILL
GAS COLLECTION SYSTEM DESIGN

Project No.: 60545602 Date: MARCH, 2018

ANSI B 279.4mm x 431.8mm

Approved: MW Checked: JC Designer: DS Project Management Initials:

Last saved by: STOVERD(2018-03-13) Last Plotted: 2018-03-13
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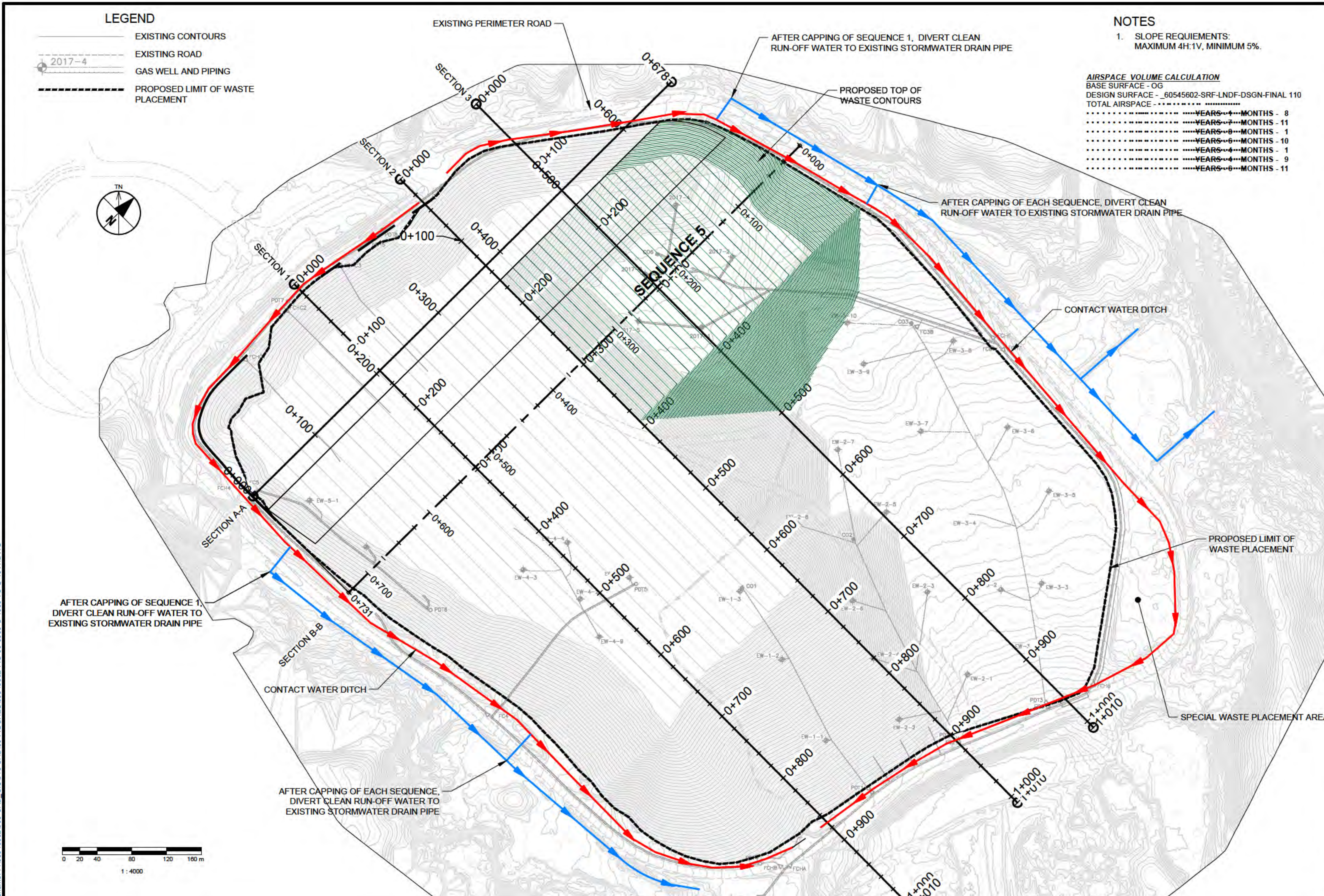

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Filename: P:\60545602\900-CAD_GIS\910-CAD\30-FIGURES\60545602-FIG-00-0000-C-1005 TO C-1011.DWG

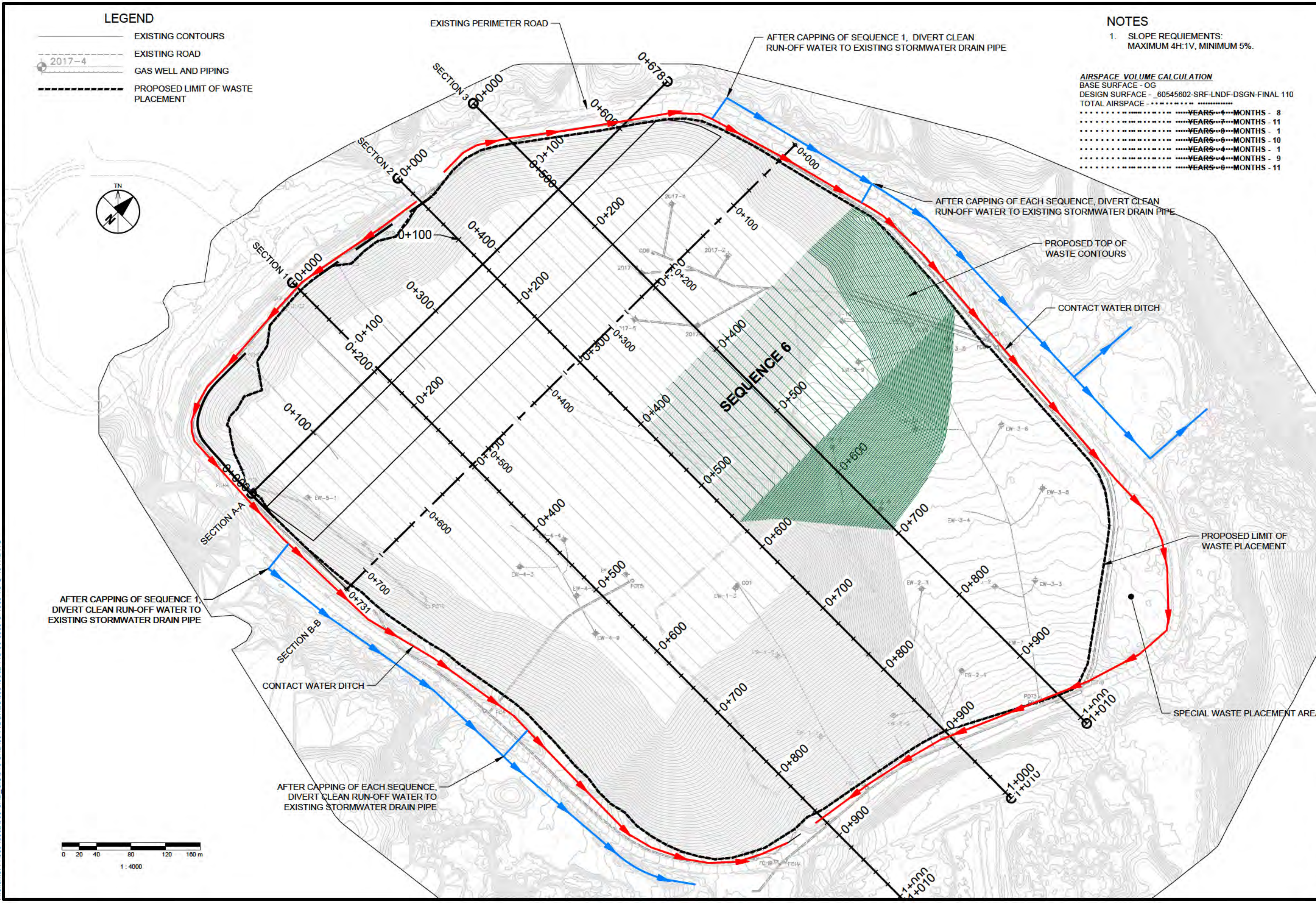
AECOM

Figure: 9

PROPOSED FILL SEQUENCE
SEQUENCE 5

ROBIN HOOD BAY LANDFILL
GAS COLLECTION SYSTEM DESIGN

Project No.: 60545602 Date: MARCH, 2018



ANSI B 279.4mm x 431.8mm Approved: MW Checked: JC Designer: DS Project Management Initials:

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Filename: P:\60545602\900-CAD_GIS\910-CAD\30-FIGURES\60545602-FIG-00-0000-C-1005 TO C-1011.DWG

AECOM

Figure: 10

PROPOSED FILL SEQUENCE
SEQUENCE 6

ROBIN HOOD BAY LANDFILL
GAS COLLECTION SYSTEM DESIGN

Project No.: 60545602 Date: MARCH, 2018

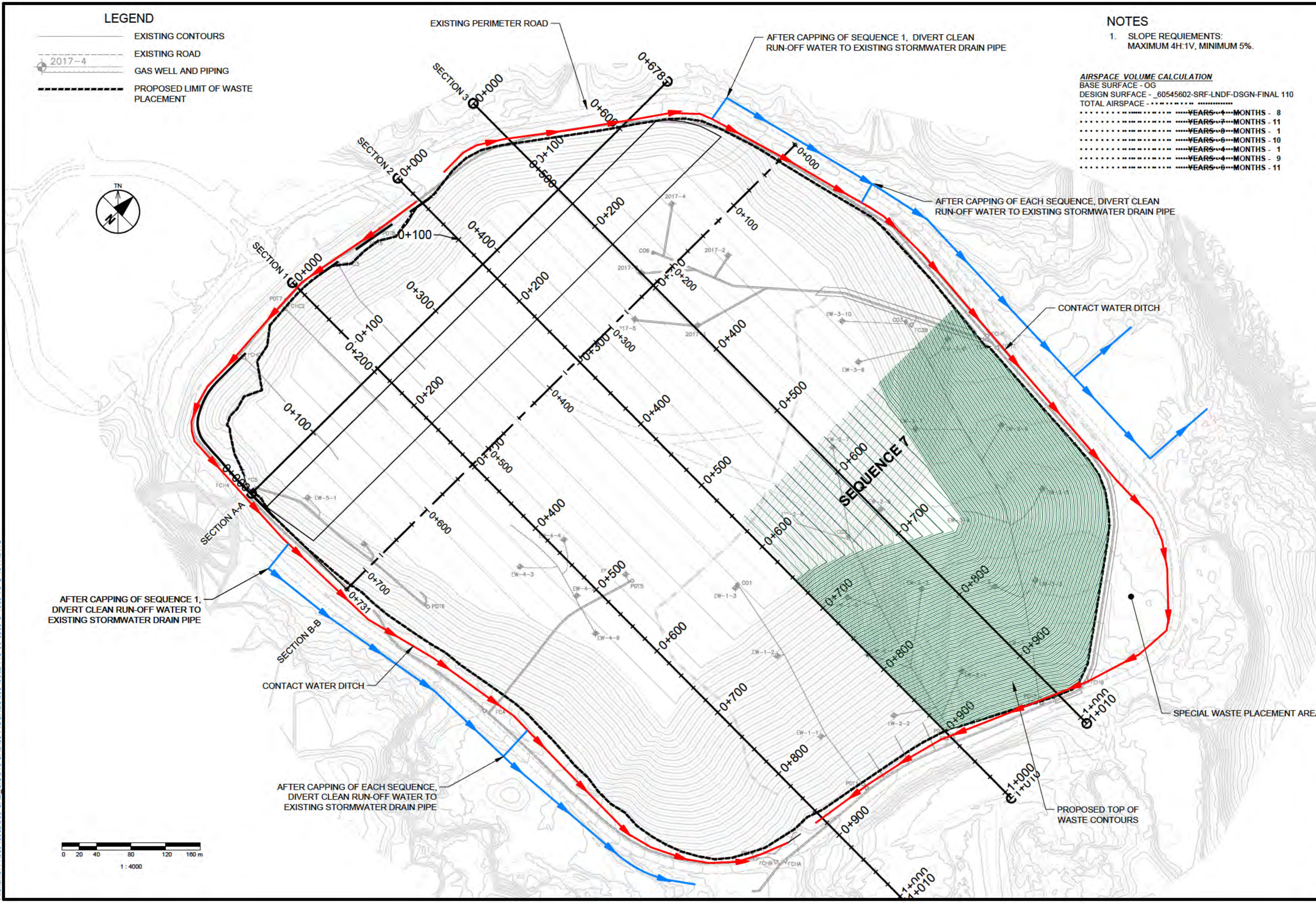

Figure: 11

AECOM

PROPOSED FILL SEQUENCE
SEQUENCE 7

ROBIN HOOD BAY LANDFILL
GAS COLLECTION SYSTEM DESIGN

Project No.: 60545602 Date: MARCH, 2018

ANSI B 279.4mm x 431.8mm Approved: MW Checked: JC Designer: DS Project Management Initials:

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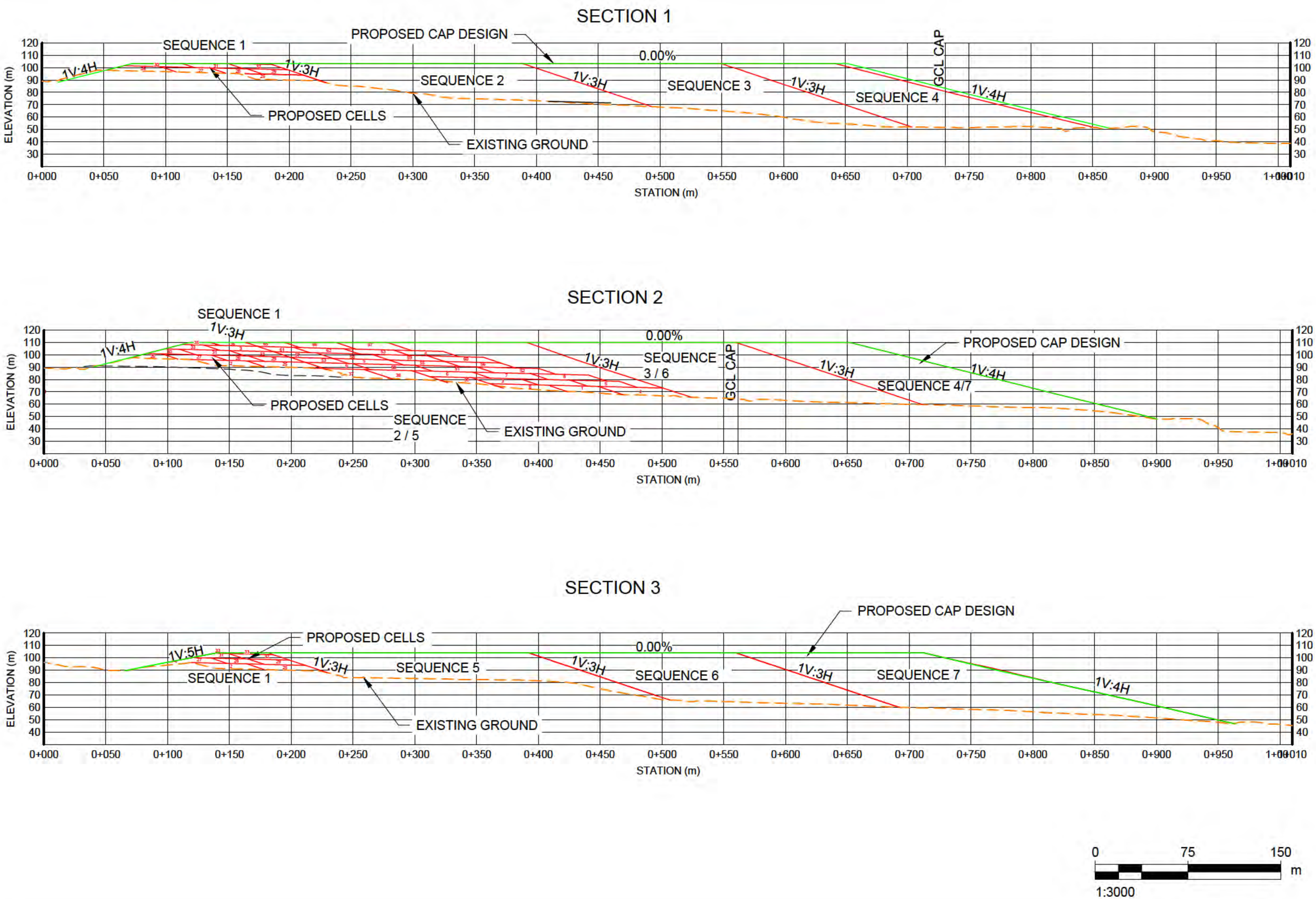

ANSI B 279.4mm x 431.8mm

Approved: MW

Checked: JC

Designer: DS

Project Management Initials:

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Filename: P:\60545602\900-CAD GIS\910-CAD\30-FIGURES\60545602-FIG-00-0000-C-1012 TO C-1013.DWG

AECOM

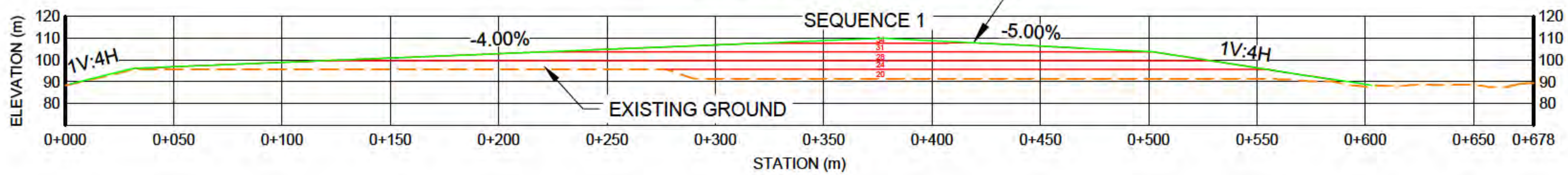
Figure: 12

PROPOSED SEQUENCING CROSS SECTIONS
110 MASL

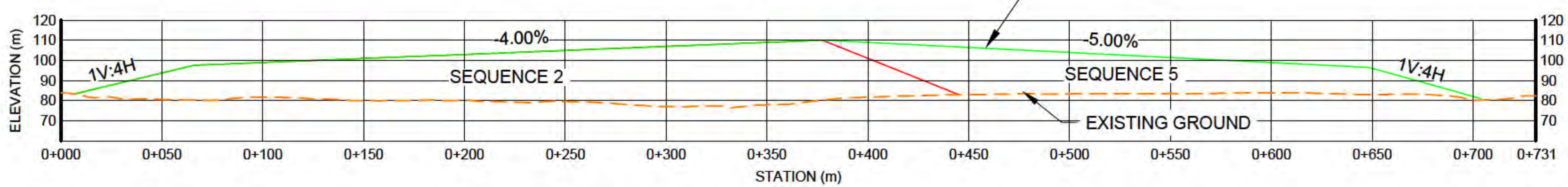
ROBIN HOOD BAY LANDFILL
GAS COLLECTION SYSTEM DESIGN

Project No.: 60545602 Date: MARCH, 2018

SECTION A-A



SECTION B-B



0 62.5 125 m

1:2500

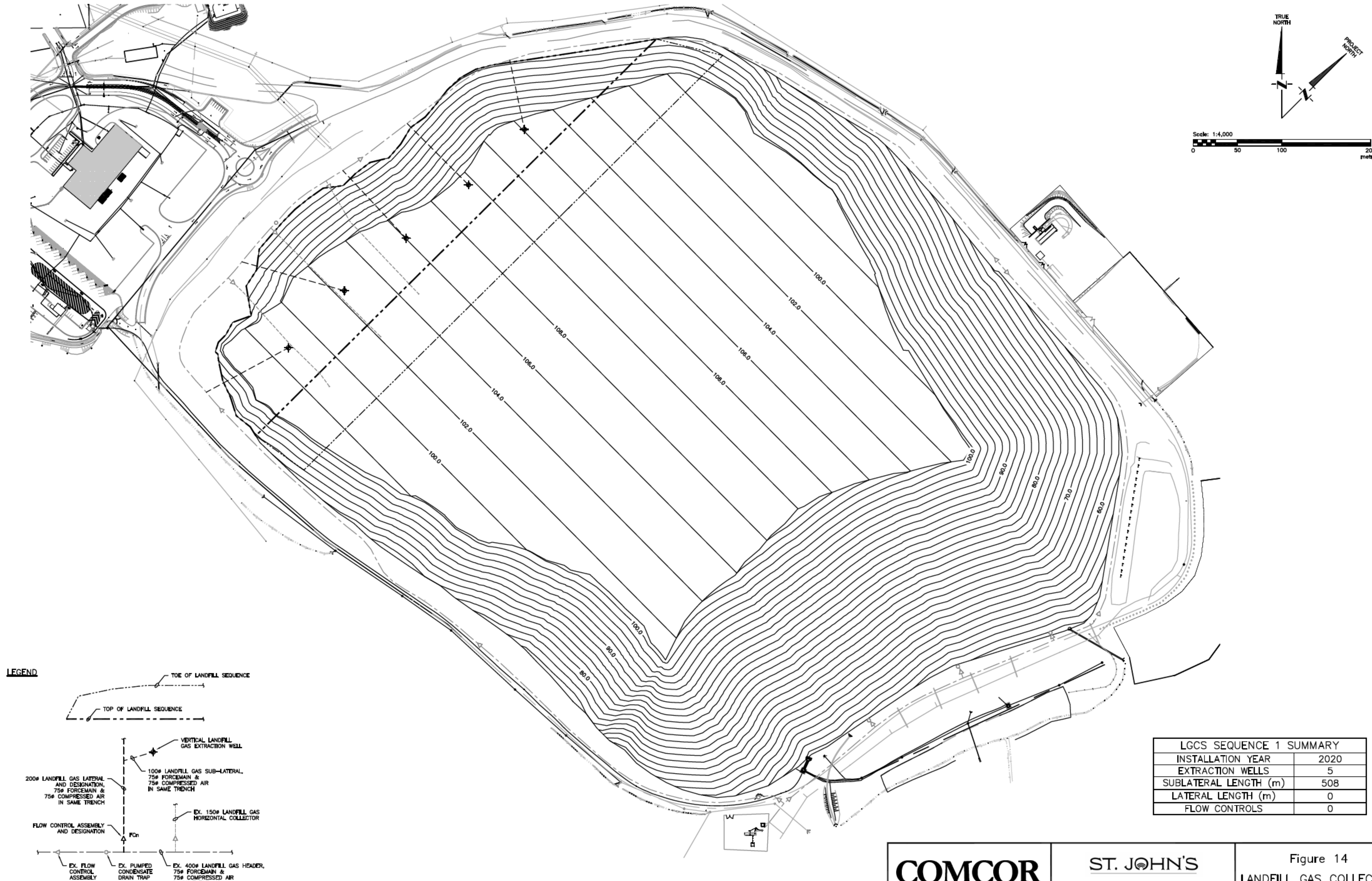
AECOM

Figure: 13

PROPOSED SEQUENCING CROSS SECTIONS
110 MASL

ROBIN HOOD BAY LANDFILL
GAS COLLECTION SYSTEM DESIGN

Project No.: 60545602 Date: MARCH, 2018



LGCS SEQUENCE 1 SUMMARY	
INSTALLATION YEAR	2020
EXTRACTION WELLS	5
SUBLATERAL LENGTH (m)	508
LATERAL LENGTH (m)	0
FLOW CONTROLS	0

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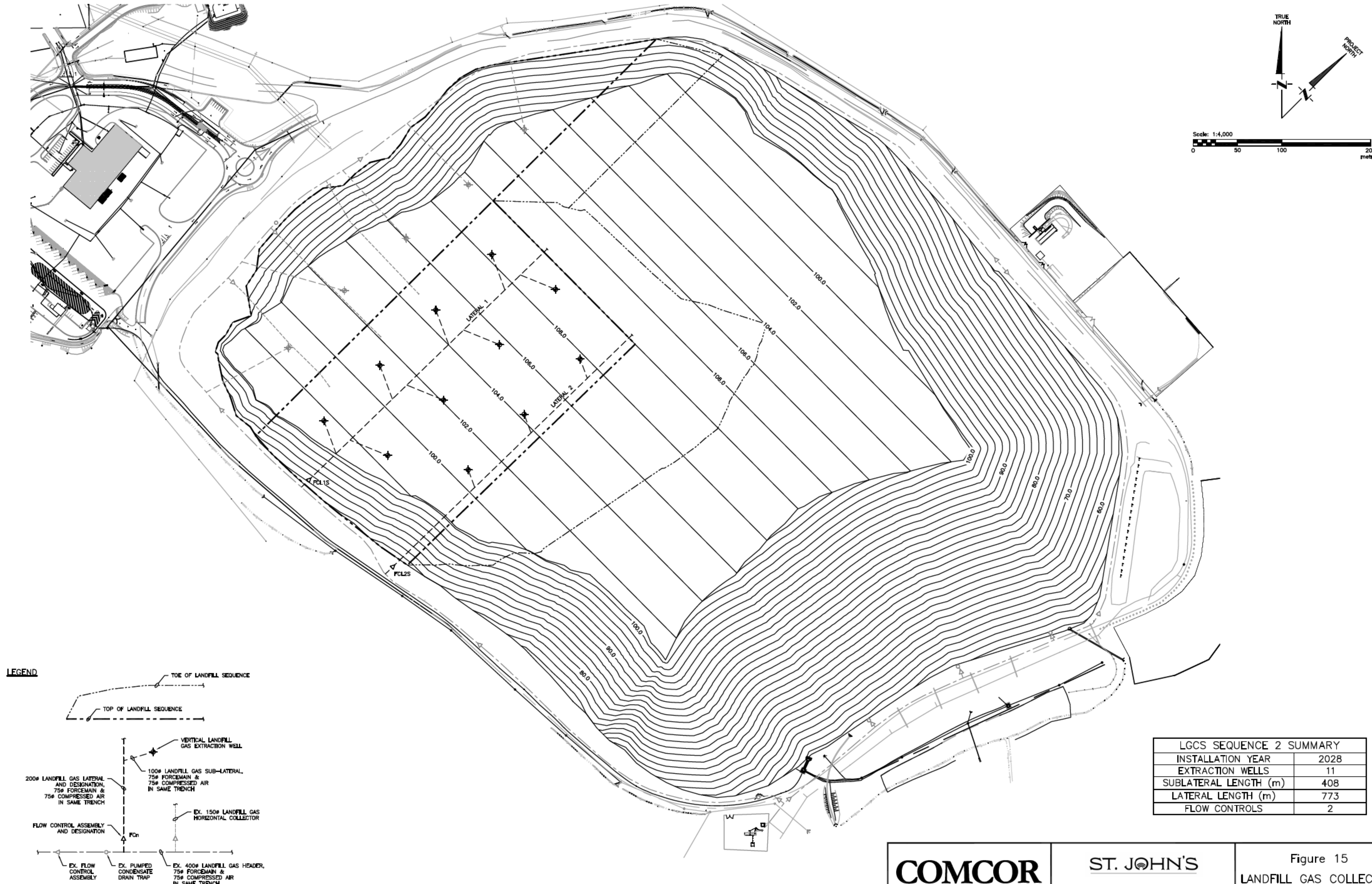
WASTE MANAGEMENT FACILITY

Figure 14
LANDFILL GAS COLLECTION SYSTEM LAYOUT – SEQUENCE 1



LGCS SEQUENCE 2 SUMMARY	
INSTALLATION YEAR	2028
EXTRACTION WELLS	11
SUBLATERAL LENGTH (m)	408
LATERAL LENGTH (m)	773
FLOW CONTROLS	2

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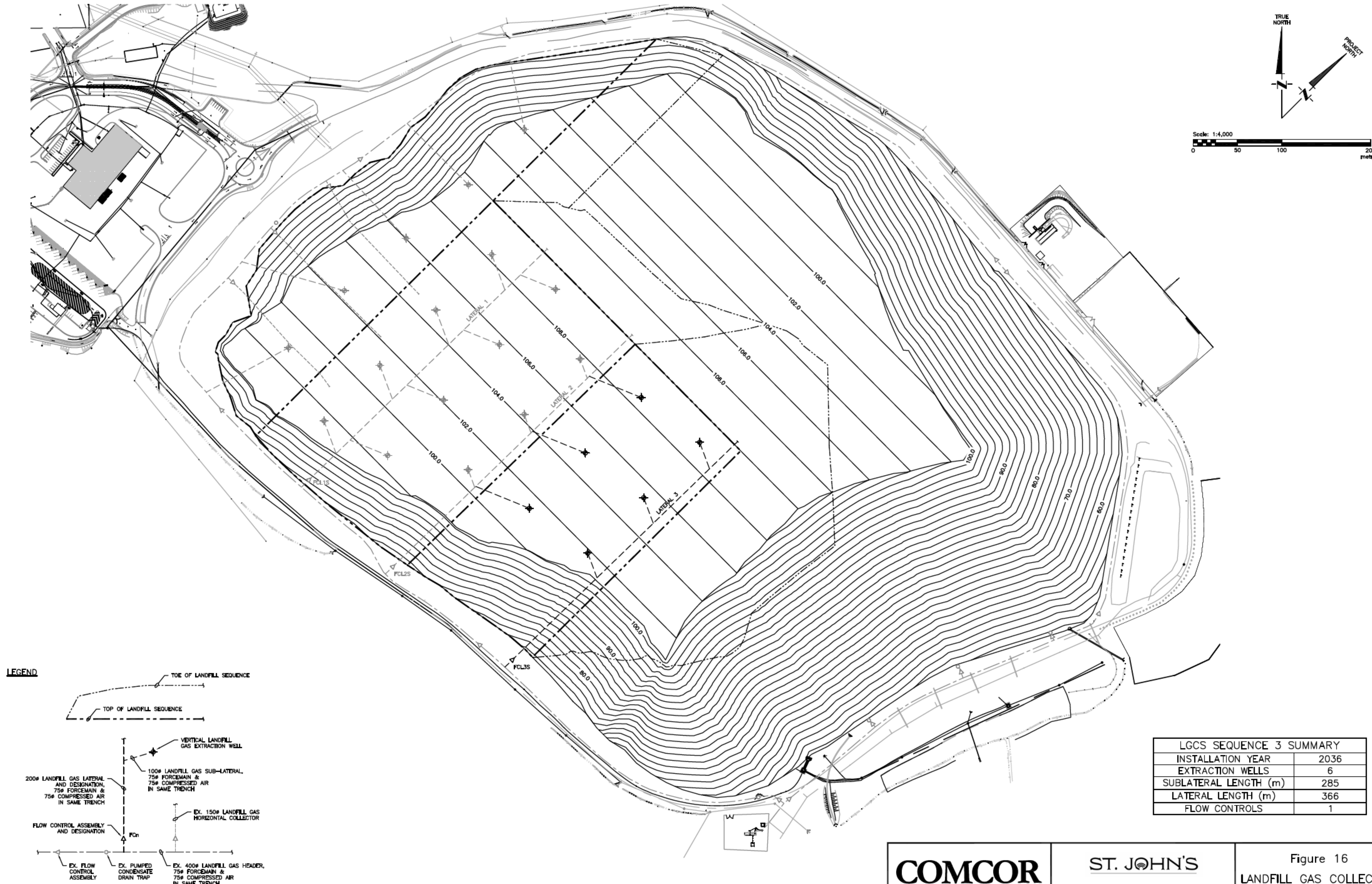
Figure 15
LANDFILL GAS COLLECTION SYSTEM LAYOUT – SEQUENCE 2



LGCS SEQUENCE 3 SUMMARY	
INSTALLATION YEAR	2036
EXTRACTION WELLS	6
SUBLATERAL LENGTH (m)	285
LATERAL LENGTH (m)	366
FLOW CONTROLS	1

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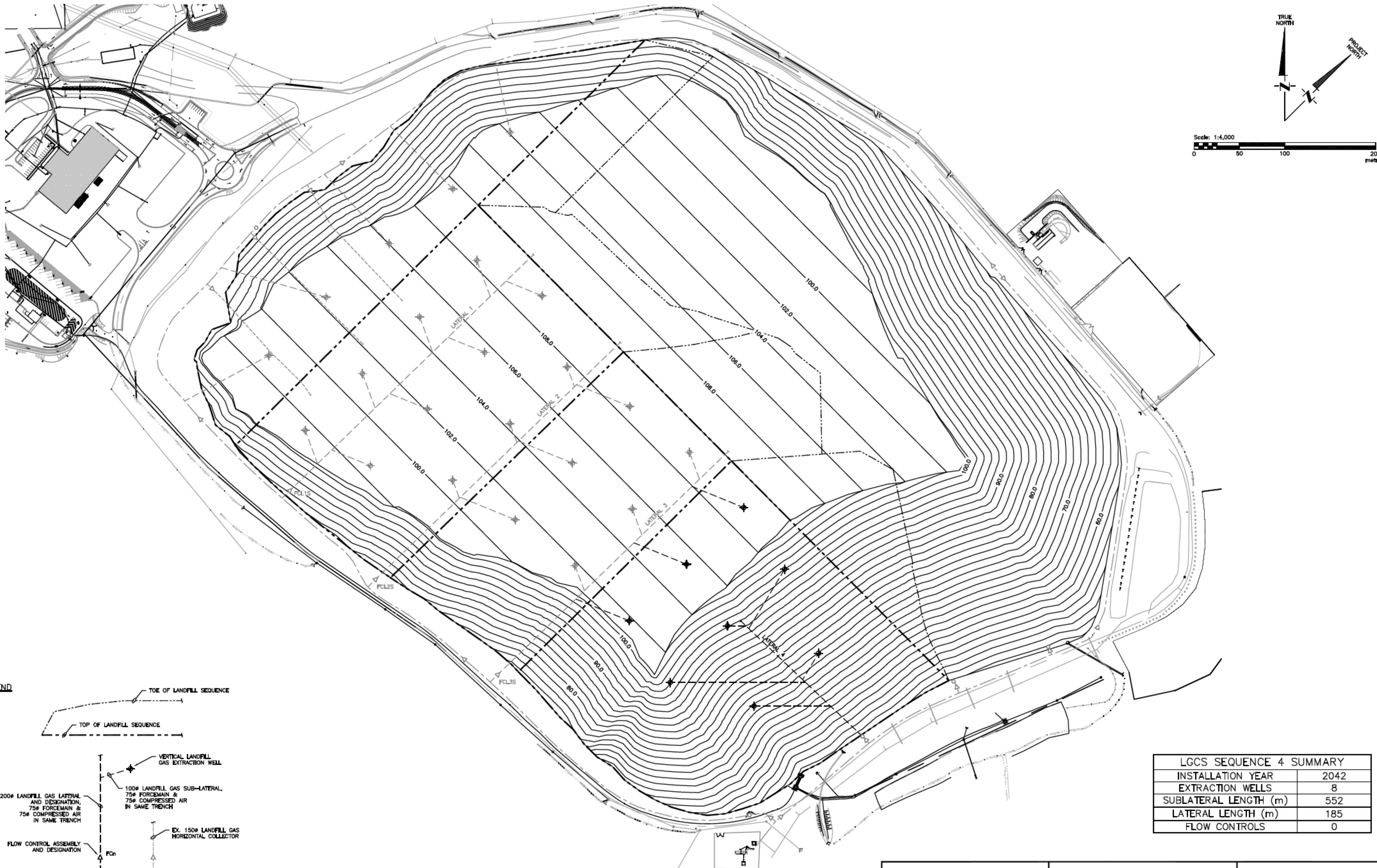
ROBIN HOOD BAY WASTE MANAGEMENT FACILITY

Figure 16
LANDFILL GAS COLLECTION SYSTEM LAYOUT – SEQUENCE 3



LEGEND

- TOE OF LANDFILL SEQUENCE
- TOP OF LANDFILL SEQUENCE
- VERTICAL LANDFILL GAS EXTRACTION WELL
- 200ø LANDFILL GAS LATERAL AND DESIGNATION, 75ø FORCEMAIN & 75ø COMPRESSED AIR IN SAME TRENCH
- 100ø LANDFILL GAS SUB-LATERAL, 75ø FORCEMAIN & 75ø COMPRESSED AIR IN SAME TRENCH
- EX. 150ø LANDFILL GAS HORIZONTAL COLLECTOR
- FLOW CONTROL ASSEMBLY AND DESIGNATION (FCn)
- EX. FLOW CONTROL ASSEMBLY
- EX. PUMPED CONDENSATE DRAIN TRAP
- EX. 400ø LANDFILL GAS HEADER, 75ø FORCEMAIN & 75ø COMPRESSED AIR IN SAME TRENCH

LGCS SEQUENCE 4 SUMMARY	
INSTALLATION YEAR	2042
EXTRACTION WELLS	8
SUBLATERAL LENGTH (m)	552
LATERAL LENGTH (m)	185
FLOW CONTROLS	0

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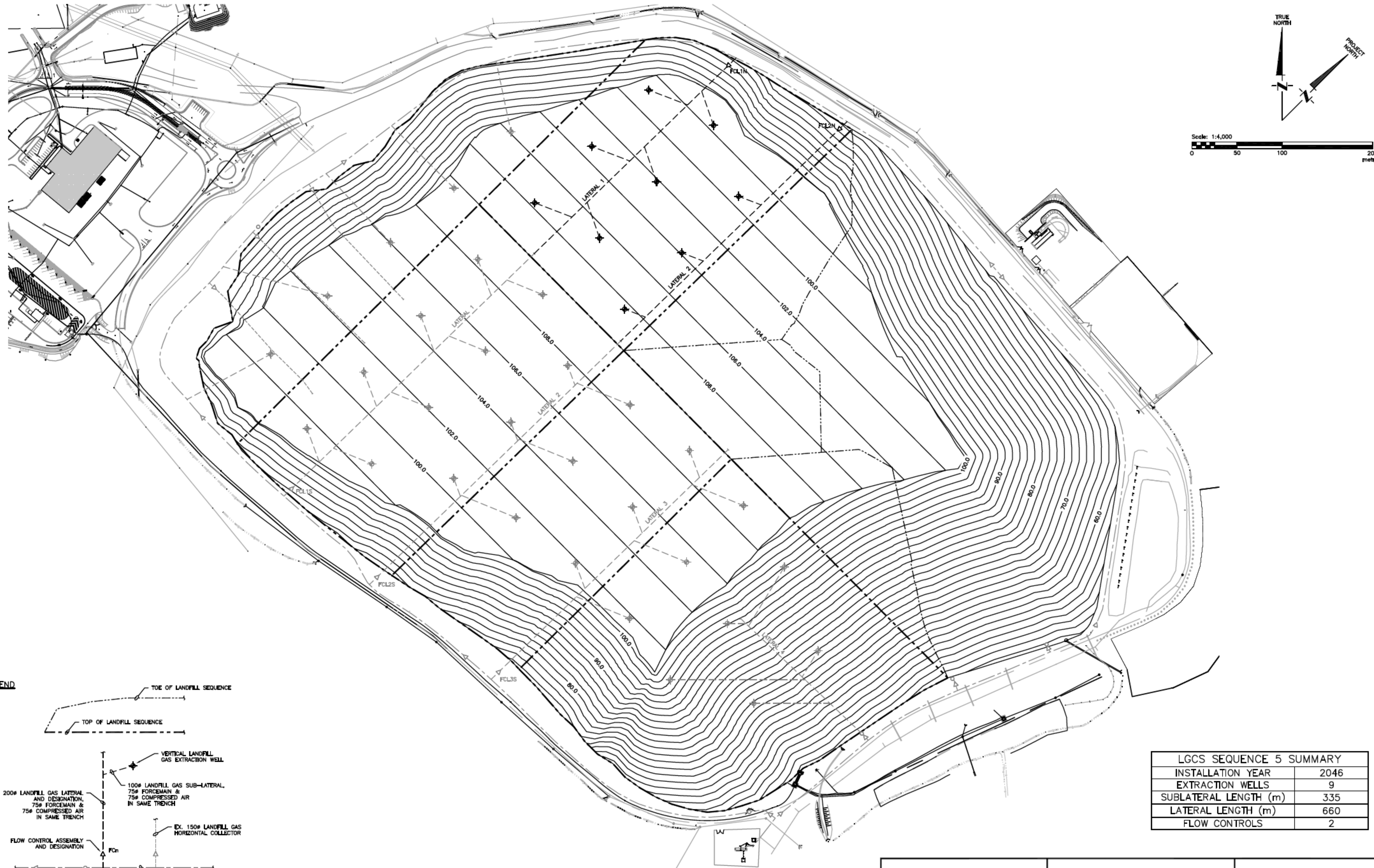
Figure 17
LANDFILL GAS COLLECTION SYSTEM LAYOUT – SEQUENCE 4



LEGEND

TOE OF LANDFILL SEQUENCE

TOP OF LANDFILL SEQUENCE

VERTICAL LANDFILL GAS EXTRACTION WELL

100ø LANDFILL GAS SUB-LATERAL, 75ø FORCEMAIN & 75ø COMPRESSED AIR IN SAME TRENCH

200ø LANDFILL GAS LATERAL AND DESIGNATION, 75ø FORCEMAIN & 75ø COMPRESSED AIR IN SAME TRENCH

EX. 150ø LANDFILL GAS HORIZONTAL COLLECTOR

FLOW CONTROL ASSEMBLY AND DESIGNATION

FCn

EX. FLOW CONTROL ASSEMBLY

EX. PUMPED CONDENSATE DRAIN TRAP

EX. 400ø LANDFILL GAS HEADER, 75ø FORCEMAIN & 75ø COMPRESSED AIR IN SAME TRENCH

LGCS SEQUENCE 5 SUMMARY	
INSTALLATION YEAR	2046
EXTRACTION WELLS	9
SUBLATERAL LENGTH (m)	335
LATERAL LENGTH (m)	660
FLOW CONTROLS	2

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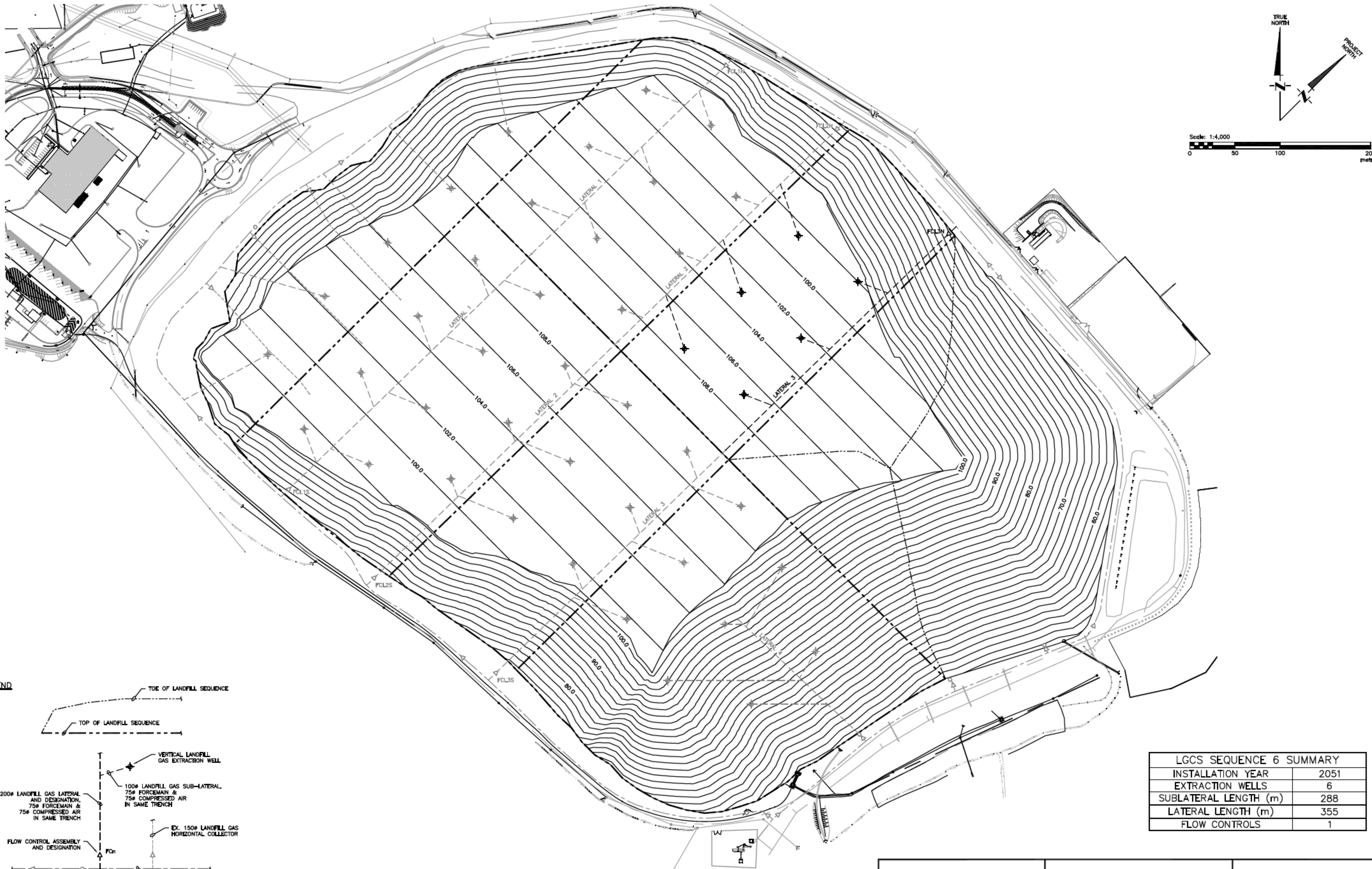
ST. JOHN'S

ROBIN HOOD BAY WASTE MANAGEMENT FACILITY

Figure 18

LANDFILL GAS COLLECTION SYSTEM LAYOUT – SEQUENCE 5



LEGEND

- TOE OF LANDFILL SEQUENCE
- TOP OF LANDFILL SEQUENCE
- VERTICAL LANDFILL GAS EXTRACTION WELL
- 100ø LANDFILL GAS SUB-LATERAL, 75ø FORCEMAIN & 75ø COMPRESSED AIR IN SAME TRENCH
- 200ø LANDFILL GAS LATERAL AND DESIGNATION, 75ø FORCEMAIN & 75ø COMPRESSED AIR IN SAME TRENCH
- EX. 150ø LANDFILL GAS HORIZONTAL COLLECTOR
- FLOW CONTROL ASSEMBLY AND DESIGNATION (FCn)
- EX. FLOW CONTROL ASSEMBLY
- EX. PUMPED CONDENSATE DRAIN TRAP
- EX. 400ø LANDFILL GAS HEADER, 75ø FORCEMAIN & 75ø COMPRESSED AIR IN SAME TRENCH

LGCS SEQUENCE 6 SUMMARY	
INSTALLATION YEAR	2051
EXTRACTION WELLS	6
SUBLATERAL LENGTH (m)	288
LATERAL LENGTH (m)	355
FLOW CONTROLS	1

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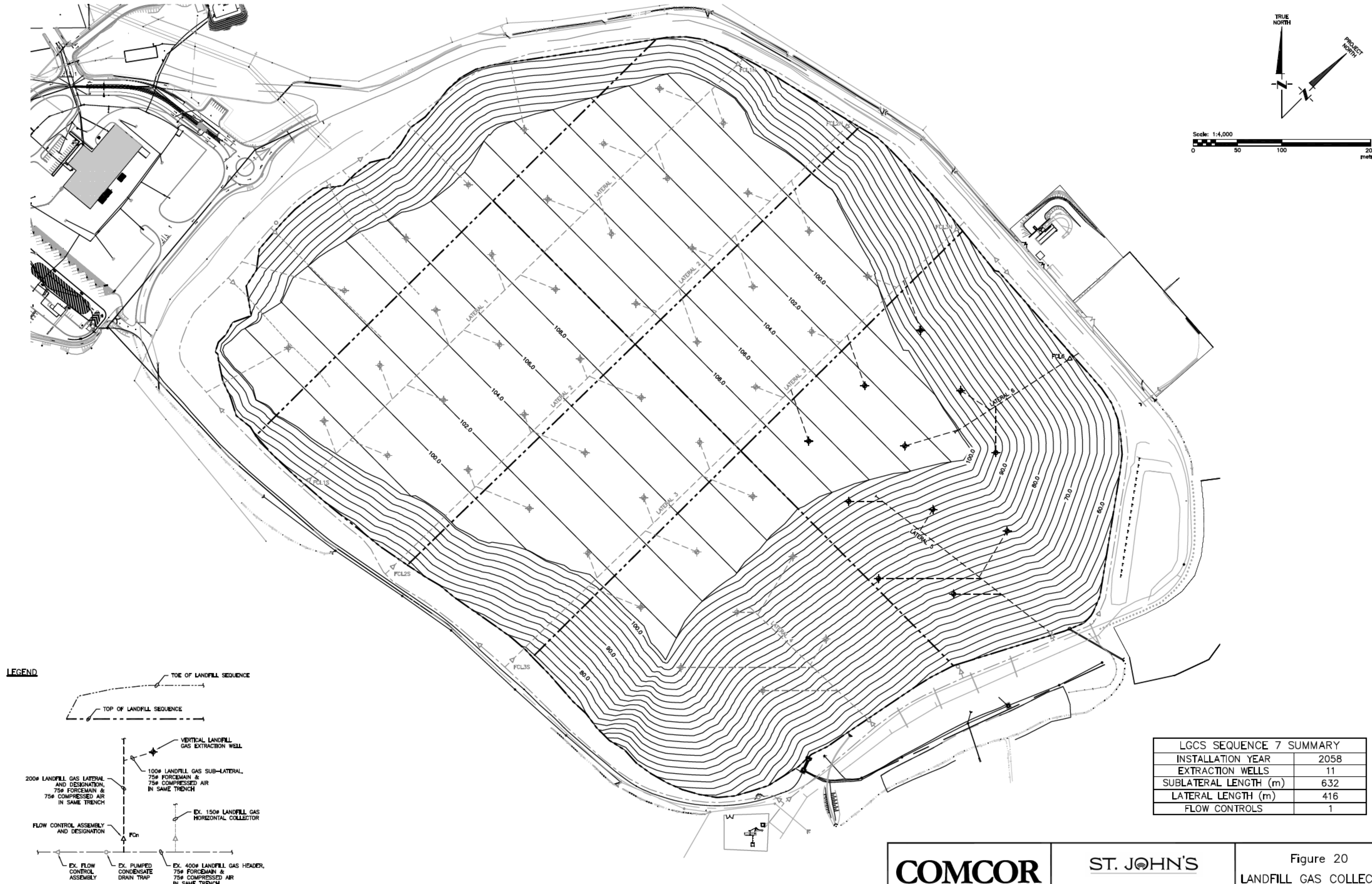
WASTE MANAGEMENT FACILITY

Figure 19
LANDFILL GAS COLLECTION SYSTEM LAYOUT – SEQUENCE 6



LGCS SEQUENCE 7 SUMMARY	
INSTALLATION YEAR	2058
EXTRACTION WELLS	11
SUBLATERAL LENGTH (m)	632
LATERAL LENGTH (m)	416
FLOW CONTROLS	1

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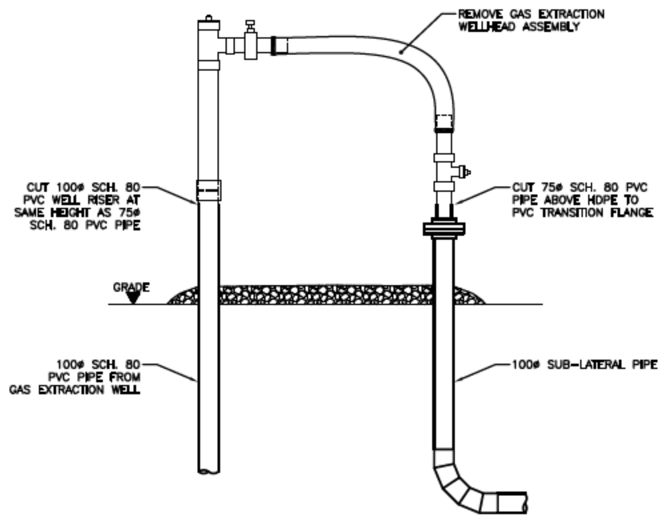
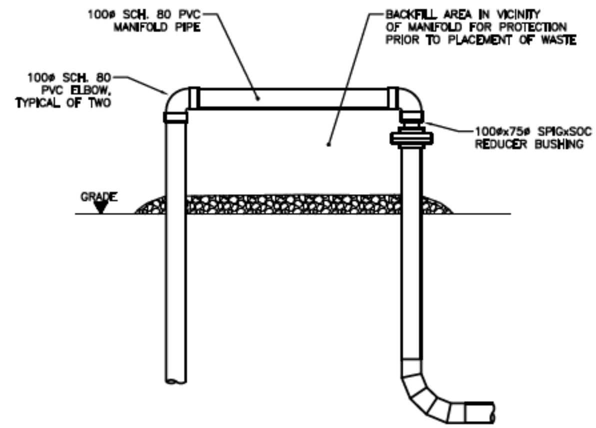
ST. JOHN'S
ROBIN HOOD BAY
WASTE MANAGEMENT FACILITY

Figure 20
LANDFILL GAS COLLECTION SYSTEM LAYOUT – SEQUENCE 7



LANDFILL GAS EXTRACTION WELL DEMOLITION DETAIL
NTS



MANIFOLD RENOVATION DETAIL
NTS

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ST. JOHN'S

ROBIN HOOD BAY
WASTE MANAGEMENT FACILITY

Figure 21

MANIFOLD RENOVATION DETAIL

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Consulting Engineers and Landfill Gas Specialists

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Cambridge, ON N1T 1Z6
tel (519) 621-6669
fax (519) 621-9944
www.comcor.com

December 21, 2018

BY EMAIL

Mr. Jonathan Murphy, P.Eng.
Waste Management Engineer
City of St. John's
Waste & Recycling Division
Department of Public Works
PO Box 908
St. John's, NL A1C 5M2

Project No. 9-535

Dear Mr. Murphy:

Re: 2018 Surface Emissions Survey
Robin Hood Bay Waste Management Facility
St. John's, Newfoundland

1.0 Background

In 2017, Comcor Environmental Limited (Comcor) was retained by the City of St. John's (City) to design and administer an expansion to the Landfill Gas Collection System (System) at the Robin Hood Bay Waste Management Facility (Site) in St. John's, Newfoundland. As part of the expansion design, Comcor completed a surface emissions survey (SES) to identify the locations and quantities of fugitive emission escaping from the landfill surface. The results of the 2017 SES were used to assist in the design of the 2017 System expansion, which consisted of 5 vertical extraction wells installed in the northwest corner of the Site.

During the summer of 2018, the City installed an additional 4 vertical landfill gas extraction wells in the northwest portion of the Site and covered the 2017/2018 System expansion area with a geosynthetic clay liner (GCL) to further reduce fugitive landfill gas emissions. A Site Plan, provided as Figure 1, shows the coverage of the current System, the location of the new GCL, and the extent of the active waste filling area. All cardinal directions mentioned in this report are in relation to project north as shown in the provided figures.

The City retained Comcor to complete a follow-up surface emissions survey to evaluate the performance of the Landfill Gas Collection System expansions and GCL installation in the northwest portion of the Site. Between September 26th and 28th, 2018, Comcor performed an SES of the Site (excluding areas immediately adjacent to the active working faces). This report discusses the results of the 2018 SES and evaluates the sources of fugitive landfill gas emissions from the waste mound at the Site.

2.0 Methodology

The surface emissions survey was completed using Comcor's SES Protocol which is based on the United States Environmental Protection Agency's (USEPA) New Source Performance Standards (NSPS) for surface emissions monitoring at municipal solid waste landfills. The Protocol's methodology generally involves walking in a 30 metre grid to detect fugitive landfill gas emissions across the waste mound. Comcor's SES Protocol is provided as Attachment A.

A Trimble SiteFID Gas Monitor (Monitor) was used to perform the survey. The Monitor uses a flame ionization detector to measure methane gas with a detection limit of 1 part per million (ppm). The Monitor is equipped with a global positioning system (GPS) which tracks the survey grid and location of all methane readings.

3.0 Operational and Site Conditions

The current Landfill Gas Collection System consists of 42 vertical extraction wells and 3 horizontal collectors connected to a full ring header. The active waste filling area is currently located west of the new vertical extraction wells installed in 2017/2018. Prior to 2018, two geosynthetic clay liners were installed as a cover system, with one GCL over top of Laterals 1, 2 and 3, and the other GCL over top of Lateral 4. A new GCL was installed over the 2017/2018 System expansion areas and tied into the existing GCL over Laterals 1, 2 and 3. The current Landfill Gas Collection System and location of the GCLs is shown in Figure 1.

Between September 26th and 28th, 2018, Comcor performed the SES over the inactive areas of the waste mound and inspected the Site for evidence of landfill gas build-up, stressed vegetation, cracks in the cover system, and areas of obvious odours. The Landfill Gas Collection System was in operation during the SES. Weather conditions during the three days of the SES were average for the season, and are summarized in Table 1 below:

Table 1
SES Weather Conditions
Robin Hood Bay Waste Management Facility
St. John's, Newfoundland

Parameter	Sept. 26, 2018	Sept. 27, 2018	Sept. 28, 2018
Temperature	12°C	16°C	14°C
Wind Speed	22 km/hr	29 km/hr	17 km/hr
Wind Direction	Southwest	Southwest	North
Cloud Cover	Mostly Cloudy	Mostly Cloudy	Drizzle
Barometric Pressure	101.1 kPa	100.4 kPa	100.7 kPa
Relative Humidity	45%	80%	100%

4.0 Results

4.1 Background Emissions

Background methane concentration readings are taken before a surface emissions survey is conducted in order to identify which surface emissions are results of the landfill, and which are from alternative sources offsite. Background readings are taken upwind from the landfill site to ensure that emissions from the landfill do not influence the background concentrations. Prior to commencing the SES, Comcor took background concentration readings upwind and downwind at a distance of 30 metres or more from the limit of waste. The average upwind and downwind concentrations were 0 ppm and 1.7 ppm, respectively. This means, on average, 1.7 ppm of the methane readings are from other areas of the Site. To compensate for this, the SiteFID automatically subtracts 1.7 ppm from each measured methane concentration and reports each data point as an adjusted concentration.

4.2 Measured Emissions

Figure 2 shows the path walked during the surface emissions survey. During the afternoon of September 26th, 2018, the SES was started by walking the area between the main haul road and the boulder barrier that protects the new GCL, as traced in blue on Figure 2. The intent was to walk the entire new GCL area by the end of the day. However, when measuring around cleanout CO6, the SiteFID flame was extinguished by a high concentration of methane leaking from the base of the landfill gas collection pipe. The SiteFID could not be restarted, and the SES was ended early for the day.

The majority of the SES was completed on September 27th, 2018, as traced in red on Figure 2. The SES was resumed at cleanout CO6, moving across the new GCL area, and then continuing over the portion of the Site north of the middle haul road. Next, the northwest corner of the Site was monitored in a dense grid in an attempt to locate the source of odours that are frequently detected from the perimeter road between the scale house and the main haul road. From there, the rest of the western side of the Site was monitored, which contains the newest waste. And lastly, the area south of the middle haul road was monitored. Note that a large area in the south of the Site was not monitored due to clean fill disposal and stockpiling operations.

Comcor met with the City and Mr. Tom Kendall to discuss the preliminary results of the SES during the morning of September 28th, 2018. It was requested that the toe of the waste footprint be monitored along the west and southwest corner of the Site, outside of the perimeter fence. Patches of melted snow are often seen in this area during the winter season. This path is traced in green on Figure 2.

In accordance with the Protocol, a minimum concentration of 1,000 ppm is commonly used as the emissions exceedance threshold. However, as a conservative measure, Comcor has reported all measurements that exceeded 200 ppm. Figure 3 presents the emissions exceedances above 200 ppm, of which there were 60 distinct locations encountered during the SES. Where multiple exceedances were monitored within a 5 metre radius, only the highest concentration was reported. Each exceedance is labelled with a location ID in Figure 3 that corresponds with the ID in the Emissions Exceedances Summary provided as Table 2.

One quarter, or 15 of the listed exceedances occurred along the southern edge of the new GCL, between the contact water ditch and the middle haul road. Concentrations were higher on the south edge of the ditch, which is expected, since the GCL was extended under the ditch and terminated on the south side. A further 11 of the listed exceedances occurred on the new GCL, of which 6 were located at liner penetrations for landfill gas collection infrastructure. Of the remaining 5 exceedances that occurred on the new GCL, 3 were thought to be at locations where the liner was damaged during installation (ID#s 4010, 4012 and 4014). Comcor provided the coordinates of these locations to Mr. Tom Kendall, and the GCL installer was brought back to Site to expose these areas. Small tears were found and repaired at location ID#s 4012 and 4014.

In the northwest corner of the Site, where odours are frequently detected from the perimeter road, a total of 7 exceedances were monitored. Several of the exceedance locations had visible cracks/holes in the cover material, and odours were apparent. On September 28th, 2018, when Comcor met with the City and Mr. Tom Kendall, it was discussed that a short horizontal collector could be installed in this area, parallel to the perimeter road, and tied in to the adjacent ring header.

No exceedances were monitored on the plateau of Cells 22, 23 and 24, which was recently covered with coarse 4" minus starting in May, 2017. Exceedances in the vicinity of these Cells were generally limited to the toe/side slopes (ID#s 4038, 4040, 4044, and 4045) and landfill gas wells/flow control assemblies (ID#s 4039, 4041, and 4043).

A total of 6 exceedances were monitored in the area around Lateral 4, all of which occurred at either a landfill gas well/pump drain trap, or along the edge of the existing GCL that covers Lateral 4. On the existing GCL that covers Laterals 1, 2 and 3, a total of 9 exceedances were monitored, all of which occurred at either a landfill gas well/flow control assembly, or along the southern edge of the existing GCL at the top of the slope of the contact water ditch.

On the last day of the SES, the toe of the waste footprint was monitored along the west and southwest corner of the Site. Several locations exhibited signs of vegetative stress, however only three exceedances were monitored, ranging from 209 to 404 ppm, and no landfill gas odours were apparent.

The highest exceedance measured during the SES occurred around the chamber of pump drain trap PDT5 and was on the order of 15,000 ppm (1.50% by volume), which is less than the lower explosive limit of methane (50,000 ppm or 5% by volume).

COMCOR

5.0 Conclusions and Recommendations

Based on the results of the 2018 surface emissions survey, the following summary/conclusions can be made:

- Even though there were more distinct methane exceedances monitored during the 2018 SES as compared to the 2017 SES (60 vs. 34), there was a perceptible decrease in landfill gas odours while traversing the survey path in 2018.

- The new GCL is significantly reducing fugitive landfill gas emissions and odours over the 2017/2018 System expansion area, and is operating as expected. While not shown in Figure 3, methane readings were mostly 0 ppm, and generally ranged between 0 and 20 ppm during the 2018 SES, as compared to the 2017 SES, where methane was consistently measured between 10 and 200 ppm over what is now the new GCL area. Methane exceedances on the new GCL area were generally limited to the southern edge of the liner as well as penetrations from landfill gas collections system infrastructure.

- Since the new GCL was installed a few weeks prior to the 2018 SES, the bentonite layer may not have been fully hydrated. The GCL should be fully hydrated after the spring thaw in 2019.

- The lack of exceedances and odours on the plateau of Cells 22, 23 and 24 may be due to the age of waste in this area. It takes approximately 1 year for the decomposition process to change from aerobic to anaerobic. Once the anaerobic bacteria start producing landfill gas, odours will likely become prevalent in this area due to the coarse 4” minus cover material.

- The most significant odours were detected in the northwest corner of the Site, just inside of the perimeter road between the scale house and the main haul road. The source of the odours was confirmed by several methane exceedances along with visible cracks/holes in the cover material.

- The highest methane concentration measured during the SES was on the order of 15,000 ppm (1.50% by volume) at pump drain trap PDT5. By comparison, the Ontario landfill standard (O.Reg. 232/98) requires that subsurface methane be lower than 25,000 ppm (2.5% by volume) at a landfill’s property line. Therefore, methane exceedances monitored at the Site do not represent a health and safety hazard.

In conjunction with the SES conducted, the following recommendations for the continued operation of the Site's landfill gas control systems are as follows:

- In the spring of 2019, after the GCL has fully hydrated, the City's Envision portable landfill gas analyzer should be used to retest exceedance locations to determine if additional repairs are required. The Envision is capable of detecting methane down to 0.1% by volume, or 1,000 ppm, so the major exceedances should register a reading. The Envision could also be used during the winter season to confirm fugitive emissions in areas where snow is melting around the Site.

- As discussed during the post-SES meeting on September 28th, 2018, a short horizontal collector could be installed in the northwest corner of the Site to deal with odours along the perimeter road between the scale house and the main haul road.

- When installing a capping system, it is best to "key in" the cap to the base liner system or the cap of an adjacent cell to prevent landfill gas from finding a way out around the edges. However, this was not possible along the south edge of the new GCL, since there was no existing cap/liner system to key into. While installing the GCL under the contact water ditch may have reduced emissions, there was still a continuous line of methane hits along the southern edge. The only feasible alternative would have been to dig down several metres along the ditch and extend the GCL down vertically to create a larger corner pocket along the entire south edge.

- Going forward, the most practical approach to minimizing landfill gas emissions in and around the new GCL is to maximize the amount of vacuum being applied to the new wells on Lateral 6 and Wells 2-9 and 2-10. Landfill gas always migrates through the easiest pathway. If vacuum influence on the new wells is increased, it should decrease the amount of gas reaching the south edge of the new GCL. This could be achieved by increasing the blower's VFD frequency and/or turning down wellhead valves in areas of the Site that are not experiencing odour issues, such as the original wells on Laterals 1, 2 and 3, so that more vacuum reaches wells in problem areas. While considering flare flame stability, Wells 2-9, 2-10 and 6-7, could be balanced with a higher than optimal oxygen concentration to maximize landfill gas control near the south edge of the new GCL.

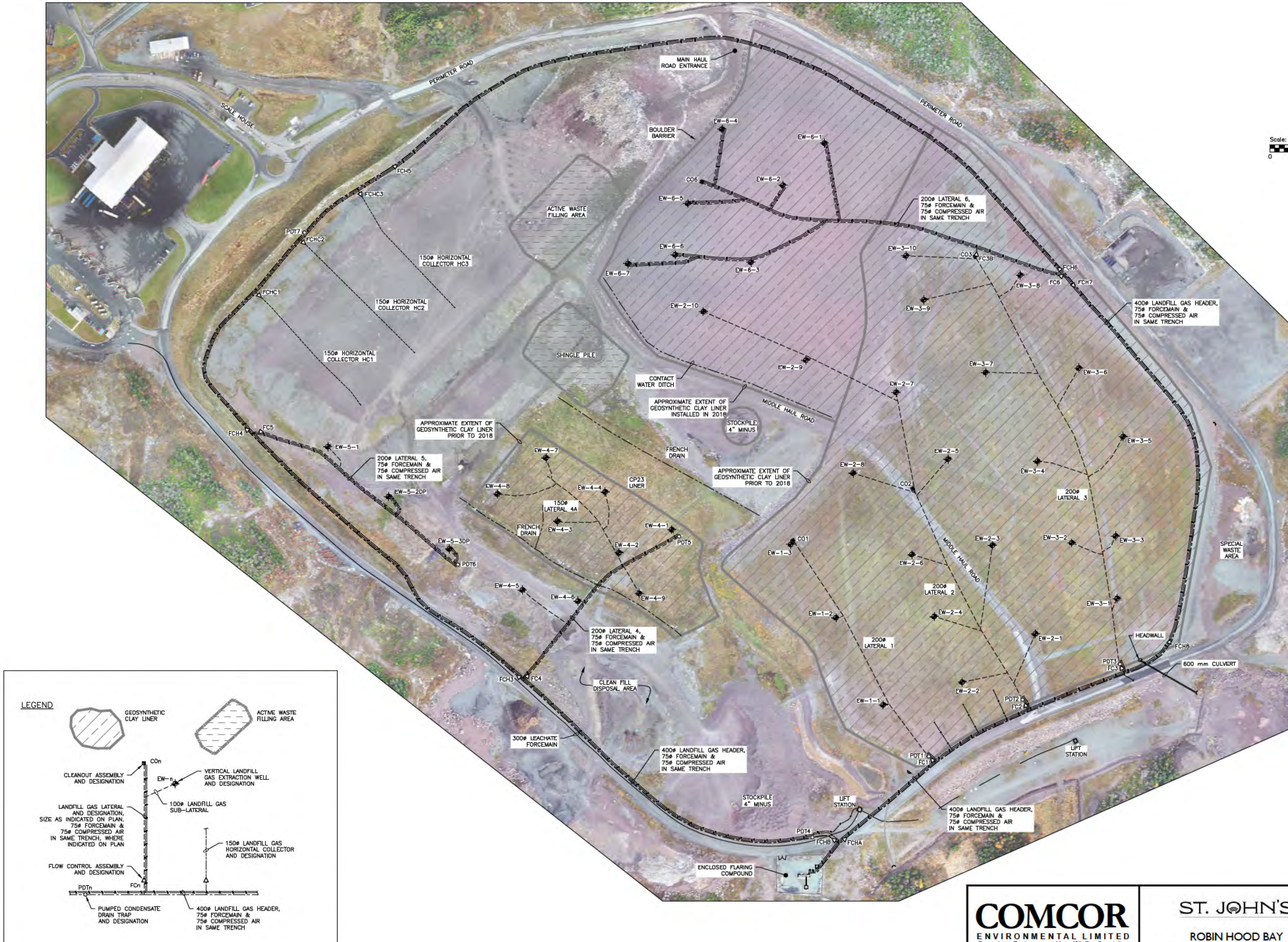
COMCOR

If you have any questions, or require clarification, please feel free to contact me at 519-621-6669 extension 246.

Yours very truly,
COMCOR ENVIRONMENTAL LIMITED

Jonathan Petsch, P.Eng.
Project Engineer

Denise Burgess, P.Eng.
Manager – Engineering



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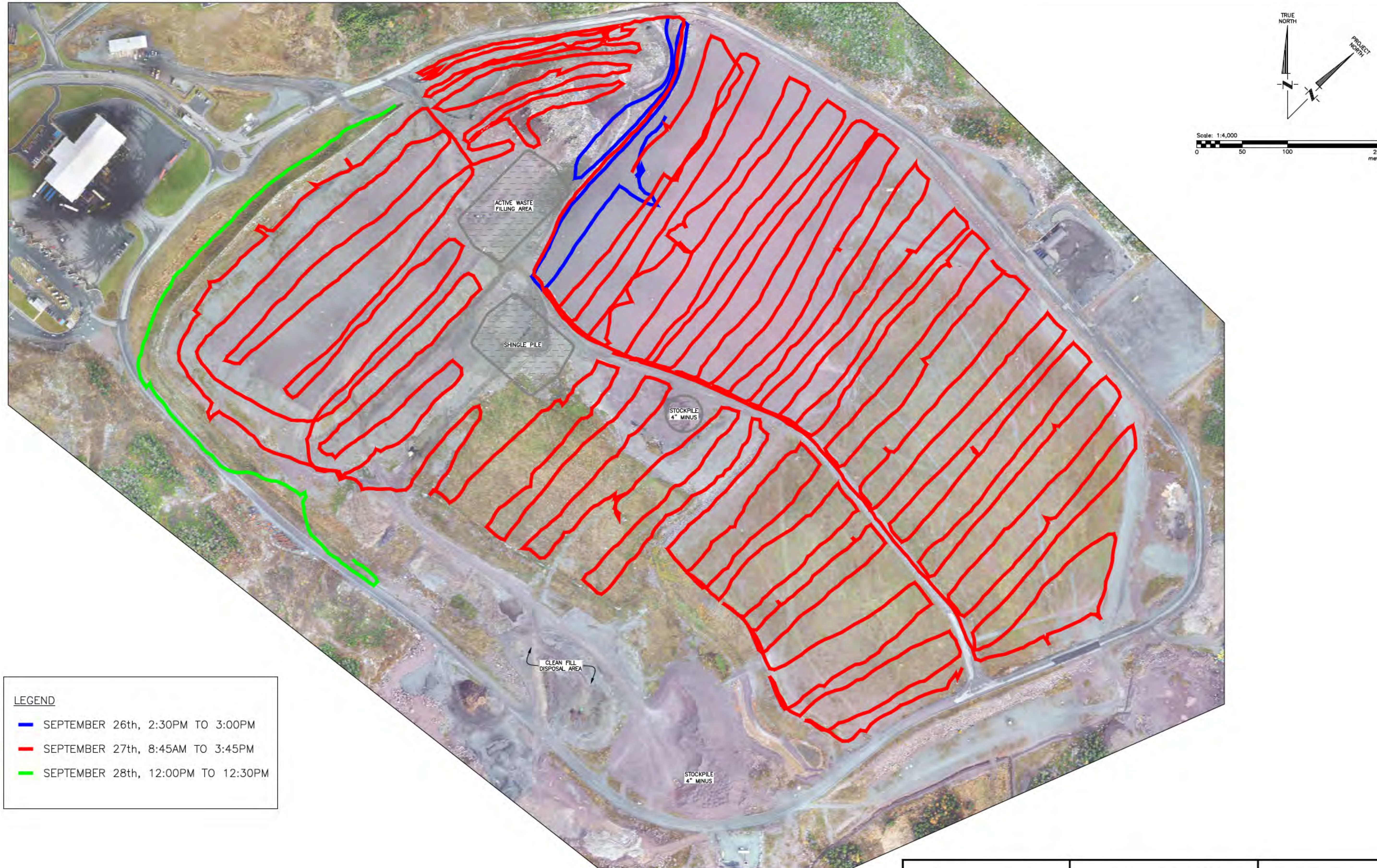
Consulting Engineers and Landfill Gas Specialists

ST. JOHN'S

ROBIN HOOD BAY WASTE MANAGEMENT FACILITY

Figure 1

SITE PLAN



LEGEND

- SEPTEMBER 26th, 2:30PM TO 3:00PM
- SEPTEMBER 27th, 8:45AM TO 3:45PM
- SEPTEMBER 28th, 12:00PM TO 12:30PM

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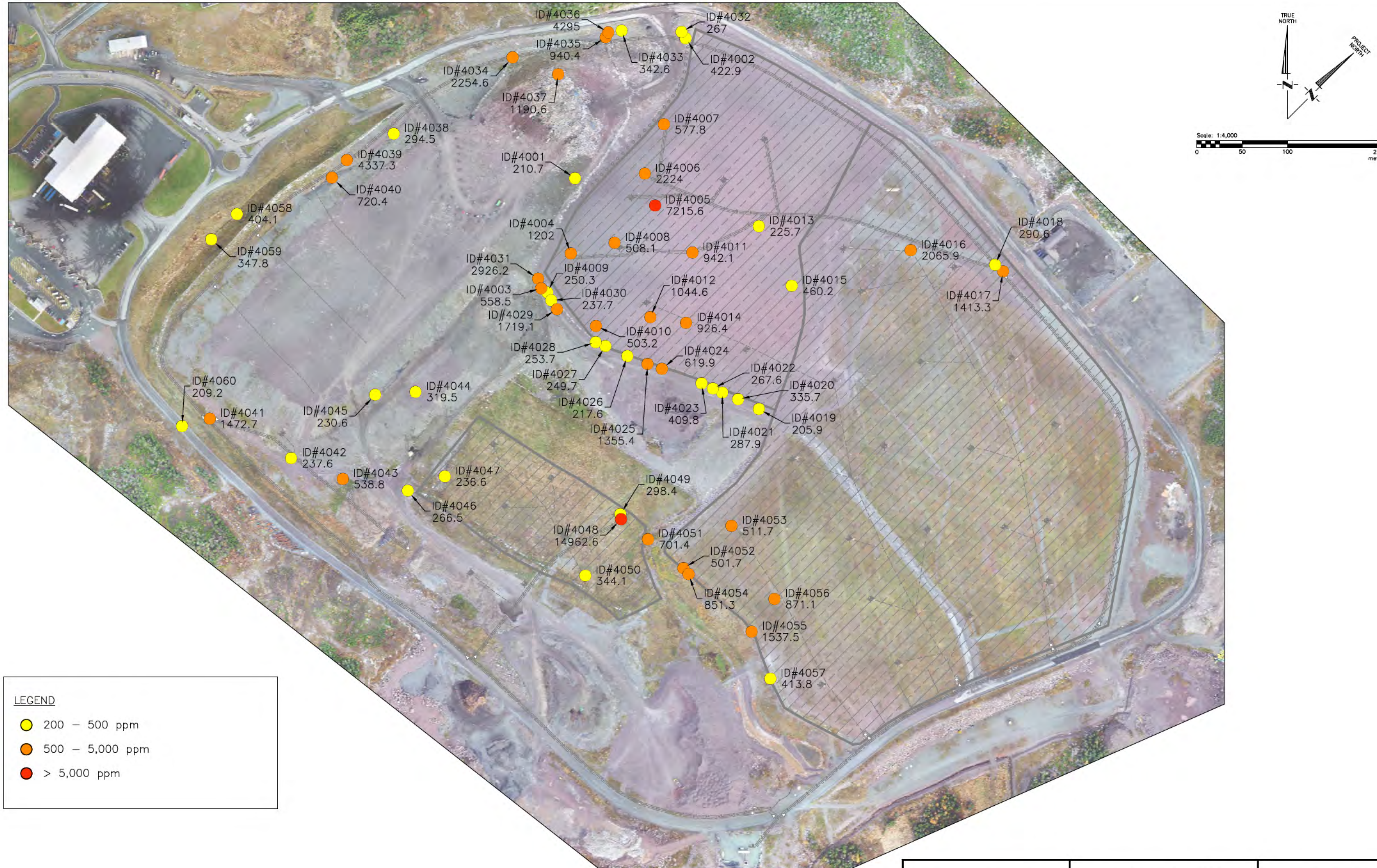
ST. JOHN'S

ROBIN HOOD BAY
WASTE MANAGEMENT FACILITY

Figure 2
SURFACE EMISSION SURVEY PATH



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ST. JOHN'S
ROBIN HOOD BAY
WASTE MANAGEMENT FACILITY

Figure 3
SURFACE EMISSION SURVEY EXCEEDANCES

Table 2
2018 Emissions Exceedances Summary
Robin Hood Bay Waste Management Facility
St. John's, Newfoundland

Point ID	Coordinates[1]				Concentration (ppm)	Comments
	Latitude	Longitude	Easting	Northing		
4001	47.605408	-52.667235	5274080.5	329819.0	210.7	
4002	47.606792	-52.665605	5274234.9	329940.9	422.9	Haul Road Entrance
4003	47.604318	-52.667738	5273959.2	329781.7	558.5	Ditch Edge of New GCL
4004	47.604663	-52.667300	5273997.7	329814.4	1202	EW-6-7
4005	47.605135	-52.666062	5274050.5	329907.3	7215.6	EW-6-5[2]
4006	47.605452	-52.666210	5274085.7	329896.0	2224	Cleanout CO6
4007	47.605940	-52.665927	5274140.1	329917.1	577.8	EW-6-4
4008	47.604767	-52.666658	5274009.4	329862.7	508.1	EW-6-6
4009	47.604278	-52.667647	5273954.7	329788.5	250.3	Ditch Edge of New GCL
4010	47.603942	-52.666935	5273917.6	329842.2	503.2	
4011	47.604667	-52.665518	5273998.7	329948.4	942.1	EW-6-3
4012	47.604028	-52.666138	5273927.4	329902.1	1044.6	
4013	47.604925	-52.664543	5274027.7	330021.6	225.7	
4014	47.603970	-52.665615	5273921.2	329941.5	926.4	
4015	47.604333	-52.664065	5273962.0	330057.8	460.2	
4016	47.604680	-52.662318	5274001.2	330189.0	2065.9	Cleanout CO3
4017	47.604467	-52.660965	5273977.9	330290.8	1413.3	Flow Control FCH7
4018	47.604532	-52.661082	5273985.1	330282.0	290.6	Flow Control FCH6
4019	47.603112	-52.664553	5273826.1	330021.7	205.9	Ditch Edge of New GCL
4020	47.603210	-52.664857	5273836.9	329998.8	335.7	Ditch Edge of New GCL
4021	47.603277	-52.665090	5273844.3	329981.3	287.9	Ditch Edge of New GCL
4022	47.603318	-52.665227	5273848.8	329970.9	267.6	Ditch Edge of New GCL
4023	47.603370	-52.665393	5273854.5	329958.4	409.8	Ditch Edge of New GCL
4024	47.603515	-52.665972	5273870.5	329914.8	619.9	Ditch Edge of New GCL
4025	47.603563	-52.666183	5273875.7	329898.9	1355.4	Ditch Edge of New GCL
4026	47.603643	-52.666478	5273884.5	329876.7	217.6	Ditch Edge of New GCL
4027	47.603743	-52.666800	5273895.5	329852.5	249.7	Ditch Edge of New GCL
4028	47.603782	-52.666942	5273899.8	329841.8	253.7	Ditch Edge of New GCL
4029	47.604110	-52.667507	5273936.1	329799.1	1719.1	Ditch Edge of New GCL
4030	47.604198	-52.667590	5273945.9	329792.8	237.7	Ditch Edge of New GCL
4031	47.604415	-52.667782	5273969.9	329778.3	2926.2	Ditch Edge of New GCL

Notes:

1. Easting and Northing coordinates based on NAD83 MTM Newfoundland Zone 1.
2. The location of EW-6-5 as shown in Figures 1 and 3 appears to be slightly off from the hit location of ID# 4005.

Table 2 - Continued
2018 Emissions Exceedances Summary
Robin Hood Bay Waste Management Facility
St. John's, Newfoundland

Point ID	Coordinates[1] Latitude	Longitude	Easting	Northing	Concentration (ppm)	Comments
4032	47.606855	-52.665663	5274241.9	329936.5	267	Haul Road Entrance
4033	47.606870	-52.666542	5274243.3	329870.4	342.6	Cracks in Cover
4034	47.606610	-52.668142	5274213.8	329750.2	2254.6	Cracks in Cover
4035	47.606805	-52.666775	5274236.0	329852.9	940.4	Cracks in Cover
4036	47.606853	-52.666737	5274241.3	329855.7	4295	Cracks in Cover
4037	47.606440	-52.667475	5274195.2	329800.4	1190.6	
4038	47.605858	-52.669890	5274129.7	329619.1	294.5	
4039	47.605598	-52.670578	5274100.5	329567.5	4337.3	Flow Control FCH5
4040	47.605425	-52.670797	5274081.2	329551.1	720.4	
4041	47.603040	-52.672603	5273815.5	329416.5	1472.7	Flow Control FC5
4042	47.602645	-52.671413	5273772.0	329506.1	237.6	
4043	47.602437	-52.670657	5273749.1	329563.1	538.8	EW-5-2DP
4044	47.603297	-52.669585	5273845.1	329643.3	319.5	
4045	47.603270	-52.670177	5273841.9	329598.8	230.6	
4046	47.602318	-52.669705	5273736.2	329634.7	266.5	Edge of Existing GCL
4047	47.602457	-52.669162	5273751.8	329675.5	236.6	EW-4-8
4048	47.602025	-52.666580	5273704.6	329869.8	14962.6	Drain Trap PDT5
4049	47.602075	-52.666590	5273710.2	329869.0	298.4	EW-4-1
4050	47.601468	-52.667108	5273642.5	329830.4	344.1	EW-4-9
4051	47.601825	-52.666187	5273682.5	329899.5	701.4	Edge of Existing GCL
4052	47.601538	-52.665670	5273650.8	329938.5	501.7	Edge of Existing GCL
4053	47.601955	-52.664962	5273697.4	329991.5	511.7	EW-1-3
4054	47.601477	-52.665593	5273644.0	329944.3	851.3	Edge of Existing GCL
4055	47.600905	-52.664673	5273580.7	330013.8	1537.5	Edge of Existing GCL
4056	47.601228	-52.664337	5273616.7	330038.9	871.1	EW-1-2
4057	47.600438	-52.664402	5273528.9	330034.4	413.8	Edge of Existing GCL
4058	47.605068	-52.672193	5274041.1	329446.4	404.1	Toe of Waste Footprint
4059	47.604818	-52.672570	5274013.2	329418.1	347.8	Toe of Waste Footprint
4060	47.602967	-52.673010	5273807.3	329385.9	209.2	Toe of Waste Footprint

Notes:

1. Easting and Northing coordinates based on NAD83 MTM Newfoundland Zone 1.

ATTACHMENT A

SURFACE EMISSIONS SURVEY PROTOCOL

SURFACE EMISSIONS SURVEY PROTOCOL

Prepared by
COMCOR ENVIRONMENTAL LIMITED
320 Pinebush Road, Suite 12
Cambridge, Ontario
N1T 1Z6

July 2013

SURFACE EMISSIONS SURVEY PROTOCOL

1. Objective and Background Information

The objective of a Surface Emission Monitoring Plan is to complete a gas assessment within a landfill footprint.

The landfill gas emissions survey is based on the United States Environmental Protection Agency's (USEPA) New Source Performance Standards (NSPS) for surface emissions monitoring at municipal solid waste landfills. Background methane concentration should be taken before each emissions survey and will be determined by monitoring upwind and downwind outside the boundary of the landfill at a distance of at least 30 metres from the limit of waste. The on-site emission survey is to be conducted as described within this document.

2. Monitoring Map

- A grid will be imposed on the available site maps. This grid will cover all areas of the landfill. The grid shows the path to be followed by the individual(s) who perform surface monitoring. The grid will be set up at 30 meter intervals.

- The maps will show the location of all gas monitors, each of which is shown with a unique identifier.

- The monitoring grid map may also indicate each area that is excluded from surface monitoring. Each excluded area is labeled and an attachment to the map has been prepared to explain the basis for each area's exclusion from monitoring. The following areas are excluded from required monitoring:

  1) Slopes that are determined by the individual(s) performing the monitoring to be too steep to be safely traversed while carrying the monitor.
  2) Areas containing only waste other than Municipal Solid Waste (for example, "construction and demolition" debris, kiln ash, etc.).
  3) Areas of known asbestos disposal.

3. Instrument and Calibration Gas Specifications

- All instruments will be field calibrated and have certification from the manufacturer or rental supplier.

4. Monitoring Schedule

- Monitoring will only occur if conditions are appropriate. Below is an outline of reasons that monitoring may not be able to be completed.

  1) Weather that is determined by the individual(s) who perform the surface monitoring to be unsafe in which to conduct outdoor activities or which may be damaging to health (i.e. , extremes of temperature, high winds, rain-snow-ice or thunder storms, snow and ice accumulation, darkness, ozone alerts, other air pollution alerts).

  2) Occurrence of meteorological conditions considered to be other than "typical".

  3) Ambient temperatures which do not rise above the minimum required ambient operational temperature of the monitoring instrument.

  4) Ambient temperatures which do not fall below the maximum allowable ambient operational temperature of the monitoring instrument.

  5) Accumulation of snow/ice to a depth in excess of the maximum allowable monitoring height-above-surface (i.e., 10 cm. = 4 inches).

  6) Wet surface conditions such that traversing the landfill would either present a hazard to the individual(s) performing the monitoring, or would damage the cover and potentially result in the creation of methane leaks.

- Where a delay in the monitoring schedule has been caused by one or more of the above conditions, monitoring will resume as soon as the condition(s) which precluded meeting the monitoring schedule subside. Documentation will be entered into the report detailing the regular monitoring schedule and conditions in which they were completed.

5. Monitoring Procedure

- Conduct monitoring ***only if*** ambient temperatures are within acceptable operating limits for the monitoring instrument; there is no snow/ice cover greater than four inches deep, weather conditions are "typical" for the area, and weather and site conditions are such that it is not dangerous to conduct monitoring.

- Warm up the instrument per the manufacturer's recommendations.

- Perform an instrument calibration prior to each monitoring day.
- At a distance of 30 meters (98 feet) from the perimeter wells on the upwind side of the landfill, face into the wind and move the probe in the air for at least 30 seconds.
- Note the meter reading and record it as “upwind reading”.
- Perform the same procedure at a distance of 30 meters (98 feet) from the perimeter wells on the downwind side of the landfill and record the meter reading as “downwind reading”.
- Average the upwind and downwind readings and record the average in “background concentration”.
- Using the surface monitoring grid map, begin walking the sampling path at the starting point on the map holding the monitor probe no more than four inches above the landfill surface. Walk at a steady pace of approximately 1.5 mph (approximately 1 step per second).
- When the instrument gives a meter reading of $\geq$ 500 ppm, stop walking and note the maximum meter reading. Record the time of detection and a unique location identifier from the GPS unit. It may be necessary to create a location identifier on the sampling grid map.
- Continue walking the sampling grid path until the entire route has been traversed.
- While traversing the grid, if any areas are seen off of the grid path that appear to have a high potential for methane leaks (i.e., stressed vegetation, noticeable surface cracks, sunken areas, etc.), deviate from the grid path and monitor these areas as if they were on the grid path. Document these areas only if a leak is recorded.
- If the TVA 1000 PID/FID gives a reading above its detectable limits use the GEM to determine methane levels.
- All areas of stressed vegetation, noticeable surface cracks, sunken areas, etc. should also be noted and the location recorded. If possible take digital pictures to record any extreme conditions.

6. Measured Exceedances

- If methane is detected at a concentration greater than 1000 ppm above background, the following steps may be taken until the exceedance is remedied:

    1. The location and concentration of the exceedance will be recorded.

    2. Adjustments to adjacent extraction wells will be made to increase gas collection in the vicinity of the exceedance. The location will be re-monitored within ten (10) calendar days of detecting the exceedance.

    3. If re-monitoring the location shows a second exceedance, cover maintenance will be performed. The location will be re-monitored within ten (10) calendar days of maintenance.

    4. If re-monitoring shows another exceedance, consideration will be given to installing additional landfill gas extraction wells.

November 5, 2010

Jason Sinyard, P. Eng., MBA
Manager - Waste Management Division
City of St. John's, P.O. Box 908
St. John’s, NL Canada A1C 5M2

RE: Odour Response Action Plan

Dear Jason:

We are pleased to present you with the following Odour Response Action Plan (the Plan) outline and action items for the Robin Hood Bay Landfill.

Executive Summary

Tech Environmental was asked to examine the Robin Hood Bay (RHB) Landfill for odour potential after an increase in complaints from neighbours. The goal of the odour study was to answer the following questions:

1. Is the recent odour in the neighbourhood solely related to RHB?
2. Why is the landfill more odorous now than it was prior to 2010?
3. What should be done to reduce landfill odour potential in the future?

While RHB is a source of odour, there is evidence that suggests all odour events in the area are not solely related to the landfill. There are sufficient other industries in the vicinity that are potential odour sources that can contribute to the neighbourhood odour. This report however focuses on the landfill and not the other potential odour sources. It was clear during the site visit and interviews with neighbours that prior to 2010 the landfill had typical odour emissions that were occasionally noticeable in the neighbourhood, but were not a significant nuisance. However, since 2010 odour complaints have risen.

Since 2009 there have been substantial upgrades to meet landfill Best Management Practices (BMPs) made at the Robin Hood Bay facility, and the public has become increasingly aware of the landfill due to the news coverage of these upgrades. There is a public assumption that landfill odour should decrease rather than increase with the improvements, but the BMPs undertaken to date focused primarily on operational efficiencies, public safety, leachate collection, recycling and a pilot scale landfill gas system. While all the BMPs are valuable, only the gas collection pilot system has had a positive affect on odour potential.

It is not unusual for a landfill to experience an increase in odour complaints if the landfill has been in the news. It is also not usual for odours from nearby facilities to be erroneously labelled landfill odours if the landfill has been in the news. However, in addition to an increase in complaints related and unrelated to the landfill due to public awareness, there has also been an increase in odour potential at the landfill site. **This odour potential is primarily related to:**

1. **a localized area of elevated sulphide emissions (an odour 'hot spot'),**
2. **landfill gas production, dispersion and capture, and**
3. **(to a lesser extent) liquid waste and biosolids disposal**

This report discusses these issues and puts forward a comprehensive Odour Response Action Plan comprised of immediate (2010), short-term (2011) and long-term action items. Many items within the plan were already part of the landfill's go-forward strategy and for some the increase in complaints and the findings of this report have accelerated their implementation schedule (some of the immediate action items have already been completed or are underway). While the immediate action items should have a positive impact on odour reduction, reducing the site's odour potential to 'acceptable levels' will likely take several months as it will require completion of the short-term items in 2011.

Background

The Robin Hood Bay landfill site began as a waste depository during World War II. It is still the City of St. John's primary solid waste disposal facility. Recently, the landfill has become a regional solid waste facility for the entire Avalon Peninsula.

Recent Capital Improvements

The landfill has benefited from many capital improvements over the last few years, all of which are considered best management practices (BMPs) for landfill operation. Unfortunately, odour complaints have increased during this same time period. Given this investment in landfill improvements, many residents and city officials have been perplexed by the increase in odour complaints, thinking that these improvements should mean fewer odour events, not more odour events. The general assumption is naturally that if odour complaints have increased, odour emissions must be worse now than in the past. However, this natural assumption is actually an oversimplification of the human perception of odour and local odour sensitivity, as well as of the odour emission potential and odour dispersion characteristics of the landfill.

While there have certainly been many necessary improvements at the landfill, these improvements were not geared directly towards odour control or landfill gas management. In fact, on a dollar-cost basis, less than 5% of the recent improvements were related to landfill gas capture and combustion. The remaining 95+% focused on site infrastructure and two very important solid waste BMPs: solid waste diversion and leachate capture.

For most of the landfill's life, nearly everything that has been sent to the landfill has ended up directly in the landfill with very little waste separation. In Europe, 90+% of the waste stream is diverted and used as new raw materials, because landfill and open space is at a premium. In Newfoundland, the economics do not make it cost-effective to divert anywhere near the levels achieved in Europe, but there are some basic items such as aluminum, plastics, and fiber wastes that can be cost-effectively diverted and reused. These items will all be sorted at the new public drop-off locations or within the state-of-the-art Materials Recycling Facility (MRF). Any items diverted save landfill space and raw materials for future generations. The diversion process, while clearly valuable, will have no positive or negative effect on landfill odour emissions.

Until recently, leachate was directed into the ocean via a stream at the eastern end of the landfill. Currently, leachate is captured and pumped to the new Riverhead wastewater treatment plant. Leachate collection and treatment is a typical landfill BMP and an important part of a modern-day landfill, but is not intended to reduce odour. The leachate capture system has not had a directly positive or negative effect on landfill odour emissions.[1]

Less than 5% of the recent capital expenditures were spent on landfill gas management. The current landfill gas pilot program pulls approximately 600 cubic feet per minute (cfm) of landfill gas and infiltration air and directs it towards the flare for combustion. This pilot program was initiated to determine the quality and quantity of methane production prior to installing a full scale system.

An integral part of the landfill gas pilot program involved covering approximately 1/3 of the landfill with an interim impervious liner system. Although the cover system and flare were not explicitly intended for odour control, odorous compounds that are created along with methane as solid waste decomposes in an oxygen-free environment are captured under the cover and oxidized in the flare prior to discharge to the air. Sulfur reducing bacteria will break down sulfate in the waste and reduce it to dissolved sulfide, which can be emitted as hydrogen sulfide (H2S). Oxidized sulfur compounds, such as sulfur dioxide, are less odorous than reduced sulfur compounds, so combustion in the flare has had a positive odour control effect.

In summary, one of the new capital improvement programs has little to no effect on odour (diversion), one has a marginal potential increase in odour (leachate conveyance), and one has a clearly positive effect (conversion of hydrogen sulfide to sulfur dioxide). While these should not be expected to have a dramatic and direct effect on odour impacts, it is reasonable to expect that odour complaints would become less frequent with all other things being equal.

However, the landfill has not been stagnant during this process, nor has the neighbourhood: both have undergone many changes in the past few years. These are the key drivers in the increase in odour complaints, as opposed to some shortcoming regarding the capital improvement programs.

Odour Science 101

Before addressing the specific circumstances in and around the Robin Hood Bay landfill, it is important to give a brief overview of odour science. It is important to understand how the neighbourhood has changed so that the tolerance for odour today can be compared to the historical tolerance. This will help us identify the acceptable level of odour, allowing the landfill to implement controls to reach that level.

[1] It is worth considering that the sewer system becomes a potential odour source if the leachate has little to no dissolved oxygen present and an abundance of dissolved sulfides. Based on visual inspection of the discharge manhole, however, there was no indication that excessive dissolved sulfides have been present during the time when complaint levels have been elevated.

Odours are noticeable, volatile substances that partition themselves in the gas phase. Each person detects a volatile compound at a different concentration, or "threshold" value, and this threshold is different for everyone. The threshold value varies considerably between compounds and can vary substantially with time, especially for a landfill facility that is continually changing its waste placement. Individual odourants can mix together and counteract each other, or they can mix together and be perceived as significantly worse than the compounds would be perceived individually. Therefore, it is important to fully understand the potential for odours from mixtures of compounds.

An odour panel analysis is often used to obtain an accurate quantification for a mixture of odorous compounds from an air sample collected for odour analysis. An odour panel is a group of five to eight individuals that will quantify or qualify the following odour parameters:

Detectability	The amount of dilutions required to reduce an odour to its detectable threshold (D/T) concentration.
Intensity	The perceived strength of the odour, usually measured by reference to the n-butanol scale.
Character	Conditioned mental response to the odour sensed (what it smells like).
Hedonic Tone	The relative pleasantness or unpleasantness of the odour sensed.

The first two parameters, Detectability and Intensity, are the most important for determining the strength and pervasiveness of a mixture of odorous compounds. The other two, Character and Hedonic Tone, are great qualifiers that can be helpful for "fingerprinting" and tracking odours in field studies.

"Smelling an odour" is a physical human reaction to a mixture of compounds. Odours from a landfill are comprised of a mixture of compounds, and all of these compounds add to the final odour mixture. "Odour Intensity" is only one aspect of odour (along with frequency, duration and character) and refers to the overall strength of a perceived odour.

Terrain and Wind Effects

On-site odour strength is an important piece of the information necessary to assess odour, but conveyance is equally important. If odour is created on-site and the wind is blowing towards the ocean, as it was during our site visit, then the odour concentration on-site is rather meaningless – the wind will blow the odours out to sea. In this scenario, an insignificant impact would occur in the residential neighbourhood regardless of on-site concentration.

Thus, meteorological and terrain conditions play a huge role in conveyance of odour from this landfill. The landfill is surrounded on two sides by complex terrain. (When there are hills that exceed the elevation of the emitting source, the terrain is called "complex terrain.") In normal terrain, odorous emissions travel along the surface and become diluted as the plume "spreads out" with distance. When surrounded by complex terrain, by contrast, plume spread can be inhibited, maintaining odour concentration over distance. Typically, odour will still dilute in the vertical direction with complex terrain, unless there is a very still-inversion day when the atmosphere pushes down. Unfortunately, this condition often occurs at Robin Hood Bay on foggy days when the wind is out of the east: landfill emissions are pushed towards the neighbourhood with little dilution in either vertical or horizontal directions.

The other important point to consider with complex terrain is that it can create pockets in which odour impacts are the same in more than one downwind direction. Based on the terrain near the landfill, it is possible for some neighbourhoods to experience downwind conditions even when the wind changes direction by 30 degrees due to channelling through the hills. This channelling has the opposite effect on some neighbourhoods that are rarely downwind. In one such neighbourhood, we spoke with a couple who had never smelled the landfill. In fact, the woman was adamant about not smelling the landfill and about her own high odour sensitivity: she said she had a heightened sense of smell because of her own personal medical conditions, and maintained that if she couldn't smell it, then her nearby neighbours couldn't either. This seeming discrepancy is due to the effects of channelling.

Landfill Odour Baseline

The terrain and wind conditions have not varied greatly over the last year, nor have the waste streams or disposal rates, so again, the question remains: What has driven the increase in odour complaints? Or to put it another way, why do some residents consider the landfill's odour impacts worse than ever before?

Active Area Prior to 2009

It is important to recognize a certain tolerance for odour existed in the surrounding neighbourhood prior to 2009. At that time, the landfill had a very large open cell with no landfill gas capture and treatment system located in the easternmost portion of the landfill (see Figure 1). Given the typical landfill gas production from municipal solid waste, it is safe to assume that odour was generated, emitted, and on occasion would travel off-site. This was confirmed through discussions with some long-term residents that have lived near the landfill for over 20 years. They described occasional odour over the years, but not nuisance odour.

Prior to 2009, it is likely that the potential for solid waste decomposition was normal, meaning that the total landfill gas production potential and rate at which landfill gas is produced were in the "normal" range. It is also likely that the hydrogen sulfide level created within the waste was typical for municipal solid waste (MSW), in the 50 to 200 parts per million (ppm) range.

With an odour detection threshold of 0.001 to 0.001 ppm for hydrogen sulfide and normal landfill gas production, normal odour concentrations found in landfill gas on-site are thousands of times higher than the odour detection threshold, but the dilution produced relative to the volume of ambient air between the landfill and the local residents is vast. Normal on-site odours do not directly imply off-site odour concerns. Typically, these concentrations are drastically diluted before they reach the landfill boundaries, further diluted when they reach the landfill property line, and even further diluted between the landfill and the nearest residents during typical weather conditions.

In normal situations, one would expect to experience n-butanol odour intensities of 1-2 on-site on a consistent basis, an odour of 3 in places on a fairly regular basis, with an occasional peak odour of 4+ in hot spots. These results indicate clear on-site odour potential. (See Appendix 3 for a discussion of the n-butanol scale.) It is clear that that this landfill with no covers, ventilation, and combustion system in place (pre-2009 status) can create odour and did have some off-site odour potential over the years.

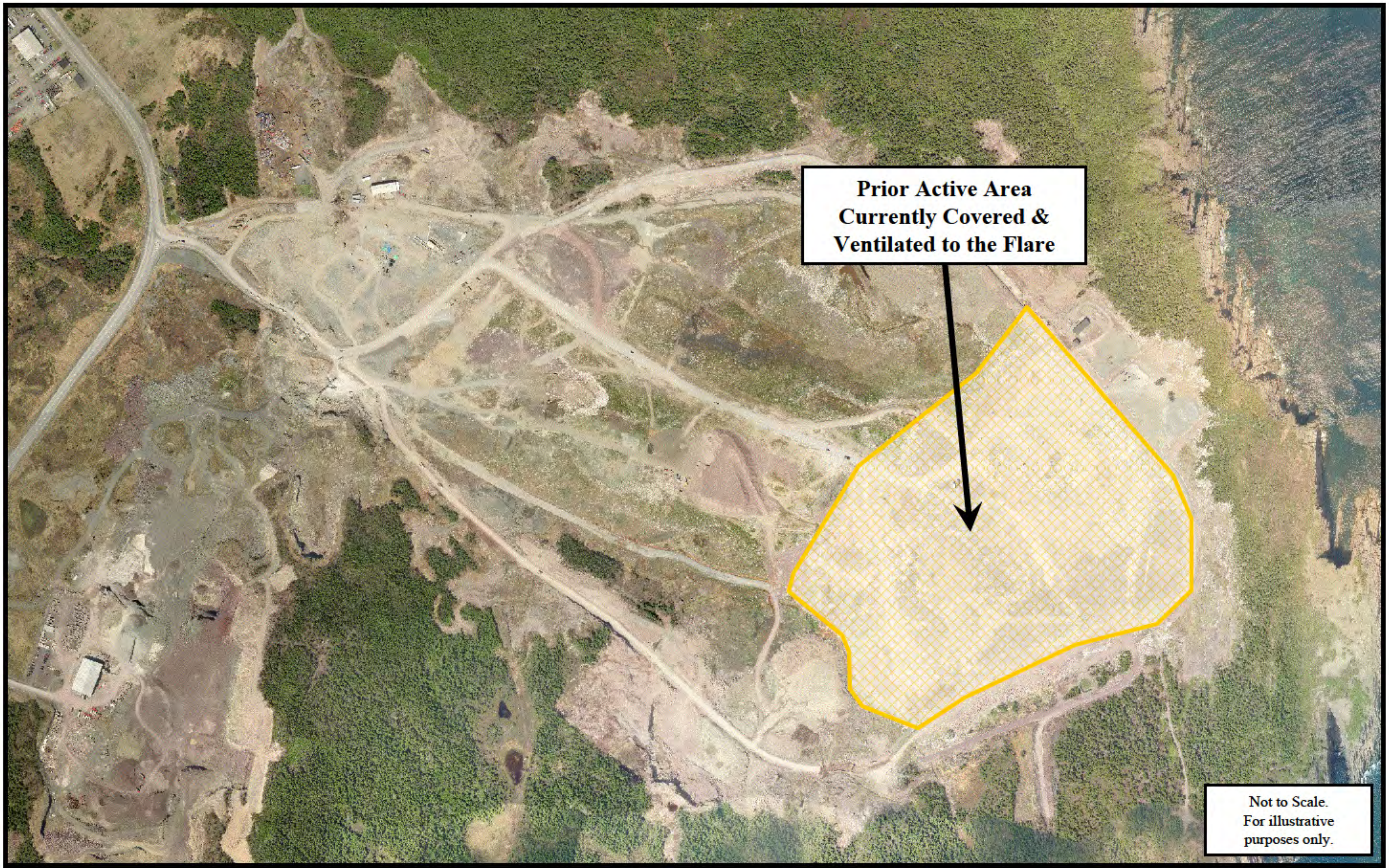


FIGURE 1.

Active Area Prior to 2009
Robin Hood Bay Landfill

TECH environmental

On-site odour levels were spread over a very large active area that was located further east than the cells today and was somewhat round in shape. If anything, it was larger in the north-south dimension than the east-west dimension and was confined to the eastern portion of the site. The location and orientation of the active area can play a large role in the potential for adequate dilution of odour from the landfill into the neighbourhood.

Active Area Changes Since 2009

Today, the previously active area discussed above is temporarily covered and ventilated to an interim candlestick flare as part of the gas management pilot system. The candlestick flare is at capacity and likely capturing 70-80% of the gas generated in this area, as industry standards require. If additional capacity was added, capture could be incrementally improved.

Once the previous active area was capped, landfilling moved to the southwestern-most portion of the landfill. First, an old road was filled in as part of the process to level off the area. Then two long lifts were added that stretch hundreds of meters from the westernmost portion of the landfill almost to the temporary capped area. There is no landfill gas capture system in place for this new waste (see Figure 2). This new active area is an odour concern because of the cell orientation, age of waste, and reduced dilution potential. It is also a concern because there was an area of elevated odour, often called a “hot-spot”.

In addition to the residual emissions from the interim capped area and the new lifts, the landfill creates odorous emissions from the liquid lagoons. The lagoons were created in 2009 to settle out fats and oils from the liquid waste to prevent them from entering the leachate system directly. These sticky wastes had previously percolated through the waste and into the leachate pumps. There was a concern that the leachate pumps, once coated with fats and oils, would require significant and frequent cleaning to prevent clogging. Prior to 2009, liquid waste was dumped directly on the ground and there were no leachate pumps. Currently, liquid waste is dumped into the lagoons, where it is thickened by gravity and evaporation. When more liquid waste is added or there are heavy rains, the liquids supernatant overflows the lower lagoon and travels down the landfill until it percolates into the landfill creating increased odour potential.

Summary of Active Area Changes during the Odour Evaluation

The following items are potentially contributing to an increase in landfill odour in the neighbourhood:

Active Area Change #1 - Elevated rainfall this past spring
Active Area Change #2 - A hydrogen sulfide “hot spot”
Active Area Change #3 - Waste placement in cells closer to the western boundary
Active Area Change #4 - Open liquid lagoons
Active Area Change #5 - Partially digested wastewater biosolids
Active Area Change #6 - Current fill area is starting to produce odorous landfill gas
Active Area Change #7 - Waste placement orientation with respect to wind conditions

Each of these changes is discussed in more detail in subsequent pages.

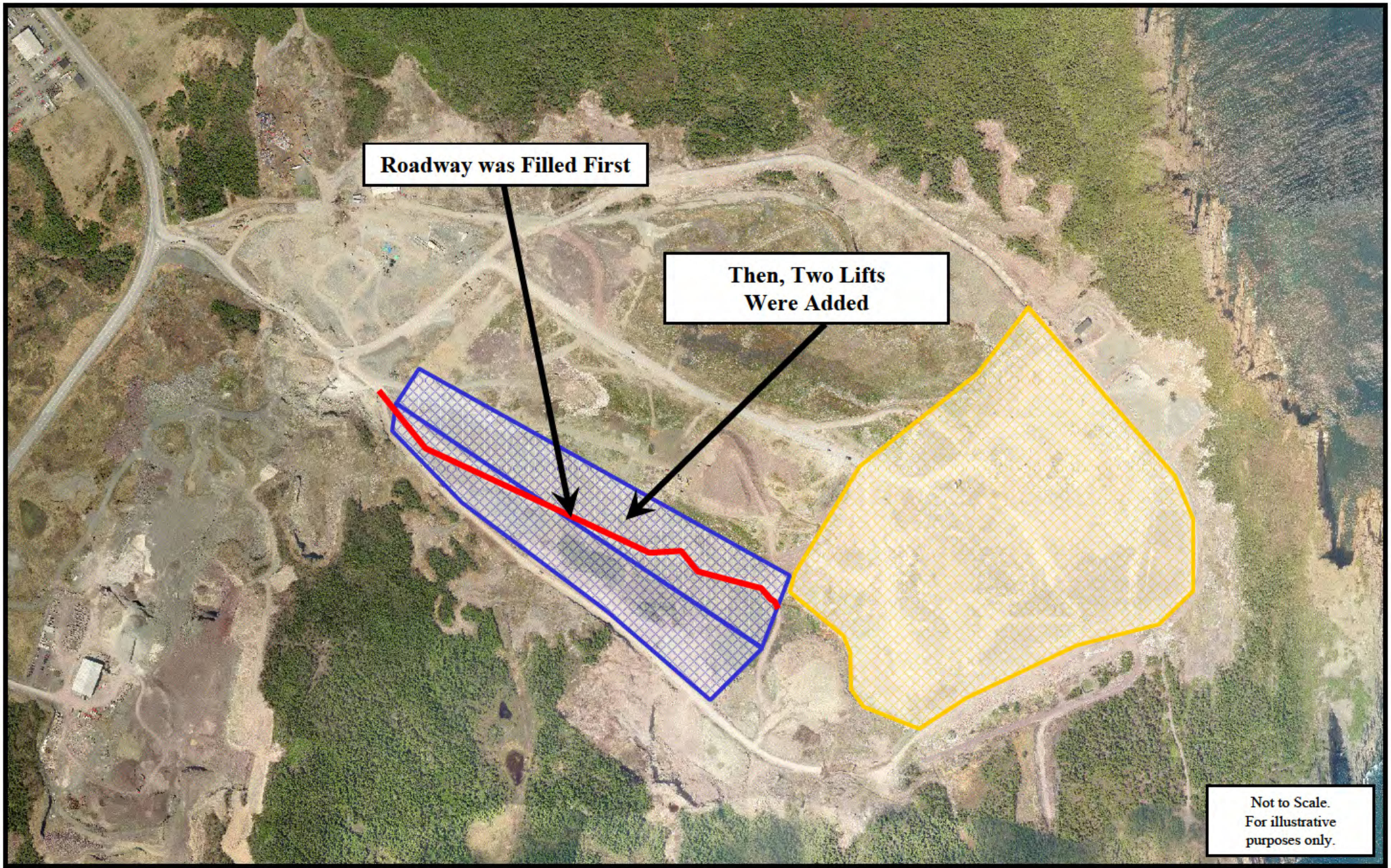


FIGURE 2.

Waste Fill Since 2009
Robin Hood Bay Landfill

TETECH environmental

Active Area Change #1 - The Impact of Water on Odour Emissions

Water is a key factor in landfill gas production; landfill gas production has an effect on odour potential, since biological activity in a landfill occurs in water. That is why closed landfills are referred to as "dry tombs." Once water is removed, microbial life cannot be supported and gas production declines dramatically. Conversely, when more water is added, there is sufficient water available for microbes to move about, procreate, and off-gas methane and other odorous compounds.

A period of heavy rainfall is likely responsible, at least in part, for increased odour emissions from the landfill. During March through May of 2010, 590 mm of rain/snow fall found its way through the landfill. This was 75% more rainfall during this period than during the same spring time periods over the last 10 previous years. It was 36% more than the average plus the standard deviation, so it was an unusually wet spring. The excessive rain, combined with the material available for daily cover (crushed rock), which is extremely permeable, clearly had a positive impact on landfill gas generation. These conditions resulted in more odorous emissions being emitted at a faster than normal rate.

Increased rainfall, however, is not the only factor adding to potential changes in odour from the landfill. (In 2005, rainfall during the spring was elevated to 80% of what it is today, but without an accompanying spike in odour complaints.)

Active Area Change #2 - Landfill Odour Emissions "Hot Spot"

After we completed an odour baseline assessment of the landfill, it became evident that there is an area within the landfill that is producing a very strong odour. Areas like this are often called "hot spots". Based on observations, the odour mixture in this hot spot is dominated by hydrogen sulfide – not typical landfill gas, which is dominated by methyl mercaptan and other reduced sulfur compounds. This odour is most likely caused by a higher-than-average concentration of gypsum wallboard. Wallboard is present in construction and demolition (C&D) waste. The quantity of C&D waste has increased over the last few decades as more construction jobs require some degree of demolition prior to construction.

Gypsum wallboard contains a hydrolyzed sulfate material that is used by certain anaerobic bacteria as an oxygen source. These bacteria consume the hydrolyzed sulfate and emit water and dissolved sulfides. The water creates a pocket in the waste for these bacteria to thrive while the dissolved sulfides mix with other materials and form an acid that drops the pH. At a low pH, other bacteria cannot live, so there are no other bacteria competing for food in this localized area. Unfortunately, as the pH drops, the dissolved sulfide is converted to hydrogen sulfide in a gaseous form. The hydrogen sulfide is emitted in much larger than normal quantities and a "hot spot" of odour is created.

As mentioned previously, hydrogen sulfide underground in landfill cells is typically between 50 and 200 ppm, and often below 50 ppm. These in-cell concentrations typically result in ambient conditions directly above the surface that are 100 to 1000 times less concentrated than inside the cell, given that they are typically diluted fairly quickly. Where elevated pockets of hydrogen sulfide production from gypsum waste exist, landfills can have gas concentrations in excess of 10,000 ppm buried underground inside the waste. Areas that have elevated hydrogen sulfide concentrations have an odour potential that is hundreds to thousands of time stronger than typically landfill gas. Luckily, hot spots are typically small in size, but there is a real concern for occasional peak odours from hotspots, leading to a measurable incremental increase in total odour.

While on-site, a Nasal Ranger (see appendix 3) was used to estimate the extent of the existing hot spot and the possible magnitude of the average odour in the hot spot area. Based on monitoring with the Nasal Ranger, the hot spot was at least 20 meters wide (north-to-south) and 50 meters long (east-to-west) in a location where the old roadway was, as shown in Figure 3. Based on the odour intensity, we estimate that hydrogen sulfide is above 1 ppm and possibly above 10 ppm in headspace above this area.

Active Area Change #3 – Newer Waste Cells are further from the Ocean

The hot spot identified has a very strong odour, but has a much smaller mass flow rate than traditional landfill gas. Traditional landfill gas actually has its own flux, or driving force. Think of the landfill as a sponge: as a landfill creates landfill gas, it will eventually fill up the void spaces in its "sponge." Any additional gas created after the "sponge" is filled would be pushed out of the landfill. Changes in atmospheric pressure will affect the capacity of the "sponge," but eventually, as long as the landfill is not completely dry, the landfill reaches a state in which landfill gas is continually being created and there is a natural flux created through the landfill surface. Once emitted, this flux meets external factors such as wind, rain, snow cover, etc. that change its concentration and dispersion characteristics.

Prior to 2009, waste was placed in cells at the easternmost portion of the landfill, where the landfill gas collection system is currently being piloted. At this location, distance to the ocean was approximately one-half of the distance from the ocean to the cells today, located on the westernmost portion of the site. The older area is substantially further away from the neighbourhood and also exposed to more adiabatic mixing.

Active Area Change #4 – Open Liquid Lagoons

Although the wind direction was not ideal for examining odour in the neighbourhood during the site visit, it was possible to examine odour downwind of the landfill on the landfill perimeter to compare typical conditions as understood before 2009 with the current conditions today.

With the wind out of the west, odour was experienced on the eastern landfill perimeter. Near the flare directly downwind of the new cells, there was a distinctive landfill gas odour; a little further north on the east side the odour changed to a very clear hydrogen sulfide dominated odour from the hot spot, and it then changed back to landfill gas continuing north along the eastern landfill access road.

The landfill gas odour started to dissipate near the northeastern corner of the landfill because the exposure from the new cells was no longer downwind. At that point a very distinctive "liquids/sludge" odour was present. Liquids are currently added in a large lagoon that overflows by gravity during large rain events and slowly during the normal discharge of new liquids. This area was extremely putrid when observed up close. Around the landfill the perimeter road, the odour was still detectable and very distinct.

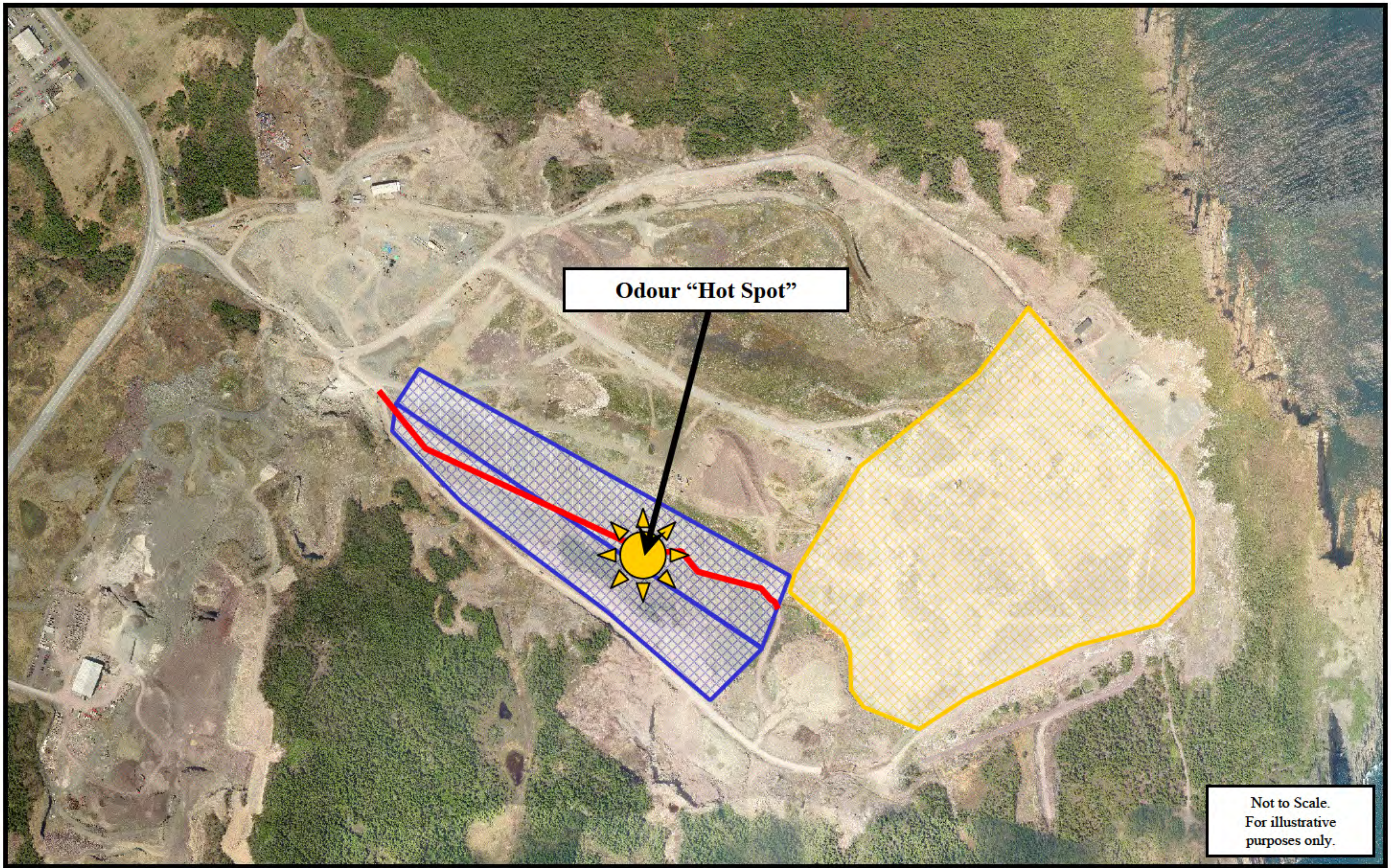


FIGURE 3.

Odour "Hot Spot"
Robin Hood Bay Landfill

Active Area Change #5 – Partially Digested Sludge (Biosolids)

Beginning in early 2010, the landfill has received one ½ full dumpster of 40+ percent digested and dried sludge every week. There have been some digester issues at the plant, and the plant found a secondary disposal method for this sludge while it works out its digestion issues.

Digested sludge, also called biosolids, from the Riverhead wastewater treatment plant has been added to the landfill as a new source over the last year. Based on a trip to the wastewater plant, an examination of the sludge, and the small quantity added, it is an odorous source but it does not have significant effect on landfill gas emissions. This could become a larger issue if greater quantities of sludge are added to the landfill. It is important to remember that even the best-thickened biosolids are still more than 50% water, and water can increase landfill gas generation.

Active Area Change #6 – Current fill area is starting to produce landfill gas

During the site visit, the current waste disposal area is off-gassing landfill gas. As waste is placed, landfill gas continually ramps up for a period of time after placement. Eventually, though, the landfill gas production rate begins to degrade. Once a cell is completed, the rate at which it creates gas begins to decelerate in an approximate first order relationship. It was clear from the site visit that the new lifts are reaching their optimal gas production rates. These cells were not present prior to 2009.

Active Area Change #7 – Waste placement orientation with respect to wind

In general, all emission sources can be categorized as point, area, or volume sources. In a landfill, point and area sources are typically present, though there are some pile sources that can be considered volume sources. Point sources at a landfill include the landfill gas flare that releases emissions from one point, but also less obvious ones, like the little fissures present in the hot spot that emit hydrogen sulfide gas. Area sources include most of the current active areas, and areas such as the liquid lagoons.

Each source type has different dispersion characteristics. Point sources are heavily influenced by nearby structures; luckily, this is usually not a concern for landfills. Area sources, by contrast, are heavily influenced by orientation and wind direction. The orientation of the new cells (area odour sources) at the Robin Hood Bay landfill is likely one of the factors that has resulted in increased complaints.

The new lifts added over the last two years are long and narrow. In certain wind directions, especially those from the ocean (easterly) towards the neighbourhood, wind will pass over these cells in a linear fashion. If the centerline of the odorous plume that is emitted from the area source is in line with the wind direction, then little dispersion is achieved, and the mass loading in this plume will increase. This phenomenon could create plumes with significant odour potential even with typical gas loading.

Summary of Potential Changes in the Active Area

In the field of odour control, we often speak of FIDO: frequency, intensity, duration and offensiveness. Each neighbor has a certain tolerance for odours based on a combination of these factors. Unfortunately, if the cells today are closer to the neighbourhood, lined up with worst-case wind conditions and further from the wind influences of the ocean, then there is a potential for a more intense experience off-site. The odour is likely more concentrated today than it was prior to 2009, if there is a more concentrated plume. A more concentrated plume will require more dispersion to dissipate; therefore, it may reach a certain neighbor more frequently, or it may linger for longer periods.

If these plumes also have elevated spikes of hydrogen sulphide, which has a rotten egg odour, are mixed with liquid waste odour or sludge odour, then today's landfill odour may be considered more offensive than landfill odours have been in the past.

Odour Response Action Plan Recommendations

Before odour control recommendations are discussed, it is important to determine the neighbourhood tolerance for odour and to discuss improvements to the facility's odour response procedures, its odour identification program, and its odour baseline assessment. While the site visit established that the off-site odour potential has likely increased since 2009, it is possible that during that time the tolerance for odour has gone up, down, or remained the same. To examine the change in odour tolerance, an odour complaint analysis is a good place to start.

Odour Complaint Analysis

Odour complaints received from April 20, 2010 to August 29, 2010 were examined as part of this odour assessment. The complaints can be categorized monthly as follows:

Month	**# of complaints**	**Complaint days**	**Complaint Areas**
April	3	3	3
May	12	6	10
June	16	11	15
July	13	6	11
August	44 *	8	17
Total	88	34	**

* including 27 complaints attributed to liquid waste applied as fertilizer to a nearby farm
** Not Applicable

The chart above is somewhat skewed by August 17, 2010 and/or August 19, 2010, when a local farmer was spreading manure as fertilizer and a number of complaints were logged. The landfill staff clearly determined that the 27 complaints logged during those two days were related to the fertilization project. Even without those complaints, however, there were still 17 complaints in August, more than in any previous month.

It is very possible that many of these odour complaints mistake the odour from other industrial sources as landfill odour, since sulfur based odourants that dominate landfill gas are also present at facilities that have storage tanks, use oil for heating, create a fused or heated product, create a food product, etc. It is not unusual for one higher-profile source to be blamed for odour from other sources. If the tolerance for odour is dropping, it is not unusual for someone to have experienced odour from a more local source over a period of time and then be convince it is from the more commonly accused odour source. While some of the complaints may be related to other sources, a majority of these complaints are still likely related to the landfill based on the site visit and landfill odour potential.

Odour complaint days average roughly ¼ of the days each month. Based on average wind conditions for the year from the St. John's airport, wind is blowing across the landfill into the neighbourhood roughly the same amount of time, (6-8 days per month, or ¼ of any given month on average). There is a fairly consistent number of complaint days, and a clear trend of increasing complaints in the table above. This combination is important. It basically suggests that the tolerance for odour is decreasing. Based on conversations with neighbors, the actual number of days that odour is noticeable in the neighbourhood is likely more than 6-8 days per month.

The second combination of concern is the number of complaint areas and the number of complaint days. While the number of days of complaints is fairly constant, the number of areas where complaints occurred are increasing dramatically. This is another clear indication of a reduction in tolerance for odour. While one could argue that the odour levels increased and increased odour potential is the reason for an increase in complaint areas, this is not a typical trend. More complaint areas translates to complaints from areas further from the facility, so even if odour increases, it would have to dissipate more before the it reaches further into the neighbourhood. If there was only a rise in odour and not a reduction in tolerance, there would be a clear increase in all three columns.

Neighbourhood Tolerance for Odours

Media coverage of nuisance odour has an effect that should not be underestimated. People have many, many things going on simultaneously in their lives, and their sensory systems cannot be attuned equally to them all; media attention to a nuisance concern can bring it to the forefront of neighbors' perceptions. This seems to be the case with the community surrounding the Robin Hood Bay Landfill.

As part of our neighbourhood assessment, we visited many of the local subdivisions surrounding the landfill. Some of these subdivisions have houses that have been completed in the last five years, with little vegetation extending upward beyond rooflines. Some of the closest neighbourhoods are currently under construction. While the landfill may have operated for a long period of time without neighboring residences as close as they are today, it still must take into account the impacts of odours from its operations on these new residences.

Based on interviews with residents, staff and city officials, there was odour emanating from the landfill in the neighbourhood prior to 2009. One woman said she has lived in the neighbourhood for 20 years and could smell the landfill on occasion over that time. Her impression was that the odour impacts today were exactly the same. Her grown children were visiting; one of them, nursing a baby, disagreed, saying that it had gotten worse over the last year. This is a great illustration of how some residents may have a high tolerance level while others may not. As the neighbourhood evolves, new residents can be expected to experience odour impacts keenly and desire improvement in the overall odour situation.

There have been numerous studies over the years that have examined individuals that have been sensitized to an odour. In addition to sensitization via the press, the individuals have been sensitized to the odour itself. As a person experiences an odour over and over, he or she "learns" to recognize it better and better. Since odour is actually a human perception of a chemical compound and not a thing in and of itself, it is very possible for someone to claim that odour is worse than it has ever been, even as a facility is working hard to cover and treat odorous sources to lower levels over time. It is important to realize that odour may have only gone up a little bit for a short period, but now the neighbors are sensitized, so the span between odour detection and recognition has shrunk. The facility should take these concerns into account and approach the odour nuisance concern with an approach that goes beyond typical landfill design modifications; such as operator odour training, complaint response procedures, developing an odour baseline.

Odour Response Action Items

The Odour Response Action Plan is divided into three parts: immediate action items, short-term action items, and long-term action items. Immediate action items are items that have been discussed with facility staff, items the staff are currently implementing or items that shall be underway in the next month. Each of these action items are discussed in more detail following this summary. Please note, because of the pending winter weather, some action items that ideally would be implemented immediately cannot be. Those action items that are weather-dependent are included in the short-term action items for the spring of 2011, since these will require conditions consistently above freezing before they can be implemented.

Immediate Action Items (2010):

1. Drill hot spot wells;
2. Drill wells in the recent active areas;
3. Connect the hot spot wells to the current landfill gas header system;
4. Add an intermediate soil cover to the hot spot area to increase capture;
5. Change biosolids (wastewater sludge) addition procedures
6. Examine each load for wallboard and segregate if there is a high percentage of it present;
7. Mix high percentage gypsum wallboard loads with soils thoroughly prior to placement;
8. Refuse liquid wastes that are of unknown origin;
9. Implement a more formal odour complaint and response procedure;
10. Install wind socks on the east and west ends of the facility;
11. Reorient future cells to run north-to-south from east-to-west; and
12. Leachate monitoring adjustments for odour potential.

Short-term action items are items that should begin in the next few months and should be completed in 2011. Implementation of some of these action items will be part of the long-term landfill gas management plan.

Short-Term Action Items (2011)

13. Complete an evaluation of alternative intermediate covers to be used for odour control;
14. Add an intermediate cover to the cells that run east-to-west;
15. Connect the new gas wells from the cells that run east-to-west;
16. Increase the size of the temporary landfill gas system by adding a second flare;
17. Train landfill operators on odour identification and odour response;
18. Establish an odour baseline for the facility
19. Monitor the odour baseline for changes in fingerprint;
20. Evaluate long-term liquid waste alternatives to reduce odour;
21. Evaluate long-term C&D separation alternatives to reduce odour;
22. Design an odour masking system for warm weather use;
23. Procure and install a meteorological tower;
24. Evaluate optimal times for intermittent masking agent use;

25. Install the odour masking agent system and begin optimal operation;
26. Install a new landfill gas header to access the current east-to-west and future north-to-south cells.
27. Examine other potential industrial sources of odour near the landfill; and
28. Develop a long-term landfill gas management plan.

Long-term action items are items that require an evaluation and review process, or may impact current landfill waste depositors and therefore will take longer than one construction season to implement, and may not be limited to the following.

Long-Term Action Items (Beyond 2011)

29. Cap the western slope as soon as the westernmost lifts reach final grade;
30. Implement long-term liquid waste alternatives to reduce odour;
31. Implement long-term C&D separation alternatives to reduce odour;
32. Design and install a permanent landfill gas header system;
33. Design and install wells to maximize capture; and
34. Design and install a permanent landfill gas combustion system.

Each action item is discussed in more detail below. Please note many of these action items have begun, and some are actually completed such as the drilling of wells in the hot-spot and active area. Others will require significant capital investments and therefore will require full designs with cost estimates included before they can be presented to the City.

Action Item #1 – Drill hot spot wells (Immediate action)

The City is adding to the landfill gas capture system by placing three new wells to capture the emissions from the hot spot. This area has a higher than average concentration of odour. The area appears to be quite limited in scope, so installing a few new wells within the limits of the hotspot would likely reduce the on-site odour and the overall odour profile.

Action Item #2 – Drill wells in recent active area (Immediate action)

The City is adding to the landfill gas capture system by placing new wells to capture the emissions from the recent lifts. These lifts are just reaching their prime landfill gas production potential. Landfill gas production typically follows a first-order rate of decay, with maximum production occurring within a few months to a few years after waste placement. Landfill gas capture should be considered as cells are built in order to capture gas during each cell's peak production period.

Unlike the hot spot, where hydrogen sulfide was found at very high levels, typical odour potential from landfill gas is driven by methyl mercaptan. Methyl mercaptan is the simplest organic sulfide and can be formed easily when there is an abundance of methane. Methyl mercaptan is problematic because it has a very low odour threshold, and therefore, even a little bit can result in nuisance exceedances.

Methyl mercaptan can be detected in concentrations in the part per trillion (ppt) level. To understand how dilute an odour can be and still be detected by human beings, imagine one drop of water in an entire swimming pool. That is roughly equal to one part per billion (ppb). A part per trillion (or ppt) is one drop of water in a *thousand* swimming pools. Persistent odours like methyl mercaptan can be detected at these low concentrations, so dispersion alone may not be sufficient to reduce odour, especially if a neighbourhood has been sensitized.

This area has a higher than typical off-site odour potential because of its orientation and proximity to the neighbourhood, so additional wells should be added and brought on-line as soon as possible.

Action Item #3 – Connect hot spot wells to landfill gas system (Immediate action)

At first it was unclear whether any of the wells installed in action items #1 and #2 could be connected on the surface (above the frost line) and survive the winter. Ideally, these wells would be connected immediately, even with temporary piping that would be abandoned next spring. The concern is that condensation will freeze in the piping. A compromise was developed to connect the hot spot wells now with temporary piping in a manner that would allow drainage, since this is the primary area of concern, and then connect both the hot spot and new lifts permanently next spring. (Action Item #15).

Action Item #4 – Add an intermediate soil cover to the hot spot area to increase capture (Immediate action)

The landfill gas system is beginning to draw gas out of the hot spot wells. In the next few weeks to months, these wells will reach equilibrium. At that time, the wells will be "balanced" to withdraw at the same rate as the gas generation rate and infiltration rate combined. Infiltration air is pulled in from the outside if the cover material is porous. With only crushed rock typically available on-site for cover material, the cover over the hotspot is very porous. The facility should use other soils to better seal the hot spot. A better seal will improve hot spot odour capture.

Action Item #5 – Change biosolids Addition Procedures (Immediate action)

Biosolids were being used in a manner similar to Action Item #4 above, to fill in low lying areas and to fix landfill breakouts. Unfortunately, this concentrates the sludge odour and sludge moisture in one location. Ideally the biosolids would be diverted for organic recovery and potential odour reduction, or if they must be landfilled, then they should be spread thinly over the active area to spread the water through the active cell. Ideally, these new lifts would have gas wells installed as soon as each lift is filled, in order to minimize odour potential from the added water in the biosolids.

Action Item #6 – Examine each waste load for wallboard (Immediate action)

Wallboard (gypsum board) contains a hydrolyzed sulfate that, when exposed to the moist conditions in landfills, becomes a food source for certain anaerobic bacteria. These naturally occurring bacteria emit dissolved sulfide that can lower the pH in a localized pocket of waste. Gypsum should be segregated to the extent possible.

Action Item #7 – Mix Gypsum and Non-Hazardous Soils (Immediate action)

When gypsum board is concentrated in one location, all other competing bacteria can no longer grow and a "hot spot" of dissolved sulfide is formed. As the pH drops, dissolved sulfides in the liquid form become hydrogen sulfide in the gaseous form and are emitted. It is important to mix any incoming gypsum with other soils so that these pockets can be minimized.

There have been studies that suggest two parts soil to one part ground gypsum (or gypsum containing construction waste fines) eliminate this concern, and one part to one part drastically reduces it. Obviously, this will not be easy to do without a change in procedures. Over the next few months, a goal of 5-10% gypsum board diversion from loads of construction & demolition waste, especially where wallboard is prevalent, would reduce drastically the potential for severe odour hot spots until a firm policy can be evaluated in action item #21 and can be implemented as part of action item #31.

Action Item #8 – Refuse liquid wastes that are of unknown origin or potential odorous (Immediate action)

Currently, liquid waste of unknown origin is being accepted at the landfill. This waste is contributing to the odour produced at the site. RHB Landfill is a solid waste management facility; as such, liquid waste is not an acceptable waste for disposal at this facility at this time. During Action item #20 a liquid waste acceptance policy can be evaluated and possible recommendations could be implemented as part of action item #30, if desirable.

In the meantime, liquid wastes should be temporarily banned as soon as possible. It is our understanding that this ban will take time to put into place. In the interim we recommend that, at a minimum, a manifest system be developed so that a manifest accompanies each load of liquid waste delivered to the landfill. This will enable the landfill operator to determine the origin of the liquid waste and the odour potential.

Only water based, non-hazardous liquid waste is acceptable, as this can be applied over the working face or another designated area at the landfill. Other non-hazardous liquid wastes should not be accepted at this time. If they are to be accepted in the future, a containment system needs to be developed to store this waste safely and appropriately.

Action Item #9 – Implement formal odour complaint and response procedures (Immediate action)

There is an odour complaint process in place today that is good for identifying some complaints, but in its current form, it is not possible to track the complaint through the response system, or confirm whether it is related to the landfill or related to another source.

Complaints should be encouraged and a formal plan should be implemented that develops a database that tracks each complaint spatially, by description, by complainer, by odour character, by intensity, and by odour source. Eventually, this database will help the foreperson respond to correct complaints more efficiently, will help establish the allowable odour baseline in Action Item #18, and will help monitor this baseline in Action Item #19.

Action Item #10 – Install wind socks on the east and west ends of the facilities (Immediate action)

Wind socks will provide wind direction information to help confirm future complaints in Action Item #9 They can be installed quickly, before the meteorological tower can be installed in action Item #23. Tech recommends the installation of two wind socks: one on the easternmost portion of the landfill and one on the westernmost portion. It is not sufficient to qualify odour complaints based on the airport wind direction because of the complex terrain around the landfill.

Two wind socks are recommended because a single wind sock would only visible from limited locations on-site. Two wind socks will provide instantaneous wind direction during the Action Item #18, baseline fingerprinting. A single windsock may experience localized wind effect and with two present, localized effects can be monitored.

Action Item #11 – Reorient future cells to run north-to-south (Immediate action)

Ideally, no more waste will be placed in an east-west configuration. Instead, the final landfill filling process should be changed so that each lift is filled from north to south. North-south lifts will ensure that landfill gas and odour emission from the active area are effectively spread out perpendicular to the worst-case wind direction for neighbourhood exposure (see Figure 4).

This placement change will not change the landfill gas emission rate or capture rate, but it will create a wider odour plume so that there will be less odour concentrated in a single east-to-west wind direction. The change in orientation will add dilution to the landfill gas emissions directly at the source.

If the cells are built in a pyramid fashion, whereby two or three of the base lifts are added first, and then the next layer is two lifts wide and the final is one lift wide, then the completion of the final western slope can be achieved first. (See insert in Figure 4.)

Waste placement will take place during later years behind this “wall” of waste. The wall will shield some of the active area odour from wind impacts, and odour that reaches the top of the filled cells will receive some additional dispersion from the turbulence as it passes over the final covered portion of the landfill.

Action Item #12 – Leachate monitoring adjustments for odour potential (Immediate action)

Leachate is not an on-site odour control issue. There have been reports of sewer odours, but it is unclear whether these odours are related to the landfill or the sewer system itself. Adjusting the leachate sampling program to include odour indicators would be necessary to know for sure whether there are any significant odours emanating from the landfill sewer. However, there was no indication of excessive dissolved sulfides based on observations made at the landfill. This monitoring should be considered as part of the landfill gas management plan.

Action Item #13 – Complete an evaluation of alternative intermediate covers to be used for odour control (Short-term action)

Currently, daily cover needs are satisfied by blasting and crushing local rock to 6-inch minus or 4-inch minus stone. This material provides an excellent daily cover. It prevents vector contact and seals in the fresh waste odour each day. Unfortunately, crushed rock is not a good interim cover material. The porous rock also does very little to prevent surface migration once landfill gas begins to build pressure.

In Action Item #4, an alternative cover material is recommended for the hot spot to minimize infiltration during evacuation. This same intermediate cover could drastically reduce odour migration at other areas of the landfill and should be considered for localized areas with higher than typical odour potential. Possible current intermediate locations would be the current east-west lifts, the lagoon area, hot spots, landfill gas breakout spots near the existing collection system, etc.

A posi-shell type material would help with this concern, and should be considered for areas where no additional waste will be placed in the very near future. Synthetic covers, such as membrane covers, should also be considered for intermediate cover material. Synthetic covers allow wells to be placed very near the surface. In essence, the landfill should choose and have available a daily cover option, an intermediate cover option, and a final cover option. Examples where intermediate cover could be considered (such as the current east-west lifts, the lagoon area, hot spots, landfill gas breakout spots near the existing collection system) could also consider surface wells with synthetic covers.

Action Item #14 – Install intermediate cover to the east-to-west cells (Short-term action)

Given that the cell orientation will change to north-to-south from east-to-west, there will be portions of these east-to-west cells that will remain at their current elevation for many years. A quasi-permanent (intermediate) cover should be considered for this area given the timeline. The cover material should be based on the completed study in Action Item #13.

Action Item #15 – Connect the new gas wells from the cells that run east-to-west (Short-term action)

Once a cover material has been selected for the east-to-west cell in Action Item #13 and designed in Action Item #14, the connection design should be completed and the wells installed.

Action Item #16 – Increase the size of the temporary landfill gas system by adding another flare (Short-term action)

The current landfill gas system is at or near capacity. To add the hot spot wells, adjustments can be made to the other existing wells to absorb these wells. Once the east-to-west cells are covered and connected to the landfill gas system, additional capacity will be necessary. This second flare would also be an interim flare and would not be designed to handle all of the future expect landfill gas flow. Instead it will be designed to handle the gas flow through the next few years.

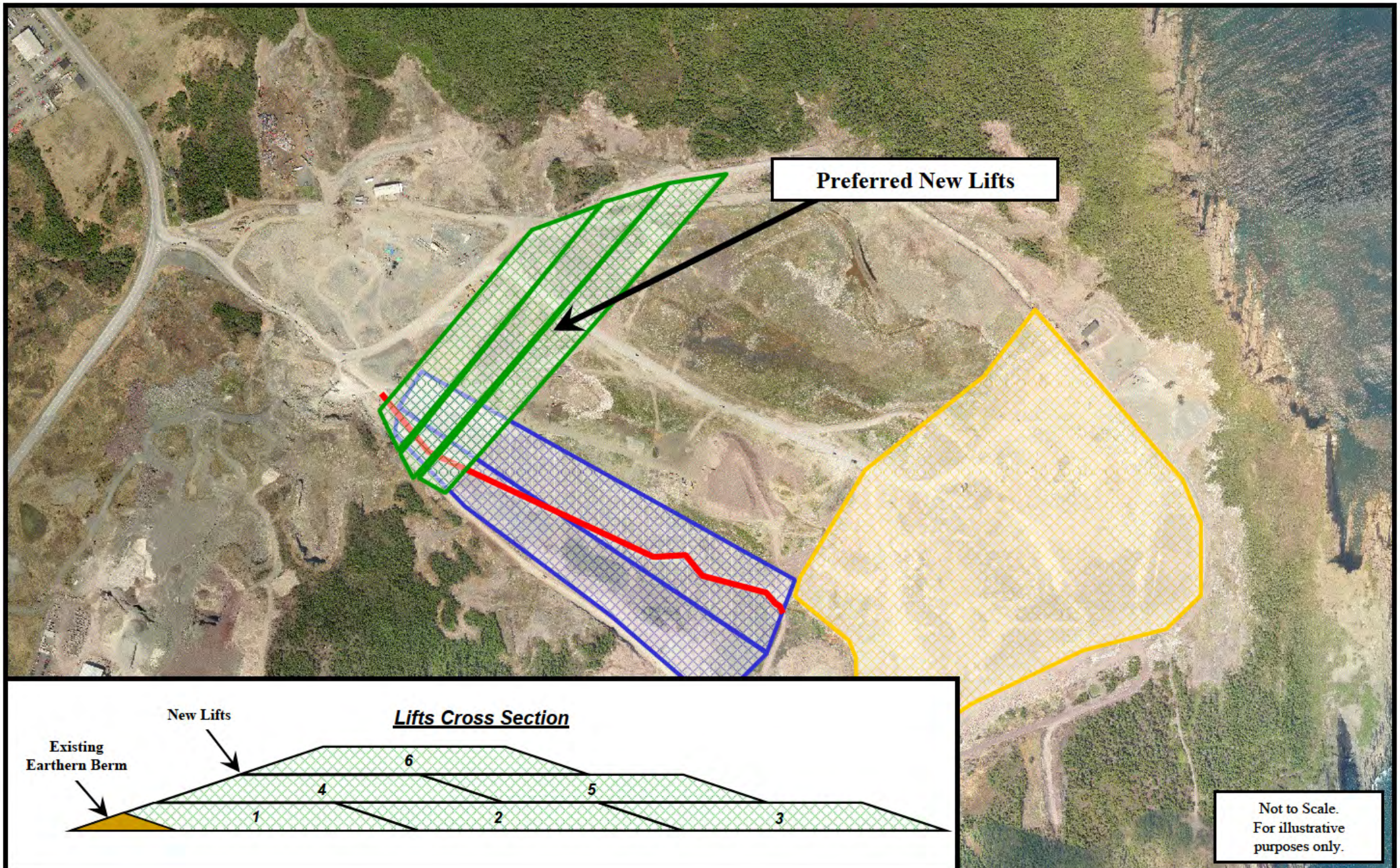


FIGURE 4.

New Preferred Lifts
Robin Hood Bay Landfill

Action Item #17 – Train landfill operators on odour identification and odour response (Short-term action)

Currently, there are no proactive odour monitoring procedures in place at the Robin Hood Bay Landfill. The current odour evaluation procedures are only in response to odour complaints. While odour potential will go down once new wells are in place, staff training should be initiated during the placement of the wells, so that operators can include baseline evaluations in their normal job duties.

Tech recommends a two day training session for all operators that will help them understand the nuances of odour, allow them to readily identify different odours, and give them the tools needed to understand when to control odours, if possible, and when to mask odours, if control is not readily possible.

Two-day courses typically consider the following topics:

- Participant Screening for Odour Sensitivity
- Introduction: What is odour and why does it vary?
- The Science of Odour: How is odour measured and discussed?
- Odour Potential: What are typical odours?
- Interactive Odour Characterization Workshop
- Odour Generation Background: How is odour produced?
- Odour Control: How are odours controlled?
- Proper Odour Field Investigations
- Odour Baseline Training Exercises

Action Item #18 – Establish an odour baseline for the facility (Short-term action)

The operators should be trained to continuously observe odour on a concentration basis. A dedicated set of odour screeners should evaluate the landfill perimeter every morning for on-site odour. The screener could be a foreperson, a manger, or an operator, but must be someone that falls within the normal odour sensitivity range. 19 out of 20 people fall in the normal range on average so there will be sufficient personnel to maintain odour screening coverage. During the odour training operators, managers, and forepersons are screened to determine whether each fall into the normal range of odour sensitivity.

Action Item #19 – Monitor the odour baseline for changes in fingerprint (Short-term action)

Ideally a foreperson, with adequate odour sensitivity would be positioned well to establish and maintain the odour baseline. Operators should be aware of the normal baseline odour and should be readily able to identify hotspots through identification of odour character. Establishing and maintaining a baseline can help operators find and improve elevated odour conditions on-site before they become an off-site concern.

Action Item #20 – Evaluate long-term liquid waste alternatives to reduce odour (Short-term action)

Currently, only an interim landfill gas pilot system has been installed. The system does not yet extend to the current active area. Liquid wastes should not be added to landfills that do not incorporate landfill gas management systems as the cells lifts are being constructed. If a full scale landfill gas management system is not desired for this facility, liquid waste should be phased out completely.

Action Item #21 – Evaluate long-term C&D separation alternatives to reduce odour (Short-term action)

Evaluate a long-term separation alternative for gypsum board and other C&D materials with odour potential.

Action Item #22 – Design an odour masking system for warm weather use (Short-term action)

Given the meteorological dynamics of this landfill, we suggest the short-term use of masking agents. We generally discourage operators from using masking agents, because long-term use can ultimately result in negative consequences. However, if used properly and sparingly on a short-term basis, they can have a positive effect by confusing odour sensitization.

The purpose of a masking agent is not to decrease odour, but to change what is referred to in odour control as the "hedonic tone," or the relative pleasantness of the odour. Obviously, sources like landfills have a very negative hedonic tone, so adding something more pleasant would potentially improve the reaction of a neighbour. Unfortunately, adding a masking agent also adds to the total odour in the area and individuals will become tired (sensitized) to pleasant odours over time, so it must be used sparingly to be effective.

It is important to note that masking agents are different from counteractants. A counteractant, in theory, binds with the odourant of concern and creates a new compound that is considered less offensive or less odorous. However, the only way for this counteraction to take place is for the odour molecule and the counteractant molecules to come together. When we are referring to odour potential in parts per million or parts per billion, one can see that there are many compounds (such as air itself) that can get in the way of these compounds finding each other. The actual counteraction, therefore, is only as good as the initial contact, and as these two materials travel away from the active area, they disperse in different patterns and at different rates. The landfill could consider a counteractant that also masks, but should realize the dispersion limitations of counteractants.

Action Item #23 – Procure and install a meteorological station; (Short-term action)

In addition to the wind socks to be used instantaneously in the field, a meteorological station that reports and data-logs wind speed, wind direction, temperature, and atmospheric pressure should be installed on the westernmost portion of the landfill at a height of 10 meters to better understand the local wind influence on a day-to-day basis and to help assess odour complaints. Tech's meteorologists can design an adequate system if desired.

Action Item #24 – Evaluate optimal times for intermittent masking agent use (Short-term action)

The masking agent system designed in Action item #22 would be applied in specific wind directions. To determine the optimal locations, we recommend performing dispersion modeling with this data and the local terrain to identify channeling pathways. This modeling can be completed over the winter.

These pathways would be candidates for counteractants/masking agents at particular times as determined by the modeling. The masking agent we would suggest would not be an obvious scent like "fruity" but something more subtle and/or indigenous to the area. When masking is considered, we typically suggest cycling different masking agent "flavours" over time. The goal of this effort is to disrupt the long-term habituation associated with landfill odours.

Action Item #25 – Install the odour masking agent system and begin optimal operation (Short-term action)

The odour masking system installation would need to be coordinated with the installation of the new landfill headers and the new north-to-south lifts. Once the optimal masking times have been explored and the system designed, installation will need to be delayed after the spring thaw, since the piping with not be buried. It will be located on the surface so it can be moved as the lifts are added to the "west wall." This system would only be used during the warmer months.

Please note the masking system should not be considered in place of odour capture, ventilation and control, or as a way to reduce the scope of the long-term landfill gas management plan. It should be included to help the landfill co-exist with its neighbours during transitional times only.

Action Item #26 – Install a new landfill gas header to access the current east-to-west and future north-to-south cells (Short-term action)

To permanently install a landfill gas piping system for the hot spot, the current east-to-west lifts, and the future north-to-south lifts, a large header will need to be installed. This header is needed sooner than the implementation of Action item #28, but should be developed in conjunction with the landfill gas management plan.

Action Item #27 – Examine other potential industrial sources of odour near the landfill (Short-term action)

As there are other possible odour contributors in the neighbourhood surrounding the landfill, it is recommended that a Phase I investigation of these industries be conducted to determine whether any of these operations have sources that contribute to odour in the area (Please see Appendix I for the location map of the other possible odour contributors that have been identified).

Action Item #28 – Develop a long-term landfill gas management plan. (Short-term action)

A directional change alone will likely not be sufficient to eliminate the odour concern, certainly not from the new lifts over time. A long-term landfill gas management plan, as outlined, in Appendix 2 should be developed.

Action Items #29 to #34 – Long-Term Action Items

The following items will become clearer as the short-term action items are completed and should be considered long-term goals for the landfill. Please note the long-term action items may not be limited to those listed below. Other action items may be identified throughout the evaluation process.

29. Cap the western slope as soon as the westernmost lifts reach final grade;
30. Implement long-term liquid waste alternatives to reduce odour;
31. Implement long-term C&D separation alternatives to reduce odour;
32. Design and install a permanent landfill gas header system;
33. Design and install wells to maximize capture; and
34. Design and install a permanent landfill gas combustion system.

It is important to recognize that many of the items on this rather long and detailed list of action items were being considered as part of the long-term solid waste and gas management master plans. Given the elevated odour levels many of the items that were "maybe" or "future" action items have become immediate or short-term items to reduce odour.

Properly designed and implemented landfill gas collection systems take time, since the design process is an iterative process. From the site visit and observations made, the facility has done a great job implementing BMPs to improve solid waste disposal and the diversion of valuable resources. There is nothing to suggest that the same success could not be applied to odour control.

If you have any questions regarding this report, please contact me at (781) 890-2220, or via email at mlannan@techenv.com.

Sincerely,

TECH ENVIRONMENTAL, INC.

Michael T. Lannan
Vice President

APPENDIX 1

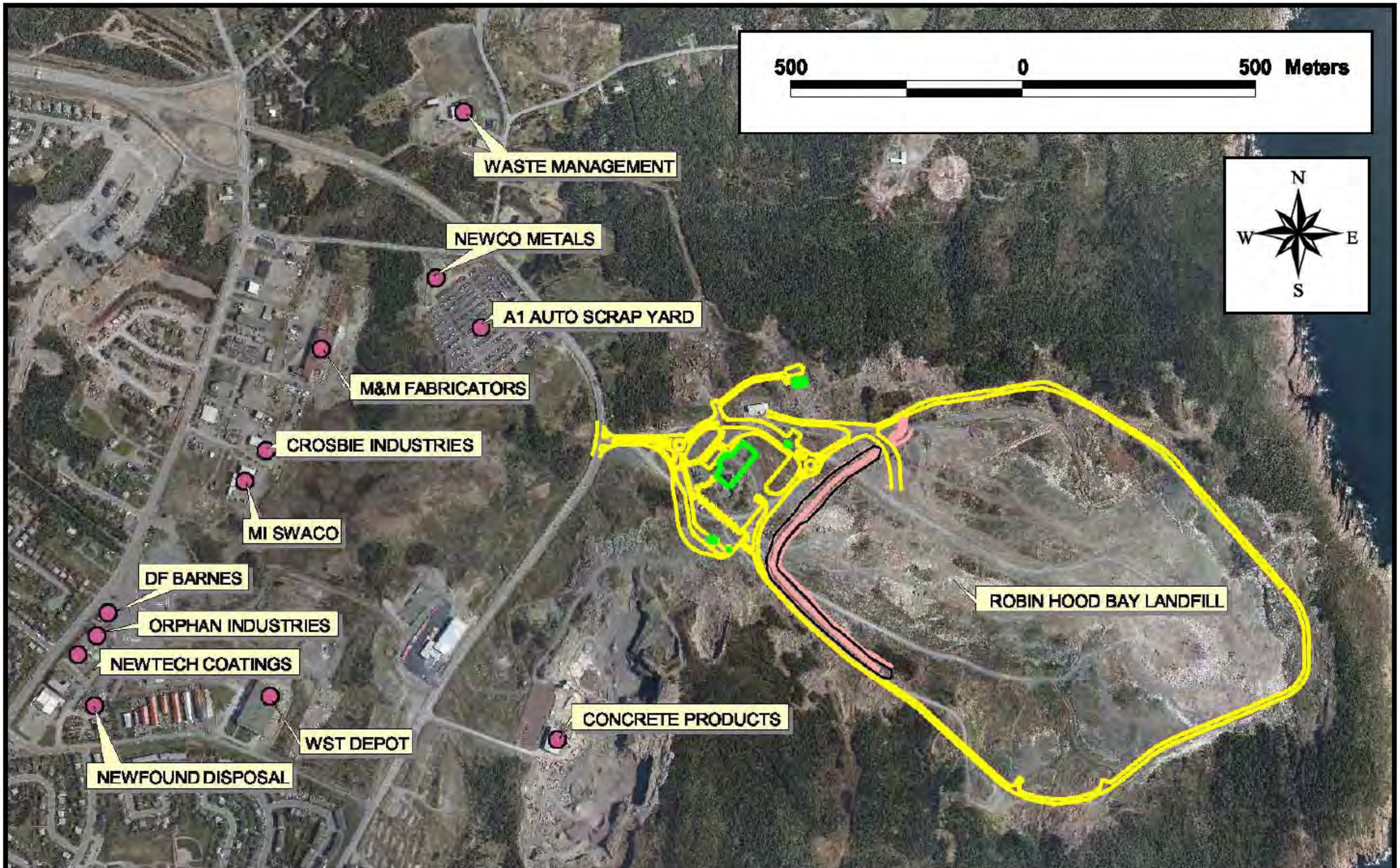


FIGURE A-1.

Industries in Immediate Area
Robin Hood Bay Landfill

TECH environmental

APPENDIX 2

Landfill Gas Management Plan

A long-term gas management plan should immediately be created for the entire site in conjunction with filling activities. Landfill gas management is an important part of best management practices for solid waste facilities. This plan should include gas collection for the completed site and interim gas collection during the site's life. At a minimum, the wellfield infrastructure of the site should be expanded to handle gas extraction from the current working area. The mechanical portion of the landfill gas collection system also needs to be upgraded to handle the increased landfill gas flows. An enclosed flare, permanent blower and control facility should be installed to allow for more gas to be collected.

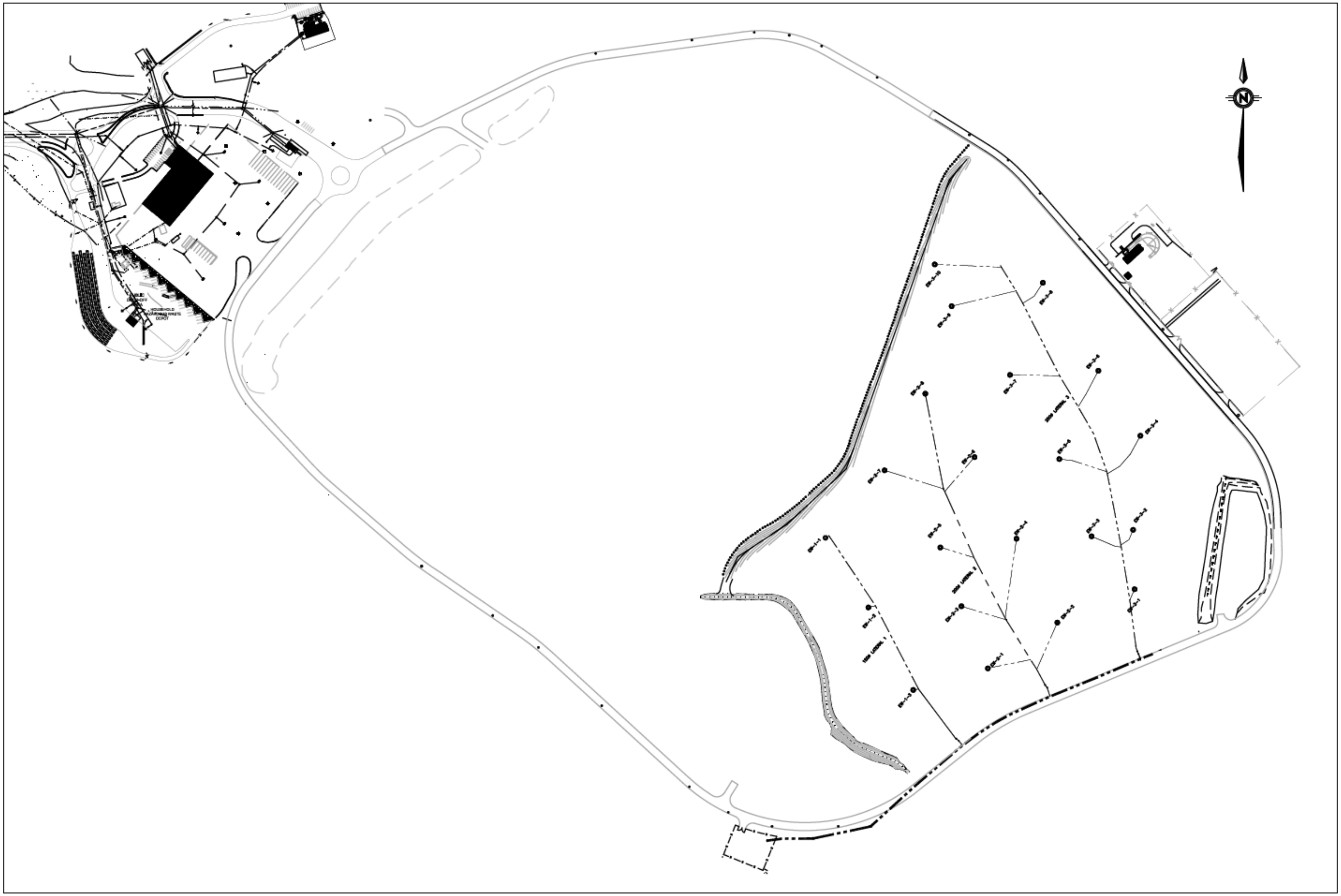
Comcor Environmental Limited (Comcor) designed and organized the installation of the current landfill gas collection and flaring system at the Robin Hood Bay (RHB) Landfill. The system currently consists of twenty-one (21) vertical extraction wells connected to buried HDPE piping which directs landfill gas to a temporary candlestick flare as shown in Figure 1. The system became operational in June 2009 and Comcor has been conducting routine monitoring and maintenance since that time. Monitoring results indicate that the recovery rate of the current collection system is on the order of 1,000 m^3/hr (600 cfm) at an average methane concentration of 59% by volume. Operating the current temporary candlestick flare at higher flow rates has proven to be difficult due to high winds and weather conditions at the site, as well as the proximity to the nearby pole-mounted electrical transformer. An enclosed flare would increase operational reliability and also be able to handle higher landfill gas flows required as the system expands.

To increase the operating life of a new flare and ultimately decrease capital costs, it is recommended that one flare size be chosen now to accommodate a wide range of flow rates that are expected to be recovered at the landfill over time. It is recommended that a 4,250 m^3/hr (2,500 cfm) enclosed flare be installed. A flare this size can be operated at turndown ratio of up to 10:1 (425 m^3/hr (250 cfm)) which will accommodate current and future flow rates over the next 40 years. It is also recommended that a permanent blower and be installed with the enclosed flare to be able to service the system for the foreseeable future.

To immediately deal with additional gas collection, it is recommended that eight (8) new gas wells be installed. Five of these wells should be spaced evenly in the new garbage placed in the lifts on the western portion of the site. In addition, three (3) wells should be installed in the areas defined during the on-site investigation as odour potential areas, i.e. the hot spot location. In order to be able to address current gas production and gas production in the immediate future, the header should be installed to the northwest corner of the landfill, as shown in Figure 2. The cost for this new wellfield infrastructure is on the order of $750,000.

As filling proceeds in the recommended west to east direction of the landfill in narrow north-south lifts, installation of a vertical well system should follow closely behind. It is recommended to extend the gas collection header to the north corner of the site to accommodate the vertical collection system as shown in Figure 3.

A complete ring header and full vertical gas collection system should ultimately be installed in conjunction with filling activities for the site. A conceptual design for the entire gas collection system complete with a ring header can be seen in Figure 4. The completed system, with a full ring header, provides redundancy to gas flows in the collection field and also enhances operational control of the overall system.



Scale: 1:6000

0 100 200 300 metres

COMCOR
ENVIRONMENTAL LIMITED
Consulting Engineers and Landfill Gas Specialists

LANDFILL GAS MANAGEMENT PLAN
CONCEPTUAL DESIGN
ROBIN HOOD BAY LANDFILL
ST. JOHN'S, NEWFOUNDLAND

Figure 1

EXISTING LANDFILL GAS COLLECTION SYSTEM

Scale: 1:6000

0 100 200 300 metres

COMCOR

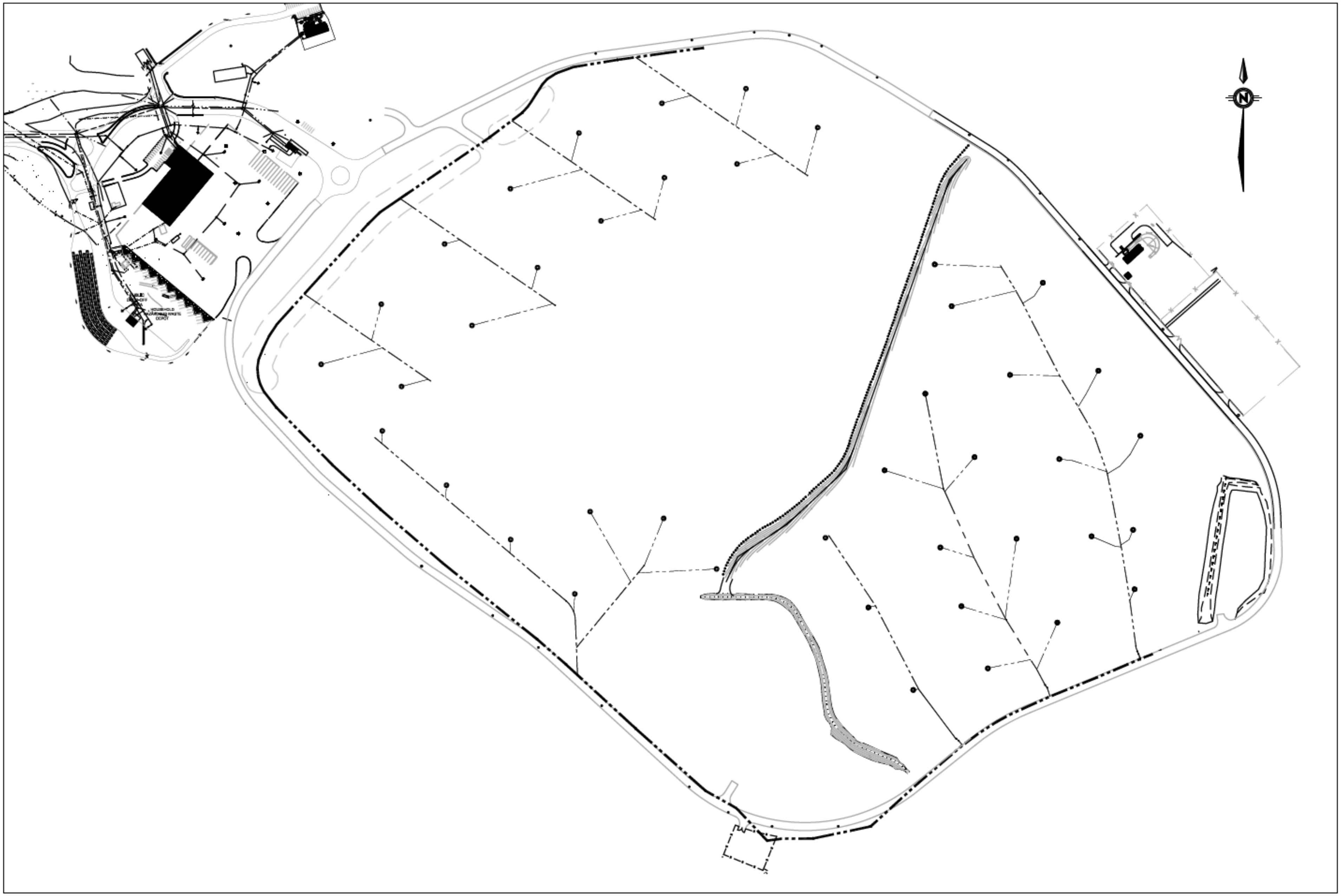
ENVIRONMENTAL LIMITED

Consulting Engineers and Landfill Gas Specialists

LANDFILL GAS MANAGEMENT PLAN
CONCEPTUAL DESIGN
ROBIN HOOD BAY LANDFILL
ST. JOHN'S, NEWFOUNDLAND

Figure 2

RECOMMENDED IMMEDIATE
SYSTEM EXPANSION



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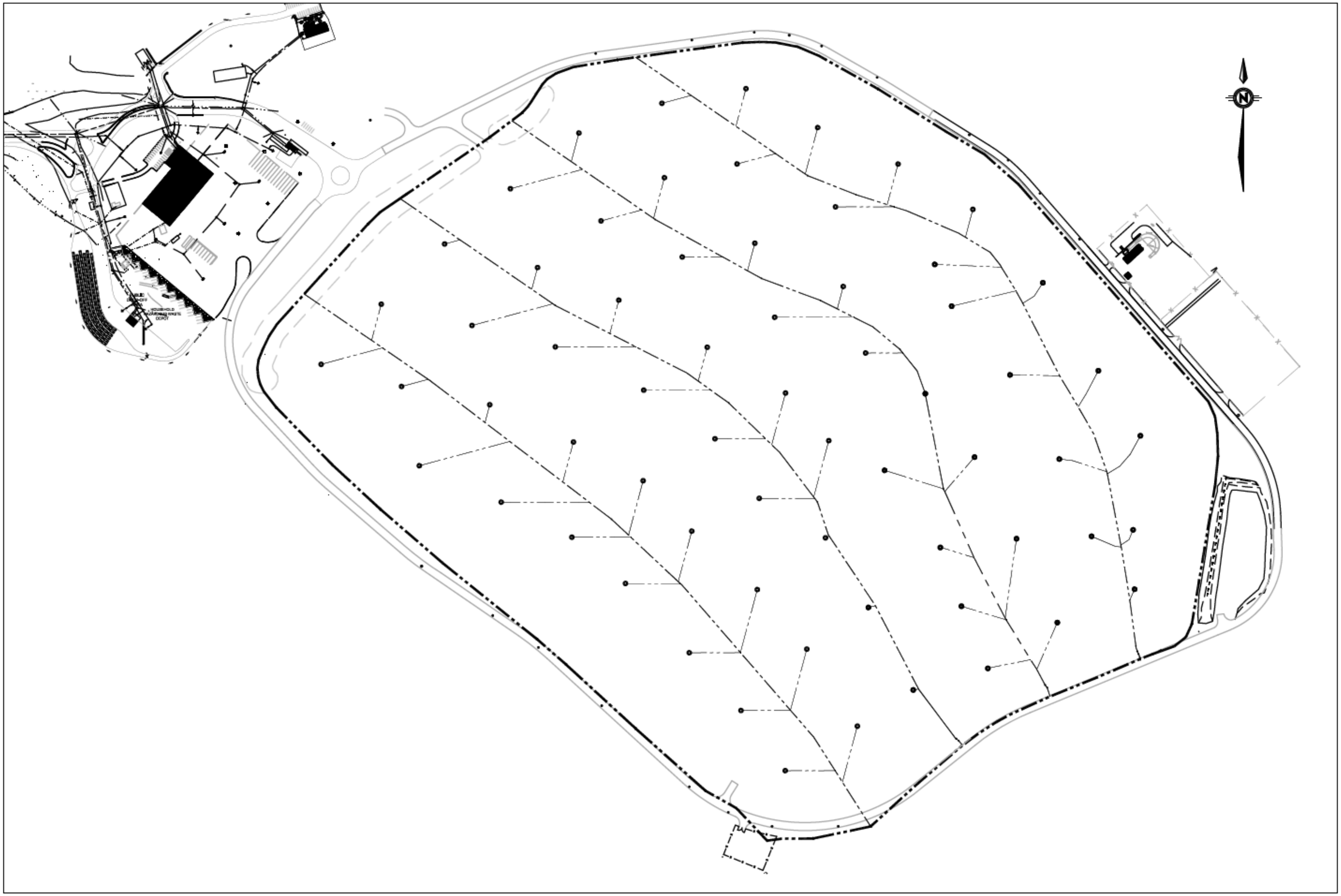
Consulting Engineers and Landfill Gas Specialists

LANDFILL GAS MANAGEMENT PLAN
CONCEPTUAL DESIGN
ROBIN HOOD BAY LANDFILL
ST. JOHN'S, NEWFOUNDLAND

Figure 3

FUTURE LATERAL EXPANSION



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LANDFILL GAS MANAGEMENT PLAN
CONCEPTUAL DESIGN
ROBIN HOOD BAY LANDFILL
ST. JOHN'S, NEWFOUNDLAND

Figure 4

FINAL LANDFILL GAS COLLECTION SYSTEM LAYOUT

APPENDIX 3
Field Olfactometer and Intensity Methods

A group of individuals is often used in a laboratory setting to determine detectibility or intensity because odour sensitivity varies among individuals. Another way to examine odour detectability is with a single trained individual in the field with a scentometer or Nasal Ranger. These instruments pull air through carbon canisters to obtain "odour-free" air to flush the odour responder's olfactory senses. The instrument then presents the odorous air in mixtures with odour free air to the odour responder. The responder starts with the most dilute mixture and keeps increasing the odour strength until it becomes detectable. At that point the odour responder knows how strong the odour is. This can be helpful when one is trying to understand how much buffer is needed from an odorous source before it reaches a neighbourhood. A Nasal Ranger was utilized during the course of this odour impact assessment. (See Figure 1 to the right).

Field quantification of odour intensity can be accomplished effectively using an "Odour Intensity Referencing Scale" (OIRS)[2], or a field odour jar kit. The OIRS is a series of bottles or jars containing fixed dilutions of a standard odourant, n-butanol, in a water solution, which can be judged against ambient odours to determine the current odour intensity of an area. The OIRS serves as a standard practice to objectively quantify the odour intensity of ambient air when conducted in accordance with ASTM #544-75 (modified). This system utilizes the lower five points of a ten point scale, in which a 1 is classified as "Very Faint", 2 is "Faint", 3 is "Noticeable", 4 is "Easily Detectable", and 5 is "Obvious".

A jar kit like this will normalize the scale for all observers. Even if one individual is more sensitive to odours than another, they will "sniff" the odour and then "sniff" the jar and perceive the same strength relative to each other. Comparing odours to a standard scale normalizes the differences in olfactory sensitivity among odour responders and provides more meaningful long-term data. Jar kits were used to assess odours on-site during this project. The use of jar kits should be considered as part of the normal daily landfill operation. (See Figure 2 to the right.)

[2] "Standard Practices for Referencing Suprathreshold Odour Intensity", ASTM E544-75 (Reapproved 1988, 1999.)

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October 16, 2017

BY EMAIL

Mr. Jonathan Murphy, P.Eng.
Waste Management Engineer
City of St. John's
Waste & Recycling Division
Department of Public Works
PO Box 908
St. John's, NL A1C 5M2

Project No. 9-523

Dear Mr. Murphy:

Re: Surface Emissions Survey
Robin Hood Bay Waste Management Facility
St. John's, Newfoundland

1.0 Background

Comcor Environmental Limited (Comcor) is currently retained by the City of St. John's (City) to design and administer an expansion to the Landfill Gas Collection System (System) at the Robin Hood Bay Waste Management Facility (Site) in St. John's, Newfoundland. The System currently consists of 33 vertical extraction wells and 3 horizontal collectors connected via a network of buried piping. The piping conveys the collected landfill gas to an enclosed flare where it is combusted for odour control.

As waste filling operations continue at the Site, additional areas have become available for landfill gas collection. Furthermore, an increase in odours from fugitive landfill gas emissions has prompted the City to expand the Landfill Gas Collection System. To assist in the design of the System expansion, Comcor recommended performing a surface emissions survey (SES) to identify the locations and quantities of fugitive emissions escaping from the landfill surface.

On July 18th and 19th, 2017, Comcor performed an SES of the Site (excluding areas immediately adjacent to the active working face). This report discusses the results of the July 6th, 2017 SES, evaluates the emission sources, and provides recommendations for the Landfill Gas Collection System expansion.

2.0 Methodology

The surface emissions survey was completed using Comcor's SES Protocol which is based on the United States Environmental Protection Agency's (USEPA) New Source Performance Standards (NSPS) for surface emissions monitoring at municipal solid waste landfills. The Protocol's methodology generally involves walking in a 30 metre grid to detect fugitive landfill gas emissions across the waste mound.

A Trimble SiteFID Gas Monitor (Monitor) was used to perform the survey. The Monitor uses a flame ionization detector to measure methane gas with a detection limit of 1 part per million (ppm). The Monitor is equipped with a global positioning system (GPS) which tracks the survey grid and location of all methane readings.

3.0 Operational and Site Conditions

The current Landfill Gas Collection System consists of 33 vertical extraction wells and 3 horizontal collectors located in the south, east and west portions of the Site. The active waste filling area is currently located on top of the horizontal collectors. There is no landfill gas collection infrastructure in the northern portion of the Site, where the newest waste is located. Two geosynthetic clay liners (GCL) are currently installed as a cover system, with one GCL over top of Laterals 1, 2 and 3, and the other GCL over top of Lateral 4. A Site Plan, provided as Figure 1, shows the coverage of the existing Landfill Gas Collection System, the location of the GCLs, and the extent of the active waste filling area.

On July 18th and 19th, 2017, Comcor performed the SES over the inactive areas of the waste mound and inspected the Site for evidence of landfill gas build-up, stressed vegetation, cracks in the cover system, and areas of obvious odours. The Landfill Gas Collection System was in operation during the SES. Weather conditions during the two days of the SES were warmer than average for the season, and are summarized in Table 1 below:

Table 1
SES Weather Conditions
Robin Hood Bay Waste Management Facility

Parameter	July 18, 2017	July 19, 2017
Temperature	24°C	23°C
Wind Speed	15 km/hr	10 km/hr
Wind Direction	West	South
Cloud Cover	Sunny	Mostly Cloudy
Barometric Pressure	102.3 kPa	102.0 kPa
Relative Humidity	60%	77%

4.0 Results

4.1 Background Emissions

Background methane concentration readings are taken before a surface emissions survey is conducted in order to identify which surface emissions are results of the landfill, and which are from alternative sources offsite. Background readings are taken upwind from the landfill site to ensure that emissions from the landfill do not influence the background concentrations. Prior to commencing the SES, Comcor took background concentration readings upwind and downwind at a distance of 30 metres or more from the limit of waste. The upwind and downwind readings at the Site were negligible (non-detect).

4.2 Measured Emissions

Figure 2 shows the path walked during the Surface Emissions Survey. The July 18th, 2017 path covers middle, east and north portions of the Site, and is traced in red and green. The July 19th, 2017 path covers the south and east portions of the Site and is traced in blue.

In accordance with the Protocol, a minimum concentration of 1,000 ppm is commonly used as the emissions exceedance threshold. However, as a conservative measure, Comcor has reported all measurements that exceeded 200 ppm. Figure 3 presents the emissions exceedances above 200 ppm, of which there were 34 distinct locations encountered during the SES. Where multiple exceedances were monitored within a 5 metre radius, only the highest concentration was reported. Each exceedance is labelled with a location ID in Figure 3 that corresponds with the ID in the Emissions Exceedances Summary provided as Table 2.

Approximately half of the listed exceedances occurred in areas of the Site with landfill gas collection. Exceedances in the older, southern areas of the Site with a GCL cover system were generally limited to locations where pipes penetrate the liner at gas extraction wells and cleanouts, or at the outer edge of the GCL. Additional exceedances in the older, southern area of the Site were detected along the side walls of the French drains near Lateral 4. However, there were very few locations with detectable landfill gas odours in areas with landfill gas collection.

The other half of the listed exceedances occurred in the northern area of the Site with the newest waste and without landfill gas collection. Of these exceedances, the majority were measured at the toe of the waste lifts, and often coincided with significant odours, leachate breakouts and/or gases visibly bubbling through standing leachate/surface water. Surprisingly, more exceedances were measured on the lower waste lift (183 masl) versus the newer, upper waste lift in the north (191 masl). Although not shown in this report, methane was consistently measured between 10 and 200 ppm along the entire walked path of the lower waste lift. In comparison, the upper waste lift only had pockets of hits between 10 and 200 ppm along the main haul road and in the northern perimeter ditch.

COMCOR

It was noted that the cover material on the upper waste lift and side slope seemed drier, finer and more homogeneous, versus the lower waste lift and side slope, which was made up of coarser rock with significantly more visible refuse.

The highest exceedance was measured at the toe of the lower waste lift and was on the order of 12,500 ppm (1.25% by volume), which is less than the lower explosive limit of methane (50,000 ppm or 5% by volume). This area was found to have the most odours during the SES.

5.0 Conclusions and Recommendations

The results of the surface emissions survey indicate that the GCL cover system used in the older areas of the Site performs well at containing landfill gas emissions and odours. While some exceedances were monitored at penetrations and at the edges of the GCL cover system, there were generally no odours detected in this area of the Site. It is recommended additional care be taken to seal pipe penetrations with sufficient bentonite clay when new landfill gas collection infrastructure or new GCL cover systems are installed. It is also recommended that additional GCL cover systems be installed to control odours and minimize surface water infiltration whenever areas of the Site have reached capacity or will not be accepting waste for an extended period of time.

Significant quantities of landfill gas and odours are being emitted in the northern area of the Site. The emissions are likely due to a combination of the coarse 4" minus cover material and lack of landfill gas collection infrastructure. The lower waste lift was found to have significantly more emissions exceedances and odours than the upper waste lift. This is likely due to the coarseness of the rock cover used on the lower lift, especially at the toe of the slope.

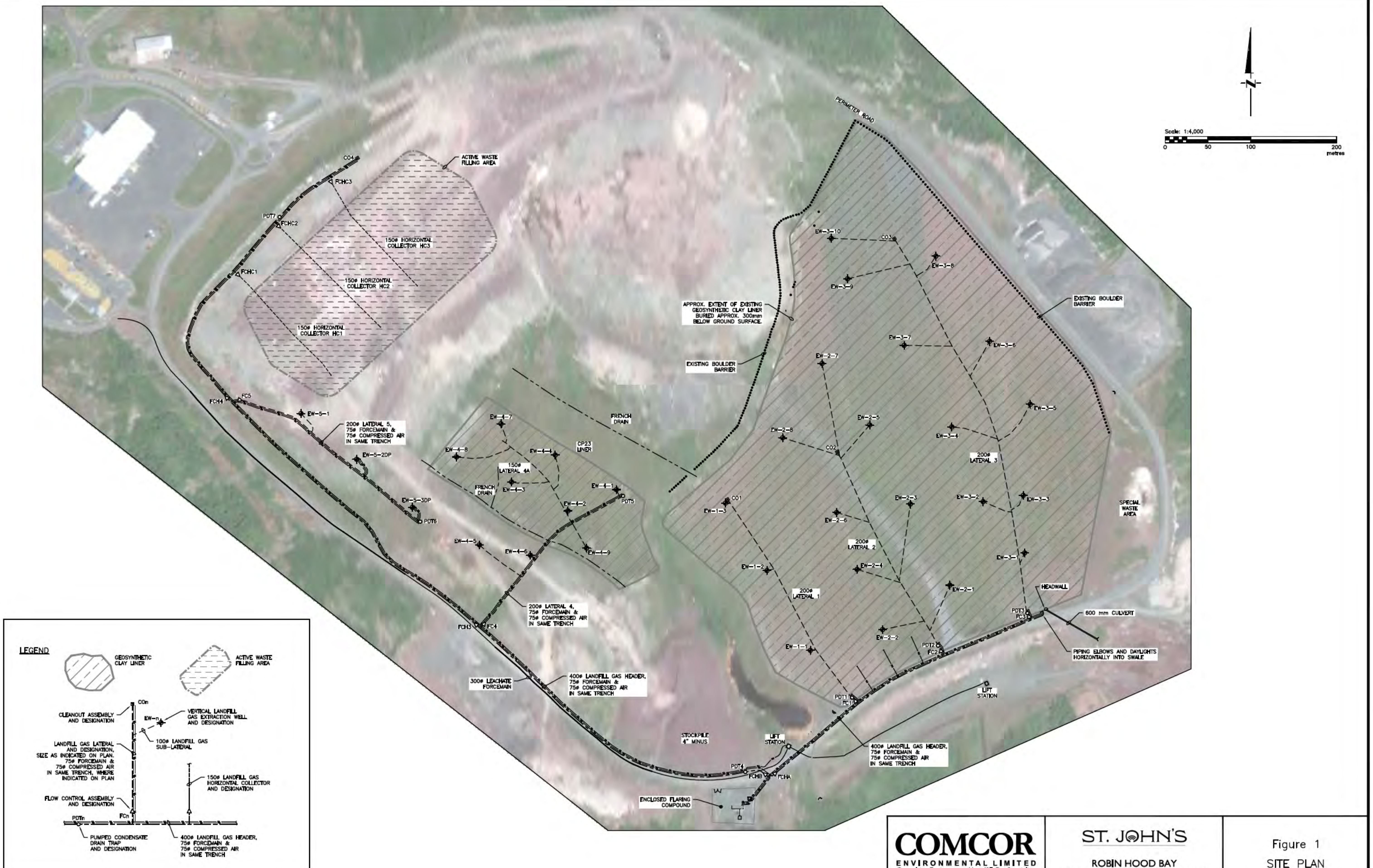
The number of emissions exceedances measured in the northern area of the Site confirms that landfill gas collection infrastructure should be installed on the lower lift to best control odours. The results of the SES support Comcor's landfill gas collection expansion design that is currently being constructed and is scheduled to be commissioned in December 2017. Figure 4 shows the extent of this expansion.

If you have any questions, or require clarification, please feel free to contact me at 519-621-6669 extension 246.

Yours very truly,
COMCOR ENVIRONMENTAL LIMITED

Jonathan Petsch, P.Eng.
Project Engineer

Denise Burgess, P.Eng.
Manager – Engineering



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ROBIN HOOD BAY
WASTE MANAGEMENT FACILITY

Figure 1
SITE PLAN

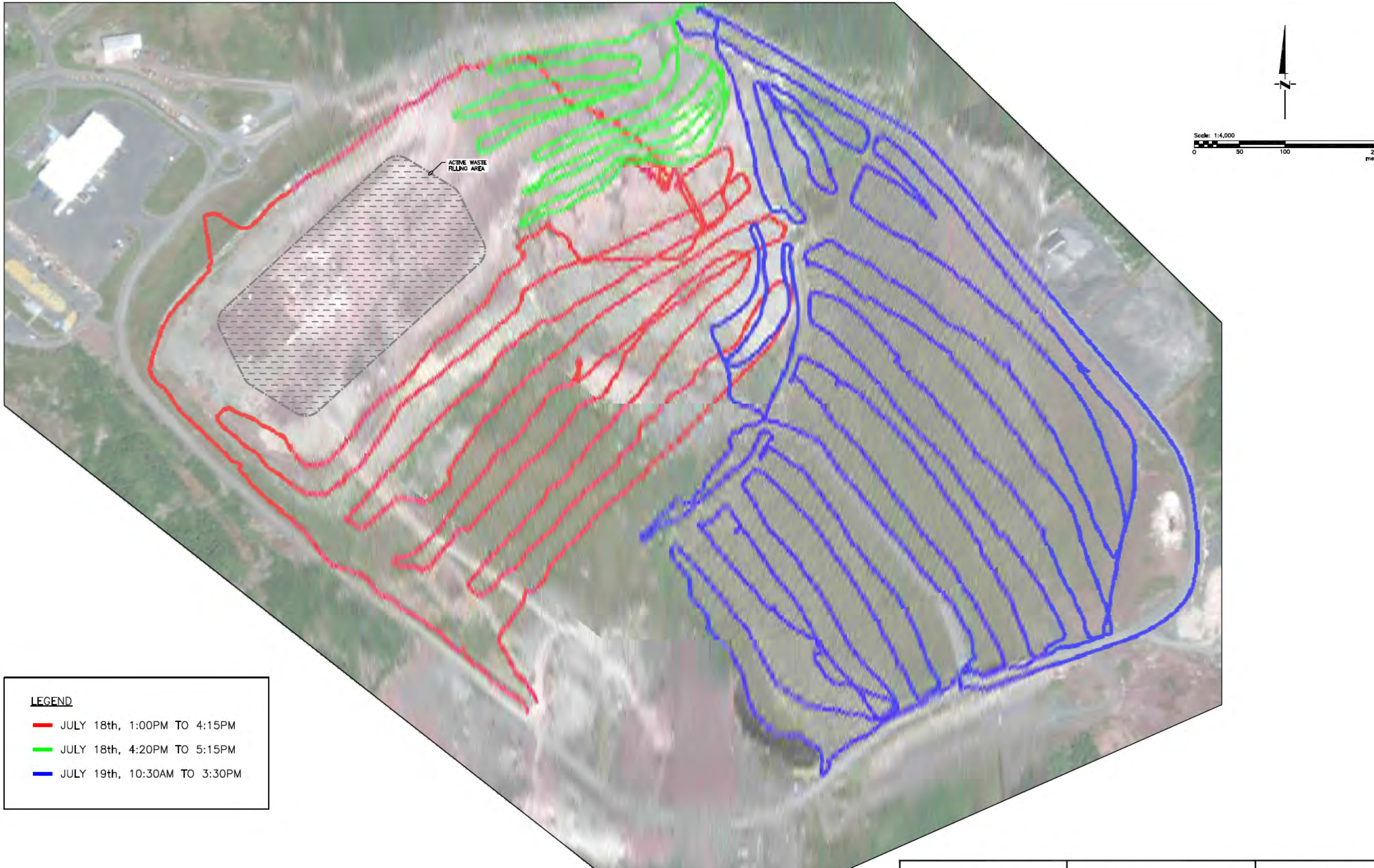

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Figure 2
SURFACE EMISSION SURVEY PATH

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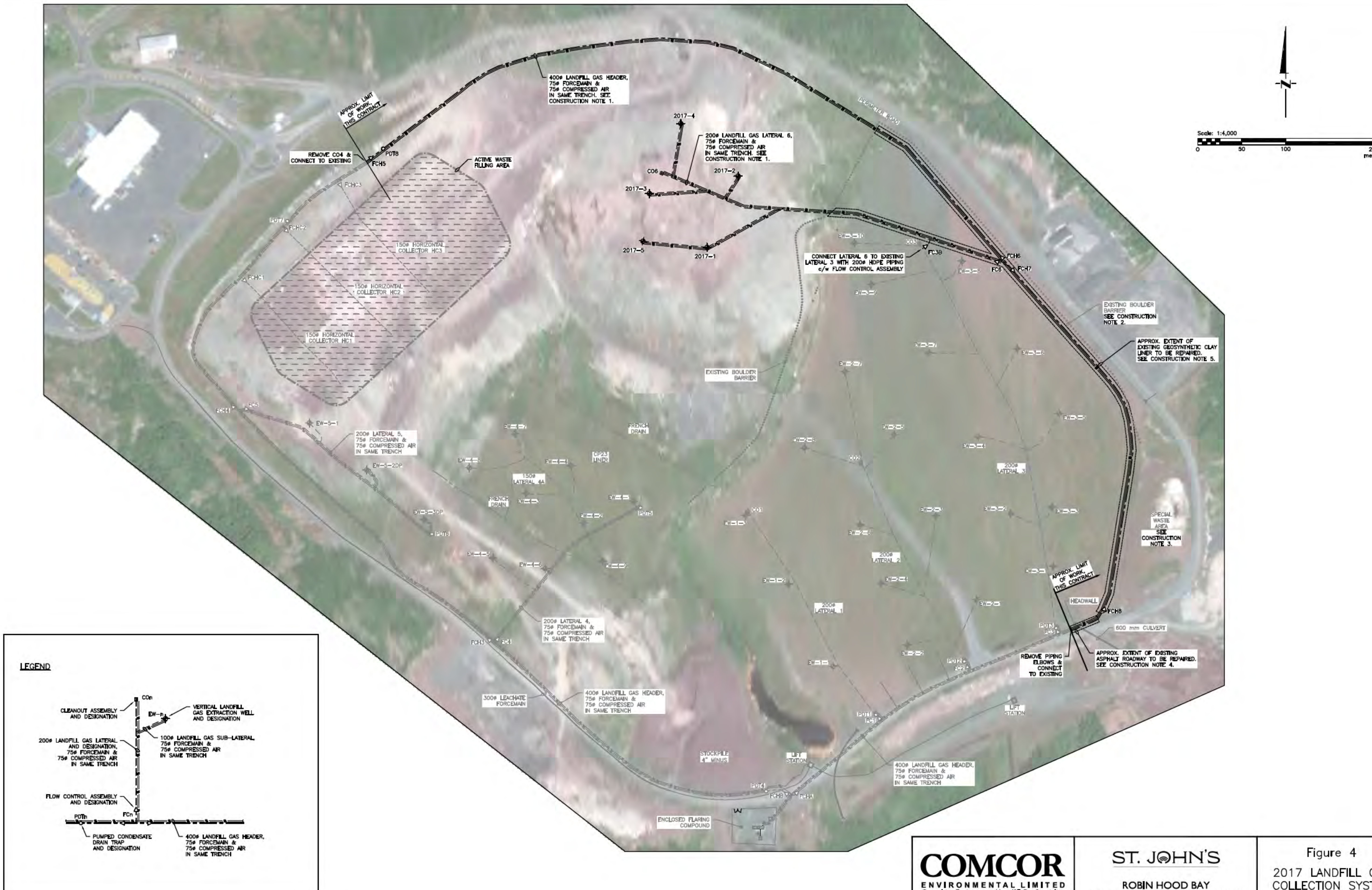
Figure 3
SURFACE EMISSION
SURVEY EXCEEDANCES



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ST. JOHN'S
ROBIN HOOD BAY WASTE MANAGEMENT FACILITY

Figure 4
2017 LANDFILL GAS COLLECTION SYSTEM EXPANSION

Table 2
Emissions Exceedances Summary
Robin Hood Bay Waste Management Facility
St. John's, Newfoundland

Point ID	Coordinates[1]				Concentration	Comments
	Latitude	Longitude	Easting	Northing	(ppm)	
2001	47.605462	-52.665802	329926.7	5274087.0	1742.6	Leachate Breakout
2002	47.605057	-52.665192	329972.7	5274042.1	302.5	
2003	47.604690	-52.665985	329913.3	5274001.1	228.4	
2004	47.604990	-52.667697	329784.4	5274033.9	1741.6	Leachate Breakout
2005	47.604972	-52.667828	329774.6	5274031.8	920.7	Leachate Breakout
2006	47.602862	-52.671538	329496.6	5273796.1	314.9	EW-5-1
2007	47.602437	-52.670692	329560.5	5273749.1	2269.5	EW-5-2DP
2008	47.603518	-52.669318	329663.2	5273869.7	7080.8	
2009	47.604395	-52.668002	329761.8	5273967.6	3233.3	
2010	47.602555	-52.670028	329610.3	5273762.4	454.6	
2011	47.602852	-52.668885	329696.1	5273795.8	552.1	Edge of GCL
2012	47.604668	-52.665680	329936.2	5273998.7	334.8	
2013	47.602387	-52.668863	329698.0	5273744.1	448.5	
2014	47.601743	-52.668030	329760.9	5273672.8	305.1	Wall of French Drain
2015	47.606225	-52.667185	329822.3	5274171.3	293.5	
2016	47.605745	-52.665985	329912.8	5274118.4	437	Bubbling Liquid
2017	47.601230	-52.664338	330038.8	5273617.0	511.8	EW-1-2
2018	47.602117	-52.665222	329971.9	5273715.3	363.4	Edge of GCL
2019	47.601953	-52.664950	329992.4	5273697.1	5016.3	EW-1-3
2020	47.601850	-52.663222	330122.4	5273686.3	856.4	EW-2-6
2021	47.602013	-52.666052	329909.5	5273703.5	204.6	
2022	47.601922	-52.666338	329888.1	5273693.2	754	Edge of GCL
2023	47.602265	-52.665565	329946.0	5273731.6	490.7	Wall of French Drain
2024	47.604428	-52.664093	330055.7	5273972.6	12522	Odours/Breakout
2025	47.604800	-52.664258	330043.1	5274013.9	305.8	Bottom of Lift
2026	47.604612	-52.664265	330042.6	5273993.0	324.1	Bottom of Lift
2027	47.604072	-52.664265	330042.9	5273932.9	262.6	Bottom of Lift
2028	47.603902	-52.664453	330028.9	5273914.0	252.5	Bottom of Lift
2029	47.601950	-52.660998	330289.6	5273698.1	224.9	EW-3-2
2030	47.603743	-52.661757	330231.6	5273897.2	4379.7	
2031	47.604817	-52.662282	330191.6	5274016.4	313.5	Cleanout CO3
2032	47.605217	-52.662172	330199.7	5274060.9	228.9	
2033	47.606878	-52.665635	329938.6	5274244.4	397.7	Haul Road Entrance
2034	47.606890	-52.665765	329928.8	5274245.7	247.2	Haul Road Entrance

Notes:
1. Easting and Northing coordinates based on NAD83 MTM Newfoundland Zone 1.

ATTACHMENT A

SURFACE EMISSIONS SURVEY PROTOCOL

SURFACE EMISSIONS SURVEY PROTOCOL

Prepared by
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July 2013

SURFACE EMISSIONS SURVEY PROTOCOL

1. Objective and Background Information

The objective of a Surface Emission Monitoring Plan is to complete a gas assessment within a landfill footprint.

The landfill gas emissions survey is based on the United States Environmental Protection Agency's (USEPA) New Source Performance Standards (NSPS) for surface emissions monitoring at municipal solid waste landfills. Background methane concentration should be taken before each emissions survey and will be determined by monitoring upwind and downwind outside the boundary of the landfill at a distance of at least 30 metres from the limit of waste. The on-site emission survey is to be conducted as described within this document.

2. Monitoring Map

- A grid will be imposed on the available site maps. This grid will cover all areas of the landfill. The grid shows the path to be followed by the individual(s) who perform surface monitoring. The grid will be set up at 30 meter intervals.

- The maps will show the location of all gas monitors, each of which is shown with a unique identifier.

- The monitoring grid map may also indicate each area that is excluded from surface monitoring. Each excluded area is labeled and an attachment to the map has been prepared to explain the basis for each area's exclusion from monitoring. The following areas are excluded from required monitoring:

    1) Slopes that are determined by the individual(s) performing the monitoring to be too steep to be safely traversed while carrying the monitor.
    2) Areas containing only waste other than Municipal Solid Waste (for example, "construction and demolition" debris, kiln ash, etc.).
    3) Areas of known asbestos disposal.

3. Instrument and Calibration Gas Specifications

- All instruments will be field calibrated and have certification from the manufacturer or rental supplier.

4. MONITORING SCHEDULE

- Monitoring will only occur if conditions are appropriate. Below is an outline of reasons that monitoring may not be able to be completed.

  1) Weather that is determined by the individual(s) who perform the surface monitoring to be unsafe in which to conduct outdoor activities or which may be damaging to health (i.e. , extremes of temperature, high winds, rain-snow-ice or thunder storms, snow and ice accumulation, darkness, ozone alerts, other air pollution alerts).

  2) Occurrence of meteorological conditions considered to be other than "typical".

  3) Ambient temperatures which do not rise above the minimum required ambient operational temperature of the monitoring instrument.

  4) Ambient temperatures which do not fall below the maximum allowable ambient operational temperature of the monitoring instrument.

  5) Accumulation of snow/ice to a depth in excess of the maximum allowable monitoring height-above-surface (i.e., 10 cm. = 4 inches).

  6) Wet surface conditions such that traversing the landfill would either present a hazard to the individual(s) performing the monitoring, or would damage the cover and potentially result in the creation of methane leaks.

- Where a delay in the monitoring schedule has been caused by one or more of the above conditions, monitoring will resume as soon as the condition(s) which precluded meeting the monitoring schedule subside. Documentation will be entered into the report detailing the regular monitoring schedule and conditions in which they were completed.

5. MONITORING PROCEDURE

- Conduct monitoring ***only if*** ambient temperatures are within acceptable operating limits for the monitoring instrument; there is no snow/ice cover greater than four inches deep, weather conditions are "typical" for the area, and weather and site conditions are such that it is not dangerous to conduct monitoring.

- Warm up the instrument per the manufacturer's recommendations.

- Perform an instrument calibration prior to each monitoring day.

- At a distance of 30 meters (98 feet) from the perimeter wells on the upwind side of the landfill, face into the wind and move the probe in the air for at least 30 seconds.

- Note the meter reading and record it as “upwind reading”.

- Perform the same procedure at a distance of 30 meters (98 feet) from the perimeter wells on the downwind side of the landfill and record the meter reading as “downwind reading”.

- Average the upwind and downwind readings and record the average in “background concentration”.

- Using the surface monitoring grid map, begin walking the sampling path at the starting point on the map holding the monitor probe no more than four inches above the landfill surface. Walk at a steady pace of approximately 1.5 mph (approximately 1 step per second).

- When the instrument gives a meter reading of $\geq$ 500 ppm, stop walking and note the maximum meter reading. Record the time of detection and a unique location identifier from the GPS unit. It may be necessary to create a location identifier on the sampling grid map.

- Continue walking the sampling grid path until the entire route has been traversed.

- While traversing the grid, if any areas are seen off of the grid path that appear to have a high potential for methane leaks (i.e., stressed vegetation, noticeable surface cracks, sunken areas, etc.), deviate from the grid path and monitor these areas as if they were on the grid path. Document these areas only if a leak is recorded.

- If the TVA 1000 PID/FID gives a reading above its detectable limits use the GEM to determine methane levels.

- All areas of stressed vegetation, noticeable surface cracks, sunken areas, etc. should also be noted and the location recorded. If possible take digital pictures to record any extreme conditions.

6. MEASURED EXCEEDANCES

- If methane is detected at a concentration greater than 1000 ppm above background, the following steps may be taken until the exceedance is remedied:

    1. The location and concentration of the exceedance will be recorded.

    2. Adjustments to adjacent extraction wells will be made to increase gas collection in the vicinity of the exceedance. The location will be re-monitored within ten (10) calendar days of detecting the exceedance.

    3. If re-monitoring the location shows a second exceedance, cover maintenance will be performed. The location will be re-monitored within ten (10) calendar days of maintenance.

    4. If re-monitoring shows another exceedance, consideration will be given to installing additional landfill gas extraction wells.

Robin Hood Bay Waste Management Facility

BRIEFING NOTE

OVERVIEW:

In November of 2007, the Provincial Government officially designated the Robin Hood Bay site as the location for the Eastern Region's Integrated Waste Management Facility. Since then, more than $50 million has been invested in this site to re-engineer it to a modern, environmentally sound integrated waste management facility that includes a landfill, a residential drop off area, a material recovery facility and administrative offices.

The site itself is owned and operated by the City of St. John's. The City is contractually obliged with the Eastern Regional Services Board to accept wastes from other municipalities in the Eastern Region. Some of the on site operations are contracted out to a third party (Residential Drop Off, Household Hazardous Waste Collection, and the Material Recovery Facility). On site land is leased from the city for a private-owned metals recycling operation.

This site is an asset for the City of St. John's and the residents of the Avalon, and it is important that tit is managed and operated effectively to ensure the environmental integrity of the site and to maintain it's operational life.

As with all landfills, there are some operational challenges. Primary challenges are litter and migration of odours off-site.

BACKGROUND:

The Robin Hood Bay Waste Management Facility annually accepts approximately 200,000 tonnes of wastes. The City of St. John's collects approximately 30,000 tonnes of wastes at the curb.

Diverting wastes away from the landfill so they can be reused is critical to extending site life. The City began curbside recycling in 2010 and is always looking to enhance and promote this program. It is expected that the City's waste diversion tonnages will increase in 2017 with the enhanced yard waste program introduced this year.

Collecting he landfill gases that are generated at Robin Hood Bay has been on-going since 2009. All gases collected are burned in order to reduce the emission of greenhouse gases from the site. Today, the City is investigating potential technologies / methodologies in order to harness this resource into a usable end product.

In an effort to optimize landfill gas collection efforts, the City has begun expansion of this system in 2017 with a focus on areas of the landfill that are known to generate odours. It is hoped that the expanded collection system will increase the economic feasibility of a project that can utilize the landfill gas. It is also believed that greater collection will also alleviate some of the off-site odour issues. Further expansion of the landfill gas collection system is again expected to take place in 2018.

STATUS:

The City is developing a Landfill Gas Management Plan which will be a comprehensive document to guide future expansion of the landfill gas collection system in conjunction with filling activities. Expected completion date for this project is November 2017.

The City has begun expansion of the current landfill gas collection system in 2017 ($1.8 million). This phase of expansion will be completed in December 2017. It is expected further work will continue in 2018.

The City has banned the curbside collection of leaves in plastic bags starting in October 2017. Leaves will only be collected if they placed at the curb in paper, yard waste bags. The leaves and the paper bags are then able to be used for compost and diverted away from the landfill.

The City has been engaged with the Provincial Government and private companies to investigate the viability of power generation from the landfill gases. Other options that can convert landfill gas into a usable form are also being studied.

WARD(S):

All

LEAD DEPARTMENT:

Public Works

EXTERNAL PARTNERS:

Eastern Regional Services Board
Municipalities / Private Users of the Facility from within the Eastern Region

BUDGET INFORMATION/ COST:

2017 Budget $15,121,482

(Includes Landfill Operations, Residential Drop Off Facility, Materials Recovery Facility and Administration Costs of Eastern Waste Management)

PUBLIC INTEREST:

There is significant interest in this facility locally and provincially.

RELATED DOCUMENTS/ LINKS:

NOTE:

Year	Scope of Work	Value
2008	Installation of approximately twenty hectares of interim cover (geosynthetic clay liner and gravel), installation of twenty gas collection wells, collection header and installation of candlestick flare	$ 6,914,202.85
2010	Odour Report and Action Plan	$ 4,400.00
2011	Installation of twelve gas collection wells, three horizontal collection wells and approximately four hectares of interim cover material	$ 2,892,975.76
2012	Upgrading old candlestick flare installed in 2008 to a 40 ft enclosed flare and blower system	$ 728,536.58
2017	Completion of LFG management plan	$ 56,613.07
2017	Installation of six (6) additional gas collection wells and completion of the gas collection header started in 2008 (approximately 1300 m)	$ 1,532,906.33
2017	Surface Emission Monitoring	$ 6,521.00
2018	Installation of approximately ten hectares of interim cover material and installation of four additional gas collection wells	$ 2,077,724.23
2018	Surface Emission Monitoring	$ 8,100.00
	TOTAL (taxes exluded)	**$ 14,221,979.82**