New York City
Department of Environmental Protection

Brookfield Avenue Landfill Remediation Project Operable Unit 1

Feasibility Study Report

March 2001

In compliance with the Order on Consent:
NYSDEC Index No. 2-43-006

STATE OF NEW YORK
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LICENSED PROFESSIONAL ENGINEER

Prepared by:

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Joel A. Miele Sr., P.E.
Commissioner

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March 28, 2001

Mr. Richard Gardineer
NYS Department of Environmental Conservation
Division of Environmental Remediation, Region 2
47-40 21st Street
Long Island City, NY 11101-5407

Subject: Final Feasibility Study Report -
Brookfield Avenue Landfill, Staten Island
NYSDEC Index No. 2-43-006

Dear Mr. Gardineer,

In accordance with Paragraph III (F) of the May 15, 1992 Order on Consent, the New York City Department of Environmental Protection (NYCDEP) is pleased to submit six (6) copies of the Brookfield Avenue Landfill Final Feasibility Study Report. The NYCDEP is also sending copies of the report to the names and project repositories listed below.

This submittal includes minor revisions in accordance with the New York State Department of Environmental Conservation (NYSDEC) Feasibility Approval letter dated February 07, 2001.

The NYCDEP will continue to work closely with the NYSDEC during the upcoming issuance of the Proposed Remedial Action Plan (PRAP), Record of Decision (ROD), and remedial design phase.

Very truly yours,

Joseph M Ketas

Joseph Ketas
Assistant Commissioner
Office of Environmental Planning & Assessment

Xc: <u>NYCDEP</u>
Mr. Robert Avaltroni
Mr. Michael Gilsenan
Mr. John Wuthenow
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DEP
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John P. Cahill
Commissioner

February 7, 2001

Mr. Joe Ketas
Assistant Commissioner
New York City
Department of Environmental Protection
59-17 Junction Boulevard, 11th Floor High-Rise
Corona, Queens 11368

Re: Feasibility Study Approval

Dear Mr. Ketas:

The New York State Department of Environmental Conservation (NYSDEC) approves the Feasibility Study (FS) for Operable Unit (OU) 1 of the Brookfield Avenue landfill site, pending the following changes:

1. Removal of sections 3.2.2, 4.2.6.

2. Removal of section 5.1, except for the last two paragraphs.

Please be advised that the Department, with the agreement of the New York City Department of Environmental Protection (NYCDEP) is selecting Alternative 2B for the proposed remedy for this site. We have agreed that the Feasibility Study does not have to be amended to reflect this decision.

In addition, from now on Richmond Creek will be referred to as Operable unit (OU) 2. The NYCDEP will be required to perform a Remedial Investigation/Feasibility Study (RI/FS) for the Creek. There will be another PRAP and ROD for OU2.

If you have any questions please call me at (718) 642-2205.

Very Truly Yours

Nigel N. Crawford

Nigel N. Crawford P.E.
NYSDEC Region 2, DER

cc: M. Kris
N. Dmytryszyn
H. Bialer
B. Warren
S. Goldstein
J. Boyer
J. Wood
J. Larkins

NYSDEC
Ms. May Ellen Kris
Mr. Nigel Crawford

Repositories
Community Board # 2
Community Board # 3
Staten Island Public Library, Richmondtown Branch
Staten Island Public Library, New Dorp Branch
Staten Island Borough Hall
NYCDEP Office of Community Outreach
NYSDEC Region II Office

Other Parties
Mr. John Olm, NYSDOH
Ms. Laurie Stevenson, NYCDOH
Ms. Susan Moon, NYC Law Department
Ms. Helen Bialer, CAC
Mr. John Larkins, SAC
Mr. Nick Dmytryszyn, SIBP
Mr. Douglas Gouzzi, ATSDR
Mr. Vincent M'Iglizio, Councilman Fiala's Office

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Section 1
Introduction

The Brookfield Avenue Landfill is presently classified by the New York State Department of Environmental Conservation (NYSDEC) as a class 2 inactive hazardous waste site. The Order of Consent from the NYSDEC, dated April 7, 1992, required the City of New York to develop and implement a remedial program for the Brookfield Avenue Landfill. On March 23, 1993, Camp Dresser & McKee (CDM) was retained by the NYCDEP to assist the Department in developing a Remedial Investigation/Feasibility Study (RI/FS) and remedial design for the site.

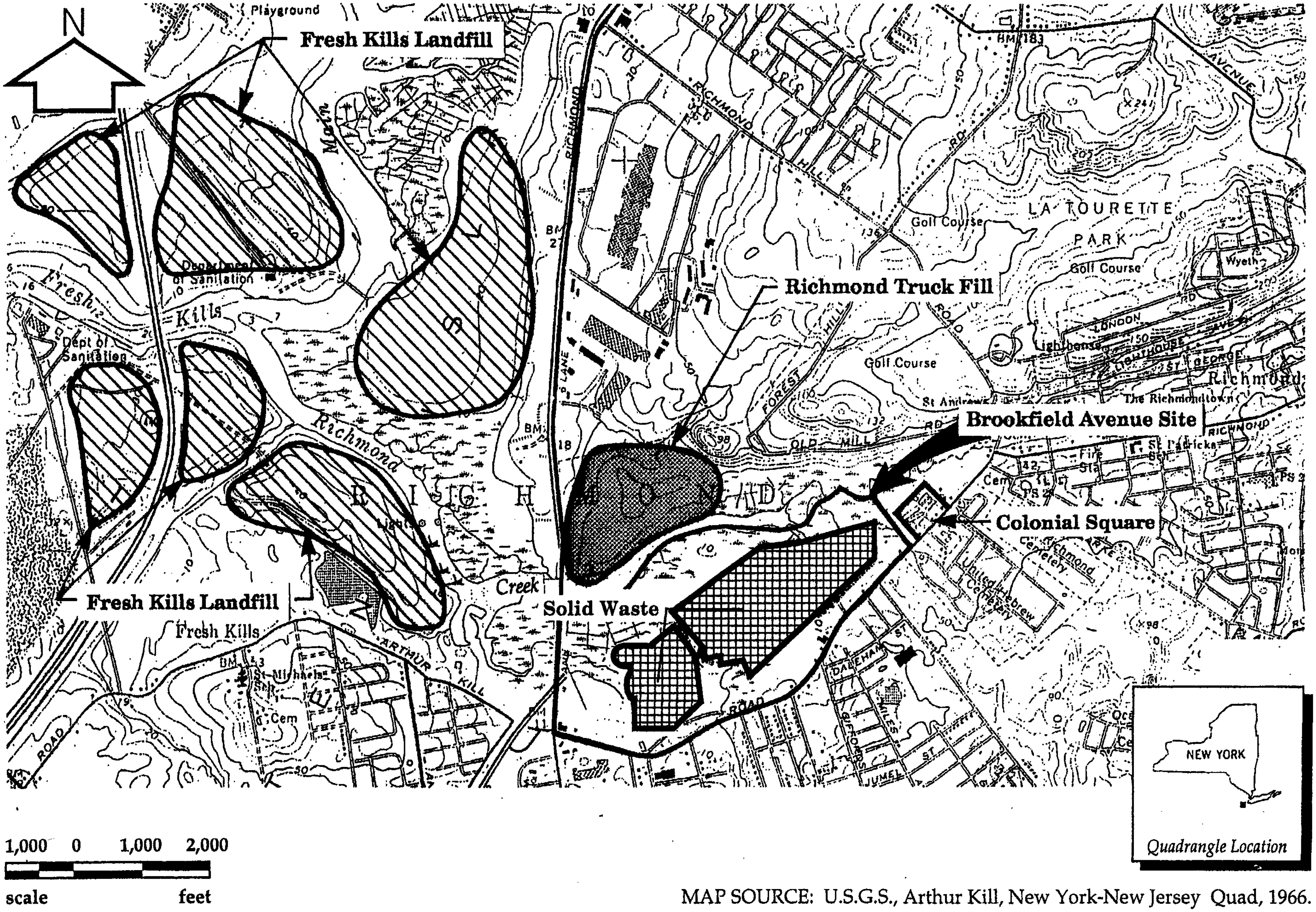
This Feasibility Study (FS) Report summarizes the remedial action objectives, it identifies and screens applicable remedial technologies, and evaluates site remediation alternatives. The FS identifies the preferred alternative approach and includes a conceptual design of the preferred alternative. This FS was conducted in accordance with the approved RI/FS Work Plan (DEP, 1993) as well as relevant NYSDEC technical guidance memoranda.

1.1 Site Description and Background

The Brookfield Avenue Landfill is located near the Richmond and Great Kills Sections of Staten Island, New York. It is bounded to the south and east by Arthur Kill Road, to the west by Richmond Avenue and to the north by Richmond Creek. The landfill, which was plotted as Section 10 and 11 of the Fresh Kills Landfill, was operated by the City of New York from 1966 through 1980. During that period, it received approximately 5.1 million cubic yards of municipal solid waste. Industrial and hazardous waste dumping may have also occurred at this site. Approximately 132 acres of the 272-acre site are occupied by solid waste. The waste pile rises to an elevation of 45 feet above mean sea level. In 1980, the New York City Department of Sanitation (NYCDOS) designated 38 acres in the eastern section of the site for closure. The closure included regrading, capping (24 inches of clay and topsoil) seeding, and installation of 10 passive vertical methane gas vents. Other City facilities have been added to the site since the landfill closure, including centralized wastewater collection systems (i.e. interceptor), the Eltingville wastewater pump station, and a number of storm sewer outfalls.

Figure 1-1 is a site location map delineating site limits as defined in the 1992 Order of Consent. Residential areas can be found to the east, south and southwest of the landfill.

Based on discussions between the NYCDEP and the NYSDEC during preparation of this document, the decision has been made to separate the Brookfield Avenue Landfill FS into two operable units (NYSDEC, 1999). The NYSDEC considers an operable unit to represent a portion of the site which, for technical or administrative reasons, can be addressed separately to eliminate or mitigate a release, threat of release or exposure pathway resulting from the site contamination. Therefore, the Brookfield Avenue



MAP SOURCE: U.S.G.S., Arthur Kill, New York-New Jersey Quad, 1966.

Figure 1-1
Site Location Map
Brookfield Avenue Landfill Remediation [illegible]oject

Landfill is being addressed in two operable units, with Operable Unit 1, or OU1, addressing the landfill and Operable Unit 2, or OU2, addressing Richmond Creek. This FS identifies and evaluates remedies primarily for OU 1.

1.2 Summary of the Results of the Remedial Investigation

The field investigations were conducted in three phases beginning in December 1993 and concluding in May 1998. Phase I field investigations, performed from December 1993 to July 1994, are described in the original project workplan. Phase II field investigations were performed from December 1996 through December 1997. Phase II included follow up study activities recommended by the City, NYSDEC, USEPA, and the community. The Phase III field investigations began in January 1998 and concluded in May 1998. Phase III activities included additional sediment toxicity testing and bioaccumulation studies as well as installation of three deep monitoring wells.

A complete description of the RI findings is contained in the Final Remedial Investigation Report (DEP, 1998). A brief summary of the major results is given below.

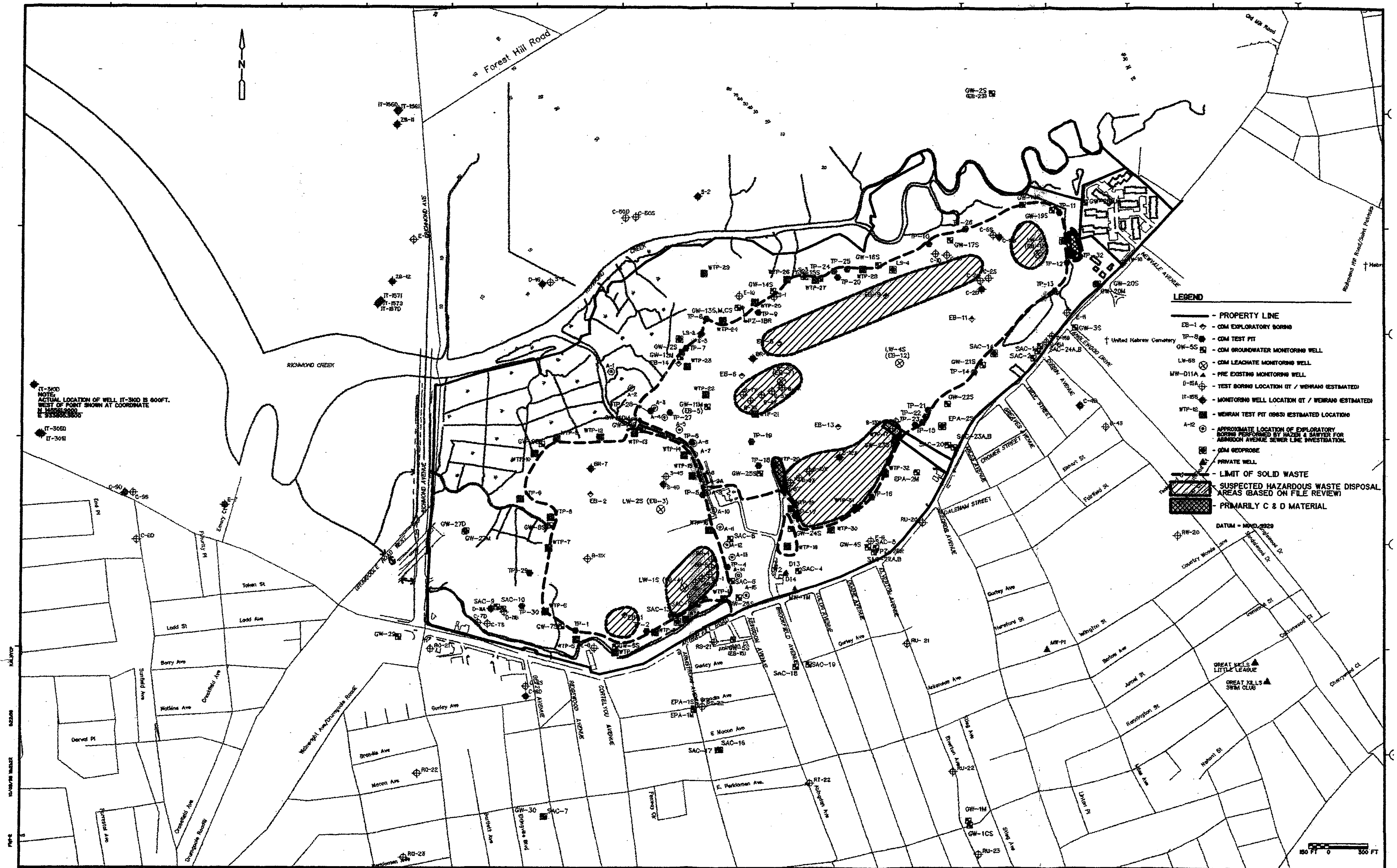
Waste Characterization

- The Brookfield Avenue Landfill is characterized by a mounded municipal/ industrial fill layer up to 45 feet thick that overlies areas previously containing both low and high salt marshes. Approximately 5 million cubic yards of waste are present. It is estimated that construction and demolition debris (C&D) makes up less than 1 percent of the waste mass. The waste age ranges from 18 to 32 years.

- There are approximately 132 acres of solid waste. All are on city property, except for one quarter of an acre near Arthur Kill Road and Giffords Avenue (northern extent of Holterman's Bakery property). Figure 1-2 illustrates the extent of solid waste, the property boundary, and areas suspected of receiving hazardous or industrial wastes.

- Historical information was used to identify six areas within the solid waste disposal area where concentrated industrial/hazardous waste may have been co-disposed with the municipal solid waste. All of these areas received focused "hot spot" or area of concern studies. The focused study areas are shown in Figure 1-3.

With the exception of one of these areas (area no. 1), they are characterized primarily as waste oil. In some areas, the waste oil contains PCBs and pesticides. These areas are recognized as source areas for contaminant emissions to groundwater, surface water and air. Area no. 1 contains a mixture of petroleum products, methyl ethyl ketone (MEK, used in lacquers) and relatively low levels of chlorinated solvents. Areas nos. 3 and 5 are recognized as higher strength source areas or "hot spots". To



REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: B. MURTAGH
DRAWN BY: R. GENCORELLI
SHEET CHK'D BY:
CROSS CHK'D BY:
APPROVED BY:
DATE: AUG., 1997

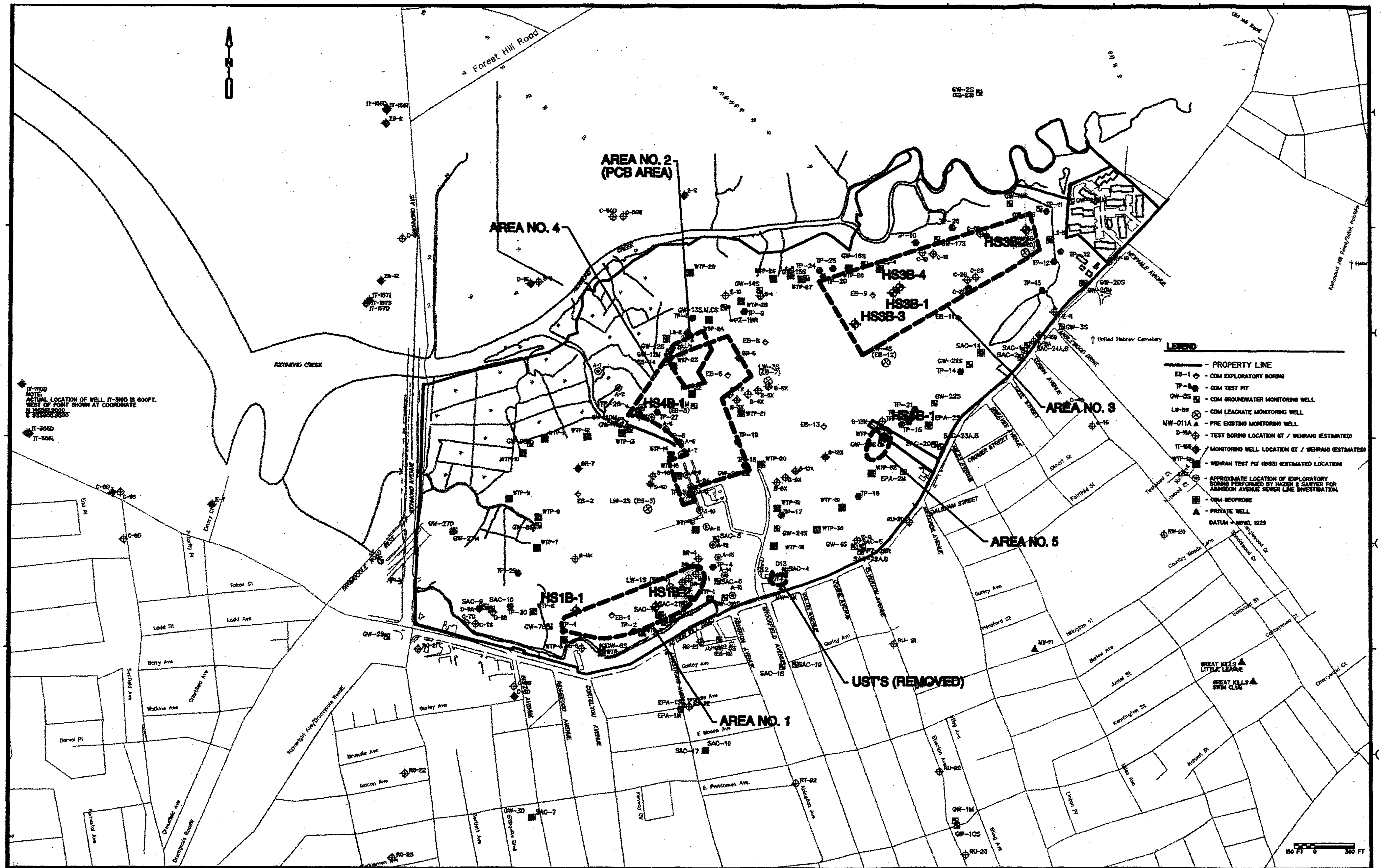
CDM Camp Dresser & McKee

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL
REMEDIATION PROJECT

LIMITS OF SOLID WASTE

PROJECT NO. 5215-12929
FILE NAME: WASTELIM
DRAWING NO.
Figure 1-2



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DATE:

CDM Camp Dresser & McKee

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL REMEDIATION PROJECT

OVERVIEW OF FOCUSED STUDY AREAS

PROJECT NO. 0216-12929
FILE NAME: OVERHSD

DRAWING NO.

Figure 1-3

address these hot spots, an interim remedial measure (IRM) plans were developed consisting of soil vapor extraction from area no. 3 and fencing and installation of an oil absorbing boom at area no. 5. The area no. 5 oil boom is already in place and fencing has been constructed. The soil vapor extraction system for area no. 3 has been conceptually designed and the environmental review process required to support air permit applications has commenced.

Hydrogeologic Characterization

- The Brookfield Avenue Landfill is underlain by two basic aquifer units and a number of confining units. The uppermost aquifer, which is in direct contact with the landfill, consists of marsh sediments, glacial till, and glacial outwash type sands. This aquifer is called the Upper Glacial aquifer. The lower aquifer consists of a series of marine sands, silts and clays. This aquifer is called the Cretaceous aquifer. Both of these aquifers contain a number of subaquifers, which were mapped as part of this study. Separating the Upper Glacial and Cretaceous aquifers is a continuous, leaky, confining unit made up of overlapping glaciolacustrine clay, glacial till, and Cretaceous clay. Groundwater mounding occurs within the waste mound reaching heads as great as 12 feet above mean sea level. This mound causes radial groundwater flow onsite. In the north, east, and west directions, this shallow groundwater discharges to the surface waters. In the southerly direction, this radial flow is countered by the regional flow which is north. This results in groundwater deflection back toward surface waters to the east and west. This turning point or deflection point occurs at the southern boundary of the site. For practical purposes, shallow groundwater from the landfill does not flow underneath the community south of the site.

  Regional groundwater flow in the Upper Glacial aquifer is to the north. Regional groundwater flow in the Cretaceous aquifer is to the south.

- The northern portion of the site (in the vicinity of Richmond Creek) is a local discharge area for the Cretaceous aquifer. Because this is a discharge area, the Cretaceous leaks upward to the Upper Glacial aquifer and eventually into Richmond Creek. Over the rest of the site, the Upper Glacial aquifer leaks downward into the Cretaceous aquifer. This results in a very complex local flow pattern in the Cretaceous aquifer.

- The Upper Glacial aquifer near Richmond Creek is moderately influenced by tidal fluctuations in the Creek. However, the influences are not strong enough to reverse flow directions over any significant areas. Tidal influences in the Cretaceous aquifer are slight and insignificant.

  Downward leakage is likely greatest in the vicinity of Arthur Kill Road where leaky confining units are thinnest.

Leachate Characterization

- The Brookfield Avenue Landfill generates approximately 95,000 gallons of leachate per day. Approximately 92,000 gallons per day (96.5%) of the leachate discharge to the local surface water bodies such as Richmond Creek and associated wetlands. It is estimated that approximately 3,500 gallons per day of leachate (3.5%) leak into the Cretaceous aquifer. Because of the complex flow pathway from the Upper Glacial to the Cretaceous, the leakage estimate of 3,500 gpd is considered a simple estimate.

- The leachate within the landfill is of moderate strength and exacerbates water quality standard contraventions in the Upper Glacial aquifer onsite and in Richmond Creek segment adjacent to the landfill.

Groundwater Quality Characterization

- Shallow groundwater at the perimeter of the solid waste mound is contaminated. This contamination extends to Richmond Creek. Exceedances of Standards, Criteria, or Guidance (SCG) in the Upper Glacial aquifer and leachate mound include: 13 volatile organic compounds (VOCs), 17 semi-volatile organic compounds (SVOCs), 8 pesticides, 2 polychlorinated biphenyls (PCBs), and 13 metals.

- The most frequently detected contaminants in the shallow groundwater include: benzene, chlorobenzene, toluene, xylene, dichlorobenzene, naphthalene, 4,4-DDE, barium, copper, iron, lead, manganese, sodium, zinc, ammonia, bromide, chloride, and sulfate.

- No VOC, SVOC or pesticide contamination was detected offsite in the Upper Glacial aquifer.

- Vertical leakage of contamination from the shallow sands to the lower portion of the Upper Glacial aquifer occurs in the southwest area (near well SAC-9), the northern corridor between the two cells (near GW-10M and GW-11M) and the Holterman's Bakery area (SAC-20).

- It is estimated that small percentages of the leachate (approximately 3-4%) leak into the Cretaceous aquifer. Because of the long travel path, contaminants in the leachate undergo significant attenuation as they migrate from the Upper Glacial to the Cretaceous aquifer. This is primarily due to dispersion and sorption. Five wells at the southern property boundary screened in the Cretaceous aquifer show very low levels of leachate indicators. SCGs are slightly exceeded for acetone, chloroform, toluene and chlorobenzene.

Air Characterization

- Four rounds of offsite, onsite, upwind and downwind ambient air samples were collected to determine landfill associated air impacts. In general, the upwind-downwind ambient air data suggest that the Brookfield Avenue Landfill is not a significant source of most VOCs. The range of values for samples taken upwind of the landfill is of comparable magnitude to the values taken at downwind ambient air sampling stations. Exceptions to this include some of the methane related compounds (dichlorodiflouromethane, trichlorofluoromethane, chloroethane), as well as possibly benzene. Although the flux box data show that the landfill is emitting VOCs, the magnitude of the emissions is not large enough to be registered as a significant change between upwind and downwind concentrations.

- The flux box emission sampling and modeling results suggest that the Brookfield Avenue Landfill is a minor source of benzene, 2-hexanone, tetrachloroethylene, carbon tetrachloride and trichloroethylene. Based on air model simulation results, offsite VOC concentrations are significantly lower than health based guidelines. Acrolein and acrylonitrile were the only compounds estimated to approach the ambient guideline concentration (AGC) at 24% and 45% of the AGC respectively. Even though flux box emission samples and air dispersion modeling suggest that the landfill is a source of acrolein and acrylonitrile in ambient air, this was not confirmed by the upwind-downwind ambient air sample analysis.

  Future projections of landfill gas production, however, show a marked increase because after the landfill is capped, conditions within the waste mass will be anaerobic. The gas collection system will be designed to capture these higher levels of gas generation.

- The Brookfield Avenue Landfill is not a significant source of inhalable particulates. PM-10 data for all four sampling rounds were not found to exceed the Federal 24-hour standard for inhalable particulates of 150 ug/m3. As a frame of reference, the ambient air results, which were taken over a 24 hour period were compared to the annual standard. Using this very conservative comparison, several samples do exceed the annual PM-10 standard of 50 ug/m3, although only one sample location (AA-2) had an average concentration (based on the four rounds) slightly greater than the annual standard (refer to RI Report for sample locations). No upwind-downwind relationship is apparent from the data. Higher concentration samples were just as likely to appear upwind as they were downwind. Because the landfill is well vegetated, it is not considered a significant source of these particulates.

- Hydrogen sulfide and mercaptans were not detected in the landfill surface emission samples. They were found at very low levels in landfill gas within the landfill.
- Based on a landfill gas generation model estimate, the Brookfield Avenue Landfill, under anaerobic conditions, would generate approximately 500 to 760 standard cubic feet per minute (scfm) of gas during the constant phase of gas generation. Flux box and passive vent measured emission rates confirmed that gas generation rates are not as high as would be expected under anaerobic conditions. Currently, anaerobic conditions are not expected to occur due to significant infiltration of air into the waste mass. Internal landfill gas sampling indicated that ambient air makes up between 20 and 60% of the gas. Gas generation rates are expected to increase, once capping is completed and air infiltration is reduced.

Soil Gas Characterization

- Testing of 25 nearby home basements found no evidence of landfill gas.
- The NYCRR Part 360 criteria for soil gases from landfills (100% LEL at the landfill property boundary) has been periodically exceeded at four probes (GP-1, GP-2, GP-5, and GP-12 as shown in Drawing No. 36, Appendix A of the RI Report).
- The exceedances only occurred once at each probe over 13 rounds of monitoring. The exceedances did not occur in the same round.
- These type of exceedances were not observed at background wells. However, the exceedances do occur in areas that are considered buried marsh areas. It is possible that these exceedances are the result of trapped marsh gas. GP-1, GP-2, and GP-5 are located at the property boundary where a surface water body separates the soil gas monitoring probe and the waste pile. These surface waters should provide a barrier to soil gas migration. It is possible that the periodic readings may be attributed to other sources of gas, particularly from the adjacent wetland/swamp areas.
- Without additional information, these readings should be considered possible indications of landfill gas. Additional probes, as recommended in the RI Report, have already been installed, and monitoring of the complete network of probes will continue.

Surface Water and Sediment Characterization

- Surface water quality contraventions in Richmond Creek, a Class SC water body, include tetrachloroethene, copper, lead, zinc, total cyanide, nickel, mercury and a number of pesticides including DDD, DDE, BHC, heptachlor, aldrin, dieldrin, and endrin. Ammonia discharged from the landfill has resulted in exceedances of the EPA continuous concentration criteria at four of eight surface water sample locations.

- The Brookfield Avenue Landfill leachate is a significant contributor to contamination to Richmond Creek. With the exception of tetrachloroethene, all of the compounds found in the surface water of Richmond Creek were also found in the Brookfield Avenue Landfill leachate.

- The sediment in Richmond Creek segment adjacent to the Brookfield Avenue Landfill contains significant levels of contamination. The contaminants in the sediments which exceed standards and which the Brookfield Avenue Landfill is believed to have contributed to include a variety of semi-volatile organics, pesticides, PCBs, iron, nickel, lead, copper, zinc and mercury.

- Initial toxicity tests included sediment from all five Brookfield Avenue landfill sediment stations. The samples were tested for acute toxicity in the fish, Menidia beryllina, the sandworm, Neries virens, and the grass shrimp, Palaemonetus pugio in 96-hour and 10-day flow through exposures. No measurable toxicity was observed for each of the test species. A second round of testing was performed to assess acute toxicity in the amphipod (Ampeli-scaabdita) and chronic toxicity and bioaccumulation in the polychaete worm (Neries virens) and mollusk (Macoma nasuta). Between 41% and 48% mortality was experienced by the amphipod, indicating a moderate amount of toxicity. Richmond Creek sediments were not found to be toxic to the polychaete worm or mollusk, based on their greater than 90% survival during the 28 day (chronic) testing. However, tissue analysis indicated an increased uptake of arsenic, cadmium, chromium, mercury and nickel in the mollusk and copper in the worm, compared to the control exposures.

Ecological Assessment

- No unique or unusual floral assemblages were noted at the site. Field reconnaissance confirmed the presence of previously identified wetlands with some minor modification of their boundaries.

- The northern tidal marsh portion of the Brookfield Avenue Landfill is part of Fresh Kills, a significant Fish and Wildlife Habitat, as designated by New York State's Coastal Management Program (CMP). The area was first listed as a Significant Habitat in September of 1992 and was assigned the highest Significance Value of the five Significant Habitats located on the north and west side of Staten Island, as determined by the CMP. It was awarded a high score in the species vulnerability category due to its use as a wintering area by the northern harrier (threatened) and long-eared owl, and as a nesting area by the barn owl (special concern species). Until the mid-1980's, a number of short eared owls (special concern species) were known to winter in the area.

Additionally, the diamondback terrapin (special concern species) was observed in 1967, but has not been confirmed since.

- The vegetative community on the capped portion of the landfill is distinctively different from that on the uncapped portion. Capped areas contain grasses and weeds that appear highly stressed. Stunted and sporadic vegetation on the capped portion may be a result of the pyritic clays used in the capping system rather than from landfill related contamination. Individual plants appear stunted and little woody vegetation is evident. Many bare spots and erosional valleys exist on the summit and slopes of the capped portion. Conversely, dense stands of tall reed dominate much of the uncapped area and signs of stress are not as evident.

- The plant community of the landfill provides potential moderate quality habitat for small birds and mammals, however, it does not constitute a major food resource for wildlife. Although some species produce nuts, berries, or fruits, they are quite scarce. No rare, threatened or endangered plants, and no plant species of special concern are known to occur onsite.

- Richmond Creek, in the vicinity of the Brookfield Avenue Landfill, is subject to widely ranging water quality characteristics (e.g., pH, salinity, temperature), depending on tide and distance downstream from the weir just east of Arthur Kill Road.

Contaminant Fate and Transport

- Contaminant transport in the Upper Glacial aquifer is predominately limited to the site. These contaminants discharge to Richmond Creek. Because of the close proximity of the landfill to the creek, little contaminant attenuation occurs in the aquifer before discharge. The exceptions to this are semi-volatile contaminants, most metals, and PCBs, which are strongly sorbed to the waste aquifer material limiting migration in the groundwater pathway.

- The potential for chemical transport to the deeper Cretaceous aquifer is likely limited because of the low downward leakage rate. Because of the relatively long travel path to this deeper aquifer, significant contaminant attenuation is likely. This attenuation is the result of chemical adsorption and physical dispersion.

- Significant volumes of water flows past the landfill during tidal cycles and rain events. These flows dilute and disperse landfill-derived groundwater/ leachate that discharges to Richmond Creek. Many of the contaminants quickly associate with suspended solids in the water column and settle to creek bottom sediments during quiescent periods in the creek. Volatilization to the atmosphere is a secondary fate and transport mechanism for the volatile organic compounds.

- The flux emissions data and modeling results suggest that the Brookfield Avenue landfill is a minor source of 2-hexanone, tetrachloroethylene, carbon tetrachloride, and trichloroethylene and a more significant source of acrolein and acrylonitrile. Air dispersion is the primary fate of air contaminant persistence.

- Offsite concentrations of air pollutants that can be attributed to emissions from the Brookfield Avenue Landfill alone do not represent either a short-term or long-term health threat. In general, the offsite concentrations are significantly lower than the NYSDEC health based guidelines. Only acrolein and acrylonitrile show maximum concentrations that represent up to 50 percent of the health based guidelines.

- The landfill has a low emission potential for respirable particulates because of the condition of the vegetative cover that currently exists.

Human Health Risks

- The carcinogenic and noncarcinogenic risks were estimated for adult and youth for two different use scenarios (current conditions and future conditions). Future conditions for this study means the existing site but no remediation. For future conditions, it is also assumed that private residences would remain onsite and that private potable wells would be permitted onsite and offsite.

- Under current conditions, three likely exposure pathways were considered: onsite residential (there are several residents on the site along Arthur Kill Road), offsite residential, and a trespasser on the site. The quantified risk for the trespasser was not calculated because the exposure time for the trespasser is less than the onsite resident. To be conservative, the risks to the onsite resident were estimated for evaluation.

  Onsite resident: - no unacceptable hazards or carcinogenic risks

  Offsite residential: - no unacceptable hazards or carcinogenic risks

  Under <u>future conditions</u>, (assuming the onsite resident remains, access to the site is limited, but potable water wells are permitted onsite), the following hazards and risks were identified.

  Onsite resident: - potential non-carcinogenic hazards due to future child ingestion of surface soil and groundwater, and inhalation of VOCs in the shower; future adult, ingestion of groundwater and inhalation of VOCs in the shower.

- unacceptable potential carcinogenic risk to future child and adult due to ingestion of groundwater and inhalation of VOCs in the shower from shallow groundwater.

Offsite resident:
- potential non-carcinogenic hazards due to future child and adult ingestion of groundwater (assumes potable water wells are installed in the future) and inhalation of VOCs in the shower fed by a deep private well.
- no unacceptable carcinogenic risks

- The current offsite adult and child receptors are not likely to have the potential for adverse health effects or carcinogenic effects. The only future exposure pathway that is greater than the acceptable EPA criteria is via direct ingestion of groundwater from the deep aquifer and inhalation of VOCs in the shower. This is not a likely exposure pathway as residents in the vicinity of the Brookfield Avenue Landfill are serviced by a public water supply, which eliminates the need for well installation at a private residence.

- The current onsite resident may be affected the most by exposures at the Brookfield Avenue Landfill. However, the results show there is no potential for adverse health effects and that potential carcinogenic risks are acceptable. There is a potential for adverse effects to a future onsite child that may ingest soil on the landfill. Potential future ingestion of groundwater from the shallow aquifer onsite and exposure to volatiles in the shower results in the potential for adverse health effects, however, residents in the vicinity of the landfill are serviced by a public water supply eliminating the need for a resident to install a well for potable use. In addition, regulatory agencies would not likely permit such wells.

Ecological Risks

- The results of the Ecological Risk Assessment (ERA) indicated that contaminants found in sediment and surface water have the potential to pose high risk to the selected ecological receptors. Risk to benthos in sediment was determined to be the greatest. High risk could be expected from arsenic, copper, lead, mercury, and chlordane and PCBs in sediment. This was confirmed by the results of the sediment toxicity testing which showed acute toxicity to the amphipod, and increased levels of some heavy metals in tissue residues of the mollusk and polychaete worm.

- The chemicals of concern (COCs) identified for surface soil, namely PAHs and metals, represent low to no risk to most terrestrial receptors. Potential low risk was associated with metals to flora, based on comparisons to the phytotoxicity benchmarks.

2

Section Two

Section 2
Remedial Action Objectives

2.1 Remedial Action Objectives

Remedial action objectives (RAOs) are developed to protect human health and the environment, which includes terrestrial and aquatic biota, sensitive or critical habitats, and endangered species. The remedial action objectives established for the Brookfield Avenue Landfill include:

1. To isolate the landfill waste material in order to provide protection to human health and the environment from direct contact or ingestion of hazardous constituents in waste soil.
2. To prevent infiltration of water through the surface of the landfill and prevent leachate from contaminating the groundwater and/or surface water and sediment.
3. To prevent human contact with, inhalation of, or ingestion of the hazardous constituents in groundwater impacted by the landfill.
4. To control air emissions from the landfill and prevent the release of contaminants above annual air guideline (AGC) concentrations, or risk-based levels.
5. To prevent leachate from impacting adjacent freshwater wetlands, tidal wetlands and to minimize impact to the wetlands during implementation of the remedial measures.

These RAOs serve as the primary basis upon which the remedial alternatives are developed and evaluated. Using the presumptive remedy approach, a limited number of media specific remedial technologies, including any identified presumptive remedies, are identified. These are then screened for site specific feasibility, technical implementability, and practicability based on readily available information from the site RI and from similar sites.

Using the presumptive remedy approach, a number of technologies are clearly applicable to the site. These are listed below according to the remedial action objective being addressed by that technology.

The first RAO for this site can be addressed by the construction of a Part 360 (or modified Part 360) landfill cap. The cap would isolate landfill material and protect human health and the environment from contact with landfill contaminants. Landfill cap alternatives are included in this evaluation.

The second RAO can also be addressed by the construction of a Part 360 (or modified Part 360) landfill cap. The landfill cap should substantially reduce the generation of leachate in the future, except for the remaining stormwater that has already infiltrated the landfill and the portion of the waste that is below the water table. A part of the objective can also be met by groundwater containment using an interceptor trench, slurry wall, or extraction well system. Construction of a french drain along the southern site boundary is also an alternative for reducing leachate discharge. Collected leachate can be treated onsite, discharged to Richmond Creek, piped to the Fresh Kills Landfill for treatment, or pre-treated and discharged to the Eltingville Pump Station, which conveys sewage to the Oak Beach WWTP.

The third RAO can be addressed by limiting access to the contaminated portions of the aquifer through one of several institutional control measures, including well permit restrictions and deed restrictions. Currently, no private wells exist in the vicinity of the landfill that serve as a supply of potable water.

The fourth RAO can be addressed by the construction of a Part 360 landfill cap, passive or active gas vents, and some form of gas destruction (flaring) or treatment. Landfill gas may potentially be treated onsite or piped to the Fresh Kills Landfill for treatment.

The fifth RAO can be addressed by technologies similar to those presented under the second RAO. Impact to wetlands during implementation of remedial measures can be addressed through waste consolidation and wetland restoration.

2.2 General Response Actions

General Response Actions are categories of activities which are applied toward remediation of contaminated sites. The remedial action objectives developed for a site dictate which general response actions should be undertaken. Within each general response action (other than No Action) there are several technology types and process options.

The general response actions identified for the Brookfield Avenue Landfill that will meet the remedial action objectives or will provide a baseline against which actions may be compared consist of the following:

No Further Action - A No Action response is always identified for the purpose of establishing a baseline with which to compare other general response actions. There are no preventative or corrective actions taken as a result of this general response action; however, monitoring of the contamination may be prescribed. In the case of the Brookfield Avenue Landfill, there is no true No Action alternative since the presumptive remedy approach is being followed.

Institutional Controls - These controls utilize actions which control contact with the contamination rather than remediating the contamination itself. These actions may be physical, such as fences or barriers, or legal such as deed restrictions, zoning changes, restrictions on water use, or security restricted access.

Containment - As a general response action, containment prevents risk to human health and the environment by restricting contact to or migration of the contaminants via the soil, water or air pathways. A number of technologies and different materials are available for use in establishing migration barriers.

Removal/ Excavation - This response action physically removes or collects the existing contaminated media from the site. Other response actions are usually necessary in order to achieve remedial action goals and objectives for the removed and collected media. Collection and removal of solids/soils media is often associated with source control activities and eventually reduces contaminant concentrations in the surrounding surface water, groundwater, biota, and air media. Collection or removal actions in water and air media may not prevent continued migration of contaminants in those media, but typically intercept the most contaminated portions of those media. Collection actions which intercept their respective media would be considered containment general response actions.

Treatment - These actions involve removal of the contaminant from contaminated media, or alteration of the contaminant. The result is a reduction in mobility, volume, or toxicity of the contaminant. This general response is usually preferred unless site or contaminant-specific characteristic make it unrealistic.

Disposal/Discharge - This general response action involves the transfer of contaminated media, concentrated contaminants, or treated materials to a site reserved for long term storage of such materials. Disposal sites are strictly regulated in operation and the types of materials that they may accept.

The general response actions presented above form the basis for identifying technology types and process options specific for the site, which are subsequently screened for effectiveness, implementability and cost.

2.3 Presumptive Remedy Approach

Because waste in landfills usually is present in large volumes and is a heterogeneous mixture of municipal waste frequently co-disposed with industrial and/or hazardous waste, treatment usually is impracticable. In such a case, EPA generally considers containment to be the appropriate response action or the "presumptive remedy" for the source area of municipal landfill sites (EPA, 1993). Presumptive remedies are preferred technologies for common categories of sites, based on historical patterns of remedy selection and EPA/NYSDEC scientific and engineering evaluation of performance data on technology application. Components of the containment presumptive remedy include:

- Landfill cap;
- Source area groundwater control to contain the plume;
- Leachate collection and treatment;
- Landfill gas collection and treatment; and/or
- Institutional controls to supplement engineering controls.

Components not addressed by the containment presumptive remedy include:

- Exposure pathways outside the source area (landfill);
- Remediating groundwater;
- Remediating contaminated surface water and sediments; and
- Remediating contaminated wetland areas.

The Remedial Investigation identified the landfill as one containing a heterogeneous mixture of municipal, industrial and hazardous waste. Several areas were identified as hot spots and received additional focused studies. Groundwater has been impacted by leachate beneath the site, and to a very limited extent, immediately south of the site. The landfill was identified as a source of several VOCs released from the landfill surface into the air. Additionally, sediment and surface water have been impacted by leachate. Based on the these general findings, the containment presumptive remedy approach remains applicable to this site. The presumptive remedy approach addresses the containment of the waste mass, leachate collection and treatment, groundwater control, air emissions, and institutional controls. The containment presumptive remedy does not apply to remediating wetlands, surface water and sediment.

To address Richmond Creek surface water, wetland areas and sediment concerns, the NYSDEC has agreed that it is appropriate to separate the Brookfield Avenue landfill project into two operable units (NYSDEC, 1999). The NYSDEC considers an operable unit to represent a portion of the site remedy, which for technical or administrative reasons can be addressed separately to eliminate or mitigate a release, threat of release or exposure pathway resulting from the site contamination. Therefore, the Brookfield Avenue Landfill shall be addressed in two separate operable units, with Operable Unit 1, or OU1, consisting of the landfill and Operable Unit 2, or OU2, consisting of Richmond Creek. Separation of the landfill and Richmond Creek into separate Operable Units in no way minimizes the City of New York's obligations under the Order of Consent Index No. 2-43-006.

The remainder of the FS Report will address remedial alternatives for only OU1, the landfill. OU2, Richmond Creek, shall commence concurrently, but separately.

For OU1, the use of presumptive remedy guidance can, in this case, provide an immediate focus to the discussion and selection of alternatives. It can help to speed the process by limiting the number of evaluated alternatives to those comprised of technologies that have been selected in the past at similar sites or for similar contaminants. By evaluating technologies that have been consistently selected at similar sites, a presumption can be developed that a particular remedy or set of remedies is appropriate for this specific type of site. Using this presumptive remedy approach, a limited number of media-specific remedial technologies, including any identified presumptive remedies, are identified. These are then screened for site specific feasibility, technical implementability, and effectiveness based on readily available information from the site RI and from similar sites. Specific technologies may not be applicable to the treatment of contamination in the concentration and form found at the site, or may be impractical due to site constraints and can be eliminated from further consideration. The remaining technologies can then be assembled into a limited number of site-wide remedial alternatives, which are subsequently subjected to a detailed, comparative evaluation. The following section begins this process by identifying the remedial technologies.

3

Section Three

Section 3
Identification of Remedial Technologies

Potential remedial actions and technologies identified as part of the presumptive remedy approach for each medium are described in this section. Potential actions/technologies are identified for air, soil, leachate/groundwater and sediment. As specified in the RI/FS Work Plan (DEP, 1993), these actions/technologies are screened for effectiveness, implementability, and cost. In accordance with guidance documents, only those actions/technologies that could be practically and effectively implemented at the site are assembled into the remedial alternatives presented in Section 5.1; these alternatives will be carried through to the Detailed Analysis of Alternatives.

3.1 Presumptive Remedy

In accordance with EPA Guidance Document 540-F-93-035, "Presumptive Remedy for CERCLA Municipal Landfill Sites" (EPA 1993), the presumptive remedy for closure of the Brookfield Landfill relates primarily to containment of the landfill mass, and collection and/or treatment of landfill gas. In addition, measures to control landfill leachate, affected groundwater at the perimeter of the landfill, and/or upgradient groundwater that is causing saturation of the landfill mass may be implemented as part of the presumptive remedy.

The 6 NYCRR Part 360 closure regulations govern the response action at the Brookfield Landfill as Applicable or Relevant and Appropriate Requirements (ARARs). The Brookfield Avenue Landfill is being closed under the Part 360 regulations that were in effect on the day the NYSDEC entered the Order of Consent with New York City for the closure of the site (May 15, 1992). The last revision to the Part 360 regulations at that time was effective January 25, 1992. Therefore, the landfill is being closed in accordance with the Part 360 regulations effective January 25, 1992.

3.1.1 Standard NYCRR Part 360 Cap

A low permeability landfill cap can be constructed over the Brookfield Landfill to create a physical barrier that: 1) prevents exposure to solid waste via direct contact, 2) significantly minimizes leachate generation and future impacts to underlying groundwater quality, and 3) controls gas emissions from the landfill. The design requirements for cap construction are specified in 6 NYCRR Part 360 Regulations, effective date January 25, 1992.

The 6 NYCRR Part 360 Regulations, Section 360-2.15(b), specify the following components for the Final Cover (starting from the bottom):

▪ Gas Venting Layer	Section 360-2.13(p)
▪ Low Permeability Layer	Section 360-2.13(g), Soil Layer; or

	Section 360-2.13(r), Geomembrane Layer
▪ Protection Layer	Section 360-2.13(r)(iii)
▪ Topsoil Layer	Section 360-2.13(s)

A typical cross-section of the required final cover is shown in Figure 3-1. The 6 NYCRR Part 360 slope requirements for cap construction are discussed in Section 3.1.4.

Design variances for each of the above cap components may be applied for under the NYSDEC "Local Government Regulatory Relief Initiative - Guidance on Landfill Closure Regulatory Relief," dated February 26, 1993. A description of each layer, its respective function, and potential design variances is provided below.

3.1.1.1 Gas Venting Layer

The purpose of the gas venting layer is to facilitate movement of gases from the landfill interior to the venting points. It is located above the rough grade and immediately below the low permeability layer.

The 6 NYCRR Part 360 Regulations allow the use of either soil or geosynthetics that meet the minimum coefficient of permeability of 1 x 10-3 cm/sec. If soil is used, the thickness of the layer must be a minimum of 12 inches, have a maximum of five percent (by weight) passing the No. 200 sieve, and be bounded on its upper and lower surfaces by a filter layer, as defined in Section 360-2.13(o).

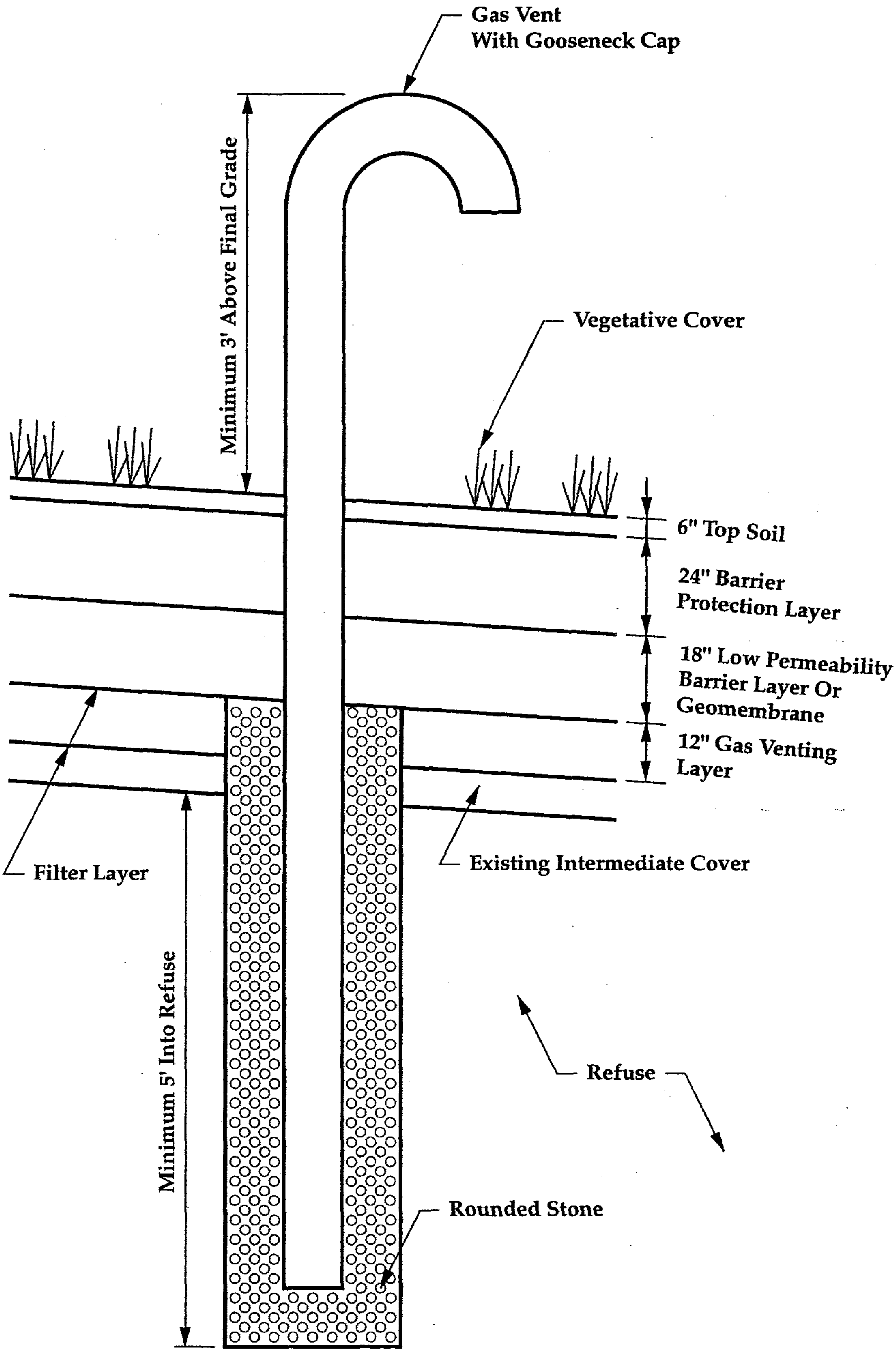
A geosynthetic drainage layer would consist of geonet placed between two layers of geotextile filter fabric. Geonet is porous synthetic product, typically constructed of High Density Polyethylene (HDPE), that is commonly used for subsurface drainage applications. The main advantages of constructing the drainage layer using geonet is that it requires less space than the sand layer and can have higher transmissivity. The cost differential between these alternatives is minimal.

A variance to eliminate the requirement for constructing the gas venting layer can be applied for. Gas venting, without the gas venting layer, would be achieved by installing at least four gas vents per acre of landfill cap versus the 6 NYCRR Part 360 requirement of one gas vent per acre.

3.1.1.2 Low Permeability Layer

The purpose of the low permeability layer is to prevent leachate generation caused by infiltration of rain water and to prevent uncontrolled movement of landfill gases to the ground surface.

The 6 NYCRR Part 360 regulation allows for the use of two alternative impermeable layers for landfill covers. The first alternative allows for the use of 18 inches of low



Not To Scale

Figure 3-1
Typical Part 360 Landfill Cap Cross Section With Gas Vent
Brookfield Avenue Landfill Remediation Project

CDM Camp Dresser & McKee

permeability soil (1x10• 7 cm/sec permeability) and the second alternative allows for the use of 40 mil thick geomembrane.

There are two different types of soils that can be used for the low permeability alternative. These types of soils are natural clays with $1x10^{-7}$ cm/sec permeability and bentonite enhanced soils that would meet the low permeability requirement of $1x1^{-7}$ cm/sec.

The natural clays that meet the low permeability requirement are also classified as "fat" clays and are difficult to work with. Optimum moisture conditions are usually required to compact the material and achieve the required in-place impermeability. Optimum conditions dictate that there is no rain or freezing or hot weather during the work activity. Rain will cause the material to become very wet and impossible to work with or to compact properly; freezing will make the material hard, and, therefore, proper compaction will not be possible; and hot weather will cause the moisture to evaporate, therefore jeopardizing compaction. Also, at the end of each day the active construction phase must be finished and compacted to avoid possible damage from climatic changes during the evening hours. In the event that an active phase has to remain open, the area usually is covered with plastic to protect the material. The absence of native clays on Staten Island, the high cost associated with transporting material either from Upstate New York, New Jersey, or mid-west states, and the complex installation procedure, eliminates this material from the options to be used for capping.

The bentonite enhanced soils involve mixing of native soils with a percentage of bentonite to achieve the required impermeability. The ratio of materials can be determined in bench scale studies and the same ratios can be used during construction at an on-site mixing plant. This type of soil is significantly less affected by climatic changes and, with the exception of heavy rains or freezing weather, the installation can be accomplished without significant delays. The cost of this material including installation ranges from $35 to $45 per cubic yard depending on the source of the native soils. The lower limit ($35) will involve use of on-site loamy soils and the upper limit ($45) is for transported native soils. Assuming use of on-site soils, the estimated cost per square yard of surface area for an 18-inch thick layer will be $17.50. Although this cost appears to be significantly lower than the clay cost, it is still more expensive than geomembranes for which analysis will be provided below. The existing side slopes at the Brookfield Landfill are gentle, and there are geomembranes available on the market that provide the required friction angle with a sufficient safety factor. Thus, there is no added advantage in using soils which, in general, provide higher friction angles. Based upon budgetary cost estimates and experience at other landfills, the cost of the construction of an 18-inch thick low permeability layer is typically more than twice that of a geomembrane.

There are a number of geomembranes that can be used for landfill capping. Traditionally, in landfill engineering the most commonly used ones are Polyethylene (PE) and Polyvinyl Chloride (PVC). The polyethylene type membranes are available in different grades such as High Density (HDPE) and Linear Low Density (LLDPE). Alternatively, a geosynthetic clay liner (GCL) may be used.

The higher density polyethylenes provide a significant advantage with respect to chemical compatibility. HDPE is resistant to most chemicals and is normally used for landfill and containment liners. Due to the stiffness and comparatively lower elongation properties of the material, HDPE is usually used in areas with uniform bedding and low settling expectations. For the same reasons (rigid nature) HDPE is more difficult to work with along the side slopes and will not readily conform to the contouring of the topography.

The LLDPE and PVC are two materials commonly used for capping landfills due to their elastic nature, ability to conform to the contouring of the topography, and ability to withstand uneven settlement.

3.1.1.3 Protection Layer

The purpose of the protection layer is to protect the geomembrane from frost action, root penetration, and physical damage. It also serves a secondary purpose by acting as a lateral drainage layer above the low permeability layer. Lateral drainage is generally essential to maintaining the slope stability of the landfill cap.

The protection layer is located above the low permeability layer. 6 NYCRR Part 360-2.13(r)(iii) specifies that this layer must have a minimum thickness of 24 inches. In addition, the lower six inches of the layer must be "free of stones" to prevent damage to the low permeability layer during construction.

A variance could be applied for to reduce the minimum protection layer thickness from 24 inches to either 18 or 12 inches. This variance has been approved by the NYSDEC at several New York City landfills.

3.1.1.4 Topsoil Layer

Above the protection layer, a minimum 6-inch layer of topsoil is necessary to maintain vegetative growth over the landfill. Upon completing placement of the topsoil layer, the entire landfill is hydroseeded to establish vegetation cover and avoid erosion of the cover layers. The seed mixture used for the hydroseeding consists of varieties of grass suitable for the local climatic conditions.

3.1.1.5 Consolidation of Waste

The purposes of waste consolidation are to reduce the area to be capped and reduce or eliminate the need for permanent structures to be constructed within wetlands. Waste would be excavated from the areas near the edge of the landfill and consolidated in depressions or spread evenly over areas to be capped. Various controls would be required during excavation, hauling and consolidation to prevent worker and neighboring area exposure to potential hazards. Temporary cover would be required over the consolidated waste, prior to final capping.

The areas where waste consolidation may be appropriate are located just north of the pump station, between the east and west cells, and along the northern edge of the west cell, near Richmond Creek. Test pitting in each of these areas has confirmed the presence of decaying MSW at thicknesses greater than 6 feet, below 10 feet (MSL) in elevation. For evaluating waste consolidation, the 10-foot elevation line is used as an informal boundary to the tidal wetlands. Section 8 will include a separate analysis (outside of the alternative comparisons) comparing waste consolidation, leaving waste in-place and capping below the 10-foot elevation line, and leaving waste in-place but locating the cap and all structures above the 10-foot elevation line.

Figure 3-2 shows the approximate locations where waste would be excavated to ensure that the cap and associated structures (access roads, barrier walls and leachate collection trenches) would be above the 10-foot elevation line. The total area to be excavated is approximately 24 acres and the volume of waste is roughly 290,000 cubic yards.

3.1.2 Landfill Gas Control

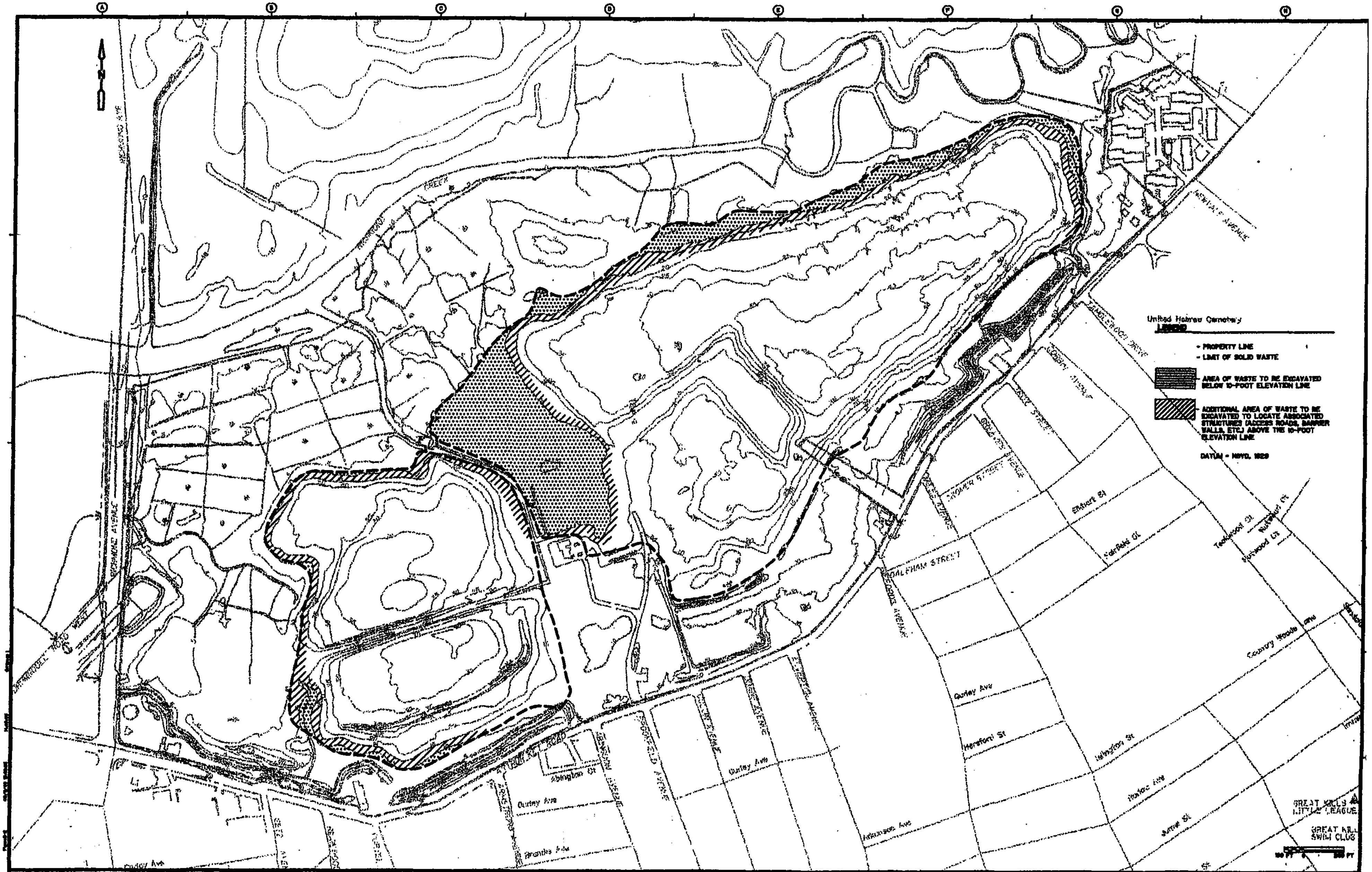
The primary purpose of the landfill gas control system is to collect landfill gases, which may accumulate at explosive concentrations, or pose health hazards associated with inhalation of hazardous compounds. Landfill gases generally consist of methane and carbon dioxide, which are produced as byproducts during anaerobic biodegradation of waste. Lower levels of hydrogen sulfide and Non-Methane Organic Compounds (NMOCs) are also present.

Control of landfill gas movement is achieved by constructing a gas venting system. The gas venting system may be either a passive system or an active system, as described below. Active systems can include: a treatment system to thermally destroy hazardous gases prior to atmospheric discharge; a treatment system to convert gas to pipeline quality gas for shipment to a pipeline; or a system, with or without pretreatment, to fire the gas in a turbine(s) engine(s) to produce electricity and/or useful heat for use at the site or for sale.

3.1.2.1 Passive Gas Control

The construction requirements for a passive gas venting system are specified in 6 NYCRR Part 360-2.13(p)(2). The system would consist of multiple vents that are installed through the landfill cap.

Passive vents operate based upon the natural pressure gradient between the landfill void space and the atmosphere. As gas is generated inside the landfill, the pressure underneath the protective cap increases to levels exceeding atmospheric pressure.



REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: J. BOYER
DRAWN BY: C. KALNY
SHEET CHK'D BY: S. GOLDSTEIN
CROSS CHK'D BY:
APPROVED BY:
DATE: JULY 2000

CDM Camp Dresser & McKee

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL
REMEDIATION PROJECT

POTENTIAL WASTE EXCAVATION AREAS

PROJECT NO. [illegible]
FILE NAME [illegible]
DRAWING NO.

Figure 3-2

The vents, which are typically constructed as wells or horizontal trenches, act as conduits that facilitate the natural release of landfill gases to the atmosphere.

The wells, installed at a minimum frequency of one well per acre, would be drilled at least five feet into the refuse using a rig equipped with a bucket auger. The diameter of vent boreholes generally ranges from 24 to 36 inches. Upon completing the borehole, the vent is installed by placing a section of 6 to 8 inch diameter perforated pipe into the hole followed by crushed stone. The vent is extended three feet above the ground surface using sections of solid pipe. A low-permeable boot is installed at the interface between the low permeability layer and the vent to maintain the integrity of the protective liner. Ventilator caps or inverted 180-degree elbow are attached to the end of vents at the ground surface to prevent the entrance of rain.

Trenches are constructed using excavation equipment. Similar to well construction, the hole is filled with a horizontal section of perforated pipe followed by crushed stone. The vent is then extended vertically to the ground surface, and equipped with a low-permeable boot and a ventilator cap or inverted elbow.

As an alternative to passive venting at each vent location, the vents could be manifolded together using flexible pipe. Gas from multiple wells would be combined through one or more common header lines and discharged to the atmosphere at select locations. The header lines can be installed either above or below the cap. Discharge locations would be selected based upon the results of dispersion modeling to minimize any impact to downwind receptors.

3.1.2.2 Active Gas Control

The main component of the active gas control system would be extraction wells and trenches, which are typically constructed as described above. The wells are equipped with a tee fitting at the top of the riser pipe that includes a valve, sampling port, and thermometer. Each well is connected, either directly or indirectly, to a main header pipe that collects gas from all of the wells. The main header and lateral header lines can be installed either above ground or below ground using flexible pipe.

The pipelines are designed based upon anticipated flow rates and structural load requirements. The main header pipe is connected to a blower, which induces a vacuum on the entire wellfield. From the blower, the gas is directed to a treatment system. Treatment systems are described in further detail in Section 3.1.2.3

3.1.2.3 Gas Treatment

Onsite Treatment

One potential method of onsite treatment would involve transporting the landfill gas to a centralized onsite treatment plant, where hazardous and undesirable constituents are thermally destroyed using a flare system. Flares have been proven to be particularly effective for removal of VOCs, achieving destruction efficiencies in excess of 98 percent. The flare equipment generally consists of the flare, flame arrestor, blower and motor, condensate trap, and electric controls.

An enclosed (ground level) flare system would be used versus an open (elevated) system. Enclosed flares consist of multiple gas burner heads placed in a refractory-lined enclosure. Open flares resemble large Bunsen burners, with candle-like flames. The enclosed flare system is more costly, but it is typically a more desirable alternative to an open system based upon aesthetics and the ability to effectively test off gas for determination of destruction efficiency.

The onsite, enclosed treatment plant would, at a minimum, be constructed on a concrete pad and enclosed by fencing to prevent vandalism. A prefabricated or masonry-type building to house the plant could also be constructed to improve aesthetics and provide additional protection to the equipment.

Another potential for onsite treatment involves converting the landfill gas, which is approximately 50% methane, to pipeline quality gas in a treatment facility. The other components, mainly CO2, would be removed and scrubbed, if necessary. The pipeline quality gas would be piped to a nearby pipeline for sale to a local gas supplier, such as Marketspan (the former Brooklyn Union Gas).

A third potential for onsite utilization is to use the landfill gas (with or without pretreatment) in an engine (or engines) or gas turbine for the production of electricity or useful heat (steam) for sale to a nearby user or utility.

Offsite Treatment

The landfill gas could be transported for treatment at the Fresh Kills Landfill. The gas would either be treated at the Fresh Kills gas recovery plant, where natural gas (methane) is recovered and sold, or at one of five flare plants planned for construction. The estimated rate of gas generation from the Brookfield Avenue Landfill is 500 to 800 standard cubic feet per minute (scfm).

3.1.3 Leachate and Groundwater Control

The purpose of leachate control is to prevent leachate from migrating offsite. The purpose of groundwater control is to prevent groundwater originating offsite from contacting the waste mass. Following cap construction, the low permeability layer of the cap will prevent downward infiltration of water through the waste mass. Hydraulic diversion of groundwater flow upgradient of the landfill may effectively lower the underlying groundwater table, thereby minimizing the saturated waste volume. Leachate and groundwater control may also be achieved through collection, treatment, and disposal. These features are discussed in further detail below.

3.1.3.1 Hydraulic Containment System

Pump and treat is the standard technology used to hydraulically control the movement of groundwater. Offsite movement of groundwater impacted by leachate is prevented by installing extraction wells or interceptor trenches along the base of the landfill, where the water is pumped from the ground to a treatment plant. The cone of depression created by pumping acts as a hydraulic barrier that prevents groundwater within its capture zone from flowing downgradient of the landfill.

The location of collector systems is typically determined based upon water quality data, aquifer flow characteristics, and the results of pump tests and/or modeling. Collection systems can be designed to contain groundwater flow from beneath the entire landfill, or from localized source areas identified based upon groundwater quality data.

Extraction wells are typically installed inside and/or along the landfill footprint, and screened at depths corresponding to the bottom of the fill. Interceptor trenches are typically constructed adjacent to the landfill along the downgradient toe of slope using conventional excavation equipment. They are generally excavated to a depth of no more than 15 feet and lined with geotextile filter fabric. A perforated collector pipe is placed at the bottom of the trench prior to backfilling it with gravel. The bottom of the trench is sloped longitudinally to facilitate gravitational flow toward collector sumps, where the water is pumped from the system to the treatment plant.

3.1.3.2 Hydraulic Diversion System

Groundwater elevation contours maps presented in the RI Report indicate that the east and west perimeter ditches, located upgradient of the landfill, currently act as hydraulic divides, which prevent inflow of shallow groundwater flow from upgradient areas. The majority of groundwater inflow occurs across an area, approximately 1,500 feet wide, which is located between the ditches. The eastern portion of this zone, which transmits the majority of the groundwater water, consists of glacial till with sand up to 20 feet in thickness. The western portion is composed of less permeable glacial till/glaciolacustrine clay-silt.

Interceptor trenches and low-permeable (barrier) walls are standard technologies used to divert groundwater flow. Based upon the above, the existing drainage system (perimeter ditches) could also be expanded to enhance the diversion of groundwater inflow. These technologies are described in further detail below.

Since the western portion of the area between the ditches consists primarily of low permeable soils, construction of a hydraulic barrier across the entire area between the ditches may not be required. A barrier system could be installed within the more permeable zone, which is approximately 1,500 feet wide and abuts the east ditch, to effectively construct a continuous hydraulic divide upgradient of the landfill.

Barrier Wall

A barrier wall (sheet piling, low-permeable grout slurry, or geomembrane) could be constructed from the east perimeter ditch across the permeable zone. The barrier wall would divert groundwater flow toward the ditches. Other beneficial locations for a barrier wall would include between the landfill and the drainage ditches, to prevent leachate from discharging to the ditches, and along the north face of the landfill to prevent discharge of leachate to Richmond Creek.

Interceptor Trench

An interceptor trench, as described in Section 3.1.3.1, could be constructed from the east perimeter ditch across the permeable zone. The downgradient side of the trench would be lined with a low permeability wall (geomembrane, sheet piling) to prevent backflow of groundwater from the landfill. The trench would capture groundwater and divert it to the east perimeter drainage ditch. Sumps would likely be required to pump the collected groundwater to an elevation for discharge to the ditches

Extension and Improvement of the East and West Perimeter Ditches

The east perimeter ditch could be extended across the permeable zone, to enhance diversion of groundwater entering the site.

3.1.3.3 Treatment and Discharge

Groundwater collected from containment systems would require some form of treatment and disposal. Options include: 1) pre-treatment (most likely oils removal to meet sewer use regulations) and disposal to the onsite pump station, 2) treatment (mainly reduction of BOD, COD and metals to meet discharge to surface water limits) and disposal to Richmond Creek, and 3) treatment at the Fresh Kills treatment plant. These options are discussed in further detail below.

Pretreatment and Discharge of Groundwater to Onsite Pump Station

Groundwater collected from containment systems could be pre-treated onsite and discharged to the NYCDEP's Eltingville Pump Station, which is located onsite. The pump station ultimately discharges to the Oakwood Beach Water Pollution Control Plant. The pre-treatment plant would be designed so that its effluent would comply with the NYCDEP Sewer Use Regulations (15 RCNY 19-01 et seq.).

Table 3-1 presents the maximum concentration of various compounds allowed for discharge into the public sewer system and the average value of the compounds found in leachate from leachate wells at the landfill. From this comparison the only constituent which may potentially require pretreatment would be total petroleum hydrocarbons (TPH's). Therefore, oil/water separation would be considered for pretreatment of groundwater/leachate.

Oil/ Water Separation

New York City's Sewer Use Regulations state that petroleum hydrocarbons in concentrations greater than 50 mg/l are excluded from discharge into public sewers. Depending on the location of collection and design of collection systems, oil may need to be removed from the waste stream prior to discharging it to the pump station. For example, leachate collected at the Hot Spot no. 5 area may benefit from oil/water

Table 3-1

NYC Sewer Use Regulations

Brookfield Avenue Landfill Remediation Project

Constituent	*Permissible Maximum Concentration (mg/l)*	*Daily Average Maximum Concentration (mg/l)*	*Brookfield Leachate Mean Value (mg/l)*
Cadmium	2	0.69	< 0.004
Chromium (hexavalent)	5	-	0.029
Copper	5	-	0.012
Cyanide (amenable)	0.2	-	-
Lead	2	-	0.019
Mercury	0.005	-	< 0.0002
Nickel	3	-	0.042
Zinc	5	-	0.074
Petroleum Hydrocarbons	50	-	-
pH range	5-11	-	7.2

es:

1. Sewer Use Regulations (15 RCNY 19-01 et seq).
2. Petroleum hydrocarbons shall mean that portion of the total oil and grease which is not eliminated from a freon (trichlorotrifluoroethane) solution by silica gel adsorption.

separation, as it was the one location where floating product was found within a well (GW-23S).

Oil/water separation is a standard process that is used to separate free floating oil, grease, and settleable solids from the groundwater influent. The process consists of an enclosed vessel that is equipped with internal baffles and coalescers that facilitate oil-water separation. Groundwater influent passes through the internal baffles and coalescers, which cause the oil to rise and coalesce underneath each of the plates. The coalesced oil then rises to the top of the vessel, where it accumulates until it is removed. The effluent from the oil/water separator typically discharges by gravitational flow.

The oil/water separation unit would be sized based upon the containment system design flow rate. Waste oil pumps would transfer the supernatant from the oil/water separator to a waste oil holding tank. Effluent from the oil water separator would be discharged by gravitational flow into an intermediate sump tank, prior to metals precipitation treatment.

3.1.3.4 Onsite Treatment of Leachate with Discharge to Richmond Creek

Groundwater collected from containment systems could be treated onsite and discharged to Richmond Creek. Applicable treatment would include biological (aerobic and anaerobic) and physical/chemical processes. A New York State Pollution Discharge Elimination System (SPDES) permit would be required to discharge effluent to Richmond Creek.

An extensive study of treatment alternatives was performed at the Fresh Kills Landfill prior to the construction of its onsite treatment plant, which is presently in operation. It is expected that the Brookfield Avenue Landfill treatment plant would be similar to the Fresh Kills Landfill Treatment Plant.

Leachate Characteristics

Based on recent sampling results, Brookfield Avenue Landfill leachate is of moderate strength, and typical of municipal solid waste landfills. Localized areas also contribute oil-related organic compounds to the leachate. The mean biological oxygen demand (BOD) and chemical oxygen demand (COD) of the leachate is approximately 200 mg/l and 1,000 mg/l respectively. Total dissolved solids are in the range of 5,000 mg/l and ammonia averages 286 mg/l. These values are consistent with leachate currently being treated at the Fresh Kills Landfill Treatment Plant.

Treatability Study Results

An extensive study of treatment alternatives was completed for the Fresh Kills Landfill as part of the Fresh Kills Leachate Treatment and Minimization Study (Fillos, circa 1992). The study examined the characteristics of leachate, the impact to surface waters, and multiple treatment technologies through bench scale testing. Fresh Kills leachate was characterized as being slightly alkaline and well-buffered; having high concentrations of organic substances (most were biologically stable) and ammonia; containing few priority pollutants; and possessing the color intensity of strong tea. The primary impact of leachate on the surrounding surface waters was its contribution to the high oxygen demand and potential eutrophication due to ammonia and nitrates. Treatment alternatives evaluated as part of the Fresh Kills study included biological treatment (activated sludge, sequencing batch reactors [SCBRs], powdered activated carbon added to activated sludge [PACT], and rotating biological contactors [RBCs], and anaerobic processes) and physical/chemical treatment (coagulation/ flocculation, air stripping, carbon adsorption, and chemical oxidation) processes.

Onsite Treatment

Based upon the design of the Fresh Kills Leachate Treatment Plant, the Brookfield Landfill treatment plant would include influent holding tanks; SBRs for ammonia and BOD removal; chemical precipitation and sedimentation for metals removal; filtration for residual suspended solids removal; and final pH neutralization. The effluent would be then be discharged to Richmond Creek.

Discharge to Richmond Creek

A SPDES permit would be required to discharge effluent to Richmond Creek. The permit would specify the maximum daily flow, water quality standards for effluent discharge, and monitoring requirements. The permitted effluent water quality criteria would, at minimum, conform with water quality standards for discharge to a class SC water body (Richmond Creek). The preliminary NYSDEC discharge limits for the Fresh Kills leachate treatment plant are shown in Table 3-2 (final discharge limits, as permitted, have not yet been made available). The permit limits for effluent discharge at Brookfield Avenue Landfill would be expected to be similar.

3.1.3.5 Offsite Treatment at the Fresh Kills Treatment Plant

Groundwater collected from containment systems could be pumped to the Fresh Kills treatment plant. The plant has a design capacity of 0.9 MGD. Information documenting current operating flow rates and anticipated future flow rates was unavailable to determine if excess treatment capacity is available.

The Fresh Kills treatment plant is located at the southern end of Section 1/9. Influent from the Brookfield Avenue Landfill would be transported to the plant by installing a transmission main that ties in to the Fresh Kills leachate collection system.

3.1.4 Stormwater Runoff and Erosion Control

3.1.4.1 Uniform Slope Design

The landfill cap would be constructed with slopes that are generally uniform from top to bottom across a given vertical cross-section. Under such conditions, stormwater runoff would travel radially from the landfill cap as overland (sheet) flow. The water would be allowed to disperse naturally at the base of the landfill at locations determined to be appropriate based upon the results of erosion, flooding, and surface

Table 3-2

Preliminary NYSDEC Discharge Limits for Leachate from The Fresh Kills Landfill

Brookfield Avenue Landfill Remediation Project

Parameter	*NYSDEC Discharge Limit (mg/l)*
BOD	45 mg/l or 85% Removal
COD	85% Removal
TKN	Monitor
TSS	45 mg/l or 85% Removal
Settleable Solids	0.2
Coliform	100/100 ml
Oil & Grease	15
Aluminum	4
Antimony	0.6
Arsenic	0.1
Barium	4
Chromium VI	0.1
Total Chromium	1
Cyanide	0.26
Copper	0.4
Fluoride	15
Iron	4.0
Lead	0.2
Manganese	2.00
Nickel	0.8
Silver	0.1
Zinc	1
Sulfide	4
2,3-Dimethylphenol	0.06
Ethylbenzene	0.08
napthalene	0.017
TOX	0.025
pH	6 - 9

water quality evaluations. Perimeter drainage structures, such as toe drains and/or swales, would be installed at all other locations to intercept and transport stormwater runoff for ultimate discharge to Richmond Creek. Subsurface drains, consisting of a sand layer or geonet would be installed above the cap to remove infiltrated water from above the liner for the purpose of maintaining slope stability.

3.1.4.2 Washboard Design

The landfill cap would be constructed with average slopes that are generally uniform from top to bottom across a given vertical cross-section. A series of lateral swales would be constructed across the slope of the cap to intercept stormwater runoff and minimize erosion. Transverse swales would be constructed perpendicular to the slope to convey runoff water from lateral swales for ultimate discharge to Richmond Creek. Subsurface drainage, consisting of a sand layer or geonet, would be installed above the cap to remove infiltrated water from above the liner for the purpose of maintaining slope stability.

3.1.4.3 Minimum Slope Variance

A variance to reduce the minimum slope requirement from four to two percent would be applied for. A two percent slope could be used for both the uniform slope and washboard designs.

3.1.4.4 Retention of Surface Water Runoff

As an alternative to natural overland flow or direct discharge of stormwater runoff to Richmond Creek, one or more retention basins would be constructed to capture runoff from the cap during storm events. Each basin would be equipped with primary and emergency spillways. During small storm events, all of the runoff water would be collected in the retention basins. The water level inside each basin would be controlled by a primary spillway, which typically consists of a perforated riser, and decrease with time by discharging the water to Richmond Creek over a two to four week period. During large storm events, the water level would be controlled by the emergency spillway, which typically consists of a headwall structure. Excess water would be released over the headwall to Richmond Creek at a controlled rate until the water level dropped below the top of the headwall. The remaining water would be discharged through the primary spillway.

3.1.5 Institutional Controls

Institutional controls would be implemented to supplement the engineering controls. Typical institutional controls for landfills include access restrictions (perimeter fencing, locked access gates) to regulate site use and deed restrictions to regulate future development.

3.1.6 Post-Closure Monitoring

The 6 NYCRR 360 regulations specify that post-closure monitoring be performed for a minimum period of 30 years. Quarterly monitoring is initially performed for a minimum period of five years. After five years, the monitoring frequency can be reduced, subject to NYSDEC approval. Post-closure monitoring would include inspection of the landfill closure system to verify its operational integrity, soil gas monitoring to verify containment of landfill gases, and groundwater sampling to verify containment of leachate. The integrity and effectiveness of potential hydraulic diversion and leachate collection systems would also be monitored. Groundwater and offgas effluent from onsite treatment plants would be monitored in accordance with their respective discharge permit requirements.

3.1.7 Future Land Use Considerations

Future land use options for landfill site would include a natural resource restoration program, passive uses or limited development for recreation or open space activities. NYCDEP anticipates that the community surrounding the Brookfield Avenue Landfill will desire a passive end use and natural setting for the site. Suitable locations on the cap could be developed for passive forms of recreation such as hiking trails and/or walking paths. Additional features, such as picnic areas, could be constructed on the landfill cap or along its perimeter to create a park-like atmosphere that blends in with the surrounding environment and adds value to the community. The NYCDEP would consult closely with the community and the Parks Department to develop these concepts.

3.2 Non-Presumptive Remedies

3.2.1 Hot Spot Remediation

Five areas of the landfill received focused study during the RI. These areas were found to contain elevated concentrations of VOCs, SVOCs, or pesticides. They are as follows:

- Area no. 1, along the southern boundary, contains low to moderate levels of phenol, and was not found to be indicative of a hot spot.
- Area no. 2, along the northern border of the fill, contains low level PCB contamination, and was not found to be indicative of a hot spot.
- Area no. 3, located in the northeast quadrant of the fill, contains relatively high levels of petroleum products. This area was designated worthy of interim remedial action. Currently, a soil vapor extraction system is being procured to remediate this area prior to final closure.
- Area no. 4 in the north-central part of the landfill was not found to be indicative of a hot spot.
- Area no. 5 contains free phase heavy oils. Visible sheen and LNAPL have been observed in the area, along with surface seeps of oil, especially after wet weather. An IRM for this area, consisting of an oil absorbent boom was

implemented. Extension of the perimeter fence has also been completed to reduce the potential for trespasser exposure to the area.

The EPA Guidance, "Presumptive Remedy for CERCLA Municipal Landfill Sites," September 1993, suggests that the decision to treat hot spots should be based upon the following general criteria: 1) the hot spot would threaten the integrity of the containment system (if left in place), or it could be excavated or treated practicably and 2) the hot spot poses a significant risk at the site. The guidance further suggests that the majority of municipal landfill sites are expected to be suitable for containment only.

The estimated extent of each area is shown in Figure 1-3. Based on the results of the RI, the only areas that warrant a non-presumptive remedy are areas 3 and 5. These areas, or "hot spots", are discussed in further detail below.

Hot Spot No. 3

Hot Spot No. 3 is located on the north side of the east cell. Information collected during the RI suggests that the west cell may have been used for bulk disposal of industrial waste, specifically including oil-type wastes. Samples collected during the RI indicated the presence of petroleum products at relatively high levels and supported the existence of a higher strength source area. This area, which was partially capped in 1984, contains approximately 300,000 cubic yards of contaminated soil. Based upon the results of the Hot Spot Workshop that took place at Staten Island Borough President's Office on February 23, 1998, soil vapor extraction (SVE) will be implemented as an IRM at Hot Spot No. 3 prior to landfill cap construction.

Hot Spot No. 5

Hot Spot No. 5 is located on the northern section of the Holtermann's Bakery parcel. Analytical results from groundwater sampling performed in 1994 indicated the presence of VOCs at elevated concentrations. Subsequent sampling performed in 1997 revealed the presence of a light non-aqueous phase liquid (LNAPL) in well GW-23S. Laboratory analysis of the LNAPL indicated that it was a highly weathered, heavy oil (similar to motor oil) that contained benzene, toluene, ethylbenzene, xylene, PCBs, and pesticides. The highly adsorptive, low volatile nature of heavy oils make free-phase recovery and vapor extraction difficult. Based upon the results of the Hot Spot Workshop that took place at Staten Island Borough President's Office on February 23, 1998, sorbent booms were installed as an IRM at Hot Spot No. 5 control seepage of the heavy oil at the ground surface.

There are several potentially applicable technologies beyond the planned IRMs for dealing with the hot spots at the Brookfield Avenue Landfill. Each technology is discussed in further detail below.

3.2.1.1 Excavation and Offsite Disposal

This technology involves excavation and offsite disposal of contaminated soils. It is technically applicable to both hot spots.

3.2.1.2 Bioventing

Bioventing is the process of aerating subsurface soils to stimulate in-situ biological activity. Similar in design to SVE, the goal of bioventing is to maximize biodegradation of aerobically biodegradable compounds. Air is continuously drawn through contaminated soils either directly from the atmosphere or from air injection wells. Nutrients and moisture may also be added to the system to increase biological degradation rates.

Bioventing requires the installation of air extraction and air injection wells (if necessary), a blower system for air movement, appurtenant piping, valves and fittings, and a system of probes, and instrumentation for monitoring operation of the system. Additional piping and equipment may also be required for nutrient and moisture injection systems.

3.2.1.3 Product Collection and Separation

This technology involves the collection of light non-aqueous phase liquid (LNAPL) at the groundwater water table using a pump and treat system, as described in Section 3.1.3.1. LNAPL and groundwater captured by the system would be treated, at minimum, using an oil/water separator and discharged to the onsite pump station or Richmond Creek, as described in Section 3.1.3.3. This technology is technically part of the containment presumptive remedy, but was included here since it is especially applicable to the hot spot areas.

4

Section Four

Section 4
Screening of Remedial Technologies

4.1 Summary of Screening Criteria

This section describes the methodology employed for remedial technology screening and presents the results of the screening evaluations.

Three criteria were used to evaluate and compare remedial technology alternatives: effectiveness, implementability, and relative cost. Brief definitions of these terms, as they apply to the screening process, are as follows:

Effectiveness - The evaluation focuses on the potential effectiveness of technologies in meeting the remedial action goals; the potential impacts to human health and the environment during construction and implementation; and how proven and reliable the process is with respect to the contaminants and conditions at the site.

Implementability - This evaluation encompasses both the technical and administrative feasibility of the technology. It includes an evaluation of treatment requirements, waste management, and the relative ease or difficulty in achieving the operation and maintenance requirements. Technologies that are clearly unworkable at the site are eliminated.

Relative Cost - Both capital cost as well as operation and maintenance costs are considered. The cost analysis is based upon engineering judgement, and each technology is evaluated as to whether costs are high, moderate, or low relative to the other options within the same category.

In addition to the above, the ability for each technology to support a natural post-closure environmental setting and future recreational use at the site was also taken into consideration.

The evaluation focuses upon the effectiveness criterion, with less emphasis on the implementability and relative cost criteria. Technologies surviving the screening process are those that are expected to achieve the remedial action objectives for the site, either alone or in combination with others.

4.2 Screening of Remedial Technology Alternatives

The remedial technology alternatives that were evaluated and compared as part of the screening process are summarized as follows:

Presumptive Remedies

- Landfill Cap
  - Standard (6 NYCRR Part 360) Cap
  - Standard Cap with Gas Venting Layer Variance

    - Standard Cap with Protection Layer Variance
    - Waste Consolidation
- Gas Control System
    - Passive Gas Venting
    - Active Gas Venting
        - Onsite Treatment
        - Offsite Treatment
- Leachate and Groundwater Control System
    - Hydraulic Containment
        - ♦ Onsite Pre-Treatment with Sewer Discharge
        - ♦ Onsite Treatment with Discharge to Richmond Creek
        - ♦ Offsite Treatment at Fresh Kills Landfill Hydraulic Barrier
- Stormwater and Erosion Control System
    - Constant Slope Design
    - Washboard Design
    - Direct Discharge of Stormwater Runoff to Richmond Creek
    - Retention of Stormwater Runoff prior to discharge to Richmond Creek

Non-Presumptive Remedies
- Hot Spot Remediation
    - Excavation and Offsite Disposal
    - Soil Vapor Extraction
    - Bioventing
    - Product Collection and Separation
- Sediment Remediation
    - Natural Attenuation
    - Wet Excavation or Dredging
        - ♦ Disposal
        - ♦ Ex-situ Treatment and Re-Use
    - Capping
    - Containment

A detailed description of each remedial technology alternative was presented in Section 3.0. A conceptual level evaluation of each remedial technology alternative is presented below, based upon the specified criteria for their evaluation and comparison with other alternatives. The results of this screening analysis are summarized in Table 4-1, presented at the end of this section.

4.2.1 6 NYCRR Part 360 Landfill Cap

4.2.1.1 Standard Cap

Site Application:

A landfill cap would be constructed over the Brookfield Landfill in accordance with the 6 NYCRR Part 360 regulations, with no design variances.

Conclusion:

As the presumptive remedy for municipal landfill closure, this alternative is, by definition, cost effective and implementable for closure of the Brookfield Landfill. It should be retained for further consideration.

4.2.1.2 Standard Cap with Gas Venting Layer Variance

Site Application:

A landfill cap would be constructed over the Brookfield Avenue Landfill in accordance with the 6 NYCRR Part 360 regulations, excluding the gas venting layer requirement. A design variance would be applied for to eliminate the gas venting layer by increasing the minimum gas vent frequency from one vent per acre to four vents per acre.

Conclusion:

This alternative would be effective and implementable. However, the cost savings associated with implementing it in conjunction with a manifolded gas venting system (described below) is expected to be marginal to none. This alternative can be eliminated from further consideration.

4.2.1.3 Standard Cap with Barrier Protection Layer Variance

Site Application:

A landfill cap would be constructed over the Brookfield Landfill in accordance with the 6 NYCRR Part 360 regulations, excluding the barrier protection layer requirement. A design variance would be applied for to reduce the minimum protection layer thickness from 24 inches to either 18 or 12 inches based upon the results of a slope stability analysis. Additional subsurface drains would be installed within the cap, where required, to prevent slope instability associated with soil saturation above the cap.

Conclusion:

This alternative is considered to be effective and implementable. It is typically used to reduce the construction cost, and the variance has been approved at a significant number of New York landfills. This alternative should be retained for further consideration. This alternative, however, must be considered in conjunction with an understanding of the amounts of soil necessary to support the selected end-use plan.

4.2.1.4 Waste Consolidation

Site Application:

Waste would be excavated from the areas near the edge of the landfill and consolidated in depressions or spread evenly over areas to be capped. Various controls would be required during excavation, hauling and consolidation to prevent worker and neighboring area exposure to potential hazards. Since much of the excavation would be below the water table, hydraulic controls would be required to prevent leachate from impacting surface water (Richmond Creek). Temporary cover would be required over the consolidated waste, prior to final capping.

The areas where waste consolidation may be appropriate are located just north of the Eltingville pump station, between the east and west cells, and along the northern edge of the east cell, near Richmond Creek (see Figure 3-2).

Conclusion:

This alternative is considered to be effective and marginally implementable. However, a variety of controls would be necessary to prevent worker and neighboring area exposure to airborne contaminants during excavation and consolidation. This alternative must be considered with respect to cost savings associated with reduced cap area, and short and long term impact to wetlands.

4.2.2 Gas Control System

A gas control system, whether it be passive or active, would be designed using the emissions estimates developed in the RI for anaerobic conditions, in conjunction with actual gas generation measurements as witnessed during the operation of the soil vapor extraction study (Hot Spot No. 3 IRM).

4.2.2.1 Passive Gas Venting System

Site Application:

Passive gas vents would be installed in accordance with 6 NYCRR Part 360 regulations at a minimum frequency of one vent per acre. Vents would extend approximately three feet above the landfill cap. Landfill gases would discharge from the vents based upon the natural pressure gradient between the landfill and the atmosphere. As an alternative, the gas vents could be manifolded, either above or below ground, to transport landfill gases to a more desirable location for onsite discharge via a common stack.

Based upon the results of air sampling and modeling included in the Remedial Investigation Report (RI), the Brookfield Avenue Landfill is considered to be a minor source in terms of the overall impact to local air quality. A potential for localized exceedances of New York State Annual Guideline Concentrations (AGCs) or Short-

Term Guideline Concentrations (SGCs) within the immediate vicinity of ground-level gas vents and/or common discharge pipes (elevated) would exist.

Conclusion:

These passive gas venting alternatives are considered to be implementable; however, their effectiveness (with regard to preventing AGC and SGC exceedances) is limited by the potential for minor on-site exceedances of AGCs/SGCs. The relative cost for passive gas venting, in general, is significantly less than active gas venting (described below). Installation of an above ground system, which would transport passively collected gas to one or more centralized discharge points, would hinder potential future site uses because of poor aesthetics and physical obstruction. The above-ground manifolded system can, therefore, be eliminated from further consideration. The passive individual gas vent and passive below-ground, manifolded gas vent alternatives are considered implementable based on cost and design. However, due to the potential for on-site exceedances of AGCs/SGCs, their effectiveness is limited. Additionally, given the existing impacts from multiple sources in the Staten Island area, the potential to impart even a minor impact air quality is not perceived favorably by the NYCDEP, NYSDEC or the local community. Therefore, based on effectiveness, passive gas venting will not be retained for further consideration.

4.2.2.2 Active Gas Venting System

Site Application:

Gases would be extracted from the landfill and sent to a treatment plant prior to atmospheric discharge. The active venting system components would be installed either above or within the landfill cap. Installation of an above-ground system would restrict virtually all future site uses because of its poor visual aesthetics and physical obstruction. A below-ground system would support most future site uses. This type of system is also used at the Fresh Kills Landfill.

Conclusion:

Active venting is more effective than passive venting, and it is implementable. The implementability of a below-ground system is considered to be more complicated than for an above-ground system and for the passive gas venting alternative, as the location of potential problems (leaks, pipe blockage) cannot be easily identified and fixed. The cost to construct and operate an active venting system is significantly higher than the passive system. The below-ground active venting alternative should be retained for further consideration. The above-ground system can be eliminated based upon its restriction of future site use and higher cost versus the passive venting alternative.

4.2.2.3 Onsite Gas Treatment (Flaring)

Site Application:

This alternative is applied in conjunction with the use of an active gas venting system. Gases extracted from the landfill would be sent to an onsite enclosed flare plant for thermal destruction prior to atmospheric discharge. The enclosed flare system would be relatively non-intrusive in terms of visual aesthetics.

Conclusion:

Onsite gas treatment using an enclosed flare is effective and implementable. The relative cost would be significantly less than the offsite treatment alternative described below. This alternative should be retained for further consideration.

4.2.2.4 Onsite Gas Treatment (Upgrading to Pipeline Quality)

Site Application:

This alternative is applied in conjunction with the use of an active gas venting system. Gases extracted from the landfill would be sent to an onsite treatment plant upgrading to pipeline quality. Other gases (CO2, NMHC, etc.) would either be treated or discharged directly to the atmosphere. Discharge of NMHCs would not be acceptable unless the quantity and/or duration was approved by the NYSDEC. Pipeline quality gas would be then piped to a nearby pipeline for sale, under contract, to a local firm (for example, Marketspan).

Conclusion:

Onsite gas treatment, where the gas is upgraded to pipeline quality, is effective and implementable. The relative cost would be significantly less than the offsite treatment alternative described below. This alternative should be retained for further consideration, but is dependent on the ability to pipe and sell the pipeline quality gas.

4.2.2.5 Onsite Gas Treatment (Using Gas in an Engine or Turbine for Power Production and/ or Useful Heat)

Site Application:

This alternative is applied in conjunction with the use of an active gas venting system. Gases extracted from the landfill would be sent to an onsite power plant where the gas may be pretreated prior to firing in an engine (or engines) or turbine (or turbines). The power produced and/or the useful heat can then be used onsite or sold to a local industry or utility.

Conclusion:

Onsite gas utilization for power production and/or useful heat is effective and implementable. The relative cost would be significantly lower than the offsite treatment alternative described below. This alternative should be retained for further consideration, but is dependent on finding uses for the power and/or useful heat produced.

4.2.2.6 Offsite Gas Treatment at Fresh Kills Landfill

Site Application:

This alternative is applied in conjunction with the use of an active gas venting system. Gases extracted from the landfill would be sent to the Fresh Kills Landfill for treatment at either the existing gas recovery plant or the closest flare plant planned for construction.

According to the NYSDEC, the existing gas recovery plant at Section 1/9 of the Fresh Kills Landfill is operating at or near capacity (6,250 scfm). The NYSDEC anticipates that the plant will pursue expanding its capacity in the near future. In order to transport gas from the Brookfield Avenue Landfill to the existing plant, approximately 10,000 linear feet of transmission main would require installation. The main would run west along Arthur Kill Road and then turn north along the access road to Section 1/9 of the Fresh Kills Landfill.

The planned flare plants are currently designed for the anticipated volume of gas generated at the Fresh Kills Landfill. Each of the five plants is designed to receive 5,000 scfm of gas from a discrete area of the landfill. None of the plants is interconnected. Each plant includes two flares in parallel, with only one flare intended to operate at a time. In order to transport gas from the Brookfield Avenue Landfill to the nearest proposed plant location (Flare Station 1/9 or 6/7), approximately 10,000 linear feet of transmission main would be required. In addition, the plant would need to be upgraded to handle the additional gas flow from the Brookfield Avenue Landfill, unless operational data indicate sufficient excess capacity exists.

Conclusion:

This alternative is effective. However it is considered to be less implementable than the onsite treatment alternatives based upon a significant number of constructibility and administrative problems associated with constructing a transmission main between the two properties. The relative cost for this alternative is also considered to be significantly higher. Considering a unit cost of $15.00 per linear foot of transmission main installed (only), the estimated cost is $150,000. Considering the full scope of work, the total cost would be significantly higher. This alternative can be eliminated from further consideration.

4.2.3 Leachate and Groundwater Control System

4.2.3.1 Hydraulic Containment

Site Application:

One method of to achieve hydraulic containment of groundwater is a pump and treat system. A pump and treat system would be installed at the landfill to prevent future impacts to downgradient water quality caused by landfill leachate. Groundwater would be pumped from select locations beneath the landfill for the purpose of creating a hydraulic barrier that prevents leachate contaminants from migrating off site. Following collection, the groundwater would be pumped to a treatment plant prior to discharge. Wells are primarily effective for applications where the landfill or underlying materials are relatively permeable. The Brookfield Avenue Landfill is generally underlain by meadow mat, silt, and clay, which are not significantly permeable. However, local areas of more permeable shallow sands are present where groundwater pumping may be effective.

Based upon the shallow depth to groundwater at the landfill along the downgradient toe of slope (approximately 5 feet below ground surface), interceptor trenches are a feasible technology for leachate and groundwater control.

Collection of groundwater from an entire landfill is generally uneconomical, unless technically warranted, due to the cost required to pump and treat a significant volume of water. One or more systems can be designed to collected groundwater from localized source areas. This approach would significantly reduce the cost to pump and treat the water based upon the reduced volume collected and would be protective of downgradient water quality.

Two of the five hot spots investigated during the RI were recommended for further consideration. Hot Spot No. 3, at the north side of the east cell contains relatively high concentrations of petroleum-based wastes. The north and east sides of Hot Spot No. 3 are leachate discharge boundaries of the landfill. Hot Spot No. 5, on the northern section of the Holtermann's Bakery, contains weathered heavy oil, BTEX compounds, PCBs and pesticides.

Three conceptual design options for leachate collection have been considered, and are presented in Figures 4-1 through 4-4.

Option 1 - Full Hydraulic Containment (Figure 4-1)

Approximately 10,000 linear feet of leachate collection trenches would be constructed around the downgradient portions of the landfill including Hot Spot 3 and Hot Spot No. 5. This system would be supplemented by an upgradient hydraulic barrier wall or collection trench to lower the groundwater table beneath the landfill.

Option 2 - Partial Hydraulic Containment (Figure 4-2)

Approximately 6,000 linear feet of leachate collection trenches would be constructed along the entire north side of the landfill. This system would be supplemented by an upgradient hydraulic barrier wall or collection trench to lower the groundwater table beneath the landfill.

Option 3 - Partial Hydraulic Containment (Figure 4-3)

Approximately 3,900 linear feet of leachate collection trench would be constructed downgradient of Hot Spot No. 3 and the west cell. This system would not be supplemented by an upgradient hydraulic barrier wall to lower the groundwater table beneath the landfill, but would include a barrier wall connecting the gap of the two leachate collection trenches at the east and west, along the north face.

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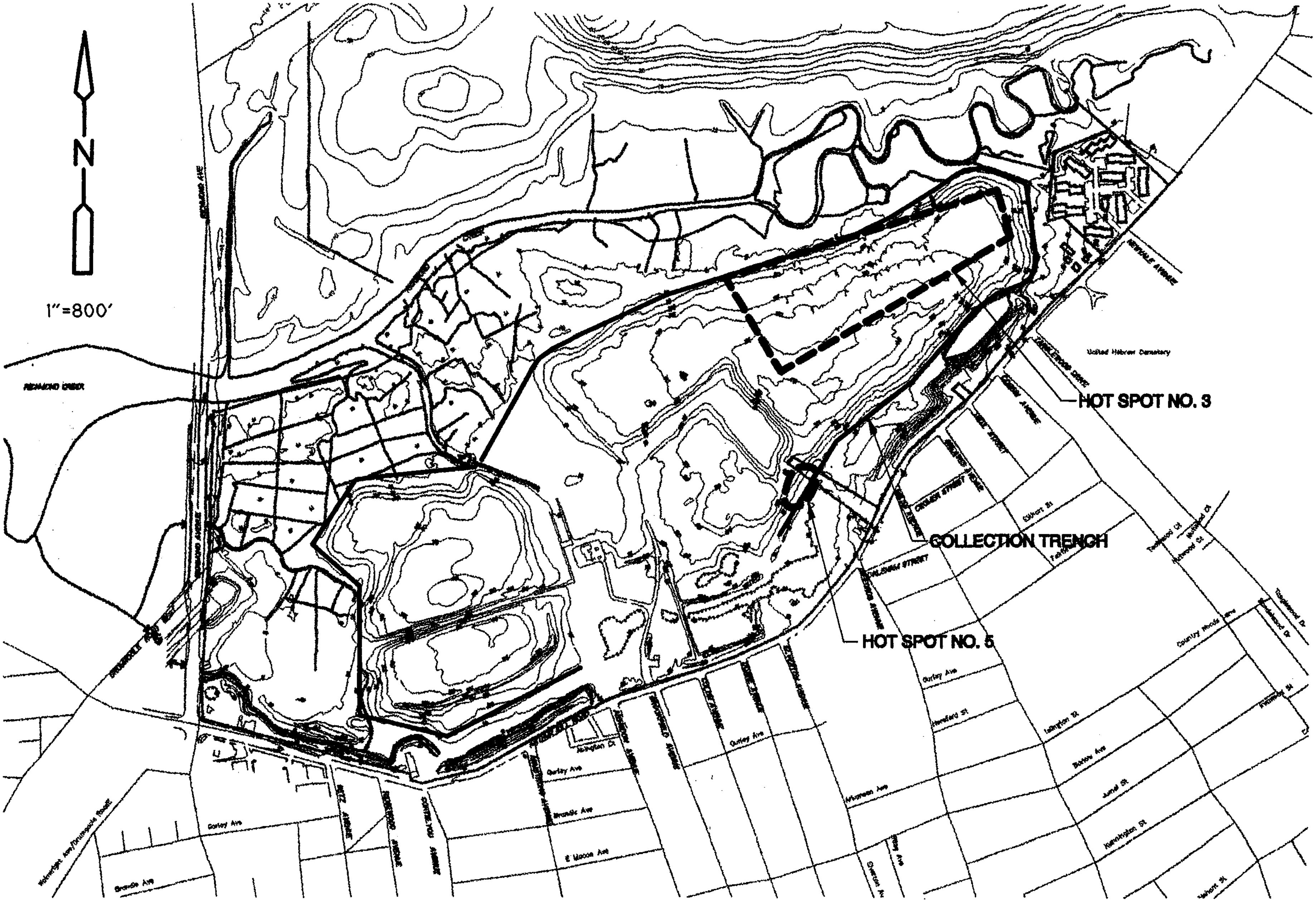

Figure 4-1

Leachate Collection Trench Location (Option 1)
Brookfield Avenue Landfill Remediation Project

CDM Camp Dresser & McKee

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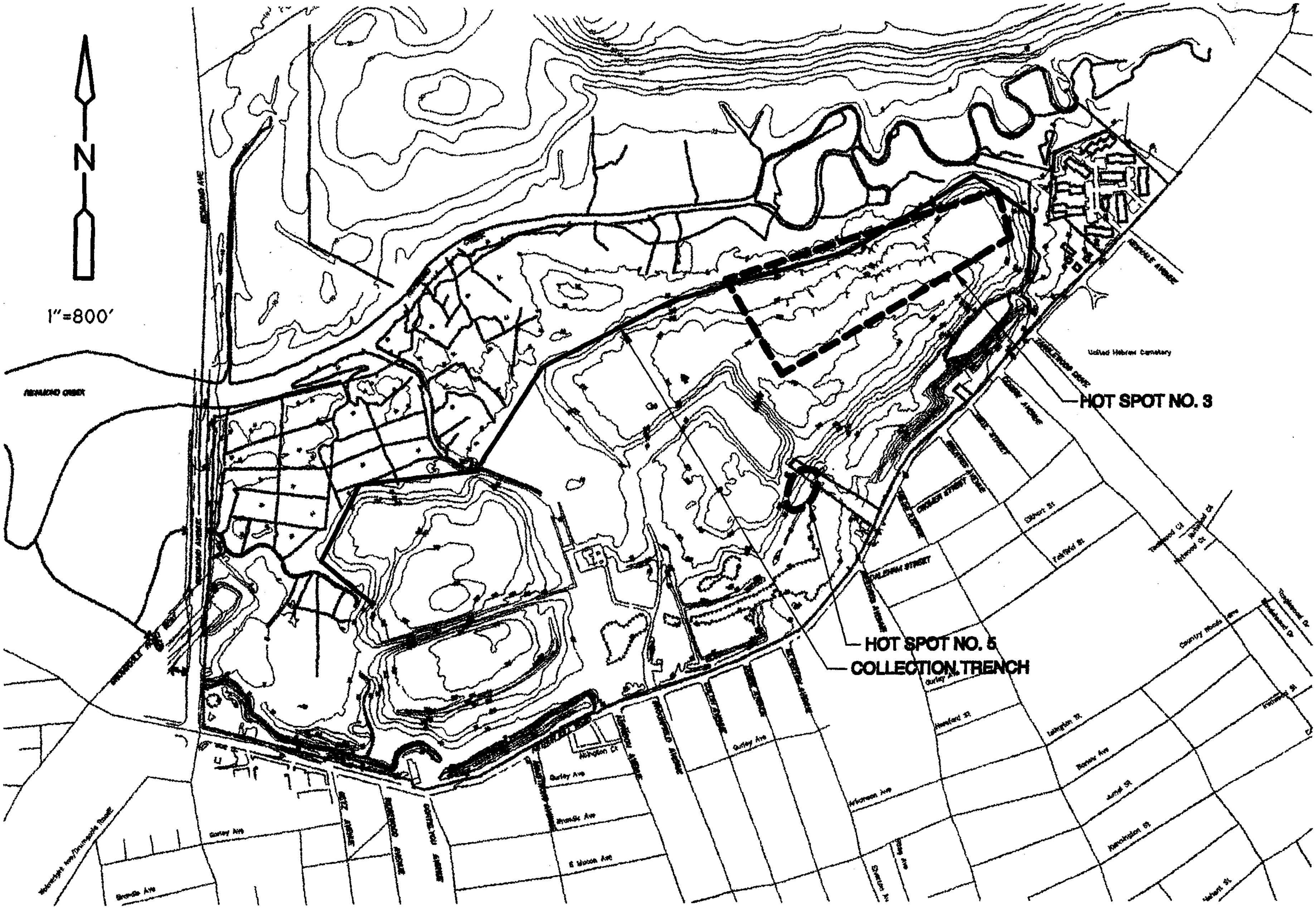

Figure 4-2

CDM Ca Dresser & McKee

Leachate Collection Trench Location (Opt 2)
Brookfield Avenue Landfill Remediation Pr ct

Figure 4-3

CDM Camp Dresser & McKee

Leachate Collection Trench Location (Option 3)
Brookfield Avenue Landfill Remediation Project

Option 4 - Limited Hydraulic Containment (Figure 4-4)

Approximately 3,000 linear feet of leachate collection trench would be constructed downgradient of Hot Spot No. 3 and Hot Spot No. 5. This system may or may not be supplemented by an upgradient hydraulic barrier wall to lower the groundwater table beneath the landfill.

Conclusion:

Installation of a leachate collection trench is considered to be effective and implementable for the purpose of leachate and groundwater containment. Based upon the shallow depth to groundwater at this site, interceptor trenches are considered to be more effective than extraction wells, and should be retained for further consideration. Although extraction wells are likely to be effective in only localized areas, they will be retained for further consideration.

Based upon existing water quality, all of the conceptual options described above are considered to be effective. Comparatively, the options are listed in decreasing order of effectiveness, based upon the level of containment they achieve. However, the relative cost differential to construct and operate these systems is significant, with Option 4 being the least costly alternative. With respect to implementability, the options are listed in increasing order based upon the potential disturbance of wetlands during construction. All of these options should be retained for further consideration.

4.2.3.2 Hydraulic Diversion

Site Application:

A barrier wall, interceptor trench, or drainage ditch would be constructed upgradient of the landfill between the east and west perimeter ditches for the purpose of lowering the groundwater table below the landfill. This may effectively reduce the rate of leachate generation by reducing the saturated volume of waste.

Conclusion:

The drainage ditch and interceptor trench alternatives are considered to be less effective than the barrier wall alternative, based upon uncertainties associated with the post-capping groundwater flow conditions. They can, therefore, be eliminated from further consideration. Installation of a barrier wall would be effective and implementable for reducing the groundwater table beneath the landfill. This alternative should be retained for further consideration.

4.2.3.3 Onsite Pre-Treatment and Discharge to the Sewer

Site Application:

This alternative is applied in conjunction with the groundwater and leachate control system hydraulic containment alternatives described above. Groundwater extracted

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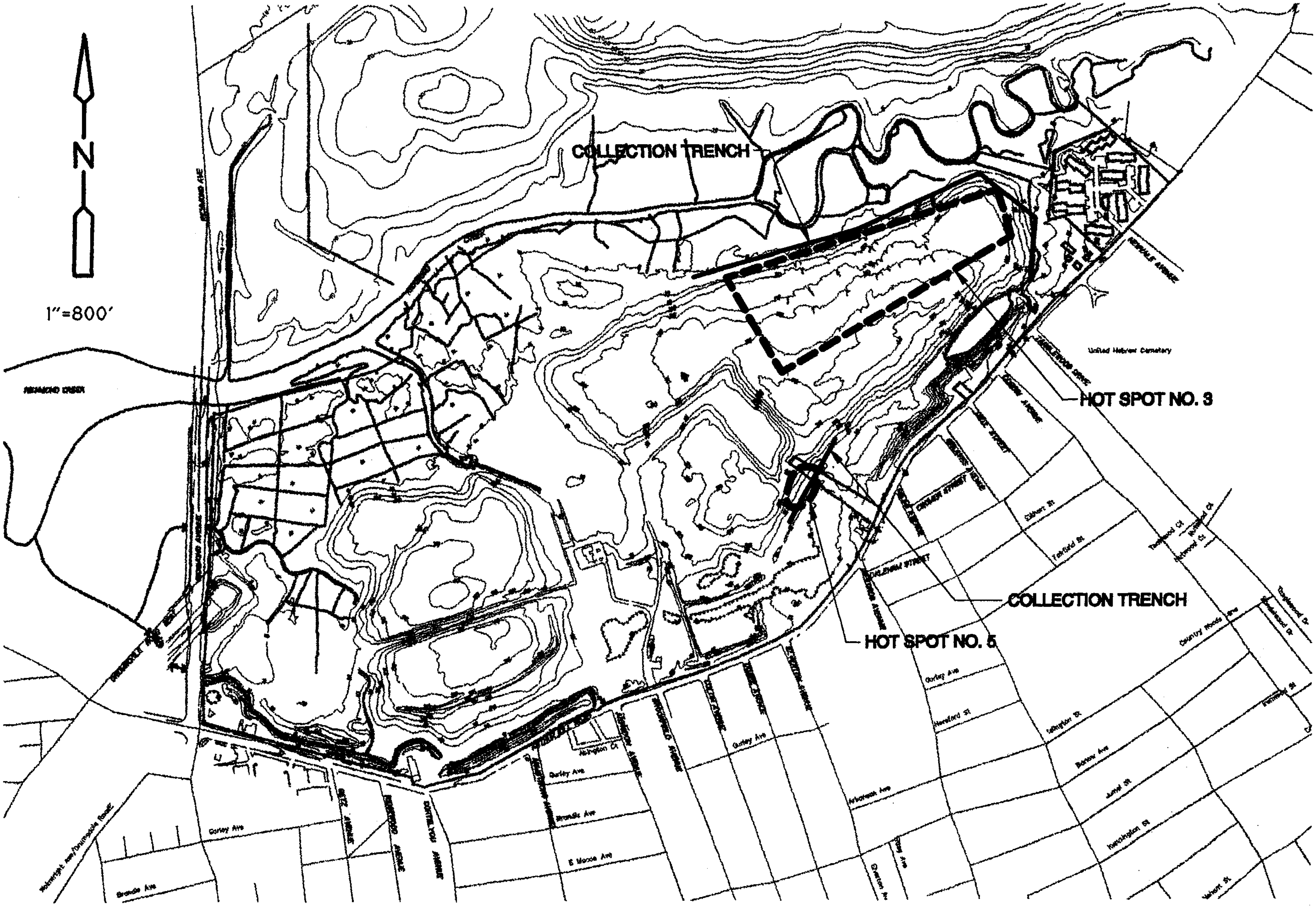

Figure 4-4

CDM Camp Dresser & McKee

Leachate Collection Trench Location (Option 4)
Brookfield Avenue Landfill Remediation Project

from beneath the landfill would be pre-treated using oil/water separation prior to discharge to the onsite Eltingville Pump Station.

Currently the Eltingville Pump Station pumps an average of 17.3 MGD to Oakwood Beach Water Pollution Control Plant (WPCP). The treatment facilities provided at Oakwood Beach WPCP include primary treatment, aeration, secondary treatment and disinfection. The plant currently has a capacity for an average of 40 MGD. Available operating data indicates the plant currently treats 30 MGD of flow. An upgrade of the Oakwood Beach WPCP is currently planned by the NYCDEP. The potential daily volume of water generated from the Brookfield Avenue Landfill is expected to be well within the plant's available treatment capacity.

Conclusion:

This alternative is considered to be cost effective and implementable, because the pump station is already in place. Only construction and operation of a pre-treatment facility is required. This alternative should be retained for further consideration.

4.2.3.4 Onsite Treatment and Discharge to Richmond Creek

Site Application:

This alternative is applied in conjunction with the groundwater and leachate control system hydraulic containment alternatives described above. Groundwater extracted from beneath the landfill would be treated onsite prior to discharging it to Richmond Creek. The treatment plant processes would be consistent with that used at the Fresh Kills Landfill treatment plant. A New York State Pollution Discharge Elimination System (SPDES) permit would be required to discharge effluent to Richmond Creek. Effluent discharged from the plant would conform with the permit discharge requirements.

Conclusion:

This alternative is considered to be an effective and implementable treatment technology. Comparably, however, it is much more difficult to implement than pretreatment followed by discharge to the sewer. Its relative cost would also be significantly higher than the pre-treatment alternative described above, based upon more stringent treatment requirements. Because of these points, this alternative can be eliminated from further consideration.

4.2.3.5 Offsite Treatment at the Fresh Kills Landfill

Site Application:

This alternative is applied in conjunction with the groundwater and leachate control system, hydraulic containment alternatives described above. Groundwater extracted from beneath the landfill would be pumped to the existing Fresh Kills treatment plant. Installation of a transmission main between the Brookfield Landfill and the Fresh Kills treatment plant would be required.

Routing alternatives were assessed based upon the following criteria:

- use existing New York City land holdings to the maximum extent possible;
- use road easements where feasible;
- minimize environmental impacts.

Based upon the above, two potential routing alternatives were identified. They would consist of installing transmission main along two of the segments listed below and shown in Figure 4-4:

- Segment A - from Brookfield Avenue Landfill Pump Station, west along Arthur Kill Road to the intersection of Richmond Avenue and Arthur Kill Road (approximately 0.6 miles);
- Segment B - from intersection of Arthur Kill Road and Richmond Avenue west along Arthur Kill Road to the Fresh Kills treatment plant (approximately 4.4 miles); and
- Segment C - from intersection of Arthur Kill Road and Richmond Avenue north along Richmond Avenue to Section 6/7 of the Fresh Kills leachate collection system (approximately 1 mile).

Segment A is the same for both alternatives. The routing differences involve completing transmission main installation along Segment B (Option 1) or Segment C (Option 2). These options are shown on Figure 4-5.

Conclusion:

Offsite treatment is an effective alternative. However, it is considered to be less implementable than onsite treatment alternatives based upon the following:

- The proposed location of the Brookfield Avenue pump station has not been finalized. Potential constructibility issues exist with respect to wetlands disturbance, private property crossings, utility crossings, and/or water crossings (Richmond Creek).

Based upon a budgetary unit cost of $50 per linear foot for transmission main installation only, it is estimated that Options 1 and 2 would cost approximately $1.3M and $420K, respectively. The total relative construction cost would be significantly higher for both alternatives, considering the full scope of work. Onsite treatment alternatives are judged to be more cost effective. Offsite treatment can, therefore, be eliminated from further consideration.

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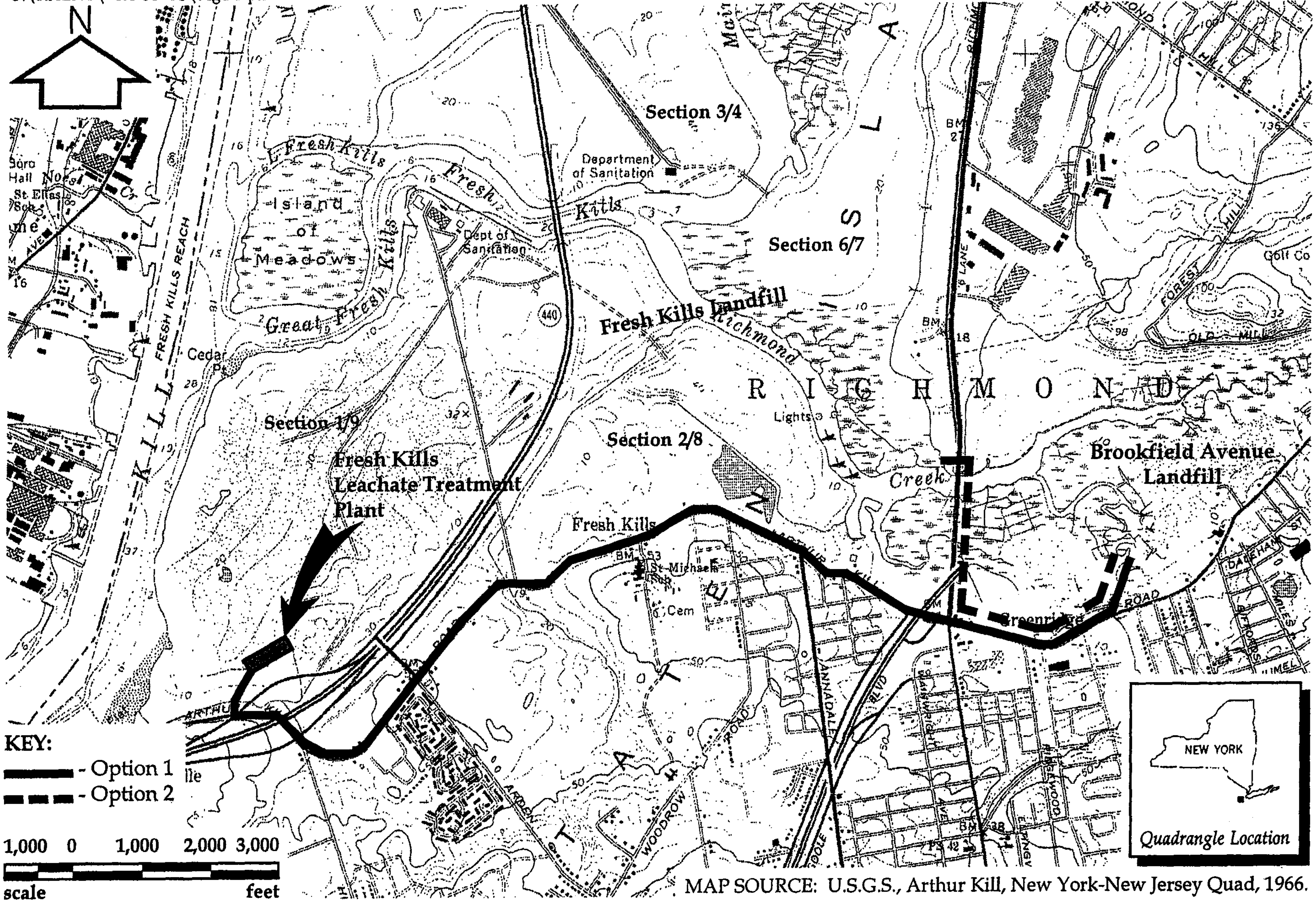

MAP SOURCE: U.S.G.S., Arthur Kill, New York-New Jersey Quad, 1966.

Figure 4-5
Routing Options To Fresh Kills Leachate Treatment Plant
Brookfield Avenue Landfill Remediation Project

4.2.4 Stormwater Runoff and Erosion Control

4.2.4.1 Constant Slope Design

Site Application:

The landfill cap would be constructed with slopes that are generally uniform from top to bottom across a given vertical cross-section. Stormwater runoff would be allowed to disperse naturally at the base of the landfill at locations determined to be appropriate based upon the results of erosion, flooding, and surface water quality evaluations. Perimeter drainage structures, such as toe drains and/or swales, would be installed at all other locations to intercept and transport stormwater runoff for ultimate discharge to Richmond Creek. A drainage layer, consisting of a sand layer or geonet, would be installed over the cap to remove infiltrated water from above the cap for the purpose of maintaining slope stability.

Stormwater retention may be required, should analysis of flow velocity and volume determine that direct runoff will not meet SCGs. Further analysis of the need for stormwater retention will be conducted during the design phase, taking into account potential changes in slope due to cap settlement over time.

Conclusion:

Constant slope design is effective and implementable at the Brookfield Avenue Landfill, based upon its gentle slopes. The relative cost would be lower than the washboard design, as described below. This type of design would also best support site reuse, in terms of aesthetics and gentle slopes. It should be retained for future consideration

4.2.4.2 Washboard Design

Site Application:

The landfill cap would be constructed with average slopes that are generally uniform from top to bottom across a given vertical cross-section. A series of lateral swales would be constructed across the slope of the cap to intercept stormwater runoff and minimize erosion. Transverse swales would be constructed perpendicular to the slope to convey runoff water from lateral swales for ultimate discharge to Richmond Creek. A drainage layer, consisting of a sand layer or geonet, would be installed over the cap, where necessary, to remove infiltrated water from above the liner for the purpose of maintaining slope stability.

Conclusion:

Washboard design is effective and implementable. It is generally considered to be more effective then the constant slope design. However, its relative cost would also be higher, based upon the installation of surface drainage structures on top of the cap. Based upon the gentle slopes of the Brookfield Avenue Landfill, the washboard design is not considered to be cost effective. Likewise, it would restrict most future site uses because of poor visual aesthetics and physical obstruction of surface drainage structures across the cap. It can, therefore, be eliminated from further consideration.

4.2.4.3 Minimum Slope Variance

Site Application:

A variance to reduce the minimum slope requirement from four to two percent would be applied for. Additional subsurface drains would be installed within the landfill cap to prevent slope instability due to saturation, where required. The potential for landfill settlement due to waste decomposition will be evaluated during the design phase to ensure that slope requirements will continue to be met well after closure is completed.

Conclusion:

A two percent slope variance is considered to be effective and implementable for both the constant slope and washboard designs, and it has been approved by the NYSDEC at other New York landfills. Based upon the gentle topography of the landfill, this variance would reduce the relative cost of cap construction for both designs based upon reduced rough grading requirements. A further evaluation of the effectiveness of a two percent slope will be evaluated in the design phase to ensure that landfill settlement does not significantly change slopes and impact runoff.

4.2.4.4 Direct Discharge of Stormwater to Richmond Creek

Site Application:

Stormwater runoff water collected landfill in drainage structures would be allowed to discharge directly to Richmond Creek at one or more discharge points.

Conclusion:

This method is effective and implementable, and less costly than discharging stormwater runoff through a retention basin (described below). It is considered less effective than a properly designed retention basin based upon the increased potential for silt transport and less flow control to Richmond Creek. It is, however, considered to be more implementable.

4.2.4.5 Stormwater Retention and Discharge to Richmond Creek

Site Application:

One or more retention basins would be constructed to capture runoff from the cap during storm events. During small storm events, all of the runoff water would be collected in the retention basins. The water level inside each basin would be controlled by a primary spillway, which typically consists of a perforated riser, and decrease with time by discharging the water to Richmond Creek over a two to four week period. During large storm events, the water level would be controlled by the emergency spillway, which typically consists of a headwall structure. Excess water would be released over the headwall to Richmond Creek at a controlled rate until the water level dropped below the top of the headwall. The remaining water would be discharged through the primary spillway.

Conclusion:

This method is effective. However, based upon the shallow water table and existing wetlands adjacent to the landfill, it is considered to be less implementable than direct discharge. A large area adjacent to the landfill, disturbance of wetlands, and filling would likely be required for construction. Its cost would be significantly more than for direct discharge. However, this alternative will be retained for further analysis during the design phase, when flow velocities and volumes can be more effectively considered.

4.2.5 Remediation of Hot Spot Areas

In addition to the IRMs already implemented (and to be implemented) at the Hot Spot areas, further consideration of remedial actions during and after final closure is warranted.

4.2.5.1 Excavation and Offsite Disposal

Site Application:

Contaminated soils would be excavated from Hot Spot areas No. 3 and 5 to remove the potential future source of groundwater contamination. Excavated materials would be placed in a temporary staging areas to dry and then would be loaded into rolloff containers for transport to a RCRA- approved disposal facility.

Transport and disposal costs of excavated material are expected to be in excess of $400 per ton. The density of the waste is expected to be approximately 1,000 pounds per cubic yard. Therefore, transport and disposal in expected to be on the order of $200 per cubic yard.

The volume of material from Hot Spot No. 3 that would require excavation and disposal, pending further field sampling to more clearly define the extent of contamination, is estimated to be approximately 300,000 cy. The quantity of material alone makes this option difficult to implement. Transport and disposal would cost on the order of $60 million.

The volume of material from Hot Spot No. 5 that would require excavation and disposal, pending further field sampling to more clearly define the extent of contamination, is estimated to be approximately 16,000 cy. Transport and disposal would cost approximately $3.2 million.

Excavation would be moderately difficult to implement at the majority of the depths encountered. Depths greater than fifteen feet start to pose a problem (shoring may become necessary) and should be considered during the evaluation of this technology. Additionally, due to the shallow depth to water at the site, shoring and dewatering may add significantly to the excavation cost. Soil below the water table will also require dewatering prior to disposal

Conclusion:

This alternative is considered to be effective for both hot spot areas. Its implementability is considered to be less than the other alternatives based upon the lack of data defining the Hot Spots, large volumes of soil requiring excavation, and/or significant exposure risks to workers during excavation. The relative cost is also considered to be higher than other more effective technologies described herein. It can, therefore, be eliminated from further consideration.

4.2.5.2 Bioventing

Site Application:

Bioventing would be implemented to stimulate in-situ aerobic biodegradation activity. A series of bioventing injection and extraction wells would be installed to aerate contaminated soils. Additional systems may also be installed to inject nutrients and water into the contaminated region.

Conclusion:

Bioventing is effective for the biological remediation of soils contaminated with SVOCs and polyaromatic hydrocarbons (PAHs), such as Hot Spot No. 3. It is not effective for remediation of the remaining hot spot area, which contains soils that are contaminated with chlorinated VOCs, PCBs, or pesticides and/or is located below the water table. Based upon the approval of SVE as an IRM at Hot Spot No. 3, bioventing can be eliminated from further consideration

4.2.5.3 Product Collection and Separation

Site Application:

A pump and treat system would be installed to remove light non-aqueous phase liquid (LNAPL) from the groundwater table at one or both hot spot areas. LNAPL and groundwater captured by the system would be treated using an oil/water separator and discharged to the onsite pump station or Richmond Creek.

Conclusion:

This technology is only effective and implementable for Hot Spot No. 5, since LNAPL is not associated with the other Hot Spot areas. It is considered to be more effective than the no action alternative, because the LNAPL would be removed at the source area rather than at the downgradient edge of the landfill by a groundwater and leachate collection system. This technology should be retained for further consideration.

4.2.5.4 No Action

Site Application:

No supplemental action would be implemented to reduce contaminant levels beyond installation of the landfill containment system (cap and control systems), and already partially implemented IRMs.

Conclusion:

This alternative is considered to be effective and implementable for all Hot Spot areas. The cap would prevent infiltration, thereby eliminating the pathway for vertical contaminant migration to groundwater. Contaminants present within the saturated zone would be effectively controlled by the leachate and groundwater control system, preventing future impacts to downgradient water quality. The planned IRM consisting of a SVE system should effectively lower contaminant levels in the area and may also be tied into the final gas control system. The oil absorbent boom at Hot Spot No. 5 will help reduce oil-related contaminants prior to the installation of the cap and leachate control systems. It is the least costly alternative of those described below. This alternative should be retained for future consideration.

Table 4-1

Summary of Remedial Technologies/Actions Screening

Brookfield Avenue Landfill Remediation Project

Component	*Remedial Action/Technology*	*Effectiveness* (1)	*Implementability* (2)	*Cost* (3)	*Eliminated from Further Consideration* (4,5)
Landfill Cap	**Type of Cap:**				
	Standard (6 NYCRR Part 360) Cap	✓	✓	High	
	Standard Cap with Gas Venting Layer Variance	✓	✓	High	✓
	Part 360 Landfill Cap with Protection Layer Variance	✓	✓	Low	
Gas Control System	**Gas Control Type:**				
	Passive Gas Venting	Limited	✓	Low	✓
	Individual Vents	Limited	✓	Low	✓
	Above-ground Manifolded System	✓	✓	Medium	X
	Below-Ground Manifolded System	✓	✓	High	✓
	Active Gas Venting	✓	✓	High	
	Above Ground Manifold System	✓	✓	High	✓
	Below Ground Manifold System	✓	✓	Medium	
	Gas Treatment Type (With Active Gas Venting):				
	Onsite Treatment	✓	✓	Medium	
	Offsite Treatment	✓	✓	High	✓
Leachate and Groundwater	**Hydaulic Containment**				
	Wells	Limited	✓	Medium	
	Interceptor Trenches	✓	✓	Medium	
	Hydraulic Diversion				
	Barrier Wall	✓	✓	Medium	
	Interceptor Trench	✓	Limited	Medium	✓
	Perimeter Drainage Ditch Extension	Limited	✓	Medium	✓
	Leachate Treatment (with Hydraulic Containment)				
	Onsite Pre-Treatment with Sewer Discharge	✓	✓	Low	
	Onsite Treatment with Discharge to Richmond Creek	✓	✓	Medium	✓
	Offsite Treatment at Fresh Kills Landfill	✓	✓	High	✓
Stormwater and Erosion Control	**Slope Design:**				
	Constant Slope Design	✓	✓	Medium	
	Washboard Slope Design	✓	✓	High	X
	Minimum Slope Variance	✓	✓	Low	
	Stormwater Discharge:				
	Direct Discharge of Stormwater Runoff to Creek	✓	✓	Low	
	Stormwater Retention and Discharge to Creek	✓	Limited	High	
Hot Spot Remediation	**Remedial Technology:**				
	Product Collection and Separation	✓	✓	Medium	
	Excavation and Offsite Disposal	✓	Limited	High	✓
	Bioventing	Limited	✓	Low	✓
	No Action	✓	✓	Low	

Notes:

(1) ✓ Given if technology/action was found to be an effective remedial option.

(2) ✓ Given if technology/action was found to be implementable.

(3) High/Medium/Low denotes cost as compared to other options in each technology/action group.

(4) ✓ Given if technology/action was eliminated from further consideration, based upon effectiveness, implementability and/or cost.

(5) X Given if technology/action was eliminated from further consideration, based upon limitations to future site use.

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5

Section Five

Section 5
Development of Site Remediation Alternatives

5.1 Summary of Site Remediation Alternatives

Based upon the results of the screening analysis presented in Section 4, six candidate alternatives for site remediation were developed. They are summarized in Table 5-1 and described below.

Alternative 1

- No Action

Alternative 2A

- 6 NYCRR Part 360 landfill cap with variable protection layer thickness (12 to 24 inches).
- Active gas collection (below ground system) and onsite treatment by flaring.
- Perimeter (active) gas collection trench between the landfill and Arthur Kill Road.
- Leachate collection downgradient of Hot Spot No. 3 and the West Cell (as shown in Figure 4-3, Option 3).
- Barrier wall along the north face of the landfill between the leachate collection trenches.
- Barrier wall separating the southeast and southwest drainage ditches from the landfill.
- Onsite treatment of leachate (oil/water separation) with discharge to the sewer.
- Institutional controls and long-term monitoring of perimeter landfill gas, groundwater and treated leachate.

Alternative 2B

- 6 NYCRR Part 360 landfill cap with variable protection layer thickness (12 to 24 inches).
- Active gas collection (below ground system) and onsite treatment by flaring.
- Leachate collection along the entire north face of the landfill (shown in Figure 4-2, Option 2).

- Barrier wall along the entire south face of the landfill.
- Product Recovery at Hot Spot No. 5 (via and oil/water separator)
- Onsite treatment of leachate (oil/water separation) with discharge to the sewer.
- Institutional controls and long-term monitoring of perimeter landfill gas, groundwater and treated leachate.

Alternative 3

- 6 NYCRR Part 360 landfill cap with variable protection layer thickness (12 to 24 inches).
- Active gas collection (below ground system) and onsite treatment by flaring.
- Leachate collection around virtually the entire landfill (as shown in Figure 4-1, Option 1)
- Barrier wall connecting the leachate collection trenches south of the landfill.
- Onsite treatment of leachate (oil/water separation) with discharge to the sewer.
- Institutional controls and long-term monitoring of perimeter landfill gas, groundwater and treated leachate.

Alternative 4

- 6 NYCRR Part 360 landfill cap with variable protection layer thickness (12 to 24 inches).
- Active gas collection (below ground system) and onsite treatment by flaring.
- Limited leachate collection adjacent to Hot Spot No. 3 and Hot Spot No. 5 (as shown in Figure 4-4, Option 4).
- Barrier wall along the entire south face of the landfill.
- Onsite treatment of leachate (oil/water separation) with discharge to the sewer.
- Institutional controls and long-term monitoring of perimeter landfill gas, groundwater and treated leachate.

Alternative 5

- 6 NYCRR Part 360 landfill cap with variable protection layer thickness (12 to 24 inches).

- Active gas collection (below ground system) and onsite treatment by flaring.
- Limited leachate collection adjacent to Hot Spot No. 3 and Hot Spot No. 5 (as shown in Figure 4-4, Option 4).
- Barrier wall separating the southeast and southwest drainage ditches from the landfill.
- Onsite treatment of leachate (oil/water separation) with discharge to the sewer.
- Institutional controls and long-term monitoring of perimeter landfill gas, groundwater and treated leachate.

The above alternatives are not intended to account for all possible combinations of remedial technologies retained for further consideration following the screening analysis (Section 4.0). Rather, the alternatives are representative of the full range of plausible site remediation alternatives that support recreational site use, considering variable degrees of design conservatism and cost. The remedy ultimately selected for the site is expected to be the same, or similar to one or more of these alternatives, but is not limited to the combinations proposed in the above alternatives.

The results of the Detailed Analysis will provide further insight regarding the benefits and drawbacks of each alternative.

Waste consolidation (e.g. excavating waste along the northern edge of the east cell, and north of the pump station and relocating on top of the landfill) will be evaluated separately in Sections 7 and 8. This technology may be applied to each of the alternatives, should the evaluation deem it appropriate.

5.2 Criteria for Performing the Detailed Analysis of Alternatives

Pursuant of the EPA guidance document, "Conducting Remedial Investigations/ Feasibility Studies for CERCLA Municipal Landfill Sites," dated February 1991, the final step in the Feasibility Study (FS) process is to evaluate these alternatives in sufficient detail to objectively compare them. This guidance document identifies seven evaluation criteria that have been demonstrated to be important decision factors in selecting the most appropriate site remediation alternative. These are:

Threshold Criteria:

- Compliance with Applicable or Relevant and Appropriate Requirements, and Standards Criteria and Guidelines (ARARs, SCGs)
- Protection of human health and the Environment

Balancing Criteria:

- Short-term effectiveness
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Implementability
- Cost

One additional criteria, designated as "modifying criteria," is also specified for assessment after the public comment period. This is:

Modifying Criteria:

- Community acceptance

Community views have been considered in developing the above alternatives to the extent they are known. As indicated in Section 4, specific emphasis has been placed on developing remedial alternatives which support a natural post-closure environment and future recreational use at the site. Such consideration will continue through the detailed analysis of site remediation alternatives, presented in the following sections.

Table 5-1

Summary of Candidate Site Remediation Alternatives

Brookfield Avenue Landfill Remediation Project

Component	*Remedial Action/Technology*	*1*	*2A*	*2B*	*3*	*4*	*5*
Landfill Cap	**Type of Cap:**						
	Standard (6 NYCRR Part 360) Cap with Variable (12"-24") Protection Layer		✓	✓	✓	✓	✓
Gas Control System	**Gas Control Type:**						
	Active Gas Venting with Below Ground Manifold System		✓	✓	✓	✓	✓
	Perimeter Active Gas Collection Trench between the Landfill and Arthur Kill Road		✓				
	Gas Treatment Type:						
	Onsite Treatment via Flaring		✓	✓	✓	✓	✓
Leachate and Groundwater	**Hydraulic Containment (interceptor trenches)**						
	Full Hydraulic Containment (Option 1)				✓		
	Partial Hydraulic Containment (Option 2)			✓			
	Partial Hydraulic Containment (Option 3)		✓				
	Limited Hydraulic Containment (Option 4)					✓	✓
	Hydraulic Diversion						
	Barrier Wall Separating South Perimeter Drainage Ditches from Landfill		✓	✓	(1)	✓	✓
	South Face (Upgradient) Barrier Wall			✓	✓	✓	
	North Face (Downgradient) Barrier Wall		✓ (2)	(1)	(1)	(1)	(1)
	Leachate Treatment (with Hydraulic Containment)						
	Onsite Pre-Treatment and Discharge to Sewer		✓	✓	✓	✓	✓
Stormwater and Erosion	**Slope Design:**						
	Variable Slope Design (2% to 4% minimum slope)		✓	✓	✓	✓	✓
Hot Spot Remediation	**Remedial Technology:**						
	Hot Spot No. 5 Product Collection and Separation			✓			
Institutional Controls	**Type of Controls**						
	Signs, Fencing and Long Term Monitoring of Soil Gas, Groundwater and Treated Leachate	✓	✓	✓	✓	✓	✓

Notes: Alternative 1 is the "No Action" alternative

✓ Denotes that remedial action/technology is included as part of the alternative.

(1) HDPE barrier wall will be incorporated as part of leachate collection trench, where present.

(2) This alternative includes a downgradient barrier wall spanning the gap created by the discontinuous leachate collection trench north of the west cell and Hot Spot No. 3. A HDPE barrier wall is also incorporated as part of the leachate collection trench, where present.

6

Section Six

Section 6
Evaluation Criteria

6.1 Introduction

Pursuant to the EPA guidance document, "Conducting Remedial Investigations/ Feasibility Studies for CERCLA Municipal Landfill Sites," dated February 1991, the final step in the Feasibility Study (FS) process is to evaluate the candidate site remedial alternatives in sufficient detail to objectively compare them. This guidance document identifies eight evaluation criteria that have been demonstrated to be important decision factors in selecting the most appropriate site remediation alternative. These criteria are subdivided into three categories, namely threshold criteria, balancing criteria, and modifying criteria, and are described in detail below.

Each alternative analysis, based on the criteria described below, is presented in Section 7, Detailed Analysis of Alternatives.

6.2 Threshold Criteria

6.2.1 Compliance with Applicable or Relevant and Appropriate Requirements (ARARS), and Standards Criteria and Guidelines (SCGs)

Alternatives were evaluated to determine if they comply with ARARs and if proposed variances are technically justified. The alternatives were also evaluated against three categories of SCGs, which are specific to site chemicals, actions, and location. These SCGs are listed in Tables 6-1 through 6-3.

The chemical-specific ARARs/SCGs were used to evaluate if the post-remediation site conditions for each alternative would impact groundwater, surface water, air, and soil above Federal, State or local standards. For example, in order to comply with the chemical-specific ARARs/SCGs the groundwater should comply with Part 703 of the NYSDEC Groundwater Quality regulations, as well as all other applicable standards listed in Table 6-1.

The action-specific ARARs/SCGs were used to evaluate if the remedial construction activities required for implementation of each alternative would negatively impact the site area. Table 6-2 lists the applicable regulations. These regulations include Federal and State air quality standards for air emissions, OSHA standards for construction activities, and 6 NYCRR Part 360 regulations for capping.

Location-specific ARARs/SCGs were used to evaluate if the remedial construction activities required for implementation of each alternative would negatively impact endangered plant and animal species and habitats, wetlands, flood plains, or coastal zone areas. Also included are regulations governing potential air emissions resulting from the proposed alternatives in areas governed by special air regulations. Table 6-3 lists the applicable regulations.

6.2.2 Protection of Human Health and the Environment

Alternatives were evaluated to determine if they will be protective of human health and the environment following site remediation. This evaluation was generally based upon the net decrease in risk that would be expected following the implementation of each alternative, considering all relevant exposure/migration pathways.

6.3 Balancing Criteria

6.3.1 Short-Term Effectiveness

The short-term impacts of each alternative were evaluated, generally considering the following: 1) risks to workers during remedial construction; 2) the effectiveness of personal protective equipment and monitoring; 3) environmental impacts caused during construction including impacts to wetlands; 4) effectiveness of engineering controls and mitigative measures implemented during and after construction, respectively; 5) manner of transport of capping materials to the site and associated impacts; and 6) time required to complete construction.

6.3.2 Long-Term Effectiveness and Permanence

Alternatives were evaluated based upon their long-term effectiveness and permanence. This evaluation focuses upon the time period following the completion of construction, and considers potential conditions occurring during and beyond the required 30-year O&M period. Significant long-term effectiveness and permanence factors include: 1) the magnitude of residual risk from untreated waste or treatment residuals; 2) the long-term reliability of engineering and institutional controls; 3) and impacts to wetlands. The evaluation considered the life expectancy for individual components of each alternative and associated long-term risks.

6.3.3 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives were evaluated based upon the degree that they utilize recycling or treatment to reduce waste toxicity, mobility, or volume. Significant factors included: 1) the quantity of hazardous contaminants that will be destroyed, treated, or recycled; 2) the degree that treatment is used to reduce site hazards; 3) the degree that treatment is irreversible; and 4) the quantity and characteristics of treatment residuals.

6.3.4 Implementability

Alternatives were evaluated based upon the relative ease or difficulty associated with their implementation, considering the technical and administrative feasibility of remedial technologies and the availability of required labor, equipment, and materials. Technical feasibility was evaluated based upon: 1) difficulties and unknowns associated with the construction and operation of a technology; 2) the reliability of the technology; 3) the ease of undertaking additional remedial actions; and 4) the ability to monitor the effectiveness of the remedy. Administrative factors include obtaining required permits and coordinating with support agencies.

Required labor, equipment and materials would include: 1) suppliers for construction materials (eg., geomembrane, geotextile, earthen materials), 2) construction and treatment equipment, 3) qualified contractors to competitively bid the construction work.

6.3.5 Cost

Alternatives were evaluated considering capital cost (including direct and indirect costs), long-term O&M costs, future capital cost, and future land use cost, as described below:

- Capital Costs - Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs.
- Equipment Costs - Equipment necessary for the remedial action (these materials remain until the site remedy is complete).
- Land and Site-Development Costs - Purchase of land and site preparation of existing property.
- Building and Services Costs - Buildings, utilities, and purchased services.
- Disposal Costs - Transporting and disposing of waste material.
- Engineering Expenses - Administration, design, construction supervision, drafting, and treatability testing.
- Legal Fees and License or Permit Costs
- Start Up and Shakedown Costs
- Contingency Allowances - To cover unforeseen circumstances.
- Operation and Maintenance Costs - Annual post-construction costs necessary to ensure the continued effectiveness of a remedial action. The following annual cost components should be considered:
    - Operating Labor Costs - Wages, salaries, training, overhead, and fringe benefits associated with post-construction operation
    - Maintenance Material and Labor Costs
    - Auxiliary Materials and Energy - Chemicals, electricity, water, and sewer, etc.
    - Disposal of Residues - To treat or dispose of residuals such as sludge from treatment processes or spent activated carbon.

- Purchased Services - Sampling costs, laboratory fees, and professional fees which can be predicted.
- Administrative Costs
- Insurance, Taxes, and Licensing Costs
- Replacement Costs
- Costs of Periodic Site Reviews - Reviews to be conducted every five years if a remedial action leaves any hazardous substances, pollutants, or contaminants at the site.
- Future Capital Costs - Costs for future remedial actions should be evaluated when there is the potential for a major component of the remedial alternative to break down or need replacement.
- Cost of Future Land Use - Potential future land use of the site is normally considered with regards to future zoning and development. However, for this study it was not considered because the future use of the site will be restricted. Recreational/open space development was assumed for all the alternatives.

A present worth analysis was performed to compare the alternatives in terms of 1998 dollars. The total present worth cost of the alternative includes the direct and indirect capital costs, and the present worth of long-term O&M costs at an annual rate of six percent. A cost sensitivity analysis may evaluate any uncertainties concerning specific assumptions made for individual costs, if necessary. At this stage of the Feasibility Study, costs are expected to be within -30 to +50 percent, as specified in USEPA guidance document "Conducting Remedial Investigation/Feasibility Studies for CERCLA at Municipal Landfill Sites."

6.4 Modifying Criteria

Modifying criteria are formally assessed after the public comment period. Prior to this time, they are considered to the extent that they are known. Specific emphasis has been placed on developing remedial alternatives which support restoring the site with a natural, open-space setting and areas suitable for recreational use.

6.4.1 Community Acceptance

Alternatives are evaluated based upon their acceptance by the community.

Table 6-1
Potentially Applicable Chemical-Specific SCGs
Brookfield Avenue Landfill, Staten Island, New York

Standard, Requirement Criteria or Limitation	Citation or Reference	Description	Comments
Federal			
** Groundwater*			
National Primary Drinking Water Standards	40 CFR Part 141	Applicable to the use of public water systems; establishes maximum contaminant levels (MCLs), monitoring requirements and treatment techniques.	Potentially applicable to offsite groundwater.
National Secondary Drinking Water Standards	40 CFR Part 143	Applicable to the use of public water systems; controls contaminants in drinking water that primarily effect the aesthetic qualities relating to public acceptance of drinking water.	Potentially applicable to offsite groundwater.
Safe Drinking Water Act	Pub. L 95-523, as amended by Pub. L. 96502, 22 USC 300 et. seq.	Sets limits to the maximum contaminant levels (MCLs) and maximum contaminant level goals (MCLGs).	Potentially applicable to offsite groundwater.
SDWA MCL Goals	40 CFR 141.50 FR 46936	Established drinking water quality goals set at levels of anticipated adverse health effects with an adequate margin of safety.	Potentially applicable to offsite groundwater.
USEPA Office of Drinking Water Health Advisories		Standards issued by the USEPA Office of Drinking Water.	
**Surface Water*			
Clean Water Act (CWA)	33 USC 1251 et.seq.	Applicable for alternatives involving treatment with point source discharges to surface water.	Criteria available for water and fish ingestion, and fish consumption for human health.

Table 6-1 (cont...)
Potentially Applicable Chemical-Specific SCGs
Brookfield Avenue Landfill, Staten Island, New York

Standard, Requirement Criteria or Limitation	Citation or Reference	Description	Comments
Toxic Pollutant Effluent Standards	40 CFR Part 129	Applicable to the discharge of toxic pollutants into navigable waters.	
General Provisions for Effluent Guidelines and Standards	40 CFR 401	Establishes legal authority and general definitions that apply to all regulations issued concerning specific classes and categories of point sources.	Provides for point source identification. Applicable to remedial action with effluent discharge.
* *Air*			
Clean Air Act	42 USC 7401 Section 112 (as amended 1993)	Establishes upper limits on parameter emissions to atmosphere.	Pollutants deemed hazardous or non-hazardous based on public health.
National Primary and Secondary Ambient Air Quality Standards	40 CFR 50	Establishes primary and secondary NAAQS under Section 109 of the Clean Air Act.	Primary NAAQS define levels of air quality necessary to protect public health. Secondary NAAQS define levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant. Applicable to remedial action alternatives that may emit pollutants to the atmosphere.
National Emissions Standards for Hazardous Air Pollutants	40 CFR 61	Establishes NESHAPs.	
**RCRA*			
Resource Conservation and Recovery Act- Identification and Listing of Hazardous Wastes	40 CFR 264.1	Defines those wastes which are subject to regulations as hazardous wastes under 40 CFR Parts 262-265 and Parts 124, 270,271.	

Table 6-1 (cont...)

Potentially Applicable Chemical-Specific SCGs

Brookfield Avenue Landfill, Staten Island, New York

Standard, Requirement Criteria or Limitation	Citation or Reference	Description	Comments
RCRA Maximum Concentration Limits	40 CFR 264	Ground Water protection standards for toxic metals and pesticides.	These provisions are applicable to RCRA regulated units that are subject to permitting.
Hazardous Waste Transportation and Disposal Requirements for PCBs	40 CFR Part 761	Requirements for manufacturing, transport and disposal of hazardous waste (PCBs)	Likely to not be applicable unless offsite disposal of PCB contaminated soils is performed.
**Other*			
USEPA Office of Research and Development Reference Doses		Reference dose issued by USEPA.	To Be Considered.
USEPA Environmental Criteria and Assessment Office- Carcinogenic Potency Factors		As developed by USEPA.	To Be Considered.
New York State			
** Soil*			
NYSDEC Soil Cleanup Objectives	NYSDEC TAGM, HWR-94-4046, January 24, 1994.	Applicable to the cleanup of contaminated soils. Cleanup goals recommended based on human health criteria, ground water protection, background levels, and laboratory quantification levels.	These objectives provide the maximum values for determining soil cleanup levels.
** Air*			
NYSDEC Division of Air Guidelines for the Control of Toxic Ambient Air Contaminants	Air Guide 1	Establishes air quality standards.	Applicable to remedial alternatives which include discharge to air.
New York Ambient Air Quality Standards	6 NYCRR 256-257	Establishes air quality standards.	Applicable to remedial alternatives which include discharge to air.

Table 6-1 (cont...)
Potentially Applicable Chemical-Specific SCGs
Brookfield Avenue Landfill, Staten Island, New York

Standard, Requirement Criteria or Limitation	Citation or Reference	Description	Comments
* *Surface Water & Ground Water*			
NYSDEC Surface Water Quality Regulations	6 NYCRR Part 703 Final Express Terms for Amendments to Title 6, Chapter X, Parts 700-706	Applicable to existing surface water quality and the discharge of runoff and contaminated groundwater into surface waters.	The nearest surface water body is Richmond Creek located north of the landfill, classified as Class SC.
NYSDEC Ground Water Quality Regulations	6 NYCRR Part 703 Final Express Terms for Amendments to Title 6, Chapter X, Parts 700-706	Applicable to the groundwater quality of both the shallow and deep aquifers; sets forth criteria for the consumption of potable water.	The local aquifers are classified as Class GA groundwater.
Ambient Water Quality Standards and Guidance Values	TOGS 1.1.1, Revised June, 1998	Establishes groundwater quality standards.	
New York Water Classifications and Quality Standards	6 NYCRR Parts 609, 700-704	Describes classification system for surface water and groundwater. Establishes standards of Quality and Purity.	Establishes required clean-up criteria based on water classification.
NYSDOH Standards Raw Water Quality	10 NYCRR 170.4	Provides water source quality standards.	May be applicable to groundwater clean-up levels.
NYSDOH Public Water Systems	10 NYCRR Part 5, Subpart 5-1	Provides water source quality standards.	No public supply wells are in the vicinity of, or impacted by the landfill.
**Sediment*			
NYSDEC DFWMR Sediment Screening Guidance	NYSDEC Technical Guidance for Screening Contaminated Sediment	Provides sediment screenign criteria and guidance.	May be applicable to clean-up of contaminated sediment.
**Hazardous Waste*			
New York Identification and Listing of Hazardous Waste Regulations	6 NYCRR part 371	Identifies hazardous wastes.	May be applicable if hazardous wastes are generated, stored or transported during remediation.
NYSDEC Land Disposal Restrictions	6 NYCRR Part 376	Identifies hazardous wastes that are subject to land disposal restrictions.	May be applicable if site remediation involves land disposal of contaminated soils.

Table 6-2
Potentially Applicable Action-Specific SCGs
Brookfield Avenue Landfill, Staten Island, New York

Standard, Requirement Criteria or Limitation	Citation or Reference	Description	Comments
Federal			
Clean Air Act	42 U.S.C. 7401	Applicable if alternatives will impact ambient air quality.	Relevant if remedial action causes air pollution above primary or secondary ambient air quality standards.
National Ambient Air Quality Standards	40 CFR Part 50	Applicable to alternatives that may emit pollutants to the air; establishes standards to protect public health and welfare.	May be relevant and appropriate if treatment of groundwater or soils involves air emissions.
Resource Conservation and Recovery Act (RCRA)	42 USC 6901-6987 40 CFR part 264 RCRA Subtitle C	Applicable to the treatment, storage, transportation and disposal of hazardous wastes and wastes listed under 6 NYCRR Part 371.	May be required for contaminated soil disposal options.
	40 CFR Part 264 RCRA Subtitle D	Applicable to management and disposal of non-hazardous wastes.	
	40 CFR Part 265	Interim standards for owners of hazardous waste facilities.	Includes design requirements for capping, treatment, and post closure care.
	40 CFR Part 262 and 263	Applicable to generators and transporters of hazardous waste.	Applicable to off-site disposal or treatment of hazardous material. Soils on-site may be deemed hazardous.
	40 CFR Part 268	Applicable to alternatives involving off-site disposal of hazardous waste; requires treatment to diminish waste toxicity.	May be required for soil disposal options.

Table 6-2 (cont.)
Potentially Applicable Action-Specific SCGs
Brookfield Avenue Landfill, Staten Island, New York

Standard, Requirement Criteria or Limitation	Citation or Reference	Description	Comments
CERCLA/SARA/NCP	40 CFR Part 300	Applicable to remedial actions at CERCLA and NYS Superfund Sites.	The Brookfield Ave. Landfill is a designated Inactive Hazardous Waste Site. (NYSDEC Site # 2-43-006)
	40 CFR 270,124	EPA administers hazardous waste permit program for CERCLA/Superfund Sites.	Covers basic permitting, application, monitoring, and reporting, requirements for off-site hazardous waste management facilties.
Clean Water Act	33 USC 1251	Restoration and maintenance of the chemical, physical and biological integrity of the nation's water.	May be applicable if groundwater and surface water are found to be negatively impacted by the site.
Safe Drinking Act Underground Injection	40 CFR Parts 144 and 146	Applicable to waste water treatment alternatives involving underground injections that may endanger drinking water sources.	Not applicable to site remedial alternatives.
Wetlands Permit	40 CFR Part 232	Applicable to remedial actions in and around wetlands.	Appicable to this site since coastal and freshwater wetlands may be impacted.
Underground Storage Tanks	40 CFR 280	Technical Standards and corrective action requirements for USTs	Likely to not apply to site since no known USTs remain.
Effluent Guidelines and Standards	40 CFR 403.5	National Pretreatment Standards and Prohibited Discharges.	Applies to potential discharge from leachate treatment (pre-treatment) system.
Occupational Safety and Health Act	29 CFR Part 1910 and 300.38	Applicable to workers and the work place during remediation of the site.	Applies to all response activities under the NCP.

Table 6-2 (cont.)

Potentially Applicable Action-Specific SCGs

Brookfield Avenue Landfill, Staten Island, New York

Standard, Requirement Criteria or Limitation	Citation or Reference	Description	Comments
Standards for Owners and Operators of Hazardous Waste Treatment and Disposal Facilities	40 CFR 264.71 and 264.72	Manifest requirements for sites receiving hazardous waste.	Not applicable to this site since hazardous waste will not be received.
Standards for Performance of New Stationary Sources	40 CFR Part 60 Subpart WWW	Standards for performance of new solid waste landfills.	Only applies to landfills that commenced construction, reconstruction or modification on or after May 30, 1991. Does not apply to activities conducted pursuant State remedial activities.
Hazardous Materials Transportation Act	49 USC ss 1801-1813, 49 CFR Parts 107, 171	Applicable to transporters of hazardous materials.	May be relevant if action results in sludge, waste or soil being transported off-site.
New York State			
Solid Waste Management Facilities	6 NYCRR Part 360	Provides regulation for solid waste management facilities (SWMFs).	Describes requirements to own, operate close, and monitor SWMFs.
NYSDEC TAGM	HWR-90-4030	Guidance for Selection of Remedial Actions at Inactive Hazardous Waste Sites.	Issued May 15, 1990.
Hazardous Waste Management	6 NYCRR Part 373	Standards for owners of hazardous waste facilities.	Includes design requirements for soil capping and treatment options, and post-closure care.
Transportation of Hazardous Materials	6 NYCRR Part 364	Regulates transportation of hazardous materials.	May be relevant if action results in off-site transport of hazardous soils.
New Discharges to Publicly Owned Treatment Works	NYSDEC DOW TOGS 1.3.8	Regulates discharges to POTWs	Applicable if discharge to the sewer is performed.

Table 6-2 (cont.)
Potentially Applicable Action-Specific SCGs
Brookfield Avenue Landfill, Staten Island, New York

Standard, Requirement Criteria or Limitation	Citation or Reference	Description	Comments
***Air**			
New York State Air Regulations	(6 NYCRR Parts 200 through 207,210,211,212 and 219)		
	6 NYCRR Part 212	General process emission sources.	Sets allowable emissions for remedial options resulting in air emissions.
	6 NYCRR Part 201, 202	Permits for construction/operations of air pollution sources.	Describes permit requirements to construct and operate the above options.
	6NYCRR Part 219	Particulate emission limits.	Limits are based on the refuse charged (lb/hr) for the above options.
New York State Air Regulations (cont.)	6NYCRR Part 211	Regulates fugitive dust emissions.	Requires control of fugitive dust emissions from excavations and transport.
	6 NYCRR Part 257	Air quality standards.	Requires control for on-site treatment
NYSDEC Draft Air guidelines-1: Guidelines for Control of Toxic Ambient air Contaminants	New York State Division of Air Resources Guidelines	Provides guidance on permit process review, gives AGCs and SCGs for ambient air based human health criteria.	Applicable to ambient air in the vicinity of the Brookfield Ave. Landfill.
***Local**			
Building Codes Sanitary Codes Fire Codes			The feasibility of each remedial alternative will be evaluated in light of applicable local codes.

Table 6-3
Potentially Applicable Location-Specific SCGs
Brookfield Avenue Landfill, Staten Island, New York

Standard, Requirement Criteria or Limitation	Citation or Reference	Description	Comments
Federal			
Fish and Wildlife Coordination Act	16 USC	Requires consultation when Federal department or agency proposes or authorizes any modification of any stream or other water body and adequate provision for protection of fish and wildlife resources.	Potentially applicable to certain site remedial alternatives.
Endangered Species Act	40 CFR 6.302 (g)	Requires Federal agencies to ensure that actions they authorize, fund or carry out are most likely to jeapordize the continued existence of endangered/threatened species or adversely modify the critical habitats of such species.	No endangered species are present in the study area.
Ocean Dumping of Dredged or Fill Material (Under the Clean Water Act)	40 CFR 230.10	Guidelines for specifications of disposal sites for dredged or fill material.	Not applicable to OU 1 since dredging will not occur, nor will offsite disposal of spoils or fill.
Executive Order On Floodplain Management	Execuitive Order No. 11988 40 CFR 6.302(a) and Appendix A	Requires Federal agencies to evaluate potential effects of actions that may take place in a floodplain to avoid, to the maximum extent possible, the adverse impacts associated with direct and indirect development of a floodplain.	A floodplain is located in the vicinity of the site.
Wetland Executive Order	Executive Order No. 11990	Details requirements for the preservation of wetlands.	Wetlands are located in the vicinity of the site.
Navigation and Navigable Waters (USACE)	33 CFR 320-330	Outlines requirements for discharge of dredge material into navigable waters.	Not applicable to OU 1 since dredging will not occur, nor will offsite disposal of spoils or fill.

Table 6-3 (cont...)
Potentially Applicable Location-Specific SCGs
Brookfield Avenue Landfill, Staten Island, New York

Standard, Requirement Criteria or Limitation	Citation or Reference	Description	Comments
Farmlands Protection	7 USC 4201 et. seq.	Protects significant or important agricultural lands from irreversible conversion to uses which result in loss of an environmental or essential food production resource.	No farmlands are located in the vicinity of the site.
New York State			
Air			
NY Environmental Conservation Law	New York Consolidated Laws Service: Environmental Conservation Law, Articles 1,3,5,7-8,19,38,70-72	Establishes requirements for the protection of air quality	Applicable if remedial activities include discharge to air.
New York Air Pollution Control Regulations	6 NYCRR Parts 220-221	Provides provisions for the prevention and control of air contamination and air pollution.	Applicable if remedial activities include discharge to air.
Water			
Use and Protection of Waters	6 NYCRR Part 608	Establishes standards for use and protection of waters	Applicable to remedial activities which affect waters.
NY Environmental Conservation Law	ECL Articles 17, 37, 71, 72	Establishes requirements for the protection of New York State waters.	Applicable to remedial activities which include discharge to groundwater or surface water.
NY State Department of State	19 NYCRR Part 600	Coastal Resources	Applies to activities conducted along NY State coasts.
Fish and Wildlife			
Endangered and Threatened Species of Fish and Wildlife	6 NYCRR Part 182	Designates endangered and threatened species for protection.	No endangered and/or threatened species are present in the vicinity of the site.
****Wetlands***			
Freshwater Wetlands	6 NYCRR Parts 661 and 663	Freshwater Weltands Regulations - Guidance for Compensatory Mitigation	Applicable if freshwater wetlands are removed or altered. Outlines compensatory mitigation.
NY Environmental Conservation Law	ECL Articles 24, 25	Establishes requirements for the protection of freshwater and tidal wetlands.	Wetlands are present in the vicinity of the site.

7

Section Seven

Section 7
Detailed Analysis of Alternatives

7.1 Introduction

The purpose of this section is to evaluate site remediation Alternatives 1 through 5, as identified in Section 5, using the eight criteria described in Section 6. The No Action scenario, Alternative 1, is included in the discussion to establish the baseline conditions for comparing the site remediation alternatives.

Alternatives 1 through 5 are individually described and evaluated below. Conceptual Site Remediation Plans for Alternatives 2A, 2B, 3, 4 and 5 are presented in Appendix A as Drawings 7-1 through 7-5, and elevation cross-sections and typical construction details are included as Drawings 7-6 and 7-7. A complete discussion detailing the evaluation of the proposed landfill capping and remediation system has been presented for Alternative 2A. Discussions for subsequent alternatives generally focus upon the respective differences between each alternative and Alternative 2A to avoid repetition. Since the extent of leachate collection and hydraulic control is the primary difference between each alternative, the detailed analysis focuses on these aspects. The results of the detailed analysis of alternatives are summarized in Table 7-1, located at the end of this section.

As noted in Section 5, Development of Site Remediation Alternatives, the alternatives presented are intended to account for the most plausible combinations of remedial technologies retained for further consideration following the screening analysis, considering variable degrees of design conservatism and cost. The alternatives were also selected with future site use as a consideration.

Details regarding preliminary analyses performed to evaluate cap slope stability, hydraulic containment and treatment of leachate and landfill gas control and treatment are presented in Appendices B through D.

The preliminary slope stability analysis presented in Appendix B concludes that stable side slopes can be achieved for each of the alternatives which propose a variable 12"-24" protection layer and variable 2% to 4% minimum side slopes. However, a more detailed analysis will be performed during the design phase to assess the impact of landfill settling on side slopes.

Appendix C includes a preliminary analysis of various leachate collection and hydraulic diversion configurations. A mathematical groundwater model was used to provide an screening type evaluation of several leachate collection and hydraulic diversion configurations with respect to: water table reduction, reduction in saturated waste volume and amount of leachate generated. The leachate containment system is analyzed in detail later in this Section, based on the results of this preliminary analysis. The leachate collection and diversion configurations analyzed in Appendix C do not exactly represent the options adopted as part of the alternatives; however, the intent was to provide a basis of comparison with respect to the effectiveness of, for example, full vs. limited leachate collection, and the presence or absence of an upgradient hydraulic barrier to divert groundwater flow.

Likewise, Appendix D contains a detailed analysis of landfill gas collection and treatment alternatives. The results of this analysis, as they pertain to the evaluation criteria, are discussed in this Section.

For discussion purposes, the term "landfill containment system" was used throughout the report to collectively describe the landfill cap, active gas collection system, leachate collection system, hydraulic diversion system, and Hot Spot No. 5 product collection system. The Hot Spot No. 5 product collection system was included in this term, because it is located within the footprint of the landfill and is included as part of Alternative 2B. Its function is isolated source removal rather than containment. Further investigation of Richmond Creek, as discussed in Section 5, has been assigned to OU2, and will not be covered in the remainder of this FS.

7.2 Alternative 1

7.2.1 Description

This alternative represents the "No Action" alternative, which is used to establish the baseline conditions for completing the comparative analysis of alternatives (see Section 8). It includes the following:

- Institutional controls
- Routine groundwater monitoring

7.2.2 Compliance with ARARs/ SCGs

Chemical-Specific ARARs/ SCGs

No active remediation is considered for this alternative. Institutional controls would consist of physical access and zoning restrictions for the landfill property. Future development and public access to the site would be limited. These restrictions would not achieve compliance with chemical-specific ARARs/SCGs for air, soil, surface water, and groundwater at the site.

Action-Specific ARARs/ SCGs

Because institutional controls and routine monitoring associated with this alternative do not involve remedial construction, treatment, removal, and/or transportation of contaminated materials at the site, this alternative would generally comply with applicable action-specific ARARs/SCGs, excluding the landfill closure requirements specified in 6 NYCRR Parts 360 and 373.

Location-Specific ARARs/ SCGs

Because this alternative is located adjacent to freshwater and coastal wetlands, it would not comply with location-specific ARARs/SCGs. The results of air sampling and landfill gas modeling performed during the Remedial Investigation (DEP, 1998) suggest that the site would not significantly affect local air quality.

7.2.3 Protection of Human Health and the Environment

Institutional controls to restrict physical access to the site would consist of warning signs and fencing around the landfill property. This would protect human health by preventing exposure. Administrative institutional controls consisting of deed restrictions and groundwater use restrictions would prevent unregulated future development of the site and use of impacted groundwater, respectively. Routine groundwater and soil gas sampling would be performed onsite to protect offsite residents.

Institutional controls would not be protective of the environment, since remediation of site contaminants would not be performed. Naturally occurring attenuation processes would decrease contaminant concentrations over time. However, leachate would continue to impact groundwater and surface water quality.

7.2.4 Short-Term Effectiveness

The institutional controls contained in Alternative 1 do not pose short-term risks to the community. There is no heavy construction associated with the implementation of institutional controls. Routine soil gas and groundwater monitoring would not pose significant short-term health risks to field personnel.

7.2.5 Long-Term Effectiveness and Permanence

Alternative 1 does not remove, reduce, or contain landfill contaminants. It is not an effective or permanent long-term solution.

7.2.6 Reduction of Toxicity, Mobility or Volume through Treatment

This alternative does not actively reduce the toxicity, mobility, or volume of landfill contaminants.

7.2.7 Implementability

This alternative is highly implementable based upon its simplicity.

7.2.8 Cost

Detailed capital and O&M cost estimates for all of the alternatives are presented in Tables 7-2 to 7-7.

The costs for the Institutional Controls include:

Capital Cost (mid-point of construction)		$2,000
Annual Operations and Maintenance Cost	(year 1)	$414,000
Annual Operations and Maintenance Cost	(years 2-5)	$413,000
Annual Operations and Maintenance Cost	(years 6 - 30)	$278,000
Total Estimated Cost (Present Worth)		$4,461,000

7.2.9 Community Acceptance

It is anticipated that the community would not accept this alternative.

7.3 Alternative 2A

7.3.1 Description

Alternative 2A consists of the following components:

- 6 NYCRR Part 360 landfill cap with variable protection layer thickness (12 to 24 inches).
- Active gas collection (below ground system) and onsite treatment by flaring.
- Perimeter (active) gas collection trench between the landfill and Arthur Kill Road.
- Leachate collection downgradient of Hot Spot No. 3 and the West Cell (as shown in Figure 4-3, Option 3).
- Barrier wall along the north face of the landfill between the leachate collection trenches.
- Barrier wall separating the southeast and southwest drainage ditches from the landfill.
- Onsite treatment of leachate (oil/water separation) with discharge to the sewer.
- Institutional controls and long-term monitoring of perimeter landfill gas, groundwater and treated leachate.

These components are illustrated on Drawing 7-1 of Appendix A. The active gas system is illustrated in Drawing 1 of Appendix D.

This and the remaining alternatives presently include capping to a minimum of 5 feet beyond the limits of waste. Alternatively, waste at the edge of the landfill could be consolidated to reduce the area to be capped and reduce or eliminate the need for permanent structures to be constructed within wetlands. Excavated waste would be consolidated in depressions at the interior of the landfill or spread evenly over areas to be capped.

The areas where waste consolidation may be appropriate are located just north of the pump station, between the east and west cells, and along the northern edge of the east cell, near Richmond Creek. Test pitting in each of these areas has confirmed the presence of decaying MSW at thicknesses greater than 6 feet, below 10 feet (MSL) in elevation. For evaluating waste consolidation, the 10-foot elevation line is used as an informal boundary to the tidal wetlands. Section 8 will include a separate analysis (outside of the alternative comparisons) comparing waste consolidation, leaving waste in-place and capping below the 10-foot elevation line, and leaving waste in-place but locating the cap and all structures above the 10-foot elevation line.

Waste consolidation is evaluated with respect to the threshold, balancing, and modifying criteria below. It is expected that a minor of amount of waste consolidation will occur at various locations along the landfill perimeter to aid in cap construction. Costs associated with incidental waste consolidation have been included with each alternative. A separate cost estimate for extensive consolidation, as described above, including the associated cost differences due to a reduction in cap size, is included in Section 8. The final decision as to whether to excavate and consolidate any waste, no matter which alternative is chosen, will be made during the design phase.

7.3.2 Compliance with ARARs/ SCGs

Chemical-Specific ARARs/ SCGs

The landfill cap acts as a physical barrier that will prevent direct exposure to buried waste, contaminated soils, landfill gases, and leachate at the ground surface. The cap would also protect future groundwater quality directly beneath the landfill by preventing downward movement of contaminants via infiltration of rain water though the buried waste.

The active gas extraction system would substantially reduce landfill gas emissions to the atmosphere. Gases generated within the landfill would be collected from a series of gas extraction wells/trenches installed below the cap and thermally destroyed at an onsite flare plant. Offsite gas migration would also be prevented by a perimeter collection trench located between the landfill and Arthur Kill Road.

The combination of the leachate collection system, downgradient barrier wall (north side) and barrier wall (south side) preventing discharge of leachate to the southeast and southwest drainage ditches would protect future offsite groundwater and surface water quality by hydraulically containing shallow groundwater beneath the landfill.

Shallow groundwater flowing outward from the landfill would be directed to, and collected at, perimeter interceptor trenches downgradient of Hot Spot No. 3 and the west cell, and pumped to an onsite treatment system. The groundwater would be treated to conform with permitted criteria for discharge to the sewer system. Based on the comparison of landfill leachate quality with the permissible maximum concentrations for discharge to the sewer, only petroleum hydrocarbon removal would be necessary. Oil/water separation would provide for sufficient petroleum hydrocarbon removal to meet the sewer use regulations.

Based upon the above, the conceptual leachate containment and collection system of Alternative 2A would comply with the chemical-specific ARARs/SCGs by preventing offsite migration of contaminants.

Waste consolidation may result in temporary air emissions above ARARs/SCGs. Leaving the waste in place, capping above the 10-foot elevation line, and locating all permanent structures above the 10-foot elevation line, may result in exceedances of ARARs/SCGs in Richmond Creek since leachate from the uncapped portion would not be controlled.

Action-Specific ARARs/ SCGs

The landfill containment system would generally comply with ARARs for landfill closure. A variance would be required to comply with property line offset requirements at the eastern end of the landfill. The flood elevation for Richmond Creek would be evaluated during the design. Perimeter access roads for the landfill would be constructed above the flood elevation to protect the containment system from potential impacts, as required.

During landfill cap construction, air emissions may increase above emissions measured during the RI. To minimize this potential, the construction health and safety plan would include routine air monitoring. Engineering controls, such as the use of water to prevent dust generation, would also be implemented to prevent significant releases of air borne contaminants.

Prior to establishment of the vegetative layer, erosion of soil particles may occur. To minimize this potential, erosion controls, such as netting, mulch, and hay, would be implemented during construction. These controls would be maintained until the vegetative layer is established.

Based upon the above, Alternative A would comply with the action-specific ARARs/SCGs. Potential air quality and erosion rate exceedances would be minimized through the use of engineering controls, as described above.

As the waste mass is excavated and consolidated, there is a potential for air emissions to exceed relevant SCGs for short periods of time, thus action-specific ARARs/SCGs for air may not be met. Leaving the waste in place, capping above the 10-foot elevation line, and locating all permanent structures above the 10-foot elevation line, may not allow action specific ARARs/SCGs to be met in Richmond Creek since leachate from the uncapped portion would not be controlled.

Location-Specific ARARs/ SCGs

Disturbance of wetland areas adjacent to and within the landfill would occur based upon construction and access requirements for the landfill containment system. To minimize disturbance, space and access requirements would be evaluated in detail during the landfill cap design. The locations and requirements for cap structures, staging areas, haul roads, and other relevant work items would be detailed in the design specifications and drawings. Restoration work would be specified, if/where required. Section 7.8 includes a preliminary analysis of waste consolidation, which is intended to minimize the amount of permanent structures required in wetlands.

During landfill area regrading, surface runoff from the landfill may induce erosion, thereby impacting adjacent surface water quality and wetland areas. To minimize this potential, engineering controls, such as berms, silt fences and diversion ditches, would be implemented.

Based upon the above, Alternative 2A would generally comply with location-specific ARARs/SCGs. The potential for surface water quality exceedances during construction would be minimized through the use of engineering controls, as described above. Restoration of disturbed fresh water and coastal wetland areas would be performed in accordance with state and federal permit requirements.

Tidal wetlands surrounding Richmond Creek would be impacted during excavation of waste. Restoration of disturbed wetlands would be required in accordance with state and federal permit requirements.

7.3.3 Protection of Human Health and the Environment

Based upon the technical function of each of its components, as described in Section 7.3.1, the landfill containment system would be protective of human health and the environment.

- Exposure via direct contact with buried waste, contaminated soils, and surface leachate; ingestion and inhalation of soil particles; and inhalation of landfill gases at the ground surface is prevented by the landfill cap.
- Exposure via inhalation of landfill gases at the ground surface and off site is prevented by the active gas extraction and treatment system.
- Exposure via ingestion of contaminated groundwater and direct contact with contaminated surface water is prevented by the groundwater containment system. Shallow groundwater beneath the landfill would be contained and

collected along its downgradient perimeter and treated onsite to remove contaminants.

As part of routine monitoring, groundwater, surface water, and soil gas samples would be collected from the perimeter of the landfill to verify containment system performance. Should analytical data indicate that significant concentration of landfill gases or contaminants are migrating offsite, additional control measures could also be implemented within the landfill.

Institutional controls would be implemented to limit future site use and development, and protect the integrity of the containment system. Physical controls, such as fencing and signs, would prevent uncontrolled access around equipment, mechanical and other sensitive areas. Administrative controls, such as deed restrictions, would prevent uncontrolled future development and ground-water use. It is anticipated that the site will be utilized as recreational/open space area following construction of the landfill containment system. This type of limited occupancy is considered to pose negligible risk and adds future value to the property. Routine site inspections and maintenance would be performed for all components of the landfill containment system to maintain their operational integrity.

Based upon the above, the containment system is considered to be protective of human health and the environment.

Various controls would be required during excavation, hauling and consolidation of waste to reduce worker and neighboring area exposure to potential hazards from airborne contaminants. Leaving the waste in place, capping above the 10-foot elevation line, and locating all permanent structures above the 10-foot elevation line would not be protective of the environment since uncapped waste may still generate leachate which would discharge to Richmond Creek.

7.3.4 Short-Term Effectiveness

Short-term risks associated with worker health and safety would exist during construction of the landfill containment system. Buried waste may be temporarily exposed during landfill regrading, gas vent construction, and perimeter drain construction. Worker risk would be minimized by preventing workers from entering areas where waste is exposed. Intrusive work would generally be performed using conventional construction equipment. Dust and landfill gases may be released during containment system construction. Dust suppressants, such as water or environmentally safe chemical products; would be used to minimize dust and gas emissions. The health and safety of workers would be routinely monitored by performing work-zone air quality monitoring. An onsite health and safety officer would ensure that appropriate levels of personnel protection are utilized. Perimeter air quality monitoring would also be performed to verify that such localized conditions do not extend beyond the designated work zone. Construction of the cap would be sequenced to minimize the area of disturbance during landfill regrading and cap construction.

Short-term risk to offsite residents related to site construction is negligible. However, inconvenience could occur associated with construction traffic, especially due to transportation of capping materials. Assuming a 5-year construction period, 5-working days per week, and a truck capacity of 16.5 cubic yards, approximately 23 trucks per day would be required to deliver enough material for the 24" protection layer alone. This compares to roughly 11 trucks per day for a 12" protection layer. It should be noted that these estimates are merely for comparison purposes. In reality, construction of the protection layer would likely occur over a shorter period of time thereby substantially increasing the number of truck trips per day.

Short-term impacts to freshwater and tidal wetlands are likely to occur due to cap and remedial system construction. Since waste has been identified in areas below the 10-foot elevation jurisdiction for tidal wetlands, disruption would occur during implementation of the cap. Additionally, construction of the leachate collection and barrier wall configuration specified in this alternative would result in minor impact to both tidal and freshwater wetlands. Short-term impacts could be minimized by use of proper controls.

Based upon the above, the short-term effectiveness of the landfill containment system construction is considered to be high. It is expected that the remedial measures for this alternative could be implemented within six years. This estimate assumes one year to design (assuming modification to the consent order) and five years for implementation.

The short-term effectiveness of waste consolidation is considered to be low. Existing tidal wetlands would be impacted through excavation and the possible release of contaminated groundwater to surface water, since a portion of the waste to be excavated is located below the water table. The short-term effectiveness of leaving the waste in place, capping above the 10-foot elevation line, and locating all permanent structures above the 10-foot elevation line would be higher since no immediate impact to wetlands would occur.

7.3.5 Long-Term Effectiveness and Permanence

Based upon the technical function of each of the containment system components, as described in Section 7.3.1, the long-term effectiveness and permanence of the landfill containment system is considered to be high. The containment system is designed to virtually eliminate all pathways for offsite contaminant migration. Although not specifically designed for this purpose, the mass of landfill contaminants would also decrease to some extent over time as a result of active gas collection and perimeter groundwater collection. The containment system would be designed to withstand erosion, differential settlement, and other sources of potential damage. Engineering controls (sampling stations, survey points) would be established and utilized on a routine basis to monitor containment system performance. A geomembrane or geosynthetic clay liner (GCL) would be used to construct the barrier layer of the landfill cap. The advantage of GCL is that it is constructed of natural, low-permeable, earth materials, and it is self-healing. Geomembrane liners are synthetically manufactured of durable, low-permeable, plastic material. Both liner materials are widely used for this purpose.

Long term impacts would be associated with construction of the cap, barrier wall and leachate collection trench in jurisdictional freshwater and tidal wetlands. Because waste has been identified in the area between the east and west cells, just north of the Eltingville Pump Station, the cap would be extended over this area. The area is part of the tidal wetlands since its falls within the 10' elevation criteria. Therefore, installation of the cap would result in significant impact. However, the long term impacts associated with leaving this area uncapped are arguably more severe than capping and construction of a barrier wall to prevent leachate migration.

The long-term effectiveness of waste consolidation is considered to be high, assuming the impacted wetlands are appropriately restored. The long-term effectiveness of leaving the waste in place, capping above the 10-foot elevation line, and locating all permanent structures above the 10-foot elevation line would be low since portions of waste would remain uncapped, allowing for leachate to continue to be generated and discharge to Richmond Creek.

7.3.6 Reduction of Toxicity, Mobility or Volume through Treatment

The landfill containment system is not designed to reduce the volume or toxicity of buried waste. The active gas collection and perimeter groundwater collection will reduce waste toxicity through treatment. Gas will be combusted in an enclosed flare. Groundwater/leachate will be pre-treated by oil/water separation and further treated at the Oak Beach WWTP. These treatment technologies will result in a reduction of toxicity and volume.

Consolidation of waste is not considered a treatment means to reduce the mobility, volume or toxicity of waste.

7.3.7 Implementability

Landfill containment system construction can be achieved using standard construction equipment, materials, and labor. Multiple vendors would be available to competitively bid the project. The construction materials are generally available for purchase. Large volumes of earthen materials required for rough grading and cap construction may be difficult and/or costly to obtain due to the location of the landfill (New York City). Comparatively, a 12" protection layer would be more implementable than a 24" protection layer. Use of a 12" protection layer for the landfill cap would significantly reduce truck traffic, compared to a 24" protection layer. As noted above, the number of truck trips required per day for a 12" and 24" protection layer would be 12 and 23, respectively.

A number of sewer lines also exist within the limits of waste. The cap would extend over such lines. Manholes would be extended so that they are accessible above the cap. Any future repairs to the lines could be performed using non-intrusive methods, or by removing and placing overlying sections of the cap.

From an administrative standpoint, significant disturbance of adjacent wetland areas is not anticipated, since most of the work would be performed within the footprint of the landfill. However, because waste material was identified in areas immediately adjacent to and within State jurisdictional wetlands, some minor disturbance of wetlands will occur. Necessary controls will be implemented to ensure disturbance is minimized. The conditions imposed by wetlands would hinder the implementability of construction to a minor extent. With all factors considered, however, the landfill containment system is expected to be highly implementable.

The implementability of waste consolidation is considered to be low. Approximately 290,000 cubic yards of waste would need to be excavated and relocated, to meet the goal of having the cap and all associated structures above the 10-foot elevation line. Leaving the waste in place, capping above the 10-foot elevation line, and locating all permanent structures above the 10-foot elevation line would be highly implementable since it would result in a reduced cap area, and eliminate the need for special controls and permits do construct in wetlands and excavate/consolidate waste.

7.3.8 Cost

Detailed capital and O&M cost estimates for all of the alternatives are presented in Tables 7-2 to 7-7, located at the end of this section. The estimated capital and operation and maintenance (O&M) costs for this alternative are as follows:

▪ Capital Cost (mid-point of construction)		$70,681,000
▪ Annual Operations and Maintenance Cost	(year 1)	$1,016,000
▪ Annual Operations and Maintenance Cost	(years 2 - 5)	$3,322,000
▪ Annual Operations and Maintenance Cost	(years 6 - 30)	$10,744,000
Total Estimated Cost (Present Worth)		$85,763,000

It is expected that a minor of amount of waste consolidation will occur at various locations along the landfill perimeter to aid in cap construction. Costs associated with this incidental waste consolidation are included in the above estimate. Costs associated with more extensive waste consolidation (and a reduced cap area) are presented in Section 8.

7.3.9 Community Acceptance

It is anticipated that this alternative would be largely viewed as acceptable by the community based upon its conservatism. It is expected that community acceptance of a variable 12" to 24" protection layer would be high, based on the increased volume of truck traffic required to implement a full 24" protection layer, given the communities perceived desire to minimize construction traffic.

A brief summary of this alternative was presented to the Staten Island Community Boards 2 and 3, on February 8 and 10, 2000 respectively. No specific comments or opinions concerning community acceptance of this particular alternative were received. General comments regarding the remediation in general were heard which included the location and appearance of the gas flare, the availability of funding to support the end use, construction and maintenance entrances and remediation of the Richmond Truck Fill site (north of Richmond Creek).

7.4 Alternative 2B

7.4.1 Description

Alternative 2B consists of the components listed below and shown in Appendix A, Drawing 7-2. Gas collection and treatment components are shown in Drawing 2 of Appendix D.

- 6 NYCRR Part 360 landfill cap with variable protection layer thickness (12 to 24 inches).
- Active gas collection (below ground system) and onsite treatment by flaring.
- Leachate collection along the entire north face of the landfill (shown in Figure 4-2, Option 2).
- Barrier wall along the entire south face of the landfill.
- Product Recovery at Hot Spot No. 5 (via and oil/water separator).
- Onsite treatment of leachate (oil/water separation) with discharge to the sewer.
- Institutional controls and long-term monitoring of perimeter landfill gas, groundwater and treated leachate.

7.4.2 Compliance with ARARs/ SCGs

Chemical-Specific ARARs/ SCGs

The landfill cap and active gas system would comply with chemical-specific SCGs, as discussed in section 7.3.2, for Alternative 2A. Because the leachate collection and barrier wall systems provides complete downgradient containment, Alternative 2B is expected to comply with chemical-specific ARARs/SCGs for groundwater.

Action-Specific ARARs/ SCGs

Alternative 2B would generally comply with the action-specific ARARs/SCGs, as described in Section 7.3.2 for Alternative 2A.

Location-Specific ARARs/ SCGs

Alternative 2B would generally comply with the location-specific ARARs/SCGs as described in Section 7.3.2. for Alternative 2A.

7.4.3 Protection of Human Health and the Environment

Alternative 2B would be protective of human health and the environment with respect to post-closure site conditions, as discussed in Section 7.3.3.

7.4.4 Short-Term Effectiveness

The short-term effectiveness of the landfill containment system is considered to be high, described for Alternative 2A in Section 7.3.4, except where noted below. Short-term impacts to freshwater and tidal wetlands would exist as described in Section 7.3.4.

The product recovery (pump and treat) system at Hot Spot No. 5 would be limited in short-term effectiveness. As stated in the RI Report, only one-half an inch of light non-aqueous phase liquid (LNAPL) was recovered over a seven month period. Generally, oils and petroleum compounds adsorb readily with waste, thereby hindering recovery effectiveness. The barrier wall south of Hot Spot No. 5 would provide downgradient control, immediately after capping, and effectively eliminate the need for product recovery.

7.4.5 Long-Term Effectiveness and Permanence

The long-term effectiveness of the cap is considered to be high, as described for Alternative 2A in Section 7.3.5.

Based on the analysis presented in Appendix C, the upgradient hydraulic diversion system consisting of a HDPE liner or slurry wall spanning the gap between the southeast and southwest perimeter drainage ditches would not significantly decrease leachate production, and would provide little benefit. The low permeability of the glacial till/glaciolacustrine clay that is present in the shallow aquifer throughout a significant portion of this area limits the flow of groundwater entering the site. Groundwater flow rates are expected to be higher at the southeast corner of the landfill, where more permeable shallow sands are present. Groundwater flowing into the site in this area is intercepted by the east pond and drainage ditch. The barrier wall between the landfill and the pond/drainage ditch would provide secondary protection from offsite groundwater contacting the waste mass in this area. This barrier wall, which is a component of all the remediation alternatives, would also serve to prevent leachate from discharging to the pond/drainage ditch.

7.4.6 Reduction of Toxicity, Mobility or Volume through Treatment

Similar to Alternative 2A, discussed in section 7.3.6, the landfill containment system is not designed to reduce the volume or toxicity of buried waste. The active gas collection, partial perimeter groundwater collection, and Hot Spot No. 5 production collection systems would reduce waste toxicity and volume.

7.4.7 Implementability

As discussed in Section 7.3.7, the implementability of the landfill containment system is considered to be high. Factors that may limit the implementability include the difficulty in obtaining large volumes of earthen materials required for rough grading and cap construction, and management of construction traffic to mitigate community impact and disruption.

7.4.8 Cost

Detailed capital and O&M cost estimates for all of the alternatives are presented in Tables 7-2 to 7-7.

The estimated capital, and operation and maintenance (O&M) costs for this alternative are as follows:

▪ Capital Cost (mid-point of construction)		$71,293,000
▪ Annual Operations and Maintenance Cost	(year 1)	$1,050,000
▪ Annual Operations and Maintenance Cost	(years 2 - 5)	$3,394,000
▪ Annual Operations and Maintenance Cost	(years 6 - 30)	$11,008,000
Total Estimated Cost (Present Worth)		$86,745,000

It is expected that a minor of amount of waste consolidation will occur at various locations along the landfill perimeter to aid in cap construction. Costs associated with this incidental waste consolidation are included in the above estimate. Costs associated with more extensive waste consolidation (and a reduced cap area) are presented in Section 8.

7.4.9 Community Acceptance

It is generally expected that this alternative would receive high acceptance from the community. As with all the alternatives, it is expected that community acceptance of a variable 12" to 24" protection layer would be high, based on the increased volume of truck traffic required to implement a full 24" protection layer, given the communities perceived desire to minimize construction traffic.

A brief summary of this alternative was presented to the Staten Island Community Boards 2 and 3, on February 8 and 10, 2000 respectively. No specific comments or opinions concerning community acceptance of this particular alternative were received. General comments regarding the remediation in general were heard which included the location and appearance of the gas flare, the availability of funding to support the end use, construction and maintenance entrances and remediation of the Richmond Truck Fill site (north of Richmond Creek).

7.5 Alternative 3

7.5.1 Description

Alternative 3 consists of the components listed below and shown in Appendix A, Drawing No. 7-3. The gas collection and treatment system is shown in Drawing 2 of Appendix D.

- 6 NYCRR Part 360 landfill cap with variable protection layer thickness (12 to 24 inches).
- Active gas collection (below ground system) and onsite treatment by flaring.
- Leachate collection around virtually the entire landfill (as shown in Figure 4-1, Option 1)
- Barrier wall connecting the leachate collection trenches south of the landfill.
- Onsite treatment of leachate (oil/water separation) with discharge to the sewer.
- Institutional controls and long-term monitoring of perimeter landfill gas, groundwater and treated leachate.

7.5.2 Compliance with ARARs/ SCGs

Chemical-Specific ARARs/ SCGs

The landfill cap and active gas system would comply with chemical-specific SCGs, as discussed in section 7.3.2, for Alternative 2A. Because the leachate collection and barrier wall systems provides complete downgradient containment, Alternative 3 is expected to comply with chemical-specific ARARs/SCGs.

Action-Specific ARARs/ SCGs

Alternative 3 would generally comply with the action-specific ARARs/SCGs, as described in Section 7.3.2.

Location-Specific ARARs/ SCGs

Alternative 3 would generally comply with the location-specific ARARs/SCGs as described in Section 7.3.2.

7.5.3 Protection of Human Health and the Environment

Alternative 3 would be protective of human health and the environment with respect to post-closure site conditions, as discussed in Section 7.3.3.

7.5.4 Short-Term Effectiveness

The short-term effectiveness of the landfill containment system is considered to be high, as described in Section 7.3.4. Short-term impacts to freshwater and tidal wetlands would exist as described in Section 7.3.4.

7.5.5 Long-Term Effectiveness and Permanence

The long-term effectiveness of the landfill containment system is considered to be high, based upon the discussion presented in Section 7.3.5. The upgradient hydraulic diversion system, as discussed in Section 7.4.3, would not significantly decrease leachate production, and would provide little long-term benefit.

7.5.6 Reduction of Toxicity, Mobility or Volume through Treatment

As discussed in section 7.3.6, the landfill containment system is not designed to reduce the volume or toxicity of buried waste. The active gas collection and perimeter groundwater collection would reduce waste toxicity to a minor extent.

7.5.7 Implementability

As discussed in Section 7.3.7, the implementability of the landfill containment system is considered to be high. Factors that may limit the implementability include the difficulty in obtaining large volumes of earthen materials required for rough grading and cap construction, and management of construction traffic to mitigate community impact and disruption.

7.5.8 Cost

Detailed capital and O&M cost estimates for all of the alternatives are presented in Tables 7-2 to 7-7.

The estimated capital, and operation and maintenance (O&M) costs for this alternative are as follows:

▪	Capital Cost (mid-point of construction)		$71,624,000
▪	Annual Operations and Maintenance Cost	(year 1)	$1,085,000
▪	Annual Operations and Maintenance Cost	(years 2 - 5)	$3,563,000

▪ Annual Operations and Maintenance Cost	(years 6 - 30)	$11,631,000
Total Estimated Cost (Present Worth)		$87,903,000

It is expected that a minor of amount of waste consolidation will occur at various locations along the landfill perimeter to aid in cap construction. Costs associated with this incidental waste consolidation are included in the above estimate. Costs associated with more extensive waste consolidation (and a reduced cap area) are presented in Section 8.

7.5.9 Community Acceptance

It is anticipated that this alternative would receive high acceptance from the community, based upon the conservatism of the conceptual design. As with each of the alternative, it is expected that community acceptance of a variable 12" to 24" protection layer would be high, based on the increased volume of truck traffic required to implement a full 24" protection layer, given the communities perceived desire to minimize construction traffic.

A brief summary of this alternative was presented to the Staten Island Community Boards 2 and 3, on February 8 and 10, 2000 respectively. No specific comments or opinions concerning community acceptance of this particular alternative were received. General comments regarding the remediation in general were heard which included the location and appearance of the gas flare, the availability of funding to support the end use, construction and maintenance entrances and remediation of the Richmond Truck Fill site (north of Richmond Creek).

7.6 Alternative 4

7.6.1 Description

Alternative 4 consists of the components listed below and shown in Appendix A, Drawing No. 7-4. The gas collection and treatment system is shown in Drawing 2 of Appendix D.

- 6 NYCRR Part 360 landfill cap with variable protection layer thickness (12 to 24 inches).
- Active gas collection (below ground system) and onsite treatment by flaring.
- Limited leachate collection adjacent of Hot Spot No. 3 and Hot Spot No. 5 (as shown in Figure 4-4, Option 4).
- Barrier wall along the entire south face of the landfill.
- Onsite treatment of leachate (oil/water separation) with discharge to the sewer.

- Institutional controls and long-term monitoring of perimeter landfill gas, groundwater and treated leachate.

7.6.2 Compliance with ARARs/ SCGs

Chemical-Specific ARARs/ SCGs

Alternative 4 would generally comply with chemical-specific ARARs/SCGs as described in Section 7.3.2. with regards to air emissions. Due to lack of complete downgradient containment of leachate, Alternative 4 would likely not comply with ARARs/SCGs for surface water and groundwater. A screening level analysis was performed in the RI report to identify areas where contaminants in groundwater exceeded 10 times the Class SC surface water standard. This approach, as described in TOGS 1.3.1, is based on a gross assumption of dilution attenuating contaminant concentrations by a factor of 10. Drawing No. 39 in the RI Report identifies locations from where groundwater or leachate seep samples resulted in exceedances of greater than 10 times the class SC surface water SCG. Five of these locations are in the area along the north face of the landfill where containment or collection is not specified for this alternative. exceedances in this area included pesticides, polynuclear aromatic hydrocarbons, and metals. Ammonia would also likely exceed surface water SCGs. Based on this screening analysis, this alternative would not comply with SCGs.

Action-Specific ARARs/ SCGs

Alternative 4 would generally comply with the action-specific ARARs/SCGs, as described in Section 7.3.2.

Location-Specific ARARs/ SCGs

Alternative 4 would generally comply with the location-specific ARARs/SCGs as described in Section 7.3.2.

7.6.3 Protection of Human Health and the Environment

Alternative 4 would generally be protective of human health and the environment with respect to post-closure site conditions, as discussed in Section 7.3.3. However, lack of leachate containment along the north face would not be protective of the environment, at least in the short-term, until leachate generation is reduced as a result of the cap.

7.6.4 Short-Term Effectiveness

The short-term effectiveness of the landfill containment system is considered to be high, as described in Section 7.3.4.

7.6.5 Long-Term Effectiveness and Permanence

The long-term effectiveness of the landfill containment system is considered to be moderate. Leachate collection would be limited to the downgradient perimeter of the landfill at Hot Spots No. 3 and No. 5. Until the cap effectively reduces leachate generation, leachate will migrate beyond the landfill and discharge to Richmond Creek.

7.6.6 Reduction of Toxicity, Mobility or Volume through Treatment

As discussed in section 7.3.6, the landfill containment system is not designed to reduce the volume or toxicity of buried waste. The active gas collection limited perimeter groundwater collection would reduce waste toxicity to a minor extent.

7.6.7 Implementability

As discussed in Section 7.3.7, the implementability of the landfill containment system is considered to be high.

7.6.8 Cost

Detailed capital and O&M cost estimates for all of the alternatives are presented in Tables 7-2 to 7-7.

The estimated capital, and operation and maintenance (O&M) costs for this alternative are as follows:

▪ Capital Cost (mid-point of construction)	$70,288,000
▪ Annual Operations and Maintenance Cost (year 1)	$1,018,000
▪ Annual Operations and Maintenance Cost (years 2 - 5)	$3,210,000
▪ Annual Operations and Maintenance Cost (years 6 - 30)	$10,333,000
Total Estimated Cost (Present Worth)	$84,849,000

It is expected that a minor of amount of waste consolidation will occur at various locations along the landfill perimeter to aid in cap construction. Costs associated with this incidental waste consolidation are included in the above estimate. Costs associated with more extensive waste consolidation (and a reduced cap area) are presented in Section 8.

7.6.9 Community Acceptance

It is anticipated that this alternative would receive low acceptance from the community. Limited containment of leachate would likely be received with a certain degree of skepticism.

A brief summary of this alternative was presented to the Staten Island Community Boards 2 and 3, on February 8 and 10, 2000 respectively. No specific comments or opinions concerning community acceptance of this particular alternative were received. General comments regarding the remediation in general were heard which included the location and appearance of the gas flare, the availability of funding to support the end use, construction and maintenance entrances and remediation of the Richmond Truck Fill site (north of Richmond Creek).

7.7 Alternative 5

7.7.1 Description

Alternative 5 consists of the components listed below and shown in Appendix A, Drawing No. 7-5. The gas collection and treatment system is shown in Drawing 2 of Appendix D.

- 6 NYCRR Part 360 landfill cap with variable protection layer thickness (12 to 24 inches).
- Active gas collection (below ground system) and onsite treatment by flaring.
- Limited leachate collection adjacent of Hot Spot No. 3 and Hot Spot No. 5 (as shown in Figure 4-4, Option 4).
- Barrier wall separating the southeast and southwest drainage ditches from the landfill.
- Onsite treatment of leachate (oil/water separation) with discharge to the sewer.
- Institutional controls and long-term monitoring of perimeter landfill gas, groundwater and treated leachate.

7.7.2 Compliance with ARARs/ SCGs

Chemical-Specific ARARs/ SCGs

Alternative 5 would generally comply with chemical-specific ARARs/SCGs as described in Section 7.3.2. with regards to air emissions. Due to lack of complete downgradient containment of leachate, Alternative 5 would likely not comply with ARARs/SCGs for surface water and groundwater, as described in Section 7.6.2.

Action-Specific ARARs/ SCGs

Alternative 5 would generally comply with the action-specific ARARs/SCGs, as described in Section 7.3.2.

Location-Specific ARARs/ SCGs

Alternative 5 would generally comply with the location-specific ARARs/SCGs as described in Section 7.3.2.

7.7.3 Protection of Human Health and the Environment

Alternative 5 would generally be protective of human health and the environment with respect to post-closure site conditions, as discussed in Section 7.3.3. However, lack of leachate containment along the north face would not be protective of the environment, at least in the short-term, until leachate generation is reduced as a result of the cap.

7.7.4 Short-Term Effectiveness

The short-term effectiveness of the landfill containment system is considered to be high, as described in Section 7.3.4.

7.7.5 Long-Term Effectiveness and Permanence

The long-term effectiveness of the landfill containment system is considered to be moderate. Leachate collection would be limited to the downgradient perimeter of the landfill at Hot Spots No. 3 and No. 5. Until the cap effectively reduces leachate generation, leachate will migrate beyond the landfill and discharge to Richmond Creek.

7.7.6 Reduction of Toxicity, Mobility or Volume through Treatment

As discussed in section 7.3.6, the landfill containment system is not designed to reduce the volume or toxicity of buried waste. The limited perimeter groundwater collection would reduce waste toxicity to a minor extent. The mobility of the contaminants would be decreased by the landfill containment system, which minimizes the pathways for offsite contaminant migration.

7.7.7 Implementability

As discussed in Section 7.3.7, the implementability of the landfill containment system is considered to be high.

7.7.8 Cost

Detailed capital and O&M cost estimates for all of the alternatives are presented in Tables 7-2 to 7-7.

The estimated capital, and operation and maintenance (O&M) costs for this alternative are as follows:

▪ Capital Cost (mid-point of construction)		$69,648,000
▪ Annual Operations and Maintenance Cost	(year 1)	$1,018,000
▪ Annual Operations and Maintenance Cost	(years 2 - 5)	$3,210,000
▪ Annual Operations and Maintenance Cost	(years 6 - 30)	$10,333,000

Total Estimated Cost (Present Worth)	$84,209,000

It is expected that a minor of amount of waste consolidation will occur at various locations along the landfill perimeter to aid in cap construction. Costs associated with this incidental waste consolidation are included in the above estimate. Costs associated with more extensive waste consolidation (and a reduced cap area) are presented in Section 8.

7.7.9 Community Acceptance

It is anticipated that this alternative would receive low acceptance from the community. Limited containment of leachate would likely be received with a certain degree of skepticism.

A brief summary of this alternative was presented to the Staten Island Community Boards 2 and 3, on February 8 and 10, 2000 respectively. No specific comments or opinions concerning community acceptance of this particular alternative were received. General comments regarding the remediation in general were heard which included the location and appearance of the gas flare, the availability of funding to support the end use, construction and maintenance entrances and remediation of the Richmond Truck Fill site (north of Richmond Creek).

TABLE 7-1

DETAILED ANALYSIS OF SITE REMEDIATION ALTERNATIVES
Brookfield Avenue Landfill
Staten Island, New York

ASSESSMENT FACTOR	ALTERNATIVE 2A	ALTERNATIVE 2B	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5	ALTERNATIVE 1
Summary of Components	- Part 360 cap with variable protection layer thickness - Active gas collection/ treatment, including a perimeter collection trench - Leachate collection/ treatment at Hot Spot no. 3 and West Cell - Barrier wall along the landfill's north face - Barrier wall separating the perimeter ditches and landfill - Institutional controls - Post-closure monitoring	- Part 360 cap with variable protection layer thickness - Active gas collection/ treatment - Leachate collection/ treatment along landfill's entire north face - Barrier wall along the landfill's south face - Product recovery at Hot Spot No. 5 - Institutional controls - Post-closure monitoring	- Part 360 cap with variable protection layer thickness - Active gas collection/ treatment - Leachate collection/ treatment around virtually the entire landfill - Barrier wall connecting ditches south of landfill - Institutional controls - Post-closure monitoring	- Part 360 cap with variable protection layer thickness - Leachate collection/ treatment at Hot Spot Nos. 3 and 5. - Barrier wall along the landfill's south face - Institutional controls - Post-closure monitoring	- Part 360 cap with variable protection layer thickness - Leachate collection/ treatment at Hot Spot Nos. 3 and 5. - Barrier wall separating the perimeter ditches and landfill - Institutional controls - Post-closure monitoring	- Institutional controls - Post-closure monitoring

TABLE 7-1(cont.)

DETAILED ANALYSIS OF SITE REMEDIATION ALTERNATIVES
Brookfield Avenue Landfill
Staten Island, New York

ASSESSMENT FACTOR	ALTERNATIVE 2A	ALTERNATIVE 2B	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5	ALTERNATIVE 1
Summary of Components	- Part 360 cap with variable protection layer thickness - Active gas collection/ treatment, including a perimeter collection trench - Leachate collection/ treatment at Hot Spot no. 3 and West Cell - Barrier wall along the landfill's north face - Barrier wall separating the perimeter ditches and landfill - Institutional controls - Post-closure monitoring	- Part 360 cap with variable protection layer thickness - Active gas collection/ treatment - Leachate collection/ treatment along landfill's entire north face - Barrier wall along the landfill's south face - Product recovery at Hot Spot No. 5 - Institutional controls - Post-closure monitoring	- Part 360 cap with variable protection layer thickness - Active gas collection/ treatment - Leachate collection/ treatment around virtually the entire landfill - Barrier wall connecting ditches south of landfill - Institutional controls - Post-closure monitoring	- Part 360 cap with variable protection layer thickness - Leachate collection/ treatment at Hot Spot Nos. 3 and 5. - Barrier wall along the landfill's south face - Institutional controls - Post-closure monitoring	- Part 360 cap with variable protection layer thickness - Leachate collection/ treatment at Hot Spot Nos. 3 and 5. - Barrier wall separating the perimeter ditches and landfill - Institutional controls - Post-closure monitoring	- Institutional controls - Post-closure monitoring

TABLE 7-1(cont.)

DETAILED ANALYSIS OF SITE REMEDIATION ALTERNATIVES
Brookfield Avenue Landfill
Staten Island, New York

ASSESSMENT FACTOR	ALTERNATIVE 2A	ALTERNATIVE 2B	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5	ALTERNATIVE 1
Compliance with ARARs/SCGs	Would generally comply with ARARs, excluding location-specific criteria for requirements of property line and wetland offsets.	Would generally comply with ARARs, excluding location-specific criteria for requirements of property line and wetland offsets.	Would generally comply with ARARs, excluding location-specific criteria for requirements of property line and wetland offsets.	Would generally comply with ARARs, excluding probable exceedances of chemical-specific criteria for groundwater and surface water and location-specific criteria for requirements of property line and wetland offsets.	Would generally comply with ARARs, excluding probable exceedances of chemical-specific criteria for groundwater and surface water and location-specific criteria for requirements of property line and wetland offsets.	Would not comply with ARARs. Would not comply with action specific criteria for landfill closure, or chemical-specific criteria for ground-water, surface water, or soil.
Protection of Human Health and the Environment	Greatly reduces risks from landfill waste and gases. Groundwater impacted by leachate would be fully contained by a perimeter collection/ treatment and barrier system.	Greatly reduces risks from landfill waste and gases. Groundwater impacted by leachate would be fully contained by a perimeter collection/ treatment and barrier system.	Greatly reduces risks from landfill waste and gases. Groundwater impacted by leachate would be fully contained by a perimeter collection/ treatment and barrier system.	Greatly reduces risks from landfill waste and gases. Groundwater impacted by leachate would be partially contained by a collection/treatment system located adjacent to Hot Spot Nos. 3 and 5.	Greatly reduces risks from landfill waste and gases. Groundwater impacted by leachate would be partially contained by a collection/treatment system located adjacent to Hot Spot Nos. 3 and 5.	Reduces risk to human health. Does not reduce risk to the environment.

TABLE 7-1(cont.)

DETAILED ANALYSIS OF SITE REMEDIATION ALTERNATIVES
Brookfield Avenue Landfill
Staten Island, New York

ASSESSMENT FACTOR	ALTERNATIVE 2A	ALTERNATIVE 2B	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5	ALTERNATIVE 1
Short-Term Effectiveness	Negligible short-term risks to human health and the environment, although minor impacts would be associated with wetlands disturbance and construction traffic.	Negligible short-term risks to human health and the environment, although minor impacts would be associated with wetlands disturbance and construction traffic	Negligible short-term risks to human health and the environment, although minor impacts would be associated with wetlands disturbance and construction traffic	Negligible short-term risks to human health and the environment, although minor impacts would be associated with wetlands disturbance and construction traffic	Negligible short-term risks to human health and the environment, although minor impacts would be associated with wetlands disturbance and construction traffic	Negligible short-term risks to human health and the environment.
Long-Term Effectiveness	Would be effective for protection of human health and the environment. Loss of wetlands due to construction of leachate controls and cap would be offset by increased quality of remaining wetlands.	Would be effective for protection of human health and the environment. Loss of wetlands due to construction of leachate controls and cap would be offset by increased quality of remaining wetlands.	Would be effective for protection of human health and the environment. Loss of wetlands due to construction of leachate controls and cap would be offset by increased quality of remaining wetlands.	Would be effective for protection of human health and the environment. Moderate attenuation of leachate contaminants would occur beyond the landfill perimeter.	Would be effective for protection of human health and the environment. Moderate attenuation of leachate contaminants would occur beyond the landfill perimeter.	Would generally be effective for protection of human health. It would be ineffective for protecting the environment, since leachate would continue to impact downgradient groundwater and surface water quality.
Reduction of Toxicity, Mobility, and Volume through Treatment	Reduction of toxicity, mobility and volume would occur as a result of active gas and leachate collection/ treatment systems.	Reduction of toxicity, mobility and volume would occur as a result of active gas, leachate, and product collection/ treatment systems.	Reduction of toxicity, mobility and volume would occur as a result of active gas and leachate collection/ treatment systems.	Reduction of toxicity, mobility and volume would occur as a result of active gas and leachate collection/ treatment systems.	Reduction of toxicity, mobility and volume would occur as a result of active gas and leachate collection/ treatment systems.	No active reduction of toxicity, mobility, or volume would occur.

TABLE 7-1 (cont...)

DETAILED ANALYSIS OF SITE REMEDIATION ALTERNATIVES
Brookfield Avenue Landfill
Staten Island, New York

ASSESSMENT FACTOR	ALTERNATIVE 2A	ALTERNATIVE 2B	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5	ALTERNATIVE 1
Implementability	Readily implementable. Minor administrative implementation issues exist concerning construction in and disturbance to wetlands.	Readily implementable. Minor administrative implementation issues exist concerning construction in and disturbance to wetlands.	Readily implementable. Minor administrative implementation issues exist concerning construction in and disturbance to wetlands.	Readily implementable. Minor administrative implementation issues exist concerning construction in and disturbance to wetlands.	Readily implementable. Minor administrative implementation issues exist concerning construction in and disturbance to wetlands.	Readily implementable.
Cost (Present Worth)	$85,763,000	$86,745,000	$87,903,000	$84,849,000	$84,209,000	$4,461,000
Community Acceptance	Acceptable with concerns regarding increased truck traffic during construction.	Acceptable with concerns regarding increased truck traffic during construction.	Acceptable with concerns regarding increased truck traffic during construction.	Likely unacceptable due to limited leachate containment.	Likely unacceptable due to limited leachate containment.	Not acceptable.

TABLE 7-2
CAPITAL COST ESTIMATE
BROOKFIELD AVENUE LANDFILL FEASIBILITY STUDY

ITEM	UNIT COST	UNITS	ALTERNATIVE 2A		ALTERNATIVE 2B		ALTERNATIVE 3		ALTERNATIVE 4		ALTERNATIVE 5		ALTERNATIVE 1	
			QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST
PRESUMPTIVE REMEDY:														
SITE PREPARATION:														
Gravel Access Roads	$40.00	LF	13,500	$540,000	13,500	$540,000	13,500	$540,000	13,500	$540,000	13,500	$540,000	0	$0
Clearing/Grubbing	$10,000.00	Acre	165	$1,650,000	165	$1,650,000	165	$1,650,000	165	$1,650,000	165	$1,650,000	0	$0
Excavation & Consolidation (allowance)	$20.00	CY	20,000	$400,000	20,000	$400,000	20,000	$400,000	20,000	$400,000	20,000	$400,000	0	$0
Rough Grading with Common Fill	$20.00	CY	253,000	$5,060,000	253,000	$5,060,000	253,000	$5,060,000	253,000	$5,060,000	253,000	$5,060,000	0	$0
CAP CONSTRUCTION:														
Hydroseeding	$4,000.00	Acre	150	$600,000	150	$600,000	150	$600,000	150	$600,000	150	$600,000	0	$0
Topsoil	$30.00	CY	121,000	$3,630,000	121,000	$3,630,000	121,000	$3,630,000	121,000	$3,630,000	121,000	$3,630,000	0	$0
Protection Layer	$30.00	CY	484,000	$14,520,000	484,000	$14,520,000	484,000	$14,520,000	484,000	$14,520,000	484,000	$14,520,000	0	$0
Barrier Layer	$1.00	SF	6,534,000	$6,534,000	6,534,000	$6,534,000	6,534,000	$6,534,000	6,534,000	$6,534,000	6,534,000	$6,534,000	0	$0
Gas Venting Layer (Geonet Composite)	$1.00	SF	6,534,000	$6,534,000	6,534,000	$6,534,000	6,534,000	$6,534,000	6,534,000	$6,534,000	6,534,000	$6,534,000	0	$0
Geonet Composite Drainage Layer (@steep slopes)	$1.00	SF	365,000	$365,000	365,000	$365,000	365,000	$365,000	365,000	$365,000	365,000	$365,000	0	$0
Erosion Control Netting	$0.25	SF	3,267,000	$817,000	3,267,000	$817,000	3,267,000	$817,000	3,267,000	$817,000	3,267,000	$817,000	0	$0
DRAINAGE SYSTEM CONSTRUCTION:														
Toe Drain	$50.00	LF	17,000	$850,000	17,000	$850,000	17,000	$850,000	17,000	$850,000	17,000	$850,000	0	$0
Drainage Swale (w/toe drain)	$15.00	LF	6,000	$90,000	6,000	$90,000	6,000	$90,000	6,000	$90,000	6,000	$90,000	0	$0
GAS COLLECTION SYSTEM CONSTRUCTION:														
Collection/Treatment System (See Appendix D)		LS		$3,045,000		$2,911,000		$2,911,000		$2,911,000		$2,911,000		$0
LEACHATE COLLECTION SYSTEM CONSTRUCTION:														
Interceptor Trenches	$15.00	SF	39,000	$585,000	68,250	$1,024,000	121,325	$1,820,000	30,000	$450,000	30,000	$450,000	0	$0
Collection Sumps, Pumps, and Appurtenances	$15,000.00	EA	4	$60,000	5	$75,000	10	$150,000	4	$60,000	4	$60,000	0	$0
Distribution Piping, Valves, and Appurtenances	$40.00	LF	7,350	$294,000	12,825	$513,000	20,600	$824,000	9,625	$385,000	9,625	$385,000	0	$0
Pretreatment System (Oil/Water Separator)		LS		$12,000		$16,000		$24,000		$6,000		$6,000	0	$0
Plant Building	$120.00	SF	400	$48,000	400	$48,000	400	$48,000	400	$48,000	400	$48,000	0	$0
GROUNDWATER DIVERSION SYSTEM:														
Barrier Wall (Separate from Collection Trench)	$15.00	SF	121,125	$1,817,000	114,000	$1,710,000	52,500	$788,000	114,000	$1,710,000	82,125	$1,232,000	0	$0
PRODUCT RECOVERY SYSTEM:														
Pump and Appurtenances (Using Well GW-23S)		LS		$0		$10,000		$0		$0		$0	0	$0
Treatment System		LS		$0		$10,000		$0		$0		$0	0	$0
SITE ACCESS, CONTROL, AND RESTORATION:														
Power Supply		LS		$10,000		$10,000		$10,000		$10,000		$10,000		$0
Asphalt Access Roads	$60.00	LF	17,000	$1,020,000	17,000	$1,020,000	17,000	$1,020,000	17,000	$1,020,000	17,000	$1,020,000	0	$0
Security (1 guard, 24 hrs)	$15,000.00	Months	72	$1,080,000	72	$1,080,000	72	$1,080,000	72	$1,080,000	72	$1,080,000	0	$0
Sign Installation/Replacement	$50.00	Each	40	$2,000	40	$2,000	40	$2,000	40	$2,000	40	$2,000	40	$2,000
Wetlands Mitigation	$40,000.00	Acre	10	$400,000	10	$400,000	10	$400,000	10	$400,000	10	$400,000	0	$0
ENGINEERING CONTROL:														
Surveying (3-man crew)	$33,000.00	Months	72	$2,376,000	72	$2,376,000	72	$2,376,000	72	$2,376,000	72	$2,376,000	0	$0
Site Erosion Control		LS		$300,000		$300,000		$300,000		$300,000		$300,000		$0
SUBTOTAL CONTAINMENT SYSTEM				$52,639,000		$53,095,000		$53,343,000		$52,348,000		$51,870,000		$2,000
Escalation to mid-point of construction (9%)		LS		$4,738,000		$4,779,000		$4,801,000		$4,711,000		$4,668,000		$200
Engineering (5%)		LS		$2,632,000		$2,655,000		$2,667,000		$2,617,000		$2,594,000		$0
Construction Management (10%)		LS		$5,264,000		$5,310,000		$5,334,000		$5,235,000		$5,187,000		$0
Contractor OH + H&S (15%)		LS		$7,896,000		$7,964,000		$8,001,000		$7,852,000		$7,781,000		$0
Contingency (15%)		LS		$7,896,000		$7,964,000		$8,001,000		$7,852,000		$7,781,000		$0
TOTAL CAPITAL COST ESTIMATE (mid-point of construction)				**$81,065,000**		**$81,767,000**		**$82,147,000**		**$80,615,000**		**$79,881,000**		**$2,000**
PRESENT WORTH (1999 Dollars)				**$70,681,000**		**$71,293,000**		**$71,624,000**		**$70,288,000**		**$69,648,000**		**$2,000**

TABLE 7-3
ANNUAL O&M COST ESTIMATE (Year 1)
BROOKFIELD AVENUE LANDFILL FEASIBILITY STUDY

			ALTERNATIVE 2A		ALTERNATIVE 2B		ALTERNATIVE 3		ALTERNATIVE 4		ALTERNATIVE 5		ALTERNATIVE 1	
ITEM	UNIT COST	UNITS	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST
OPERATION:														
GENERAL:														
Operator (average of 1 person, full time)		LS		$65,000		$65,000		$65,000		$65,000		$65,000		$0
Security (2 person, 24-hours per day)		LS		$184,992		$184,992		$184,992		$184,992		$184,992		$184,992
GAS TREATMENT:														
Electricity		LS		$36,000		$36,000		$36,000		$36,000		$36,000		$0
LEACHATE TREATMENT:														
Electricity		LS		$4,000		$5,000		$10,000		$4,000		$4,000		$0
Product Disposal		LS		$4,000		$6,000		$12,000		$1,500		$1,500		$0
PRODUCT TREATMENT:														
Electricity		LS		$0		$200		$0		$0		$0		$0
Tank Trailer Rental		LS		$0		$11,000		$0		$0		$0		$0
Product Disposal		LS		$0		$1,500		$0		$0		$0		$0
MAINTENANCE:														
LANDFILL CAP:														
Hydroseeding (5% damage)	$4,000.00	Acre	10	$40,000	10	$40,000	10	$40,000	10	$40,000	10	$40,000	0	$0
Topsoil (5% loss)	$30.00	CY	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	0	$0
Protection Layer (5% loss, top 6")	$30.00	CY	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	0	$0
Fence Repair	$25.00	LF	300	$8,000	300	$8,000	300	$8,000	300	$8,000	300	$8,000	300	$8,000
Access Road Resurfacing/Repairs	$5.00	SY	3,400	$17,000	3,400	$17,000	3,400	$17,000	3,400	$17,000	3,400	$17,000	0	$0
Miscellaneous Repairs/Improvements		LS	1	$10,000	1	$10,000	1	$10,000	1	$10,000	1	$10,000	1	$10,000
GAS COLLECTION/TREATMENT SYSTEM:														
Maintenance and Indirect Costs (insurance, overhead, etc.)		LS		$113,000		$109,000		$109,000		$109,000		$109,000		$0
Flare Compliance Testing (Only Required at Start-up)		LS	1	$20,000	1	$20,000	1	$20,000	1	$20,000	1	$20,000	0	$0
LEACHATE COLLECTION/TREATMENT SYSTEM														
Maintenance (annual average, 10 yr equipment life)		LS		$36,600		$60,400		$99,800		$45,100		$45,100		$0
SITE INSPECTION & MONITORING:														
Routine Site Inspections	$1,500.00	Event	12	$18,000	12	$18,000	12	$18,000	12	$18,000	12	$18,000	12	$18,000
Groundwater Sampling (25 wells)	$27,000.00	Event	4	$108,000	4	$108,000	4	$108,000	4	$108,000	4	$108,000	4	$108,000
Landfill Gas Sampling (25 wells)	$2,000.00	Event	4	$8,000	4	$8,000	4	$8,000	4	$8,000	4	$8,000	4	$8,000
Surface Water Sampling (5 stations)	$4,500.00	Event	4	$18,000	4	$18,000	4	$18,000	4	$18,000	4	$18,000	4	$18,000
Leachate Sampling (treated, prior to sewer discharge)	$600.00	Event	26	$15,600	26	$15,600	26	$15,600	26	$15,600	26	$15,600	0	$0
Annual Reporting	$5,000.00	Event	1	$5,000	1	$5,000	1	$5,000	1	$5,000	1	$5,000	1	$5,000
SUBTOTAL				$1,075,000		$1,111,000		$1,148,000		$1,077,000		$1,077,000		$360,000
Contingency (15%)		LS		$161,250		$166,650		$172,200		$161,550		$161,550		$54,000
TOTAL ANNUAL COST (Year 1)				$1,236,000		$1,278,000		$1,320,000		$1,239,000		$1,239,000		$414,000
PRESENT WORTH (1999 Dollars)				**$1,016,000**		**$1,050,000**		**$1,085,000**		**$1,018,000**		**$1,018,000**		**$340,000**

TABLE 7-4
ANNUAL O&M COST ESTIMATE (Year 2 to 5)
BROOKFIELD AVENUE LANDFILL FEASIBILITY STUDY

			ALTERNATIVE 2A		ALTERNATIVE 2B		ALTERNATIVE 3		ALTERNATIVE 4		ALTERNATIVE 5		ALTERNATIVE 1	
ITEM	UNIT COST	UNITS	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST
OPERATION:														
GENERAL:														
Operator (average of 1 person, full time)		LS		$65,000		$65,000		$65,000		$65,000		$65,000		$0
Security (2 person, 24-hours per day)		LS		$184,992		$184,992		$184,992		$184,992		$184,992		$184,992
GAS TREATMENT:														
Electricity		LS		$36,000		$36,000		$36,000		$0		$0		$0
LEACHATE TREATMENT:														
Electricity		LS		$4,000		$5,000		$10,000		$4,000		$4,000		$0
Product Disposal		LS		$4,000		$6,000		$12,000		$1,500		$1,500		$0
MAINTENANCE:														
LANDFILL CAP:														
Hydroseeding (5% damage)	$4,000.00	Acre	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Topsoil (5% loss)	$30.00	CY	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	0	$0
Protection Layer (5% loss, top 6")	$30.00	CY	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	0	$0
Fence Repair	$25.00	LF	300	$8,000	300	$8,000	300	$8,000	300	$8,000	300	$8,000	300	$7,500
Access Road Resurfacing/Repairs	$5.00	SY	3,400	$17,000	3,400	$17,000	3,400	$17,000	3,400	$17,000	3,400	$17,000	0	$0
Miscellaneous Repairs/Improvements		LS	1	$10,000	1	$10,000	1	$10,000	1	$10,000	1	$10,000	1	$10,000
GAS COLLECTION/TREATMENT SYSTEM:														
Maintenance and Indirect Costs (insurance, overhead, etc.)		LS		$113,000		$109,000		$109,000		$109,000		$109,000		$0
LEACHATE COLLECTION SYSTEM:														
Maintenance (annual average, 10 yr equipment life)		LS	1	$37,000	1	$60,000	1	$100,000	1	$45,000	1	$45,000	1	$0
SITE INSPECTION & MONITORING:														
Routine Site Inspections	$1,500.00	Event	12	$18,000	12	$18,000	12	$18,000	12	$18,000	12	$18,000	12	$18,000
Groundwater Sampling (25 wells)	$27,000.00	Event	4	$108,000	4	$108,000	4	$108,000	4	$108,000	4	$108,000	4	$108,000
Landfill Gas Sampling (25 wells)	$2,000.00	Event	4	$8,000	4	$8,000	4	$8,000	4	$8,000	4	$8,000	4	$8,000
Surface Water Sampling (5 stations)	$4,500.00	Event	4	$18,000	4	$18,000	4	$18,000	4	$18,000	4	$18,000	4	$18,000
Leachate Sampling (treated, prior to sewer discharge)	$600.00	Event	12	$7,200	12	$7,200	12	$7,200	12	$7,200	12	$7,200	0	$0
Annual Reporting	$5,000.00	Event	1	$5,000	1	$5,000	1	$5,000	1	$5,000	1	$5,000	1	$5,000
SUBTOTAL				$1,007,000		$1,029,000		$1,080,000		$973,000		$973,000		$359,000
Contingency (15%)		LS		$151,050		$154,350		$162,000		$145,950		$145,950		$53,850
TOTAL ANNUAL COST (Year 2 to 5)				$1,158,000		$1,183,000		$1,242,000		$1,119,000		$1,119,000		$413,000
PRESENT WORTH (1999 Dollars)				$3,322,000		$3,394,000		$3,563,000		$3,210,000		$3,210,000		$1,185,000

TABLE 7-5
ANNUAL O&M COST ESTIMATE (Year 6 to 30)
BROOKFIELD AVENUE LANDFILL FEASIBILITY STUDY

			ALTERNATIVE 2A		ALTERNATIVE 2B		ALTERNATIVE 3		ALTERNATIVE 4		ALTERNATIVE 5		ALTERNATIVE 1	
ITEM	UNIT COST	UNITS	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST
OPERATION:														
GENERAL:														
Operator (average of 1 person, full time)		LS		$65,000		$65,000		$65,000		$65,000		$65,000		$0
Security (2 person, 24-hours per day)		LS		$184,992		$184,992		$184,992		$184,992		$184,992		$184,992
GAS TREATMENT:														
Electricity		LS		$36,000		$36,000		$36,000		$0		$0	0	$0
LEACHATE TREATMENT:														
Electricity		LS		$4,000		$5,000		$10,000		$4,000		$4,000	0	$0
Treatment		LS		$4,000		$6,000		$12,000		$1,500		$1,500	0	$0
MAINTENANCE:														
LANDFILL CAP:														
Hydroseeding (5% damage)	$4,000.00	Acre	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Topsoil (5% loss)	$30.00	CY	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	0	$0
Protection Layer (5% loss, top 6")	$30.00	CY	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	6,050	$182,000	0	$0
Fence Repair	$25.00	LF	300	$8,000	300	$8,000	300	$8,000	300	$8,000	300	$8,000	300	$7,500
Access Road Resurfacing/Repairs	$5.00	SY	3,400	$17,000	3,400	$17,000	3,400	$17,000	3,400	$17,000	3,400	$17,000	0	$0
Miscellaneous Repairs/Improvements		LS	1	$10,000	1	$10,000	1	$10,000	1	$10,000	1	$10,000	1	$10,000
GAS COLLECTION/TREATMENT SYSTEM:														
Maintenance and Indirect Costs (insurance, overhead, etc.)		LS		$113,000		$109,000		$109,000		$109,000		$109,000		$0
LEACHATE COLLECTION SYSTEM:														
Maintenance (annual average, 10 yr equipment life)		LS		$37,000		$60,000		$100,000		$45,000		$45,000		$0
SITE INSPECTION & MONITORING:														
Routine Site Inspections	$1,500.00	Event	4	$6,000	4	$6,000	4	$6,000	4	$6,000	4	$6,000	4	$6,000
Groundwater Sampling (25 wells)	$27,000.00	Event	1	$27,000	1	$27,000	1	$27,000	1	$27,000	1	$27,000	1	$27,000
Landfill Gas Sampling (25 wells)	$2,000.00	Event	1	$2,000	1	$2,000	1	$2,000	1	$2,000	1	$2,000	1	$2,000
Surface Water Sampling (5 stations)	$4,500.00	Event	1	$5,000	1	$5,000	1	$5,000	1	$5,000	1	$5,000	1	$4,500
Leachate Sampling (treated, prior to sewer discharge)	$600.00	Event	4	$2,400	4	$2,400	4	$2,400	4	$2,400	4	$2,400	0	$0
Annual Reporting	$5,000.00	Event	1	$0	1	$0	1	$0	1	$0	1	$0	1	$0
SUBTOTAL				$885,000		$907,000		$958,000		$851,000		$851,000		$242,000
Contingency (15%)		LS		$132,750		$136,050		$143,700		$127,650		$127,650		$36,300
TOTAL ANNUAL COST (Year 6 to 30)				$1,018,000		$1,043,000		$1,102,000		$979,000		$979,000		$278,000
PRESENT WORTH (1999 Dollars)				**$10,744,000**		**$11,008,000**		**$11,631,000**		**$10,333,000**		**$10,333,000**		**$2,934,000**

TABLE 7-6
PRESENT WORTH COST
BROOKFIELD AVENUE LANDFILL CLOSURE

ITEM	PRESENT WORTH					
	Alternative 2A	Alternative 2B	Alternative 3	Alternative 4	Alternative 5	Alternative 1
Capital Cost	$70,681,000	$71,293,000	$71,624,000	$70,288,000	$69,648,000	$2,000
O&M Cost (year 1)	$1,016,000	$1,050,000	$1,085,000	$1,018,000	$1,018,000	$340,000
O&M Cost (years 2-5)	$3,322,000	$3,394,000	$3,563,000	$3,210,000	$3,210,000	$1,185,000
O&M Cost (years 6-30)	$10,744,000	$11,008,000	$11,631,000	$10,333,000	$10,333,000	$2,934,000
TOTAL	**$85,763,000**	**$86,745,000**	**$87,903,000**	**$84,849,000**	**$84,209,000**	**$4,461,000**

TABLE 7-7
COST ESTIMATE ASSUMPTIONS

CONSTRUCTION COST

SITE PREPARATION:

- Gravel access roads would be constructed around the landfill to facilitate access by construction vehicles and equipment. Access roads would generally be installed at the base of the landfill sideslope.
- Clearing and grubbing would be performed approximately 10% beyond the landfill area to permit construction of access roads and leachate control system, and improvements to existing topography adjacent to the landfill.
- Rough grading would be required to improve existing topography on top of the landfill and achieve minimum slope requirements. At minimum, 6 inches of screened fill material would cover the top of the landfill. The rough grade would be in direct contact with the gas venting layer of the landfill cap.
- None of the existing features on top of the landfill would require replacement or mitigation following cap construction.
- Existing wetlands located within the footprint of access roads would not require mitigation. Wetlands disturbed beyond the limits of roads to facilitate equipment and vehicle access would be replaced following cap construction.

CAP CONSTRUCTION:

- Cap construction costs are based on 24-inch barrier protection layer. Actual barrier portection layer will likely vary from 12 to 24 inches. Depending on end use, a greater than 24-inch protection layer may be required.
- The landfill cap would be generally constructed with a minimal amount of cutting into fill and allowing for active and/or passive recreation end use.
- Geogrid composite drainage layer would be installed above the barrier layer along steep slopes to maintain slope stability.
- The barrier layer would be constructed of 40-mil geomembrane liner or geosynthetic clay liner.
- The gas venting layer would be constructed of a geonet composite.
- Earthen construction materials would be shipped to Staten Island by barge and hauled locally to the site, or they could be hauled from source areas in New Jersey. The unit costs for such materials would be approximately 25% to 33% higher than those typical of suburban areas to New York City.
- The landfill cap will cover existing utility lines that are located within or surrounded by buried waste.

GAS AND LEACHATE CONTROL SYSTEMS:

- Systems would be generally constructed as shown on the drawings.
- The barrier wall would be constructed of bentonite slurry or HDPE.
- Effluent from the leachate collection system would be pre-treated on site by oil/water separation and discharged to the existing pump station (sewer system).
- A detailed cost analysis for the gas control system is presented in Appendix D.

STORMWATER RUNOFF CONTROL SYSTEM:

- Stormwater would generally discharge from the landfill via overland flow. Depending on the final end use selected, some stormwater may be diverted to one or more retention ponds located north of the Eltingville pump station.
- V-shaped drainage ditches would be constructed in crowned areas to convey runoff beyond the landfill perimeter to existing drainage channels or low-lying areas for

TABLE 7-7 (cont.)
COST ESTIMATE ASSUMPTIONS

recharge.

SITE ACCESS:

- Asphalt roads would be constructed around the landfill to facilitate access by vehicles and equipment to perform routine inspections, monitoring, and long-term maintenance. Access roads would generally be installed at the base of the landfill sideslope over gravel roads used during construction.
- The existing fence is sufficient for site control, excluding routine maintenance. New warning signs would be installed along the fence line.

OPERATION AND MAINTENANCE

- Operation and maintenance of the landfill cap and treatment systems would be performed for 30 years, excluding the product recovery system (1 year).
- On average, one operator would be on-site at all times (during the workday) to operate and maintain the landfill treatment systems.
- The annual maintenance cost of the landfill cap is based upon 5% grass replacement, 5% topsoil replacement, and 5% protection layer replacement over its top 6 inches.
- The annual maintenance cost of treatment systems was generally estimated based upon the capital cost of process equipment divided by the anticipated life of the system (eg. 10 yrs).
- Flare complaince testing would only be required at start-up. Associated costs are included in the Year 1 O&M costs.

LONG-TERM MONITORING

- Long-term monitoring would be performed for 30 years following construction.
- Site inspections would be performed monthly for the initial 5 years of O&M, and then quarterly.
- Groundwater sampling (25 wells), surface water sampling (5 stations), and landfill gas monitoring would be performed quarterly for the initial 5 years of O&M, and then annually.
- Monitoring reports would be submitted to regulatory agencies on an annual basis.

PRESENT WORTH ANALYSIS

WORK SCHEDULE:

▸ Design and Bid	1999 through 2000
▸ Construction	2001 through 2003
▸ O&M/Long-Term Monitoring	2004 through 2033 (30 yrs)

EFFECTIVE RATE OF RETURN:

- Funding for landfill closure, O&M, and long-term monitoring would be initially allocated in 1999.
- The funds would be placed in an interest-bearing account that achieves a 4% effective annual rate of return (interest less inflation).
- Funds are withdrawn annually to pay for services based upon the above schedule.

8

Section Eight

Section 8
Comparative Analysis of Alternatives

8.1 Introduction

The previous section described each of the six site remediation alternatives and individually evaluated them based upon the eight criteria specified in EPA guidance document "Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites" (EPA, 1991). The purpose of this section is to identify the benefits and drawbacks of each alternative through comparative analyses according to these eight criteria.

The results of the comparative analysis are detailed below and summarized in Table 8-1 located at the end of this section. Each alternative is ranked qualitatively (high, medium, low) for each of the eight criteria, as they compare to each other. It is noted that Alternatives 2A through 5 comply with the presumptive remedy for landfill closure, as specified in EPA Guidance Document 540-F-93-035, "Presumptive Remedy for CERCLA Municipal Landfill Sites" (EPA, 1993). Alternative 1 (No Action) is not intended to comply with the presumptive remedy. It is intended to establish the baseline conditions for performing comparative analyses only.

While only Alternatives 2A through 5 have been set up for comparison, they only represent part of the possible combination of remedial technologies that could be employed at the site. Slight variations to each alternative are noted in the text, as possible technologies to be used. These may result in better and more economical solutions to be ultimately implemented at this site. The benefits of waste consolidation, leaving the waste in place and capping, and leaving the waste in place but not capping below the 10-foot elevation line are also compared.

8.2 Compliance with ARARs/ SCGs

Chemical-Specific ARARs/ SCGs

Alternatives 2A through 5 differ with respect to landfill gas control, perimeter leachate containment, and upgradient groundwater diversion. Leachate collection and upgradient groundwater diversion both apply to the protection of downgradient water (groundwater, surface water) quality.

Alternative 3 is conceptually the most restrictive in terms of collection and containment, since its collection system encompasses the entire downgradient perimeter of the landfill and its containment and diversion system covers the entire upgradient portion. With respect to water quality SCGs, Alternatives 2A, 2B and 3 are considered to be equivalent since each should effectively eliminate leachate migration offsite. Alternatives 4 and 5, may not provide enough leachate containment to prevent SCG exceedances in Richmond Creek. Alternative 1 (no action) would not achieve compliance with water quality criteria.

Alternatives 2A through 5 (active gas extraction, onsite treatment) are generally equivalent regarding air quality, and would comply with air SCGs following containment system construction. Although Alternatives 2B, 3 and 4 do not have an active gas collection trench along the south boundary of the landfill, the presence of the barrier would effectively prevent offsite migration of soil gas. Based on current conditions, Alternative 5 (which lacks a barrier wall or gas collection trench along the south boundary) would comply with SCGs, however following capping, the potential for lateral migration may increase. Localized exceedances of soil gas SCGs could occur. Alternative 1 (no action) would not comply with air quality SCGs.

Leaving the waste in place and capping it would better comply with chemical specific ARARs/SCGs, compared to excavating and consolidating, since short term exceedances of air and surface water SCGs may occur during the excavation of wastes. Leaving the waste in place and not capping below the 10-foot elevation line would result in the greatest potential for non-compliance with chemical specific ARARs/SCGs.

Action-Specific ARARs/ SCGs

Action-specific standards for all alternatives include the 6 NYCRR Part 360 regulations for landfill closure, OSHA health and safety protocols, CERCLA/SARA regulations for hazardous wastes, air quality standards for air emissions, and erosion control standards. Alternative 1 would not comply with the 6 NYCRR Part 360 regulations. Alternatives 2A through 5 would generally comply, excluding the specified design variances that are subject to NYSDEC approval. The other referenced standards would be addressed during the remedial design, considering site-specific conditions; all alternatives would generally conform with their respective requirements.

Leaving the waste in place and capping it would better comply with action specific ARARs/SCGs, compared to excavating and consolidating, since short term exceedances of air and surface water SCGs may occur during the excavation of wastes. Leaving the waste in place and not capping below the 10-foot elevation line would result in the greatest potential for non-compliance with action specific ARARs/SCGs.

Location-Specific ARARs/ SCGs

Disturbance of freshwater and coastal wetland areas, surface water bodies, and associated ecosystems located adjacent to, and within the landfill would occur with Alternatives 2A through 5, based upon construction and access requirements for the landfill containment system. To minimize disturbance, space and access requirements would be evaluated in detail during the landfill cap design. The locations and requirements for cap structures, staging areas, haul roads, and other relevant work items would be detailed in the design specifications and drawings. Restoration work would be specified, if/where required. Alternatives 2A, 2B and 3 would result in more wetland disturbance than Alternatives 4 and 5 due to construction of the more extensive leachate collection and barrier systems along the north face of the landfill.

Leaving the waste in place and not capping below the 10-foot elevation line would best comply with action specific ARARs/SCGs, since no wetlands would be disturbed. Excavating and consolidating to eliminate the need for hard structures to be permanently placed below the 10-foot elevation line would compare more favorably with respect to location-specific ARARs/SCGs since the wetlands could be restored following excavation.

8.3 Protection of Human Health and the Environment

Alternatives 2A, 2B and 3 would be highly protective of human health and the environment with regard to the landfill, as they virtually achieve full containment of contaminants via all relevant exposure pathways. Alternatives 4 and 5 would be marginally less protective of the environment considering the lack of complete downgradient leachate containment.

The preliminary hydraulic analysis results (see Appendix C) suggest that an upgradient low-permeable wall would only be moderately effective for reducing leachate generation associated with waste buried below the water table. Therefore, Alternatives 2A would only be marginally less effective than Alternatives 2B and 3 in terms of leachate control and protection of the environment.

Alternative 1 would not provide added protection to the environment. Human health would be effectively protected by the implementation of institutional controls. The associated risk for this alternative is considered to be moderate, primarily based upon continued impacts to groundwater and surface water by leachate.

The product recovery system at Hot Spot No. 5 (Alternative 2B) would not provide additional protection to the environment or human health, compared to the other alternatives, excluding Alternative 1. The presence of either a downgradient leachate collection trench or upgradient barrier wall, in the other alternatives, would provide equal protection of human health and the environment, with respect to Hot Spot No. 5.

Capping to at least 5 feet beyond the existing limits of solid waste would provide the most protection of human health and the environment, compared to excavation/ consolidation and leaving the waste in place and not capping below the 10-foot elevation line. The possibility of worker and neighboring area exposure to contaminants is much greater under the excavation/consolidation scenario, as is the threat of releases to the environment (surface water).

8.4 Short Term Effectiveness

Alternatives 2A through 5 are considered to be generally equivalent in terms of the short-term effectiveness of the landfill containment system. These risks are largely associated with potential dust generation, increased landfill gas emissions, erosion, exposure to waste materials during containment system construction, truck traffic, and wetlands impact. Engineering controls would be implemented during construction to minimize the potential risks and impacts to wetlands.

The short-term effectiveness of Alternative 1 is considered to be high, since the landfill and adjacent wetlands and water bodies would not be disturbed. In addition, workers would not be exposed to risks specific to containment system construction, as described above. Risk to the community would be prevented by institutional controls. Additionally, the community would not be exposed to the risks and inconveniences associated with heavy construction traffic.

Capping to at least 5 feet beyond the existing limits of solid waste would be most effective in the short-term, compared to the excavation/consolidation alternatives. The possibility of worker and neighboring area exposure to contaminants is much greater under the excavation/consolidation scenario, as is the threat of releases to the environment. Excavation would result in short-term impacts to wetlands and possibly workers.

8.5 Long Term Effectiveness and Permanence

With respect to the landfill cap, The long term effectiveness of Alternatives 2A through 5 are considered to be equal, based on the long term reliability of the cap.

With respect to variances for the slope and protection layer, the following is noted as it applies to long-term effectiveness.

- The slope variance from (4% to 2%) would be significant with respect to preventing ponding on top of the cap. It only applies to the plateau areas of the landfill, which may be more prone to localized flat or depressed areas caused by differential settlement. The occurrence of such areas can be prevented with routine inspection and maintenance. In addition, effective subsurface drainage could be achieved by installing the barrier layer in a washboard configuration that utilizes slopes in excess of four percent (where needed), while the final grade remains uniform at two percent.

- The protection layer protects the barrier layer from damage and acts as a lateral drainage layer to prevent water accumulation above the barrier layer. The results of a preliminary slope stability analysis (Appendix A) suggest that slope stability could be achieved while using the specified construction variances. Geogrid and/or textured liner are available construction materials that could be used to achieve appropriate design safety factors at limited number of locations, where side slopes of 25 to 33 percent would be required.

The leachate collection systems of Alternative 2A, 2B, and 3 prevent shallow contaminated groundwater beneath the landfill from degrading downgradient surface water and groundwater quality. The results of a preliminary hydraulic analysis (see Appendix C) suggest that leachate can be effectively controlled without full perimeter containment. An upgradient barrier wall, connecting to southeast and southwest drainage ditches, would only be marginally more effective in the long term, in preventing groundwater from contacting waste.

Alternatives 2A, 2B and 3 are more effective in the long-term than Alternatives 4 and 5 based upon a more extensive leachate collection and containment systems. Since it is unlikely that capping alone will lower the water table to below the bottom of the waste mass, leachate will still be generated and may discharge to Richmond Creek. Therefore, the potential for risk to the environment from untreated waste would be higher in Alternatives 4 and 5.

Alternatives 2A through 5 would result in long-term impacts to wetlands, since capping is specified for areas where waste coincides with wetlands. The largest of these areas is north of the Eltingville Pump Station, between the east and west cells (approximately 9 acres). The majority of this area is below the 10-foot elevation defining tidal wetlands. Capping is necessary to prevent infiltration of rainwater, and leachate generation. Construction of the cap would eliminate this area as a wetland. However, leaving the waste uncapped may pose long-term risk to the environment.

Alternative 1 would be effective for long-term protection of human health, assuming that institutional controls (physical, administrative) remain in place and are maintained/enforced. However, no effective increase in protection to the environment would occur.

Excavating/consolidating and extending the cap to 5 feet below the existing limits of solid waste are considered equally effective alternatives in the long-term, assuming wetlands elsewhere are restored to reflect the loss associated with leaving the waste in place and installing a cap. Leaving the waste in place and installing the cap above the 10-foot elevation line would be least effective in the long-term.

8.6 Reduction of Toxicity, Mobility or Volume through Treatment

With respect to leachate, the greatest reduction of toxicity, mobility and volume through treatment would be achieved by Alternative 3, since it has the most extensive leachate collection system. With respect to landfill gas, the highest greatest reduction of toxicity, mobility and volume through treatment would be achieved by Alternative 2A due to the active gas collection trench near the south boundary.

Because of the nature of the waste at Hot Spot No. 5, the product recovery system of Alternative 2B, is expected to result in only a minimal increase in reduction of toxicity, mobility and volume through treatment, compared to the other alternatives.

Alternative 1 would not actively reduce the toxicity, mobility, or volume of any contaminated materials.

Neither capping to 5-feet below the present extent of waste or excavating/ consolidating are considered treatment methods, therefore they cannot be evaluated with respect to this criteria.

8.7 Implementability

Alternatives 2A through 5 are considered equally implementable with respect to the landfill cap. The implementability of the cap in Alternatives 2A through 5, compared to Alternative 1 (no action), is reduced based on administrative (permitting) and construction requirements for working in and around tidal and freshwater wetlands. Alternatives 4 and 5 are marginally more implementable than Alternatives 2A, 2B and 3, due to less wetland disturbance.

Implementability of the leachate collection and containment systems of Alternative 5 is expected to be the highest, followed by (in order) Alternative 4, 2A, 2B and 3. This is based on the extent of the collection trench and barrier wall to be constructed, and the fact that a barrier wall is easier to implement and operate than a lined leachate and collection trench.

All alternatives, excluding the no action alternative, are expected to be equal in terms of monitorability.

Leaving the waste in place, capping and installing permanent structures only above the 10-foot elevation line would be the most implementable. Capping to 5-feet below the present extent of waste would be the next most implementable option. Excavation/consolidation of wastes would be the least implementable due to the large volume (290,000 cubic yards) to be moved, and the difficult working conditions (below the water table).

8.8 Cost

The present worth of the five alternatives are summarized below:

Alternative 1	$4,461,000
Alternative 2A	$85,763,000
Alternative 2B	$86,745,000
Alternative 3	$87,903,000

Alternative 4	$84,849,000
Alternative 5	$84,209,000

A cost comparison of waste consolidation and leaving the waste in place is presented in Table 8-2. Excavation and consolidation of waste to allow for no permanent structures to be placed below the 10-foot elevation line is estimated to cost approximately $8.2 million. The cap savings realized due to the condensed waste mass would amount to nearly $5.2 million. Therefore, excavation/consolidation would result in an overall cost increase of $3 million.

Comparatively, leaving the waste in place and constructing or restoring 48.7 acres of wetlands elsewhere would cost just under $2 million. This is based on the assumption that the NYSDEC will require that 2 new acres of wetlands be replaced for every 1 acre destroyed, as has been the case at other sites across the state. Leaving the waste in place and reducing the cap size to prevent installation of permanent structures below the 10-foot elevation line would result in cost savings of approximately $5.1 million.

8.9 Community Acceptance

It is currently anticipated that Alternatives 2A, 2B and 3 would be accepted by the community, based on complete leachate containment and presence of an active gas collection system. Alternatives 4 and 5 would receive less acceptance based on the lack of complete leachate containment. Alternative 2A may receive slightly higher acceptance due to the active gas collection trench, which reduces gas volume and toxicity through treatment, rather than a barrier wall that would prevent migration, but not necessarily reduce volume or toxicity. Alternative 1 would not be accepted by the community.

This section will be updated based upon the results of the public meeting, to be held prior to finalizing the Feasibility Study report.

TABLE 8-1

COMPARATIVE ANALYSIS OF SITE REMEDIATION ALTERNATIVES
Brookfield Avenue Landfill
Staten Island, New York

ASSESSMENT FACTOR	ALTERNATIVE 2A	ALTERNATIVE 2B	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5	ALTERNATIVE 1
Compliance with ARARs/SCGs	High	High	High	Medium	Medium	Low
Protection of Human Health and the Environment	High	High	High	Medium	Medium	Medium
Short-Term Effectiveness	Medium	Medium	Medium	Medium	Medium	High
Long-Term Effectiveness	High	High	High	Medium	Medium	Low
Reduction of Toxicity, Mobility, and Volume	Medium	Medium/High	High	Medium/Low	Medium/Low	Low
Implementability	Medium	Medium	Medium	Medium	Medium	High
Cost	High	High	High	Medium*	Medium*	Low
Community Acceptance	High	High	High	Medium	Medium	Low

* Costs for Alternatives 2A through 5 differ by less than 5%. For comparative purposes, Alternatives 4 and 5 are slightly less than Alternatives 2A, 2B and 3.

TABLE 8-2
COST COMPARISON OF WASTE CONSOLIDATION VERSUS CAPPING IN-PLACE
Brookfield Avenue Landfill, Staten Island New York

	Excavation/Consolidation				*Leaving Waste in Place/ Capping Below 10-foot Elevation Line*				*Leaving Waste in Place/ Capping Above 10-foot Elevation Line*			
Item	Quantity	Unit Price	Unit	Cost	Quantity	Unit Price	Unit	Cost	Quantity	Unit Price	Unit	Cost
Excavation (including necessary controls)	290,000	$8.00	CY	$2,320,000	-	-	-	-	-	-	-	-
Hauling	290,000	$4.00	CY	$1,160,000	-	-	-	-	-	-	-	-
Consolidation (Grading)	290,000	$8.00	CY	$2,320,000	-	-	-	-	-	-	-	-
Common Fill for Intermediate Cover	72,500	$20.00	CY	$1,450,000	-	-	-	-	-	-	-	-
Wetlands Restoration	24.4	$40,000	acre	$974,380	-	-	-	-	-	-	-	-
Wetlands Replacement*	-	-	-	-	48.7	$40,000	acre	$1,948,760	-	-	-	-
Subtotal				$8,224,380				$1,948,760				$0
Cap Savings (Less Quantity & Cost)												
Hydroseeding	-24.4	$4,000.00	acre	-$97,438	-	-	-	-	-24.4	$4,000.00	acre	-$97,438
Topsoil	-19,683	$30.00	CY	-$590,480	-	-	-	-	-19,683	$30.00	CY	-$590,480
Protection Layer	-78,731	$30.00	CY	-$2,361,920	-	-	-	-	-78,731	$30.00	CY	-$2,361,920
Barrier Layer	-1,062,864	$1.00	SF	-$1,062,864	-	-	-	-	-1,062,864	$1.00	SF	-$1,062,864
Gas Venting Layer (Geonet Composite)	-1,062,864	$1.00	SF	-$1,062,864	-	-	-	-	-1,062,864	$1.00	SF	-$1,062,864
Subtotal				-$5,175,566				$0				-$5,175,566
Totals (- is Savings/ + is Extra Costs)				**$3,049,000**				**$1,949,000**				**-$5,176,000**

Notes:

* Assumes 2 acres replaced (enhanced or restored elsewhere) for every 1 acre destroyed.

Costs do not reflect changes to the conceptual End Use Plan which may occur under each scenario

9

Section Nine

Section 9
Recommended Alternative

9.1 Selection of Recommended Alternative

The preceding sections have presented a detailed and comparative analysis of five different remedial alternatives. In addition, a No Action scenario was included to establish the baseline conditions for comparing the site remediation alternatives. The alternatives were developed to represent the full range of feasible site remediation alternatives, based on the presumptive remedy approach, considering variable degrees of design conservatism and cost. Each alternative is capable of supporting a variety of active and passive end use scenarios, although minor modifications may be required.

Based on the results of the detailed and comparative analysis, Alternatives 2A is selected as the recommended alternative. Alternatives 2B and 3 are generally equal to 2A in terms of compliance with ARARs, protection of human health and the environment, long-term effectiveness, and cost. Although Alternatives 2B and 3 provide a slightly higher reduction of toxicity, mobility and volume through treatment, Alternative 2A is expected to be more implementable based on the reduced extent of the leachate collection system. The south face (upgradient) barrier wall of Alternatives 2B and 3 is not expected to significantly reduce the amount of water entering the landfill due to the relatively impermeable stratigraphy of the area.

The ultimate remedy selected for the site will be identified in the Proposed Remedial Action Plan (PRAP) issued by the NYSDEC. The PRAP may select a remedy that matches one of the alternatives or contains elements of a number of the alternatives presented in this FS.

9.2 End Use Concept

The End Use Concept for the Brookfield Avenue Landfill provides a unique opportunity to restore the site using native plant communities, and to provide both active and passive recreational uses following the site capping and closure construction. An illustration of the conceptual End Use Plan is provided in Figure 9-1.

The Brookfield Avenue Landfill is a 272-acre site consisting of 132 acres of landfill and 140 acres of buffer area consisting of wetlands, woodlands, tidal marsh, stream corridors and ponds. The site has three physiographic areas. The central area of the site is relatively level and consists of ponds, wetlands and the Eltingville pump station. A number of storm and sanitary sewers run through this area. Only the northern 9 acres of this area will require capping. The western area of the site consists of two landfill mounds totaling approximately 33 acres. An interceptor sewer line runs east to west separating the mounds. The eastern area of the site consists of a single, 90-acre landfill mound surrounded by wetlands, ponds, woodlands and tidal marsh. This area is bordered on the far eastern side by Colonial Square.

All of the landfill areas will require the removal of existing vegetation, regrading, and installation of a low permeability cap and revegetation. The portions of the site with no history of landfilling include the wetlands, woodlands and stream corridors between Arthur Kill Road and the southern edge of the landfilled areas, and the tidal salt marsh between Richmond Creek and the northern edge of the landfill areas (although waste was found during the field investigation in portions of the tidal marsh). For these non-landfill areas, the concept is to selectively remove exotic plant species and add new appropriate plant materials to strengthen the existing plant communities. Landfill areas will require regrading for capping and closure. These areas would be revegetated using the following native plant communities:

- Atlantic White Cedar
- Red Maple and Sweetgum
- Heath Pitch Pine Oak
- Pitch Pine Oak
- Pitch Pine
- Maritime Post Oak
- Oak
- Oak Holly
- Coastal Shrubland
- Coastal Grassland
- Freshwater Wetlands and Ponds

Central Area

The End Use Plan for the Brookfield Avenue Landfill provides for a formal park entrance in the central area of the site at the intersection of Arthur Kill Road and Brookfield Avenue. Those entering the site would be welcomed by an education center, restrooms, parking, a wetlands meadow interpretive area and access to the pedestrian trails leading to the site's interior. Immediately to the north would be a maintenance compound consisting of the existing pump station, the proposed landfill gas flare and leachate treatment facilities, and required park and landfill maintenance facilities. Further north would be a wetlands area and retention ponds that would emulate the ponds and wetlands lost to cap construction and provide a means of storm water collection and management for the interior of the site, if direct runoff was deemed inappropriate during the design phase. The wetland area and retention pond would be constructed only if the waste from this area was removed and consolidated.

The appropriate use for this area will be further assessed during the design phase. A paved road would provide access to a canoe and kayak launching area adjacent to the existing storm water outfall, which flows into Richmond Creek. This launch site would consist of a small parking area, restrooms and launching dock. To the west, the paved road would provide vehicle access to the active recreation areas on the western side of the site.

Western Area

Under this plan, the active recreation areas would be focused on the northwestern and west side of the site. These areas provide the fewest potential conflicts with hotspots and other environmental problems identified in the remedial investigation report and also offer no significant problems in site development. An active recreation area consisting of 7.5 acres for field sports, supported by paved access roads, parking, restrooms, lighting and an equipment storage building, are proposed for the northwestern landfill mound. Further to the west, the paved access road would terminate at an open meadow area supported by parking, a shelter and restrooms. These active recreation areas would be linked to a passive recreation area on the southwestern mound, enhanced wetland and woodland buffer areas to the south and west, and salt marsh to the northwest.

Eastern Area

The eastern side of the site would be primarily passive recreation in nature. Consistent with the overall End Use Plan, the wetland and woodland buffer area between Arthur Kill Road and the landfill would be upgraded by means of selective removal of exotic plant materials and replanting to enhance the indigenous plant communities. Stream banks in this area may require some reshaping to allow these plant communities to become fully established. Following construction of the cap, the eastern landfill mound would be revegetated with plant materials indicated in the native plant communities list, above. Large open areas of warm season grasses and shrubland would be planted to contrast and complement the areas that are reforested. As with the construction of the cap in the western area of the site, a significant focus of the plan would be the minimization of encroachment into wetland and tidal marsh areas. Along the northern side of this area, planting on the cap would attempt to match and expand the existing woodland area. Existing ponds and wetlands in the drainageway leading to the central portion of the site would be emulated through the creation of detention ponds and wetland areas bordered by red maple and Sweetgum plantings. This drainage system would utilize the surface water flow generated from the interior of the site. The higher elevations and long views and vistas on the eastern mound would be enhanced to provide observation points and historical markers linked by over 4.5 miles of hiking/interpretive trails and unpaved service roads, leading across the site and back to the central part of the site.

End Use Implementation Phasing

Construction related to the capping, closure and end use implementation would be as follows:

1. Selective removal of exotic species from wetlands and woodlands, and the reinforcement of the buffer area between Arthur Kill Road and the landfill areas from Richmond Avenue in the west to Colonial Square in the east.
2. Preparation of the western side of the site for the construction of passive and active recreation areas.
3. Preparation of the central areas of the site for the future construction of a formal park entrance, education center, interpretive area, parking, maintenance compound, detention ponds and canoe/kayak launching area.
4. Preparation of the eastern side of the site as a passive recreation area, including such features as hiking trails and observation areas.

Costs of End Use Implementation

The estimated capital, operating and maintenance costs for construction of the End Use Plan are listed in Table 9-1. The end use plan presented herein is a concept. It is important to note that certain components of the selected alternative match those of the conceptual End Use Plan. If the conceptual end use plan is adopted, design changes to the recommended alternative would be performed during the design phase, to match those of the end use plan.

The selected alternative assumes a 24-inch barrier protection layer, which should support all components of the conceptual end use plan; however, further study during the design phase would be necessary to determine if a thicker barrier protection layer, or additional controls are needed. In the instance the conceptual end use plan is not implemented, all aspects of the recommended alternative, including the estimated costs, would remain unchanged.

The combined present worth cost of the recommended alternative and conceptual end use cost are as follows:

	Recommend Alternative		Conceptual End Use Plan
Capital Cost	$70,681,000		$6,340,000
O&M Cost (Year 1)	$1,016,000		$145,000
O&M Cost (Year 2-5)	$3,322,000		$508,000
O&M Cost (Year 6-30)	$10,744,000		$1,868,000
TOTAL	$85,763,000		$8,861,000
COMBINED TOTAL		$94,624,000	

9.3 Immediate Recommended Actions

Prior to the final selection of a recommended alternative, a work session should be held to discuss the results of the detailed and comparative analyses of alternatives, as presented in Sections 7 and 8, respectively. The purpose of the work session would be to:

1. Confirm the position of state/regulatory agencies and the public regarding design-critical issues associated with construction offset requirements at property lines, wetland areas and surface water bodies located within and/or adjacent to the limits of waste, and utility lines located within the limits of waste;
2. Further discuss future site use; and
3. Reach an initial consensus regarding the recommended alternative

Following the work session, the recommended alternative, including the conceptual plan and cost estimate, would be incorporated into the Final Feasibility Study Report.

TABLE 9-1
CONCEPTUAL END USE PLAN COST ESTIMATE
BROOKFIELD AVENUE LANDFILL FEASIBILITY STUDY

CAPITAL COSTS(1) ITEM	Western Area	Central Area	Eastern Area	TOTAL
1. Restoration Planting	$846,550	$100,000	$1,634,250	$2,580,800
2. Street Tree Planting	$65,925	$44,550	$0	$110,475
3. Wetland Plugs	$0	$338,490	$0	$338,490
4. Gravel Pavement	$210,000	$185,000	$0	$395,000
5. Trails (gravel 3' wide)	$38,000	$8,000	$77,000	$123,000
6. Signage (LF of Trails)	$3,000	$5,000	$4,000	$12,000
7. Pond and Wetland Liner	$0	$312,211	$180,589	$492,800
8. Soil (6" between Liners)	$0	$185,014	$107,015	$292,029
SUBTOTAL	$1,163,475	$1,178,265	$2,002,854	$4,344,594
Escalation to last year of construction (10.3%)				$447,000
Predesign Studies (10%)				$434,000
Engineering (10%)				$434,000
Contractor Fees (10%)				$434,000
Extended Warranty (2%)				$87,000
SUBTOTAL				$6,180,594
Contingency (20%)				$1,236,000
TOTAL CAPITAL COST ESTIMATE (last year of construction)				**$7,417,000**
PRESENT WORTH (1999 Dollars)				**$6,340,000**

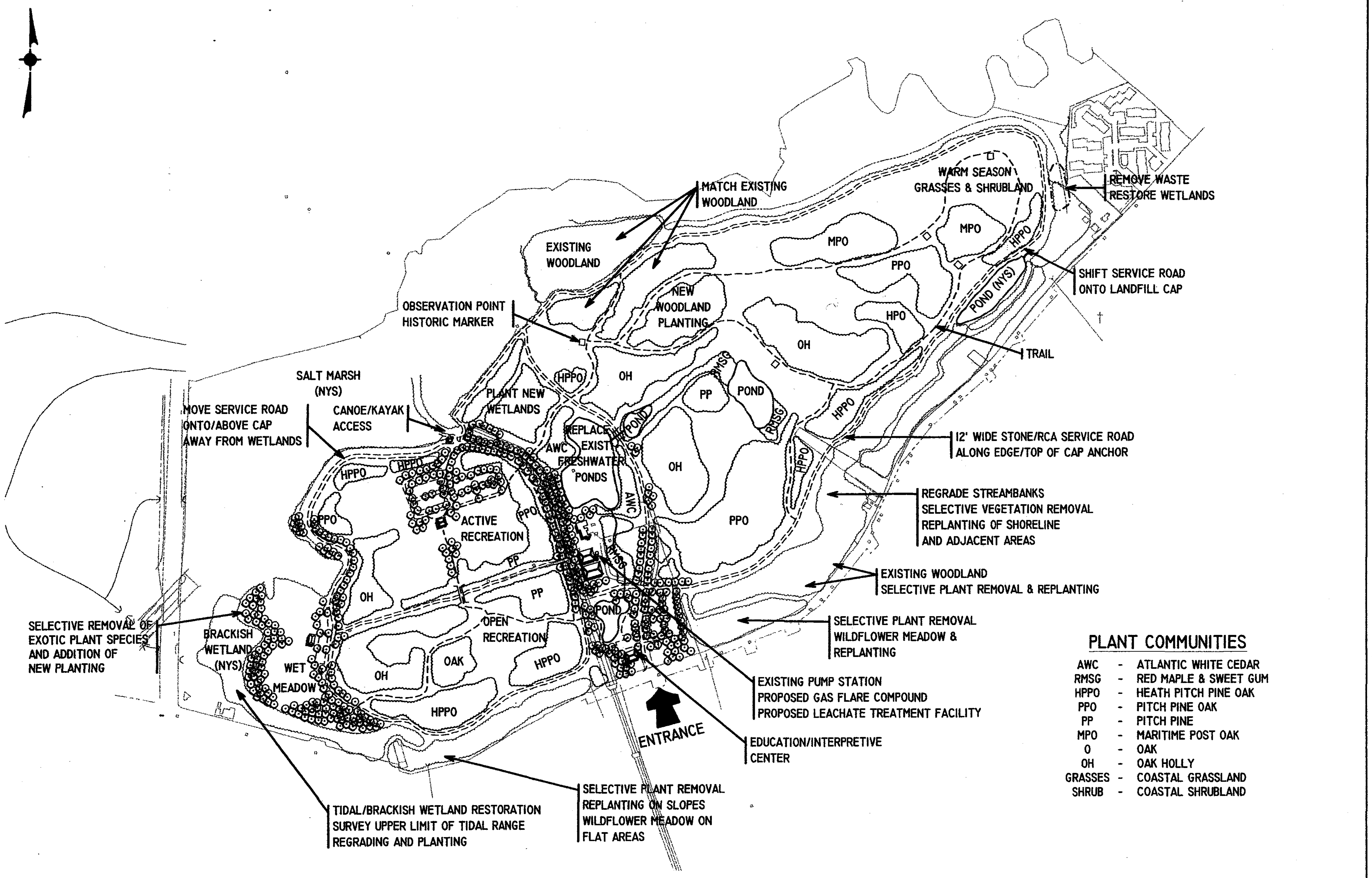
ANNUAL OPERATING COSTS ITEM		
1. DIRECT ANNUAL OPERATING COSTS		
Utilities		
Electricity	473,000 kwh @ $0.15/kwh (BUG)	$46,000
Labor	1,000 hrs @ $20/hr(3)	$20,000
Supervisor	15% of operator labor	$3,000
Maintenance		
Labor	1,000 hrs @ $22/hr(3)	$20,000
Materials	100% of maintenance labor	$20,000
SUBTOTAL DIRECT ANNUAL OPERATING COSTS		$109,000
2. INDIRECT ANNUAL OPERATING COSTS		
Overhead	60% of O&M Costs	$65,000
Administrative	2% of Direct Annual Operating Costs	$2,000
Insurance	1% of Direct Annual Operating Costs	$1,000
SUBTOTAL DIRECT ANNUAL OPERATING COSTS		$68,000
TOTAL ANNUAL OPERATING COSTS		**$177,000**
PRESENT WORTH (1999 DOLLARS) YEAR 1		**$145,000**
PRESENT WORTH (1999 DOLLARS) YEAR 2 - 5		**$508,000**
PRESENT WORTH (1999 DOLLARS) YEAR 6 - 30		**$1,868,000**

Notes:

(1) Costs do not include standard materials required for a Part 360 cap. These costs have been included in the cost estimates for each alternative.

(2) 175,000 gallon = 4"/acre/year

(2) Assumes 5 hrs x 1 shift x 2,000 hrs per year = 1,000 hrs.



PLANT COMMUNITIES

AWC	-	ATLANTIC WHITE CEDAR
RMSG	-	RED MAPLE & SWEET GUM
HPPO	-	HEATH PITCH PINE OAK
PPO	-	PITCH PINE OAK
PP	-	PITCH PINE
MPO	-	MARITIME POST OAK
O	-	OAK
OH	-	OAK HOLLY
GRASSES	-	COASTAL GRASSLAND
SHRUB	-	COASTAL SHRUBLAND

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C.F.V. E.H.G.
C.F.V./J.M. T.F.M.

WILLIAM F. COSULICH ASSOCIATES, P.C.
ENVIRONMENTAL ENGINEERS

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL
REMEDIATION PROJECT

CONCEPTUAL END USE PLAN

1215
JAN. 2000
1"=300'

FIGURE 9-1

S:\1215\1229\END USE\ F09-1 03/19/01 14:56 GENCORELLI/AJ

10

Section
Ten

Section 10
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Appendix
A

APPENDIX A

DRAWINGS
(CONCEPTUAL SITE REMEDIATION PLANS)

NOTES:
1. ELEVATION CONTOURS SHOWN CORRESPOND TO THE TOP OF CAP, AS CONSTRUCTED IN GENERAL ACCORDANCE WITH THE 6 NYCRR PART 360 REGULATIONS (4 x MINIMUM SLOPE, 24 INCH PROTECTION LAYER). HOWEVER, A VARIABLE 12 TO 24 INCH PROTECTION LAYER WILL BE USED (24 INCHES IN AREAS VULNERABLE TO EROSION, 12 INCHES ELSEWHERE) FINAL CAP ELEVATIONS WILL BE DETERMINED DURING THE DESIGN PHASE. CAP TO EXTEND 5 FEET BEYOND THE LIMITS OF WASTE (MIN.).
2. LEACHATE CONTROLS INCLUDE SHALLOW GROUNDWATER COLLECTION DOWNGRADIENT OF HOT SPOT NO. 3 AND THE WEST CELL; GROUNDWATER DIVERSION BETWEEN THE LANDFILL AND THE PERIMETER DRAINAGE DITCHES; AND GROUNDWATER DIVERSION DOWNGRADIENT OF THE EAST CELL WHERE THE LEACHATE COLLECTION TRENCH IS ABSENT.
3. STORMWATER RUNOFF CONTROL INCLUDES NATURAL OVERLAND FLOW/DISCHARGE AND PERIMETER COLLECTION/DISCHARGE, WHERE SHOWN.
4. THE ACTIVE GAS CONTROL AND TREATMENT SYSTEM IS SHOWN ON DRAWING 1 OF APPENDIX D.

S:\5215\12929\FS\ 01/13/00 09:10:01 10:28:16 GENCORELLRJ Fig7-1

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: MWM/JDB
DRAWN BY: R. GENCORELLI
SHEET CHK'D BY:
CROSS CHK'D BY:
APPROVED BY:
DATE: JULY, 1999

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consulting
engineering
construction
operations

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL REMEDIATION PROJECT

CONCEPTUAL SITE REMEDIATION PLAN ALTERNATIVE "2A"

PROJECT NO. 5215-12929
FILE NAME: FIG7-1

DRAWING NO.
7-1

LEGEND

- PROPERTY LINE
- LIMIT OF SOLID WASTE
- 48 - POST CAPPING CONTOURS
- 20 - EXISTING CONTOURS
- ACCESS ROAD
- LEACHATE COLLECTION TRENCH (WITH DOWNGRADIENT BARRIER WALL)
- BARRIER WALL
- DRAINAGE CHANNEL RUNOFF FLOW
- ■ - LEACHATE COLLECTION SUMP

NOTES:

1. ELEVATION CONTOURS SHOWN CORRESPOND TO THE TOP OF CAP, AS CONSTRUCTED IN GENERAL ACCORDANCE WITH THE 6 NYCRR PART 360 REGULATIONS (4 % MINIMUM SLOPE, 24 INCH PROTECTION LAYER). HOWEVER, A VARIABLE 12 TO 24 INCH PROTECTION LAYER WILL BE USED (24 INCHES IN AREAS VULNERABLE TO EROSION, 12 INCHES ELSEWHERE) FINAL CAP ELEVATIONS WILL BE DETERMINED DURING THE DESIGN PHASE. CAP TO EXTEND 5 FEET BEYOND THE LIMITS OF WASTE (MIN.).
2. LEACHATE CONTROLS INCLUDE UPGRADIENT GROUNDWATER DIVERSION AND SHALLOW GROUNDWATER COLLECTION ALONG THE ENTIRE DOWN GRADIENT PERIMETER OF THE LANDFILL.
3. STORMWATER RUNOFF CONTROL INCLUDES NATURAL OVERLAND FLOW/DISCHARGE AND PERIMETER COLLECTION/DISCHARGE, WHERE SHOWN.
4. THE ACTIVE GAS CONTROL AND TREATMENT SYSTEM IS SHOWN ON DRAWING 1 OF APPENDIX D.

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: MWM/JDB
DRAWN BY: R. GENCORELLI
SHEET CHK'D BY:
CROSS CHK'D BY:
APPROVED BY:
DATE: JULY, 1999

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NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL
REMEDIATION PROJECT

CONCEPTUAL SITE REMEDIATION PLAN
ALTERNATIVE "3"

PROJECT NO. 5215-12929
FILE NAME: ALT_A1
DRAWING NO.
7-3

S:\5215\12929\FS\ ALT_A1 01/13/00 09:23:31 2:10:36 GENCORELLIRJ

LEGEND

- PROPERTY LINE
- LIMIT OF SOLID WASTE
48 - POST CAPPING CONTOURS
20 - EXISTING CONTOURS
- ACCESS ROAD
- LEACHATE COLLECTION TRENCH (WITH DOWNGRADIENT BARRIER WALL)
- BARRIER WALL
- DRAINAGE CHANNEL RUNOFF FLOW
■ - LEACHATE COLLECTION SUMP

NOTES:

1. ELEVATION CONTOURS SHOWN CORRESPOND TO THE TOP OF CAP, AS CONSTRUCTED IN GENERAL ACCORDANCE WITH THE 6 NYCRR PART 360 REGULATIONS (4 x MINIMUM SLOPE, 24 INCH PROTECTION LAYER). HOWEVER, A VARIABLE 12 TO 24 INCH PROTECTION LAYER WILL BE USED (24 INCHES IN AREAS VULNERABLE TO EROSION, 12 INCHES ELSEWHERE) FINAL CAP ELEVATIONS WILL BE DETERMINED DURING THE DESIGN PHASE. CAP TO EXTEND 5 FEET BEYOND THE LIMITS OF WASTE (MIN.).
2. LEACHATE CONTROLS INCLUDE UPGRADIENT GROUNDWATER DIVERSION ALONG THE ENTIRE SOUTH FACE OF THE LANDFILL AND SHALLOW GROUNDWATER COLLECTION ALONG THE LANDFILL PERIMETER AT HOTSPOTS NO. 3 AND NO. 5.
3. STORMWATER RUNOFF CONTROL INCLUDES NATURAL OVERLAND FLOW/DISCHARGE AND PERIMETER COLLECTION/DISCHARGE, WHERE SHOWN.
4. THE ACTIVE GAS CONTROL AND TREATMENT SYSTEM IS SHOWN ON DRAWING 2 OF APPENDIX D.

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: M. MINER
DRAWN BY: R. GENCORELLI
SHEET CHK'D BY:
CROSS CHK'D BY:
APPROVED BY:
DATE: JULY, 1999

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BROOKFIELD AVENUE LANDFILL REMEDIATION PROJECT

CONCEPTUAL SITE REMEDIATION PLAN ALTERNATIVE "4"

PROJECT NO. 5215-12929
FILE NAME: ALT_C
DRAWING NO.
7-4

S:\5215\12929\FS\ ALT_C 01/13/00 09:37:29 9:37:08 GENCORELLI.RJ

LEGEND

- PROPERTY LINE
- LIMIT OF SOLID WASTE
48 - POST CAPPING CONTOURS
20 - EXISTING CONTOURS
- ACCESS ROAD
- LEACHATE COLLECTION TRENCH (WITH DOWNGRADIENT BARRIER WALL)
- BARRIER WALL
- DRAINAGE CHANNEL RUNOFF FLOW
■ - LEACHATE COLLECTION SUMP

NOTES:

1. ELEVATION CONTOURS SHOWN CORRESPOND TO THE TOP OF CAP, AS CONSTRUCTED IN GENERAL ACCORDANCE WITH THE 6 NYCRR PART 360 REGULATIONS (4% MINIMUM SLOPE, 24" VARIABLE PROTECTION LAYER). HOWEVER, A VARIABLE 12 TO 24 INCH PROTECTION LAYER WILL BE USED (24 INCHES IN AREAS VULNERABLE TO EROSION, 12 INCHES ELSEWHERE). FINAL CAP ELEVATIONS WILL BE DETERMINED DURING THE DESIGN PHASE. CAP EXTENDS TO 5 FT. BEYOND THE LIMIT OF WASTE (MIN.).
2. LEACHATE CONTROLS INCLUDE SHALLOW GROUNDWATER COLLECTION ALONG THE LANDFILL PERIMETER AT HOT SPOTS NO. 3 AND NO. 5 AND GROUNDWATER DIVERSION BETWEEN THE LANDFILL AND THE PERIMETER DRAINAGE DITCHES.
3. STORMWATER RUNOFF CONTROLS WOULD INCLUDE NATURAL WETLAND FLOW/DISCHARGE AND PERIMETER COLLECTION/DISCHARGE, WHERE SHOWN.
4. THE ACTIVE GAS CONTROL AND TREATMENT SYSTEM IS AS SHOWN ON DRAWING 2 OF APPENDIX D.

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: MWM/JDB
DRAWN BY: R. GENCORELLI
SHEET CHK'D BY:
CROSS CHK'D BY:
APPROVED BY:
DATE: JULY, 1999

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BROOKFIELD AVENUE LANDFILL REMEDIATION PROJECT

CONCEPTUAL SITE REMEDIATION PLAN ALTERNATIVE "5"

PROJECT NO. 5215-12929
FILE NAME: ALT_D

DRAWING NO.
7-5

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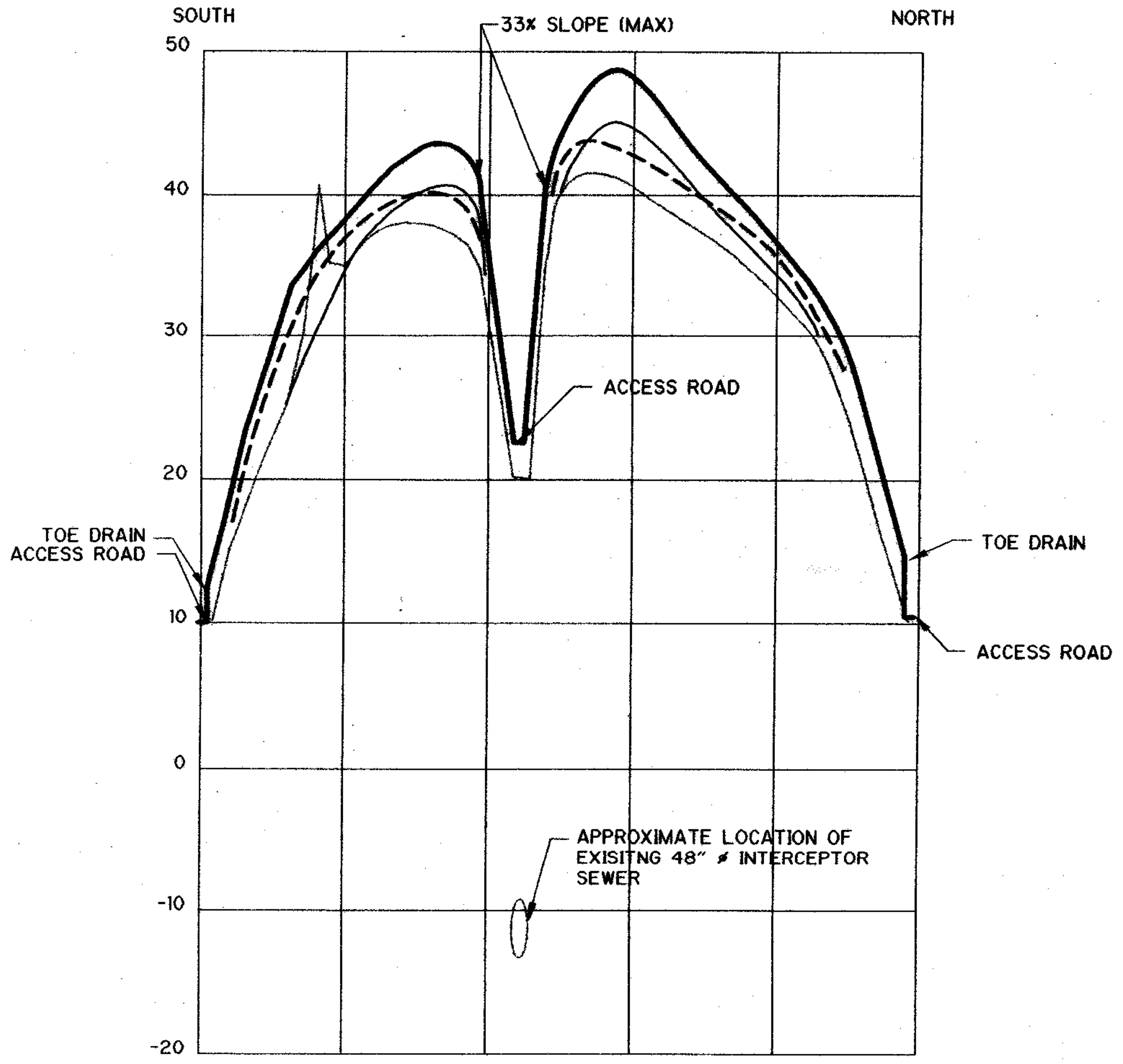
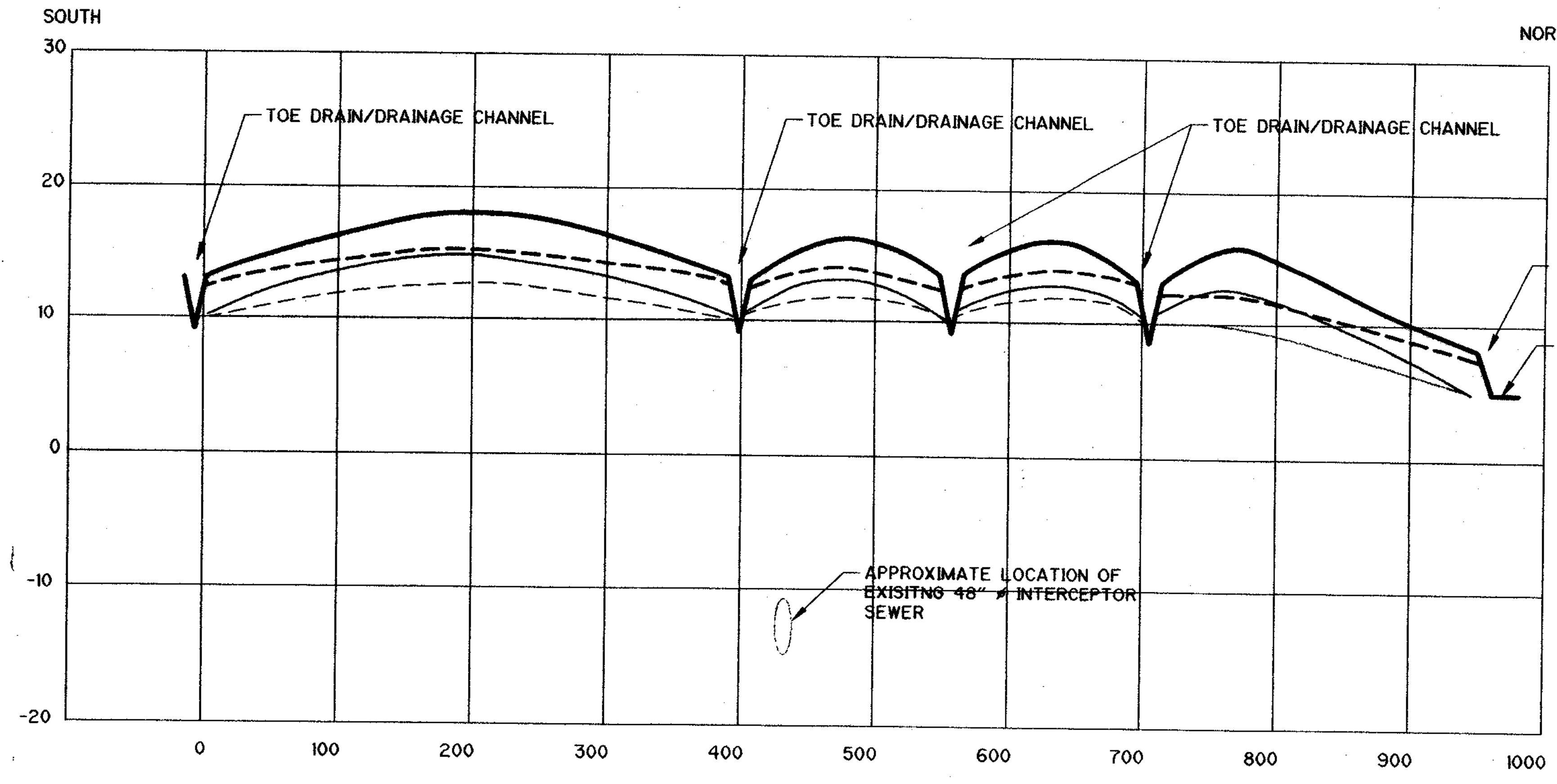
ALT_D



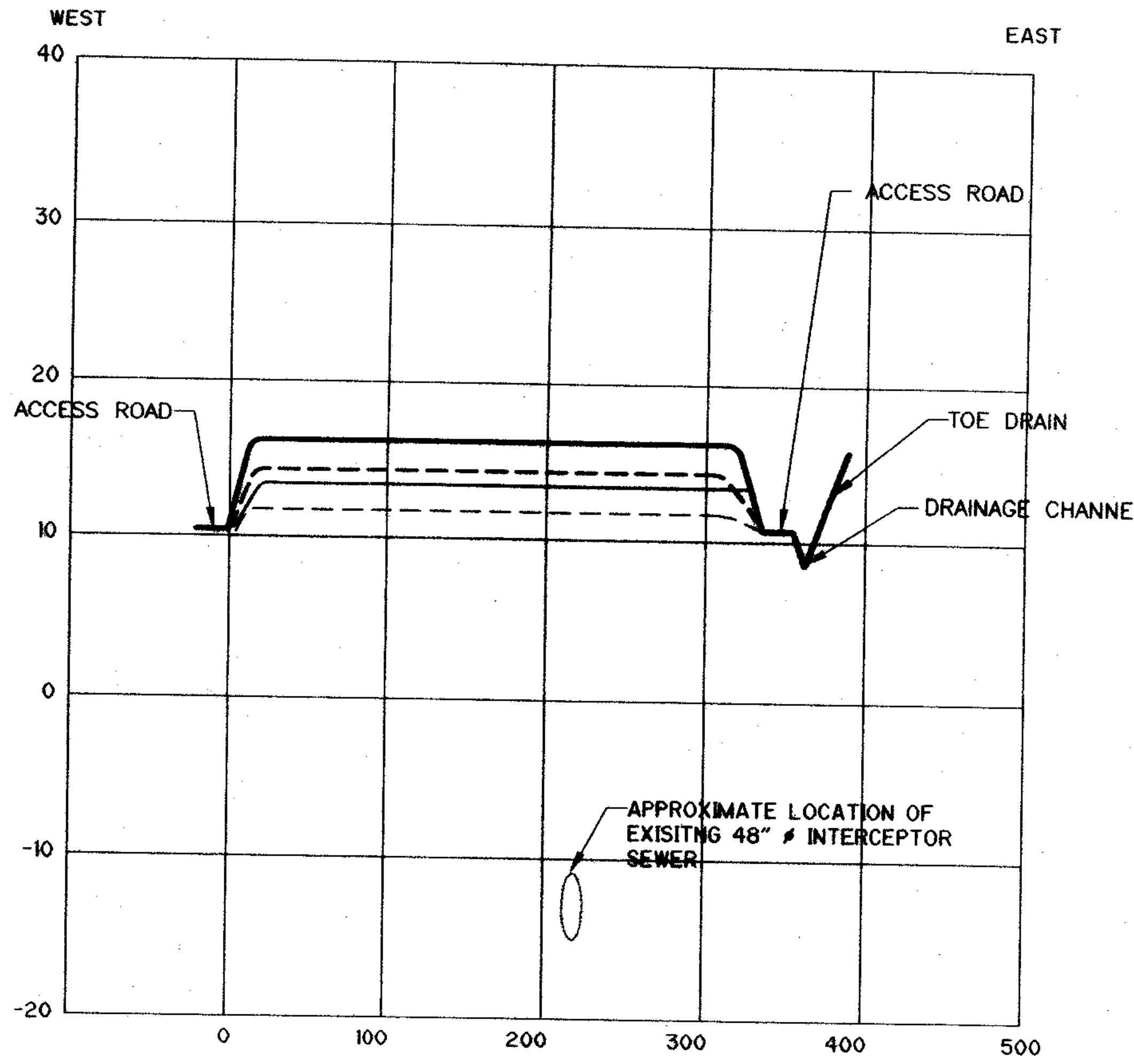
SECTION 1
7-1

1" = 300' HORIZ.
1" = 10' VERT.



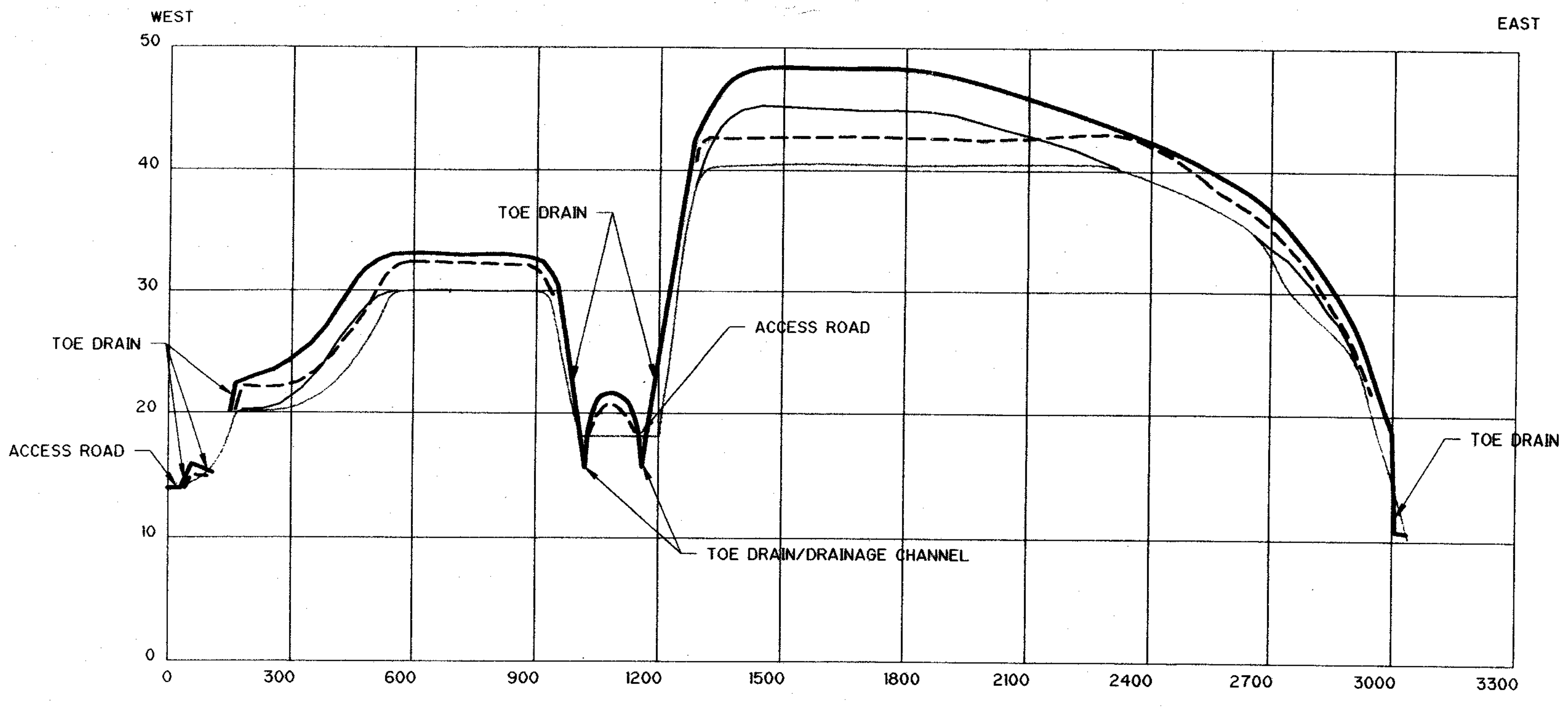
SECTION 2
7-1

1" = 100' HORIZ.
1" = 10' VERT.



SECTION 3
7-1

1" = 100' HORIZ.
1" = 10' VERT.



SECTION 4
7-1

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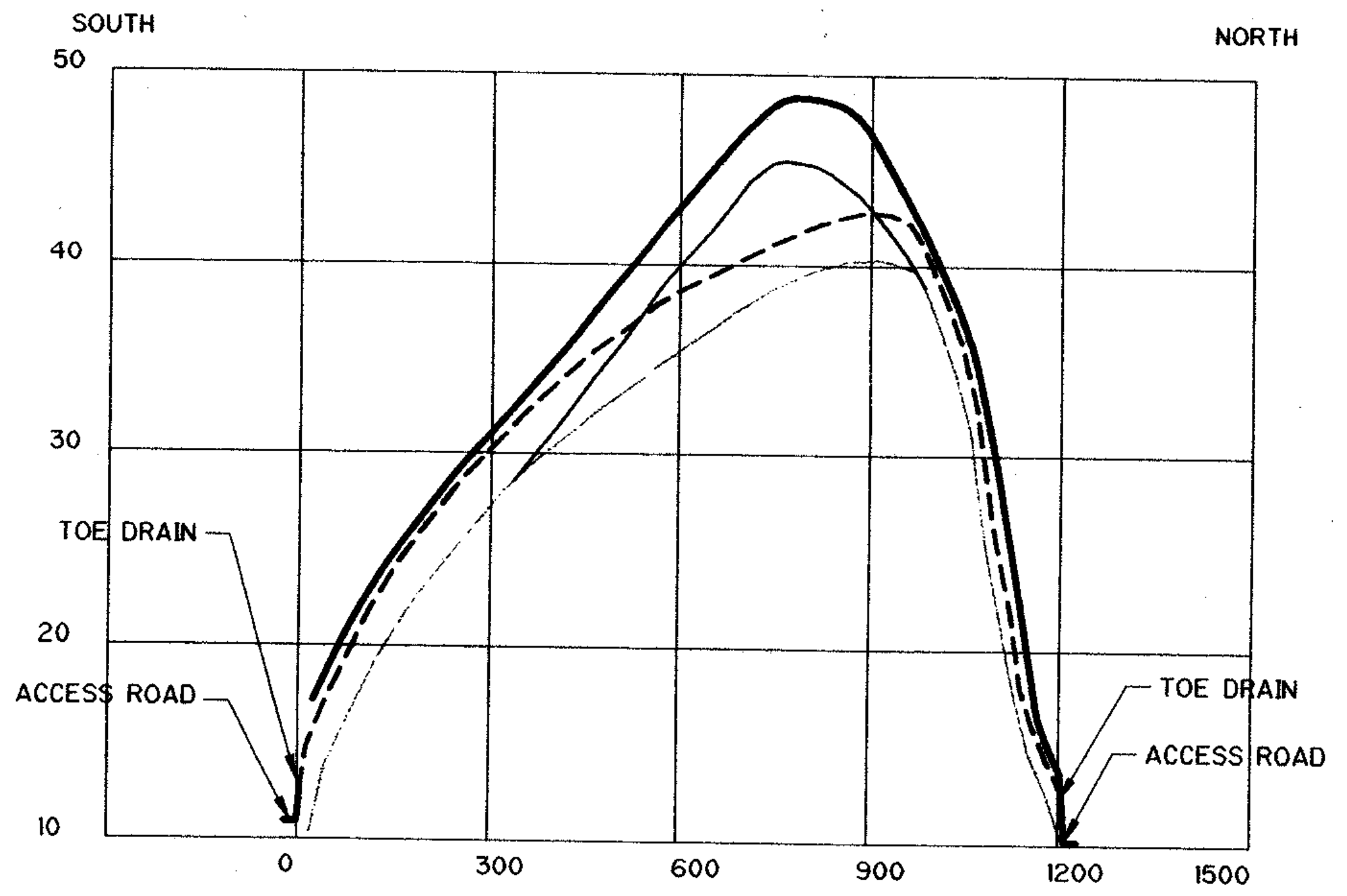
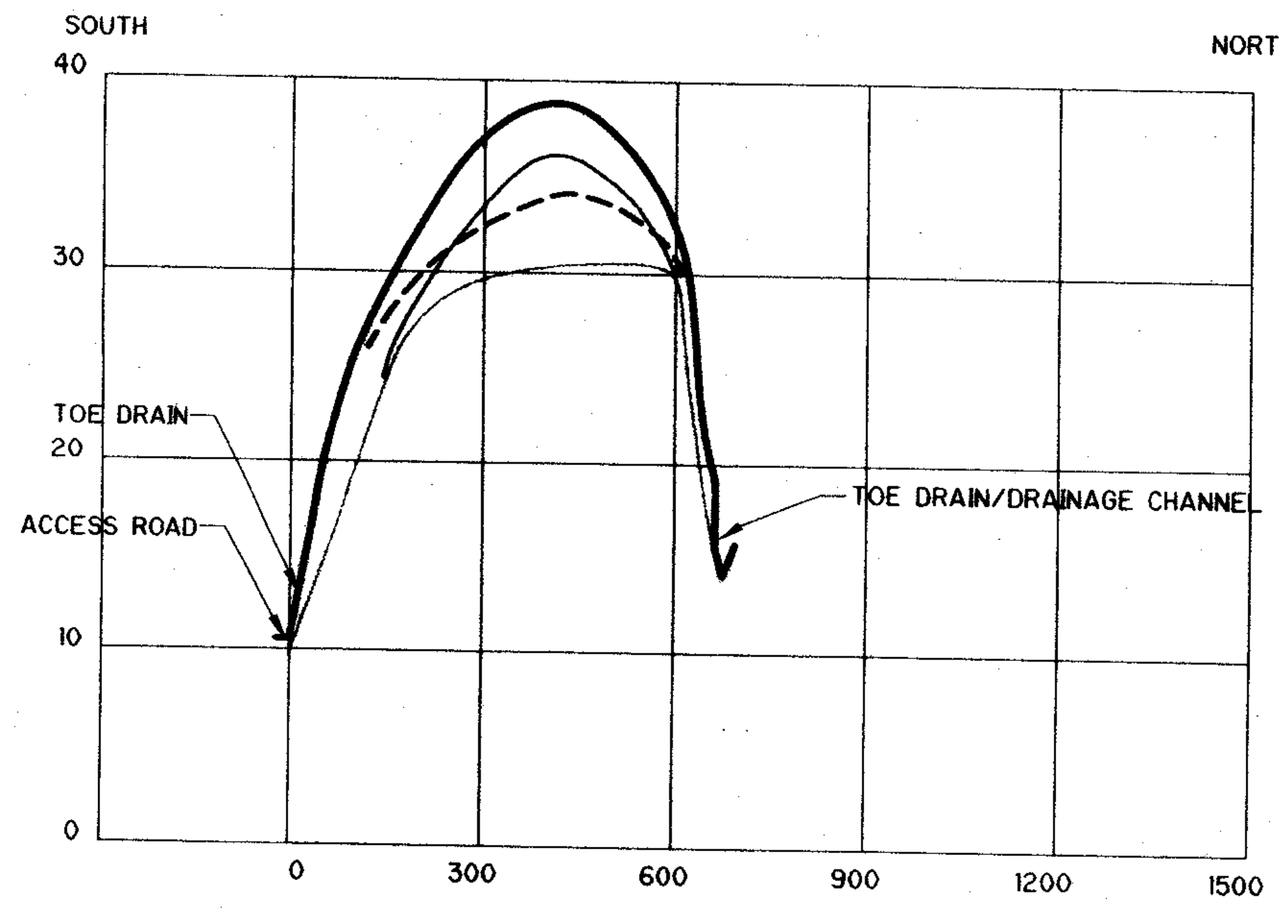
1" = 10' VERT.



SECTION 5
7-1

1" = 300' HORIZ.
1" = 10' VERT.



SECTION 6
7-1

1" = 300' HORIZ.
1" = 10' VERT.

LEGEND

- EXISTING GRADE
- ROUGH GRADE (NO VARIANCE)
- ROUGH GRADE (2% SLOPE, 18" PROTECTION LAYER, VARIANCES)
- FINAL GRADE (NO VARIANCES)
- FINAL GRADE (2% SLOPE, 18" PROTECTION LAYER, VARIANCES)

NOTE:
1. ALL ALTERNATIVES ASSUME A VARIABLE 12"-24" PROTECTION LAYER. 24" PROTECTION LAYER TO BE USED IN AREAS VULNERABLE TO EROSION OR NECESSARY TO SUPPORT A PARTICULAR END USE. A MIMIMUM 12" PROTECTION LAYER MAY BE USED IN OTHER, LESS CRITICAL AREAS. FOR EACH SECTION, BOTH 24", 4% SLOPE AND 18" 2% SLOPE ARE SHOWN FOR DEMONSTRATION PURPOSES.

150 FT 0 300 FT

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: MWM
DRAWN BY: R. GENCORELLI
SHEET CHK'D BY:
CROSS CHK'D BY:
APPROVED BY:
DATE: JULY, 1999

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BROOKFIELD AVENUE LANDFILL REMEDIATION PROJECT

CONCEPTUAL SITE REMEDIATION PLAN CROSS - SECTIONS

PROJECT NO. 5215-12929
FILE NAME: FIG7-5

DRAWING NO.
7-6

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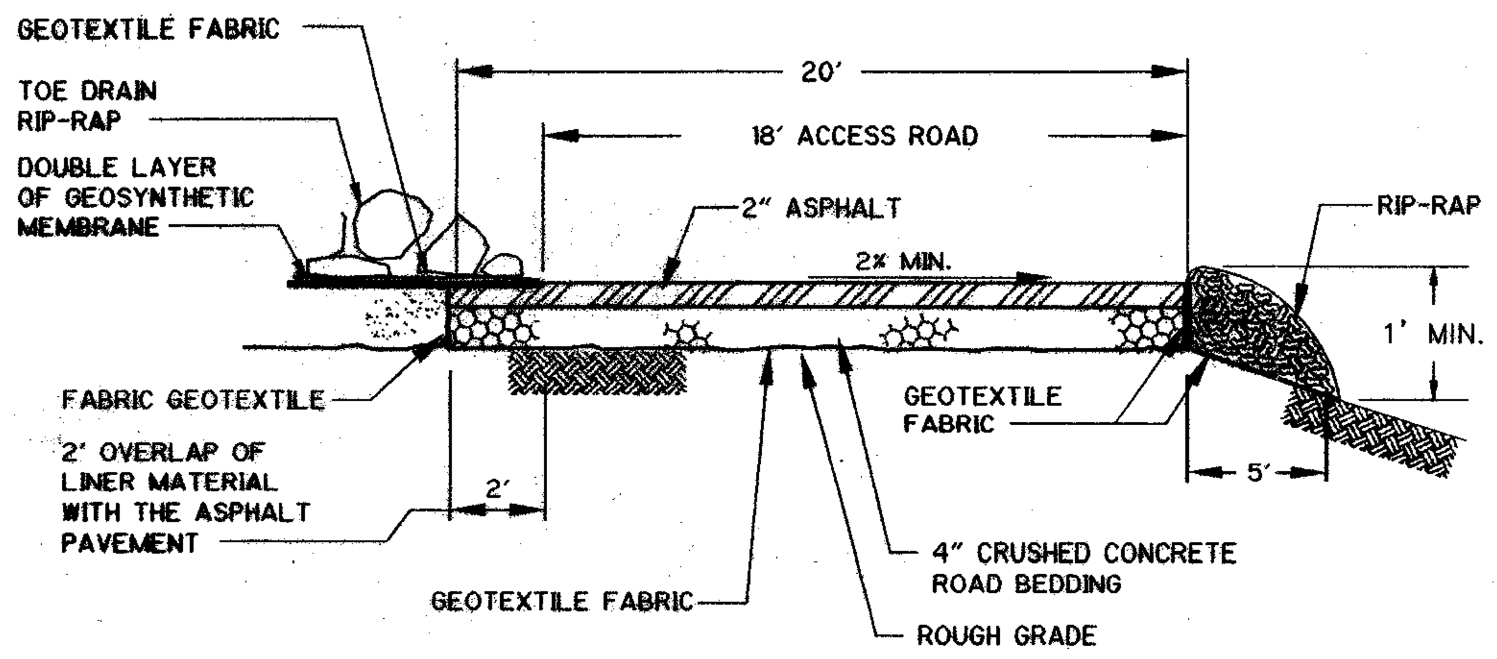
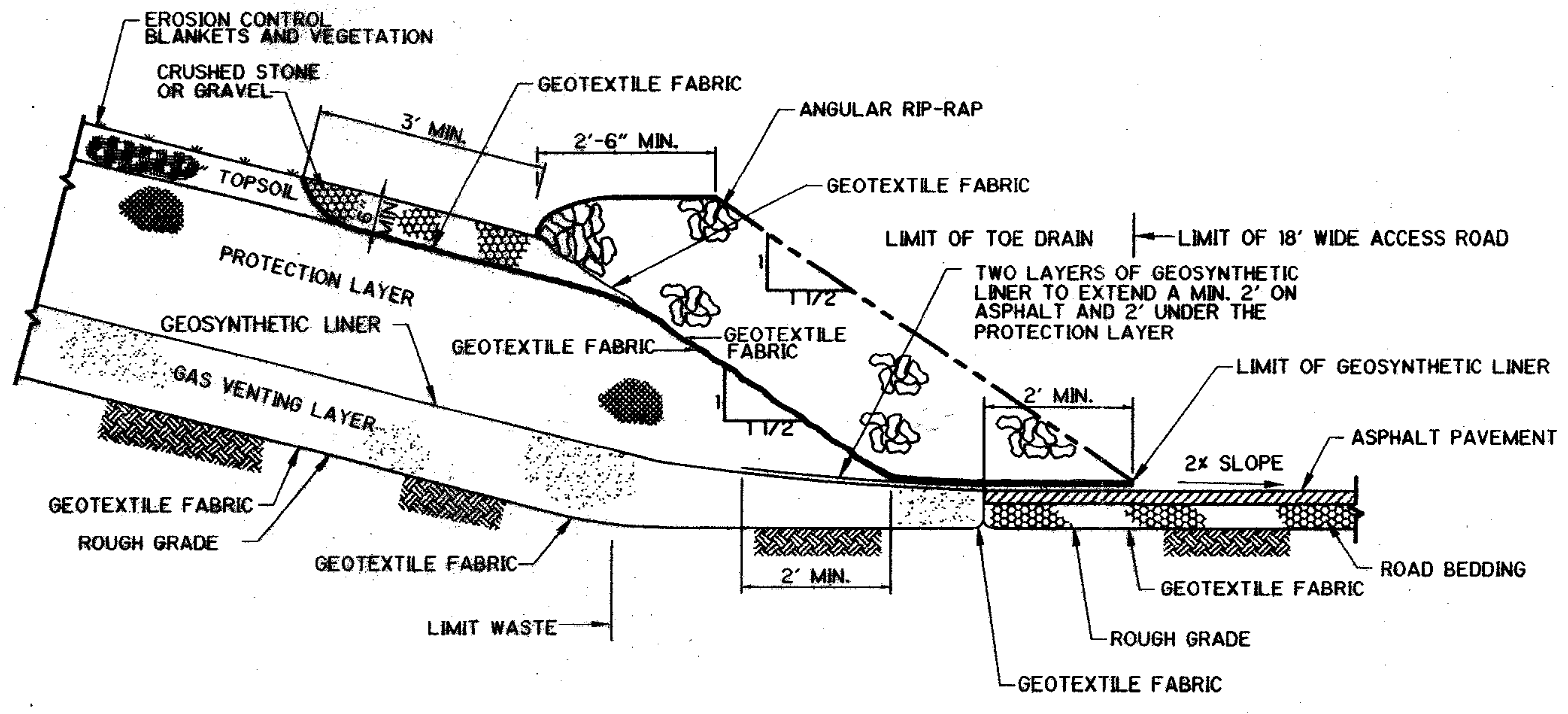
FIG7-5
02/01/99 13:22:47
11:52:35
KALNYCP



NOTE:
THE SIDES OF THE ACCESS ROAD WILL BE ADJUSTED TO ACCOMMODATE DRAINAGE CHANNELS AND TOE DRAINS. DETAILS FOR ALL CONDITIONS WILL BE DEVELOPED DURING THE DESIGN PHASE.

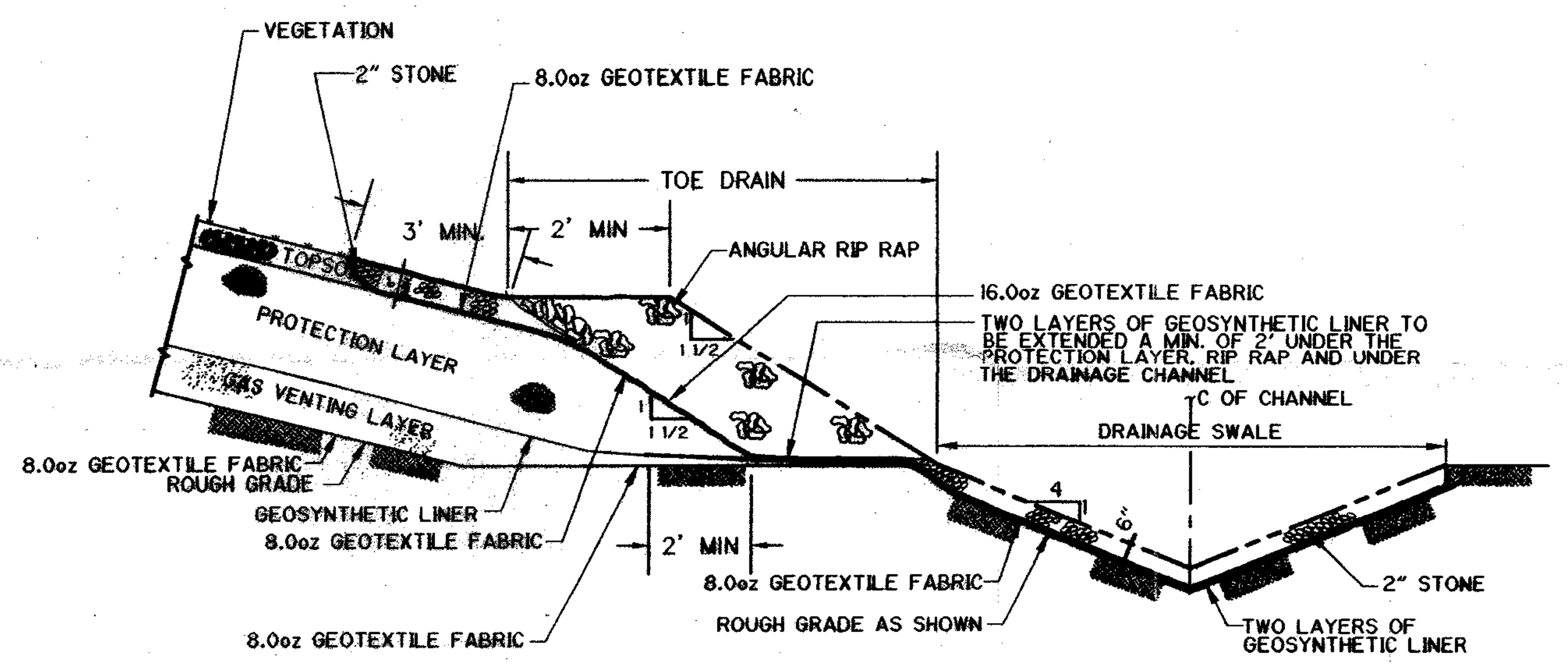
ASPHALT ROAD CROSS-SECTION

DETAIL A
NTS -



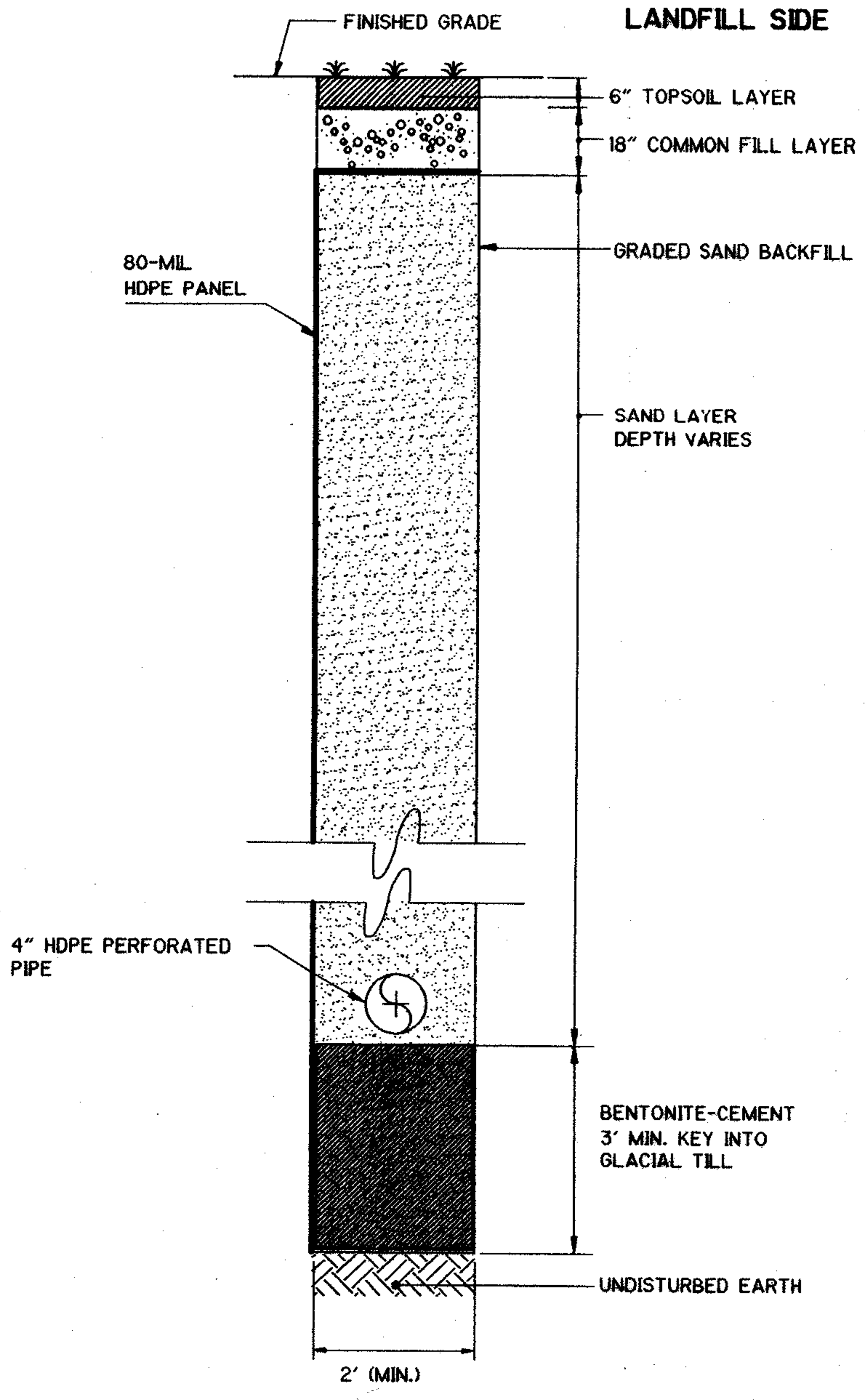
TOE DRAIN/ACCESS ROAD

DETAIL B
NTS -



TOE DRAIN/STONE-LINED DRAINAGE CHANNEL

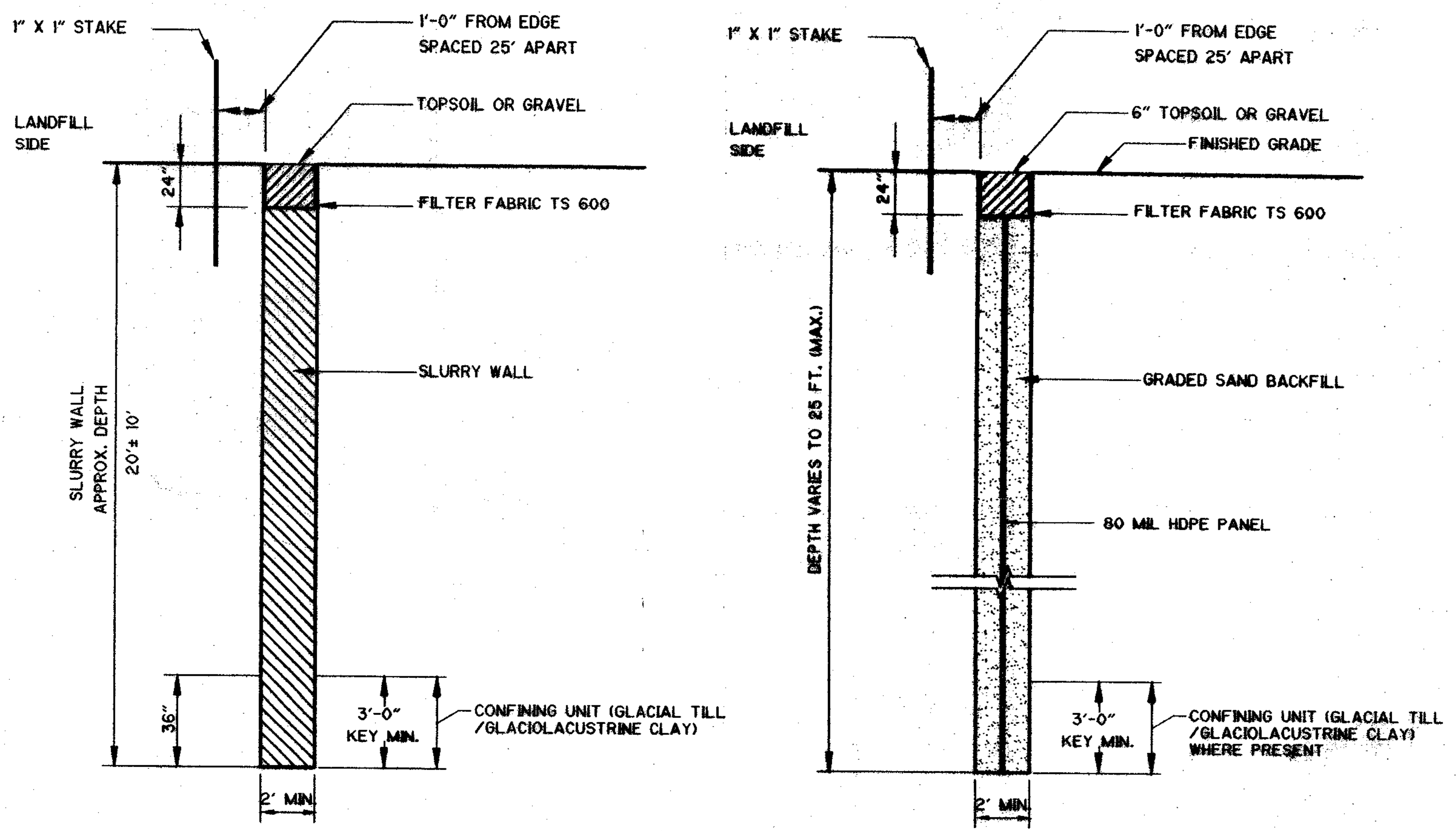
DETAIL C
NTS -



SECTION

LEACHATE COLLECTION TRENCH

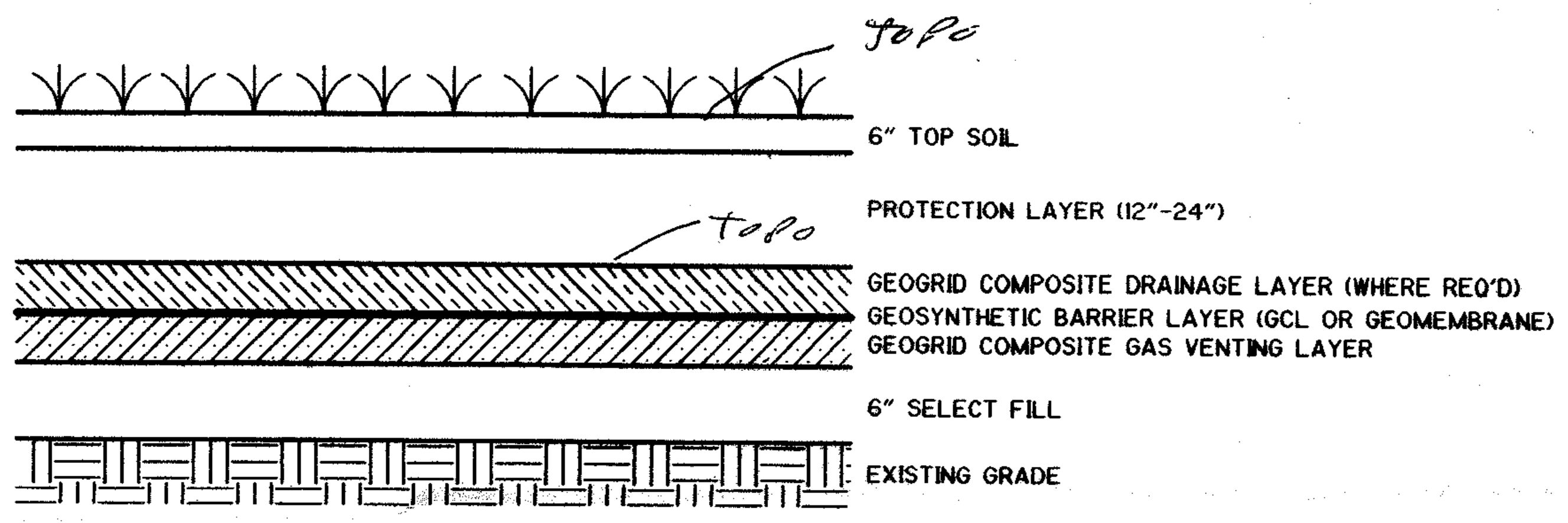
DETAIL D
NTS -



SLURRY WALL

HDPE BARRIER WALL

DETAIL E
NTS -



LANDFILL CAP

DETAIL F
NTS -

S:\5215\12929\FS\ FSDETLS 01/08/99 17:13:00 13:34:50 GENCORELLI.RJ

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: MWM/JDB
DRAWN BY: R. GENCORELLI
SHEET CHK'D BY:
CROSS CHK'D BY:
APPROVED BY:
DATE: JULY, 1999

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BROOKFIELD AVENUE LANDFILL REMEDIATION PROJECT

CONCEPTUAL SITE REMEDIATION PLAN DETAILS

PROJECT NO. 5215-12929
FILE NAME: FSDETLS
DRAWING NO.
7-7

Appendix B

APPENDIX B

BACKUP CALCULATIONS
FOR THE PRELIMINARY SLOPE STABILITY ANALYSIS

Technical Memorandum

To: *Brookfield Avenue Landfill File*

From: *Michael W. Miner, P.E., P.P.*

Subject: *Preliminary Slope Stability Analysis*

Date: *December 4, 1998 (Revised December 15, 1999)*

A preliminary slope stability analysis was performed as part of the Detailed Analysis of Site Remediation Alternatives to evaluate the post-capping stability of landfill side slopes. The results of this analysis were used to evaluate the long-term effectiveness and cost of the cap design alternatives, assuming a variable 12-inch to 24-inch protection layer, and variable 2% to 4% side slopes.

The potential failure plane was assumed to coincide with the interface between the barrier layer and the protection layer. Critical slopes were evaluated using the Hydrologic Evaluation of Landfill Performance (HELP) model to estimate the maximum saturation thickness above the barrier layer. The stability of each critical slope was then calculated as the ratio of resisting forces to driving forces, as detailed in the attachments to this memorandum. Critical slopes exhibiting a factor of safety in excess of 1.5 were considered to be stable.

The technical approach was as follows:

1. A cap with 2% minimum slope and a 12-inch thick protection layer was modeled at nine different side slope locations. For calculation purposes, it was assumed that either smooth or textured geomembrane would be used for barrier layer construction. Textured geomembrane was considered at side slope locations which required a higher friction angle. Slopes exhibiting a factor of safety less than 1.5 were additionally modeled considering the use of a geogrid composite drainage layer above the barrier layer to increase subsurface drainage.

2. Caps woth 2% minimum slope with an 18-inch thick protection layer and 4% minimum slope with a 24-inch thick protection layer were modeled at side slope locations determined to be critical based upon the results from the 2% slope 12-inch cap. These locations were modeled as described above.

Based upon the results of this preliminary analysis, stable side slopes can be achieved for all cap configurations considered. A geogrid composite drainage layer would be required for slope stability between the two cells located at the western end of the landfill for all configurations. This drainage layer would also be required along interior side slopes corresponding to the L-shaped area of the landfill for the 2% sloped, 12-inch cap. Slope stability at this location could be achieved using textured geomembrane liner for the other cap configurations, without the use of a drainage layer.

TECHNICAL METHODOLOGY

[redacted]

Geosynthetic Landfill Cover Design Methodology and Construction Experience in the Pacific Northwest

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ABSTRACT

The use of geosynthetics in landfill covers has increased in recent years and are likely to be required for most municipal solid waste (MSW) landfills in the U.S. by the new Environmental Protection Agency (EPA) subtitle D regulations. Critical cover-design concerns are stability and drainage. An infinite slope analysis that uses the properties of site-specific materials is considered appropriate for evaluating stability. Estimating the amount of seepage into the drainage layer above a geomembrane cover on steep slopes is critical for designing proper spacing of the layer's drainage outlets. The design should be based on interface shear strength and permeability testing with site-specific materials.

Well-prepared specifications and a construction quality assurance program are crucial to successful geosynthetic cover installations. This paper reflects experience gained from designing and constructing landfill covers with geomembranes on 11 projects totaling over 200 acres in Oregon and Washington. Lessons learned from these projects will lead to improvements in future designs.

INTRODUCTION

Geomembranes are increasingly used in landfill cover designs because they

- Are often preferred in regulations
- Reduce long-term leachate generation better than soil-only covers, especially in wet climates
- May reduce long-term liability by limiting future leachate generation and controlling gas
- Often cost less than low-permeability soil

Recent EPA regulations (Federal Register, 1991) will likely require composite covers (geomembrane over soil) on most new MSW landfills that have bottom geomembrane liners. Koerner and Danial (1992) discuss the trends, benefits, and issues related to using geomembranes in landfill covers. Special design issues for landfill covers with geomembranes include

- Cover slope stability
- Settlement (total and differential)
- Landfill gas control
- Side slope seeps
- Construction methods and materials

Other more standard civil design items such as access roads, erosion, surface drainage structures, and vegetation must account for the special issues listed above.

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All elements of the completed design must be considered when budgeting for long-term maintenance and planning for future site end use.

This paper describes a typical landfill cover design using a geomembrane barrier layer. The design discussion focuses on slope stability, taking into account partial saturation and seepage forces in the cover. Construction issues and production rates relating to the layered elements of the cover design are described at the end of the paper.

TYPICAL COVER DESIGN ELEMENTS AND MATERIALS

The following are the elements, from bottom to top, of a typical landfill cover with a geomembrane barrier layer (see Figure 1).

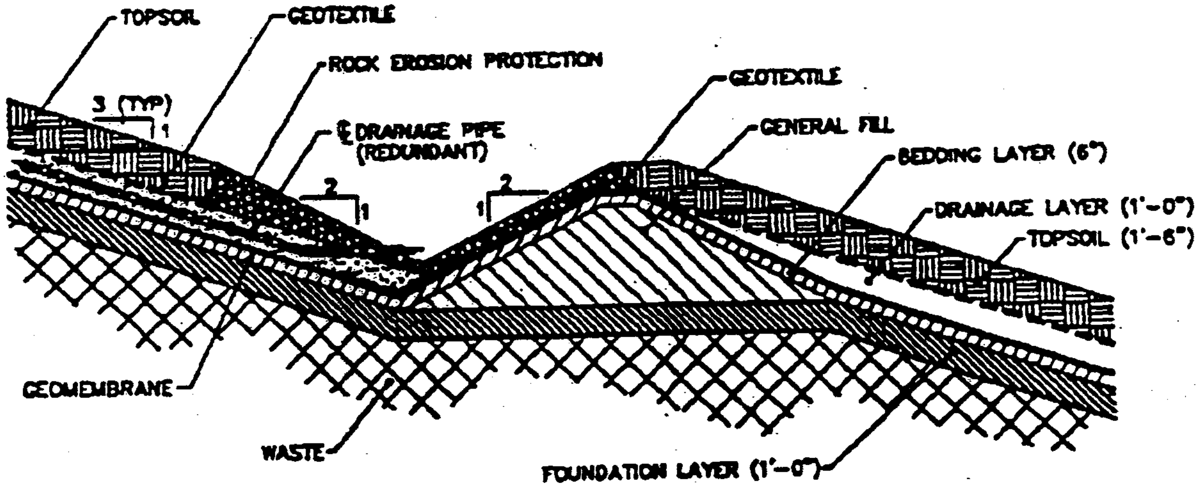

FIGURE 1. TYPICAL LANDFILL COVER SECTION WITH GEOMEMBRANE BARRIER LAYER AND INTERMEDIATE BENCH DITCH

Foundation Soil Overlying the Waste. This layer provides a firm foundation for subsequent cover construction. It is usually installed during landfill operations, or during cover construction when regrading is required. Typically at least 1 foot (30 cm) thick, it consists of general soil material that can be compacted. Some types of waste, such as ash, can even be used. Compaction requirements are not stringent (approximately 90 percent of standard Proctor maximum dry density) because the layer is not expected to support footings for structures. Structures can be constructed on the final cover but require considerations beyond the scope of this paper.

Geomembrane Bedding Layer. This layer typically consists of 6 inches (15 cm) of sand because sand particles have good frictional characteristics, are easy to grade, are of appropriate size for intimate contact with the geomembrane, can convey side slope seeps, and can transmit gas from shallow horizontal collection trenches. Cover design under Subtitle D (EPA, 1992a) will generally require this layer to be part of a composite cover to act as a hydraulic barrier and consist of 18 inches (46 cm) of soil with a hydraulic conductivity no greater than $2x10^{-5}$ feet/minute ($1x10^{-5}$ cm/sec) for most MSW landfills that have bottom geomembrane liners.

Geomembrane. This is the barrier layer that replaces the conventional soil barrier. Key design concerns relating to the geomembrane include interface shear strength with adjacent materials and ability to handle differential settlement. EMCON has found only textured polyethylene products provide the required interface shear strength for steep (3:1) slopes at a reasonable cost. These products, especially the lower density variety, also have three-dimensional strain capabilities that would generally not be exceeded by differential settlements expected on landfill covers.

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Drainage Layer. This is typically 1 foot (30 cm) of sand or gravel. Geosynthetic drainage elements, such as a geonet-geotextile composite, are generally not cost competitive with natural drainage materials in the Northwest. Most natural drainage material can be obtained and installed for about $10 per cubic yard (0.76 m^3) or about $0.37 per square foot (0.09 m^2) for a 1-foot (30 cm) thick layer. The cost of geocomposite drainage layers is usually significantly more than this, depending on the materials selected. No compaction requirements are specified for this layer.

Geotextile Filter. A filter is generally required between the topsoil and the drainage layer. Sometimes the relative gradations of the drainage and topsoil layers act as a natural filter, precluding the need for an additional filter. In either case the potential for clogging and piping should be checked either by strict filter design criteria, such as those developed by the Corps of Engineers (Cedergren, 1989), or by geotextile filter design methods with site-specific soils, as published in literature (GRI, 1991). If it is not known at the design stage what soil materials will be used, the specifications should require a method for selecting the proper geotextile.

Topsoil. The thickness of this layer depends on the type of vegetation to be established. The layer can be divided into two sublayers: a lower, rooting layer with less organic content and an upper, organic-rich layer. Most designs specify a rooting layer at least 1-foot (30 cm) thick overlain by 6 inches (15 cm) of organic soil. The topsoil layer should be at least as thick as the rooting depth of the proposed vegetation. Although compaction is generally not specified, to avoid overly loose placement the material should be subjected to at least two passes of construction equipment. If permeability is a concern, a minimum compaction can be specified for the rooting layer.

The elements described above are typical of the cover designs used in the Northwest. The following discussions on cover stability and construction reference these elements, but would be applicable to any layered cover section.

LABORATORY TESTING FOR THE COVER DESIGN

Topsoil. Tests required for topsoil include saturated unit weight, gradation, and permeability. Gradation is used to evaluate the filter design between the topsoil and the drainage layer. Looser (more permeable) soil produces more conservative permeability test results. Laboratory sample preparation should replicate as closely as possible the expected field placement condition.

Drainage Layer. This material also requires saturated unit weight, gradation, and permeability testing. Gradation test results should be checked for maximum allowable fines content, gap gradation, and filter compatibility with the topsoil. A dense sample would produce a more conservative permeability test result than a loose sample.

Geotextile. The main criteria for selecting a geotextile, if one is needed, are construction survivability and filtration between the topsoil and drainage layer. The GRI (1991) or Christopher and Holtz (1985) references are recommended as good sources that discuss the appropriate testing and material selection criteria for geotextile filters. The requirement for interface shear strength with adjacent soils is discussed below.

Geomembrane. Geomembrane cover material selection criteria (other than those required by state regulations) include construction survivability, ability to maintain integrity under total and differential landfill settlement conditions, cover slope stability, and cost. Secondary considerations, which could be primary considerations for certain projects, include ease of installation; construction quality assurance requirements; susceptibility and resistance to animal and plant penetration; ability to install in climatic extremes of hot and cold; aging durability; and, if the liner needs solvents for welding, health, safety, and environmental considerations. The testing and specifications required for the project will depend on the project's design considerations. Once a product type is selected, product specifications will generally require a cover geomembrane to meet minimum physical requirements for strength and elongation and provide minimum required interface friction with the adjacent soils (discussed below).

Geosynthetic-Soil Interfaces. Shear strength should be evaluated for the following interfaces:

- Topsoil-geotextile
- Geotextile-drainage material
- Drainage material-geomembrane
- Geomembrane-bedding soil

Typically the critical interface is where the drainage material meets the geomembrane, which should be the only interface where pore pressures may build up. With proper materials selection, the other interfaces should be able to provide adequate stability for slopes up to 33 percent.

The American Society for Testing and Materials is currently preparing a standard for interface direct-shear testing. It would be prudent to perform the testing with a minimum 1-foot (0.09 m^2) square shear box; under saturated conditions; to sandwich the geosynthetic between the actual materials it will experience in the design; and to use the range of normal loads anticipated in the final cover (e.g., 150 to 400 pounds per square foot [7.2 to 19.1 kPa]). An experienced laboratory with proper testing equipment sensitive at these low, normal loads should be used.

STABILITY ANALYSIS

The following procedure is for a potential cover failure sliding parallel to the slope, with the drainage layer-geomembrane interface the primary plane of weakness.

Description of the Problem. The stability analysis theory for a cover on a slope is well documented (Koerner, 1990; Lambe and Whitman, 1969; Giroud and Beech, 1989). It can consist of calculating the force vectors for the entire slope, including toe resistance, or it can be simplified somewhat for a uniform cover section by performing an infinite slope analysis. The method used will depend on the degree of conservatism wanted, its impact on design decisions, and the relative magnitude of the toe resistance compared to overall slope resistance. In many cases with long cover slopes toe resistance accounts for less than 5 percent of slope resistance. If an infinite slope analysis yields a factor of safety (FS) less than desired then the results can be checked by including toe resistance and re-evaluating the FS.

The method discussed in this paper is the infinite slope analysis. The most important parameters to consider in such an analysis are the slope angle, the shear strength of the potential failure plane parallel to the slope, and the amount of water above the potential failure plane (i.e., pore pressures acting on that plane). The unit weights of the materials above the potential failure plane have a small influence on the analysis. The most difficult of the parameters to estimate are the pore pressures acting on the potential failure plane. The potential failure plane of a geomembrane cover is assumed to be the drainage layer-geomembrane interface.

The problem is relevant to slopes steeper than about 15 percent (6.7H:1V), depending on the interface shear strength. Figure 2 depicts the variation in FS with slope angle (β) for a fully saturated infinite slope (worst case condition) assuming an interface friction parameter (ϕ) of 28 degrees (a typical low-end value between textured polyethylene and granular drainage materials). In this case imminent failure (FS=1.0) would occur at a slope of about 22 percent (4.5:1) and FS equal to 1.5 is obtained at a slope of about 15 percent (6.7:1). Landfills in Oregon and Washington are commonly constructed with slopes as steep as 33 percent.

Pore Pressures Acting on the Drainage Layer-Geomembrane Interface. Estimating the amount of head that builds up over the geomembrane requires consideration of the spacing and orientation of underdrain collectors, which collect water from within the drainage layer and discharge it outside the cover section. At a minimum the drainage layer will discharge at the slope toe. The need for additional intermediate discharge locations from the drainage layer is determined by the amount of water it collects and the minimum FS required for stability.

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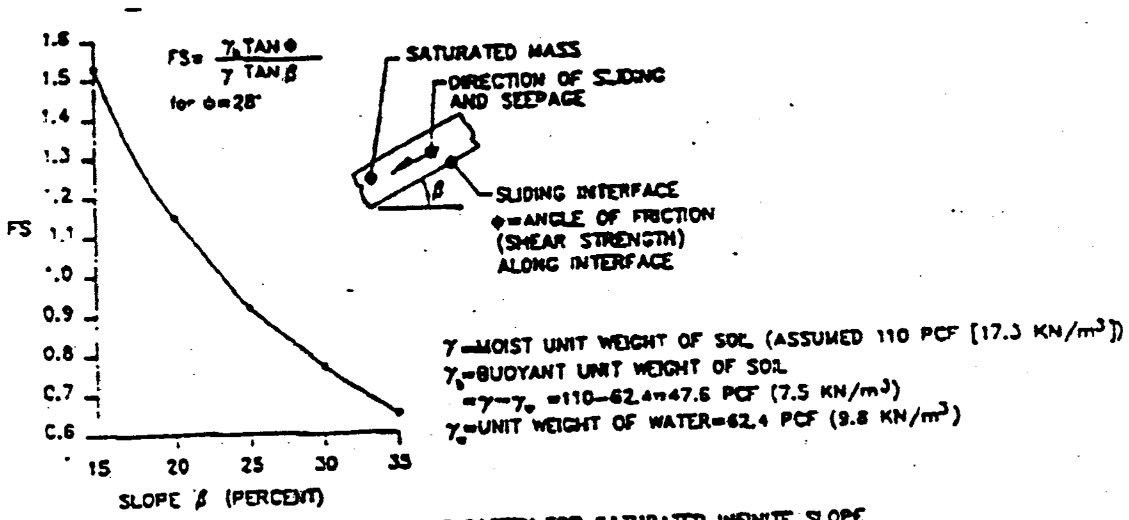

FIGURE 2. SLOPE ANGLE VS. FACTOR OF SAFETY FOR SATURATED INFINITE SLOPE

At least two methods can be used to provide intermediate discharge from the drainage layer: pipes (or collection ditches) running up and down the slope, and pipes (or collection ditches) running subparallel to the slope contours. The latter method seems to be more efficient and has been preferred in Oregon and Washington. The methods of analysis discussed here use this method. Figure 1 shows an example of an intermediate bench ditch that allows discharge from the drainage layer and that controls surface water runoff. The required spacing between drainage outlets is obtained by estimating the head buildup over the geomembrane and performing an infinite slope stability analysis. Head buildup can be estimated as follows (see Figure 3):

1. Assume that the topsoil is saturated during heavy rain, sheet flow is occurring over the surface, and water is percolating through the topsoil at a rate governed by its hydraulic conductivity (k_1). Using a hydraulic gradient (i_1) of 1 over an area (A_1) of unit width and length (L), the percolation into the drainage layer (Q_w) from the topsoil is based on Darcy's law as

$$Q_{(w)} = (k_1)\,(i_1)\,(A_1) = (k_1)\,(1)\,(1)\,(L) = (k_1)\,(L) \qquad (1)$$

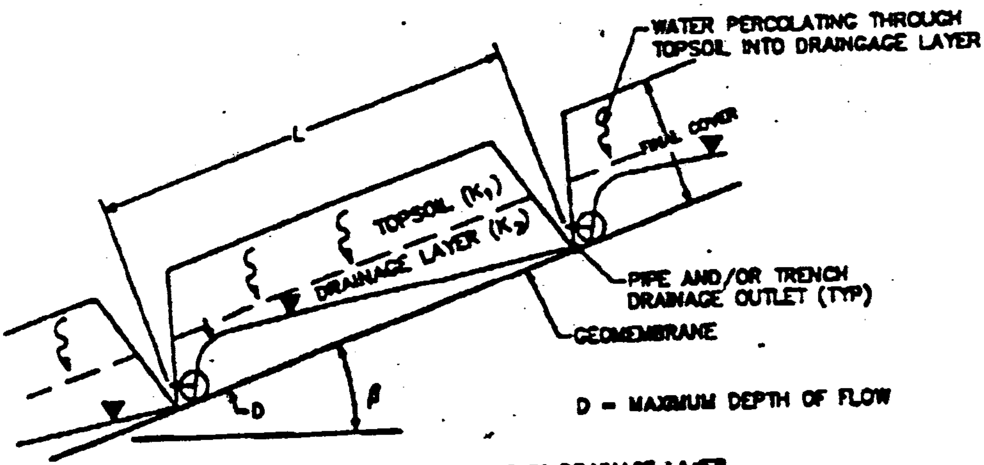

FIGURE 3. SCHEMATIC OF HEAD BUILDUP IN DRAINAGE LAYER

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2. Apply the equation of continuity: $Q_{(in)} = Q_{(out)}$. $Q_{(out)}$ is the discharge flow rate in the drainage layer (assumed to flow parallel to the slope) at the downstream (discharge) end of a slope length (L). $Q_{(out)}$ is governed by the hydraulic conductivity of the drainage material (k_2); the gradient (i_2), which is the sine of the slope angle (β); and the area (A_2) normal to the flow equal to a unit width times the flow depth (D). (2)

$$Q_{(out)} = (k_2)(i_2)(A_2) = (k_2)\sin(\beta)(1)(D)$$

3. Keep the maximum flow depth (D) less than the drainage layer thickness in this model because it is assumed that the topsoil is fully saturated. If the flow in the drainage layer rises to touch the bottom of the topsoil layer, according to this model there will be an incremental jump in pore pressures exerted on the geomembrane from the depth of the drainage layer to the full depth of the cover section. Therefore, by setting (D) equal to the drainage layer thickness, an equation can be written to solve for (L), which immediately shows the importance of estimating the relative permeabilities of the topsoil and drainage layers. (3)

$$L = (k_2)\sin(\beta)(D)/(k_1)$$

This method of estimating head buildup is conservative, though may not be unrealistic, because it does not account for evapotranspiration reducing the amount of water percolating through the topsoil. Some engineers promote the use of HELP (Schroeder, 1989) or other water balance models to estimate percolation into the drainage layer. The conservative model discussed here, however, is preferable for Northwest conditions. During the critical winter months soils are saturated by substantial antecedent rainfall, and plants are not only subject to long periods of total saturation during this time but are either dormant or relatively inactive. It is not difficult to imagine that such percolation conditions modeled above occurred in the Northwest several times during the winters of 1989-90 and 1990-91, both of which had up to 100-year storm events. Only a few minutes of these conditions can initiate a slope failure. It may not be prudent for a water balance model to include evapotranspiration for a condition during several minutes of an intense rainstorm after weeks of antecedent rainfall.

The following results were calculated for a site near Portland, Oregon, to illustrate the discrepancy between the results of the model described above and those of the HELP model to predict the maximum anticipated flow into the drainage layer. A hydraulic conductivity of $2x10^{-5}$ ft/min ($1x10^{-5}$ cm/sec) was used for the topsoil in both methods.

Water Percolating into Drainage Layer through Topsoil:
- HELP Model: 0.007 inch per hour
- Method described in this paper: 0.14 inch per hour
- Difference: Factor of 20
- Influence on selecting spacing of discharge points: Factor of 20

Although on average the HELP model may produce a good, and even conservative, estimate of the amount of liquid that would percolate annually through the topsoil, it may not estimate the peak amount that would control the stability analysis in an extreme, yet reasonable, situation. Estimating the maximum reasonable amount of water percolation through a topsoil layer is an area for potential future study and refinement.

Infinite Slope Analysis. The general geometry of a partially-saturated slope with seepage parallel to the surface is shown in Figure 4(a). The free-body diagram and force polygon for a vertical slice of the cover soils above the geomembrane are shown in Figure 4(b). Note that the pore pressure uplift force is based on the partial flow not shown in Figure 4(a).

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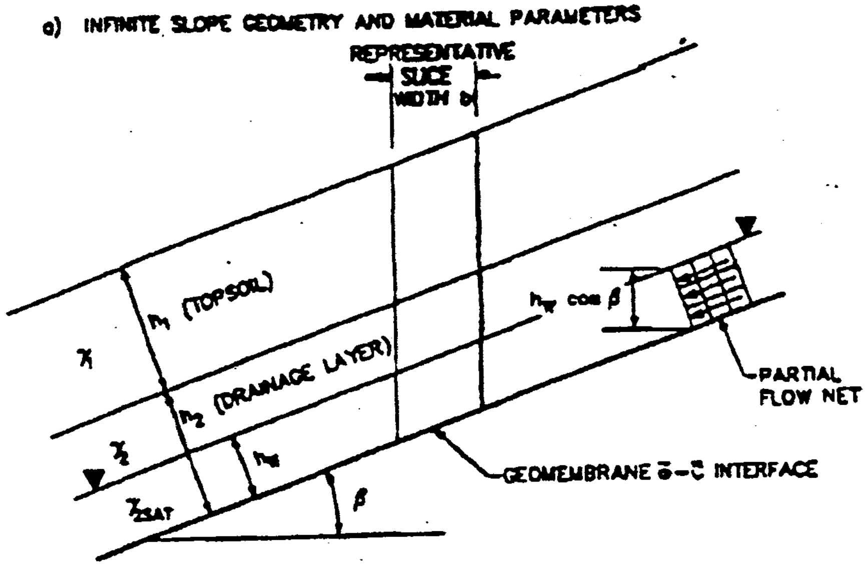


b) FORCES

$W = [h_1 \gamma_1 + (h_2 - h_w)\gamma_2 + h_w \gamma_{2SAT}] b/\cos\beta$

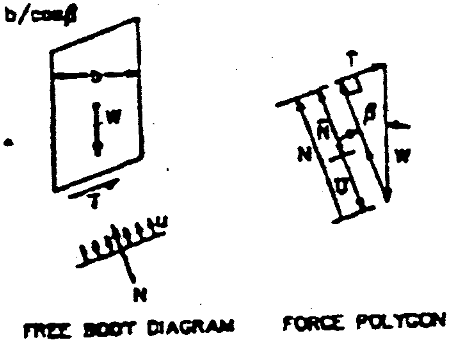
$u = \gamma_w h_w \cos\beta$

$\bar{U} = ub/\cos\beta = \gamma_w h_w b$

$N = W\cos\beta$

$T = W\sin\beta$

$\bar{N} = N - \bar{U}$



Geometric Parameters: β = slope angle; h_1 = thickness of topsoil; h_2 = thickness of drainage layer; h_w = average height of water in drainage layer normal to slope; b = width of representative slice.

Material Parameters: γ_1 = saturated unit weight of topsoil; γ_2 = moist unit weight of drainage layer; γ_{2SAT} = saturated unit weight of drainage layer; γ_w = unit weight of water; $\bar{\phi}$ = effective friction parameter for shear strength at base of drainage layer; $\bar{c}$ = effective cohesion parameter for shear strength at base of drainage layer.

Forces: u = pore pressure on base of drainage layer; $\bar{U}$ = uplifting water force; W = total weight of slice; N = total force normal to slope exerted by weight; T = tangential force to slope exerted by weight; $\bar{N}$ = effective normal force.

FIGURE 4. INFINITE SLOPE STABILITY WITH SEEPAGE PARALLEL TO SLOPE
(MODIFIED AFTER DUNN ET AL. 1980, p.241)

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The effective stress normal to base of the slice, $\bar{\sigma}$, is

$$\bar{\sigma} = \frac{\bar{N}}{b/\cos\beta} = [h_1\gamma_1 + (h_2 - h_w)\gamma_2 + h_w\gamma_{2SAT} - h_w\gamma_w]\cos\beta \tag{4}$$

The shear stress exerted tangential to the slice base, τ, is

$$\tau = \frac{T}{b/\cos\beta} = [h_1\gamma_1 + (h_2 - h_w)\gamma_2 + h_w\gamma_{2SAT}]\sin\beta \tag{5}$$

The shear strength at base of the slice, S, is

$$S = \bar{c} + \bar{\sigma}\tan\bar{\phi} \tag{6}$$

The factor of safety, defined as the ratio of the resisting shear strength divided by the driving shear stress, is

$$FS = \frac{S}{\tau} = \frac{\bar{c} + [h_1\gamma_1 + (h_2 - h_w)\gamma_2 + h_w\gamma_{2SAT} - h_w\gamma_w]\tan\bar{\phi}}{[h_1\gamma_1 + (h_2 - h_w)\gamma_2 + h_w\gamma_{2SAT}]\tan\beta} \tag{7}$$

Because the depth of saturation in the drainage layer varies, the FS would vary also. A common procedure is to compute the average FS by using the average water depth in the drainage layer, assumed to be half the maximum water depth (D) used in Equation (2). The method therefore computes an average factor of safety for the slope length between drainage discharge points. Locations upgradient of the average flow depth will have a slightly higher FS, and downgradient locations, a slightly lower FS.

The design methodology would be to compute the FS for a given cover geometry and materials properties using Equation (7), and using one half the maximum water depth (D) used in Equations (2) and (3). If the FS is acceptable, use the maximum drainage discharge spacing (L) computed in Equation (3). If the FS is unacceptably low, reduce the distance (L), recompute the average flow depth (D/2) in the drainage layer, and recompute the FS. Iterate until the FS is acceptable.

<u>Design Example.</u> Given: thickness (h_1) of 1.5 feet (45 cm) of topsoil with a saturated unit weight (γ_1) of 115 pcf (18 KN/m^3) and hydraulic conductivity (k_1) of 2x10^{-4} ft/min (1x10^{-4} cm/sec); thickness (h_2) of 1 foot (30 cm) of drainage layer with moist unit weight (γ_2) of 100 pcf (15.7KN/m^3), saturated unit weight (γ_{2SAT}) of 105 pcf (16.5 KN/m^3) and hydraulic conductivity (k_2) of 0.2 ft/min (0.1 cm/sec); slope angle (β) of 3:1 (18.4 degrees); and interface friction parameter (ϕ) of 30 degrees. Unit weight of water (γ_w) = 62.4 pcf (9.8 KN/m^3).

Find: Maximum allowable spacing (L_{max}) between drainage outlets designed subparallel to slope contours such that the maximum depth (D) of accumulated water in the drainage layer is one foot (30 cm), and a minimum average FS of 1.5 is maintained.

Solution:

$$L_{(max)} = (k_2)\sin(\beta)(D)/(k_1) = 0.2\sin(18.4)(1)/0.0002 = 316\,ft\,(96\,m)$$

$$FS = \frac{[(h_1)(\gamma_1) + (h_2 - D/2)(\gamma_2) + (D/2)(\gamma_{2SAT}) - (D/2)(\gamma_w)]\tan(\phi)}{[(h_1)(\gamma_1) + (h_2 - D/2)(\gamma_2) + (D/2)(\gamma_{2SAT})]\tan(\beta)} \tag{8}$$

$$= \frac{[(1.5)(115) + (1 - .5)(100) + (.5)\ (105) - (.5)(62.4)]\tan(30)}{[(1.5)(115) + (1 - .5)(100) + (.5)(105)]\tan(18.43)} = 1.5\ (ok)$$

<u>Factor of Safety.</u> Geotechnical engineers often feel comfortable with a minimum FS of 1.5 for long-term static slope stability conditions. This value originated from dam

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designs and may or may not be applicable to landfill slope stability in general, or cover stability in particular. The EPA (1992b) suggests that a FS between 1.25 and 1.5 might be acceptable depending on the level of certainty in the shear strength parameters. The following factors should be considered when selecting a minimum FS for a landfill cover: experience with geosynthetics has a relatively short history; level of confidence in assumed material properties; factors of safety may already be included in the estimated material properties; and the situation being analyzed is considered a worst case that will occur a small percentage of the time. A minimum FS of 1.5 has been used without failures attributable to underdesign of the drainage layer in the Northwest.

Seismic Considerations. New Subtitle D regulations require checking all elements of landfill design for stability due to seismic loading. A Newmark-type analysis (Newmark, 1965) is recommended for the cover. Consideration should be given to how much saturation should be allowed for in the drainage layer for the analysis (using the maximum amount computed for static stability would probably be overly conservative), and what amount of deformation would be acceptable. Because cover deformation is not life-threatening, and because it could be inspected and repaired after the event, the acceptable amount should be somewhat higher than the amount for a bottom liner. Acceptable deformations for bottom liners have been cited as 6 to 12 inches (15 to 30 cm) for a conservatively selected design earthquake (Seed and Bonaparte, 1992). One approach is to use these same criteria for covers modeled in a dry condition because the chance of an earthquake occurring at the same time as the maximum conservative saturation condition discussed in this paper is much more remote than the earthquake alone. Another approach is to recognize that the cover system does not directly affect the ability of a lined landfill to contain waste, and that it can be inspected and repaired. Therefore, the cover could be allowed to sustain a higher level of deformation, say on the order of one to three feet (30 to 90 cm). Often a design that is satisfactory for the worst case static condition with a reasonable FS is acceptable for a seismic condition.

CONSTRUCTION ISSUES AND PRODUCTION

The following paragraphs describe construction issues related to major elements of a final cover section, surface water ditches, and geomembrane penetrations. Anticipated production rates for constructing major elements of a cover are also provided for planning and scheduling purposes.

Settlement Considerations. Design changes on landfill closures are nearly unavoidable, mainly because landfills settle. Landfill owners and operators, however, expect the designer to achieve the lowest possible construction costs by preparing such complete bid packages that contractor claims and change orders during construction are minimized. Nevertheless, design changes to account for settlement must be expected, planned for, and executed during the construction phase of the project.

Design elements particularly susceptible to settlement are the horizontal and vertical control for roads, ditches and pipelines. For example, the design of both the

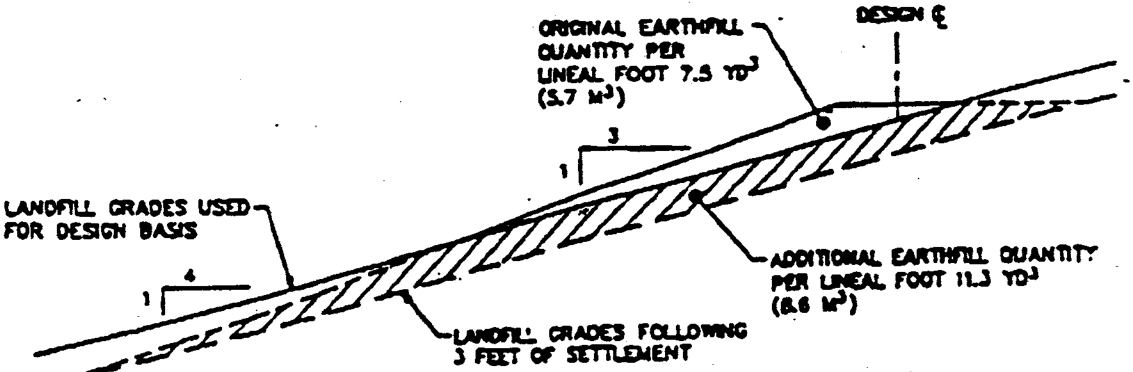

FIGURE 5. EFFECT OF SETTLEMENT ON ROAD DESIGN WITH SET HORIZONTAL AND VERTICAL CONTROL

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horizontal and vertical alignment of a road for the side hill of a landfill was based on topographic mapping prepared 12 months before construction. Figure 3 shows the effect of 3 feet of settlement on an actual road section designed on a 4:1 side slope. Accommodating this settlement required either increasing the material to construct the road to design grades and alignments or rapidly redesigning the horizontal and vertical alignment during construction. The increased quantity of soil required to build the road to design grades was 11.3 cubic yards (8.6m³) per lineal foot (0.3m) at a potential additional cost to the client of $158 per lineal foot. This would have added approximately $450,000 to the total project cost. Redesigning the road was the less expensive option, even if the contractor had put in a claim for delay.

Such design problems can be avoided. Instead of specifying set horizontal and vertical control in the bid documents, it would be better to design a typical road cross section relative to the final cover, set a general horizontal alignment, and require minimum cross slopes and longitudinal grades. Although more field engineering is involved, settlement makes this extra work inevitable. Final alignment of items that can be affected by settlement should not be fixed until the construction phase of the project.

Foundation Soil. A critical element in planning foundation layer construction is estimating the quantity of soil required to meet the design intent. Often landfill surfaces are poorly graded, have refuse exposed in areas, and have areas requiring significant earthfills to meet minimum final slope requirements. Assuming an average depth of foundation soil based on a typical cover cross section usually results in underestimating the quantity required to complete the work.

Experience has shown that for poorly graded landfills, where the refuse was recently placed and where daily cover is minimal, the quantity of soil required to provide a uniform grade and a 1-foot (30 cm) minimum depth of soil cover is 2 to 3 cubic feet (0.06 to 0.08m³) of soil per square foot (0.09m²) of landfill area.

Production rates for placing foundation layer soil depend on the source of the material, available equipment, and site access. If soil is available on-site near the construction area daily quantities of 5,000 to 10,000 cubic yards (3,800 to 7,650m³) per day can be achieved. If the soil source is from off-site, a large trucking fleet will be required and production of more than 6,000 cubic yards (4,600m³) per day is difficult to achieve.

Bedding Soil. The critical element in placing bedding layer soil is preparing a well graded subgrade (top of foundation soil). A well graded subgrade will minimize the quantity of bedding soil required to meet minimum thickness requirements. A rough graded subgrade with holes or ridges will require higher quantities of bedding soil, raise costs, and slow the schedule. Closely spaced grade control is also a key to constructing a quality uniform-depth bedding layer. Spacing grade control on a 50-foot (15m) grid is common.

Bedding soil, particularly where it is used to transmit gas or leachate, is typically a processed and imported soil. Production rates of 1,500 to 2,000 cubic yards (1,150 to 1,500m³) per day can be achieved which result in 2 to 3 acres (0.8 to 1.2 hectares) of completed bedding layer per day.

Geomembrane. Critical elements for geomembrane installation are maintenance of the bedding layer grades during deployment, quality seaming, and protection of the geomembrane during placement of the drainage layer.

Equipment and foot traffic can rut and put holes in a sandy bedding layer. Repair of this disrupted grade is required for a quality geomembrane installation. A smooth foundation for geomembrane installation is also critical to seaming operations and for avoiding undue stress on the geomembrane materials.

A large amount of information has been written concerning obtaining quality geomembrane seams. It is not the intent of this paper to describe geomembrane seam construction in detail (see, for example, EPA, 1989). However, in summary, the following should be considered:

- Qualified personnel should perform the work.
- Welding equipment should be well maintained and checked frequently to assure proper operation. This is particularly important for the heating elements of welding machines.
- The installer should have a well planned quality control plan and the Owner should provide on-site representation to assure compliance with the plan and provide quality assurance testing.
- Test equipment should be well maintained, properly calibrated, and meet the requirements of the test procedures.

Production rates for geomembrane installation vary significantly based on complexity of projects, project size and schedule. Installations of 100,000 square feet (9,300m^2) per day for polyethylene are not uncommon. For planning purposes, however, production rates of 30,000 to 40,000 square feet (2,800 to 3,700m^2) per day are reasonable.

Drainage Layer. The drainage layer component of a final cover, particularly for steep slopes, is the most difficult to construct and the most important for the design. Many things can go wrong and planning to prevent problems is essential to success.

The drainage material must meet gradation and permeability requirements. Discovering that a product does not meet these requirements following its placement on the geomembrane can be costly. Removing material from the top of geomembrane is much more difficult than placing it.

A good quality control plan can avoid this problem by verifying material compliance with specifications before the material is placed. This may include source sampling and testing before approval of the material is granted. Monitoring delivery of material to the site is also important. Providing on-site testing capabilities can speed up the quality assurance monitoring of the material.

Drainage material placement should be monitored closely to assure no damage is done to the geomembrane, wrinkles are controlled, and proper thickness is achieved. Low ground pressure dozers work well to place this material but often require long pushes from the point where the material is delivered.

Drainage material placement is often the critical path in scheduling a cover project. The time required to produce the material, available trucking for delivery, and equipment necessary to handle the material on-site all need to be considered. Production rates of 3,000 to 4,500 cubic yards (2,300 to 3,400m^3) per day can be achieved, but logistical plans for this production rate must take into account that this means about 250 truck loads of material will be delivered per day.

Geotextile. Installation of geotextile is straight forward. Items to consider are protection from ultraviolet degradation and seaming of the product in the field. Production rates to meet schedules are usually not a problem.

Topsoil. Topsoil is placed at the end of a project, and the key to its success is constructing it in time to seed it, get vegetation to germinate, and protecting top soil from erosion. Simple methods of erosion protection that have proven effective are track walking a slope so that dozer tracks are deep and perpendicular to the line of slope, and covering the completed soil layer with 2 to 4 inches (5 to 10 cm) of straw. In colder climates this helps insulate seed and provides additional erosion protection. More sophisticated erosion control methods are available if needed. Production rates are usually between those for foundation soil and drainage layer.

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Ditches. The most common construction error for surface water ditches is not paying attention to the cross sectional details of the ditch. The ditch in Figure 1 is a good example. In this ditch the design water depth is the highest elevation of geomembrane. If during construction the geomembrane is not brought up on the downstream side of the ditch and the contractor decides to maintain the overall depth of ditch with soil, then the soil above the geomembrane on the downstream side of the ditch must contain the water. If this soil is permeable or erodible the ditch can fail at high water levels, and damage the downslope cover. Protection against this problem is a good design, quality ditch installation, good quality control, and detailed construction staking and construction techniques.

Geomembrane Penetration. Two common problems occur with penetrations through geomembrane covers: (1) stresses are put on the geomembrane boot during drainage layer construction that result in boot failures or failures of the pipe penetrating the geomembrane, and (2) landfill gas escapes.

Figure 6 shows a detail that has been constructed successfully on cover projects that prevents these problems. The key to this detail is not the detail itself, but the timing of installation. The geomembrane boot should not be welded to the geomembrane cover until the major portion of drainage layer is placed. Geomembrane covers move during drainage layer placement, particularly on slopes. If the boot is installed prior to drainage layer placement then movement of the geomembrane transfers stresses to the area of the rigid pipe penetration. Landfill gas losses through the boot are prevented by the hydrated bentonite shown on the detail.

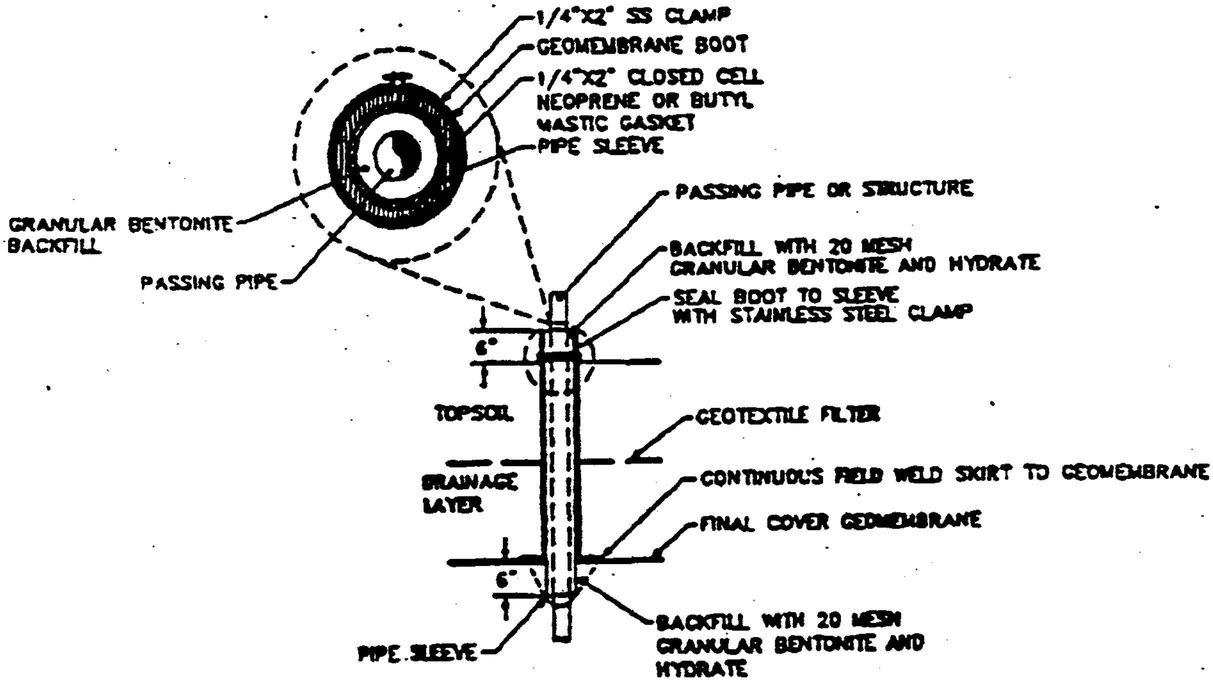

FIGURE 6. GEOMEMBRANE BOOT PENETRATION

Overall Production Rate. Overall construction time for a typical 25-acre (10-hectare) project is on the order of 3 to 4 months, although projects up to twice this size have been constructed in the same amount of time. Key factors affecting the schedule are the amount of equipment and manpower used by the contractor, efficient scheduling and construction management, well prepared drawings and specifications, and cooperation between the owner, engineer, and contractor.

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SUMMARY AND DISCUSSION

1. Using geomembranes for landfill covers has increased in recent years because they perform better and are often more cost-effective than soil-only covers. The new Subtitle D regulations will likely require geomembrane final covers on most new landfills that have bottom geomembrane liners. Engineers need to develop an understanding and methodology for designing such landfill covers.

2. Two important considerations in designing geomembrane covers are the interrelated issues of slope stability and drainage. The infinite slope method is appropriate for modeling cover slope stability. Applying Darcy's law to an assumed saturated topsoil condition is a conservative yet rational method for estimating maximum head buildup in the drainage layer above the geomembrane for use in the infinite slope analysis.

3. The actual materials that will be used for each project should be tested to obtain design parameters. In cases where material selection is left to the contractor, provisions should be made in the specifications to address minimum or maximum allowable material properties and conformance testing so that the design intent is met.

4. Construction project planning should include provisions for field engineering modifications to allow for landfill settlement.

5. Construction quality control and quality assurance monitoring is important for

- Soil material conformance testing
- Geosynthetic material conformance testing and installation observation
- Grade tolerances and layer thickness control
- Construction details such as ditch cross sections and pipe boot installation

6. Construction planning and sequencing can improve efficiency and allow realistic scheduling.

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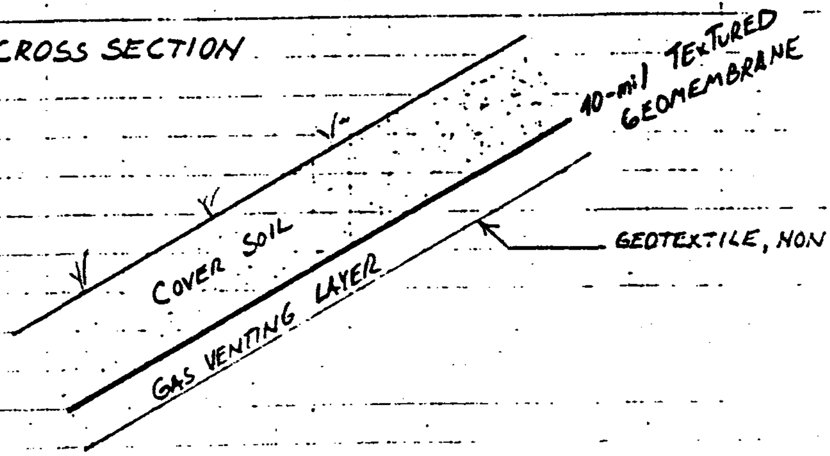
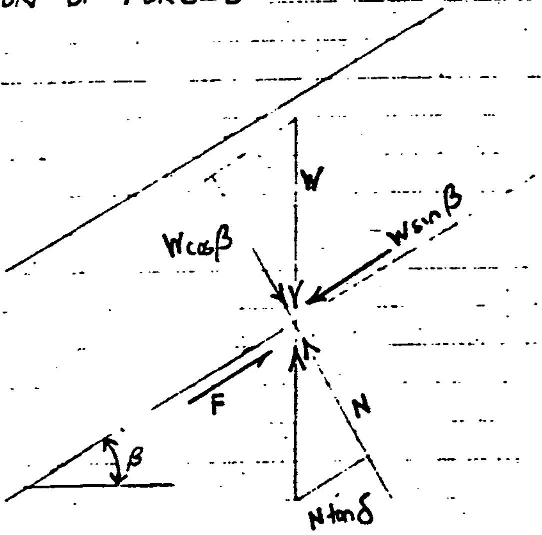
STABILITY OF COVER SOILS – UNSATURATED

TYPICAL CROSS SECTION



RESOLUTION OF FORCES



W is weight of soil on cover

β is slope angle

δ is friction angle between cover soil and geomembrane

$$\text{Factor of Safety} = F.S. = \frac{\text{Resisting Forces}}{\text{Driving Forces}} = \frac{F}{W\sin\beta}$$

$$F.S. = \frac{N\tan\delta}{W\sin\beta} = \left[\frac{W\cos\beta}{W\sin\beta}\right]\tan\delta = \frac{\tan\delta}{\tan\beta} \triangleleft\!\!-\!\!-$$

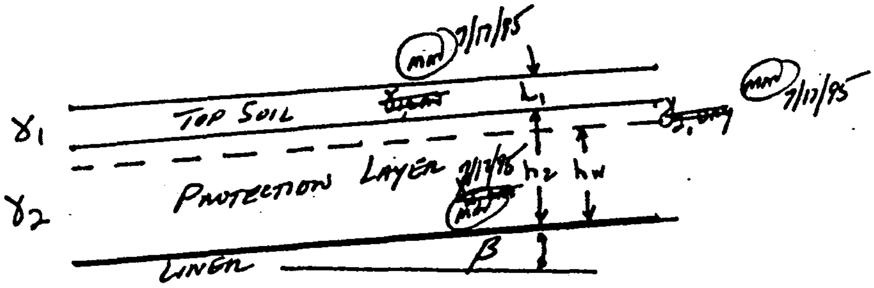
The maximum sideslope which will be used on the landfill will be 25%
∴ $\beta = 14.04°$

The friction angle between a textured LLDPE liner and sand is 30° (from manufacturer) and between a non-textured [redacted] liner and sand is [redacted] 20° MWM 10/20/98
The friction angle between a non woven geotextile and sand is 26° (from "Designing with Geosynthetics", Koerner, 1990 Prentice Hall, NJ, Table 5.5)

III. SATURATED SLOPE STABILITY FACTORS

SAFETY FACTORS ARE CALCULATED USING THE METHOD PRESENTED AT THE GEOSYNTHETICS '93 CONFERENCE, IN A PAPER TITLED "GEOSYNTHETIC LANDFILL COVER DESIGN METHODOLOGY AND CONSTRUCTION EXPERIENCE IN THE PACIFIC NORTHWEST." (SEE ATTACHMENT 4).

THERE ARE THREE SCENARIOS TO BE MODELED: PARTIALLY SATURATED ($h_w < h_2$), PARTIALLY SATURATED (~~hw~~ MW 7/17/95 $h_2 < h_w < h_1 + h_2$), AND SATURATED.



① PARTIALLY SATURATED ($h_w < h_2$)

$$FS = \frac{C + (h_1\gamma_1 + (h_2 - h_w)\gamma_2 + h_w \gamma_{2sat} - h_w \gamma_w] \tan \phi}{[h_1\gamma_1 + (h_2 - h_w)\gamma_2 + h_w \gamma_{2,sat}] \tan \beta}$$

WHERE: C = EFFECTIVE COHESION PARAMETER FOR SHEAR STRENGTH AT BASE OF DRAINAGE LAYER

β = SLOPE ANGLE

ϕ = EFFECTIVE FRICTION PARAMETER FOR SHEAR STRENGTH AT THE BASE OF THE DRAINAGE LAYER.

h_1, h_2, h_w = HEIGHT OF TOPSOIL, PROTECTION LAYER, AND WATER, RESPECTIVELY. MW

$\gamma_1, \gamma_2, \gamma_w$ = UNIT WEIGHTS OF TOPSOIL, PROTECTION LAYER, AND WATER, RESPECTIVELY.

$\gamma_{1SAT}, \gamma_{2SAT}$ = SATURATED UNIT WEIGHTS OF TOP SOIL AND PROTECTION LAYER, RESPECTIVELY.

② PARTIALLY SATURATED ($h_2 < h_w < h_1 + h_2$)

$$FS = \frac{C + [(h_1 - (h_w - h_2))\gamma_1 + (h_w - h_2)\gamma_{1,SAT} + h_2 \gamma_{2,SAT} - h_w \gamma_w] \tan \phi}{[(h_1 - (h_w - h_2))\gamma_1 + (h_w - h_2)\gamma_{1SAT} + h_2 \gamma_{2,SAT}] \tan \beta}$$

(2) FULLY SATURATED [redacted]

$$FS = \frac{C + [h_1 \gamma_{1SAT} + h_2 \gamma_{2SAT} - (h_1 + h_2)\gamma_W] \, TAN \, \phi}{[h_1 \gamma_{1SAT} + h_2 \gamma_{2SAT}] \, TAN \, \beta}$$

THESE THREE EQUATIONS TAKE INTO ACCOUNT THAT THE TOPSOIL LAYER (h_1) IS <u>NOT</u> NECESSARILY SATURATED, DEPENDING ON THE RESULTS OF THE HELP3 ANALYSIS. THE METHOD PRESENTED IN THE GEOSYNTHETICS '93 CONFERENCE WAS SPECIFICALLY DEVELOPED FOR LANDFILLS FOUND IN THE PACIFIC NORTHWEST, WHERE TOPSOILS ARE SUBJECTED TO LONG PERIODS OF ANTECEDENT RAINFALL DURING WINTER MONTHS.

THE CONSTANTS USED FOR THESE EQUATIONS WERE DETERMINED AS FOLLOWS:

$C = 0$ (ASSUME SOIL W/OUT COHESIVE PROPERTIES; SEE ATTACHMENT 5)

MNM 10/20/98

$h_1 = 0.5'$ 1-2' (VARIABLE) [redacted]

$h_2 =$ [redacted]

$\gamma_W = 62.4 \ lb/CF$

h_W = VARIABLE; DETERMINED USING THE HELP MODEL [redacted]

$\phi = 30°$ (ASSUME TEXTURED LINER, [redacted]
$20°$ (ASSUME SMOOTH LINER FOR SLOPES [redacted])

β = VARIABLE WITH THE SECTION BEING ANALYZED. (2-33%) [redacted]

γ_1 : RIVERHEAD SANDY LOAM, MAX. DENSITY ≈ 130 lb/CF
ASSUME 85% COMPACTION
$\rightarrow 130 \times 0.85 = \underline{110 \ lb/CF}$, (topsoil)

MNM

7/17/95

$\gamma_{1,SAT}$: FOR SATURATED SOILS, $\gamma d = \frac{(\text{SPECIFIC } \cancel{\text{GRAVITY}} \text{ WEIGHT SOIL})(\text{SPECIFIC GRAVITY WA}}{1 + e}$

A TYPICAL VALUE FOR SPECIFIC GRAVITY OF SOIL IS 2.65; $\gamma_{WATER} = 62.4$ (SEE ATTACHMENT 9).

$$e = \frac{\gamma_W \cdot SG_{SOIL}}{\gamma d} - 1 = \frac{(62.4 \ lb/CF)(2.65)}{110 \ lb/CF} - 1 = 0.503 ✓$$

7/17/95

$$n \ (\text{POROSITY}): \quad e = \frac{n}{1-n} \rightarrow 0.503 = \cancel{\frac{n}{n-1}} \ \frac{n}{1-n}$$

$$\Rightarrow n = 0.3348 ✓$$

$$\gamma_{1SAT} = \gamma_{1DRY} + n\gamma_W = 110 \ lb/CF + (0.335)(62.4 \ lb/CF) = \underline{131 \ lb/CF} ✓$$

6/

γ_2 : FROM SOIL TESTING OF SOILS FROM ON-SITE BORROW AREAS, MAX. DENSITY = 130 lb/CF. AT 90% COMPACTION $\gamma_2 = 117$ lb/CF

$\gamma_2 = 117$ lb/CF ← ✓
(PROTECTION LAYER)

$\gamma_{2,SAT}$: $e = \frac{\gamma_w \, SG_{SOIL}}{\gamma_{dry}} - 1 = \frac{62.4\,(2.65)}{117} - 1 = 0.413$ ✓

$\left(e = \frac{n}{1-n}\right) \rightsquigarrow n = 0.413(\cancel{1-n})$ 7/17/95 $\frac{}{1-n}$ $\rightsquigarrow n = 0.292$ ✓

$\gamma_{2,SAT} = \gamma_{2,DRY} + \gamma_w n = 117 + 0.292(62.4) = 135.2$ lb/CF ✓

$\gamma_{2,SAT} = 135$ lb/CF ← ✓

FACTORS OF SAFETY FOR ALL THREE SCENARIOS WILL BE CALCULATED IN THE FOLLOWING DEMONSTRATION. THE RESULTS FOR ALL SLOPES ARE SUMMARIZED IN A SPREADSHEET TABLE PROGRAMMED WITH THE APPROPRIATE FORMULAS AND VALUES:

FER T
TES 10 R
R
EVISED
ULATION

SLO 4 (PARTIALLY SATURATED, $h_2 > h_w$)

$h_w = 22.80" \rightsquigarrow 1.91'$ ✓
$S = 25.0\%$
SLOPE $\beta = 14.036°$
$\phi = 30°$

MM 7/17/95 MM

$FS = ~~[(0.5 - 1.91~~ ~~[(0.5~~ 1.9$

$= \frac{[(0.5)(110) + (2 - 1.91)(117) + (1.91)(135) - 1.91(62.4)] \tan 30°}{[0.5(110) + (2-1.91)(117) + 1.91(135)] \tan(14.036)}$

$= \frac{(55 + 10.53 + 257.85 - 119.84) \tan 30}{(55 + 10.53 + 257.85) \tan 14.036}$

$= \frac{203.54(0.88)}{322.38}$

$= 1.460$ ✓ ✓

FrictionFlex®
Application Data

SLT's FrictionFlex® process provided the industry's first textured liner. It is the only geomembrane texturing process ever to be granted a U.S. Patent. It, in fact, has been awarded two*. In direct contrast to blown-film geomembranes which are textured or made rough by a process which actually erodes the sides of the sheet, the FrictionFlex process is additive. SLT begins with 24-foot wide SLT HyperFlex® or UltraFlex® sheet manufactured to the industry's most exacting standards. Only after the sheet passes all QC, is texturing added to one or both sides as required by the application. When the engineer utilizes SLT geomembranes textured by the FrictionFlex process, increased facility design capacity, service life and total revenue potential can be obtained. Containment slopes, vertical expansions and perimeter slopes in closures share the benefits of greater air-space and superior cover stability.

Most importantly, the advantages of FrictionFlex are available without compromise of any performance property or other issue of secure containment. The patented manufacturing process enables SLT to produce a textured liner exhibiting similar mechanical and chemical properties demanded of SLT's premium grades of smooth geomembrane liners, whether HyperFlex, UltraFlex, or other Polyethylene.

An added feature of SLT's process is that an edge, 6-to-8 inches wide, is left smooth to aid in welding and field quality control. This allows standard installation equipment and procedures to ensure expedient construction.

The following reflects independent data confirming superior FrictionFlexed liner performance in contact with soils and synthetics:

- **High coefficient of friction with soils**
- **High coefficient of friction with synthetics**
- **Premium grade mechanical and chemical properties**
- **Excellent Strength Elongation**

SLT Textured Liner Materials				Typical Smooth HDPE
Material	**Coefficient of Friction**	**Adhesion (per square foot)**	**Average Friction Angle (degrees)**	**Comparable Friction Angle**
Sandy Glacial Till	0.74	27	36	20
Sandy Clay	0.70	65	35	18
Smooth Clay	0.62	39	32	16
Ottawa Sand	0.59	21	30	19
Non-woven Polyester Geotextile	0.54	116	28	11
Non-woven Polypropylene Geotextile	0.65	133	33	12

NOTE: The above data is approximate. SLT recommends that specific data be developed for all application designs. Shear box testing of the specific geosynthetic and natural components of the composite is necessary to establish an appropriate design basis. SLT will be pleased to provide any necessary material samples for such purposes and invites comparative procedures.

*U.S. Patent No. 4,885,201
5,075,135

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[redacted]

TABLE 5.5 FRICTION VALUES AND EFFICIENCIES (IN PARENTHESES) FOR (a) SOIL-TO-GEOMEMBRANE, (b) GEOMEMBRANE-TO-GEOTEXTILE, AND (c) SOIL-TO-GEOTEXTILE COMBINATIONS*

(a) Soil-to-geomembrane friction angles

Geomembrane	Soil types Concrete sand ($\phi = 30°$)	 Ottawa sand ($\phi = 28°$)	 Mica schist sand ($\phi = 26°$)
EPDM	24° (0.77)	20° (0.68)	24° (0.91)
PVC			
rough	27° (0.88)	—	25° (0.96)
smooth	25° (0.81)	—	21° (0.79)
CSPE	25° (0.81)	21° (0.72)	23° (0.87)
HDPE	18° (0.56)	18° (0.61)	17° (0.63)

use 20°

(b) Geomembrane-to-geotextile friction angle

Geotextile	Geomembrane EPDM	PVC Rough	 Smooth	 CSPE	 HDPE
nonwoven, needle-punched	23°	23°	21°	15°	8°
nonwoven, melt-bonded	18°	20°	18°	21°	11°
woven, monofilament	17°	11°	10°	9°	6°
woven, slit film	21°	28°	24°	13°	10°

(c) Soil-to-geotextile friction angle

Geotextile	Soil types Concrete sand ($\phi = 30°$)	 Ottawa sand ($\phi = 28°$)	 Mica schist sand ($\phi = 26°$)
nonwoven, needle-punched	30° (1.00)	26° (0.92)	25° (0.96)
nonwoven, melt-bonded	26° (0.84)		—
woven, monofilament	26° (0.84)	—	—
woven, slit film	24° (0.77)	24° (0.84)	23° (0.87)

Source: After Martin, et al. [8]

*Efficiency values in parentheses are based on the relationship $E = (\tan \delta)/(\tan \phi)$

on smooth geotextiles giving the lowest friction values. For reference purposes, Part c of Table 5.5 gives the soil-to-geotextile friction values that are necessary for slope design of lined slopes with geotextiles under or over the liner.

The frictional behavior of geomembranes placed on clay soils is of considerable importance in the composite liners of waste landfills. Current requirements are for the

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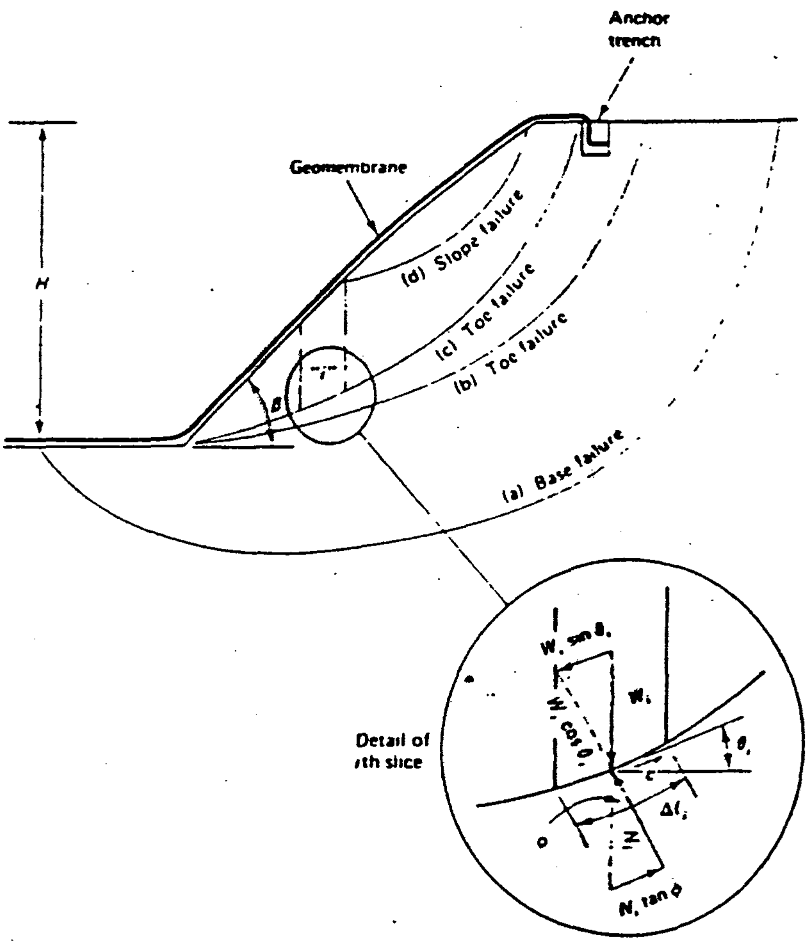

Figure 5.22 Various types of geomembrane covered soil slope stability failures.

c = the cohesion of the soil,
R = the radius of the failure circle, and
n = the number of slices utilized.

Note that in this equation R factors out from both numerator and denominator and cancels out. This is not the case if other terms, such as seismic forces and live loads, are involved. Once the factor of safety has been calculated for the arbitrarily selected center and radius of the assumed circle, a search is conducted to determine what particular circle gives the lowest factor of safety. When found, this value is evaluated under the criteria that $FS < 1.0$ is unacceptable, $FS \cong 1.0$ is incipient failure, and $FS > 1.0$ is stable, with higher values being even safer. $FS \geq 1.5$ is often a targeted value. If the FS value is too low, the slope angle β is decreased until the FS value is adequate.

USE FS = 1.5

The process described above is very time-consuming, and numerous design charts

"Designing with Geosynthetics", Koerner, 1990
Prentice Hall, New Jersey

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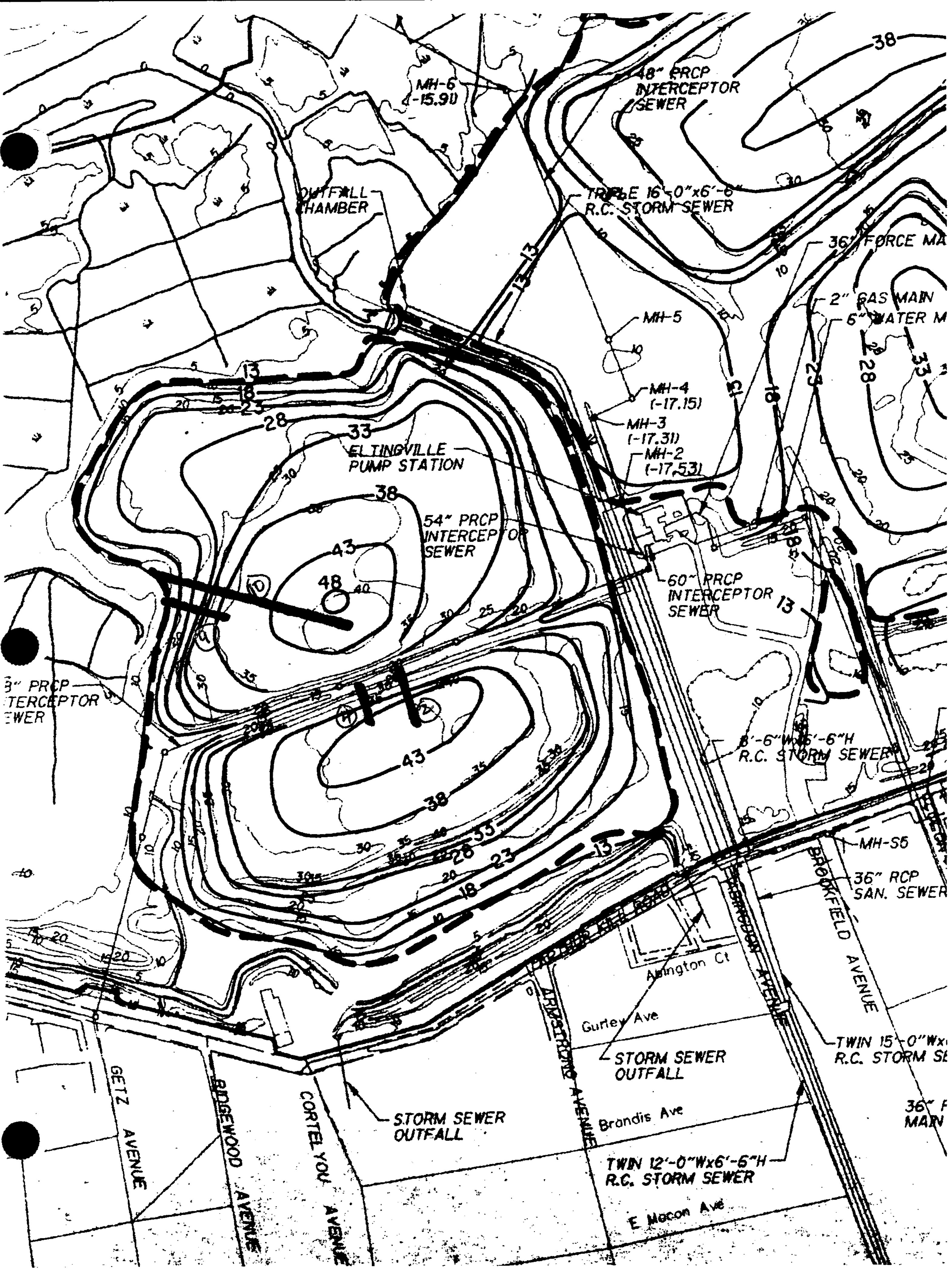
SLOPE LOCATIONS


MH-6
(-15.91)
48" PRCP INTERCEPTOR SEWER
OUTFALL CHAMBER
TRIPLE 16'-0"x6'-6" R.C. STORM SEWER
36" FORCE MA
2" GAS MAIN
6" WATER M
MH-5
MH-4
(-17.15)
MH-3
(-17.31)
MH-2
(-17.53)
ELTINGVILLE PUMP STATION
54" PRCP INTERCEPTOR SEWER
60" PRCP INTERCEPTOR SEWER
8" PRCP
TERCEPTOR
EWER
8'-6"Wx6'-6"H R.C. STORM SEWER
MH-S5
36" RCP SAN. SEWER
BROOKFIELD AVENUE
ARRINGTON AVENUE
Arrington Ct
Gurley Ave
Brandis Ave
E Macon Ave
ARMSTRONG AVENUE
STORM SEWER OUTFALL
STORM SEWER OUTFALL
TWIN 15'-0"Wx
R.C. STORM S
36" F
MAIN
TWIN 12'-0"Wx6'-6"H R.C. STORM SEWER
GETZ AVENUE
RIDGEWOOD AVENUE
CORTELYOU AVENUE
ARDEN HILL ROAD
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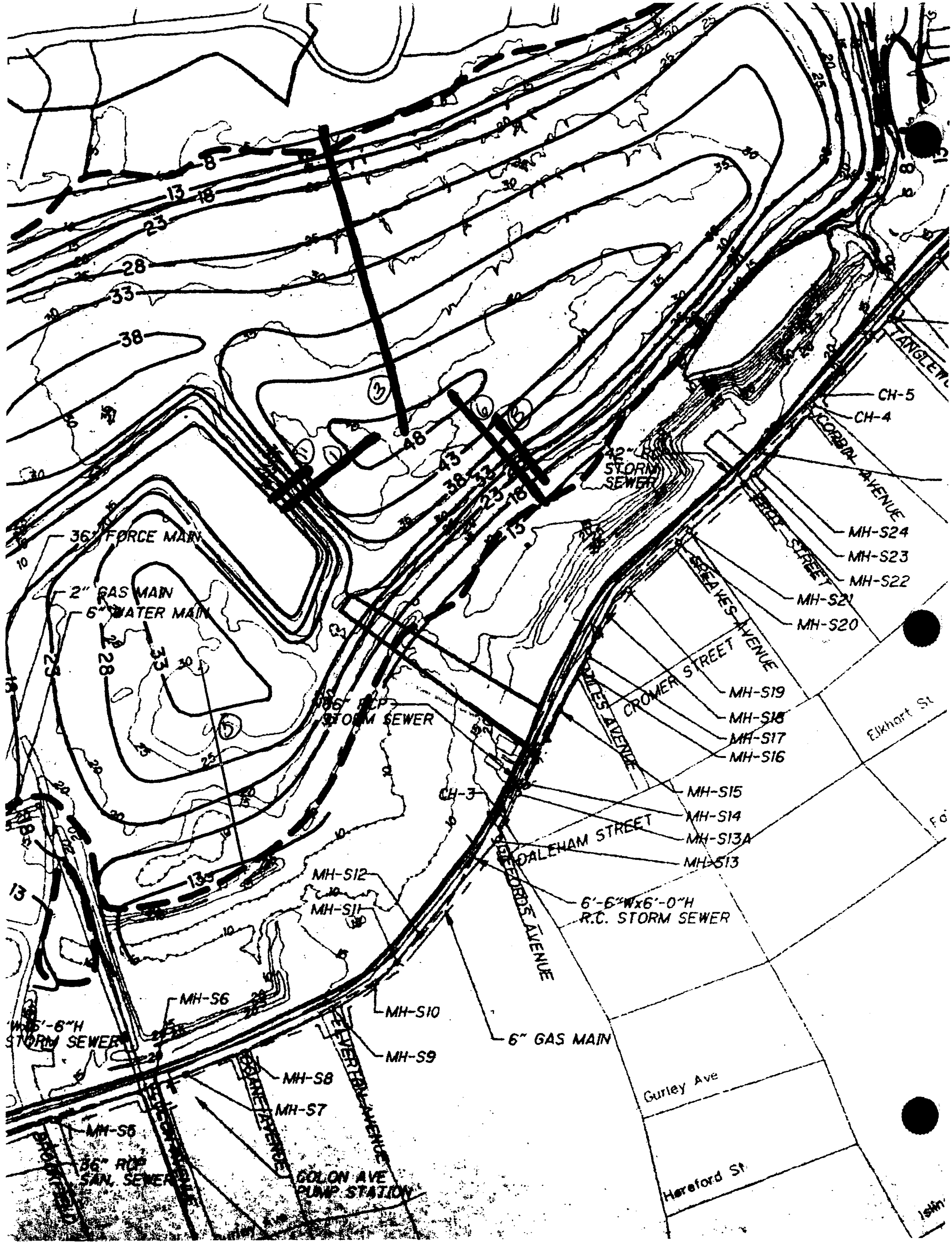
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TANGLEWO
CH-5
CH-4
CORBIN AVENUE
42" RCP STORM SEWER
MH-S24
MH-S23
MH-S22
MH-S21
MH-S20
PROBY STREET
SPEAKES AVENUE
CROMER STREET
MH-S19
MH-S18
MH-S17
MH-S16
Elkhart St
MH-S15
MH-S14
MH-S13A
MH-S13
DALEHAM STREET
36" FORCE MAIN
2" GAS MAIN
6" WATER MAIN
36" RCP STORM SEWER
CH-3
MH-S12
MH-S11
6'-6"Wx6'-0"H R.C. STORM SEWER
MH-S10
MH-S9
6" GAS MAIN
MH-S6
W5'-6"H STORM SEWER
MH-S8
MH-S7
MH-S5
36" RCP SAN. SEWER
COLON AVE PUMP STATION
Gurley Ave
Hereford St
Islin
Fo

12-INCH PROTECTION LAYER, 2% SLOPE
HELP MODEL RESULTS
NO GEOGRID DRAINAGE LAYER

Project Brookfield Ave. Job No. ______ Date 10/20/98
Computed By MWM Checked By ______ Date Checked ______
Client NYCDEP Page No. ______

SLOPE STABILITY ANALYSIS

ALTERANTIVE D - 2% MINIMUM SLOPE, 12" PROTECTION LAYER

Location	Slope (degrees)	Slope Length (ft)	Friction Angle (degrees)	Friction Angle (radians)	Hw	Hw	Resisting Term	Driving Term	FS
Partially Saturated (H2>Hw)									
	0	0	0	0.00	0.00	0.00	0.00	0.00	ERR
Partially Saturated [H2<Hw<(H1+H2)]									
2	17.7	130	30	0.52	17.64	1.47	62.40	35.38	1.76
4	33	90	30	0.52	13.81	1.15	70.03	63.74	**1.10**
8	12.5	200	20	0.35	17.99	1.50	38.90	25.06	1.55
9	13.9	180	30	0.52	17.94	1.50	61.79	27.86	2.22
11	22.7	110	30	0.52	16.80	1.40	64.07	45.04	**1.42**
Saturated [Hw=(H1+H2)]									
1	9.7	330	20	0.35	18.00	1.50	38.89	19.45	2.00
2	17.7	330	30	0.52	18.00	1.50	61.68	35.49	1.74
3	4.5	800	20	0.35	18.00	1.50	38.89	9.02	4.31
5	4.2	550	20	0.35	18.00	1.50	38.89	8.42	4.62
6	10.3	350	20	0.35	18.00	1.50	38.89	20.65	1.88
8	12.5	200	20	0.35	18.00	1.50	38.89	25.06	1.55
9	13.9	180	30	0.52	18.00	1.50	61.68	27.87	2.21
10	6.6	500	20	0.35	18.00	1.50	38.89	13.23	2.94

C= 0 unitless
SG1 = 110 lb/cf
SG1 (sat) = 131 lb/cf
SG2 = 117 lb/cf
SG2(sat) = 135 lb/cf
SG w = 62.4 lb/cf
h1 = 0.5 ft
h2 = 1 ft

Note:

1. Friction angles of 20 and 30 degrees are representative of smooth and textured geomembrane.

```
****************************************************************************
****************************************************************************
**                                                                        **
**                                                                        **
**        HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                  **
**         HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                    **
**           DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**             USAE WATERWAYS EXPERIMENT STATION                         **
**        FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                **
**                                                                        **
**                                                                        **
****************************************************************************
****************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATd1ba.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outd1.OUT


TIME: 20:45   DATE: 10/21/1998


****************************************************************************

  TITLE: Brookfield Avenue Landfill - 2% Minimum Slope, 12" Protection Layer

****************************************************************************


  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                            LAYER  1
                            --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER  6
         THICKNESS                 =     6.00  INCHES
         POROSITY                  =    0.4530 VOL/VOL
         FIELD CAPACITY            =    0.1900 VOL/VOL
         WILTING POINT             =    0.0850 VOL/VOL
         INITIAL SOIL WATER CONTENT =   0.1901 VOL/VOL
         EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
      NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
             FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                            LAYER  2
                            --------

                   TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER  5
         THICKNESS                 =    12.00  INCHES
         POROSITY                  =    0.4570 VOL/VOL
         FIELD CAPACITY            =    0.1310 VOL/VOL
         WILTING POINT             =    0.0580 VOL/VOL
```

```
  INITIAL SOIL WATER CONTENT =    0.0906 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
  SLOPE                  =    9.70  PERCENT
  DRAINAGE LENGTH            =   330.0    FEET


                LAYER 3
                -------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
            MATERIAL TEXTURE NUMBER  35
  THICKNESS                 =      0.10   INCHES
  POROSITY                  =     0.0000 VOL/VOL
  FIELD CAPACITY            =     0.0000 VOL/VOL
  WILTING POINT             =     0.0000 VOL/VOL
  INITIAL SOIL WATER CONTENT =    0.0000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
  FML PINHOLE DENSITY        =     0.00   HOLES/ACRE
  FML INSTALLATION DEFECTS   =     0.00   HOLES/ACRE
  FML PLACEMENT QUALITY      = 1 - PERFECT


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
        SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
        FAIR STAND OF GRASS, A SURFACE SLOPE OF 10.%
        AND A SLOPE LENGTH OF  330. FEET.

 SCS RUNOFF CURVE NUMBER             =   70.30
 FRACTION OF AREA ALLOWING RUNOFF    =   100.0   PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE  =   285.000  ACRES
 EVAPORATIVE ZONE DEPTH              =    18.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE   =     2.228  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE  =     8.202  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE  =     1.206  INCHES
 INITIAL SNOW WATER                  =     0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS    =     2.228  INCHES
 TOTAL INITIAL WATER                 =     2.228  INCHES
 TOTAL SUBSURFACE INFLOW             =     0.00   INCHES/YEAR


        EVAPOTRANSPIRATION AND WEATHER DATA
        -----------------------------------

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
        NEW YORK          NEW YORK

   MAXIMUM LEAF AREA INDEX               = 2.00
   START OF GROWING SEASON (JULIAN DATE) = 108
   END OF GROWING SEASON (JULIAN DATE)   = 302
   AVERAGE ANNUAL WIND SPEED             = 12.20 MPH
   AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 65.00 %
   AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 68.00 %
   AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
   AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 68.00 %


 NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
        COEFFICIENTS FOR    NEW YORK          NEW YORK
```

```
           NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

       JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
       -------   -------   -------   -------   -------   -------
         3.11      3.08      4.10      3.76      3.46      3.15
         3.67      4.32      3.48      3.24      3.77      3.68


    NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    NEW YORK         NEW YORK

           NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

       JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
       -------   -------   -------   -------   -------   -------
        31.80     33.30     41.00     51.90     61.70     71.00
        76.40     75.30     68.20     57.50     47.10     36.20


    NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    NEW YORK         NEW YORK

               STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   1
-------------------------------------------------------------------
                                INCHES        CU. FEET    PERCENT
                               --------      ----------   -------
 PRECIPITATION                   38.62     39954312.000   100.00

 RUNOFF                           0.974     1007974.560     2.52

 EVAPOTRANSPIRATION              31.317    32399222.000    81.09

 DRAINAGE COLLECTED FROM LAYER  2  1.3053   1350389.370     3.38

 PERC./LEAKAGE THROUGH LAYER  3   0.000062       64.099     0.00

 AVG. HEAD ON TOP OF LAYER  3     2.4660

 CHANGE IN WATER STORAGE          5.023     5196669.500    13.01

 SOIL WATER AT START OF YEAR      2.500     2585961.250

 SOIL WATER AT END OF YEAR        7.523     7782631.500

 SNOW WATER AT START OF YEAR      0.000           0.000     0.00

 SNOW WATER AT END OF YEAR        0.000           0.000     0.00

 ANNUAL WATER BUDGET BALANCE      0.0000         -8.725     0.00

*******************************************************************************


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   2
-------------------------------------------------------------------
                                INCHES        CU. FEET    PERCENT
```

```
*******************************************************************************

        PEAK DAILY VALUES FOR YEARS   1 THROUGH   10
  ------------------------------------------------------------
                            (INCHES)    (CU. FT.)
                            ---------   ----------
  PRECIPITATION                     3.96     4096818.000

  RUNOFF                          3.149    3257642.0000

  DRAINAGE COLLECTED FROM LAYER  2        0.02934    30351.85550

  PERCOLATION/LEAKAGE THROUGH LAYER  3    0.000001        1.26689

  AVERAGE HEAD ACROSS LAYER  3          18.000

  SNOW WATER                        2.75     2845338.2500

  MAXIMUM VEG. SOIL WATER (VOL/VOL)            0.4557

  MINIMUM VEG. SOIL WATER (VOL/VOL)            0.0571
*******************************************************************************
```

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**             HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                   **
**             DEVELOPED BY ENVIRONMENTAL LABORATORY                        **
**               USAE WATERWAYS EXPERIMENT STATION                          **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELP3\SDATd2BA.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELP3\outd2.OUT


TIME:  1:41    DATE: 10/21/1998


******************************************************************************

  TITLE: Brookfield Avenue Landfill - 2% Minimum Slope, 12" Protection Layer

******************************************************************************


  NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
        WERE SPECIFIED BY THE USER.


                   LAYER  1
                   --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
             MATERIAL TEXTURE NUMBER  6
     THICKNESS                 =    6.00   INCHES
     POROSITY                  =    0.4530 VOL/VOL
     FIELD CAPACITY            =    0.1900 VOL/VOL
     WILTING POINT             =    0.0850 VOL/VOL
     INITIAL SOIL WATER CONTENT =   0.1901 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
    NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
          FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                   LAYER  2
                   --------

             TYPE 2 - LATERAL DRAINAGE LAYER
             MATERIAL TEXTURE NUMBER  5
     THICKNESS                 =   12.00   INCHES
     POROSITY                  =    0.4570 VOL/VOL
     FIELD CAPACITY            =    0.1310 VOL/VOL
     WILTING POINT             =    0.0580 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =     0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
SLOPE                    =   17.70  PERCENT
DRAINAGE LENGTH            =   130.0    FEET


              LAYER  3
              --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
           MATERIAL TEXTURE NUMBER  35
THICKNESS                =     0.10  INCHES
POROSITY                 =    0.0000 VOL/VOL
FIELD CAPACITY             =     0.0000 VOL/VOL
WILTING POINT             =    0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =    0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =     0.00   HOLES/ACRE
FML PLACEMENT QUALITY       = 1 - PERFECT


         GENERAL DESIGN AND EVAPORATIVE ZONE DATA
         ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF 18.%
       AND A SLOPE LENGTH OF  130. FEET.

SCS RUNOFF CURVE NUMBER             =     72.50
FRACTION OF AREA ALLOWING RUNOFF   =   100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =   285.000  ACRES
EVAPORATIVE ZONE DEPTH              =    18.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =     2.228  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     8.202  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =     1.206  INCHES
INITIAL SNOW WATER                =    0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    2.228  INCHES
TOTAL INITIAL WATER               =    2.228  INCHES
TOTAL SUBSURFACE INFLOW            =     0.00   INCHES/YEAR


         EVAPOTRANSPIRATION AND WEATHER DATA
         -----------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
       NEW YORK          NEW YORK

   MAXIMUM LEAF AREA INDEX              = 2.00
   START OF GROWING SEASON (JULIAN DATE) =  108
   END OF GROWING SEASON (JULIAN DATE)   =  302
   AVERAGE ANNUAL WIND SPEED            = 12.20 MPH
   AVERAGE 1ST QUARTER RELATIVE HUMIDITY  = 65.00 %
   AVERAGE 2ND QUARTER RELATIVE HUMIDITY  = 68.00 %
   AVERAGE 3RD QUARTER RELATIVE HUMIDITY  = 72.00 %
   AVERAGE 4TH QUARTER RELATIVE HUMIDITY  = 68.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
       COEFFICIENTS FOR    NEW YORK          NEW YORK
```

```
         NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

  JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
  -------   -------   -------   -------   -------   -------
   3.11      3.08      4.10      3.76      3.46      3.15
   3.67      4.32      3.48      3.24      3.77      3.68


      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR   NEW YORK        NEW YORK

       NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

  JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
  -------   -------   -------   -------   -------   -------
   31.80     33.30     41.00     51.90     61.70     71.00
   76.40     75.30     68.20     57.50     47.10     36.20


      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR   NEW YORK        NEW YORK

                STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

           ANNUAL TOTALS FOR YEAR   1
------------------------------------------------------
                          INCHES      CU. FEET    PERCENT
                          --------    ----------  -------
PRECIPITATION                 38.62     39954312.000   100.00

RUNOFF                      0.045     46278.805     0.12

EVAPOTRANSPIRATION              30.280   31326518.000    78.41

DRAINAGE COLLECTED FROM LAYER  2     4.8872     5056052.500     12.65

PERC./LEAKAGE THROUGH LAYER  3     0.000042      43.732     0.00

AVG. HEAD ON TOP OF LAYER  3      1.6798

CHANGE IN WATER STORAGE          3.408      3525440.750     8.82

SOIL WATER AT START OF YEAR       2.500      2585961.250

SOIL WATER AT END OF YEAR        5.907     6111402.000

SNOW WATER AT START OF YEAR        0.000         0.000     0.00

SNOW WATER AT END OF YEAR        0.000         0.000     0.00

ANNUAL WATER BUDGET BALANCE        0.0000       -22.011     0.00

*******************************************************************************


*******************************************************************************

           ANNUAL TOTALS FOR YEAR   2
------------------------------------------------------
                          INCHES      CU. FEET    PERCENT
```

```
******************************************************************************

        PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
  ----------------------------------------------------------
                              (INCHES)    (CU. FT.)
                              ---------  ----------
   PRECIPITATION                     3.96      4096818.000

   RUNOFF                         2.941     3042340.7500

   DRAINAGE COLLECTED FROM LAYER  2         0.18086    187105.03100

   PERCOLATION/LEAKAGE THROUGH LAYER  3     0.000001         1.24142

   AVERAGE HEAD ACROSS LAYER  3          17.638

   SNOW WATER                        2.75      2845338.2500


   MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.4548

   MINIMUM VEG. SOIL WATER (VOL/VOL)              0.0536
******************************************************************************
```

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****************************************************************************
****************************************************************************
**                                                                        **
**                                                                        **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE             **
**             HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                 **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                USAE WATERWAYS EXPERIMENT STATION                       **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                        **
**                                                                        **
****************************************************************************
****************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATd3BA.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outd3.OUT


TIME:  1:45    DATE:  10/21/1998


****************************************************************************

  TITLE: Brookfield Avenue Landfill - 2% Slope, 12" Protection Layer

****************************************************************************


  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                          LAYER  1
                          --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  6
      THICKNESS                 =     6.00  INCHES
      POROSITY                  =   0.4530 VOL/VOL
      FIELD CAPACITY            =   0.1900 VOL/VOL
      WILTING POINT             =   0.0850 VOL/VOL
      INITIAL SOIL WATER CONTENT =   0.1901 VOL/VOL
      EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
    NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
           FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER  5
      THICKNESS                 =    12.00  INCHES
      POROSITY                  =   0.4570 VOL/VOL
```

```
FIELD CAPACITY            =    0.1310 VOL/VOL
WILTING POINT             =    0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =   0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
SLOPE                     =    4.50  PERCENT
DRAINAGE LENGTH           =    800.0   FEET


              LAYER  3
              --------

         TYPE 4 - FLEXIBLE MEMBRANE LINER
          MATERIAL TEXTURE NUMBER  35
THICKNESS                 =    0.10  INCHES
POROSITY                  =    0.0000 VOL/VOL
FIELD CAPACITY            =    0.0000 VOL/VOL
WILTING POINT             =    0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =   0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY       =    0.00   HOLES/ACRE
FML INSTALLATION DEFECTS  =    0.00   HOLES/ACRE
FML PLACEMENT QUALITY     =  1 - PERFECT


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF  4.%
       AND A SLOPE LENGTH OF  800. FEET.

SCS RUNOFF CURVE NUMBER              =   67.90
FRACTION OF AREA ALLOWING RUNOFF     =   100.0   PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =   285.000  ACRES
EVAPORATIVE ZONE DEPTH               =   18.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =   2.228  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =   8.202  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =   1.206  INCHES
INITIAL SNOW WATER                   =   0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =   2.228  INCHES
TOTAL INITIAL WATER                  =   2.228  INCHES
TOTAL SUBSURFACE INFLOW              =   0.00   INCHES/YEAR


        EVAPOTRANSPIRATION AND WEATHER DATA
        -----------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
       NEW YORK          NEW YORK

   MAXIMUM LEAF AREA INDEX                   = 2.00
   START OF GROWING SEASON (JULIAN DATE)     = 108
   END OF GROWING SEASON (JULIAN DATE)       = 302
   AVERAGE ANNUAL WIND SPEED                 = 12.20 MPH
   AVERAGE 1ST QUARTER RELATIVE HUMIDITY     = 65.00 %
   AVERAGE 2ND QUARTER RELATIVE HUMIDITY     = 68.00 %
   AVERAGE 3RD QUARTER RELATIVE HUMIDITY     = 72.00 %
   AVERAGE 4TH QUARTER RELATIVE HUMIDITY     = 68.00 %
```

```
      NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR     NEW YORK          NEW YORK

             NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

    JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
    -------    -------    -------    -------    -------    -------
     3.11       3.08       4.10       3.76       3.46       3.15
     3.67       4.32       3.48       3.24       3.77       3.68


      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR     NEW YORK          NEW YORK

           NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

    JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
    -------    -------    -------    -------    -------    -------
     31.80      33.30      41.00      51.90      61.70      71.00
     76.40      75.30      68.20      57.50      47.10      36.20


      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
             COEFFICIENTS FOR     NEW YORK          NEW YORK

                 STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

                  ANNUAL TOTALS FOR YEAR   1
  ----------------------------------------------------------------
                                 INCHES        CU. FEET    PERCENT
                                --------      ----------   -------
  PRECIPITATION                   38.62     39954312.000   100.00

  RUNOFF                          1.189      1230061.120     3.08

  EVAPOTRANSPIRATION             31.925     33028254.000    82.67

  DRAINAGE COLLECTED FROM LAYER 2   0.2778      287442.969     0.72

  PERC./LEAKAGE THROUGH LAYER 3   0.000069        71.209     0.00

  AVG. HEAD ON TOP OF LAYER 3     2.7423

  CHANGE IN WATER STORAGE         5.228      5408495.000    13.54

  SOIL WATER AT START OF YEAR     2.500      2585961.250

  SOIL WATER AT END OF YEAR       7.727      7994456.000

  SNOW WATER AT START OF YEAR     0.000            0.000     0.00

  SNOW WATER AT END OF YEAR       0.000            0.000     0.00

  ANNUAL WATER BUDGET BALANCE     0.0000         -12.505     0.00

*******************************************************************************


*******************************************************************************
```

```
******************************************************************************

        PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
  --------------------------------------------------------------
                              (INCHES)     (CU. FT.)
                              --------    ----------
    PRECIPITATION                      3.96      4096818.000

    RUNOFF                          3.165     3274166.7500

    DRAINAGE COLLECTED FROM LAYER  2          0.00429       4440.00732

    PERCOLATION/LEAKAGE THROUGH LAYER  3     0.000001         1.26689

    AVERAGE HEAD ACROSS LAYER  3           18.000

    SNOW WATER                         2.75      2845338.2500

    MAXIMUM VEG. SOIL WATER (VOL/VOL)               0.4557

    MINIMUM VEG. SOIL WATER (VOL/VOL)              0.0584
******************************************************************************
```

```
          COEFFICIENTS FOR    NEW YORK          NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

     JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
     -------   -------   -------   -------   -------   -------
      3.11      3.08      4.10      3.76      3.46      3.15
      3.67      4.32      3.48      3.24      3.77      3.68


        NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
               COEFFICIENTS FOR    NEW YORK          NEW YORK

            NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

     JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
     -------   -------   -------   -------   -------   -------
      31.80     33.30     41.00     51.90     61.70     71.00
      76.40     75.30     68.20     57.50     47.10     36.20


        NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
               COEFFICIENTS FOR    NEW YORK          NEW YORK

                    STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

                ANNUAL TOTALS FOR YEAR   1
------------------------------------------------------------
                              INCHES      CU. FEET     PERCENT
                             --------    ----------    -------
  PRECIPITATION                 38.62      39954312.000    100.00

  RUNOFF                         0.026       27080.299      0.07

  EVAPOTRANSPIRATION            29.839      30870242.000     77.26

  DRAINAGE COLLECTED FROM LAYER  2    6.9862    7227545.000    18.09

  PERC./LEAKAGE THROUGH LAYER  3    0.000025      26.058      0.00

  AVG. HEAD ON TOP OF LAYER  3     1.0003

  CHANGE IN WATER STORAGE          1.768     1829430.120     4.58

  SOIL WATER AT START OF YEAR      2.500     2585961.250

  SOIL WATER AT END OF YEAR        4.268     4415391.500

  SNOW WATER AT START OF YEAR      0.000         0.000     0.00

  SNOW WATER AT END OF YEAR        0.000         0.000     0.00

  ANNUAL WATER BUDGET BALANCE      0.0000      -11.448     0.00
*******************************************************************************



*******************************************************************************

                ANNUAL TOTALS FOR YEAR   2
```

```
******************************************************************************

        PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
------------------------------------------------------------------------
                                    (INCHES)    (CU. FT.)
                                    --------    ---------
   PRECIPITATION                        3.96     4096818.000

   RUNOFF                              2.879     2978493.5000

   DRAINAGE COLLECTED FROM LAYER  2        0.30015    310523.18700

   PERCOLATION/LEAKAGE THROUGH LAYER  3     0.000001         0.97169

   AVERAGE HEAD ACROSS LAYER  3          13.806

   SNOW WATER                            2.75     2845338.2500

   MAXIMUM VEG. SOIL WATER (VOL/VOL)             0.4064

   MINIMUM VEG. SOIL WATER (VOL/VOL)            0.0538

******************************************************************************
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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**             HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                   **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATd5BA.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outd5.OUT


TIME:  1:51    DATE:  10/21/1998


******************************************************************************

  TITLE:  Brookfield Avenue Landfill - 2% Minimum Slope, 12" Protection Layer

******************************************************************************


  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                    LAYER  1
                    --------

               TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  6
      THICKNESS                =     6.00  INCHES
      POROSITY                 =   0.4530 VOL/VOL
      FIELD CAPACITY           =   0.1900 VOL/VOL
      WILTING POINT            =   0.0850 VOL/VOL
      INITIAL SOIL WATER CONTENT =   0.1901 VOL/VOL
      EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
    NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
           FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                    LAYER  2
                    --------

               TYPE 2 - LATERAL DRAINAGE LAYER
                 MATERIAL TEXTURE NUMBER  5
      THICKNESS                =    12.00  INCHES
      POROSITY                 =   0.4570 VOL/VOL
      FIELD CAPACITY           =   0.1310 VOL/VOL
```

```
WILTING POINT             =    0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
SLOPE                  =    4.20  PERCENT
DRAINAGE LENGTH           =   550.0   FEET


                 LAYER  3
                 --------

         TYPE 4 - FLEXIBLE MEMBRANE LINER
           MATERIAL TEXTURE NUMBER  35
THICKNESS                =    0.10  INCHES
POROSITY               =    0.0000 VOL/VOL
FIELD CAPACITY            =    0.0000 VOL/VOL
WILTING POINT             =    0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =    0.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =    0.00   HOLES/ACRE
FML PLACEMENT QUALITY      = 1 - PERFECT


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF  4.%
       AND A SLOPE LENGTH OF  550. FEET.

SCS RUNOFF CURVE NUMBER           =    68.60
FRACTION OF AREA ALLOWING RUNOFF   =   100.0   PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =   285.000  ACRES
EVAPORATIVE ZONE DEPTH            =    18.0   INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =     2.228  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     8.202  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =     1.206  INCHES
INITIAL SNOW WATER                =    0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    2.228  INCHES
TOTAL INITIAL WATER               =    2.228  INCHES
TOTAL SUBSURFACE INFLOW           =    0.00   INCHES/YEAR


        EVAPOTRANSPIRATION AND WEATHER DATA
        -----------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
       NEW YORK          NEW YORK

   MAXIMUM LEAF AREA INDEX              = 2.00
   START OF GROWING SEASON (JULIAN DATE) =  108
   END OF GROWING SEASON (JULIAN DATE)   =  302
   AVERAGE ANNUAL WIND SPEED            = 12.20 MPH
   AVERAGE 1ST QUARTER RELATIVE HUMIDITY  = 65.00 %
   AVERAGE 2ND QUARTER RELATIVE HUMIDITY  = 68.00 %
   AVERAGE 3RD QUARTER RELATIVE HUMIDITY  = 72.00 %
   AVERAGE 4TH QUARTER RELATIVE HUMIDITY  = 68.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

```
          COEFFICIENTS FOR   NEW YORK        NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    3.11      3.08      4.10      3.76      3.46      3.15
    3.67      4.32      3.48      3.24      3.77      3.68


      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR   NEW YORK        NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    31.80     33.30     41.00     51.90     61.70     71.00
    76.40     75.30     68.20     57.50     47.10     36.20


      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR   NEW YORK        NEW YORK

             STATION LATITUDE = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   1
--------------------------------------------------
                         INCHES        CU. FEET     PERCENT
                        --------      ----------    -------
PRECIPITATION               38.62     39954312.000   100.00

RUNOFF                      1.177      1217757.120     3.05

EVAPOTRANSPIRATION         31.870     32970908.000    82.52

DRAINAGE COLLECTED FROM LAYER  2     0.3568      369103.375     0.92

PERC./LEAKAGE THROUGH LAYER  3     0.000068          70.750     0.00

AVG. HEAD ON TOP OF LAYER  3       2.7243

CHANGE IN WATER STORAGE            5.216     5396490.500    13.51

SOIL WATER AT START OF YEAR        2.500     2585961.250

SOIL WATER AT END OF YEAR          7.716     7982451.500

SNOW WATER AT START OF YEAR        0.000           0.000     0.00

SNOW WATER AT END OF YEAR          0.000           0.000     0.00

ANNUAL WATER BUDGET BALANCE        0.0000        -17.750     0.00

*******************************************************************************


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   2
```

```
*******************************************************************************

        PEAK DAILY VALUES FOR YEARS   1 THROUGH   10
---------------------------------------------------------
                                (INCHES)    (CU. FT.)
                                --------    ---------
   PRECIPITATION                      3.96      4096818.000

   RUNOFF                           3.164     3273638.2500

   DRAINAGE COLLECTED FROM LAYER  2          0.00534       5528.86670

   PERCOLATION/LEAKAGE THROUGH LAYER  3    0.000001        1.26689

   AVERAGE HEAD ACROSS LAYER  3           18.000

   SNOW WATER                          2.75      2845338.2500

   MAXIMUM VEG. SOIL WATER (VOL/VOL)             0.4557

   MINIMUM VEG. SOIL WATER (VOL/VOL)             0.0586
*******************************************************************************
```

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**             HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                   **
**             DEVELOPED BY ENVIRONMENTAL LABORATORY                        **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATd6BA.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outd6.OUT


TIME:  1:53    DATE:  10/21/1998


******************************************************************************

  TITLE: Brookfield Avenue Landfill - 2% Minimum Slope, 12" Protection Layer

******************************************************************************


  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                           LAYER  1
                           --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  6
     THICKNESS                =    6.00  INCHES
     POROSITY                 =    0.4530 VOL/VOL
     FIELD CAPACITY           =    0.1900 VOL/VOL
     WILTING POINT            =    0.0850 VOL/VOL
     INITIAL SOIL WATER CONTENT =    0.1901 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
   NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
          FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                           LAYER  2
                           --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER  5
     THICKNESS                =   12.00  INCHES
     POROSITY                 =    0.4570 VOL/VOL
     FIELD CAPACITY           =    0.1310 VOL/VOL
```

```
WILTING POINT            =   0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =   0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
SLOPE                =   10.30  PERCENT
DRAINAGE LENGTH            =   350.0   FEET


          LAYER  3
          --------

        TYPE 4 - FLEXIBLE MEMBRANE LINER
         MATERIAL TEXTURE NUMBER  35
THICKNESS              =    0.10  INCHES
POROSITY              =    0.0000 VOL/VOL
FIELD CAPACITY           =    0.0000 VOL/VOL
WILTING POINT            =   0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =    0.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =     0.00   HOLES/ACRE
FML PLACEMENT QUALITY      = 1 - PERFECT


       GENERAL DESIGN AND EVAPORATIVE ZONE DATA
       ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF 10.%
       AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER            =    70.30
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =    285.000  ACRES
EVAPORATIVE ZONE DEPTH             =    18.0     INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =     2.228  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     8.202  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =     1.206  INCHES
INITIAL SNOW WATER                 =    0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     2.228  INCHES
TOTAL INITIAL WATER                =    2.228  INCHES
TOTAL SUBSURFACE INFLOW            =     0.00   INCHES/YEAR


       EVAPOTRANSPIRATION AND WEATHER DATA
       -----------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
       NEW YORK           NEW YORK

  MAXIMUM LEAF AREA INDEX              = 2.00
  START OF GROWING SEASON (JULIAN DATE) =  108
  END OF GROWING SEASON (JULIAN DATE)   =  302
  AVERAGE ANNUAL WIND SPEED            = 12.20 MPH
  AVERAGE 1ST QUARTER RELATIVE HUMIDITY  = 65.00 %
  AVERAGE 2ND QUARTER RELATIVE HUMIDITY  = 68.00 %
  AVERAGE 3RD QUARTER RELATIVE HUMIDITY  = 72.00 %
  AVERAGE 4TH QUARTER RELATIVE HUMIDITY  = 68.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

```
          COEFFICIENTS FOR    NEW YORK         NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    3.11      3.08      4.10      3.76      3.46      3.15
    3.67      4.32      3.48      3.24      3.77      3.68


     NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    31.80     33.30     41.00     51.90     61.70     71.00
    76.40     75.30     68.20     57.50     47.10     36.20


     NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

             STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   1
-------------------------------------------------------------------
                              INCHES      CU. FEET    PERCENT
                             --------    ----------   -------
PRECIPITATION                 38.62     39954312.000   100.00

RUNOFF                         0.844      873292.000     2.19

EVAPOTRANSPIRATION            31.315    32397306.000    81.09

DRAINAGE COLLECTED FROM LAYER  2     1.6402    1696883.250     4.25

PERC./LEAKAGE THROUGH LAYER  3     0.000061        63.515     0.00

AVG. HEAD ON TOP OF LAYER  3        2.4436

CHANGE IN WATER STORAGE          4.820     4986792.000    12.48

SOIL WATER AT START OF YEAR      2.500     2585961.250

SOIL WATER AT END OF YEAR        7.320     7572753.500

SNOW WATER AT START OF YEAR      0.000           0.000     0.00

SNOW WATER AT END OF YEAR        0.000           0.000     0.00

ANNUAL WATER BUDGET BALANCE      0.0000        -25.407     0.00

*******************************************************************************


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   2
```

```
********************************************************************************

      PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
-------------------------------------------------------------
                              (INCHES)    (CU. FT.)
                              --------   ----------
  PRECIPITATION                         3.96     4096818.000

  RUNOFF                           3.138    3245916.2500

  DRAINAGE COLLECTED FROM LAYER  2          0.03936     40718.12890

  PERCOLATION/LEAKAGE THROUGH LAYER  3     0.000001        1.26689

  AVERAGE HEAD ACROSS LAYER  3         18.000
                                      ----------
  SNOW WATER                            2.75     2845338.2500

  MAXIMUM VEG. SOIL WATER (VOL/VOL)             0.4557

  MINIMUM VEG. SOIL WATER (VOL/VOL)             0.0571
********************************************************************************
```

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**            HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                    **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                 USAE WATERWAYS EXPERIMENT STATION                        **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELP3\SDATd7BA.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELP3\outd7.OUT


TIME:  1:56    DATE:  10/21/1998


******************************************************************************

  TITLE:  Brookfield Avenue Landfill - 2% Minimum Slope, 12" Protection Layer

******************************************************************************


  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                             LAYER  1
                             --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  6
     THICKNESS                =    6.00  INCHES
     POROSITY                 =    0.4530 VOL/VOL
     FIELD CAPACITY           =    0.1900 VOL/VOL
     WILTING POINT            =    0.0850 VOL/VOL
     INITIAL SOIL WATER CONTENT  =    0.1901 VOL/VOL
     EFFECTIVE SAT. HYD. COND.   =  0.720000011000E-03 CM/SEC
    NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
           FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                             LAYER  2
                             --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER  5
     THICKNESS                =   12.00  INCHES
     POROSITY                 =    0.4570 VOL/VOL
     FIELD CAPACITY           =    0.1310 VOL/VOL
```

```
    WILTING POINT           =   0.0580 VOL/VOL
    INITIAL SOIL WATER CONTENT =   0.0906 VOL/VOL
    EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
    SLOPE                  =   2.70  PERCENT
    DRAINAGE LENGTH          =  1700.0   FEET


                  LAYER 3
                  --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER 35
    THICKNESS              =    0.10  INCHES
    POROSITY               =   0.0000 VOL/VOL
    FIELD CAPACITY          =    0.0000 VOL/VOL
    WILTING POINT           =   0.0000 VOL/VOL
    INITIAL SOIL WATER CONTENT =   0.0000 VOL/VOL
    EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
    FML PINHOLE DENSITY       =   0.00  HOLES/ACRE
    FML INSTALLATION DEFECTS   =   0.00  HOLES/ACRE
    FML PLACEMENT QUALITY     = 1 - PERFECT


            GENERAL DESIGN AND EVAPORATIVE ZONE DATA
            ----------------------------------------

   NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
          FAIR STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF 1700. FEET.

   SCS RUNOFF CURVE NUMBER            =   65.80
   FRACTION OF AREA ALLOWING RUNOFF   =   100.0   PERCENT
   AREA PROJECTED ON HORIZONTAL PLANE =   285.000  ACRES
   EVAPORATIVE ZONE DEPTH             =   18.0   INCHES
   INITIAL WATER IN EVAPORATIVE ZONE  =    2.228  INCHES
   UPPER LIMIT OF EVAPORATIVE STORAGE =    8.202  INCHES
   LOWER LIMIT OF EVAPORATIVE STORAGE =    1.206  INCHES
   INITIAL SNOW WATER                 =    0.000  INCHES
   INITIAL WATER IN LAYER MATERIALS   =    2.228  INCHES
   TOTAL INITIAL WATER                =    2.228  INCHES
   TOTAL SUBSURFACE INFLOW            =    0.00   INCHES/YEAR


            EVAPOTRANSPIRATION AND WEATHER DATA
            -----------------------------------

   NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          NEW YORK          NEW YORK

      MAXIMUM LEAF AREA INDEX              = 2.00
      START OF GROWING SEASON (JULIAN DATE) = 108
      END OF GROWING SEASON (JULIAN DATE)   = 302
      AVERAGE ANNUAL WIND SPEED            = 12.20 MPH
      AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 65.00 %
      AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 68.00 %
      AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
      AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 68.00 %


   NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

```
          COEFFICIENTS FOR    NEW YORK         NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    3.11      3.08      4.10      3.76      3.46      3.15
    3.67      4.32      3.48      3.24      3.77      3.68


      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    31.80     33.30     41.00     51.90     61.70     71.00
    76.40     75.30     68.20     57.50     47.10     36.20


      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

             STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   1
 ----------------------------------------------------------------
                               INCHES        CU. FEET      PERCENT
                              --------      ----------     -------
 PRECIPITATION                   38.62      39954312.000    100.00

 RUNOFF                          1.239       1281923.120      3.21

 EVAPOTRANSPIRATION             32.032      33138384.000     82.94

 DRAINAGE COLLECTED FROM LAYER  2   0.0823      85167.867     0.21

 PERC./LEAKAGE THROUGH LAYER  3  0.000070      72.417         0.00

 AVG. HEAD ON TOP OF LAYER  3    2.7892

 CHANGE IN WATER STORAGE         5.267       5448770.000     13.64

 SOIL WATER AT START OF YEAR     2.500       2585961.250

 SOIL WATER AT END OF YEAR       7.766       8034731.000

 SNOW WATER AT START OF YEAR     0.000             0.000      0.00

 SNOW WATER AT END OF YEAR       0.000             0.000      0.00

 ANNUAL WATER BUDGET BALANCE     0.0000           -4.502      0.00

*******************************************************************************


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             ANNUAL TOTALS FOR YEAR   2
```

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*******************************************************************************

          PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
    ----------------------------------------------------
                                 (INCHES)    (CU. FT.)
                                 --------   ----------
     PRECIPITATION                     3.96     4096818.000

     RUNOFF                       3.166     3275343.2500

     DRAINAGE COLLECTED FROM LAYER  2        0.00129      1338.33740

     PERCOLATION/LEAKAGE THROUGH LAYER  3    0.000001       1.26689

     AVERAGE HEAD ACROSS LAYER  3       18.000

     SNOW WATER                        2.75     2845338.2500

     MAXIMUM VEG. SOIL WATER (VOL/VOL)            0.4557

     MINIMUM VEG. SOIL WATER (VOL/VOL)            0.0587

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3.01   (14 OCTOBER 1994)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELP3\SDATd8BA.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELP3\outd8.OUT


TIME:  1:59    DATE:  10/21/1998


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  TITLE:  Brookfield Avenue Landfill - 2% Minimum Slope, 12" Protection Layer

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  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                   LAYER  1
                   --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   6
    THICKNESS                 =    6.00  INCHES
    POROSITY                  =    0.4530 VOL/VOL
    FIELD CAPACITY            =    0.1900 VOL/VOL
    WILTING POINT             =    0.0850 VOL/VOL
    INITIAL SOIL WATER CONTENT  =    0.1901 VOL/VOL
    EFFECTIVE SAT. HYD. COND.   =  0.720000011000E-03 CM/SEC
  NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                   LAYER  2
                   --------

              TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   5
    THICKNESS                 =   12.00  INCHES
    POROSITY                  =    0.4570 VOL/VOL
    FIELD CAPACITY            =    0.1310 VOL/VOL
```

```
     WILTING POINT            =   0.0580 VOL/VOL
     INITIAL SOIL WATER CONTENT =   0.0906 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
     SLOPE                 =   12.50  PERCENT
     DRAINAGE LENGTH          =  200.0    FEET


                    LAYER 3
                    -------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER 35
     THICKNESS             =    0.10  INCHES
     POROSITY              =   0.0000 VOL/VOL
     FIELD CAPACITY          =   0.0000 VOL/VOL
     WILTING POINT           =   0.0000 VOL/VOL
     INITIAL SOIL WATER CONTENT =   0.0000 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
     FML PINHOLE DENSITY       =    0.00  HOLES/ACRE
     FML INSTALLATION DEFECTS   =    0.00  HOLES/ACRE
     FML PLACEMENT QUALITY     = 1 - PERFECT


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

   NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
          FAIR STAND OF GRASS, A SURFACE SLOPE OF 12.%
          AND A SLOPE LENGTH OF 200. FEET.

   SCS RUNOFF CURVE NUMBER           =   71.50
   FRACTION OF AREA ALLOWING RUNOFF   =   100.0    PERCENT
   AREA PROJECTED ON HORIZONTAL PLANE =   285.000  ACRES
   EVAPORATIVE ZONE DEPTH            =   18.0    INCHES
   INITIAL WATER IN EVAPORATIVE ZONE   =    2.228  INCHES
   UPPER LIMIT OF EVAPORATIVE STORAGE =    8.202  INCHES
   LOWER LIMIT OF EVAPORATIVE STORAGE =    1.206  INCHES
   INITIAL SNOW WATER               =    0.000  INCHES
   INITIAL WATER IN LAYER MATERIALS   =    2.228  INCHES
   TOTAL INITIAL WATER              =    2.228  INCHES
   TOTAL SUBSURFACE INFLOW          =    0.00   INCHES/YEAR


           EVAPOTRANSPIRATION AND WEATHER DATA
           -----------------------------------

   NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          NEW YORK          NEW YORK

      MAXIMUM LEAF AREA INDEX             = 2.00
      START OF GROWING SEASON (JULIAN DATE) = 108
      END OF GROWING SEASON (JULIAN DATE)   = 302
      AVERAGE ANNUAL WIND SPEED             = 12.20 MPH
      AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 65.00 %
      AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 68.00 %
      AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
      AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 68.00 %


   NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
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          COEFFICIENTS FOR    NEW YORK          NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    3.11      3.08      4.10      3.76      3.46      3.15
    3.67      4.32      3.48      3.24      3.77      3.68


      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK          NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    31.80     33.30     41.00     51.90     61.70     71.00
    76.40     75.30     68.20     57.50     47.10     36.20


      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK          NEW YORK

             STATION LATITUDE  = 40.47 DEGREES


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             ANNUAL TOTALS FOR YEAR   1
---------------------------------------------------
                          INCHES      CU. FEET    PERCENT
                          ------      --------    -------
PRECIPITATION               38.62     39954312.000   100.00

RUNOFF                      0.535      553160.500     1.38

EVAPOTRANSPIRATION         30.958    32027202.000    80.16

DRAINAGE COLLECTED FROM LAYER  2     2.4494     2534007.500     6.34

PERC./LEAKAGE THROUGH LAYER  3     0.000053        54.335     0.00

AVG. HEAD ON TOP OF LAYER  3      2.0877

CHANGE IN WATER STORAGE          4.678     4839888.000    12.11

SOIL WATER AT START OF YEAR        2.500     2585961.250

SOIL WATER AT END OF YEAR        7.178     7425849.000

SNOW WATER AT START OF YEAR        0.000           0.000     0.00

SNOW WATER AT END OF YEAR        0.000           0.000     0.00

ANNUAL WATER BUDGET BALANCE        0.0000         -0.318     0.00
*******************************************************************************



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             ANNUAL TOTALS FOR YEAR   2
```

```
********************************************************************************

       PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
   -----------------------------------------------------
                           (INCHES)    (CU. FT.)
                           --------   ----------
   PRECIPITATION                 3.96     4096818.000

   RUNOFF                      3.046    3150896.7500

   DRAINAGE COLLECTED FROM LAYER  2        0.06193     64072.37110

   PERCOLATION/LEAKAGE THROUGH LAYER  3     0.000001         1.26591

   AVERAGE HEAD ACROSS LAYER  3           17.986

   SNOW WATER                     2.75      2845338.2500

   MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.4557

   MINIMUM VEG. SOIL WATER (VOL/VOL)             0.0556
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******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATd9BA.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outd9.OUT


TIME:  2: 2   DATE: 10/21/1998


******************************************************************************

  TITLE: Brookfield Avenue Landfill - 2% Minimum Slope, 12" Protection Layer

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  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                          LAYER  1
                          --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER  6
        THICKNESS                  =    6.00  INCHES
        POROSITY                   =    0.4530 VOL/VOL
        FIELD CAPACITY             =    0.1900 VOL/VOL
        WILTING POINT              =    0.0850 VOL/VOL
        INITIAL SOIL WATER CONTENT =    0.1901 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
      NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
             FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

                       TYPE 2 - LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER  5
        THICKNESS                  =   12.00  INCHES
        POROSITY                   =    0.4570 VOL/VOL
        FIELD CAPACITY             =    0.1310 VOL/VOL
```

WILTING POINT = 0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC
SLOPE = 13.90 PERCENT
DRAINAGE LENGTH = 180.0 FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35
THICKNESS = 0.10 INCHES
POROSITY = 0.0000 VOL/VOL
FIELD CAPACITY = 0.0000 VOL/VOL
WILTING POINT = 0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY = 0.00 HOLES/ACRE
FML INSTALLATION DEFECTS = 0.00 HOLES/ACRE
FML PLACEMENT QUALITY = 1 - PERFECT

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
FAIR STAND OF GRASS, A SURFACE SLOPE OF 14.%
AND A SLOPE LENGTH OF 180. FEET.

SCS RUNOFF CURVE NUMBER = 71.80
FRACTION OF AREA ALLOWING RUNOFF = 100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 285.000 ACRES
EVAPORATIVE ZONE DEPTH = 18.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 2.228 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 8.202 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.206 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 2.228 INCHES
TOTAL INITIAL WATER = 2.228 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
NEW YORK NEW YORK

MAXIMUM LEAF AREA INDEX = 2.00
START OF GROWING SEASON (JULIAN DATE) = 108
END OF GROWING SEASON (JULIAN DATE) = 302
AVERAGE ANNUAL WIND SPEED = 12.20 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 65.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 68.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 68.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING

```
          COEFFICIENTS FOR    NEW YORK         NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

     JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
     -------   -------   -------   -------   -------   -------
      3.11      3.08      4.10      3.76      3.46      3.15
      3.67      4.32      3.48      3.24      3.77      3.68


     NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

     JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
     -------   -------   -------   -------   -------   -------
      31.80     33.30     41.00     51.90     61.70     71.00
      76.40     75.30     68.20     57.50     47.10     36.20


     NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

             STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   1
--------------------------------------------------------------
                             INCHES      CU. FEET    PERCENT
                            --------    ----------   -------
PRECIPITATION                  38.62     39954312.000   100.00

RUNOFF                       0.254     262442.125    0.66

EVAPOTRANSPIRATION              30.832     31897408.000    79.83

DRAINAGE COLLECTED FROM LAYER  2      3.1964     3306842.500     8.28

PERC./LEAKAGE THROUGH LAYER  3       0.000049        51.152     0.00

AVG. HEAD ON TOP OF LAYER  3          1.9648

CHANGE IN WATER STORAGE            4.338      4487579.500     11.23

SOIL WATER AT START OF YEAR         2.500      2585961.250

SOIL WATER AT END OF YEAR          6.837      7073540.500

SNOW WATER AT START OF YEAR          0.000           0.000      0.00

SNOW WATER AT END OF YEAR          0.000           0.000      0.00

ANNUAL WATER BUDGET BALANCE          0.0000         -10.917      0.00

*******************************************************************************


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   2
```

```
********************************************************************************

        PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
----------------------------------------------------------
                              (INCHES)    (CU. FT.)
                              --------    ----------
  PRECIPITATION                      3.96     4096818.000

  RUNOFF                          3.019     3123506.2500

  DRAINAGE COLLECTED FROM LAYER  2          0.09000     93107.63280

  PERCOLATION/LEAKAGE THROUGH LAYER  3     0.000001         1.26284

  AVERAGE HEAD ACROSS LAYER  3           17.943

  SNOW WATER                         2.75     2845338.2500


  MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.4557

  MINIMUM VEG. SOIL WATER (VOL/VOL)              0.0557
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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE              **
**                 HELP MODEL VERSION 3.01 (14 OCTOBER 1994)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELP3\SDATd10b.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELP3\outd10.OUT


TIME:  2: 5     DATE: 10/21/1998


******************************************************************************

  TITLE: Brookfield Avenue Landfill - 2% Minimum Slope, 12" Protection Layer

******************************************************************************


  NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
        WERE SPECIFIED BY THE USER.


                     LAYER  1
                     --------

               TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  6
     THICKNESS              =     6.00  INCHES
     POROSITY               =     0.4530 VOL/VOL
     FIELD CAPACITY         =     0.1900 VOL/VOL
     WILTING POINT          =     0.0850 VOL/VOL
     INITIAL SOIL WATER CONTENT =     0.1901 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
   NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                     LAYER  2
                     --------

               TYPE 2 - LATERAL DRAINAGE LAYER
                 MATERIAL TEXTURE NUMBER  5
     THICKNESS              =    12.00  INCHES
     POROSITY               =     0.4570 VOL/VOL
     FIELD CAPACITY         =     0.1310 VOL/VOL
```

WILTING POINT = 0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC
SLOPE = 6.60 PERCENT
DRAINAGE LENGTH = 500.0 FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35
THICKNESS = 0.10 INCHES
POROSITY = 0.0000 VOL/VOL
FIELD CAPACITY = 0.0000 VOL/VOL
WILTING POINT = 0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY = 0.00 HOLES/ACRE
FML INSTALLATION DEFECTS = 0.00 HOLES/ACRE
FML PLACEMENT QUALITY = 1 - PERFECT

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
FAIR STAND OF GRASS, A SURFACE SLOPE OF 7.%
AND A SLOPE LENGTH OF 500. FEET.

SCS RUNOFF CURVE NUMBER = 69.20
FRACTION OF AREA ALLOWING RUNOFF = 100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 285.000 ACRES
EVAPORATIVE ZONE DEPTH = 18.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 2.228 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 8.202 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.206 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 2.228 INCHES
TOTAL INITIAL WATER = 2.228 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
NEW YORK NEW YORK

MAXIMUM LEAF AREA INDEX = 2.00
START OF GROWING SEASON (JULIAN DATE) = 108
END OF GROWING SEASON (JULIAN DATE) = 302
AVERAGE ANNUAL WIND SPEED = 12.20 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 65.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 68.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 68.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING

```
          COEFFICIENTS FOR    NEW YORK         NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

  JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
  -------   -------   -------   -------   -------   -------
    3.11      3.08      4.10      3.76      3.46      3.15
    3.67      4.32      3.48      3.24      3.77      3.68


     NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

  JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
  -------   -------   -------   -------   -------   -------
   31.80     33.30     41.00     51.90     61.70     71.00
   76.40     75.30     68.20     57.50     47.10     36.20


     NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

             STATION LATITUDE  = 40.47 DEGREES


******************************************************************************

             ANNUAL TOTALS FOR YEAR   1
-----------------------------------------------------------
                              INCHES       CU. FEET    PERCENT
                              -------     ---------    -------
PRECIPITATION                 38.62     39954312.000    100.00

RUNOFF                         1.127     1166410.620      2.92

EVAPOTRANSPIRATION            31.690    32785302.000     82.06

DRAINAGE COLLECTED FROM LAYER  2          0.6388       660906.250      1.65

PERC./LEAKAGE THROUGH LAYER  3        0.000067          69.426      0.00

AVG. HEAD ON TOP OF LAYER  3        2.6730

CHANGE IN WATER STORAGE              5.163      5341637.500     13.37

SOIL WATER AT START OF YEAR          2.500      2585961.250

SOIL WATER AT END OF YEAR            7.663      7927599.000

SNOW WATER AT START OF YEAR          0.000            0.000      0.00

SNOW WATER AT END OF YEAR            0.000            0.000      0.00

ANNUAL WATER BUDGET BALANCE         0.0000          -14.360      0.00
******************************************************************************


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             ANNUAL TOTALS FOR YEAR   2
```

```
***************************************************************************

       PEAK DAILY VALUES FOR YEARS   1 THROUGH   10
  -------------------------------------------------------------
                              (INCHES)    (CU. FT.)
                              --------   ----------
   PRECIPITATION                    3.96     4096818.000

   RUNOFF                         3.163    3271910.7500

   DRAINAGE COLLECTED FROM LAYER  2         0.00985      10192.93360

   PERCOLATION/LEAKAGE THROUGH LAYER  3     0.000001          1.26689

   AVERAGE HEAD ACROSS LAYER  3          18.000

   SNOW WATER                       2.75     2845338.2500

   MAXIMUM VEG. SOIL WATER (VOL/VOL)             0.4557

   MINIMUM VEG. SOIL WATER (VOL/VOL)             0.0578
***************************************************************************
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******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3.01 (14 OCTOBER 1994)                    **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATd11b.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outd11.OUT


TIME:  2:38    DATE: 10/21/1998


******************************************************************************

  TITLE: Brookfield Avenue Landfill - 2%Minimum Slope, 12" protection layer

******************************************************************************


  NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
        WERE SPECIFIED BY THE USER.


                          LAYER  1
                          --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                   MATERIAL TEXTURE NUMBER  6
      THICKNESS                =     6.00  INCHES
      POROSITY                 =   0.4530 VOL/VOL
      FIELD CAPACITY           =   0.1900 VOL/VOL
      WILTING POINT            =   0.0850 VOL/VOL
      INITIAL SOIL WATER CONTENT =   0.1901 VOL/VOL
      EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
    NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
          FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

                   TYPE 2 - LATERAL DRAINAGE LAYER
                   MATERIAL TEXTURE NUMBER  5
      THICKNESS                =    12.00  INCHES
      POROSITY                 =   0.4570 VOL/VOL
      FIELD CAPACITY           =   0.1310 VOL/VOL
```

```
WILTING POINT            =    0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
SLOPE                  =   22.70  PERCENT
DRAINAGE LENGTH           =   110.0    FEET


               LAYER  3
               --------

        TYPE 4 - FLEXIBLE MEMBRANE LINER
         MATERIAL TEXTURE NUMBER  35
THICKNESS              =     0.10  INCHES
POROSITY               =    0.0000 VOL/VOL
FIELD CAPACITY            =    0.0000 VOL/VOL
WILTING POINT            =    0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =     0.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =     0.00   HOLES/ACRE
FML PLACEMENT QUALITY      = 1 - PERFECT


      GENERAL DESIGN AND EVAPORATIVE ZONE DATA
      ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF 23.%
       AND A SLOPE LENGTH OF  110. FEET.

SCS RUNOFF CURVE NUMBER              =    73.00
FRACTION OF AREA ALLOWING RUNOFF     =   100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =   285.000  ACRES
EVAPORATIVE ZONE DEPTH               =    18.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =     2.228  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =     8.202  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =     1.206  INCHES
INITIAL SNOW WATER                   =     0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =     2.228  INCHES
TOTAL INITIAL WATER                  =     2.228  INCHES
TOTAL SUBSURFACE INFLOW              =     0.00   INCHES/YEAR


      EVAPOTRANSPIRATION AND WEATHER DATA
      -----------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
       NEW YORK          NEW YORK

   MAXIMUM LEAF AREA INDEX                 =  2.00
   START OF GROWING SEASON (JULIAN DATE)   =  108
   END OF GROWING SEASON (JULIAN DATE)     =  302
   AVERAGE ANNUAL WIND SPEED               = 12.20 MPH
   AVERAGE 1ST QUARTER RELATIVE HUMIDITY   = 65.00 %
   AVERAGE 2ND QUARTER RELATIVE HUMIDITY   = 68.00 %
   AVERAGE 3RD QUARTER RELATIVE HUMIDITY   = 72.00 %
   AVERAGE 4TH QUARTER RELATIVE HUMIDITY   = 68.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

```
          COEFFICIENTS FOR   NEW YORK          NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

  JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
  -------   -------   -------   -------   -------   -------
   3.11      3.08      4.10      3.76      3.46      3.15
   3.67      4.32      3.48      3.24      3.77      3.68


     NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR   NEW YORK          NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

  JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
  -------   -------   -------   -------   -------   -------
   31.80     33.30     41.00     51.90     61.70     71.00
   76.40     75.30     68.20     57.50     47.10     36.20


     NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR   NEW YORK          NEW YORK

             STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   1
---------------------------------------------------------------
                                INCHES      CU. FEET     PERCENT
                                ------      --------     -------
PRECIPITATION                    38.62     39954312.000   100.00

RUNOFF                           0.031        32078.471     0.08

EVAPOTRANSPIRATION              29.990     31025658.000    77.65

DRAINAGE COLLECTED FROM LAYER  2 5.9014     6105286.000    15.28

PERC./LEAKAGE THROUGH LAYER  3  0.000036         36.777     0.00

AVG. HEAD ON TOP OF LAYER  3    1.4126

CHANGE IN WATER STORAGE          2.698      2791262.000     6.99

SOIL WATER AT START OF YEAR      2.500      2585961.250

SOIL WATER AT END OF YEAR        5.198      5377223.500

SNOW WATER AT START OF YEAR      0.000            0.000     0.00

SNOW WATER AT END OF YEAR        0.000            0.000     0.00

ANNUAL WATER BUDGET BALANCE      0.0000         -10.263     0.00
*******************************************************************************


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   2
```

```
******************************************************************************

        PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
------------------------------------------------------------
                          (INCHES)    (CU. FT.)
                          ----------  -------------
   PRECIPITATION                 3.96     4096818.000

   RUNOFF                      2.906   3006453.5000

   DRAINAGE COLLECTED FROM LAYER  2        0.24872    257313.39100

   PERCOLATION/LEAKAGE THROUGH LAYER  3    0.000001        1.18239

   AVERAGE HEAD ACROSS LAYER  3         16.800

   SNOW WATER                    2.75     2845338.2500

   MAXIMUM VEG. SOIL WATER (VOL/VOL)             0.4402

   MINIMUM VEG. SOIL WATER (VOL/VOL)             0.0541

******************************************************************************
```

12-INCH PROTECTION LAYER, 2% SLOPE
HELP MODEL RESULTS
WITH GEOGRID DRAINAGE LAYER

CDM Camp Dresser & McKee, Inc.

Project Brookfield Ave.
Job No.
Date 10/20/98
Computed By MWM
Checked By
Date Checked
Client NYCDEP
Page No.

SLOPE STABILITY ANALYSIS

ALTERANTIVE D - 2% MINIMUM SLOPE, 12" PROTECTION LAYER WITH DRAINAGE NET

Location	Slope (degrees)	Slope Length (ft)	Friction Angle (degrees)	(radians)	Hw	Hw	Resisting Term	Driving Term	FS
Partially Saturated (H2>Hw)									
4	33	90	30	0.52	0.04	0.00	99.15	56.78	1.75
Partially Saturated [H2<Hw<(H1+H2)]									
11	22.7	110	20	0.35	0.07	0.01	61.38	38.39	1.60
Saturated [Hw=(H1+H2)]									
	0	0	0	0.00	0.00	0.00	0.00	0.00	ERR

C= 0 unitless
SG1 = 110 lb/cf
SG1 (sat) = 131 lb/cf
SG2 = 117 lb/cf
SG2(sat) = 135 lb/cf
SG w = 62.4 lb/cf
h1 = 0.5 ft
h2 = 1 ft

Note:

1. Friction angles of 20 and 30 degrees are representative of smooth and textured geomembrane.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3.01   (14 OCTOBER 1994)                  **
**               DEVELOPED BY ENVIRONMENTAL LABORATORY                      **
**                 USAE WATERWAYS EXPERIMENT STATION                        **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATd4sb.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outd4s.OUT


TIME: 20: 8    DATE: 10/21/1998


******************************************************************************

  TITLE: Brookfield Avenue Landfill - 2% Minimum Slope, 12" Protection Layer with Drainage Net

******************************************************************************


  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                        LAYER  1
                        --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  6
     THICKNESS                =    6.00  INCHES
     POROSITY                 =   0.4530 VOL/VOL
     FIELD CAPACITY           =   0.1900 VOL/VOL
     WILTING POINT            =   0.0850 VOL/VOL
     INITIAL SOIL WATER CONTENT =   0.1901 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  =  0.720000011000E-03 CM/SEC
    NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
           FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                        LAYER  2
                        --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER  5
     THICKNESS                =   12.00  INCHES
     POROSITY                 =   0.4570 VOL/VOL
     FIELD CAPACITY           =   0.1310 VOL/VOL
```

```
WILTING POINT             =   0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =   0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC


              LAYER 3
              --------

         TYPE 2 - LATERAL DRAINAGE LAYER
          MATERIAL TEXTURE NUMBER 34
THICKNESS                 =    0.20  INCHES
POROSITY                  =   0.8500 VOL/VOL
FIELD CAPACITY            =   0.0100 VOL/VOL
WILTING POINT             =   0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT =   0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 33.0000000000    CM/SEC
SLOPE                     =  33.30  PERCENT
DRAINAGE LENGTH           =   90.0   FEET


              LAYER 4
              --------

         TYPE 4 - FLEXIBLE MEMBRANE LINER
          MATERIAL TEXTURE NUMBER 35
THICKNESS                 =    0.10  INCHES
POROSITY                  =   0.0000 VOL/VOL
FIELD CAPACITY            =   0.0000 VOL/VOL
WILTING POINT             =   0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =   0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY       =    0.00  HOLES/ACRE
FML INSTALLATION DEFECTS  =    0.00  HOLES/ACRE
FML PLACEMENT QUALITY     = 1 - PERFECT


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF 33.%
       AND A SLOPE LENGTH OF   90. FEET.

SCS RUNOFF CURVE NUMBER              =   73.70
FRACTION OF AREA ALLOWING RUNOFF     =  100.0   PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =  285.000  ACRES
EVAPORATIVE ZONE DEPTH               =   18.2   INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =   2.228  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =   8.372  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =   1.207  INCHES
INITIAL SNOW WATER                   =   0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =   2.228  INCHES
TOTAL INITIAL WATER                  =   2.228  INCHES
TOTAL SUBSURFACE INFLOW              =   0.00   INCHES/YEAR


        EVAPOTRANSPIRATION AND WEATHER DATA
        -----------------------------------
```

```
     NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
            NEW YORK           NEW YORK

       MAXIMUM LEAF AREA INDEX              =  2.00
       START OF GROWING SEASON (JULIAN DATE) =  108
       END OF GROWING SEASON (JULIAN DATE)   =  302
       AVERAGE ANNUAL WIND SPEED             = 12.20 MPH
       AVERAGE 1ST QUARTER RELATIVE HUMIDITY  = 65.00 %
       AVERAGE 2ND QUARTER RELATIVE HUMIDITY  = 68.00 %
       AVERAGE 3RD QUARTER RELATIVE HUMIDITY  = 72.00 %
       AVERAGE 4TH QUARTER RELATIVE HUMIDITY  = 68.00 %


     NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR    NEW YORK           NEW YORK

            NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

   JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
   -------    -------    -------    -------    -------    -------
    3.11       3.08       4.10       3.76       3.46       3.15
    3.67       4.32       3.48       3.24       3.77       3.68


     NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR    NEW YORK           NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
   -------    -------    -------    -------    -------    -------
    31.80      33.30      41.00      51.90      61.70      71.00
    76.40      75.30      68.20      57.50      47.10      36.20


     NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR    NEW YORK           NEW YORK

               STATION LATITUDE = 40.47 DEGREES


*******************************************************************************

              ANNUAL TOTALS FOR YEAR   1
------------------------------------------------------------------

                               INCHES        CU. FEET     PERCENT
                               -------      ---------     -------
  PRECIPITATION                    38.62     39954312.000    100.00

  RUNOFF                         0.006      6404.950     0.02

  EVAPOTRANSPIRATION                  28.294    29271472.000    73.26

  DRAINAGE COLLECTED FROM LAYER  3      11.2469    11635526.000    29.12

  PERC./LEAKAGE THROUGH LAYER  4       0.000000        0.430     0.00

  AVG. HEAD ON TOP OF LAYER  4        0.0008

  CHANGE IN WATER STORAGE            -0.927      -959085.125    -2.40

  SOIL WATER AT START OF YEAR         2.228       2304770.500

  SOIL WATER AT END OF YEAR          1.301      1345685.250
```

```
*******************************************************************************

        PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
----------------------------------------------------------
                              (INCHES)    (CU. FT.)
                              --------   ----------
  PRECIPITATION                   3.96      4096818.000

  RUNOFF                         2.825     2922238.0000

  DRAINAGE COLLECTED FROM LAYER  3      1.78306    1844666.25000

  PERCOLATION/LEAKAGE THROUGH LAYER  4    0.000000        0.00705

  AVERAGE HEAD ACROSS LAYER  4           0.043

  SNOW WATER                      2.75      2845338.2500

  MAXIMUM VEG. SOIL WATER (VOL/VOL)             0.2933

  MINIMUM VEG. SOIL WATER (VOL/VOL)             0.0568

*******************************************************************************
```

```
*******************************************************************************
*******************************************************************************
**                                                                           **
**                                                                           **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                 **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                   USAE WATERWAYS EXPERIMENT STATION                       **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                           **
**                                                                           **
*******************************************************************************
*******************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATd11s.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outd11s.OUT


TIME: 20:31    DATE: 10/21/1998


*******************************************************************************

  TITLE: Brookfield Avenue Landfill - 2% slope, 12" protection layer with drainage net

*******************************************************************************


  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                      LAYER  1
                      --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                   MATERIAL TEXTURE NUMBER   6
     THICKNESS                =    6.00  INCHES
     POROSITY                 =    0.4530 VOL/VOL
     FIELD CAPACITY           =    0.1900 VOL/VOL
     WILTING POINT            =    0.0850 VOL/VOL
     INITIAL SOIL WATER CONTENT =    0.1901 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
   NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
          FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                      LAYER  2
                      --------

                 TYPE 2 - LATERAL DRAINAGE LAYER
                   MATERIAL TEXTURE NUMBER   5
     THICKNESS                =   12.00  INCHES
     POROSITY                 =    0.4570 VOL/VOL
     FIELD CAPACITY           =    0.1310 VOL/VOL
```

```
WILTING POINT           =   0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =   0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC


          LAYER  3
          --------

        TYPE 2 - LATERAL DRAINAGE LAYER
          MATERIAL TEXTURE NUMBER  34
THICKNESS             =    0.20  INCHES
POROSITY              =    0.8500 VOL/VOL
FIELD CAPACITY          =    0.0100 VOL/VOL
WILTING POINT           =    0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 33.0000000000     CM/SEC
SLOPE                 =   22.70  PERCENT
DRAINAGE LENGTH         =    110.0    FEET


          LAYER  4
          --------

        TYPE 4 - FLEXIBLE MEMBRANE LINER
          MATERIAL TEXTURE NUMBER  35
THICKNESS             =    0.10  INCHES
POROSITY              =    0.0000 VOL/VOL
FIELD CAPACITY          =    0.0000 VOL/VOL
WILTING POINT           =    0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY      =    0.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =    0.00   HOLES/ACRE
FML PLACEMENT QUALITY      = 1 - PERFECT


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF 23.%
       AND A SLOPE LENGTH OF  110. FEET.

SCS RUNOFF CURVE NUMBER            =   73.00
FRACTION OF AREA ALLOWING RUNOFF   =   100.0   PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =   285.000  ACRES
EVAPORATIVE ZONE DEPTH             =   18.2   INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =    2.228  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =    8.372  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =    1.207  INCHES
INITIAL SNOW WATER                 =   0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    2.228  INCHES
TOTAL INITIAL WATER                =   2.228  INCHES
TOTAL SUBSURFACE INFLOW            =    0.00   INCHES/YEAR


        EVAPOTRANSPIRATION AND WEATHER DATA
        -----------------------------------
```

```
    NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
           NEW YORK          NEW YORK

       MAXIMUM LEAF AREA INDEX              =  2.00
       START OF GROWING SEASON (JULIAN DATE) =  108
       END OF GROWING SEASON (JULIAN DATE)   =  302
       AVERAGE ANNUAL WIND SPEED             = 12.20 MPH
       AVERAGE 1ST QUARTER RELATIVE HUMIDITY  = 65.00 %
       AVERAGE 2ND QUARTER RELATIVE HUMIDITY  = 68.00 %
       AVERAGE 3RD QUARTER RELATIVE HUMIDITY  = 72.00 %
       AVERAGE 4TH QUARTER RELATIVE HUMIDITY  = 68.00 %


    NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    NEW YORK          NEW YORK

           NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

  JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
  -------    -------    -------    -------    -------    -------
    3.11       3.08       4.10       3.76       3.46       3.15
    3.67       4.32       3.48       3.24       3.77       3.68


    NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    NEW YORK          NEW YORK

       NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

  JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
  -------    -------    -------    -------    -------    -------
   31.80      33.30      41.00      51.90      61.70      71.00
   76.40      75.30      68.20      57.50      47.10      36.20


    NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    NEW YORK          NEW YORK

               STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR    1
 ----------------------------------------------------------
                              INCHES      CU. FEET    PERCENT
                             --------    ----------   -------
  PRECIPITATION                   38.62     39954312.000   100.00

  RUNOFF                        0.003        3108.327    0.01

  EVAPOTRANSPIRATION                28.038     29007068.000    72.60

  DRAINAGE COLLECTED FROM LAYER  3      11.5060    11903540.000    29.79

  PERC./LEAKAGE THROUGH LAYER  4      0.000000        0.470     0.00

  AVG. HEAD ON TOP OF LAYER  4        0.0013

  CHANGE IN WATER STORAGE           -0.927      -959391.125    -2.40

  SOIL WATER AT START OF YEAR        2.228      2304770.500

  SOIL WATER AT END OF YEAR          1.300      1345379.250
```

```
******************************************************************************

      PEAK DAILY VALUES FOR YEARS   1 THROUGH   10
  --------------------------------------------------------
                            (INCHES)    (CU. FT.)
                            --------    ---------
   PRECIPITATION                  3.96     4096818.000

   RUNOFF                       2.826    2923905.0000

   DRAINAGE COLLECTED FROM LAYER  3      1.79048   1852343.37000

   PERCOLATION/LEAKAGE THROUGH LAYER  4    0.000000      0.00737

   AVERAGE HEAD ACROSS LAYER  4          0.074

   SNOW WATER                     2.75     2845338.2500

   MAXIMUM VEG. SOIL WATER (VOL/VOL)          0.2936

   MINIMUM VEG. SOIL WATER (VOL/VOL)          0.0561
******************************************************************************
```

24-INCH PROTECTION LAYER, 4% SLOPE
HELP MODEL RESULTS

CDM Camp Dresser & McKee, Inc.

Project	Brookfield Ave.	Job No.		Date	10/20/98
Computed By	MWM	Checked By		Date Checked	
		Client	NYCDEP	Page No.	

SLOPE STABILITY ANALYSIS

ALTERANTIVE A - 4% MINIMUM SLOPE, 24" PROTECTION LAYER

Location	Slope (degrees)	Slope Length (ft)	Friction Angle (degrees)	Friction Angle (radians)	Hw	Hw	Resisting Term	Driving Term	FS
Partially Saturated (H2>Hw)									
2	17.7	130	30	0.52	18.55	1.55	127.15	56.08	2.27
4	33	90	30	0.52	11.55	0.96	142.10	107.25	**1.32**
11	22.7	110	20	0.35	15.25	1.27	84.60	51.51	1.64
Partially Saturated [H2<Hw<(H1+H2)]									
9	13.9	180	20	0.35	25.96	2.16	70.36	45.65	1.54
Saturated [Hw=(H1+H2)]									
	0	0	0	0.00	0.00	0.00	0.00	0.00	ERR

C= 0 unitless
SG1 = 110 lb/cf
SG1 (sat) = 131 lb/cf
SG2 = 117 lb/cf
SG2(sat) = 135 lb/cf
SG w = 62.4 lb/cf
h1 = 0.5 ft
h2 = 2 ft

Note:

1. Friction angles of 20 and 30 degrees are representative of smooth and textured geomembrane.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                   **
**             DEVELOPED BY ENVIRONMENTAL LABORATORY                        **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATa2ba.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outa2.OUT


TIME:  2:54    DATE:  10/21/1998


******************************************************************************

  TITLE: Brookfield Avenue Landfill - 4% Minimum Slope, 24" Protection Layer

******************************************************************************


  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                            LAYER  1
                            --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  6
        THICKNESS                 =     6.00  INCHES
        POROSITY                  =   0.4530 VOL/VOL
        FIELD CAPACITY            =   0.1900 VOL/VOL
        WILTING POINT             =   0.0850 VOL/VOL
        INITIAL SOIL WATER CONTENT =  0.1901 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
      NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
             FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                            LAYER  2
                            --------

                   TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER  5
        THICKNESS                 =    24.00  INCHES
        POROSITY                  =   0.4570 VOL/VOL
        FIELD CAPACITY            =   0.1310 VOL/VOL
```

```
WILTING POINT            =    0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
SLOPE                  =    17.70  PERCENT
DRAINAGE LENGTH           =    130.0   FEET



              LAYER 3
              --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
           MATERIAL TEXTURE NUMBER 35
THICKNESS               =    0.10  INCHES
POROSITY               =    0.0000 VOL/VOL
FIELD CAPACITY           =    0.0000 VOL/VOL
WILTING POINT            =    0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY       =    0.00  HOLES/ACRE
FML INSTALLATION DEFECTS  =    0.00  HOLES/ACRE
FML PLACEMENT QUALITY     = 1 - PERFECT



        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF 18.%
       AND A SLOPE LENGTH OF 130. FEET.

SCS RUNOFF CURVE NUMBER            =    72.50
FRACTION OF AREA ALLOWING RUNOFF   =   100.0   PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =   285.000  ACRES
EVAPORATIVE ZONE DEPTH             =    20.0   INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =    2.409  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =    9.116  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =    1.322  INCHES
INITIAL SNOW WATER                 =    0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    3.315  INCHES
TOTAL INITIAL WATER                =    3.315  INCHES
TOTAL SUBSURFACE INFLOW            =    0.00   INCHES/YEAR



        EVAPOTRANSPIRATION AND WEATHER DATA
        ------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
       NEW YORK          NEW YORK

   MAXIMUM LEAF AREA INDEX              = 2.00
   START OF GROWING SEASON (JULIAN DATE) = 108
   END OF GROWING SEASON (JULIAN DATE)   = 302
   AVERAGE ANNUAL WIND SPEED            = 12.20 MPH
   AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 65.00 %
   AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 68.00 %
   AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
   AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 68.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

```
          COEFFICIENTS FOR    NEW YORK         NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    3.11      3.08      4.10      3.76      3.46      3.15
    3.67      4.32      3.48      3.24      3.77      3.68


      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    31.80     33.30     41.00     51.90     61.70     71.00
    76.40     75.30     68.20     57.50     47.10     36.20


      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

             STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR    1
-------------------------------------------------------------------
                                INCHES      CU. FEET      PERCENT
                               --------    ----------    -------
 PRECIPITATION                    38.62    39954312.000   100.00

 RUNOFF                           0.003        3008.615     0.01

 EVAPOTRANSPIRATION              29.569    30590590.000    76.56

 DRAINAGE COLLECTED FROM LAYER  2    4.2958    4444197.000    11.12

 PERC./LEAKAGE THROUGH LAYER  3    0.000039       40.399     0.00

 AVG. HEAD ON TOP OF LAYER  3      1.5542

 CHANGE IN WATER STORAGE          4.752     4916488.500    12.31

 SOIL WATER AT START OF YEAR      4.221     4366798.000

 SOIL WATER AT END OF YEAR        8.973     9283286.000

 SNOW WATER AT START OF YEAR      0.000           0.000     0.00

 SNOW WATER AT END OF YEAR        0.000           0.000     0.00

 ANNUAL WATER BUDGET BALANCE      0.0000        -11.693     0.00
*******************************************************************************


*******************************************************************************

             ANNUAL TOTALS FOR YEAR    2
```

```
******************************************************************************

          PEAK DAILY VALUES FOR YEARS   1 THROUGH   10
------------------------------------------------------------------------
                                    (INCHES)    (CU. FT.)
                                    --------   ----------
   PRECIPITATION                        3.96     4096818.000

   RUNOFF                              2.838    2936200.5000

   DRAINAGE COLLECTED FROM LAYER  2           0.13883    143622.28100

   PERCOLATION/LEAKAGE THROUGH LAYER  3      0.000001          1.30551

   AVERAGE HEAD ACROSS LAYER  3          18.549

   SNOW WATER                           2.75     2845338.2500

   MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.3446

   MINIMUM VEG. SOIL WATER (VOL/VOL)              0.0542
******************************************************************************
```

```
****************************************************************************
****************************************************************************
**                                                                        **
**                                                                        **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                 **
**             HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                 **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                USAE WATERWAYS EXPERIMENT STATION                       **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                        **
**                                                                        **
****************************************************************************
****************************************************************************


PRECIPITATION DATA FILE:    C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELP3\SDATa4ba.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELP3\outa4.OUT


TIME:  3:22    DATE:  10/21/1998


****************************************************************************

  TITLE:  Brookfield Avenue Landfill - 4% Minimum Slope, 24" Protection Layer

****************************************************************************


  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                         LAYER  1
                         --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                   MATERIAL TEXTURE NUMBER   6
     THICKNESS                 =     6.00  INCHES
     POROSITY                  =    0.4530 VOL/VOL
     FIELD CAPACITY            =    0.1900 VOL/VOL
     WILTING POINT             =    0.0850 VOL/VOL
     INITIAL SOIL WATER CONTENT =   0.1901 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  =  0.720000011000E-03 CM/SEC
   NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
          FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                         LAYER  2
                         --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                   MATERIAL TEXTURE NUMBER   5
     THICKNESS                 =    24.00  INCHES
     POROSITY                  =    0.4570 VOL/VOL
     FIELD CAPACITY            =    0.1310 VOL/VOL
```

```
WILTING POINT            =   0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =   0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
SLOPE                  =  33.30  PERCENT
DRAINAGE LENGTH            =   90.0   FEET


                 LAYER 3
                 --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
           MATERIAL TEXTURE NUMBER 35
THICKNESS              =    0.10  INCHES
POROSITY               =   0.0000 VOL/VOL
FIELD CAPACITY           =    0.0000 VOL/VOL
WILTING POINT            = `  0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =    0.00  HOLES/ACRE
FML INSTALLATION DEFECTS   =     0.00  HOLES/ACRE
FML PLACEMENT QUALITY      =  1 - PERFECT


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
      SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
      FAIR STAND OF GRASS, A SURFACE SLOPE OF 33.%
      AND A SLOPE LENGTH OF  90. FEET.

SCS RUNOFF CURVE NUMBER          =    73.70
FRACTION OF AREA ALLOWING RUNOFF  =   100.0   PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =   285.000  ACRES
EVAPORATIVE ZONE DEPTH           =    20.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =     2.409  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     9.116  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =     1.322  INCHES
INITIAL SNOW WATER               =    0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     3.315  INCHES
TOTAL INITIAL WATER              =    3.315  INCHES
TOTAL SUBSURFACE INFLOW          =     0.00   INCHES/YEAR


        EVAPOTRANSPIRATION AND WEATHER DATA
        -----------------------------------

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
      NEW YORK          NEW YORK

   MAXIMUM LEAF AREA INDEX              = 2.00
   START OF GROWING SEASON (JULIAN DATE) =  108
   END OF GROWING SEASON (JULIAN DATE)   =  302
   AVERAGE ANNUAL WIND SPEED            = 12.20 MPH
   AVERAGE 1ST QUARTER RELATIVE HUMIDITY  = 65.00 %
   AVERAGE 2ND QUARTER RELATIVE HUMIDITY  = 68.00 %
   AVERAGE 3RD QUARTER RELATIVE HUMIDITY  = 72.00 %
   AVERAGE 4TH QUARTER RELATIVE HUMIDITY  = 68.00 %


NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

```
          COEFFICIENTS FOR    NEW YORK        NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

    JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
    -------   -------   -------   -------   -------   -------
     3.11      3.08      4.10      3.76      3.46      3.15
     3.67      4.32      3.48      3.24      3.77      3.68


       NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK        NEW YORK

       NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

    JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
    -------   -------   -------   -------   -------   -------
     31.80     33.30     41.00     51.90     61.70     71.00
     76.40     75.30     68.20     57.50     47.10     36.20


       NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK        NEW YORK

             STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   1
------------------------------------------------------------
                               INCHES      CU. FEET    PERCENT
                              --------   ----------   -------
  PRECIPITATION                  38.62      39954312.000   100.00

  RUNOFF                         0.014        14083.831      0.04

  EVAPOTRANSPIRATION            29.646      30670230.000    76.76

  DRAINAGE COLLECTED FROM LAYER  2      5.8423     6044195.000    15.13

  PERC./LEAKAGE THROUGH LAYER  3     0.000021         21.998      0.00

  AVG. HEAD ON TOP OF LAYER  3     0.8363

  CHANGE IN WATER STORAGE        3.118      3225782.750     8.07

  SOIL WATER AT START OF YEAR    4.221      4366798.000

  SOIL WATER AT END OF YEAR      7.339      7592580.500

  SNOW WATER AT START OF YEAR    0.000            0.000     0.00

  SNOW WATER AT END OF YEAR      0.000            0.000     0.00

  ANNUAL WATER BUDGET BALANCE    0.0000          -1.055     0.00

*******************************************************************************


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   2
```

```
********************************************************************************

          PEAK DAILY VALUES FOR YEARS   1 THROUGH   10
 -------------------------------------------------------
                              (INCHES)     (CU. FT.)
                              --------    ----------
  PRECIPITATION                    3.96      4096818.000

  RUNOFF                        2.839     2936616.0000

  DRAINAGE COLLECTED FROM LAYER  2        0.21807    225603.79700

  PERCOLATION/LEAKAGE THROUGH LAYER  3      0.000001         0.81284

  AVERAGE HEAD ACROSS LAYER  3          11.549

  SNOW WATER                       2.75      2845338.2500

  MAXIMUM VEG. SOIL WATER (VOL/VOL)            0.3446

  MINIMUM VEG. SOIL WATER (VOL/VOL)            0.0543
********************************************************************************
```

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**           HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                  **
**             HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                   **
**               DEVELOPED BY ENVIRONMENTAL LABORATORY                      **
**                 USAE WATERWAYS EXPERIMENT STATION                        **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATa9ba.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outa9.OUT


TIME:  2:59    DATE: 10/21/1998


******************************************************************************

  TITLE: Brookfield Avenue Landfill - 2% Minimum Slope, 24" Protection Layer

******************************************************************************


  NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
        WERE SPECIFIED BY THE USER.


                            LAYER  1
                            --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                   MATERIAL TEXTURE NUMBER  6
      THICKNESS                =    6.00  INCHES
      POROSITY                 =   0.4530 VOL/VOL
      FIELD CAPACITY           =   0.1900 VOL/VOL
      WILTING POINT            =   0.0850 VOL/VOL
      INITIAL SOIL WATER CONTENT =  0.1901 VOL/VOL
      EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
     NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
           FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                            LAYER  2
                            --------

                   TYPE 2 - LATERAL DRAINAGE LAYER
                   MATERIAL TEXTURE NUMBER  5
      THICKNESS                =   24.00  INCHES
      POROSITY                 =   0.4570 VOL/VOL
      FIELD CAPACITY           =   0.1310 VOL/VOL
```

```
WILTING POINT            =   0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
SLOPE                    =   13.90  PERCENT
DRAINAGE LENGTH            =   180.0    FEET


              LAYER  3
              --------

         TYPE 4 - FLEXIBLE MEMBRANE LINER
          MATERIAL TEXTURE NUMBER  35
THICKNESS               =    0.10  INCHES
POROSITY                =    0.0000 VOL/VOL
FIELD CAPACITY            =    0.0000 VOL/VOL
WILTING POINT             =    0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY       =     0.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =     0.00   HOLES/ACRE
FML PLACEMENT QUALITY      = 1 - PERFECT


         GENERAL DESIGN AND EVAPORATIVE ZONE DATA
         ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF 14.%
       AND A SLOPE LENGTH OF  180. FEET.

SCS RUNOFF CURVE NUMBER            =   71.80
FRACTION OF AREA ALLOWING RUNOFF   =   100.0   PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =   285.000  ACRES
EVAPORATIVE ZONE DEPTH             =   20.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =    2.409  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =    9.116  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =    1.322  INCHES
INITIAL SNOW WATER                 =    0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    3.315  INCHES
TOTAL INITIAL WATER                =    3.315  INCHES
TOTAL SUBSURFACE INFLOW            =    0.00   INCHES/YEAR


         EVAPOTRANSPIRATION AND WEATHER DATA
         -----------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
       NEW YORK          NEW YORK

  MAXIMUM LEAF AREA INDEX              = 2.00
  START OF GROWING SEASON (JULIAN DATE) = 108
  END OF GROWING SEASON (JULIAN DATE)   = 302
  AVERAGE ANNUAL WIND SPEED            = 12.20 MPH
  AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 65.00 %
  AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 68.00 %
  AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
  AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 68.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

```
          COEFFICIENTS FOR     NEW YORK          NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

    JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
    -------    -------    -------    -------    -------    -------
     3.11       3.08       4.10       3.76       3.46       3.15
     3.67       4.32       3.48       3.24       3.77       3.68


       NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR     NEW YORK          NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

    JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
    -------    -------    -------    -------    -------    -------
     31.80      33.30      41.00      51.90      61.70      71.00
     76.40      75.30      68.20      57.50      47.10      36.20


       NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR     NEW YORK          NEW YORK

             STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR    1
-------------------------------------------------------------------
                         INCHES        CU. FEET     PERCENT
                         -------      ----------    -------
 PRECIPITATION              38.62      39954312.000    100.00

 RUNOFF                     0.000        502.491       0.00

 EVAPOTRANSPIRATION         29.588     30610452.000     76.61

 DRAINAGE COLLECTED FROM LAYER  2        3.3473     3462965.500      8.67

 PERC./LEAKAGE THROUGH LAYER  3       0.000053         54.856      0.00

 AVG. HEAD ON TOP OF LAYER  3        2.1119

 CHANGE IN WATER STORAGE         5.684      5880346.500     14.72

 SOIL WATER AT START OF YEAR      4.221      4366798.000

 SOIL WATER AT END OF YEAR        9.905     10247144.000

 SNOW WATER AT START OF YEAR        0.000          0.000      0.00

 SNOW WATER AT END OF YEAR          0.000          0.000      0.00

 ANNUAL WATER BUDGET BALANCE        0.0000         -9.771     0.00
*******************************************************************************


*******************************************************************************

             ANNUAL TOTALS FOR YEAR    2
```

```
******************************************************************************

        PEAK DAILY VALUES FOR YEARS   1 THROUGH   10
  ------------------------------------------------------------
                               (INCHES)   (CU. FT.)
                               --------   ---------
   PRECIPITATION                    3.96    4096818.000

   RUNOFF                          2.841    2939652.0000

   DRAINAGE COLLECTED FROM LAYER  2     0.07008      72496.14060

   PERCOLATION/LEAKAGE THROUGH LAYER  3    0.000002        1.82724

   AVERAGE HEAD ACROSS LAYER  3        25.962

   SNOW WATER                       2.75    2845338.2500

   MAXIMUM VEG. SOIL WATER (VOL/VOL)             0.4121

   MINIMUM VEG. SOIL WATER (VOL/VOL)             0.0541

******************************************************************************
```

```
*******************************************************************************
*******************************************************************************
**                                                                           **
**                                                                           **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                    **
**             HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                    **
**             DEVELOPED BY ENVIRONMENTAL LABORATORY                         **
**               USAE WATERWAYS EXPERIMENT STATION                           **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                  **
**                                                                           **
**                                                                           **
*******************************************************************************
*******************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATa11b.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outa11.OUT


TIME:  3: 2    DATE: 10/21/1998


*******************************************************************************

  TITLE: Brookfield Avenue Landfill - 4% minimum slope, 24" protection layer

*******************************************************************************


  NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
        WERE SPECIFIED BY THE USER.


                    LAYER  1
                    --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  6
     THICKNESS               =     6.00  INCHES
     POROSITY                =   0.4530 VOL/VOL
     FIELD CAPACITY          =   0.1900 VOL/VOL
     WILTING POINT           =   0.0850 VOL/VOL
     INITIAL SOIL WATER CONTENT =   0.1901 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
   NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                    LAYER  2
                    --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER  5
     THICKNESS               =    24.00  INCHES
     POROSITY                =   0.4570 VOL/VOL
     FIELD CAPACITY          =   0.1310 VOL/VOL
```

```
WILTING POINT            =    0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
SLOPE                  =  22.70  PERCENT
DRAINAGE LENGTH            =   110.0   FEET


              LAYER  3
              --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
           MATERIAL TEXTURE NUMBER  35
THICKNESS                =    0.10  INCHES
POROSITY                 =    0.0000 VOL/VOL
FIELD CAPACITY           =    0.0000 VOL/VOL
WILTING POINT            =    0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =    0.00  HOLES/ACRE
FML INSTALLATION DEFECTS   =    0.00  HOLES/ACRE
FML PLACEMENT QUALITY      = 1 - PERFECT


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF 23.%
       AND A SLOPE LENGTH OF  110. FEET.

SCS RUNOFF CURVE NUMBER             =   73.00
FRACTION OF AREA ALLOWING RUNOFF  =   100.0   PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =   285.000  ACRES
EVAPORATIVE ZONE DEPTH             =   20.0   INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =    2.409  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =    9.116  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =    1.322  INCHES
INITIAL SNOW WATER                =   0.000  INCHES
INITIAL WATER IN LAYER MATERIALS  =    3.315  INCHES
TOTAL INITIAL WATER               =   3.315  INCHES
TOTAL SUBSURFACE INFLOW           =    0.00   INCHES/YEAR


        EVAPOTRANSPIRATION AND WEATHER DATA
        -----------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
       NEW YORK          NEW YORK

  MAXIMUM LEAF AREA INDEX           = 2.00
  START OF GROWING SEASON (JULIAN DATE) =  108
  END OF GROWING SEASON (JULIAN DATE)   =  302
  AVERAGE ANNUAL WIND SPEED           = 12.20 MPH
  AVERAGE 1ST QUARTER RELATIVE HUMIDITY  = 65.00 %
  AVERAGE 2ND QUARTER RELATIVE HUMIDITY  = 68.00 %
  AVERAGE 3RD QUARTER RELATIVE HUMIDITY  = 72.00 %
  AVERAGE 4TH QUARTER RELATIVE HUMIDITY  = 68.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

```
          COEFFICIENTS FOR    NEW YORK         NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

  JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
  -------   -------   -------   -------   -------   -------
    3.11      3.08      4.10      3.76      3.46      3.15
    3.67      4.32      3.48      3.24      3.77      3.68


     NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

  JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
  -------   -------   -------   -------   -------   -------
   31.80     33.30     41.00     51.90     61.70     71.00
   76.40     75.30     68.20     57.50     47.10     36.20


     NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK         NEW YORK

             STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

              ANNUAL TOTALS FOR YEAR   1
-------------------------------------------------------
                                INCHES      CU. FEET     PERCENT
                               --------    ----------    -------
 PRECIPITATION                    38.62     39954312.000  100.00

 RUNOFF                           0.006       6577.986     0.02

 EVAPOTRANSPIRATION              29.678     30703510.000   76.85

 DRAINAGE COLLECTED FROM LAYER  2    4.8652     5033263.500    12.60

 PERC./LEAKAGE THROUGH LAYER  3    0.000030        30.779     0.00

 AVG. HEAD ON TOP OF LAYER  3     1.1834

 CHANGE IN WATER STORAGE          4.070      4210935.000    10.54

 SOIL WATER AT START OF YEAR      4.221      4366798.000

 SOIL WATER AT END OF YEAR        8.291      8577733.000

 SNOW WATER AT START OF YEAR      0.000         0.000     0.00

 SNOW WATER AT END OF YEAR        0.000         0.000     0.00

 ANNUAL WATER BUDGET BALANCE      0.0000       -5.785     0.00
*******************************************************************************


*******************************************************************************

              ANNUAL TOTALS FOR YEAR   2
```

```
******************************************************************************

          PEAK DAILY VALUES FOR YEARS   1 THROUGH  10
----------------------------------------------------
                         (INCHES)    (CU. FT.)
                         --------    ---------
  PRECIPITATION                3.96    4096818.000

  RUNOFF                   2.839    2936727.2500

  DRAINAGE COLLECTED FROM LAYER  2       0.16968    175544.48400

  PERCOLATION/LEAKAGE THROUGH LAYER  3    0.000001        1.07341

  AVERAGE HEAD ACROSS LAYER  3        15.251

  SNOW WATER                    2.75    2845338.2500

  MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.3447

  MINIMUM VEG. SOIL WATER (VOL/VOL)             0.0542
******************************************************************************
```

18-INCH PROTECTION LAYER, 2% SLOPE
HELP MODEL RESULTS

CDM Camp Dresser & McKee, Inc.

Project	Brookfield Ave.	Job No.		Date	10/20/98
Computed By	MWM	Checked By		Date Checked	
		Client	NYCDEP	Page No.	

SLOPE STABILITY ANALYSIS

ALTERANTIVES B & C - 2% MINIMUM SLOPE, 18" PROTECTION LAYER

Location	Slope (degrees)	Slope Length (ft)	Friction Angle (degrees)	Friction Angle (radians)	Hw	Hw	esisting Ter	riving Ter	FS
Partially Saturated (H2>Hw)									
11	22.7	110	30	0.52	17.02	1.42	96.67	58.12	1.66
Partially Saturated [H2<H1<(H1+H2)]									
2	17.7	130	30	0.52	23.52	1.96	83.58	47.29	1.77
Saturated [Hw=(H1+H2)]									
9	13.9	180	30	0.52	24.00	2.00	82.63	37.25	2.22

C= 0 unitless

SG1 = 110 lb/cf

SG1 (sat) = 131 lb/cf

SG2 = 117 lb/cf

SG2(sat) = 135 lb/cf

SG w = 62.4 lb/cf

h1 = 0.5 ft

h2 = 1.5 ft

Note:

1. Friction angles of 20 and 30 degrees are representative of smooth and textured geomembrane.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**             HELP MODEL VERSION 3.01 (14 OCTOBER 1994)                    **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELP3\SDATC2BA.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELP3\outC2.OUT


TIME:  3:30    DATE: 10/21/1998


******************************************************************************

  TITLE: Brookfield Avenue Landfill - 2%Minimum Slope, 18" protection layer

******************************************************************************


  NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
        WERE SPECIFIED BY THE USER.


                          LAYER  1
                          --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER  6
     THICKNESS                 =     6.00  INCHES
     POROSITY                  =     0.4530 VOL/VOL
     FIELD CAPACITY            =     0.1900 VOL/VOL
     WILTING POINT             =     0.0850 VOL/VOL
     INITIAL SOIL WATER CONTENT =    0.1901 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
   NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

                 TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER  5
     THICKNESS                 =    18.00  INCHES
     POROSITY                  =     0.4570 VOL/VOL
     FIELD CAPACITY            =     0.1310 VOL/VOL
```

```
  WILTING POINT            =  0.0580 VOL/VOL
  INITIAL SOIL WATER CONTENT =  0.0906 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
  SLOPE              =  17.70  PERCENT
  DRAINAGE LENGTH          =  130.0   FEET


              LAYER  3
              --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
           MATERIAL TEXTURE NUMBER  35
  THICKNESS             =   0.10  INCHES
  POROSITY              =   0.0000 VOL/VOL
  FIELD CAPACITY           =   0.0000 VOL/VOL
  WILTING POINT            =   0.0000 VOL/VOL
  INITIAL SOIL WATER CONTENT =   0.0000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
  FML PINHOLE DENSITY        =   0.00  HOLES/ACRE
  FML INSTALLATION DEFECTS   =   0.00  HOLES/ACRE
  FML PLACEMENT QUALITY      = 1 - PERFECT


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
        SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
        FAIR STAND OF GRASS, A SURFACE SLOPE OF 18.%
        AND A SLOPE LENGTH OF  130. FEET.

 SCS RUNOFF CURVE NUMBER            =   72.50
 FRACTION OF AREA ALLOWING RUNOFF   =   100.0   PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =   285.000  ACRES
 EVAPORATIVE ZONE DEPTH             =   20.0   INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =   2.409  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =   9.116  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =   1.322  INCHES
 INITIAL SNOW WATER                 =   0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =   2.771  INCHES
 TOTAL INITIAL WATER                =   2.771  INCHES
 TOTAL SUBSURFACE INFLOW            =   0.00   INCHES/YEAR


        EVAPOTRANSPIRATION AND WEATHER DATA
        -----------------------------------

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
       NEW YORK          NEW YORK

   MAXIMUM LEAF AREA INDEX                 = 2.00
   START OF GROWING SEASON (JULIAN DATE) = 108
   END OF GROWING SEASON (JULIAN DATE)   = 302
   AVERAGE ANNUAL WIND SPEED              = 12.20 MPH
   AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 65.00 %
   AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 68.00 %
   AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
   AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 68.00 %


 NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

```
          COEFFICIENTS FOR    NEW YORK          NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    3.11      3.08      4.10      3.76      3.46      3.15
    3.67      4.32      3.48      3.24      3.77      3.68


      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK          NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
   -------   -------   -------   -------   -------   -------
    31.80     33.30     41.00     51.90     61.70     71.00
    76.40     75.30     68.20     57.50     47.10     36.20


      NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK          NEW YORK

             STATION LATITUDE = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   1
-------------------------------------------------------------
                                INCHES       CU. FEET     PERCENT
                               --------    ----------    -------
  PRECIPITATION                   38.62    39954312.000   100.00

  RUNOFF                          0.007        7411.912     0.02

  EVAPOTRANSPIRATION             29.569    30590590.000    76.56

  DRAINAGE COLLECTED FROM LAYER  2    4.9176     5087496.500    12.73

  PERC./LEAKAGE THROUGH LAYER  3    0.000045        46.246     0.00

  AVG. HEAD ON TOP OF LAYER  3     1.7789

  CHANGE IN WATER STORAGE         4.126     4268781.000    10.68

  SOIL WATER AT START OF YEAR     3.134     3242035.250

  SOIL WATER AT END OF YEAR       7.260     7510816.500

  SNOW WATER AT START OF YEAR     0.000           0.000     0.00

  SNOW WATER AT END OF YEAR       0.000           0.000     0.00

  ANNUAL WATER BUDGET BALANCE     0.0000        -13.095     0.00

*******************************************************************************


*******************************************************************************

             ANNUAL TOTALS FOR YEAR   2
```

```
****************************************************************************

          PEAK DAILY VALUES FOR YEARS   1 THROUGH   10
  ------------------------------------------------------------
                              (INCHES)    (CU. FT.)
                              ---------   ----------
    PRECIPITATION                     3.96     4096818.000

    RUNOFF                          2.861    2959620.7500

    DRAINAGE COLLECTED FROM LAYER  2        0.13660    141317.18700

    PERCOLATION/LEAKAGE THROUGH LAYER  3    0.000002        1.65530

    AVERAGE HEAD ACROSS LAYER  3         23.519

    SNOW WATER                        2.75     2845338.2500

    MAXIMUM VEG. SOIL WATER (VOL/VOL)            0.4517

    MINIMUM VEG. SOIL WATER (VOL/VOL)            0.0543

****************************************************************************
```

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**       HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                      **
**        HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                        **
**          DEVELOPED BY ENVIRONMENTAL LABORATORY                           **
**            USAE WATERWAYS EXPERIMENT STATION                             **
**       FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                    **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATC9BA.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outC9.OUT


TIME:  3:33   DATE: 10/21/1998


******************************************************************************

  TITLE: Brookfield Avenue Landfill - 2% Minimum Slope, 18" Protection Layer

******************************************************************************


  NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
        WERE SPECIFIED BY THE USER.


                 LAYER  1
                 --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  6
    THICKNESS              =    6.00  INCHES
    POROSITY               =   0.4530 VOL/VOL
    FIELD CAPACITY         =   0.1900 VOL/VOL
    WILTING POINT          =   0.0850 VOL/VOL
    INITIAL SOIL WATER CONTENT =   0.1901 VOL/VOL
    EFFECTIVE SAT. HYD. COND.  = 0.720000011000E-03 CM/SEC
   NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
          FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                 LAYER  2
                 --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  5
    THICKNESS              =   18.00  INCHES
    POROSITY               =   0.4570 VOL/VOL
    FIELD CAPACITY         =   0.1310 VOL/VOL
```

```
WILTING POINT              =    0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
SLOPE                 =   13.90  PERCENT
DRAINAGE LENGTH            =   180.0'  FEET


            LAYER  3
            --------

        TYPE 4 - FLEXIBLE MEMBRANE LINER
         MATERIAL TEXTURE NUMBER  35
THICKNESS              =    0.10  INCHES
POROSITY               =   0.0000 VOL/VOL
FIELD CAPACITY            =    0.0000 VOL/VOL
WILTING POINT             =   0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =    0.00  HOLES/ACRE
FML INSTALLATION DEFECTS   =    0.00  HOLES/ACRE
FML PLACEMENT QUALITY      = 1 - PERFECT


      GENERAL DESIGN AND EVAPORATIVE ZONE DATA
      ------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF 14.%
       AND A SLOPE LENGTH OF  180. FEET.

SCS RUNOFF CURVE NUMBER            =    71.80
FRACTION OF AREA ALLOWING RUNOFF   =   100.0   PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =  285.000  ACRES
EVAPORATIVE ZONE DEPTH             =    20.0   INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =     2.409  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     9.116  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =     1.322  INCHES
INITIAL SNOW WATER                 =    0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     2.771  INCHES
TOTAL INITIAL WATER                =    2.771  INCHES
TOTAL SUBSURFACE INFLOW            =     0.00   INCHES/YEAR


      EVAPOTRANSPIRATION AND WEATHER DATA
      -------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
       NEW YORK          NEW YORK

  MAXIMUM LEAF AREA INDEX               = 2.00
  START OF GROWING SEASON (JULIAN DATE) =  108
  END OF GROWING SEASON (JULIAN DATE)   =  302
  AVERAGE ANNUAL WIND SPEED             = 12.20 MPH
  AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 65.00 %
  AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 68.00 %
  AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
  AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 68.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

```
      COEFFICIENTS FOR    NEW YORK         NEW YORK

      NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

  JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
  -------   -------   -------   -------   -------   -------
   3.11 .   3.08      4.10      3.76      3.46      3.15
   3.67     4.32      3.48      3.24      3.77      3.68


    NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    NEW YORK         NEW YORK

      NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

  JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
  -------   -------   -------   -------   -------   -------
   31.80     33.30     41.00     51.90     61.70     71.00
   76.40     75.30     68.20     57.50     47.10     36.20


    NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    NEW YORK         NEW YORK

              STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

              ANNUAL TOTALS FOR YEAR   1
--------------------------------------------------------------
                                    INCHES       CU. FEET      PERCENT
                                   --------     ----------     -------
 PRECIPITATION                      38.62      39954312.000    100.00

 RUNOFF                              0.008         8457.504      0.02

 EVAPOTRANSPIRATION                 29.588     30610452.000     76.61

 DRAINAGE COLLECTED FROM LAYER  2    3.3235     3438330.750      8.61

 PERC./LEAKAGE THROUGH LAYER  3      0.000061        63.567      0.00

 AVG. HEAD ON TOP OF LAYER  3        2.4471

 CHANGE IN WATER STORAGE             5.700      5897017.000     14.76

 SOIL WATER AT START OF YEAR         3.134      3242035.250

 SOIL WATER AT END OF YEAR           8.834      9139053.000

 SNOW WATER AT START OF YEAR         0.000            0.000      0.00

 SNOW WATER AT END OF YEAR           0.000            0.000      0.00

 ANNUAL WATER BUDGET BALANCE         0.0000          -9.221      0.00

*******************************************************************************


*******************************************************************************

              ANNUAL TOTALS FOR YEAR   2
```

```
******************************************************************************

        PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
  ------------------------------------------------------------
                              (INCHES)    (CU. FT.)
                              --------   ----------
  PRECIPITATION                    3.96      4096818.000

  RUNOFF                          2.912     3012955.0000

  DRAINAGE COLLECTED FROM LAYER  2          0.06998      72393.13280

  PERCOLATION/LEAKAGE THROUGH LAYER  3    0.000002         1.68917

  AVERAGE HEAD ACROSS LAYER  3        24.000

  SNOW WATER                       2.75     2845338.2500

  MAXIMUM VEG. SOIL WATER (VOL/VOL)            0.4558

  MINIMUM VEG. SOIL WATER (VOL/VOL)            0.0547

******************************************************************************
```

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01   (14 OCTOBER 1994)                **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:   C:\PROGRA~1\HELP3\PDATBAL.D4
TEMPERATURE DATA FILE:     C:\PROGRA~1\HELP3\TDATBAL.D7
SOLAR RADIATION DATA FILE: C:\PROGRA~1\HELP3\SRDATBAL.D13
EVAPOTRANSPIRATION DATA:   C:\PROGRA~1\HELP3\ETDATBAL.D11
SOIL AND DESIGN DATA FILE: C:\PROGRA~1\HELP3\SDATC11B.D10
OUTPUT DATA FILE:          C:\PROGRA~1\HELP3\outC11.OUT


TIME:  3:35    DATE:  10/21/1998


******************************************************************************

  TITLE:  Brookfield Avenue Landfill - 2%minimum slope, 18" protection layer

******************************************************************************


  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                            LAYER  1
                            --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   6
      THICKNESS                  =     6.00   INCHES
      POROSITY                   =     0.4530 VOL/VOL
      FIELD CAPACITY             =     0.1900 VOL/VOL
      WILTING POINT              =     0.0850 VOL/VOL
      INITIAL SOIL WATER CONTENT =     0.1901 VOL/VOL
      EFFECTIVE SAT. HYD. COND.  =  0.720000011000E-03 CM/SEC
   NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
          FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                            LAYER  2
                            --------

                     TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   5
      THICKNESS                  =    18.00   INCHES
      POROSITY                   =     0.4570 VOL/VOL
      FIELD CAPACITY             =     0.1310 VOL/VOL
```

```
WILTING POINT            =    0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0906 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
SLOPE                    =   22.70  PERCENT
DRAINAGE LENGTH          =   110.0    FEET


              LAYER 3
              -------

        TYPE 4 - FLEXIBLE MEMBRANE LINER
          MATERIAL TEXTURE NUMBER  35
THICKNESS                =    0.10   INCHES
POROSITY                 =    0.0000 VOL/VOL
FIELD CAPACITY           =    0.0000 VOL/VOL
WILTING POINT            =    0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =    0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY      =    0.00   HOLES/ACRE
FML INSTALLATION DEFECTS =    0.00   HOLES/ACRE
FML PLACEMENT QUALITY    = 1 - PERFECT


      GENERAL DESIGN AND EVAPORATIVE ZONE DATA
      ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
       FAIR STAND OF GRASS, A SURFACE SLOPE OF 23.%
       AND A SLOPE LENGTH OF  110. FEET.

SCS RUNOFF CURVE NUMBER            =   73.00
FRACTION OF AREA ALLOWING RUNOFF   =   100.0   PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =   285.000  ACRES
EVAPORATIVE ZONE DEPTH             =   20.0   INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =    2.409  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =    9.116  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =    1.322  INCHES
INITIAL SNOW WATER                 =    0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    2.771  INCHES
TOTAL INITIAL WATER                =    2.771  INCHES
TOTAL SUBSURFACE INFLOW            =    0.00   INCHES/YEAR


      EVAPOTRANSPIRATION AND WEATHER DATA
      -----------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
       NEW YORK          NEW YORK

  MAXIMUM LEAF AREA INDEX              = 2.00
  START OF GROWING SEASON (JULIAN DATE) = 108
  END OF GROWING SEASON (JULIAN DATE)   = 302
  AVERAGE ANNUAL WIND SPEED            = 12.20 MPH
  AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 65.00 %
  AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 68.00 %
  AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
  AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 68.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

```
          COEFFICIENTS FOR    NEW YORK          NEW YORK

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
-------   -------   -------   -------   -------   -------
 3.11      3.08      4.10      3.76      3.46      3.15
 3.67      4.32      3.48      3.24      3.77      3.68


     NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK          NEW YORK

        NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL   FEB/AUG   MAR/SEP   APR/OCT   MAY/NOV   JUN/DEC
-------   -------   -------   -------   -------   -------
 31.80     33.30     41.00     51.90     61.70     71.00
 76.40     75.30     68.20     57.50     47.10     36.20


     NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    NEW YORK          NEW YORK

             STATION LATITUDE  = 40.47 DEGREES


*******************************************************************************

             ANNUAL TOTALS FOR YEAR    1
---------------------------------------------------
                        INCHES       CU. FEET    PERCENT
                        -------     ----------   -------
PRECIPITATION                  38.62     39954312.000   100.00

RUNOFF                       0.009        9546.161     0.02

EVAPOTRANSPIRATION                29.678     30703510.000    76.85

DRAINAGE COLLECTED FROM LAYER  2      5.5582      5750271.000     14.39

PERC./LEAKAGE THROUGH LAYER  3      0.000034        35.163      0.00

AVG. HEAD ON TOP OF LAYER  3       1.3516

CHANGE IN WATER STORAGE          3.374      3490956.000      8.74

SOIL WATER AT START OF YEAR        3.134      3242035.250

SOIL WATER AT END OF YEAR         6.508      6732991.500

SNOW WATER AT START OF YEAR         0.000           0.000     0.00

SNOW WATER AT END OF YEAR         0.000           0.000     0.00

ANNUAL WATER BUDGET BALANCE          0.0000          -7.127     0.00
*******************************************************************************


*******************************************************************************

             ANNUAL TOTALS FOR YEAR    2
```

```
*******************************************************************************

        PEAK DAILY VALUES FOR YEARS    1 THROUGH   10
-------------------------------------------------------------------------
                              (INCHES)     (CU. FT.)
                              ----------   ------------
 PRECIPITATION                        3.96      4096818.000

 RUNOFF                           2.845     2943165.7500

 DRAINAGE COLLECTED FROM LAYER  2         0.18931      195847.15600

 PERCOLATION/LEAKAGE THROUGH LAYER  3     0.000001         1.19756

 AVERAGE HEAD ACROSS LAYER  3          17.015

 SNOW WATER                           2.75      2845338.2500

 MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.3839

 MINIMUM VEG. SOIL WATER (VOL/VOL)              0.0543

*******************************************************************************
```

Appendix C

APPENDIX C

PRELIMINARY HYDRAULIC ANALYSIS OF LEACHATE COLLECTION AND DIVERSION SYSTEMS

Memorandum

To: *File*

From: *John Boyer, CDM*

Subject: *Preliminary Groundwater Model Analysis of Leachate collection*

Date: *December 1, 1998 (Revised December 1999)*

Modeling Approach

A mathematical model of groundwater flow was developed during the remedial investigation phase to analyze the local groundwater flow regime. The model development and application is discussed in Section 3.4.2.5 of the Final Remedial Investigation Report. This technical memorandum details the use of this model to provide a screening level evaluation of several leachate collection and hydraulic diversion system configurations. Because of a variety of factors, including the complex site stratigraphy, the effects of tidal fluctuation on the groundwater table, the lack of information on the cretaceous aquifer, and budget constraints, the model was developed to a point such that it is capable of providing a screening level evaluation of remedial alternatives. Final design decisions will require additional analysis to support the screening results of this model.

The purpose of the groundwater modeling was to estimate/evaluate the following:

1. The reduction in the water table following the installation of an impermeable cap over the waste mass.

2. The effectiveness of several leachate collection trench configurations in reducing the saturated waste volume.

3. The amount of leachate which may be collected under several collection trench configurations.

4. The effectiveness of a hydraulic diversion system in reducing leachate generation.

To better evaluate the above, discretization (grid spacing) of the model was slightly increased near the southern site boundary. The updated model grid contains 949 non-uniformly spaced nodes and 1,854 elements. Node spacing at the site is ranges between 100 to 200 feet. The grid in the vicinity of the landfill is shown in Figure 1.

Model simulations were performed to evaluate the hydrogeologic conditions under the following scenarios: 1) capping of the landfill; 2) six varying leachate collection and hydraulic diversion system configurations. All model simulations were run as steady-state simulations using long term averages of precipitation and recharge.

Although the barrier wall had only limited effectiveness, it was used as the method of hydraulic diversion in all remaining simulations for several reasons. Primarily, the model is capable of more accurately representing a barrier wall and estimating its effectiveness, compared to the collection trench. Some uncertainty exists as to whether a collection trench would allow for complete drawdown to the pipe elevation, as was simulated in the model. Also, a barrier wall would potentially be easier to implement and operate.

The leachate collection and hydraulic diversion systems, as described above, were incorporated into the following model simulations:

A. Simulates conditions resulting from the impermeable cap; a leachate collection trench along the entire north, east and west face of the landfill, and a significant portion of the south face; and a barrier wall near the southern boundary connecting the west drainage ditch and east pond. This scenario is further referred to in this analysis as **Scenario A.** It is identical to the leachate collection and diversion system configuration of **Alternative 3** in the FS Report.

B. Simulates conditions resulting from the impermeable cap; a leachate collection trench along the entire north face, portions of the east and west face, and at the Hot Spot No. 5 location; and a barrier wall near the southern boundary connecting the west drainage ditch and east pond. This scenario is further referred to in this analysis as **Scenario B.**

C. Simulates conditions resulting from the impermeable cap; a leachate collection trench downgradient of Hot Spot Nos. 3 and 5; and a barrier wall near the southern boundary connecting the west drainage ditch and east pond. This scenario is further referred to in this analysis as **Scenario C.**

D. Simulates conditions resulting from the impermeable cap and a leachate collection trench downgradient of Hot Spot Nos. 3 and 5. This scenario is further referred to in this analysis as **Scenario D.**

E. Simulates conditions resulting from the impermeable cap and leachate collection system of **Scenario B** without collection at Hot Spot No. 5. The upgradient diversion wall was replaced with a continuous downgradient barrier wall, to limit infiltration of clean groundwater into the collection trench and provide a secondary leachate containment system. The barrier wall in this area could be keyed into the glaciolucustrine clay/glacial till confining unit, the top of which is at 10 to -20 feet MSL. This scenario is further referred to in this analysis as **Scenario E.**

F. Simulates conditions resulting from the impermeable cap and leachate collection system along the north face of the west cell and downgradient of Hot Spot No. 3. The upgradient diversion wall was replaced with a continuous downgradient barrier wall, to limit infiltration of clean groundwater into the collection trench and provide a secondary leachate containment system. This scenario is further referred to in this analysis as **Scenario F.**

G. Simulates existing conditions at the landfill. Recharge was applied to the landfill based on the HELP model estimates detailed in the Final RI Report. This scenario is further referred to in this analysis as **Scenario G.**

H. Simulates the resulting water table drop due to installation of an impermeable (Part 360) cap only. No leachate collection or hydraulic diversion was simulated. This scenario is further lining the drainage ditch itself.

Because of the relative ineffectiveness of the upgradient barrier wall which exists as part of Scenario C, and since the extent of the collection trench is identical for Scenario C and D, Scenario D (which lacks the barrier wall) provides an almost identical degree of containment as Scenario C.

Scenario E provides a degree of containment similar to Scenario B. Containment along the north face of the landfill is further assured by the downgradient barrier wall. Migration of leachate to the Cretaceous aquifer is estimated to be less than 30,000 cf per year. As previously discussed, discharge to the drainage ditches may be prevented by constructing a barrier wall between the landfill and ditches.

Scenario F provides a similar degree of containment as Scenario E. Containment along the entire north face of the landfill is further assured by the downgradient barrier wall. Migration of leachate to the Cretaceous aquifer is estimated to slightly higher than Scenario E, but still less than 50,000 cf per year. As previously discussed, discharge to the drainage ditches may be prevented by extending the cap to an elevation below the drainage ditch bottom or by lining the drainage ditch itself.

Upgradient vs. Downgradient Hydraulic Barrier
An upgradient hydraulic diversion system, as simulated by the barrier wall, provides little benefit to leachate control. A barrier wall, in the form of a slurry wall, or HDPE lined collection trench, may be more effective downgradient, between the landfill and Richmond Creek. A downgradient barrier wall would provide a secondarily mechanism for leachate containment, and reduce the amount of "clean" groundwater collected from the downgradient side of the collection trench.

Conclusions

Based on the results of the preliminary groundwater modeling analysis presented above, the following conclusions can be made:

- Installation of the cap alone will reduce the amount of saturated waste by approximately 15 percent. Following cap construction and under average conditions of precipitation and recharge, approximately 44 mcf of waste will remain below the water table. 100 mcf of waste will not be saturated, and therefore should not contribute to leachate generation.
- Scenario A provides near 100% containment of leachate. However, the upgradient barrier wall does not appear to be an effective component of this scenario, or Scenarios B and C.
- Scenarios B through D are decreasingly less effective in controlling leachate migration to surface waters and reducing infiltration to the Cretaceous aquifer. However, additional controls such as construction of a barrier wall between the landfill and drainage ditches, may provide additional and sufficient containment in areas without a collection trench.
- A downgradient barrier wall will provide an effective secondary containment mechanism in associating with a collection trench, while moderately reducing the amount of clean groundwater collected.

Table 1

Model Simulation Results

Brookfield Avenue Landfill Groundwater Model Technical Memrandum

Model Scenario	*Scenario Details*			*Average Thickness of Saturated Waste (feet)*	*Volume of Saturated Waste (cubic feet)*	*Estimated Flow Rate of Collected Leachate and Groundwater (gals. per min.)*
	Cap	*Leachate Collection*	*Hydraulic Diversion*			
G	No	None	None	9.4	52,700,000	-
H	Yes	None	None	7.7	44,600,000	-
A	Yes	complete	upgradient barrier wall	2.1	12,300,000	117
B	Yes	near-complete	upgradient barrier wall	4.4	25,300,000	53
C	Yes	limited	upgradient barrier wall	5.7	33,200,000	13
D	Yes	limited	None	5.5	31,900,000	12
E	Yes	near-complete	downgradient barrier wall	4.9	28,700,000	35
F	Yes	near-complete	downgradient barrier wall	5.8	33,700,000	20

APPENDIX C

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Modeling Approach

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The purpose of the groundwater modeling was to estimate/evaluate the following:

1. The reduction in the water table following the installation of an impermeable cap over the waste mass.

2. The effectiveness of several leachate collection trench configurations in reducing the saturated waste volume.

3. The amount of leachate which may be collected under several collection trench configurations.

4. The effectiveness of a hydraulic diversion system in reducing leachate generation.

To better evaluate the above, discretization (grid spacing) of the model was slightly increased near the southern site boundary. The updated model grid contains 949 non-uniformly spaced nodes and 1,854 elements. Node spacing at the site is ranges between 100 to 200 feet. The grid in the vicinity of the landfill is shown in Figure 1.

Model simulations were performed to evaluate the hydrogeologic conditions under the following scenarios: 1) capping of the landfill; 2) six varying leachate collection and hydraulic diversion system configurations. All model simulations were run as steady-state simulations using long term averages of precipitation and recharge.

All modeling was done prior to the final formulation of the Alternatives 1 through 5, as they appear in the FS Report. Therefore, the leachate collection and diversion system configurations described as part of this analysis do not necessarily correspond exactly to those appearing in the FS Report. The final leachate collection and diversion system configurations, which are included as components of the alternatives, were selected based on the results of this analysis.

Leachate Collection Trench. The leachate collection trench is conceived as a passive system in which the permeability of the trench material (gravel or permeable sand) and the slotted pipe which conveys the collected leachate is high enough to draw down the water table to the pipe invert elevation. Sumps would be installed at select locations to convey the collected leachate to a centralized location for treatment. The leachate collection trenches were simulated by fixing the heads at nodes along the trench at the pipe invert elevations. For modeling purposes, a pipe slope of 0.2% was used. Trench depths ranged from -2 feet mean sea level (MSL) to -9 feet MSL.

Hydraulic Diversion. After installation of the impermeable cap, the primary mechanism for leachate generation would be from groundwater entering the site from the south and contacting the waste. Several options were evaluated for diverting this groundwater. These included a groundwater collection trench and a barrier wall system (slurry wall or sheet piling). To potentially divert groundwater from the south, a collection trench would span the length not covered by the drainage ditches at an elevation less than 0 feet MSL. Sumps would be required to pump the groundwater back to the drainage ditch elevation for discharge. To prevent the collection of leachate, the trench would be lined with an impermeable liner (HDPE) along the north side.

A model run was completed to simulate a collection trench with a maximum elevation of 0 feet MSL and a minimum elevation of -3 feet MSL. The flow collected by the trench was estimated to be less than 60 gallons per minute (gpm), under average conditions. The water table drop at the landfill resulting from fixing heads at the bottom of the trench ranged from 1 to 6 feet; however, this is assuming no resistance to flow in the trench and complete drawdown to the bottom of the trench. The requirement of sumps to actively pump the collected groundwater to the water surface in the drainage ditches would make this type of system less favorable than a passive, barrier type system, as discussed below.

The effectiveness of an impermeable barrier connecting the drainage ditches was also evaluated. The barrier wall was simulated to represent a 3 ft. thick slurry wall, with a hydraulic conductivity of less than 1×10^{-7} cm/sec. To be effective, a barrier wall should be keyed into a confining unit. The shallow aquifer in this area is primarily a low conductive glacial till ($K_h = 1.8 \times 10^{-4}$ cm/sec). An even less conductive glaciolacustrine clay/glacial till unit ($K_h = 2.6 \times 10^{-5}$ cm/sec) is present at depths from 0 feet MSL to -20 feet MSL in the eastern half of this area. The slurry wall was simulated in the model to extend to a depth of -10 feet MSL along the western half, or approximately 15 feet into the glacial till. Along the eastern section, the slurry wall was extended to the top of the glaciolucustrine clay\glacial till unit.

Based on the model simulation, the water table at the landfill is expected to drop less than 1 foot as the result of an impermeable barrier wall. Figure 2 shows contours of the expected water table decline. The limited effectiveness of a barrier wall is not surprising since the shallow aquifer is comprised mainly of glacial till and clays which are not highly conductive. Because of this, the rate of groundwater flow between the ditches is low. The more permeable shallow sands which exist along the eastern one-quarter of the southern site boundary allow for a slightly higher groundwater flow rate entering the site. Much of this flow is intercepted by the eastern drainage ditch and pond.

Although the barrier wall had only limited effectiveness, it was used as the method of hydraulic diversion in all remaining simulations for several reasons. Primarily, the model is capable of more accurately representing a barrier wall and estimating its effectiveness, compared to the collection trench. Some uncertainty exists as to whether a collection trench would allow for complete drawdown to the pipe elevation, as was simulated in the model. Also, a barrier wall would potentially be easier to implement and operate.

The leachate collection and hydraulic diversion systems, as described above, were incorporated into the following model simulations:

A. Simulates conditions resulting from the impermeable cap; a leachate collection trench along the entire north, east and west face of the landfill, and a significant portion of the south face; and a barrier wall near the southern boundary connecting the west drainage ditch and east pond. This scenario is further referred to in this analysis as **Scenario A.** It is identical to the leachate collection and diversion system configuration of **Alternative 3** in the FS Report.

B. Simulates conditions resulting from the impermeable cap; a leachate collection trench along the entire north face, portions of the east and west face, and at the Hot Spot No. 5 location; and a barrier wall near the southern boundary connecting the west drainage ditch and east pond. This scenario is further referred to in this analysis as **Scenario B.**

C. Simulates conditions resulting from the impermeable cap; a leachate collection trench downgradient of Hot Spot Nos. 3 and 5; and a barrier wall near the southern boundary connecting the west drainage ditch and east pond. This scenario is further referred to in this analysis as **Scenario C.**

D. Simulates conditions resulting from the impermeable cap and a leachate collection trench downgradient of Hot Spot Nos. 3 and 5. This scenario is further referred to in this analysis as **Scenario D.**

E. Simulates conditions resulting from the impermeable cap and leachate collection system of **Scenario B** without collection at Hot Spot No. 5. The upgradient diversion wall was replaced with a continuous downgradient barrier wall, to limit infiltration of clean groundwater into the collection trench and provide a secondary leachate containment system. The barrier wall in this area could be keyed into the glaciolucustrine clay/glacial till confining unit, the top of which is at 10 to -20 feet MSL. This scenario is further referred to in this analysis as **Scenario E.**

F. Simulates conditions resulting from the impermeable cap and leachate collection system along the north face of the west cell and downgradient of Hot Spot No. 3. The upgradient diversion wall was replaced with a continuous downgradient barrier wall, to limit infiltration of clean groundwater into the collection trench and provide a secondary leachate containment system. This scenario is further referred to in this analysis as **Scenario F.**

G. Simulates existing conditions at the landfill. Recharge was applied to the landfill based on the HELP model estimates detailed in the Final RI Report. This scenario is further referred to in this analysis as **Scenario G.**

H. Simulates the resulting water table drop due to installation of an impermeable (Part 360) cap only. No leachate collection or hydraulic diversion was simulated. This scenario is further referred to in this analysis as **Scenario H**.

Results

Reduction in Saturated Thickness of Waste

The simulated water table elevations under scenarios A through F are shown in plan view and cross section in Figures 3a through 8b. Table 1 lists the estimated volume of saturated waste resulting from the water table elevation of each scenario. Also listed is the estimated rate of leachate and groundwater collected via the collection trenches.

Installation of the cap is estimated to reduce the water table within the waste mass by an average of 2 feet. Figure 9 depicts, in cross section, the expected water table decline due to the cap. The amount of saturated waste is expected to decrease from 52.7 million cubic feet (mcf) to 44.6 mcf.

Scenario A provides the greatest reduction in the water table. On average, the water table is estimated to decline an average of 5.6 feet, compared to capping alone, reducing the saturated waste volume to 12.3 mcf. Since heads were fixed at the pipe invert elevation in the bottom of the collector trench, this elevation has a significant influence on the water table. For example, if the trench bottom was to set at an elevation ranging from -4 ft. MSL to -11 ft. MSL, the water table elevation would potentially drop another two feet over the elevations used in simulation A. The elevations used were based on engineering judgement factoring in the depth of the trench, the bottom of waste and slope. It is expected that the elevations used in the simulations would be deep enough to effectively collect the leachate.

Containment of Leachate

Scenario A provides the greatest level of leachate containment. Near 100% containment is expected since the collection trenches span all downgradient portions of the landfill. As estimated in the Remedial Investigation Report, approximately 170,000 cubic feet (cf) per year of groundwater impacted by leachate, under present conditions, is expected to migrate through the shallow flow system to the Cretaceous aquifer. Because of the onsite reduction in heads in the shallow flow system, and the resulting change in the vertical gradient between the shallow flow system and the Cretaceous aquifer, no leachate is expected to migrate to the Cretaceous aquifer in Scenario A.

Scenario B is slightly less effective in containing leachate, compared to Scenario A. The absence of a collection trench along the southwest corner of the west cell allows for a portion of leachate to discharge in the west drainage ditch, based on the head contours shown in Figure 4. Additionally, if the east pond remains, following cap construction, leachate from the east cell may also discharge here, and be transported to Richmond Creek. Migration of leachate to the Cretaceous aquifer is estimated to be less than 20,000 cf per year under Scenario B.

In locations where the leachate collection trench is absent, the discharge of leachate to the drainage ditches may be prevented by constructing a barrier wall with an impermeable material (HDPE for example), to prevent groundwater (and leachate) discharge.

Under Scenario C, leachate will not be contained along the perimeter of the entire west cell, and nearly 1,200 feet along the north face of the east cell. Migration of leachate to the Cretaceous aquifer is estimated to be less than 50,000 cf per year. As previously discussed, discharge to the drainage ditches may be prevented by extending the cap to an elevation below the drainage ditch bottom or by lining the drainage ditch itself.

Because of the relative ineffectiveness of the upgradient barrier wall which exists as part of Scenario C, and since the extent of the collection trench is identical for Scenario C and D, Scenario D (which lacks the barrier wall) provides an almost identical degree of containment as Scenario C.

Scenario E provides a degree of containment similar to Scenario B. Containment along the north face of the landfill is further assured by the downgradient barrier wall. Migration of leachate to the Cretaceous aquifer is estimated to be less than 30,000 cf per year. As previously discussed, discharge to the drainage ditches may be prevented by constructing a barrier wall between the landfill and ditches.

Scenario F provides a similar degree of containment as Scenario E. Containment along the entire north face of the landfill is further assured by the downgradient barrier wall. Migration of leachate to the Cretaceous aquifer is estimated to slightly higher than Scenario E, but still less than 50,000 cf per year. As previously discussed, discharge to the drainage ditches may be prevented by extending the cap to an elevation below the drainage ditch bottom or by lining the drainage ditch itself.

Upgradient vs. Downgradient Hydraulic Barrier
An upgradient hydraulic diversion system, as simulated by the barrier wall, provides little benefit to leachate control. A barrier wall, in the form of a slurry wall, or HDPE lined collection trench, may be more effective downgradient, between the landfill and Richmond Creek. A downgradient barrier wall would provide a secondarily mechanism for leachate containment, and reduce the amount of "clean" groundwater collected from the downgradient side of the collection trench.

Conclusions

Based on the results of the preliminary groundwater modeling analysis presented above, the following conclusions can be made:

- Installation of the cap alone will reduce the amount of saturated waste by approximately 15 percent. Following cap construction and under average conditions of precipitation and recharge, approximately 44 mcf of waste will remain below the water table. 100 mcf of waste will not be saturated, and therefore should not contribute to leachate generation.
- Scenario A provides near 100% containment of leachate. However, the upgradient barrier wall does not appear to be an effective component of this scenario, or Scenarios B and C.
- Scenarios B through D are decreasingly less effective in controlling leachate migration to surface waters and reducing infiltration to the Cretaceous aquifer. However, additional controls such as construction of a barrier wall between the landfill and drainage ditches, may provide additional and sufficient containment in areas without a collection trench.
- A downgradient barrier wall will provide an effective secondary containment mechanism in associating with a collection trench, while moderately reducing the amount of clean groundwater collected.

Table 1
Model Simulation Results
Brookfield Avenue Landfill Groundwater Model Technical Memrandum

Model Scenario	*Scenario Details*			*Average Thickness of Saturated Waste (feet)*	*Volume of Saturated Waste (cubic feet)*	*Estimated Flow Rate of Collected Leachate and Groundwater (gals. per min.)*
	Cap	*Leachate Collection*	*Hydraulic Diversion*			
G	No	None	None	9.4	52,700,000	-
H	Yes	None	None	7.7	44,600,000	-
A	Yes	complete	upgradient barrier wall	2.1	12,300,000	117
B	Yes	near-complete	upgradient barrier wall	4.4	25,300,000	53
C	Yes	limited	upgradient barrier wall	5.7	33,200,000	13
D	Yes	limited	None	5.5	31,900,000	12
E	Yes	near-complete	downgradient barrier wall	4.9	28,700,000	35
F	Yes	near-complete	downgradient barrier wall	5.8	33,700,000	20

o:\brkfld\fs\Techtab1.xls

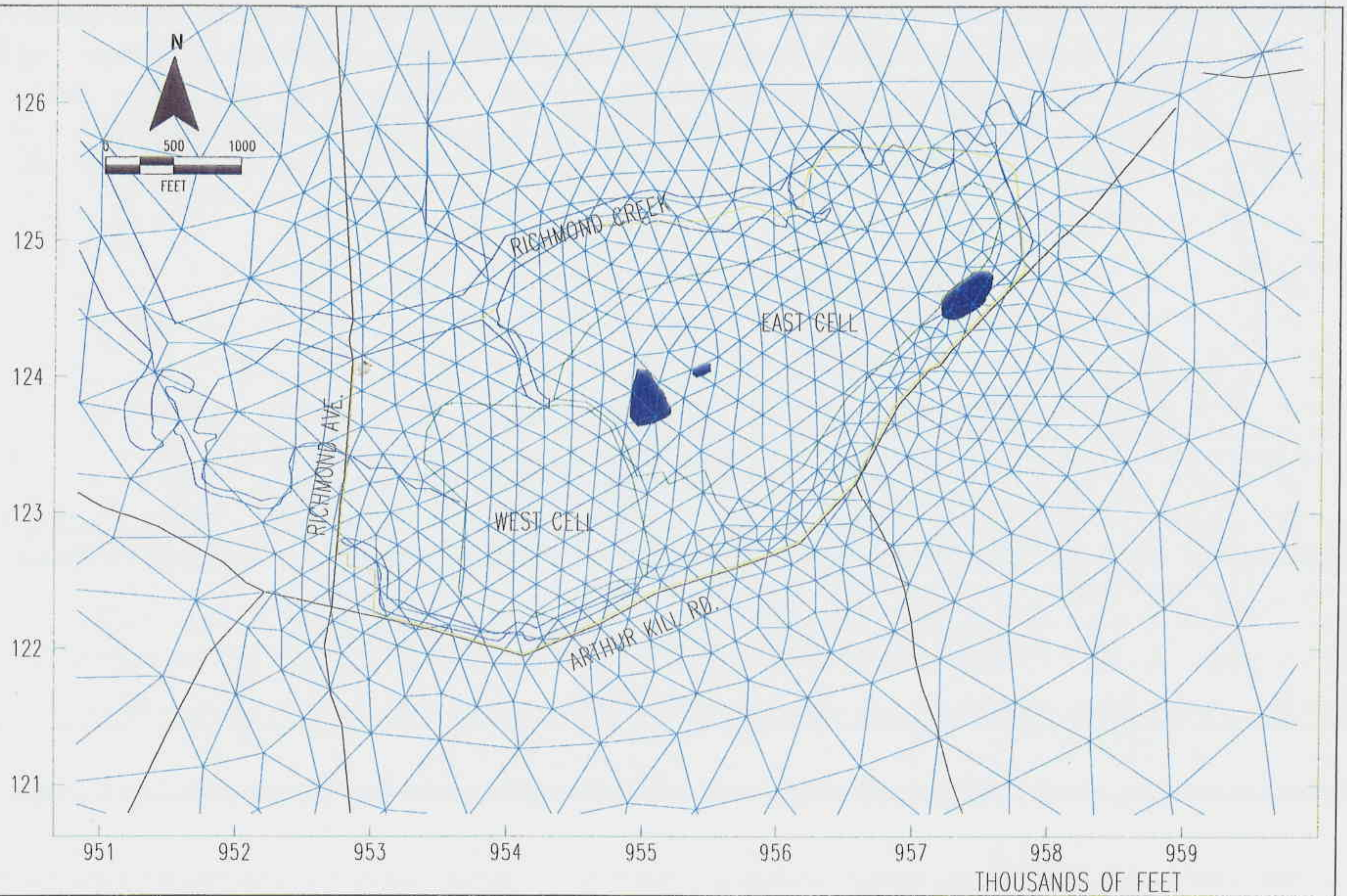


FIGURE
1

FINITE ELEMENT GRID
BROOKFIELD AVENUE LANDFILL AND VICINITY

CDM
environmental engineers, scientists, planners, & management consultants

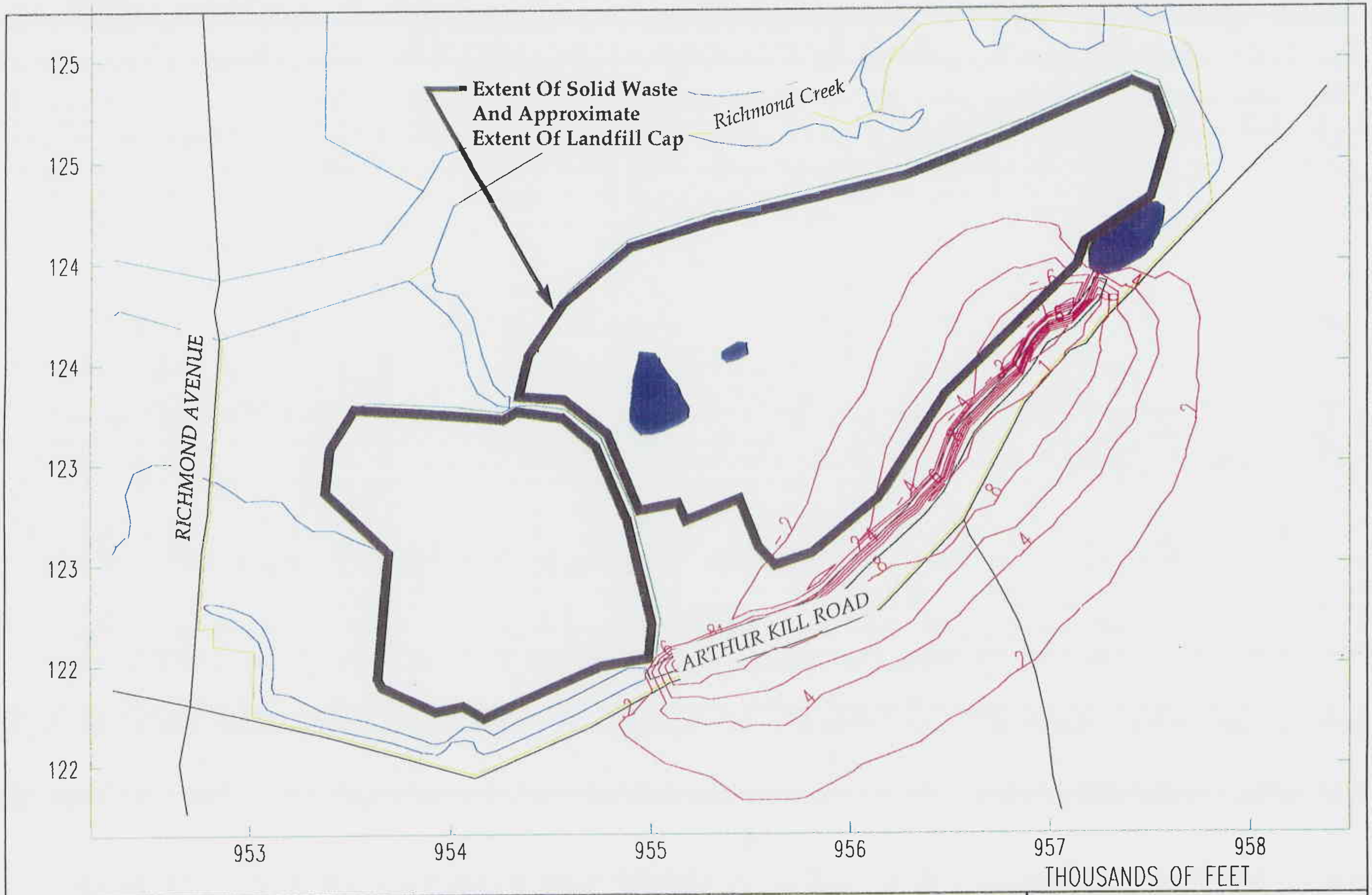


FIGURE
2

SIMULATED CHANGE IN WATER TABLE DUE TO UPGRADIENT SLURRY WALL
CONTOUR INTERVAL SHOWN IS 0.2 FT.

CDM
environmental engineers, scientists,
planners, & management consultants

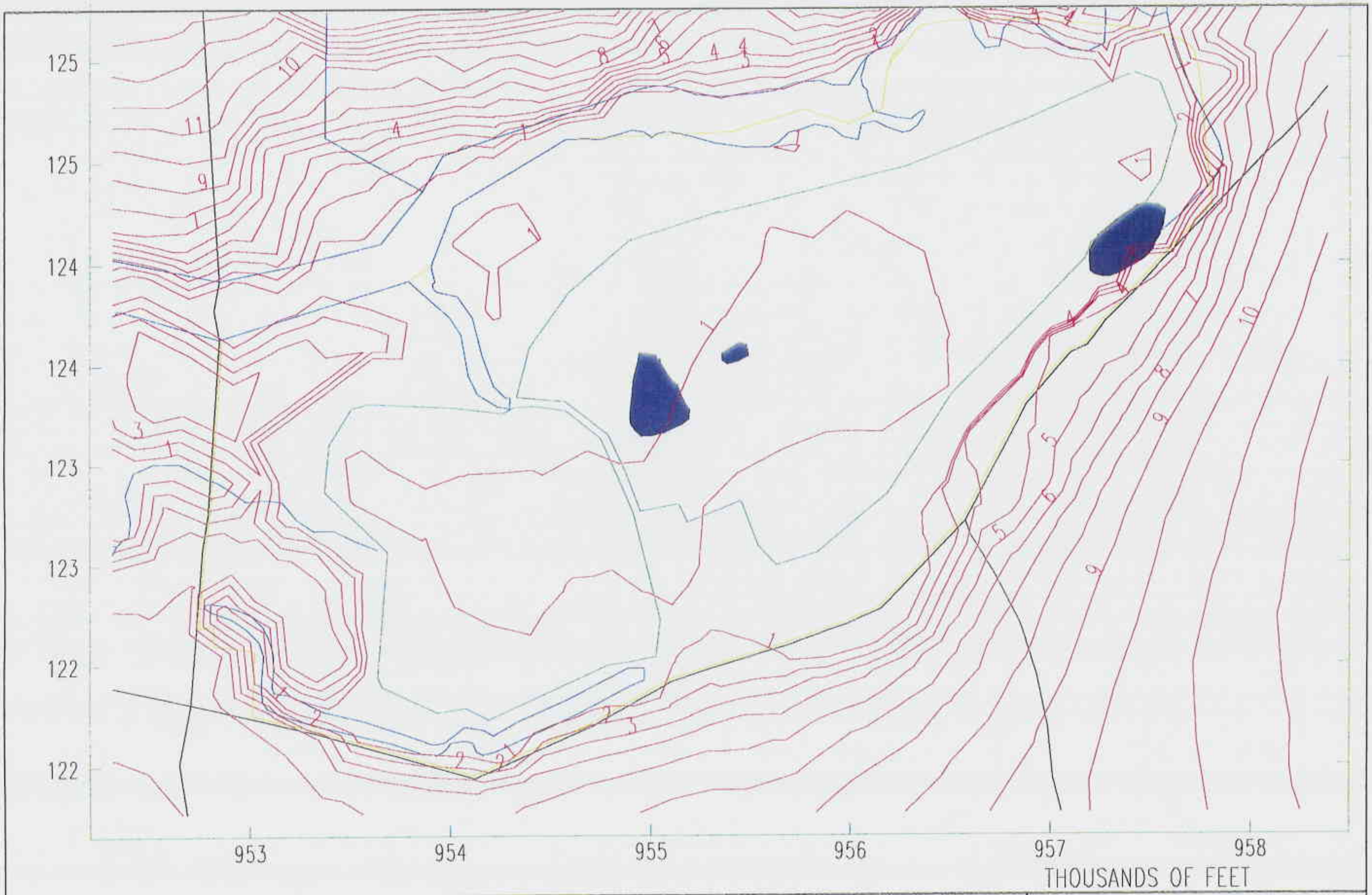
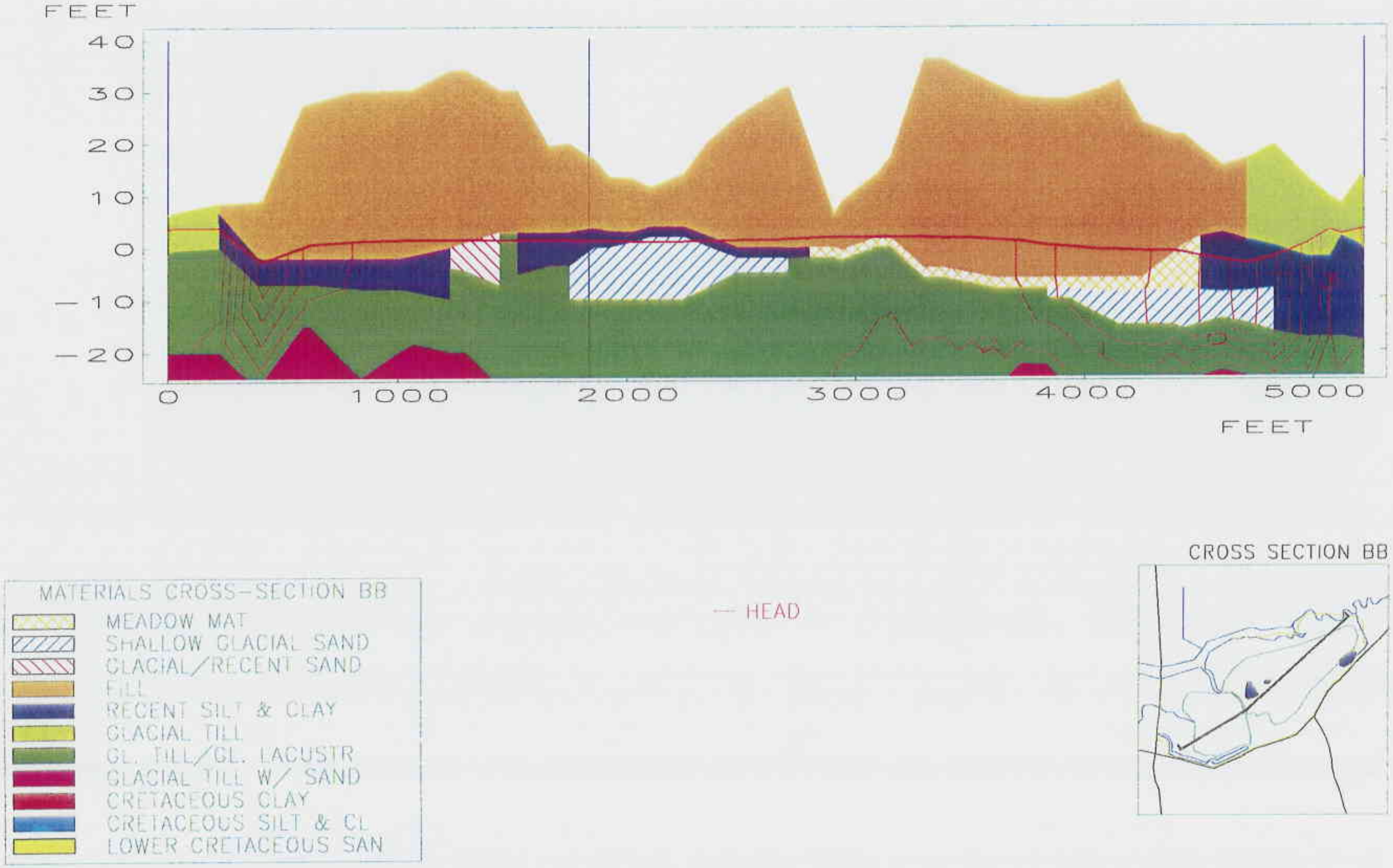


FIGURE
3A

SIMULATED WATER TABLE CONTOURS
SCENARIO A
CONTOUR INTERVAL SHOWN IS 1 FT.

CDM
environmental engineers, scientists, planners, & management consultants



FIGURE

3B

WEST-EAST CROSS SECTION SHOWING SIMULATED WATER TABLE
SCENARIO A

CDM

environmental engineers, scientists, planners, & management consultants

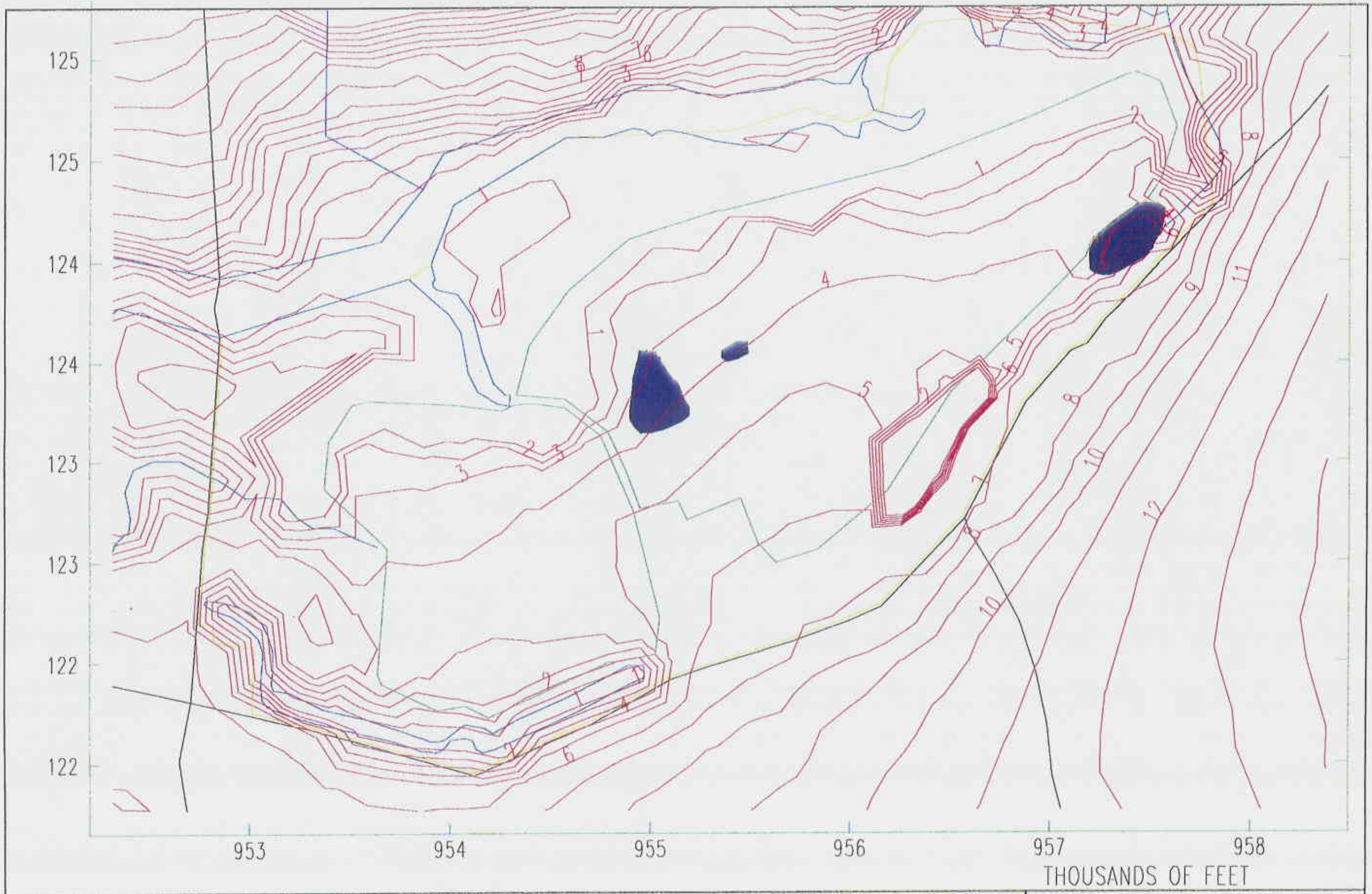


FIGURE
4A

SIMULATED WATER TABLE CONTOURS
SCENARIO B
CONTOUR INTERVAL SHOWN IS 1 FT.

CDM
environmental engineers, scientists, planners, & management consultants

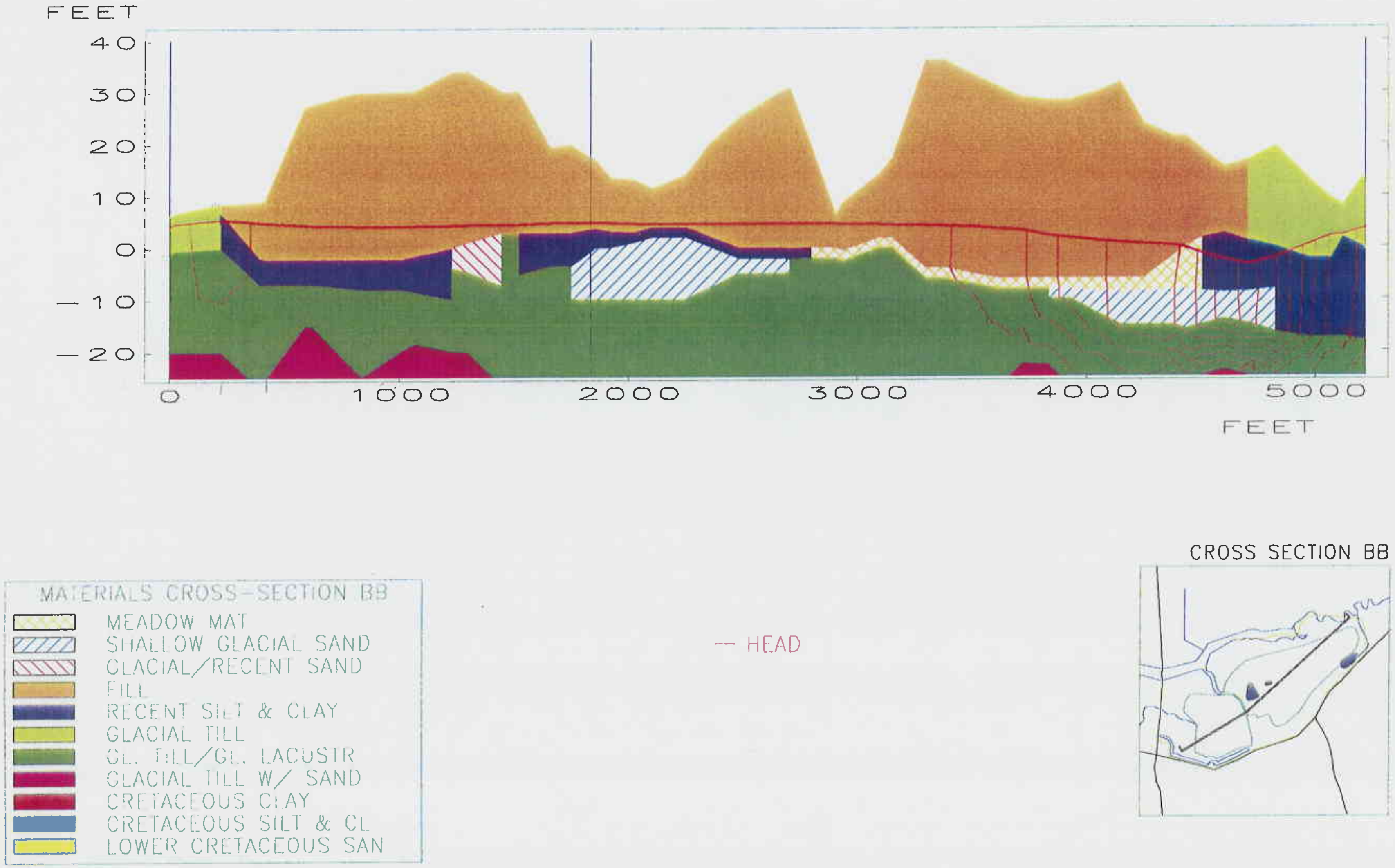


FIGURE
4B

WEST-EAST CROSS SECTION SHOWING SIMULATED WATER TABLE
SCENARIO B

CDM
environmental engineers, scientists, planners, & management consultants

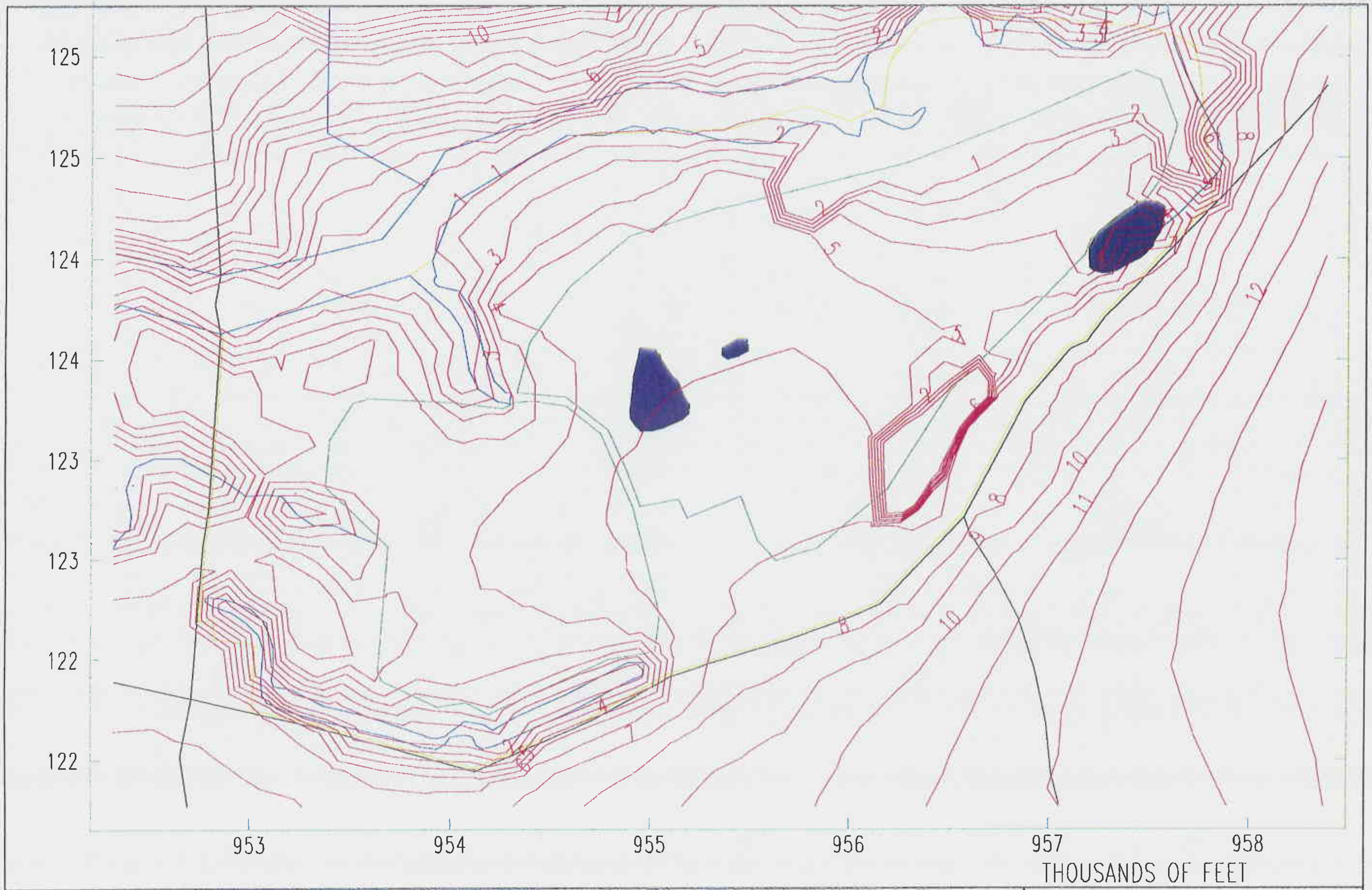
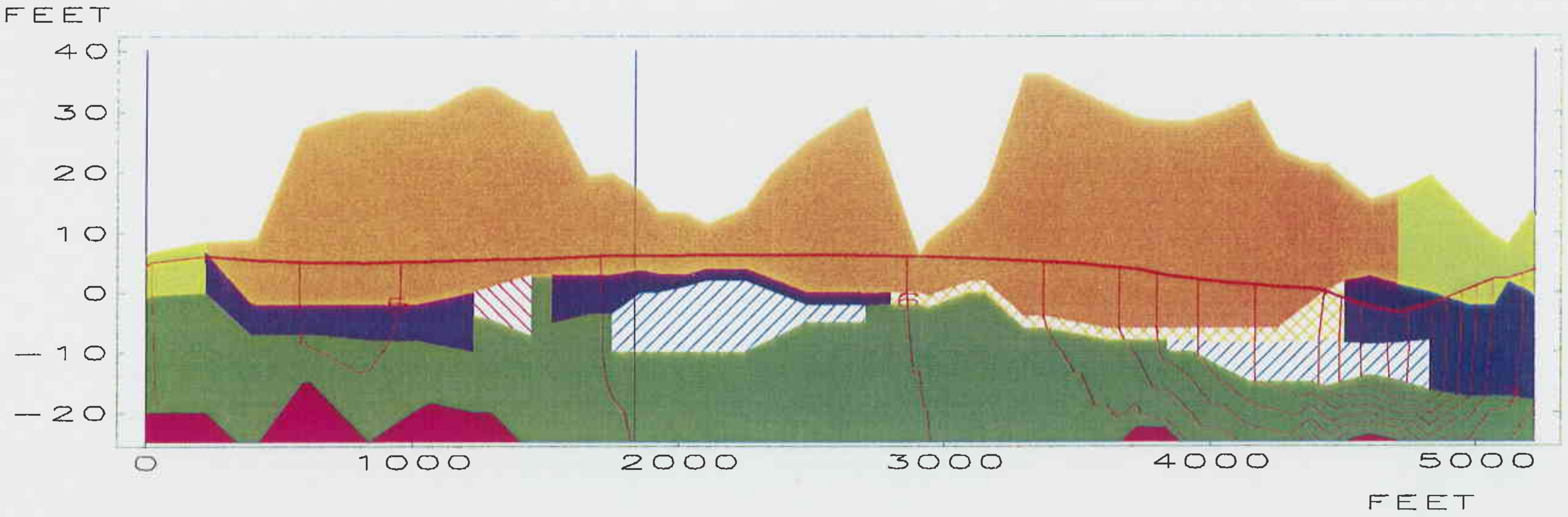


FIGURE
5A

SIMULATED WATER TABLE CONTOURS
SCENARIO C
CONTOUR INTERVAL SHOWN IS 1 FT.

CDM
environmental engineers, scientists, planners, & management consultants



CROSS SECTION BB

FIGURE
5B

WEST-EAST CROSS SECTION SHOWING SIMULATED WATER TABLE
SCENARIO C

CDM
environmental engineers, scientists, planners, & management consultants

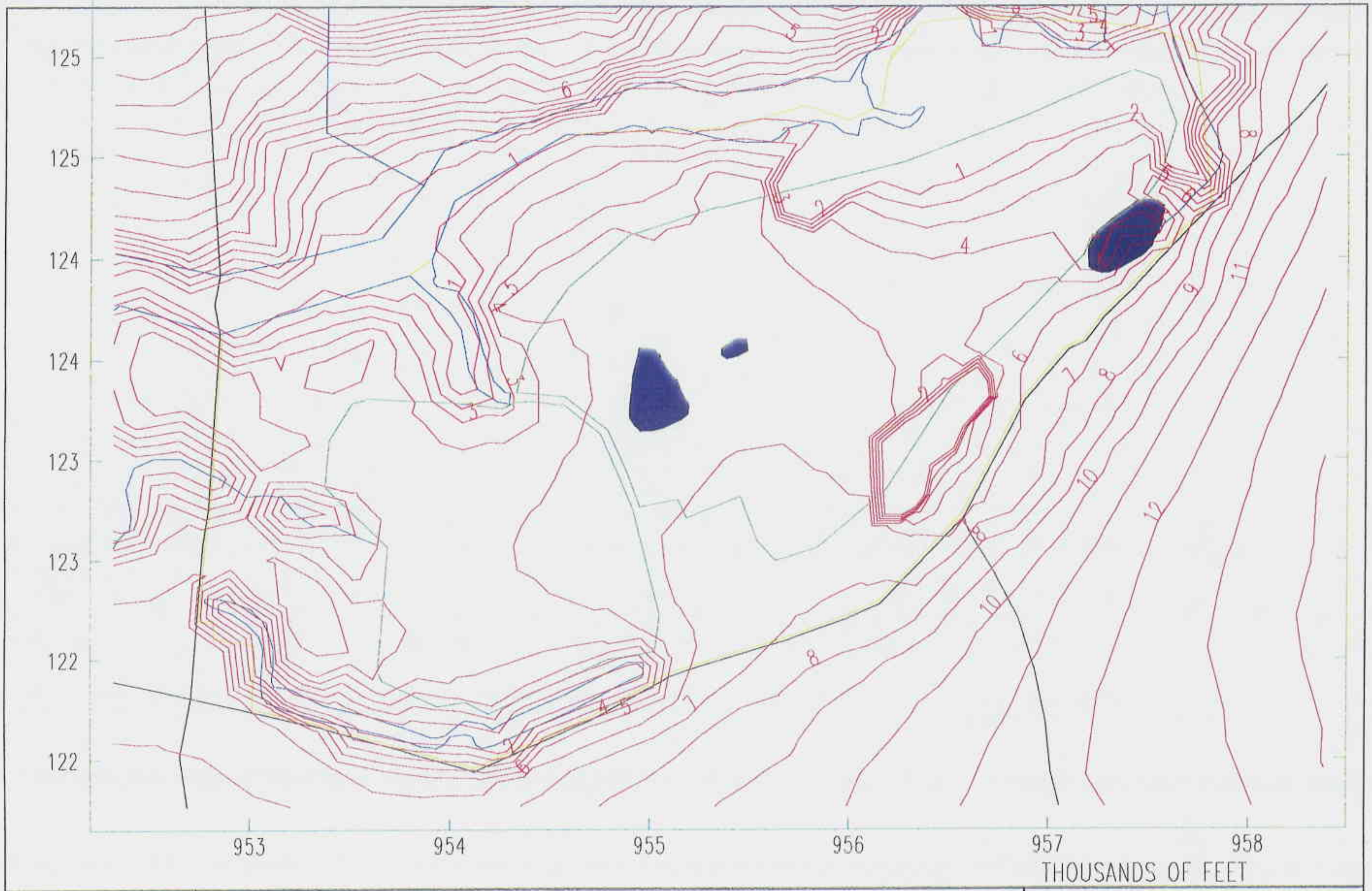


FIGURE
6A

SIMULATED WATER TABLE CONTOURS
SCENARIO D
CONTOUR INTERVAL SHOWN IS 1 FT.

CDM
environmental engineers, scientists, planners, & management consultants

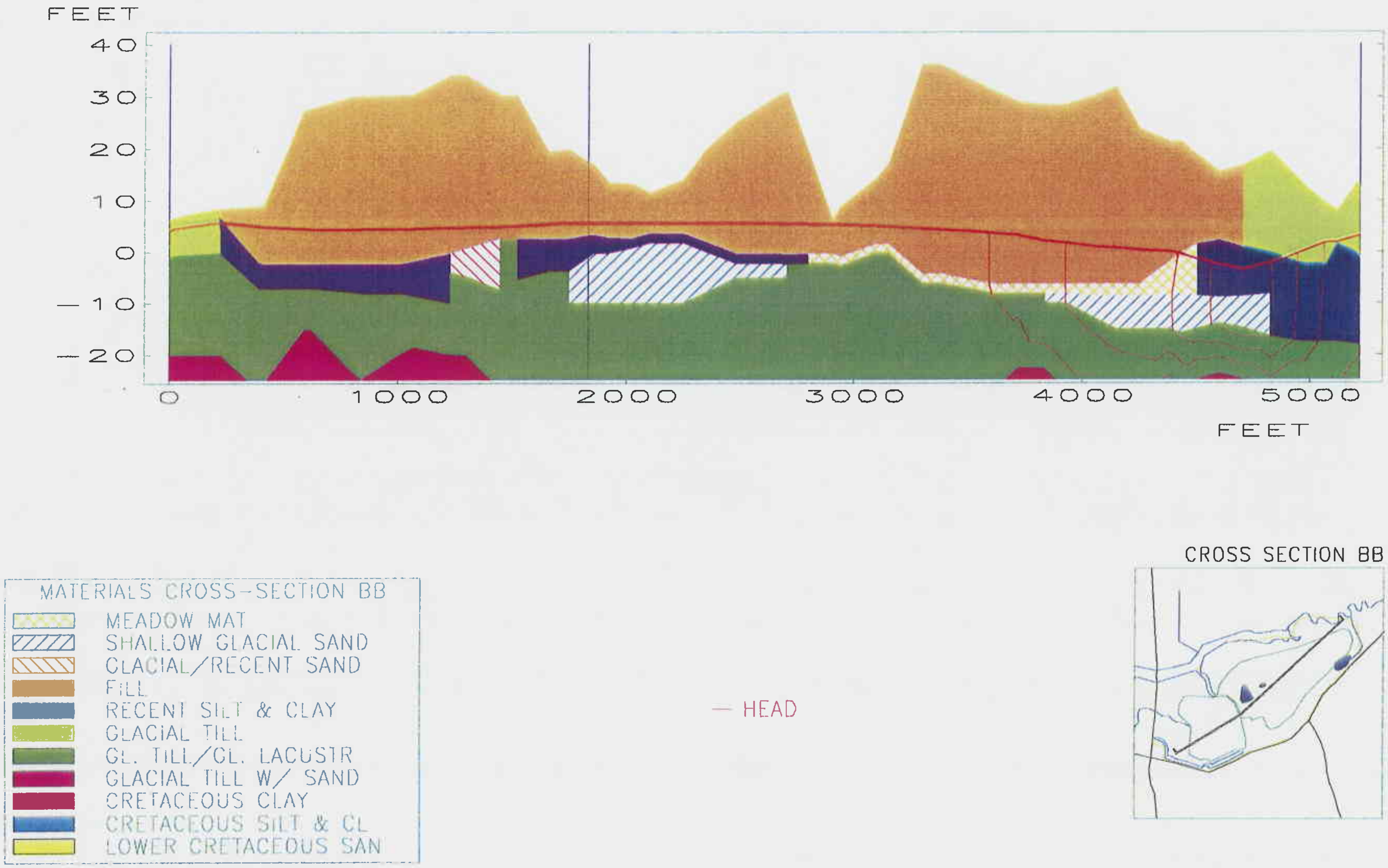


FIGURE
6B

WEST-EAST CROSS SECTION SHOWING SIMULATED WATER TABLE
SCENARIO D

CDM
environmental engineers, scientists, planners, & management consultants

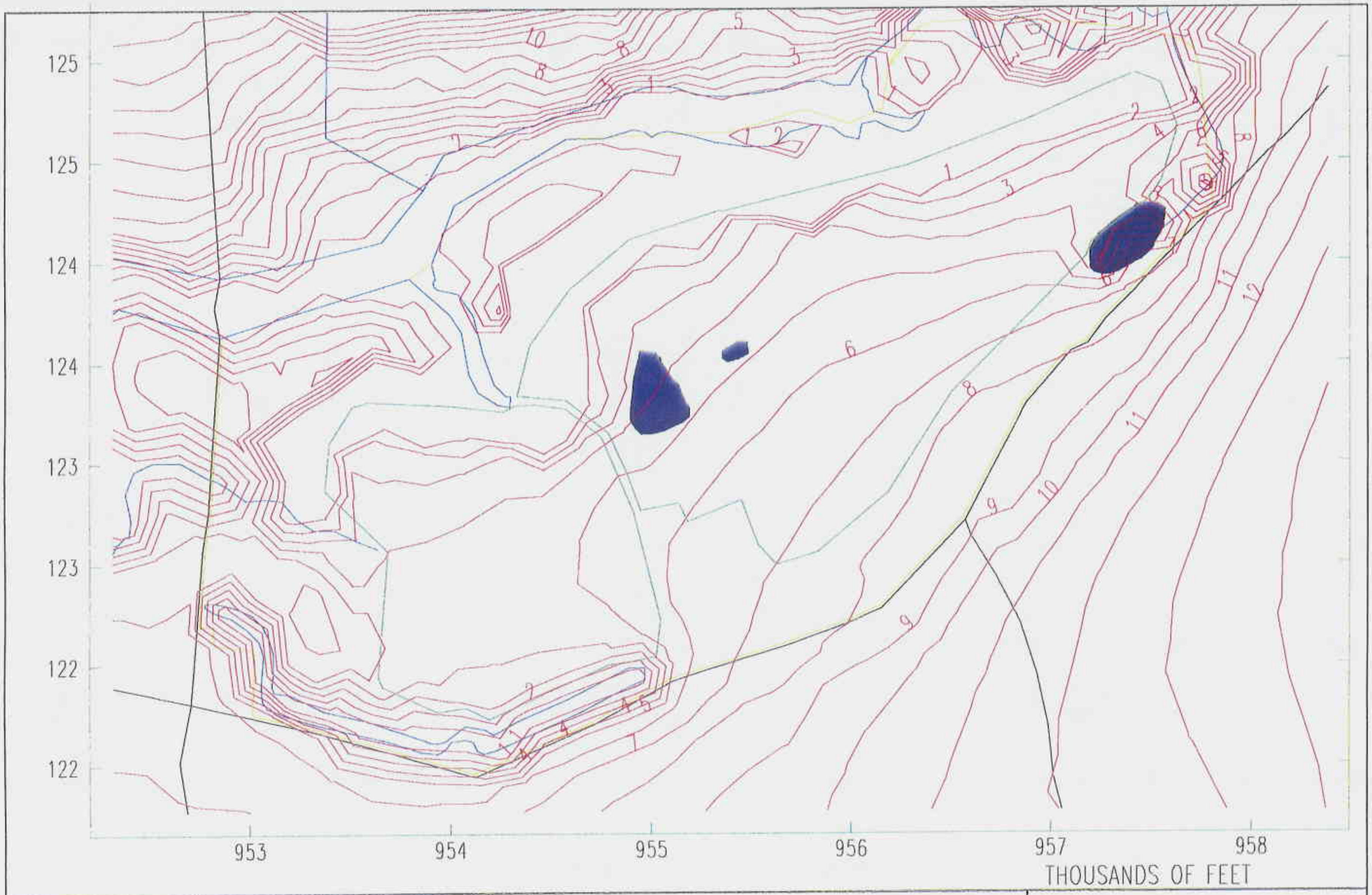
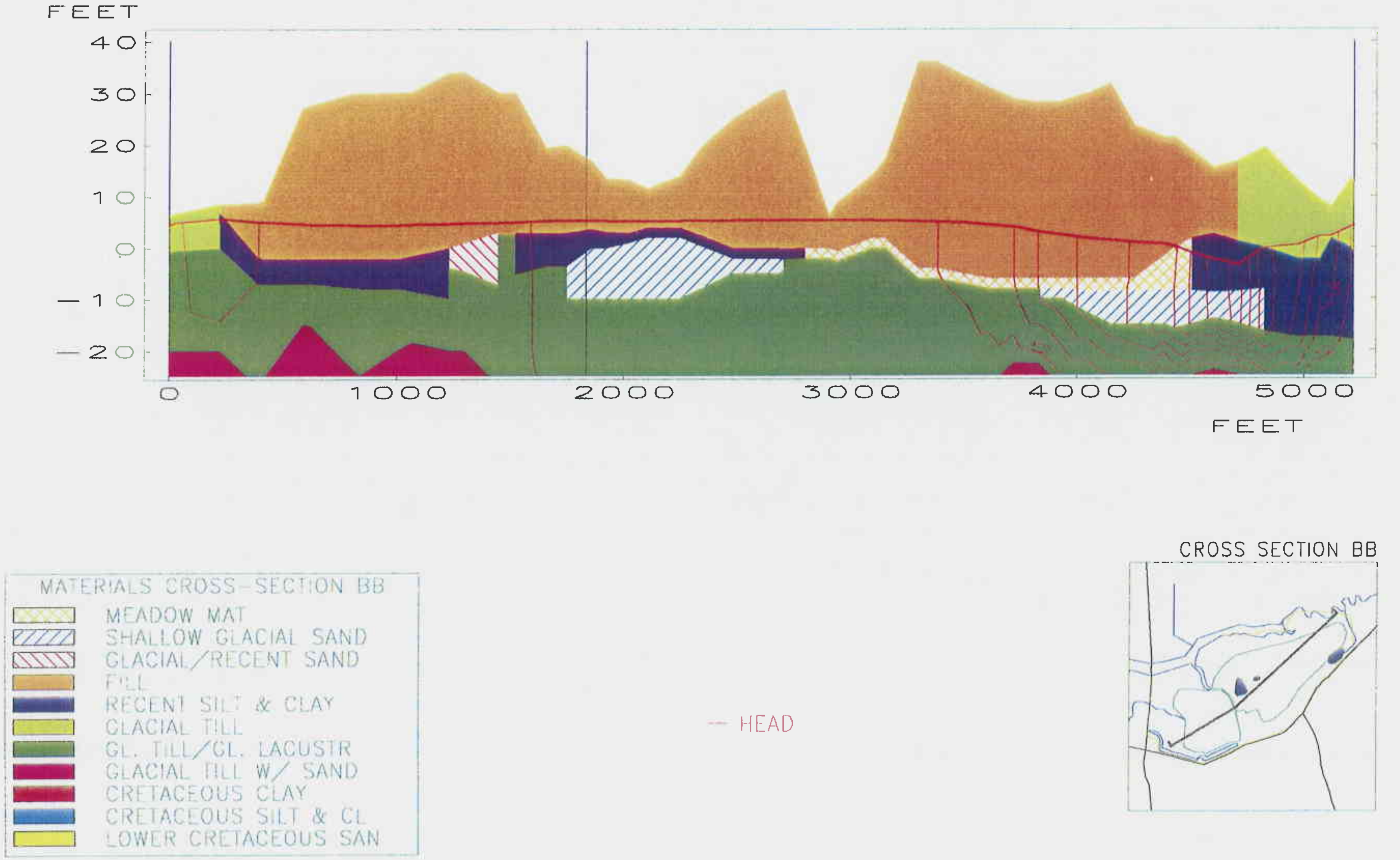


FIGURE
7A

SIMULATED WATER TABLE CONTOURS
SCENARIO E
CONTOUR INTERVAL SHOWN IS 1 FT.

CDM
environmental engineers, scientists, planners, & management consultants



FIGURE

7B

WEST-EAST CROSS SECTION SHOWING SIMULATED WATER TABLE
SCENARIO E

CDM

environmental engineers, scientists, planners, & management consultants

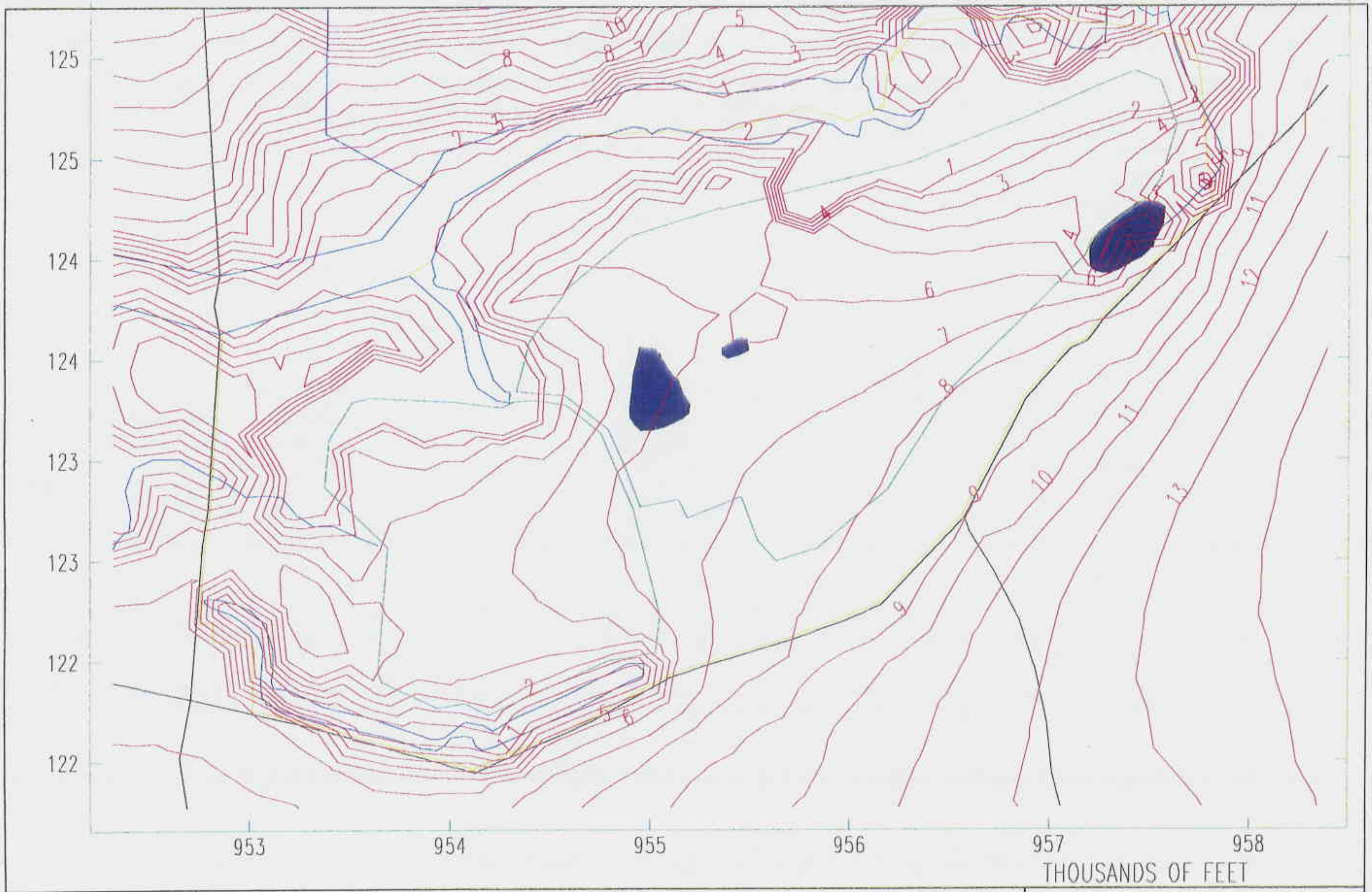


FIGURE
8A

SIMULATED WATER TABLE CONTOURS
SCENARIO F
CONTOUR INTERVAL SHOWN IS 1 FT.

CDM
environmental engineers, scientists, planners, & management consultants

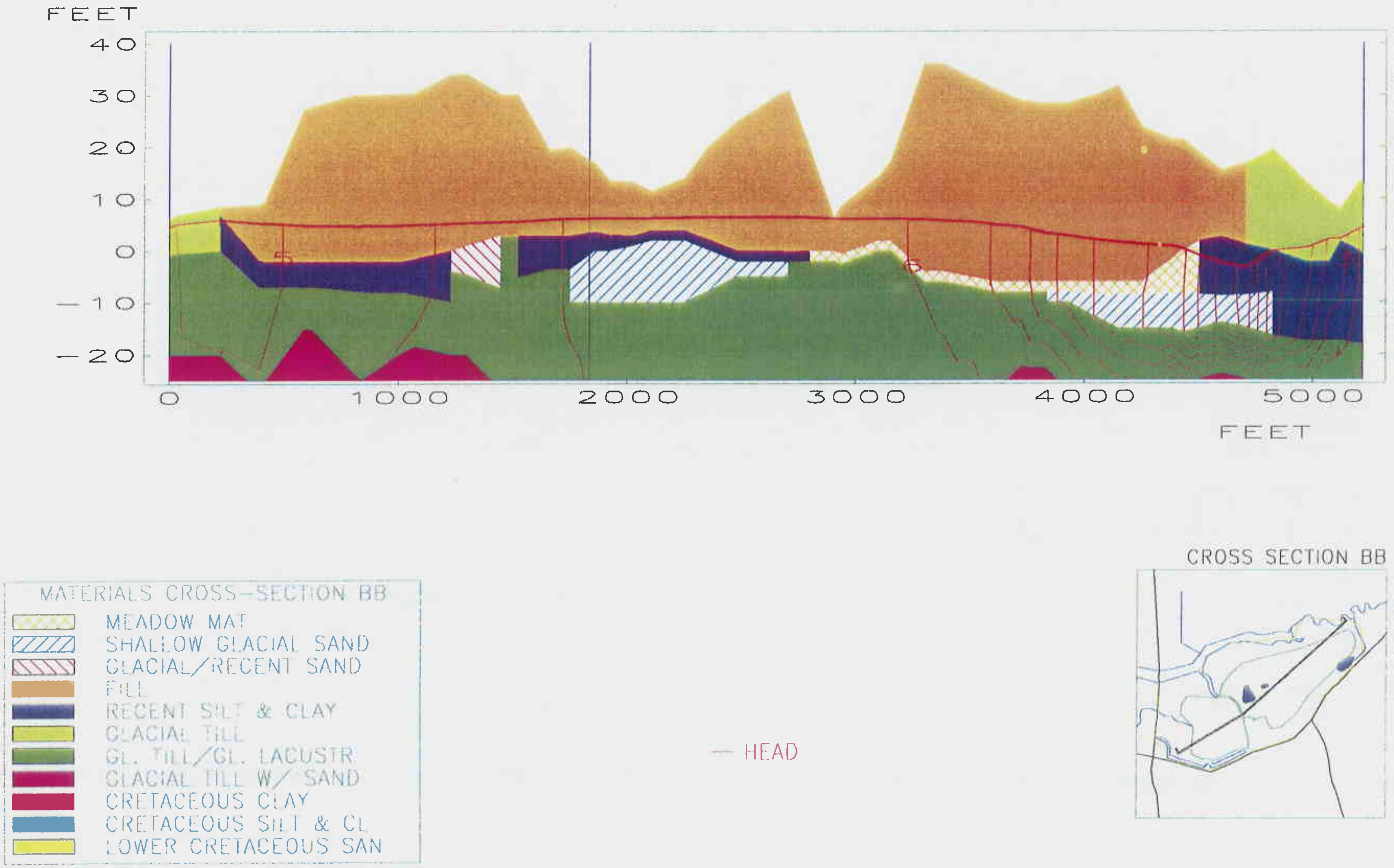


FIGURE
8B

WEST-EAST CROSS SECTION SHOWING SIMULATED WATER TABLE
SCENARIO F

CDM
environmental engineers, scientists, planners, & management consultants

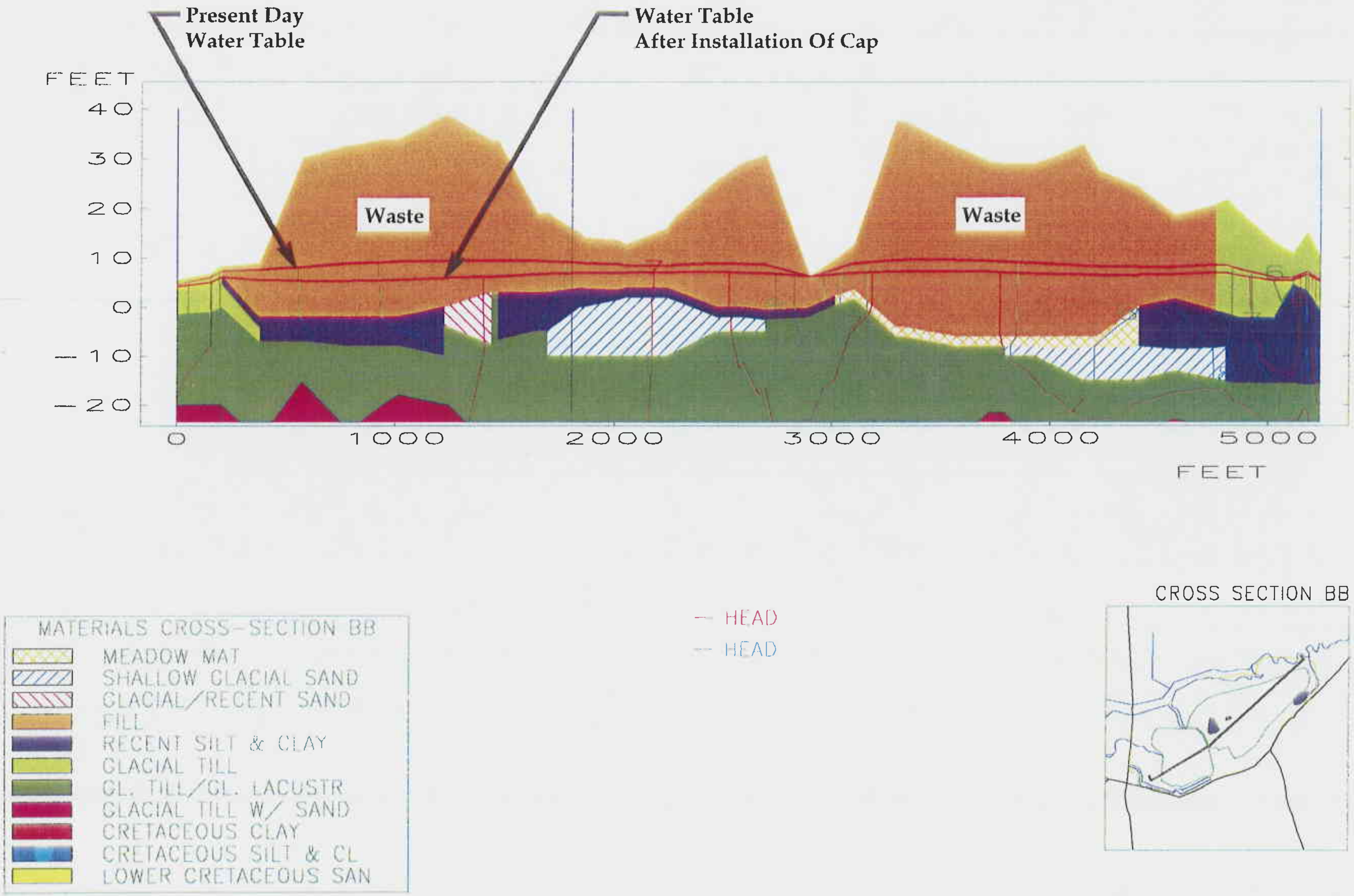


FIGURE
9

SIMULATED WATER TABLE CONTOURS
SCENARIO H (CAP ONLY)
CONTOUR INTERVAL SHOWN IS 1 FT.

CDM
environmental engineers, scientists, planners, & management consultants

Appendix D

APPENDIX D

PRELIMINARY GAS COLLECTION/TREATMENT ANALYSIS

TECHNICAL MEMORANDUM

LANDFILL GAS COLLECTION AND TREATMENT
BROOKFIELD AVENUE LANDFILL
FEASIBILITY STUDY

PREPARED FOR
CAMP DRESSER AND MCKEE

DECEMBER 1999

WILLIAM F. COSULICH ASSOCIATES, P.C.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

TECHNICAL MEMORANDUM
LANDFILL GAS COLLECTION AND TREATMENT
BROOKFIELD AVENUE LANDFILL FEASIBILITY STUDY

TABLE OF CONTENTS

List of Appendices

Section 1

1.0 BACKGROUND

In order to develop an appropriate set of landfill gas control alternatives, it is important to understand the history of landfill operations, the age and composition of the waste and the objectives of the gas collection and control program. Following is a summary of the history of landfill operations and the results of the Remedial Investigation (RI) as presented by Camp Dresser and McKee (CDM) in the Final Remedial Investigation Report for the Brookfield Avenue Landfill Remediation Project, September 1998.

1.1 History of Landfill Operations

The Brookfield Avenue landfill is a 272-acre site located near Richmond and Great Hills sections of Staten Island, New York. It is bounded to the south by Arthur Kill Road, to the west by Richmond Avenue and to the north by Richmond Creek.

Before 1960, prior to use as a landfill, the Brookfield Avenue site was a coastal marshland area with little topographic relief. Site topography was altered by the filling, resulting in a site with both flat areas and areas with slopes exceeding 8 percent. The landfill ranges in height from 15 to 40 feet above surrounding grades, with the general landfill area being fairly level. Stands of ponded water are located on both the east and west sides of the main landfill access road, and a tidally-influenced pond is located at the southeast corner of the landfill. The landfill site is located in a low-lying area adjacent to the shoreline of Richmond Creek. The topography within one mile south of the site rises from approximately mean sea level (msl) to about 80 feet above msl. Northeast of the site, across Richmond Creek, elevations rise to approximately 250 feet above msl within 1.5 miles.

As the Brookfield Avenue Landfill is located in a low-lying coastal marsh area, site runoff drains into the marsh. Some on-site storm water runoff is directed to on-site drainage channels, which flows east and west parallel to Arthur Kill Road, emptying into local streams which feed into Richmond Creek. From Richmond Creek, surface water flows west to the Fresh Kill and from there into the Arthur Kill.

This NYCDOS data indicates that 50 percent of landfill capacity was utilized by 1974 and that half of the waste has now been in the landfill for 25 years with the remaining 50 percent of the waste now being at least 18 years old. NYCDOS also reported that the waste composition was 60 percent residential, 30 percent commercial and 10 percent demolition. The average waste thickness at completion was reportedly 20 feet ± with a maximum thickness of 40 feet ±. NYCDOS reported that, based on scale records, a total of 4,131,301 tons of solid waste were landfilled at the Brookfield Avenue Landfill.

When the site became inactive in 1980, NYCDOS designated 38 acres in the eastern section of the site for closure, and identified the project as Phase I. This partial closure included regrading, capping (24 inches of clay and topsoil), and seeding the area, and installing 10 passive vertical methane gas vents along the southern side of the capped area. The first phase of the project started in October 1982 and was completed in 1984. Additionally, the truck scale was demolished in the fall of 1981. Along the southern perimeter of the landfill, a 525-foot long passive methane collection trench was installed to halt the migration of methane gas toward the residences near the landfill.

The westerly portion of the site is bisected by a 42-inch sanitary sewer main, constructed between 1981 and 1982. The Eltingville Pump Station, constructed on the landfill site in 1984, is still in operation. A 16-foot by 6.5-foot storm sewer bisects the site, originating at Arthur Kill Road and Abingdon Avenue. A 36-inch wastewater force main also bisects the site from the Eltingville Pump Station running south across Rockland Avenue and up Colon Avenue. In addition, a number of storm sewer outfalls along Arthur Kill Road discharge to two drainage ditches running east and west on the site.

1.2 Remedial Investigation

In order to estimate the quantity of solid waste and the potential for landfill gas generation, the Remedial Investigation (RI) for the Brookfield Avenue Landfill undertook a series of data collection activities including:

Extent and Depth of Waste

Twenty-three soil borings were installed and 32 test pits were excavated in order to define the depth and extent of solid waste on the Brookfield Avenue Landfill. The Eastern Cell (landfill area east of the Eltingville pump station) is estimated to be 91 acres and the Western Cell (landfill area north and west of the Eltingville pump station) is estimated to be 41 acres.

The current in-place volume of municipal solid waste was estimated by CDM to be 5.11 million cubic yards. The existing mounded waste layer varies in thickness from 0 to 45 feet within average thickness of 20 feet. The waste age ranges from 32 to 18 years with 50 percent of the landfill waste volume over 25 years.

Historical Monitoring

Historically, gas and odors have been a concern in the Brookfield Avenue Landfill area. In 1983, a NYCDOS consultant began a monitoring program in which test pits and piezometers were monitored for soil gas. From the data obtained, the NYCDOS consultant concluded that the gas was being released through the landfill surface and that no off-site landfill gas migration was occurring.

In mid July, 1984 through summer 1985, a NYCDOS consultant began weekly monitoring of combustible gas levels along Arthur Kill Road. Levels of combustible gas in excess of the lower explosive limit for methane were detected from July through September 1984. As a result, a passive vent interceptor trench was constructed by NYCDOS in September 1984, extending in three segments from Brookfield Avenue to Doane Avenue. Combustible gas levels gradually declined in the area over the remaining monitoring period.

Temporary Gas Probes

Monitoring of the 65 temporary gas probes (bar notes 18 inches deep) was completed in 10 rounds December 1993 to April 1994. Several conclusions can be drawn from the temporary gas probes (TGP) monitoring. The data indicates no significant lateral migration of landfill gas according to the Part 360 criteria.

Permanent Gas Probes

Monitoring of the 18 permanent gas probes (1/2-inch pipe to water table) was conducted in 12 rounds. These wells were installed along the southern, eastern and western site perimeter using 1/2-inch steel pipe extending from 1 foot below ground to the water table. Two permanent soil gas probes, GP-19 and GP-20, were installed to observe background soil gas concentrations and conditions in near high marsh soils. Readings were taken to determine % LEL, hydrogen sulfide and methane. The following conclusions are made from the data:

- The NYCRR Part 360 criteria for soil gases from landfills (100 percent LEL at the landfill property boundary) has been periodically exceeded at four probes (GP-1, GP-2, GP-5 and GP-12).
- The exceedances only occurred once at each probe over 12 rounds of monitoring. The exceedances did not occur in the same round.
- These types of exceedances were not observed on background wells (GP-19 and GP-20). However, the exceedances do occur in areas that are considered buried marsh areas. It is possible that these exceedances are the result of trapped marsh gas.

Internal Landfill Gas Wells

A total of four landfill gas samples were collected from the landfill in order to obtain data on gas species and their concentrations. This information is necessary for the evaluation of possible landfill gas treatment technologies.

Analysis of the four samples indicates sporadic detection of VOCs within all samples. The most commonly encountered VOCs include the petroleum based species such as benzene, ethylbenzene and xylenes. Additionally, methanol was detected at LW-4S at a relatively high estimated concentration of 180,000 ppbv. Detected chlorinated VOCs included vinyl chloride, 1,1-dichloroethane, chloroform, 1,2-dichloroethene and chlorobenzene. Additionally, Freon 114 was detected in all four samples. In general, VOCs detected within the four samples are consistent with the soil gas studies conducted as part of the hot spot investigation, as well as the flux box samples.

Passive Vent Emission Monitoring

A total of ten 4-inch PVC, vertical passive vents exist on the eastern portion of the landfill, along the southern face. All 10 vents were monitored for percent methane, total hydrocarbons, total non-methane hydrocarbons and gas flow rate using an LEL meter, OVA, OVM, and an intrinsically safe air velocity meter. Based on the monitoring data, the two vents that exhibited the highest gross emission rates were selected for sampling (PV-1 and PV-7). The samples were collected and analyzed for the same parameters as the flux box samples (TO-14 volatile organics, hydrogen sulfide, hydrogen cyanide, methyl mercaptan and methane).

Landfill Gas Modeling

Landfill gas generation rates over time were estimated by CDM with a computer program called Landfill Gas Manager. These estimates were intended for use in evaluating the feasibility of landfill gas control alternatives.

The CDM LFGAS model is designed to estimate methane production rates within the landfill under completely anaerobic conditions. The model was not used to estimate present rates of methane production for this estimate CDM used field collected data form. Landfill gas generation rate estimates following capping will be used, in combination with collected field data, to assess the feasibility and provide design parameters for the design of the gas collection system.

rate was expected to become negligible. Under this simulation, by 2015, the gas generation rate will drop to 350 scfm and then will subsequently drop to less than 50 scfm by 2020.

The LFGAS model was also run assuming a slightly lower moisture content of 42 percent. For this run, the growth phase for the landfill was simulated to occur from 1966 through 1984. The constant phase was simulated to start in 1984 at a gas generation rate of 494 scfm and will last approximately 20 years. The tail-off phase will begin in approximately 2004 and continue to approximately the year 2050 when the gas generation rate was expected to become negligible. Under this simulation, the steady state gas production would be 494 scfm through 2025, going below 350 scfm around the year 2035.

1.0 BACKGROUND

In order to develop an appropriate set of landfill gas control alternatives, it is important to understand the history of landfill operations, the age and composition of the waste and the objectives of the gas collection and control program. Following is a summary of the history of landfill operations and the results of the Remedial Investigation (RI) as presented by Camp Dresser and McKee (CDM) in the Final Remedial Investigation Report for the Brookfield Avenue Landfill Remediation Project, September 1998.

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As the Brookfield Avenue Landfill is located in a low-lying coastal marsh area, site runoff drains into the marsh. Some on-site storm water runoff is directed to on-site drainage channels, which flows east and west parallel to Arthur Kill Road, emptying into local streams which feed into Richmond Creek. From Richmond Creek, surface water flows west to the Fresh Kill and from there into the Arthur Kill.

The New York City Department of Sanitation (NYCDOS) reportedly began operating the Brookfield Avenue Landfill in August of 1966 as a municipal solid waste disposal facility. During the 14 years of operation at the Brookfield Landfill, only about 132 acres of the site received refuse. The other 140 acres served as a buffer zone between the landfill and the residences to the south and east. The facility served the 450,000 residents of Staten Island, accepting approximately 1,000 tons of refuse per day until its closure in December of 1980. Prior to closure, the landfill operated 24 hours per day, six days per week, with household refuse and construction debris delivered by the sanitation department and private garbage trucks. The loaded trucks were weighed on scales on site, their weight and the type of material they were hauling were recorded, then they were directed to an active area to deposit their load. The waste was dumped in lifts reaching up to 15 feet high and approximately 150 feet wide. Once a cell was completed, the lifts were compacted and cover material was applied. Access for public drop-off was permitted on the seventh day of the week. Residents were required to sign in and unload in an area specifically designated for public drop-off. Salvageable material suitable for recycling was removed by a private contractor.

In August of 1980, NYCDOS Office of Resource Recovery provide data on the history of landfilling at the Brookfield Avenue Landfill to the New York State Energy Office, Bureau of Resource Development. The landfill records indicated that it was being filled at the rate of approximately 300,000 tons per year of solid waste as follows:

Fill Rate	Years
710,334 tons	1966 thru 1969
639,110 tons	1969 thru 1971
964,110 tons	1972 thru 1974
892,164 tons	1975 thru 1977
925,000 tons	1978 thru 1980

This NYCDOS data indicates that 50 percent of landfill capacity was utilized by 1974 and that half of the waste has now been in the landfill for 25 years with the remaining 50 percent of the waste now being at least 18 years old. NYCDOS also reported that the waste composition was 60 percent residential, 30 percent commercial and 10 percent demolition. The average waste thickness at completion was reportedly 20 feet ± with a maximum thickness of 40 feet ±. NYCDOS reported that, based on scale records, a total of 4,131,301 tons of solid waste were landfilled at the Brookfield Avenue Landfill.

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The westerly portion of the site is bisected by a 42-inch sanitary sewer main, constructed between 1981 and 1982. The Eltingville Pump Station, constructed on the landfill site in 1984, is still in operation. A 16-foot by 6.5-foot storm sewer bisects the site, originating at Arthur Kill Road and Abingdon Avenue. A 36-inch wastewater force main also bisects the site from the Eltingville Pump Station running south across Rockland Avenue and up Colon Avenue. In addition, a number of storm sewer outfalls along Arthur Kill Road discharge to two drainage ditches running east and west on the site.

1.2 Remedial Investigation

In order to estimate the quantity of solid waste and the potential for landfill gas generation, the Remedial Investigation (RI) for the Brookfield Avenue Landfill undertook a series of data collection activities including:

- Installation of soil borings to determine the depth and characteristics of the waste.
- Excavation of test pits to define the extent of waste.
- A review of historical landfill gas monitoring.
- Residential basement screening for landfill gas.
- A walkover survey.
- Flux box sampling of surface emissions.
- Sampling of temporary gas probes.
- Sampling of permanent gas probes.
- Sampling of internal landfill gas wells.
- Passive vent emissions monitoring.
- Landfill gas modeling.

Landfill gas is formed as a byproduct of waste decomposition and volatilization of chemicals within the waste mass. Presumptive remedial measures require landfill gases to be managed for as long as they are expected to be generated. The objectives of the RI landfill gas characterization were to:

- Determine the composition of landfill gases.
- Determine the landfill gas emission rate and the routes of gas migration (i.e., subsurface soil migration, passive landfill gas vents, landfill surface fluxes).
- Determine the extent of subsurface migration of landfill gases.
- Determine whether any landfill gases are accumulating in nearby residential basements as a result of subsurface migration.
- Estimate the rate of landfill gas generation.

Extent and Depth of Waste

Twenty-three soil borings were installed and 32 test pits were excavated in order to define the depth and extent of solid waste on the Brookfield Avenue Landfill. The Eastern Cell (landfill area east of the Eltingville pump station) is estimated to be 91 acres and the Western Cell (landfill area north and west of the Eltingville pump station) is estimated to be 41 acres.

The current in-place volume of municipal solid waste was estimated by CDM to be 5.11 million cubic yards. The existing mounded waste layer varies in thickness from 0 to 45 feet within average thickness of 20 feet. The waste age ranges from 32 to 18 years with 50 percent of the landfill waste volume over 25 years.

Historical Monitoring

Historically, gas and odors have been a concern in the Brookfield Avenue Landfill area. In 1983, a NYCDOS consultant began a monitoring program in which test pits and piezometers were monitored for soil gas. From the data obtained, the NYCDOS consultant concluded that the gas was being released through the landfill surface and that no off-site landfill gas migration was occurring.

In mid July, 1984 through summer 1985, a NYCDOS consultant began weekly monitoring of combustible gas levels along Arthur Kill Road. Levels of combustible gas in excess of the lower explosive limit for methane were detected from July through September 1984. As a result, a passive vent interceptor trench was constructed by NYCDOS in September 1984, extending in three segments from Brookfield Avenue to Doane Avenue. Combustible gas levels gradually declined in the area over the remaining monitoring period.

Residential Basement Screening

This screening activity monitoring 25 home basements once a month for 3 months. The screening found no evidence of explosive levels of combustible landfill gases. In fact, the results suggest that no landfill gases are entering the home basements.

Walkover Survey

A walkover survey was performed over the east and west cells of the landfill in order to classify areas of low, medium and high surface emissions of landfill gases. In general, the partially capped area of the landfill is a low emission area with the remainder of the landfill being characterized as relatively medium-high emission areas. Some local areas on the west cell are also relatively low emission areas probably due to relatively thick cover materials caused by the sewer construction project in that area.

Flux Box Sampling (Non-point Source)

The concentration of landfill gases emitted from the surface of the landfill was estimated using the emission isolation flux chamber (flux box). Hydrogen sulfide and mercaptans were not detected in the flux boxes. Methane was detected in each flux box at varying concentrations.

Emission rates for non-methane organic compounds (NMOCs) were calculated by averaging contaminant fluxes over all four rounds for each source area. If the Brookfield Avenue Landfill were producing "normal" amounts of methane, for example, the 2,600 to 4,000 tons per year as calculated by the landfill gas model, then normal NMOC emission rates would be expected to be two orders of magnitude less. The measured emission rate of 12 tons per year is consistent with this ratio.

Temporary Gas Probes

Monitoring of the 65 temporary gas probes (bar notes 18 inches deep) was completed in 10 rounds December 1993 to April 1994. Several conclusions can be drawn from the temporary gas probes (TGP) monitoring. The data indicates no significant lateral migration of landfill gas according to the Part 360 criteria.

Permanent Gas Probes

Monitoring of the 18 permanent gas probes (1/2-inch pipe to water table) was conducted in 12 rounds. These wells were installed along the southern, eastern and western site perimeter using 1/2-inch steel pipe extending from 1 foot below ground to the water table. Two permanent soil gas probes, GP-19 and GP-20, were installed to observe background soil gas concentrations and conditions in near high marsh soils. Readings were taken to determine % LEL, hydrogen sulfide and methane. The following conclusions are made from the data:

- The NYCRR Part 360 criteria for soil gases from landfills (100 percent LEL at the landfill property boundary) has been periodically exceeded at four probes (GP-1, GP-2, GP-5 and GP-12).
- The exceedances only occurred once at each probe over 12 rounds of monitoring. The exceedances did not occur in the same round.
- These types of exceedances were not observed on background wells (GP-19 and GP-20). However, the exceedances do occur in areas that are considered buried marsh areas. It is possible that these exceedances are the result of trapped marsh gas.

Internal Landfill Gas Wells

A total of four landfill gas samples were collected from the landfill in order to obtain data on gas species and their concentrations. This information is necessary for the evaluation of possible landfill gas treatment technologies.

Sample locations were within 2 to 10 feet of leachate wells LW-2S, LW-3S, LW-4S and LW-5S. Each probe was driven approximately 5 feet into the landfill. Assuming 1' to 2' of cover, this may equate to only 3 feet into the waste. LW-2S is located in the Western Cell, LW-3S is located in the northwestern part of the East Cell, LW-4S is located in the middle of the capped portion of the eastern cell and LW-5S is located at the eastern end of the east cell. Samples were screened in the field using a Landtech GA-90 landfill gas meter and analyzed by Air Toxics Ltd. for TO-14 VOCs, hydrogen sulfide, hydrogen cyanide, mercaptans, carbon dioxide and methane.

Methane concentrations within the collected samples ranged from a high of 65 percent (total volume) at LW-2S, 50 percent at LW-4S, 49 percent at LW-5S to a low of 8.4 percent at LW-3S. Typical concentration range of methane for MSW landfill gas is 45 to 60 percent (Tchobanoglous, et al., 1993). Carbon dioxide concentrations ranged from 11 percent at LW-4S to 20 percent at LW-3S. A typical concentration range for carbon dioxide is 40 to 60 percent. CDM believes that the measured variations from expected ranges is likely the result of dilution from the infiltration of ambient air through the landfill surface. This may also be due to the shallow depth at which the samples were collected.

The Brookfield Avenue Landfill is a relatively flat, shallow landfill with a high ratio of surface are to depth. Beneath the surface, a portion of the waste is located below the water table and, therefore, does not produce significant amounts of methane at this time. The portion above the water table is all within approximately 20 feet of the surface. Because of this, it is not surprising that sampling found relatively high rates of air infiltration. This suggests that methane production within the landfill is not yet significant because, in the relatively shallow unsaturated zone of waste, aerobic conditions still exist that inhibit the development of methanogenic bacteria. Oxygen is toxic to methanogenic bacteria and, in the absence of methanogenic bacteria, methane will not be produced. This suggests that methane production could increase sharply once the landfill is capped and the unsaturated zone of waste begins to increase as the water table drops.

Analysis of the four samples indicates sporadic detection of VOCs within all samples. The most commonly encountered VOCs include the petroleum based species such as benzene, ethylbenzene and xylenes. Additionally, methanol was detected at LW-4S at a relatively high estimated concentration of 180,000 ppbv. Detected chlorinated VOCs included vinyl chloride, 1,1-dichloroethane, chloroform, 1,2-dichloroethene and chlorobenzene. Additionally, Freon 114 was detected in all four samples. In general, VOCs detected within the four samples are consistent with the soil gas studies conducted as part of the hot spot investigation, as well as the flux box samples.

Passive Vent Emission Monitoring

A total of ten 4-inch PVC, vertical passive vents exist on the eastern portion of the landfill, along the southern face. All 10 vents were monitored for percent methane, total hydrocarbons, total non-methane hydrocarbons and gas flow rate using an LEL meter, OVA, OVM, and an intrinsically safe air velocity meter. Based on the monitoring data, the two vents that exhibited the highest gross emission rates were selected for sampling (PV-1 and PV-7). The samples were collected and analyzed for the same parameters as the flux box samples (TO-14 volatile organics, hydrogen sulfide, hydrogen cyanide, methyl mercaptan and methane).

Landfill Gas Modeling

Landfill gas generation rates over time were estimated by CDM with a computer program called Landfill Gas Manager. These estimates were intended for use in evaluating the feasibility of landfill gas control alternatives.

The CDM LFGAS model is designed to estimate methane production rates within the landfill under completely anaerobic conditions. The model was not used to estimate present rates of methane production for this estimate CDM used field collected data form. Landfill gas generation rate estimates following capping will be used, in combination with collected field data, to assess the feasibility and provide design parameters for the design of the gas collection system.

Approximately 859,280 tons or 34% of the total waste mass is located beneath the water table. This waste was not included in the totals since under conditions of complete saturation, gas generation rates would be negligible. No modeling analysis was performed to assess the impact of lowering the water table on the gas generation rates.

Under normal conditions, the rate of decomposition of the solid waste, as measured by gas production, reaches a peak within the first 2 years of decomposition and then slowly tapers off, continuing in many cases for periods up to 25 years or more (Tchobanoglous, et al., 1993). Based on this fact, as previously discussed, over 50% of the waste at the Brookfield Avenue Landfill is at least 25 years old and in a declining phase of gas generation.

The LFGAS program presents the yearly waste receipts and landfill gas generation in tabular and graphic presentations for a period of 75 years. In calculating the results for gas generation, the percent methane in the gas, the percentage of the landfill gas that is non-methane organic compounds (NMOCs expressed as hexane) and the percent recovery of generated gas need to be defined. For this calculation, these values were assumed to be the default values of 50 percent methane, 8,000 ppm (by volume, dry basis) expressed as hexane in the landfill gas and 85 percent recovery of generated gas. In addition, the volumetric gas generation rate was calculated at standard conditions (one atmosphere and 60°F or 15.5°C).

CDM estimated the volume of solid waste at the landfill from site maps showing the elevations and extent of waste, as determined by numerous test pits and exploratory borings. Based on a waste volume of 5,114,016 ft^3 and an average waste density of 1000 lb/ft^3, CDM estimated that the total landfill receipt for the period 1966 through 1980 was 2,557,008 tons. Of this amount, only 1,697,758 tons were expected to be (under average conditions) above the water table, and therefore, 34% of the total was not modeled as a source of landfill gas. This simulation was run using a moisture content of 45 percent. The growth phase for the landfill was simulated to occur from 1966 through 1984. The constant phase was simulated to start in 1984 at a gas generation rate of 762 scfm and last approximately 20 years until 2004. The tail-off phase was simulated to begin in approximately 2004 and continue until 2030 when the gas generation rate was expected to become negligible. Under this simulation, by 2015, the gas generation rate will drop to 350 scfm and then will subsequently drop to less than 50 scfm by 2020.

The LFGAS model was also run assuming a slightly lower moisture content of 42 percent. For this run, the growth phase for the landfill was simulated to occur from 1966 through 1984. The constant phase was simulated to start in 1984 at a gas generation rate of 494 scfm and will last approximately 20 years. The tail-off phase will begin in approximately 2004 and continue to approximately the year 2050 when the gas generation rate was expected to become negligible. Under this simulation, the steady state gas production would be 494 scfm through 2025, going below 350 scfm around the year 2035.

Section 2

2.0 DESCRIPTION OF LANDFILL GAS REMEDIATION TECHNOLOGIES

Presented in this section is a description of full-scale commercially available technologies for the collection and treatment of landfill gas. The technologies identified below represent potential options for treatment of landfill gas, which has been extracted/collected from the landfill via a system of wells and piping connected to a blower station. Volatile organic compounds are the primary constituents of extracted/collected landfill gas for which treatment would be required.

2.1 Collection

Potential landfill gas collection technologies are described and evaluated below. These include:

- Perimeter Collection
  - Wells
  - Trench
- Waste Mass Collection
  - Passive Vents
  - Active Recovery Wells

2.1.1 Perimeter Collection Wells

<u>Technology Description</u>: A perimeter landfill gas collection system generally comprises a series of wells, either horizontal or vertical, installed around the perimeter of the landfill to intercept subsurface gas migration. The wells are connected by a piping network to a vacuum blower station, which induces a negative pressure at the well heads. The landfill gas exhausted from the blower station may be discharged to the atmosphere or treatment may be required.

<u>Initial Evaluation Results</u>: Since the depth to groundwater at the toe of the landfill is generally between 6 to 8 feet below grade, use of wells to implement perimeter landfill gas

collection does not represent a viable option and it will not be retained for further evaluation. In particular, vertical wells are most appropriate when the depth to groundwater is 20-25 feet.

2.1.2 Perimeter Trenches

Technology Description: Perimeter trenches represent an alternate means to intercept landfill gas and minimize off-site subsurface migration. These trenches are filled with a material to collect the gas. Generally, trenches are constructed down to the water table or the depth of waste, whichever is shallower. These trenches are generally employed too passively collect and vent landfill gas. If odors or other non-methane emissions are a potential problem a cap can be added to the top of the trench with a gas collection pipe placed 18 to 24 inches below grade to collect gas and move it to an offset emission point or to a treatment facility.

Initial Evaluation Results: Since the depth to groundwater at the Brookfield Avenue Landfill is generally 6 to 8 feet. The installation of perimeter trenches as a gas migration control option represents a viable option and will be given further consideration.

2.1.3 Passive Vents

Technology Description: Passive vents typically consist of shallow wells installed in the landfill mass in conjunction with construction of a low permeability landfill cap in order to provide a means for release of gas pressure beneath the cap. The landfill gas is passively discharged through the well heads to atmosphere as a result of natural pressure and/or concentration gradients.

Initial Evaluation Results: Passive vents are a widely used, well proven means of releasing gas from capped landfills. However, while the remedial investigation results indicate that landfill emissions would not result in exceedances of local air quality, the cumulative inputs from various nearby sources suggest that passive gas venting would not be acceptable based on NYCDEP, NYSDEC and local community concern. Therefore, passive gas venting will not be retained for further evaluation.

2.1.4 Active Gas Collection Wells

Technology Description: Active recovery wells are frequently installed directly into a landfill to prevent uncontrolled release of landfill gas to the atmosphere, minimize off-site subsurface gas migration and/or prevent gas buildup beneath a capping system. Similar to a perimeter collection system, the recovery wells are connected to a series of pipes and a vacuum blower station which induces a negative pressure at the well heads thereby extracting the gas from the landfill mass. Treatment is sometimes required prior to discharge of the recovered landfill gas to atmosphere in order to prevent potential safety and health hazards, as well as odor nuisances. Recovery wells are installed in landfills for the purpose of gas control and/or generation of electricity.

Initial Evaluation Results: The use of active recovery wells is a well proven technology for preventing uncontrolled landfill gas emissions, minimizing subsurface gas migration and preventing buildup of landfill gas beneath a capping system. Therefore, this technology will be retained for further evaluation.

2.2 Treatment

Potential landfill gas treatment technologies are described and evaluated below. These include:

- Destruction through flaring
- Destruction through internal combustion engines or gas turbines and the generation of electric power
- Treatment and upgrade of landfill gas to pipeline quality for resale

Although similar in many ways, these technology alternatives require significant differences in terms of application, infrastructure requirements and capital costs for equipment. For purposes of this evaluation, the gas collection system used to extract gas and deliver it to the treatment technology is considered to be identical.

2.2.1 Flaring

Technology Description: Flaring is an open or closed combustion process in which the oxygen required for combustion is provided by either natural drafting or forced air. Open flares can be located at ground or elevated levels and can operate with or without supplemental gas depending upon the quantity (cfm) and quality (Btu value) of the landfill gas. Because open flares cannot be easily sampled, the conditions necessary to achieve high (i.e., 98 percent) destruction efficiencies are difficult to determine. Enclosed flares are usually at ground level and are enclosed with a fire resistant material that extends above the top of the flame (i.e., refractory shell). The temperature above the flame with this type of flare can be easily monitored to achieve proper combustion conditions. In general, enclosed flares allow better combustion control and as a result, can achieve 70 percent to 99.9 percent destruction efficiencies. Since landfill gas is typically saturated with condensate, which may cause excessive corrosion of the burner tips, in open or enclosed flares, a knockout device and/or filter is utilized to reduce the amount of gas condensate in the gas stream and extend the life of the landfill gas flare.

The high temperatures, which can be, achieved with flares (in the order of magnitude from 1,000°F to 2,000°F) results in a relatively high plume rise and good dispersion of the by-products of combustion. Flare combustion efficiencies depend on the heating value (i.e., Btu value) and density of the landfill gas, flame temperature, residence time, turbulence and available quantities of oxygen.

Flaring has the advantage of offering relatively low capital cost, high reliability, minimal maintenance and good treatment flexibility over time. Good treatment flexibility is a function of the flare's ability to adapt to a wide range of gas volumes and varying methane percentage. For example, a flare rated for a maximum of 1,150 scfm with 50 percent methane can function down to a minimum of 120 scfm with 50 percent methane with only minor adjustments to the burners.

Flaring has the disadvantage that it does not produce any revenues to offset operating costs.

Following are the estimated budget costs for a flare assembly to be installed at the Brookfield Avenue Landfill. Based upon the landfill gas model, CDM estimated the landfill gas generation rate to peak at 762 scfm during the constant phase using a moisture content of 45%. Assuming a 50% contingency factor to account for the potential reduction in the amount of saturated waste due to the landfill cap and leachate controls, the maximum gas generation rate is conservatively estimated to be 1,150 scfm.

Estimated Budget Costs for Enclosed Flare: The estimated capital, operating and maintenance costs for an enclosed flare are summarized as follows:

Capital Costs – Enclosed Flare

Item	Unit	Quantity	Unit Cost	Total
Gas Flare	Ea.	1	$269,000	$269,000[1]
			Subtotal	$269,000
			10% Predesign Studies	27,000
			10% Engineering	27,000
			10% Construction and Field Expenses	27,000
			10% Contractor Fees	27,000
			1% Startup	3,000
			1% Performance Test	3,000
			Subtotal	$383,000
			10% Contingency	38,000
			Total Capital Costs	$421,000[2]

Notes:

(1)John Zink Company

(2)Costs include direct and indirect capital costs.

Annual Operating Costs – Enclosed Flare		
Direct Annual Operating Costs		
Operating Labor		
Operator	548 hrs @ $20/hr	$11,000
Supervisor	15% of operator labor	$2,000
Maintenance		
Labor	548 hrs @ $22/hr	$12,000
Materials	100% of maintenance labor	$12,000
Annual Service Contract for Flare and Blower		$18,000
Subtotal Direct Annual Operating Costs		$55,000
Indirect Annual Operating Costs		
Overhead	25% of O&M Costs	$9,250
Administrative	1.0% of Total Capital Costs	$4,000
Insurance	0.5% of Total Capital Cost	$4,200
Subtotal Indirect Annual Operating Costs		$35,000
	Estimated Total Annual Operating Costs	$90,000

Capital Costs of Enclosed Flare Assembly	$421,000
Annual O&M Costs of Flare	$90,000

Initial Evaluating Results: Based on the high temperatures that can be achieved by flares, and their availability, reliability and good dispersion of the by-products of the combustion process, flares have the technical feasibility to control and treat landfill gas emissions. Therefore, this technology will be considered further.

2.2.2 Internal Combustion Engine and Gas Turbine/Generator Sets

Technology Description: Internal combustion engines and gas turbines have been used in tandem with generator sets to combust landfill gas and produce electricity for a number of years. Additionally, the internal combustion engine/generator set is a desirable remedial action technology because of its short construction time, ease of installation and operational capacity, and its ability to achieve 98 percent or better destruction efficiencies of the landfill gas stream. However, with the varying heating value of landfill gas, internal combustion engines will operate erratically and burning raw landfill gas will decrease the life of the engine. To increase the performance and life of an internal combustion engine, the quality of the landfill gas must be improved by incorporating a knock-out drum and filter as with the flare. Additionally, a scrubbing system can be used to remove acid and sulfur compounds from the landfill gas prior to combustion in the engine.

According to one USEPA study of the landfill gas projects generating electricity, the majority utilize internal combustion engines because of the higher capital costs associated with gas turbines and the requirements for larger volumes of high quality gas generated over a longer period of time, in order for turbines to be cost effective.

Internal combustion engine/generator sets have the advantage that they can produce electricity which can be used on site or be sold off site to a local utility. They have the disadvantage that they require high capital costs particularly when they must be sized large enough to provide the redundancy needed to ensure zero downtime. As an alternative to 100 percent redundancy, a less costly alternative would be to provide a backup flare rather than a backup internal combustion engine/generator set.

Following are the estimated budget costs for an internal combustion engine and generator sets to be installed at the Brookfield Avenue Landfill. Essential components of the system include a scrubber, two internal combustion engine/generator sets to provide 100 percent redundancy, connections to the Consolidated Edison (Con Ed) power distribution system and connections to on-site users. Preliminary conversations with Con Ed are the basis for connections to the power distribution system and the power purchase price of 2.5 to 3.0 cents/kw versus the 15 cents/kw sale price to run systems on site. Based upon CDM's landfill gas model, for purposes of this evaluation, the landfill gas generation rate is estimated at 1,150 scfm at 50 percent methane from 2000 to 2015 when the gas generation rate drops to 450 . Beginning in 2016 through 2030, supplemental fuel would be required to continue to generate electrical power and revenues at the rates established between 2000 to 2015.

Costs For Internal Combustion Engines/Generator Sets: The estimated capital, operating and maintenance costs for Internal Combustion Engines/Generator sets are the same and are summarized as follows:

Capital Costs – Internal Combustion Engines/Generator Sets

Item	Unit	Quantity	Unit Cost	Total
Gas Scrubbing System	Ea.	1	272,000	\$272,000[1]
Reciprocating Generators	Ea.	2	485,000	\$970,000[2]
Transmission Line and Switch Gear	LS	1	120,000	\$120,000[3]
			Subtotal	\$1,362,000
			10% Predesign Studies	136,000
			10% Engineering	136,000
			10% Construction and Field Expenses	136,000
			10% Contractor Fees	136,000
			1% Startup	14,000
			1% Performance Test	14,000
			Subtotal	\$1,934,000
			10% Contingency	193,000
			Total Capital Costs	\$2,127,000[4]

Notes:

(1)U.S. Filter/R.S. Environmental, Inc.

(2)W.A. Kraft Corp. (Waukesha/Dresser)

(3)Consolidated Edison

(4)Costs include direct and indirect capital costs.

Annual Operating Costs – Internal Combustion Engines/Generator Sets		
Direct Annual Operating Costs		
Utilities		
Supplemental Fuel (Natural Gas)	2,102,400 therm @ $0.75/therm (BUG)	$1,567,000(1)
Operating Labor		
Operator	1,095 hrs @ $20/hr	$23,000(1)
Supervisor	15% of operator labor	$4,000
Maintenance		
Labor	1,095 hrs @ $22/hr	$23,000(1)
Materials	100% of maintenance labor	$23,000
Annual Service Contract for Combustion Engines/Generator Sets		$24,000
Subtotal Direct Annual Operating Costs		$97,000
Indirect Annual Operating Costs		
Overhead	60% of O&M Costs	$44,000
Administrative	2.0% of Total Capital Costs	$43,000
Insurance	1.0% of Total Capital Cost	$21,000
Subtotal (Indirect Annual Operating Costs)		$108,000
	Estimated Total Annual Operating Costs (2000 to 2015)(2)	$205,000
	Estimated Total Annual Operating Costs (2016 to 2030)(3)	$1,772,000

Notes:

(1) Beginning in year 2016, assumes a 50% drop in landfill gas production equal to a drop from 50% methane by volume to an approximate 25% by volume methane concentration from combined flows of landfill gas collection and treatment system 450 scfm (350 scfm gas production rate + 100 scfm gas trench).

Conversions: 25% vol. *882 Btu/scf = 221 Btu/scf.
(300-Btu/scf) x Blower Flow/582 = 231 scf of natural gas required or
203,700 Btu/min (÷ 100,000) = 2 therms/min = 2,102,400 therms/yr.

(2) Assumes 1 hr. x 3 shifts x 365 days = 548 hrs.

(3) Assumes no cost for supplemental fuel through 2015.

(4) Assumes purchase of supplemental fuel for power production.

Capital Costs of Scrubber, Internal Combustion Engine/Generator Sets	$2,127,000
Annual O&M Costs of Engine/Generators Sets	$205,000
Annual Cost of Supplemental Fuel (2015-2030)	$1,567,000
Annual Revenues for Sale of Electricity	$299,000

Initial Evaluation Results: Internal Combustion Engine/Generator Sets represent a high maintenance technology for landfill gas treatment, which is typically only implemented for electric power generation. While there may be some potential uses for electrical power on-site, the advanced age and small size of the waste mass and the low projected gas generation rates do not support electrical power generation as a viable long term landfill gas treatment alternative. Beginning in the year 2015, gas generation rates are projected to drop to only 450 scfm, which means that, in order to continue to generate electricity at the rates for 2000 to 2015, supplemental gas fuel would need to be burned to offset the drop in methane. This supplemental fuel will quickly offset the revenues from the sale of power. Therefore, this technology would not be cost effective and will not be retained for further evaluation.

2.2.3 Treatment and Upgrade

Technology Description: The treatment and upgrade of landfill gas from the Brookfield Avenue Landfill would require significant purification followed by compression of the purified gas and delivery to the nearest possible point of connection to a Brooklyn Union Gas (KeySpan) pipeline or sale to a single user. No potential single user could be identified in the immediate area of the Brookfield Avenue Landfill so this option will not be considered further. Based upon discussions with KeySpan representatives, the closest introduction point to a KeySpan gas transmission line would be the introduction point used by the landfill gas processing and purification facility at Freshkills Landfill which is approximately (estimated by CDM) 10,000 feet from the site. Because of concerns over landfill gas quality, KeySpan would not allow the gas to be introduced into smaller local transmission lines. Therefore, this alternative must include the cost of a high pressure gas line to move the gas to the gas transmission line that is accessed by Freshkill Landfill gas purification facility.

Advantages of processing and sale of landfill gas are the revenues generated from the sale of the gas. Disadvantages include the high capital costs required for equipment to process, compress and transmit the gas to a point of sale. In addition, users such as pipeline companies typically want to renegotiate purchase contracts on an annual basis and the price paid can fluctuate substantially as the result of demand, placing the seller at the mercy of the buyer.

Costs for Treatment and Upgrade of Landfill Gas: Following are the estimated budget costs for landfill gas processing and transmission for sale to KeySpan. For purposes of this evaluation, the landfill gas was estimated to be 1,150 scfm with 50 percent methane from 2000 to 2015 after which the gas generation is projected to rate drop to 450 scfm. The corresponding 50% drop in methane production would result in this alternative no longer being cost effective.

Capital Costs – Treatment and Upgrade

Item	Unit	Quantity	Unit Cost	Total
Gas Compressor System	LS	1	552,000	$552,000(1)
Membrane System	LS	1	346,000	$346,000(1)
Instrumentation/Electrical	LS	1	481,000	$481,000(1)
Gas Transmission Line	LF	10,000	15.00	$150,000(2)
			Subtotal	$1,529,000
			10% Predesign Studies	153,000
			10% Engineering	153,000
			10% Construction and Field Expenses	153,000
			10% Contractor Fees	153,000
			1% Startup	15,000
			1% Performance Test	15,000
			Subtotal	$2,171,000
			10% Contingency	217,000
			Total Capital Costs	$2,388,000(3)

Notes:
(1)Landfill Energy Systems
(2)CDM, Vol. I, FS
(3)Costs include direct and indirect capital costs.

Annual Operating Costs – Treatment and Upgrade		
Direct Annual Operating Costs		
Utilities		
Compressor Electricity	280,000 KWH @ $0.15/KWH (BUG)	$42,000(1)
Operating Labor		
Operator	1,095 hrs @ $20/hr	$22,000(2)
Supervisor	15% of operator labor	$3,000
Maintenance		
Labor	1,095 hrs @ $22/hr	$12,000(2)
Materials	100% of maintenance labor	$24,000
Annual Service Contract for Gas Treatment and Transmission		$24,000
Subtotal Direct Annual Operating Costs (without Supplemental Fuel)		$127,000

Annual Operating Costs – Treatment and Upgrade for Sale		
Indirect Annual Operating Costs		
Overhead	60% of O&M Costs	$37,000
Administrative	2.0% of Total Capital Costs	$48,000
Insurance	1.0% of Total Capital Cost	$24,000
Subtotal (Indirect Annual Operating Costs)		$109,000
	Estimated Total Annual Operating Costs(3)	$236,000

Notes:
(1)Assumes power consumption of 3 compressors
(2)Assumes 1 hr x 3 shifts x 365 days = 548 hrs.
(3)Assumes no cost for supplemental fuel

Capital Costs of LFG Treatment and Upgrade	$2,388,000
Annual O&M Costs of LFG Treatment and Upgrade	$236,000
Annual Revenues from the Sale of LFG	$366,000

Initial Evaluation Results: The treatment and upgrade for sale represents a high maintenance and high capital cost alternative for landfill gas treatment. This alternative is typically only implemented on-sites where high long-term gas generation rates can be assured. While there is a potential user for the gas the advanced age and small size of the waste mass and the low projected gas generation rates do not support the high capital costs needed to implement such a system. Beginning in the year 2015, gas generation rates are projected to drop to only 450 scfm with a corresponding 50% reduction in methane production. This alternative would then no longer be cost effective. Therefore, this technology will not be retained for further evaluation.

2.3 Landfill Gas Collection and Treatment Technologies and Alternatives

Based on the Landfill gas generation data developed under the Remedial Investigation and the descriptions and reviews of the remedial technologies presented above and the results of the Remedial Investigation summarized in Section 1.2, flaring is the specific treatment technology selected for use under each of the alternatives (except Alternative 1 - No Action) developed as a result of the screening analysis in Volume I of the Feasibility Study for the Brookfield Avenue Landfill. Flaring offers the most flexibility and dependability in treating potentially declining methane gas volumes. Flaring is also a proven technology with respect to destruction of VOCs and NMHOCs.

Following is a summary of the technologies that are retained for further consideration. The technologies are grouped into two options, A and B. Option A is a component of Alternative 2A. Option B is a component of Alternatives 2B, 3, 4 and 5.

Alternative A

Option A

- Below Ground Landfill Gas Collection Wells
- Below Ground Manifolds and Header Pipe to Blower Station
- Perimeter Gas Collection Trench
- Treatment of Landfill Gas via Flaring
- Perimeter Gas Monitoring

Option B

- Below Ground Landfill Gas Collection Wells
- Below Ground Manifolds and Header Pipe to Blower Station
- Treatment of Landfill Gas via Flaring
- Perimeter Gas Monitoring

Section 3

3.0 DESCRIPTION AND COST OF ALTERNATIVES

This section presents a detailed description of landfill gas collection and treatment Options A and B. Options A and B are similar except Option A included an active gas collection trench near the south boundary combined with other closure technology alternatives in the Feasibility Study.

Perimeter Gas Monitoring

In addition to each of the landfill gas collection and treatment technologies considered, NYSDEC requires perimeter gas monitoring to ensure that 25 percent of the Lower Explosive Limit (LEL) is not exceeded at the property line. Therefore, both options include perimeter gas monitoring wells along the property line bordering Arthur Kill Road, Richmond Avenue and Colonial Square Apartments. Because there is a history of concern over the off-site migration of landfill gas and because the RI noted LEL exceedances at the property line monitoring well, spacing is recommended to be a minimum of 300 feet apart except between Abingdon and Colon Avenues, around Holterman's Bakery and along the property line shared with Colonial Square, where the monitoring wells should be spaced a minimum of 150 feet apart. Special consideration for monitoring in and around any permanent structures that are to remain within the property line of the landfill will need to be made as part of the design phase of the project.

Interim Remedial Measure

Options A and B provide for the connection of the Interim Remedial Measure (IRM) for Hot Spot No. 3, which will be installed prior to capping. Under this approach, the seven vapor recovery wells will be connected to the new landfill gas header system via manifold piping. Due to the much lower vacuum that will be available through the landfill gas collection system, the available vacuum for the seven vapor recovery wells will be only about 12.7 scfm each or approximately 90 scfm compared to the 400 scfm of available capacity planned for the IRM. The existing manifold piping and temporary blower/flare pad constructed as part of the IRM would be removed.

Collection and Treatment System Sizing

Based upon the results of the RI and CDM's landfill gas model, the landfill is expected to generate 762 scfm of landfill gas during the constant phase of generation. However, this is assuming an amount of unsaturated waste as exists under present day conditions. Following capping of the landfill, the groundwater table is expected to drop within the waste mass an average of 2 feet. Additionally, leachate collection trenches may further lower the groundwater table resulting in an increased amount of unsaturated waste, and potentially, increased gas production. To account for this uncertainty, CDM has determined that a contingency factor of 50% should be added bringing the constant phase generation rate to approximately 1,150 scfm of landfill gas. This estimate will need to be refined following field tests and predesign studies outlined below.

Without the necessary field data to support a site-specific zone of influence and gas recovery well spacing, a minimum extraction rate of approximately 12 scfm is recommended at each well head. Based upon a gas recovery well spacing of 260 feet (used in one USEPA study), this would result in 90 gas recovery wells with an extraction capacity of 12.7 scfm at each well head. It is recommended that all gas wells be tied into the active collection system. Approximately 11 active vents would be used in the 11-acre area north of the Eltingville Pump Station which is a relatively thin layer of waste (5 feet to 10 feet thick) consisting of mostly C and D debris, with a depth to water table of only 5 feet. Because of the expected low gas production from these vents, they will be connected to the active gas vent trench to control potential VOC emissions and odors.

Because the landfill gas generation rate is expected to tail off over time, the system must have the capability to handle a reduced flow. It is therefore recommended that the gas collection system utilize three variable speed blower/motor assemblies arranged in parallel, two as primaries and one as a standby. Each blower/motor assembly will need to be capable of between 700 and 250 scfm. Similarly, the flare must be capable of handling a range of flow, 1,150 scfm down to a 250 scfm, utilizing supplemental fuel if gas production drops below 250 scfm.

Predesign Studies

Prior to initiating the design of the gas collection and treatment system, a number of engineering predesign studies will need to be completed in order to more accurately determine the sizing, radius of influence and spacing of system components. These studies need to include:

1. Installation of two extraction wells in each of landfill areas A, B, C, D and E (see Figure 3-12 or RI Report) and a series of steady state dynamic tests to determine sustainable gas recovery rates, zone of influence and spacing for gas recovery wells.
2. Collection and analysis of landfill gas samples, taken during steady state tests, to determine sustained levels of methane, carbon dioxide, nitrogen and oxygen.
3. In-place density tests and moisture content analysis to determine actual waste densities and moisture content in each area of the landfill.
4. Sensitivity modeling runs using the landfill gas model with the new field data to confirm maximum and minimum landfill gas generation rates over time.
5. Evaluation of gas migration mitigation measures to be taken to avoid gas migration into existing structures and buried utility trenches on-site.

3.1 Option A

Option A includes active gas collection via a below ground system, on-site treatment by flaring, an active perimeter gas venting trench and perimeter monitoring wells at the property line. See Appendix A for plan drawings and Appendix B for miscellaneous details. Following is a detailed description of system components and a cost estimate for this alternative.

3.1.1 Description of Option A

As previously noted, the gas collection and treatment system for Option A consists of the following elements.

Active Gas Collection Wells

One hundred and one (101) active gas collection wells with flexible connections to collection manifolds will be installed to collect gas from the waste mass. The active gas collection wells will be 4-inch PVC pipe (slotted below the cap) with booted liner penetrations. The wells will extend to a maximum depth of 10 feet above groundwater. Well heads will be installed above the impermeable cap, buried below ground in the barrier protection layer.

Collection Manifolds

Collection manifolds will connect the collection wells to a perimeter collection header. Collection manifolds will be 4-inch polyethylene pipe placed below ground, buried in the barrier protection layer. The collection manifolds will also be buried below the access road where they come off the cap and connect to a perimeter collection header line via a butterfly valve, in a valve box, adjacent to the perimeter road.

Perimeter Collection Header

The perimeter collection header will consist of 4-inch to 8-inch polyethylene pipe to transport the gas to the blower station. The header line will be placed parallel to the outside edge of the access road and buried a minimum of 18 inches below ground.

Blower Station

The blower station will consist of three blower/motor assemblies arranged in parallel, two primaries and one standby. Each blower motor assembly will be rated at a maximum of 700 cfm and will consist of incoming gas header pipe connections, water separator (knockout), a belt-driven blower with an explosion-proof motor, recirculation piping and three flame arrestors.

Gas Flare

The gas flare assembly will include necessary piping and connections from the blower/motor assembly, a refractory lined shell, stainless steel burners, motor-operated louvers, compressed air and supplemental gas supply lines, temperature sensor ports, sampling ports, manway, viewing ports, and a remote control panel with data recorder.

Blower/Flare Pad and Enclosure

The blower station and the gas flare assembly will require a 60-foot by 35-foot concrete pad surrounded by an 8-foot high concrete block enclosure.

Gas Venting Trench

A gas venting trench will be constructed along the outside edge of the access road, beyond the gas collection header. The trench will be excavated to a depth of 1 foot below the seasonal low water table or 1 foot below low tide, whichever is deeper, and filled with washed stone. A 4-inch flexible pipe will be placed in the trench at a depth of 36 inches below ground. Six inches above the pipe, a 6-foot wide geomembrane will be placed to prevent excess air from infiltrating into the trench. The pipe will be connected to the blower station and gas flare in order to control landfill gas and odor emissions. Because of the expected low gas generation in the 11 acres north of the Eltingville Pump Station, the active gas vents in this area may be tied into the gas venting trench.

Perimeter Gas Monitoring Wells

Forty four perimeter gas monitoring wells will be installed along the property line. Wells will be installed along the southern property line adjacent to Arthur Kill Road. Gas monitoring wells will be constructed of 4-inch slotted pipe with protective casing and locking caps. Well depths will vary, but the bottom of the well screen will extend to the seasonal low water table.

3.1.2 Costs For Option A

The estimated capital, operating and maintenance costs for Alternatives A and B are the same and are summarized as follows:

Capital Costs –Option A				
Item	**Unit**	**Quantity**	**Unit Cost**	**Total**
Active Gas Collection Wells	Ea.	101	$3,500	$353,000
Collection Manifolds and Appurtenances	L.F	18,500	$25	471,000
Valve and Valve Box	Ea.	56	$1,000	56,000
Perimeter Collection Header	L.F.	16,800	$35	588,000
Gas Venting Trench	L.F.	2,100	$40	84,000
Blower Station	Ea.	1	$78,700	54,000
Gas Flare	Ea.	1	$269,000	269,000
Enclosure	L.S.	1	$32,000	32,000
Supplemental Gas Line	L.S.	1	$23,100	23,000
Perimeter Gas Monitoring Wells	Ea.	44	$4,500	18,000
			Subtotal	$1,948,000
			10% Predesign Studies	195,000
			10% Engineering	195,000
			10% Construction and Field Expenses	195,000
			10% Contractor Fees	195,000
			1% Startup	20,000
			1% Performance Test	20,000
			Subtotal	$2,768,000
			10% Contingency	277,000
			Total Capital Costs	$3,045,000(1)

Notes:
(1)Costs include direct and indirect capital costs.

Annual Operating Costs –Option A		
Direct Annual Operating Costs		
Utilities		
Blower Electricity	236,520 KWH @ $0.15/KWH (BUG)	$36,000(1)
Operating Labor		
Operator	548 hrs @ $20/hr	$11,000(2)
Supervisor	15% of operator labor	$2,000
Maintenance		
Labor	548 hrs @ $22/hr	$12,000(2)
Materials	100% of maintenance labor	$12,000

Annual Operating Costs –Option A		
Annual Service Contract for Flare and Blower		$18,000
Subtotal Direct Annual Operating Costs		$91,000
Indirect Annual Operating Costs		
Overhead	60% of O&M Costs	$22,000
Administrative	2.0% of Total Capital Costs	$61,000
Insurance	1.0% of Total Capital Cost	$30,000
Subtotal (Indirect Annual Operating Costs)		$113,000
	Estimated Total Annual Operating Costs	$204,000(3)

Notes:
(1)Assumes power consumption of new blower motors (20 hp x 0.663) = 13.3 kw x 2 = 27 kw.
(2)Assumes 0.5 hrs x 3 shifts x 365 days = 548 hrs.
(3)Assumes no cost for supplemental fuel.

3.2 Option B

This alternative includes active gas collection via a below ground system, on-site treatment by flaring, and perimeter monitoring wells at the property line. See Appendix A for plan drawings and Appendix B for miscellaneous details. Following is a detailed description of system components and a cost estimate for this alternative.

3.2.1 Description of Option B

Active Gas Collection Wells

One hundred and one (101) active gas collection wells with flexible connections to collection manifolds will be installed to collect gas from the waste mass. The active gas collection wells will be 4-inch PVC pipe (slotted below the cap) with booted liner penetrations. The wells will extend to a maximum depth of 10 feet above groundwater. Well heads will be installed above the impermeable cap, buried below ground in the barrier protection layer.

Collection Manifolds

Collection manifolds will connect the collection wells to a perimeter collection header. Collection manifolds will be 4-inch polyethylene pipe placed below ground, buried in the barrier protection layer. The collection manifolds will also be buried below the access road where they come off the cap and connect to a perimeter collection header line via a butterfly valve, in a valve box, adjacent to the perimeter road.

Blower Station

The blower station will consist of three blower/motor assemblies arranged in parallel, two primaries and one standby. Each blower motor assembly will be rated at a maximum of 700 cfm and will consist of incoming gas header pipe connections, water separator (knockout), a belt-driven blower with an explosion-proof motor, recirculation piping and three flame arrestors.

Gas Flare

The gas flare assembly will include necessary piping and connections from the blower/motor assembly, three flame arrestors, a refractory lined flare shell, stainless steel burners, motor-operated louvers, compressed air and supplemental gas supply lines, temperature sensor ports, sampling ports, manway, viewing ports, and a remote control panel with data recorder.

Blower/Flare Pad and Enclosure

The blower station and the gas flare assembly will require a 60-foot by 35-foot concrete pad surrounded by an 8-foot high concrete block enclosure.

Perimeter Gas Monitoring Wells

Forty-four perimeter gas monitoring wells will be installed along the property line. Wells will be installed along the southern property line adjacent to Arthur Kill Road. Gas monitoring wells will be constructed of 4-inch slotted pipe with protective casing and locking caps. Well depths will vary, but the bottom of the well screen will extend to 1 foot below the seasonal low water table or low tide, whichever is deeper.

3.2.2 Costs for Option B

The estimated capital, operating and maintenance costs for Alternative C are summarized as follows:

Capital Costs – Option B				
Item	**Unit**	**Quantity**	**Unit Cost**	**Total**
Active Gas Collection Wells	Ea.	101	$3,500	$353,000
Collection Manifolds and Appurtenances	L.F	18,850	$25	471,000
Valve and Valve Box	Ea.	56	$1,000	56,000
Perimeter Collection Header	L.F.	16,800	$35	588,000
Blower Station	Ea.	1	$78,700	54,000
Gas Flare	Ea.	1	$309,000	269,000
Enclosure	L.S.	1	$32,000	32,000
Supplemental Gas Line	L.S.	1	$23,100	23,000
Perimeter Gas Monitoring Wells	Ea.	44	$4,500	18,000
Subtotal				$1,864,000
10% Predesign Studies				186,000
10% Engineering				186,000
10% Construction and Field Expenses				186,000
10% Contractor Fees				186,000
1% Startup				19,000
1% Performance Test				19,000
Subtotal				$2,646,000
10% Contingency				265,000
Total Capital Costs				$2,911,000(1)

Notes:

(1)Costs include direct and indirect capital costs.

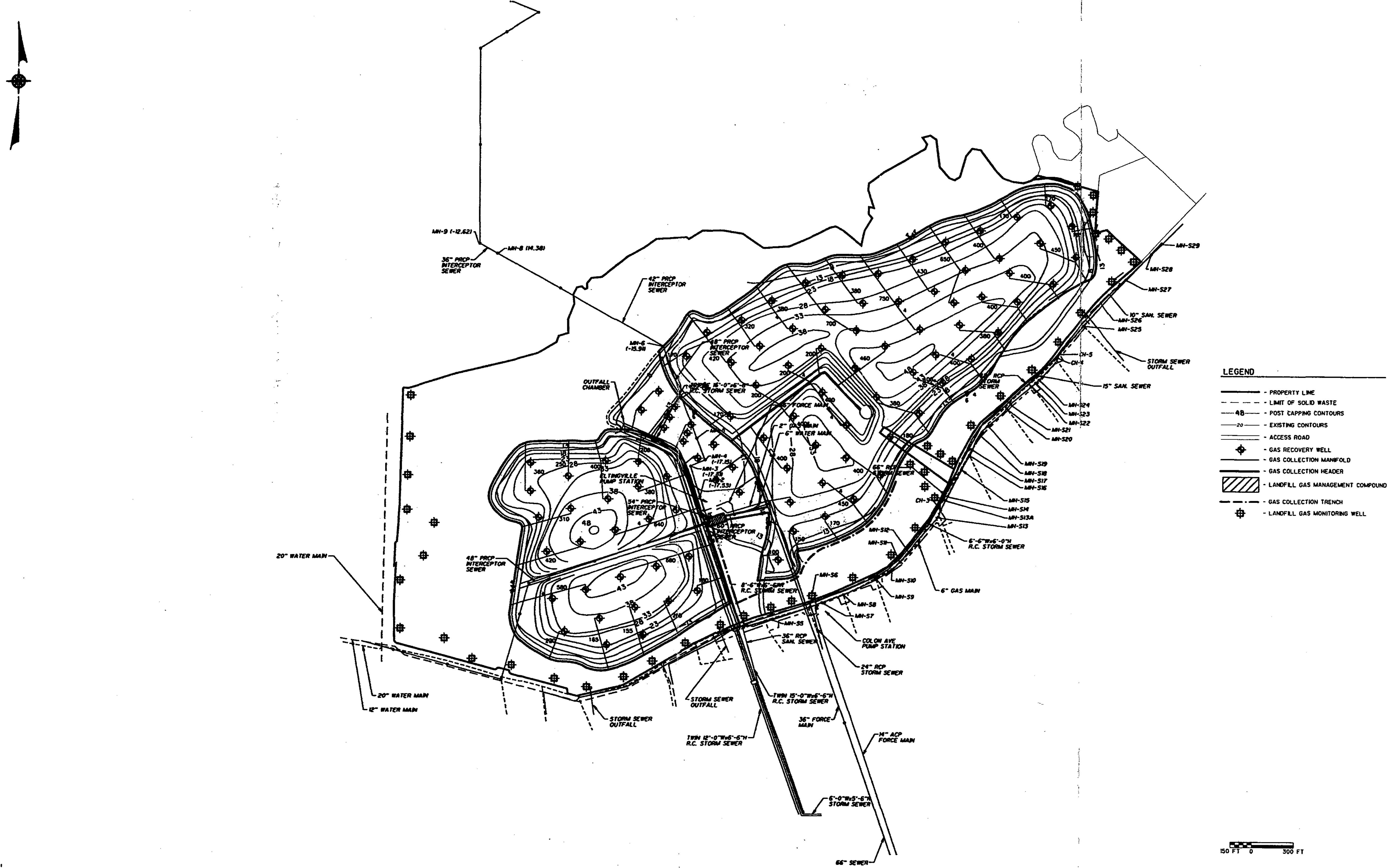
Annual Operating Costs – Option B

Direct Annual Operating Costs		
Utilities		
Blower Electricity	236,520 KWH @ $0.15/KWH (BUG)	$36,000(1)
Operating Labor		
Operator	548 hrs @ $20/hr	$11,000(2)
Supervisor	15% of operator labor	$2,000
Maintenance		
Labor	548 hrs @ $22/hr	$12,000(2)
Materials	100% of maintenance labor	$12,000
Annual Service Contract for Flare and Blower		$18,000
Subtotal Direct Annual Operating Costs		$91,000
Indirect Annual Operating Costs		
Overhead	60% of O&M Costs	$22,000
Administrative	2.0% of Total Capital Costs	$58,000
Insurance	1.0% of Total Capital Cost	$29,000
Subtotal Indirect Annual Operating Costs		$109,000
	Estimated Total Annual Operating Costs	$200,000(3)

Notes:

(1)Assumes power consumption of 2 new 20 hp blower motors (20 hp x 0.663) = 13.3 kw x 2 = 27 kw.
(2)Assumes 0.5 hrs/shift x 3 shifts x 365 days = 548 hrs.
(3)Assumes no cost for supplemental fuel.

Appendix A



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FILE NAME: 1215-1
DATE: SDM/12-29-99

NO.	DATE	REVISION	INT.
1	12/20/99	REVISE GAS EXTRACTION WELLS	CFV

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DESIGNED BY:
CHECKED BY:

WFC

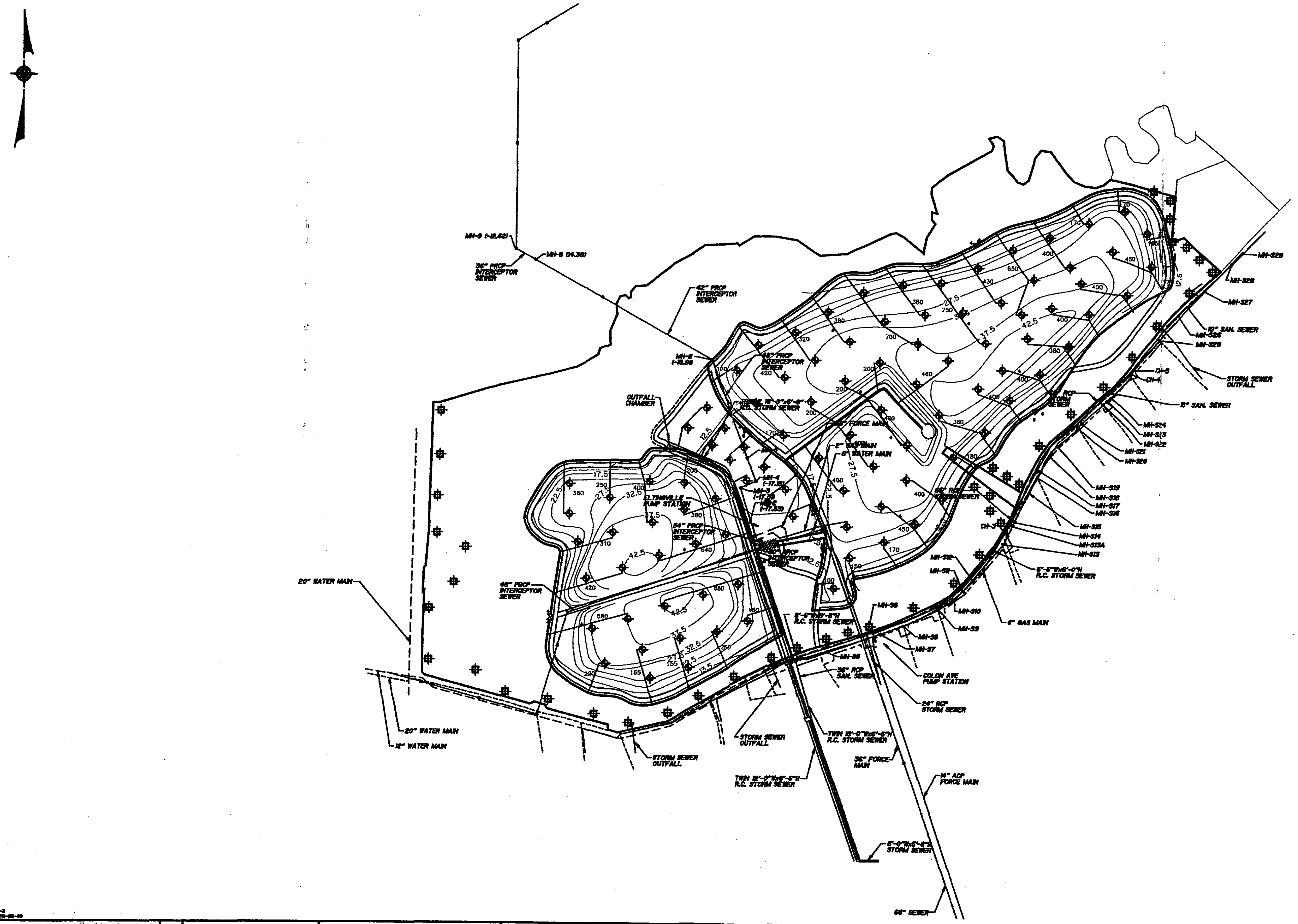
WILLIAM F. COSULICH ASSOCIATES, P.C.
ENVIRONMENTAL ENGINEERS

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL REMEDIATION PROJECT

GAS COLLECTION/TREATMENT CONCEPTUAL SITE REMEDIATION PLAN
OPTION "A"
(FOR ALTERNATIVE 2A)

PROJECT NO.: 1215-11
DATE: DECEMBER 1999
SCALE: AS NOTED
DRAWING NO.: 1
DRAWING 1 OF 4



LEGEND

- PROPERTY LINE
- LIMIT OF SOLID WASTE
48 - POST CAPPING CONTOURS
20 - EXISTING CONTOURS
- ACCESS ROAD
- GAS RECOVERY WELL
- GAS COLLECTION MANIFOLD
- GAS COLLECTION HEADER
▨ - LANDFILL GAS MANAGEMENT COMPOUND
- LANDFILL GAS MONITORING WELL

150 FT 0 300 FT

DIRECTORY: 1215
FILE NAME: 1215-3
DATE: [illegible]

NO.	DATE	REVISION	INIT.
1	12/20/99	REVISE GAS EXTRACTION WELLS	CPV

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NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL REMEDIATION PROJECT

GAS COLLECTION/TREATMENT CONCEPTUAL SITE REMEDIATION PLAN OPTION "B" (FOR ALTERNATIVES 2B, 3, 4 & 5)

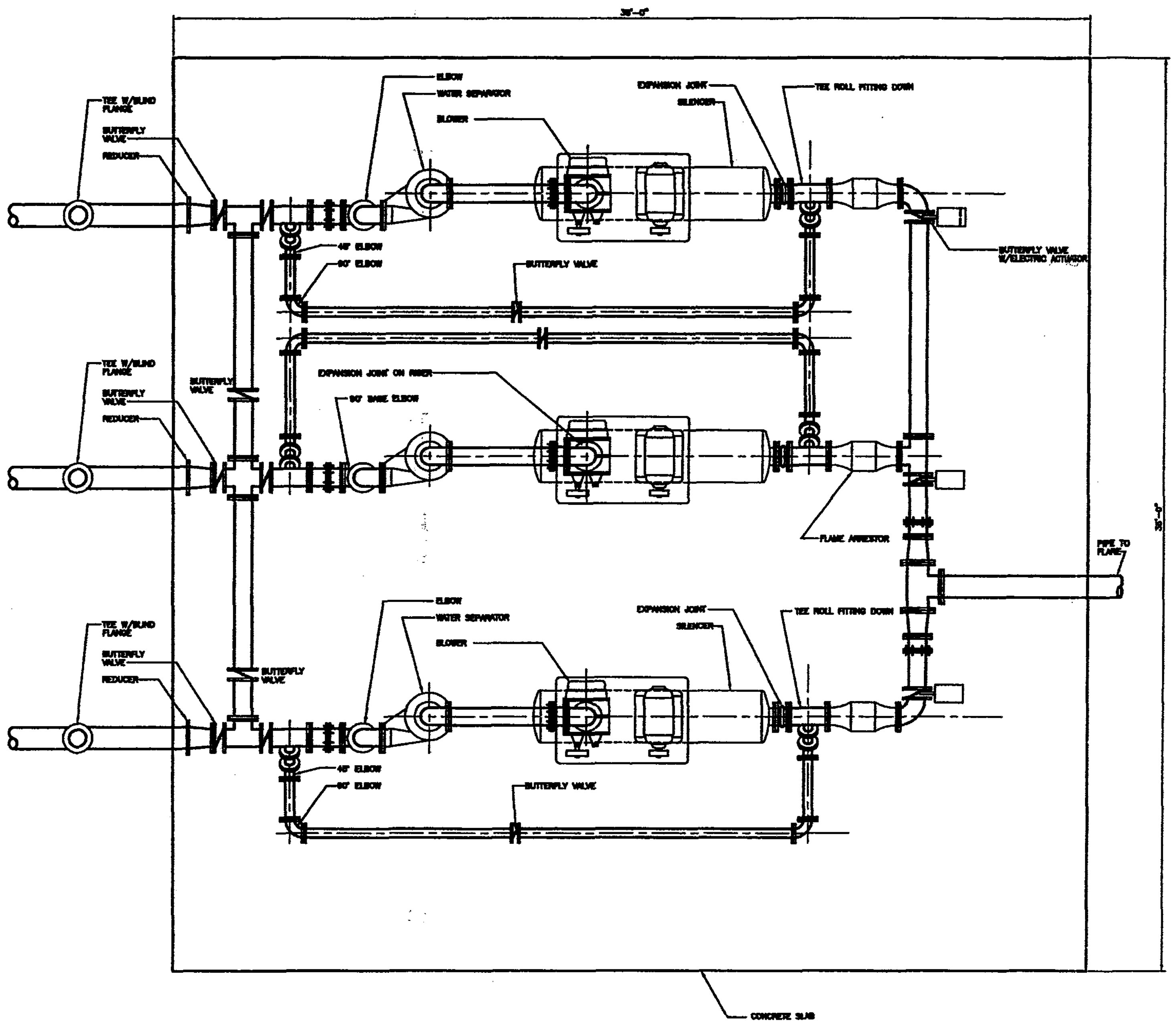
PROJECT NO.
1215-11

DATE:
DECEMBER 1999

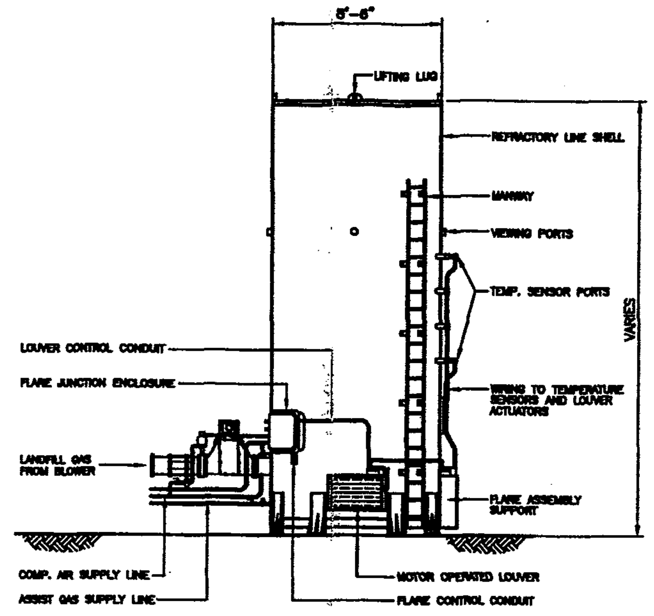
SCALE:
AS NOTED

DRAWING NO.
2
DRAWING 2 OF 4

Appendix B



LANDFILL GAS BLOWER/MOTOR ASSEMBLY
PLAN
N.T.S.



TYPICAL ENCLOSED FLARE ASSEMBLY
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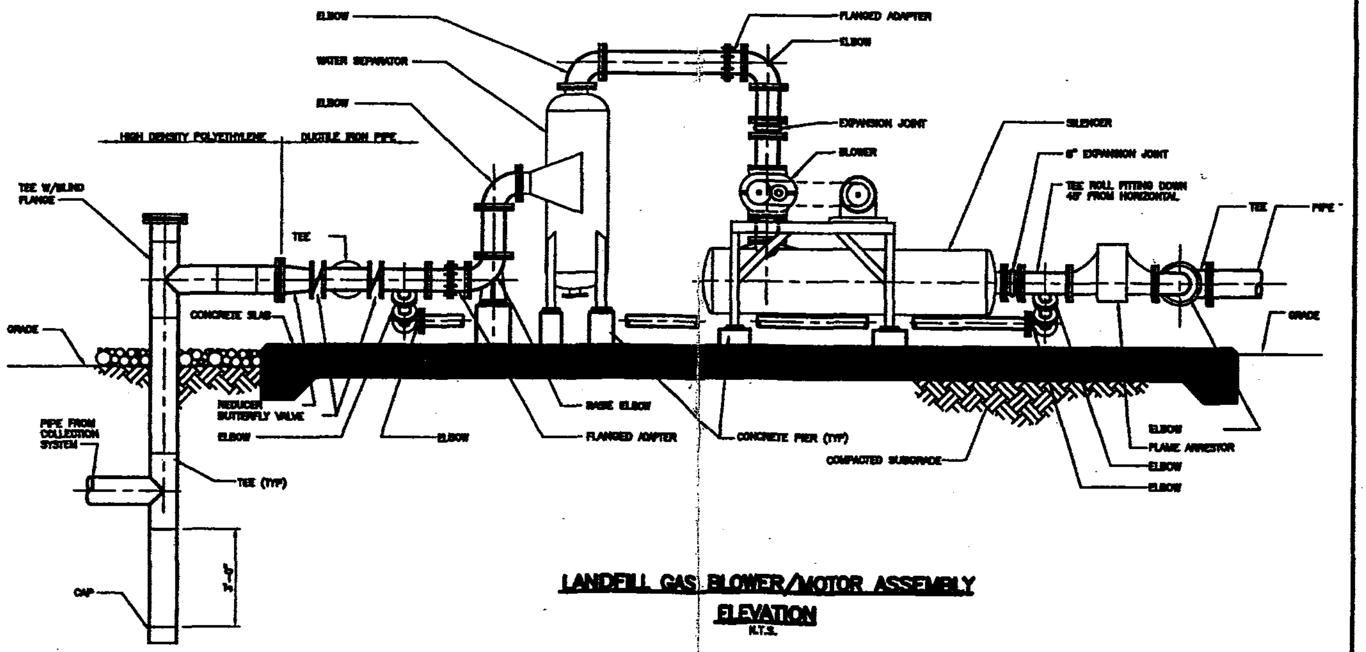

LANDFILL GAS BLOWER/MOTOR ASSEMBLY
ELEVATION
N.T.S.

DIRECTORY: 1215
FILE NAME: 1215-5
DATE: (SDN/12-22-99)

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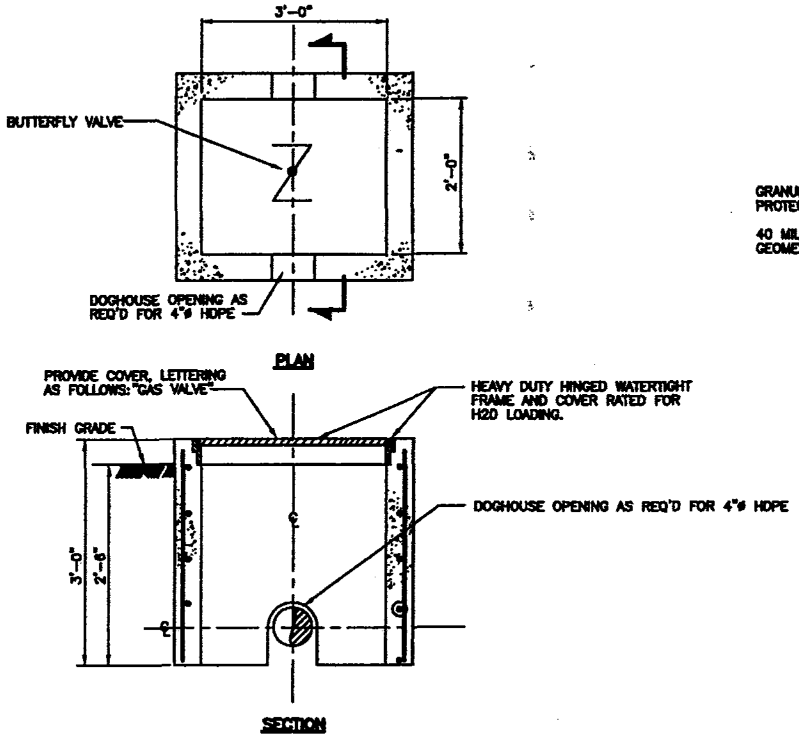
ENVIRONMENTAL ENGINEERS

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL
REMEDIATION PROJECT

BLOWER AND FLARE COMPOUND

PROJECT NO.
1215-11
DATE:
DECEMBER 1999
SCALE:
AS NOTED
DRAWING NO.
3
DRAWING
3 OF 4



TYPICAL GAS VALVE MANHOLE DETAIL

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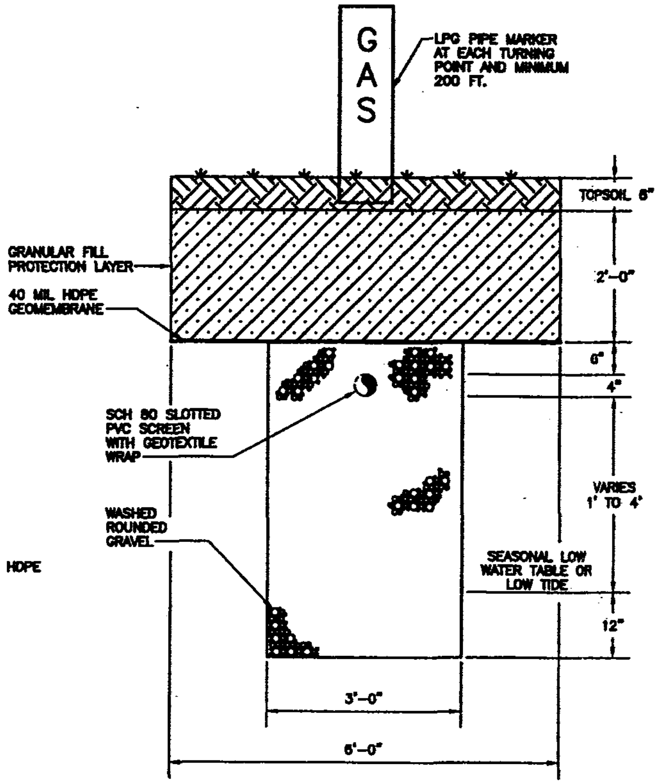

GAS VENTING PIPE TRENCH DETAIL

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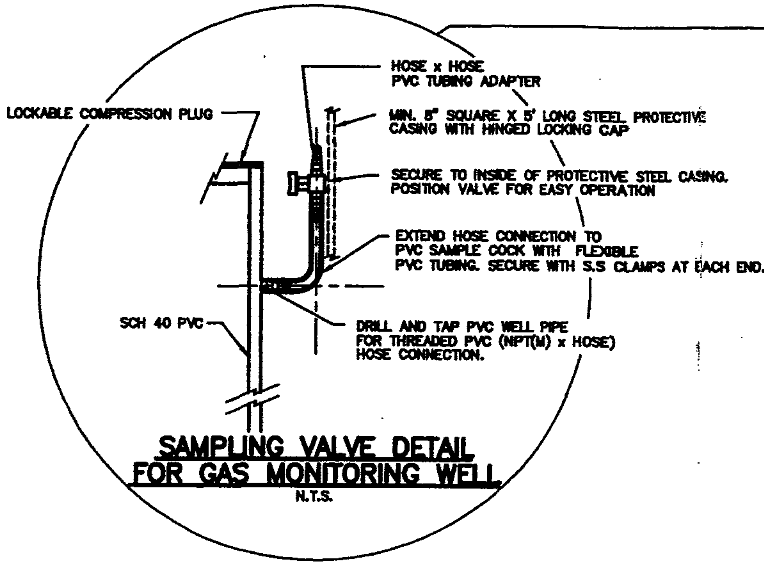

SAMPLING VALVE DETAIL FOR GAS MONITORING WELL

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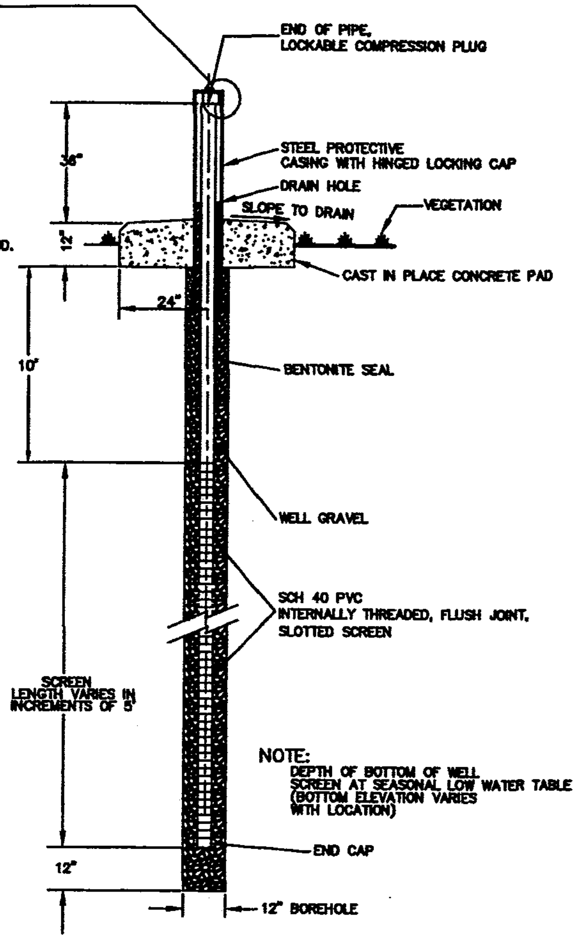

TYPICAL LANDFILL GAS MONITORING WELL DETAIL

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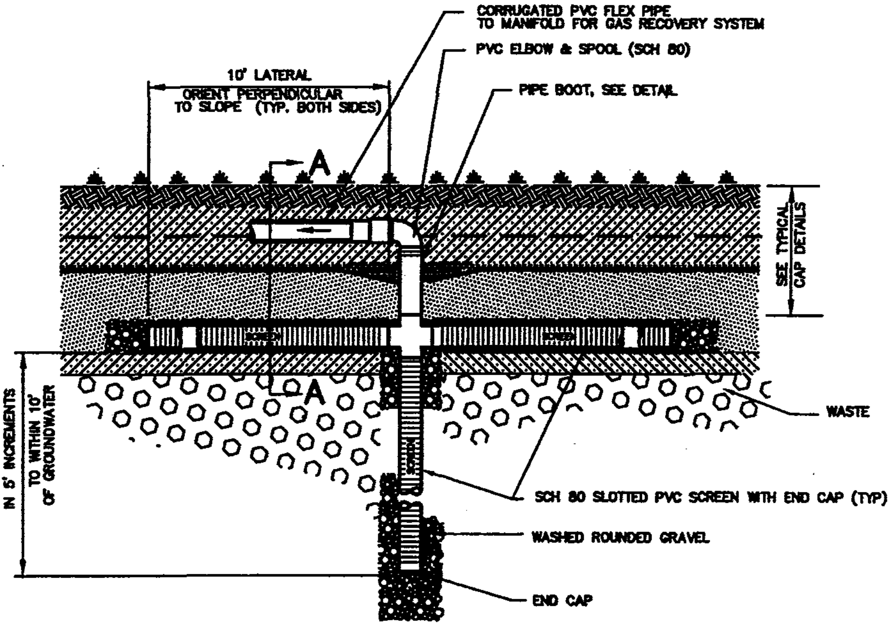

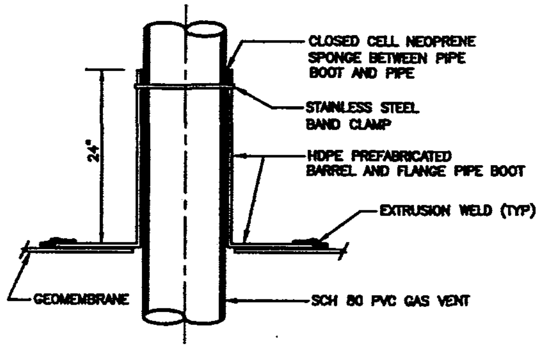

TYPICAL PIPE BOOT DETAIL

N.T.S.

ELEVATION

LANDFILL GAS RECOVERY WELL DETAIL

N.T.S.

DIRECTORY: 1215
FILE NAME: 1215-6
DATE: (BCM/12-28-99)

NO.	DATE	REVISION	INT.

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ENVIRONMENTAL ENGINEERS

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL REMEDIATION PROJECT

MISCELLANEOUS LANDFILL GAS DETAILS

PROJECT NO.
1215-11
DATE:
DECEMBER 1999
SCALE:
AS NOTED

DRAWING NO.
4
DRAWING
4 OF 4