APPENDIX F

Leachate Study

EARTH TECH | AECOM

City of Brandon

Landfill Leachate Study – DRAFT

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LANDFILL LEACHATE STUDY – DRAFT

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SECTION 1.0
INTRODUCTION

The City of Brandon (City) retained the services of Earth Tech AECOM. to assess options for the management of leachate and snow melt at the Eastview Landfill as well as the feasibility of developing a snow dump site at an alternate location.

The analysis is based on the following:

1. Review of the existing data.
2. Leachate quality data from the existing cells.
3. Snow melt records from the City's database.
4. Discussions with the operational staff.
5. A site review undertaken on January 22, 2008.
6. Comments provided by the operational staff in general.

1.1 BACKGROUND

The City's Eastview landfill was commissioned in 1979 and is located on the south side of Victoria Avenue East, opposite the Manitoba Hydro Steam Generating Plant about 1.6 km east of the eastern built-up area of the City. The landfill occupies the NW ¼ Sec. 17 Twp. 10 Rge. 18W (**Figure 1.1**), except for the most westerly 400 ft of the most northerly 1,089 ft of the NW ¼ (Manitoba Hydro). The most easterly 400 ft in width of the most northerly 1,000 ft in depth of the NW ¼ is held by the City on separate title (Certificate No. 12333). The City has owned the most easterly 250 ft of the most northerly 110 ft of the NW¼ Sec. 17 Twp. 10 Rge. 18W since 1964 (Certificate No. 97945).

The landfill currently includes 12 cells as indicated in **Figure 1.2**. The construction year of each cell is listed in **Table 1.1** below. Currently, the first to tenth cells are closed and only the 11th and 12th cells are active and receive solid wastes.

Table 1.1: Landfill Cell Construction Years

Landfill	Phase of Year	Landfill	Phase of Year
1st	1977	7th	1994
2nd	1978	8th	1996
3rd	1979	9th	1998
4th	NA	10th	1999
5th	NA	11th	2001
6th	NA	12th	2003

NA – Information not available.

An interceptor drain (consisting of either a 12" perforated storm sewer or an 8" perforated storm sewer based on location in the landfill) was installed along the east periphery of the landfill in approximately 1994 or 1995 as shown in **Figure 1.2**. The drain was constructed of perforated polyvinyl chloride ultra-rib pipe and reportedly flows at 1/2 to 2/3 capacity on average.

A relatively deep ditch (between 3.5 m to 4.5 m) parallels the south boundary of the landfill from the southwest corner eastward to about 2/3 of the way to the eastern boundary, where it becomes quite shallow. It continues eastward to the property boundary then northward to the Assiniboine River. It was constructed primarily to intercept groundwater entering the landfill.

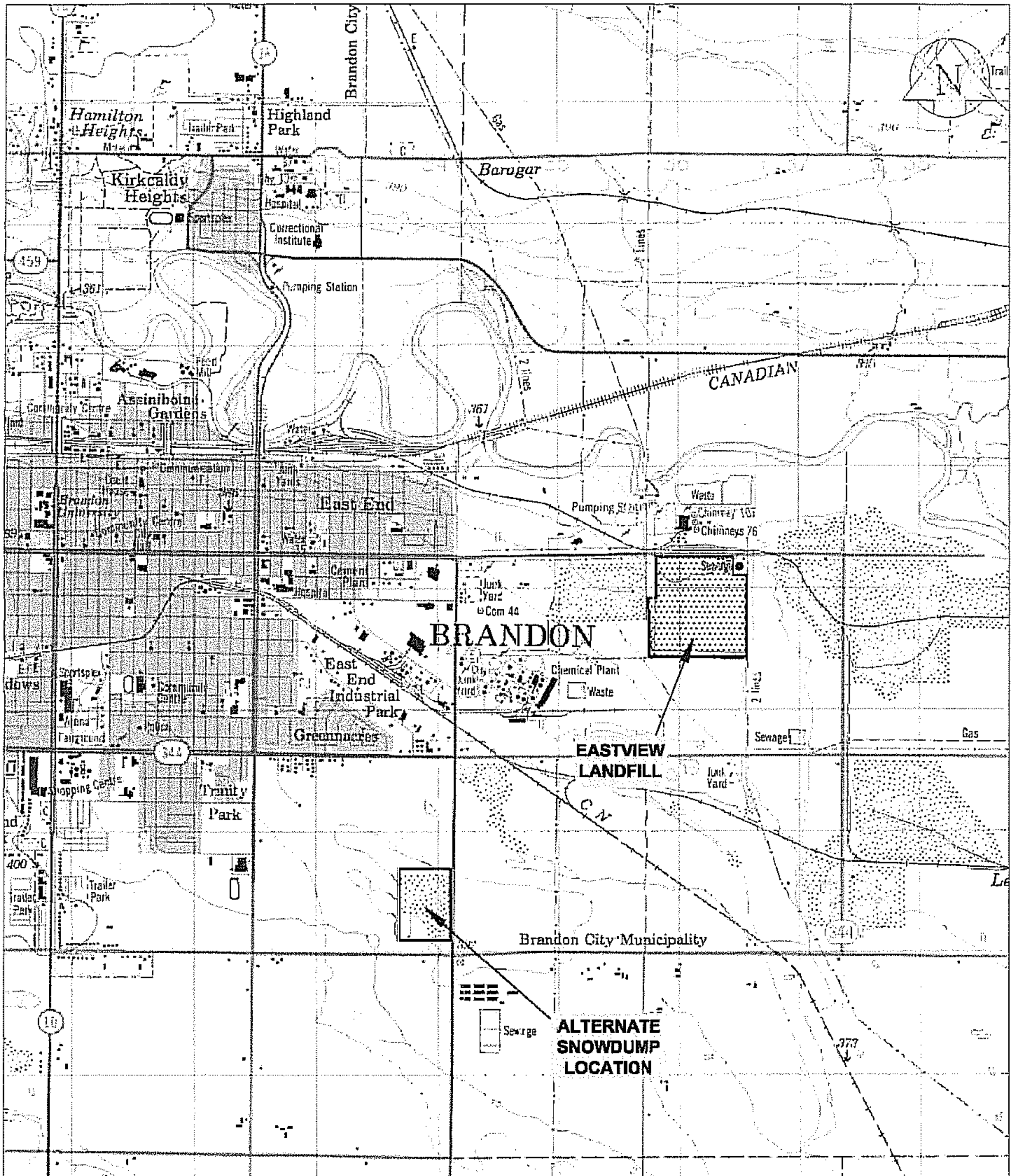
Along with solid waste disposal, the landfill has recently been used as the snow dump site for all snow collected by City crews from streets and parking lots. The designated snow dump area is identified on **Figure 1.2**. As an alternative, a new location at an abandoned landfill previously operated by the City was considered for operating a new snow dump site **(Figure 1.1)**. The abandoned landfill is located southeast of the City of Brandon, Manitoba on 17th Street East, north of Provincial Highway 110 (SE ¼ Section 12, Township 10, Range 19W).

1.2 STUDY OBJECTIVES

The study objective is to ensure that untreated leachate does not enter the environment and that snow melt can be managed in an environmentally sound manner.

The specific objectives of this study are listed below:

1. Undertake a sampling and analysis program of the leachate and snow melt.
2. Review the experience of other jurisdictions and review regional and local regulatory framework pertaining to leachate and snow melt management options.
3. Review leachate and snow melt management options for the City (including an alternate snow dump site at an abandoned landfill located southeast of the City of Brandon on 17th Street East, north of Provincial Highway 110).
4. Review the potential options with Manitoba Conservation.
5. Prepare a conceptual level cost estimate for the works and document in the form of a report.



Source: Survey and Mapping Branch, Department of Energy, Mines and Resources, Brandon 62G/13, 5th Edition.

EarthTech

Earth Tech (Canada) Inc. Winnipeg, Manitoba 204.477.5381

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LANDFILL LEACHATE STUDY
EASTVIEW LANDFILL
BRANDON, MB

SITE LOCATION PLAN

L:\work\103000\103779\02a-CAD\ENV\Location Plan.dwg 08-07-07 03:23pm Layout:FIG 1.1

FORM 8.5x11
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Section 2.0
Literature Review and Regulatory Requirements

SECTION 2.0
LITERATURE REVIEW AND REGULATORY REQUIREMENTS

A review of the leachate and snow management systems and related regulatory requirements has been completed. The regulatory and general management practices in various national and international jurisdictions have been reviewed and documented in the following text.

2.1 GENERAL

Leachate is the liquid formed when water passes through the waste in a landfill cell. Leachate may also arise as a result of the compaction or chemical reaction of waste material with high moisture content. The water can percolate from rain, melted snow or the waste itself. Many organic and inorganic compounds become part of the leachate as the liquid moves through the landfill. The composition of leachate varies widely depending upon the age of the landfill and the type of waste that it accepts. Usually both dissolved and suspended material can be present in the leachate. Generally, leachate contains high strength organic contaminants, high concentrations of ammonia and toxic substances such as heavy metals, etc. Therefore, leachate can affect the environment if released untreated.

In older landfills and those without proper liner systems between the waste and the underlying geology, leachate from waste could migrate into the groundwater. More modern landfills have membrane systems which separate the waste from the surrounding soils along with a leachate collection system which is laid on the membrane to convey the leachate to a collection or treatment facility.

In order to eliminate adverse impacts to the environment and prevent groundwater contamination, leachate needs to be managed in an environmentally sound manner.

Similar to leachate management, this section also provides some discussion on snow melt management experience used at other sites and the related regulatory framework.

2.2 LEACHATE MANAGEMENT SYSTEMS

Leachate treatment/management presents specific problems that differ from those associated with the treatment of domestic or industrial wastewater. Typically, these include:

- Varying flow rates as a result of storm events.
- Varying concentrations of multiple contaminants. Leachate can contain very high concentrations of ammonia which are toxic to biological organisms in some treatment systems. Heavy metals and other compounds could also result in toxic effects on the microorganisms in the sewage stream as well.

- Variation of contaminant composition over time as a result of landfill aging, as observed in the City of Brandon's (the City's) case. Leachate could be very acidic depending upon the stage of the landfill. However, leachate pH may return to neutral along with aging of municipal solid waste landfills after the initial period of acidogenic leachate decomposition.

A specific treatment requirement may involve the use of primary, secondary and tertiary processes. These processes have been categorized as physical, chemical or biological treatment systems and are described below.

2.2.1 Physical Treatment Processes

Air Stripping

The following sections discuss the removal of methane, ammonia, and other volatile organics from leachate using air stripping.

Methane Stripping

Methane is more soluble in water than oxygen. At 20°C, about 25 mg of methane will dissolve in a litre of water from a pure methane atmosphere. Leachates from within a biologically active landfill will generally be extracted from a gaseous environment comprising typically 60% methane and 40% carbon dioxide (by volume). In these circumstances, at temperatures of between 40°C and 20°C, methane can dissolve resulting in concentrations between 10 and 15 mg/L. Even at landfills where relatively diluted leachates are collected from surface seepages, perimeter ditches etc., concentrations of methane in the order of 2 to 5 mg/L are often encountered, and values can vary widely on a day-to-day basis. A concentration of dissolved methane as low as 1.4 mg/L is known to be capable of giving rise to an explosive level of methane gas for confined spaces in contact with such liquid (Buswell and Larson 1937 and Larson, 1938). Measures are being applied to control levels of dissolved methane in discharges of leachate into public sewer systems. Therefore, in the United Kingdom, a factor of safety of ten times is being applied by regulators to discharges of leachate into public sewer systems, and a limit of 0.14 mg/L of dissolved methane is widely applied by receiving sewerage authorities. **Figure 2.1** shows the relationship of required air to methane concentration.

However, in US and Canada there are no known leachate treatment plants that are specifically designed to addresses the Methane issue. Often, the practice is to provide explosion proof rated equipment.

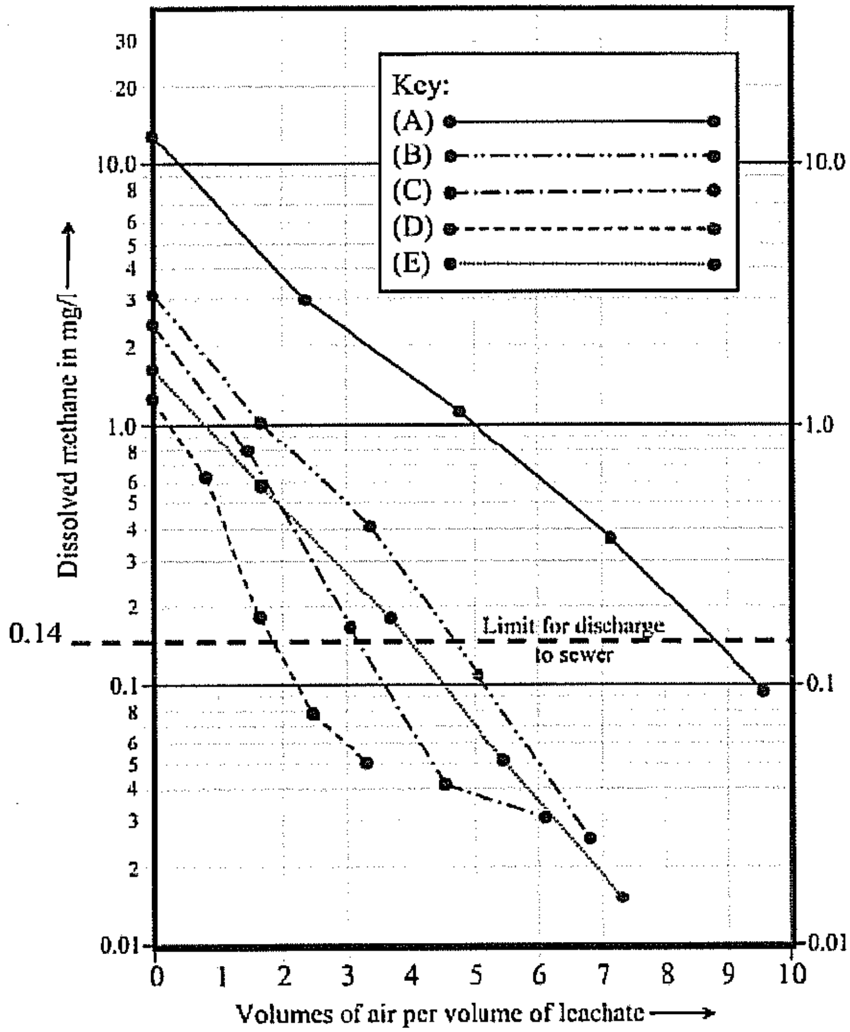


Figure 2.1: Reduction in Concentrations of Dissolved Methane in Five Samples of Landfill Leachate, In a Four Reactor Continuous Flow Air Stripping System, as a Function of Air Volume Used (Robinson et. al., 1999)

Ammonia-N Removal

Air stripping removes ammonia as a gas from the leachate. The first stage of the process raises the pH to approximately 12, so that the ammonia is in the unionized form (NH_3) rather than the ionized form (NH_4^+). Sodium hydroxide or lime is used to raise the pH. Although lime costs less than sodium hydroxide, it produces large volumes of lime sludge and causes scaling in downstream processes.

The second stage of the process is sedimentation and/or filtration to remove suspended solids. The suspended solids consist of those originally in the leachate and those that precipitate due to the pH change. Solids removal is necessary to prevent media blockage in the ammonia stripping column.

The pre-treated leachate stream is fed into the top of the air stripping column where it is distributed equally across the column. The leachate trickles down the column, which contains mass transfer media. Normal practice is to use polypropylene random media packing. The leachate exits the stripper at the base of the column. Air is blown through the bed of media, counter-current to the liquid flow. Ammonia from the leachate transfers to the air during this counter-current contact. Ammonia laden air exits the top of the column through a demister.

At very high concentrations of ammonia-N, the stripping process is increasingly cost-effective. However, it becomes difficult or costly to achieve low effluent concentrations of ammonia-N, below 50 mg/L or 100 mg/L. On this basis, ammonia stripping will generally only prove to be cost-effective where partial pre-treatment is required, for example, prior to discharge into the public sewer, or before further removal of ammonia-N in a subsequent stage of biological treatment.

In achieving relatively low effluent values of ammonia-N (e.g. < 50 mg/L), very large volumes of air will be required and this generally makes air stripping uncompetitive in terms of cost for such applications.

Ammonia stripping can be carried out in tanks or lagoons, packed towers or in counter current, multi-stage reactors.

In many cases, the evaluation of treatment options often indicates that biological treatment rather than physical/chemical treatment is the most cost-effective method for removing ammonia.

Other Volatile Contaminants

Significant removal of a number of trace organic components often present in landfill leachates can be achieved during air stripping treatment processes. For instance, xylene and toluene are shown to have 40% and 20% removal after air stripping, respectively. It should be noted that both of these parameters have been detected in the City's leachate stream.

Reverse Osmosis

Reverse osmosis (RO) treatment is a potential treatment option that is achieved when pressure is applied to the concentrated side of a membrane forcing purified water into the dilute side, with the rejected impurities from the concentrated side being washed away in the reject water. The membrane material is either spiral wound around a tube, or hollow fibres bundled together.

The RO extracts clean water from the solution of organic and inorganic contaminants that constitute landfill leachate. The process exploits the natural phenomenon of osmosis whereby two aqueous solutions with different concentrations are separated by a semi-permeable membrane; water from the weakest solution will pass through the membrane to dilute the higher concentration solution on the other side. The process will continue until solutions on both sides of the membrane have the same concentration.

With RO the process is reversed. Pressure is applied to an aqueous solution (leachate) against a semi-permeable membrane forcing the water molecules to pass through the membrane, thus forming the clean "permeate". The majority of the solutes or contaminants will be left behind forming the "concentrate". In contrast to normal filtration where solids are eliminated from a liquid, reverse osmosis succeeds in removing dissolved components. **Figure** 2.2 highlights the spectrum of filtration capabilities from conventional filtration to RO.

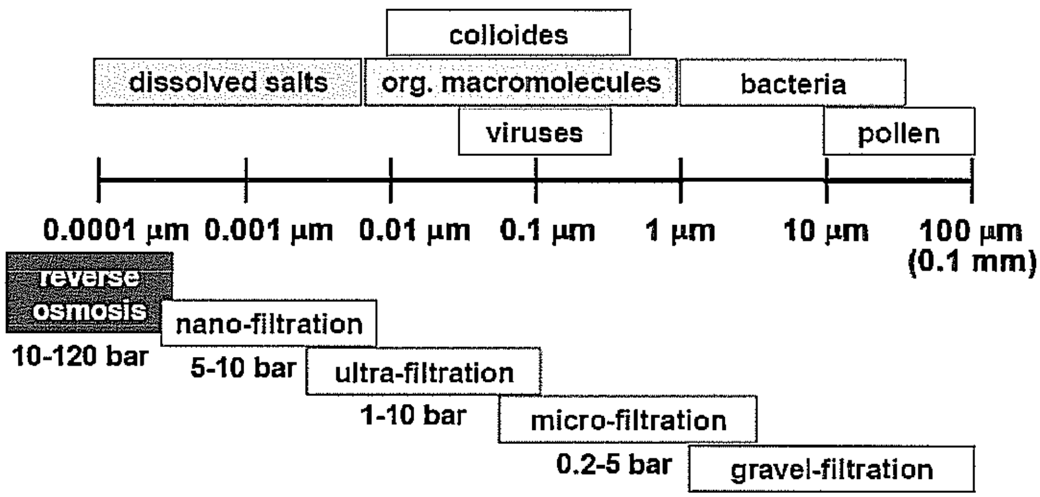


Figure 2.2: Typical Range of Material Removed From Various Filtration Processes

Most commercially available RO plants are constructed as two-stage plants with contaminant removal rates exceeding 99.6%. Where unusually high strength leacbate is treated or very stringent discharge limits apply, three-stage plants can be employed and achieve contaminant removal rates exceeding 99.98%.

RO leachate treatment plants are widely used at landfill sites throughout Europe including Germany, France, Holland, Belgium, Italy, Switzerland, Spain, Portugal and Greece. More than 100 plants are currently in operation with some for more than ten years.

The main advantage of the RO process, in treating leachate, is the high quality of permeate produced. More than 99.9% of the contaminants can be retained and their release to the environment avoided.

The capability of intermittent operation and relatively low impact to their operation in the event of variability in the influent leachate stream are also advantages of this type of system.

Commercial plants are generally modular plants that are fully automated and capable of being monitored and controlled remotely. Standard modules are available with leachate throughput capacities from 30 m^3/day up to 200 m^3/day housed in a single container as shown in **Figure 2.3.**

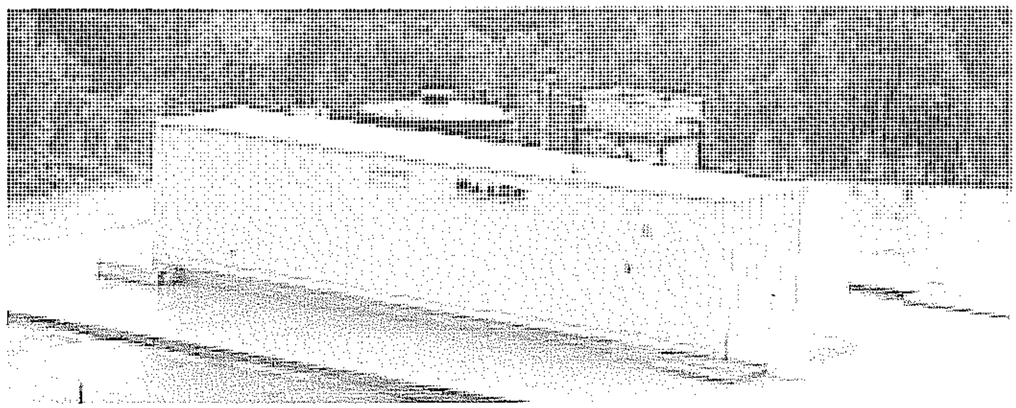


Figure 2.3: Typical Container Mounted RO Modular Plant

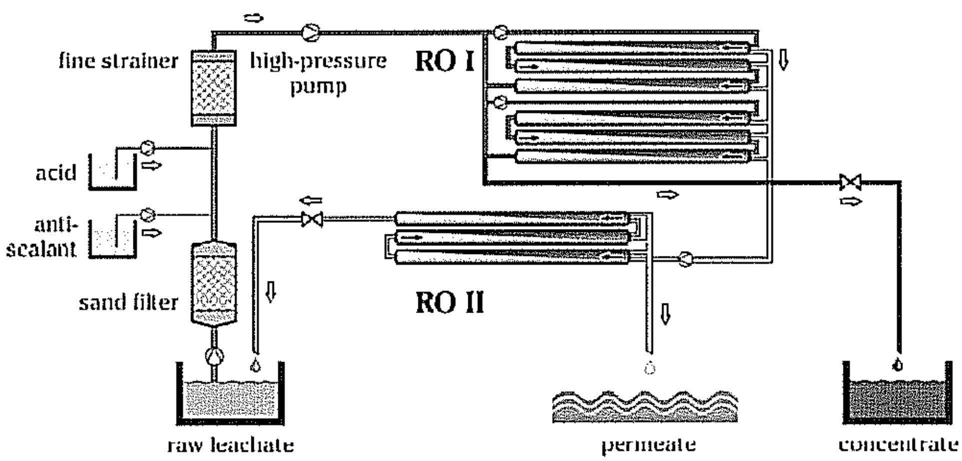


Figure 2.4: Typical RO Arrangement for Leachate Treatment

Generally, RO units are preceded with biological and/or other fine filtration process to avoid frequent plugging of the RO modules. A typical RO setup is highlighted in **Figure 2.4.**

In the majority of cases, concentrate is returned to the landfill. In other instances, the concentrate is disposed of off-site. In addition, all chemicals required for effective operation of an RO plant are contained in the concentrate. This amounts to about 0.3% of each m^3 of leachate treated. Disposal of concentrate is a key factor for consideration. To date, concentrates have widely been re-circulated back to the landfill. This approach could result in concentrating the contaminant in the influent stream to the mechanical plant and disruption of the overall operation of the system. Secondary concentrate treatment processes, such as evaporation and dryers, have been used to reduce volumes further in countries such as Germany, the Netherlands, Belgium, France, Portugal and Spain where RO plants are most widely used for leachate treatment.

Solids Removal

It may be necessary to remove solids from either raw leachates or from pre-treated leachates prior to disposal. Typical processes most commonly used include sedimentation/settlement, sand filtration, dissolved air flotation (DAF), activated carbon adsorption or ion exchange.

Sedimentation and Settlement

Conventional sedimentation is rarely applied for leachate pre-treatment. Generally, the use of coagulation and flocculation processes, not only to reduce levels of suspended solids in leachates, but also to provide additional removal of colloidal and other contaminants, are more common.

Sand Filtration

Sand filtration involves the passage of the effluent through a high quality sand media with a specific particle size ranging from 0.8 to 1.7 mm. The application of sand filtration for raw leachate is not common. Operational difficulties such as generation of biological sludges or uncontrolled partial biological processes might potentially cause significant difficulties such as rapid plugging of the filter media resulting in significantly reduced run times, disposal of backwash waste water etc.

The use of sand filtration processes as a tertiary treatment step is more viable to further polish the quality of the effluents. The resulting final effluent from a sand filtration system can have low levels of residual solids, and the process is particularly useful for discharge to a surface water body. The interception of solids can also be a useful technique for the removal of substances capable of bioaccumulation, which may be present in biological solids or in some colloids.

Dissolved Air Flotation

DAF is a process for the removal of fine suspended material from an aqueous suspension, in which solid particles are attached to small air bubbles, causing them to float to the surface. Attraction between the air bubbles and the particles results from adsorptive forces, or physical entrapment of bubbles within the particle, colloid or floc. Chemical conditioning is generally used to increase the effectiveness of the DAF process.

The rising particles float to the surface of the water, forming a scum/sludge layer which is removed, usually by means of mechanical scrapers or scoops. Treated water flows out from a lower level.

Significant removal of ammonia, chemical oxygen demand (COD), biological oxygen demand (BOD), total organic carbon and nitrates has been observed in DAF installations for leachate treatment.

There are two known examples of DAFs in use for leachate treatment. They include the Arpley Landfill in Warrington, United Kingdom where the DAF system polishes effluent at the leachate treatment plant and the Marston vale plant in Bedfordshire.

Activated Carbon Adsorption

Adsorption is the transfer of organic compounds from a liquid phase onto the surface of a solid material, and the extent of adsorption is related to the chemical and physical properties of each. For the removal of organic compounds from leachates, activated carbon has been found to be cost-effective and is widely used in the water treatment industry. In the field of drinking water or groundwater treatment, activated carbon is widely used to remove trace levels of organic substances that can impart flavours to water.

Activated carbon is highly porous, with a wide range of pore sizes, and very large surface areas. It can typically be made from coal, wood, peat, coke or coconut and adsorption capacities of greater than 10% by weight are possible.

The performance of activated carbon for removal of organic compounds is influenced by the:

- Capacity of a specific carbon to adsorb a specific organic compound.
- Concentration of the organic compound in the feed.
- Contact time between water and carbon.
- Loading rate applied to the carbon.
- Presence of other organic compounds which may compete for adsorption sites.

Activated carbon is capable of removing significant quantities of BOD and COD, however due to the relatively high costs of activated carbon, it is generally more economical to combine biological treatment and activated carbon processes.

Powdered activated carbon (PAC) may, in certain circumstances, cost less than granular activated carbon (GAC), but cannot be reactivated and so must be disposed of after a single use. PAC is dosed as a slurry to achieve a desired concentration (of PAC) within an aerated or fully mixed reactor.

For either PAC or GAC treatment systems, the key concerns relate to the disposal or regeneration of the activated carbon itself.

Ion Exchange

Ion exchange removes ions from an aqueous solution by the exchange of anions or cations between contaminants and the exchange medium. Ion exchange materials typically consist of resins made from synthetic organic materials, which contain ionic functional groups to which exchangeable ions are attached.

Ion exchange processes are most widely used in potable water treatment, and have been successfully applied to nitrate removal, or to water softening. For nitrate removal, water is passed through a bed of synthetic resin beads, which remove anions including nitrate from the water, exchanging them for equivalent amounts of chloride. When the capacity for exchange is saturated, the bed is taken out of operation and the resin regenerated with sodium chloride brine, which returns the resin to the chloride form. The bed is then rinsed with clean water and returned to service. Used regenerant contains high concentrations of sodium chloride, as well as nitrate (and sulphate) removed from the bed, and must be disposed.

Application of ion exchange processes to the treatment or polishing of landfill leachate has, to date, been limited by the very high concentrations of anions (e.g. chloride, nitrate-N) and cations (e.g. sodium, calcium) present in raw or biologically pre-treated leachates. This continues to restrict any cost-effective applications of ion exchange for leachate treatment.

The complexity and variability in composition of leachate, including the presence of multiple contaminants, makes it unlikely that naturally occurring ion exchange materials will be suitable for treating leachate. The presence of hydrocarbons may also cause the media to become less effective.

As with RO, ion exchange is a concentration step and identical considerations apply to the disposal of the concentrate that is produced, involving considerable cost. Electricity consumption is typically high. Very large quantities of acid and other chemicals are also required. High use of chemicals and power typically result in overall high O and M costs for this process. Also concentrated leachate results in chloride concentrations in excess of 60,000 mg/L in the concentrate sludge. Disposal of highly concentrated sludge also becomes a problem for the operation of this process.

2.2.2 Chemical Treatment Processes

Chemical Oxidation

Chemical oxidation processes are potential treatment options for the removal of specific organic and inorganic pollutants from landfill leachates, but are unlikely to provide full treatment of the wide range of contaminants present in typical samples. In practice, the application of such processes will be restricted by cost, by the rate of reaction possible (oxidation rates for some organic compounds may be too slow), and by the availability of alternative treatment processes for specific contaminants.

For leachate, the amount of chemical oxidant required in practice is generally greater than the theoretical mass calculated from first principles. This is due to a number of reasons, including incomplete oxidant consumption, and lack of specificity of the desired process – oxidant also being consumed by other chemical reactions. Oxidation reactions are often pH dependent, and control of pH values may be an important consideration. For treatment of landfill leachate, a limited range of oxidants have found successful application to date, primarily ozone or hydrogen peroxide. Use of other oxidants has been limited by concerns about formation of toxic reaction by-products – for example, chlorine and chlorine compounds giving rise to trihalomethanes, or other halogenated compounds.

For specific conditions, the chemical oxidation processes can provide particular benefits. For example, at elevated pH values, cyanide can be oxidized to carbon dioxide and nitrogen using sodium hypochlorite. It is likely, therefore, that chemical oxidation processes will find occasional application in leachate treatment, and only then to deal with individual and site-specific circumstances. Ozonation and the use of hydrogen peroxide will probably account for most chemical oxidation applications.

For chemical oxidation processes, the storage and handling of potentially hazardous chemicals must also be addressed and considered, and appropriate standards of design and care applied. If extreme conditions are required within a treatment reactor, then high standards of control and containment become even more important safety considerations.

Because of their nature, advanced chemical oxidation processes continue to be developed at a bench scale level. Examples include wet air oxidation, and electrochemical oxidation systems. To date, these technologies have not been successfully applied to leachate treatment.

Ozonation

Ozonation is well established as a treatment technology for drinking water, where it is used as a disinfectant, to degrade substances of concern, and to enhance the performance of other treatment processes. Ozonation is not widely employed for the treatment of sewage or industrial wastewaters. Ozone is the strongest practical oxidant available for waste water treatment, and is used for:

- Oxidation of organic materials, especially recalcitrant organic compounds, to enhance their removal by subsequent treatment – especially in biological processes.
- Disinfection.
- Taste, odour and colour removal.
- A pre-oxidant stage to enhance removal of turbidity and algae within subsequent treatment processes.
- Precipitation of iron and manganese.

Capital costs of ozone treatment are relatively high (typically $500,000 to $700,000 to dose 150 mg/L into 200 m^3 of effluent/day), due to the high cost of equipment for ozone generation. Electricity comprises the majority of operational costs, which can also be high especially for a stronger leachate stream. Ozonation is typically viewed as an expensive polishing option, appropriate only in specific circumstances for leachate treatment, such as complete destruction of less biologically degradable pesticides in final effluents. Case studies have demonstrated that such systems can operate reliably on landfill sites.

Pesticides, aromatics, alkanes and alkenes are examples of compounds readily and successfully treatable by ozonation. Ozone treatment is generally only appropriate as a polishing step in the treatment of landfill leachates, following extensive biological pre-treatment to remove degradable organic compounds that might otherwise result in excessive consumption of ozone.

Particularly during treatment of landfill leachates, ozonation can result in generation of very reactive brominated intermediate compounds (e.g. bromal = tribromoacetaldehyde). Experience has demonstrated that although such compounds exhibit significant toxicity, they can be readily and completely degraded within an appropriately designed reed bed polishing system.

There is only one example of a full-scale leachate treatment plant in the United Kingdom where ozonation has been applied as a polishing stage for leachate treatment. In that instance, ozonation was applied to meet extremely stringent effluent toxicity criteria, before discharge into a very sensitive receiving watercourse. The plant has operated successfully since 1994, particularly for the complete removal of a number of pesticides, such as mecoprop and isoproturon, in biologically pretreated leachate.

Although variants of ozonation, involving combined treatment with hydrogen peroxide and/or Ultraviolet irradiation, are capable of providing increased oxidation potential by the enhanced generation of hydroxyl radicals, such processes have rarely been applied to treatment of landfill leachates.

Hydrogen Peroxide

For leachate treatment, peroxide treatment systems range from very simple drip feed dosing into open leachate lagoons, through pumped dosing into the inlet of large recirculation pumps, to fully engineered dosing systems into mixed reactors. Dosing of hydrogen peroxide has sometimes also been incorporated within simple methane stripping systems for leachate (see previous section), in order to meet limits for discharge of leachate into public sewers. Hydrogen peroxide and potassium permanganate have also been used successfully to treat odorous leachate.

In leachate treatment, hydrogen peroxide oxidation has been applied principally to oxidize sulphide, although experience from other industries has shown that many other contaminants which might be found in leachates can also potentially be treated (e.g. phenols, sulphite, cyanide, formaldehyde, etc).

Principal concerns over hydrogen peroxide relate to storage and handling issues and ensuring that, in the event of spillage, adequate controls are in place (spill kits, containment and training) to protect sensitive environmental receptors.

Chemical Precipitation of Metals

Concentrations of heavy metals in leachates from landfills containing primarily household wastes are relatively low. Typical values are generally lower than those measured in samples of domestic sewage, and far lower than levels of metals being treated at sewage treatment works, where inputs of industrial effluent have also been received. Significant removal of some of the heavy metals in leachate can be achieved during aerobic biological treatment. If specific circumstances require such metal removal, chemical precipitation processes are widely employed for this purpose. Precipitation is widely employed for the removal of concentrations of heavy metals from industrial wastewaters, and although many chemicals have been used (e.g. hydrated lime, quicklime, magnesium hydroxide, sodium hydroxide), hydrated lime and calcium hydroxide, have been most widely used, and are generally the cheapest.

Coagulation and Flocculation

Chemical coagulation and flocculation are used for the removal of waste materials present in suspended or colloidal form. Colloids represent particles typically within a size range from 1 nm to 0.1 nm (10^{-7} to 10^{-8} cm). These particles do not settle out by normal settlement, and are not readily removed by conventional physical treatment processes.

Coagulants, usually salts of iron or aluminum, are added at controlled pH values to form solid precipitates termed floc, which contain the colloidal particles, and can then be separated out using conventional solid/liquid separation processes. The process of flocculation encourages floc growth by gentle mixing, to suit the subsequent separation process being used.

In leachate treatment at United Kingdom landfills, full-scale coagulation/flocculation systems have rarely, if ever, been applied to raw leachates, and only occasionally to biologically pre-treated effluents. In Germany, coagulation and flocculation processes are more widely applied to both raw and treated leachates, and extensive experience is available. Common applications have included:

- Removal of turbidity and colour from biologically treated effluents.
- Reduction in COD values associated with colloidal materials.
- Removal of PAC in effluent polishing (see previous section).

- Reduction in suspended solids concentrations, to protect subsequent treatment stages (e.g. in activated carbon columns).

2.2.3 Biological Treatment Processes

Anaerobic Treatment

Anaerobic digestion is a process for degrading organic matter in closed vessels in the absence of air. Biogas comprising methane and carbon dioxide is a product of the process. The process has been very successfully applied to the digestion and conditioning of sludges from sewage treatment works.

Effluent after anaerobic treatment is in a reduced state, and will generally contain relatively high concentrations of dissolved methane, ammoniacal-N, sulphides, and amines, that will make it unsuitable for discharge to surface waters. Discharge to sewer systems may entail risks of methane gas or sulphide in the sewer, and subsequent aerobic treatment processes are widely applied.

The main benefits of anaerobic treatment usually relate to reduction of high COD values. Applications for leachate treatment have been rare.

The main problems with anaerobic digestion of leachate can be summarized as follows:

- The process does not remove ammoniacal-N at all and indeed is more likely to increase concentrations of this main contaminant of landfill leachates. Secondary aerobic biological and other processes will generally be essential.
- A COD value in raw leachate in excess of about 10,000 mg/L is essential if the anaerobic treatment process is to be self-sufficient in energy. At most modern landfills, the acetogenic phase where this is the case for leachates is relatively short-lived. Such is the case for Brandon.
- The anaerobic processes being used are far more efficiently provided within the landfill body itself, where optimum and stable temperatures are likely to be present. Recirculation of acetogenic leachates in a controlled way may well enable this to be carried out successfully, with resulting landfill gas collected by the existing systems. However, this activity is beyond the remit of this document and should be considered as part of the overall landfill process.

Aerobic Treatment

During aerobic biological treatment, organic compounds can be largely oxidized to carbon dioxide and water, and ammoniacal-N can be removed by oxidation (nitrification) to nitrate. Nitrification is a widely adopted biological treatment process for domestic and industrial effluents, although relatively high concentrations of ammoniacal-N (often greater than 1,000 mg/L) in leachates can require specific process designs, if treatment efficiency is not to be inhibited by toxic effects.

In some instances, at an increasing number of locations, concern about the impacts of releases of high concentrations of nitrate in effluents (e.g. eutrophication, potable water concerns, etc.), require these to be reduced prior to discharge. The process of denitrification can be combined within the treatment process, within an anoxic reactor or as part of anoxic stage of a reaction. In an anoxic environment, absence of either oxygen molecules or other chemically bound oxygen, means that bacteria instead use the oxygen in the nitrate compound to oxidize organic compounds. Simple organic compounds such as methanol are often added at this stage of treatment, to provide a readily degradable oxygen demand. The nitrate is thereby reduced to nitrogen gas, which is safely released into the atmosphere (which comprises 80% by volume of nitrogen gas).

Aerobic biological treatment plants are therefore designed to be able to perform the following main treatment processes:

- Denitrification of organic carbon compounds.
- Nitrification of ammoniacal-N.
- Full or partial denitrification of nitrate-N.

Each of the treatment processes is affected by communities of bacteria, which metabolize the contaminants. A well-designed treatment process must ensure that the bacteria are provided with optimal growth conditions, and are mixed intimately with the leachate to be treated with oxygen and nutrients as necessary and at appropriate temperatures and pH values. Issues related to this control are discussed in general terms below, and apply to a variety of different aerobic biological treatment systems.

Because a range of different aerobic biological treatment systems, when appropriately designed, have many common features in terms of treatment processes, key issues have been considered below in more detail, with respect to:

- Treatment of COD and BOD.
- Treatment of ammoniacal-N.
- Treatment of trace organic and other compounds.

For one kilogram of ammoniacal-N that is nitrified:

- 4.27 kg of dissolved molecular oxygen is consumed.
- 7.14 kg of alkalinity, as calcium carbonate, is destroyed.
- 0.22 kg of new cells are synthesized.

Biological denitrification is the reduction of nitrate nitrogen to nitrogen gas by facultative heterotrophic organisms that use organic carbon for energy and as a carbon source.

Both nitrification and denitrification bacteria are relatively sensitive to environmental conditions (compared with those groups which oxidize organic substrates) and either one or both stages can be easily inhibited by:

- Low pH values (below about 6.5).
- Insufficient dissolved oxygen (below about 2 mg/L).
- Low temperatures (below 5°C), or high temperatures (above 35°C).
- Toxic inhibition.

For one kilogram of nitrate nitrogen that is denitrified:

- At least 2.47 kg of methanol are used.
- 0.45 kg of new cells are synthesized.
- 3.57 kg of alkalinity are formed.

Although aerobic biological treatment processes have been widely applied to the treatment of domestic wastewaters, and of industrial effluents, there are several specific characteristics of leachates that must be recognized in the design of appropriate facilities. These are considered in turn below:

- High concentrations of ammoniacal-N, generally > 500 mg/L and regularly in excess of 1,000 mg/L at modern landfills, are many times stronger than levels of 25 to 30 mg/L typically encountered in domestic wastewaters.
- Although direct toxicity of ammoniacal-N to nitrification processes is not a significant issue in sewage treatment, wide experience in leachate treatment systems has demonstrated that (at typical pH values in the range 7 to 8), concentrations of 80 mg/L of ammoniacal-N or above significantly inhibit the nitrification process. A number of full-scale leachate treatment plants have failed as a result of lack of knowledge about this process. Actual levels of toxicity are related to presence of free ammonia, which in turn is a function of ammoniacal-N concentration and pH-value (at higher pH-values, a higher percentage of total ammoniacal-N is present as free ammonia). Leachate treatment designs must take account of these issues for example, direct application of over 1,000 mg/L of ammoniacal-N to bacteria on the surface of an attached growth system will lead to significant toxic inhibition. Furthermore, acidity produced during nitrification will often require very large additions of alkalinity to buffer pH values. Additionally there is occasionally sufficient alkalinity, measured as calcium carbonate present in the leachate to neutralize the acid reaction of nitrification.
- High concentrations of other contaminants can lead to problems not generally encountered in the treatment of domestic or other weaker wastewaters. Degradation of high (> 5,000 mg/L) BOD and COD values can generate high volumes of organic

sludge, which may clog attached growth systems and require routine removal from suspended growth systems. It is to be noted that in Brandon's case, the leachate stream is fairly stabilized and does not have high concentrations of BOD. High concentrations of iron, calcium and other metals may lead to similar problems with inorganic sludges or deposits. High salinity may require that bacteria being used to effect treatment are gradually acclimatized to the leachate being treated, and this may take several months before optimum treatment rates are achieved.

- Variability of quality and quantity of leachate to be treated is also a key issue.

Aerated Lagoons, Activated Sludge, Sequencing Batch Reactor (SBRs), Membrane Bioreactors (MBRs), Moving Bed Bioreactors (MBBR) and Rotating Biological Contactors (RBCs) are some examples of aerobic systems that have been commonly applied for leachate treatment.

Aerated Lagoons

Initial attempts to treat leachates, during the 1970s and 1980s, used simple aerated lagoons and achieved some success. Lagoons were often large, typically 1 m to 2 m deep and a small, sub-surface aeration system was generally used to provide oxygen inputs and slow circulation of the lagoon. However, these systems were rarely adequate to provide turbulent mixing of biological solids.

The main concern with the use of simple aerated lagoons for the treatment of leachates is the ability of designers to provide a robust system, capable of providing consistent and reliable treatment of a specified leachate to a required standard. Although any aeration of leachate will undoubtedly provide some degree of improvement in leachate quality, whether this can be provided efficiently and consistently is doubtful, especially during the winter months. Apart from inefficient use of energy, other concerns with this type of process include large land requirements, indeterminate requirements for de-sludging of the lagoon, sensitivity to temperature, and potential for odours.

Activated Sludge

During activated sludge treatment, the aeration tank is completely mixed, generally by use of a vigorous aeration system, and receives controlled and steady inflows of raw leachate continuously. Mixed liquor overflows continuously from the aeration tank, into a sludge separation stage, generally comprising a settlement reactor. Here, biomass/sludge is settled, to be returned into the aeration reactor, and a clarified effluent is decanted from the surface, for discharge or further treatment.

Additions of nutrients (primarily phosphorus) and of alkalinity to buffer acidity generated during the nitrification process, are required routinely, and biological sludge must be wasted from the process, and disposed of on a regular hasis, especially while treating leachates containing substantial levels of biodegradable organic materials.

The weakness of the activated sludge process for leachate treatment lies primarily in the intensive nature of the continuous sludge separation/effluent clarification process. Any short-term variations in the ability of biomass to flocculate and settle are rapidly exhibited by poor effluent quality. In particular, for a wastewater such as leachate, where treated effluent may contain in excess of 1,000 mg/L of nitrate-N, the development of slightly anoxic conditions within the settlement tank at any time, can lead to uncontrolled denitrification, with bubbles of nitrogen gas attaching themselves to sludge flocs, causing them to rise to the surface and impact on final effluent quality.

Sequencing Batch Reactors

The SBR treatment process has been developed as an automated, extended aeration system that is particularly well suited to the higher organic strength and concentrations of ammoniacal-N in landfill leachates. The SBR operation makes for efficient aeration, high rates of dilution of incoming leachates and high resistance to shock loading. There are many of these aerobic biological leachate treatment systems successfully installed in Europe.

An SBR is a cyclically operated, suspended growth, activated sludge process. The only conceptual difference between the SBR and a conventional activated sludge system is that each SBR tank carries out functions such as aerobic biological treatment, equalization, settlement of solids, effluent clarification and decanting, over a time sequence rather than in spatially separate tanks. The ability to vary the time sequence, (compared to the inflexibility of specific volumes of separate tanks) provides a very rohust and flexible treatment system. SBR systems that have been designed for particular loading rates, of ammoniacal-N or of organic contaminants, will have considerable flexibility to receive this as either small volumes of strong leachate, or as larger volumes of weaker leachate. This can be important as leachate character changes over time to ensure that optimum treatment performance is maintained.

A typical cycle of operation for SBR treatment of landfill leachate is therefore:

- FILL AND REACT: During a period of from 18 to 20 hours, leachate is gradually fed into the SBR, during which time the reactor is aerated, and pH value is controlled.
- SETTLE: Aeration is stopped for between one and two hours, during which period sludge flocculates and settles, and supernatant liquor is clarified.

- DECANT: Effluent is decanted from the surface of the SBR, by means of one of a number of options (bellmouth overflow, floating decant – either gravity or pumped, etc.), typically during a period of one or two hours depending on volume involved. Decanting stops and the treatment cycle then recommences. In leachate treatment, the process is readily automated, and generally operated within a 24 hour cycle, in a tank which provides a typical mean hydraulic retention time (HRT) of ten days or longer when treating strong leachates. In general terms, for such leachates, selection of a shorter HRT does not reduce operational costs at all, and may only result in marginal reduction in capital costs.

Membrane Bioreactors

The MBR process is essentially an advanced form of the traditional activated sludge process, where the biological part of the process is combined with ultrafiltration (UF) membrane technology, for separation of return sludge from a clarified/filtered effluent. This replaces the need for a separate settlement tank, which is often the rate limiting step in conventional effluent treatment.

The separation of biomass from a clarified and treated effluent is accomplished by a cross flow filtration process, within an efficient UF system. This retains all biomass and all suspended solids typically larger than about 0.02 μm, including all bacteria. The concentrated sludge separated out by the system is continually returned to the bioreactor as return sludge, as in a conventional activated sludge system. However, because of the improved efficiency of the solids separation stage, much higher concentrations of biomass can be maintained within the bioreactor, where mixed liquor suspended solids values of up to 20,000 mg/L are typical. This allows more intensive treatment to take place, reducing the size of plant required for a given loading of contaminants. The bioreactor stage of treatment is also often operated at increased pressure, to further increase treatment rates. Pressurized aeration tanks allow a reduction in the volume of air utilized because of greater oxygen transfer efficiency. This in turn leads to greater control with regard to foaming and the emission of volatile organic chemicals and other odorous substances. The key part of the process is the membrane filtration stage. Processes such as turbulent and directed air flows along membrane surfaces have also improved control of membrane clogging, and have minimized the size of UF units required for a given application. Recent developments use automatically controlled sequences of forward and back flushing of the UF modules to maintain the flux rate. The mounting of cross flow modules externally to the aeration tank can greatly facilitate the cleaning process.

There are over 50 known MBR plants in Europe. High concentrations of BOD, COD and ammonia are being removed at these plants, which range from 100 m^3/day to as high as 2,500 m^3/day. Like the SBR process, treatment of leachate in an MBR is readily automated, with process control achieved through a programmable logic controller and operator interface PC. The more intensive nature of the process, with relatively short hydraulic retention times, higher concentrations of solids in mixed liquor, and pressurized reactors, demands a higher degree of monitoring than is required for an SBR and failsafe controls and auto shutdown facilities are essential. Foam control is generally more important than in other aerobic biological processes.

Moving Bed Bioreactor

The MBBR process employs a submerged ring media onto which micro organisms attach. The biomass retained on the ring media provides effective treatment for the effluent. The ring media are kept in motion by coarse bubble aeration. The air introduced into the tank is sufficient to ensure thorough mixing and turnover of the media within the reactor.

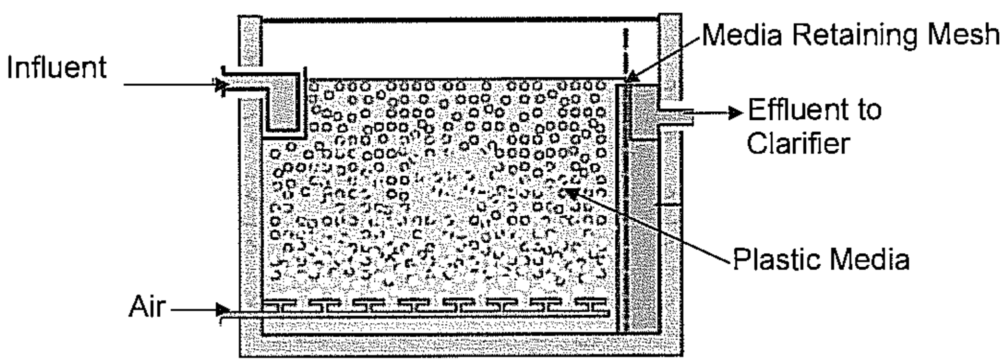


Figure 2.5: Typical Schematics of MBBR Reactor System

For a high strength waste, such as leachate, in comparison to the attached growth fixed film systems, the MBBR is more robust to the shock loads. In addition, the pH maintenance in attached growth process for the full height of the media is difficult, however in MBBR the dissolution of pH control chemical in the bioreactor is relatively easier.

If there is a high hydrocarbon content in the leachate there is a danger that this will negatively impact the performance of the media, preventing the development of a biomass. In suspended growth systems the hydrocarbons are emulsified and metabolized.

Typically, for leachate waste streams, the process train would incorporate a screen upstream of the MBBR reactor and a clarifier downstream of the reactor.

Rotating Biological Contactors

A RBC is an aerobic, fixed-film biological treatment system, comprising a series of closely spaced, plastic (polystyrene, polyvinyl chloride or polyethylene) circular discs on a horizontal shaft. Discs are often large, up to 3 m or 4 m in diameter, and provide a very large surface area on which bacteria can grow.

A typical unit of 6 m in length, of 3.5 m diameter, can have a surface area that approaches 10,000 m^2, based on up to 200 m^2 of surface/m^3 of rotor volume.

The rotor system is mounted in a contoured basal tank, to partially immerse (typically 40%) of the discs in the leachate, which flows at right angles to the discs, through the basal tank. The discs develop a slime layer of attached bacteria across their entire wetted surfaces, as they rotate slowly through the wastewater, generally at between 1.5 and 2 rpm. This means that bacteria alternatively contact contaminants within the wastewater, and then the atmosphere for adsorption of oxygen. Excess growth of biomass is sheared off during rotation of the system, and the stripped solids are carried with the effluent to a clarifier, where they are separated from the final effluent.

In order to maintain adequate temperatures for treatment, in the order of 20°C, in cold climatic conditions the rotors are sometimes buried in the ground and/or enclosed within a roof system, which must be ventilated for optimum oxygen transfer. To minimize the area of rotor required, incoming leachate is generally heated.

RBCs provide a greater degree of flexibility for treatment of leachate than otber attached growth systems. In particular, by adjustment of the configuration of the basal tank and rotor, the mixing characteristics of the system can be modified, to reduce the degree of "plug flow", and encourage the system to operate more like a completely mixed reactor. This provides some of the benefits of rapid dilution of incoming leachates that are provided by extended aeration processes such as SBRs.

Nevertheless, RBCs are generally most effective for methanogenic leachates. Since high concentrations of degradable COD found in acetogenic leacbate can result in excessive sludge growth, and clogging of interstices within rotors. RBC systems are also most effective for concentrations of ammoniacal-N below 500 mg/L, although because of their modular construction, they can be operated in series to optimize nitrification efficiency.

Factors affecting the treatment efficiency of RBC systems include the type and concentrations of organics present, hydraulic residence time, rotational speed, media surface area exposed and submerged (which is readily modified by adjusting the depth of water in the basal tank), and pre and post-treatment systems added.

RBCs were first developed in Europe during the 1950s and 1960s and have the advantage of relatively low energy use to provide aeration; when compared with suspended growth systems, energy consumption may be only 20% as great. RBC systems have occasionally treated methanogenic leachates at German landfills, sometimes after chemical oxidation has been used to reduce biodegradable COD to low levels. For RBC plants optimum loading is 1 to 2 g N/m^2 of media surface per day, at ambient temperatures, in methanogenic leachates.

As in most aerobic biological systems treating leachates, issues related to handling chemicals such as high strength alkalis (e.g. sodium hydroxide) or phosphoric acid apply. Since dosing of these will generally be automated at larger plants, risks will be reduced. Provision of facilities such as emergency eyewash baths, and emergency showers adjacent to areas at risk is good practice. Use of removable clear Perspex sheets in front of dosing pumps, to provide additional protection, is often recommended. Odours are unlikely to be an issue in a well operated and designed RBC, and noise levels will be very low. Production of foam during treatment has never been reported as an issue. A high level of automation is possible with RBCs and it is also appropriate to incorporate safety measures such as fail-safe procedures, interlocks, alarms, telemetry and emergency dial-out systems.

Leachate Recirculation

Leachate recirculation involves extracting leachate from the collection system underneath, and applying to the top of the landfill. Landfills with leachate recirculation are also known as "wet landfills" or "flushing landfills"; they provide a viable on-site leachate management method, and are one of many technologies commonly used to manage leachate from landfills. This method can significantly reduce the amount of leachate, and it is especially effective when the leachate is sprayed on the surface of the landfill due to the enhanced evaporation. During leachate recirculation, leachate is collected and re-injected into the waste mass. Leachate is treated through biological processes, precipitation, and sorption when it continues to flow through the landfill. This approach accelerates the organic substance decomposition and methane gas production in landfills.

The time required for landfill stabilization varies widely among the different type of landfills. **Figure 2.6** illustrates the approximate time for landfill stabilization under different conditions.

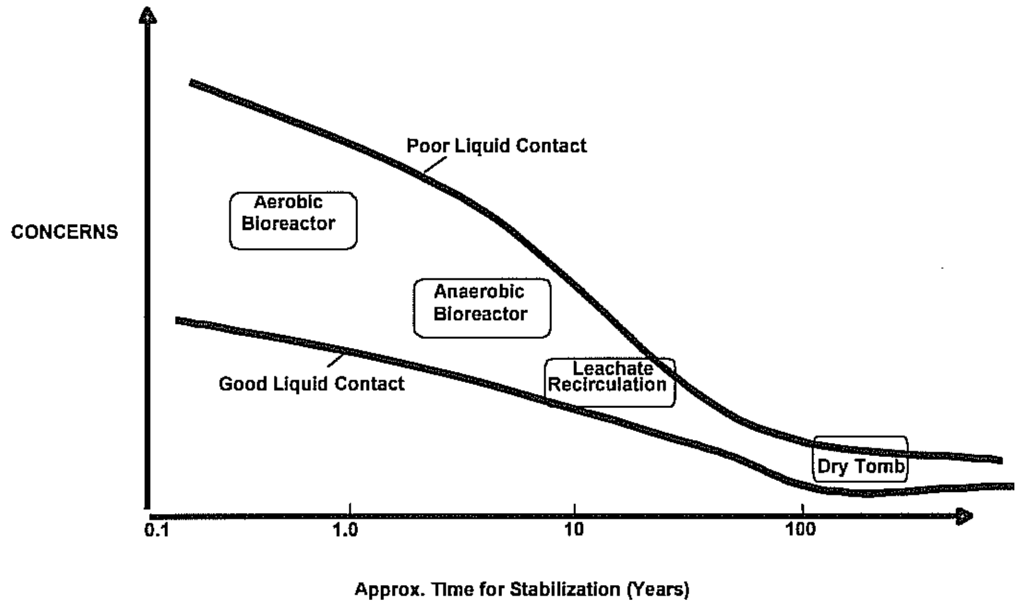


Figure 2.6: Illustrations of Approximate Time of Landfill Stabilization

Leachate recirculation has several advantages, listed as follows:

1. Store leachate in the landfill and avoid leachate treatment costs.
2. Enhance and accelerate methane gas generation and energy recovery.
3. Result in significant settlement quickly; i.e., recover voids.
4. Speed up landfill stabilization, avoid long-term monitoring and maintenance.
5. Waste mining is possible.
6. Voids in municipal solid waste (MSW) are reduced.

Typically, there are five commonly used methods to re-introduce leachate back into landfills; they are surface spraying, surface ponding, leachate field injection, shallow well and deep well injection.

In addition to the above-mentioned advantages, leachate recirculation has several drawbacks, as listed below:

- Leachate recirculation tends to substantially increase the concentrations of conservative materials and make it a more difficult waste to treat.
- Landfills that become over saturated may result in potential problems, such as excessive head on the liner, leachate outbreaks and increased risk of groundwater contamination due to the leakage of associated leachate constituents through the liner system.

- Leachate recirculation may not perform efficiently when unshredded plastic bags prevent waste from being exposed to moisture.
- Possibility of equipment break down.
- Time limit of leachate recirculation at the landfill.

In the United States, regulatory requirements allow leachate recirculation at landfills that are designed and equipped with composite liners and leachate collection systems constructed to maintain less than a 30 cm depth of leachate over the liner.

It is recommended that leachate recirculation should not be applied in a single lined landfill which relies on groundwater monitoring to detect the failure of the liner to prevent significant leachate leakage. Leachate recirculation can and should only be employed in appropriately designed and constructed composite lined landfills where the lower liner serves as a leak detection system for its upper liner. Clean water leaching of the fermented solid waste residues must be applied after leachate recirculation in order to remove leachate constituents from municipal solid waste as they may provide a threat to groundwater quality.

In addition to the requirements and concerns listed above, a well established methane recovery system is also required to address greenhouse gas emissions.

The Keele Valley Maples, Ontario landfill site practices leachate recirculation and eventually discharges the leachate to the sewer system. At this landfill site, a perforated pipe system surrounded by gravel is constructed on top of the liner to drain off the collected leachate. This leachate collection system drains into a pumping station that discharges the leachate into the York-Durham sanitary sewer system for treatment at a sewage treatment plant.

There are greater than 100 landfills in the U.S. that practice this technique.

2.3 OTHER LEACHATE TREATMENT EXPERIENCE

The following is a brief discussion on literature reviewed for specific treatment systems being employed in various parts of the world.

Leachate Treatment in England and Wales

The SBR technique is widely practiced in the United Kingdom for leachate treatment. The first aerobic SBR leachate treatment system was established on a site in mid-Wales in 1982. This system was the basis of many similar systems based on modified SBR technology.

Two case studies of leachate treatment are discussed below from England and Wales.

Methane Stripping at Red Moss Landfill, Lancashire, United Kingdom

Red Moss is a large, closed landfill located in north-west England. The leachate generated from this landfill is permitted to discharge to the public sewer without biological treatment.

Because the landfill is in the methanogenic period, the raw leachate contains up to 10 mg/L dissolved methane that is considered explosive. The limit on the dissolved methane concentration is less than 0.14 mg/L before the leachate is discharged into the sewer. A methane stripping plant was installed to remove the dissolved methane. The methane-stripping plant consists of two banks of aeration reactors with each bank having four separate reactors with separate air supplied to each reactor.

Aerobic Biological Leachate Treatment at Buckden Landfill, Cambridgeshire, United Kingdom

The United Kingdom regulations became tighter for wastewater discharges into the environment during mid to late 1990s, and tighter limits were imposed on leachate effluent quality. It was recognized that an advanced but cost-effective on-site treatment technology was needed to reliably achieve strict discharge limits.

The Buckden landfill generated leachate containing significant concentrations of herbicides, mecoprop and isoproturon at that time. The biological treatment process could not sufficiently remove isoproturon even though these herbicides did not impair the efficiency of the biological leachate treatment process. A reed bed and ozonation process was designed to control the non-biodegradable fraction of the leachate.

The full-scale plant consists of twin SBRs, each of them designed for a capacity of 100 m^3/day. A 2,000 m^2 reed bed is used as the secondary treatment process and an ozonation plant follows as a tertiary polishing process which is capable of dosing up to 500 g/hour of ozone. The typical dosing rate is 150 mg/L. The treated effluent is discharged into the River Great Ouse. The plant has been successfully running since it was commissioned in 1994, and effluent COD values of between 250 mg/L and 350 mg/L were regularly achieved between 1995 and 2000.

Leachate Management System in Hong Kong, China

During the 1990s, the Environmental Protection Department of the Hong Kong Government developed a solid waste management strategy which included the development of three large strategic landfill sites as named West New Territories (WENT) Landfill, South East New Territories (SENT) Landfill and North East New Territories (NENT) Landfill, each with an estimated capacity of 25 to 40 million m^3. The on-site leachate management system for those landfills consists of an effective impermeable liner collection system, leachate collection pipes and three dedicated mechanical leachate treatment facilities: SENT Landfill Leachate Treatment Plant, WENT Landfill Leachate Treatment Plant and NENT Landfill Leachate Treatment Plant. The leachate treatment process incorporates a number of aerated lagoons. The NENT was the first plant constructed with a capacity of 1,400 m^3/d. The WENT has been in operation since 1998 with a design flow rate of 1,800 m^3/d. Air stripping techniques are employed to reduce high ammoniacal nitrogen influent concentrations of 6,700 mg/L to levels below 100 mg/L.

Leachate Management System in South Africa

Vissershok Landfill in South Africa receives up to 2,000 tonnes of MSW daily from the City of Cape Town, including some low to medium level hazardous waste. Leachate is generated from this landfill in a rate of up to 80 m^3/day of and requires treatment to very high standards. Aerobic biological SBR technology is applied with nitrification and denitrification processes followed by a reed bed planted with Phragmites. An ammoniacal nitrogen concentration of less than 1 mg/L is routinely achieved from initial concentrations of over 1,200 mg/L. Raw influent leachate values of over 2,000 mg/L COD are reduced by approximately 50% to 60%. The treated effluent is used for dust damping across the site.

Leachate Treatment in the United States

There are three best practice treatment (BPT) options referenced by the United States Environmental Protection Agency (EPA). BPT Option 1 consists of equalization followed by biological treatment with clarification. Biological treatment is preferred by regulators due to the effectiveness for removing large organic loads commonly associated with leachate. Approximately 30% of facilities apply biological treatment and 13% apply a combination of equalization and biological treatment. BPT Option 2 consists of Option 1 plus the addition of a multimedia filter following biological treatment. The filter is expected to assist in the total suspended solids (TSS) control. Approximately 10% of facilities in the United States use Option 2. BPT Option 3 is based on zero or alternate discharge. The options for alternate discharge include deep well injection, solidification, and controlled discharge to a centralized plant. About 37 facilities inject untreated leachate discharge underground. Approximately 103 facilities discharge to centralized wastewater treatment plants. Only one facility solidifies the leachate.

The United States EPA rated Option 2 as the preferred BPT technology incorporating aerated equalization, chemical precipitation and biological treatment and secondary clarification and filtration.

The United States EPA has not established pre-treatment standards for discharge to centralized wastewater treatment facilities.

Leachate Treatment in Ontario, Canada

In accordance with the Incorporation of the Reasonable Use Concept into MOEE Groundwater Management Activities (Ontario Guideline B-7, last revision date: April 1994), a bio-filter landfill leachate treatment facility was built and put into operation in Simcoe County, Ontario. The leachate treatment facility consists of five concrete tanks. Leachate is pre-treated at the landfill site before it is fed to three tanks which are used as a roughing bio-filter (with a designed loading rate of 0.5 m^3/m^2/day). The effluent from the roughing bio-filter is discharged to two subsequent tanks which are used for polishing (with a designed loading rate of 0.7 m^3/m^2/d). The total capacity of the facility is 16 m^3/day. This facility was built and placed into service in mid-1996. The treated effluent BOD generally ranges from 5 to 40 mg/L from raw leachate BOD ranges of 100 to 1,500 mg/L. Temperature has significant impact on this biological treatment system and treatment performance has been poor when influent temperatures drop to near 0°C.

Leachate Treatment in Edmonton, Alberta, Canada

Clover Bar landfill is an engineered landfill owned and operated by the City of Edmonton. It has a leachate treatment plant and landfill gas recovery system as well as a number of recycling initiatives. More than 100 wells have been drilled in and around the Clover Bar landfill for sampling and testing to ensure that leachate is not migrating into the groundwater. The leachate generated and settled at the bottom of the landfill is contained by a compacted clay liner, and is drawn out by series of collection pipes and conveyed to the leachate treatment plant. After treating the leachate to an acceptable quality, effluent is disposed to the City's municipal sewage system.

Leachate Treatment in Winnipeg, Manitoba, Canada

The Brady road landfill site is one of 28 landfill sites in Winnipeg and it is the only active sanitary landfill site owned, operated and maintained by the City of Winnipeg at the time of writing this report. The Brady landfill occupies a 35 acre area with an average depth of 25 ft. It started serving the City in 1973 and receives an average of approximately 1,200 tons of waste per day.

The Brady landfill is located in an area containing clay soil with good containment properties. The leachate generated from the Brady landfill is drawn out by collection piping installed at the base of the landfill and transported to the North End Water Pollution Control Centre for treatment.

2.4 SNOW MELT MANAGEMENT

2.4.1 National Snow Melt Management

No facility for snow melt treatment in Canada has been cited. General practice has been that the snow melt is directed to a sewer system or overland drainage to a surface water body. Data on the existence of snow melt treatment facilities in other parts of the world also has not been found. Locally, the practice in larger municipalities such as Winnipeg is mainly to divert the snow melt to overland discharge via the local drainage system. Some snow dump sites are close to the sewer system and the melt-water is directed to the City sewer network.

2.4.2 Snowmelt Management in Other Regions

A number of studies conducted in Canada on snow dump site melt-water quality indicate that high levels of chloride, lead, iron, phosphorus, BOD, and TSS are usually present in snow dump runoff. Adverse impacts of melt-water on aquatic life are typically related to elevated levels of metals, organic toxicants, and salt. The run-off of excess road salt has been known to cause extensive contamination of surface and groundwater.

The above contaminants may enter snow by following processes:

- Air borne particulates from local urban activities as well as long distance transport of pollutants from activities unrelated to the locale.
- Vehicular deposition of petroleum products/additives and metals.
- The direct application of salt and anti-skid grits.
- Roadway deterioration.

However, literature review suggests that there is no practical or economical way of removing the chlorides found in snow (Syntheses of Best Practices Road Salt Management, Transportation Association of Canada). As cited in literature, the majority of practices for snow melt management are direct surface discharge or surface discharge after storage and partial treatment.

2.5 REGULATORY STIPULATIONS

2.5.1 Canadian Regulatory Framework

Landfill related regulations and guidelines vary across Canada. In Canada, it is the responsibility of the province to make and implement waste disposal regulations and policies. Generally, for most of the provinces, the regulations fall short of stipulating detailed, or any, leachate-related effluent quality requirements. Most regulatory framework is focused on the overall landfill design and operation. The province of Quebec has published limits for landfill effluent requirements.

Alberta: In the Province of Alberta, the Environmental Protection and Enhancement Act and the Public Health Act intends to mitigate the adverse impacts associated with landfills on groundwater utilizing Waste Control Regulation (A.R. 192/96). Part of the stipulation is that the jurisdictions/operators can apply for alternate standards if enough justification is provided and the required number of groundwater monitoring wells are installed. Facilities accepting 10,000 tonnes or less of non-hazardous waste per year (Class II and Class III landfills) must meet A.R. 192/96 regulation requirements to ensure that their activities are in compliance with Alberta's environmental laws. The following landfills require an approval under the Activities Designation Regulation (A.R. 211/96) of Environmental Protection and Enhancement Act:

- Landfills that accept more than 10,000 tonnes of waste/year.
- Landfills that accept hazardous waste.
- Landfills that are located in a ravine, gully or coulee or over a buried valley.

Class II landfills shall include a liner and leachate collection system that provides for containment of the waste constituents and allows gathering and collection of leachate; a groundwater monitoring system, which shall consist of at least three groundwater monitoring well locations from the landfill (two down-gradient and one up-gradient); and a run-on and run-off control system to prevent flow onto the active portion of the landfill for events up to at least the peak discharge from the larger of a 1 in 25 year storm or snow melt event.

The province stipulates that the groundwater quality during the operating and post closure period shall be equal to or less than the specified standards - chloride at 250 mg/L, sodium at 200 mg/L, sulphate at 500 mg/L and pH at 6.5 to 8.5.

The City of Edmonton Consolidated Sewers Use Bylaw (Bylaw No. 9675, December 13, 2007) states that the liquid from a snow dump site may be released into the sanitary sewer provided that the wastewater does not contain a hazardous waste, prohibited waste or restricted waste.

Quebec: There is a two tier system for leachate regulations in Quebec for leachate treatment, these are:

1. utilize the underlay soil via infiltration and
2. regulation related to specific leachate collection and treatment systems.

Regulations state that for soil infiltration and treatment systems, landfills are to be developed on sites with soil characteristics such that the percolation rate shall be more than five years to migrate 300 m depth. In the event that the rate is more accelerated than 300 m over five years, special measures are required to prevent groundwater contamination. For sites where the percolation rate is anticipated to be more accelerated (e.g. a two year period for a downward movement over 300 m depth), the leachate should be collected and treated adequately before discharge. The province regulates the leachate effluent quality by tracking the concentrations of heavy metals, chlorides, coliforms, BOD, COD, sulfides, cyanides and phenolic compounds compared to specified limits. In addition, the province regulates that the treatment facility must be at least 50 m from some sensitive areas and 300 m from others.

In the Province of Quebec, the "Regulation respecting snow elimination sites, Environment Quality Act (R.S.Q., c. Q-2, s. 31, pars. a to c, e, f, g, g.1, s. 109.1 and s. 124.1; 1997, c. 21, s. 1)" regulates snow disposal. It states "snow that is removed and transported for elimination purposes may be placed for final deposit only at an elimination site for which a certificate of authorization needs to be issued under Section 22 of the Environment Quality Act (R.S.Q., c. Q-2) or, in the case of an elimination site established before the date of the coming into force of this Regulation, for which a depollution programme has been approved by the Minister of the Environment and Wildlife under Sections 116.2 to 116.4 of the aforesaid Act. The operator of a snow elimination site, established before the date of the coming into force of this Regulation shall, notwithstanding the foregoing, have two years from that date to have a depollution programme for the site approved by the Minister; in the meantime, the operator may continue to receive the snow brought to the site. The depollution programme shall be such that no later than the expiry of the period agreed upon in the programme, which period may not extend beyond 1 November 2002, all the corrective measures provided for by the program will have been applied."

Manitoba: In this province, the Consolidated Acts and Acts of Continuing Application as amended from time to time, are grouped into three subcategories: Continuing Consolidation of the Statutes of Manitoba (CCSM), Municipal Acts and Private Acts. C.C.S.M. number E125 contains Waste Disposal Grounds Regulation 150/91 which states that waste or leachate is to be contained within the boundaries of the waste disposal ground site and not contaminate groundwater. There are no specific guidelines for leachate effluent however, there are general guidelines for the surface water discharge in Manitoba entitled: "The Manitoba Water Quality Standards, Objectives, and Guidelines: Technical Draft" that can be used as a reference for leachate discharge to a surface water body. These guidelines are summarized in **Table 2.1**:

Table 2.1: Provincial Draft Guidelines for Surface Water Discharge

Parameters	Maximum Concentrations (mg/L unless noted otherwise)
Fecal Coliform	200 MPN/100 mL
BOD	30
TSS	30
TDS	3000
Phenols	0.002
Aluminum	5
Cadmium	0.08
Copper	0.1
Nickel	1
Zinc	50
Lead	0.1
Mercury	0.003
Sulfates	1000
Nitrate and Nitrite	100

The City of Winnipeg consolidated their Sewer Bylaw (Bylaw No. 7070/97) and updated it on March 26, 2008. The Bylaw indicates that "no person shall discharge or cause to be discharged or have the potential to discharge into any City sewer, a wastewater with characteristics described in Section 25 without an Over-strength Wastewater Discharge Licence". Restricted Materials are defined in Part 5 of the Sewer Bylaw, and no person shall discharge or cause to be discharged into any sewer in the City any wastewater which has characteristics exceeding the limits as summarized in **Table 2.2** below.

Table 2.2: Restricted Materials and Sewer Discharge limits by Bylaw No. 7070/97

Restricted Materials	Bylaw Limits mg/L	Restricted Materials	Bylaw Limits mg/L
BOD	300	Lead	2
TSS	350	Mercury	0.1
Synthetic or Petroleum Oil and Grease	100	Nickel	5.0
Temperature	61	Silver	5.0
pH	5.5 ~ 11.0	Zinc	5.0
Aluminum	50.0	Total Sulphide	10.0
Arsenic	1.0	Free Cyanide or Total Cyanide	2.0 10.0
Cadmium	0.5	Total Purgeable Hydrocarbons or Total Semivolatile Hydrocarbons	10.0 100.0
Chromium	5.0	Benzene	0.5
Copper	5		

In order to prevent disruption to the municipal wastewater treatment operation, there is a potential for changing the regulatory requirements so that discharge of leachate to the sewer system would be prohibited.

For snow dump sites in Manitoba, Manitoba Conservation's "Guidelines for Management of Snow Disposal Sites" dated February 1995, is used to ensure that snow dump sites are "safe for the public, environmentally stable and that their operation minimizes negative impacts on local soils and receiving waters." The guidelines are intended for use across the province of Manitoba and all "federal, provincial, municipal, civic, public and private sites to which snow removed from other locations is transported and disposed, and at which not less than 100 cubic metres of snow have been deposited in any one operational year, can be operated under these Guidelines." The framework for the protection of soils includes site selection, soil sampling frequency, analytes and applicable CCME soil guideline criteria, further assessment and rehabilitation requirements along with decommissioning, waste management and site fencing requirements. The framework for the management of melt water includes required set backs, melt water retention requirements, waste management, and restrictions pertaining to proximity to bodies of water.

2.5.2 International Regulatory Framework

The leachate management strategies are different from country to country due to solid waste management and ground/surface water protection regulations and guidelines varying internationally.

Europe

The Council Directive 1999/31/EC of 26 April 1999 implemented the requirements for waste and landfills to prevent and reduce the adverse effects on the environment from landfills.

In Europe, Integrated Pollution Prevention and Control (IPPC) is a regulatory system that employs an integrated approach to control the environmental impacts of leachate disposal. It involves the determination by the regulator of appropriate controls to protect the environment, through a single permitting process. To gain a permit, landfill operators have to demonstrate in their applications, in a systematic way, that the techniques they are using or are proposing to use are the best available techniques (BAT) for their installation, and meet certain other requirements, taking into account relevant local factors. The essence of BAT is that the techniques selected to protect the environment should achieve an appropriate balance between environmental benefits and the costs incurred by landfill operators. However, whatever the costs involved, no installation may be permitted where its operation would cause significant pollution.

The BAT approach of IPPC differs from regulatory approaches based on fixed national emissions limits (except where General Binding Rules or Standard Permits are issued). The legal instrument that ultimately defines BAT is the permit, and permits can only be issued at the installation level.

BAT includes the technical components, process control, and management of the installation. Departures from those benchmark levels can be justified at the installation level by taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. If any mandatory European Union emission limits or conditions are applicable, they must be met.

The BAT approach complements, but differs fundamentally from, regulatory approaches based on Environmental Quality Standards (EQS). BAT requires measures to be taken to prevent emissions - and measures that simply reduce emissions are acceptable only where prevention is not practicable. Thus, if it is economically and technically viable to reduce emissions further, or prevent them altogether, then this should be done irrespective of whether or not EQSs are already being met. The BAT approach first considers what emission prevention can reasonably be achieved and then checks to ensure that the local environmental conditions are secure. The BAT approach is therefore the more precautionary one because the release level achieved may be better than that simply required to meet an EQS.

If the application of BAT might lead to a situation in which an EQS is still threatened, a more effective technique will be required for that installation. The Regulations allow for expenditure beyond BAT where necessary, and, ultimately, an installation will only be permitted to operate if it does not cause significant pollution.

The assessment of indicative BAT takes place at a number of levels. At the European level, the European Commission issues a "BAT reference document" (BREF) for each main IPPC sector. It also issues "horizontal" BREFs for a number of general techniques which are relevant across a series of industrial sectors. The BREFs are the result of an exchange of information between regulators, industry and other interested parties in Member States. Member States should take them into account when determining BAT, but they are allowed flexibility in their application.

To assist operators and the regulator's officers in respectively making and determining applications for PPC permits, this section summarizes the indicative BAT requirements (i.e. what is considered to represent BAT for a reasonably efficiently operating installation in the sector). The indicative BAT requirements may not always be absolutely relevant or applicable to an individual installation when taking into account site-specific factors, but will always provide a benchmark against which individual applications can be assessed.

United States

In 1976, the Resource Conservation and Recovery Act (Solid Waste Disposal Act) (RCRA) came into effect, and it was amended every one to two years until 1996. RCRA makes regulations on managing solid waste, hazardous waste, and underground storage tanks holding petroleum products or certain chemicals.

The primary goals of RCRA are as below:

- Protect human health and the environment from the potential hazards of waste disposal.
- Conserve energy and natural resources.
- Reduce the amount of waste generated, and to ensure that wastes are managed in an environmentally sound manner.

RCRA Subtitle D regulations require:

- New MSW landfills are to be designed to control contaminant migration. The groundwater protection performance standard for landfills specifies that contaminant concentrations in groundwater cannot exceed the amounts shown in **Table 2.3** below. Approved states may establish state-specific protocols for meeting these standards.

Table 2.3: Groundwater Protection Performance Standards

Chemical	Maximum Concentration Limit (mg/L)	Chemical	Maximum Concentration Limit (mg/L)
Arsenic	0.05	Lindane	0.004
Barium	1.0	Lead	0.05
Benzene	0.005	Mercury	0.002
Cadmium	0.01	Methoxychlor	0.1
Carbon tetrachloride	0.005	Nitrate	10.0
Chromium (hexavalent)	0.05	Selenium	0.01
2,4-Dichlorophenoxy	0.1	Silver	0.05
1,4-Dichlorobenzene	0.075	Toxaphene	0.005
1,2-Dichloroethane	0.005	1,1,1-Trichloromethane	0.2
1,1-Dichloroethylene	0.007	Trichloroethylene	0.005
Endrin	0.0002	2,4,5-Trichlorophenoxy acetic	0.01
Fluoride	4.0	Vinyl Chloride	0.002
Source: USEPA			

- New MSW landfills and expansions of existing MSW landfill facilities are to be constructed with a composite liner and a leachate collection system or meet a groundwater protection performance standard, unless an approved state issues alternative standards. The required liner consists of a flexible membrane placed over a clay layer, forming one composite liner. **Figure 2.7** illustrates liner configurations.

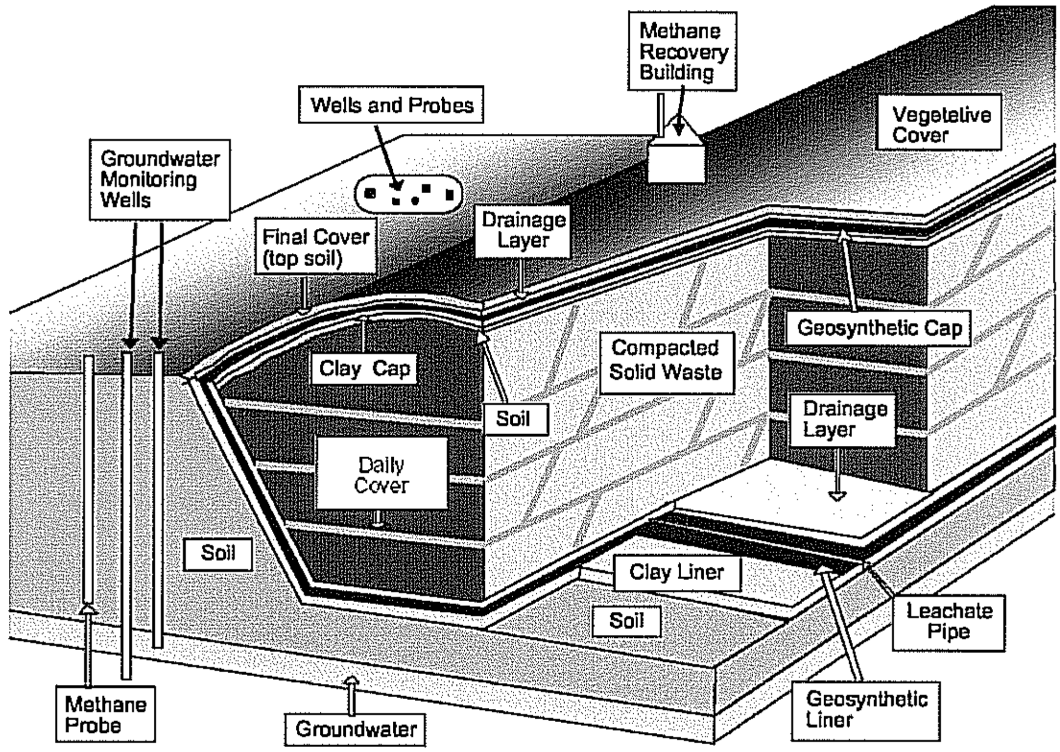


Figure 2.7: A Typical MSW Landfill Schematic Diagraph (Source: P.O'Leary and P. Walsh, University of Wiconsin-Madison Solid and Hazardous Waste Education Center, reprinted from Waste Age 1991 to 1992.)

Currently, the United States federal regulations allow leachate recirculation under certain circumstances, such as those MSW landfills which are designed and operated with the composite liner proscribed by 40 CFR Part 258.40. MSW landfills with alternative liner systems in place are not allowed to practice leachate recirculation. Some states that generally have the regulatory flexibility will come with EPA program approval. The United States EPA may revise the federal regulations to allow leachate recirculation at landfills with alternative liner systems in the future.

Based on RCRA, the individual States began to set solid waste reduction goals and improve effectiveness of waste management programs. For example, the Wyoming Department of Environmental Quality regulates that "leachate is not allowed to enter any surface water, either on-site or off-site, unless authorized by a National Pollutant Discharge Elimination System permit pursuant to the Clean Water Act." Even though the United States EPA municipal landfill regulations only address a few "hazardous chemicals" in groundwater, the State of California requires protection of groundwater quality from all chemicals that can impair its uses, such as total dissolved solids, hardness, alkalinity, chloride, sulfate, etc. present in MSW leachate that can readily pollute groundwater and impair its use.

Section 3.0
Leachate and Snow Melt Loadings and Characterization

SECTION 3.0
LEACHATE AND SNOW MELT LOADINGS AND CHARACTERIZATION

On-site sampling and third party analyses were conducted at the City of Brandon Landfill to investigate the leachate and snow melt hydraulic loading and characteristics. The following sections outline the sampling program methodology and results of the work.

3.1 SAMPLING METHODOLOGY

The sampling program consisted of two events. The first event occurred in early spring on March 5, 2008 and included the collection of two leachate samples (LCH01 and LCH02) and two snow melt samples (composite sample SN01 and BH1), and included a trip blank for quality assurance. The second event occurred in late spring on May 26, 2008 and included the collection of two leachate samples (LCH01 and LCH02), three snow melt samples (SW1, SW2 and BH01), and two replicate samples for quality assurance (BH01A and LCH01A). After each event, samples were submitted to Maxxam Analytics Inc. of Winnipeg, Manitoba for analysis. Both events included groundwater elevation measurements at 27 on-site monitoring wells and three off-site monitoring wells.

All monitoring well and sample locations from both sampling events are shown on **Figure 3.1.**

3.1.1 Leachate Sampling Program

Two leachate samples (LCH01 and LCH02) were collected during each of the sampling events on March 5 and May 26, 2008, respectively. The first sample (LCH01) was obtained from a manhole located along the southern perimeter of the Site, which collects leachate from the tenth Phase Cell (circa 1999). The second sample (LCH02) was obtained from a manhole located in the northeast portion of the site, just north of the 11th Phase Cell. In addition to collecting leachate from the more current cells, Phase 11 (circa 2001) and Phase 12 (circa 2003), this manhole also collects leachate diverted from the seventh Phase Cell (1994). The locations of the leachate samples were captured using a handheld Garmin GPS 12 device and are indicated in **Figure 3.1.**

Leachate Sampling Procedures

The samples were collected using new, dedicated, 4 cm diameter disposable polyethylene bailers. For each sample, the bailers were handled using new nitrile gloves to eliminate the potential for cross-contamination between manholes. The leachate samples were dispensed from the bailers into clean laboratory bottles, and preserved according to laboratory requirements.

LEGEND

●LCH01 SAMPLE LOCATION

θBH16 MONITORING WELL LOCATION

EarthTech

Winnipeg, Manitoba 204.477.6081

▲S ...RING WELL AND SAMPLE LOCATION PLAN

designed	scale	yy-mm-dd
	BAR	08-06-25
drawn LB	project no. 103779	
checked SJB	drawing no.	rev.
approved	FIGURE 3.1	

L:\work\103000\103779\02a-CAD\ENV\2008 Site MW Sample

2-1-A.

FORM 11x17
REV. 04-11-22

For each sample, the containers were tightly sealed and placed into a plastic Ziploc bag and then placed in a cooler with ice packs for delivery to Maxxam Analytics Inc. of Winnipeg, Manitoba for analysis.

3.1.2 Snow Melt Sampling Program

During the early spring sampling event on March 5, 2008, two snow melt samples were collected; one composite sample was obtained from the snow stockpile (SN01) and one groundwater sample was collected from monitoring well BH1 (BH1). During the late spring event on May 26, 2008 three snow melt samples were collected; one melt water sample was obtained from the pond adjacent to the snow stockpile (SW1), one melt water sample was obtained from the end of the ditch along the southern boundary of the property (SW2), and one groundwater sample was again collected from monitoring well BH1 (BH01). The locations of the snow melt samples were captured using a handheld Garmin GPS 12 device and are illustrated in **Figure 3.1**.

Snow Stockpile Sampling Procedures

On March 5, 2008 a snow stockpile sample (SN01) was obtained by collecting five representative sub-samples (S1 to S5) throughout the stockpile at a depth of 30 cm beneath the stockpile surface, vertically staggered throughout the slope of the pile. Sampling equipment included a shovel, pail, and scoop which were cleaned prior to each use, and handled using clean nitrile gloves. Using the scoop, the sub-samples were collected, placed in the pail and individually mixed to create a more homogenous snow sample. Each sub-sample was then sealed in a plastic Ziploc bag with a minimal volume of air, and placed in a cooler with ice packs to facilitate a slow melt while maintaining a cool temperature. The following morning the five partially melted snow samples were poured from the Ziploc bags into a cleaned pail and mixed (to increase homogeneity) using a scoop to create a composite liquid sample (SN01). The sample was dispensed from the pail into clean laboratory bottles, which were preserved according to laboratory requirements. The bottles were tightly sealed and placed into a plastic Ziploc bag and then placed in a cooler with ice packs for delivery to Maxxam Analytics Inc. of Winnipeg, Manitoba for analysis.

Melt Water Sampling Procedures

On May 26, 2008 melt water samples were obtained from the pond adjacent to the snow stockpile (SW1), and from the end of the ditch along the southern boundary of the property (SW2).

The samples were collected with a cleaned pail and dispensed into clean laboratory bottles, which were preserved as necessary. New nitrile gloves were used to eliminate the potential for cross-contamination between samples.

For each sample, the containers were tightly sealed and placed into a plastic Ziploc bag and then placed in a cooler with ice packs for delivery to Maxxam Analytics Inc. of Winnipeg, Manitoba for analysis.

Groundwater Sampling Procedures

On both March 5 and May 26, 2008 groundwater samples BH1 and BH01 were obtained from groundwater in monitoring well BH1, respectively. The groundwater samples were collected using the following procedure:

- Groundwater elevations were measured in all the 27 on-site wells prior to groundwater sample collection.
- The monitoring well was developed using a new, dedicated, 4 cm diameter disposable polyethylene bailer to remove three times the well volume of groundwater (28 L) or until the well was effectively dry. The volume of removed water was measured to ensure that sufficient purging was achieved. The well was allowed to recover prior to the collection of samples for field and laboratory analysis for approximately two hours.
- Each dedicated bailer was handled using new nitrile gloves to eliminate the potential for cross-contamination between monitoring wells.
- The water samples were dispensed from the bailers into clean laboratory bottles, and were preserved according to laboratory requirements.
- The containers were tightly sealed and placed into plastic Ziploc bags which were then placed in a cooler with ice packs for delivery to Maxxam Analytics Inc. of Winnipeg, Manitoba for analysis.
- All the purge water from the well was disposed of on-site.

3.1.3 Groundwater Monitoring

On both March 5 and May 26, 2008 groundwater elevation measurements were measured at 27 on-site monitoring wells and three off-site monitoring wells. Groundwater elevations were determined by measuring the distance from the top of the polyvinyl chloride well casing of known elevation to the static water level with an Solinst Model #122 Interface Meter.

3.1.4 Laboratory Analytical Program

The initial leachate samples collected on March 5, 2008 were submitted to Maxxam Analytics Inc. for analysis of alkalinity, ammonia, chloride, chemical oxygen demand (COD), conductivity, hardness, total oil and grease, pH, sulphate, total kjeldahl nitrogen (TKN), total phosphorus, metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, sodium, nickel, potassium, zinc, mercury), and total suspended solids (TSS). For the second leachate sampling event on May 26, 2008, collected samples were also analyzed for benzene, phenol, biochemical oxygen demand (BOD), and methane parameters.

The initial snow melt samples collected on March 5, 2008 were submitted to Maxxam for analysis of COD, chloride, nitrate, metals (calcium, chromium, iron, lead, magnesium, sodium, nickel), sulphate, total phosphorus, and TSS. For the snow melt samples collected on May 26, 2008, BOD was also analyzed.

All samples were delivered to the laboratory for analysis within one day of sample collection. All samples were kept in a cooler with ice packs during transport to reduce temperature fluctuations prior to analysis.

Copies of the chains of custody, laboratory Quality Assurance/Quality Control reports, and laboratory certificates of analysis can be found in the Appendix.

3.1.5 Quality Assurance/Quality Control Program

As outlined in **Sections 3.1.1** and **Sections 3.1.2**, Earth Tech AECOM. field personnel followed pre-defined field procedures for quality control. These procedures ensured that representative samples were collected and that the risk of cross-contamination was minimized.

For the initial sampling event on March 5, 2008 a trip blank was also submitted for laboratory analysis for quality assurance. A trip blank is distilled water that is provided by the testing laboratory. The distilled water bottles are not opened at any time during the sample collection or shipping process. The trip blank is used to identify potential errors in the laboratory procedures, such as bottle washing and sample handling. If the trip blank is handled properly, all analytes should be reported as below detectable limits.

During the second sampling event on May 26, 2008 two replicate samples, BH01A (replicate of BH01) and LCH01A (replicate of LCH01), were collected in the field and submitted for laboratory analysis for quality assurance. Due to the heterogeneous nature of leachate, replicate samples were collected to assess the variability of the leachate strength. For each sample pair, the results were averaged and used as a best representative sample, or the maximum values were use to facilitate conservative estimates.

3.2 SELECTION OF APPLICABLE ENVIRONMENTAL QUALITY GUIDELINES

The results of the laboratory snow melt analyses have been compared to Manitoba Conservation's Water Quality Standards, Objectives, and Guidelines (2002) for surface water (SWQG).

3.3 LEACHATE LOADING AND CHARACTERIZATION

For the City's landfill, a regular leachate monitoring program has not been in place. Site specific data needed to be collected and analyzed to obtain information regarding the leachate's quantity and quality. With the help of the City's landfill operation staff, the leachate was sampled and tested on March 5, 2008 and May 26, 2008 to determine the leachate characteristics during freezing and melt off periods. The samples were collected from locations identified in **Figure 3.1**.

Leachate from Cell No. 7 joins with the leachate generated from Cells No. 11 and No. 12 and is collected by a common manhole. Utilizing an electric pump through a manhole located at the north end of Cell No. 11, the leachate is then conveyed to the sewage treatment plant via the trunk sewer pipe. Sample LCH02 was extracted from this manhole.

Cell No. 8 (1996), Cell No. 9 (1998), and Cell No. 10 (1999) drain into manholes located along the southern boundary of the property which are the manholes that are manually pumped out. Sample LCH01 was collected from the manhole located south of the Cell No. 10.

3.3.1 Leachate Loading

There is no leachate loading information for Cell No's. 1 to 6. These self-contained clay-lined cells are the oldest cells and leachate pumping has not been required from these cells.

To avoid pump system freezing, the operation staff does not pump leachate from the system from the first or second week of November until the following spring. In 2008, the operation staff indicated that the pumping of the leachate started in the last week of March at a rate of approximately 3.2 to 3.5 L/s (50 to 55 gpm) and operated continuously for approximately five weeks to pump leachate that had accumulated during the winter months. Following the initial pumping, additional pumping has been conducted intermittently. According to information provided by the landfill operation staff, an average of 0.13 L/s (2 gpm) has been estimated as the pumping rate for the rest of pumping period. Based on above information, the leachate quantity from Cells 7 to 12 can be estimated as follows:

- From the middle of November to the end of April (approximately 165 days), the pumped leachate quantity was 3.5 L/s (55 gpm) * 3,600 sec/hr * 24 hr/d * 35 d = 2,772,000 imperial gal = 10,500 m^3

?

- Starting from beginning of May to the middle of November (approximat days), the leachate quantity would be 0.13 L/s (2 gpm) * 60 min/hr * 24 hr/d = 576,000 imperial gal = 2,180 m^3
- Total of the above is 10,500 m^3 + 2,180 m^3 = 12,680 m^3

Leachate generated from the eight to tenth cells is mixed together. Based on the information provided by landfill operation staff, 150,000 kg of leachate was hauled to municipal sewage treatment plant in 2001. About two to three years ago, approximately two to three loads (3,000 gallons each) were hauled. It is expected that there may be a similar number of loads required for the year 2008. Based on above information, this stream of leachate quantity can be estimated as following:

- Assume the density of leachate is 1,000 kg/m^3, then 150,000 kg = 150 m^3
- Three loads of 3,000 gallons each = 9,000 imperial gal = 34 m^3

For comparison purposes, the hauled leacbate is only about 0.27 to 1.2 percent of the pumped leachate quantities, which is not significant.

The total leachate quantity is the sum of pumped stream and hauled stream, which is approximately 12,714 m^3 to 12,830 m^3/year.

3.3.2 Leachate Characterization

Leachate characteristics vary significantly from one landfill to another depending upon the type of material being landfilled, age of the landfill, and the climatic and environmental factors. Usually leachate contains both dissolved and suspended materials, and the contaminants can be divided into four groups: dissolved organic matter (alcohols, acids, aldehydes, short chain sugars etc.), inorganic macro components (common cations and anions including sulfate, chloride, iron, aluminum, zinc and ammonia), heavy metals (lead, nickel, copper, mercury), and xenobiotic organic compounds such as halogenated organics (Polychlorinated biphenyls, dioxins etc.). Leachate from new landfill cells usually has high concentrations of organic matter and nitrogen. As landfill cells age, the landfill material becomes more stabilized; therefore the leachate from such cells has generally lower nitrogen and organic contents. Moreover, the concentration of phosphorus and heavy metals in leachate from old landfill cells are usually low. The anaerobic conditions cause precipitation of the heavy metals by binding them to other compounds such as sulfides. As a result, the leachate from stabilized cells (old cells) carries much lower pollutant loadings than the leachate from new cells. A summary of key leachate characteristics, based on literature review, is shown in **Table 3.1**.

Table 3.1: General Leachate Characteristics of Old and New Landfill Cells

Parameter	Unit	Old Landfill	New Landfill
pH	-	6.6 to 8.0	4.5 to 8.9
BOD	mg/L	50 to 200	2,000 to 20,000
COD	mg/L	100 to 3,000	3,000 to 40,000
NH_4-N	mg/L	20 to 40	10 to 2,000
Total-P	mg/L	5 to 10	5 to 100
VFAs	mg/L	50 to 100	9,000 to 25,000

For the City's landfill characterization, similar old cell versus new cell correlations were analyzed. **Table 3.2** shows the results of leachate laboratory analysis. For comparison purposes, historical analysis data from 2002 is also listed. Older cells are related to the landfill cells that are older than 6 years while newer cells represent newer landfill cells established after the year 2002.

Based on the results presented in **Table 3.2**, the following conclusions can be made:

- A comparison of lab analysis results shows that the concentrations of most pollutants in sample LCH02 are much higher than those in sample LCH01 (hardness, total ammonia, total COD, conductivity, TKN, total phosphorus, TSS, dissolved sulphate, alkalinity, metals, methane gas, BTEX and F1 hydrocarbons, etc.).
- The pH of all leachate samples range from 7.6 to 7.9, which is a suitable range for biological treatment processes.
- Average BOD_5 concentrations from sample LCH02 are approximately 3.8 times the sample concentrations from LCH01.
- Average COD concentrations from sample LCH02 are approximately three times the sample concentrations from LCH01.
- TKN concentrations in both samples LCH01 and LCH02 are almost equal to the total ammonia concentration, which indicates nitrogen in the leachate is mainly composed of ammonia nitrogen (NH_4-N). Ammonia nitrogen contributes to approximately 82.4% to 100% of TKN.
- The nitrate and nitrite concentrations of the leachate samples are negligible.
- Total suspended solids content of the leachate samples ranges from 10 mg/L to 120 mg/L. The concentration of total suspended solids for sample LCH02 ranges from 2 to 12 times the concentration of sample LCH01.
- Total phosphorus content from LCH02 is much higher than LCH01 for both leachate sample collection dates.

Table 3.2: City of Brandon Leachate Characteristics

Parameters	Units	5-Mar-08			26-May-08				Historical			
		LCH01	LCH02	Trip Blank	LCH01	LCH01A	LCH01/01A Average	LCH02	New cells		Old cells	
Hardness (CaCO3)	mg/L	2000	2300	<1	1000	1800	1400	2200				
Inorganic Parameters												
Total Ammonia-N	mg/L	210	480	0.09	260	240	250	460	222	183	21.2	95.6
Total BOD	mg/L	-	-	-	32	17	24.5	92	-	-	-	-
Total Chemical Oxygen Demand (COD)	mg/L	320	920	<4	330	320	325	1000	589	759	328	272
Conductivity	umho/cm	10000	13800	<2	8330	9960	9145	12600	8480	11600	2730	4370
Total Kjeldahl Nitrogen (TKN)	mg/L	210	520	0.3	260	200	230	560	224	189	24.9	98.8
pH	pH units	7.7	7.7	6.6	7.9	7.6	7.75	7.9	7.25	7.62	7.68	7.08
Phenols-4AAP	mg/L	-	-	-	0.1	0.105	0.1025	0.75	-	-	-	-
Total Phosphorus	mg/L	0.84	5.2	0.011	0.15	0.27	0.21	3.9	0.25	0.22	0.06	0.08
Total Suspended Solids	mg/L	10	120	<10	10	13	11.5	26	380	380	65	140
Dissolved Sulphate (SO_4)	mg/L	113	<20	<1	321	78	199.5	279	-	-	-	-
Alkalinity (Total as $CaCO_3$)	mg/L	3290	5130	2	2420	3230	2825	4190	-	-	-	-
Dissolved Chloride (Cl)	mg/L	1600	1900	<1	1300	1500	1400	1900	-	-	-	-
Petroleum Hydrocarbons												
Total Oil & Grease	mg/L	4.1	5.7	<0.5	2.6	2.2	2.4	1.2	-	-	<5	10
Metals												
Mercury (Hg)	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0005	<0.0005	<0.0005	<0.0005
Total Arsenic (As)	mg/L	0.055	0.062	<0.001	0.1	0.097	0.0985	0.062	<0.05	<0.05	<0.05	<0.05
Total Cadmium (Cd)	mg/L	<0.0001	<0.0005	<0.0001	<0.0001	<0.0001	-	0.0001	0.003	<0.003	<0.003	<0.003
Total Calcium (Ca)	mg/L	230	180	<0.2	240	230	235	230	-	-	-	-
Total Chromium (Cr)	mg/L	0.006	0.03	<0.005	0.011	0.01	0.0105	0.022	0.003	<0.003	<0.003	<0.003
Total Copper (Cu)	mg/L	<0.001	<0.005	<0.001	<0.001	0.001	0.001	0.002	0.1	0.153	0.091	0.041
Total Iron (Fe)	mg/L	1.9	14	<0.1	0.6	0.6	0.6	5.4	-	-	-	-
Total Lead (Pb)	mg/L	<0.0005	<0.003	<0.0005	<0.0005	<0.0005	-	0.0015	<0.01	<0.01	<0.01	<0.01
Total Magnesium (Mg)	mg/L	400	600	<0.05	440	420	430	510	-	-	-	-
Total Manganese (Mn)	mg/L	0.68	0.72	<0.002	1.3	1.2	1.25	0.65	-	-	-	
Total Nickel (Ni)	mg/L	0.07	0.2	<0.001	0.1	0.098	0.099	0.18	0.083	0.129	0.024	0.05
Total Potassium (K)	mg/L	170	440	<0.2	210	200	205	420	242	245	50.2	108
Total Sodium (Na)	mg/L	920	1700	<0.1	1200	1200	1200	1500	-	-	-	-
Total Zinc (Zn)	mg/L	0.006	0.04	0.007	<0.005	0.007	-	0.051	0.167	0.213	0.0885	0.052
Fixed Gases												
Methane	L/m^3	-	-	-	14	19	16.5	25	-	-	-	-
Methane	mg/L	-	-	-	9.3	12.7	11	16.6	-	-	-	-
BTEX & F1 Hydrocarbons												
Benzene	ug/L	-	-	-	3.4	3.7	3.55	7	-	-	-	-
Toluene	ug/L	-	-	-	5.5	6.1	5.8	360	-	-	-	-
Ethylbenzene	ug/L	-	-	-	15	16	15.5	27	-	-	-	-
o-Xylene	ug/L	-	-	-	14	15	14.5	20	-	-	-	-
p+m-Xylene	ug/L	-	-	-	37	42	39.5	61	-	-	-	-
Total Xylenes	ug/L	-	-	-	51	58	54.5	81	-	-	-	-
Surrogate Recovery (%)												
1,4-Difluorobenzene	%	-	-	-	95	98	96.5	96	-	-	-	-
4-Bromofluorobenzene	%	-	-	-	119	114	116.5	107	-	-	-	-
D10-Ethylbenzene	%	-	-	-	98	100	99	100	-	-	-	-
D4-1,2-Dichloroethane	%	-	-	-	96	91	93.5	88	-	-	-	-

Note: Sample LCH01 ages from 9 to 12 years, and sample LCH02 ages from 5 to 14 years.

- Concentrations of metals (mercury, arsenic, cadmium, calcium, chromium, copper, lead, magnesium, manganese, nickel, potassium, sodium and zinc), with the exception of total iron and total nickel, were low in all the leachate samples tested
- Methane concentrations range from 9.3 to 16.6 mg/L, which is much higher than the 0.14 mg/L permissible discharge concentration of dissolved methane stated by most sewage treatment authorities under the European Union ATEX Directive.

3.4 SNOW MELT LOADING AND CHARACTERIZATION

In order to recommend environmentally sound snow melt management options, the information regarding snow melt loading and characteristics needed determination. Samples were also collected from the snow melt-off streams. With the help of the City's landfill operation staff, the snow melt-off was sampled and tested on March 5, 2008 and May 26, 2008 to determine melt-off characteristics representative of freezing and melting periods. The samples were collected from locations identified in **Figure 3.1**.

3.4.1 Snow Melt Loading

No accurate data was available on the quantity of the snow melt water. However, the City provided the volume of snow dumped for the winter seasons of 2006 – 2007 and 2007 – 2008. There is also no accurate representative data on the snow densities at the disposal site. The common values of snow densities range from 0.4 to 0.6 during the beginning of the spring thaw. The water equivalency is then calculated by multiplying the snow density by the dumped snow volume. **Table 3.3** shows the summary of the past two winters' snow dump volume data (from City of Brandon records) and calculated snow melt volume.

Table 3.3: Snow Dump Volume Summary (density 0.4 to 0.6)

Year	Snow Volume Cubic yards	Snow Volume (m^3)	Snow melt Volume (m^3)
2006-2007	48,040	36,729	14,692 to 22,037
2007-2008	49,000	37,463	14,985 to 22,478

Based on historical climate information, City of Brandon temperatures rose above 0°C in late March or early April. City staff have observed that snow has remained in the stockpile until the middle of June over the last two years. Thus, the snow melting period is about 75 days or 2.5 months. The estimated average snow melt flow rate is 300 m^3/day (to be conservative, the larger snow melt volume of 22,478 m^3 was used for the calculation). Assuming that 80% of snow melts within 15 days, this would result in a maximum daily melt water flow rate of approximately 1,200 m^3/day.

3.4.2 Snow Melt Characterization

In order to characterize snow melt and to recommend environmentally sound management options, the collected samples were analyzed for the parameters listed in **Table 3.4**. The list of analytes was derived based on experience at other locations.

Sample SN01 represents the slower snow melting period of early spring, while both sample SW1 and SW2 represent the accelerated snow melting period of late spring. As shown in **Table 3.4**, the strength of sample SN01 is greater than sample SW1 and SW2 in terms of COD, total phosphorus, TSS, dissolved chloride, and most metals. The strength of sample SW2 is greater than sample SW1 in terms of dissolved sulphate and some metals including boron, cadmium, chromium, lithium, magnesium, selenium, strontium and uranium. The trend of greater snow melt strength at the slow snow melting period corresponds with MacPlan's investigation on snow melt done in 1992 in Winnipeg, and a number of other studies in Canada on snow dump site melt-water quality. During past studies, high levels of chloride, lead, iron, phosphorus, BOD, and TSS have been reported in snow dump runoff. It has been noted that the high level of dissolved chloride has a significant relationship with street salt program, and the level of lead is related to the number of automobiles in the snow collecting area.

Adverse impacts of melt-water on aquatic life are typically related to elevated levels of metals, organic toxicants, and salt. The runoff of excess road salt has caused extensive contamination of surface and groundwater. However, further study is warranted to calculate dilution rates and the resulting net impact on the water body.

As indicated in **Table 3.4**, the following parameters exceed or may exceed the Surface Water Quality Guidelines (SWQG):

- There is no BOD data available for the slow snow melting period. However, based on the COD analysis result of 400 mg/L, BOD would probably exceed the 30 mg/L SWQG.
- TSS is 43 times greater than the SWQG during the slow snow melting period.
- Dissolved chloride exceeds the SWQG in various locations during both sampling events. It is likely that this is the result of salt application on city streets. The investigation of snow melt characteristics in the City of Winnipeg completed by MacPlan in 1992 indicated that higher chloride concentrations occurred at the beginning of the snow melt season and did not correspond to the peak snow melt flow rate. This phenomenon might be caused by the high solubility of chloride which makes it readily leachable as the water percolates down through the snow pile at the early stage of snow melt season.

Table 3.4: City of Brandon Snowmelt Characteristics

Calculated Parameters	Units	5-Mar-08		26-May-08					Surface Water Quality Guideline
		SN01	BH1	SW1	SW2	BH01	BH01A	BH01/01A Average	
Inorganics									
Total Ammonia-N	mg/L	-	-	-	-	-	-	-	4
Total BOD	mg/L	-	-	<2	<2	<2	<2	<2	30
Total Chemical Oxygen Demand (COD)	mg/L	400	20	30	29	4	16	10	-
Conductivity	umho/cm	-	-	-	-	-	-	-	1000
Total Kjeldahl Nitrogen (TKN)	mg/L	-	-	-	-	-	-	-	-
pH	pH unit	-	-	-	-	-	-	-	6.5-9
Phenols-4AAP	mg/L	-	-	-	-	-	-	-	0.004
Total Phosphorus	mg/L	3.5	0.02	0.095	0.039	0.072	0.14	0.106	N/A
Total Suspended Solids (TSS)	mg/L	**1300**	**71**	**60**	19	**120**	**120**	**120**	30
Dissolved Sulphate (SO_4)	mg/L	12	215	62	314	279	278	278.5	N/A
Dissolved Chloride (Cl)	mg/L	**720**	25	**490**	**340**	32	33	32.5	250
Nitrite (N)	mg/L	0.07	<0.01	-	-	-	-	-	-
Nitrate (N)	mg/L	2	<0.1	1	170	<0.1	<0.1	<0.1	-
Nitrate + Nitrite	mg/L	2	<0.1	-	-	-	-	-	-
Metals									
Mercury (Hg)	mg/L	-	-	-	-	-	-	-	0.0001
Total Aluminum (Al)	mg/L	-	-	0.41	0.035	0.51	0.45	0.48	-
Total Antimony (Sb)	mg/L	-	-	0.0007	<0.0005	<0.0005	<0.0005	<0.0005	-
Total Arsenic (As)	mg/L	0.024	0.032	0.002	<0.001	0.031	0.03	0.0305	0.15
Total Barium (Ba)	mg/L	-	-	0.14	0.12	0.042	0.039	0.0405	-
Total Beryllium (Be)	mg/L	-	-	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-
Total Bismuth (Bi)	mg/L	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	-
Total Boron (B)	mg/L	-	-	0.08	0.51	0.15	0.13	0.14	-
Total Cadmium (Cd)	mg/L	**0.0034**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0024
Total Calcium (Ca)	mg/L	160	190	74	380	180	180	180	1000
Total Chromium (Cr)	mg/L	0.067	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.074
Total Cobalt (Co)	mg/L	-	-	0.0011	<0.0005	0.0008	0.0008	0.0008	-
Total Copper (Cu)	mg/L	**0.085**	0.004	0.004	0.002	0.002	0.002	0.002	0.009
Total Iron (Fe)	mg/L	**52**	**3.1**	**1.2**	<0.1	**3**	**2.8**	**2.9**	0.3
Total Lead (Pb)	mg/L	**0.13**	0.0015	**0.0094**	<0.0005	**0.0048**	0.0012	**0.003**	0.0025
Total Lithium (Li)	mg/L	-	-	0.012	0.079	0.055	0.053	0.054	-
Total Magnesium (Mg)	mg/L	46	65	29	120	61	58	59.5	-
Total Manganese (Mn)	mg/L	3.2	0.88	0.39	0.024	0.8	0.8	0.8	-
Total Molybdenum (Mo)	mg/L	-	-	0.006	0.002	0.012	0.011	0.0115	-
Total Nickel (Ni)	mg/L	**0.061**	0.005	0.005	<0.005	0.004	0.004	0.004	0.052
Total Potassium (K)	mg/L	19	8.6	15	23	8.3	8.2	8.25	-
Total Selenium (Se)	mg/L	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	-
Total Silicon (Si)	mg/L	-	-	2.5	1.5	15	15	15	-
Total Silver (Ag)	mg/L	-	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Total Sodium (Na)	mg/L	530	13	320	160	12	11	11.5	-
Total Strontium (Sr)	mg/L	-	-	0.17	0.69	0.7	0.7	0.7	-
Total Tellurium (Te)	mg/L	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	-
Total Thallium (Tl)	mg/L	-	-	<0.00005	0.00008	<0.00005	<0.00005	<0.00005	-
Total Thorium (Th)	mg/L	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	-
Total Tin (Sn)	mg/L	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	-
Total Titanium (Ti)	mg/L	-	-	0.017	<0.005	0.025	0.02	0.0225	-
Total Tungsten (W)	mg/L	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	-
Total Uranium (U)	mg/L	-	-	0.0009	0.0078	0.0039	0.0039	0.0039	-
Total Vanadium (V)	mg/L	-	-	0.002	<0.001	0.003	0.003	0.003	-
Total Zinc (Zn)	mg/L	**0.63**	0.018	0.055	0.019	0.019	0.016	0.0175	0.12
Total Zirconium (Zr)	mg/L	-	-	<0.001	<0.001	0.001	0.001	0.001	-

Notes:

BH1: groundwater sample collected from monitoring well BH1 on March 5, 2008.

BH01: groundwater sample collected from monitoring well BH1 on May 26, 2008.

BH01A: replicate of sample taken from monitoring well BH1 on May 26, 2008.

SN01: composite sample from five locations throughout the snow stockpile as indicated in Figure 3.1.

SW1: from the pond adjacent to the snow pile.

SW2: from the end of the ditch along the southern boundary of the property.

The analysis results exceeded surface water quality guidelines are shown in bold.

Table 3.5: Results of Groundwater Monitoring

Monitoring Well ID	Top of Monitoring Well Elevation (m)	Groundwater Elevation March 5, 2008 (m)	Groundwater Elevation May 26, 2008 (m)
BH1	370.460	361.119	361.008
BH2	369.193	363.559	363.738
BH2D	369.252	358.564	358.355
BH3	365.730	360.782	361.437
BH3-5E	363.570	360.474	361.905
BH3-5W	363.651	360.880	360.977
BH4	368.804	dry	365.300
BH4M	368.940	363.075	363.539
BH4D	368.850	358.061	358.363
BH5	362.494	356.029	355.823
BH5D	362.556	353.282	352.742
BH5W	363.060	355.762	355.473
BH6	361.346	354.524	354.015
BH7	361.687	354.802	354.345
BH8	361.838	355.629	355.383
BH8W	362.008	355.732	355.544
BH9	362.778	357.668	358.116
BH10	361.508	357.459	357.619
BH10D	361.763	353.739	353.207
BH11	361.808	356.163	356.119
BH11D	361.818	356.141	356.101
BH12	377.889	dry	dry
BH13	363.654	359.463	359.468
BH14	366.667	361.795	362.096
BH15	368.963	365.446	365.640
BH16	369.716	365.521	365.693
BH17	368.887	361.030	361.133
BH18	363.825	359.693	359.749
BH19	362.523	355.500	355.105
BH20	370.660	365.120	365.373

- Some metals exceeded the SWQG, including cadmium, copper, iron, lead, nickel and zinc. MacPlan also found that the lead concentrations were higher in the middle and at the end of the melt season in the City of Winnipeg. Contrary to the characteristics of chloride, the low solubility of lead resulted in it being combined with solids contained in the snow melt water.

3.5 GROUNDWATER MONITORING RESULTS

On March 5, 2008, groundwater elevations ranged from 353.282 m (BH5D) to 365.521 m (BH16). On May 26, 2008, groundwater elevations ranged from 352.742 m (BH5D) to 365.693 m (BH16). The average groundwater elevation in the shallow groundwater aquifer was 359.444 m on March 5, 2008 and 359.775 m on May 26, 2008. The calculated groundwater elevations measured in the wells are presented in **Table 3.5**. Based on both the March and May 2008 data, groundwater generally enters the landfill from the south and west and trends to the northeast. **Figure 3.2 and Figure 3.3** illustrate the inferred shallow groundwater elevation contours and direction of flow at the site on March 5 and May 26, 2008, respectively.

3.6 QUALITY ASSURANCE/QUALITY CONTROL RESULTS

Generally speaking with respect to the trip blank submitted for quality control purposes from the initial sampling event on March 5, 2008, all parameters were reported below detectable limits, with the exception of total ammonia (0.09 mg/L), total kjeldahl nitrogen (0.3 mg/L), total phosphorus (0.011 mg/L), alkalinity (2 mg/L), and total zinc (0.007 mg/L). As listed in **Table 3.2**, these parameters reported concentrations which were above laboratory detectable limits, but are not a concern given the very low concentrations.

The average of LCH01 and LCH01A sample results are presented in **Table 3.2** to more accurately represent the strength of the leachate. The average of BH01 and BH01A sample results are presented in **Table 3.4**.

3.7 DESIGN CRITERIA

There are two potential approaches for leachate treatment: pretreatment and discharge to the existing municipal wastewater treatment plants (WWTP); or installation of a dedicated mechanical leachate treatment plant.

Based on leachate quantity and quality information as noted in **Table 3.1**, the design criteria for leachate treatment can be determined. To be conservative, values from sample LCH02 were selected as the basis for the design calculations.

3.7.1 Pre-treatment

Since the strengths of leachate are normally significantly greater than most municipal wastewater, pretreatment may be needed to avoid overloading the municipal wastewater plant. For comparison purposes, the City of Winnipeg Bylaw (Bylaw No.7070/97 consolidation update: March 26, 2008) is referenced to represent typical limits for discharge of leachate to the sewer. **Table 3.6** indicates the City of Brandon's leachate characteristics and the City of Winnipeg's effluent requirements to identify when pre-treatment is necessary.

Table 3.6: Leachate Characteristics and Pre-Treatment Effluent Requirements

Parameters	Units	Influent Concentration	Effluent Requirement (Bylaw No.7070/79)
Hardness (CaCO3)	mg/L	2,250	N/A
Inorganics			
Total Ammonia-N	mg/L	470	N/A
Total BOD	mg/L	92	300
Total COD	mg/L	960	N/A
Conductivity	umho/cm	13,200	N/A
TKN	mg/L	540	N/A
pH	pH	7.5 - 8.0	5.5 - 11.0
Temperature	°C	--	61
Phenols-4AAP	mg/L	0.75	N/A
Total Phosphorus	mg/L	4.55	N/A
Total Suspended Solids	mg/L	73	350
Dissolved Sulphate (SO4)	mg/L	279	N/A
Alkalinity (Total as CaCO3)	mg/L	4,660	N/A
Dissolved Chloride	mg/L	1,900	N/A
Petroleum Hydrocarbons			
Total Oil and Grease	mg/L	3.45	100
Metals			
Mercury	mg/L	< 0.0001	0.1
Total Arsenic	mg/L	0.062	1.0
Aluminum	mg/L	--	50.0
Total Cadmium	mg/L	0.0001	0.5
Total Calcium (Ca)	mg/L	205	N/A
Total Chromium (Cr)	mg/L	0.026	5.0
Total Copper (Cu)	mg/L	0.002	5.0
Total Iron (Fe)	mg/L	9.7	N/A
Total Lead (Pb)	mg/L	0.0015	2.0
Total Magnesium (Mg)	mg/L	555	N/A
Total Manganese (Mn)	mg/L	0.685	N/A
Total Nickel (Ni)	mg/L	0.19	5.0
Total Potassium (K)	mg/L	430	N/A
Total Sodium (Na)	mg/L	1,600	N/A
Silver (Ag)	mg/L	--	5.0
Total Zinc (Zn)	mg/L	0.0455	5.0

Table 3.6: Leachate Characteristics and Pre-Treatment Effluent Requirements (continued)

Parameters	Units	Influent Concentration	Effluent Requirement (Bylaw No.7070/79)
Fixed Gases			
Methane	L/m^3	25	N/A
Methane	mg/L	16.6	N/A
Benzene	ug/L	7	N/A
Toluene	ug/L	360	N/A
Ethylbenzene	ug/L	27	N/A
o-Xylene	ug/L	20	N/A
p+m-Xylene	ug/L	61	N/A
Total Xylenes	ug/L	81	N/A
Surrogate Recovery (%)			
1,4-Difluorobenzene	%	96	N/A
4-Bromofluorobenzene	%	107	N/A
D10-Ethylbenzene	%	100	N/A
D4-1,2-Dichloroethane	%	88	N/A

As depicted in **Table 3.6**, most of the leachate parameters analyzed do not exceed the sewer discharge requirements. The pretreatment process may not be needed for Brandon leachate to discharge to the WWTP if temperature, aluminum and silver were not exceeding the requirements. However, the EA licence is anticipated to be changed to no longer allow leachate treatment at the WWTP. In addition, methane concentrations range from 9.3 to 16.6 mg/L (much higher than 0.14 mg/L, the permissible discharge concentration of dissolved methane limited by most sewage treatment authorities under European Union ATEX Directive). In the City's experience, the City has been discharging leachate into the sewer system for many years now and has not observed any adverse effects in the sewage treatment system. To further control the potential risk, the City could schedule maintenance of the sewer system in the area by controlling the discharge of the leachate to prevent any potential safety risk.

3.7.2 Dedicated Mechanical Treatment Plant

If leachate cannot be discharged to the WWTP, SWQGs would apply to effluent discharged from a leachate treatment system. **Table 3.7** shows the influent concentrations (averages of two sampling events) and potential effluent requirements adapted from the SWQG.

Table 3.7: Leachate Treatment Design Criteria

Parameters	Units	Influent Concentration	Effluent Requirement
Hardness (CaCO3)	mg/L	2,250	
Inorganics			
Total Ammonia-N	mg/L	470	4.0
Total BOD	mg/L	92	30
Total COD	mg/L	960	
Conductivity	umho/cm	13,200	1000
TKN	mg/L	540	
pH	pH	7.5-8.0	6.5-9
Phenols-4AAP	mg/L	0.75	0.004
Total Phosphorus	mg/L	4.55	N/A
TSS	mg/L	73	30
Dissolved Sulphate	mg/L	279	N/A
Alkalinity (Total as CaCO3)	mg/L	4,660	
Dissolved Chloride	mg/L	1,900	250
Petroleum Hydrocarbons			
Total Oil and Grease	mg/L	3.45	
Metals			
Mercury	mg/L	< 0.0001	0.0001
Total Arsenic	mg/L	0.062	0.15
Total Cadmium	mg/L	0.0001	0.0024
Total Calcium	mg/L	205	1000
Total Chromium	mg/L	0.026	0.074
Total Copper	mg/L	0.002	0.009
Total Iron	mg/L	9.7	0.3
Total Lead	mg/L	0.0015	0.0025
Total Magnesium	mg/L	555	
Total Manganese	mg/L	0.685	
Total Nickel	mg/L	0.19	0.052
Total Potassium	mg/L	430	
Total Sodium	mg/L	1600	
Total Zinc	mg/L	0.0455	0.12
Fixed Gases			
Methane	L/m^3	25	
Methane	mg/L	16.6	

Table 3.7: Leachate Treatment Design Criteria (continued)

Parameters	Units	Influent Concentration	Effluent Requirement
BTEX			
Benzene	ug/L	7	370
Toluene	ug/L	360	2.0
Ethylbenzene	ug/L	27	90
o-Xylene	ug/L	20	0.3
p+m-Xylene	ug/L	61	
Total Xylenes	ug/L	81	
Surrogate Recovery (%)			
1,4-Difluorobenzene	%	96	
4-Bromofluorobenzene	%	107	
D10-Ethylbenzene	%	100	
D4-1,2-Dichloroethane	%	88	

The treatment system loading rates for the dedicated treatment system have been calculated and summarized in **Table 3.8** below. The average annual loading rate was calculated by using influent concentrations as indicated in **Table 3.7** above, and an estimated flow rate of 12,830 m^3/year (as previously noted). A peaking factor of 1.6 was assumed to determine the peak flow rate of approximately 20,000 m^3/year.

Table 3.8: Leachate Treatment System Loading Rates

Parameters	Average Loading (kg/yr)	Average Loading (kg/d)	Peak Loading (kg/yr)	Peak Loading (kg/d)
Hardness (CaCO3)	28,868	79.1	45,000	123.3
Inorganics				
Total Ammonia-N	6,030	16.5	9,400	25.8
Total BOD	1,180	3.23	1,840	5.04
Total COD	12,317	33.7	19,200	52.6
Conductivity	169,356	464.0	264,000	723.3
TKN	6,928	19.0	10,800	29.6
pH				
Phenols-4AAP	9.6	0.026	15.0	0.041
Total Phosphorus	58.4	0.16	91.0	0.25
Total Suspended Solids	937	2.57	1,460	4.00
Dissolved Sulphate	3,580	9.81	5,580	15.29
Alkalinity (Total as CaCO3)	59,788	163.8	93,200	255.3
Dissolved Chloride	24,377	66.8	38,000	104.1
Petroleum Hydrocarbons				
Total Oil and Grease	44.3	0.12	69.0	0.19
Metals				
Mercury				
Total Arsenic	0.80	0.0022	1.24	0.0034
Total Cadmium	0.0013	3.52E-06	0.0020	5.48E-06
Total Calcium	2,630	7.21	4,100	11.23
Total Chromium	0.334	9.14E-04	0.520	1.42E-03
Total Copper	0.026	7.03E-05	0.040	1.10E-04
Total Iron	124	0.34	194	0.53
Total Lead	0.019	5.27E-05	0.030	8.22E-05
Total Magnesium	7,121	19.5	11,100	30.4
Total Manganese	8.79	0.024	13.70	0.038
Total Nickel	2.44	0.0067	3.80	0.0104
Total Potassium	5,517	15.1	8,600	23.6
Total Sodium	20,528	56.2	32,000	87.7
Total Zinc	0.58	0.0016	0.91	0.0025
Fixed Gases				
Methane	213.6	0.59	332.9	0.91
BTEX				
Benzene	0.090	2.46E-04	0.140	3.84E-04
Toluene	4.619	1.27E-02	7.200	1.97E-02
Ethylbenzene	0.346	9.49E-04	0.540	1.48E-03
o-Xylene	0.257	7.03E-04	0.400	1.10E-03
p+m-Xylene	0.783	2.14E-03	1.220	3.34E-03
Total Xylenes	1.039	2.85E-03	1.620	4.44E-03

Section 4.0
Alternate Management Options

SECTION 4.0
ALTERNATE MANAGEMENT OPTIONS

This section provides leachate and snow melt management options for the City of Brandon (City) based on literature review, leachate loading and characteristics, as well as snow melt loading and characteristics.

4.1 LEACHATE MANAGEMENT OPTIONS

Technically, there are many options and alternatives available for leachate treatment on-site or off-site. These options can be broadly categorized as:

- Option 1 Municipal sewer discharge with or without pre-treatment.
- Option 2 Leachate recirculation or "bioreactor".
- Option 3 A dedicated full treatment system with or without surface discharge which could include a natural evaporation pond; deep well injection; or a dedicated mechanical treatment plant (which may use physical, chemical, biological or thermal processes).

The relevant details of these Options are outlined herein upon which the City could evaluate the selection of potential processes after discussions with the regulator. The evaluation criteria can be based on all or a suitable combination of the following technical considerations.

- Cost effectiveness.
- Capability to meet the stipulated effluent quality requirements.
- Amenable to changes in the leachate quality over time.
- Ability to remove difficult contaminants, i.e. total dissolved solids.

4.1.1 Option 1 Municipal Sewer Discharge With or Without Pre-Treatment

Municipal Sewer Discharge Without Pre-Treatment

Leachate treatment in municipal wastewater treatment plants (WWTP) is often the most economical solution practiced world wide. At present, the landfill leachate generated at the Eastview landfill is discharged to the City's municipal WWTP without any pre-treatment.

There are some general concerns/issues with the leachate discharge to the municipal WWTP. These concerns are shock loading to the municipal WWTP and discharge of containments that are not conventionally handled at the municipal WWTP.

The shock loading has not been a known issue to date with the City's operation which incorporates leachate disposal to the municipal WWTP. Even though, as discussed in **Section 3.0**, none of the tested leachate parameters exceed typical sewer discharge requirements, yet, there are concerns raised by the regulator as to the existence of the non-conventional parameters in the leachate stream which are difficult to track by general sampling and testing.

A partial list of the non-conventional parameters includes heavy metals, complex cyclic organic compounds, Endocrine Disrupting Chemicals (EDC) and prions. Prion proteins, which are known to be somewhat resistant to biodegradation, have not been studied well enough by the wastewater treatment industry. The knowledge of the extent of possible contamination, level of dormancy in the environment and possible treatment is very limited. One option to address the concern of perceived risk of prions entering the wastewater biosolids stream is to manage the prion related contamination at the landfill site. The City can prohibit, if not already done, the burial of the dead animal carcasses at the landfill site. If the City is able to manage this risk, the concerns can be addressed to some degree.

Upon discussions with the regulator, another parameter of concern is EDC's. Similar to the prions, the knowledge database on the effect, treatment and extent of contamination level is very limited. From literature, there is some evidence indicating possible removal of some EDC's through the biological treatment processes; however, the results are not conclusive.

Therefore, prior to implementing a solution for the treatment of EDC or prion type contaminants, a full understanding of the contaminant characteristics is essential. The understanding of the full impact and chemistry of these chemicals is still at the early stages of research work. Because of the perceived concerns, it is expected by the regulator that some degree of enhanced treatment be implemented and the effluent not to be discharged to the municipal WWTP.

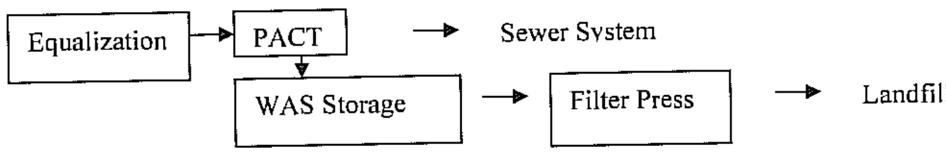
Even though discharge to the sewer is one of the most economical solutions for the leachate treatment, the regulator is expected to impose restrictions on the leachate discharge to the municipal WWTP system. Therefore, this option has not been carried forward for any further review. If the City wishes to pursue this Option further, a detailed scientific study analyzing the impact of the leachate discharge on the biosolids stream and municipal WWTP effluent can be conducted which would incorporate a comprehensive laboratory analysis and desktop research work.

The cost to conduct such a research study would be dependent upon the extent of laboratory work required and regulator discussions.

Municipal Sewer Discharge with Pre-Treatment

As outlined in **Section 2**, there are no existing discharge standards for specific leachate disposal. The system design for the pre-treatment would be a suitable approach base. It is known from past literature studies that some of the recalcitrant chemicals that are known to exist in the leachate streams can be removed to some degree by activated carbon adsorption and biological treatment. One approach that the City could follow for the pre-treatment would be the implementation of a PACT® type of system for the pre-treatment. Some degree of flow equalization would be required upstream of the PACT system. The methane generation concerns can be mitigated by providing all the system components upstream of the PACT as explosion proof. It is anticipated that as the leachate stream approaches the aeration tank (PACT tank), the methane will dissipate from the solution. Controlled headspace air extraction can be designed to avoid any build-up in the plant area.

Based on the above approach the treatment train will be as follows:



4.1.2 Leachate Recirculation

Leachate recirculation is commonly practiced and is a relatively economical leachate reduction technique. However, this type of technique should only be applied to an adequately lined landfill which is complimented with groundwater monitoring to detect the potential failure of the designed liner. Leachate recirculation can, and should only, be employed in appropriately designed and constructed composite lined landfills as the lower liner serves as a leak detection system for its upper liner. In addition to the above requirements and concerns, a well established methane recovery system is also required to address the issue of greenhouse gas emissions.

For the City's landfill, the existing cells have not been designed with a future consideration for the implementation of a recirculation system. Any retrofit modifications required to meet the requirements of a recirculation system would likely be cost prohibitive. If implemented as such, it may result in continued accumulation of leachate in the landfills cells, a rise in the head of leachate and the potential for breakthrough of the landfill liner system. The risk associated with leachate breakthrough is the contamination of surrounding ground water system. For these reasons, leachate recirculation is not recommended as a leachate management option for the existing cells of the Eastview landfill.

4.1.3 Dedicated Full Treatment Option

A dedicated full treatment plant is another option for leachate treatment for the City. In practice, a leachate evaporation pond or a mechanical leachate treatment plant are two potentially viable alternatives.

Due to shallow groundwater conditions and other sensitivities associated with groundwater resources in the area, deep well injection has not been considered any further.

Leachate Evaporation Pond

An evaporation pond is a relatively simple and cost effective leachate management system. To determine the feasibility of an evaporative pond for leachate management, evaporation and precipitation in the Brandon region as well as leachate generation rates at the Brandon facility were examined.

Precipitation data was obtained from Environment Canada for the Brandon meteorological station (latitude 49° 54.600' N, longitude 99° 57.000' W) for the period of record of 1941 to 2007 (Environment Canada 2008a). To account for wet years in evaporation pond sizing, the 95th percentile for precipitation at Brandon was determined. The evaporation pond sizing was based on the annual precipitation value below which 95% of the observations occur. The 95th percentile was determined to be 587 mm. As a comparison, Climate Normals for Brandon were examined and the average annual precipitation in Brandon was 472 mm (Environment Canada 2008b).

According to Agriculture and Agri-Food Canada, the mean annual gross evaporation in the Brandon area is approximately 790 mm (Agriculture and Agri-Food Canada 2008). As evaporation rates of leachate will be less than that of water due to salinity, the mean annual gross evaporation was reduced by 10% to 711 mm/year to account for the presence of salts and their impact on evaporation (INEEL 2001).

The difference between the salinity-corrected gross evaporation and 95th percentile for precipitation is the estimated amount of leachate that can be evaporated on an annual basis and is shown in the following **Table 4.1**.

Table 4.1: Amount of leachate that can be evaporated on an annual basis based on 95th percentile for precipitation

Gross Evaporation (corrected for salinity)	711 mm
Precipitation (95th Percentile)	587 mm
Estimated amount of leachate that can be evaporated	124 mm

As indicated in **Section 3.3.1**, an estimated maximum of 12,830 m^3 of leachate is generated at the Brandon facility on an annual basis. Based on the estimated amount of leachate that can be evaporated, an average of 103,500 m^2 of evaporation pond surface area could be required (12,830 m^3/ 0.124 m = 103,500 m^2).

Based on the analysis above, some of the issues that need to be addressed for this Option are as follows:

- Climatic conditions (i.e. long winter period and short dry summer season, low average temperature and evaporation rate) dictate the requirement for a large land area to implement evaporation pond Option. The City's landfill does not have sufficient land available for this purpose. Selection of other locations in the community could result in several concerns such as odour in the neighbouring residential areas as well as the costs associated with the hauling of the leachate.

- An evaporation pond needs to be well lined to prevent groundwater contamination.

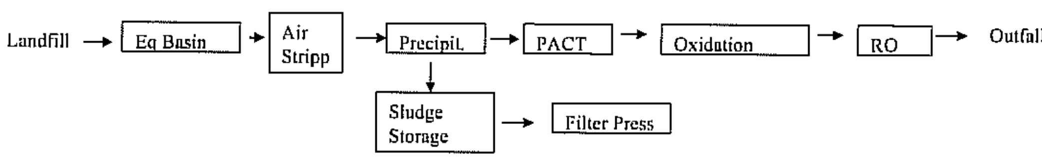
It is understood that the existing Cell 4 at the Brandon lagoon site would no longer be utilized for the Wyeth's wastewater storage in the near future (25 years). One possible Option is to consider the available lagoon cell for use as a landfill leachate evaporation pond. If City wishes to implement this Option, some modifications of the existing Cell 4 may be required. Once implemented, the leachate could be hauled to the evaporation pond on batch mode basis. On periodic basis, the dried solids would be hauled back to the landfill site for disposal.

Mechanical Plant

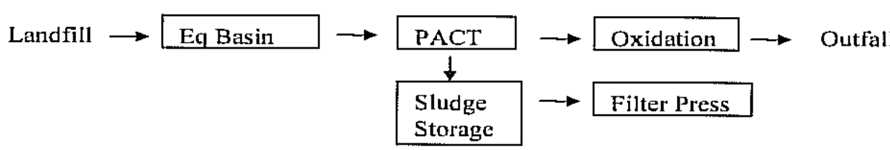
Considering regulatory trends in the future, building a dedicated mechanical plant is another option for the City's leachate treatment. This would require discharge of the treated effluent to the nearby Assiniboine River via existing outfall piping, provided it is permissible by the regulator.

Based on the leachate characteristics as described in **Section 3.0**, the following process treatment trains have been evaluated:

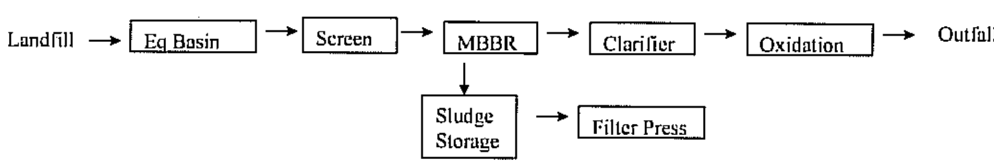
Treatment Train Alternative 1:



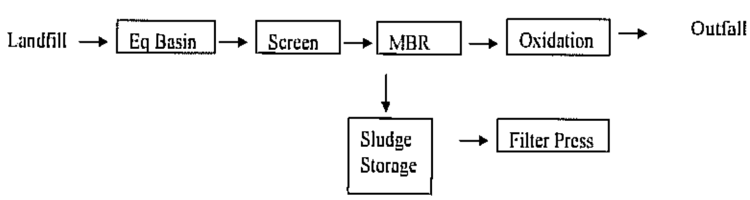
Treatment Train Alternative 2:



Treatment Train Alternative 3:



Treatment Train Alternative 4:



The treated effluent quality from all four of the above listed alternatives would be different. Alternative 1 provides for treatment of the leachate to the best quality. Alternative 2 is expected to address the heavy metal and organic parameter's removal but is not expected to provide the same level as Alternative 1. Alternatives 3 and 4 will address some heavy metal and recalcitrant organic removal but the quantities are expected to be significantly lower than Alternative 1. For Alternatives 2 to 4, removal of dissolved salts and recalcitrant compounds is anticipated to be negligible. Also for Alternatives 2 to 4, instead of air stripping for methane removal, the treatment system components upstream of the aeration basin (MBBR, MBR, PACT) can be designed as explosion proof.

For Alternatives 2 to 4, the level of chloride removal can be negotiated with the regulator and variance can be requested for this parameter. If the variance is granted, no RO process would be required in any of the Alternatives. It should be noted that the waste sludge generation from Alternatives 1 and 2 is expected to be more than from Alternatives 3 and 4.

A detailed description of the process units incorporated in the above four Alternatives is provided as follows:

Equalization

An equalization tank could be used to equalize the leachate flow variation and prevent shock loading to the downstream processes.

Air Stripping

Air stripping could be used to remove methane gas from the leachate stream prior to it's handling in the downstream processes. The added advantage of this process will be the reduction of the ammonia. Details of the air stripping process are provided in **Section 2.0**. For the City's application, this process could be implemented in a packed tower (**Figure 4.1:** Typical View of the Packed Tower) or an aeration tank (**Figure 4.2**). The typical packed tower air stripper includes a spray nozzle at the top of the tower to distribute contaminated water over the packing in the column, a fan to force air countercurrent to the water flow, and a sump at the bottom of the tower to collect decontaminated water. Auxiliary equipment that can be added to the basic air stripper includes an air heater to improve removal efficiencies; automated control systems with sump level switches and safety features such as differential pressure monitors, high sump level switches, and explosion-proof components (must be considered for the City's application); and air emission control and treatment systems, such as activated carbon units, catalytic oxidizers, or thermal oxidizers.

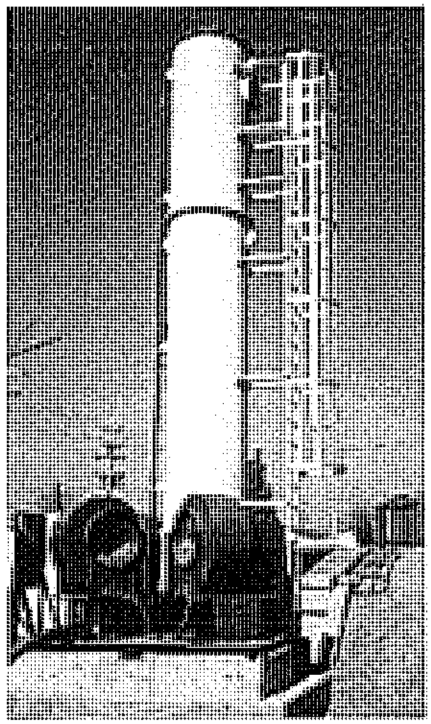


Figure 4.1: Typical View of the Packed Tower

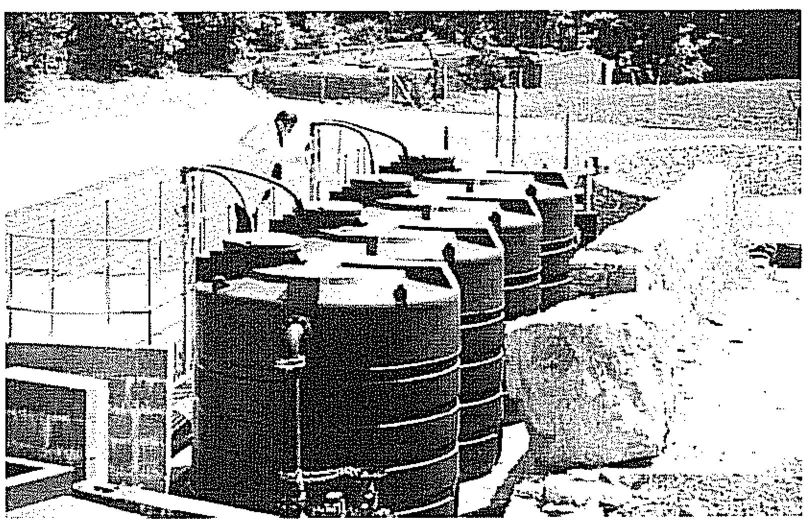


Figure 4.2: Typical Aeration Tank Installation

Aeration tanks strip volatile compounds by bubbling air into a tank through which contaminated water flows. A forced air blower and a distribution manifold are designed to ensure air-water contact without the need for any packing materials. The baffles and multiple units ensure adequate residence time for stripping to occur. Aeration tanks are typically sold as continuously operated skid-mounted units. The advantages offered by aeration tanks are considerably lower profiles (i.e. less than 2 m or 6 ft high), than packed towers that are 5 m to 12 m (15 ft to 40 ft) high. The high tanks would result in a much larger profile building. The discharge air from aeration tanks can be treated using the same technology as for packed tower air discharge treatment.

Precipitation/Sedimentation

The chemical precipitation/sedimentation process can be used to remove heavy metals. The chemical reaction and settling processes can be realized in a single unit - contact clarifier. Lime is a commonly used chemical due to its economic advantages and treatment efficiency. Also, it would provide alkalinity for the subsequent biological nitrification process. A typical setup of this process for the City's application is illustrated in **Figure 4.3**.

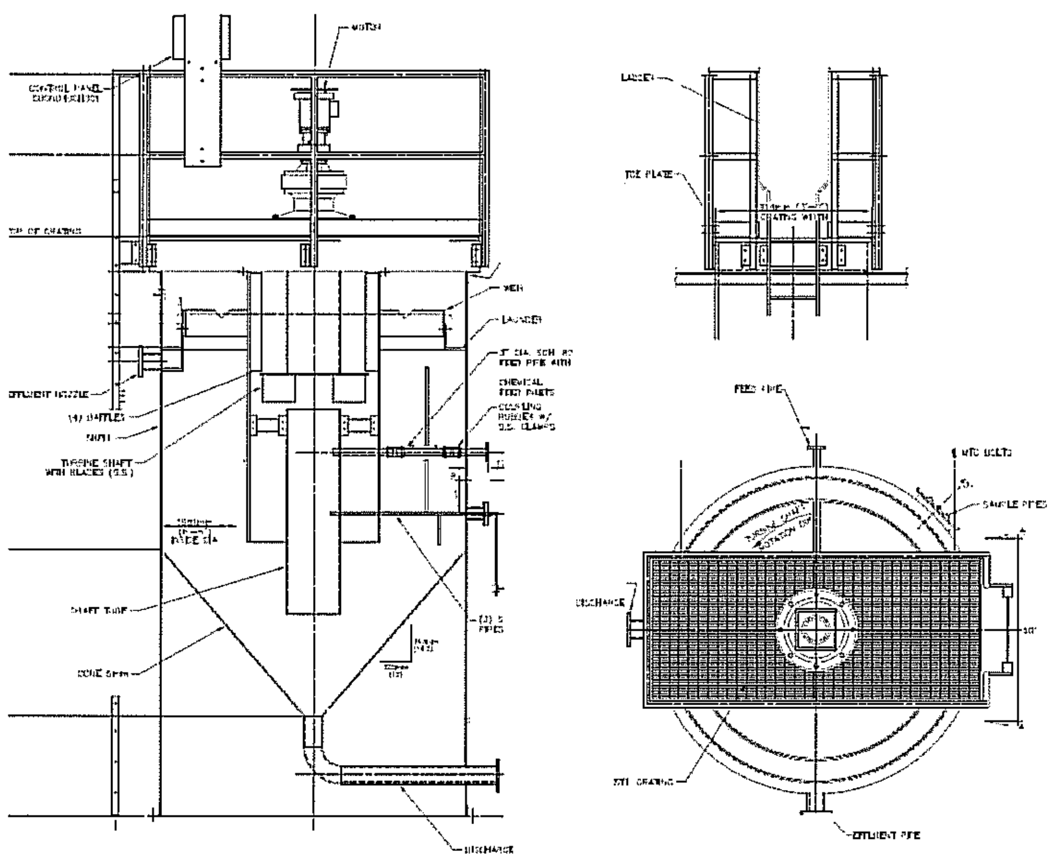


Figure 4.3: Typical Coagulation and Settling Process Unit Schematics

Biological Treatment Process

There are three process types that have been considered for the biological treatment process:

1. PACT (Sequence Batch Reactor (SBR) with Powdered Activated Carbon (PAC)).
2. Membrane Bioreactor (MBR) system.
3. Moving Bed Bioreactor (MBBR) system

A brief description of each biological process unit is provided in the following text.

Membrane Bioreactor System

Detailed information about the operation of the MBR system is provided in Section 2.0. For MBR process components, five different vendors were contacted including Veolia, GE, Huber, Memcore, Toray and WesTech. Only two vendors responded with a quotation.

The key components of the MBR package system for the City's operation would be a 2 mm fine screen, a membrane/aeration tank, a fine and coarse bubble diffuser system, three membrane modules and associated instrumentation.

It is estimated that the steel membrane/aeration tank would be approximately 6 m long 2.5 m wide and 3 m high. A total of three single-stack membrane modules would be required for a total membrane surface area of 470 m^2. The design is based on 55 m^3/day peak flow, which translates into a net flux of 4.9 $L/m^2 \cdot hr$ @ 5°C. The membranes will be polyvinylidene fluoride and the membrane module would be constructed of 316 grade stainless steel.

The MBR system would also incorporate various flow meters, pH meter, magnetic flow meter, permeate pump, blower and chemical feed systems (including a 1.5 m diameter clean-in-place tank).

A typical layout of the tank system is provided in **Figure 4.4.**

ITEM	EQUIPMENT DESCRIPTION	MAT'L	ITEM	EQUIPMENT DESCRIPTION
1	PANELS	–	8	COARSE BUBBLE BLOWERS – 1 DUTY & 1 STANDBY (STACKED)
2	CONTAINER	–	9	CIP TANK: 4'-0" DIA
3	MODEL TANK: 7'-0" W X 20'-0" L X 9'-6" H (INSIDE DIM.)	STL	10	CHEMICAL TANK – CITRIC ACID
4	TMP STAND PIPE: 6" DIA	PVC	11	CHEMICAL TANK – HYPOCHLORITE
5	FINE BUBBLE DIFFUSERS	–	12	CHEMICAL TANK – CAUSTIC
6	MBR-100 MEMBRANE MODULES	–	13	CIP RECIRCULATION PUMP
7	FINE BUBBLE BLOWERS 1 DUTY & 1 STANDBY (STACKED)	–	14	ACCESS LADDER

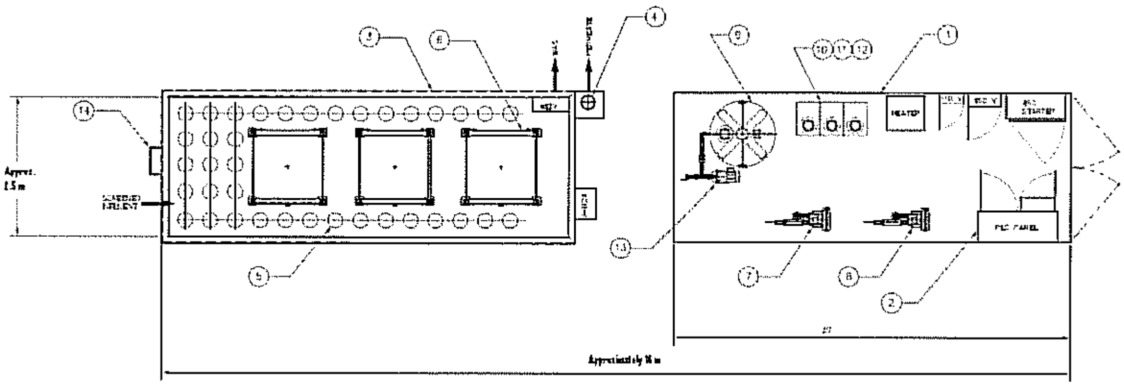


Figure 4.4: MBR System Layout

There have been several reports of MBR systems being unable to handle leachate treatment. Several vendors were contacted to obtain quotations for their membrane systems as outlined above, however none of the contacted vendors were willing to offer the MBR system for this application except WesTech and Veolia. The reported common issues with MBRs are organics fouling, bio-fouling, chemical fouling, metals fouling, and extra-cellular polymeric substances/biomass "waste" accumulation in the reactor that will affect MBR system's performance. The only MBR system known to have been installed in Canada (installed by Zenon Membrane (now GE) in New Brunswick, Canada in 2000) has been shut down due to operational difficulties and high operational costs. Because of the negative history associated with this type of process application and the general unwillingness of manufacturers to provide a product of this type, it is recommended that this process should not be considered further.

PACT (Sequence Batch Reactor with Powdered Activated Carbon Process)

The PACT system is a patterned wastewater treatment process that is able to treat organics (COD and BOD), ammonia/TKN, and adsorb a fraction of the metals. The combination of PACT and SBR would be operated in batch mode, and there would be two batches every day for the City's application. **Figure 4.5** shows the schematic PACT process.

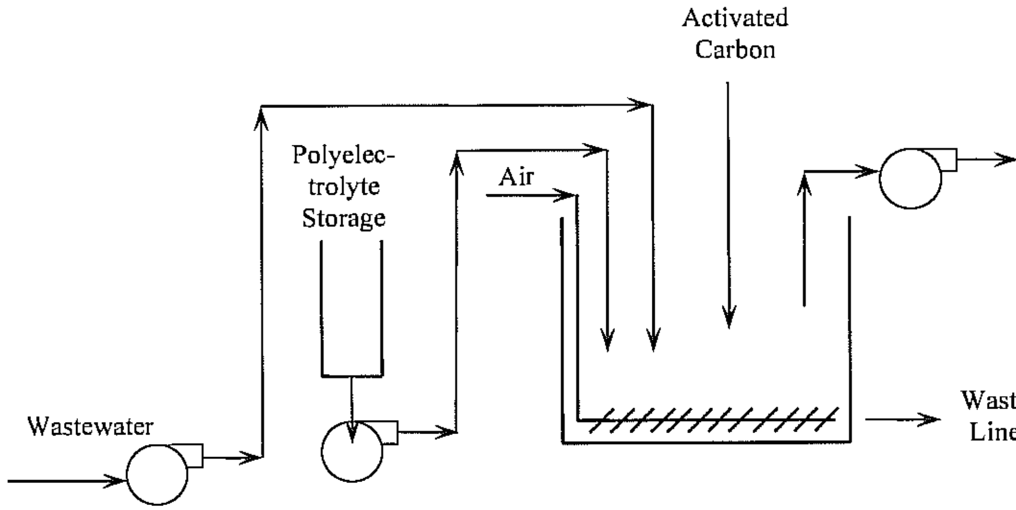


Figure 4.5: Batch PACT® System Schematic

For the City's application, the PACT system would consist of an aeration tank, air diffusers, a blower system, a polymer system, a sludge pump and related instrumentation and controls. The unit would have approximate dimensions of 3.7 m x 3.7 m x 6.4 m.

The operation of the PACT reactor would be as follows:

Step 1: Leachate would be pumped into the aeration tank where it comes in contact with a mixture of biological solids and powdered activated carbon.

Step 2: Contents would be aerated. Aeration cycle length would be dependent upon the waste strength and the level of treatment desired. During aeration, the biodegradable portion of the waste would be treated biologically, while the non-biodegradable contaminants are adsorbed on the carbon particles.

Step 3: Aeration would cease and tank contents would be allowed to settle. Solids would settle to the bottom of the tank while the clarified effluent would be drawn off for discharge to the receiving stream.

The operational sequence is also depicted in **Figure 4.6**.

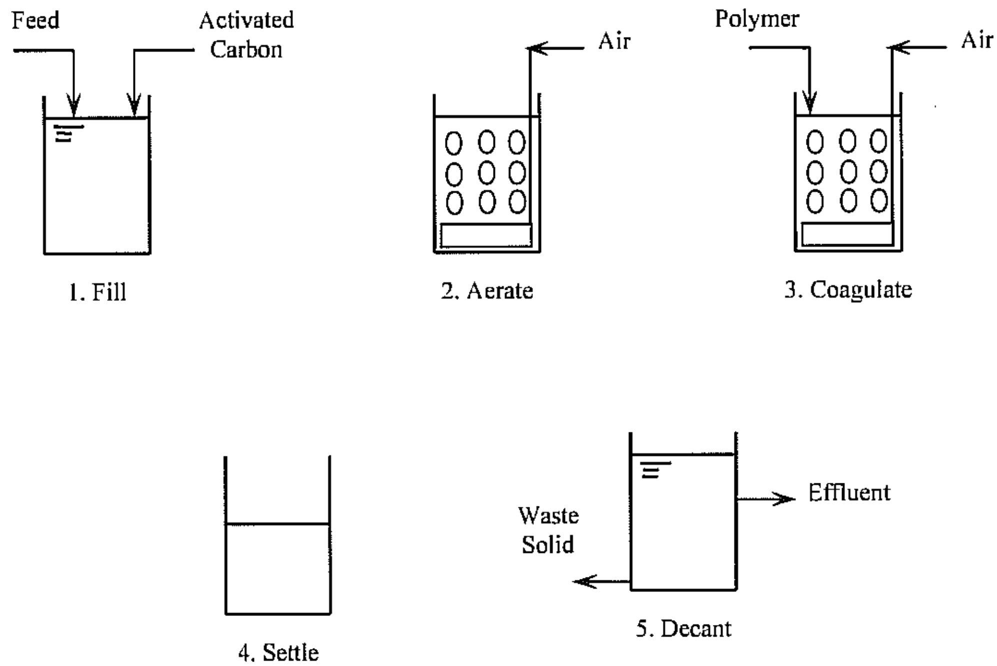


Figure 4.6: Batch PACT® Operating Sequence

Solids would be retained in the tank for use with the next batch of waste, except for that portion which is periodically withdrawn for dewatering and disposal. Makeup powdered carbon would be added directly to the tank as needed. A typical system layout has been depicted in **Figure** 4.7.

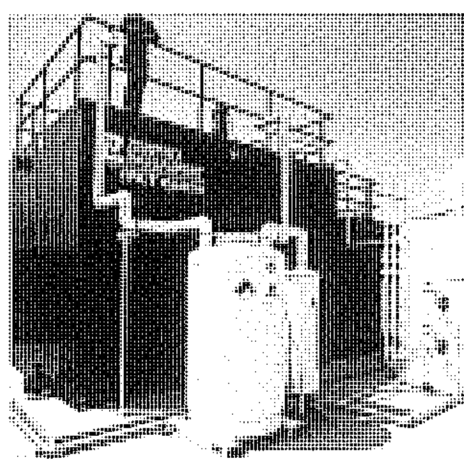


Figure 4.7: Typical PAC Layout

MBBR

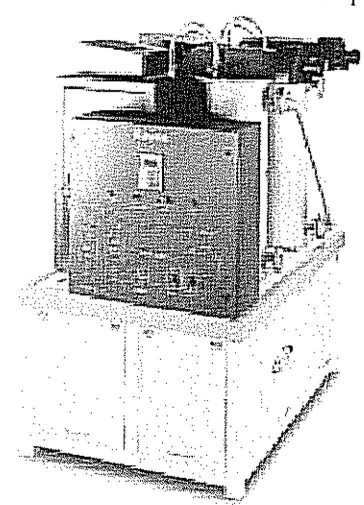
Similar to the previous options, it is assumed that the leachate would be treated throughout the year utilizing the storage available in the landfill cells. The MBBR proposed design would incorporate one (1) process train of three (3) reactors in series. The design would allow for the addition of more media to accommodate an increase in load, if required in the future. The effluent from the MBBR tankage would require clarification prior to the discharge. The critical design condition would happen during the winter with a wastewater temperature of 10^0C. For this condition, the biological volume of reactor required will be equivalent to summer temperature but during winter, the MBBR reactors air consumption will be doubled compared to the summer condition.

The process system train will include:

- Equalization tank approximately 100 m3 (annual sizing)
- MBBR tank volume = 80 m3 (3 reactors) (annual sizing)
- Number of trains = 1
- Number of reactors per train = 3
- Reactor #1 for BOD/Ammonia removal = 3 m long x 3m wide x 3.0 m SWD
- Reactors #2 and #3 for nitrification = 3 m long x 3m wide x 3.0 m SWD
- Recommended freeboard = 0.8 m minimum
- Total retention time = 57 hours
- Percentage fill of biofilm carrier elements = 50% of K3 Type Media for #1 , #2 and #3
- A total of 48 m3 of carrier elements
- Aeration system = AnoxKaldnes Medium Bubble
- Residual D.O. level = 3 mg/L for summer; 6.5 mg/L for winter
- Total air requirement = 230 SCFM @ 5.5 psig discharge pressure (summer) and 530 SCFM @ 5.5 psig discharge pressure (winter)
- Sieve assembly in 304L stainless steel to retain the carrier elements
- Medium Bubble aeration system in 304L stainless steel including header and lateral piping within the reactors.
- Two (2) positive displacement blowers (one duty one standby) of 20 HP including acoustic enclosure and accessories. (2 x 100% capacity)
- One prefabricated secondary clarifier for TSS removal in carbon steel including all internal parts.
- One (1) polymer skid including manual polymer preparation system and dosing pump
- Associated valves and flow meter, DO probes and control system

Ultraviolet Oxidation

The Ultraviolet (UV) oxidation process for the removal of complex organic carbon and disinfection should be considered for the City's leachate treatment effluent. It is anticipated that some of compounds such as xylene and toluene may be removed at the PACT process stage, however for removal of some complex organics and disinfection purposes, UV oxidation should be considered. A packaged Calgon RayOx 2 x 30 Kw unit has been considered.



In this system, a high-powered, medium-pressure lamp emits high energy UV radiation through a quartz sleeve into the contaminated water. An oxidizing agent, typically hydrogen peroxide, is added to the contaminated water and is activated by the UV light to form oxidizing species called hydroxyl radicals. The hydroxyl radical then reacts with the dissolved contaminants, initiating a rapid cascade of oxidation reactions that ultimately fully oxidizes (mineralizes) the contaminants. The hydroxyl radical typically reacts several million times faster than chemical oxidants such as ozone and hydrogen peroxide.

Reverse Osmosis Membrane

All leachate constituents that exceed the leachate guidelines are expected to be removable utilizing the treatment process units listed in the preceding text. However, the removal of dissolved salts would require application of a reverse osmosis (RO) process. If the regulator stipulates the requirements of chloride in the effluent stream, the City would be required to implement a RO process. The unit has a small footprint and high effluent quality. However, RO systems are expected to reject approximately 25% of the feed stream, and this waste stream requires disposal at the landfill. As a result, there will be continuous build up in the landfill cells which would impact the upstream process once the leachate is introduced to the system at the front end of the plant. One option for the RO-rejected stream management is to apply another RO system to concentrate the reject stream. This arrangement would produce a relatively small stream of highly concentrated waste but would still require disposal in the landfill once again resulting in eventual concentration buildup. In addition, the RO process has high capital, operation and maintenance costs and requires the use of cleaning chemicals which would eventually contribute to the net load at the front end of the plant.

Sludge Treatment and Disposal

The sludge generated from physical/chemical and biological treatment process can be handled in an aerated sludge storage tank, and then can be dewatered by a filter press. The dewatered sludge cake can be disposed back into the landfill. The filtrate from the filter press can be discharged back to the front of the mechanical plant.

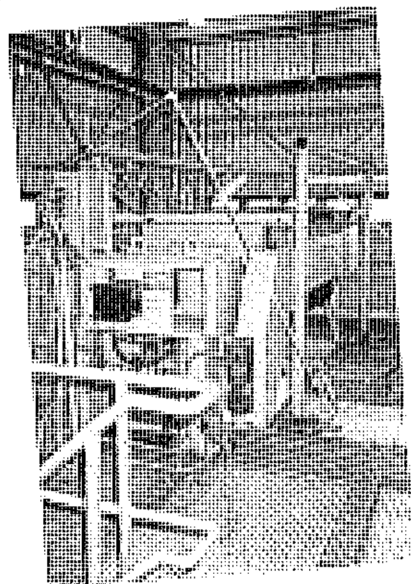


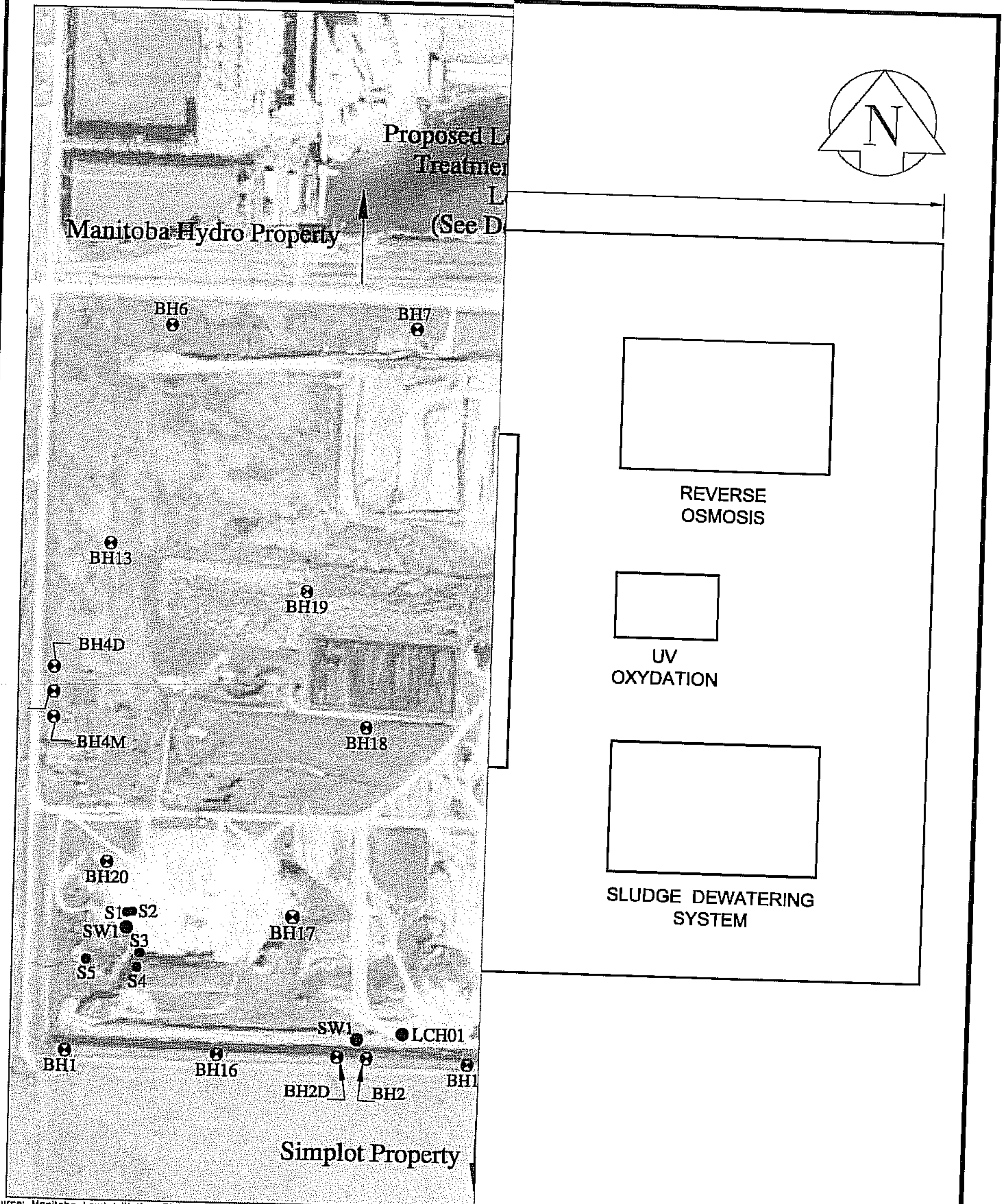
Figure 4.8: Typical Filter Press Layout for Solids Management

An approximate preliminary layout plan of a dedicated mechanical plant is shown in **Figure 4.9**. The cost estimates based on the above listed process treatment alternatives are presented in **Section 5**.

4.2 SNOW MELT MANAGEMENT OPTIONS

4.2.1 On-Site Management

Groundwater elevations from the two sampling events were compared to historical trends from a previous groundwater investigation conducted by Earth Tech in 2004. According to the July 2005 report, the average shallow groundwater elevation in December 2004 was 359.646 m and ranged from 355.086 to 365.623 m. Average shallow groundwater elevations during previous groundwater monitoring events in October 2002, May 2002, April 2001, December 2000 were 358.142, 358.100, 359.593, and 359.495 m, respectively. It was reported that the difference in average shallow groundwater elevations may have been due to seasonal fluctuations or heavy precipitation events. The 2008 measured groundwater levels seem consistent with these historical levels. The average groundwater elevation in the shallow groundwater aquifer was 359.444 m on March 5, 2008 and 359.775 m on May 26, 2008.



Source: Manitoba Land Initiative, Digital Imagery, 4305523C.

LEGEND

●LCH01 SAMPLE LOCATION

⊗BH16 MONITORING WELL LOCATION

EarthTech

a) Inc. Winnipeg, Manitoba 204.477.6381

D LEACHATE TREATMENT PLANT LOCATION

designed	scale BAR	yy-mm-dd 08-06-25
drawn LB	project no. 103779	
checked SJB	drawing no. FIGURE 4.9	rev.
approved		

L:\work\103000\103779\D2a-CAD\ENV\Leachate Treatment F

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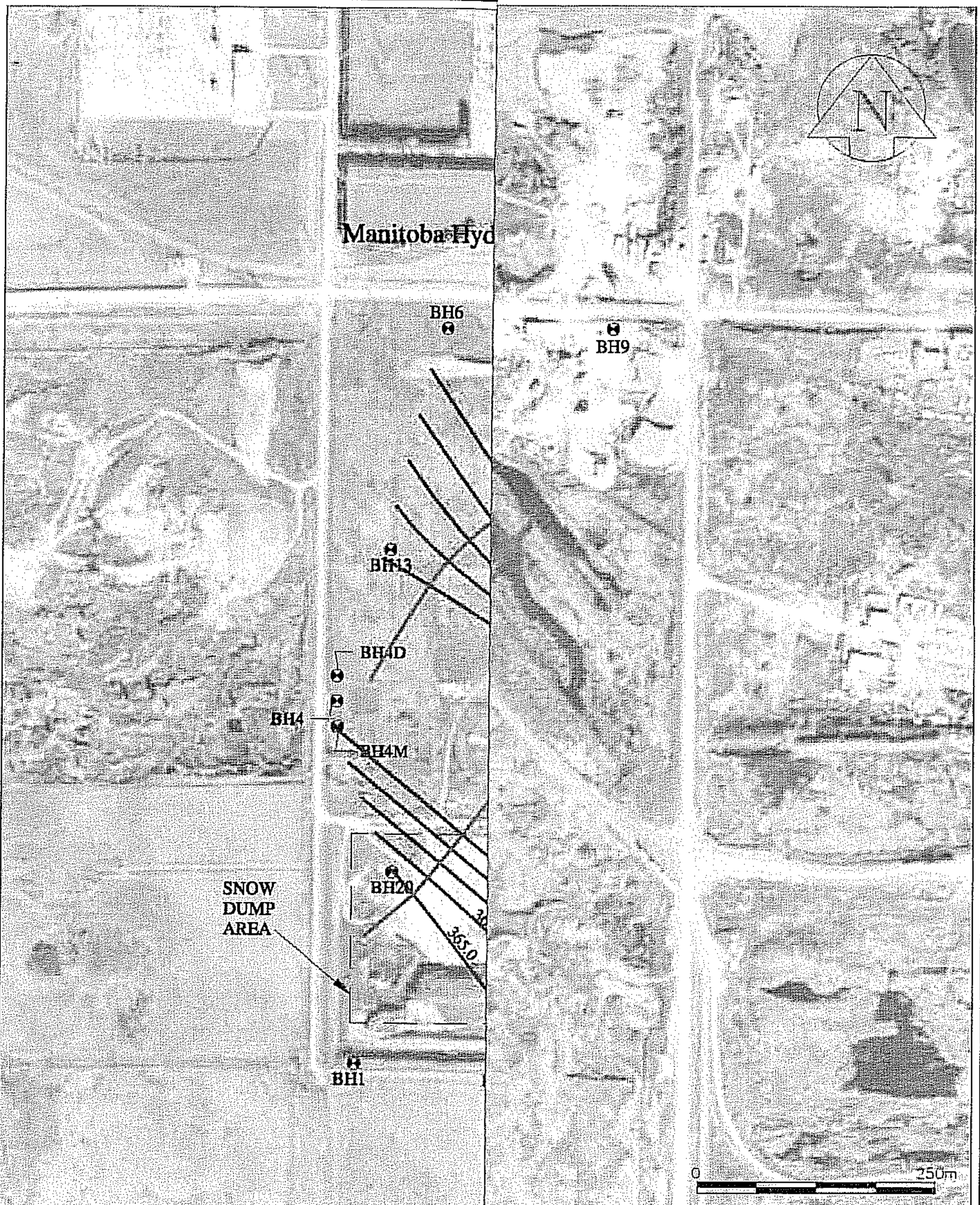
REV. 04-11-22

Groundwater elevations were also compared from the March 3 and May 26, 2008 sampling events to determine if there was any significant change in elevation that could be attributed to the snow melt. BH1 is within close proximity of the snow stockpile and according to inferred shallow groundwater contours, if snow melt water was significantly infiltrating groundwater, a significant increase in groundwater elevation would be probable in BH1. On March 3, 2008 prior to any significant snow melt run-off, the groundwater elevation in BH1 was 361.119 m. On May 26, 2008, after the bulk of the snow stockpile had melted, the groundwater elevation dropped slightly to 361.008 m in BH1.

Additionally, significant changes to groundwater elevation would typically have an impact on groundwater flow direction. Therefore, the inferred shallow groundwater flow direction calculated for the March 5 and May 26, 2008 monitoring events were compared to the previous groundwater investigation conducted by Earth Tech in 2004. According to the July 2005 report, the addition of eight monitoring wells in the interior of the landfill and along the southern perimeter of the landfill in 2004 refined the knowledge of the groundwater flow direction in the area, indicating a northeastern direction of flow, particularly in the vicinity of the snow dump area **(Figure 4.10)**. Groundwater levels measured during the 2008 groundwater monitoring event indicated a northeastern direction of groundwater flow which appears consistent to the findings of the 2004 investigation, indicating that groundwater flow direction has remained relatively unchanged. Since the snow dump has been operational since winter 2006, a groundwater flow direction change would be expected if snow dump activities were having an impact on groundwater elevation. As there was no significant increase in elevation when comparing the 2008 monitoring events, and groundwater flow direction seems to be consistent with historical data, it appears that snow melt run-off is having little or no impact on groundwater elevations in the immediate vicinity of the snow dump area.

Samples were collected from BH1 during both sampling events to determine if the snow dump melt water was having any impact on shallow groundwater at the site. Samples collected from BH1 were analyzed for the same parameters as the snow melt samples. A number of studies on snow dump melt water quality have been undertaken in Canada. High levels of chloride, lead, iron, phosphorus, BOD, and total suspended solids (Earth Tech, 2004) are typical, and are largely dependant on an area's site-specific street salting programs and the number of automobiles. Using these indicator parameters, groundwater samples BH1 (March 5, 2008) and BH01 (May 26, 2008) were compared to the snow melt samples (SN01, SW1, and SW3). Based on the results, no correlation was observed between the snow melt quality results and the groundwater quality results. This indicates that the snow melt is having little or no impact on groundwater characteristics.

Based on these observations, current snow melt management does not appear to have any significant impact to groundwater levels or flow direction.



Source: Manitoba Land Initiative, Digital Imagery, 4305523C.

LEGEND

ΘBH16 MONITORING WELL LOCATION

—361.5— GROUNDWATER CONTOUR LINE

——> GROUNDWATER FLOW DIRECTION

EarthTech

da) Inc. Winnipeg, Manitoba 204.477.6381

RED GROUNDWATER
CONTOURS, 2004

designed	scale	yy-mm-dd
	BAR	08-07-18
drawn LB	project no. 103779	
checked SJB	drawing no.	rev.
approved	FIGURE 4.10	

L: \work\103000\103779\02a-CAO\ENV\2004 Historical Inferre

#16 A

FORM 11x17
REV. 04-11-22

4.2.2 Off-Site Management

As an alternative, a new location at an abandoned landfill previously operated by the City was considered for operating a snow dump site. The abandoned landfill is located southeast of the City of Brandon, Manitoba on 17th Street East, north of Provincial Highway 110 (SE ¼ Section 12, Township 10, Range 19W).

The elevation of the site is approximately 390 m above sea level. Nearby bodies of water include the Assiniboine River, which is located approximately 3.3 km northeast of the site, as well as a number of small ponds and rivers (Atlas of Canada 2008). Groundwater Pollution Hazard Areas and Aquifer maps for the region indicate that the site (and most of Brandon) is located within a Groundwater Pollution Hazard Area, with minor sand and gravel aquifers at the surface.

Reportedly, while backfilling the landfill it was sloped towards 17th Street East from west to east and south to north, to allow runoff to travel out the northeast corner of the property. The addition of a snow dump at this location would increase the current drainage load. The effect of this additional load would need to be analyzed for downstream environmental impacts.

There is currently no infrastructure, buildings or access roads to facilitate a snow dump site at the proposed alternate location. Facilities for tracking, weighing and stockpiling snow loads would need to be implemented. Staffing and operational procedures would need to be developed, along with appropriate health and safety considerations. A groundwater monitoring program would also need to be established for due diligence to monitor any potential impacts to groundwater.

The above-mentioned operational considerations are cost-intensive and are already implemented, or could be easily implemented, at the current landfill location. As well, because the alternate location is situated within a groundwater pollution hazard area, a study would need to be conducted and submitted to Manitoba Conservation to determine the extent, if any, of groundwater impacts from the proposed snow dump operations. As a result, using the abandoned landfill as a potential snow dump location is cost prohibitive and is not considered a recommended option for this study. However, should the City of Brandon decide to proceed with this option, rough costs associated with developing a new snow dump site have been provided in **Section 5**.

4.2.3 Recommended Snow Melt Management Option

Based on the discussion presented in **Sections 4.2.1** and **4.2.2**, no change in the current snow melt management program is recommended for municipal snow disposal. However, should the City of Brandon decide to proceed with developing a new snow dump site at their alternate location, approval must first be obtained from Manitoba Conservation to develop in a groundwater pollution hazard area.

Section 5.0
Cost Analysis

SECTION 5.0
COST ANALYSIS

5.1 LEACHATE TREATMENT OPTIONS AND ALTERNATIVES

For the dedicated treatment Option, the treatment train Alternative 1, as presented in Section 4.0 would likely meet the surface water discharge criteria as described in Section 2.0. Discharge of the treated effluent would be performed using a suitably designed pump station and forcemain. There would likely be some cost associated with the improvement of the existing pumping system for leachate extraction. Alternatives 2 to 4 (as described in Section 4) would provide significant improvement in the effluent quality but may not meet all requirements at the point of discharge. A pilot study would be required to identify the level of treatment achievable from each process train alternative.

The Evaporation Pond option would likely have some operational cost i.e. hauling of the leachate to the pond site, the extraction of the dried solids and transportation back to the landfill. However, the capital and operational cost of this Option would also likely be lower than the dedicated mechanical plant Alternatives. A cost analysis of the various Options has been presented under Item 5.2.

5.1.1 Leachate Treatment Cost Estimates

A cost comparison of all four Alternatives along with the evaporation pond development costs have been presented in Table 5.1.

Table 5.1: Capital Costs Associated with Different Treatment Options

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Evaporation Pond
Pre-Treatment	$300,000	$50,000	$50,000	$50,000	$0
Secondary Treatment	1,000,000	1,000,000	$720,000	$1,080,000	$2,800,000
Tertiary Treatment (Ultraviolet Oxidation, Oxidation, Reverse Osmosis, Package)	650,000	$200,000	$200,000	$200,000	$0
Sludge Treatment	250,000	$250,000	$250,000	$250,000	$0
Pre-Engineered Wastewater Treatment Plant Building & Infrastructure	900,000	$800,000	$800,000	$800,000	$0
Sub Total	$3,100,000	$2,300,000	$2,020,000	$2,380,000	$2,800,000
Total (including 25% contingency)	$3,875,000	$2,875,000	$2,525,000	$2,975,000	$3,500,000

For the Evaporation Pond Option, the cost assumes insitu clay material with the installation of a HDPE 60 mil single liner. If the existing Cell 4 can be utilized complete with it's existing clay liner as an evaporation pond, the cost will be substantially reduced. There would be minor modifications of the Cell required which are expected to cost less than $1,000,000 (including Cell sludge removal to the adjacent Cells). We have assumed that a single liner may be acceptable by the regulators. However, if a double liner is required, the cost would require adjustment.

These costs do not include any engineering, administration, contractor profit or taxes. The costs for influent and effluent pump stations are also not included. All costs are based on estimated flows. It is recommended that prior to proceeding with the detailed design, the City conduct a detailed monitoring and confirmation of the leachate generation rates and revisit the estimated cost accordingly. In addition, discussions must be initiated with the regulator to obtain some guidelines as to the effluent requirements for the leachate treatment plant to further streamline the process treatment train and reduce cost (specifically, the need for reverse osmosis to treat chloride).

Once the leachate hydraulic load data is further refined with the additional annual leachate generation data monitoring, the cost analysis should also be revisited. Further review of the existing infrastructure is required to ascertain the feasibility of incorporating existing infrastructure components in the design. There may be potential cost savings if the existing tanks for the equalization of the leachate stream can be utilized. However, a new equalization tank has been assumed for the estimates.

For surface water discharge, it is assumed that the City of Brandon would install a new forcemain that would discharge to the existing outfall that the City uses to discharge the treated municipal effluent to the Assiniboine River. This arrangement would be subject to the environmental approval process for the facility.

5.2 SNOW DISPOSAL SITE OPTION

Based on on-site investigation and subsequent analysis, the City can continue the use of the existing site at the Eastview landfill for snow disposal. There are no additional cost implications of this Option.

5.2.1 Alternate Snow Disposal Site Cost Estimate

Rough cost estimates are summarized in Table 5.2, based on Earth Tech's experience from a variety of projects completed over the last five years. At this time snow disposal sites do not require licencing in Manitoba, so licencing costs have not been included in the rough cost estimate. Also, costs associated with a baseline environmental assessment have not been included, which the City of Brandon may choose to undertake to satisfy general due diligence requirements.

Table 5.2: Rough Cost Estimate for a New Snow Disposal Site

Snow Disposal Site Element	Cost
Site Assessment	
Topo Survey	2,000
Drainage Plan	10,000
Geotechnical Investigation	10,000
Groundwater/Aquifer Investigation	80,000
Construction	
Weigh scale/office building (~7 m x 4 m - 28 m^2)	250,000
Weigh scale (if required)	100,000
Site drainage	265,000
Settling pond (if required)	200,000
Access roads, security fencing, trash screens/weirs and lights	400,000
Snow pad (~15,000 m^2) (potential liner, berms, sloping etc.)	180,000
Operation	
Site supervisor	41,000/annum
Dozer operator	34,000/annum
Equipment purchase/operation costs	7,500/annum (rental)
Facility Maintenance (fences, yards, etc.)	12,000/annum
Utility Costs (site building heating, lighting, phone, water)	3,000/annum
Monitoring	
Surface soil samples - every 3 years at 3 samples per hectare (analysis of sodium, calcium, magnesium, lead, nickel, chromium, chlorides)	15,000 per 3 years
Decommissioning	
Environmental Site Assessment, remediation as required	To be determined at the time of decommissioning

Section 6.0
Summary and Recommendations

SECTION 6.0
SUMMARY AND RECOMMENDATIONS

The analysis of the City of Brandon's leachate suggests that leachate from the old landfill cells has generally stabilized. Overall, there are several parameters that exceed the Manitoba Water Quality Standards, Objectives and Guidelines. To enable discharge to a surface water body, the leachate generated from the City's landfill site would require some degree of treatment.

NO REGULATIONS HOWEVER

If the City wishes to continue the current practice of leachate discharge to the WWTP, a further detailed research study would be required to study the effect of the leachate disposal on the WWTP effluent streams and regulator approval would be required.

For the dedicated WWTP and discharge to surface water Option, it is recommended that the City should initiate discussions with the regulator to identify the required effluent quality criteria. Once the effluent criteria is established, the treatment train can be selected based on a pilot plant scale study of the selected Options. It is also recommended that prior to proceeding with the detailed design, the City must confirm the leachate flow projections.

Alternative 1 which incorporates Equalization Basin, Air Stripping, Precipitation, Powdered Activated Carbon, Ultraviolet Oxidation and Reverse Osmosis is expected to provide the best effluent quality. However, Alternative 1 is the most costly Alternative. The three other Alternatives provide lesser degrees of treatment but may be able to satisfy the treatment requirements of number of parameters of concern, once identified as a design criteria.

Utilizing the existing Cell 4 as an Evaporation Pond is the least cost Option. However, the City should initiate discussions with the regulator to identify the specific requirements of the regulator for an evaporation pond.

The estimated cost of Alternative 1 is $3.88 M. Alternatives 2 to 4 are expected to cost in the range of $2.5 M to $2.99 M. The least cost Option of utilizing the existing Cell 4 as an evaporation pond is expected to cost in the range of $1.00 M.

Based on on-site investigation and subsequent analysis, the City could continue the use of the existing site at the Eastview landfill for snow disposal. If this is the intent, there are no additional cost implications of this Option.

Section 7.0
References

SECTION 7.0
REFERENCES

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APPENDIX G

Gas Flaring Report

ANNUAL MONITORING REPORT
CITY OF BRANDON

EASTVIEW LANDFILL
LANDFILL GAS COLLECTION AND FLARING SYSTEM
2013

Prepared for

THE CITY OF BRANDON

Prepared by

INTEGRATED GAS RECOVERY SERVICES INC.

2013 ANNUAL MONITORING REPORT
CITY OF BRANDON

EASTVIEW LANDFILL
LANDFILL GAS COLLECTION AND FLARING SYSTEM
2013

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

The City of Brandon (the City) operates the Landfill Gas Collection and Flaring System at the Eastview Landfill in Brandon, Manitoba. This document was prepared to satisfy Condition 9 of the City's Licence 2932,which requires an annual report to the Director each year. The system became operational full time in January of 2012 after approval to operate was received by the Office of the Fire Commissioner.

Operation of the system including maintenance and monitoring was completed by Integrated Gas Recovery Services (IGRS) and its partner company Comcor Environmental Limited (Comcor). IGRS has completed this report as per the requirements of the Certificate.

This report outlines work performed and data collected during the operation of the Landfill Gas Collection and Flaring System during 2013.

2.0 LANDFILL GAS COLLECTION SYSTEM

There are two main components of the LGCFS that require monitoring. These include:

- Landfill Gas Collection Wellfield
- Mechanical System

The purpose and procedures associated with the monitoring of each of these components are discussed separately below. The recommended monitoring frequency is presented in Table 1.

Table 1: Summary of Monitoring Frequency

System Component	Monitoring Frequency
Wellfield Monitoring	Monthly
Remote Mechanical System Monitoring	Weekly
Mechanical System Monitoring	Monthly

2.1 Wellfield System Monitoring

The wellfield system monitoring consists of measuring vacuum/pressure in each well and lateral pipe, as well as the percentage of methane, oxygen and carbon dioxide in the landfill gas at these measurement locations. These measurements were taken using a proper gas meter/analyzer such as a Landtec GEM-2000, or equivalent. Vacuum fluctuations were noted, as it can be an indication of water within in the piping system.

Each wellhead was monitored for the velocity of gas using an anemometer. The measured velocities were used to calculate landfill gas flow rates by multiplying the velocity by the pipe cross-sectional area.

The monitoring data collected during the monthly round is beneficial to determine if the wellfield is operating as intended. Changes to the wellhead valve position were made to ensure maximum gas collection from the landfill. The system was monitored and field balanced by a technician experienced in the operation of this type of system.

The system monitoring data and valve position can be found in Table 2.

2.2 Mechanical System Monitoring

The PLC also provides information on the operating status of the system, and records all data electronically which can be downloaded when required. Specific details on these items are included in the Flare Operation and Maintenance Manual. At a minimum the PLC records:

- Landfill gas composition and temperature
- Flare operating times
- Blower operating times
- Landfill gas flow rate
- Volume of landfill gas collected and flared

These items were also monitored remotely and were reviewed at minimum on a weekly basis to ensure that all parameters outlined above are being recorded and that all system data indicates that the overall system is operating properly. The system review was carried out by a technician experienced in the operation of such systems.

Comcor staff also carried out the maintenance of the system as outlined by the Operations and Maintenance Manual. Repairs to the pilot ignition system were completed in December due to issues with moisture freezing in the ignition chamber.

The flare data for 2013 has been compiled, and is found in Appendix A.

2.2.1 System Pressure Measurements

Monitoring ports at the inlet and the outlet to the blower were measured and recorded on a monthly frequency, using a suitably scaled pressure gauge. Gauge fluctuations were noted, as it can be an indication of water within the system.

Wellfield monitoring data for 2013 has been compiled, and is found in Table 2 .

2.2.2 System Gas Measurements

The purpose of the main blower skid gas analyzer system is to monitor the oxygen and methane concentrations of the landfill gas being transferred by the LGFCS to the flare. As a safety precaution, if either the oxygen concentration gets too high, or the methane concentration gets too low, an alarm is sent to the main computer control panel PLC to shut the system down.

Table 2 2013 Brandon Monitoring Data

		10-Jan-13	13-Feb-13	1-Mar-13	11-Apr-13	24-Jun-13	25-Jun-13	July	August	12-Sep-13	8-Oct-13	November	December
Plant	**Wellfield**	-3.90	-3.40	-5.10		-2.80	-3.20	-3.40	-3.10	-3.32	-3.30		-6.00
	Inlet		-3.9			-3.1	-3.3	-3.6	-3.3	-3.6	-3.8	NO	-6.7
	Outlet	5.50	9.30	4.80		3.80	4.50	4.90	4.50	4.60	5.30	ROUND	7.10
	CH4	40.70	44.10	34.30		39.40	40.00	38.20	35.50	36.80	36.10		30.20
	CO2	28.90	37.00						30.30	31.70	33.20	SYSTEM	30.70
	O2	4.20	3.80	5.60		1.40	1.40	1.90	2.00	1.40	1.90	DOWN	2.10
	flow	neter out for servic	out for service	180.00		195.00	206.00	205.00	203.00	207.00	205.00	DUE	205.00
	VFD %	28.00	31.00	25.80		24.00	25.00	26.00	25.00	25.00	26.00	TO	31.00
	Blower Hrs	8680.6	9308.6	9639		12365.5	12384.7		13483	14021	14638	PILOT	15497
	Comp Air	84.60		90.00		100.10	92.40	87.60	90.00	99.00	94.00	ISSUES	81.50
	Air Hrs	1063.22		1069.07		1039.00	1039.40	1040.00	1042.00	1079.00	1081.00		1083.00
	Starts												
GW 1-1	**Well**	-0.30	-0.50	0.00	0.00	0.09	-0.77	-0.76	-1.33	-1.48	-1.43		-4.00
	Lat	-2.63	-2.90	-5.01	-2.40	-2.34	-2.22	-2.32	-2.18	-2.53	-2.68		-5.84
	CH4	28.50	25.30	0.50	0.40	60.10	53.10	52.80	49.10	49.20	48.20		28.80
	CO2	18.30	21.70	0.00	0.30	37.90	36.00	36.00	35.00	35.00	36.60		21.70
	O2	10.20	11.30	19.10	19.90	0.20	1.80	1.20	1.70	1.70	1.70		10.00
	Max (m/s)	-	-	-	-	2.28	2.19	1.03	0.91	0.48	0.77		blocked
	Min (m/s)	-	-	-	-	1.69	1.81	0.55	0.71	0.00	0.61		with
	Temp (deg. C)	-	-	-	-	31.60	24.50	23.60	23.80	24.20	17.70		ice
	Flow (cfm)	-	-	-	-	19.2	19.3	7.6					
	Valve/Comment	closed -> n/c	closed	closed	closed	closed -> 1/2 turn open	1/2T, no change	plus 1/4 turn open	n/c 3/4	n/c 3/4	0.75 to 2T		closed 1 T
GW 1-2	**Well**	-1.80	-1.91	-5.00	-1.10	-0.33	-0.40	-0.31	-0.31	-0.32	-0.28		-0.27
	Lat	-2.66	-2.88	-5.06	-2.35	-2.24	-2.24	-2.29	-2.18	-2.54	-2.65		-5.84
	CH4	34.00	33.90	0.60	1.00	27.20	24.50	25.30	27.80	30.70	32.90		36.10
	CO2	27.90	30.40	0.50	0.80	27.90	26.20	25.90	30.10	33.00	34.20		28.40
	O2	1.00	1.10	20.70	18.90	0.20	1.60	1.50	0.30	0.80	0.30		5.50
	Max (m/s)	0.66	0.73	-	-	0.58	1.66	1.16	0.44	0.44	0.47		0.77
	Min (m/s)	0.49	0.49	-	-	0.53	0.96	0.82	0.00	0.00	0.00		0.00
	Temp (deg. C)	1.80	6.80	-	-	30.40	24.70	23.60	23.40	24.60	12.30		-20.10
	Flow (cfm)	5.6	5.9	-	-	5.4	12.7	9.6					
	Valve/Comment	2T -> 1T	n/c	closed	closed	1/2 turn -> 1/4 turn open	1/4T, no change	1/4T, no change	1/4T, no change	1/4T, no change	1/4T		1/4T
GW 1-3	**Well**	-1.00	-0.90	0.30	-0.80	-1.47	-1.51	-1.34	-1.48	-1.66	-1.49		-1.21
	Lat	-2.82	-2.85	-5.00	-2.31	-2.12	-2.25	-2.29	-2.16	-2.51	-2.56		-5.84
	CH4	29.60	23.10	63.20	49.30	29.10	28.90	25.30	33.10	31.30	28.00		29.60
	CO2	24.50	24.70	38.70	31.70	26.70	27.10	25.90	29.70	1.80	26.30		20.50
	O2	5.60	8.10	0.40	2.10	2.80	2.50	1.50	1.20	2.00	5.10		12.20
	Max (m/s)	-	-	-	-	0.82	0.62	1.16	0.75	0.66	0.85		0.84
	Min (m/s)	-	-	-	-	0.70	0.47	0.82	0.74	0.52	0.00		0.00
	Temp (deg. C)	-	-	-	-	28.40	26.00	23.60	26.60	26.00	12.00		-20.30
	Flow (cfm)	-	-	-	-	7.3	5.3	9.6					
	Valve/Comment	cracked -> closed	closed	opened 1/2 turn	opened 1/4	3/4 turn, no change	3/4T, no change	3/4T, no change	3/4T, no change	3/4T, no change	3/4 to cracked		cracked
GW 1-4	**Well**	-0.40	-0.46	-0.82	-0.91	-0.78	-0.85	-1.03	-0.76	-0.81	-0.82		-0.32
	Lat	-2.91	-2.90	-4.70	-2.17	-2.13	-2.17	-2.18	-2.13	-2.51	-2.74		-5.83
	CH4	44.10	45.10	39.10	38.60	35.00	35.80	34.10	30.30	39.30	38.00		59.70
	CO2	28.60	28.70	28.00	29.10	30.10	30.60	30.90	21.90	33.10	35.50		37.70
	O2	4.90	3.20	8.50	0.90	0.40	0.30	0.50	7.90	0.10	0.00		1.90
	Max (m/s)	2.43	2.37	2.31		1.58	2.54	2.82	2.58	1.64	1.49		0.66
	Min (m/s)	1.98	2.21	2.08		1.48	2.13	2.36	2.64	1.53	1.34		0.00
	Temp (deg. C)	4.00	8.10	9.30		25.20	24.30	24.80	25.80	24.70	13.30		-21.10
	Flow (cfm)	21.3	22.1	21.2	0.0	14.8	22.6	25.0					
	Valve/Comment	cracked -> n/c	opened 1/4 turn	n/c	n/c	no change	1/4T, no change	1/4T, no change	1/4T to cracked	1/4T to cracked	cracked		cracked

GW 1-5	Well	-0.04	-0.10	-0.06	0.00	-0.04	-0.09	-0.03	0.00	0.01	0.03		0.09
	Lat	-2.89	2.93	-4.56	-2.30	-2.13	-2.21	-2.25	-2.13	-2.52	-2.71		-5.78
	CH4	29.10	18.30	1.80	1.60	30.40	35.40	36.40	49.30	26.00	56.70		55.20
	CO2	23.90	16.80	1.10	1.10	21.40	24.80	23.70	35.50	21.90	42.80		43.10
	O2	4.90	9.70	18.60	19.80	9.20	6.90	6.10	0.80	8.80	0.40		1.00
	Max (m/s)	-	-	-	-	-	-	-	-	-	x		-
	Min (m/s)	-	-	-	-	-	-	-	-	-	x		-
	Temp (deg. C)	-	-	-	-	-	-	-	-	-	x		-
	Flow (cfm)	-	-	-	-	-	-	-	-	-	x		-
	Valve/Comment	cracked -> closed	closed	closed	closed	closed, no change	closed, nc	closed, nc	closed, nc	closed, nc	closed		closed, nc
GW 1-6	Well	-2.70	-2.73	-0.04	-0.10	-0.39	-0.28	-0.38	-0.22	-0.25	-0.13		-0.02
	Lat	-2.70	-2.80	-4.51	-2.31	-2.16	-2.20	-2.28	-2.12	-2.51	-2.45		-5.64
	CH4	49.60	30.20	0.60	47.30	18.50	17.30	21.50	23.00	23.20	38.80		61.60
	CO2	29.60	28.60	0.10	29.90	23.20	22.90	21.40	26.30	25.60	34.50		37.40
	O2	3.30	11.00	18.90	1.30	0.90	1.20	1.00	0.40	0.70	0.20		0.50
	Max (m/s)	-	-	-	-	0.89	0.57	0.46	1.15	0.97	2.28		0.61
	Min (m/s)	-	-	-	-	0.69	0.44	0.00	0.75	0.84	2.09		0.00
	Temp (deg. C)	-	-	-	-	32.40	27.10	28.30	25.60	26.10	15.60		-21.90
	Flow (cfm)	-	-	-	-	7.6	4.9	2.2					
	Valve/Comment	closed -> n/c	closed	closed	opened 1/4	no change	1/4T, no change	1/4T, no change	1/4T, no change	14T to cracked	cracked		cracked
LEACHATE CLEAN OUT	Well				-2.30	-1.53	-1.54		-1.31	-0.06	-0.23		-5.65
	Lat				-2.30	-2.13	-2.21		-2.13	-2.51	-2.45		-5.64
	CH4				42.30	37.10	34.80		30.30	44.60	57.20		35.70
	CO2				36.10	27.40	26.30		21.90	31.40	42.70		27.70
	O2				4.60	5.50	6.10		7.90	2.10	0.00		8.80
	Max (m/s)				-	2.28	2.74		2.58	0.97	2.28		0.61
	Min (m/s)				-	2.20	1.94		2.64	0.84	2.09		0.00
	Temp (deg. C)				-	35.00	28.20		25.80	26.10	15.60		-21.60
	Flow (cfm)				-	21.6	22.6	0.0					
	Valve/Comment				Big "O" to GW1	no change	1.5T, no change		closed 1/4T	cracked	cracked to 1T		1T
GW 1-7	Well	-1.00	-1.13	-1.34	-2.10		-1.29	-1.45	-1.15	-1.28	-1.29		0.01
	Lat	-2.95	-2.91	-4.53	-2.22		-2.18	-2.17	-2.12	-2.50	-2.43		-6.06
	CH4	45.70	46.30	39.30	38.30		29.80	30.00	33.40	37.60	37.10		58.30
	CO2	28.90	30.70	29.00	31.30		28.00	29.20	30.70	32.10	34.00		39.90
	O2	4.50	3.80	5.10	1.30		0.90	0.80	0.70	0.10	1.20		0.80
	Max (m/s)	2.60	2.51	3.00	-		1.59	1.62	1.89	1.70	1.88		0.48
	Min (m/s)	2.08	2.32	2.91	-		1.52	1.39	1.75	1.60	1.69		0.00
	Temp (deg. C)	3.40	7.30	5.30	-		23.60	24.10	22.50	22.10	13.30		-21.70
	Flow (cfm)	22.6	23.3	28.5	-	0.0	15.0	14.5					
	Valve/Comment	1T -> n/c	opened 1/4 turn	n/c	n/c		1.25T, no change	1.25T, no change	1.25T, no change	1.25T, no change	1.25T		1.25T
GW 2-1	Well	-2.60	-2.70	-2.58	-1.23	-0.86	-1.11	-1.34	-1.53	-1.68	-1.68		-3.07
	Lat	-3.03	-2.89	-4.40	-2.11	-2.31	-2.20	-2.24	-1.86	-2.61	-2.57		-5.66
	CH4	26.80	33.00	24.30	31.00	56.20	53.60	50.20	43.50	40.10	38.00		46.60
	CO2	21.60	28.60	20.10	26.40	38.30	37.80	36.40	35.60	35.10	36.00		35.50
	O2	7.70	5.10	11.40	2.60	0.30	0.30	0.40	0.10	0.20	0.50		2.10
	Max (m/s)	3.79	2.88	4.28	-	1.09	1.39	1.23	1.54	1.41	1.32		0.91
	Min (m/s)	3.29	2.64	4.00	-	0.93	1.12	1.00	1.49	1.30	1.57		0.00
	Temp (deg. C)	5.70	11.60	9.80	-	29.10	26.50	23.80	27.90	26.10	21.30		-20.10
	Flow (cfm)	34.2	26.7	40.0	-	9.8	12.1	10.8					
	Valve/Comment	4T -> 1.5T	n/c	closed 1/2 turn	n/c	1T -> 1/4T open	1.25 -> 1.5T open	plus 1/4 turn open	plus 1/4 turn open	1.75T	1/75t		1.75T
GW 2-2	Well	-2.90	-2.88	-4.25	-2.21	-2.07	-2.15	-2.26	-2.11	-2.13	-2.38		-0.10
	Lat	-3.20	-2.89	-4.60	-2.21	-2.14	-2.22	-2.31	-2.18	-2.58	-2.42		-5.83
	CH4	43.30	39.90	40.70	38.30	34.70	36.10	35.20	30.40	31.10	31.50		14.70
	CO2	31.10	30.30	31.90	29.40	28.40	30.40	29.90	30.50	30.20	34.00		10.00
	O2	1.50	3.90	2.10	2.20	1.60	0.20	0.40	0.40	0.20	0.60		16.80
	Max (m/s)	1.75	1.81	1.90	-	0.90	3.61	4.11	0.94	0.69	1.27		0.44
	Min (m/s)	1.72	1.69	1.81	-	0.86	3.35	3.85	0.88	0.44	1.05		0.00
	Temp (deg. C)	1.80	9.80	2.70	-	26.00	23.50	24.30	25.60	24.10	14.00		-20.80
	Flow (cfm)	16.8	16.9	17.9	-	8.5	33.6	38.4					
	Valve/Comment	2T -> n/c	n/c	n/c	n/c	no change	2T, no change	2T, no change	2T, no change	2T, no change	2T		2T

GW 2-3	**Well**	0.40	0.00	-5.46	-2.20	-0.10	0.00	-0.08	0.14	-0.30	-0.31		-1.70
	Lat	-3.01	-2.91	-5.46	-2.23	-2.33	-2.23	-2.24	-2.17	-2.76	-2.55		-5.60
	CH4	40.80	38.30	2.30	31.30	41.70	60.40	56.40	60.40	38.00	41.80		51.10
	CO2	30.00	27.90	1.70	25.70	34.10	38.80	37.60	39.70	31.70	33.70		40.30
	O2	3.40	2.10	20.10	4.10	1.60	0.40	0.90	0.10	2.10	1.90		1.30
	Max (m/s)	0.98	0.75	-	-	0.73	0.79	0.63	0.44	0.44	0.85		1.01
	Min (m/s)	0.86	0.69	-	-	0.54	0.48	0.51	0.00	0.00	0.58		0.44
	Temp (deg. C)	-3.70	9.10	-	-	29.20	26.10	27.00	27.50	26.30	13.10		-19.60
	Flow (cfm)	8.9	7.0	-	-	6.1	6.1	5.5					
	Valve/Comment	cracked -> n/c	opened 1/4 turn	closed	cked valve op	no change	cracked, no change	cracked, no change	cracked to 1/4T	1/4 T	1/4T		1/4T
GW 2-4	**Well**	-0.50	-0.61	-4.00	-1.86	-1.28	-1.19	-1.55	-1.82	-1.79	-2.05		-3.90
	Lat	-2.82	-2.89	-5.21	-2.17	-2.34	-2.23	-2.25	-2.16	-2.57	-2.48		-5.88
	CH4	26.10	29.30	63.10	43.10	49.30	49.80	48.50	42.30	42.30	47.10		21.20
	CO2	18.70	26.40	38.20	31.70	35.70	35.80	36.60	31.20	30.80	36.80		13.50
	O2	11.00	2.40	0.40	2.00	1.00	0.90	1.20	3.20	2.90	2.60		13.80
	Max (m/s)	-	-	-	-	0.77	1.95	2.18	0.68	0.54	0.81		0.60
	Min (m/s)	-	-	-	-	0.67	1.53	1.86	0.55	0.45	0.62		0.00
	Temp (deg. C)	-	-	-	-	29.00	25.10	24.30	27.10	24.80	13.30		-19.50
	Flow (cfm)	-	-	-	-	7.0	16.8	19.5					
	Valve/Comment	racked -> closed	closed	opened 1/4 turn	opened 1/4	no change	1/2T ->1T open	plus 1/4 turn open	n/c 1.25	n/c 1.25	1.25T		1.25T
GW 2-5	**Well**	-0.70	-0.79	-4.64	-2.31	-1.34	-1.43	-1.28	-1.40	-1.50	-0.03		0.22
	Lat	-2.89	-2.90	-4.63	-2.33	-2.12	-2.21	-2.32	-2.18	-2.58	-2.54		-5.89
	CH4	34.50	35.80	12.20	29.70	29.80	30.00	31.80	32.70	22.80	33.70		55.60
	CO2	24.00	31.00	8.70	25.50	27.50	28.40	27.70	29.60	20.10	25.60		44.00
	O2	7.10	2.40	17.70	3.60	2.50	2.10	1.80	1.90	8.30	8.40		0.30
	Max (m/s)	1.33	1.37	0.40	-	1.21	0.86	0.79	0.84	-	x		-
	Min (m/s)	1.24	1.19	0.40	-	1.06	0.69	0.61	0.77	-	x		-
	Temp (deg. C)	1.00	8.60	0.40	-	28.10	24.50	25.00	27.90	-	x		-
	Flow (cfm)	12.4	12.4	3.9	-	11.0	7.5	6.8		-	x		-
	Valve/Comment	1/2T -> 1/4T	n/c	valve just cracked	losed 1/4 turn	no change	1T, no change	1T, no change	1T, no change	closed	closed		closed
GW 2-6	**Well**	-0.40	-0.52	-1.30	-1.47	-0.91	-0.80	-0.99	-0.59	-0.55	-0.42		-1.07
	Lat	-2.96	-2.81	-4.61	-2.18	-2.35	-2.24	-2.34	-2.19	-2.53	-2.51		-5.91
	CH4	23.80	25.70	22.90	30.70	31.40	31.50	30.50	31.10	33.50	31.70		50.60
	CO2	16.30	20.70	17.70	28.10	29.30	29.50	29.50	28.40	29.40	26.00		36.10
	O2	11.90	1.80	10.80	3.10	2.10	2.10	2.00	2.40	2.80	6.80		0.50
	Max (m/s)	-	-	0.92	-	0.56	0.67	0.68	1.59	0.48	0.44		0.92
	Min (m/s)	-	-	0.86	-	0.55	0.50	0.59	1.49	0.00	0.00		0.60
	Temp (deg. C)	-	-	3.10	-	28.90	24.90	24.10	26.50	24.60	11.60		-18.20
	Flow (cfm)	-	-	8.6	-	5.4	5.7	6.1					
	Valve/Comment	racked -> closed	closed	closed 1/4 turn	n/c	no change	1/4T, no change	1/4T, no change	1/4T, no change	1/4T, no change	1/4T		1/4T
GW 2-7	**Well**	-2.90	0.00	-4.52	-2.22		-2.19	-2.25	-2.12	-2.45	-2.46		-5.82
	Lat	-2.98	-2.91	-4.60	-2.30		-2.22	-2.22	-2.14	-2.50	-2.50		-5.87
	CH4	15.90	50.30	0.40	21.70		33.80	34.10	35.90	39.80	39.80		27.70
	CO2	11.30	29.90	0.20	18.30		29.90	28.80	29.20	30.80	32.90		20.10
	O2	14.70	1.30	19.90	12.10		1.40	1.30	2.50	2.40	2.80		5.40
	Max (m/s)	-	-	-	-		0.73	0.62	0.44	0.84	0.44		0.44
	Min (m/s)	-	-	-	-		0.51	0.50	0.00	0.65	0.00		0.00
	Temp (deg. C)	-	-	-	-		25.10	25.50	27.10	23.30	116.00		-21.30
	Flow (cfm)	-	-	-	-	0.0	6.0	5.4					
	Valve/Comment	2T -> closed	valve frozen	closed	closed		1T, no change	1T, no change	1T, no change	1T, no change	1T		1T
GW 2-8	**Well**	-0.17	0.00	-0.08	0.00	-2.31	-2.18	-2.15	-2.00	-2.30	-2.28		-5.12
	Lat	0.00	0.00	-4.60	-2.31	-2.33	-2.32	-2.19	-2.12	-2.48	-2.47		-6.20
	CH4	46.50	-	14.20	10.60	24.50	24.70	26.00	27.80	30.30	31.90		40.00
	CO2	14.90	-	11.60	9.90	27.20	27.60	26.80	30.70	32.50	34.20		26.60
	O2	12.30	-	12.40	10.10	0.20	0.20	0.30	0.20	0.20	0.30		2.80
	Max (m/s)	frozen	frozen	0.40	-	0.93	1.97	1.66	1.12	1.12	0.92		0.53
	Min (m/s)	down	down	0.40	-	0.85	1.49	1.41	1.06	0.93	0.76		0.00
	Temp (deg. C)	lateral	lateral	-4.00	-	25.90	25.50	25.10	23.50	25.10	11.40		-19.50
	Flow (cfm)	port	port	3.9	-	8.6	16.7	14.8					
	Valve/Comment	1T -> n/c	n/c	n/c	closed	2T -> 1T open	1T, no change	1T-> 3/4T open	3/4T no change	3/4T no change	3/4T		3/4T

GW 2-9	Well	0.00	0.00	-0.06	0.00	-1.18	-0.87	-2.00	-0.59	-0.54	-0.44		0.01
	Lat	-2.90	-2.90	-4.59	-2.32	-2.32	-2.27	-2.23	-2.16	-2.49	-2.51		-5.70
	CH4	50.80	30.00	1.30	15.30	33.70	31.40	32.40	31.00	35.30	31.90		43.50
	CO2	32.20	28.60	1.10	8.60	32.20	31.30	31.80	30.10	31.30	28.50		35.20
	O2	1.50	8.50	19.00	9.10	2.70	3.30	2.80	3.50	3.10	6.60		4.30
	Max (m/s)	-	-	-	-	0.76	1.45	1.38	0.44	0.40	0.44		0.66
	Min (m/s)	-	-	-	-	0.65	1.26	1.11	0.00	0.00	0.00		0.00
	Temp (deg. C)	-	-	-	-	31.50	26.40	27.30	27.50	24.80	11.50		-20.80
	Flow (cfm)	-	-	-	-	6.8	13.1	12.0					
	Valve/Comment	closed -> n/c	n/c	closed	closed	no change	cracked, no change	cracked, no change	cracked, no change	cracked, no change	barely cracked		barely cracked
GWH 1,2,3	Well	-	-	-4.32	-	-	-	-	-		-0.94		
	Lat	-	-	-4.18	-	-	-	-	-	not monitored	-2.00		
	CH4	-	-	25.40	-	-	-	-	-		17.20		buried
	CO2	-	-	18.60	-	-	-	-	-	landfill	22.90		im
	O2	-	-	0.90	-	-	-	-	-	work	2.60		snow
	Max (m/s)	-	-	-	-	-	-	-	-	in			
	Min (m/s)	-	-	-	-	-	-	-	-	this			
	Temp (deg. C)	-	-	-	-	-	-	-	-	area			
	Flow (cfm)	-	-	-	-	-	-	-	-				
	Valve/Comment	-	-	in manhole	-	-	-	-	-				
GWH 4	Well	-1.70	-1.68	-3.14	-2.04	-1.34	-1.37	-1.51	-1.33	-1.40	-1.39		-2.21
	Lat	-2.01	-2.89	-4.49	-2.33	-2.22	-1.98	-1.78	-2.10	-2.37	-2.30		-5.35
	CH4	32.50	36.70	28.90	34.70	33.00	33.70	33.60	33.50	31.80	30.20		22.20
	CO2	29.10	31.30	26.40	31.10	32.20	32.60	33.10	32.40	32.20	33.30		26.70
	O2	1.50	2.40	1.30	3.20	0.00	0.20	0.00	0.00	0.00	0.20		2.50
	Max (m/s)	2.93	2.68	2.46	-	2.30	1.28	2.36	1.88	2.44	2.28		3.49
	Min (m/s)	2.68	2.41	2.18	-	2.20	0.75	2.04	1.65	2.31	2.20		3.06
	Temp (deg. C)	16.50	9.90	11.90	-	30.30	29.20	29.60	29.70	27.10	25.70		8.70
	Flow (cfm)	27.1	24.6	22.4	-	21.7	9.8	21.2	-				
	Valve/Comment	2T -> 1/2T	n/c	surging n/c	surging n/c	surging n/c	1/2T, no change	1/2T, no change	1/2T, no change	1/2T, no change	1/2T		1/2T
GWH 5	Well	cap stuck	stuck	n/a	n/a	-	-	-	-	-0.81	-1.25		-2.74
	Lat	-2.43	-2.74	-4.54	-2.31	-1.58	-1.27	-1.22	-1.29	-2.22	-1.66		-4.90
	CH4	29.20	32.60	26.80	32.60	40.90	41.30	44.10	41.90	61.60	38.30		31.80
	CO2	24.30	29.30	30.20	30.70	34.00	34.60	35.10	34.10	38.90	34.70		28.30
	O2	4.90	3.60	5.60	3.00	0.10	0.30	0.00	0.10	0.00	0.20		2.90
	Max (m/s)	2.71	2.36	2.61	-	2.84	1.99	2.07	1.58	2.05	1.77		3.02
	Min (m/s)	2.68	2.18	2.24	-	1.90	1.36	1.68	1.07	1.81	1.48		2.57
	Temp (deg. C)	14.50	8.90	9.80	-	28.50	29.10	27.10	28.80	26.80	21.50		16.80
	Flow (cfm)	26.0	21.9	23.4	-	22.9	16.2	18.1					
	Valve/Comment	2T -> 1/2T	n/c	surging n/c	surging n/c	surging n/c	1/2T, no change	1/2T, no change	1/2T, no change	0.5 to 1.5T	1.5T		1.5T
GWH 6	Well	0.00	-0.10	4.60	3.10	-0.23	-0.24	-0.22	-0.25	-0.25	-0.21		-0.46
	Lat	-3.51	-0.90	4.60	3.10	-0.30	-0.26	-0.29	-0.22	-0.25	-0.27		buried
	CH4	59.70	55.70	63.10	60.70	35.80	36.00	41.60	33.10	34.00	36.90		28.30
	CO2	38.20	31.60	40.20	39.20	32.40	32.00	34.80	29.80	31.00	33.50		29.60
	O2	0.20	1.80	0.10	0.00	1.30	1.40	1.60	2.60	2.50	2.50		2.90
	Max (m/s)	6.77	0.40	0.40	-	3.05	2.86	2.46	2.43	2.61	2.57		port
	Min (m/s)	6.57	0.40	0.40	-	2.98	2.72	2.32	2.37	2.66	2.25		buried
	Temp (deg. C)	14.40	4.60	0.40	-	27.40	27.50	26.80	28.30	26.10	21.70		
	Flow (cfm)	64.4	3.9	3.9	-	29.1	26.9	23.1					
	Valve/Comment	cracked -> 2T	full open	n/c	n/c	no change	full, no change	full, no change	full, no change	full, no change	full		full
GWH 7	Well	-0.20	-0.20	0.00	1.10	-0.40	-0.34	-0.35	-0.33	-0.34	-0.29		-0.60
	Lat	-1.87	-1.00	0.02	1.10	-0.46	-0.40	-0.48	-0.37	-0.36	-0.38		-0.81
	CH4	59.20	56.80	63.20	61.70	40.60	41.10	44.40	39.70	35.80	36.20		34.10
	CO2	28.80	32.00	43.70	39.20	34.50	34.20	36.70	33.60	31.90	33.30		34.90
	O2	0.00	1.60	0.80	0.00	0.50	0.10	0.30	0.90	2.10	2.50		1.50
	Max (m/s)	4.55	0.40	0.40	-	3.66	3.23	3.14	2.95	3.07	3.18		3.24
	Min (m/s)	4.34	0.40	0.40	-	3.54	3.10	2.89	2.74	2.94	3.06		3.03
	Temp (deg. C)	5.40	4.10	4.50	-	21.40	21.80	22.60	22.40	22.70	14.40		5.80
	Flow (cfm)	42.9	3.9	3.9	-	34.8	30.6	29.1					
	Valve/Comment	cracked -> 2T	full open	n/c	n/c	no change	full, no change	full, no change	full, no change	full, no change	full		full

GWH 8	**Well**	0.00	-2.30	-1.36	-1.70	-0.28	-0.30	-0.43	-0.44	-0.48	-0.45		-1.19
	Lat	-1.49	-2.40	-2.30	-2.00	-0.87	-0.68	-0.74	-0.59	-0.64	-0.65		buried
	CH4	60.50	55.70	27.00	33.60	50.40	49.30	36.00	33.20	33.90	36.00		32.20
	CO2	38.70	33.00	25.60	30.10	39.90	38.90	35.60	30.20	31.90	34.60		34.00
	O2	0.00	1.10	6.20	4.10	0.10	0.20	0.30	2.10	2.00	1.40		0.70
	Max (m/s)	3.79	4.63	7.31	-	2.34	2.42	2.74	2.96	3.03	3.07		port buried
	Min (m/s)	3.60	4.41	7.20	-	2.02	2.33	2.56	2.92	2.83	3.02		
	Temp (deg. C)	3.40	13.70	16.50	-	26.60	24.70	24.90	22.90	25.90	19.50		
	Flow (cfm)	35.7	43.7	70.1	-	21.1	22.9	25.6					
	Valve/Comment	cracked -> 2T	n/c	closed to 1 turn open	n/c	1.5T -> 2T open	2->3T open	3T, no change	3T, no change	3T, no change	3T		3T
GWH 9	**Well**	0.04	-1.30	-1.24	-1.63	-0.30	-0.37	-1.13	-0.96	-1.05	-1.22		-2.82
	Lat	-1.59	-2.80	-2.85	-2.10	-1.44	-1.22	-1.43	-1.23	-1.41	-1.41		buried
	CH4	57.30	53.20	22.50	31.70	53.60	52.60	43.40	47.00	46.30	45.60		35.70
	CO2	35.30	32.10	21.70	30.00	38.70	38.60	36.40	34.30	36.20	36.80		33.50
	O2	1.20	1.00	10.30	3.80	0.20	0.00	0.30	0.00	0.10	0.10		0.30
	Max (m/s)	2.13	2.28	3.61	-	1.56	1.64	2.36	2.30	2.64	2.53		port buried
	Min (m/s)	2.07	2.11	3.53	-	1.50	1.51	2.19	2.24	2.59	2.41		
	Temp (deg. C)	8.20	13.20	18.90	-	27.90	27.70	26.80	27.60	26.40	20.90		
	Flow (cfm)	20.3	21.2	34.5	-	14.8	15.2	22.0					
	Valve/Comment	cracked ->1T	n/c	closed 1 turn	n/c	3/4T -> 1T open	1->2T open	2T, no change	2T, no change	2T to 3T	3t TO 5t		5T
GWH 10	**Well**	0.02	-1.10	-0.20	0.00	-0.06		-0.07	-0.07	-0.01	-0.05		-0.17
	Lat	-1.70	-2.80	-2.96	-0.21	-0.60		-0.28	-0.60	-0.34	-0.70		buried
	CH4	58.90	56.70	21.60	39.80	39.20		37.50	41.40	42.20	34.90		45.20
	CO2	38.60	33.00	19.50	28.40	34.60		37.10	37.10	36.60	33.20		33.40
	O2	0.10	1.00	10.10	2.10	0.60		1.80	0.10	0.20	0.60		3.60
	Max (m/s)	0.95	0.40	1.30	-	1.28		0.55	0.44	0.44	0.49		port buried
	Min (m/s)	0.76	0.40	1.21	-	0.99		0.52	0.00	0.00	0.00		
	Temp (deg. C)	-0.70	4.50	7.70	-	27.60		28.00	26.90	26.60	13.80		
	Flow (cfm)	8.3	3.9	12.1	-	11.0	0.0	5.2					
	Valve/Comment	closed -> 1/4T	full open	closed 1/4 turn	at frozen/sag?	no change		no change	no change	+1T	NO CHANGE		no change

Having records of the gas concentrations also allows for better analysis of the system and aids in troubleshooting when problems arise.

A pump, located within the gas analyzer system cabinet in the control room, is used to draw a continuous sample of process gas from the header pipe on the blower discharge side. After entering the analyzer, the sample is drawn through a de-mister and a series of filters to remove any particulate or moisture that may affect the monitoring equipment. The methane and oxygen concentrations of the sample are then measured by an infra-red methane analyzer and oxygen analyzer. The methane and oxygen concentrations are displayed on separate LED display screens mounted on the front face of the gas analyzer panel. The gas analyzer system will send signals to the PLC that will trigger a number of system alarms/warnings including low methane and high oxygen.

All system failures and/or alarms are displayed on the main control circuit panel. Any alarms that shut down the system are relayed by the auto messaging to the system operator.

During 2013 the system operated as intended with the analyzer data recorded at an interval of 5 minutes or better and any system alarms were sent to the operator. This data was recorded and summarized into a daily value and can be found in Appendix A.

In addition to the main system analyser, concentrations of methane (CH_4), carbon dioxide (CO_2) and oxygen (O_2) were measured manually, recorded monthly at the blower inlet and blower outlet, and compared to the insitu monitoring devices to ensure accuracy. These measurements were taken using a proper gas meter/analyzer such as a Landtec GEM-2000, or equivalent.

2.2.3 System Flow Rate Measurements

Landfill gas velocities and temperatures at each landfill gas extraction well in the wellfield were measured and recorded on a monthly basis using an anemometer. These velocities were used to calculate landfill gas flow rates by multiplying by the pipe's cross sectional area.

A thermal mass flow meter continuously calculates flows to the flare and this data was recorded on an interval of 5 minutes or less. The flow meter experienced a fault in November of 2012. After inspection by Comcor staff, it was concluded that the flow meter had to be removed from the system for service. The flows during this period were estimated based on blower speed.

The monitoring completed in 2013 is found in Table 2 and a summary of all data can be found in Appendix A.

3.0 FLARE AND GREENHOUSE GAS EMISSIONS

3.1 Flare Emissions

The flare stack is equipped with a thermocouple that measures the temperature in the flare stack. This thermocouple is monitored by the system control panel PLC at intervals of 5 minutes or better. The control system is continuously monitoring the flame conditions and will shut down the LGCFS system immediately if flame is lost.

If the system shuts down for any reason, the fail safe valve will close and prevent any non-combusted landfill gas from being released to the atmosphere, thereby controlling the emissions from the flare.

3.2 Greenhouse Gas Emissions

The landfill gas comprises primarily methane and carbon dioxide in approximately equal amounts. In addition there are other trace amounts of a large number of compounds. Methane and carbon dioxide are greenhouse gases but methane has a global warming potential 21 times that of carbon dioxide. By combusting the methane in the flare the resultant products are carbon dioxide and water vapour which reduces its global warming potential by approximately 95 percent.

The control panel records both flow and methane gas concentration being collected from the system and sent to be combusted in the flare. These quantities are measured and recorded at intervals of 5 minutes or less. The data collected can be readily processed to calculate the greenhouse gas emission reduction expressed as carbon dioxide equivalents.

For the Eastview Landfill, greenhouse gas emissions have been calculated based on operational data and can be found in Appendix A.

4.0 CONDENSATE COLLECTION SYSTEM

The purpose of the Condensate Collection System component of the LGCFS is to remove moisture from the landfill gas and to collect condensate from the collection laterals/header pipes. Collection and removal of the condensate increases the efficiency of the landfill gas collection in the wellfield and minimizes the moisture being passed through the mechanical system.

Condensate and moisture are removed from the system at three main locations. First, relative low points have been provided in the gas collection header to allow any free moisture to drain by gravity out of the underground gas collection system. In the wellfield, this moisture drains into condensate gravity style and pump style drain traps which have pneumatic pumps installed inside the sump. Next, prior to the gas entering the blowers, a condensate moisture separator removes most of the residual water droplets remaining in the gas. At this stage the residual water drains by gravity into the condensate chamber.

The condensate chamber stores the water until the pump at the bottom of the chamber is activated either manually or automatically through a series of floats. The water is then pumped through a 75 mm diameter HDPE forcemain and is discharged into the sanitary sewer manhole.

The condensate Collection System operated as intended during 2013.

5.0 SITE ACTIVITIES

During 2013, the leachate collection system cleanout located in the central area of the landfill was connected to the LFGCS. This was initially connected via a length of big O piping in April of 2013, and made a permanent connection with HDPE in September.

6.0 CONCLUSIONS AND RECOMMENDATIONS

1. The system was operational throughout 2013, with the exception of an extended period of down time in November due to pilot issues. Alteration of the pilot system may be necessary in 2014 to ensure these issues do not occur again in the future.

2. The system should continue to operate on a full-time basis and be monitored according to the Operation and Maintenance Manual for the site.

All of which is Respectfully Submitted,

INTEGRATED GAS RECOVERY SERVICES

Shannan McGarr, B.Sc.
Wellfield Operations Manager

APPENDIX A

FLARE DATA

	CO2 Equivalents			Landfill Gas Flow						Methane	Oxygen		Temp			Blower
Date	Yearly	Monthly	Daily	Yearly	Monthly	Daily	Daily	**Avg**	**Total**	Avg	Avg	**Flare**	Min.	Avg.	Max.	**Daily**
	Tonnes CO2	Tonnes CO2	Tonnes CO2	scf	scf	meter3	scf	**scfm**	**MMBTU**	(%)	(%)	**Starts**	°C	°C	°C	**Hours**
Jan 1 2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan 2 2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan 3 2013	38	38	38	259275	259275	7345	259275	180	84	31.9	9.5	1	-14	382	743	13.1
Jan 4 2013	87	87	49	518361	518361	7339	259086	180	108	41	4.7	0	-13	377	734	20.1
Jan 5 2013	87	87	0	518541	518541	5	180	180	0	0	0	0	0	0	0	0
Jan 6 2013	87	87	0	518541	518541	0	0	0	0	0	0	0	0	0	0	0
Jan 7 2013	123	123	36	777819	777819	7345	259278	180	78	29.9	9.6	1	-1	392	757	13.5
Jan 8 2013	173	173	50	1036992	1036992	7342	259173	180	111	42.3	0	0	343	578	750	22.8
Jan 9 2013	217	217	44	1296141	1296141	7341	259149	180	96	36.7	5	0	317	510	755	24.4
Jan 10 2013	263	263	46	1555251	1555251	7340	259110	180	101	38.7	4.5	0	353	570	741	23.9
Jan 11 2013	310	310	47	1814373	1814373	7340	259122	180	104	39.5	4.4	0	294	570	698	23.8
Jan 12 2013	353	353	43	2073813	2073813	7349	259440	180	95	36.4	4.8	0	276	554	762	23.9
Jan 13 2013	395	395	42	2332917	2332917	7340	259104	180	92	35.3	4.6	0	358	667	758	23.8
Jan 14 2013	435	435	40	2592018	2592018	7340	259101	180	89	33.9	4.7	0	307	645	749	23.8
Jan 15 2013	479	479	44	2851368	2851368	7347	259350	180	97	37.1	4	0	72	549	734	23.9
Jan 16 2013	509	509	30	3110490	3110490	7340	259122	180	67	25.5	8.9	0	-13	305	710	15.3
Jan 17 2013	548	548	39	3369591	3369591	7340	259101	180	87	33	4.6	0	337	607	740	22.8
Jan 18 2013	589	589	41	3629040	3629040	7350	259449	180	91	34.5	4.4	0	393	518	651	23.8
Jan 19 2013	589	589	0	3629220	3629220	5	180	180	0	0	0	0	0	0	0	10
Jan 20 2013	589	589	0	3629220	3629220	0	0	0	0	0	0	0	0	0	0	0
Jan 21 2013	619	619	30	3888141	3888141	7335	258921	180	66	25	10.8	1	-18	304	703	12
Jan 22 2013	661	661	42	4147584	4147584	7350	259443	180	92	35.2	4.4	0	353	650	735	23.8
Jan 23 2013	699	699	38	4406682	4406682	7340	259098	180	83	31.7	4.8	0	75	507	670	23.8
Jan 24 2013	749	749	50	4665807	4665807	7340	259125	180	111	42.3	2.6	0	-9	520	661	22.7
Jan 25 2013	802	802	53	4925244	4925244	7349	259437	180	117	44.7	2.4	0	-18	444	638	23.3
Jan 26 2013	860	860	58	5184342	5184342	7340	259098	180	129	49	1.7	0	199	329	677	23.8
Jan 27 2013	926	926	66	5443494	5443494	7341	259152	180	146	55.9	1.1	0	136	220	424	23.9
Jan 28 2013	993	993	67	5702613	5702613	7340	259119	180	149	56.7	1.1	0	59	172	676	23.8
Jan 29 2013	1053	1053	60	5962053	5962053	7349	259440	180	133	50.5	1.8	0	-5	355	707	23.3
Jan 30 2013	1098	1098	45	6221175	6221175	7340	259122	180	100	38.3	3.1	0	362	523	692	23.8
Jan 31 2013	1137	1137	39	6480339	6480339	7342	259164	180	87	33.1	3.9	0	289	549	701	23.8
Feb 1 2013	1175	38	38	6739452	259113	7340	259113	180	85	32.4	4	0	75	463	696	23.9
Feb 2 2013	1212	75	37	6998658	518319	7343	259206	180	81	30.9	4.1	0	75	465	693	23.8
Feb 3 2013	1255	118	43	7257753	777414	7340	259095	180	95	36.1	3.4	0	73	427	702	23.8
Feb 4 2013	1301	164	46	7517184	1036845	7349	259431	180	102	38.9	2.9	0	231	478	697	23.8
Feb 5 2013	1301	164	0	7517366	1037027	5	182	180	0	0	0	0	0	0	0	12
Feb 6 2013	1327	190	26	7776304	1295965	7335	258938	180	58	22.2	10.6	1	-15	318	617	11.9
Feb 7 2013	1370	233	43	8035756	1555417	7350	259452	180	95	36.3	3.5	0	210	379	692	23.8
Feb 8 2013	1401	264	31	8294854	1814515	7340	259098	180	68	26.1	8.3	0	-3	342	696	17.6
Feb 9 2013	1401	264	0	8295034	1814695	5	180	180	0	0	0	0	0	0	0	0
Feb 10 2013	1401	264	0	8295034	1814695	0	0	0	0	0	0	0	0	0	0	0
Feb 11 2013	1401	264	0	8295034	1814695	0	0	0	0	0	0	0	0	0	0	0
Feb 12 2013	1401	264	0	8295034	1814695	0	0	0	0	0	0	0	0	0	0	0
Feb 13 2013	1421	284	20	8554300	2073961	7344	259266	180	44	17	15.5	1	-5	130	691	5.8
Feb 14 2013	1488	351	67	8899728	2419389	9785	345428	240	149	42.6	3.6	0	24	603	756	23.5
Feb 15 2013	1549	412	61	9245212	2764873	9787	345484	240	136	38.8	4.7	0	296	588	757	23.9
Feb 16 2013	1606	469	57	9590664	3110325	9786	345452	240	125	35.8	5.1	0	407	584	747	23.7
Feb 17 2013	1659	522	53	9936648	3456309	9801	345984	240	117	33.3	5.3	0	348	606	764	22.9
Feb 18 2013	1707	570	48	10282112	3801773	9786	345464	240	105	30	6.1	0	277	431	760	23.9
Feb 19 2013	1743	606	36	10541315	4060976	7343	259203	180	81	30.7	6.3	0	320	603	772	23.8

Feb 20 2013	1779	642	36	10800431	4320092	7340	259116	180	80	30.6	6.1	0	314	492	639	23.8
Feb 21 2013	1813	676	34	11059904	4579565	7350	259473	180	76	28.9	6	0	312	467	694	23.9
Feb 22 2013	1850	713	37	11319089	4838750	7342	259185	180	81	30.8	5.6	0	283	467	754	24.5
Feb 23 2013	1888	751	38	11578199	5097860	7340	259110	180	83	31.6	5.5	0	321	499	735	23.8
Feb 24 2013	1923	786	35	11837285	5356946	7339	259086	180	78	29.8	6.1	0	330	552	781	23.9
Feb 25 2013	1960	823	37	12096557	5616218	7345	259272	180	81	30.7	5.8	0	330	607	777	24.2
Feb 26 2013	1995	858	35	12355682	5875343	7340	259125	180	77	29.3	6.2	0	341	598	763	23.8
Feb 27 2013	2005	868	10	12426603	5946264	2009	70921	179	21	29.3	6.2	2	-18	664	752	23.9
Feb 28 2013	2042	905	37	12683459	6203120	7286	256856	178	82	31.4	5.8	0	309	555	750	22.8
Mar 1 2013	2081	39	39	12944132	260673	7384	260673	181	87	32.9	5.5	0	302	471	727	23.8
Mar 2 2013	2121	79	40	13203267	519808	7341	259135	180	87	33.3	5.3	0	316	580	746	23.9
Mar 3 2013	2160	118	39	13460352	776893	7283	257085	178	86	33.1	5.4	0	358	543	727	23.9
Mar 4 2013	2197	155	37	13719004	1035545	7327	258652	180	82	31.3	6	0	437	628	695	23.8
Mar 5 2013	2234	192	37	13977595	1294136	7325	258591	180	81	30.8	6.2	0	372	583	742	23.9
Mar 6 2013	2272	230	38	14234710	1551251	7284	257115	179	84	32.4	5.6	0	307	487	738	23.8
Mar 7 2013	2311	269	39	14493119	1809660	7320	258409	179	85	32.6	5.5	0	340	516	693	24.8
Mar 8 2013	2348	306	37	14750234	2066775	7284	257115	179	83	31.7	5.7	0	372	638	759	23.1
Mar 9 2013	2386	344	38	15007153	2323694	7278	256919	178	83	31.9	5.7	0	322	571	738	23.9
Mar 10 2013	2424	382	38	15268200	2584741	7395	261047	181	83	31.4	6	0	305	597	725	21.9
Mar 11 2013	2463	421	39	15524987	2841528	7274	256787	178	86	33.2	5.8	0	312	550	740	24.8
Mar 12 2013	2499	457	36	15787853	3104394	7447	262866	183	80	30.2	7.1	0	301	557	750	23.8
Mar 13 2013	2539	497	40	16050211	3366752	7432	262358	182	88	33	6.1	0	301	456	705	23.9
Mar 14 2013	2575	533	36	16307570	3624111	7290	257359	179	80	30.8	6.4	0	332	592	745	23.4
Mar 15 2013	2612	570	37	16567823	3884364	7372	260253	181	81	30.8	6.1	0	378	602	686	23.8
Mar 16 2013	2649	607	37	16825258	4141799	7293	257435	179	81	31	6.5	0	299	584	757	23.9
Mar 17 2013	2689	647	40	17084054	4400595	7331	258796	180	89	34	5.8	0	297	487	719	23.9
Mar 18 2013	2726	684	37	17342150	4658691	7311	258096	179	82	31.2	6.7	0	285	489	747	23.7
Mar 19 2013	2761	719	35	17601419	4917960	7345	259269	180	78	29.7	7.2	0	357	613	741	23.9
Mar 20 2013	2798	756	37	17861322	5177863	7362	259903	180	81	31	6.5	0	331	580	749	23.8
Mar 21 2013	2834	792	36	18116686	5433227	7234	255364	177	79	30.5	6.1	0	296	472	750	23.9
Mar 22 2013	2870	828	36	18375884	5692425	7343	259198	180	78	29.9	6.3	0	315	522	743	24.7
Mar 23 2013	2905	863	35	18633690	5950231	7303	257806	179	77	29.4	6.5	0	352	618	743	23.2
Mar 24 2013	2940	898	35	18891445	6207986	7302	257755	179	77	29.5	6.5	0	407	635	749	23.6
Mar 25 2013	2975	933	35	19149445	6465986	7309	258000	179	78	29.7	6.3	0	398	659	762	23.9
Mar 26 2013	3011	969	36	19408724	6725265	7345	259279	180	80	30.4	6.1	0	310	504	733	23.9
Mar 27 2013	3047	1005	36	19665613	6982154	7277	256889	179	79	30.3	6.1	0	314	465	716	23.7
Mar 28 2013	3083	1041	36	19924237	7240778	7326	258624	180	79	30.3	6.1	0	298	576	760	23.9
Mar 29 2013	3120	1078	37	20184406	7500947	7370	260169	180	82	31.2	5.8	0	469	697	767	23.8
Mar 30 2013	3157	1115	37	20443485	7760026	7339	259079	180	82	31.2	5.7	0	324	698	768	23.9
Mar 31 2013	3193	1151	36	20701369	8017910	7305	257884	179	79	30.1	5.9	0	324	582	743	23.9
Apr 1 2013	3230	37	37	20962211	260842	7389	260842	181	81	30.9	5.6	0	397	673	760	23.8
Apr 2 2013	3268	75	38	21222416	521047	7371	260205	181	83	31.7	5.2	0	326	539	751	23.9
Apr 3 2013	3309	116	41	21482532	781163	7369	260116	181	91	34.6	4.2	0	322	527	750	23.7
Apr 4 2013	3350	157	41	21744329	1042960	7416	261797	182	90	34.1	4	0	300	551	725	23.9
Apr 5 2013	3394	201	44	22002454	1301085	7312	258125	179	97	37.2	3	0	297	446	614	23.9
Apr 6 2013	3436	243	42	22258824	1557455	7263	256370	178	92	35.6	3.3	0	315	541	663	23.9
Apr 7 2013	3477	284	41	22515188	1813819	7262	256364	178	91	35.1	3.4	0	304	488	645	23.7
Apr 8 2013	3517	324	40	22777859	2076490	7441	262671	182	89	33.5	3.8	0	309	558	721	23.9
Apr 9 2013	3542	349	25	22940995	2239626	4621	163136	180	56	33.7	3.6	0	269	617	744	15.9
Apr 10 2013	3573	380	31	23151869	2450500	5974	210874	181	69	0	0	0	0	0	0	18.8
Apr 11 2013	3597	404	24	23277209	2575840	3551	125340	186	52	41.3	2.9	1	412	590	650	9.1
Apr 12 2013	3655	462	58	23638224	2936855	10227	361015	219	127	34.5	3.9	0	347	611	745	27.9
Apr 13 2013	3704	511	49	23954040	3252671	8947	315816	219	109	34.1	4	0	334	507	753	23.9

Apr 14 2013	3753	560	49	24268755	3567386	8915	314715	219	108	33.9	3.8	0	401	585	656	23.8
Apr 15 2013	3800	607	47	24581240	3879871	8852	312485	217	104	32.8	3.9	0	311	544	709	23.9
Apr 16 2013	3841	648	41	24869753	4168384	8172	288513	200	90	30.8	4.4	0	329	566	746	23.7
Apr 17 2013	3882	689	41	25138034	4436665	7600	268281	186	91	33.5	3.4	0	344	629	734	23.9
Apr 18 2013	3926	733	44	25405019	4703650	7563	266985	185	96	35.6	2.7	0	356	638	720	23.9
Apr 19 2013	3969	776	43	25671396	4970027	7546	266377	185	95	35.4	2.8	0	278	563	717	23.6
Apr 20 2013	4013	820	44	25935737	5234368	7488	264341	184	96	36	2.7	0	268	459	720	23.9
Apr 21 2013	4057	864	44	26201353	5499984	7524	265616	185	98	36.4	2.8	0	331	487	727	23.7
Apr 22 2013	4102	909	45	26470063	5768694	7612	268710	187	99	36.5	3	0	285	540	736	24.6
Apr 23 2013	4150	957	48	26737839	6036470	7585	267776	186	106	38.9	2.3	0	413	679	739	23.8
Apr 24 2013	4196	1003	46	27004104	6302735	7543	266265	185	101	37.6	2.4	0	201	522	728	22.8
Apr 25 2013	4241	1048	45	27270202	6568833	7538	266098	185	100	37.2	2.4	0	307	538	727	23.8
Apr 26 2013	4285	1092	44	27537016	6835647	7559	266814	185	97	35.9	2.7	0	298	615	735	23.9
Apr 27 2013	4331	1138	46	27803893	7102524	7560	266877	185	102	37.7	2.5	0	323	588	725	23.8
Apr 28 2013	4374	1181	43	28070128	7368759	7542	266235	185	96	35.5	3.1	0	318	495	734	23.9
Apr 29 2013	4420	1227	46	28336349	7634980	7541	266221	185	101	37.5	2.7	0	308	497	734	23.8
Apr 30 2013	4461	1268	41	28603194	7901825	7559	266845	185	91	33.6	3.3	0	278	478	696	23.9
May 1 2013	4497	36	36	28872095	268901	7617	268901	187	80	29.6	4.1	0	292	484	721	23.7
May 2 2013	4537	76	40	29142842	539648	7670	270747	188	88	32	3.4	0	285	510	726	22.9
May 3 2013	4579	118	42	29411471	808277	7610	268629	187	93	34.1	2.9	0	269	476	714	23.8
May 4 2013	4620	159	41	29677358	1074164	7532	265887	184	90	33.6	3.1	0	277	519	721	23.9
May 5 2013	4663	202	43	29946014	1342820	7610	268656	187	95	35.1	2.9	0	297	596	737	23.8
May 6 2013	4706	245	43	30212968	1609774	7562	266954	185	95	35	3	0	374	645	737	23.9
May 7 2013	4749	288	43	30479259	1876065	7543	266291	185	94	34.9	3	0	312	604	731	23.9
May 8 2013	4788	327	39	30746763	2143569	7578	267504	186	85	31.5	3.6	0	523	597	654	23.9
May 9 2013	4828	367	40	31012695	2409501	7533	265932	185	89	33.1	3.3	0	93	556	724	23.8
May 10 2013	4869	408	41	31277606	2674412	7504	264911	184	91	33.8	3.2	0	283	476	728	23.9
May 11 2013	4909	448	40	31544547	2941353	7562	266941	185	87	32.3	3.4	0	288	495	726	23.7
May 12 2013	4952	491	43	31811230	3208036	7555	266683	185	94	34.9	3	0	283	504	716	23.9
May 13 2013	4996	535	44	32078032	3474838	7558	266802	185	98	36.3	2.8	0	340	467	733	23.9
May 14 2013	5023	562	27	32242209	3639015	4651	164177	187	59	35.4	2.8	2	24	579	724	17.5
May 15 2013	5051	590	28	32400878	3797684	4495	158669	183	61	38.5	2.9	1	316	534	718	13
May 16 2013	5093	632	42	32675347	4072153	7775	274469	187	94	34.4	3.2	0	315	509	718	23.7
May 17 2013	5135	674	42	32946254	4343060	7674	270907	187	93	34.2	3.1	0	290	484	709	22.9
May 18 2013	5177	716	42	33214186	4610992	7590	267932	186	93	34.5	3	0	337	549	674	24.9
May 19 2013	5219	758	42	33480820	4877626	7553	266634	186	94	34.8	2.9	0	470	595	664	23.9
May 20 2013	5261	800	42	33756531	5153337	7810	275711	186	93	34.4	2.9	0	361	613	691	23.7
May 21 2013	5304	843	43	34026885	5423691	7659	270354	191	95	34.7	3	1	471	609	686	23.7
May 22 2013	5347	886	43	34307088	5703894	7938	280203	195	95	33.6	3.1	0	356	595	727	23.5
May 23 2013	5389	928	42	34583812	5980618	7839	276724	192	94	33.6	3.1	0	338	539	707	23.7
May 24 2013	5433	972	44	34858274	6255080	7775	274462	191	97	34.9	2.9	0	303	456	599	23.9
May 25 2013	5476	1015	43	35131556	6528362	7742	273282	190	96	34.6	2.9	0	370	523	613	23.9
May 26 2013	5519	1058	43	35404000	6800806	7718	272444	189	96	34.7	2.9	0	332	480	671	23.7
May 27 2013	5564	1103	45	35677498	7074304	7748	273498	190	100	36	2.7	0	354	498	713	23.9
May 28 2013	5609	1148	45	35946332	7343138	7616	268834	188	99	36.6	2.5	0	303	511	693	23.9
May 29 2013	5653	1192	44	36222177	7618983	7814	275845	191	96	34.5	2.8	0	331	566	735	23.9
May 30 2013	5694	1233	41	36465016	7861822	6879	242839	193	89	36.4	2.4	0	70	602	685	21.8
May 31 2013	5746	1285	52	36772436	8169242	8709	307420	189	114	36	2.1	0	531	656	725	25.9
Jun 1 2013	5789	43	43	37045906	273470	0	273470	190	95	34.2	2.4	0	311	519	701	23.9
Jun 2 2013	5834	88	45	37321504	549068	7807	275598	191	99	35.3	2.2	0	293	566	727	23.8
Jun 3 2013	5878	132	44	37591093	818657	7637	269589	187	97	35.6	2.1	0	291	490	704	22.9
Jun 4 2013	5908	162	30	37775490	1003054	5224	184397	187	66	35.2	2.2	0	310	512	610	18.9
Jun 5 2013	5966	220	58	38133946	1361510	10154	358456	190	129	36.1	2	0	316	515	679	29.9

Jun 6 2013	6012	266	46	38406332	1633896	0	272386	189	100	36.4	2	0	297	575	725	23.3
Jun 7 2013	6059	313	47	38678659	1906223	0	272327	189	103	37.3	1.9	0	312	596	734	24.9
Jun 8 2013	6105	359	46	38947758	2175322	0	269099	187	101	37	2	0	341	493	681	23.9
Jun 9 2013	6151	405	46	39220234	2447798	0	272476	189	101	36.6	2.1	0	296	575	707	22.9
Jun 10 2013	6197	451	46	39497095	2724659	0	276861	192	102	36.5	2.1	0	313	557	720	23.9
Jun 11 2013	6242	496	45	39772276	2999840	0	275181	191	100	35.8	2.2	0	323	556	727	25.4
Jun 12 2013	6287	541	45	40047845	3275409	0	275569	191	98	35.2	2.3	0	325	578	717	23.1
Jun 13 2013	6332	586	45	40322920	3550484	0	275075	191	99	35.6	2.1	0	299	481	700	23.9
Jun 14 2013	6379	633	47	40593028	3820592	0	270108	188	103	37.6	1.9	0	291	518	710	23.9
Jun 15 2013	6425	679	46	40866489	4094053	7747	273461	190	102	36.8	2	0	321	608	725	23.9
Jun 16 2013	6470	724	45	41137852	4365416	0	271363	188	99	36	2	0	332	599	716	22.8
Jun 17 2013	6514	768	44	41416816	4644380	7903	278964	194	98	34.6	2.1	0	321	554	723	23.9
Jun 18 2013	6561	815	47	41699554	4927118	0	282738	196	103	35.9	2	0	290	583	735	23.9
Jun 19 2013	6608	862	47	41981628	5209192	0	282074	196	103	36.2	2	0	307	511	715	23.5
Jun 20 2013	6654	908	46	42262573	5490137	0	280945	195	103	36.1	2	0	407	534	598	23.5
Jun 21 2013	6700	954	46	42542297	5769861	0	279724	194	101	35.7	2	0	309	542	713	23.9
Jun 22 2013	6748	1002	48	42824509	6052073	7995	282212	196	106	37.1	1.8	0	314	557	708	23.9
Jun 23 2013	6799	1053	51	43102917	6330481	0	278408	193	112	39.9	1.3	0	266	523	707	23.9
Jun 24 2013	6849	1103	50	43380887	6608451	0	277970	194	111	39.3	1.5	1	300	583	724	23.8
Jun 25 2013	6901	1155	52	43668413	6895977	0	287526	200	115	39.6	1.4	0	299	506	703	23.9
Jun 26 2013	6956	1210	55	43966557	7194121	0	298144	207	121	40.1	1.1	0	316	569	721	23.9
Jun 27 2013	7008	1262	52	44262583	7490147	0	296026	206	115	38.5	1.4	0	300	435	710	24.9
Jun 28 2013	7026	1280	18	44368219	7595783	0	105636	205	40	37.3	1.6	0	275	559	726	9.7
Jun 29 2013	7026	1280	0	44368219	7595783	0	0	0	0	0	0	0	0	0	0	0
Jun 30 2013	7026	1280	0	44368219	7595783	0	0	0	0	0	0	0	0	0	0	0
Jul 1 2013	7026	0	0	44368219	0	0	0	0	0	0	0	0	0	0	0	0
Jul 2 2013	7071	45	45	44565316	197097	0	197097	203	99	49.9	1.5	1	299	638	708	14.8
Jul 3 2013	7134	108	63	44859749	491530	0	294433	204	138	46.4	1.4	0	321	539	685	22.8
Jul 4 2013	7194	168	60	45155308	787089	0	295559	205	133	44.6	1.5	0	267	553	708	24.5
Jul 5 2013	7252	226	58	45451432	1083213	0	296124	206	128	42.6	1.6	0	329	584	720	23.9
Jul 6 2013	7308	282	56	45746213	1377994	0	294781	205	124	41.7	1.6	0	318	490	699	23.9
Jul 7 2013	7362	336	54	46038097	1669878	0	291884	203	120	40.5	1.7	0	320	536	720	23.2
Jul 8 2013	7416	390	54	46331664	1963445	0	293567	204	118	39.8	1.7	0	299	530	711	22.2
Jul 9 2013	7468	442	52	46624096	2255877	0	292432	203	116	39.1	1.8	0	316	555	717	24.5
Jul 10 2013	7521	495	53	46918344	2550125	8335	294248	205	117	39.2	1.7	0	361	649	730	24.1
Jul 11 2013	7575	549	54	47212889	2844670	8344	294545	204	119	39.9	1.6	0	312	505	677	23.8
Jul 12 2013	7628	602	53	47509503	3141284	8402	296614	206	117	39	1.8	0	309	599	738	22.9
Jul 13 2013	7679	653	51	47806634	3438415	8417	297131	206	113	37.5	1.9	0	258	564	717	23.9
Jul 14 2013	7729	703	50	48103316	3735097	8405	296682	206	110	36.8	1.9	0	318	562	716	23.9
Jul 15 2013	7781	755	52	48401684	4033465	8452	298368	207	115	38.2	1.7	0	307	469	699	23.9
Jul 16 2013	7831	805	50	48698213	4329994	8400	296529	206	111	37	1.9	0	302	522	729	23.9
Jul 17 2013	7881	855	50	48992365	4624146	8333	294152	205	110	37.1	1.8	1	321	581	723	23.8
Jul 18 2013	7934	908	53	49288690	4920471	8394	296325	206	118	39.2	1.6	0	290	545	719	23.9
Jul 19 2013	7976	950	42	49530276	5162057	6844	241586	206	93	37.9	1.8	0	291	499	706	19.5
Jul 20 2013	8036	1010	60	49882232	5514013	9970	351956	207	132	37	1.9	0	315	529	701	28.5
Jul 21 2013	8089	1063	53	50179205	5810986	8412	296973	206	117	38.9	1.6	0	303	514	721	23.9
Jul 22 2013	8139	1113	50	50472828	6104609	8318	293623	204	110	37.1	1.9	0	294	489	708	23.7
Jul 23 2013	8189	1163	50	50771231	6403012	8453	298403	207	111	36.6	1.9	0	368	604	740	23.9
Jul 24 2013	8240	1214	51	51066368	6698149	8361	295137	205	111	37.3	1.8	0	268	522	710	23.9
Jul 25 2013	8289	1263	49	51359287	6991068	8298	292919	203	109	36.6	2	0	123	523	717	23.9
Jul 26 2013	8338	1312	49	51656380	7288161	8416	297093	206	108	35.9	2	0	300	542	714	23.9
Jul 27 2013	8389	1363	51	51953544	7585325	8418	297164	207	112	37.1	1.9	0	328	583	724	22.8
Jul 28 2013	8439	1413	50	52248157	7879938	8346	294613	204	111	37.2	2	0	312	528	722	25.2

Jul 29 2013	8490	1464	51	52542485	8174266	8338	294328	204	112	37.5	1.9	0	303	552	725	23.9
Jul 30 2013	8541	1515	51	52840164	8471945	8433	297679	207	112	37.3	1.8	0	302	583	727	23.9
Jul 31 2013	8592	1566	51	53136452	8768233	8393	296288	206	112	37.4	1.8	0	74	487	730	23.9
Aug 1 2013	8643	51	51	53431616	295164	8361	295164	205	112	37.5	1.8	0	303	525	726	23.9
Aug 2 2013	8692	100	49	53724781	588329	8305	293165	204	109	36.6	2	0	351	593	721	23.9
Aug 3 2013	8741	149	49	54018411	881959	8318	293630	204	107	36.1	2	0	306	556	717	22.9
Aug 4 2013	8792	200	51	54312522	1176070	8332	294111	204	112	37.7	1.7	0	288	488	691	23.6
Aug 5 2013	8844	252	52	54605472	1469020	8299	292950	203	115	38.8	1.6	0	332	612	722	23.9
Aug 6 2013	8895	303	51	54899650	1763198	8333	294178	204	112	37.7	1.8	0	331	546	696	22.9
Aug 7 2013	8945	353	50	55197704	2061252	8443	298054	207	111	36.9	1.9	0	332	564	720	23.9
Aug 8 2013	8995	403	50	55495822	2359370	8445	298118	207	111	36.8	1.9	0	305	520	732	23.9
Aug 9 2013	9044	452	49	55792994	2656542	8418	297172	206	109	36.3	2	0	293	499	716	23.9
Aug 10 2013	9094	502	50	56091033	2954581	8443	298039	207	111	36.7	1.9	0	305	592	723	23.9
Aug 11 2013	9144	552	50	56387916	3251464	8410	296883	206	111	36.9	1.9	0	307	624	736	24.7
Aug 12 2013	9193	601	49	56683562	3547110	8375	295646	205	108	36.3	2.1	0	306	580	729	23.9
Aug 13 2013	9242	650	49	56977491	3841039	8326	293929	205	108	36.1	-1.6	0	311	508	713	22.9
Aug 14 2013	9292	700	50	57274014	4137562	8400	296523	205	111	37	2	0	308	538	720	25.4
Aug 15 2013	9342	750	50	57565274	4428822	8251	291260	202	109	37.1	2	0	296	514	710	23.9
Aug 16 2013	9392	800	50	57856828	4720376	8259	291554	202	111	37.5	1.9	0	309	545	726	23.9
Aug 17 2013	9437	845	45	58119037	4982585	7428	262209	204	99	37.4	2	0	296	551	718	23.2
Aug 18 2013	9437	845	0	58119037	4982585	0	0	0	0	0	0	0	0	0	0	0
Aug 19 2013	9437	845	0	58119037	4982585	0	0	0	0	0	0	0	0	0	0	0
Aug 20 2013	9475	883	38	58283429	5146977	4657	164392	203	83	48.8	2	1	386	586	708	11.4
Aug 21 2013	9530	938	55	58577205	5440753	8322	293776	204	122	41.2	2.3	0	314	574	727	0
Aug 22 2013	9553	961	23	58704514	5568062	3606	127309	202	50	39	2.4	0	348	621	728	12.4
Aug 26 2013	9594	1002	41	58883200	5746748	5062	178686	203	91	50.4	1.9	1	174	534	706	12.8
Aug 27 2013	9655	1063	61	59176037	6039585	8295	292837	203	135	45.1	2.1	0	326	575	719	23.9
Aug 28 2013	9714	1122	59	59473746	6337294	8434	297709	207	131	42.9	2	0	319	556	716	23.9
Aug 29 2013	9772	1180	58	59767972	6631520	8335	294226	206	127	42.1	2.1	0	319	567	715	24.7
Aug 30 2013	9830	1238	58	60064516	6928064	8401	296544	206	127	42.4	1.8	0	313	524	715	22.7
Aug 31 2013	9886	1294	56	60359459	7223007	8355	294943	205	124	41.5	2	0	201	549	725	23.9
Sep 1 2013	9940	54	54	60655248	295789	8379	295789	206	119	39.6	2.3	0	308	560	705	23.9
Sep 2 2013	9995	109	55	60951847	592388	8402	296599	206	120	40.1	2	0	301	525	704	22.8
Sep 3 2013	10047	161	52	61244288	884829	8284	292441	203	116	39.1	2.3	0	362	588	723	23.9
Sep 4 2013	10099	213	52	61540533	1181074	8392	296245	206	114	38.1	2.4	0	305	517	700	23.7
Sep 5 2013	10152	266	53	61832491	1473032	8271	291958	203	116	39.3	2.1	0	302	512	713	23.9
Sep 6 2013	10204	318	52	62124188	1764729	8263	291697	203	115	38.9	2.2	0	300	568	724	23.9
Sep 7 2013	10255	369	51	62421334	2061875	8418	297146	206	112	37.2	2.5	0	382	569	723	23.9
Sep 8 2013	10309	423	54	62718506	2359047	8418	297172	206	118	39.4	2	0	328	506	679	23.8
Sep 9 2013	10361	475	52	63010944	2651485	8284	292438	203	116	39.1	2.1	0	321	534	713	23.9
Sep 10 2013	10413	527	52	63307918	2948459	8413	296974	206	114	37.9	2.3	0	319	609	730	23.7
Sep 11 2013	10462	576	49	63602945	3243486	8358	295027	205	108	36.2	2.5	0	301	517	740	23.9
Sep 12 2013	10511	625	49	63899030	3539571	8387	296085	206	108	36.2	2.2	0	315	642	729	24.9
Sep 13 2013	10564	678	53	64194637	3835178	8374	295607	205	117	39	1.6	0	298	519	678	23.8
Sep 14 2013	10614	728	50	64488472	4129013	8324	293835	204	111	37.4	2.1	0	135	586	726	22.9
Sep 15 2013	10663	777	49	64784565	4425106	8388	296093	206	107	35.8	2.2	0	293	601	721	23.7
Sep 16 2013	10715	829	52	65078747	4719288	8334	294182	204	115	38.7	1.7	0	290	473	684	26.6
Sep 17 2013	10768	882	53	65371639	5012180	8297	292892	204	116	39.1	1.7	0	306	570	701	22.9
Sep 18 2013	10819	933	51	65662209	5302750	8231	290570	202	113	38.6	1.8	0	308	519	699	23.7
Sep 19 2013	10869	983	50	65957138	5597679	8355	294929	205	110	37	2	0	282	557	725	23.9
Sep 20 2013	10919	1033	50	66254537	5895078	8425	297399	206	111	36.8	1.9	0	319	547	711	23.8
Sep 21 2013	10970	1084	51	66550381	6190922	8381	295844	206	113	37.7	1.7	0	300	470	680	23.7
Sep 22 2013	11023	1137	53	66842779	6483320	8283	292398	203	116	39.2	1.6	0	301	480	706	23.9

Sep 23 2013	11074	1188	51	67137207	6777748	8341	294428	204	113	38	1.8	0	121	531	718	23.9
Sep 24 2013	11124	1238	50	67436874	7077415	8489	299667	208	111	36.7	1.9	0	395	597	707	23.8
Sep 25 2013	11176	1290	52	67733828	7374369	8412	296954	206	114	37.9	1.7	0	303	460	688	23.9
Sep 26 2013	11226	1340	50	68026609	7667150	8294	292781	204	111	37.6	1.8	0	337	510	669	23.8
Sep 27 2013	11275	1389	49	68318414	7958955	8266	291805	203	108	36.6	1.9	0	320	598	731	23.9
Sep 28 2013	11326	1440	51	68609995	8250536	8260	291581	202	112	37.9	1.7	0	379	636	723	23.8
Sep 29 2013	11378	1492	52	68905824	8546365	8380	295829	206	115	38.3	1.7	0	313	563	716	23.7
Sep 30 2013	11429	1543	51	69198022	8838563	8277	292198	203	112	37.9	1.8	0	387	611	726	24.9
Oct 1 2013	11478	49	49	69495821	297799	8436	297799	207	109	36.1	2.1	0	334	568	734	23.8
Oct 2 2013	11525	96	47	69789286	591264	8313	293465	204	105	35.2	2.1	0	457	663	735	22.9
Oct 3 2013	11572	143	47	70086712	888690	8425	297426	206	103	34.3	2.1	0	299	588	723	22.8
Oct 4 2013	11619	190	47	70381078	1183056	8339	294366	204	103	34.6	2	0	341	580	723	23.9
Oct 5 2013	11668	239	49	70674223	1476201	8304	293145	204	108	36.4	1.7	0	282	560	716	23.8
Oct 6 2013	11718	289	50	70968628	1770606	8340	294405	204	109	36.7	1.7	0	297	583	722	23.8
Oct 7 2013	11768	339	50	71264960	2066938	8394	296332	206	109	36.5	1.7	0	325	547	729	23.9
Oct 8 2013	11818	389	50	71557153	2359131	8277	292193	203	110	37.1	1.9	0	290	572	739	23.2
Oct 9 2013	11865	436	47	71854522	2656500	8424	297369	206	104	34.6	2.3	0	298	595	740	25.1
Oct 10 2013	11915	486	50	72151175	2953153	8404	296653	206	111	36.8	1.9	0	296	527	722	22.9
Oct 11 2013	11966	537	51	72446067	3248045	8354	294892	205	113	38	1.7	0	283	533	715	23.8
Oct 12 2013	12015	586	49	72739443	3541421	8311	293376	204	108	36.3	1.5	0	188	406	728	23.9
Oct 13 2013	12063	634	48	73037088	3839066	8432	297645	207	106	35.2	1.5	0	427	647	728	23.8
Oct 14 2013	12112	683	49	73331028	4133006	8327	293940	204	109	36.5	1.4	0	292	550	720	23.8
Oct 15 2013	12164	735	52	73625895	4427873	8353	294867	205	114	38.1	1.2	0	286	603	716	23.9
Oct 16 2013	12216	787	52	73919516	4721494	8318	293621	204	115	38.8	1.2	0	293	554	716	23.8
Oct 17 2013	12267	838	51	74214842	5016820	8366	295326	205	112	37.5	1.4	0	278	587	711	23.8
Oct 18 2013	12319	890	52	74510221	5312199	8367	295379	205	115	38.5	1.3	0	291	578	716	23.9
Oct 19 2013	12371	942	52	74804138	5606116	8326	293917	204	114	38.3	1.3	0	313	596	729	23.9
Oct 20 2013	12421	992	50	75099276	5901254	8361	295138	205	110	36.7	1.5	0	274	465	704	23.8
Oct 21 2013	12471	1042	50	75396624	6198602	8423	297348	206	111	36.9	1.4	0	246	578	722	23.8
Oct 22 2013	12520	1091	49	75688990	6490968	8282	292366	203	109	36.7	1.5	0	263	553	720	23.9
Oct 23 2013	12569	1140	49	75978909	6780887	8213	289919	201	108	36.6	1.5	0	260	541	731	24.8
Oct 24 2013	12618	1189	49	76269249	7071227	8225	290340	202	107	36.5	1.4	0	263	543	720	23.9
Oct 25 2013	12670	1241	52	76565640	7367618	8396	296391	206	116	38.5	1.2	0	284	476	671	22.8
Oct 26 2013	12721	1292	51	76863661	7665639	8442	298021	207	113	37.5	1.4	0	271	530	704	23.8
Oct 27 2013	12769	1340	48	77156375	7958353	8292	292714	203	105	35.4	1.7	0	323	555	710	23.9
Oct 28 2013	12816	1387	47	77450732	8252710	8339	294357	205	104	35	1.6	0	315	582	711	23.8
Oct 29 2013	12868	1439	52	77744844	8546822	8332	294112	204	114	38.2	1.2	0	286	537	709	23.9
Oct 30 2013	12921	1492	53	78038169	8840147	8309	293325	205	117	39.3	1.2	2	179	576	722	23.7
Oct 31 2013	12973	1544	52	78329575	9131553	8255	291406	202	115	39.1	1.3	0	329	637	736	22.9
Nov 1 2013	13022	49	49	78622755	293180	8305	293180	203	108	36.4	1.6	0	270	554	731	23.8
Nov 2 2013	13072	99	50	78920483	590908	8434	297728	207	110	36.6	1.4	0	287	594	731	23.9
Nov 3 2013	13097	124	25	79062284	732709	4017	141801	209	55	38.2	1.3	0	43	463	604	15.2
Nov 4 2013	13097	124	0	79062284	732709	0	0	0	0	0	0	0	0	0	0	0
Nov 5 2013	13097	124	0	79062285	732710	0	1	1	0	0	0	0	0	0	0	0
Nov 6 2013	13097	124	0	79062286	732711	0	1	1	0	0	0	0	0	0	0	0
Nov 7 2013	13097	124	0	79062287	732712	0	1	1	0	0	0	0	0	0	0	0
Nov 8 2013	13097	124	0	79062288	732713	0	1	1	0	0	0	0	0	0	0	0
Nov 9 2013	13097	124	0	79062289	732714	0	1	1	0	0	0	0	0	0	0	0
Nov 10 2013	13097	124	0	79062290	732715	0	1	1	0	0	0	0	0	0	0	0
Nov 11 2013	13097	124	0	79062291	732716	0	1	1	0	0	0	0	0	0	0	0
Nov 12 2013	13097	124	0	79062292	732717	0	1	1	0	0	0	0	0	0	0	0
Nov 13 2013	13097	124	0	79062293	732718	0	1	1	0	0	0	0	0	0	0	0
Nov 14 2013	13097	124	0	79062294	732719	0	1	1	0	0	0	0	0	0	0	0

Nov 15 2013	13097	124	0	79062295	732720	0	1	1	0	0	0	0	0	0	0	0
Nov 16 2013	13097	124	0	79062296	732721	0	1	1	0	0	0	0	0	0	0	0
Nov 17 2013	13097	124	0	79062297	732722	0	1	1	0	0	0	0	0	0	0	0
Nov 18 2013	13097	124	0	79062298	732723	0	1	1	0	0	0	0	0	0	0	0
Nov 19 2013	13097	124	0	79062299	732724	0	1	1	0	0	0	0	0	0	0	0
Nov 20 2013	13097	124	0	79062300	732725	0	1	1	0	0	0	0	0	0	0	0
Nov 21 2013	13097	124	0	79062301	732726	0	1	1	0	0	0	0	0	0	0	0
Nov 22 2013	13097	124	0	79062302	732727	0	1	1	0	0	0	0	0	0	0	0
Nov 23 2013	13097	124	0	79062304	732729	0	2	2	0	0	0	0	0	0	0	0
Nov 24 2013	13097	124	0	79062305	732730	0	1	1	0	0	0	0	0	0	0	0
Nov 25 2013	13097	124	0	79062306	732731	0	1	1	0	0	0	0	0	0	0	0
Nov 26 2013	13097	124	0	79062307	732732	0	1	1	0	0	0	0	0	0	0	0
Nov 27 2013	13097	124	0	79062308	732733	0	1	1	0	0	0	0	0	0	0	0
Nov 28 2013	13097	124	0	79062309	732734	0	1	1	0	0	0	0	0	0	0	0
Nov 29 2013	13097	124	0	79062310	732735	0	1	1	0	0	0	0	0	0	0	0
Nov 30 2013	13097	124	0	79062311	732736	0	1	1	0	0	0	0	0	0	0	0
Dec 1 2013	13097	0	0	79062312	1	0	1	1	0	0	0	0	0	0	0	0
Dec 2 2013	13133	36	36	79193864	131553	3727	131552	202	79	59.4	0.8	3	8	592	644	8.7
Dec 3 2013	13207	110	74	79486696	424385	8295	292832	203	162	54.7	0.9	0	512	613	704	23.9
Dec 4 2013	13275	178	68	79780793	718482	8331	294097	204	149	50.1	1	0	263	521	706	23.9
Dec 5 2013	13337	240	62	80078097	1015786	8422	297304	207	137	45.7	1.2	0	291	413	650	23.8
Dec 6 2013	13390	293	53	80373748	1311437	8375	295651	205	118	39.4	1.5	0	182	567	718	23.8
Dec 7 2013	13440	343	50	80670122	1607811	8396	296374	206	110	36.5	1.7	0	374	651	720	23.9
Dec 8 2013	13488	391	48	80966274	1903963	8389	296152	206	107	35.5	1.7	0	297	634	734	23.9
Dec 9 2013	13534	437	46	81263469	2201158	8419	297195	207	101	33.6	1.8	0	309	603	734	23.8
Dec 10 2013	13559	462	25	81438460	2376149	4957	174991	204	56	31.7	2	0	14	576	724	16.2
Dec 11 2013	13583	486	24	81565805	2503494	3607	127345	208	53	40.9	1.3	3	221	618	717	8.3
Dec 12 2013	13628	531	45	81860947	2798636	8361	295142	205	99	33.1	1.7	0	100	572	723	24.1
Dec 13 2013	13668	571	40	82143032	3080721	7991	282085	204	89	31	2.1	1	46	504	604	22.9
Dec 14 2013	13709	612	41	82439865	3377554	8409	296833	206	90	30.1	2.2	0	78	565	733	23.9
Dec 15 2013	13750	653	41	82735750	3673439	8382	295885	205	91	30.3	2.2	0	311	451	667	23.8
Dec 16 2013	13797	700	47	83032115	3969804	8395	296365	206	103	34.3	1.8	0	316	523	714	23.8
Dec 17 2013	13850	753	53	83326784	4264473	8347	294669	205	116	38.9	1.5	0	293	486	721	23.8
Dec 18 2013	13869	772	19	83425569	4363258	2798	98785	206	42	42	1.2	0	349	540	700	8
Dec 20 2013	13920	823	51	83720927	4658616	8367	295358	205	112	37.5	1.4	0	397	638	736	23.8
Dec 21 2013	13967	870	47	84017024	4954713	8388	296097	206	104	34.7	1.6	0	245	520	695	23.9
Dec 22 2013	14012	915	45	84312076	5249765	8358	295052	205	100	33.5	1.8	0	267	554	720	24.2
Dec 23 2013	14059	962	47	84609402	5547091	8423	297326	207	104	34.4	1.6	0	264	510	721	23.8
Dec 24 2013	14107	1010	48	84905096	5842785	8376	295694	205	106	35.3	1.5	0	275	557	733	23.9
Dec 25 2013	14153	1056	46	85202972	6140661	8438	297876	207	102	33.9	1.6	0	243	575	728	23.9
Dec 26 2013	14200	1103	47	85500995	6438684	8442	298023	207	103	34.3	1.6	0	288	480	717	23.8
Dec 27 2013	14249	1152	49	85800322	6738011	8479	299327	208	107	35.4	1.6	0	274	522	682	23.9
Dec 28 2013	14297	1200	48	86098045	7035734	8434	297723	207	106	35.2	1.9	0	72	556	709	23.8
Dec 29 2013	14346	1249	49	86392554	7330243	8343	294509	205	109	36.6	1.6	0	241	581	715	23.8
Dec 30 2013	14393	1296	47	86689471	7627160	8411	296917	206	103	34.1	1.9	0	245	483	722	23.9
Dec 31 2013	0	0	43	0	0	8398	296449	206	94	31.3	2.3	0	92	569	712	23.4

APPENDIX H

Groundwater Monitoring Report

PINCHIN ENVIRONMENTAL

MEMBER OF THE PINCHIN GROUP

2013 Water Quality Monitoring Report
Eastview Landfill
Brandon, Manitoba

Prepared for:
City of Brandon
900 Richmond Avenue East
Brandon, MA R7A 6A2

Attention: Mr. Ian Broome

November 2013

Pinchin File: 78108

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DRAWINGS

APPENDICES

1.0 INTRODUCTION

Pinchin Environmental Ltd. ("Pinchin") was retained by the City of Brandon ("Brandon") to complete the 2013 Annual Water Quality Monitoring and Reporting ("2013 WQR") for the Brandon Eastview Landfill. This report pertains to recent monitoring data collected throughout 2013 to constitute the 2013 WQR. The Site Location Plan and Aerial Location Plan have been provided on Figures 1 and 2, respectively, and all figures have been provided in Appendix I. The Eastview Landfill (hereafter referred to as the "Site") is located south of Victoria Avenue on 33rd Street East within the municipal boundaries of Brandon, Manitoba.

1.1 Scope of Work

This WQR describes the 2013 summer groundwater and surface water quality monitoring in accordance with the environmental monitoring requirements as established in the City of Brandon's Class 1 landfill operations permit as issued and managed by Manitoba Conservation. The Eastview Landfill results are currently required to be reported to Manitoba Conservation on an annual basis.

The scope of work conducted as part of the sampling and analysis program was as follows:

- Complete one groundwater and surface water sampling event during the summer of 2013 and provide a water quality monitoring report;
- Water samples were to be collected from each of the thirty monitoring wells and from each of the three dugouts/trenches. Sampling methodologies were to be completed in compliance to Appendix 7 Sampling Protocols established in the Manitoba Conservation Guideline N094-01-E;
- Thirty-one water samples were to be submitted to an accredited laboratory for analysis of organic and inorganic parameters, listed in Table 1 of the Waste Disposal Ground Permit 301 1.17, Background Water Quality Chemical and Microbiological Parameters; and
- Prepare a report in compliance with the City of Brandon's operating permit (3011.17) as issued by Manitoba Conservation under Regulation 150/91.

1.2 Background

The Eastview Landfill consists of 61.47 ha of land located on 33rd Street East in Brandon. The Site layout, including the location of the monitoring wells, is shown on Figure 2. The Site includes a waste collection area, composting (windrow) area, three surface water retention dugouts/trenches, as well as thirty groundwater monitoring wells.

The purpose of the monitoring program was to maintain compliance with the environmental monitoring requirements as established in the City of Brandon's Class 1 landfill operations permit as issued and managed by Manitoba Conservation.

Pinchin was provided with the following historical report:

- *Results of Groundwater and Surface Water Monitoring Program, Eastview Landfill, City of Brandon, Manitoba.* AMEC, August 2011.

According to the previous 2011 Monitoring Report by AMEC, the following additional reports are also on file with the City of Brandon:

- *2004 Groundwater Monitoring Program at the Eastview Landfill Located in Brandon, Manitoba.* Earth Tech Canada Inc., July 2005;
- *Groundwater Monitoring Program at the Eastview Landfill Located in Brandon, Manitoba.* Earth Tech Canada Inc., February 2003; and
- *Report on the Groundwater Quality Entering and Leaving the Eastview Landfill, Brandon, Manitoba.* Earth Tech (Canada) Inc., May 2001.

2.0 METHODOLOGY

To perform the water quality monitoring activities, Pinchin completed the following tasks at the Eastview Landfill as detailed below:

- As a series of samples were collected from multiple locations using standard purging and sampling equipment, an effort was made to minimize potential for cross-contamination by initiating sampling at the lesser-contaminated sampling stations and progress to locations with higher potential levels of contamination. In addition, when equipment is used at more than one sampling location (i.e., water level meter), the equipment is cleaned, using Alconox™, methanol, and rinsed with distilled water in the field, between each sampling location;
- Static groundwater levels were measured at all monitoring well locations during each monitoring event using a water level tape. Measurements were collected from the top of riser pipe (which have been previously surveyed) and were compared to previously collected data to determine the water table trends and anomalies;
- Monitoring wells were purged during each sampling event prior to the collection of samples. Pinchin purged a minimum of three (3) well volumes to a maximum of six (6) well volumes until the well volume column was representative of the surrounding formation;
- Field water quality parameters were collected from each sampling station using a calibrated YSI-556 water quality meter to measure field parameters including:
    - Dissolved Oxygen ("DO");
    - Conductivity, Salinity, and Specific Conductivity;
    - pH;
    - Temperature;
    - Total Dissolved Solids ("TDS"); and
    - Oxidation-Reduction Potential ("ORP").

- The primary consideration was to obtain a representative sample of the groundwater body by guarding against mixing the sample with stagnant water in the well casing. Groundwater samples were collected from each groundwater monitoring installation in accordance with standard professional practices. Dissolved parameters were field-filtered using an in-line 0.45 micron disposable filter. Upon completion of field sampling and monitoring activities, all samples collected were submitted for analyses to a laboratory accredited by the Canadian Association for Laboratory Accreditation (CALA) in accordance with the International Standards ISO/IEC 17025 "*General Requirement for the Competence of Testing and Calibration Laboratories*" dated December 15, 1999. All parameters were tested using approved procedures and the analytical methods;
- Water samples were analyzed at pre-determined sampling station for parameters determined during previous investigations and the City of Brandon;
- All sample containers were provided by the laboratory (certified clean), and were appropriate for the parameters being analyzed. All sample containers were labelled with their respective sampling locations and date. Sample collection equipment (bailers and samplers) were dedicated to one sampling location only. Water quality samples were collected by trained field staff using clean disposable nitrile gloves. Field-filtering and preservation was completed appropriately during sampling and samples were kept cool by storing and transporting them in coolers with ice; and
- Samples were packed in a cooler, complete with ice, for shipment to the analytical laboratory. The packing was suitable to ensure bottles were not damaged in transit, and the coolers were sealed at the Site. All samples were submitted to the laboratory under a chain of custody procedure. References on the chain of custody to specific samples matched sample identifications on the sample bottles. Samples were shipped to ensure sample shipment and arrival, and resulting storage time, prior to laboratory analysis, did not exceed allowable limits.

3.0 MONITORING SUMMARY

3.1 Groundwater Monitoring

The Eastview Landfill is monitored by a system of groundwater monitoring wells and surface water sampling points. The monitoring wells were installed at various times since 1999, and have provided a long-term record of groundwater quality data for the evaluation of the Site performance. Historically, a total of twenty-seven monitoring wells were installed at numerous locations across the Site, with three monitoring wells located off-Site. The three off-Site wells are located to the northeast of the Site, which is the inferred groundwater flow direction, and provide a record of the water quality downgradient of the landfill through natural attenuation. Currently, a total of thirty monitoring wells are in use. The location of all monitoring wells is shown on Figure 2. The borehole logs for approximately twenty monitoring well installations are provided in Appendix II.

Based on the 2013 round of monitoring (the most recent monitoring), groundwater flow beneath the landfill Site has been illustrated on Figure 2. Based on the 2013 monitoring results, groundwater appears to flow in a north to northeast direction toward the Assiniboine River, which is the likely groundwater discharge point. This pattern of groundwater flow is similar to the historical groundwater monitoring events.

Wells BH9 and BH10/BH10D are located downgradient to the northeast of the Eastview Landfill. The majority of the remaining wells are located to the north, south, east and west of the Site, with three wells, BH17, BH18 and BH19, being located within the operating landfill. During July 2013, wells BH11 and BH12 were observed to be dry and thus, a sample was unable to be retrieved.

3.2 Surface Water Monitoring

Water quality in the vicinity of the Eastview Landfill is currently monitored and assessed using three on-Site surface water monitoring stations. The Assiniboine River is located north and east of the Site at approximately 400 and 800 m distance, respectively, and eventually flows in a southeasterly direction beyond the Brandon city limits.

Surface water monitoring points have historically been established on the Eastview Landfill and are identified as SW1, SW2 and SW3, as shown on Figure 2. SW1 is located on the west side of a small retention pond, which is located near the southwest corner of the landfill. SW2 is located on the west side of a small retention pond, which is located near the northwest corner of the landfill. SW3 is located at the east end of a drainage ditch, which is located near the southwest landfill boundary.

During July 2013, surface water levels were low at SW3 and thus, a sample was unable to be retrieved.

3.3 Field Monitoring

Water level information is obtained from the entire monitoring well network. The static water level data and field parameters measured throughout July 2013, which includes pH, conductivity and temperature, were collected at the various groundwater and surface water sampling locations. The results can be found on the table below:

2013 Brandon Eastview Landfill Field Results

BH Location	Sample Date	Depth to water (M)	Water Temp °C	mS/cCm	mS/cm	DO%	DO mg/L	pH	pHmV	ORP
BH-4D	07/31/13	8.42	11.06	1.649	1.293	29.7	3.08	7.47	-50.0	-84.8
BH-4S	08/01/13	2.80	11.50	2.425	1.901	72.7	7.49	7.65	-51.6	-32.2
BH-4M	08/01/13	5.69	10.13	1.844	1.365	29.9	3.26	7.64	-50.2	-62.8
BH-13	07/31/13	2.96	12.10	1.994	1.506	42.3	5.51	7.36	-34.9	-53.1
BH-6 Lab Dup 2013	07/31/13	5.94	10.20	1.776	1.343	23.7	2.52	7.66	-52.2	-80.7
BH-7	07/31/13	6.73	11.20	2.560	1.949	33.1	3.51	7.54	-41.3	-74.0
BH-11D	07/31/13	8.50	10.50	2.773	2.154	22.6	2.35	7.34	-34.5	-52.5
BH-8W	07/30/13	6.69	9.06	1.874	1.338	36.5	3.98	7.94	-51.4	-26.4
BH-8	07/30/13	6.47	10.50	2.850	2.112	27.5	2.94	7.94	-42.0	-60.0
BH-5	07/30/13	5.81	9.76	1.659	1.217	39.3	4.30	7.66	-51.4	-23.4
BH-5D	07/30/13	8.99	8.50	2.237	1.650	31.8	3.47	7.61	-46.0	-34.1
BH-5W	07/30/13	6.87	9.66	0.910	0.694	18.6	1.99	7.64	-49.5	-78.7
BH-3-5E	07/25/13	1.98	12.97	2.956	2.279	34.4	3.59	7.60	-27.0	23.1
BH-3-5W	07/30/13	1.90	13.00	2.218	1.736	29.8	3.07	7.11	-2.1	76.6
BH-3	07/25/13	4.29	11.68	2.846	2.129	19.6	2.10	7.62	-29.1	11.1
BH-4	07/25/13	2.67	12.50	2.230	1.706	56.1	5.94	7.81	-27.0	32.2
BH-1	07/25/13	8.31	9.50	1.204	0.925	35.3	3.71	7.55	-44.0	-8.0
BH-16	07/25/13	3.90	9.40	2.659	1.969	24.4	2.64	7.62	-36.8	-0.3
BH-2	07/25/13	4.64	9.91	2.148	1.611	22.6	2.42	7.81	-46.5	1.7
BH-2D	07/25/13	9.09	9.04	2.473	1.769	20.3	2.47	7.23	-38.2	-3.2
BH-15	07/25/13	2.76	12.82	2.607	2.005	57.8	6.11	7.90	-43.0	57.5
BH-18	08/01/13	3.39	13.50	1.665	1.315	78.0	7.98	7.55	-34.6	-29.4
BH-19	08/01/13	6.59	12.50	1.082	0.852	29.5	3.01	7.58	-41.8	-89.5
BH-17	08/01/13	7.38	11.50	1.756	1.494	37.7	3.56	7.37	-20.5	-65.1
BH-20	08/01/13	4.80	11.81	3.024	2.266	42.5	4.53	7.75	-29.6	-87.5
SW-1	08/06/13	N/A	22.60	1.405	1.340	158.2	13.58	9.62	-14.2	-91.6
SW-2	07/31/13	N/A	20.37	2.159	1.968	0.6	8.04	8.06	-127.4	-160.9
BH-10	08/01/13	3.68	18.13	1.333	0.999	41.5	4.00	7.85	-55.1	-76.6
BH-10D	08/01/13	7.14	12.05	1.482	1.033	20.5	2.28	7.34	-51.8	-36.9
BH-9	08/01/13	3.80	12.23	1.206	0.839	42.9	4.74	7.74	-48.2	53.7
BH-11	07/25/13	DRY								
BH-12	07/25/13	DRY								

4.0 CHEMICAL ANALYSIS

In total, twenty-eight groundwater samples were analysed, plus duplicates, as well as two surface water samples. The samples were submitted under chain of custody to AGAT Laboratories in Mississauga, Ontario. The laboratory Certificates of Analysis for all water quality samples analysed are provided in Appendix III. AGAT is accredited by CALA and their Quality Analysis / Quality Control ("QA/QC") program meets or exceeds ISO/IEC 17025 "General Requirement for the Competence of Testing and Calibration Laboratories", dated December 15, 1999. The results of AGAT's internal QA/QC are documented within each Certificate of Analysis.

The annual water quality sampling at the Eastview Landfill included the following analyses:

- General Chemistry: Bicarbonate/Carbonate, Hydroxide, Alkalinity, Hardness, pH, Conductivity, Turbidity, TSS, TDS, TS, Total Cyanide, Ammonia, TKN, Total Phosphorous;
- Anions: Chloride, Nitrate, Nitrite, Sulphate;
- Cations: Calcium, Magnesium, Potassium, Sodium;
- Metals: Arsenic, Barium, Beryllium, Cadmium, Copper, Iron, Lead, Manganese, Nickel, Selenium, Silver, Zinc;
- Mercury;
- Polyaromatic Hydrocarbons: Naphthalene, Benzo(a)pyrene, Anthracene;
- CCME F1-F4;
- VOC: Benzene, Toluene, Ethylbenzene, Xylene, Vinyl Chloride;
- Organophosphorous Pesticide: Diazinon;
- Phenoxy Acid Herbicide: 2,4-D;
- Fecal Coliforms; and
- Total Coliforms.

5.0 WATER QUALITY RESULTS

The results of the analysis were to be compared with the Guidelines for *Canadian Drinking Water Quality*, dated August 2012 ("Guidelines"). The Guidelines are established by the Federal-Provincial-Territorial Committee on Drinking Water (CDW) and published by Health Canada. This summary table is updated regularly and published on Health Canada's website (www.healthcanada.gc.ca/waterquality). It supersedes all previous electronic and printed versions, including the 6th edition of the Guidelines for Canadian Drinking Water Quality (1996). A copy of the Guideline is included in Appendix IV. Table 1 indicating all samples along with the analytical results is provided in Appendix V.

5.1 Total Coliforms / Fecal Coliforms

Total coliforms were noted in every water sample retrieved from the Site exceeding the Guidelines of 'none detectable per 100 mL' with the exception of sampling stations BH-3-5W and BH-2.

Fecal coliforms are not regulated within the Guidelines and were only noted at sampling stations BH-8W, BH-8, BH-5, BH-5D, BH-5W, BH-3-5E, BH-3-5W, BH-3, BH-4, BH-16, BH-2D, BH-15, BH-19, SW-1, SW-2 and BH-10.

5.2 Pesticides 2,4-D and Diazinon

All analytical results indicated that the concentrations of these two parameters were all below the laboratory reportable detections limits for all samples analysed.

5.3 Petroleum Hydrocarbon Fractions (PHCs) F1-F4

All analytical results indicated that the concentrations of PHCs F1-F4 were all below the laboratory reportable detections limits for all samples analysed.

5.4 Polycyclic Aromatic Hydrocarbons (PAHs)

All analytical results indicated that the concentrations of Naphthalene, Anthracene and Benzo(a)pyrene were all below the laboratory reportable detections limits for all samples analysed.

5.5 Volatile Organic Compounds (VOCs)

All analytical results indicated that the concentrations of Vinyl Chloride, Benzene, Toluene, Ethylbenzene and Xylene Mixture were all below the laboratory reportable detections limits for all samples analysed, with the exception of sample station BH-3-5W and surface water station SW-2. BH-3-5W exhibited measurable concentrations of Benzene, but was still well below the Guidelines. SW-2 exhibited measurable concentrations of Toluene, but was still well below the Guidelines.

5.6 Nutrients (Nitrate / Nitrite)

All analytical results indicated that the concentrations of Nitrite were all below the laboratory reportable detections limits for all samples analysed.

Analytical exceedances of the Guidelines were noted for Nitrate at sampling stations BH-3-5E, BH-3, BH-4, BH-16, BH-2 and BH-15. All remaining sampling points were well below the Guidelines for this parameter.

5.7 General Chemical Parameters

All analytical results indicated that the concentrations of the various General Chemical parameters were all below the Guidelines for all samples analysed.

5.8 Metals

All analytical results indicated that the concentrations of the various Metals were all below the Guidelines for all samples analysed, with the exception of sample stations BH-5W, BH-3-5W and SW-2. Analytical exceedances of the Guidelines were noted for Arsenic at sampling stations BH-5W, BH-3-5W and SW-2.

5.9 Aesthetic Objectives

Some water quality exceedances were noted for various metals and general chemical parameters that have an 'Aesthetic Objective' from sampling stations across the Site. However, these Aesthetic Objectives are designed and related to drinking water systems. As groundwater is not being consumed in the vicinity of the landfill, these exceedances of the Aesthetic Objectives should not pose a risk. The exceedances of the Aesthetic Objectives can be viewed on Table 1 in Appendix V.

6.0 TREND ANALYSIS

The current and previous groundwater quality data were reviewed with the objective of identifying any apparent trends or inconsistencies in the monitoring record. In addition, a time-concentration graph was developed for TDS a common landfill indicator parameter. The groundwater trend graph comparing all monitoring wells is presented in Appendix VI.

7.0 SUMMARY AND CONCLUSIONS

The Eastview Landfill is monitored by a system of groundwater monitoring wells and surface water sampling points. The monitoring wells were installed at various times since 1999, and have provided a long-term record of groundwater quality data for the evaluation of the Site performance. Historically, a total of twenty-seven monitoring wells were installed at numerous locations across the Site, with three monitoring wells located off-Site. The three off-Site wells are located to the northeast of the Site, which is the inferred groundwater flow direction, and provide a record of the water quality downgradient of the landfill through natural attenuation.

Analytical exceedances of the Guidelines were noted for Arsenic at sampling station BH-5W. However, sampling stations BH-5 and BH-5D, which are downgradient of BH-5W, and located closer to the east property boundary, did not indicate concerns with respect to Arsenic. As such, the Arsenic exceedance at BH-5W appears to be a localized concern within the landfill confines.

A review of the groundwater quality monitoring data for the Eastview Landfill indicates that the Site is having minor hydrogeochemical impact on the groundwater system below the landfill. Trends in the data are similar to the historical data with leachate impacts attenuating accordingly prior to the downgradient off-Site monitoring well system. In summary, the Eastview Landfill is continuing to operate as a natural attenuation type facility with no unusual or anomalous data from the historical data.

8.0 DISCLAIMER

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of the third parties. If additional parties require reliance on this report, written authorization from Pinchin will be required. Pinchin disclaims responsibility of consequential financial effects on transactions or property values, or requirements for follow-up actions and costs. No other warranties are implied or expressed.

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Pinchin makes no other representations whatsoever, including those concerning the legal significance of its findings, or as to other legal matters touched on in this report, including, but not limited to, ownership of any property, or the application of any law to the facts set forth herein. With respect to regulatory compliance issues, regulatory statutes are subject to interpretation and these interpretations may change over time.

9.0 SIGNATURE PAGE

We trust that the foregoing information is satisfactory for your present requirements.

Should you have any questions about the report or require additional information, please contact the undersigned.

Yours truly,

PINCHIN ENVIRONMENTAL LTD.

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APPENDIX I

Closure Plan

Environment

City of Brandon

Waste Disposal Closure

Prepared by:

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www.aecom.com

Project Number:

60154068 (404.19)

Date:

June, 2010

Statement of Qualifications and Limitations

The attached Report (the “Report”) has been prepared by AECOM Canada Ltd. (“Consultant”) for the benefit of the client (“Client”) in accordance with the agreement between Consultant and Client, including the scope of work detailed therein (the “Agreement”).

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- must be read as a whole and sections thereof should not be read out of such context
- were prepared for the specific purposes described in the Report and the Agreement
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time

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- in the case of subsurface, environmental or geotechnical conditions, is not responsible for variability in such conditions geographically or over time

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- as required by law
- for use by governmental reviewing agencies

Any use of this Report is subject to this Statement of Qualifications and Limitations. Any damages arising from improper use of the Report or parts thereof shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report.

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Winnipeg, MB, Canada R3P 0Y7
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204 477 5381 tel
204 284 2040 fax

June 9, 2010

Mr. Ian Broom
Director of Public Works; Operational Services Division
City of Brandon
410 9th Street
Brandon, Manitoba
R7A 6A2

Dear Mr. Broom:

Project No: 60154068

Regarding: Waste Disposal Closure

AECOM is pleased to provide you with three (3) copies of our Final Waste Disposal Closure plan for the City of Brandon Waste Disposal Ground (Eastview Landfill).

We thank you for the opportunity to complete this work on behalf of the City of Brandon. Should you have any questions or require additional information please contact Craig Blair at (204) 477-5381.

Sincerely,
AECOM Canada Ltd.

Ron Typliski, P.Eng.
Vice-President, Manitoba District
Canada West Region

CB:snb
Encl.

Distribution List

# of Hard Copies	PDF Required	Association / Company Name
3	X	City of Brandon

Revision Log

Revision #	Revised By	Date	Issue / Revision Description
A	Craig Blair	May 18, 2010	Draft issued for client review
B	Septa Rendra	June 7, 2010	Final Review
C	Craig Blair	June 9, 2010	Final Review

AECOM Signatures

Report Prepared By:

Danielle MacDonald, E.I.T.
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Report Reviewed By:

Craig Blair, P. Eng.
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PROVINCE OF MANITOBA
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Report Reviewed By:

Septa Rendra, Ph.D., P.Eng. (ON and AB)
Environmental Engineer

APEGM
Certificate of Authorization
AECOM Canada Ltd.
No. 4671 Date: 2010/06/09

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Appendices

1. Introduction

1.1 Location

AECOM Canada Ltd. (AECOM) was retained by the City of Brandon (Brandon) to complete a decommissioning plan for the existing Brandon waste disposal ground (Eastview Landfill). Brandon is located approximately 212 km west of Winnipeg, MB, on the Trans-Canada Highway 1. The landfill is located at 3000 Victoria Avenue, directly east of the city's centre. The site location is presented in the Drawing 00-C-T01 of Appendix A.

1.2 Current Conditions

Existing solid waste management practices at the Eastview Landfill consist of full residential and commercial waste disposal for the City of Brandon. It is the only waste disposal facility available to Brandon, a municipality populated by 41, 511 people (2006)[1]. Since over 5,000 residents are serviced, the facility operates as a Class I Waste Disposal Ground (WDG) under the Manitoba Environment Act (the Act). As a Class 1 operation, the City of Brandon is required by the Province of Manitoba to hold an environmental licence in accordance with Section 11 and in the format of Schedule B of the Act[2].

An environmental licence must be issued by requirement of the Province of Manitoba, for new construction, expansion of an existing one, or the ongoing operation of a WDG. The licence specifies that the WDG shall satisfy requirements as set out in Section 11 and Schedule B of the Act as amended, or as otherwise specified in the WDG regulations, issued in July 1991. Terms and Conditions of this licence dictate landfill design, construction and operation.

The landfill is open to the public from November to March, Monday to Friday, 8:00 am to 5:45 pm, and on Saturdays, 8:00 am to 4:45 pm. From April to October, access is extended during the week to 7:45 pm, and the Saturday schedule is extended to include holidays. Additionally, the landfill is also open on Sunday from 11:00 am to 6:45 pm during the summer season.[3] The public is permitted full access to the disposal sites, after reporting to the scale house operator, who manages the collection of tipping fees and scale records. The facility is locked during closure, and is supervised by at least one employee on-site during operational hours.

The current facility layout and operations include:

- Former and active disposal areas;
- Full depot for residential and commercial waste, including contaminated soil, all directed to the tipping face;
- Leachate collection and pumped to a wastewater treatment facility;
- Scale house and operator;
- City snow removal dump site;
- Clean fill disposal;

[1] Statistics Canada (2010). *2006 Community Profiles – Brandon, Manitoba*. retrieved on May 4, 2010 from http://www12.statcan.gc.ca/census-recensement/2006/dp-pd/prof/92-591/details/Page.cfm?Lang=E&Geo1=CSD&Code1=4607062&Geo2=PR&Code2=46&Data=Count&SearchText=Brandon&SearchType=Begins&SearchPR=01&B1=All&Custom=

[2] Province of Manitoba (1991). *Waste Disposal Grounds Regulation (E125-M.R. 150/91).The Environment Act (C.C.S.M. c. E125)*. The Queen's printer for the Province of Manitoba.

[3] City of Brandon, *General Information – City of Brandon, Manitoba, Canada*, retrieved on May 4, 2010 from http://www.city.brandon.mb.ca/Main.nsf/Pages+By+ID/416

- Separation of metals, batteries, propane tanks, tires, yard compost, waste wood, and tree brush from ordinary refuse stream (mostly residential), which is stored in designated areas;
- Freon depleting devices depot;
- A recycling facility; and
- Tree chipping and composting.

Since construction in 1977, there have been 12 Phases that have been constructed and closed as the Site, and at the time this report waste was being placed in the Phase 13. The volume of material that has been placed in the first 12 Phase has been estimated to be 2,396,875 m^3. This estimate assumes that the original ground elevation of the closed cells is similar to the elevation of the exposed base of Phase 13. This estimate also assumes that the construction practices that are typically used at the current facility were also used during the previous Phases of construction. If an average compaction achieved was assumed to be 800 kg/m^3, than the waste accommodated by this airspace would be estimated to be 1,917,500 tonnes.

The present extent of landfill development and location of landfill ancillary operations is shown on Drawing 00-C-T02 of Appendix A.

1.3 Scope of Work

To provide the City of Brandon with the necessary information to execute a plan for closure of the Eastview Facility, AECOM has completed the following tasks:

- Confirmation between AECOM and the City of Brandon regarding project scope, budget, and schedule;
- Established formal lines of communication;
- Collected, requested, and assembled all necessary and available information from the City in order to conduct the site assessment;
- Reviewed existing information; and
- Conducted a landfill site visit.

The City of Brandon has requested that the existing Eastview Landfill be assessed for the following:

- The current waste generation estimate received by the landfill;
- An estimate of the remaining useable life of the landfill site based on waste generation and available airspace;
- A conceptual drawing of the proposed future development;
- Estimation of closure costs;
- An estimation of ongoing maintenance cost following site closure (post closure); and
- Preparation and submission of a report providing costing models and site development drawings.

2. Site Life

2.1 Population

Using census information from Statistics Canada, the average population increase per year for the City of Brandon is 0.6% from 1996 to 2006. The details of this growth are described in Table 2.2. By projecting this growth from 2006, the population calculated for 2010 was estimated to be 42,516.

Table 1 – Population of the City of Brandon

	Brandon	Percent Increase
Population 1996	39,145	-
Population 2001	39,716	1.4%
Population 2006	41,511	4.5%
Average population increase/year		0.6%
Projected Population for 2010	42,516	

2.2 Waste Generation

The Eastview Landfill currently utilizes approximately half of the available land area for area fill disposal, therefore, a significant amount of potential airspace remains for use. The remaining site life in years must be determined in order to plan for the final closure and post closure management and costs. In order to calculate the amount of airspace used per year, the waste generation value for the Eastview Landfill was calculated by two methods:

The first method was evaluation by population size. A factor of 3.0 kg/capita/day was used to calculate the waste generated by a population of 42, 516, estimated for 2010. (See Table 2.1) Based on this approximation, Brandon produces approximately 46,555 tonnes/year of solid waste.

The second approach incorporated the annual tonnage of waste received by the Eastview Landfill, obtained from records kept by the City of Brandon. Table 2.2 represents the amount of refuse disposed of by area fill methods in 2009.

Table 2 – Waste Generation Profile

Waste Source	Waste received in 2009 (tonnes)
Commercial	31,258.79
Private Delivery	2971.61
City Residential Collection	10,249.24
City Internal Collection	264.86
Spring Cleanup	15.37
Asbestos	56.83
Contaminated Soil	78.86
TOTAL	**44,897.56**

From the two methods, an average waste generation of 45,000 tonnes/year has been estimated for the purpose of this report. This only discloses waste delivered for area fill methods, and does not approximate the waste diverted for material recovery or composting.

2.3 Site Capacity

In order to establish the potential capacity limits of the landfill, the remaining land area available for phase development was evaluated. The solid waste capacity of the future development was calculated using the following assumptions:

- Phase Development based on drawings within Appendix A, consisting of expansion into areas currently used for stockpiling, contained within the limits of the west and north lying berms, and southwest located material recovery facility, and nearby recycling drop off areas;
- Final landform as illustrated on Drawings 00-C-T03 and 00-C-T04;
- Waste to cover soil ratio of 4:1 (includes daily cover only);
- All areas of future development will include an engineered compacted clay liner (1100 mm);
- Final cap will require 1.10 m engineered soil cover; and
- Compacted waste density of 800 kg/m^3.

The following illustrates the estimated site capacity developed from Drawings 00-C-T03 and 00-C-T04:

Available Airspace

Gross airspace made available by design..........2,629,139 m^3
Total soil requirement for daily cover material.....525,828 m^3
Net Airspace for accepted waste (volume)..........2,103,311 m^3
Net Airspace for accepted waste (mass) ....1,682,649 tonnes

Additional Airspace provided for Final Cover and Cell Liner

Total soil requirement for final cap material........243,568 m^3
Total soil requirement for cell liner material........172,345 m^3

The drawings 00-C-T03 and 00-C-T04 describe the final design contours. Using the existing elevations of the (excavated) Phase 13 (2009), the area proposed for development will also be excavated to the same base elevations, providing a 2% grade across the cell liner for northeast drainage.

For the purposes of the conceptualized design, the subsurface soil and groundwater conditions were assumed to be continuous between Phase 13 (2009) and the development area. A geotechnical investigation that incorporates a complete drilling plan of the site will need to be competed to confirm the subsurface assumptions. Soil logs made available from a series of boreholes drilled in 2004 have been assessed for indications of the subsurface soil conditions, but will not serve as confirmatory documents and a full assessment is required. The existing soil logs suggest unconsolidated layers of sand and clay till extending from the surface to varied extents (6 – 12 m). See Appendix B for 2004 Soil Logs.

The net airspace made available by mass was calculated assuming a compaction rate of 800 kg/m^3, assuming standard compaction equipment is employed. Increased surface contact time and the number of passes between the compactor and tipping face could achieve up to 900 kg/m^3, thus increasing the capacity of the available airspace. To further conserve airspace, the waste to soil cover ratio (4:1) could be increased by employing alternate daily cover and reducing soil cover use.

In addition to the development and expansion of the waste disposal area, the capacity for diverted waste, contaminated soil, and snow dumping have not been accommodated for in the design. The existing stockpiling area will be used within the design of the phase development, and therefore, the stockpile material will be relocated. Future storage for these items must be assessed if Eastview Landfill will continue receiving them post development. Berm and access road requirements were also not addressed and considered outside of the scope of this report.

In Table 2.3, the waste generated by the City of Brandon and received by Eastview is presented over a projection period of three decades. The estimated value (45,000 tonnes/ year) for 2009 has been positively adjusted by 0.6% for each successive year, reflecting the population growth trends of Brandon. Therefore, the waste generated for 2010 was approximated at 45,270 tonnes, and continues to expand over time with the population. Based on these rates and the extents of the proposed design, the Eastview Landfill will have reached capacity at 2042, with a remaining capacity to accept 36,017 tonnes of solid waste. This extends the landfill site life by 32 years from 2010, including the remaining capacity of Phase 13 (2009).

Table 3 – Projection of Waste Generated and Available Airspace

Year	Waste Generated (tonnes)	Accumulated Waste (tonnes)	Capacity Remaining at Year End[a] (tonnes)	Estimated Airspace Remaining at Year End[b] (m^3)
2010	45,270	45,270	1,637,379	2,046,724
2011	45,542	90,812	1,591,837	1,989,797
2012	45,815	136,626	1,546,022	1,932,528
2013	46,090	182,716	1,499,933	1,874,916
2014	46,366	229,083	1,453,566	1,816,958
2015	46,644	275,727	1,406,922	1,758,652
2016	46,924	322,651	1,359,998	1,699,997
2017	47,206	369,857	1,312,792	1,640,990
2018	47,489	417,346	1,265,303	1,581,628
2019	47,774	465,121	1,217,528	1,521,911
2020	48,061	513,181	1,169,468	1,461,835
2021	48,349	561,530	1,121,119	1,401,398
2022	48,639	610,170	1,072,479	1,340,599
2023	48,931	659,101	1,023,548	1,279,436
2024	49,225	708,325	974,324	1,217,905
2025	49,520	757,845	924,804	1,156,005
2026	49,817	807,662	874,987	1,093,733
2027	50,116	857,778	824,871	1,031,089
2028	50,417	908,195	774,454	968,068
2029	50,719	958,914	723,735	904,669
2030	51,023	1,009,937	672,711	840,889
2031	51,330	1,061,267	621,382	776,727
2032	51,638	1,112,905	569,744	712,180
2033	51,947	1,164,852	517,797	647,246
2034	52,259	1,217,111	465,538	581,922
2035	52,573	1,269,684	412,965	516,206
2036	52,888	1,322,572	360,077	450,096
2037	53,205	1,375,777	306,872	383,589
2038	53,525	1,429,302	253,347	316,684
2039	53,846	1,483,148	199,501	249,376
2040	54,169	1,537,317	145,332	181,665
2041	54,494	1,591,811	90,838	113,548
2042	**54,821**	**1,646,632**	**36,017**	**45,022**

Note:

[a] Calculation based on available airspace for accepted waste, determined by design

[b] Conversion from metric tonnes to cubic metres using a compacted waste density of 800 kg/m^3

3. Closure

3.1 Closure Requirements

Manitoba Conservation, in the approval for the landfill, requires that a closure be accompanied by a Waste Disposal Ground Closure form and notification to the director as set out in Schedule E of the Waste Disposal Grounds Regulations of the Environment Act (C.C.S.M. c. E125) by the Province of Manitoba. Notice of closure may be filed at the Land Title Office for the district in which the WDG is located under Section 13 of the Act[4].

Further recommendations to be made outside of the requirements by the Act include advanced public notice of closure via signage and advertisements, site clean-up of any loose waste existing around the site, ensuring restricted public access following closure (locked gate and perimeter fencing), and a final survey delineating the extent of the landfill both prior to and following completion of the final cap. Construction of dwellings have been prohibited by the Act on or within 400 m of any existing or former waste disposal ground, and are therefore not a pursuable option for end use of the subject property.

3.2 Closure Procedure

For scheduled fill development and in preparation of final landfill closure, the site should be supervised when open. Equipment will be used to reshape and compact the waste on a regular basis. In this manner, most grading and reshaping of the landfill required prior to installing the final cap may be completed by judicious placement of incoming waste over the site life, therefore, minimizing re-contouring following closure.

The final contours of the landfill should promote drainage away from the site to discourage infiltration and leachate production while also preventing erosion. To suit these criteria, a 4H:1V slope is proposed for the side slopes with a 2% grade upwards to the crown of the landfill, directing drainage to the northeast.

The construction of a final cover for a cell including placement of topsoil and subsoil needs to be constructed to satisfy the intended future use of the cell. In the absence of regulated specific closure requirements, generally accepted best practices have been employed, and the following final cover design is recommended:

- Topsoil of 0.15 m over subsoil;
- Subsoil of 0.35 m over protection layer;
- Barrier layer that is constructed by compacting clay soils to a thickness of not less than 0.60 m measured perpendicular to the compacted waste surface, and which achieves a maximum permeability of 1×10^{-7} m/sec;
- Contoured such that no water pools over the landfill cells; and
- Grade to achieve a minimum slope of 2% and not to exceed 30%.

To minimize the amount of leachate that will be generated and handled, a policy will be implemented to monitor top of waste elevations to assist in planning the placement of final cover within a year of reaching final elevations. This policy will allow the initial settlement of the landfill to occur prior to construction of the final cap.

[4] Province of Manitoba (1991). *Waste Disposal Grounds Regulation (E125-M.R. 150/91).The Environment Act (C.C.S.M. c. E125*). The Queen's printer for the Province of Manitoba.

4. Post-Closure Requirements

To ensure care of structural and contaminant management of the facility, a post-closure plan should operate in place for a period no less than 25 years. Typically, the Post-Closure Care Period is also specified to continue until the following circumstances occur:

- Groundwater quality performance standards are met at the points of compliance;
- Subsurface landfill gas concentrations are below explosive limits at subsurface gas monitoring locations;
- The leachate constituents are lower than the groundwater performance standard criteria concentrations; or
- The accumulated volume of leachate is equal to or less than the previous year's accumulated volume of leachate for five consecutive years.

During the Post-Closure Care Period the landfill is responsible to the following activities:

- Protecting and maintaining the integrity of the final cover system;
- Providing repairs to the final cover system as necessary to correct settlement, subsidence, erosion, leachate break-out; and
- Protecting, maintaining, and monitoring groundwater, leachate, and landfill gas.

During the Post-Closure Care Period the landfill should inspect the final cover system at least two (2) times per year, and complete an annual report that includes:

- Annual groundwater monitoring;
- Annual landfill gas monitoring;
- Leachate monitoring report;
- Record of maintenance and repairs completed; and
- Report of any remedial or corrective action taken.

4.1 Groundwater Monitoring

Groundwater monitoring programs have been previously conducted on the Eastview Landfill property to assess ongoing conditions. The 2004 Groundwater Monitoring Program[5] identified parameter exceedances of regulated criteria for nitrate, iron, chloride, sodium, and manganese. The results of the laboratory groundwater analyses were compared to Canadian Council of Ministers of the Environment (CCME) Canadian Environmental Quality Guidelines, Drinking Water Criteria (December 2003). This indicated that sources of contaminants originated from off site sources to the south, but also the existing leachate conditions. Expansion of the landfill will therefore require continued regular groundwater monitoring which will include assessment of the additional phases. Semi-annual groundwater sampling in spring and fall of the monitoring wells on-site should include analysis of general chemical parameters for a minimum of one up-gradient background location and two locations down-gradient. Water elevation, pH, and conductivity should be measured in the field. Parameters analysed by a certified laboratory should include: total dissolved solids, chemical oxygen demand, total petroleum hydrocarbon, ammonia nitrogen, carbonate, bicarbonate, calcium, chloride, magnesium, nitrate, phosphorous, potassium, sodium, sulphate, and

[5] Earth Tech (Canada) Inc. (2005), *2004 Groundwater Monitoring Program at the Eastview Landfill Located in Brandon, Manitoba.*

dissolved metals. After 10 years of consistent results, the sampling frequency could be reduced to an interval of once every five years. Methane gas concentrations may also be measured from the well network at the time of groundwater sampling.

Existing monitoring wells within the proposed area of development may be compromised during construction of the new phases. Prior to the preparation of each phase development, wells at risk of damage should be decommissioned with bentonite in order to protect the underlying groundwater.

4.1.1 Monitoring Well Installation

In order to monitor groundwater flow patterns and determine if and how the landfill is impacting the surrounding groundwater, monitoring wells shall be added to the existing network and installed following each phase closure. Additional wells shall be installed along the north and west border to replace wells decommissioned during the progression of landfill development. From previous monitoring events, it has been determined that the groundwater flow at the Eastview Landfill is generally to the northeast. AECOM recommends utilizing the existing well network of BH10D, BH10, BH11D, BH11, BH7, and BH6D as down-gradient sampling wells, and BH20 and BH17 as up-gradient sampling wells. The use of existing wells installed on-site will be subject to the current conditions upon inspection.

5. Closure and Post-Closure Costs

In order to accumulate sufficient funds to meet the closure and post-closure obligations the landfill should establish a reserve fund specifically to cover these costs. The fund should be accumulated by setting aside a fixed amount per tonne of waste received into the landfill. The development of this closure, post-closure allocation is provided in the following tables.

Table 4 - Closure Costs

Item	Unit Price	Quantity	Cost
Final Contour Cap (221 425 m^2)			
- Barrier Layer (0.6 m)	\$25.00/ m^3	133,000 m^3	\$ 3,325,000
- Subsoil (0.35 m)	\$25.00/ m^3	78,000 m^3	\$ 1,950,000
- Topsoil (0.15 m)	\$25.00/ m^3	33,000 m^3	\$ 825,000
- Seeding	\$2.00/ m^2	220,000 m^2	\$ 440,000
Monitoring Well Decommissioning	Lump sum	9	\$ 7000
Monitoring Well Installation	Lump sum	11	\$ 15,000
Litter Clean up	Lump sum	1	\$ 5000
Grading	Lump sum	7,000 m^3	\$ 25,000
TOTAL			**\$ 6,592,000**

Table 5 - Post-Closure Costs

Component	Annual Cost
Site Inspections/Audits	\$ 5,000
Groundwater Monitoring	
- Professional Fees	\$ 15,000
- Laboratory Fees	\$ 8,000
- Expenses	\$ 2,000
Environmental Contingency	\$ 5,000
Final Cap Maintenance	\$ 15,000
Surface Water Monitoring	\$ 10,000
Gas Monitoring	\$ 10,000
Leachate Management	\$ 25,000
Total Annual Cost	**\$ 95,000**
Total Cost over 25 years	**\$ 2,375,000**

Table 6 - Closure and Post-Closure Costs

Component	Estimated Airspace tonnes	Closure Cost	Allocation \$ per tonne
Closure Cost	1,682,649	\$ 6,592,000	\$ 3.92
Post Closure	1,682,649	\$ 2,500,000	\$ 1.41
TOTAL			**\$ 5.33**

All of the closure and post-closure costs were developed using 2010 dollars. Based on the cost development analysis, it is recommended that closure and post-closure allocation be set at \$ 5.35 per metric tonne of waste disposed of at the landfill, in addition to any current disposal fees collected for the existing facilities. This assumes that the current tipping fee does not include any closure set aside fees. It is recommended that these costs be reviewed and adjusted as needed on a regular five year basis.

6. Implementation Plan

In order to prepare for the closure of the Eastview Landfill, the City of Brandon must complete the following items:

- Secure closure and post closure funding;
- Update the Class I Disposal Permit to reflect expanded landfill footprint;
- Conduct a geotechnical assessment of the future development area to assess the subsurface soil and groundwater conditions;
- Complete an updated Master Plan for the existing facilities and the future development;
- Complete an Operations Manual outlining a management plan for the future development to amend to the current operational practices; and
- Conduct regular topographical surveys to assess the waste elevation and monitor remaining site capacity.

7. References

City of Brandon, *General Information – City of Brandon, Manitoba, Canada*, retrieved on May 4, 2010 from http://www.city.brandon.mb.ca/Main.nsf/Pages+By+ID/416

Manitoba Operations Services Division – Sanitation Association, *Solid Waste Management Plan*, October 2007.

Province of Manitoba (1991*). Waste Disposal Grounds Regulation* (E125-M.R. 150/91).*The Environment Act (*C.C.S.M. c. E125). The Queen's printer for the Province of Manitoba.

Statistics Canada (2010). *2006 Community Profiles – Brandon, Manitoba*. retrieved on May 4, 2010 from http://www12.statcan.gc.ca/census-recensement/2006/dp-pd/prof/92-591/details/Page.cfm?Lang=E&Geo1=CSD&Code1=4607062&Geo2=PR&Code2=46&Data=Count&SearchText=Brandon&SearchType=Begins&SearchPR=01&B1=All&Custom

APPENDIX J

Annual Report (2013)

Eastview Landfill 2013 Annual Report: Manitoba Conservation

City of Brandon

Operational Services Department

By: Scott Haddow

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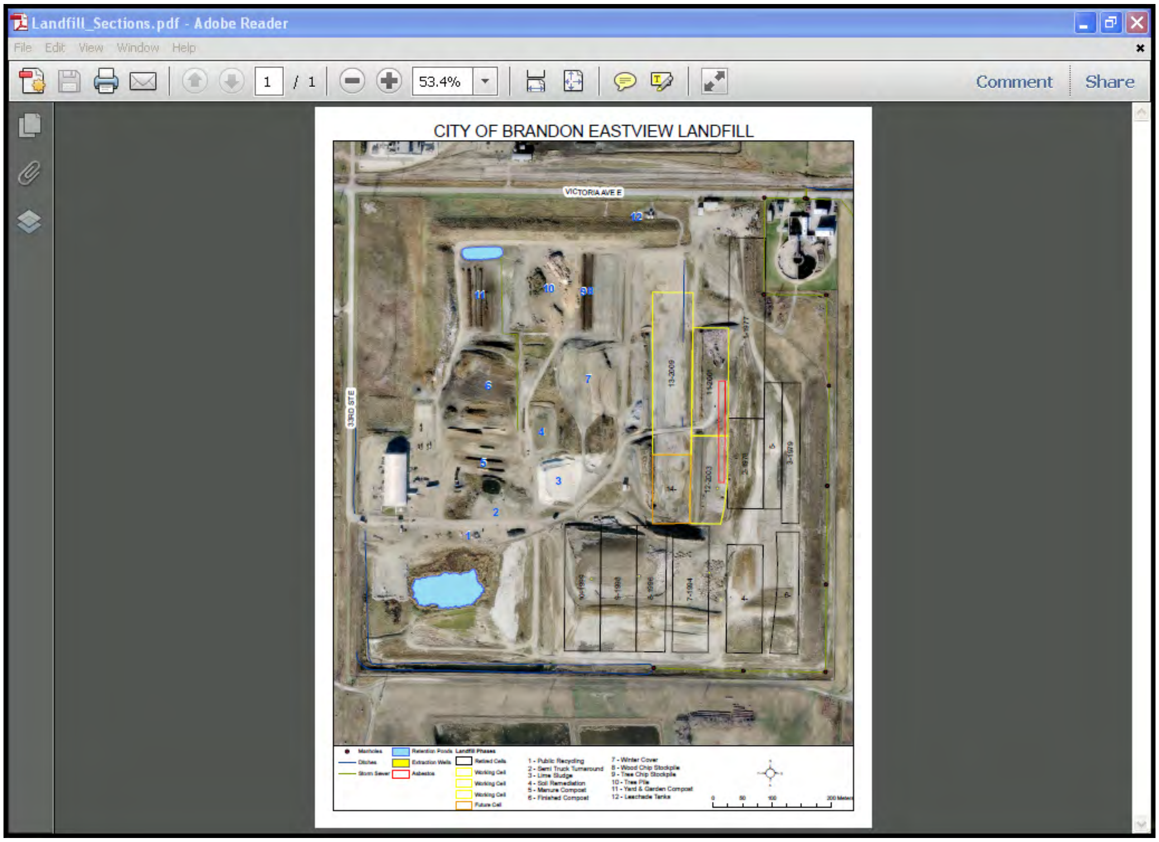
Introduction

This annual report covers the period from January 1, 2013 to December 31, 2013, and has been prepared in accordance with our Waste Disposal Ground Operating Permit number 3011.17. The permit was issued April 8, 2008 pursuant to the provisions of Manitoba Regulation 150/91 under the direction of Manitoba Conservation. The Eastview Landfill Site operates as a Class 1 Waste Disposal Ground (WDG) under the Manitoba Environment Act.

The current facility layout and operations include:

- Former and active disposal areas;
  - Full depot for residential and commercial waste, including contaminated soil, all directed to the tipping face;
  - Leachate collection that is pumped to a wastewater treatment facility;
  - Scale house and operator
  - Snow removal dump site (City use only)
  - Clean fill disposal;
  - Concrete disposal area;
  - Landfill gas collection system (waiting to be commissioned by Department of Labour);
  - Material Recovery Facility (MRF);
  - Separation of metals, propane tanks, tires, yard waste and tree brush from waste stream which is stored in designated areas of the site;
  - Freon depleting device depot;
  - Eco-Centre for used oil, filters and containers;
  - Tree chipping and composting; and
  - E-Waste Depot

Below is a copy of the landfill section map.



The purpose of this report is to meet the operational reporting requirements by providing the following information at a minimum:

- Updates to the operating manual;
- Closure/Post closure plans and financial evaluation;
- Planned improvements
- Records of waste, recyclable materials, and compost quantities;
- A review of environmental monitoring data;
- Details on environmental protection programs;
- Operational information

Updates to the Operating Manual

The operations manual was submitted in 2008 to meet the requirements of the operating permit. The manual was completed internally by Sanitation administration and was to address at a minimum the following:

- Cell developing and sequencing;
- Waste receiving, placement and covering;
- Nuisance control;
- Surface water management;
- Landfill gas management;

- Leachate management;
- Monitoring and reporting: and
- Inspections and maintenance

The operating manual also provides criteria for the acceptance, handling and disposal of special wastes such as hydrocarbon impacted soils, mold and asbestos. The manual provides information for dealing with hot loads within City Refuse trucks, commercial haulers, and commercial and residential self haulers.

Closure and Post Closure Plans

In the spring of 2010 through an RFP process Aecom Environmental from Winnipeg, Manitoba was chosen to complete the Closure and Post Closure plans. Information was provided, for review, to Aecom using historical data supplied by landfill staff. A landfill site visit was conducted by the consultant responsible for the plan to conduct a site assessment.

A criterion was established by the City of Brandon so that the assessment is based on the following:

- Current waste generation estimate received at the Eastview Landfill Site;
- An estimate of the remaining useable life of the landfill site based on waste generation and available airspace;
- Estimated closure costs;
- An estimation of ongoing maintenance costs following site closure (post closure); and
- Preparation and submission of a report providing costing models and site development drawings.

According to Aecom the estimated useful life of the existing landfill site is 32 years or a estimated closure date of 2042. This was based on a number of factors including:

- The amount of air space currently available;
- Current population trends;
- Current diversion efforts;
- Generation trends;
- Technology currently used for compaction of waste generated (currently 800 kg/m^3); and
- Daily cover

Aecom in its report provided detailed information on the requirements and procedures required leading up to the closure of the current site along with post closure requirements. This information shall be provided along with this report.

An implementation plan was included as part of the plan to allow management to prepare for the pending closure of the landfill in a fiscally responsible manner. Working with Treasury, Sanitation administration needs to look at including these costs into its Capital Reserve planning.

At the current time the fee structure does not allocate any funds for the closure and post–closure plans. Based on 2010 dollars Aecom is recommending funds be allocated at a rate of $5.35 per metric tonne of waste disposed of at the landfill in addition to the current fees.

Planned Improvements and Major Projects in 2013

As part of the City of Brandon budget process Council and administration budgeted for a number of improvements and projects to take place at the Eastview Landfill site during 2013. They include the Landfill gas project, organics collection pilot project, and the completion of the Closure/Post-closure plan.

2013 Project Update: <u>Ground and Surface Water Monitoring</u>

During the summer of 2013 Pinchin Environmental completed the sampling and analysis of ground and surface water in compliance with the protocol established by Manitoba Conservation. Each of the thirty two (32) samples was submitted to an accredited laboratory for analysis. A certificate of analysis was provided for each of the samples. Each of the groundwater monitoring well locations and the surface water sampling locations had at least one or more parameters that exceeded the CCME Canadian Drinking Water Quality Guidelines.

A final report was provided to the City of Brandon in January of 2014 in accordance with operating permit 3011.17 as issued by Manitoba Conservation under Regulation 150/91. The full report will be attached to this report. A full copy of this report will be attached to the year-end report.

2013 Project Update: <u>Curbside Organics Collection Pilot Program</u>

During the winter of 2013 Sanitation Section staff and administration organized and attended 10 -15 public education meetings aimed at getting an additional 2,500 households registered for the green cart program. This effort paid off as the 3,000th, including the 500 pilot project participants, household was registered in August of 2013. These carts were purchased as a result of the funding agreement that was announced by the province in December of 2012

During the collection period of April to November 2013 almost 900 tonnes of organic material was diverted from the landfill. With full participation not being reached until mid-August 2013 it can be assumed that the amount diverted in the future will exceed the numbers above.

Solid Waste Quantities

As part of the City of Brandon's Solid Waste Management System, the City owns and operates the Eastview Landfill Site located at NW 17-10-18, in the City of Brandon. This landfill is considered a Class 1 site, due to population (>5,000), services not only residents of the City, but also a number of municipalities within close proximity to the site along with commercial and industrial businesses. Starting in 2011 started receiving solid waste from the RM of Cornwallis rather than it going to its own landfill. These types of partnerships could ultimately lead to the Eastview Landfill Site being considered more of a regional landfill rather than one mainly just for residents and businesses within the City of Brandon.

Since 2012 waste was disposed of in cell 13. With the large size of this cell it was still possible to segregate the larger commercial vehicles from the smaller residential vehicles that regularly use the site.

Active Cell

All waste generated within the City of Brandon is either hauled directly by City refuse trucks, commercial haulers or self-hauled by small businesses and residents. In 2013 the total amount of waste disposed of in the active cell was 44,067.92 tonnes.

Active Cell

Table 1: Eastview Landfill Material Quantities (Active Cell)

Material	2012 Quantity (Tonnes)	2013 Quantity (Tonnes)
Active Cell		
Asbestos	388.40	322.58
Commercial Mixed Refuse	28,588.98	29,393.66
Residential Mixed Refuse	2,812.57	3,262.50
City Residential	10,433.17	10,296.96
City Internal	467.06	438.29
WWTF Sludge	268.32	353.93
Total Waste to Cell	42,958.50	44,067.92

Comparatively, in 2012 a total 42,958.50 tonnes of solid waste was disposed of at the Eastview Landfill Site or an increase of approximately 1,100 tonnes. All waste except asbestos is placed at the tipping face where it is packed in place and covered with a layer of fill material.

Asbestos is placed along the East side of the cell 11-12 where it is surveyed, before it can be buried. In order for anyone to bring asbestos to the landfill site for disposal they first need to purchase a daily permit. A separate permit is required for each day that asbestos is being delivered on site. Contractors or anyone responsible for the disposal of asbestos must insure that safe handling of the material occurs when transporting and disposing.

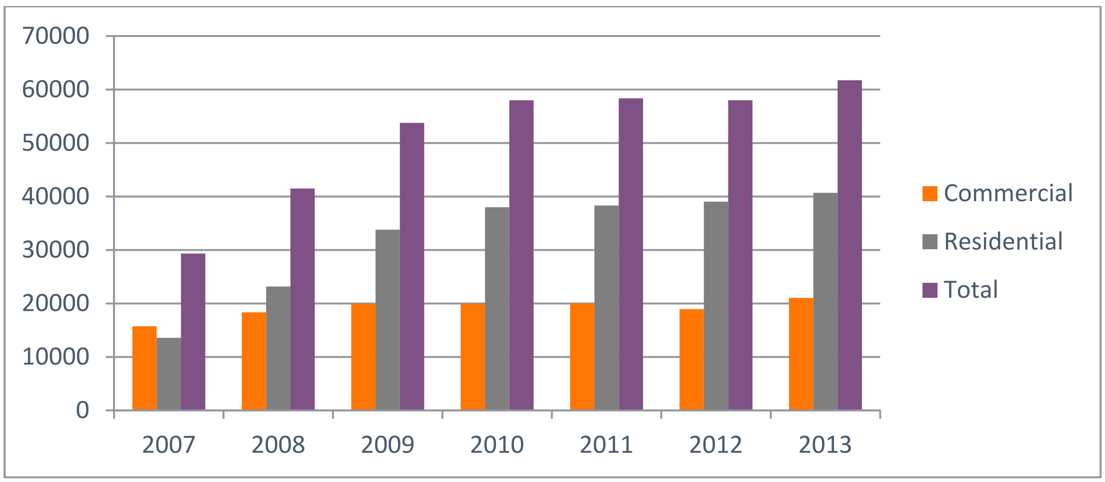
The Eastview Landfill has been accepting sludge from the Waste Water Treatment Facility (WWTF) for a number of years. A total of 353.93 tonnes was disposed of in 2013 at the landfill site. Sanitation staff is responsible for the pickup and delivery of this material to the landfill site. Pickups are scheduled for Mondays, Wednesdays and Fridays throughout the year.

Residential refuse is the waste hauled to the landfill site by homeowners and/or occupiers of residential property. This includes all material that is not considered recyclable, compostable or requires special handling. City residential is the waste hauled by City of Brandon refuse trucks and delivered to the active cell.

City internal waste is the refuse that is hauled to the landfill site and dropped off in the cell by other City departments.

Since 2007 the landfill has seen a noticeable increase in the number of visitors entering the landfill site. The following graph illustrates the dramatic increase in site visits and in particular residential users. The reason for this shift we can attribute to a couple of factors. The first being the removal of the residential tipping fees near the end of 2007 and the second the change in collection system that made it necessary for residents to dispose of large bulkier items different from the previous system as approximately 2/3 of customers were used to the larger shared containers.

Chart1. Visitors to Eastview Landfill Site



Recycling and Organics Material Weights

During 2013 the Sanitation Department of City of Brandon continued in its efforts to divert as much material from the active cell as possible. This effort is made in order to extend the useful life of the landfill and spread the costs of developing new cells over longer periods of time.

In July of 2010 the Sanitation section implemented a Curbside Organic Collection Pilot Project in order to determine the feasibility of providing a similar service to residents of Brandon currently being serviced by our collection system and what impact it may have on our diversion efforts. At the December 21st, 2011 city council meeting a recommendation to extend the organics collection program to additional 5500 single family dwellings up to a 6 unit property was approved by council. Through the implementation of a full scale organics collection program the city expects to increase diversion rates beyond the 50% target for residential waste.

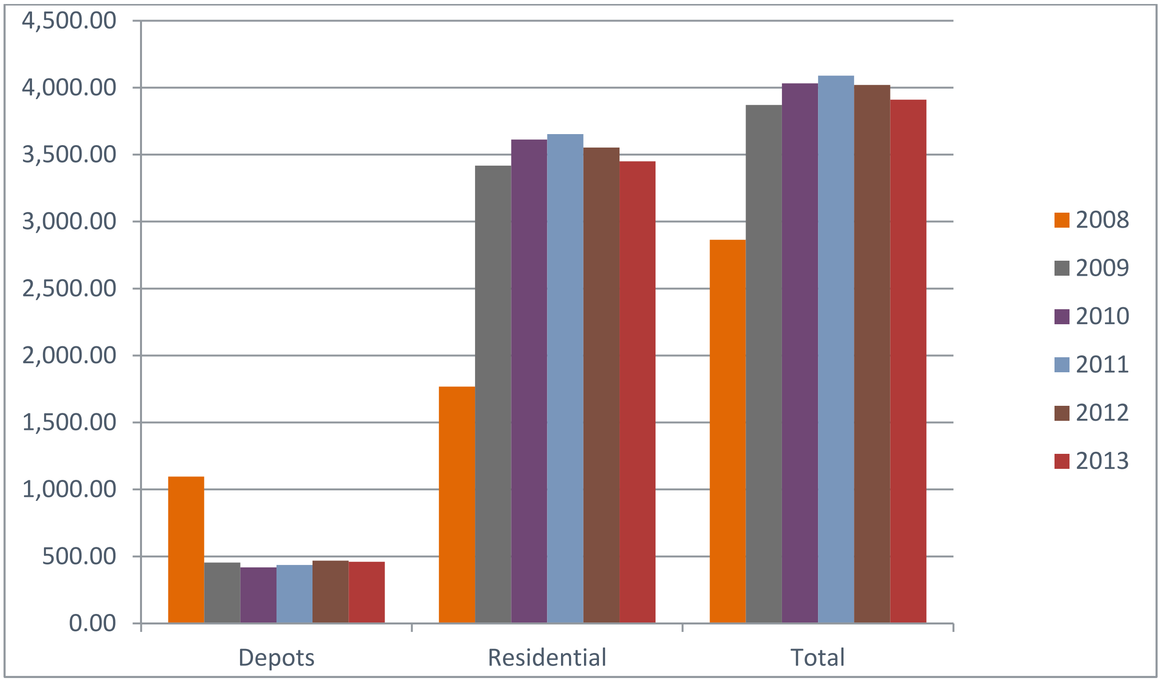
Early results have been favourable as another 315 tonnes was collected as part of the pilot project during the 2012 collection period. That works out to 630 kgs per participating household. There were 500 residents participating in the pilot project and the feedback we received allowed us to make the recommendation we did.

Table 2: Recycling Comparison between 2013 & 2012

Material	2013 Quantity (Tonnes)	2012 Quantity (Tonnes)
City of Brandon		
Brandon – Depots	460.50	467.94
Brandon – Residential	3,449.62	3,552.68
Total	3,910.12	4,020.62
Commercial		
Commercial – Mixed	1,746.20	1,856.80
Commercial – OCC	1,753.57	2,171.47
Commercial – Shred	233.62	166.68
Total	3,733.39	4,194.95
Grand Total	7,643.51	8,215.56
Increase/Decrease (Percentage)		572.05 (6.96)

Information provided in this table was provided by Emterra Environmental

Chart 2. Depot vs. Residential



Compost Facility

Since the early 1990's the City of Brandon has been operating a yard and tree trimming collection facility. In the mid to late 90's the facility was upgraded to include a retention pond for the collection of any surface water runoff that originates from the compost piles.

In 2013 9,902.58 tonnes of compostable material was collected on site and diverted from the active cell. The City of Brandon has a number of depots located around the city to provide residents with a convenient means of disposing of their yard waste.

Trees and wood that are diverted from the landfill cell are grinded down to a manageable site and used as part of the composting process and also as an absorbent in the cell during wet periods. In 2013, 3,668.31 tonnes of trees and wood were diverted from the landfill.

Table 3: Eastview Landfill Organic Quantities

Material	2013 Quantity (Tonnes)	2012 Quantity (Tonnes)
Organics (Yard Waste & Manure)		
Commercial	4,476.65	5,482.51
Internal	12.57	3.72
Residential	1,208.02	786.12
Depot	538.03	673.41
Total Organics (Yard Waste & Manure)	6,235.27	6,945.76
Organics (Trees & Wood)		
Trees	1,793.33	1,990.77
Christmas Trees	29.07	13.03
Wood	1.845.91	1,683.10
Total Organics (Trees & Wood)	3,668.31	3,686.90
Total Organics	9,903.58	10,632.66

Yard waste and trees that are chipped are placed in windrows where they are processed into a reusable material using a compost turner attached to a front end loader. Once the compost process is finished it is placed in a large pile, mixed with black dirt, screened and then used by the Parks Board along City boulevards and other public areas. In 2013 the material that was processed was tested by A & L laboratories and it came back as a Class “A” compost. With the results in the City began to give the finished product away during special events such as; Earth Day, Compost Day and other environmental type of events.

Landfill Gas Volume

In 2013 approximately 86,689,471 (scf) of landfill gas was produced from the landfill and flared off in an environmentally friendly manner. This amounted to approximately 14,393 tonnes of CO_2E being diverted from the landfill site during the year.

Table 4

	2012	2013
annual CO2 equivalents	9321	14393
Landfill Gas Flow (scf)	55076212	86689471

Waste Reduction and Diversion Initiatives

Residential Drop-off Area

At the Eastview Landfill Site there are a number of areas that are used for residential and commercial customers. Right inside the gate there are containers located for the drop off of plastic, paper, small amounts of cardboard and tin.

Inside the landfill customers are able to drop off grass, trees, wood, metal, tires and glass in separate piles along the south side of the main landfill road. People delivering these items more often than not have loads mixed with other items that are non-recyclable. The scale operator is responsible for insuring that each customer is notified of the need to separate each material into the proper pile and not to contaminate any pile with mixed refuse.

Customers entering the landfill with large amounts of recyclable materials are encouraged to deliver these items directly into the MRF.

Curbside Collection Program

The curbside collection program that was first implemented in October of 2008 continues to provide the City of Brandon with the desired results it was looking for when making the change.

Contamination of the recycling is a common problem with this type of collection system. Public Education and outreach programs will be paramount as we try to reduce the amount of contamination entering the recycling stream.

In 2013 after a consultation process with effected property owners and an RFP process the City switched from City service to a commercial service for the collection of refuse and recycling at properties with 7 or greater dwelling units. The change started in November of 2013 and was completed by December 31st, 2013. By removing these bins from multi-family properties it allowed the Sanitation Section to reutilize these carts for the green cart program, saving approximately $100,000 in capital costs.

Recycling Depots

The recycling depot system was first implemented in the City of Brandon in 1990. At that time there was only 3 locations for drop off and they were limited to only metals as that was the only product that could be sold locally. At that time materials were picked up on a weekly basis.

At its peak before the introduction of the new collection system nine (9) depots were located around the City of Brandon for residents to drop off their recyclable materials. The need to service these sites also grew from weekly to daily collection.

A major downfall of the depot network is the amount of illegal dumping that occurs at these sites. This has a negative impact on our recycling efforts as many loads become contaminated and valueless. We tend to see large volumes of items that are not recyclable end up at the depots. In 2013 there was 127.07 tonnes of material collected at the depots that was delivered to the tipping face and buried.

E-Waste

In June of 2007, the City of Brandon in partnership with Green Manitoba started a pilot project to start an E-waste collection program for residential customers. This program would run from May to the end of September each year. City staff stacks each item on pallets and secures them for travel. Once enough products are collected to fill a truck, it shall be delivered to Noranda Sims in Ontario for processing. Approximately 291.90 tonnes or 15 semi loads of E-waste was diverted from the landfill in 2013.

In May of 2009 Green Manitoba announced, in a press release, that we would be moving from a pilot project to a year round program with 11 sites around the province, including Brandon.

“Electronic waste depots will accept the following materials from residential sources only: TVs, VCRs, stereos, microwaves, phones, computer equipment, laptops, printers, scanners, fax machines and copiers. All e-waste collected will be sent for proper end-of-life recycling and no materials will be sent to landfills, the minister said.

During the last two years, Manitobans have dropped off more than one million kilograms of electronic waste at temporary collection depots operated by local communities, businesses and non-profit recycling centres. This is the equivalent of diverting 95 semi-trailer loads of electronic waste out of landfills by recycling the waste through the provincial E-waste Roundup program.”

Tires

Tire Stewardship Manitoba was launched in April of 2008 as a not-for-profit organization to help manage the problem of scrap tires. In 2013 865.22 tonnes of scrap tires were accepted at the Eastview Landfill Site.

Properly managed scrap tires reduce environmental risk and create jobs and economic opportunities in Manitoba. Manitoba’s scrap tire products are sold locally and internationally. Scrap tires can be used to make flooring products for agricultural, recreational, and industrial use. They are used for artificial turf fields, rubberized asphalt, blast mats, geo-technical projects and energy recovery.”

Tire Stewardship Manitoba announced in the fall of 2010 that it is embarking on a 5 year plan to continue its mandate.

Metals

In 2013, a total of 643.63 tonnes of recycled metal was removed from the Eastview Landfill site. All metals are collected on site, loaded and hauled by Gerard Metals for processing and then sent to its end market. In October of 2011 the contract for removing metals was awarded to Gerard Metals of Portage.

In 2013 589 Freon devices were delivered, compared to 684 in 2012, to the Eastview Landfill for proper disposal. The City had a contract with Ron's appliance for the removal of the freon. Once the freon is removed the metals can they be included with the items that are collected by Gerrard Metals.

Extending Landfill Life

The main purpose in developing programs to increase diversion is to safely and efficiently manage products in the most environmentally way at the end of their useful life. Through these efforts we gain the added benefit of extending the life of our current landfill. In the hierarchy of waste there are 7 options for handling waste with the least favoured being disposal and the preferred option being prevention.

Progress on Recommendations from Solid Waste Management Plan

As part of the Solid Waste Management Plan approved by council in the fall of 2007 there were 19 recommendations accepted as part of that plan. A timeline was also developed as part of the plan to provide guidance to staff, administration and council on when each of the recommendations should be implemented.

Recommendation #1 – Develop and implement a formal Operations Manual in compliance with the proposed Operating Permit issued by the Provincial Government.

As required, in section 16 of the operating permit, an operations manual was submitted to the Director for approval. It addressed all the requirements of section 16 and others. An operating manual was provided for the Landfill Gas Flaring and collection System by the company contracted to develop and build the system in accordance with Manitoba Department of Labour Regulations. The system operates under a separate license from the landfill site which currently operates with an operating permit.

Recommendation #2 – Develop a Contingency and Emergency Response Plan in accordance with the Industrial Emergency Response Planning Guide (MIAC September, 1996).

A draft copy of this plan was developed during the last quarter of 2007. In cooperation with Brian Kayes, director of Emergency Preparedness, this plan was adopted in February of 2008 to meet the requirements. A contingency plan for the landfill gas and flaring system was completed in 2010.

Recommendation #3 – Conduct an engineering study on Leachate/surface water run off and develop a system to manage these streams to comply with the proposed Operating Permit.

The City of Brandon has conducted several studies over the years that address these issues and have put in place management systems that comply with the new permit. In the fall of 2009 the City of Brandon entered into an agreement with AMEC Earth & Environmental to monitor and analyze the groundwater wells and the retention ponds placed on site to collect surface water.

A Leachate management system has also been put in place in order to contain this material on site before it has a chance to seep into the ground water.

Recommendation #4 – In conjunction with Recommendation #3, conduct an engineering study for utilizing the old landfill as a snow dump.

An engineering study was completed in July 2008 by Earth Tech (Canada) Inc. where a couple of options were presented. The first option was to continue utilizing the existing location as a snow dump. The second option was to locate the snow dump at the old landfill site located on 17th Street East south of Richmond Avenue east.

It was the recommendation of Earth Tech to continue dumping snow at its current location as the proper management systems are already in place to monitor any possible impacts to the groundwater.

Recommendation #5 – In conjunction with Recommendation #3 and #4, develop a sampling and monitoring plan for seepage and surface / ground water discharge.

In the fall of 2009 the City of Brandon entered into an agreement with AMEC Earth & Environmental to perform the collection and laboratory analysis of groundwater samples from thirty (30) existing monitoring wells and surface water samples from four (4) surface water retention dugouts/trenches at the Eastview Landfill Site.

The purpose of this monitoring program was to maintain compliance with the conditions of the operating permit issued in April of 2008.

Recommendation #6 – Develop an annual reporting process / format for submission to the Province as per the proposed Operating Permit.

A monitoring program has been put in place for the monitoring and reporting of surface water, ground water, landfill gas and Leachate management. A reporting system has also been established for reporting quantities and types of waste being delivered to the landfill on a daily, monthly and yearly basis.

Recommendation # 7 – Explore alternate compaction equipment at the time the existing compactor is being replaced.

The old trash compactor was replaced during 2009 and it was felt that the timing of this change would not allow for the required amount of time to study a change of this magnitude. The expected life cycle of this machine is 5 years, which will allow the department time to investigate any possible alternate options as required by this recommendation.

Recommendation # 8 – Implement a residential recycling / garbage collection system that include the following elements:

- **The collection system would be split into two systems; one for garbage and one for recyclables (additional refuse containers could be purchased and owned by the owner).**
- **Each residence would be provided with one 95 gallon garbage container and one 95 gallon recycling container.**
- **Each residence would be provided with a 5 gallon kitchen waste container that could be used to collect waste to go to the organics depots.**

Implementation of this recommendation was completed in early October of 2008 and the system went live on October 14. Trucks and carts were supplied by Joe Johnson Equipment Inc (JJEI) and Toter Inc. Distribution of the carts was completed by Cart Men, Inc in partnership with JJEI and Toter. Cart-Men were also responsible for recording serial numbers that are designated to a specific address in a format acceptable to the City of Brandon. In regards to the 5 gallon kitchen waste container, only 1.6 gallon containers were provided during implementation due to budget limitations.

Recommendation # 9 – Convert the existing depots except for the one at the Shopper's Mall into organic / yard waste depots

The conversion was completed shortly after the implementation of the new collection system was finalized. Due to feedback from residents a few of the old depots were converted back into regular depots, accepting paper, plastics and metals, to help with residents who produce more recycling than their carts can handle in a one week period.

Recommendation # 10 – Establish a bulk item collection system with a nominal pick up fee.

A policy was developed in late 2007 and was put into effect on January 1, 2008.

Recommendation # 11 – Work with business and industry to support the establishment of individual workplace recycling programs.

Starting on January 1, 2011 after a year of educating commercial establishments and haulers a new policy was implemented that would see commercial waste generators and/or haulers charged an extra fee if their loads contained more than 5% of recyclable material by volume.

Recommendation # 12 – Remove the Residential Tipping Fee of $3.00.

This fee was removed from the fee schedule on January 1, 2008 and since that time the number of site visits from residential customers has increased from just over 13,000/year, 2007, to 38,309 in 2011. This alone has proven that the fee associated with residents bringing garbage to the landfill was a barrier for most.

Recommendation # 13 – Remove the Freon Depleting Device Fee.

This fee was also removed at the start of 2008 and we saw a huge spike in the number of these devices delivered to the landfill. In 2011 approximately 532 of these devices were disposed of at the landfill. A contract was awarded to a local contractor for the removal of Freon from each device. Once removed the devices are shipped to our scrap dealer.

Recommendation # 14 – Establish a Commercial Recycling Tipping Fee and start the process of the implementing a spread between Commercial Refuse and Recycling Fees.

After an initial education process this program was implemented on January 1st, 2011. Commercial recycling volumes increased by 8.24% in 2011 while residential volumes increased slightly at 1.43%

Recommendation # 15 – Update the bylaw to reflect the changes in the system.

During 2009 Sanitation staff and administration worked on preparing a recommendation to council to better align the bylaws with the new collection system. Approval of the bylaws is expected to take place in 2010

Recommendation # 16 – Update the bylaw to establish enforceable consequences for none compliance to the system.

In the summer of 2010 council approved the recommendation to change the old bylaw to the new bylaw. It brought our bylaws in line with our new collection system. In 2011 council approved the recommendation by administration and staff to update the by-law to include back lanes.

Recommendation # 17 – Contract with a communication/education professional to develop an education program to support the changeover in system.

Sanitation staff and administration have worked closely with the Director of Communications to ensure that the message being delivered with regards to the approved recommendations are consistent.

Recommendation # 18 – Establish an ongoing reporting system to provide diversion information to the community.

With the change from MPSC to the stewardship company called Multi Material Stewardship Manitoba a change in reporting has been made and as a result the City of Brandon is in the process of addressing the need to report information to the public in a more consistent manner.

Recommendation # 19 – Research and develop the next phase of this strategy based on progress in reaching a 50% diversion target, considering changes in Green Manitoba's programming and in evaluating new technology.

Generally speaking organic material accounts for a minimum of 40% of the waste stream. A 2009 residential waste composition study showed 26.5% of waste generated is food waste. Yard waste was not included in the study. With the approval from council on December 21, 2011to expand the organics collection program in 2011 the target goal of 50% has become more realistic.

Environmental Protection Programs – Monitoring and Reporting

Leachate Management

In 1994 the Sanitation Department developed its first lined waste cell in phase 7 of the cell development plan. This cell was lined using a clay max liner. In addition to the liner a Leachate collection system was included in the design of this cell. The purpose of this collection system was to insure that Leachate that is produced as a result of precipitation and snow melt is contained on site before it can have a negative impact on the surrounding environment.

Also there is 8 manholes around the perimeter of the landfill that collects leachate before it is able to migrate into the ground water offsite.

Leachate is defined as the product of water percolating through refuse and collected in a lined refuse cell with perforated pipes that collect the Leachate and transport it to a manhole

In addition to phase 7 completed in 1994 phases 11, 12 & 13 all drain into a manhole at the North end of cell 7, where it is then pumped directly to the Leachate storage tanks located directly west of the old scale building. This occurs approximately seven (7) months of the year.

Phases 8, 9 & 10 have been closed and capped with 3 to 5 feet of clay. We are not seeing the volume of Leachate coming out of these cells that we did when they were active.

This has reduced the need to have the manholes pumped on a regular basis. Where we used to pump these manholes weekly and sometime daily during periods of high precipitation we are now only required to pump as needed.

Development of cell 13 was planned in conjunction with cell 11 so that Leachate produced from cell 13 runs into cell 11 and then drains to the manhole at the north end.
Once Leachate is contained in the storage tanks the waste water treatment facility can control the flow of the Leachate to its site for treatment.

Surface/ Ground Water Monitoring Program

In 2013, 30 groundwater and 4 surface water locations were sampled at the monitoring well locations shown on the landfill map provided in Appendix 1. Sampling was completed in compliance with Sampling Protocols established in the Manitoba Conservation Guideline NO94-01-E. A copy of the report shall be provided with this annual report.

Contaminated Soil Remediation Facility

Located at the landfill site north of the lime sludge pile is the soil remediation facility. At this location contractors deliver soil contaminated with hydrocarbons from soil remediation projects or environmental accident sites. Soil is considered contaminated when it is found to be above the required CCME Guidelines. The material is treated on site with the use of a rome plow attached to a track type dozer and once the level of hydrocarbons meets the guidelines stated in Guideline 96-05, Treatment Disposal of Petroleum

Contaminated Soil, June 1996, revised April 2002; it becomes a beneficial product that w can then be used as cover material in the cell.

The site at the landfill has been developed to insure that any surface water runoff is captured in the retention pond at the North end of the landfill.

A. Soil Receiving and Placement

The main objective of the S.R.F at the Eastview Landfill is to reduce hydrocarbon concentrations to acceptable levels such that the soils are suitable for appropriate re-use.

A permit is required for disposal of contaminated soils. Permits are sold and issued by the City of Brandon. Any loads of contaminated soil arriving at the landfill without a proper permit will not be accepted for remediation. The supervisor may also request lab analysis reports from the company doing the excavation.

1. Low Concentration Levels

Contaminated soil which contains levels below Manitoba Level III criteria for soil will be used directly as landfill cover material upon approval by the Site Supervisor and the local regional office of Manitoba Environment.

2. Permits

Upon arrival of a load of contaminated soil with proper permits, the Scale Operator shall record the permit number and attach it to any weigh tickets relating to the permit for documentation and invoicing.

3. Location

The S.R.F is clearly marked by signs and marker posts to prevent unauthorized access onto the treatment area and possible disturbance or compaction. When the driver is unfamiliar with location and placement procedures for the soil remediation facility. The Scale Operator shall radio the site supervisor or any available site personal to escort the driver to the S.R.F area and place the load accordingly depending on the particular type of contaminate.

4. Load Placement

All loads placed in the treatment area should be spread in an even layer in a manner that avoids compaction and inter-mixing of different soil shipments. Occasionally (depending on placement area available) soil may be placed in windrows which should not exceed 1 m in height. The windrows will require periodic mixing in a similar fashion to a treatment layer.

B. Soil Remediation Procedures

1. Treatment Layer
The final thickness of the treatment layer normally should not exceed 300 mm or the effective mixing depth of on-site equipment (rome plow), whichever is less.

2. Debris
Boulders and other large debris should be removed from the treatment layer to avoid potential damage to the tilling/aeration equipment, and to provide for optimum soil tillage.

3. Aeration
Handling of material will be done by employees that have read and understands the proper handling techniques that have been put forward in the GOG's and SOP's . The material is to be aerated by our rome plow which will be pulled with a track type dozer. Depending on the stability of soil more than 1 pass may be required to turn and fully aerate the impacted soil.

4. Irrigation
The treatment layer shall be thoroughly aerated (mixed) on a regular basis. In most cases, a tillage frequency of 1 to 2 weeks should provide optimum soil aeration. Periodic irrigation of the treatment layer may be necessary to avoid desiccation or prevent excessive wind blown dust. However, saturation of the soil should be avoided to prevent run off from occurring and potential migration of contaminates outside S.R.F facility.

5. Equipment Contamination

After material has been aerated, the rome plow is to placed in an area that will not interfere with ongoing work but must remain in the soil remediation facility. The track type dozer must be cleaned off so no contaminates leave the area and have the chance of falling off and contaminating other areas.

C. Inspections and Maintenance

Regular inspections shall be made by the operator at the time of aeration. S/he will report to the site supervisor any:
-Erosion, slope increase or damage to the berms surrounding the S.R.F area.
-Excessive “ponding” of surface water.
-Improper placement of contaminated loads.
-Visible signs of migration or leaching of surface water and/or contaminates.
Once reported to the supervisor s/he shall take corrective actions to insure the proper maintenance of the S.R.F

D. Surface Water Management

The Eastview Landfills S.R.F is designed to contain internal storm runoff and seepage in order to prevent offsite losses. Surface water is controlled by the use of ditches, along with a properly graded land surface. Prior to any discharge or removal of impounded surface water from the PCS treatment facility, thorough laboratory testing of the water for petroleum hydrocarbon compounds will be conducted and the results reviewed by Manitoba Environment.

E. Monitoring and Reporting

All contaminated soil material entering the landfill will be weighed and logged at the scale by the scale attendant. The attendant will log where the material originated, the hauler that has brought the material into the site and the final placement of the load. The weigh scales Wesdis software program can generate reports on any contaminated soil entering the landfill based on a variety of parameters.
E.g. Origin, Company, Hauler, type of material etc.
Information is also transferred to an Excel spreadsheet by the Scale Operator at the end of each shift.

Household Hazardous Waste (HHW)

Since 1999 the City of Brandon in partnership with the Rotary Club of Brandon has been operating twice yearly HHW collection depots at the public works complex on Richmond Avenue East. Residents are encouraged to drop off any unwanted Household Hazardous Waste so that it can be disposed of in an environmentally responsible manner.

Starting on May 1st, 2012 the first phase of the Product Care Manitoba program was implemented with the following locations being allowed to accept paint and/or fluorescent lights for disposal.

1. Windsor Plywood – Paint only
2. J & G Rona – paint only
3. Janzen's Paint & Decorating – paint only
4. General Paint – paint only
5. Brandon Home Hardware – paint only

The new HHW that was set up in the fall of 2012 or winter of 2013 has seen a steady flow of visitors to the facility since it has opened. Landfill staff have been provided training from Product Care Manitoba and Miller Environmental during regular site visits to ensure the safe and proper handling of these potentially dangerous products takes place.

Eco Centre

In 2013 a total of 13,200 litres of used oil, 800 litres of glycol, 1,037 kgs of used filters and 1,145 kgs of used oil jugs were collected at the eco-centre. All used oil, filters and containers are collected on a regular basis by Miller Environmental Group where they are taken to be processed and recycled into a valuable new product.

Operational Information

Contingency Plan Implementation

In February of 2008 the Sanitation department adopted its new Landfill Contingency/Emergency Response Plan in order to meet the requirements of its new operating permit. As required by the permit it was developed and shall be maintained in accordance with the Industrial Emergency Response Planning Guide (MIAC September, 1996)

In 2010, no incidents were reported where we had to implement the Emergency Response Plan. As part of an annual review an update to the plan was developed for the inclusion of the landfill gas and flaring system.

Weigh Scale Operations

The scale is operated by staff that is trained on the weigh scale program (WESDIS) to help expedite the flow of traffic in and out of the landfill site. The scale operator is responsible to both monitor and control the material accepted into the landfill. If any loads are considered suspicious by the operator he/she shall communicate with landfill operators to more closely monitor unloading.

All loads are weighed on the inbound scale and weighed again on the out bound scale to get a net weight that customers are then billed according to City of Brandon Fee Schedule. The scale operator is also responsible for setting up new customers and updating existing customer information as required. The scale operator communicates with customers on the location that drop off will occur depending on the types and amounts of waste being delivered.

Based on information provided by the customer the scale operator shall segment loads by type of material to help determine the amounts of each type of waste that are entering the site on any given day. The scale operator shall also insure that all permits are taken out by haulers of special waste such as asbestos and contaminated soil to insure that safe disposal of this material takes place.

Training of new staff on weigh scale operations takes place with guidance from the scale operator to insure that all procedures and tasks are being completed in a consistent manner. Training will take place to insure proper opening procedures takes place, account setup, weighing procedures, reporting standards are being met, monitoring of loads and proper closing procedures takes place.

Nuisance Control

When activity is noticed at the landfill we first determine the type of nuisance. Once this occurs we have two (2) courses of action that we take. The landfill manager will be notified of the type of nuisance, the location of the sighting and number. He will then notify either animal control or the contractor to take the proper course of action in managing the situation.

In 2012, sightings of nuisances were back within reasonable levels when compared to the previous year's activity. The facility continues to be monitored on a monthly basis by the contractor responsible for this service. Areas of concern that were brought to Sanitation Section administrations attention was the areas underneath the conveyor belts. The contractor was given notification to remove debris from these areas to minimize opportunities for nuisance activity.