THE CITY OF WINNIPEG
WATERWORKS, WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

VOLUME 1 OF 2

OCTOBER, 1993

KGS GROUP

KONTZAMANIS ▪ GRAUMANN ▪ SMITH ▪ MACMILLAN INC.
CONSULTING ENGINEERS & PROJECT MANAGERS

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October 29, 1993

File No. 92-107-06

The City of Winnipeg
Waterworks, Waste and Disposal Department
1500 Plessis Road
Box 178 Transcona P.O.
Winnipeg, Manitoba
R2C 2Z9

ATTENTION: Mr. B.D. McBride, P.Eng.
Manager of Engineering

RE: Landfill Site Disposition Study
<u>Final Report</u>

Dear Mr. McBride:

Please find enclosed the final report for the Landfill Site Disposition Study, including ten (10) copies of Volume 1 - Report and four (4) copies of Volume 2 - Appendices. Drawing SWD-13, City of Winnipeg Landfill Map is also enclosed on computer disk.

The study covers a wide range of topics on the 34 landfill sites within the City limits. We appreciate the opportunity to have provided engineering services on this interesting and diverse study. We look forward to ongoing involvement on the landfill sites, to assist you as required.

Yours very truly,

Bert Smith

J. Bert Smith, P.Eng.
Chief Geotechnical Engineer/Hydrogeologist

JBS/pc
Enclosure

STRUCTURAL ▪ GEOTECHNICAL ▪ ENVIRONMENTAL ▪ HYDRAULICS ▪ HYDROGEOLOGY ▪ MUNICIPAL ▪ MECHANICAL ▪ ELECTRICAL
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EXECUTIVE SUMMARY

The City of Winnipeg maintains some responsibility for 35 landfill sites within the City and surrounding area. In September 1992, the City retained KGS Group to review the status of the sites and prepare a report to update the last program review which was conducted in 1984. Items evaluated included methane gas, leachate, groundwater, topography and cover, and site utilization. Key objectives of the study included:

- reducing potential hazards from methane gas migration
- minimizing constraints on land use adjacent to landfill sites.
- assessing leachate production and requirements for groundwater protection
- identifying potential land uses
- reviewing landfill management regulations and state-of-the-art practice
- identifying work priorities

Field studies were limited to site walkovers in Fall 1992 and a leachate sampling program in Spring 1993.

Regional Background Data

Winnipeg's waste disposal sites include two active landfills, Summit Road and Brady Road Landfills, and 33 non-operating landfills. Many of the landfills began as nuisance grounds in outlying areas of the separate cities which later formed Unicity. The earliest site, Saskatchewan Avenue landfill, dates back to the late 1800s. Many sites were established in the 1950s and 1960s. Only four sites have operated since the late 1970s, including Summit Road, Brady Road and Kilcona Landfills, and McPhillips Street Dump (Ash Dump). Most landfills received mixed

municipal and industrial wastes. Three sites are primarily wood waste and soil fill, and four sites received primarily incinerated ash and refuse. City policy since 1979 has been to divert hazardous waste from land disposal.

Winnipeg's mean annual generally cooler and drier climate, with hot windy summers, may result in less leachate and gas production than in many other northern urban centres in Canada and the United States. Nevertheless, there is significant gas generation and leachate production.

Many older landfills were developed in low lying depressions in the relatively flat topographic surface. Eight sites are located close to major ditches, creeks or rivers. Surface water runoff from other sites flows to the City's storm sewer system.

Geologic deposits beneath Winnipeg consist of (in descending order) a complex zone of silty clay and silt, glaciolacustrine clay, silt till and carbonate bedrock. Winnipeg's widespread surficial clay deposits limit gas and leachate migration, in comparison to more permeable geologic environments. Gas migration is of concern in unsaturated silt and fractured clay and in till deposits close to waste. Leachate migration is of concern in shallow silts and through fractured clays, particularly where there is little clay overlying till.

Groundwater is usually found within 3 m of ground surface in the upper silty clays and silts. The bedrock piezometric surface is generally lower than the water table, producing downward gradients. Groundwater movement through the low permeability clay is believed to be primarily through fractures, with very slow, if any, recharge through the clay matrix. Groundwater in the bedrock flows from the east, northwest and southwest towards major pumping areas in the

centre of the City. Groundwater quality is fresh to slightly brackish and hard in the east and northwest, and brackish to saline in the southwest.

The upper carbonate aquifer is developed as a domestic water supply in outlying areas north and east of the City (Kilcona, Cordite Road Landfills and McPhillips Street Dump). Deeper bedrock zones are developed further west (Summit Road Landfill). Most industrial groundwater users pump groundwater for cooling or heating, using a system of supply and return wells. Major consumptive uses include air cooling (with discharge to the river), industrial production, and landscape irrigation.

Landfill Site Inventory

Site specific information was summarized on topical data bases including site characteristics, land use, hydrogeology, monitoring, and topography and cover. General site conditions were illustrated on landfill site sections for comparative use.

Landfill Gas

Landfill gas is produced by waste decomposition and generally consists of methane and carbon dioxide, with small concentrations of nitrogen and oxygen, and trace concentrations of other constituents. Landfill gas can be explosive and toxic and produce asphyxiating conditions and odours. Analyses of gas composition from Kilcona Landfill are within typical ranges.

The City of Winnipeg methane policy is generally equivalent in concept to other North American jurisdictions surveyed. Revisions to the policy are required to clarify and incorporate city practice and interpretation, to incorporate building design guidelines and environmental concerns, and to revise and/or upgrade landfill gas monitoring programs.

Methane migration was assessed for each site. High methane migration was found at twelve sites (six frequently, six with isolated readings), where methane concentrations in probes outside waste were greater than 20% Lower Explosive Limit, LEL (1 percent methane). These sites may exceed existing methane policy guidelines.

Moderate methane migration was found at three sites, where probes outside of waste had methane concentrations above trace concentrations (0.1 percent methane) and below 20% LEL (1 percent methane). Low methane migration was found at nineteen sites, where trace to no methane was detected in probes outside of waste.

At Summit Road Landfill, additional gas probes are needed to verify the adequacy of the control zone and to investigate potential gas migration in the till. Probes are particularly needed to the east where there is no control zone and where there is potential for future development. At Kilcona landfill, recent gas migration beyond the east cell needs investigation. At Brady Road Landfill, methane concentrations are high inside the landfilling site in the southwest area, adjacent to the control zone.

Existing strategies used by the City to control methane migration include natural barriers (saturated ditch or clay), control zones, engineered barriers, and building monitoring or methane detection systems.

Potential actions recommended to increase confidence in monitoring strategies include installing additional gas probes, increasing monitoring frequency, acquiring land in control zones, confirming that natural features are barriers, confirming that control zones are adequate, and implementing safety measures for residential properties within waste boundaries.

Assessing the effectiveness of the barrier at Kimberly is difficult because of the presence of waste outside the barrier and the infrequent monitoring. Periodic barrier testing and increased monitoring frequency of outside probes is recommended.

Active methane detection systems at Harold Hatcher School, Terry Sawchuk Arena and Brady Road Landfill Scale house appear to be performing adequately. Development of a contingency plan in the event of a water main break is recommended at Eatons Garden City. Maintenance of crawlspace openings in elevated buildings is necessary. Methane control measures should be implemented at Leila Avenue West Landfill where development is proposed. Guidelines should be developed for inspection, monitoring frequency and enforcement for buildings constructed adjacent to or on waste.

Priority action is needed at Riel Dump to increase resident safety in homes constructed within site boundaries. Possible action includes an emergency response plan, resident notice and education, weeping tile ventilation in homes, investigation of constructed clay barriers, investigation of the quantities of methane migrating near homes, and possible use of interceptor trenches in the landfill.

Energy production potential was found to be possible, but uneconomical at Kilcona Landfill. The potential should be evaluated for the Brady Landfill, as conditions change.

The proposed landfill gas monitoring program focuses on control zone monitoring, increased monitoring frequency at select probes and special investigations.

Leachate Control

Leachate is generated as liquids come in contact with waste, including precipitation, surface water, groundwater and water within the waste. Leachate is generally high in soluble inorganic and organic parameters, with lower to trace levels of metals, volatile organic compounds and other contaminants.

Landfill designs can incorporate either natural attenuation or containment design principles, with evaluation by performance or design criteria. Leachate management is included with containment designs. The Brady Road Landfill uses containment design principles, as does the Kilcona Landfill, to a less extent. The earlier landfill sites, including Summit Road Landfill, were established prior to development of these design principles. A review of landfill design issues at Brady Road Landfill would be prudent, relative to state of the art practice.

Leachate is collected at Brady Road Landfill, Kilcona Landfill (Perimeter System), and Summit Road Landfill (Partial System). Expansion of the collection system and more frequent pumping of leachate is needed at Summit Road, where leachate heads are high, and in those areas of Brady Road landfill without collection. Additional leachate probes at Kilcona landfill are needed to define leachate levels.

Leachate levels are at the water table or at ground surface at most sites, with the landfill base elevation below the water table. Leachate is above ground surface or perched at several sites.

Leachate collected at City sites is of typical quality. Highest organic strengths are seen in younger sites. Increased dissolved solids are monitored in the ash sites, and there are higher metal levels in sites with ash and industrial waste. Various volatile organic contaminants were found in leachate at five sites, including hydrocarbons and some solvents.

Proposed leachate programs include additional leachate probe installation, leachate extraction and leachate monitoring using indicator parameters, and an expanded characterization for organic contaminants. Leachate migration should be evaluated in the upper silts and clays when development is proposed adjacent to landfill control zones.

Groundwater and Surface Water

Groundwater pollution potential factors for a landfill site include clay thickness below excavation, leachate head, hydraulic gradient, waste volume, waste type and waste age. Sites with higher groundwater pollution potential include Summit Road Landfill, Harcourt Street Landfill, St. Boniface Landfill II, and Kimberly Landfill.

Monitoring wells have been installed at four sites, including Summit Road, Kilcona Landfill, St. Boniface Landfill I, and Brady Road. Water supply wells near the landfills are sampled including the above five sites, plus McPhillips Street Ash Dump, Cordite Road Landfill and Harcourt Street Landfill. The Brady Road Landfill site was not included in the evaluation.

Limited groundwater impacts at a few locations at Kilcona Landfill appear to be related to monitoring well construction, localized iron bacterial problems, and localized bacterial and possibly sewage influence. None appear to be related to the landfill.

Groundwater impacts at a monitoring well and two private wells at Summit Road Landfill have been attributed to local well construction problems and aquifer water quality variations. The monitoring system is being expanded, however, to better characterize impacts due to the landfill. Local impacts on one water supply near the sludge drying beds and on three industrial cooling or process water supplies near the Harcourt Street site do not appear to be related to landfill operations. Monitoring wells are recommended at the Harcourt Street Landfill to define groundwater impacts.

Proposed groundwater programs include monitoring well installation at priority sites near groundwater supply users, evaluation of hydrogeologic conditions at select sites, sampling focused on indicator parameters and other parameters of concern, and data management.

Surface water concerns include subsurface leachate migration, leachate breakout and erosion. Surface water monitoring is proposed at three sites.

Topography and Cover

Final topography and cover are critical to limiting infiltration and leachate production. Landfill topography design principles include positive drainage, short flow distances, surface water routing, and minimum and maximum grades.

Final cover design principles vary from a simple clay cap to a composite membrane cap. Elements include (from waste up) a grading or venting layer, low permeability cap, rooting layer and vegetated topsoil layer.

City of Winnipeg sites include twenty essentially flat sites, thirteen hills or graded landforms and two ungraded sites. Visible settlement, erosion and slope failures have occurred at several sites. Compacted clay cover (not containing waste) exists or is proposed only at Summit Road, Brady Road and Kilcona landfills, with some cover at Cordite Landfill. Other landfills require cover documentation or placement. Refinement of the conceptual end use plan at Summit Landfill is proposed to incorporate engineering landfill design considerations.

Proposed topography and cover programs address safety, erosion and slope stability, surface water contamination, and leachate production.

Site Utilization

Existing land uses include developed recreational areas, undeveloped areas, residential and school, commercial/industrial structures and activities, snow disposal and waste disposal.

End use planning and design issues include selection of surface material, surface grading, vegetation, foundation design and maintenance. Site profiles and an overview of development opportunities and constraints are developed for each site.

Institutional Issues

Jurisdictional authority between City departments and other agencies and the private sector should be addressed in the following areas: waste cleanup, landfill gas control maintenance in buildings, landfill operations, land use conflicts (snow dumping), funding for long-term maintenance, land acquisition in control zones, and utility and developer awareness of landfill locations and hazards.

Work Priorities

Work priorities are recommended based on safety, landfill integrity and ongoing performance, relative to landfill gas, groundwater and surface water contamination, and leachate production. Emphasis should be given to landfill gas issues at the Riel site and Leila Avenue West; to safety issues related to cover at recreational sites (Bonner, Redonda sites, Riel, Barry, Shaftesbury); cover integrity due to erosion (Cordite, Kilcona, Saskatchewan Avenue Landfill); and to ongoing monitoring of landfill gas, leachate and water quality as identified in the report.

ACKNOWLEDGEMENTS

KGS Group extends our thanks and appreciation to the many people who contributed to this Landfill Disposition Study.

The information and expertise provided by the City of Winnipeg, Waterworks, Waste and Disposal Department was greatly valued, including input from Mr. Tony Kuluk, Mr. Colin Potter, Mr. Ray Mikolash, Mr. Frank DeVries, Mr. Dave Moerman and Mr. Kelly Kjartanson.

For regional information on domestic and industrial groundwater use within the City, we thank Mr. Frank Render, Mr. Jim Petsnik, Mr. John Little and Mr. Dan Sie of Manitoba Natural Resources, Water Resources Branch.

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92-107-0601 Upper Carbonate Piezometric Surface and Industrial Wells

1.0 INTRODUCTION

The City of Winnipeg maintains some responsibility for 35 landfill sites within the City and surrounding area. The location and approximate area of the sites is shown on Figure 1 and Drawing SWD E-13. The majority of the landfill sites have ceased operation, with the exception of the active Brady Road and Summit Road Landfills. Many sites have been closed for over 20 years.

In 1979, the City of Winnipeg prepared an environmental assessment of the 35 sites and began a Landfill Environmental Program (City of Winnipeg 1979). The mandate was to evaluate methane gas hazards on properties surrounding landfill sites, identify sites requiring methane gas controls, and re-evaluate the methane control zones which provided land use constraints around each site. The methane control zones ranged from 120 to 215 m (400 to 700 ft).

From 1979 to 1984 the City began a systematic program of landfill site investigations which included definition of waste boundaries using air photos interpretation and test hole drilling; installation and frequent monitoring of methane gas probes in waste, soils and buildings; assessment of leachate elevation; and remedial actions including the installation of gas barriers at two sites.

In 1984, a report was prepared for the City of Winnipeg Committee on Works and Operation which recommended reductions to the waste boundaries and control zones at many sites (City of Winnipeg 1984a). New control zones of 0 to 90 m (0 to 300 ft) were proposed along with monitoring schedules and guidelines for future remedial actions.

In September 1992, the City retained KGS Group to review and update the 1984 report, substantially expanding the scope to include leachate production and groundwater protection, in addition to methane gas migration.

2.0 SCOPE OF WORK

The objectives of this study included those of the original 1979 environmental assessment and additional requirements as follows:

- to reduce the potential of personal injury or property damage arising from the generation and migration of methane gas from landfill sites;
- to minimize any special constraints on the use of land adjacent to landfill sites, by reducing or eliminating the zones of concern around such landfill sites;
- to assess the production of leachate in the landfill; and
- to assess the requirements for the protection of groundwater from liquid pollutants.

The status of each of the 35 sites was reviewed, and requirements for rehabilitative work and potential enhancements for land use have been identified.

The items evaluated included:

- methane gas
- leachate
- groundwater
- topography and cover
- site utilization

As part of each site evaluation, the study included an assessment of:

- Present site utilization and potential for other opportunities;
- Present environmental monitoring, instrumentation and control programs, relative to the objectives of the environmental program;
- Pertinent Regulations and state-of-the-art practice in post-closure care of landfills;
- Alternatives for rehabilitation and/or site enhancement where applicable, complete with costs and benefits of each alternative, and
- Recommendations for each site.

The study has been conducted primarily by review of site information provided by the Waterworks, Waste and Disposal Department, as well as background data obtained from provincial departments and various publications and sources as referenced. Field studies were limited to site walkovers in Fall 1992, along with a leachate sampling program in Spring 1993.

The study is presented in two volumes. Volume 1 contains the report text, tables, figures and drawings. Support documentation is provided in the appendices in Volume 2, which have been keyed to the major report topics.

Data bases are stored on computer disk for use by the City for future data management.

Details of site boundaries, control zones and instrumentation are provided on a set of drawings titled "Locations and Boundaries of Landfills and Dump Sites, revised June 1989", prepared by the City of Winnipeg.

3.0 REGIONAL BACKGROUND DATA

3.1 POPULATION AND WASTE DISPOSAL HISTORY

The number, type and location of waste sites reflects the population growth of the various municipalities which formed Unicity in 1972.

The dates of landfill operation for the City sites are plotted on Figure 2. The area serviced and the waste types are summarized in Appendix B, Table B-1-1.

Incineration was used in the early years with disposal at the Saskatchewan Avenue (No. 15) Landfill beginning in the late 1800s and continuing at the McPhillips Street Ash Dump (No. 10) until 1979. Incinerators were also used at the Kimberly Landfill (No. 7) and Redonda Dump (No. 5).

Many sites began as public nuisance grounds in the rural areas of Winnipeg, including Bonner Avenue Landfill (No. 9), Shaftesbury Boulevard Dump (No. 19), Charleswood Road Landfill (No. 20) and others. Refuse was partially burned at many sites to reduce volumes. Wood waste, street sweepings, leaves and soil fill were disposed at Riel Dump (No. 33), Lot 61 St. Marys Road Dump (No. 32) and River Road Dump (No. 35).

Industrial disposal occurred at several sites, notably the St. Boniface Sites (Nos. 2, 3, 4), Elmwood Landfill (No. 26), Nairn Avenue Landfill (No. 27) and the Cadboro Road Sites (Nos. 23 and 24). Little information is available about specific industrial wastes disposed. The St. Boniface sites were reported to have received large amounts of packing house waste and possibly refinery waste, while the Cadboro Road East site received animal wastes and auto wrecking yard wastes.

Many of the landfills were established in the 1950s and 1960s. By the late 1970s, waste disposal became more centralized with only four operating landfills, McPhillips Street Dump (No. 10), Summit Road Landfill (No. 18), Brady Road Landfill (No. 25) and Kilcona Landfill (No. 36).

From 1979 to 1984 hazardous wastes were diverted from the Kilcona and Summit Road Landfills to the Brady Road Landfill for detonation. Since 1979 City policy has been to divert hazardous wastes from land disposal. Although discouraged by the City, some household quantities of hazardous waste enter the landfill when residents dispose of these materials with municipal refuse instead of bringing materials to hazardous waste depots. Gasoline contaminated soils were accepted at Kilcona, Summit and Brady Road Landfills, until 1992.

3.2 CLIMATE

Climatic data for Winnipeg (International Airport) is summarized on Figure 3, using 30 year average data, 1950 to 1980 (Environment Canada) for temperature, precipitation, evaporation and wind.

Temperature

Mean monthly temperature varies from -19°C in January to 19.6°C in July. Extremes range from a mean maximum of -14°C in January and 25.9°C in July, to a mean minimum of -24°C in January and 13.3°C in July.

Precipitation

Average annual precipitation is 526 mm of which 411 mm is rainfall and 125 mm is snowfall. June, July and August are the wettest months, with over 75 mm of rainfall each month.

Evaporation and Potential Evapotranspiration

Mean monthly evaporation data are plotted on the precipitation data. These represent actual evaporation pan measurements. Evaporation is a function of temperature, humidity, solar radiation and wind speed. Potential evapotranspiration measures both evaporation and plant water usage and is also a function of available water in the soil, plant type and growth stage. Potential evapotranspiration was calculated for Winnipeg using Thornthwaite's method of calculation, as referenced in the EPA 1975 water balance method (USEPA 1975) and plotted on Figure 3. Calculated values are less than pan evaporation values and will result in more conservative estimates of leachate production rates.

Significance of Climate to Landfill Management

Climate is a significant factor in the production of both landfill gas and leachate. Moisture and heat accelerate gas production while cool, dry conditions slow decomposition. Precipitation and evapotranspiration are used to calculate a water balance for the landfill and ultimately to predict the volume of water that will infiltrate into the cover and be available for leachate production.

Winnipeg's climate is significantly drier and cooler for most of the year than most areas in eastern Canada and the north central and northeastern United States, where many larger landfills are situated. In the summer months, however, Winnipeg has as much or more evapotranspiration than these areas. For example, precipitation in London Ontario averages 959 mm per year in comparison to 526 mm in Winnipeg, while evaporation, (measured at the closest station in Windsor, Ontario) averages 734 mm per year in comparison to Winnipeg's 781 mm.

Among the major cities in the western Canadian prairie provinces, Regina, (Saskatchewan) and Calgary (Alberta) are also significantly drier. Average annual precipitation is 413 mm and 472 mm respectively. Edmonton, Alberta is most comparable to Winnipeg in population and climate, with an average annual precipitation of 528 mm.

Leachate extraction programs have been established at Brady Road Landfill, where full collection systems were installed in cells constructed after 1987. Data on leachate volumes collected at Summit, Kilcona and Brady Landfills is now available. Since only a portion of the total leachate volume in the landfills is collected, calculation of leachate generation rates is difficult. There are no other large sites in the province with which to compare data. The closest large landfill to the east, in Thunder Bay is in a warmer and wetter climate zone, with installation of a partial perimeter collection system underway for 1993-1994.

The effect of the cool climate on leachate temperatures was investigated by the City in July 1987 to assess the temperature of the refuse mass (Appendix A-1, Figure A-1-1 and Table A-1-1). Temperatures at the base of most probes ranged from 8 to 13°C. Landfill gas production at temperatures below 15°C is generally limited according to research studies (Hydrogeology Consultants 1984).

Although Winnipeg's climate may result in less gas and leachate production than in other cities, monitoring data show that significant gas generation does occur, (for example at Kilcona Landfill), and that leachate buildup will occur at sites which have been excavated below surface and are without collection systems and proper covers.

The drier climate does provide opportunities for significantly minimizing leachate production, when final landfill topography is designed to maximize runoff, a final cap is designed to limit infiltration, and a soil layer with vegetative cover is established above the cap to maximize evapotranspiration.

These factors are discussed further with respect to final landfill closure in Section 8.0.

3.3 TOPOGRAPHY

Topography in the Winnipeg area is flat, dominated by the glacial lake plain of former Lake Agassiz. The regional topographic map (University of Manitoba 1983) shows the land surface sloping gently from the east and west toward the banks of the Red River, which are at approximately el 228.6 m geodetic within the city limits.

Topographic elevations rise to 237.7 m east and west of the Red River over much of the study area, with elevations up to 240.8 m northwest of the City limits. Slopes are generally less than 0.1% to 0.2%, with slopes up to 0.4% in the far northwest corner. Local topographic highs generally reflect the underlying bedrock and till topography.

The river and creek systems have incised steep valleys in local areas. Other topographic features, such as the glaciofluvial sand and gravel deposits in the Birds Hill area and the exposed bedrock of the Little Mountain Park area, are outside of the City Limits. Many older landfills were developed in low lying depressions.

3.4 DRAINAGE

Winnipeg lies within the drainage basins of the Red and Assiniboine Rivers which join and flow northward. The basins extend west into Saskatchewan and south into North Dakota and Minnesota in the United States. The local drainage system is presented on Figure 1.

The City lies within five sub-drainage basins as follows:

Assiniboine River Drainage Basin

- Lower Assiniboine Sub-basin (Northwest Winnipeg)
  - Sturgeon Creek
  - Omands Creek

Red River Drainage Basin

- La Salle River Sub-basin (Southwest Winnipeg)
  - La Salle River

- Netley Creek/Grassmere Creek Sub basin (North Winnipeg)
  - Grassmere Creek (outside the City limits but within the City Drainage)
  - (Parkdale Creek and Netley Creek are located further north outside of the City's drainage)

- Cooks Creek/Devils Creek Subbasin (Northeast Winnipeg)
  - Bunns Creek
  - (Cooks Creek and Devils Creek are located further north outside of the City's drainage)

- Seine River Sub basin (Southeast Winnipeg)
  - Seine River

Several sites are located close to major ditches, creeks or rivers as follows:

Red River	- No. 30 Red-Assiniboine (The Forks) (Adjacent)
	- No. 31 Corydon/Osborne Dump (Adjacent)
Seine River	- No. 1 Beliveau Road (Adjacent)
Cordite Drain	- No. 8 Cordite Road, (Adjacent), No. 6 Redonda Landfill, No. 36 Kilcona Landfill
Grassmere Drain	- No. 10 McPhillips Street Dump
Omands Creek	- No. 15 Saskatchewan Avenue (Adjacent)
Sturgeon Creek	- No. 18 Summit Road

Within developed areas, the City's storm sewer system forms the drainage network, directing surface water runoff to the rivers and creeks. Storm sewer districts from the 35 City landfill sites have not been identified in this study, however, the information is available from the City of Winnipeg Works and Operation.

The potential for surface water contamination from the landfill sites is evaluated in Section 7.4.

3.5 GEOLOGY

Regional geology of the Winnipeg area is shown in typical section on Figure 4. The Winnipeg area is underlain by Paleozoic carbonate bedrock which was deposited, uplifted and subsequently eroded. A karst topography was produced in the limestones and dolomites, characterized by solution channels, sinkholes and caverns, some of which have been filled with unconsolidated materials ranging from clays to sands.

Glacial activity initially removed the eroded bedrock surface. A dense till unit was deposited beneath the ice on the bedrock surface. As the glaciers retreated to the north, Glacial Lake Agassiz was formed.

Softer, water laid tills were deposited next, followed by the glaciolacustrine silty clays and silts which form the surficial deposits of Winnipeg today. Extensive peat deposits developed in poorly drained low lying areas. The high organic content of many of the Winnipeg topsoils contributes to methane production in landfills where soil and wood wastes have been disposed. Methane may also be detected beneath many buildings, built directly over natural organic rich topsoil.

Characteristics of each of the units as described in the 1983 Geological Engineering Study are summarized on Figure 4. A discussion of the significance of these characteristics to landfill management is presented below.

Surficial Geology

Surficial units consist of (in descending order) a complex zone of silty clay and silt, glaciolacustrine silty clay, and silt till.

Complex Zone - The upper 3 m of silty clay and silt deposits is significant for landfills because of the potential for gas migration through unsaturated silt zones. Lateral leachate migration can also occur through saturated or unsaturated silt zones, because of their higher permeability with respect to the surrounding clay.

Glaciolacustrine Clay - The 9 to 12 m thick clay deposits overlying till and bedrock provide a low permeability zone between contamination sources and the bedrock aquifer. The upper weathered brown clay contains fractures which may transmit leachate or, if unsaturated, may transmit gas at a greater rate than the clay matrix. Clay deposits in west and northwest Winnipeg are thinner due to higher bedrock topography. A major active site No. 18 Summit Road Landfill and two small sites (No. 17 Harcourt Street and No. 16 Barry Avenue) are located in this thin clay area.

Silt Till - The 3 to 6 m thick silt till forms the upper water bearing deposit beneath the clay. Where a thin clay thickness overlies the till, gas and leachate can be more easily transmitted into the till. Gas migration in the till has been documented at No. 17 Harcourt Street Landfill. Till thicknesses vary widely, with the till unit absent in some areas.

Bedrock - The Paleozoic Carbonate bedrock has been uplifted and eroded (Figure 4). The oldest units form the bedrock surface in the east part of the City, while younger units are found towards the west. The bedrock surface is highly irregular. Site specific drilling is necessary at some landfill sites to verify bedrock depth. Where the underlying bedrock has a low transmissivity, as at the Summit Road site, the upper fractured bedrock rubble zone functions as the uppermost permeable zone. The carbonate aquifer within the bedrock forms a major groundwater flow system in the Winnipeg area.

3.6 HYDROGEOLOGY

3.6.1 Aquifer Systems

The main aquifer systems in the Winnipeg area include the carbonate bedrock aquifer and, locally, the shallow perched water table in the overburden within the silt zone overlying the clay unit.

Overburden - The clay deposits act as an aquitard, partially confining the carbonate bedrock. Groundwater is first encountered at the water table which is usually within 3 m below ground surface in the silty clays and silts of the upper complex zone. A perched water table is often found above this zone within the tan silt layer. The piezometric surface of the bedrock aquifer is generally lower, ranging from 6 to 24 m below ground surface in 1983) producing strong downward vertical gradients between the clay and the bedrock. Groundwater flows at very slow rates primarily through higher permeability silt zones and fractures in the clay. Typical horizontal field hydraulic conductivity values are in the order to 1×10^{-8} to 1×10^{-9} cm/sec.

The extent to which recharge contributes to clay porewater at depth has been the subject of much research using isotope testing. Additional studies of pore waters in the clay at the Brady Road Landfill are being conducted in 1993, by University of Waterloo students. Most studies have found very little evidence of recharge in the clay matrix at depth and agree that fracture flow, even through very small fractures, is the primary method of recharge (KGS Group 1992).

Bedrock - Three high transmissivity aquifer zones are found within the carbonate bedrock.

- Upper Carbonate Aquifer
  - Upper 15 to 30 m
  - Partially confined by overburden above and less pervious rock below
  - Transmissivity 25 to 2500 m^2/day (2,000 to 200,000 USGPD/ft)
  - Storage Coefficient 1×10^{-5}

- Middle Carbonate Aquifer
  - Found in western Winnipeg at approximately 90 m below ground surface where the upper zone is less pervious
  - Transmissivity 250 to 1250 m^2/day (20,000 to 100,000 USGPD/ft)
  - Storage Coefficient 1×10^{-4} to 1×10^{-5}

- Lower Carbonate Aquifer
  - Bottom 7.5 m to 15 m of carbonate sequence at a depth of 145 m
  - Minor aquifer
  - Transmissivity less than 62 m^2/day (500 USGPD/ft)

The saline sandstone aquifers of the Winnipeg Formation are found below the Carbonate aquifer. The aquifers are separated by the upper shale unit of the Winnipeg Formation, which acts as a confining layer between the carbonate and the sandstone units.

3.6.2 Bedrock Aquifer Characteristics near Landfill Sites

Regional information was used to characterize the bedrock aquifer, since bedrock wells have been installed at only a few landfill sites. Well records for provincial observation wells closest to landfill sites were obtained. A summary table was prepared showing the sites (grouped by general location), the closest observation wells, and selected stratigraphic, well construction and pumping information where available (Appendix A-2-1).

Hydrographs for these bedrock wells were selected to show long term trends in piezometric surface elevation and to evaluate current conditions (Appendix A, Figure A-2-1 to A-2-9). The hydrographs for these wells were analyzed and maximum, minimum and average values were selected for the entire observation period and for 1992 (Appendix A, Table A-2-1).

Current (1992) bedrock piezometric conditions near landfill sites were compared with the 1980 piezometric surface map (University of Manitoba 1983) by plotting average 1992 piezometric elevations and contouring (Drawing 92-107-0601). The map is constructed on a very limited 1992 data base and provides a rough estimate of current conditions near landfill sites.

Flow Directions and Gradients

Groundwater flow is primarily horizontal and is assumed to follow the hydraulic gradient regionally. Local bedrock channels in fractures, joints and bedding planes will produce local variations in flow directions. Groundwater flows from three major directions as follows:

- From the East - recharge in eastern till/glaciofluvial upland and Birds Hill aquifer
- From the Northwest - recharge in thin tills northwest of Winnipeg
- From the Southwest - recharge from thin tills and fluvial deposits over shale uplands on west.

Pumping in the City has depressed the piezometric surface from an estimated 3 to 6 m below groundsurface in 1894, up to 24 m or more in 1983 (University of Manitoba 1983). In 1980, the piezometric surface was lowest in the downtown and St. Boniface areas (approximate elevation 216 m). The centre of the cone appears in approximately the same location in 1992, however, piezometric elevations have rebounded 2 to 3.5 m near the centre of the cone reflecting reduced industrial pumping, decreasing outward with distance. Current piezometric elevations south and east of the City near the floodway, and west in Murray Industrial Park are comparable to 1980 elevations.

The groundwater gradient in the bedrock ranges from 0.0008 to 0.001 m/m (1980 data) over much of the City.

Groundwater Quality

In the east and northwest, water in the recharge area is fresh, becoming slightly brackish and very hard in the discharge area. Total dissolved solids range from 300 to 1500 mg/l and chloride ranges from less than 10 to 500 mg/l.

In the southwest, groundwater is brackish and saline. Saline waters from wells in sandstone aquifers have contaminated the carbonate aquifer in parts of the City. Regional water quality was summarized for each site, using water quality concentration maps for total dissolved solids, chloride and sulfate (University of Manitoba 1983). Results are plotted on Figure 5. Sites overlying brackish and saline aquifers in the southwest such as the Charleswood sites, Cadboro Road sites and Brady Road site area easily recognized by their high TDS (>5000 mg/l), chloride (>1000 mg/l) and sulphate (>1000 mg/l) concentrations. The aquifers beneath the sites have been classified into potable and non-potable on the basis of the regional information. In west Winnipeg, (Summit Road and Harcourt Street sites) groundwater varies in salinity, but is still used as a drinking water source in some areas.

More complete groundwater chemistry data for the Provincial observation wells near landfill sites is provided in Appendix A, Table A-2-2 for reference.

Significance of Bedrock Aquifer Characteristics to Landfill Management

The character of the bedrock, transmissivity, flow directions and water quality are important in evaluating the impact of the sites on groundwater supplies. Near Kilcona Landfill in the east part of the City, water supplies are developed in the Upper Carbonate aquifer often just under the clay, while near the Summit Road landfill, many water supplies are developed in a much deeper zone, potentially providing some added protection where the overlying rock is less pervious.

Areas in the downgradient groundwater flow direction have the potential to be affected by any leachate discharge to bedrock. Gradient and transmissivity can be used to estimate the dilution potential of the bedrock aquifer. Knowledge of background water quality is essential to interpret monitoring results and to select monitoring parameters that will be good indicators of leachate contamination.

3.6.3 Aquifer Use

Domestic Use - The Carbonate aquifer is used for domestic water supply in outlying and suburban areas of Winnipeg. All provincial water well records for wells within the City were obtained. Locating these wells with respect to the landfills was not pursued because of the time involved. The 1992 data base can be used by the City to update well construction records in developing areas. The City of Winnipeg and Manitoba Environment have sampled and analyzed groundwater from domestic wells in proximity to the following landfill sites: No. 36 Kilcona Landfill, No. 8 Cordite Road Landfill, No. 17

Harcourt Street Landfill, No. 18 Summit Road Landfill, No. 10 McPhillips Street Dump, No. 11 McPhillips Street Landfill. This generally annual monitoring program has resulted in a comprehensive data base at these locations.

Industrial Use - Industrial groundwater users near landfill sites were identified in consultation with Manitoba Natural Resources, Water Resources Branch. Landfill sites were grouped by location. Data on the type of use, well depth and discharge rates was summarized for each user (Appendix A, Table A-3-1). The location and discharge of industrial users was plotted on Drawing 92-107-0601 with a key indicating if the use was consumptive or non-consumptive.

Most industrial users pump groundwater for cooling or heating, using a system of supply and return wells. Consumptive uses (where groundwater is not recharged to the aquifer) include air cooling with discharge to the river, industrial production such as fish processing and beer production, irrigation for golf courses and lawns, and dust control.

The presence of an industrial water supply close to the landfill may alter the groundwater flow system near the site. Industrial wells have been part of the routine groundwater monitoring by the City at the Harcourt Street Landfill and the St. Boniface Landfills.

4.0 LANDFILL SITE INVENTORY

A topical data base prepared to summarize pertinent information for each site is presented in Appendix B. Major topics were as follows:

- ***Site Characteristics*** - Including disposal history, waste type and landfill dimensions (Appendix B, Table B-1-1).

- ***Land Use*** - Classification of site by ownership/control and land use category (recreation, undeveloped, residential, school, commercial/industrial, disposal (Appendix B, Table B-1-2).

- ***Hydrogeology and Geology*** - Summarized from regional and site specific data (where available) including site stratigraphy (silt, clay, till and bedrock), groundwater elevation (overburden and bedrock piezometric surface) and leachate build-up in the landfill (Appendix B, Table B-1-3).

- ***Landfill Site Sections*** - Geology, groundwater and landfill geometry shown on Figures 6 to 10. Sections represent general site conditions and groundwater pollution potential and are intended for comparative use. Site specific information should be used for any detailed evaluations. Data sources are identified in the notes to Table B-1-3.

- ***Gas, Leachate and Groundwater Monitoring*** - Current (1992) status emphasized including landfill gas, leachate and gas monitoring (Appendix B, Table B-1-4). Details of groundwater monitoring locations are presented in Appendix E-1.

- ***Topography and Cover*** - Including topographic shape, cover type and thickness, vegetation, drainage, settlement, erosion and potential hazards (Appendix B, Table B-1-5).

5.0 LANDFILL GAS

5.1 BACKGROUND

5.1.1 Landfill Gas Generation and Composition

Landfill gas is produced as organic matter decomposes by bacterial action in a waste site. Production is related to waste composition and age, moisture content, waste temperature and climate. Production will initially increase as waste begins to decompose and will eventually peak, and then decrease as available organic matter becomes depleted. Very old landfills can continue to produce landfill gas as shown by some Ontario sites over 70 years old (Hydrology Consultants 1984).

Major constituents of landfill gas include:

- Methane 45-60%
- Carbon Dioxide 40-60%
- Nitrogen 2-5%
- Oxygen 0.1-1.0%

Trace constituents include water vapour, hydrogen sulphide, mercaptans, carbon monoxide, ammonia and volatile organic compounds (Tchobanoglous 1993).

The distribution of these gases within the landfill varies with time. Aerobic decomposition of new waste first produces nitrogen and oxygen. Anaerobic but non-methanogenic decomposition is established next producing carbon dioxide. Microbial activity then increases, producing organic acids and hydrogen. Methanogenic organisms then convert these acids and hydrogen to methane and carbon dioxide, eventually reaching a steady state production which then decreases with time as the organic material is used up. The rate at which these processes occur varies significantly with temperature, moisture, and waste compaction.

In Winnipeg, a significant volume of waste is disposed in compacted, frozen blocks in winter. This would theoretically delay decomposition until the waste thaws and reaches temperatures conducive to decomposition.

More specific data on these rates could be obtained from gas generation measurements at Brady Road Landfill as new cells are developed and closed.

5.1.2 Health and Safety Impacts of Landfill Gas

Landfill gas can affect health and safety on a landfill, or in surrounding areas, in the following ways:

- ***Explosion*** - methane gas is explosive at concentrations of 5% to 15% in air.
- ***Asphyxiation*** - generation of methane and carbon dioxide produce low oxygen conditions in enclosed spaces.
- ***Odour*** - organic acids, esters and organosulphur compounds in decomposing waste produce odours.
- ***Toxic Effects*** - Hydrogen sulphide, benzene and toluene can be found in landfill gas at levels above toxicity standards (Farquhar 1991).

5.2 CHARACTERISTICS OF LANDFILL GAS IN WINNIPEG

In Winnipeg landfill gas has been routinely analyzed for methane. Vinyl chloride was analyzed in landfill gas at 8 sites in 1987 because of its toxic properties (Appendix C, Table C-2-2). A comprehensive analysis of landfill gas from the Kilcona Landfill was prepared as part of an evaluation of energy production potential (Environmental Technologies Inc. 1992). The average gas composition from 3 test wells at the Kilcona landfill was as follows (reported in percent by volume):

• Methane	57.5%
• Carbon Dioxide	40.02%
• Nitrogen	2.18%
• Oxygen	0.3%

A total concentration of trace volatile organic compounds of 210 μg/l was detected in landfill gas sampling as summarized in Appendix C, Table C-2-1. Vinyl chloride concentrations of 0 to 2.6 ppm volume were detected at the 8 landfills sampled in 1987. The evaluation of volatile emissions from landfills is discussed in Section 5.3.7.

5.3 LANDFILL GAS POLICIES - STATE OF THE ART REVIEW

5.3.1 Background - City of Winnipeg Landfill Gas Policy

The City of Winnipeg has developed several documents outlining their methane gas policies:

- Methane Gas Policy WT-3 (City of Winnipeg 1979)
- Report of the Committee of Works and Operations Methane Gas Policy, October 2, 1984 (City of Winnipeg 1984a)
- Policy for Building on Landfill Sites (City of Winnipeg No. 1)
- Policy Regarding Building Permits Adjacent to Landfills (City of Winnipeg No. 2)
- Policy For Building on Nairn-Elmwood Landfill Sites (City of Winnipeg 1989b)
- Provision CW 1100-R4 (Section 18) Construction Safety in and Around Landfills (City of Winnipeg No. 3)
- Design Guidelines for Landfill Sites Construction (City of Winnipeg No. 4).

Pertinent documents are included in Appendix C-1-1 and C-1-2. These policies cover conditions for construction of buildings both on waste and adjacent to waste in a control zone of a specified radius. The policies also specify monitoring strategies for waste and soil and set methane levels, above which the implementation of methane control measures at the landfill will be considered.

In 1984, the City established zones of concern, or control zones, around each landfill based on methane monitoring 1979 to 1984. The zone of concern is defined as the area outside the waste site that could be affected by methane gas migration. Prior to site specific investigations which began in late 1979, these zones had been set at a 231 m (700 ft) radius from the waste boundary. This radius was reported to be a potential distance that methane might migrate in Winnipeg. Current control zones are listed on Table 1 as follows:

• 90 m (300 ft)	7 sites
• 45 m (150 ft)	15 sites
• 15 m (50 ft)	11 sites
• Site boundary (0 m)	4 sites

In the following sections, the City of Winnipeg Policy and Province of Manitoba regulations are summarized for each aspect of gas management and compared to methane regulations or policies in the following jurisdictions as summarized in the references listed:

- Province of Ontario (Ontario Ministry of the Environment)
- United States Environmental Protection Agency (USEPA)
- State of Wisconsin
- City of Edmonton (1993)
- City of Calgary (1993)
- City of Regina (1993)

Aspects of gas management not addressed by the City of Winnipeg Policy are also noted where they occur. The implementation of each of the policies by the City is discussed with examples.

5.3.2 Province of Manitoba Regulations

The Province of Manitoba regulates solid waste disposal sites under Manitoba regulation 150/91 (Province of Manitoba 1988). These regulations require that buildings be set back a distance of 400 m from a landfill. An official communication from the Province commenting on the suitability of the City of Winnipeg Methane Control Policy is needed to confirm that the City policy of 15 to 90 m setback is acceptable in place of the Provincial regulation. The City Methane control policy specifies smaller control zones (15 to 90 m) than the Province. The City of Winnipeg should request that the Province either accept the City Policy in lieu of the 400 m setback, or specify how the City must comply with the regulation. An official letter from the Province should be obtained on this matter to clarify regulatory responsibility.

Manitoba Environment is preparing proposed guidelines for Class 1 waste disposal grounds (those serving greater than 5000 persons) which include specifying a requirement for a gas migration control system (Conyette 1993). At this time the Province of Manitoba does not regulate air emissions from landfills. Air regulations refer only to point sources.

5.3.3 Standards for Landfill Gas at Waste and Property Boundaries

The standards for landfill gas at waste and property boundaries are summarized on Table 2 for the City of Winnipeg and other jurisdictions.

City of Winnipeg

Policy - The lower explosive limit (LEL) of methane is 5% in air. City policy states that if gas concentrations immediately outside of the fill exceed 20% LEL (1% methane), gas barrier controls (with monitoring) are to be considered at the landfill. Where gas concentrations immediately outside the fill are less than 20% LEL, long term monitoring would be continued. Long-term monitoring is necessary, since gas generation and migration can vary with weather conditions and soil disturbance, and because gas production is not anticipated to be reduced greatly in the foreseeable future (City of Winnipeg 1984).

Implementation - The City policy has been implemented as follows:

- Where the property boundary is beyond the waste boundary, the 1% methane standard applies at the property boundary instead of the waste boundary.

- Where no buildings exist beyond the property boundary, no controls are implemented. Probes have been drilled close to the waste boundaries first and then into the control zone. Barrier controls have been constructed at Kimberly Landfill and Margaret Park Landfill. Landfill gas management strategies have been developed for sites where methane is found beyond the waste boundary. These strategies include soil probe and building monitoring, reliance on natural barriers such as ditches and high water tables and engineering controls as discussed in Section 5.5.3.

Other Jurisdictions

Province of Ontario - Specific standards for waste sites were not available. The Province of Ontario guidelines require that where barriers and controls are installed on properties, gas concentrations should be less than 20% LEL (1% methane) in soil, between the barriers and the structures to be protected (Province of Ontario 1987a).

USEPA Subtitle D Regulations - The USEPA Subtitle D regulations require maintenance of less than 100% LEL (5% methane) at the property boundary of an active solid waste site (USEPA 1991a).

State Of Wisconsin - The State of Wisconsin requires that landfills maintain a methane concentration of less than 1.25% methane (25% LEL) in soils or air at or beyond the landfill property boundary (State of Wisconsin 1988).

City of Edmonton - Not specified

City of Calgary - Not specified

City of Regina - Not specified

Evaluation

The City criteria of 20% LEL (1% methane) provides a 5 fold safety factor, which is as stringent or more stringent than other jurisdictions examined. ***An explicit statement of the point where this criteria applies is needed in the policy.*** In cases where the City does not own the control zone, methane may exceed 20% on vacant adjacent property, without City action. ***The policy should also state a performance standard for barrier systems of less than 20% LEL in soil outside the barrier.*** The City policy should specify a standard for methane concentrations in air which could include analysis of gas dissipation in air as has been done at the Kimberly site. Gas concentration in air can be an issue at landfills with barriers, operating landfills, or larger closed landfills, with gas venting and stacks, where off-site migration of methane and other gases in air is possible.

5.3.4 Standards for Construction on Landfill Waste

The standards for construction on landfill waste are summarized on Table 3 for the City of Winnipeg and other jurisdictions.

City of Winnipeg

Policy - The City policy for Building on Landfill Sites requires that elevated construction must be used for enclosed buildings overlying waste, such that the lowest part of the floor is a minimum of 750 mm above finished grade level. Other conditions required include free air access under the building, venting around the building, measures to prevent methane transmission through underground services, safety measures during construction, evaluation of waste compatibility with structures, inspections, monitoring and legal arrangements (City of Winnipeg No. 1).

A special policy applies to the Nairn and Elmwood Landfill sites, where random pockets of waste are spread out over a large area. At the Nairn and Elmwood sites, a property proposed for a building site must be investigated with a drilling program. If the methane generating material is found within the proposed building limits, the material must be replaced with inorganic fill. Methane protective measures must also be incorporated in the design of buildings and services (City of Winnipeg 1989b).

Implementation - New buildings are required to use elevated construction. Other buildings previously constructed on waste are constructed with gas controls and/or are monitored as discussed in Section 5.7.

Other Jurisdictions

Province of Ontario - The Province of Ontario uses a decision tree when dealing with potential methane problems (Province of Ontario 1993). The guidance is only used where methane production has peaked and is now declining. This usually occurs after at least 10 years have elapsed since closure of the landfill, or much longer where landfills have been encapsulated. Building on waste is not recommended by Ontario MOE and approvals under these guidelines are extremely rare (Geherls, Ontario Ministry of the Environment Personal Communication).

The guidelines allow enclosed structures to be constructed on a landfill, if the methane concentration in the waste is less than 10% LEL (0.5% methane); or if the waste is to be removed; or if an air space separation is maintained between the waste and the proposed building.

If the methane concentration in the waste is between 10% and 20% LEL, the building may be constructed with gas controls and monitored with alarm devices. If gas monitoring between protective facilities and the structure to be protected remains below 20% LEL for 3 years, measured when active gas controls are not functioning, the alarm and monitoring systems may be decommissioned. Construction could also be delayed until 3 years of monitoring have established whether or not controls are required.

State of Wisconsin - Wisconsin Solid Waste Regulations prohibit building on abandoned landfills of any type or age. Exemptions for development may be granted based on recent guidelines (Wisconsin Department of Natural Resources 1992b):

- Where methane levels in waste are greater than 25% LEL, no construction is allowed on waste, regardless of engineering control proposed.

- Where methane values are between 0% LEL and 25% LEL, construction may take place with safeguards such as vents, trenches, methane alarms, flexible membrane liners under foundations, and construction with slab foundations. A venting system with a vapour barrier of a specified design is also required.

- Where methane values in the waste are 0% LEL, no engineering safeguards are needed.

City of Calgary - The City of Calgary has no formal policy with respect to development over former landfill sites. Detailed studies and documentation of structural stability and methane gas control is required by developers. Open air storage or temporary buildings have been allowed.

City of Edmonton - No formal gas policy

City of Regina - No formal gas policy

Evaluation

The City of Winnipeg policy is more "stringent" than the Ontario or Wisconsin Policies, since the City allows only elevated construction on waste, regardless of methane generation. The City policy addresses landfill gas buildup, utilities and construction safety, but does not specifically address other factors that may still apply to elevated construction and which are addressed by Wisconsin, such as:

- measures to prevent disturbing the landfill cap,
- settlement and breakage of utility lines and potential contamination of water supplies or increased gas or leachate generation from leakage of water and/or sewage into the waste,
- potential vertical migration of gas and leachate to underlying aquifers via foundation piles (particularly driven piles).

5.3.5 Standards for Construction Adjacent to Landfill Waste

Standards for construction adjacent to landfill waste are presented in Table 4 for the City of Winnipeg and other jurisdictions.

City of Winnipeg

Policy - Building permits are granted for construction in control zones adjacent to waste where test results indicate there does not appear to be "significant" amounts of gas in soil (City of Winnipeg No. 2). Builders must drill or excavate to a radius equal to the control zone around their building to prove that there is no waste under the building. Where "significant" amounts of landfill gas are reaching the site, building permits may be granted, where acceptable safety measures are incorporated. If the City's monitoring program is not in place at the particular site, the owner must also maintain acceptable gas probes and grant the City access for testing for 3 years. The City is also open to petition to reduce a control zone, subject to technical verification by the proponent.

Implementation - The policy does not specify a number for "significant" levels of landfill gas. In practice, levels of methane greater than or equal to 20% LEL (1% methane) in the subsurface in the control zone are considered significant and would require building control measures. If levels are less than 20% LEL, an evaluation is done on a site specific basis based on the City's historical monitoring at the site and on a monitoring system set up by the proponent. A specified period of monitoring is not set, since landfill gas concentrations may vary widely with weather conditions. A three year monitoring period has been used in some cases.

Other Jurisdictions

Ontario - Province of Ontario guidelines (Ontario Ministry of the Environment 1987a) specify using a calculation to determine the distance landfill gas will migrate before reaching 10% LEL. The empirical equation is D=10H where H equals the depth of the landfill between the ground surface and the water table. These numbers are based on data from Ontario waste sites. The calculation of the distance D in effect establishes a numerical zone of concern.

No building restrictions apply in the area adjacent to waste where the methane concentration in the waste is less than 10% LEL. Where the methane concentration in the waste is >10% LEL, no restrictions apply if there is a barrier present or if the proposed building is outside the distance D=10H. Methane levels in soil outside a barrier are required to be <20% LEL.

The need for landfill gas controls is assessed based on methane concentrations in the subsurface when the proposed building is within the distance D=10H, where there are no barriers. Where methane in the subsurface is >20% LEL, landfill gas controls are required. Where methane is <20% LEL, buildings can either proceed with landfill gas control, or monitor to establish landfill gas concentrations in the subsurface. If initial landfill gas concentrations in the subsurface of <10% were encountered, one year of monitoring would be generally required. If initial concentrations of 10% to 20% LEL were encountered, five years of monitoring would be required.

Site conditions must be assessed for landfill gas where there is a change in landfill use within 500 m of a landfill (Ontario Ministry of the Environment 1987b).

State of Wisconsin - Wisconsin prohibits new groundwater well development within 366 m (1200 feet) of a landfill, thus restricting development in or beyond potential control zones in areas using groundwater supplies (State of Wisconsin 1988).

City of Calgary - The Province of Alberta is resolving conflicting legislation which requires landfills to be set back 450 m (1500 ft) from residences, but requires residences to be set back only 305 m (1000 ft) from landfills (City of Calgary 1993).

City of Edmonton - No policy

City of Regina - No policy

Evaluation

The City of Winnipeg policy uses a strategy similar to that of Ontario. Permits are required only in the zone of concern. In Winnipeg, the zone of concern was established using the D=10H empirical formula adjusted on a site specific basis and verified with monitoring. Shallow water tables within 5 m of ground surface further limit gas migration potential. The basic premise of Ontario and City of Winnipeg policies is the same. Where methane concentrations in soil are greater than 20% LEL, controls are required. Other situations are evaluated with monitoring.

5.3.6 Landfill Gas in Buildings

City of Winnipeg

Policy - City policy does not explicitly state maximum allowable methane concentrations in buildings. The City requires that methane in buildings not exceed 20% LEL (City of Winnipeg Landfill Environmental Section, Personal Communication). To monitor this, an "alarm level" of 5% LEL or 0.25% methane in air is established. If concentrations in enclosed spaces exceed the alarm level, action is required to reduce concentrations.

Other Jurisdictions

Province of Ontario - Where control facilities are required, they must insure that methane concentrations in, beneath and immediately adjacent to structures and in any associated conduits and trenches are maintained below 20% LEL (Ontario Ministry of the Environment 1993).

USEPA Subtitle D - The concentration of methane gas generated by the landfill must not exceed 25% LEL in facility structures, excluding gas control or recovery system components (USEPA 1991a).

State of Wisconsin - The concentration of explosive gases in any facility structure must not be in excess of 25% of the LEL, excluding the leachate collection system or gas control or recovery system components (State of Wisconsin 1988).

City of Calgary - No policy

City of Edmonton - No policy

City of Regina - No policy

Evaluation

Existing practices should be incorporated into the policy. City practice uses a methane action level in buildings which is one quarter of the maximum methane level allowed. The 5% LEL becomes the maximum level allowed. The policy does not specify what methane concentrations must be maintained beneath and immediately adjacent to structures, or in conduits and trenches.

5.3.7 Non-Methane Emissions

City of Winnipeg

Policy - The City has no policy regarding non-methane air emissions from landfills.

Other Jurisdictions

USEPA Subtitle D - USEPA requires that landfills comply with State Air Regulations. Regulations proposed in May 1991 would require landfills which emit greater than 150 megagrams/yr of non-methane organic compounds to design and install gas collection systems (USEPA 1991a). Landfills with design capacities of over 100,000 tonnes per year are subject to this regulation.

State of Wisconsin - The State of Wisconsin requires hazardous air contaminant controls for all new landfills (1992), as well as existing larger landfills with approved capacities of greater than (380,000 m^3) 500,000 yd^3. Controls consist of an active gas extraction system and a specific combustor (Wisconsin Department of Natural Resources 1992b).

Environment Canada - No policy

City of Calgary - No policy

City of Edmonton - No policy

City of Regina - No policy

Evaluation

Limited landfill gas analyses for non-methane constituents has been conducted by the City at several sites and by Environmental Technologies Inc. (ETI) at Kilcona Landfill (Appendix C-2, Table C-2-1 and C-2-2). ETI has calculated the yearly emission rate of non-methane organic compounds (NMOCS) for Kilcona Landfill, based on gas generation rates obtained during their study. The rate equals the landfill gas generation rate, multiplied by the NMOC emission concentration. Based on a landfill gas generation rate of 74,865 m^3/day and a NMOC concentration of 210 μg/l (210 x 10^{-3} g/m^3), they have calculated an emission rate of 5.74 megagrams/yr or (5.74 t/yr). This would be below the EPA standards, were they adopted in Canada. Periodic monitoring of NMOCS at the three major sites (Kilcona, Summit, Brady) over the years should be conducted to assess conditions.

5.3.8 Gas Monitoring

City of Winnipeg

Policy - The City of Winnipeg 1979 policy specified monitoring frequencies for gas probes, structures, and in some cases, underground structures. Quarterly and semi-annual (twice per year) monitoring was most frequently required, with monthly or annual monitoring specified in several cases. Gas monitoring schedules for Summit Road, Brady Road and Kilcona Landfills were specified as semi annual (City of Winnipeg 1979).

Implementation - The frequency of landfill gas monitoring has been severely restricted by decreasing funding. The 1979 monitoring schedule was never fully implemented. Annual monitoring is now the norm at most sites, with additional monitoring scheduled when gas migration potential is high (such as a sudden freeze up after a rain).

Other Jurisdictions

Monitoring requirements are generally specified for operating and closed licensed landfills.

USEPA Subtitle D - USEPA Subtitle D regulations require at least quarterly monitoring of gas probes.

State of Wisconsin - The State of Wisconsin requires new facilities to install gas probes outside the limits of waste on all sides of the facility in granular soil and in other soil formations where gas migration may occur. At least one set of gas probes are required to be designed at the elevation of the base of the facility, unless the geologic environment prevents migration. Each time sampling is performed, records must be kept of air temperature, ground conditions (frozen, dry, saturated), barometric pressure and information as to whether the barometric pressure is rising or falling. At least quarterly monitoring is required.

Province of Ontario - Not Specified

City of Calgary - Not Specified

City of Edmonton - Not Specified

City of Regina - Not Specified

Evaluation

A proposed landfill gas monitoring program and frequency is discussed in Section 5.9.

The City keeps some records of weather conditions but these do not necessarily include regular notes on air temperature, ground conditions, and barometric pressure (value and direction of trend). The information can be obtained from several weather stations in the Winnipeg area. A written plan to identify and document weather conditions conducive to gas migration should be included in the gas policy.

Probe placement has occurred inside the waste and in the control zone, on the outer limit of the control zone. Probes are not necessarily placed on all sides of the facility but are concentrated in areas of concern, such as between the waste and housing or services.

Probes are generally extended to an elevation beneath the base of the facility as well as in shallow formations.

5.4 GAS PROBE DESIGNS, MONITORING EQUIPMENT AND PROCEDURES

Gas Probe Designs

The City of Winnipeg has used five basic gas probe designs to monitor landfills, as shown in Appendix C-1-3.

The 50 mm (2 inch) diameter Type A probes were initially installed in 300 mm (10 inch) diameter boreholes because of limited access to small diameter drilling equipment. Probes were ineffective because the large borehole diameter made sealing difficult and moisture collected in the probe.

The 50 mm Type B probes were then installed in smaller 125 mm boreholes. Subsequent probe designs decreased both borehole diameters (Type C 90-100 mm, Type D 50 to 75 mm) and probe diameters (Type C 25 mm, Type D 12.7 mm). Probes are constructed of PVC pipe with a slotted section below surface. The slotted portion is backfilled with a granular pack, with a bentonite clay slurry seal installed above the granular pack. Probes were constructed with either protective casings or as ground level probes. To avoid volatile fumes, rivets are used to attach pipe, rather than solvents.

Gas testing in shallow zones 1 to 1.5 m (3 to 5 feet) below surface in buildings, yards and barriers is performed by pushing a piece of rebar, inserting a thin diameter tubing and placing a seal at the top of the hole. Designs for typical slab gas probes installed in buildings are also presented in Appendix C-1-3.

Monitoring Equipment

A portable gas detector is used to measure methane concentrations in probes and buildings. The Gastech Model NP-204 portable natural gas indicator is used to measure both concentrations less than or equal to 100% LEL, and percent methane in air for more concentrated samples. Syringe samples are taken from inline surgical rubber tubing installed in ports in gas probes. Samples are analyzed for percent methane using gas chromatography (GC). GC samples are run routinely, particularly in perimeter areas where very low concentrations of gas are detected.

Monitoring Procedures

The monitoring procedures followed by the City are outlined in Monitoring Standards for Landfill Gas (City of Winnipeg 1984b). These include:

- Maintenance and operation of gas detectors
- Test procedures for monitoring gas probes
- Maintenance of gas probes due to flooding or probe leaks
- Building entry procedures
- Sampling locations in structures and service corridors (watermains and sewers)
- Sample handling
- Toxic atmospheric protection
- Procedures regarding explosive gas concentrations in buildings

5.5 LANDFILL GAS CONDITIONS

5.5.1 Analysis of Monitoring Data

The City of Winnipeg gas monitoring data was analyzed to classify landfill sites according to observed methane migration. A summary of gas data 1985-1992 prepared by the City of Winnipeg was entered on a data base and manipulated to present monitoring records for each site. Probes were classified as either inside (in waste) or outside (generally in the control zone) the waste site. The number of readings at each methane concentration was totalled for each year. Detailed summaries of gas data taken before 1985 were prepared for select sites to identify trends established in this period, when monitoring was more frequent, and to identify specific probes with higher gas readings.

The summaries are presented in Appendix C-2, Table C-2-3. Where detailed summaries were prepared of 1980 to 1984 data, they are attached to the general summary of 1985-1992 data for each site. Detailed summaries of 1985 to 1992 data were prepared for the Kimberly, Riel, Summit and Kilcona Landfills. Other comments on gas analyses are summarized in Appendix C-2, Table C-2-4.

Sites were classified into three categories depending on the typical methane concentrations in probes within the control zones (outside the waste), as presented in Table 5.

- ***High Methane Migration*** - Where outside probes contained methane >20% LEL either frequently (six sites) or with isolated readings (six sites). These sites may exceed the existing methane policy guidelines of >20% LEL at waste and property boundary.

- ***Moderate Methane Migration*** - Where outside probes contained methane at levels <20% LEL, but above trace concentrations of 0.1% methane (three sites). Methane concentrations in the waste probes were used to classify sites within each category. All four of these sites had high (>100% LEL) methane concentrations in waste.

- ***Low Methane Migration*** - Where outside probes contain 0% methane to 0.1% methane (19 sites). Methane concentrations in waste were high (>100% LEL) at four sites, moderate (<100% LEL) at 8 sites and low (0% gas) at 7 sites.

The classification was used to identify sites which exceed the methane policy and to support monitoring recommendations. Detailed analysis of the adequacy of probe placement at each site was beyond the scope of this study. A detailed analysis is required for all sites, particular those with high and moderate methane concentrations in waste.

5.5.2 Landfill Gas Trend Analysis

Summit Road

A monitoring location plan and landfill gas data for No. 18 Summit Road Landfill is presented in Appendix C-3, Figure C-3-1 to C-3-3 and Table C-3-1.

Summit Landfill

Methane concentrations in waste range from 4 to 6 percent methane at probe L109, 18 to 26 percent methane at probe L108 in the northwest corner, and up to 80 percent methane in probes P12L, 13L, and 10L in the northeast and north central portion of the site.

Probes in the control zone west of the site registered methane levels less than detection, with an occasional trace reading of up to 0.1 percent methane. There are no probes in the control zone on the east side. One probe adjacent to waste in the east central (P11E) area registered up to 44 percent methane in 1980 but is now below detection. Methane data has been collected infrequently in probes in the control zone. For example, at P19E, probes were sampled six times from 1980 to 1985 and three times since 1985.

Probes are needed in the control zone around the perimeter of the site. Methane concentrations in till should be measured because of the proximity of till to the base of the site. Development plans for housing east of the landfill have been proposed (Hilderman Witty 1990). Verification of the adequacy of the east control zone should be completed prior to future development.

Kilcona Landfill

A location plan and landfill gas data for No. 36 Kilcona Landfill is presented in Appendix C-3, Figure C-3-4 and C-3-5 and Table C-3-2 and C-3-3.

Substantial methane concentrations of up to 75 percent methane have been measured in the waste. Despite generally high readings, concentrations in August 1983 were trace and July 1992 were 4 percent methane, showing the variable nature of seasonal readings.

Extensive gas probes were originally placed around the west cell. Currently two gas probes are installed on the west and northeast sides. Around the east cell, five probes monitor the south and west side, two probes monitor the area between the cell and the lake and one probe monitors the area between the lake and the club house.

Probes P11E, (south of the west cell) and P20E (west of the west cell) had methane levels of 27 percent and 4 percent methane respectively, in 1982 and 1983. Methane has not been detected above trace concentrations at other probes with the following exception.

Trace methane concentrations below the LEL have occurred at probe P15E, south of the east cell along Springfield Road (Figure C-3-4). Probes beneath the Old scale house (Parks Maintenance Building) ranged from 0.3 to 0.9 percent methane in 1992, an increase from previous years. Probes 17E and 16E between the scale house and the east cell did not have elevated readings (Table C-3-3). Monitoring frequency should be increased to investigate apparent changes in gas migration around the east cell. Additional gas probes should be installed around the west cell to monitor landfill gas migration, particularly along the west and northwest areas where surface water barriers do not exist. The need for landfill gas venting and collection should be examined for Kilcona Landfill in the future.

Brady Landfill

Landfill gas data for No. 25 Brady Road Landfill is presented in Appendix C-3, Table C-3-4. Landfill gas has not been detected in probes along the south edge of the control zone (P21E, 22E, 23E, 34E). Within the landfill, methane concentrations range from 0-100 percent methane. Methane concentrations of 0.8 to 14 percent were found at P32E close to the southwest corner of the site.

5.5.3 Landfill Gas Management Strategies

The City of Winnipeg's gas policy requires the maintenance of methane concentrations less than 20% LEL at the waste or property limit, where there is a reason for protection. Methane concentrations have exceeded 20% LEL in the control zones at 11 sites. Exceedances were isolated occurrences at five of these sites.

The existing strategies used by the City to control methane migration at the sites are summarized on Table 6. Site plans with pertinent methane data are presented in Appendix C-4, Figure C-4-1 to C-4-6. Strategies vary from site to site, but include one or more of the following:

- ***Natural Barriers*** -
  - Reliance on the presence of a saturated ditch as a barrier to methane migration.
  - Reliance on clay barrier and high water table to prevent gas migration (Riel Dump)
- ***Control Zones*** -
  - Installation of probes at waste edge and midway in control zone, extrapolation of values to verify control zone distance (eg. St. Boniface II Landfill).

- Setting maximum control distance in high migration environments (ex. Harcourt Street Landfill).

- ***Engineered Barriers*** - Installation of membrane barriers (Kimberly and Margaret Park Landfill)

- ***Buildings*** - Building monitoring (eg. St. Boniface I Landfill)
  - Installation of methane detection or venting systems (Lot 61 St. Marys Road)

Other protective measures used around buildings are discussed in Section 5.7.2.

Table 6 contains potential actions to increase confidence in existing strategies and in certain cases add safety measures. These actions include:

- Confirming that natural features and conditions are barriers to gas migration using monitoring.
- Confirming that existing control zones are adequate by installing probes at the outer limit of control zones.
- Installing additional gas probes
- Increasing monitoring frequency at soil or building probes
- Assessing landfill gas migration rates (methane flux)
- Acquiring land in control zones
- Implementing safety measures for residential properties within waste boundary.

5.6 BARRIER CONTROLS

5.6.1 Kimberly Landfill

A membrane barrier was installed at the Kimberly Landfill in 1982 to limit landfill gas migration. Gas migration hazards have been minimized by the barrier, in combination with a high water table and the maintenance of a control zone, with no development along London Street. Gas monitoring data was reviewed to evaluate the effectiveness of the barrier in decreasing gas migration (Appendix C-2, Table C-2-3).

Probes installed within the barrier trench, but on the outside of the membrane showed high landfill gas concentrations (up to 50 percent methane through 1986). Concentrations of 40 percent methane were detected in vents installed to passively remove gas. Probes outside of the barrier trench in back of Green Valley Bay showed methane levels above the lower explosive limit (P18E up to 14 percent methane, in the mid to late 1980s) or greater than 20% LEL (P103 E up to 2 percent methane) all after the barrier was installed. Probes outside of the barrier trench along London Street also show high methane concentrations (P52E up to 50% methane) after barrier construction.

These high readings have been attributed to the presence of waste buried outside of the barrier along approximately 25 percent of the length of the barrier. Along London Street, the barrier does not extend to the full depth of the refuse. Saturated conditions in the refuse, however, are believed to limit gas migration.

The frequency of observations has decreased since barrier installation, making it difficult to detect the seasonal peaks seen in previous years. Landfill gas results in probes inside and outside of the landfill, and in the barrier trench on the outside of the membrane are summarized in Appendix C-5, Figure C-5-1.

The total number of observations (all probes) has declined from approximately 500 per year in 1980-1982 to 1 or none per year. The barrier was installed February/March 1982. Present monitoring only in summer months or sporadically makes evaluation of trends difficult.

For the inside probes, the percentage of readings where methane has been detected above 100% LEL has decreased since 1987. It is not clear if this represents infrequent monitoring, climatic changes, or a decrease in gas production. The Kimberly Landfill is believed to have a high landfill gas production. For example, landfill gas pressures diffusing up from the surface were high enough to overturn sod which had been placed over the soccer field.

For the barrier probes, the percentage of readings, where methane was detected at concentrations greater than 20% LEL, increased from to 1984 to 1986 and decreased in 1990 and 1992. Probes were not monitored between 1987 and 1990.

For the outside probes, the percentage of readings at concentrations less than detection has increased with a corresponding decrease in frequency of readings. Monitoring frequency is not sufficient to verify how well the barrier is working.

The monitoring program should focus on frequent monitoring of select probes outside the waste and additional installation of probes at a sufficient distance from waste. The membrane barrier should be tested periodically to assure its integrity. Injection of propane inside the barrier and measuring propane levels outside the barrier has been a testing method successfully used in the past at this site. A contingency plan should be developed to respond to a sudden change in environmental conditions including leachate extraction, cover placement or other construction activities or sudden breaks in water main or gas line. Any plans to actively extract landfill gas should be defined so that the potential for spontaneous combustion within the landfill is minimized.

5.6.2 Margaret Park Landfill

A membrane barrier was installed in March 1982 at Margaret Park Landfill to limit landfill gas migration. Landfill gas data for Margaret Park Landfill is summarized in Appendix C-2.

Probes were constructed as follows:

- Boundary Probes - P17E 300 m east of control zone near Aikens Street; P-15E 200 m south east of control zone near Southall Drive.
- Probes adjacent to waste - P45E, closest probe to Vince Leah Community Centre; P30E, 38E, 39E, west perimeter.
- Probes in control zone - P35E (12 m from waste near community centre), new probes P78E and P77E (20 m and 12 m from waste respectively near Southall Drive).
- Barrier Probes - "B" suffix installed in barrier trench.

Probes were monitored frequently (up to 39 times) in 1980. Monitoring decreased in frequency in 1981 (8 to 16 times), 1982 (4 to 7 times) and generally annually 1983 to 1992.

High gas concentrations some reaching up to 50 percent methane were detected in outside probes adjacent to the landfill in 1980 to 1982, as shown by probes P9E, P38E, P45E and P30E.

At distances away from the waste (P35E, P15E and P17E), landfill gas concentrations were generally less than detection to slightly over trace, except for November 1982 where all three probes registered as greater than 100 percent LEL.

In 1983, after barrier construction, probes previously showing high methane readings (P9E, P38E, P30E) were generally less than detection except for P38E which continued to have readings of 25 percent methane in 1983 and slightly over trace concentrations in 1984. Probe P38E, however, was on the inside of the membrane barrier. Probe P45E was no longer monitored. Monitoring may not have been frequent enough in 1983 and 1984 to detect high gas migration events such as the increases in November 1983. Methane concentrations were below detection in the 1985 annual monitoring of four probes outside the waste (P9E, 17E, 30E, 35E).

Two gas probes (P78E and P77E) have been monitored since 1986 with nondetectable gas concentrations. Water levels were reported as 2.5 m below ground surface in probes in 1990. Saturated conditions may be limiting gas migration in deeper soils, however, upper silts may still remain unsaturated and available for gas migration. Data from monitoring the Vince Leah Community Centre is summarized in Table 8 and Appendix C, Table C-6-1. No methane was detected in the 2 floor slab probes, 2 point sources or 1 mid-air sample taken in 1992.

Recommendations for future monitoring of soil gas probes at Margaret Park Landfill are proposed in Table 10 including monitoring twice per year when climatic conditions are likely to maximize gas migration.

5.6.3 Leila Avenue (West) Landfill

A recent development proposal in the Leila Avenue west area includes housing within the landfill control zone. Landfill gas control measures and/or adjustments in development plans are needed to protect future residences.

Removal of waste material and disposal at Brady Road and Summit Road Landfills could be evaluated as an alternative.

5.7 BUILDING CONTROLS AND MONITORING

A summary of buildings incorporating engineering controls or being monitored for methane is presented for buildings on landfills in Table 7, for buildings within control zones in Table 8, and for buildings outside of control zones in Table 9. Monitoring data from buildings is presented in Appendix C-6.

5.7.1 Active Monitoring Systems

Active methane detection systems are in place at five sites as summarized on Table 7, 8 and 9 including Harold Hatcher School, Terry Sawchuk Arena, Eaton's Garden City, Brady Road Landfill weigh scale and Nova Vista Lodge.

Harold Hatcher School (No. 6 Redonda Landfill)

The Harold Hatcher Primary School is partly constructed directly on the refuse. There is a crawl space at grade, under the structural slab divided into three zones by grade beams. A compacted clay underliner provides the primary protection against methane gas migration, with continuous forced air crawlspace ventilation as secondary protection. A 24 point gas monitoring system will trigger an alarm if methane levels in the crawlspace exceed concentrations of 20% LEL. The alarm triggers an increase of approximately five fold in the ventilation rate. System maintenance is performed bimonthly and air sampling is done biannually. Over the life of the school, test results have shown no measurable methane levels in the crawlspace air, but the levels below the clay liner exceed LEL levels. It is important to maintain the ventilation system and the integrity of the clay liner.

Terry Sawchuk Arena (No. 7 Kimberly Landfill)

The Terry Sawchuk Arena is built on a former incinerator site, within the control zone of the Kimberly Avenue Landfill. The arena including ice surface, clubhouse and dressing rooms are assumed to be founded on clay with a granular subbase. A continuous two point methane monitoring system is located in the crawlspace accessible from the ice cleaning/mechanical rooms. The clay liner appears to be preventing significant methane migration into the building.

Eaton's Garden City (No. 13 Leila Avenue Landfill)

Eaton's retail store is in the Garden City Shopping Centre. The southeast corner of the building is constructed on the former Leila Avenue Landfill. The building is a structural slab on grade with no crawlspace, and has a hard asphalt surface surrounding the store. A water main loops the building and penetrates the refuse, providing a possible methane pathway. There is a partial methane barrier cutoff trench and back-up methane detectors inside the cafeteria exhaust duct. Monitoring by maintenance staff is apparently sporadic. Annual air sampling by WWDD personnel has not shown any detectable levels of methane. Ongoing methane monitoring is important, given the asphalt perimeter and the water main loop.

Brady Road Landfill

The weigh scale at the Brady Road landfill is equipped with a methane detection system. The pit of the scale is built below grade and therefore provides a location where methane can collect. A single head detection system, with the detector head located in the pit, is provided. District 6 landfill operating personnel maintain the system. Annual testing is done by the Landfill Environmental Section. Air samples from floor slab probes and mid-air points in the scale pit have not registered any detectable levels of methane in the past.

5.7.2 Passive Controls

Elmwood Nairn Sites

Several private buildings along Nairn Avenue are constructed with membranes or some other form of passive protection, as described in Tables 7 and 8. They have not been evaluated in this study.

Elevated Construction

Several buildings have been constructed above grade, as summarized on Table 7. Although a simple engineering solution, buildings constructed with crawl spaces must be inspected and maintained to assure free venting beneath the building. Maintenance was poor at the Gateway Community Centre (Bonner Avenue Landfill), where gravel walkways have sloughed into crawlspace openings. Clear inspection and remediation authority must be given to the City personnel in order to maintain safe conditions in these structures.

5.7.3 Building Monitoring Without Engineering Controls

Buildings are monitored at nine sites with buildings on landfills (Table 7), seven sites with buildings within methane control zones (Table 8), and three sites with buildings outside of control zones (Table 9). Landfill gas monitoring results for 1992 are summarized in Appendix C-6, Table C-6-1. A trend analysis of gas data was prepared to show concentrations with time and monitoring frequency for buildings with frequent monitoring. Results are presented on Figure C-6-1 to C-6-5.

In some cases methane detected during frequent monitoring in earlier years is not detected with annual or less frequent monitoring. A review of monitoring frequency for buildings should be conducted.

5.7.4 Priority Site - Riel Dump

A description of the conditions at the Riel site is included in Appendix B-2-1.

The residences on Ashworth Street and the south side of Meadowood Drive were constructed prior to establishment of the current policy for building on landfill sites. These residences do not satisfy the current City of Winnipeg guidelines for structures built on or within control areas of landfill sites. The establishment of a methane gas contingency plan for these residences is required.

Because of the high priority nature of the Riel site, the City has conducted extensive gas monitoring of residences around the site, as frequently as weekly in the past. Methane gas presence has not been detected to date in these houses at point sources, including floor cracks and floor drains. Methane gas levels are very high in soil probes assumed to be outside the clay liner surrounding these houses. This suggests that the clay liner installed during the construction of houses on Ashworth Street, and the in-situ clay separating houses on Meadowood Drive from the landfill site, may be effectively preventing migration of methane in the houses. Although landfill gas concentrations in soil probes are high, gas production volumes (flux) have not been measured. Low gas production would also result in limited landfill gas migration.

Previous studies have shown that the danger of a methane gas explosion is predominantly the result of a sudden release of methane into a confined area. Adequate ventilation should be provided to avoid buildup of methane gas.

Leachate has also been noted oozing into basement drains during past inspections.

An action plan for the Riel area should be designed. Possible contingency measures for the Riel site, requiring further evaluation include:

- Increasing homeowner/resident notification and education through letters/contact such as the resident notification program at River Road Landfill. Also advising homeowners to be aware of cracks in foundation walls and basement floors.
- Maintaining groundwater saturation in the clay barriers (by normal grass watering near barrier) so that cracks are not allowed to develop in the clay.

- Promoting continuous operation of bathroom fans in situations of suspected methane gas build-up, as an interim measure.

- Confirming of the integrity of the clay liner barrier, with additional probes and regular monitoring.

- Establishing the methane flux potential from probes adjacent to the houses to better quantify risk.

Pending the results from the above, the following additional measures may be required:

- Convert the existing weeping tile system in houses to a gas collection system, using external venting; passive ventilation (whirly fans) with provision for future mechanical ventilation.

- Establishment of interceptor trenches complete with passive ventilation in the open field along the west and north perimeter of the landfill site bordering on the east line of Ashworth Street and the lane south of Meadowood Drive respectively. A passive ventilation system should have provision for future mechanical ventilation, as required.

- Establish an emergency response plan in the event of a watermain or natural gas line break.

5.7.5 Design of Methane Control Measures

Existing City of Winnipeg Policy and Design Guidelines

The City presently has a policy for building on landfill sites. In conjunction with the policy, a set of design guidelines for landfill site construction has also been established. The policy deals with construction on landfill sites and does not differentiate or recognize construction requirements within landfill control zones. The only type of construction allowed on a landfill site, according to the present policy, is elevated construction. The design guidelines however, differentiate between acceptable methods of construction on landfill sites and off landfill sites (off landfill is presumed to be within the landfill control zone). The design guidelines imply that construction types other than elevated construction, are allowed on landfill sites, provided that suitable landfill gas mitigation is provided. In practice, these other construction types are only allowed at the Nairn and Elmwood sites, and only under certain conditions. Figures 11 and 12 illustrate the structure of the present policy and design guidelines.

Other specific comments on the existing policy and design guidelines are:

- Neither the policy nor design guidelines address groundwater contamination via vertical leachate migration along piles
- Guidelines do not recognize a saturated clay liner as an acceptable gas migration barrier. Given the satisfactory performance history of clay in the Winnipeg area, use of saturated clay barriers should be re-evaluated.
- Given the development of more rugged synthetic liners over the past number of years, a review of the membrane/collection system details presented in the design guidelines is in order, including producing an updated list of suitable membranes.
- Efforts are required to consolidate building requirements related to landfill gas control and overall building code requirements, ie:

  - trap seal primers on floor drains
  - soil gas venting systems
  - utility connection requirements

The existing policy and design guidelines are rigid in their structure and as a result require updating periodically. The updating should reflect advancements made in technology and should consolidate the policy and design guidelines.

Proposed Policy and Guidelines

The drafting of a new policy must realize that site specific conditions predominate when determining the mitigation requirements of a particular development. Flexibility to adjust to site conditions is important. In order to provide this flexibility, while at the same time maintaining rigid control over mitigation measures, a site specific pre-development screening phase is proposed. The screening phase would include a landfill specific risk assessment. The assessment would identify landfill sites and related control zones as being suitable for full or partial development. Considerations in screening a particular landfill site for development include:

- age of the landfill
- landfill gas and leachate generating potential
- security of the landfill with respect to landfill gas and leachate controls
- geotechnical conditions which affect the possibility of environmental pollution
- extent of development which may or may not be allowed

A secondary consideration in drafting a new policy is the manner in which it is presented. Possible developers should be made aware of the potential risks related to methane. Guidelines should be provided for developing facilities designed to mitigate potential hazardous situations. The guidelines should have sufficient flexibility to allow innovation, as it relates to site investigation and monitoring.

Figure 13 provides a proposed framework for a new policy. The framework incorporates the design guidelines into the policy and attempts to deal with the issues presented above.

5.8 ENERGY PRODUCTION POTENTIAL

5.8.1 Potential Uses For Landfill Gas

Utilizing status-quo technology, potential end uses for landfill gas are summarized below.

Medium Grade Fuel - Landfill gas is typically used as a medium grade fuel for internal combustion engines, boilers or gas turbines for generation of electrical power.

High Grade Fuel - By removing carbon dioxide and other gaseous components, landfill gas can be upgraded to a higher BTU quality fuel, comparable to natural gas. Once upgraded, the gas can be blended with pipeline quality natural gas and applied in industrial use or as transportation fuel.

Alternative Fuel Production - Landfill gas can be considered for use in the production of methanol and other synthetic fuels/fuel additives. These potential end uses are somewhat speculative at the present time, as the production of alternative fuels from landfill gas has yet to be demonstrated on a full scale production capacity.

Flaring - Flaring landfill gas does not create a potential energy source but serves to reduce potentially toxic emissions into the atmosphere.

All potential end uses of landfill gas are controlled by a number of economic, social, technological and regulatory factors. Presently, the costs per unit volume of recovered, marketable landfill gas (or derivative of landfill gas) are generally higher than the purchase price of pipeline quality natural gas.

Under these conditions, the recovery and distribution of landfill gas as an energy source can become an economically non-viable option. The presence of an end-user in proximity to a landfill, may make this option more attractive, as transportation and other associated costs could be minimized.

5.8.2 Production Potential of Landfill Gas in Winnipeg

Kilcona Landfill

The results of the investigation conducted by Environmental Technologies Inc. (report dated December 31, 1992) indicate that approximately 70 percent of the methane gas generated within the landfill could be collected.

Estimated rates of daily methane recovery from the landfill were predicted to be:

- 28,300 m^3/day (1.0 mmscfd) in 1993
- 14,150 m^3/day (0.5 mmscfd) in 2011
- 9,905 m^3/day (0.35 mmscfd) in 2020.

The Gross Heating Value of the landfill gas from the Kilcona Landfill was reported as 581 Btu/scf (@ 60°F and 760 mm of Hg).

The market study conducted by Environmental Technologies Inc. concluded that the only end use viable for the landfill gas is to upgrade the landfill gas to pipeline quality, although this option would not be a high revenue generator. The low purchase price for electricity within the Winnipeg area, and the absence of any high volume "economically proximal end users" for even medium Btu gas, makes landfill gas use at Kilcona economically unattractive. The study suggested that the viability of extracting landfill gas could increase with a government incentive, given in return for reducing atmospheric pollution. The nature of the incentive could be variable, ranging from a subsidy based upon electricity or gas produced, to a tax credit based upon capital and/or operating costs.

Another alternative suggested for at least partial utilization of the landfill gas is for heating buildings and providing hot water at the adjacent Kilcona Park recreational complex. The site would not likely be capable of using all of the gas recovered but partial consumption would provide a more favourable option than simply flaring the landfill gas.

Brady Road Landfill

Energy production potential should be reviewed in Winnipeg as the Brady Road site develops. Economics can change substantially over the long site life proposed. Site development plans at Brady Road should include flexibility to incorporate gas generation facilities and/or compatible power users.

5.9 LANDFILL GAS MONITORING

5.9.1 Strategy

Monitoring requirements were set in the 1985 methane policy, to provide a basis to set control zones. Monitoring was performed frequently to identify seasonal trends, after which the frequency was reduced.

After the control zones were set, the objectives of monitoring were to verify the control zone distances and to detect changes in conditions that may lead to increased gas migration. Monitoring has not been conducted more frequently than annually since 1985 because of staff and financial constraints. Staff has compensated for the reduced frequency by sampling during weather events that would increase gas migration, such as a heavy rainfall. Despite these efforts, recent annual monitoring data does not always show the earlier evidence of gas migration found when sampling was more frequent. This assumes that gas conditions have not changed greatly over the 12 year monitoring period.

The following strategy is suggested to guide future landfill gas monitoring:

- ***Probe Location***
  - Install new probes in the control zone
  - Emphasize monitoring of control zones probes
  - Verify the outer limit of the control zone, beginning with sites where methane is >20% LEL at the waste boundary.

- ***Monitoring Frequency***
  - Monitor more frequently at sites with high gas migration (Quarterly).
  - Monitor two times per year at sites with moderate gas migration.
  - If monitoring frequency must be reduced further, consider monitoring two times every other year, instead of once per year.
  - Continue to select weather events conducive to methane migration and extend monitoring into early spring and late fall freeze up and thaw periods.

- ***Laboratory Analysis***
  - Retain frequent gas chromatograph (GC) testing as a check on field instrument problems. Portable meters would have to be operated and maintained to a higher degree than at present if GC testing were decreased.
  - retain chromatography use in building monitoring program and at sensitive sites.

- ***Special Investigations***
  - Use periods of intensive monitoring to answer specific questions - such as verifying if a ditch is acting as a barrier.

5.9.2 Proposed Landfill Gas Monitoring Program

The proposed landfill gas monitoring program is presented in Table 10. In general, the monitoring frequency would be increased. A site specific evaluation should be conducted for each site to select new probe locations and to identify probes to be monitored.

The proposed gas monitoring program includes quarterly monitoring at eleven sites, twice per year monitoring yearly at six sites, twice per year monitoring in alternate years at 13 sites and discontinued monitoring at three sites. Individual site monitoring may result in the addition of new probes and the reduction in monitoring of some existing probes with an overall reduction in the number of probes monitored at the site.

6.0 LEACHATE CONTROL

6.1 LEACHATE GENERATION AND COMPOSITION

Leachate is generated as liquids come in contact with waste. Precipitation, surface water, groundwater, or water within the waste itself, can all contribute to leachate production. Contaminants are released from waste by physical, chemical and biological processes. Soluble contaminants enter the leachate first, followed by contaminants produced by biodegradation. Contaminants that measure the organic strength of leachate such as COD (Chemical Oxygen Demand), are very high in raw, young leachates, then decrease in concentration with waste age and exhibit wide seasonal variability.

Typical inorganic and organic leachate quality data from new and mature landfills, as summarized by Tchobanoglous (1993), is presented in Appendix D-1, Table D-1-1. A summary of Wisconsin municipal leachate chemical characteristics prepared by Kmet (1982) is presented in Appendix D-1, Table D-1-2.

Health related heavy metals, such as arsenic, cadmium, chromium and lead, generally are found in leachate at concentrations of less than 1 mg/l, except where the waste is a source of metals such as plating or battery wastes. Many metals exceed water quality objectives for surface and drinking waters. Non-health related metals such as total iron, manganese and zinc are found at higher concentrations, in the order to tens of mg/l for manganese and zinc, and up to thousands of mg/l for iron. Most leachate is analyzed for total metals. High iron and manganese concentrations in soil or sediment often account for these excessive concentrations.

Other organic compounds, such as volatile organic compounds (VOCs), base-neutral organics, agricultural chemicals, and PCBs, are found in varying concentrations in leachate, depending on the waste disposed. Where hazardous industrial wastes were uncontrolled or disposed with municipal refuse, the number and concentration of these organic parameters increases. Organic contaminants in leachate have been extensively researched in the United States and have lead to USEPA requirements to monitor groundwater for these constituents (USEPA 1991a). USEPA requirements focus on semi-annual detection monitoring of volatile organic compounds (called "Appendix I" constituents) in groundwater. Assessment monitoring of a longer list of hazardous constituents (termed "Appendix II" constituents) is required in the United States to investigate statistically significant changes in VOC concentrations.

Leachate quality at the City of Winnipeg Landfills is discussed in Section 6.4.

6.2 LEACHATE CONTROL-STATE OF THE ART REVIEW

6.2.1 Liners and Base Preparation

Early landfills, such as many of the older Winnipeg sites, were developed in low areas, in vacant landfill or in pits, with no environmental controls. Landfill design concepts have evolved over the past 20 years as the requirements for groundwater and surface water protection have increased.

Site designs generally fall into two categories as follows:

- ***Natural Attenuation Designs*** - which rely on natural soils, groundwater or surface water drainage to reduce contaminant concentrations to acceptable levels by such processes as ion-exchange, chemical precipitation, dispersion and dilution. Natural attenuation designs rely on a moderate to low permeability hydrogeologic environment which will maximize attenuation and minimize contamination, without the need for leachate collection.

- ***Containment Designs*** - which incorporate a low permeability liner to collect leachate and direct it to another location, such as a wastewater treatment plant. Containment designs are used in all hydrogeologic environments, including sites excavated below the water table in clays, as in Winnipeg.

A summary of liner and base preparation design requirements in Canada and the United States is presented in Table 11. Two approaches are used:

- ***Performance Criteria*** - which specify compliance with groundwater, surface water or other environmental standards.

- ***Design Criteria*** - which may specify a certain type of liner material, thickness etc. These may be required by regulation or suggested in guidance or policy. The particular designs required or recommended are believed to be adequate to meet the performance standard of that jurisdiction.

Recent federal regulation of municipal solid waste landfills in the United States (USEPA 1991a) has dramatically changed landfill design practice there. All municipal landfills are required to use a composite liner consisting of 0.6 m of compacted low permeability clay beneath a geomembrane liner. The USEPA design requirements have resulted in the closure of many smaller landfills, which had previously used natural attenuation designs, and the centralization of waste disposal services in many areas. States, such as Wisconsin, are revising existing regulations or writing new regulations to conform to these USEPA requirements.

In Canada, the provinces retain responsibility for waste disposal regulations. Ontario has a well developed waste program and uses a combination of performance criteria and design policy and guidance. Much of the design guidance is unwritten and specific to regional situations, but includes natural attenuation and containment designs and combinations of the two.

In Manitoba, waste disposal regulations cite a groundwater performance standard. Design guidance is being prepared which includes clay liner and composite liner containment designs. Design practice at landfills in Calgary and Edmonton is included, on Table 11 for reference.

6.2.2 Leachate Management

Leachate management requirements vary with site design, as presented in Table 12. In the United States, leachate collection is required. In Ontario, collection and treatment is evaluated on a site specific basis. Manitoba is developing guidance for leachate collection. Leachate management concerns include:

- ***Maximum leachate head*** - of <30 cm on liner to reduce infiltration through the liner (USEPA 1991a and State of Wisconsin 1988). Wisconsin regulations state detailed minimum requirements for collection systems. As presented in Appendix D-2, Table D-2-2.
- ***Leachate Treatment*** - at wastewater treatment plant (Wisconsin).
- ***Leachate Recirculation*** - practised in various jurisdictions, prohibited in Wisconsin because of past experience with leachate build-ups.
- ***Maintenance*** - most landfills in the United States are required to function for 20 or 30 years. Ontario requires systems to function for the contaminating lifespan of the facility.

6.3 CITY OF WINNIPEG LANDFILLS

Excavation, base compaction and leachate collection were incorporated to varying degrees in the three sites operated by the City of Winnipeg after 1978, including Kilcona, Summit and Brady Road Design and construction details for these three sites are summarized in Appendix D-2, Table D-2-1 (Excavation and Base Compaction) and Table D-2-2 (Leachate Collection System Design). Specifics of these three sites are discussed below.

6.3.1 Kilcona Landfill

Excavation and Base Preparation

- Hydrogeologic evaluation done prior to excavation (Cherry 1976)
- Excavation extended to 6 m depth, as recommended
- Recompaction recommended and attempted, unsuccessfully

Perimeter Leachate Collection System

- 100 mm perforated collector pipe inert installed in a 0.5 m wide by 1 m deep perimeter trench, backfilled with a sand/gravel mixture.
- Eight existing 150 mm diameter riser pipes (four in the west cell, four in the east cell) installed in a 0.3 m by 0.3 m trench in the excavation side walls and backfilled with compacted granular material.
- Leachate heads monitored using risers around both cells and in probes installed in west cell.
- Approximately 1 million litres of leachate were removed in 1992.

Performance

Several design and construction features limit the effectiveness of the collection system, as follows:

- Some leachate may travel through fractures in the clay since the base recompaction was not achieved. Compaction and reworking of clay on the base by working machinery may have resulted in partial recompaction.

- The interior base of the landfill was recommended to be constructed with a 1.5 percent slope. It is not clear if this slope was created, or if the interior base of the landfill slopes toward the collection system.

- The sand/gravel backfill used in the trenches is much less efficient than the graded gravel backfills now used at the Brady Landfill and may be subject to clogging.

- The riser pipe is not connected to the collector pipe. This forces the leachate to filter through the granular material from the collector pipe requiring use of a special jet pump, slowing the leachate removal process.

Leachate elevations range from 1 to 5 m above the cell base elevation, with individual mounding up to 10 m above the base; as presented in Appendix D-3, Figure D-3-1 (leachate probes west cell), and Figure D-3-2 (leachate risers east cell) and Table D-3-2, and discussed below.

West Cell - Leachate elevations in the west cell have been measured in leachate probes as shown in Appendix D-3, Figure D-3-1. Probes have been screened at various levels, ranging from the site base; approximate elevation 225 m (probes L1, L4, L8A, L9 and L10) to waste up to 4 m above ground surface (el 231 m) (probes L2, L5, L6, and L8B).

Widely varying leachate levels have been encountered in the probes. For example, in 1992, liquid was encountered in 5 probes (L1, L10, L6, L8A and L9). Leachate ranged from el 226 m, approximately 1 m above site base (probe L9) to el 236 m, 5 m above ground surface and 11 m above the site base (probes L6 and L8A).

Leachate risers within the west cell show leachate at el 224 to 226 m (1 to 2 m above base grade) with head decreasing in late 1992. High leachate elevations have been attributed to perched leachate zones within the waste or to surface water infiltration into probes in areas that have settled. A few probes are blocked, producing apparent dry readings above probe bottom elevations. Reconstruction of probes or additional probes are needed to better define leachate elevations and monitor the effectiveness of the leachate extraction program.

East Cell - Leachate levels in the east cell perimeter are approximately 2 m above base grades. Probes are needed to measure heads in the centre of the site.

6.3.2 Summit Road Landfill

Excavation and Base Preparation

- A detailed hydrogeologic evaluation was not prepared prior to site development.
- Excavation to a 5 m depth occurred exposing till in areas of high bedrock.
- Current operations restrict development in areas of high bedrock

Partial Leachate Collection System

- Operations began in 1964 with no provisions for leachate collection
- Most of the landfill base had already been excavated and filled prior to 1987 and 1988, when two leachate collection systems were installed in newly excavated cells in the southwest corner.
- The collection systems consists of two perpendicular lines, bisected by a third collector.

Performance

The partial collection system has had little effect on reducing leachate levels to date. Approximately 3 million litres was pumped in 1992. Leachate elevations are presented in Appendix D-3, Figure D-3-3 and Appendix C-3, Table C-3-1. Leachate elevations at probes P10L, 12L and 13L at the east perimeter are close to or above prairie elevation of 238 m, about 3 to 5 m above base grades. Leachate elevation is rising at probe P10L. Other probes within the site also show high elevations. Leachate extraction should receive a high priority because of the high pollution potential at the site. The City is investigating leachate collection options including:

- determining the radius of influence of existing collection system by using high capacity pumps and longer pumping periods.
- investigating methods of leachate extraction from the entire site.

6.3.3 Brady Road

Excavation and Base Preparation

- Excavation to 6 m depth below original ground surface
- Recompaction was recommended if fractures found
- Recompaction not done, based on difficulties at Kilcona Landfill
- Existing machinery may provides some degree of reworking

Leachate Collection System

- Landfilling operations started in 1973 with no leachate collection system.
- Leachate collection in the 1987 and 1988 cells. Complete leachate collection system designed for cells 1989 - present.

- Collection system uses pipes spaced at 50-60 m with a herring bone base producing a maximum flow distance of 25-30 m to collection pipes.
- Base grades are sloped at a 2% grade toward the collection pipe.
- Graded trench backfill material is coarse and carbonate rock content is restricted.
- A granular drainage blanket is used only in the design of future cells in a "secondary collection area" where it will be used to replace trenches and pipes which would be beyond the reach of cleaning equipment.
- Studies proposed to verify the permeability of the base (which is used in lieu of a drainage blanket) have not been performed.

Performance

A detailed analysis of the performance of the existing system was not conducted. A table of leachate levels is included in Appendix C-3, Table C-3-4.

The City indicates that work is ongoing to install additional probes in operating cells and measure the radius of influence of leachate extraction. Remedial work is being done to install perimeter leachate collection in pre-1987 cells constructed without leachate extraction. In these cells, leachate heads are 3 to 6 m above base grades (at ground surface to 3 m below ground surface).

Part of the scope of work for this study was to compare existing solid waste management designs to state of the art practice. This has been done in a general manner, since design decisions at the Brady Landfill have been made by the City of Winnipeg and their Consultant considering many factors, such as the degree of environmental protection needed, economics, past operational and construction experience and site configuration. Several areas are highlighted below in which the design or operation is substantially different than current state of the art practice. The City may choose to review these areas to determine if they have been addressed adequately in previous discussions.

- Leachate collection efficiencies could be improved by placing a uniform high permeability granular blanket over the entire base to ensure free flow of leachate to collection lines. Refuse placed directly on the base of the landfill will not have a uniform permeability and may restrict leachate flow as waste decomposes. Leachate collection efficiencies are very sensitive to changes in blanket permeability.

- A documented recompaction program of the upper 1.5 m of clay on both base and sidewalls would provide more assurance that access to clay fractures is limited. Groundwater inflow would also be further reduced.

- Collection systems are typically pumped frequently, so that the head on the liner does not exceed 0.3 m, generally the thickness of the granular blanket. Increases in collection frequency and possible modifications to the collection system may be required to maintain this minimal head buildup. Modifications in phasing, cell size, surface water control and intermediate and final cover may be able to further reduce infiltration and limit leachate generation.

- Stripping of daily or intermediate clay cover or at a minimum providing windows through the clay cover will be necessary to prevent the buildup of perched layers of leachate and allow leachate to move vertically through waste to the collection system. Perched leachate layers can result in leachate breakout with resulting surface water impacts and potential slope instabilities.

6.3.4 Leachate Levels at Landfills Without Collection Systems

Typical leachate levels at all the landfills are shown on landfill site sections Figures 6 to 10. Leachate levels at landfills without collection systems were obtained from summaries of water elevations in gas and leachate probes constructed within the waste. In many cases probes are located only on the periphery of a site and do not necessarily represent levels at maximum excavation depths or levels at the cell centre. The illustrations show three conditions as summarized below.

Leachate Levels at Water Table or Ground Surface - present at most sites with cell base grades below water table. Percolation through poor cover materials, combined with groundwater inflow, results in leachate levels equilibrating with or in some cases exceeding groundwater levels. Examples include: Summit Road Landfill, St. Boniface Landfill II, McPhillips Street Landfill (Figures 6, 7 and 8 respectively). Where leachate levels exceed water table elevations, the potential for flow of leachate into upper silts and clays is increased. Sites with deeper cell inverts, such as McPhillips Street Landfill, contain much greater leachate volumes per hectare than sites with shallow excavations such as the Bonner Avenue Landfill (Figure 9).

Leachate Levels Above Ground Surface - occur at pre 1987 cells of Brady Landfill (Figure 10) and at the Saskatchewan Avenue landfill (Figure 9). Both of these sites have had leachate breakout in the past.

Perched Leachate Levels - suspected at sites where some probes show high leachate elevations and others do not, such as Cadboro Road East (Figure 10).

Leachate breakout has been recorded at four sites in the past, consistent with leachate levels above ground surface, including:

Brady Road Landfill (pre 1987 cells)
St. Boniface Landfill I
Saskatchewan Avenue Landfill
Cadboro Road West Landfill

The need for additional probes and leachate extraction at these sites is discussed in Section 6.5.

6.4 LEACHATE QUALITY

Sampling Quality

Leachate quality has been monitored at 19 sites by the City since the early 1980s. Leachate probes are monitored at all sites including Summit, Brady and Kilcona. The leachate extraction system, are monitored at Summit, Brady and Kilcona.

Parameters analyzed at the probes include:

- ***Inorganics*** - alkalinity, calcium, magnesium, hardness, residue, sulphate, sodium, chloride
- ***Nutrients*** - phosphorous, total Kjeldahl nitrogen, ammonia nitrogen, nitrate plus nitrite nitrogen
- ***Organics*** - total organic carbon, soluble organic carbon, volatile fatty acids
- ***Metals*** - iron, manganese, cadmium, chromium, copper, nickel, lead, zinc.

Additional parameters analyzed in the extraction system samples include:

Arsenic, mercury, cyanide, pesticides, herbicides, insecticides, hydrocarbons, PCBs. Some non-quantitative scans for other organic chemicals have also been performed.

Samples generally are taken annually, although not all probes are sampled at each site. A Wattera pump and dedicated tubing is used to collect samples. Samples are not filtered or preserved in the field, but are returned to the lab on the day of sampling. No measurements of field pH and conductivity are taken, but pH is measured the same day at the lab and conductance is measured as soon as possible. It is preferred that specific conductance be used in lieu of total dissolved solids (TDS) for leachate samples with very high TDS, because of problems with the TDS analyses in these situations (City of Winnipeg Laboratory Services).

With the exception of calcium and magnesium samples, where sediment is allowed to settle and the sample decanted, metal samples are digested with nitric and hydrochloric acid. This yields a total metals analysis, which may include suspended matter and chemical precipitates.

Sampling Data

Leachate quality data was obtained on computer disc. Because of the large volume of data the following data files were created for parameters to represent major leachate characteristics:

- ***Specific Conductance*** - overall ionic content represents chloride, sulphate, hardness and other dissolved parameters.
- ***Chloride*** - typical conservative parameter
- ***Total Kjeldahl Nitrogen and soluble organic carbon*** - organic strength
- ***Lead*** - health related metal

For each site maximum, minimum, average and standard deviation values were calculated for each parameter, both for each probe and for all probes as a set at each landfill site. Median values were also calculated (representing the value with an equal number of readings greater than or less than the median value). The median is less influenced by extreme values in a range than the average value. Results are presented in Table D-4-1. Values for all probes at each site are presented on a larger scale in Figure 14. Sites are ranked by median concentration. The leachate has the following characteristics:

- ***Organic Strength*** - Organic strength as represented by total Kjeldahl nitrogen and soluble organic carbon, is higher at the relatively new sites, Kilcona, Summit and Brady. Cadboro Road West and St. Boniface Landfill I also had substantial organic strength.

- ***Inorganic Strength*** - Inorganic strength as represented by specific conductance and chloride was significantly higher at the McPhillips Street Dump and Saskatchewan Avenue landfill, both of which contain incinerator ash. A similar trend is observed for sulphate (not shown). Chloride values are variable. Clay cover materials and groundwater infiltration are also sources of chloride and may contribute to leachate.

- ***Metals*** - Metals concentrations are variable, as shown by the large ranges of lead (Figure 14). Ash disposed at Kimberly and Saskatchewan Avenue landfills may contribute to higher lead concentrations. Industrial wastes from past auto wrecking disposal at Cadboro Road East may also contribute to elevated metals concentrations. Some of the higher lead readings may be influenced by particulate matter in leachate samples.

Leachate quality data comparing analyses at leachate probes at Summit Road Landfill with analyses from the recovery program is presented in Appendix D-4, Figure D-4-1. Quality in the probes is in the range of leachate recovered in the pumping program.

Leachate Recovery Program

Analyses of leachate for the leachate recovery program is presented in Appendix D-4, Table D-4-2. Mean values have been used in the ranking in Figure 14.

Analyses of special parameters are summarized for each site on Appendix D-4, Table D-4-3 (Insecticides), Table D-4-4 (Herbicides), Table D-4-5 (Pesticides), Table D-4-6 (PCB's, Hydrocarbons, and select Inorganics).

These parameters are compared to CCME remediation criteria for water where they exist (CCME 1991). Of the agricultural chemicals, the herbicide trifluarin at concentrations 51 to 82 μg/l is the only one exceeding CCME Criteria for water of 45 μg/l. No criteria exist for many of the compounds.

Hydrocarbons (gasoline and fuel oil) are found in leachate at all three sites in concentrations up to 3 ppm gasoline. Arsenic concentrations exceeded CCME criteria for water (50 μg/l) at Brady landfill (160 μg/l). Mercury concentrations also exceeded CCME standards of 0.1 μg/l at Brady manhole No. 3 with a concentration of 1.1 μg/l.

Volatile Organics

Leachate from the following five sites was selected for analysis of volatile organic compounds: No. 3 St. Boniface Landfill, No. 17 Harcourt Street Landfill, No. 18 Summit Road Landfill, No. 24 Cadboro Road Landfill and No. 36 Kilcona Landfill. Samples from Brady Road landfill were not obtained for this analysis, but should receive highest priority in subsequent sampling. Samples were obtained by City staff on May 3, 1993, shipped directly to Enviro-Test Laboratories in Edmonton and received that evening.

Samples were obtained using dedicated high density polyethylene (HDPE) tubing and foot valves (Wattera system). A second, small diameter (3/8") dedicated HDPE tube was inserted to create a siphon, thus minimizing sample aeration. The samples were collected in 40 ml vials with teflon lined septum lids. Sample bottles were completely filled to eliminate headspace. The Summit Road Landfill sample may have results lower than expected, due to 1 ml of headspace in the sample.

A summary of the volatile organic compounds detected in the scan is presented in Appendix D-4 Table D-4-7. The full laboratory report, including the list of all compounds analyzed and detection limits, is presented in Appendix D-4-1. The leachate samples analyzed show typical low to moderate concentrations of volatile organic compounds for non-hazardous waste landfills. These include common industrial solvents and hydrocarbon compounds. Leachate is not expected to meet drinking water criteria, however, existing standards in Canada (CCME 1991 - Remediation Criteria) and the United States (USEPA 1991b - Primary Drinking Water Regulations) are noted for comparison. The Summit Road leachate contains the greatest number and greatest concentration of parameters, despite some possible volatile loss during and after sampling. Groundwater samples at Summit Road landfill should be analyzed for volatile organic compounds to determine if these compounds are entering the bedrock aquifer.

Significance of Leachate Quality Data

Leachate extracted in the recovery program must meet treatment plant limits. A description of the extraction program and treatment concerns, prepared by the City, is presented in Appendix D-4-2. Leachate volumes pumped are summarized in Appendix D-3, Table D-3-1.

In 1990 a pilot project was under taken to check the feasibility of leachate pumping and treatment from the three landfill collection systems. The leachate was transported to the North End Water Pollution Control Centre for treatment.

On a daily basis, a maximum of 80,000 litres of leachate spread over a twenty four hour period was hauled to the NEWPCC, with no quantifiable effect on the treatment plant. During the pilot project the treatment plant was handling about 250 million liters per day of sewage, which represents normal dry weather conditions. The extra 80,000 litres of high strength leachate added to the system (0.03 percent by volume) did not require any changes to the treatment process.

6.5 PROPOSED LEACHATE PROGRAMS

6.5.1 Leachate Probe Installation

Leachate probes should be installed to monitor head buildup near the centre and across the sites listed in Table 13. Other sites may be added in future to confirm leachate heads. Leachate migration should be evaluated in the upper silts and clays when development is proposed adjacent to landfill control zones.

6.5.2 Leachate Extraction Programs

Leachate extraction programs should be considered at sites with high and moderate potential for groundwater contamination. Proposed leachate extraction priorities are listed in Table 14. The effect of the program, on gas migration must be evaluated, since saturated conditions appear to inhibit landfill gas migration at many sites.

Leachate extraction at Summit Road and Brady Road Landfills should receive high priority, because of the high groundwater pollution potential at Summit and the ongoing operations at Brady Road.

The leachate extraction program at Summit Road Landfill should be expanded to include the entire site. Pumping frequency and volumes should be increased to reduce leachate head in the site.

Leachate extraction at No. 11 McPhillips Street Landfill and No. 4 St. Boniface Landfill will require relocation of snow disposal off these properties.

6.5.3 Leachate Monitoring

The proposed leachate monitoring program is presented in Table 15. The following strategy is proposed for leachate monitoring.

- Retain representative annual monitoring for sites with higher and moderate groundwater pollution potential. The number of probes may be reduced, but the locations should be refined, as noted in Table 13.
- Decrease frequency or eliminate sampling for well documented leachate at other sites, including wood waste sites.
- Use indicator parameters and selected heavy metal parameters, particularly for health related metals.
- Expand organic characterization of leachate for select sites as described on Table 16.

7.0 GROUNDWATER AND SURFACE WATER

7.1 EVALUATION OF GROUNDWATER POLLUTION POTENTIAL

7.1.1 Overview

Most of the City of Winnipeg sites were established and operated at a time when it was not standard practice to design engineering controls to minimize groundwater contamination. Landfills were located within municipalities on available land. Groundwater pollution potential considerations played little or no role in locating sites. As a result of these historical practices, numerous landfill sites are distributed across a large area of the City and are found in a variety of hydrogeologic environments.

Groundwater is found within the overburden clays and silts, as well as in the silt till and the carbonate aquifer which underlies the clay. This study has focused on pollution potential of the silt till and the bedrock aquifer. These units are hydraulically interconnected and the bedrock is used both as a drinking water supply in rural areas of Winnipeg, and as an industrial cooling, process and irrigation supply in developed areas of the City. Where landfills are excavated through significant surficial silt deposits, the potential also exists for leachate migration horizontally into these silt deposits.

7.1.2 Pollution Potential Factors

Several factors determine the groundwater pollution potential of a site in the Winnipeg area, as shown on Figures 6 to 10. The main factors include clay thickness, leachate head, hydraulic gradient, waste volume, waste type and waste age, as discussed below.

Clay Thickness Below Excavation - The surficial clay deposits, above the till and the carbonate aquifer, provide a low permeability zone separating contamination sources from the bedrock. Clay thicknesses decrease regionally toward the west and northwest of the City. Bedrock may be close to surface in certain areas due to the irregular bedrock surface which reduces clay thicknesses locally. The excavation depth of the waste sites also varies at different sites. Because of these variables, the thickness of clay between the base of the waste and the underlying till becomes a critical factor in assessing groundwater pollution potential. A site with a deep excavation in an area of thin clay may be close to, or in contact with, the silt till. A similar site in another part of the City may have a significant clay depth between the base of the site and the till.

Leachate Head - Leachate head is a factor, since it is related to excavation depth. Sites that have excavations that are filled with leachate contain a greater volume of saturated waste and contaminated liquid than do sites with shallow excavations or those constructed on the surface. The extent of leachate or groundwater mounding within the landfill above the water table, or extent of perched mounds within the cells, also affect the leachate head.

Hydraulic Gradient - The clay provides a low permeability zone beneath the waste, but it is not impermeable. Flow continues at a very slow rate within the matrix of the clay and at a faster rate along fractures which are common in the upper 15 to 20 feet. The rate of flow (velocity, v) is determined by the permeability (K) and effective porosity (n_e) of the clay and the hydraulic gradient (i), using the relationship $v = Ki/n_e$ In the absence of site specific permeability and porosity data, these factors are assumed to be constant, leaving the hydraulic gradient as the variable factor.

The hydraulic gradient can be measured between the base of the landfill (where the head is equal to the leachate elevation) and the piezometric surface (elevation) of the bedrock aquifer, as approximated from 1992 values monitored in provincial observation wells. Where the bedrock piezometric surface is lower due to influences such as industrial pumping, the hydraulic gradient is higher.

Waste Volume - The waste volume is also significant since it determines the amount of contaminants available to be leached. At large landfills, infiltration into the subsurface also occurs over a greater area.

Waste Type - Waste types determine the chemical composition of the leachate. Leachate produced by wood waste and construction fills can have significant organic strength, but are not as likely as municipal and industrial landfills to contain other contaminants such as metals, synthetic organic compounds and hydrocarbons.

Waste Age - Waste age also contributes to pollution potential. Leachate from very old landfills is generally lower in organic strength as measured by such parameters as biochemical oxygen demand and total Kjeldahl nitrogen. Some synthetic organic chemicals, metals and inorganic compounds, will remain in significant concentrations, so that leachate from older landfills remains a potential contaminant source.

7.1.3 Classification of Sites

The City of Winnipeg sites were classified into main categories according to groundwater pollution potential to the silt till and carbonate bedrock aquifers, as shown on Figures 6 to 10.

Sites overlying potable aquifers were classified separately from those overlying non-potable aquifers. Sites have also been grouped into high, moderate and low pollution potential for general reference purposes, based on the following criteria and a somewhat subjective assessment.

Site were initially ranked on the basis of relative travel time for leachate at the bottom of a landfill to reach the silt till aquifer. Regional and site specific information contained in Appendix B Table B-3 was used. The leachate head and piezometric elevation were used to calculate a hydraulic gradient and a relative velocity (v). Relative travel times (t) were calculated using the relationship t=d/v where d (distance) equals the depth of clay between the bottom of the excavation and the top of the till.

Adjustments to this ranking were made on the basis of site volume (as approximated by site area), waste type, and potential for surface infiltration.

The classification scheme serves as a general evaluation tool with respect to groundwater in the silt till and bedrock. It does not reflect the potential hazard from leachate migration in the upper silts, which is of concern wherever substantial silt deposits are present. Changes in the bedrock piezometric surface due to regional trends or local changes in industrial pumping will change the calculated gradients and relative ranking. Additional site specific information should be used to confirm or adjust estimates based on regional information.

7.2 EVALUATION OF GROUNDWATER QUALITY DATA

Groundwater quality has been monitored using available domestic wells and site monitoring wells at or near seven landfills. Monitoring wells have been installed by the City at four sites. Select water supply wells near these seven landfills have been sampled. A summary of groundwater monitoring locations, including well construction information and sampling dates, is presented in Appendix E-1. A brief evaluation of water quality results for six of the landfills is presented below. Evaluation of monitoring results for the Brady Road Landfill is ongoing separately by the City and is beyond the scope of this study.

Groundwater data for each site was summarized on tables for the respective sites, in Appendix E. Graphs of water quality with time were prepared for several parameters which are good indicators of leachate in groundwater. The graphs show trends with time and compare water quality in different areas near a site. Water quality data were used as received from the City. A data quality review should be performed to identify possible errors in reporting or transcription at the lab, but was beyond the scope of this study. Occasional sudden decreases in hardness concentrations are attributed to the collection of softened water samples.

7.2.1 Kilcona Landfill and Cordite Landfill

The location of monitoring and water supply wells at the Kilcona and Cordite Road landfills is presented in Appendix E-2, Figure E-2-1. Water quality graphs are presented in Appendix E-2, Figures E-2-2 to E-2-8. Complete water quality data is presented in Appendix E-2, Table E-2-1, for Cordite Landfill, and in Table E-2-2 for the Kilcona Landfill.

Monitoring Wells

At the Kilcona Landfill, 19 monitoring wells installed by the City have been sampled, two of which are now abandoned. Three wells are located north of the site (Wells 19, 5, and 6). Seven wells are located south of the lake system near Springfield Road. The remaining three wells are located west and southwest of the West Cell. Well depths range from 17 to 33.5 m (58 to 110 ft), with casing typically extending to 15 m (50 feet), just into the upper portion of the underlying Carbonate bedrock.

Water quality plots for monitoring wells are presented in Appendix E-2, Figure E-2-2 (Chloride and Alkalinity) and Figure E-2-3 (Total Dissolved Solids and Hardness). Groundwater quality in the monitoring wells does not appear to have been affected by the Kilcona Landfill. Well 9 south of the west cell increased suddenly in pH, alkalinity, turbidity, colour and conductivity in 1991 and 1992. This does not appear to be caused by the leachate (which has a neutral to acidic pH) and the source should be investigated.

Variations in background quality appear to have a pattern. The lowest dissolved solids (400-550 mg/l), chloride (50-75 mg/l) and hardness concentrations are found south of the east cell (Wells 2 and 7). The highest background readings (TDS 500-750 mg/l, chloride 100-125 mg/l) are found south and west of the west cell (Wells 4, 8, 9 and 10) and along the middle segment of Knowles Avenue (36-6). Intermediate readings are found long the northwest side of the landfill (Wells 11, 12, 19 and 5). Trends do not appear to be influenced by well depth. Chloride and TDS values decreased in most wells along the south side, while slight increases were observed in wells along the north side (36-19, 5, 6). The observed increases have not exceeded early background values (1980-1982). Other parameters have not shown similar increases, with the exception of high iron concentrations at well 36-12 along the west edge of the site. This is an old, large diameter production well with a black iron casing and a iron bacteria problem which is not associated with landfill operations.

Water Supply Wells

Monitoring of area water supply wells, around the Kilcona and Cordite Landfills, shows similar trends. Wells are constructed from 17 to 51 m (57 to 166 feet) deep, with casing depths ranging from 13 to 24 m (44 to 80 feet) except for a deeper casing at the Washroom building. Total dissolved solids and chlorides were lowest (TDS 500-600 mg/l, chloride 50-75 mg/l) along the east third of the Kilcona Site from Knowles Avenue (Figure E-2-8) south, including Springfield Road (Figures E-2-4 and 5) and the area east of the Cordite Landfill (Figures E-2-6 and 7). Decreasing or stable concentrations of parameters were observed in this area.

In the centre third of the Kilcona site, along Knowles Avenue (Figure E-2-8), TDS and chloride were highest (up to 125 mg/l chloride). Increasing trends were observed in all three wells.

Concentrations were intermediate in the western third along Norris Road, the west part of Knowles Avenue, and Grassie Boulevard.

The Grainmaster well (36-21) has experienced elevated bacterial counts since 1989. Several nutrients are also elevated from previous background concentrations in the well including phosphorus (up to 0.24 mg/l, in 1992 background <0.01 mg), nitrate plus nitrite nitrogen (up to 0.27 mg/l, in 1990 background <0.01 mg/l). Sulphate is also elevated (up to 290 mg in 1991, background 80 to 93 mg/l).

Septic systems are a potential source of contamination to private wells and should be evaluated if trends continue to increase.

7.2.2 Summit Road Landfill

The location of monitoring and water supply wells at the Summit Road Landfill is presented in Appendix E-3, Figure E-3-1. Water quality graphs are presented in Appendix E-3, Figures E-3-2 to E-3-8. Complete water quality data is presented in Table E-3-1.

The regional bedrock groundwater flow direction in the developed portion of the aquifer is to the southeast. Water supplies are generally developed in the high transmissivity zones of the Fort Garry member below elevation 210 m. This is more than 20 m below the Summit landfill base. Water supply well casings typically extend only into the upper bedrock. The lower permeability units found above the developed zone, such as the Gunn Formation, may provide some barrier to vertical migration from the rubble zone to the developed portion of the aquifer.

Downward vertical hydraulic gradients are present between the clay and the upper bedrock in most areas of the site. Upward hydraulic gradients may have existed in the past in areas of deeper excavation, where the bottom of the excavation may have approached the piezometric surface. High leachate elevations would now produce downward gradients in these areas.

The zone of broken rock below the till, referred to as the rubble zone, is an upper permeable zone, above the bedrock zone normally developed for a water supply in other areas of Winnipeg. This rubble zone is suitable for monitoring leachate impact, because its permeability is higher than the upper portion of the bedrock. Flow directions are not well defined in the rubble zone, and may be controlled by bedrock topography and deviate from regional flow directions.

Monitoring Wells

Four monitoring wells have been sampled at the Summit Road Landfill prior to 1992. Four additional monitoring wells were installed in November 1992. All of these wells are installed in the rubble zone. Monitoring wells have been located at the east end of the site (Wells 2, 3 and 4) and (more recently) south of the site. One well (Well 1) is located west of the site. Graphs of indicator parameters for monitoring wells are presented in Appendix E-3 Figures E-3-2 to E-3-4.

Regionally there are high concentrations of chloride and sulfate in the bedrock resulting in increase dissolved solids content that may mask leachate impacts, if they occur.

At the northeast corner of the landfill, Well 2 has shown very high levels of chloride in the past (>900 mg/l) and has continued to decrease in concentrations of TDS, specific conductance and chloride (Appendix E-3, Figures E-3-2 and E-3-3). City staff indicate that they do not have confidence in the water quality data from that well. A reliable monitoring point is needed in the northeast area. Well 1 on the west side of the landfill is lowest in total dissolved solids, conductivity, hardness, sulphate and chloride.

On the east side of the site, Wells 3 and 4 have higher concentrations of these parameters. Sulphate has been high and very variable in Well 3 throughout the monitoring period and was high in well 4 in 1991-1992. Chloride has increased at Well 3, from approximately 550 mg/l prior to 1985, to over 600 mg/l.

Nutrients (total Kjeldahl nitrogen (TKN) and ammonia nitrogen) remain at low concentrations near detection limits of 1 mg/l. In contrast, TKN in leachate ranged from 21 to 300 mg/l while ammonia nitrogen in leachate ranged from 18 to 273 mg/l. Total organic carbon (TOC) has fluctuated, reaching peaks when wells were installed in 1981, and again in 1985 and 1989. Few consistent trends are observed. TOC values in leachate are typically high ranged from 37 to over 30,000 mg/l.

Water Supply Wells

Five water supply wells are located in the vicinity of the landfill site, west of Summit Road (Appendix E-3, Figures E-3-5 to E-3-7). Sunnybrook Farm (Well 13) west of the site has been sampled once (1980) and had a low chloride concentration of approximately 200 mg/l.

Santana Kennels northwest of the site has a Kennel well (Well 5) and a residence well No. 6. At the residence well, sulphate, chloride and hardness, total dissolved solids and specific conductance have increased since monitoring started in 1988.

To the south, the well at the Optimist Park (Well 7) has had consistently very high concentrations of chloride (900 to 1000 mg/l), sulphate (>600 mg/l), specific conductance (>3500 μmhos/cm) and hardness (>100 mg/l).

The Slusarchuk well (Well 8) located southeast of the Optimist Park, has concentrations of chloride and total dissolved solids intermediate between the Kennel residence (Well 6) and the Optimist Park Well (Well 7). Nutrients and total organic carbon show no unusual trends.

Water supply wells east of Summit Road (along Sturgeon Road) show generally lower concentrations of chloride and dissolved solids than those wells closer to the site (Appendix E-3, Figure E-3-8). Higher nitrates (2.5 mg/l) were found at Well 12 along Sturgeon Road.

Future Work

Additional work at Summit Road Landfill should focus on the following areas:

- Characterizing groundwater flow directions and quality around the perimeter of the landfill in the rubble zone and the bedrock aquifer zone, including reconstruction or replacement of well 2, additional well installations, and analysis for volatile organic compounds such as hydrocarbons and solvents.
- Investigating the source of high indicator parameters south of the landfill, including additional installations between the landfill and the Optimist Club.
- Investigating the source of high indicator parameters northwest of the landfill near the Kennels.
- Annual monitoring of water supply wells 5, 6, 7, 8, 13 and other wells in close proximity to the landfill.
- Periodic monitoring of water supply wells 10, 11, 12, 9, 15 and other wells east of Summit Road.

7.2.3 Harcourt Street Landfill (No. 17)

Seven water supply wells have been monitored near Harcourt Street Landfill. Five are located on Appendix E-3, Figure E-3-1 (southeast corner). Wells 5 and 6 are located further south. Water quality graphs are presented in Appendix E-4, Figure E-4-1. Complete water quality tables are presented in Appendix E-4, Table E-4-1.

Water supply development ranges from 36 m to 107 m below ground surface, according to a limited number of well construction reports. North of Saskatchewan Avenue, nitrates have been high in the Butler Well (No. 1), up to 33 mg/l in 1990. South of Saskatchewan Avenue the following conditions were noted in process and cooling water wells:

- Boeing Well (Well 4) - Increasing trend of chloride and sodium and high chromium concentrations (29 to 43 μg/l). The well is 67 m deep and is cased to 30 m. Bedrock is found at 5.4 m below ground surface.
- Winpak Well (Well 5) - High chromium concentrations (18 to 490 μg/l), high copper and zinc. The well is 107 m deep and is cased to 25 m. Bedrock is found at 9.7 m below ground surface.
- Air Transport Building (Well 7) - High Chemical oxygen demand (COD) - (15 to 58 mg/l) and high bacteria counts, High total Kjedahl nitrogen (4 mg/l) and ammonia (1.3 mg/l) in 1989 decreasing in 1992. The well is 89 m deep and is cased to 27 m. Bedrock is found at 7.3 m below ground surface.

All three wells draw water from zones 15 to 25 m below the top of bedrock. The upper bedrock is described in the Winpack and Air Transport Building logs as shale and red limestone, with major fractures noted in the Winpak log only below 38 m. This indicates that the upper bedrock may be less fractured than the developed aquifer zones and may retard the movement of contaminants vertically in the upper bedrock.

Industrial activities at Murray Industrial Park are another potential source of contaminants (chromium) to these wells. Leakage from sewer lines which have been installed through areas of high bedrock have caused nutrient and bacterial problems in the area in the past and may be a potential contamination source at the Air Transport Building.

Future Work

Future work at the Harcourt Street should focus on definition of groundwater quality at the landfill, including installation of monitoring wells around the site and sampling for indicator parameters including nutrients and chromium. Chromium concentrations in leachate at the Harcourt Street site reached 750 μg/l at probe P23L in 1988.

7.2.4 St. Boniface Landfill I (No. 3) No. 3

Two monitoring wells and 2 industrial wells are sampled at the St. Boniface Landfill I site (Appendix E-5, Figure E-5-1). Water quality graphs are presented in Appendix E-5 Figure E-5-2 and complete water quality data is presented in Table E-5-1. Monitoring wells are constructed to 30 m (Well 1) and 72 m (Well 2) and cased to 18 to 20 m. No construction information was available for the water supply wells. The landfill monitoring wells had consistently lower chloride and total dissolved solids than industrial wells. The Schneider (Well 4) had high and fluctuating chloride values and high sodium values. The monitoring wells had a higher alkalinity than the industrial wells.

Future Work

- Existing wells should be monitored for volatile organic contaminants
- The source of high chloride and sodium at the Schneider well should be investigated.
- Monitoring of these four wells should continue.

7.2.5 McPhillips Street Dump (No. 10)

Eight water supply wells have been monitored near the McPhillips Street Dump (Ash Dump) located north of the Perimeter highway (Appendix E-6, Figure E-6-1). Water quality graphs are presented in Appendix E-6, Figure E-6-2. Complete water quality tables are presented in Appendix E-6 Table E-6-1. Well construction information is available for only the Macus well (Well 1) located east of the site on PTH-8. The well is constructed to 59 m and cased to 27 m.

Groundwater quality has remained stable with TDS values of 1000 to 1200 mg/l and chloride values of 200 to 400 mg/l. Water quality at Sokal Industries (Well 5) south of the sludge drying beds, has shown elevated nitrates, sulphates, zinc alkalinity, hardness and total dissolved solids. This water supply is a culvert installed in a hole drilled for piles, and appears to be influenced by surface or shallow contamination unrelated to landfill operations. The water supply should be properly abandoned and grouted to protect both the users and the aquifer.

Future Work

- Continued monitoring of area wells should be continued.

7.3 PROPOSED GROUNDWATER PROGRAMS

7.3.1 Monitoring Well Installation

Monitoring wells should be installed in the bedrock at all sites near groundwater supply users and at sites with high pollution potential or special concerns. Nine priority sites are proposed for monitoring well installation (Table 17). Other sites may be selected for investigation in the future. The number of wells, well locations and depths should be selected on a site specific basis. In general, three to four wells are recommended for each site.

7.3.2 Groundwater Monitoring Program

The proposed groundwater monitoring program for the bedrock aquifer is outlined in Table 18.

Parameters - Indicator parameters are proposed to identify water quality changes. Metals should be analyzed less frequently. A list of proposed metals should be developed considering lab capabilities, previous results and site specific leachate quality. Monitoring well samples for metals must be filtered in the field prior to acidification. The in line filters can be easily used with the current sampling equipment.

Volatile organics testing is proposed for monitoring wells at Summit Road Landfill and may be considered at other sites where volatile organics are found in leachate. Domestic wells close to landfills should be sampled for the same parameters as monitoring wells, in addition to any potable water parameters desired for health purposes.

Frequency - Sampling frequency for monitoring wells should be increased to twice per year at large sites near water supply users or sites with high pollution potential including Kilcona, Cordite Road, Summit Road and Harcourt Street Landfills. Where new monitoring wells are installed they should be sampled twice per year for two years to establish initial conditions. Annual monitoring is proposed for all other monitoring wells.

Water supply well monitoring should be reviewed on a site specific basis. The number of water supply wells monitored 1990 to 1992 is listed on Table 18. Other wells were sampled prior to this date. In general, annual monitoring should continue at water supplies used for drinking. A system of alternate sampling of wells every other year, could be used to cover the wells near Kilcona and Cordite Landfills. Monitoring of non-consumptive industrial wells may be decreased.

Indicator parameters on Table 18 plus additional potable water parameters should be used. A shorter list of indicator parameters or field conductivity measurements may be sufficient to define long term trends at water supplies more distant from landfills. Where groundwater monitoring wells are recommended, but not yet installed, sampling at private wells should be continued until the new monitoring well data is evaluated.

7.4 SURFACE WATER POLLUTION POTENTIAL

Surface water pollution concerns are listed in Table 19. These include subsurface leachate migration and discharge to creeks, ditches and rivers; leachate breakout; and erosion of waste.

Surface water monitoring is proposed at three sites, as shown on Table 20. Upstream and downstream samples should be taken spring, summer and fall and analyzed for List A of the leachate parameters in Table 15. Field sampling should also be done for specific conductance, total dissolved solids, pH and temperature. The need for subsequent surface water monitoring can be established, based on a assessment of these results.

Inspection of sites for leachate breaks, seepage and staining should continue in order to identify future problems at other sites.

8.0 TOPOGRAPHY AND COVER

8.1 STATE OF THE ART PRACTICE

The final topography and cover system of the landfill are critical elements in limiting infiltration and leachate production.

Topography

Landfill topography should follow the following principles.

- Maintain positive drainage to perimeter areas
- Create the shortest possible runoff flow distances across waste
- Provide adequate surface water routing along grassed or lined swales
- Maintain adequate topslope grades to accommodate settlement and maintain positive drainage. For example, a minimum 5% grade is recommended in Ontario and required by the State of Wisconsin.
- Avoid overly steep site slopes that may be subject to erosion or slope failure. (For example, a maximum 4:1 grade is required by the State of Wisconsin).

Final Cover

A survey of final cover systems is presented in Table 21. Cover systems consist of a low permeability cap constructed over waste, and a topsoil and rooting layer to limit erosion, establish vegetation and protect the cap from cracking.

A grading layer of granular material is often added to provide a uniform surface for clay compaction. A gas venting or collection system is added beneath the cap in a granular layer where required. In Wisconsin, where composite liners (geomembrane and clay) are used, policy requires the construction of a composite cap.

8.2 TOPOGRAPHY

An inventory of existing site topography, drainage, settlement and erosion at the City landfill sites is summarized in Appendix B-1 Table B-1-5. Twenty sites are essentially flat, thirteen sites are hills or graded landforms, and two sites are ungraded. Settlement is visible at several sites including Kilcona (local loss of positive drainage), Cordite and Summit Landfills. Erosion is severe on the steep slopes at Cordite landfill. Slope failures have occurred in the past at Saskatchewan Avenue, Cordite Road and Kilcona Landfills. Slope stability work is ongoing at Kilcona Landfill.

8.3 FINAL COVER

An evaluation of existing final cover was conducted from test hole logs at the sites and visual inspections, as presented on Table 22. The sites are grouped into major categories with respect to cover, including compacted clay over, no cover, cover with exposed waste, and cover with possible construction debris (some undocumented).

Compacted Clay Cover - Only Cordite, Kilcona, Summit and Brady Road landfills have or are proposed to have a compacted clay cover. Cover is undocumented in large areas at Cordite landfill.

At Summit Road and Brady Road landfills, 2 m of clay is proposed. The City has not used a rooting or topsoil layer, but seeds directly into the clay to establish vegetation. The 2 m of clay used by the City is thicker than the 1 m combined cover system required in Wisconsin. Kilcona landfill has been used to demonstrate the effectiveness of vegetative growth. There is a need to evaluate the extent of clay cracking. If cracks are deep, a protective upper soil layer for rooting should be installed or constructed.

No Cover - Two sites have exposed waste with no cover. The CNR Dugald Road Landfill is privately owned and used as a storage site. The Corydon Osborne site, popular as a historical "bottle" site may be a safety hazard.

Cover With Exposed Waste -Three sites have areas of exposed waste, including Kimberly Landfill (tires and debris), Leila Avenue Landfill (tar type waste on playing field) and Shaftesbury Landfill (uncovered metal debris and wastes).

Other Sites - All other sites contain clay or other material, described as "fill", sometimes also containing construction debris, glass, ash, etc. At 18 sites, large areas of the surface were undocumented with respect to cover.

8.4 SUMMIT ROAD LANDFILL

The conceptual final use plan for the Summit Road Landfill is to construct a generic landscape which would be suitable for a variety of after-use activities (Hilderman Witty 1990). Proposed features include:

- Creation of landforms on top of the existing landform including hills, hollows and upland areas (three areas 2 to 10 percent grades, 1.3 to 10 percent grades, 3 percent grades)
- Constructing a series of terraces (max 5H:1V) and slopes (min 2 percent grade) on the west side of the landfill
- Minimizing drainage to the east
- Providing surface water retention ponds to also be used as a cover source and potential source of irrigation water and wildlife habitat
- Creating a drainage channel system with the landfill surface sloped at 3 percent toward the drains
- Improving soil structure and fertility for revegetation
- Revegetation of the site including grasses, shrubs and trees.

There is a need to incorporate engineering environmental concerns in the final use concept for landfill development and closure. Final contours and drainage should minimize leachate infiltration, especially since most of the site does not currently have a leachate collection system and the grades are close to the till deposits overlying the carbonate aquifer.

The concept report stated a 3 percent grade would be adequate to maintain positive runoff even with settlement. As a comparison, the Province of Ontario recommends and the State of Wisconsin requires new landfills to be designed with a minimum slope of 5 percent and maximum slopes of 4:1. The latter requirements should be adopted for the Summit Landfill.

There has been a significant settlement history at the Kilcona Landfill, resulting in undrained depression areas that have ponded up. Because it is critical to minimize leachate infiltration, slopes should be designed to maximize runoff and may need to be increased in some areas.

At the Summit Road Landfill, a bowl shaped landform is proposed in the northeast and central portion of the site to provide shelter from the wind. This topography would result in reduced runoff of surface water in the bottom of the "bowl" overlying a central area of waste, and increased infiltration. A hill shaped landform would minimize the infiltration, although it may be less flexible for some uses.

An adequate separation distance should be maintained between surface retention ponds and the waste, to minimize potential leachate infiltration into the ponds. A cover design, incorporating a compacted low permeability clay cap and an overlying rooting layer plus topsoil, would both restrict infiltration into the waste and provide a soil structure suited to revegetation.

Irrigation should be monitored carefully. Overwatering could increase infiltration. Vegetation should not disturb the cap integrity. Rooting zones for some trees may disturb the clay cap. Access must be maintained for present and future environmental monitoring points, including groundwater wells and piezometers, leachate and gas probes, and the leachate extraction system.

The final design should allow for future remedial measures, such as leachate extraction from cells without collection systems or landfill gas extraction. Documentation of all phases of closure should be provided. A long term maintenance plan and monitoring schedule will be needed and a plan for supporting these costs should be identified and put in place prior to site closure.

8.5 PROPOSED TOPOGRAPHY AND FINAL COVER PROGRAM

Details of the cover should be documented at all large landfills, with emphasis on those sites with high or moderate pollution potential and those sites used for recreation. Replacing or adding cover should be done on a site specific basis, to limit any increases in gas migration. Adding cover at Lot No. 61 St. Marys Road and Kimberly Landfill has increased gas migration in the past.

Action priorities for topography and cover programs at selected landfill sites are listed on Table 23, under the following categories:

- Safety
- Erosion and Slope Stability
- Surface Water Contamination
- Leachate Production

The categories are given in order of priority, with individual sites listed in sequence from highest to lowest priority for action. Initially the emphasis should be placed on safety to address sites with exposed waste, and sites developed as recreational areas for day care, tot lots, play grounds, etc. Sites susceptible to erosion and stability problems are also a high priority for remedial action. Sites with potential for surface water contamination and leachate production are considered to be longer term concerns, but also require attention. Inspection and maintenance of cover at all landfill sites should be performed annually.

9.0 SITE UTILIZATION

9.1 EXISTING LAND USE

Existing Land Use of all 35 landfill sites is summarized in Appendix B-1, Table B-1-2. Major land uses include:

Developed Recreational Areas	11 sites
Undeveloped Areas	12 sites
Residential or School	3 sites
Commercial/Industrial Structures & Activities	4 sites
Snow Disposal	3 sites
Waste Disposal	2 sites

9.2 POTENTIAL SITE UTILIZATION

Overview

The majority of landfill sites in the Winnipeg area are closed and presently being used for either recreational purposes, or industrial/commercial operations. At most sites the clay and topsoil cover requires upgrading to meet current required engineering standards to preserve the integrity of the cell. At several locations tires, glass, and other waste products penetrate the surface, causing safety and maintenance concerns. The land use is unlikely to change, however, remedial site improvements may be warranted for topography, cover and monitoring of leachate, landfill gas and groundwater.

Many landfill sites are no longer in use and are undeveloped, however, their end use is predictable on the basis of the ownership and adjacent land use. Public lands (owned by the City of Winnipeg) which are adjacent to residential areas, will likely be developed for recreational uses. Those properties that are presently adjacent to industrial/commercial operations, will likely be adopted for industrial/commercial use as well, based on the property's zoning and isolation from residential areas. The future development of these sites will require appropriate planning to satisfy design engineering criteria.

The Summit Road Landfill Site is unique in that it is near closure, and a variety of options remain for its end use. Conceptual closure plans provide for a diverse landscape upon closing, to potentially accommodate a variety of activities. There is a need to consider, in further detail, the end use of the Summit Road Landfill Site, and apply the engineering standards developed through this study.

Issues

The main issues in the planning and design of end use activities for the site are related primarily to cover, landfill gas and leachate/water quality. The clay and surface cover are critical aspects of end use planning, to ensure the waste products are isolated from the surface and that infiltration is minimized to comply with the engineering standards. In order to ensure the integrity of the cover, the following planning and design issues require consideration:

- ***Surface Material*** - The finished surfacing for the planned activities must be designed to maintain the cover integrity. Activities such as motocross sports will eventually erode the surface, and trails must be planned accordingly. Surfaces that promote infiltration are undesirable. Whether the use is related to recreation or industrial/commercial operations, the surfacing, and cover depth must be planned accordingly.

- ***Surface Grading*** - Surfaces that are too steeply graded are subject to erosion, which may eventually jeopardize the cover. Surface drainage that results in water accumulation and ponding is to be avoided. Generally, the level of the surface over landfill areas is irregular, being prone to settlement, and is therefore not ideal for playing fields.

- ***Vegetation*** - Selection of trees, shrubs, and ground covers require care to ensure that roots do not penetrate the clay cover and increase its permeability. Properly planned vegetative cover can assist in controlling surface erosion and infiltration into the clay cap.

- ***Foundation Design*** - Facilities which require deep footings or piles (such as goal posts, baseball backstops, and play structures) require designs which satisfy the foundation requirements without allowing infiltration into the waste, or leachate seepage at surface. The waste will settle and generally does not provide sufficient support capacity. Building structures may require specialized design controls, including elevated construction or ventilation requirements to prevent methane gas hazards.

- ***Maintenance*** - The ongoing surveillance and maintenance of the site is necessary in order to monitor any changes to the site conditions and identify any potential problems. A mechanism for the active surveillance and maintenance should be established for the sites.

Landfill Site Profile

The existing conditions and use for each site has been documented, and the likely end use options have been identified. A profile for each site, characterizing the appearance, use, and nature of the overall condition of the landfill is summarized in Appendix F, Table F-1. Also included for each site is an overview of development opportunities and constraints, and general recommendations.

Monitoring Well Installation and Sampling

5. Implement items for future work as discussed in Section 7.3 at Kilcona, Summit, St. Boniface and Harcourt Street Landfills, with priority on Summit Road Landfill.

6. Design, locate and install three to four monitoring wells each, at nine sites listed in Table 17, to provide and/or improve monitoring close to the sites.

7. Evaluate and/or update hydrogeologic conditions at these sites, based on the drilling and sampling program, including groundwater flow directions and groundwater quality.

8. Establish background conditions at new wells at nine sites by sampling twice per year for two years and annually thereafter.

9. Implement the proposed bedrock groundwater monitoring program listed on Table 18, including sampling monitoring wells twice per year at four sites and annually at six sites.

10. Priorize monitoring of approximately 45 water supply wells monitored in 1990-1992, based on use as drinking water supply, proximity to landfill, well depth and construction. Evaluate need for follow up monitoring of wells sampled prior to 1990 and any new wells constructed. Select appropriate indicator parameters on site specific basis.

Surface Water Monitoring

11. Implement the surface water monitoring program listed in Table 20 at Beliveau Road Dump (Seine River), Saskatchewan Avenue Dump (Omand's Creek), Summit Road Landfill (Sturgeon Creek), Kilcona and Brady Road Landfill including collection and analysis of upstream and downstream samples in spring, summer and fall, evaluation of results, and recommendation for ongoing surface water monitoring.

11.4 TOPOGRAPHY AND COVER

1. Document cover at all large landfills, those with high or moderate pollution potential, and those used for recreation, beginning with the priority sites listed in Table 23. Add cover as needed, with precautions to prevent associated excess lateral gas migration.

2. Evaluate the need for a rooting zone soil to be placed over the clay to prevent excessive cracking of the clay cap and infiltration into the waste.

3. Repair erosion gullies at Cordite Landfill and Kilcona Landfill and restore positive drainage at Kilcona Landfill, St. Boniface Landfill II and McPhillips Street Landfill.

4. Inspect and maintain cover at all landfill sites on an annual basis.

5. Revise final use plan for Summit Landfill to include measures to limit infiltration and incorporate other engineering concerns.

11.5 SITE UTILIZATION

Take steps to ensure the development and end use of landfill sites is compatible with engineering constraints related to cover material, landfill gas, leachate and groundwater protection.

11.6 INSTITUTIONAL ISSUES

Address jurisdiction authority between City Departments and private/commercial groups for the following areas: waste cleanup, gas control maintenance in buildings, landfill operations, land use conflicts (snow dumping), funding for long-term maintenance, land acquisition in control zones, utility and developer awareness of landfill locations and hazards.

REFERENCES

Canadian Council of Ministers of the Environment (CCME). 1991. Interim Canadian Environmental Quality Criteria for Contaminated Sites. Report CCME EPC-CS34 September 1991.

Cherry, J.A. 1976. Hydrogeologic Conditions at the Proposed Northwest Park Sanitary Landfill Site. Prepared for the Waterworks, Waste and Disposal Division, City of Winnipeg, January 23, 1976.

City of Calgary. 1993. Memo Solid Waste Management Practices Survey for the City of Winnipeg. Prepared by R. Boone, Engineering and Environmental Services Department, Solid Waste Services Division March 4, 1993.

City of Edmonton. 1993. Memo on Landfill Design prepared by D. Thompson, Waste Management Branch. March 16, 1993.

City of Regina. 1993. Memo on Solid Waste Management Practices prepared by G.A. Nieminen, Environmental Engineering, Municipal Engineering Department.

City of Winnipeg, 1993. Laboratory Services Division. Personal Communication.

City of Winnipeg, 1992. Landfill Environmental Section. Personal Communication.

City of Winnipeg. 1989a. Environmental Protection Program Leachate and Leachate Collection System Kilcona Park Sanitary Landfill. Prepared by C. Potter, Waterworks, Waste and Disposal Division. March 1989.

City of Winnipeg. 1989b. Policy for Building on Nairn-Elmwood Landfill Sites. October 1989

City of Winnipeg. 1984a. Report of the Committee on Works and Operations dated October 2, 1984. Methane Gas Policy - Landfill Environmental Program, File WT-3.

City of Winnipeg. 1984b. Monitoring Standards for Landfill Gas Prepared by Waterworks, Waste and Disposal Department, F. DeVries, January, 1984.

City of Winnipeg. 1979. Report of the Executive Policy Committee May 31, 1979. Methane Gas Policy.

City of Winnipeg. No. 1. Policy For Building on Landfill Sites. Waterworks, Waste and Disposal Department.

City of Winnipeg. No. 2. Policy Regarding Building Permits Adjacent to Landfills.

City of Winnipeg. No. 3. Provision CW 1100-R4. Chapter 18. Construction Safety in and Around Landfills. Waterworks, Waste and Disposal Department.

City of Winnipeg. No. 4. Design Guidelines for Landfill Site Construction. Waterworks, Waste and Disposal Department.

Conyette, C. 1993. Speaking Notes on the Proposed Manitoba Environment Guidelines for Class 1 Waste Disposal Grounds for Solid Municipal Wastes. Delivered at the Short Course on Landfill Leachate and Methane Gas Generation and Control. May 20, 1993, Winnipeg Branch Canadian Geotechnical Society.

Environment Canada. 1984. Canadian Climate Normals Volume 2, 3, 5 and 9.

Environmental Technologies Inc. 1992. Kil-Cona Park Landfill Gas Evaluation Test Program Report and Landfill Gas Utilization Market Study, December 1992.

Farquhar, G. 1991. Lecture Notes. Landfill Gas Migration and Control. Presented at Sanitary Landfill Leachate and Gas Management. University of Wisconsin Extension. December 3-6, 1991.

Geherls, Jim. 1993. Ontario Ministry of the Environment. Personal Communication.

Hilderman, Witty, Crosby, Hanna and Associates. 1990. Summit Road Landfill Site After Use Study. September 1990.

Hydrology Consultants. 1984. Study of Gas Production and Migration at Closed Sanitary Landfill Sites. Ministry of the Environment Project No. 78-023-13 December 1984.

KGS Group. 1992. Four Mile Road Site, Supplementary Report, Detailed Site Investigation. Prepared for the Manitoba Hazardous Waste Management Corporation. January 1992.

Kmet, P., and P.M. McGinley. 1982. Chemical Characteristics of Leachate from Municipal Solid Waste Landfills in Wisconsin. Presented at the Fifth Annual Madison Waste Conference, September 22-24, 1982. Sponsored by Department of Engineering, University of Wisconsin - Extension.

Ontario Ministry of the Environment. 1993. Appendix A to "Guideline for Assessing Methane Hazards from Landfill Sites, November 1987", April 16, 1993.

Ontario Ministry of the Environment. 1987. Guideline for Assessing Methane Hazards from Landfill Sites, November 1987.

Province of Manitoba. 1988. Environmental Act. C.C.M.E. c.E125. Manitoba Regulation 164/88 Classes of Development Regulation.

State of Wisconsin. 1988. Solid Waste Management Rules Chapter NR500 to 520, Wisconsin Administrative Code.

Tchobanglous, G., H. Theisen and S. Vigil. 1993. Integrated Solid Waste Management Engineering Principles and Management Issues. McGraw-Hill Inc.

United States Environmental Protection Agency. USEPA. 1991a. EPA Criteria For Municipal Solid Waste Landfills. 40 CFR 258, October 9, 1991. (EPA Subtitle D of the Resource Conservation and Recovery Act RCRA).

United States Environmental Protection Agency (USEPA). 1991b. Current and Proposed National Primary and Secondary Drinking Water Regulations. Regional X Drinking Water Program revised July 30, 1991.

United States Environmental Protection Agency. 1975. Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites. October 1975. EPA 530/SW-168.

University of Manitoba. 1983. Geological Engineering Report for Urban Development of Winnipeg. Department of Geological Engineering. February, 1993. Prepared by A. Baracos, D.H. Shields and B. Kjartanson.

Wisconsin Department of Natural Resources. 1992a. Guidelines For Review of Requests for Exemptions to Construct an Abandoned Landfill. Bureau of Solid and Hazardous Waste Management.

Wisconsin Department of Natural Resources. 1992b. Wisconsin Solid Waste Management Permit Program Application for Determination of Adequacy. Bureau of Solid and Hazardous Waste Management. July 1992.

TABLES

TABLE 1

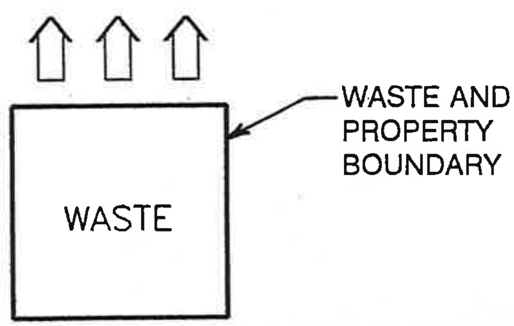
LANDFILL GAS CONTROL ZONES
ESTABLISHED 1984

RADIUS FROM WASTE BOUNDARY							
90 m (300 FEET)		45 m (150 FEET)		15 m (50 FEET)		SITE BOUNDARY (0 m)	
8	Cordite Rd. Landfill	2	St. Boniface Dump	1	Beliveau Dump	21	Charleston St. Dump
11	McPhillips St. Landfill	3	St. Boniface I Landfill	5	Redonda Dump	30	CN-Osborne Site
17	Harcourt St. Landfill	4	St. Boniface II Landfill	9	Bonner Landfill	31	CN-Red-Assiniboine Site
18	Summit Rd. Landfill	6	Redonda Landfill	10	McPhillips St. Dump		
24	Cadboro Rd. (West) Landfill	7	Kimberly Landfill	15	Saskatchewan Ave. Dump		
25	Brady Rd. Landfill	12	Margaret Park Landfill	16	Barry Ave. Dump		
36	Kilcona Landfill	14	Leila West Landfill	13	Leila Ave. Landfill (Park Area)		
		22	Charleswood South Landfill	20	Charleswood Rd. Landfill		
		23	Cadboro Rd. (East) Landfill	28	Brooklands Landfill		
		19	Shaftesbury Dump	29	CNR/Dugald Road Landfill		
		26	Elmwood Landfill	32	Lot 61 (St. Mary's Road Dump)		
		27	Nairn Ave. Landfill				
		33	Riel Dump				
		35	River Road Dump				
		13	Leila Ave. Landfill (Developed Area)				

TABLE 2

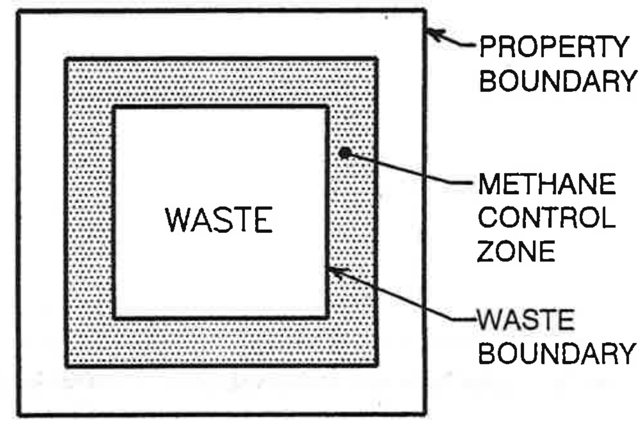
STANDARDS FOR LANDFILL GAS CONCENTRATIONS AT WASTE AND PROPERTY BOUNDARIES

1. WASTE ADJACENT TO PRIVATE PROPERTY



JURISDICTION	STANDARD
City Winnipeg	20% LEL Property Boundary
Manitoba	N/S
Ontario	No Operating Limit
USEPA	100% LEL Property Boundary
Wisconsin	25% LEL (soils or air) Property Boundary
Calgary, Edmonton, Regina	N/S

2. BUFFER ZONE BETWEEN WASTE AND PROPERTY BOUNDARY



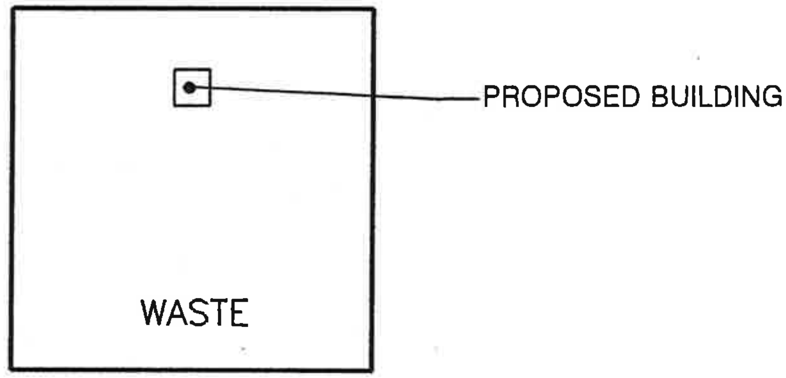
JURISDICTION	STANDARD
City Winnipeg Policy	20% LEL Waste Boundary
City Winnipeg Practice	20% LEL Property Boundary
Manitoba	N/S
Ontario	No Operating Limit
USEPA	100% LEL Property Boundary
Wisconsin	25% LEL (soils or air) Property Boundary
Calgary, Edmonton, Regina	N/S

NOTES:

LEL - Lower Explosive Limit
N/S - Not Specified
N/A - Not Available

TABLE 3

STANDARDS FOR CONSTRUCTION ON LANDFILL WASTE



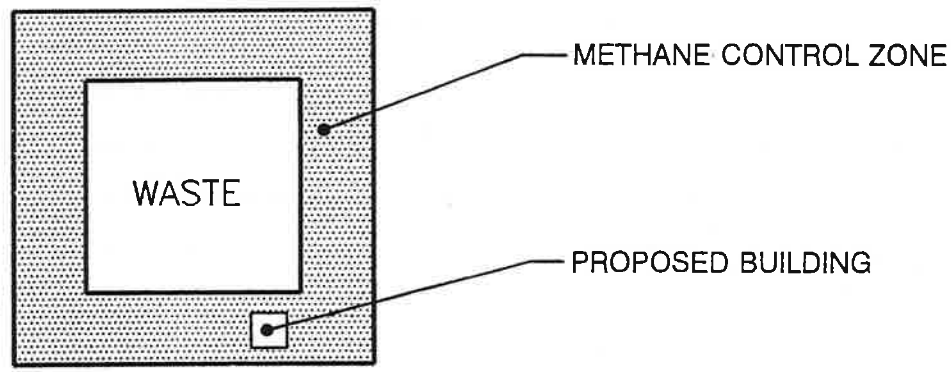
CONSTRUCTION ON WASTE IS ALLOWED WHERE								
JURISDICTION	CONSTRUCTION IS ELEVATED & VENTILATED	WASTE IS REMOVED	METHANE IN WASTE				BUILDING SETBACK
			0% LEL	>0% LEL, <10% LEL	>10% LEL	>25% LEL	
CITY OF WINNIPEG	YES	NO (1)	if elevated and ventilated required				
CITY OF CALGARY	Open air storage or trailers ONLY						305 m for buildings (landfill setback is 450 m from buildings)
CITY OF EDMONTON							No policy
CITY OF REGINA							No policy
MANITOBA							
ONTARIO	YES	YES	YES(2)	YES with controls(2)			
USEPA	NOT APPLICABLE						
WISCONSIN			YES	YES with controls	YES with controls	NO	

NOTES:

1. City of Winnipeg Elmwood Nairn Sites - Yes with controls.
2. Building on waste is not recommended in Ontario and approval is extremely rare.

TABLE 4

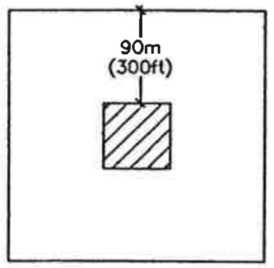
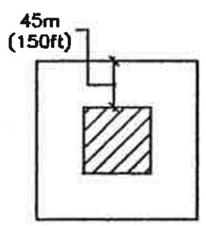
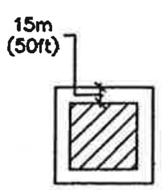
STANDARDS FOR CONSTRUCTION ADJACENT TO LANDFILL WASTE



AGENCY	CONSTRUCTION ADJACENT TO WASTE IS ALLOWED				
	WITHOUT PHYSICAL CONTROLS WHERE				WITH CONTROLS
	LOCATION	METHANE IN WASTE	METHANE IN SUBSURFACE	BARRIER PRESENT	METHANE IN SUBSURFACE
CITY OF WINNIPEG	Construction is out of control zone		Site specific eval.		Controls required if >20% LEL
MANITOBA	distance is >400m or methane control policy exists				
ONTARIO	distance >D=10H, gas conditions assessed if land use change within 500 m of landfill	<10% LEL	Site specific eval.	barrier reduces soil methane to <20% LEL	Controls required if >20% LEL
CITY OF CALGARY	distance is >305 m from waste				
CITY OF EDMONTON	No policy				No policy
CITY OF REGINA	No policy				No policy
USEPA	Not specified				
WISCONSIN	Not specified, restriction on water supply development, within 366 m of waste				

TABLE 5

METHANE MIGRATION AT LANDFILL SITES
LANDFILL GAS MIGRATION WITHIN CONTROL ZONES

METHANE CONTROL ZONE	METHANE MIGRATION (Control Zone Probes)							
	HIGH (>20% LEL)		MODERATE (<20% LEL)			LOW (0% GAS TO TRACE <0.1% METHANE)		
	FREQUENT READINGS	ISOLATED READINGS	METHANE GENERATION (Waste Probes)			METHANE GENERATION (Waste Probes)		
			HIGH (>100% LEL)	MODERATE (<100% LEL)	LOW (0% GAS)	HIGH (>100% LEL)	MODERATE (<100% LEL)	LOW (0% GAS)
	11 McPhillips St. Landfill 8 Cordite Rd. Landfill 17 Harcourt St. Landfill	24 Cadboro Rd. W. 18 Summit Road 36 Kilcona Park Landfill				25 Brady Road Landfill		
	3 St. Boniface Landfill I 7 Kimberly Landfill 33 Riel Dump	35 River Road Dump 4 St. Boniface Landfill II	22 Charleswood Rd. (South) Landfill 6 Redonda Landfill 26 Elmwood Landfill			2 St. Boniface Dump 12 Margaret Park (Barrier)	14 Leila Ave. Landfill 19 Shaftesbury Blvd. Dump 23 Cadboro Road (East) Landfill 13 Leila Ave. Landfill Dev. 27 Narin Ave. Landfill	
		32 Lot 61, St. Mary's Road Dump				20 Charleswood Rd. Landfill 9 Bonner Ave. Landfill	10 McPhillips St. Dump 29 CNR-Dugald Rd. Landfill 28 Brooklands Landfill (Organic fill methane varies)	1 Beliveau Rd. Dump 5 Redonda Dump 15 Saskatchewan Ave. Dump 16 Barry Ave. Dump
								21 Charleston St. Dump 30 Corydon -Osborne Dump 31 Red-Assin. River Junction Dump

NOTES:

1. Classification based on detailed summaries of 1980 or 1982 to 1985 data (by probe) plus 1985-1992 data summaries provided by City of Winnipeg Landfill Environmental Section.
2. Where outside probes show trace (<0.1%) methane concentrations, sites are classified as low methane migration.
3. High, medium and low classifications are comparative within the primarily clay environment in Winnipeg. Migration potential exists within the till/bedrock at sites No. 17 Harcourt Street and No. 18 Summit Road.
4. Summit Road landfill classifications based on one time reading (Probe 11E).

▨ WASTE AREA

TABLE 5

METHANE MIGRATION AT LANDFILL SITES
LANDFILL GAS MIGRATION WITHIN CONTROL ZONES

TABLE 6

LANDFILL GAS MANAGEMENT STRATEGIES AT SELECT SITES

CONTROL ZONE	SITE	METHANE CONCENTRATION		LAND OWNERSHIP CONTROL ZONE	EXISTING STRATEGY	POTENTIAL ACTIONS
		ADJACENT TO WASTE	PROPERTY LINE			
90 m	**#8 Cordite Road Landfill:**					
	• South Side	40 to 70% methane	Edge of waste is property line	Private (open fields)	Installed 2 probes in Cordite Drain. Found no gas Relied on Cordite Drain to act as a barrier.	• Confirm ditch as a barrier to gas migration to south. Perform intensive monitoring for limited period.
	• East Side	7 to 60% methane	Edge of waste is property line	Private	None	• Install probes on East side of Plessis Road in control zone. If probes reach >20% LEL, action needed.
	• West Side	>20% LEL	Edge of waste is property line	Commercial (Westland Steel)	Building monitoring Natural Methane also present under buildings	• Continue Building Monitoring.
	• North Side	Not monitored		Railway		
	#17 Harcourt Road Landfill	5 to 10% methane (in till/bedrock)	Edge of waste is property line	North of Sask. Ave.-private. South of Sask Ave. Industrial (Boeing)	Boeing observes control zone on property south of Saskatchewan Ave. Boeing control zone set 90 m to structures. Waste only 3.7 m thick.	• Verify that 90 m zone adequate buffer for migration in till/bedrock north of Saskatchewan Ave.
	#11 McPhillips Street Landfill	up to 20% methane	Edge of waste is property line	Private	No development adjacent to site.	• Acquire control of Buffer Area • Add monitoring at edge of buffer to verify that 90 m zone sufficient. • Alert potential developers.
	#18 Summit Road Landfill	44% methane Adjacent to east side of waste at P11E in 1980	East edge of waste is property line.	Private not developed.	There is no development.	• The City is pursuing the purchase of the control zone east of the site. • Increase probes and monitoring frequency • Investigate gas migration in till.
	#24 Cadboro Road West	Over 20% LEL on west at Brady Road	Edge of Brady Road is property line.	Private	Maximum Control zone of 90 m was set.	• Add probes to define conditions in control zone consider acquiring control zone property alert potential developers.
45 m	#3 St. Boniface I Landfill	Some probes adjacent to waste >20% LEL 6 to 95% methane	Some probes at property line >20% LEL	Commercial/Industrial	45 m control zone setback based on 4.6 to 6.1 m refuse depth. Buildings monitored on south. North probes installed at property boundary. Railway ditch to south partially saturated acts as a barrier near high methane areas.	• Continue building monitoring. • Take action if ditch becomes dry. • Confirm ditch as a barrier to gas migration ie: saturation potential for gas migration in any unsaturated silts.

TABLE 6

LANDFILL GAS MANAGEMENT STRATEGIES AT SELECT SITES
(Continued)

CONTROL ZONE	SITE	METHANE CONCENTRATION		LAND OWNERSHIP CONTROL ZONE	EXISTING STRATEGY	POTENTIAL ACTIONS
		ADJACENT TO WASTE	PROPERTY LINE			
45 m	#4 St. Boniface II Landfill	2-18% Methane (up to 65% once)	Edge of waste is property line.	Commercial/Industrial	Rely on saturated municipal ditch on east to cut off migration to businesses. CN Rail line bounds south and west perimeter, complete with ditching. Control zone set based on migration distances extrapolated from on-site probes.	• Take action if ditch becomes dry.
	#7 Kimberly Landfill	>20% LEL	Waste is up to property line on east and south over property line on west, set back from property line on part of north.	Residential NW,SW,E Kildonan E Regional Secondary School to south.	Barrier trench installed along east & NW perimeter Waste is present in areas outside NW of barrier. Rely on high water levels in waste below barrier trench to seal barrier. Tested barrier with propane for leaks after installation.	• Continue arena monitoring and maintenance of detection system. • Retesting barrier for leaks periodically. • Install additional outside probes to verify that barrier is functioning-target areas near Sawchuck Bay and south near high school. • Increase monitoring frequency of select probes in adjacent residential areas.
	#33 Riel Dump	Homes built within landfill limits. Backyard probes Ashworth St. up to 80% methane. Backyard probes Meadowood 6-40% methane. Control zone probes are <20% LEL.	Waste is over property line.	Residential N,W,E	Rely on apparent clay barrier around homes and high water tables. Annual building monitoring.	• Address resident safety. • Increase monitoring frequency.
45 m	#35 River Road Dump	>20% LEL	Housing built on waste.	Residential (E,S) St. Vital Park (N,W)	Rely on 45 m control zone and building monitoring.	• Continue building monitoring. • Evaluate other safety measures for homes.
15 m	#32 Lot 61 St. Mary's Road Dump	Occasional readings between 20% LEL and 100% LEL in early 1980s in northeast.	Waste setback 15 m from property line.	City Winnipeg	Building controls at nursing home, intensive probe installations and monitoring.	• Confirm readings in northeast zone at P16 and P34E. • Confirm adequacy of 15 m control zone in northeast area.

NOTES:

1. Strategies are selected for sites with methane greater than 20% LEL in control zone.

TABLE 7
LANDFILL GAS MANAGEMENT - BUILDINGS ON LANDFILLS

	SITE NAME	ADDRESS	TYPE OF CONTROL	MONITORING		MONITORED BY		SUMMARY OF RESULTS	
				1992 FREQ.	LOCATION	LAND-FILL SEC-TION	OTHER	1992 <DET.	MAX.% METHANE (≥10 YEAR RECORD)
3	St. Boniface I Landfill	33 Fournier	None	Regular	PS		Civic Properties		20
				Quarterly	M	X			?Graph
		215 Panet Rd.	None	Regular	PS		Civic Properties		14
				Quarterly	M	X			
		150 Warman Rd.	None	Regular	PS		Civic Properties		60
				Quarterly	M	X			
6	Redonda Landfill	Harold Hatcher School	Operating active ventilation system hooked up to methane detection system with alarms	Continuous	D		School Division		
		Ground Probe	None	Quarterly	P (Centre Crawl Space) M	X			47
					P (South Crawl Space) M	X			63
7	Kimberly Landfill	Terry Sawchuk Arena	Ventilation system on standby hooked up to methane detection system (calibrated bi-monthly). Alarm and ventilation system activated by methane concentration of 1% LEL. Alarm off and building evacuated at methane concentrations of 2% LEL.	Continuous	D	Main-tained			
				2 samples	M in Crawl Space	X		X	
9	Bonner Ave. Landfill	Gateway Community Club	Elevated construction with passively vented crawl space back half of building	Annual	Service Crawl Space	X		X	
13	Leila Ave. Landfill	Eaton's/Garden City	Partial barrier trench. Methane detection system and alarm	Continuous	D		Eaton's		
				Annual	PS and M near probe parts	X		X	
23	Cadboro Rd. (East) Landfill	Bridgewater Park Gun Club	Elevated construction, passively vented crawl space.	Annual	PS, M	X		X	
		Bridgewater Park 2 Trailers	Elevated construction, skirting with vents around crawl space						
27	Nairn Ave. Landfill	994 Nairn Ave.	Waste excavated and replaced with clean fill. Membrane under slab.	Annual	P	X			5
33	Riel Dump	Meadowood/Riel residences	None	Annual	PS, M	X		X	
35	River Road Dump	Kilmarnock Bay residences	None	Annual	P, PS, M	X		X	

NOTES: P = Probes under floor Slab
PS = Point Sources (floor cracks, etc.)
M = Mid air
D = Methane Detection System

TABLE 8
LANDFILL GAS MANAGEMENT - BUILDINGS WITHIN CONTROL ZONES

SITE		ADDRESS	TYPE OF CONTROL	MONITORING		MONITORED BY		SUMMARY OF RESULTS	
				1992 FREQ.	LOCATION	LANDFILL SECTION	OTHER	1992 <DET.	MAX. % METHANE (≥10 YEAR RECORD)
6	Redonda Landfill	Redonda Landfill residences	None	Annual	PS, M	X		X	
7	Kimberly Landfill	Probes between barrier and Green Valley Bay residences	Barrier around landfill	Monthly	Soil probes	X			Pole vents - up to 39.6% Methane in 1992, Probe 0.27% to 0.90% Methane
		Green Valley Bay residences	None	Annual	PS, M	X		X	
12	Margaret Park Landfill	Margaret Park Community Club	Barrier around landfill, none in club	Annual	P, PS, M	X		X	
18	Summit Rd. Landfill	Old Scale House, Service Bldg., Maintenance Bldg.	None	Annual	PS, P	X		X	
25	Brady Rd. Landfill	District 6 Landfill Scale House	Monitoring in crawl space. Methane detection system with alarms	Continuous	D	X	Maintained by District Operator		
				Annual	P, M in Scale pit	X		X	
26/ 27	Elmwood/Nairn Ave. Landfill	41 Industrial/Commercial Buildings	21 buildings on or near Nairn/Elmwood Landfill have some form of passive protection from methane migration	Annual	P, PS, M	X			Some >5% in 1992
36	Northeast Park Landfill (Kilcona)	District 4 Ex. Scale House	None	Monthly	P	X			Trace

NOTES:
P = Probes under floor Slab
PS = Point Sources (floor cracks, etc.)
M = Mid air
D = Methane Detection System

TABLE 9
LANDFILL GAS MANAGEMENT - BULDINGS OUTSIDE OF CONTROL ZONES

SITE		ADDRESS	TYPE OF CONTROL	MONITORING		MONITORED BY		SUMMARY OF RESULTS	
				1992 FREQ.	LOCATION	LANDFILL SECTION	OTHER	1992 <DET.	MAX. % METHANE (≥10 YEAR RECORD)
3	St. Boniface I Landfill	1025 Dugald Road	None	Annual	P, PS (floor crack)	X			43
		700 Mission	None	Annual	P, PS	X			25
					(Floor crack)				9
		835 Mission	None	Annual	P	X			42
8	Cordite Road Landfill	165 Cordite Road	None	Annual	P, PS	X			40
					(Floor crack)	X			12
32	Lot 61, St. Mary's Rd. Dump	Nova Vista Lodge	Barrier trench surrounding building	Annual	M in crawl spaces	X		X	

NOTES:
P = Probes under floor Slab
PS = Point Sources (floor cracks, etc.)
M = Mid air
D = Methane Detection System

TABLE 10

PROPOSED LANDFILL GAS MONITORING

SITE	QUARTERLY	TWICE PER YEAR	TWICE EVERY SECOND YEAR	DISCONTINUE UNLESS CONDITIONS CHANGE
#1 Beliveau Road Dump			X	
#2 St. Boniface Dump			X	
#3 St. Boniface Landfill I	X			
#4 St. Boniface Landfill II	X			
#5 Redonda Dump			X	
#6 Redonda Landfill		X		
#7 Kimberly Landfill	X			
#8 Cordite Road Landfill	X			
#9 Bonner Avenue Landfill			X	
#10 McPhillips Street Dump			X	
#11 McPhillips Street Landfill	X			
#12 Margaret Park Landfill		X		
#13 Leila Avenue Landfill			X	
#14 Leila Avenue (West) Landfill	X			
#15 Saskatchewan Avenue Dump			X	
#16 Barry Avenue Dump			X	
#17 Harcourt Street Landfill	X			
#18 Summit Road Landfill	X			
#19 Shaftesbury Boulevard Dump			X	
#20 Charleswood Road Landfill			X	
#21 Charleston Street Dump				X
#22 Charleswood Road (South) Landfill		X		
#23 Cadboro Road (East) Landfill		X		
#24 Cadboro Road (West) Landfill		X		
#25 Brady Road Landfill	X or as specified in environmental monitoring program			
#26 Elmwood Landfill		X		
#27 Nairn Avenue Landfill		X		
#28 Brooklands Landfill				X
#29 CNR Dugald Road Landfill				X
#30 Corydon-Osborne Dump	-	-	-	
#31 Red-Assiniboine River Junction Dump	-	-	-	
#32 Lot 61, St.Mary's Road Dump			X	
#33 Riel Dump	X			
#35 River Road Dump			X	
#36 Kilcona Park Landfill	X			

NOTES:

1. Monitoring should take place when climatic conditions maximize gas migration.
2. Probes should be selected on site specific basis to emphasize monitoring in the control zone in areas of concern.
3. Monitoring frequency selected based on methane migration history 1980 or 1982 to 1992.
4. Water levels in gas probes should be measured at the time of sampling.
5. Gas flux should be monitored on a select basis for sites with high gas concentrations.

TABLE 10

PROPOSED LANDFILL GAS MONITORING

TABLE 11

SURVEY OF LINER AND BASE PREPARATION DESIGN

JURISDICTION	DESIGN CRITERIA							PERFORMANCE CRITERIA	
	RECOMPACTED EARTH LINER			COMPOSITE LINER					
				GEOMEMBRANE		COMPACTED SOIL			
	THICKNESS	MATERIAL	HYDRAULIC CONDUCTIVITY (cm/sec)	THICKNESS	MATERIAL	THICKNESS	MATERIAL	CRITERIA	POINT OF APPLICATION
MANITOBA REGULATIONS	Guidelines to discuss site designs							Contain leachate within boundaries of site. Do not contaminate groundwater	Boundary of site not specified. Guidelines to establish compliance boundaries.
ONTARIO POLICY AND REGULATIONS (1)	not specified typically 0.9 to 1.5 m	earth or clay	not specified		Composite allowed. Synthetic Membrane liner without clay not approved when leachate containment required in perpetuity.			Reasonable use concept applied to groundwater: 50% of difference between background and Ontario Drinking Water Objectives for non-health related parameters 25% of difference for health-related parameters. Provincial water quality objectives applied to surface water.	Adjacent Property Adjacent Property
CITY OF EDMONTON Requirements	1.5 m	clay	1×10^{-7}cm/sec					no evidence of contamination in monitoring wells	site perimeter
CITY OF CALGARY PRACTICE - Site in natural clay environment - Site in Gravel pit (>50m to groundwater table)	not specified trench lined w/0.6 m clay (granular cover 0.3m)	clay	1×10^{-7} cm/sec						
CITY OF REGINA - Existing Landfill (fractured clay over low permeability silt) - Proposed Landfill	No liner			Composite being evaluated					
USEPA SUBTITLE D REGULATIONS		not permitted except in combination with a composite liner		min. 30 mil min. 60 mil	Flexible membrane High Density Polyethylene (HDPE)	0.6 m (2 ft)	soil hydraulic conductivity $\leq 1 \times 10^{-7}$ cm/sec	Option for a site specific design that ensures compliance with drinking water standards in the uppermost aquifer	At property boundary or no more than 150 m from fill
STATE OF WISCONSIN CURRENT REGULATIONS	1.5 m	clay	$\leq 1 \times 10^{-7}$					Groundwater must meet groundwater quality standards. Designed to meet a Preventive Action Limit equivalent to 10-50% of the groundwater standard depending on the contaminant to the extent technically and economically feasible.	At property boundary or at distance of 150 ft from waste, whichever is less.
CURRENT PRACTICE (1992)				not specified	Geomembrane	1.5 m (5 ft)	clay		
PROPOSED REVISIONS TO REGULATIONS				min. 60 mil	HDPE	1.2 m (4 ft)	clay		

NOTES:

TABLE 11
SURVEY OF LINER AND BASE PREPARATION DESIGN

TABLE 12

SURVEY OF LEACHATE MANAGEMENT

	COLLECTION	DESIGN CRITERIA	PERFORMANCE CRITERIA	TREATMENT	LEACHATE RECIRCULATION
MANITOBA REGULATIONS	not specified, proposed in guidelines	not specified	contain leachate within boundaries of site. Do not contaminate groundwater	not specified	not specified
ONTARIO POLICY AND GUIDELINES	degree of collection and treatment defined by proposal	not specified	must function for the contaminating lifespan of site, reasonable use concept and Provincial water quality standards applied		allowed to stabilize waste if leachate head concerns addressed
CITY OF EDMONTON PRACTICE		not specified active landfill has perimeter collection system		Pilot Scale Testing	Recirculation trials scheduled for 1993
CITY OF CALGARY PRACTICE		not specified leachate collected at 2 sites		Leachate directed to evaporation ponds, treatment in wastewater plant on one occasion	
CITY OF REGINA	not practised, no leachate buildup				
USEPA SUBTITLE D REGULATIONS	required	not specified	design to maintain <30 cm depth of leachate over liner	not specified	allowed if landfill has a composite liner
STATE OF WISCONSIN REGULATIONS	required	detailed minimum requirements	post closure head of $\leq$ 30 cm on liner	all leachate removed to be disposed at an approved wastewater treatment facility capable of accepting the leachate in accordance with its permit	prohibited

TABLE 12

SURVEY OF LEACHATE MANAGEMENT

TABLE 13

PROPOSED LEACHATE PROBE INSTALLATIONS

SITE	PROBE LOCATIONS
#7 Kimberly Landfill	Distribute across centre
#8 Cordite Landfill	Distribute across centre
#23 Cadboro Road East	Distribute across centre
#24 Cadboro Road West	Distribute across centre
#36 Kilcona Landfill	Repair or install in west cell, install in east cell

TABLE 14

LEACHATE EXTRACTION

SITE	ACTION
#18 Summit Road	Expand collection to entire site
#25 Brady Road	Expand collection to Pre-1987 cells
Sites in Table 13	If head buildup occurs
#11 McPhillips Street Landfill	If snow disposal stops
#4 St. Boniface Landfill II	If snow disposal stops
Other Sites	To remedy leachate breakouts or migration in shallow silts as needed

TABLE 15

PROPOSED LEACHATE MONITORING PROGRAM

Site	No Monitoring At Present	Add to Program	Monitoring Frequency (See List A, B, C, D)			
			Annually	Every 2 Years	Every 5 Years	One Time Scan
#1 Beliveau Road Dump				AB		
#2 St. Boniface Dump	X				A	
#3 St. Boniface Landfill I			A,B			C,D
#4 St. Boniface Landfill II			A,B			C,D
#5 Redonda Dump	X					
#6 Redonda Landfill	X				A	
#7 Kimberly Landfill			A,B			C,D
#8 Cordite Road Landfill			A,B			C,D
#9 Bonner Avenue Landfill	X					
#10 McPhillips Street Dump				A,B		
#11 McPhillips Street Landfill			A,B			CD
#12 Margaret Park Landfill					A	
#13 Leila Avenue Landfill	X	X	A,B			C(D)
#14 Leila Avenue (West) Landfill	X	X	A,B			C(D)
#15 Saskatchewan Avenue Dump				A,B		
#16 Barry Avenue Dump	X				A	
#17 Harcourt Street Landfill			A,B			C,D
#18 Summit Road Landfill			A,B			C,D
#19 Shaftesbury Boulevard Dump	X					
#20 Charleswood Road Landfill	X				A	
#21 Charleston Street Dump	X					
#22 Charleswood Road (South) Landfill				AB		
#23 Cadboro Road (East) Landfill			A,B			C,D
#24 Cadboro Road (West) Landfill			A,B			C,D
#25 Brady Road Landfill			A,B			C,D
#26 Elmwood Landfill				A,B		C,D
#27 Nairn Avenue Landfill	X				A	
#28 Brooklands Landfill	X				A	
#29 CNR Dugald Road Landfill	X					
#30 Corydon-Osborne Dump	X					
#31 Red-Assiniboine River Junction Dump	X					
#32 Lot 61, St.Mary's Road Dump	X				A	
#33 Riel Dump					A	
#35 River Road Dump					A	
#36 Kilcona Park Landfill			A,B			C,D

LIST A
INDICATOR PARAMETERS

Specific Conductance
pH
Total Hardness
Total Alkalinity
Total Kjeldahl Nitrogen
Chloride
Sulfate
Soluble Organic Carbon

LIST B
HEAVY METALS
(Filtered Sample)

Cadmium
Chromium
Lead
and other metals

LIST C

Volatile Organic
Compounds
(EPA 624)

LIST D

Base Neutral*
Extractable
Organic Compounds
EPA (625)

NOTES:

1. Representative Probes at each site should be selected for sampling based on past monitoring results.
2. Other parameters can be analyzed as needed for leachate treatment purposes.
3. Arsenic and mercury should be analyzed on representative samples to establish baseline data on leachate.

TABLE 15

PROPOSED LEACHATE MONITORING PROGRAM

TABLE 16

PRIORITY FOR PROPOSED ORGANICS SCREENS OF LEACHATE

PRIORITY	SITE	CONCERN	ANALYSES PERFORMED
HIGHER	#18 Summit Road Landfill	Large active site, high bedrock groundwater pollution potential	VOCs 5/93
	#25 Brady Road Landfill	Active site, leachate extraction program	
	#36 Kilcona Park Landfill	Potable aquifer high domestic use	VOCs 5/93
	#8 Cordite Road Landfill	Potable aquifer high domestic use	
	#17 Harcourt Street Landfill	High groundwater pollution potential	VOCs 5/93
	#11 McPhillips Street Landfill	Potable aquifer potential future development	
	#23 Cadboro Road (East) Landfill	Industrial waste disposed	
	#24 Cadboro Road (West) Landfill	High surface water (ditch) pollution potential	VOCs 5/93
	#3 St. Boniface Landfill I	Industrial - potential refinery wastes	VOCs 5/93
	#4 St. Boniface Landfill II	Industrial - potential refinery wastes	
	#2 St. Boniface Dump	Refinery wastes	
	#7 Kimberly Landfill	Potable aquifer, nearby industrial users (Cooling Irrigation)	
	#13 Leila Avenue Landfill	Exposed asphalt waste	
	#14 Leila Avenue (West) Landfill	Hydrocarbons disposed, high water table, development proposed	
LOWER	#26 Elmwood Landfill	Unknown wastes	

NOTES:

1. A representative probe must be selected for sampling.
2. Samples must be collected following quality assurance/quality control procedures.

TABLE 17

PROPOSED MONITORING WELL INSTALLATIONS

PRIORITY	SITE	CONCERN
HIGHER	#18 Summit Road Landfill	Improve network on north, west and east
	#36 Kilcona Park Landfill	Improve network between site and domestic users on Knowles Avenue Document current groundwater flow direction
	#17 Harcourt Street Landfill	Monitor between site and domestic and industrial users
	#8 Cordite Road Landfill	Monitor between site and domestic users
	#4 St. Boniface Landfill II	Monitor between site and industrial users
	#7 Kimberly Landfill	Monitor between site and industrial users
	#11 McPhillips Street Landfill	Potable aquifer-Document groundwater quality leaving site
	#23 Cadboro Road (East) Landfill	Non-potable aquifer - Verify clay depth and groundwater quality leaving site
LOWER	#24 Cadboro Road (West) Landfill	Non-potable aquifer - Verify clay depth and groundwater quality leaving site

NOTES:

1. Installations are proposed for bedrock aquifer.
2. Other sites may also be considered for investigation in the future.
3. Number of wells, well locations and well depths should be selected on a site specific basis.

TABLE 18

PROPOSED GROUNDWATER MONITORING PROGRAM IN BEDROCK AQUIFER

SITE	MONITORING WELLS				DOMESTIC COMMERICAL INDUSTRIAL WELLS
			Proposed		
	Existing Wells	Install Wells	Monitoring Twice Per Year	Frequency Annual	Monitored 1990-1992
#1 Beliveau Road Dump	-	-	-	-	-
#2 St. Boniface Dump	-	-		-	-
#3 St. Boniface Landfill I	2	-		X	2
#4 St. Boniface Landfill II	-	X		X	-
#5 Redonda Dump	-	-			-
#6 Redonda Landfill	-	-			-
#7 Kimberly Landfill	-	X		X	-
#8 Cordite Road Landfill	-	X	X		10
#9 Bonner Avenue Landfill	-	-			-
#10 McPhillips Street Dump	-	-			4
#11 McPhillips Street Landfill	-	X		X	-
#12 Margaret Park Landfill	-	-			-
#13 Leila Avenue Landfill	-	-			-
#14 Leila Avenue (West) Landfill	-	-			-
#15 Saskatchewan Avenue Dump	-	-			-
#16 Barry Avenue Dump	-	-			-
#17 Harcourt Street Landfill	-	X	X		7
#18 Summit Road Landfill	4 + 4 new wells	Add	X		7
#19 Shaftesbury Boulevard Dump	-	-			-
#20 Charleswood Road Landfill	-	-			-
#21 Charleston Street Dump	-	-			-
#22 Charleswood Road (South) Landfill	-	-			-
#23 Cadboro Road (East) Landfill	-	X		X	-
#24 Cadboro Road (West) Landfill	-	X		X	-
#25 Brady Road Landfill	X	Specified in Environmental Protection Program			
#26 Elmwood Landfill	-				-
#27 Nairn Avenue Landfill	-				-
#28 Brooklands Landfill	-	-			-
#29 CNR Dugald Road Landfill	-	-			-
#30 Corydon-Osborne Dump	-	-			-
#31 Red-Assiniboine River Junction Dump	-	-			-
#32 Lot 61, St.Mary's Road Dump	-	-			-
#33 Riel Dump	-	-			-
#35 River Road Dump	-	-			-
#36 Kilcona Park Landfill	11	Add	X		15

PARAMETERS

Monitoring Wells

Water elevation
Total Dissolved Solids
Specific Conductance
pH
Total Alkalinity
Total Hardness
Total Kjeldahl Nitrogen
Nitrate plus nitrite as Nitrogen
Chloride
Sulphate
Sodium
Soluble Organic Carbon
Dissolved Iron (filtered) sample
\+ Select metals less frequently

Domestic Wells

All water quality parameters specified for monitoring wells plus additional potable water parameters as required.

NOTES:

1. Other domestic wells in the area or new wells constructed in the future may also be considered for monitoring.
2. Volatile organic parameters should be analyzed at selected monitoring wells at Summit Road Landfill or other sites based on results of leachate analyses.
3. Other domestic or commercial wells were sampled prior to 1990 at McPhillips Street Dump, Summit Road Landfill and Kilcona Landfill.
4. Sites with new installations should be monitored twice per year for 2 years to establish background conditions.

TABLE 18

PROPOSED GROUNDWATER MONITORING PROGRAM
IN BEDROCK AQUIFER

TABLE 19

SURFACE WATER POLLUTION CONCERNS

SITE	CONCERN
#1 Beliveau Road Dump	Potential leachate discharge to Seine River
#24 Cadboro Road (West) Landfill	Potential for leachate breakout and discharge to ditch
#15 Saskatchewan Avenue Dump	Potential leachate discharge to Omand's Creek
#30 Corydon-Osborne Dump	Potential erosion of waste into Red River
#3 St. Boniface Landfill I #4 St. Boniface Landfill II	Leachate ponds and breakout Potential leachate discharge to ditch
#18 Summit Road Landfill	Potential contaminated groundwater discharge to Sturgeon Creek

TABLE 20

PROPOSED SURFACE WATER MONITORING

SITE	LOCATION
#1 Beliveau Road Dump	Seine River
#15 Saskatchewan Avenue Dump	Omand's Creek
#18 Summit Road Landfill	Sturgeon Creek
#36 Kilcona Landfill	Surface water ponds
#25 Brady Road Landfill	Review present surface water monitoring program

NOTE:

1. Upstream and downstream samples should be taken spring, summer and fall and analyzed for List A of leachate parameters on Table 15.

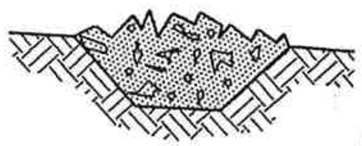
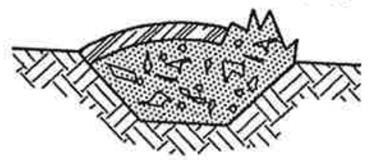
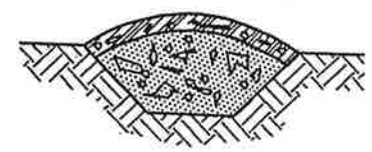
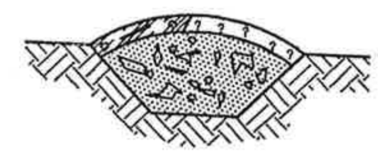
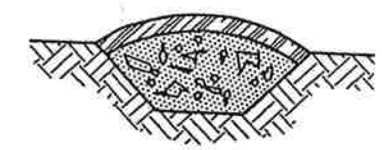
TABLE 21

SURVEY OF FINAL COVER

	TOPSOIL AND ROOTING LAYER		LOW PERMEABILITY CAP		
	THICKNESS	MATERIAL	THICKNESS	MATERIAL	PERMEABILITY (K)
MANITOBA - Class 2 & 3 Regulations - Class 1 Guidelines	not specified to be proposed	not specified	minimum 0.5 m	compacted earth	not specified
ONTARIO POLICY AND GUIDELINES	not specified	not specified	not specified	synthetic membrane not encouraged clay acceptable	
CITY OF EDMONTON	30 cm 60 cm	Topsoil Native silty soils	0.6 m	clay	1 x 10^{-7}cm/sec
CITY OF CALGARY	15 cm	loam seeding	1 m	clay	
CITY OF REGINA Recommended For existing site closure	10 cm 45 cm	topsoil clay till	0.9 m 0.6 m	clay foundation layer beneath clay	$\leq$1 x 10^{-6} cm/sec
USEPA SUBTITLE D REGULATIONS	15 cm	earthen material capable of sustaining plant growth	0.5 m	earthen material	$\leq$ bottom liner. If no liner, K of cap $\leq$ K of subsoils or no greater than 1x10^{-5} cm/sec whichever is less
STATE OF WISCONSIN REGULATIONS					
Existing Facilities	15 cm	topsoil	0.6 m	fine grained soil	Max 1x10^{-5} cm/sec or permeability $\leq$ bottom liner system
New Facilities 1992	15 cm 50-76 cm	topsoil soil cover layer	0.6 m	clay barrier, 50% P200	$\leq$ 1x10^{-7} cm/sec (construction specification)

TABLE 22

LANDFILL COVER EVALUATION

NO COVER	COVER WITH EXPOSED WASTE	COVER IS "FILL" MAY CONTAIN CONSTRUCTION DEBRIS, GLASS, ASH ETC.	LARGE AREAS UNDOCUMENTED COVER APPEARS TO BE "FILL" MAY CONTAIN CONSTRUCTION DEBRIS GLASS, ASH ETC.	COMPACTED CLAY COVER
				
29 CNR Dugald Road Landfill 30 Corydon-Osborne Dump	7 Kimberly Landfill 13 Leila Avenue Landfill 19 Shaftesbury Blvd. Dump	2 St. Boniface Dump 4 St. Boniface Landfill II 6 Redonda Landfill 9 Bonner Landfill 12 Margaret Park Landfill 13 Leila Avenue Landfill 14 Leila Avenue Landfill West 17 Harcourt Street Landfill 31 Red-Assiniboine River	1 Beliveau road Landfill 3 St. Boniface Site I 5 Redonda Dump 7 Kimberly Landfill 10 McPhillips Street Dump 11 McPhillips Street Landfill 15 Saskatchewan Avenue Dump 16 Barry Avenue Dump 19 Shaftesbury Boulevard Dump 22 Charleswood Road 23 Cadboro Road East 24 Cadboro Road West 26 Elmwood Landfill 27 Nairn Avenue Landfill 28 Brooklands Landfill 32 Lot 61, St. Mary's Road Dump 33 Riel Dump 35 River Road	**CLOSED SITES** 8 Cordite Road Landfill (0.6-1.2 m) large areas undocumented) 36 Kilcona (1.5-4.6 m) **ACTIVE SITES** 18 Summit Road Landfill (2 m required) 25 Brady Road Landfill (2 m required)

NOTES:

1. Field investigations to document cover type and thickness are required on all sites with fill cover.
2. Closure plans for Summit Road Landfill and Brady Road Landfill should include a plan for cover documentation.

TABLE 22

LANDFILL COVER EVALUATION

TABLE 23

PROPOSED TOPOGRAPHY AND COVER PRIORITIES

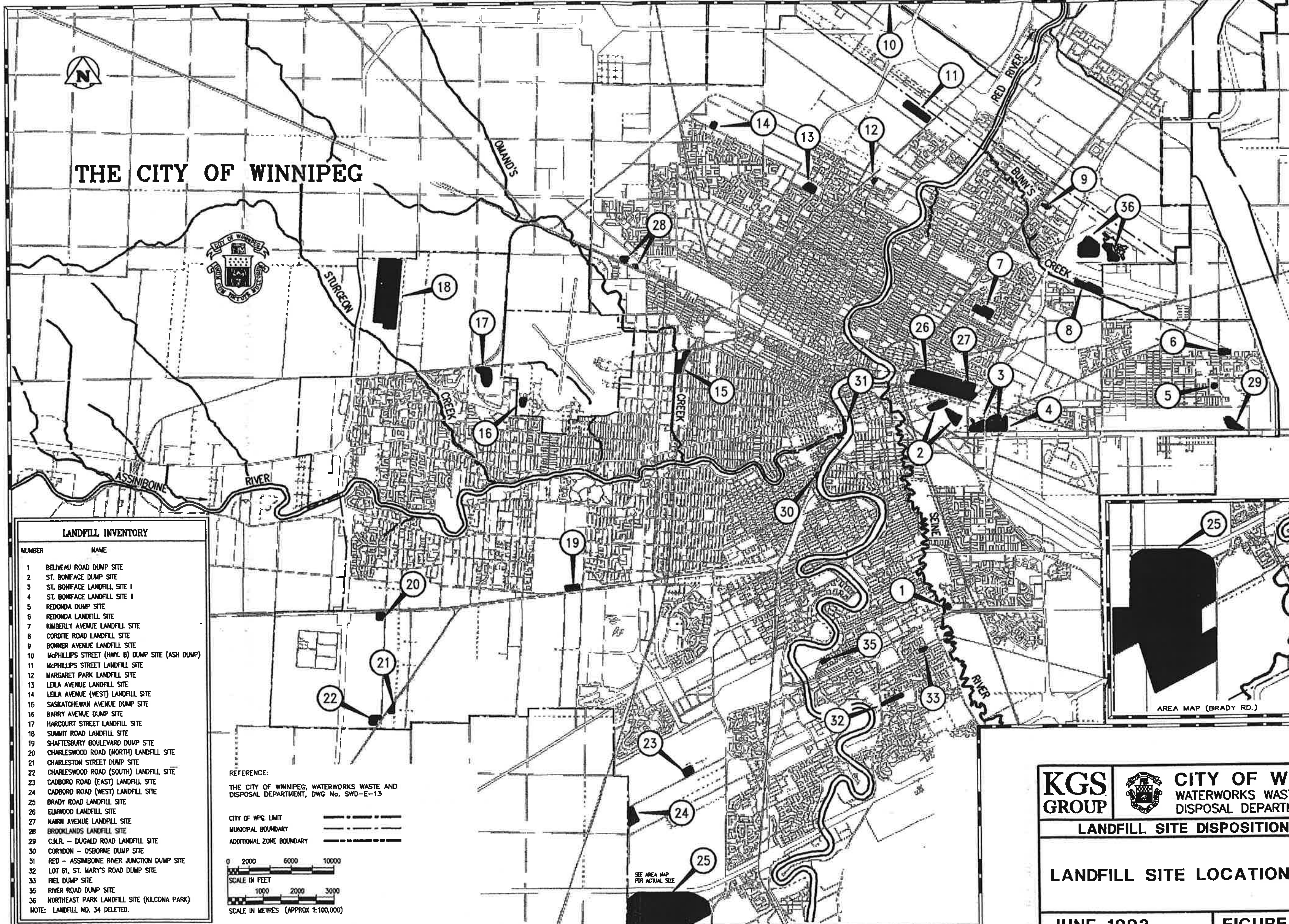
SITE	RECOMMENDED ACTION
1. SAFETY	
Exposed Waste	
13 Leila Avenue Landfill	Remove "Asphalt" waste, replace cover.
7 Kimberly Landfill	Perform ongoing maintenance on exposed tires/waste.
19 Shaftesbury Blvd. Dump	Grade and cover landfill
Recreation Areas	
9 Bonner Avenue	Document cover in day care playground, replace if waste found.
6 Redonda Landfill	Document cover in tot lot, replace if needed, review cover landscaping at school yard.
33 Riel Dump	Document cover in playing fields.
16 Barry Avenue Dump	Document cover on hill, replace if waste found.
5 Redonda Dump	Document cover on hill, replace if waste found.
2. EROSION AND SLOPE STABILITY	
8 Cordite Landfill	Repair Erosion Gully and inspect slopes. Document cover and replace if thin.
36 Kilcona Landfill	Restore positive drainage at landfill top and inspect slopes. Repairs erosion gullies. Continue inspection.
15 Saskatchewan Avenue Landfill	
3. SURFACE WATER CONTAMINATION	
24 Cadboro Road West	Document cover along ditches and add if necessary to prevent future leachate breakout.
3 St. Boniface I Landfill	Add cover as necessary in areas of leachate breakout.
4. LEACHATE PRODUCTION	
18 Summit Road	Document and develop closure detail.
36 Kilcona	Document and refine geometry to maintain positive runoff.
25 Brady Road Landfill	Document and add cover to pre-1987 cells as needed.
4 St. Boniface Landfill II	Regrade topography to produce positive runoff.
11 McPhillips Street Landfill	Add cover and regrade to limit infiltration.

NOTES:

1. Other sites require cover documentation as noted in previous tables.
2. Excavation or replacement of cover should be done on a site specific basis to limit any increases in gas migration.

FIGURES

(PLOT FACTOR .28=1)
432mm X 279mm/ BASE SCALE: 1:1



KGS GROUP

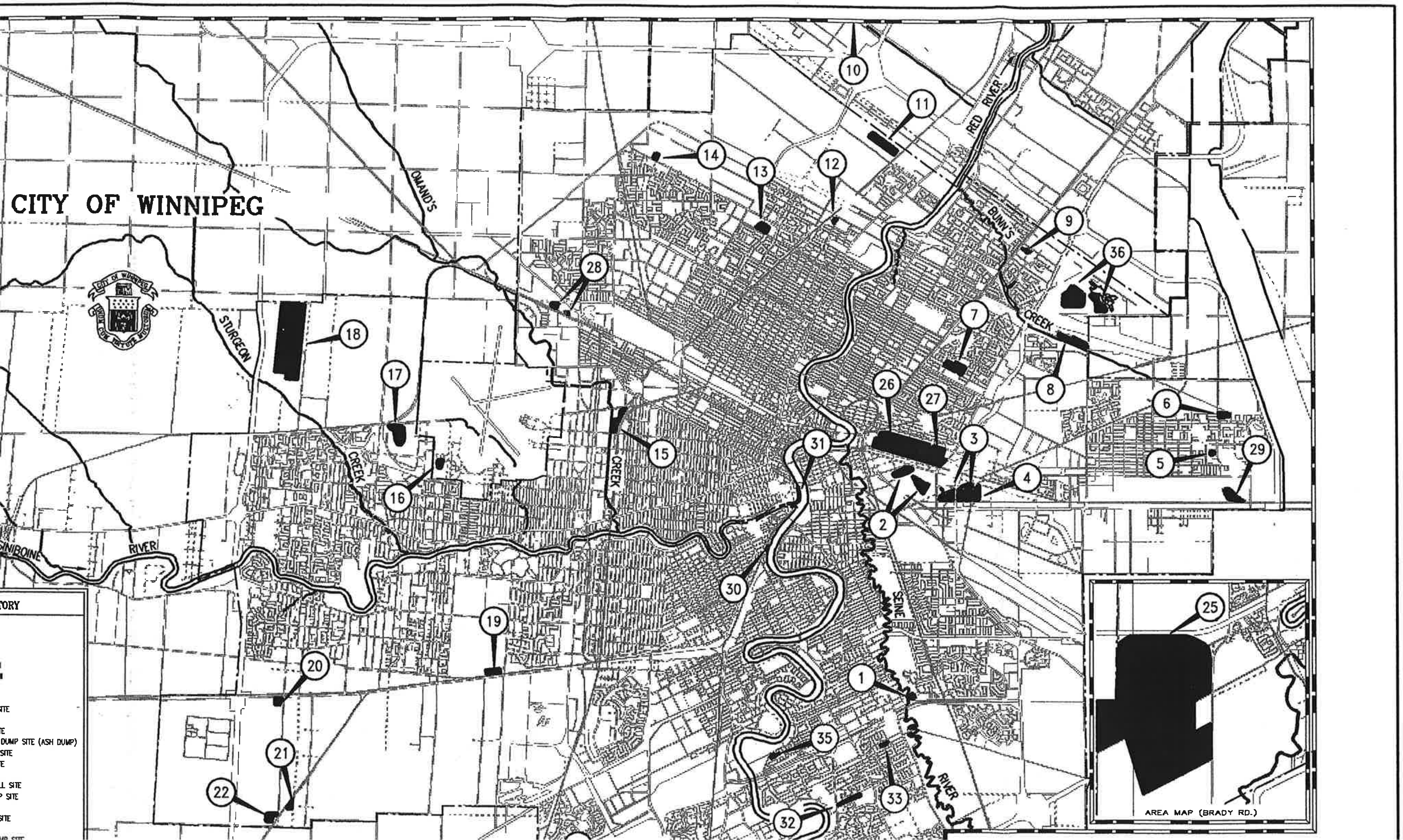
CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

LANDFILL SITE LOCATIONS

JUNE 1993 | FIGURE 1

KGS No. 92-107-06F1


CITY OF WINNIPEG
OMAND'S
STURGEON
CREEK
RED RIVER
BUNN'S
CREEK
CREEK
SEINE
RIVER
RIVER
SINIBOINE
TORY
DUMP SITE (ASH DUMP)
AREA MAP (BRADY RD.)
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4
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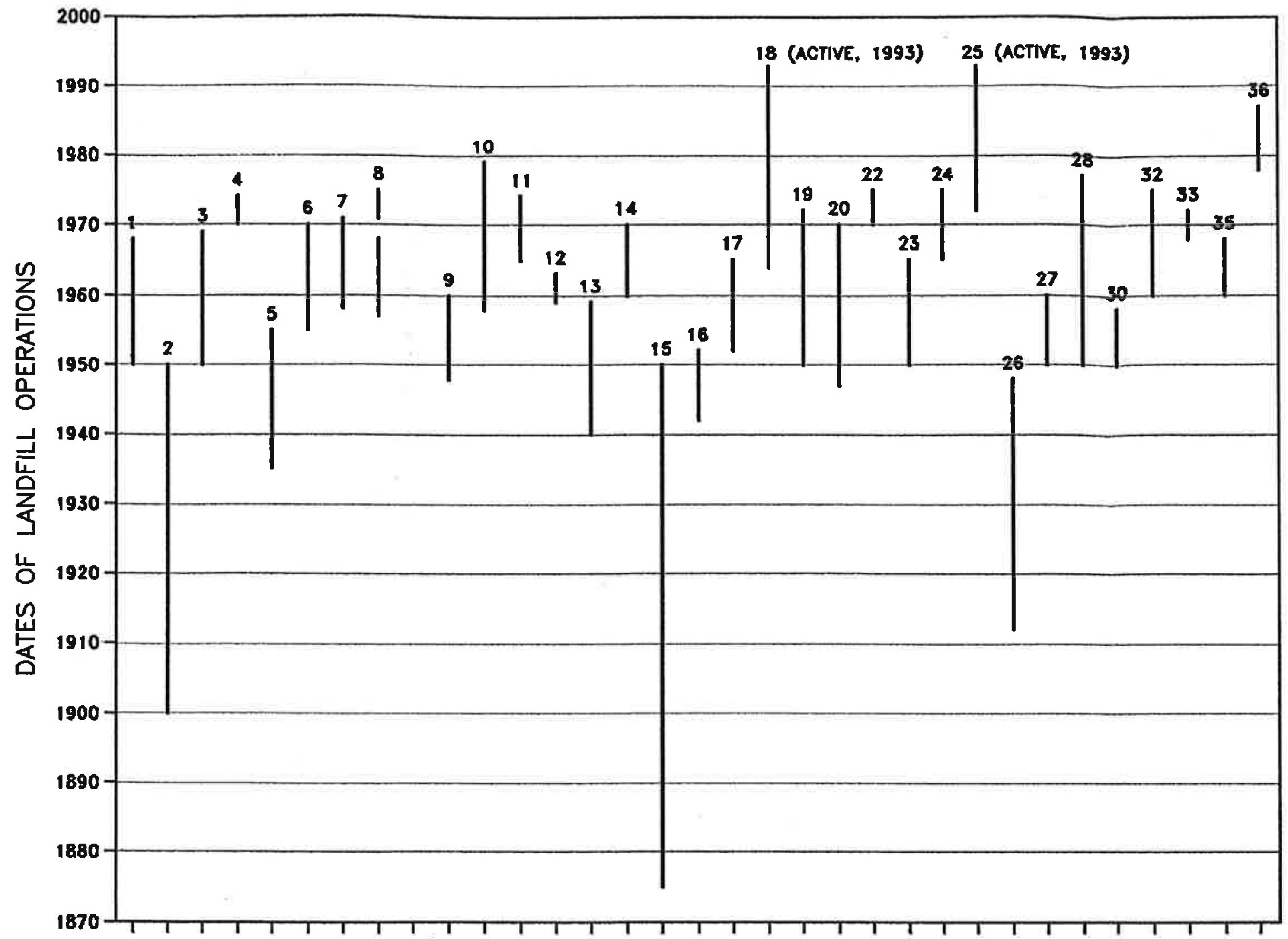
432mm X 279mm/ BASE SCALE: 1:1



LANDFILL INVENTORY

NUMBER	NAME
1	BELIVEAU ROAD DUMP SITE
2	ST. BONIFACE DUMP SITE
3	ST. BONIFACE LANDFILL SITE I
4	ST. BONIFACE LANDFILL SITE II
5	REDONDA DUMP SITE
6	REDONDA LANDFILL SITE
7	KIMBERLY AVENUE LANDFILL SITE
8	CORDITE ROAD LANDFILL SITE
9	BONNER AVENUE LANDFILL SITE
10	McPHILLIPS STREET (HWY. 8) DUMP SITE (ASH DUMP)
11	McPHILLIPS STREET LANDFILL SITE
12	MARGARET PARK LANDFILL SITE
13	LEILA AVENUE LANDFILL SITE
14	LEILA AVENUE (WEST) LANDFILL SITE
15	SASKATCHEVAN AVENUE DUMP SITE
16	BARRY AVENUE DUMP SITE
17	HARCOURT STREET LANDFILL SITE
18	SUMMIT ROAD LANDFILL SITE
19	SHAFTESBURY BOULEVARD DUMP SITE
20	CHARLESWOOD ROAD (NORTH) LANDFILL SITE
21	CHARLESTON STREET DUMP SITE
22	CHARLESWOOD ROAD (SOUTH) LANDFILL SITE
23	CADBORO ROAD (EAST) LANDFILL SITE
24	CADBORO ROAD (WEST) LANDFILL SITE
25	BRADY ROAD LANDFILL SITE
26	ELMWOOD LANDFILL SITE
27	NAIRN AVENUE LANDFILL SITE
28	BROOKLANDS LANDFILL SITE
29	C.N.R. - DUGALD ROAD LANDFILL SITE
30	CORYDON - OSBORNE DUMP SITE
31	RED - ASSINIBOINE RIVER JUNCTION DUMP SITE
32	LOT 61, ST. MARY'S ROAD DUMP SITE
33	RIEL DUMP SITE
35	RIVER ROAD DUMP SITE
36	NORTHEAST PARK LANDFILL SITE (KILCONA PARK)

NOTE: LANDFILL NO. 34 DELETED.

NOTE:

1. DATES UNAVAILABLE FOR SITES 29 (CNR DUGALD) AND 31 (RED – ASSINIBOINE RIVER)
2. NO WASTE FOUND AT SITE 21 CHARLESTON STREET DUMP SITE

KGS No. 92-107-06F2

KGS GROUP

CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

WASTE DISPOSAL HISTORY

JUNE 1993

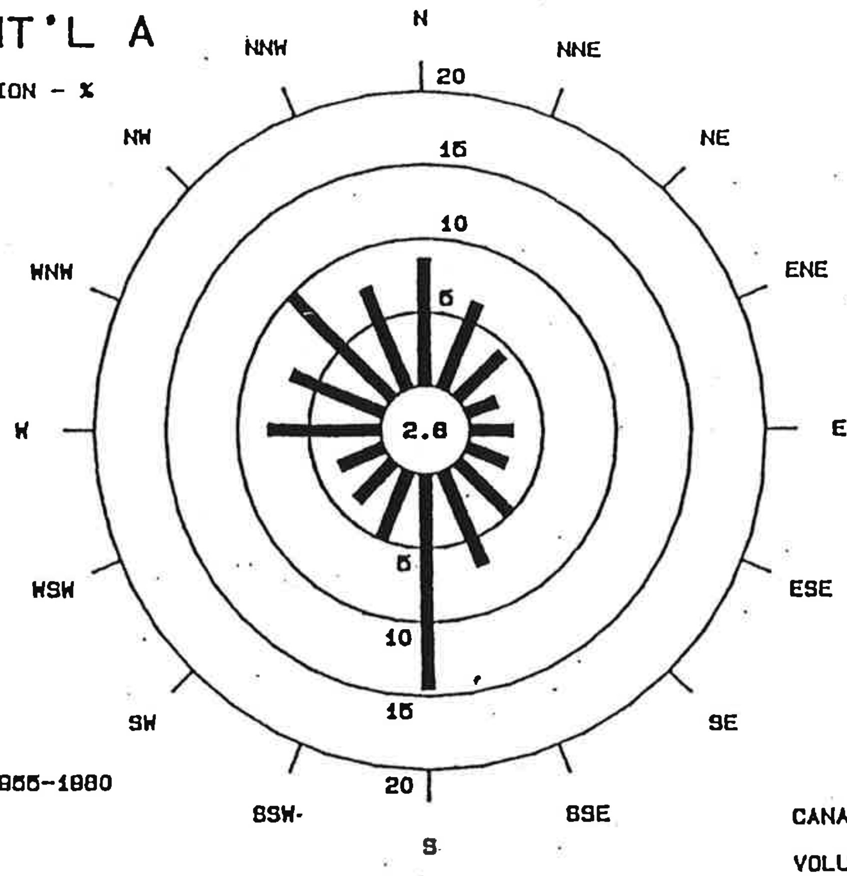
FIGURE 2

WINNIPEG INT'L A

FREQUENCY BY DIRECTION – %

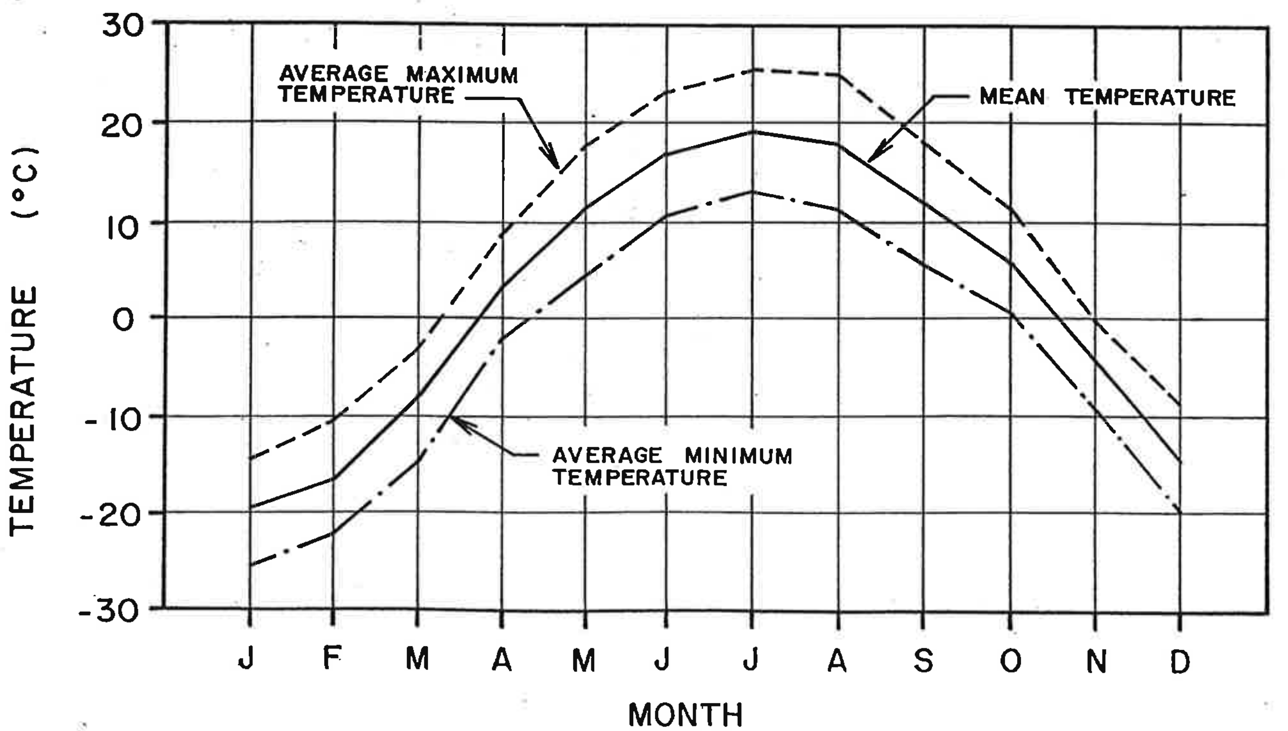
Dotn	Speed	Freq
N	20.8	8.6
NNE	18.1	6.9
NE	15.8	4.3
ENE	14.8	2.1
E	16.1	2.8
ESE	17.8	2.8
SE	18.0	4.8
SSE	20.2	8.8
S	21.7	14.5
SSW	17.0	5.0
SW	14.5	3.8
WSW	15.2	3.8
W	16.4	7.8
WNW	18.2	8.9
NW	21.5	10.0
NNW	22.2	7.4

PERIOD OF RECORD: 1955–1980

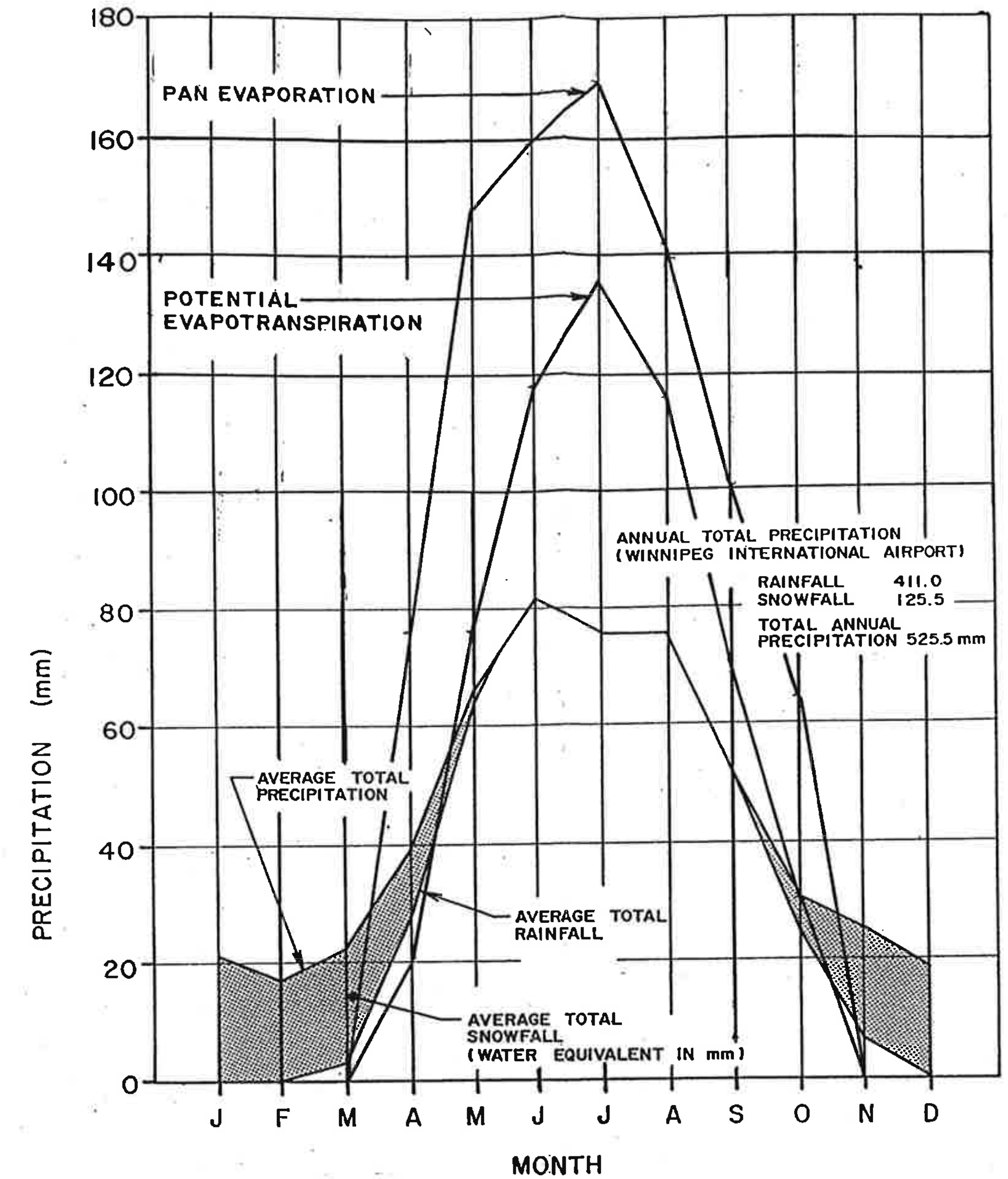


CANADIAN CLIMATE NORMALS
VOLUME 5 : WIND
1951–1980

ANNUAL WIND ROSE



AVERAGE TEMPERATURE (WINNIPEG INTERNATIONAL AIRPORT)



PRECIPITATION, PAN EVAPORATION AND POTENTIAL EVAPOTRANSPIRATION

PAN EVAPORATION (mm)	
MAY	148
JUNE	159
JULY	169
AUG	142
SEPT	100
OCT	64
TOTAL:	782 mm

POTENTIAL EVAPOTRANSPIRATION (mm)	
APRIL	21
MAY	76
JUNE	118
JULY	136
AUG	116
SEPT	70
OCT	30
TOTAL:	567 mm

KGS GROUP

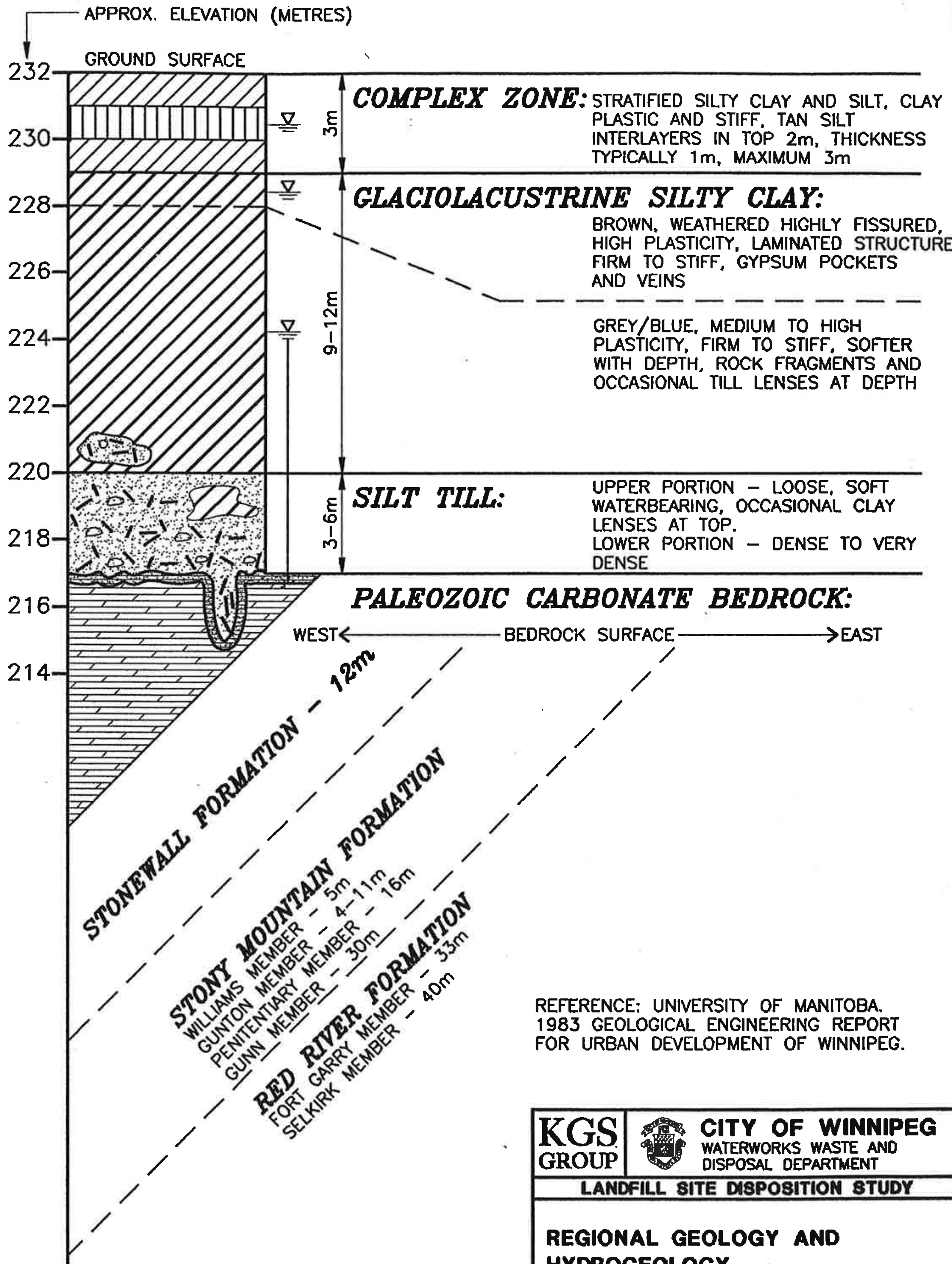
CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

CLIMATOLOGICAL DATA

JUNE 1993 | **FIGURE 3**

KGS No. 92-107-06F3



KGS GROUP

CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

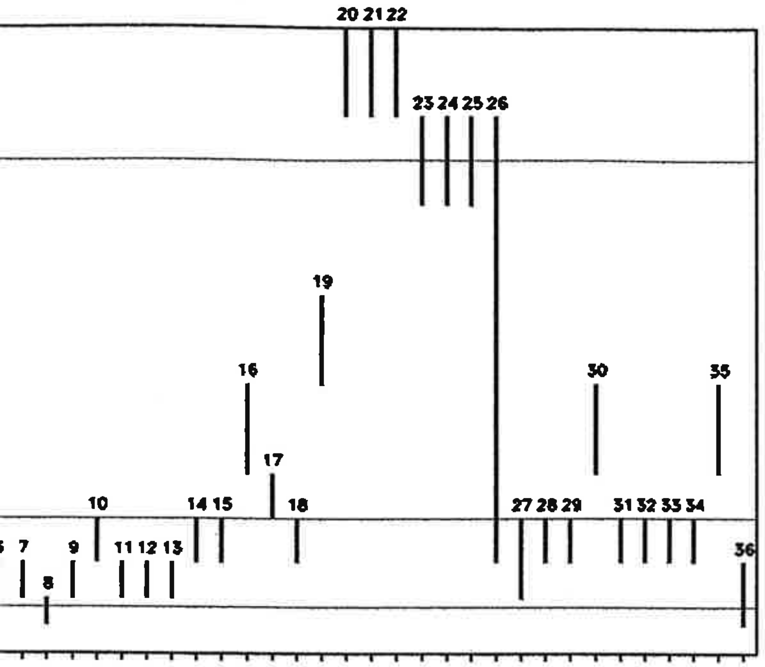
REGIONAL GEOLOGY AND HYDROGEOLOGY

JUNE 1993 | **FIGURE 4**

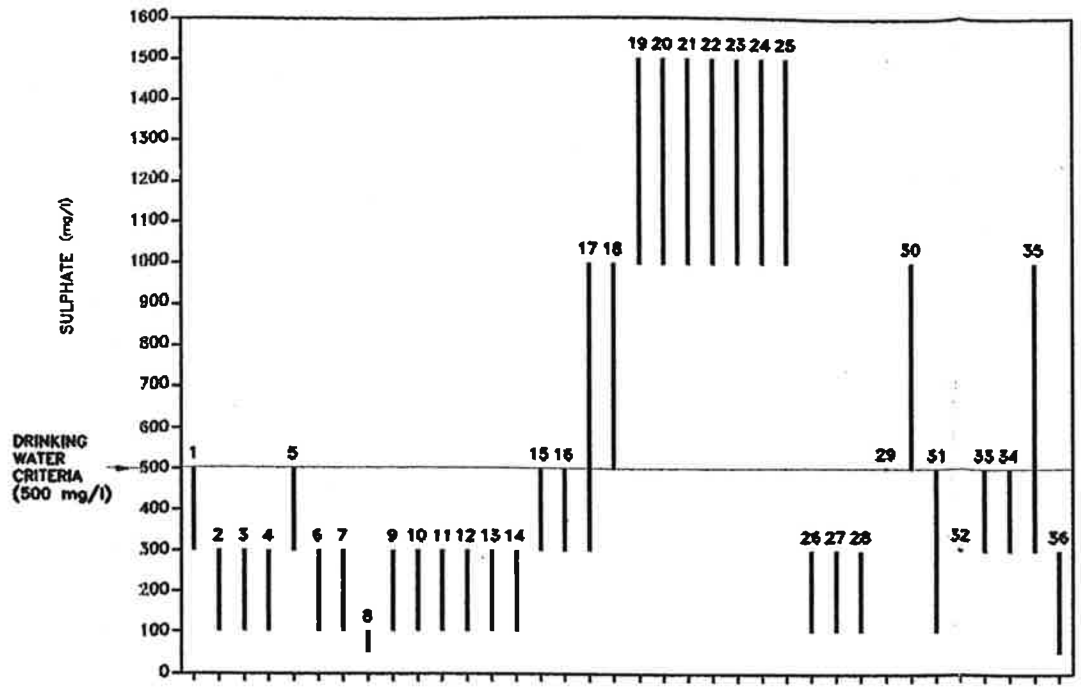
216mm x 279mm/ SCALE: 1:15

KGS NO. 92-107-06F4

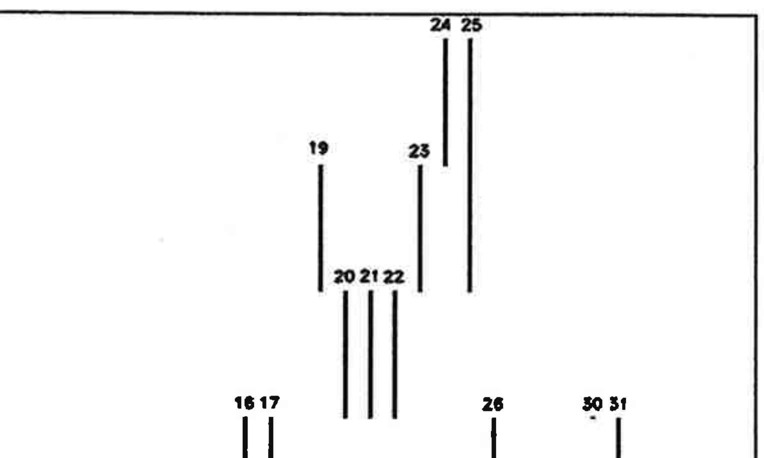
TOTAL DISSOLVED SOLIDS



SULPHATE



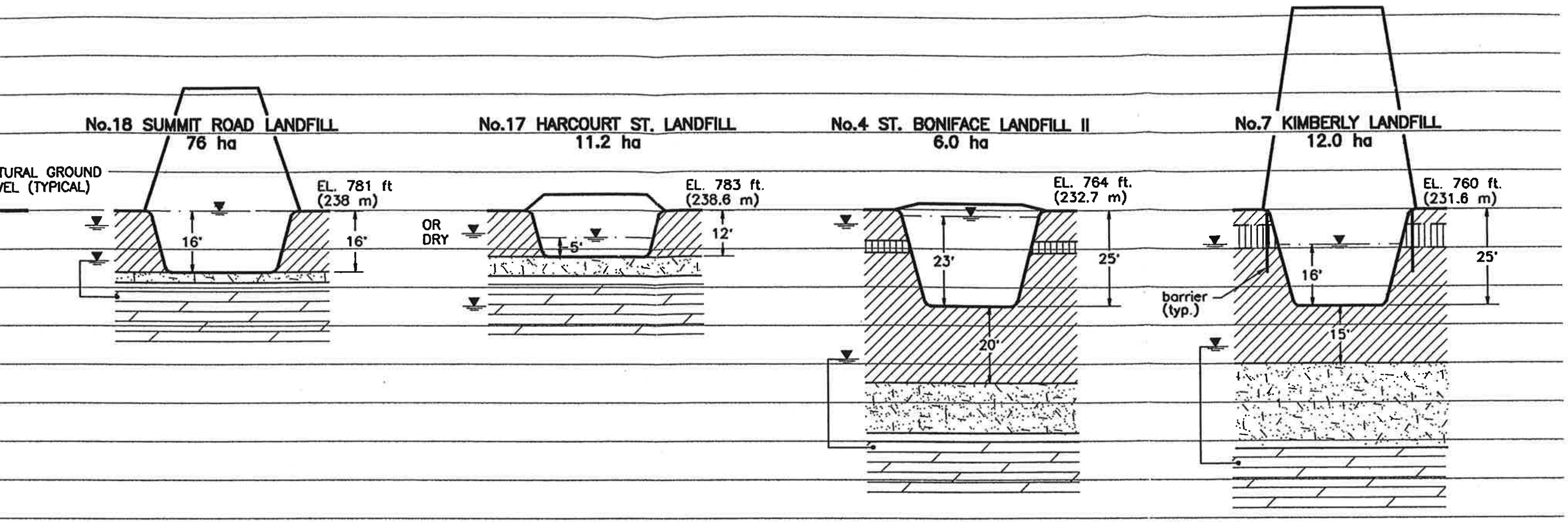
CHLORIDE



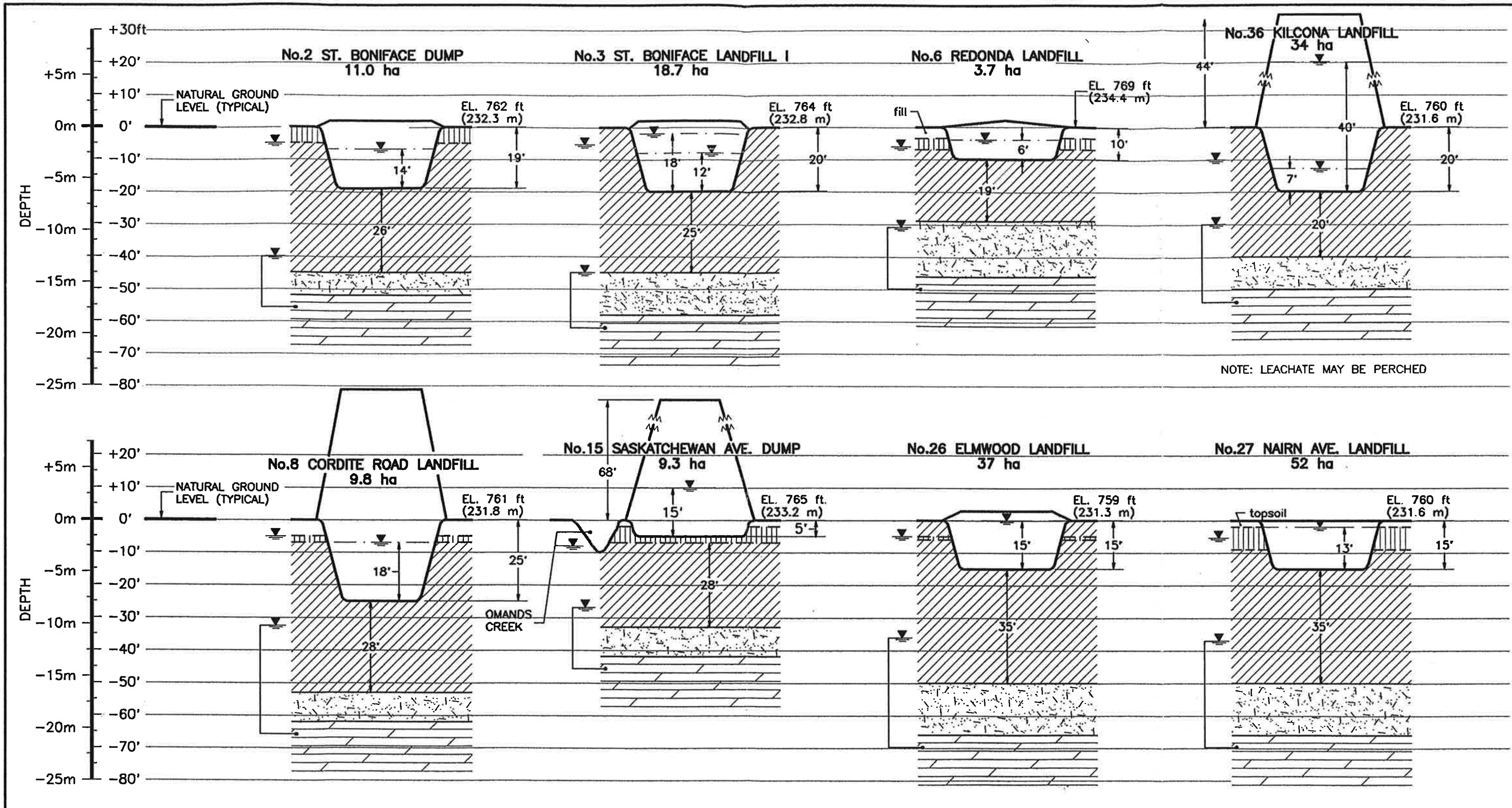
LANDFILL INVENTORY			
NUMBER	NAME		
1	BELIVEAU ROAD DUMP SITE	21	CHARLESTON STREET DUMP SITE
2	ST. BONIFACE DUMP SITE	22	CHARLESWOOD ROAD (SOUTH) LANDFILL SITE
3	ST. BONIFACE LANDFILL SITE I	23	CADBORO ROAD (EAST) LANDFILL SITE
4	ST. BONIFACE LANDFILL SITE II	24	CADBORO ROAD (WEST) LANDFILL SITE

NOTES:

1. SOURCE: UNIVERSITY OF MANITOBA 1983 PLATES 15,16 & 17.
2. RANGES ARE APPROXIMATE, LOCAL VALUES MAY VARY.



VERTICAL SCALE = 1" = 30'



LEGEND

(symbol)	SILT	(symbol)	CARBONATE BEDROCK
(symbol)	CLAY	(symbol)	WATER ELEVATION
(symbol)	SILT TILL	12.0 ha	LANDFILL AREA

VERTICAL SCALE = 1" = 30'

HORIZONTAL SCALE = N.T.S.

NOTE:

1. DIAGRAMS REPRESENT GENERAL SITE CONDITIONS. ACTUAL CONDITIONS MAY VARY.

KGS GROUP

CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

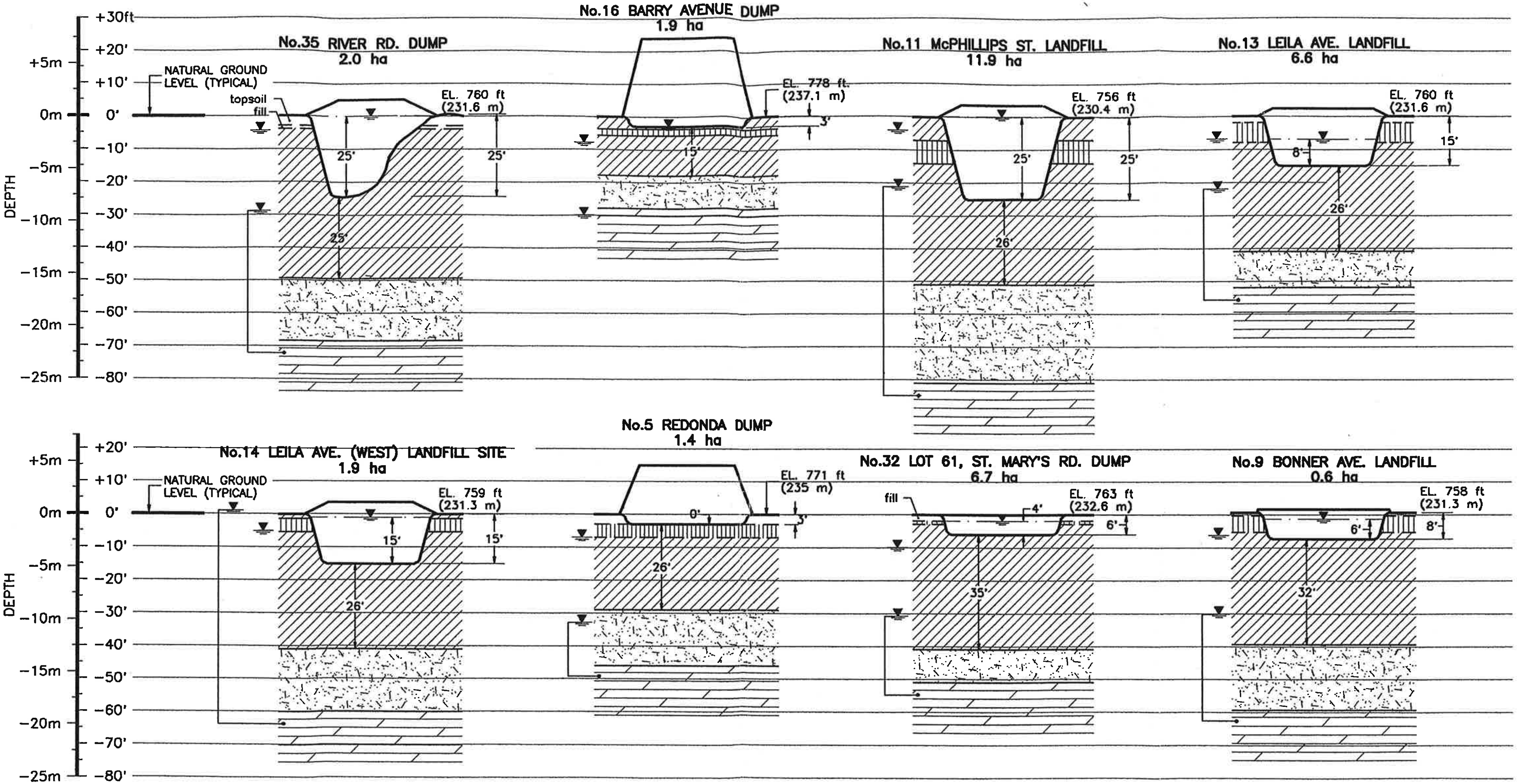
LANDFILL SITE DISPOSITION STUDY

LANDFILL SITE SECTIONS
POTABLE AQUIFER
MODERATE GROUNDWATER POLLUTION POTENTIAL PART 1

JUNE 1993 | **FIGURE 7**

432mm X 279mm/ SCALE: 1"=30'

KGS No. 92-107-06F7



VERTICAL SCALE = 1" = 30'
HORIZONTAL SCALE = N.T.S.

LEGEND

SILT	CARBONATE BEDROCK
CLAY	WATER ELEVATION
SILT TILL	12.0 ha LANDFILL AREA

NOTE:

1. DIAGRAMS REPRESENT GENERAL SITE CONDITIONS. ACTUAL CONDITIONS MAY VARY.

KGS GROUP

CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

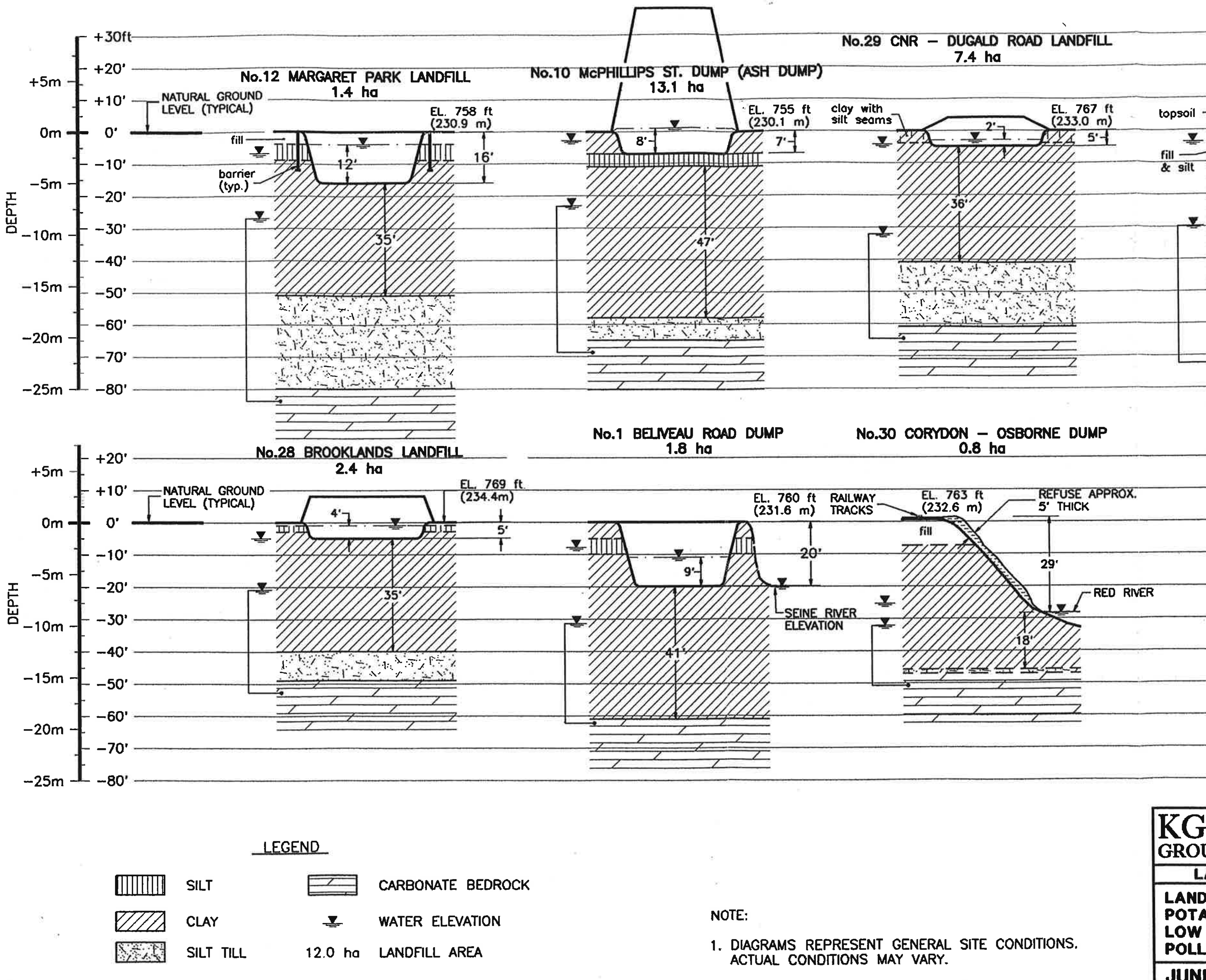
LANDFILL SITE SECTIONS
POTABLE AQUIFER
MODERATE GROUNDWATER POLLUTION POTENTIAL PART 2

JUNE 1993

FIGURE 8

KGS No. 92-107-06F8

432mm X 279mm/ SCALE: 1"=30'



NOTE:

1. DIAGRAMS REPRESENT GENERAL SITE CONDITIONS. ACTUAL CONDITIONS MAY VARY.

432mm x 279mm/ SCALE: 1"=30'

KGS No. 92-107-06F9

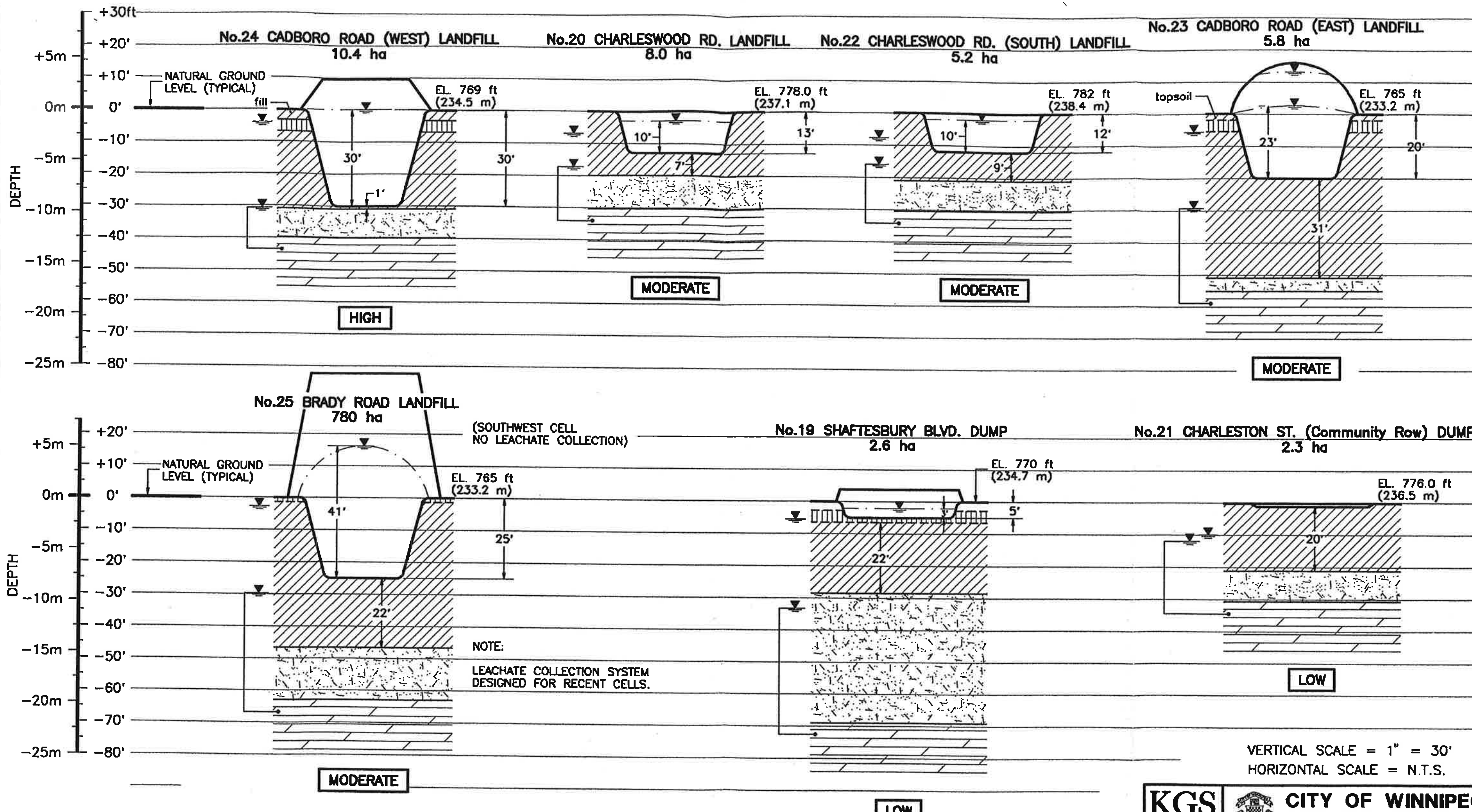
KGS GROUP

CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

LANDFILL SITE SECTIONS POTABLE AQUIFER LOW GROUNDWATER POLLUTION POTENTIAL

JUNE 1993 | FIGURE 9



432mm x 279mm/ SCALE: 1"=30'

LEGEND

- SILT
- CLAY
- SILT TILL
- CARBONATE BEDROCK
- WATER ELEVATION
- 10.4 ha LANDFILL AREA

NOTE:

1. DIAGRAMS REPRESENT GENERAL SITE CONDITIONS. ACTUAL CONDITIONS MAY VARY.

KGS GROUP

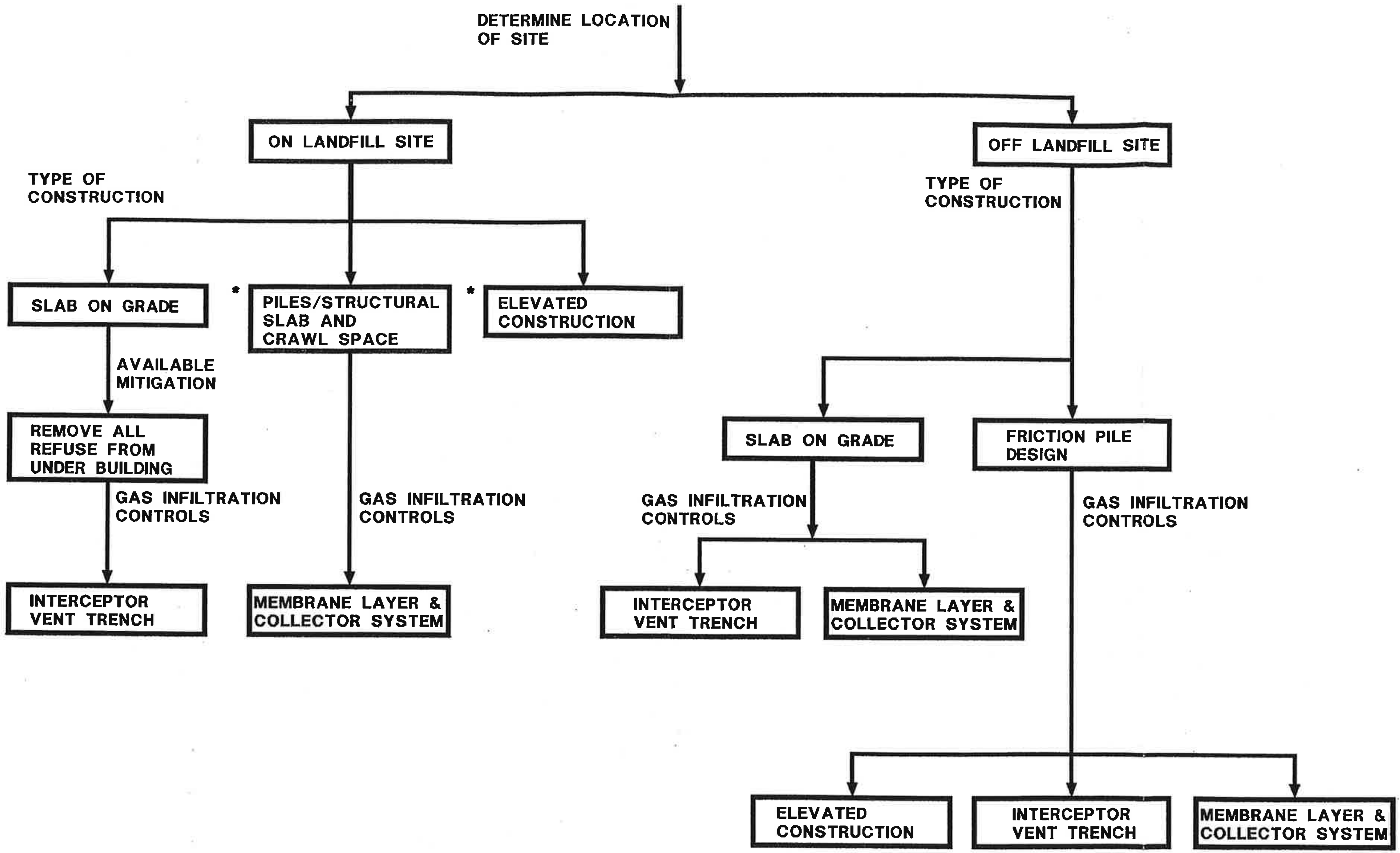
CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

**LANDFILL SITE SECTIONS
NONPOTABLE AQUIFER
GROUNDWATER POLLUTION POTENTIAL**

JUNE 1993 | FIGURE 10

KGS No. 92-107-0610



* FOUNDATION DESIGN MUST TAKE INTO ACCOUNT REDUCED EFFECTIVE LENGTH OF PILES.

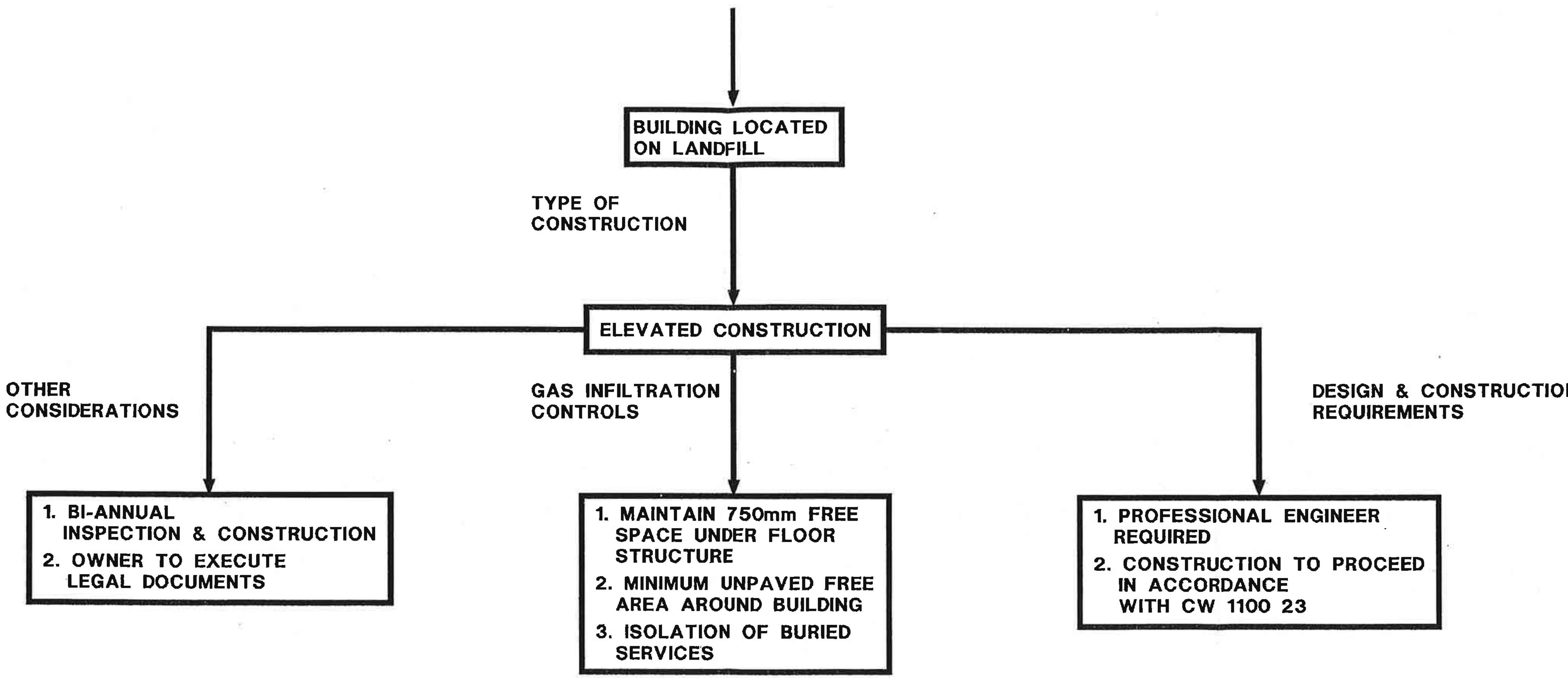
KGS GROUP | CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

EXISTING POLICY FOR BUILDING ON LANDFILL SITES

JUNE 1993 | FIGURE 11

92-107-0611



KGS GROUP

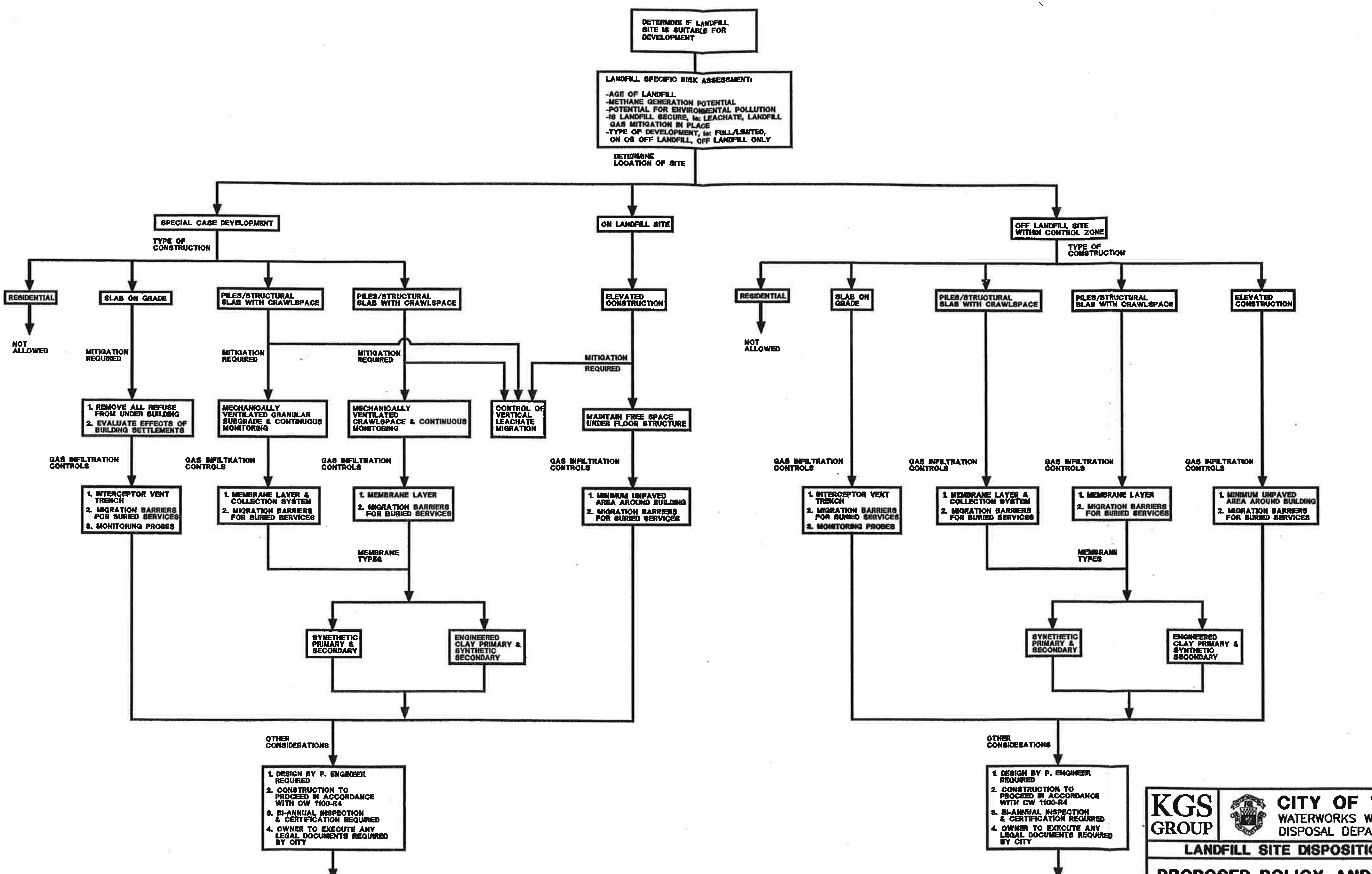
CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

EXISTING DESIGN GUIDELINES FOR LANDFILL SITE CONSTRUCTION

JUNE 1993 | FIGURE 12

92-107-0512



KGS GROUP

CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

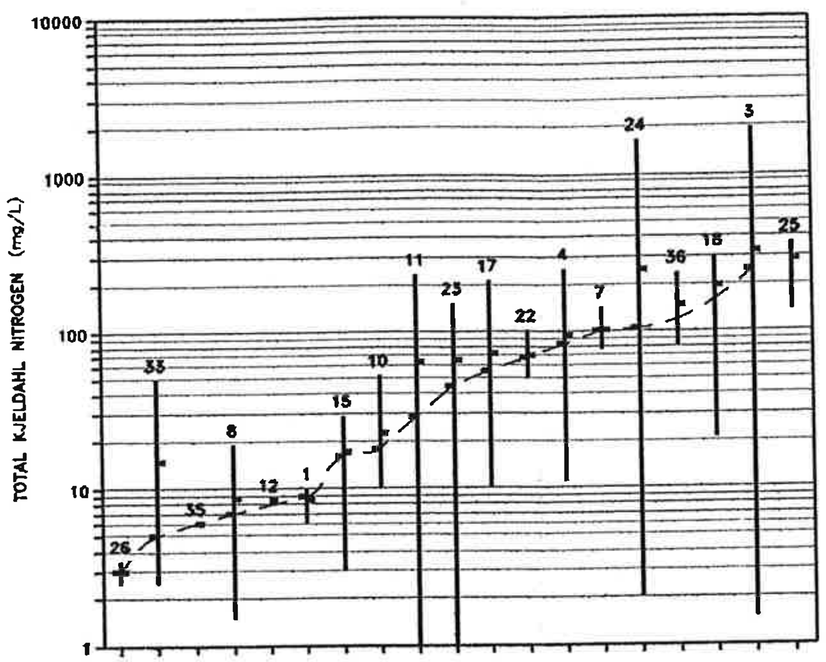
LANDFILL SITE DISPOSITION STUDY

PROPOSED POLICY AND GUIDELINES FOR CONSTRUCTION ON OR NEAR LANDFILLS

JUNE 1993 | FIGURE 13

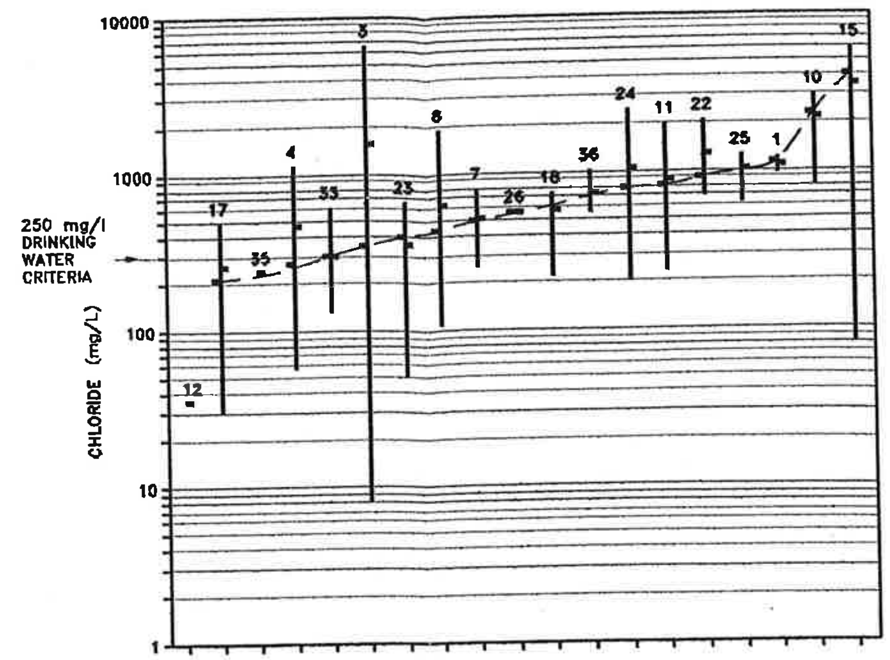
432mm X 279mm/ BASE SCALE: 1:1

TOTAL KJELDAHL NITROGEN

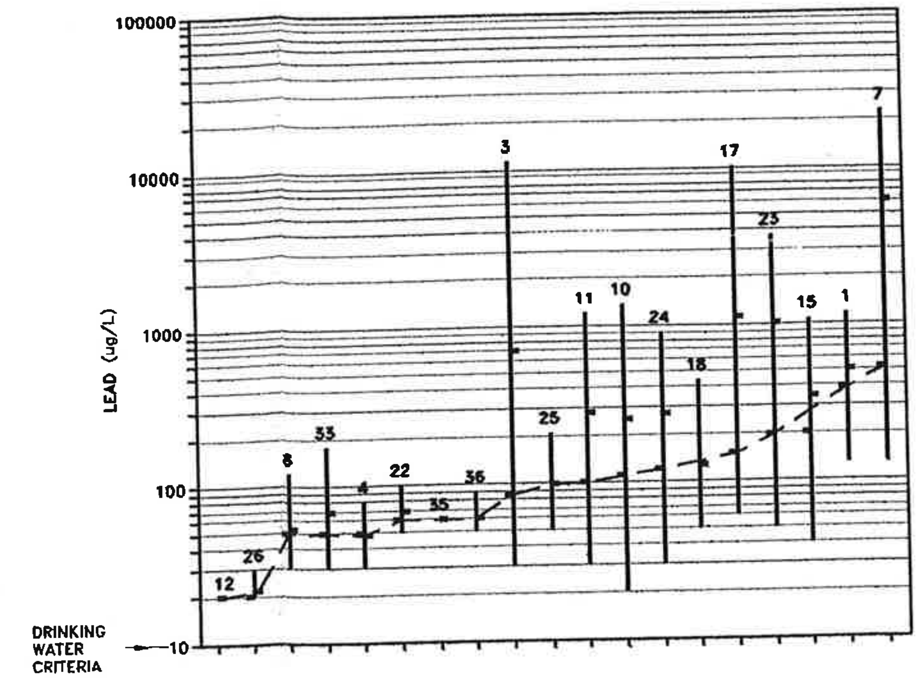


MEDIAN VALUE,
(EQUAL NUMBER OF VALUES ABOVE AND BELOW)

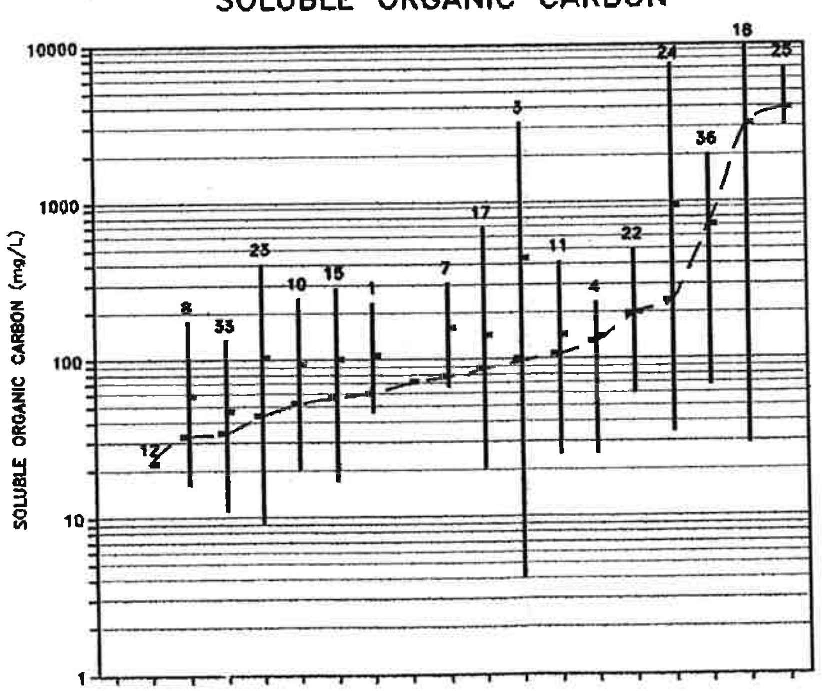
CHLORIDE



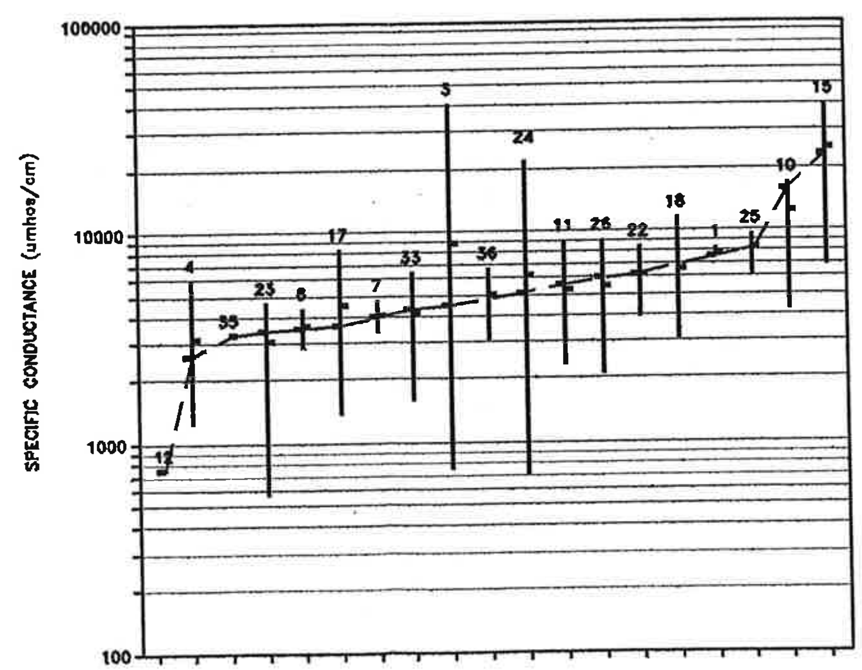
LEAD



SOLUBLE ORGANIC CARBON



SPECIFIC CONDUCTANCE



LANDFILL INVENTORY

NUMBER	NAME		
1	BELIVEAU ROAD DUMP SITE	21	CHARLESTON STREET DUMP SITE
2	ST. BONIFACE DUMP SITE	22	CHARLESWOOD ROAD (SOUTH) LANDFILL SITE
3	ST. BONIFACE LANDFILL SITE I	23	CADBORO ROAD (EAST) LANDFILL SITE
4	ST. BONIFACE LANDFILL SITE II	24	CADBORO ROAD (WEST) LANDFILL SITE
5	REDONDA DUMP SITE	25	BRADY ROAD LANDFILL SITE
6	REDONDA LANDFILL SITE	26	ELMWOOD LANDFILL SITE
7	KIMBERLY AVENUE LANDFILL SITE	27	NAIRN AVENUE LANDFILL SITE
8	CORDITE ROAD LANDFILL SITE	28	BROOKLANDS LANDFILL SITE
9	BONNER AVENUE LANDFILL SITE	29	C.N.R. - DUGALD ROAD LANDFILL SITE
10	McPHILLIPS STREET (HWY. 8) DUMP SITE (ASH DUMP)	30	CORYDON - OSBORNE DUMP SITE
11	McPHILLIPS STREET LANDFILL SITE	31	RED - ASSINIBOINE RIVER JUNCTION DUMP SITE
12	MARGARET PARK LANDFILL SITE	32	LOT 61, ST. MARY'S ROAD DUMP SITE
13	LEILA AVENUE LANDFILL SITE	33	RIEL DUMP SITE
14	LEILA AVENUE (WEST) LANDFILL SITE	35	RIVER ROAD DUMP SITE
15	SASKATCHEVAN AVENUE DUMP SITE	36	NORTHEAST PARK LANDFILL SITE (KILCONA PARK)
16	BARRY AVENUE DUMP SITE		
17	HARCOURT STREET LANDFILL SITE		NOTE: LANDFILL NO. 34 DELETED.
18	SUMMIT ROAD LANDFILL SITE		
19	SHAFTESBURY BOULEVARD DUMP SITE		
20	CHARLESWOOD ROAD (NORTH) LANDFILL SITE		

NOTES:

1. VALUES REPRESENT LEACHATE COLLECTION SAMPLES FOR BRADY ROAD, SUMMIT AND KILCONA LANDFILLS.
2. VALUES REPRESENT LEACHATE PROBES FOR ALL OTHER SITES.
3. SAMPLE IS DIGESTED FOR LEAD ANALYSIS. PARTICULATE MATTER IN SAMPLE LIKELY ACCOUNTS FOR VERY HIGH RANGE READINGS.

KGS GROUP

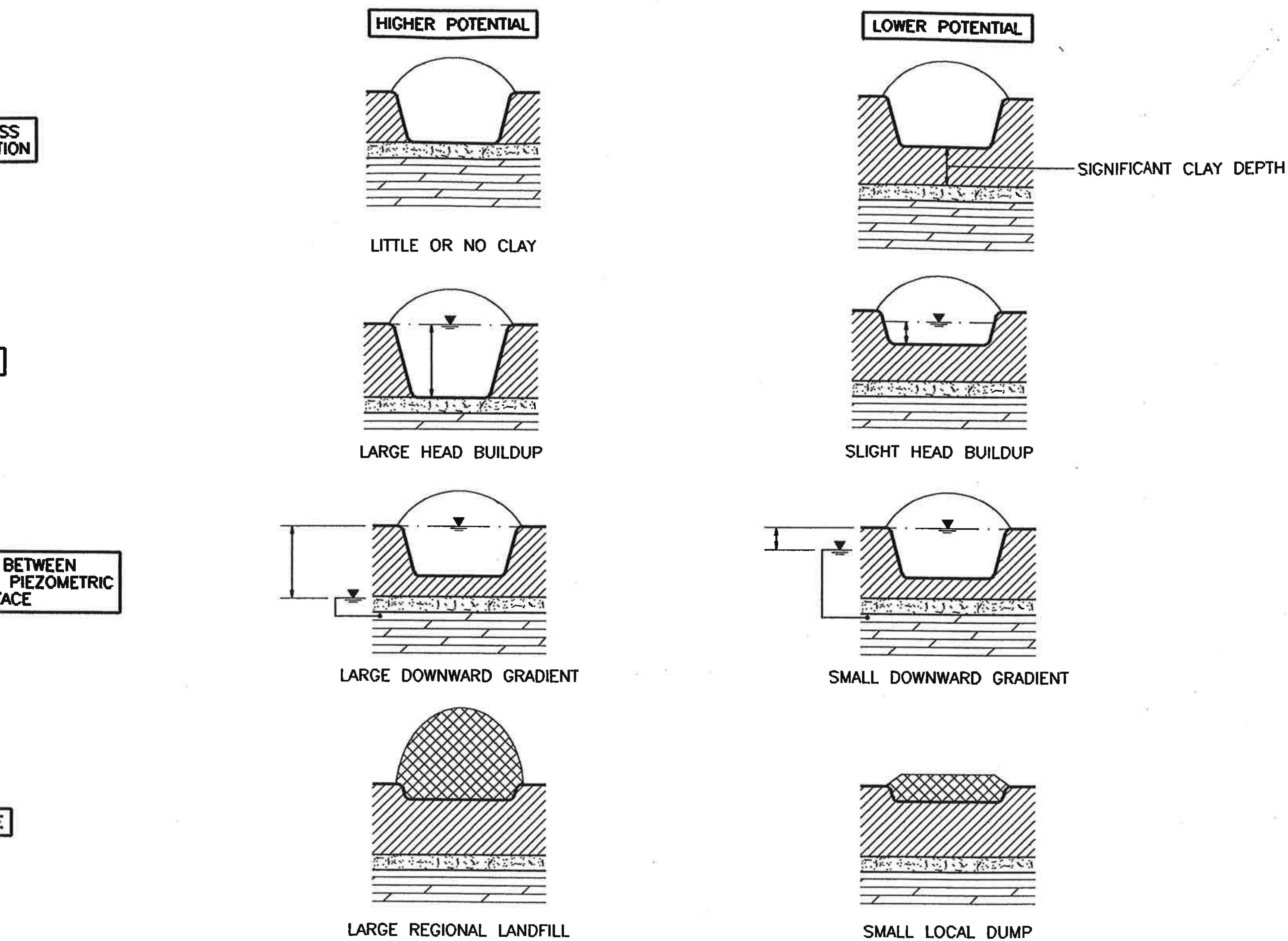
CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

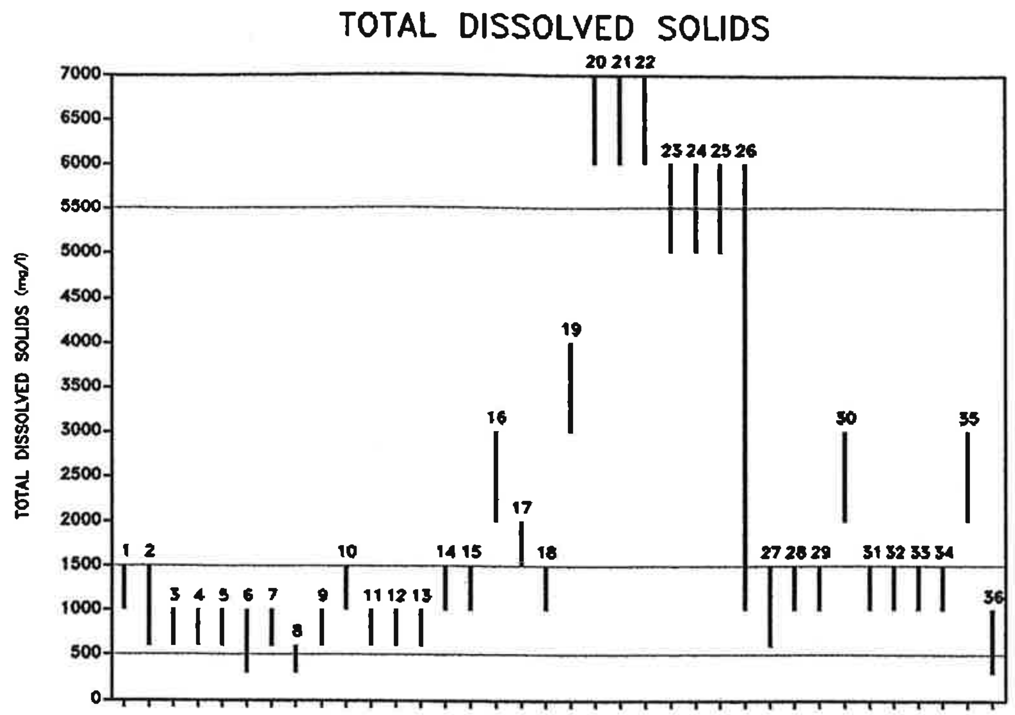
LANDFILL SITE DISPOSITION STUDY

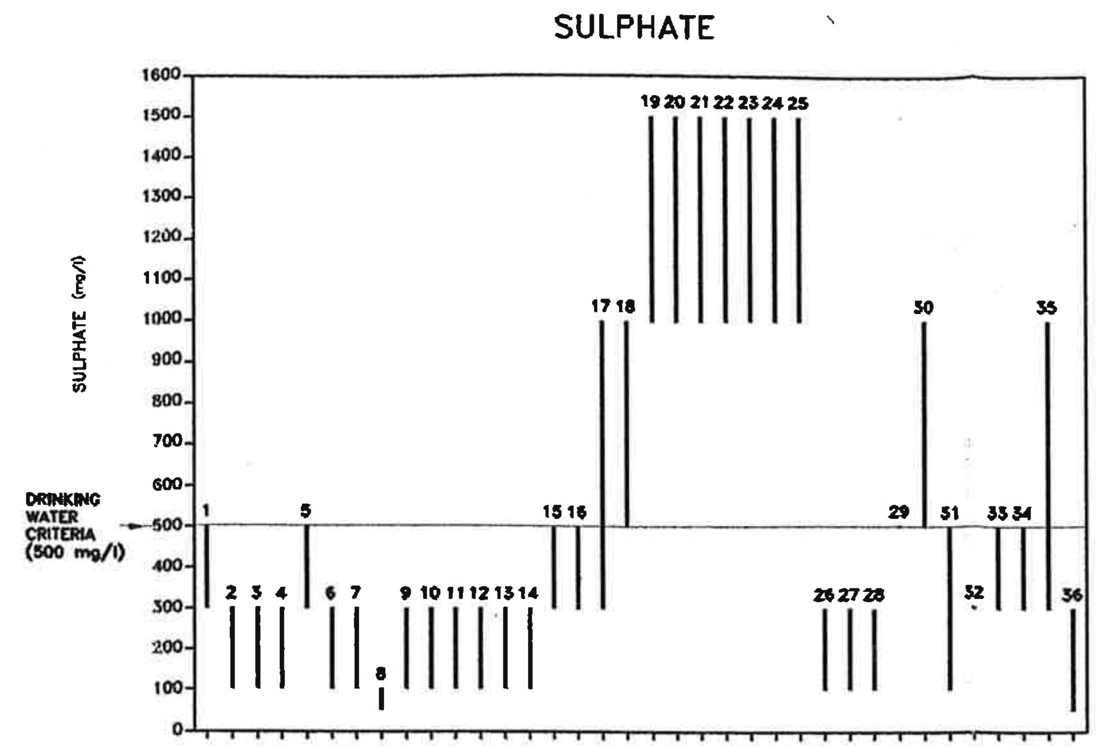
LEACHATE QUALITY

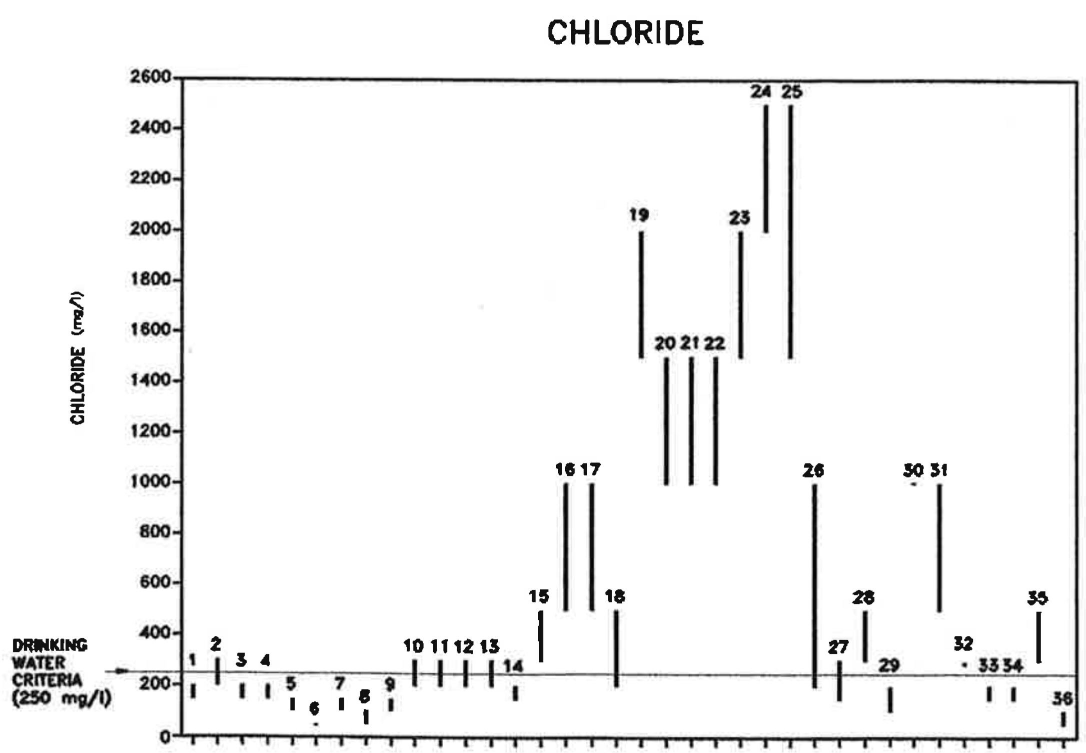
JUNE 1993 | **FIGURE 14**

KGS No. 92-107-0614


HIGHER POTENTIAL
LOWER POTENTIAL
SS
TION
SIGNIFICANT CLAY DEPTH
LITTLE OR NO CLAY
LARGE HEAD BUILDUP
SLIGHT HEAD BUILDUP
BETWEEN
PIEZOMETRIC
ACE
LARGE DOWNWARD GRADIENT
SMALL DOWNWARD GRADIENT
LARGE REGIONAL LANDFILL
SMALL LOCAL DUMP







LANDFILL INVENTORY

NUMBER	NAME
1	BELIVEAU ROAD DUMP SITE
2	ST. BONIFACE DUMP SITE
3	ST. BONIFACE LANDFILL SITE I
4	ST. BONIFACE LANDFILL SITE II
5	REDONDA DUMP SITE
6	REDONDA LANDFILL SITE
7	KIMBERLY AVENUE LANDFILL SITE
8	CORDITE ROAD LANDFILL SITE
9	BONNER AVENUE LANDFILL SITE
10	McPHILLIPS STREET (HWY. 8) DUMP SITE (ASH DUMP)
11	McPHILLIPS STREET LANDFILL SITE
12	MARGARET PARK LANDFILL SITE
13	LEILA AVENUE LANDFILL SITE
14	LEILA AVENUE (WEST) LANDFILL SITE
15	SASKATCHEWAN AVENUE DUMP SITE
16	BARRY AVENUE DUMP SITE
17	HARCOURT STREET LANDFILL SITE
18	SUMMIT ROAD LANDFILL SITE
19	SHAFTESBURY BOULEVARD DUMP SITE
20	CHARLESWOOD ROAD (NORTH) LANDFILL SITE
21	CHARLESTON STREET DUMP SITE
22	CHARLESWOOD ROAD (SOUTH) LANDFILL SITE
23	CADBORO ROAD (EAST) LANDFILL SITE
24	CADBORO ROAD (WEST) LANDFILL SITE
25	BRADY ROAD LANDFILL SITE
26	ELMWOOD LANDFILL SITE
27	NAIRN AVENUE LANDFILL SITE
28	BROOKLANDS LANDFILL SITE
29	C.N.R. - DUGALD ROAD LANDFILL SITE
30	CORYDON - OSBORNE DUMP SITE
31	RED - ASSINIBOINE RIVER JUNCTION DUMP SITE
32	LOT 61, ST. MARY'S ROAD DUMP SITE
33	RIEL DUMP SITE
35	RIVER ROAD DUMP SITE
36	NORTHEAST PARK LANDFILL SITE (KILCONA PARK)

NOTE: LANDFILL NO. 34 DELETED.

NOTES:

1. SOURCE: UNIVERSITY OF MANITOBA 1983 PLATES 15,16 & 17.
2. RANGES ARE APPROXIMATE, LOCAL VALUES MAY VARY.

KGS GROUP

CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

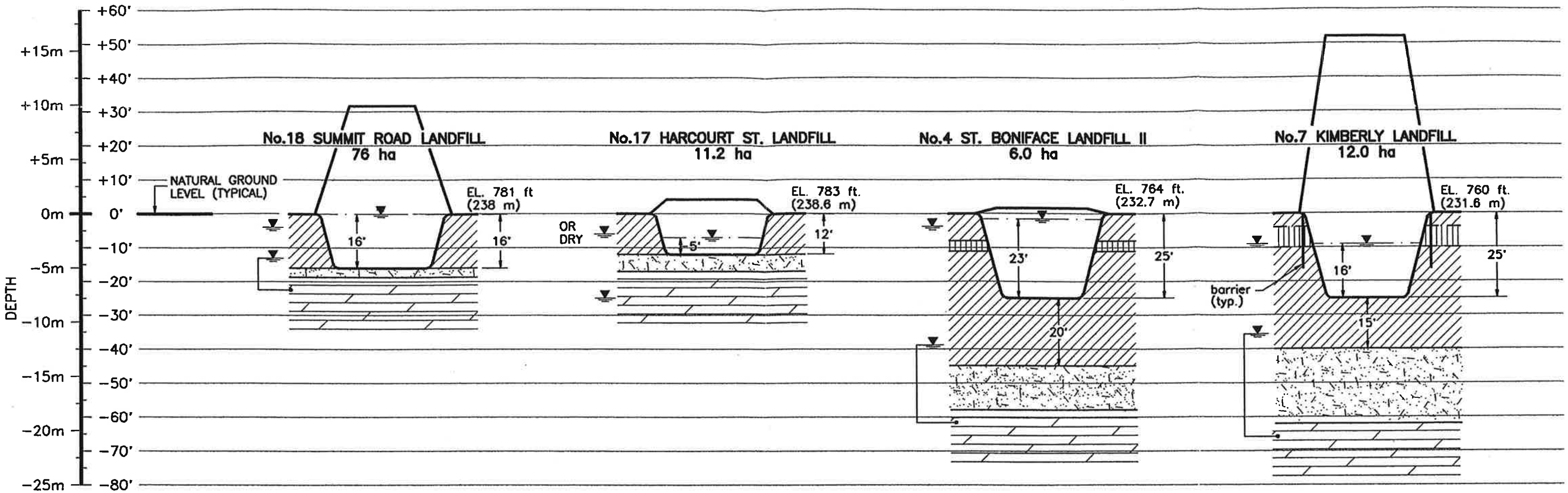
REGIONAL BEDROCK GROUNDWATER QUALITY

JUNE 1993 | **FIGURE 5**

432mm X 279mm/ BASE SCALE: 1:1

KGS No. 92-107-06F5

432mm x 279mm/ SCALE: 1"=30'



VERTICAL SCALE = 1" = 30'
HORIZONTAL SCALE = N.T.S.

LEGEND

	SILT		CARBONATE BEDROCK
	CLAY		WATER ELEVATION
	SILT TILL	12.0 ha	LANDFILL AREA

NOTE:

1. DIAGRAMS REPRESENT GENERAL SITE CONDITIONS. ACTUAL CONDITIONS MAY VARY.

KGS GROUP

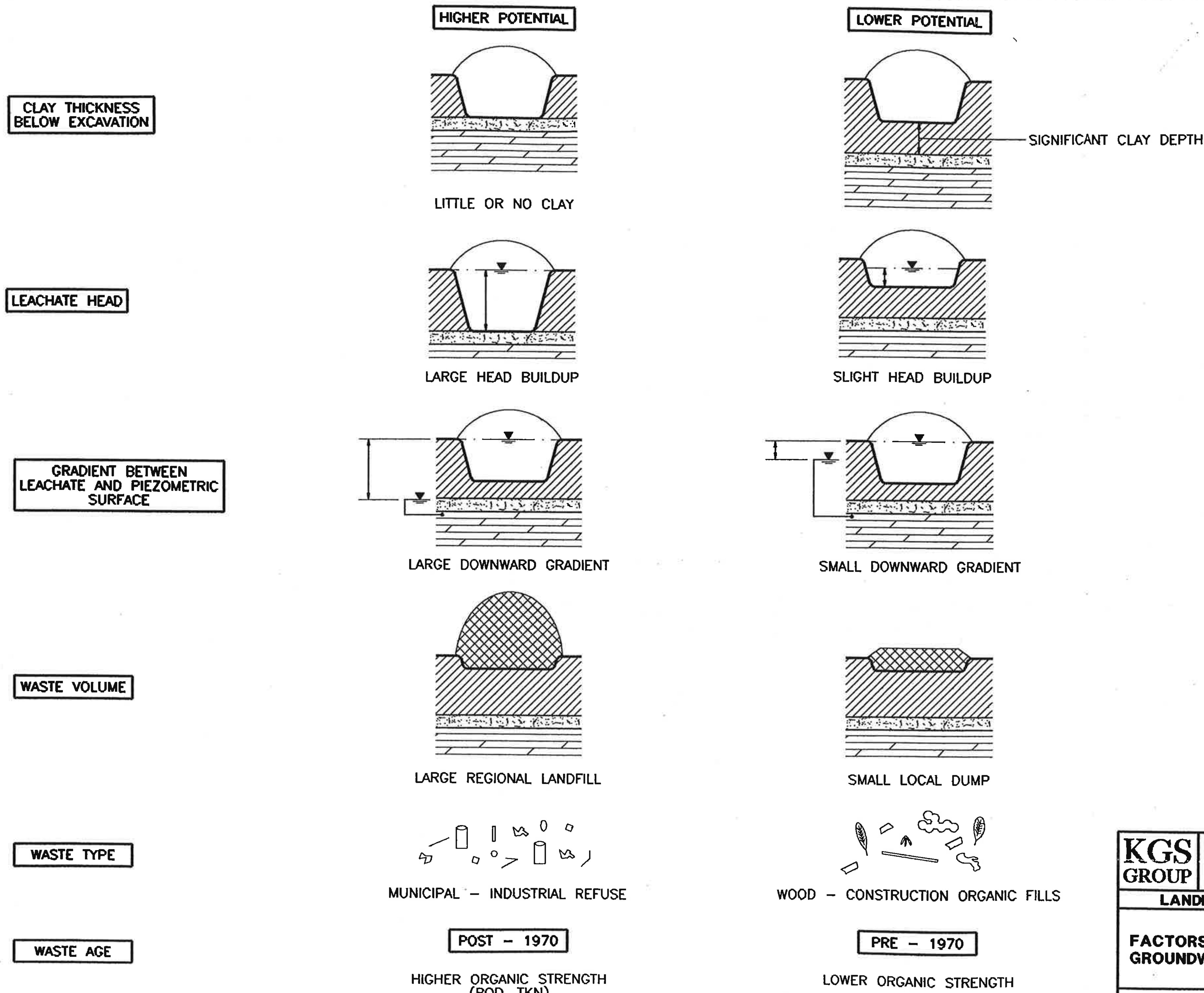
CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

LANDFILL SITE SECTIONS
POTABLE AQUIFER
HIGH GROUNDWATER
POLLUTION POTENTIAL

JUNE 1993	FIGURE 6

KGS No. 92-107-06F6



KGS GROUP

CITY OF WINNIPEG
WATERWORKS WASTE AND DISPOSAL DEPARTMENT

LANDFILL SITE DISPOSITION STUDY

FACTORS DETERMINING GROUNDWATER POLLUTION POTENTIAL

JUNE 1993 | FIGURE 15

432mm X 279mm/ BASE SCALE: 1"=30'

KGS No. 92-107-0615