

AFTER~USE REPORT ~ SITE F
HALTON REGION LANDFILL TECHNICAL
STUDY

SCHEDULE E ~ F

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Landplan
landscape architects
environmental scientists

AFTER-USE REPORT SITE F

Halton Region Landfill Technical Study

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The Landplan Collaborative Ltd.
Landscape Architects, Environmental Scientists
319 Woolwich Street
Guelph, Ontario
N1H 3W4

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1.0 Executive Summary

The Site F After-use Report concerns the selection and description of the recommended after-use for the proposed Regional Landfill at a concept level of detail.

Review of Stage 2C Study

In the Phase 2, Stage 2C of Halton's Environmental Assessment studies references to possible after-use options for the recommended sites recognized the Environmental Protection Act provision for Ministry of the Environment approval for uses of lands on completed landfills for a minimum period of 25 years after closure. The after-uses identified for Site F generally included passive recreation, conservation and some active recreation activities. Reference was also made to possibly locating the Halton Region Museum at the landfill site. The after-uses that were identified were generally consistent with public comment, the preferences of the Town of Burlington and land use policies as expressed in the Parkway Belt West Plan (incorporated in municipal Official Plans).

Q
cross →
re
open space*

Evaluation of Features

The features of Site F and the surrounding landscape were considered in the evaluation of the after-use concepts. Site constraints identified potential limitations to after-use options. The constraints that were discussed included the need to integrate after-use with the biophysical (e.g. Sassafrass Woods Environmentally Sensitive Area) and land use characteristics of the area; the need to minimize the height of the landfill, integrate contours and establish perimeter screen of vegetation. Existing natural vegetation and rare plants should be protected where feasible and incorporated into the after-use concept. The shortage of indigenous topsoil and the setting of the site constrained agricultural rehabilitation.

now
prov
base plus
now over
21'

can't
protect
prov 3 rare
plants

There were no heritage structures identified on Site F.

In addition to the site constraints the analysis recognized that the public use of surrounding open space at Bayview Park and the Bruce Trail would preclude some after-use activities, such as hunting. The setting of Site F provides opportunities for passive recreation linkages. The

Site setting was less suitable for industrial support and commercial after-uses.

Evaluation of After-Use Concepts

The after-use proposals were organized in a "long list" of potential activities including: conservation, passive recreation, active recreation, agriculture and industrial/commercial concepts. The specific after-uses were evaluated in two stages - screening and concept evaluation.

Ten screening criteria were developed to evaluate the after-use proposal. No active recreation, agricultural or commercial/industrial after-uses were retained after screening. The conservation and passive recreation uses included: natural area reforestation, buffer area, biking and ski trails, outdoor education, interpretive trails and viewing areas, and picnicking.

Concept evaluation involved setting five objectives for examining the relative strengths and weaknesses of each concept. The natural area reforestation was considered the most appropriate concept for after-use. Its major strengths were its compatibility with the area, protection/integration

with local natural vegetation (eg. Sassafrass Woods ESA); flexibility protection of valuable natural resources and minimal environmental disruption. Both the objectives used to evaluate the concept and the concept itself were consistent with the Stage 2C Study.

Recommended Mitigative Measures

NB
The concept involved importing sufficient topsoil to allow the establishment of native indigenous trees and shrubs on the site. Local surface water features, visual characteristics and contours will be integrated with the surroundings where possible. The after-use plan may allow for compatible multiple use of the site in the future. *Q*

*NB
how much
needed
daily
&
over-
bedding
of site*
Mitigative measures were proposed in the form of development guidelines. These included minimum topsoil need of 0.5 to 1.5 m over refuse; control of methane and carbon dioxide gas in the soil; soil structure and fertility needs; the use of native species, visual buffering requirements; protection and incorporation of existing vegetation on site; reclamation staging; and a series of environmental protection measures. *Q*

2.0 Review of Stage 2C Study

Reference was made to landfill after-use in the study prepared for Halton Region as part of its Environmental Assessment, referred to as the Phase 2, Stage 2C Selection of Preferred Site. After-use was discussed in the following technical studies:

- Biophysical Assessment
- Agricultural Assessment
- Social Impact Assessment
- Hydrogeologic-Hydrologic Assessment and Conceptual Design
- Visual Assessment
- Landuse and Planning Assessment

The Biophysical Assessment (Bird and Hale Limited, 1985) identified the need to reduce impact on the existing vegetation and significant plant species. Natural vegetation was identified as a good potential buffer for screening and habitat purposes. The Report recommended that native species be used in rehabilitating the site; consideration was given to transplanting the native flora displaced by landfilling.

LAB
Linda
Hallas
testified
not
recommended

The Agricultural Assessment (Ecological Services for Planning Ltd. 1985) indicated that agricultural after-use potential of Site F was limited. General mitigative measures for all sites were proposed for agricultural rehabilitation. These measures included:

- . reduction of infiltrating water
- . prevention of soil contamination
- . prevention of the migration of gases toxic to plants
- . provision of 1 to 1.2 m of minimum soil cover over final lifts
- . a series of measures to improve soil fertility and tillage
- . a cropping program and series of crop monitoring requirements

changed now { The Social Impact Assessment (Myra Schiff Consultants Limited 1985) recommended that the Bayview Park Horse Ring facilities be relocated. *Q.*

Hydrology Consultants of Trow (1985), -

Hydrogeologic - Hydrologic Assessment and Conceptual Design Report proposed a landfill design concept for Site F including after-use. A preliminary set of site design parameters included:

Violated
this over
20

maximum height of final contour at 15 m above existing grade

- final contour side slopes at 4:1 ratio
- a minimum buffer area of 100 m from the edge of the area to be landfilled to the property line.

Source of water
existing 1/2 of water
SP - well
where
leachate
flows

It was noted that the minimum buffer area around Site F was not maintained on the west side of the site. Stream diversions, drainage channels and swales were to be generally designed to ensure that surface water runoff from the north to south grade of Site F was directed away from active landfilling.

Q

The Visual Assessment prepared by The Landplan Collaborative Ltd. (1985) included recommendations to reduce visual impact. The need for vegetation buffering and screening was stressed. In the context of after-use the following measures to mitigate potential visual intrusion were proposed:

- the final contours of the landfill should reflect the natural contours of the land in the area
- rehabilitation should occur as soon as possible after closure
- screening vegetation should be designed to reflect existing patterns and slopes
- native species should be used for planting

- . existing vegetation should be preserved and incorporated into after-use
- . the height of the landfill should be kept as low as possible

For Site F, specific recommendations included the need for heavy screening with plant material and the need to rehabilitate to a visually unobtrusive condition as soon as possible after construction.

The Landuse and Planning Assessment (Walker, Wright, Young Associates Limited 1985) discussed generic after-use and concurrent uses of landfill sites with possible after-uses for sites. This report noted the Environmental Protection Act authority to regulate after-use "within a period of twenty-five years" after closure (pg. 8-1). Also, the Region of Halton Official Plan considers that landfill sites are interim uses until the land is rehabilitated. With respect to Site F, the Report noted that the City of Burlington Official Plan Amendment No. 49 did not include specific policies for after-use of landfills.

The Walker Wright Young Report (1985) identified the need for potential after-use concepts to be flexible to respond to changes in policy and technology. The primary forms of after-use included open space, recreation, and agricultural rehabilitation. Within these generic categories the advantages of progressive rehabilitation, and concurrent use opportunities were stressed. A range of possible constraints was discussed which included:

- . gas generation and migration
- . leachate generation
- . settlement
- . contour design

It was recommended that no built structures or servicing occur "on or in close proximity to, a landfill site" (pg. 8-6). A variety of appropriate after-uses was discussed, comprising:

- H51
- . natural revegetation (with no public access)
 - . recreational uses (supervised - passive and active)
 - . energy from gas

Specifically for Site F, the following potential after-uses were listed for consideration:

- . active and passive urban recreational after-uses

- . revegetation to native trees and other vegetation
- . open space linkages to the Bruce Trail
- . construction of greenhouse facilities
- . picnic areas and camp grounds
- . garden plots
- . landfill gas production as fuel for after-use or adjacent industrial use.

For Site F, agricultural rehabilitation was not considered an appropriate after-use. 

3.0 Methods

This section is subdivided into general methods, which were used to select recommended after-use concepts for both Sites F and D and methods specific to Site F.

3.1 General Methods

The methods used to identify and recommend after-use concepts for the proposed landfills at Sites F and D involved review of reports and published literature on the topics of landfill after-use, revegetation/reclamation of landfills, and the Phase 2 Stage 2C studies of the Environmental Assessment; discussions with practitioners in the field of landfill after-use, with municipal staff and other consultants; and, a review of the consultants' site constraints. In addition, a reconnaissance survey of examples of landfill after-use and post closure practices was undertaken in the local area.

The following sequence of steps was taken to identify potential after-uses and arrive at a recommended after use(s) for each site:

- . literature on landfill after-use and the reports from the earlier stages of the Environmental Assessment were reviewed
- . a memorandum on generic site constraints was produced by each consultant involved with after-use
- . practitioners, agencies, municipalities with experience in landfill after-use were contacted.
- . the reconnaissance level landfill survey was undertaken
- . a "long list" of potential after-uses for Sites F and D was compiled.
- . methods to evaluate the potential after-uses and selected preferred after-use concepts were developed
- . screening criteria were used to eliminate the less appropriate after-use options from further consideration
- . after-use options remaining after screening were evaluated comparatively to select one or two recommended after-uses for each site
- . the recommended after-use concepts were described and their impact on the sites was assessed.

Throughout this process close liaison was maintained among the consultants and Halton staff. An Agricultural Rehabilitation Report (Ecological Services for Planning 1986) was produced which evaluated each site for its potential for rehabilitation to an agricultural after-use. The results of that assessment are included in this document as an appendix.

3.2 Methods Specific to Site F

The difference between the general study methods and those used specifically for Site F concerned the development of several final landfill design options for the latter. Although the impact of the different options on the potential after-use for Site F was not major, each option had different impact on the feasibility of retaining existing vegetation. The incorporation of existing forest vegetation with its ability to screen after-use views, provide wildlife habitat and form a nucleus of revegetation to natural forest was important. Q.

The Agricultural Rehabilitation Report (Ecological Services for Planning, 1986) indicated that an economically viable

agricultural after-use was not feasible for Site F. Consequently any agricultural after-use options were screened out of consideration for Site F.

There were no heritage features identified on Site F, consequently no methods for incorporating and evaluating heritage concerns were used for Site F.

4.0 Criteria for the Evaluation of After-Use

The criteria for the evaluation of after-use were developed from a range of published sources, current practice and discussion among members of the project team. The following is a review of the characteristics of Site F that are relevant to after-use; a discussion of site constraints; opportunities for after-use; and the screening and evaluation criteria used in after-use selection.

4.1 Site F Features and Characteristics

Site F is located north of the North Service Road, in the City of Burlington. The site is west of King Road and adjacent to the closed Bayview Sanitary Landfill now known as Bayview Park. The site is on the north half of Lots 2 and 3, in Concession I, and on the south half of Lot 3, Concession II of the geographical Township of East Flamborough. The Site Plan area, exclusive of perimeter buffers located on the north and south and a 50 m buffer adjacent to a hydro right-of-way, is estimated at 69.8 ha (172.6 acres).

The biophysical characteristics of Site F have

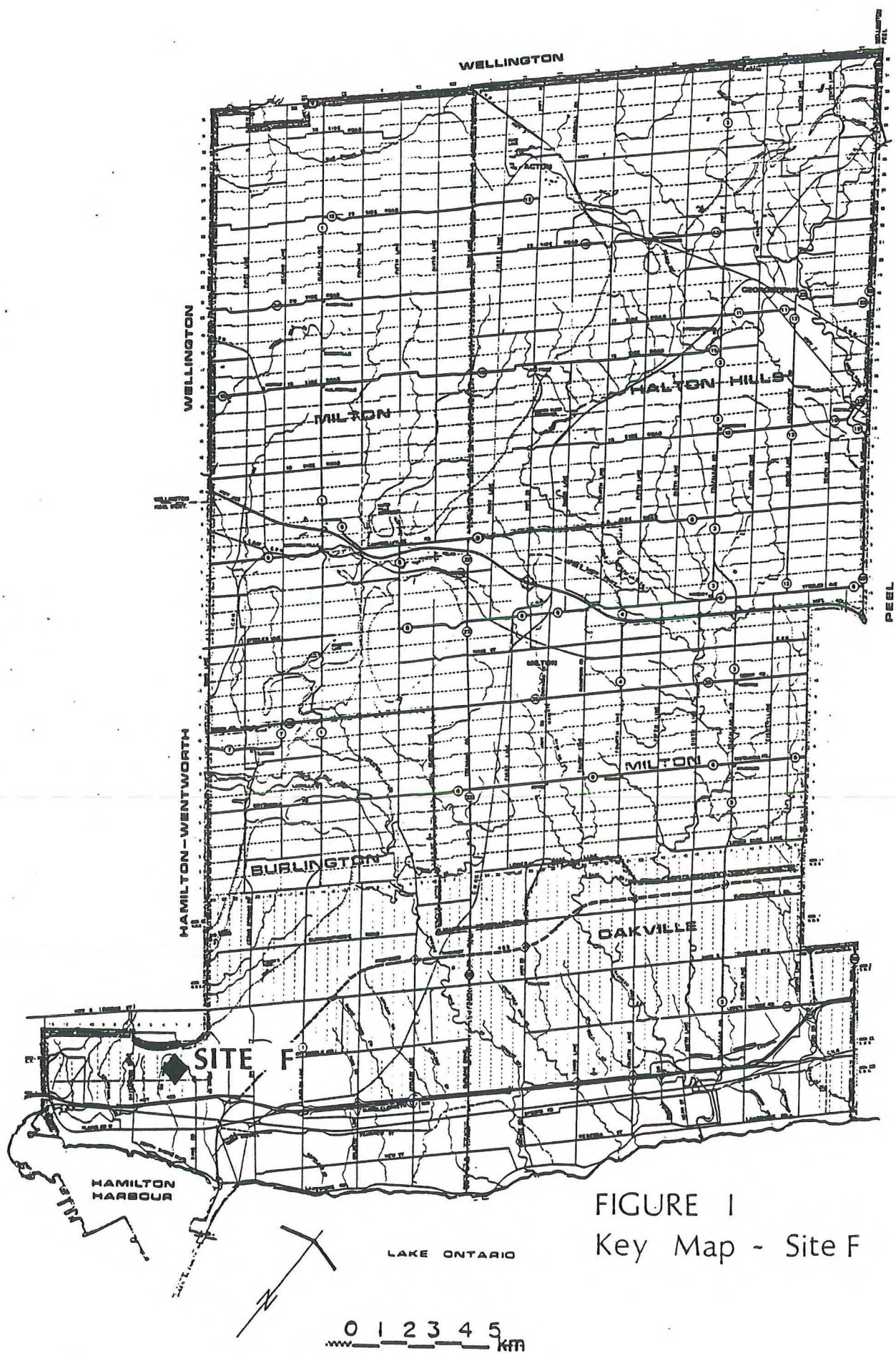


FIGURE I
Key Map - Site F

been well described by Proctor and Redfern (1982) and Bird and Hale (1986). The site lies on the south slope of the Niagara Escarpment and slopes generally to the southeast. The site is traversed by several deeply incised ravines through which several intermittent streams in the Indian Creek drainage area run. The vegetation of the site is comprised of several communities including woodland, scrub, wet graminoid meadow, and plantation. The woodland is composed of an oak-hickory forest, the composition of which is considered rare in Ontario (Proctor and Redfern 1982). The site also contains a number of provincially and locally rare plant species. These are discussed in detail in Bird and Hale (1986) and Proctor and Redfern (1982).

*proposed
Heller*

7. On roughly 56% of the site the topsoil has been completely removed from past quarrying. In undisturbed areas the soils are clay loams in the Oneida and ^{no disturbance on site} ~~Chingony~~ series with depths up to 60 cm. In the areas where soil disturbance has occurred the sub-soil is often exposed.

*1.80%
else
where*

The surrounding land uses consist of an adjacent closed landfill site (Bayview Park) now used as

a public park, a utility corridor, and local roads and a freeway corridor. The current Regional landfill site lies to the west as does the Sassafrass Woods Environmentally Sensitive Area (ESA No. 4). There are parcels of land with industrial uses, farms, residences and a quarry in the vicinity. The intensity of development in the area of the Site is relatively low. The Bruce Trail with associated natural vegetation and viewing areas is located north of the Site.

There are no heritage features on Site F.

4.2 Site Constraints

The consultants identified and discussed potential constraints to after-use in their respective areas of expertise. They also proposed design requirements to mitigate potential problems with after-use. A summary of the constraints that were identified follows:

4.2.1 Potential Engineering Design and Operations Constraints

The integrity of the one metre cap (e.g. from plant root penetration) used to cover the top of the landfill would have to be maintained. The contours would have to be shaped to drain surface water off the top of the landfill. No impoundments of water over refuse would be allowed. Activities which promoted erosion (eg. trail bikes) required control. Differential settlement of the refuse would probably occur. No closed structures should be built on the landfill.

The completed landfill would contain manholes, possibly pump station and fan houses (for removing landfill gas) and internal roads in the buffer area. (The latter may be removable after closure).

In the Design and Operations Report for Site F (1986) general development guidelines to achieve an appropriate after-use were specified which essentially confirmed the preliminary assessment of potential constraints. The Design and

Operations Report also indicated that the proposed concept for the landfill would be Option 3 (Hydrology Consultants of Trow Ltd., 1986).

4.2.2 Land use and Regional Planning

The planning constraints are taken from Walker Wright Young Associates (1985, 1986).

4.2.2.1 Parkway Belt West Plan

Site F falls within the City of Burlington and the area designated by the Parkway Belt West Plan. This Plan takes precedence over any municipal plan. It has been incorporated into the Regional Official Plan and the Burlington Official Plan.

An after-use would have to comply with the Parkway Belt West policies and regulations. The existing permitted use (Section 5.5.1, Uses in the General Complementary Use Area) include agricultural, institutional and public uses of "low density, ... low intensity" in character. Within the Special Complementary Use Area

(covering the southern portion of Site F) low-density industrial development is allowed subject to approval of a zoning by-law and the appropriate development agreements.

4.2.2.2 Region of Halton

Section D.3.8 of the Regional Plan indicates that landfill is considered an interim use, and that end uses should be suggested by local plans and in accordance with the requirements of the Ontario Ministry of the Environment.

With respect to Site "F", the Regional Official Plan incorporates the policies of the Parkway Belt West Plan which is described above.

4.2.2.3 City of Burlington

The local Official Plan incorporates the Parkway Belt West Plan and a sanitary landfill is considered to conform. The Parkway Belt regulations effectively comprise the zoning by-law within the Parkway Belt area. These regulations would permit the sanitary landfill

use as well as a passive recreation after-use, agricultural rehabilitation and open space use. (Walker, Wright, Young, 1985).

4.2.3 Provincial Policies

The Environmental Protection Act regulates the after-use of sanitary landfills.

Section 45 of the Environmental Protection Act requires the approval of the Minister for all uses of lands on completed landfills within 25 years of cessation of landfilling operations. The Ministry is giving active consideration to a requirement for control in perpetuity, rather than for 25 years.

The Ministry's position is clarified in its Interim Guidelines for the Use of Land Adjacent to or On Completed Landfilled Areas (1981) which considers the potential effects of methane gas and requires the use of buffer areas to ensure that landfill gas does not create a hazard in developed areas. Where no artificial gas control facilities are in place, a buffer extending a distance of ten times the depth of the landfill from the edge of the fill area

would be kept free of development, subject to any additional studies which may be undertaken. Where artificial gas control facilities are in place, the required buffer would be not less than twenty metres. The onus is placed on the person wishing to undertake the development to prove that no hazard will be created.

4.2.4 Air Quality

Control measures for dust, and odour may not affect after-use. These aspects however, would affect concurrent use particularly adjacent to any active areas of landfilling. The Phase 2 Stage 2C of Halton's Environmental Assessment report on air quality did conclude that a high degree of permanent dust suppression can be achieved in the long term by revegetating areas when complete (Senes 1985, pg. 2-3).

4.2.5 Biophysical

7. The primary constraints at Site F were the adjacent Sassafras Woods (ESA No. 4) and the Oak-Hickory complex on site.

The ESA abutts the northwest boundary of the Site. This area must be protected from impacts associated with the construction activities and changes to the hydrologic regime. After-use should include a buffer area to protect the ESA.

Q The Oak-Hickory complex in the south-central portion of Site F supports a diversity of significant and rare plant species. If possible this existing natural vegetation should be retained and incorporated into a suitable after-use plan which would help maintain its biological value and reduce visual intrusion.

The pattern of surface runoff from the north down-gradient to the south part of the site should be maintained where feasible in the after-use contours, particularly as Indian Creek, a tributary of 16 Mile Creek occurs on the site.

4.2.6 Agricultural

Constraints to agricultural rehabilitation and after-use on Site F included the roughly 56% of the soils which were of agricultural capability

Q. class VII because of topsoil removal and severe soil disturbance (Ecological Services for Planning Ltd. 1986). The agricultural after-use consultant noted the potentially steep slopes and relatively small amounts of flat and gently sloping land would reduce the probability of maintaining viable farm enterprises. (The area around the site supports a range of land uses including many that are non-agricultural, and was considered "an urban fringe area ... exposed to considerable development pressure" (Ecological Services for Planning 1986).]

4.2.7 Visual

Site F is affected visually mainly by two factors. The first is the site's elevation relative to the areas to be screened; the second is that the site has a limited buffer area.

At the detailed design stage proximity of the site to the Niagara Escarpment scarp will require sensitive grading to integrate the site to the surrounding contours. Since the base of the steepest part of the scarp is about 200 m (656 ft.) it was recommended that the highest

portion of the landfill at this end not exceed this elevation. Existing grade at the northern end is about 188m (617 ft.). *Amended* This area of the site should not exceed ten to twelve metres of fill above grade. The land in the area naturally slopes at five to ten percent and the new contours should follow this slope. Side slopes in the valley system are at 20 to 25 percent so that edges to water courses and drainage ditches should be similar.

The extensive natural vegetation on site reflects the visual character of the surrounding area and would act as a visual screen during the construction and post construction life of the landfill. Removal of vegetation will increase the visual impact of the landfill and the after-uses.

4.3 After-use Opportunities

A number of potential after-uses for Site F have been identified.

4.3.1 Identified Potential After-uses

The Stage 2, Phase 2C Report of Halton's Environmental Assessment (Walker Wright Young Associates 1985) identified, "public-oriented after-use" as most appropriate for the Site. It was felt that the "environmental context of the area" favours uses with more "natural character". Passive uses such as hiking and garden plots were also mentioned.

Walker Wright Young (1985) also reports that: During the Phase 2 Stage 2C selection process the Consultant team was approached by the curator of the Halton Regional Museum. In a memorandum submitted to Regional Council, the Museum outlined its requirements for building space and future requirements for expansion. At present the site is on about two ha of land and would require an additional five ha for future expansion and parking. Both site areas D and F were considered to be viable options, however, the supply of services (ie. a water line) and isolation from major points of public access were considered to be a liability. A subsequent

conversation clarified that the Museum was looking at utilizing land in association with the landfill. This land would be adequately buffered (berms and trees) to reduce the potential effect of noise and dust. The building would be subject to the provisions in Section 45 of the Environmental Protection Act.

Contact with the City of Burlington's Parks and Recreation staff indicated their preference for passive uses which capitalized on the natural character of the Niagara Escarpment and surrounding public open space.

4.3.2 Site F Biophysical Features and Setting

Site F is located in a prominent area along the Niagara Escarpment. Its surroundings are open, rural in character with natural forest and hedgerows. It affords a good view of the lands to the south and Lake Ontario. The site provides potential linkages to public open space: the future rehabilitated Regional

landfill site at Burlington, the Escarpment, Bayview Park and the Bruce Trail.

There are well developed complexes of natural vegetation on site with documented biological value and interest. Hedgerows and the surrounding shrublands and wooded areas provide opportunities for wildlife corridors, recreation, visual screening and wildlife habitat potential.

Consequently, conservation and passive open space focussed activities are suggested for after-use.

4.4 Evaluation of After-uses

The after-use options that were considered for Site F are listed in Table 1. For convenience they have been grouped into categories based on the similarity of after-use activity.

The "long list" of potential after-uses was developed from the reviews of literature

TABLE 1.

'LONG LIST' OF POTENTIAL AFTER-USES

i) Conservation

1. natural areas, preserves
2. buffer areas to protect adjacent sensitive natural features
3. wildlife production/hunting

ii) Passive Recreation Activities

1. pedestrian/cross country ski trails
2. interpretive trails outdoor education, viewing areas
3. picnic areas

iii) Active Recreation Activities

1. sports fields (soccer, baseball, football)
2. equestrian facilities, trails
3. archery ranges, skeet and trap shooting facilities
4. municipal garden plots
5. golf course

Table I (cont'd)

6. camping and organized day uses
7. botanical garden, arboretum, museum

iv) Agriculture

1. farming enterprizes with field crop and forage production

v) Commercial/Industrial

1. greenhouses
2. horticultural production area, nursery
3. open storage areas, parking facilities

the Stage 2C reports and current practice. The evaluation of the "long list" options was undertaken in two stages:

- i screening
- ii concept evaluation

Screening was designed to eliminate after-use options that were clearly inappropriate for a given site, or were, in the opinion of the consultants, problematical or requiring significantly more detailed work to establish feasibility.

Concept evaluation involved assessment of the after-use options that survived screening to select one or two preferred options for each site.

4.4.1 Screening of After-use Options

The consultant's approach to screening was to undertake a qualitative evaluation of each after-use with respect to its appropriateness for Site F. The objective of the screening was to retain as many options for after-use while removing from active consideration those

after-uses that were clearly unsuitable. Screening was an exercise of selective elimination.

The criteria used to screen the after-use options were developed from a review of literature sources, discussions with the project team, Municipal staff and the Consultant's knowledge of the site and its surroundings. The criteria were not considered of equal weight, and their application was essentially based on best professional judgement.

4.4.2 Screening Criteria

The following criteria were used to screen the long list of candidate after-uses for Site F:

- ✓ 1. Screen out after-uses requiring functional area larger than available at Site F.
- ✓ 2. Screen out after-uses that require urban or high density population in the vicinity of the Site
3. Screen out after-uses requiring relatively large amounts of flat or gently sloping contiguous land

4. Screen out after-uses requiring site wide coverage of deep, fertile, workable soils
5. Screen out after-uses that are incompatible with the rural, urban fringe character of the site and its surroundings
6. Screen out after-uses with special and/or high traffic volume access and parking requirements
- X 7. Screen out after-uses that are in conflict with Municipal or Provincial government policies
- X 8. Screen out after-uses with problematical or risky design, construction or operational characteristics
- X 9. Screen out after-uses with unestablished or uncertain user-demand
- X 10. Screen out after-uses with significant safety or public acceptability concerns.

5.0 Evaluation of After-use Proposals

The evaluation process occurred in two stages: screening and concept evaluation. Table 2 summarizes the results of the screening process. Following screening, the evaluation of the after-uses that were not screened out is described.

5.1 Results of Screening

The screening results are summarized in Table 2. A list of the after-uses for Site F that remained after screening are listed below:

<u>Category</u>	<u>After-Use</u>
i) Conservation	. natural area . <u>buffer area</u>
ii) Passive Recreation	. hiking and ski trails . outdoor education, interpretive trails, viewing areas . <u>picnic</u> areas NSO
iii) Active Recreation	(none)

TABLE 2, SUMMARY OF AFTER-USE SCREENING

AFTER-USE	REQUIREMENTS	CRITERIA NOT SATISFIED	COMMENTS	SCREENING RESULTS
i) <u>Conservation</u>				
1. Natural Area	- topsoil suitable for tree growth; minimum depth of 1.5 m of soil cover under reforested area of landfill - controlled access (eg. all terrain vehicles - control of soil gas and contaminants - supply of native, indigenous plant material	none	large amounts of topsoil may be required - not required over all of site; no need for soils to be routinely workable	retained
2. Buffer Area	- topsoil suitable for some tree growth; minimum 1.5 m depth of soil cover to cover smaller area - control of soil gas and contaminants - access control (e.g. all terrain vehicles) - incorporate existing plant communities where feasible	none	topsoil requirement similar to above however less area for reforestation with concomittant less soil requirements	retained

TABLE 2 - Con't)

AFTER-USE	REQUIREMENTS	CRITERIA NOT SATISFIED	COMMENTS	SCREENING RESULTS
3. Wildlife Production and Hunting	. topsoil required for extensive natural planting; minimum depth 1.2 m under reforested area . strictly controlled and regulated access . municipal policies which allow firearms discharge . clubhouse, game management facilities, pens . varied topography and cover . control of soil gas and contaminants . supplemental food	Criteria 1,5,7, and 10	. problems with limited area to sustain natural populations of wildlife . conflicts with public use of surrounding open space and Bruce Trail . potential conflict with ESA No. 4. . safety and public acceptability concerns . conflict with City policy on routing south of Hwy. 5.	eliminated
ii) <u>Passive Recreation</u>				
1. Trails - hike and ski	. topsoil suitable for extensive natural plantings; minimum depth for reforested areas 1.2 m; for field areas 0.5 m . variety of topography and vegetation . control of soil gas and contaminants	none	. winter recreation may be constrained by difficulty of maintaining natural snow on slopes . potential exists with all recreation after-uses for trespass in private land, ESA; all terrain vehicles	retained

TABLE 2 - (Con't)

AFTER-USE	REQUIREMENTS	CRITERIA NOT SATISFIED	COMMENTS	SCREENING RESULTS
2. Interpretive Trails and Outdoor Education; Viewing Areas	. minimum area for trail distances of 1-2 km 2-5 km, 5-10 km . adequate provision of snow cover retention and wind protection in winter . parking facilities for 30 cars . shelter for inclement weather . topsoil suitable for extensive plantings over landfill areas; minimum depth 1.2 m for trees, 0.5 m for field . varied topography and vegetation . interpretive features . vistas for viewing . built facilities for gathering, orientation, administration and maintenance . potable water, services . parking for 50 cars . interpretive trails	none	passive recreational after-uses are generally mutually compatible and mutually supportive with outdoor education. major additional requirement is the need to plan for interpretive features	retained

TABLE 2 (Con't)

AFTER-USE	REQUIREMENTS	CRITERIA NOT SATISFIED	COMMENTS	SCREENING RESULTS
3. Picnic Areas	. open field areas of 2-5 ha . washrooms, shelters, potable water . topsoil suitable for fields with scattered trees and shrubs . parking for 50 cars . varied topography and vegetation	none	. generally summer use only; would be integrated with other passive activities for all seasons	retained
iii <u>Active Recreation</u>				
1. Sport Fields	. large, flat, well drained open areas, minimum 2-5 ha . parking facilities, 30 cars minimum . spectator viewing and change facilities (preferred) . fields require good depth of topsoil, good sod base (0.5 m topsoil minimum) . controlled access, fencing . lighting (preferred)	Criteria 3, 9	. major concern is the terrain . potential problem with demand for these types of facility at the location of Site F. (playing fields located in other areas of the municipality) . potential problem of constructing structures on or near landfilled area	eliminated

TABLE 2 - (Con't)

AFTER-USE	REQUIREMENTS	CRITERIA NOT SATISFIED	COMMENTS	SCREENING RESULTS
2. Equestrian Facilities	. flat, well drained area for ring, showing, viewing and holding facilities - minimum area approximately 3 ha . parking facilities, 30 car minimum plus trailer storage . controlled access . trails of 3 m width and varying length over safe terrain . trail slopes not exceeding 15%	Criteria 3,9	. the acceptability of this after-use depends on the status of Bayview Horse Ring - no need for two facilities . terrain (steep slopes) would be a constraint to trails . potential construction difficulties for viewing and holding facilities on or near landfilled area.	eliminated
3. Archery, Skeet	. strictly controlled and regulated access/activity . several flat, well drained open areas of 2-3 ha area each (eg. 6 ha total) . fenced buffer areas for safety . compliance with municipal by-laws on firearms and discharge of weapons . parking	Criteria 7, 10	. conflict with City policies on discharge of firearms . conflict with public use of surrounding open space and the Bruce Trail	eliminated

TABLE 2 - (Con't)

AFTER-USE	REQUIREMENTS	CRITERIA NOT SATISFIED	COMMENTS	SCREENING RESULTS
4. Garden Plots	. flat to gently rolling well drained topography (area varies) . minimum 1.2 m soil cover plus topsoil of high quality . parking . proximity to user demand . controlled fenced access . potable water supply	Criteria 2, 10	. garden plots have been identified by Burlington staff as a suitable after use, however, the location may not attract sufficient users . potential problem with public acceptance of garden produce grown on a rehabilitated landfill	eliminated
5. Golf Course	. minimum area of 45 ha (18 holes) on flat-rolling terrain . relatively flat terrain not exceeding 10-15% slopes in active area; to 20% slopes between fairways . potable water for irrigation of greens . parking for 200-300 cars (approx. 1 ha) . built facilities for clubhouse, maintenance, washrooms, retail space . topsoil: 1.2 m maximum on greens and planted areas; 0.5 m on fairways	Criteria 1, 3, 9	. limited useable area on Site F for standard golf course layout . possible difficulties with construction and location of support facilities, servicing	eliminated

TABLE 2 - (Con't)

AFTER-USE	REQUIREMENTS	CRITERIA NOT SATISFIED	COMMENTS	SCREENING RESULTS
6. Camping	. tree cover, extensive planting . controlled access (fence) . no differential subsidence, no leachate springs . MOE requirements for watermain and sewer services . flat to rolling terrain for 10-12 ha. Slopes not to exceed 6% . parking for 30 cars . build facilities (washrooms, retail, showers, laundry) . services . controlled access . services (electric, water, possible sanitary)	Criteria 3, 9	. possible impact on ESA No. 4 or surrounding natural areas . site location may be of limited potential to sustain viable level of use	eliminated

TABLE 2 - (Con't)

AFTER-USE	REQUIREMENTS	CRITERIA NOT SATISFIED	COMMENTS	SCREENING RESULTS
7. Botanical Garden/ Arboretum/Museum	. topsoil of 1.2m minimum depth cover . large area irrigation . built facilities (greenhouses, maintenance, retail administration) . parking for 300 cars, buses . services (electric, water, sanitary) . flat to gently rolling land	criteria 3,6,9	. terrain suitable for beds and public viewing would be a problem on Site F. . possible competition with Royal Botanical Gardens; uncertain demand for facility . Museum currently undergoing site selection study	eliminated
iv) <u>Agriculture</u>	. minimum of 1.5 m of soil cover over surface . final contours with no greater than 5% slopes . control of soil contaminants and gas	criteria 3,4	. Agricultural Rehabilitation Report rejects agriculture as an option for Site F because of lack of soil, cost/benefit assumptions and location	eliminated
v) <u>Commercial/ Industrial</u>	. construction of greenhouse structure (est. 1000 m²) on stable flat area . parking for 30 cars plus truck access/loading facilities . management, maintenance and service facilities . flat outdoor storage area	criteria 8,9	. unresolved demand for these facilities at this location . construction over refuse problematical . greenhouses would not occupy entire site therefore they would have to be integrated with other uses . possible after-use in the long term depending on demand for facilities	eliminated

TABLE 2 - (Con't)

AFTER-USE	REQUIREMENTS	CRITERIA NOT SATISFIED	COMMENTS	SCREENING RESULTS
2. Horticultural Production Area/Nursery	. full services . controlled access . possible integration with methane collection system for fuel . parking for 30 cars plus truck access/loading facilities . maintenance and service facilities - . irrigation . flat outdoor storage area . full services . controlled access . minimum of 1.5 m soil cover over refuse . final surface contained to 1-5% slopes . control of soil contaminants and gas	criteria 3,4	. the problem of terrain, soil availability and the potential difficulties of maintaining production of economic crops on difficult soils (gas and moisture) precludes this option	eliminated

TABLE 2 - (Concluded)

AFTER-USE	REQUIREMENTS	CRITERIA NOT SATISFIED	COMMENTS	SCREENING RESULTS
3. Open Storage/ Parking Areas	. relatively flat well drained area with maximum 1-5% slopes . strict control on differentiable subsidence . controlled and regulated access (fenced security) . area for storage and parking variable according to demand (eg. 5-25 ha) . proximity to industrial/commercial users.	criteria 3,9	. the location of Site F and the unresolved demand for materials stage precludes this use . after use constrained by need for flat terrain	eliminated

Category After-Use

iv) Agriculture (none)

v) Commercial/
industrial (none)

The results of screening reflect the preferences of the Phase 2 Stage 2c Environmental Assessment regarding after-use for Site F. Passive recreation, public open space and conservation activities were generally preferred. The major limitations of the site - its steep terrain, lack of topsoil and location, balanced with the opportunities afforded by the proximity of forested open space, parks, and the Niagara Escarpment-Bruce Trail were ~~the~~ major determinants of after-use options. Q

The after-use options requiring more site development such as greenhouses, a museum, and a golf course were screened out because they required an investment of resources that could not be resolved at the "concept level" of investigation. Here, the approach was conservative - as there were a number of less problematical and more appropriate alternatives to draw upon. In the long term, active recreation, commercial/industrial uses could be

built, once demand and investment scenarios are established. Passive recreation and conservation after-uses allow considerable flexibility in planning for possible sequential use of the Site. There is also opportunity to plan different passive recreation activities to include activities in the buffer area or, with some active recreation options.

5.2 Concept Evaluation

Comparative evaluation involved an assessment of each of the after-use options retained from screening in terms of its relative strengths and weaknesses.

Specific criteria were not formulated for this stage of evaluation, rather, each option was assessed on relative terms on how it fulfilled the opportunities of the site and the general objectives of:

- . maintaining compatibility with the surrounding landscape
- . minimizing environmental disruption and protecting resources
- . satisfying expressed public and municipal preferences
- . maintaining planning and design flexibility

- . producing an appropriate public benefit.

Each of these objectives for after-use is self explanatory. They were interpreted within the context of the need to produce a publically acceptable, appropriate means of long term use of the landfill after closure.

5.2.1 Natural Area Concept

The natural area concept is to restore Site F to self-maintaining, essentially natural ecosystems that are representative of the later stages of plant succession in the area. The concept involves extensive reforestation of native, primarily indigenous species of trees and shrubs, using where possible existing vegetation on site.

This after-use will be highly compatible with the surrounding landscape (eg. ESA No. 4, rehabilitated Regional Landfill, existing forest and hedgerow vegetation); it represents minimal environmental disruption. The biological resources of the area will be provided with the greatest amount of protection with this option. Planning flexibility in terms of future land-use and multiple use is good at least until the vegetation has reached a higher

stage of maturity (estimated at 50 years after establishment). There is opportunity for staged planting and some concurrent use.

The weaknesses of this concept concern the large amounts of soil required, availability of suitable native plant material for reforestation and the need to strictly control gas and leachate contamination of the soil.

NB

5.2.2 Buffer Area Concept

The buffer area concept is to provide a screen of woody vegetation in association with field and shrub areas to buffer the Sassafrass Woods ESA and abutting private land. The program for establishing a buffer area is similar to the natural area concept. It differs in its need for less topsoil, and fewer trees. The plant material would not necessarily be restricted to indigenous species.

The buffer area after-use would be compatible with the surrounding landscape; environmental disruption would be minimal and the concept is generally consistent with expressed preferences. Planning flexibility in terms of future land-use and multiple use is very good. There may be potential to

integrate passive recreation activities that do not encourage access to the ESA or private lands.

Natural resources, such as rare plants, uncommon plant communities or wildlife is not as well protected as with the natural area concept.

5.2.3 Hiking and Ski Trails

Hiking and ski trails refer to summer and winter unsupervised trail use along established routes and across open space. It is anticipated that trails will be linked to the Bruce Trail and to public lands in the vicinity of the site. The trails, for general walking, jogging, viewing, cross country skiing or snowshoeing will be planned through various cover types: old field, shrub and hedgerows, and reforested land on the site.

The character of the vegetation and topography will be compatible with the surrounding land-use. Environmental disruption should be minimal although heavy use may result in potential disturbance to local wildlife and the possibility of erosion and soil compaction in trail areas.

Biological resources may not be as well protected as with the natural area concept as there is no specific requirement to maintain a habitat type or protect rare plants. Species selected for reforestation may not be representative of existing biologically important communities (eg. the Oak-Hickory complex). This after-use is compatible with municipal preferences although there is potential for disturbance of the ESA if visitors leave the trail system. Public benefit will be primarily achieved through recreation use.

5.2.4 Interpretive Trails, Outdoor Education and Viewing

These activities can be combined with the hiking and ski trails discussed above or with the following picnic area after-use concept. The major features which distinguish these activities from the other passive recreation after-uses are the need to incorporate educational features, viewing areas and provide more organized trail design. The vegetation of the site will consist of a variety of cover types with areas designed to feature unique plants, attract wildlife or demonstrate natural phenomena.

These after-use activities are compatible with the local landscape and generally compatible with other uses in the area. They have an obvious public benefit; there is fairly good planning flexibility.

Biological resources in ESA No. 4 may be subject to disturbance if the volume of site users is heavy. The major draw back of this after-use is the time required to establish suitable educational features. Heavy use may result in inconvenience to the local residents.

5.2.5 Picnic Areas

Picnic areas are similar in character to the preceding after-uses and will probably be included in most passive recreation concepts for after-use. The major difference between picnic areas and other uses occurs in the degree of site development. The site will exhibit greater field and open vegetation. Water for drinking, refuse pick-up, sanitary services and first aid facilities will be required along with internal access roads. The volume of use will be higher than the other concepts in this category.

The major disadvantages are the increased local disturbance; additional traffic and the need for more site development and maintenance.

This after-use will be less compatible with the other land uses in the area; environmental disruption will be greater.

5.3 Results of Concept Evaluation

The recommended after-use concept for Site F is the natural area concept. It has several advantages over other concepts.

By incorporating the existing natural vegetation where feasible, greater protection of the uncommon plant communities and rare flora is more probable than with the other areas. The natural area offers the best opportunity for flexible planning. Other concepts have less stringent requirements for reforestation and involve a larger amount of site development.

The natural area after-use is completely compatible with the landscapes that exist now and that are planned for the currently operating landfill. The potential for inconvenience to surrounding residents

is the lowest of all the after-use concepts considered.

Finally, opportunities exist for sequential use as the vegetation becomes established and develops. Long term public benefit is served by the protection of resources and the provision of local open space.

6.0 Description of After-Use Design Concept

The attached plan (Fig. 2) illustrates the conceptual design of this after-use. The major features of this concept are discussed below.

6.1 Revegetation of the Landfill

The proposed concept involves a large amount of revegetation of the landfill with trees and shrubs. Site F is currently covered with a mixture of vegetation communities including woodland, scrub, wet graminoid meadows and a plantation. It is not feasible to re-establish the wet meadows on the landfill owing to the necessity of restricting water penetration through the cap. Also in view of the objective of re-establishing "natural" vegetation, plantations would not be considered.

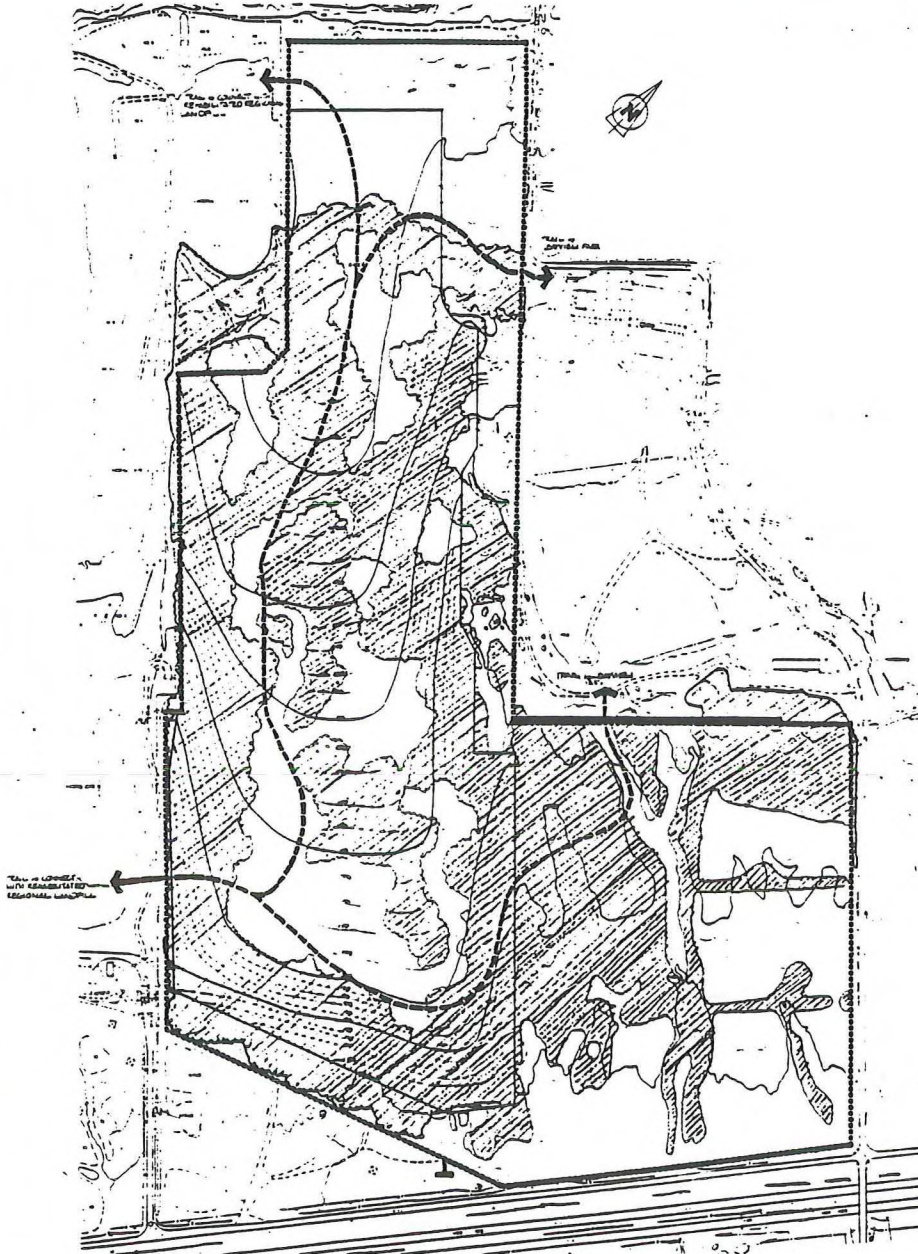
The re-vegetation concept will mainly involve the establishment of woodland vegetation. Shrub areas in the after-use plan would utilize those species now found in shrub vegetation units. Woodland units will ideally be composed of Red Oak, White Oak, Sugar Maple, Shagbark Hickory, and White Ash. These are the species listed as dominants by Proctor and

THE REGIONAL MUNICIPALITY OF HALTON

AFTER USE CONCEPT Site F Map 2

LEGEND

- LANDS OF SITE
- TRUCK DRAG SERVICE AREA
- VEGETATION WOODLOT



NOTE: WOODLOT INFORMATION
OBTAINED FROM WILSON WRIGHT
YOUNG ASSOCIATES LIMITED



The Canadian Collaborative Ltd.	
3111 Woodworth Street Guelph, Ontario N1H 1A6 714 422-1111	
DATE: OCT 1988	
BY: [Signature]	
SCALE: 1:2000	
PROJECT: 0-18	
DRAWN BY: GARDIN	

Redfern (1982) for Site F. Constraints may be imposed on the use of some of these species owing to their deep rooted habit. The total 2m of cover (cap and topsoil) is essential to accommodate after establishment of trees in certain areas of the site. MB

Much research has been carried out by Flower and his colleagues at Rutgers University in New Jersey on the effects of landfill vegetation, and how landfills can be designed to accommodate after-use planting. They have conducted research at both a practical level by determining the response of 19 woody species to planting on landfills, to more detailed work on the response of specific species to noxious gases and the way in which plant growth is inhibited. Their major findings have been supported by other reports (Van Heuit 1979, op. cit. Harris, 1983, MacKenzie 1985).

There are several characteristics of landfills which create problems for establishing vegetation. By far the most important problem is the production of gases, notably methane (CH_4) and carbon dioxide (CO_2), from the decomposing refuse. These gases displace free oxygen (O_2) in the root zone with resulting deleterious effects on plant growth. In

addition, CO_2 is toxic to the roots and inhibits their survival. The other two problems related to landfills are; soil compaction from using heavy machinery on the final cover and nutrient-poor soils being used for final grading.

The latter two problems can be overcome. Soil nutrients can be provided by either securing high grade topsoil for final grading or amending the soil cover with organic matter and nutrients. Soil quality can, and should, be tested over the whole site prior to any planting. Soil compaction can be alleviated to an acceptable extent by avoiding heavy use of machinery for final grading, the addition of soil amendments, and breaking up of subsoil prior to planting.

The problem of migrating landfill gases is more difficult to deal with but a few minimum precautions will maximize plant survivorship. Most important is the establishment of a satisfactory depth of topsoil over the clay cap. Gilman et al. (1983) recommend a minimum of 90 cm of good soil cover for acceptable growth of woody plants. The top 20 cm of this should be topsoil to accommodate fine feeder roots. Other landfills where revegetation has been attempted have had more than 90 cm of topsoil. The

Southside Landfill in Edmonton, Alberta, for example, has two metres of cover in areas designated for trees and shrubs. By the time the landfill was completed a cover of four metres was actually achieved in every place (MacKenzie 1985). Flower and his co-workers have examined landfills with cover depths as great as six metres (Flower et al. 1981).

Plant survival can also be enhanced by insulating the root zones of individual plants or clumps of plants from the gases. Several similar methods for doing this have been suggested. A pit is excavated up to 1.2 m below ground level (thus often penetrating the clay cap). The bottom of the pit is lined with 30 cm of clay, or alternatively road gravel is used combined with four or six mm plastic sheeting. Four inch diameter vent stacks run up either side of the pit to relieve gas accumulation beneath the bottom liner. The remainder of the pit is filled with good quality soil. Some schemes also incorporate a drain and trap to allow water to drain from the "enclosure" without landfill gases entering.

Species should be selected with biological characteristics that make them less susceptible to

landfill gases.

A difficulty with this approach is that very few species have been rigorously tested to determine their suitability for landfill vegetation. Also, there are often other restrictions on species selection. For instance, site conditions (eg. low soil moisture, climate) may preclude some species regardless of their tolerance to anaerobic conditions. There may also be other constraints such as the desire to restrict the introduction of exotic species and produce a landscape design that is compatible with the existing Regional Landfill.

Based on the literature survey and discussions with practitioners in the field in view of the costs associated with isolating root systems with lined pits, it is recommended that the site be covered with sufficient topsoil to support woody growth. A minimum of approximately 1.5 m of soil cover with at least 30 cm of topsoil (A/Ap horizon material) should be used. Some areas will require less soil cover. Deep rooted species may require 2 m of cover over refuse or special methods such as gas venting or insulation to ensure growth. Q.

6.2 Description of After-use

Site F has been designed to re-establish natural vegetation and may include access through the site in the form of trails. The concept has incorporated the preservation of portions of the Oak-Hickory complex. As well, the plan stresses buffer planting along all boundaries particularly the north (adjacent to ESA) and east side (adjoining Bayview Park). Planting has been placed to encourage quick cover of the site, and provide a maximum of screening. (Map 2).

The trail system proposed connects with the rehabilitation of the existing Regional landfill site and connections to Bayview Park and King Road linking up to the Bruce Trail and Niagara Escarpment.

① Rehabilitation would be staged throughout the site as each phase is completed. Buffer screens along the edge should be completed first. It is assumed the service area would provide the future entrance and parking to the site. The service road for the existing Regional Landfill will be used for the proposed landfill at Site F.

7.0 Conclusions

The most appropriate after-use for the proposed Regional Landfill at Site F is revegetation to reflect the natural forests that are characteristic of the Site and the area. A trail linkage to integrate the site with the surrounding public open space and the Bruce Trail has been included. The major advantages of this concept are:

- . it is highly compatible with the local landscape
- . it takes advantage of the presence of local public open space visually and with trail linkage
- . it is generally consistent with local public and municipal preferences
- . it allows for flexibility in long-range planning through multiple use, sequential use and incorporation of new technical knowledge on landfill revegetation as staged rehabilitation occurs
- . it maximizes the protection of important

biological resources, wildlife habitat

- . there will be minimal environmental impact on site surrounding features

7.1 Comparison with Phase 2, Stage 2C Study

The recommended after-use concept is consistent with the analysis and recommendations of the Phase 2, Stage 2C Reports.

The thrust of the Stage 2C study was to support generally passive after-uses for Site F. These included activities that were recreational in an open space context, revegetation to native tree species, some active recreation activities: picnicking, garden plots and campgrounds. In addition there was a preliminary proposal by the curator of the Halton Regional Museum in a report to Regional Council to consider locating the new site for the Museum in association with the landfill. This after-use proposal and the other suggestions for active recreational after-use concepts were screened from further consideration in our evaluation process. It should be noted, however, that the site planning flexibility inherent in the

recommended concept allows consideration of possible joint use of the site. In the long term some active recreation may be appropriate for the Site if the policies of the local and regional municipalities support it.

The Phase 2, Stage 2C study recommended that no built structures or servicing occur on the active land filled area.

For Site F the agricultural rehabilitation option was not considered appropriate (see Appendix).

8.0 Recommended Mitigative Measures

A series of guidelines for implementing the after-use concept on Site F follows. General guidelines for mitigation will be augmented and expanded once the detailed design for the recommended after-use is undertaken.

8.1 Guidelines for Mitigation

- . Use native plant material indigenous to the region wherever possible for screening and revegetation of the landfill
- . Preserve and incorporate as much of the existing material vegetation on site as possible
- . Undertake staged reclamation and revegetation of the site as landfilling progresses
- . Establish perimeter screenings of vegetation as soon as possible once the Site is confirmed. Vegetation screens should be established before construction begins

- . Shape final contours to reflect the terrain character of the surrounding landscape; 'tie' contours into abutting land to reflect continuity of landform and grade
- . Establish perimeter and entrance control of access to prevent disturbance by off-road and all-terrain vehicles
- . Control the movement of construction machinery and vehicles to designated travel areas to ensure minimal impact on preserved vegetation.
- . Establish effective erosion control practices on disturbed soils and rehabilitated areas
- . Conserve all topsoil; salvage indigenous plant material for reclamation where appropriate
- . Protect Indian Creek and other surface water features from significant siltation and changes in water quality.

- . Establish an appropriate site monitoring program to monitor and evaluate site soils, plant material and potential disturbance to off-site environment.
- . Control the use and ensure safe disposal of potential soil and water pollutants on site; do not use herbicides, dust control chemicals.

9.0 References

Barman Coulter Swallow, Associates, 1985. Final Technical Report No. 9. Phase 2, Stage 2C. Selection of Preferred Site, Noise Assessment. Regional Municipality of Halton.

Bird and Hale Ltd., 1985. Final Technical Report. No. 2, Phase 2, Stage 2C, Selection of Preferred Site, Biophysical Assessment. Regional Municipality of Halton.

Ecological Services for Planning, 1985. Final Technical Report No. 4, Phase 2, Stage 2C, Agricultural Assessment. Regional Municipality of Halton.

Ecological Services for Planning, 1985. Preliminary site design requirements for rehabilitation to an arable agricultural after-use memorandum.

Ecological Services for Planning 1986. Halton Regional Landfill Technical Study, Agricultural Impact and Rehabilitation Report.

Flower, F. B., Ida Leone, E. F. Gilman, and John Arthur, 1977. Vegetation Kills in Landfill Environs. 3rd Ann. Municipal Solid Waste Res. Symposium - Proceedings, St. Louis, Missouri.

Flower, F. B., Edward Gilman and Ida Leone, 1981. Landfill Gas, what it does to trees and how its injurious effects may be prevented. Jour. Arb. 8(2): 43-52.

Gilman, E. F., Franklin Flower, and Ida Leone, 1983. Standardized Procedures for Planting Vegetation on Completed Sanitary Landfills. (EPA -600/82-83-055). Municipal Env. Res. Lab. - Project Summary. 4 p.

Harris, D. W. ca. 1983. Arboriculture, Care of Trees, Shrubs, and Vines in the Landscape. Prentice Hall Inc., New Jersey.

Hydrology Consultants of Trow Limited, 1985. Landfill EPA Studies (letter report). August 14, 1985.

MacKenzie, D. C. 1985. Canadians Convert Landfills for Parks and Recreation. World Wastes. (April issue).

Proctor and Redfern. 1982. Environmental Appraisal. Sanitary Landfill Proposed for the National Sewer Pipe Company, Burlington, Ontario. 95 p.

Senes, 1985. Final Technical Report No. 6, Phase 2, Stage 2C Selection of Preferred Site, Air Quality Assessment. Regional Municipality of Halton.

The Landplan Collaborative Ltd., 1985. Final Technical Report No. 10, Phase 2, Stage 2C, Selection of Preferred Site, Visual Assessment, Regional Municipality of Halton.

Van Heuit, R. E., 1979. Sanitation Districts of Los Angeles County: Generation of Methane Gas in Sanitary Landfills and its effect on Growth of Plant Materials. (Unpublished). Delivered at 1979 meetings of the American Society of Consulting Arborists. (Abstract in Horizontes, 1980, D. C. : Amer. Assoc. Nurserymen, Sept. 1).

**HALTON REGION LANDFILL
TECHNICAL STUDY**

**AGRICULTURAL IMPACT AND
REHABILITATION REPORT**

ECOLOGICAL SERVICES FOR PLANNING LTD.

OUR FILE: GRH03
July, 1986

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APPENDIX

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B	Sample Site Locations
C	Soil Chemical and Physical Analyses

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MAPS

MAP

1	Location Map
2	Site D - Soil Capability for Agriculture
3	Site F - Soil Capability for Agriculture

HALTON REGION LANDFILL TECHNICAL STUDY
AGRICULTURAL IMPACT AND REHABILITATION REPORT

1. SUMMARY AND RECOMMENDATIONS

This study was undertaken to address the following objectives:

- (1) To assess the feasibility of restoring the two proposed candidate landfill sites, D and F, to an agricultural afteruse.
- (2) To develop a detailed agricultural rehabilitation program for restoration of site(s) to an agricultural afteruse.
- (3) To develop a post-rehabilitation land management and monitoring program.

The feasibility of restoring the two proposed candidate landfill sites, D and F, to an agricultural afteruse was assessed by examining surrounding land use, agricultural capability, rehabilitation problems, ongoing post-rehabilitation problems and relative costs of rehabilitation. On the basis of this analysis, it is recommended that Site D be rehabilitated to an agricultural afteruse, whereas Site F should not be rehabilitated for arable agricultural purposes.

The reasons are as follows:

- o Site D is located in an area where the surrounding land use activities are primarily agriculture, whereas land use activities adjacent to Site F are primarily non-agricultural in nature.
- o Site D is located on lands with medium to high soil capability for agriculture, whereas Site F contains lands that are mostly marginal or non-productive for arable agriculture.
- o Adequate topsoil and subsoil materials are available for rehabilitation of Site D to an agricultural afteruse,

whereas large volumes of topsoil and subsoil will have to be imported for Site F. The importation of additional topsoil/subsoil materials will add approximately \$4,890,800 to the cost of rehabilitating Site F as compared to Site D.

A detailed agricultural rehabilitation program has been developed and is presented for Site D. The program consists of a series of fifteen recommendations which address specific aspects of soil stripping and stockpiling, reapplication of soil material, soil restoration, post-rehabilitation land management and post-rehabilitation monitoring.

Implementation of the proposed program will lead to satisfactory rehabilitation of Site D for arable agricultural production.

2.0 BACKGROUND AND STUDY OBJECTIVES

This study was undertaken at the request of the Region of Halton and addresses the agricultural impact and rehabilitation component of the Halton Region Landfill Technical study. The agricultural rehabilitation of a landfill site is a concept involving a land use change, in order to accommodate two separate resource utilization objectives.

Two sites, Site D and Site F, are presently under consideration for a municipal landfill site for the Halton Region. Site D is located southeast of First Line and Britannia Road in the Town of Milton while Site F is located at Highway 403, North Service Road and King Road in the City of Burlington (Map 1).

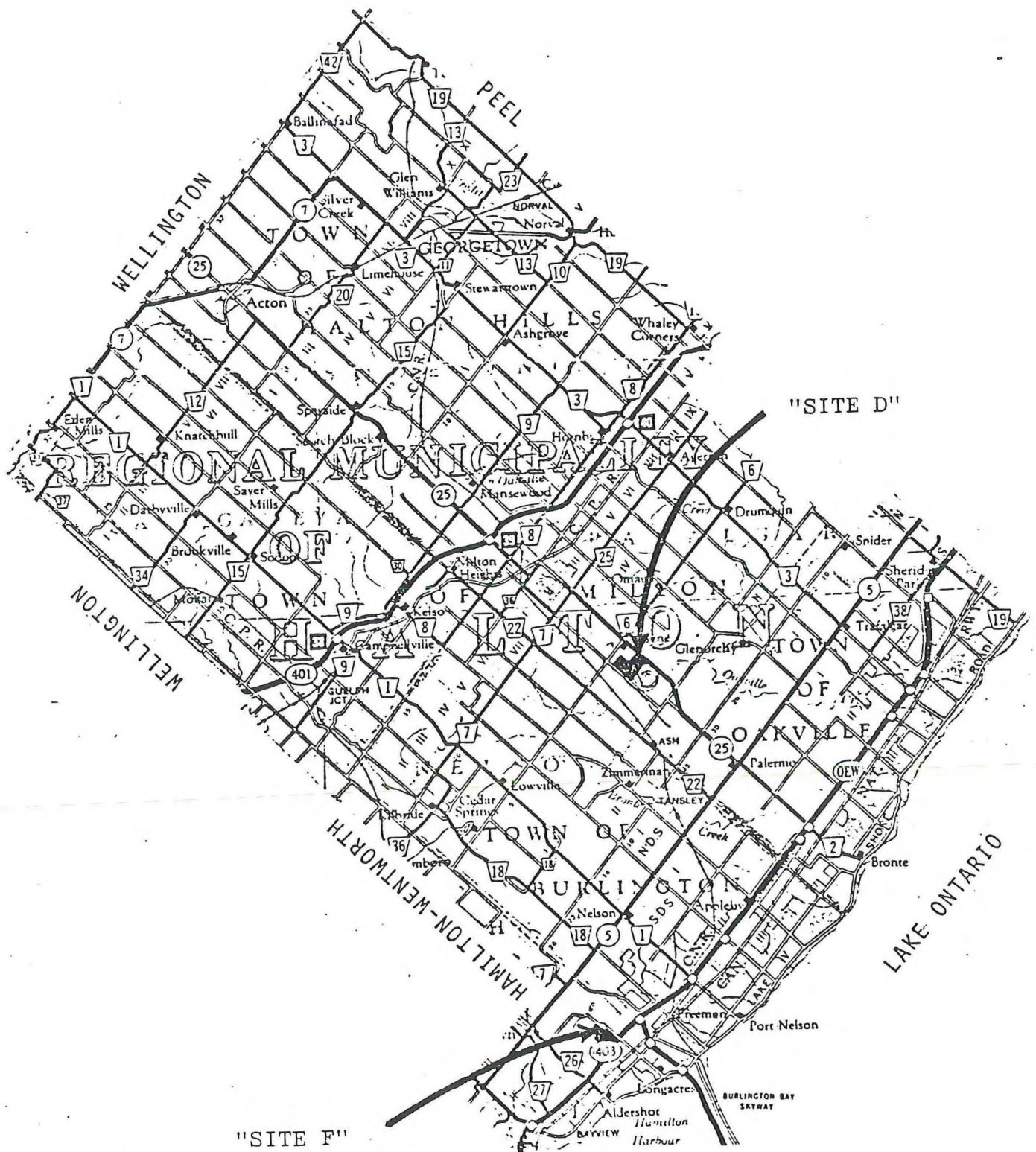
The objectives of this study are as follows:

- (1) To assess the feasibility of restoring the two proposed candidate landfill sites, D and F, to an agricultural afteruse.

The specific objectives are:

- o to examine onsite and surrounding land use and agricultural characteristics;
- o to carry out a detailed analysis of onsite soil conditions and agricultural capability;
- o to examine rehabilitation problems;

Map 1 - LOCATION MAP



scale-1:250,000

- o to examine ongoing post-rehabilitation problems; and,
 - o to examine cost of rehabilitation.
- (2) To develop a detailed agricultural rehabilitation program for restoration of site(s) to an agricultural afteruse.

The specific objectives are to address:

- o overburden removal;
 - o soil stripping and stockpiling;
 - o reapplication of soil material; and,
 - o soil restoration.
- (3) To develop a post-rehabilitation land management and monitoring program.

3.0 FEASIBILITY OF RESTORING SITES D AND F TO AN AGRICULTURAL AFTERUSE

3.1 Onsite and Surrounding Agricultural Land Use

Site D is situated in an area designated as agriculture in the 1984 Town of Milton Official Plan. Land use activities surrounding Site D are primarily agriculture (Table 3).

The Stage 2C Environmental Assessment report ranked Site D as having a high impact on agriculture.

Site F is situated entirely within the Parkway Belt West. It lies adjacent to the existing Regional landfill site, a closed landfill site (Bayview Park), Highway 403 and a hydro corridor. The urban area of Burlington is located south of Site F, below Highway 403 and an active quarry is in operation just east of the site, adjacent to King Road.

Agricultural activities near Site F occur primarily to the north of the site, immediately above the escarpment face.

The Stage 2C Environmental Assessment report ranked Site F as having a low impact on agriculture.

3.2 Soil Inventory and Agricultural Capability

3.2.1 Site D

The soils on Site D have developed in a slightly stony, fine textured glacial till. They consist of two soil series, the Chinguacousy and Jeddo, which differ in morphology and are the imperfectly drained and poorly drained members of the catena, respectively. These soils are described by Gillespie et al, 1970, The Soils of Halton County.

Soils of the Chinguacousy Series are imperfectly drained and occur primarily on undulating topography in this area. These soils have a 20 to 30 cm very dark, greyish brown, clay loam surface A horizon overlying a mottled brown, clay B horizon which is 20 to 25 cm thick. The soil parent material (C horizon) is a mottled grey, clay loam till.

Soils of the Jeddo Series are poorly drained and occur primarily on nearly level topography within Site D. These soils contain an A horizon which is 15 to 25 cm thick, dark brown in colour and clay loam in texture. The B horizon is a mottled, dark greyish brown, and is 20 cm thick. The soil parent material is a mottled grey, clay loam till.

The Chinguacousy soils are rated as CLI Class 1 while the Jeddo soils are rated as CLI Class 3 for agriculture due to low permeability and wetness limitations.

The Soil Series and slope categories form the basis for the site map of Soil Capability for Agriculture (Map 2). Using a planimeter, the relative occurrence of the soil capability classes was calculated (Table 1). Class 1 and 3 soils are almost equally represented within Site D. Class 1 soils occupy the slightly undulating areas while Class 3 soils are found in the depressional areas.

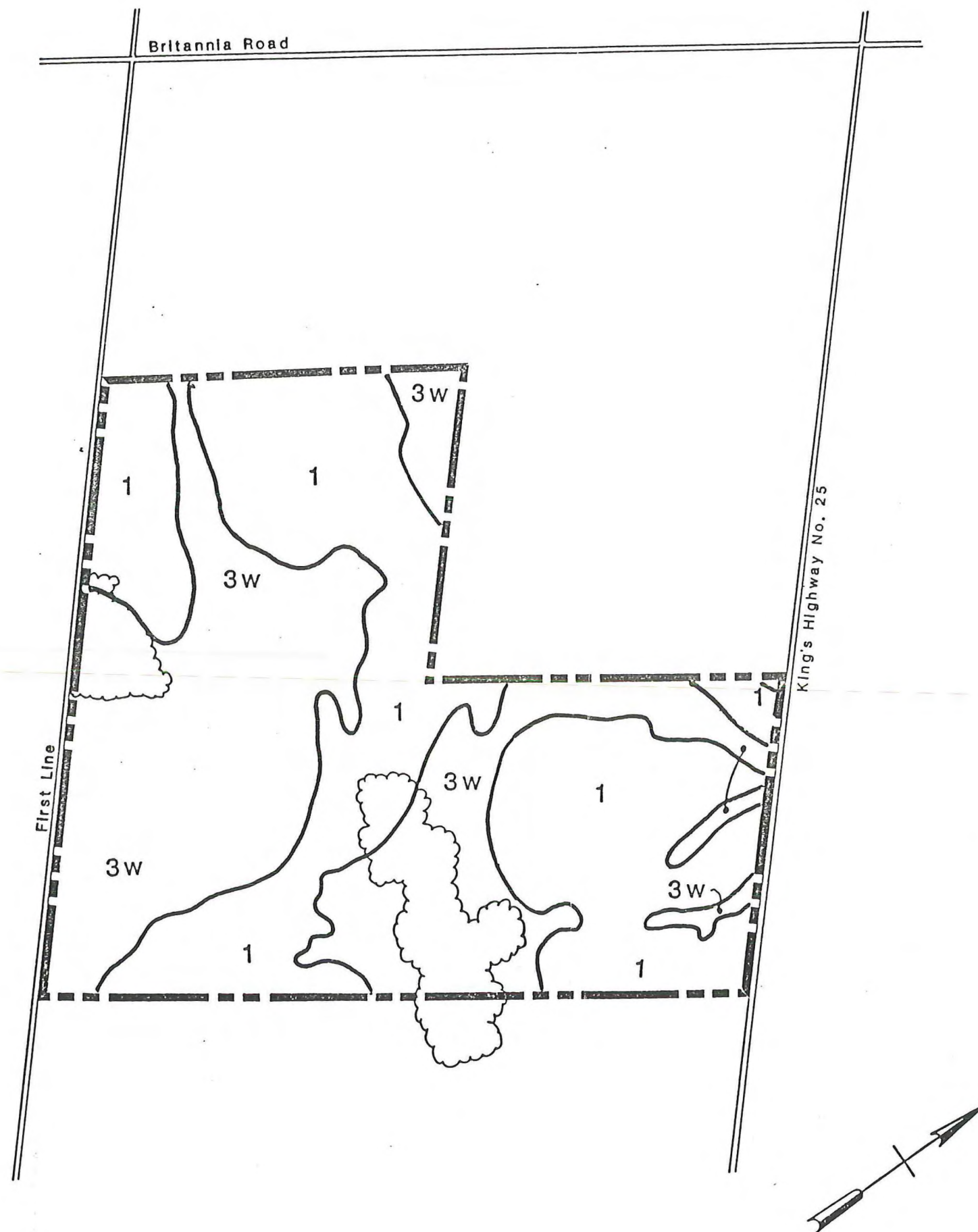
3.2.2 Site F

The soils on Site F have developed in slightly stony, fine textured,

TABLE 1: PERCENTAGE OCCURRENCE OF AGRICULTURE
CAPABILITY CLASSES - SITES D AND F*

Capability Class	SITE D		SITE F	
	Area (ha)	Per Cent	Area (ha)	Per Cent
1	71.2	51	---	---
2	---	---	17.8	19
3	68.4	49	---	---
4	---	---	23.5	25
7	---	---	52.5	56
TOTAL	139.6	100	93.8	100

* as per Maps 2 and 3, respectively



LEGEND

 site plan area
 wooded

capability class → 3w ← capability subclass

CAPABILITY SUBCLASS	LIMITATION TYPE
w	excess water

scale - 1:10,000

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Halton Region Landfill
Technical Study

SITE D - SOIL SAMPLE POINTS
SOIL CAPABILITY
FOR AGRICULTURE



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MAP NO.
2

glacial till. Bedrock, consisting of reddish Queenston shale, outcrops at the surface in steeply sloping areas. Elsewhere onsite, bedrock is generally found within 10 meters or less of the soil surface.

Only one Soil Series, the moderately well drained Oneida Series, is found on Site F. The Oneida soils are moderately well drained and occur on very gently to very strongly sloping, complex topography. These soils normally have a 15 to 20 cm thick, dark brown, loam to clay loam surface A horizon overlying a 40 to 45 cm thick, brown to reddish brown, clay loam B horizon. The C horizon is a slightly stony, dark brown to dark yellowish brown, clay loam till.

Oneida soils are high in natural fertility, and are rated as CLI Class 1 for agriculture where slopes are not a limiting factor. In the southern part of the Site F lands, just north of the Ontario Hydro corridor, Oneida soils are found on moderate sloping complex topography. They do not appear to be severely eroded and have been rated CLI Class 4. In the extreme northern part and in the southeast corner of Site F, Oneida soils have developed on very gently sloping topography and are rated as CLI Class 2. Within Site F, there is a significant area of highly eroded soils which occur primarily on very strong sloping, complex topography. The soils found on these slopes are rated as CLI Class 7 due to topography and erosion limitations.

The Soil Series and slope categories form the basis for the soil capability for agriculture ratings (Map 3). The relative occurrence

North Service Road
Hwy. 403



LEGEND

site plan area
wooded

capability class 7te capability subclass

CAPABILITY SUBCLASS	LIMITATION TYPE
t	topography
e	erosion damage

scale - 1:10,000

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Technical Study

SITE F - SOIL SAMPLE POINTS
SOIL CAPABILITY
FOR AGRICULTURE



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MAP NO.
3

of the soil capability classes was calculated with a planimeter (Table 1). Site F consists of 56 percent Class 7 soils, 25 percent Class 4 and 19 percent Class 2 lands. Sample points and a more detailed analyses of physical and chemical soil characteristics for Sites D and F are found in Appendix B and C, respectively.

3.3 Rehabilitation Problems

On both sites, replacement of an adequate rooting medium consisting of one meter of topsoil plus B and C horizons overlying 0.5 m of clay cover is recommended for agricultural restoration. Minimum total thickness of the cover materials should be 1.5 m.

Sufficient topsoil and subsoil are available for restoration purposes at Site D (Hydrology Consultants of Trow Limited). A shortage of existing topsoil and subsoil will create major rehabilitation problems at Site F, since large quantities of these materials have to be trucked from off site (Table 2).

Calculations to determine the availability of topsoil and subsoil for rehabilitation purposes on Site F were done using the areas of Class 2 and 4 lands which contain a complete soil profile (Class 7 areas usually lack A and B horizons due to erosion). Since soil is not being stripped from the buffer zones, these areas were subtracted from the area of soils having a complete solum. Table 2 shows the amount of soil material available on Site F which could be used for restoration purposes, and provides a means for estimating the amount of material to be imported to provide 1 m of rooting medium, in addition to the 0.5 m clay cover (Figure 1).

TABLE 2. SOIL COVER REQUIREMENTS FOR REHABILITATION-SITE F

	Ap horizon* <u>(m³ x 1000)</u>	B+C horizon** <u>(m³ x 1000)</u>	Total <u>(m³ x 1000)</u>
Soil required (69.8 ha)	139.6	558.4	698.0
Soil available onsite (27.0 ha - exclusive of buffer zones)	54.0	216.0	270.0
Soil required from offsite	85.6	342.4	428.0

*assume Ap horizon (topsoil) depth-20 cm

**assume B+C horizon depth-80 cm

Natural gas venting will occur along fissures and failure planes in the clay cover at both sites and localized impacts on plant growth can be expected. Further, provision is included in the final design for installation of a gas venting system at Site D, if required.

3.4 Ongoing Post-Rehabilitation Problems

Ongoing post-rehabilitation problems will be similar on both sites. These include differential settlement and regrading for maintenance of surface drainage and farm machinery operations.

Monitoring programs are required on both sites.

3.5 Relative Costs of Rehabilitation

The relative costs of rehabilitation are shown in Table 3. These costs are based on the amount of soil material available for restoration at each site, agricultural subsoiling and negative returns to cropping. Other costs of rehabilitation, e.g. soil grading, fertilization, etc., have not been included since they will be similar for both sites. Table 2 outlines the soil cover requirements while Table 4 itemizes the relative costs for initial land rehabilitation. The cost estimates are based on a minimum rooting zone of 1 m. The 0.5 m clay cover (Figure 1) is not included in the cost estimate. Costs for topsoil/subsoil are excluded at Site D since adequate materials are available onsite.

TABLE 3: FEASIBILITY OF AGRICULTURAL REHABILITATION-
SITES D AND F

CHARACTERISTICS	SITE D	SITE F
<u>1. On-site and Surrounding Agricultural Characteristics</u>		
o Area of Site	139.6 ha	93.8 ha
o Land Quality		
Class 1 and 2	51%	19%
Class 3	49%	--
Class 4	--	25%
Class 7	--	56%
o Depth of Overburden	>15 m	0-1 m in south part increasing to 10 m in north part
o Present surrounding activity	agricul- ture	quarry, active landfill site, closed landfill site, hobby farms
o Surrounding agricultural activity (1981 Census data)		
Number of farms	32	14
Farmed area	1479 ha	233 ha
Number of owner operated farms	17	12
Owner operated farm area	237 ha	175 ha
Farm area rental	932 ha	58 ha
o Road access to site	Hwy. 25; Concession roads	Off Hwy.403 via North Service Road; back entrance from escarpment via King Road
o Agricultural Ranking from Environmental Assessment Report	High agricultural impact	Low agricultural impact

Table 3 (cont'd)

SITE D

SITE F

2. Rehabilitation Problems

- o Site design requirements
Minimum cover over garbage-
1.5 m

Material
available
(CL-SiC)

Material
available (SiCL-
weathered
Queenston shale)

- o 1m topsoil/subsoil over clay
cover to ensure adequate
rooting medium

Topsoil/
subsoil
available on
site

Large quantities
of topsoil/
subsoil required
from off-site

- o Gas venting system

Natural gas
venting
restricted
to failures
in clay
seal; mini-
mizes crop-
ping area
exposed to
injury

Similar to Site D

- o Final surface contoured to
1-5% slopes

Site pres-
ently flat

Present slopes
5-10% up to
20-25% on valley
side slopes

3. Ongoing Post Rehabilitation Problems

- o Subsidence

Ongoing

Ongoing

- o Differential Settlement

Levelling
or grading
required for
drainage and
farm machin-
ery operation

Same as Site D

Table 3 (cont'd)

	SITE D	SITE F
3. <u>Ongoing Post Rehabilitation Problems</u> (cont'd)		
o Monitoring Program for soil chemical and physical properties and crop production	Required	Required
4. <u>Relative Cost of Rehabilitation*</u>		
o Soil replacement:		
Topsoil & Subsoil	----	\$3,077,300
Hauling	----	1,813,500
o Agricultural Subsoiling	\$ 31,500	29,900
o Negative returns to cropping (forage over 25 year period)*	<u>107,200</u>	<u>101,900</u>
	\$138,700	\$5,022,600
o Monitoring program	similar on both sites.	

* See Appendix A for details of cost/benefit analysis related to alternative cropping systems for site rehabilitation.

Table 4: Relative Land Rehabilitation Cost Requirements by Site*

	Site D	Site F
	(1985 dollars)	
Additional Topsoil/Subsoil - 428,000 cu.m. @ \$7.19	**	3,077,300
Topsoil Haulage - 725,417 tonnes @ 5c/tonne/km assuming 50km round trip	**	1,813,500
Agricultural Subsoiling - 72.9ha @ \$432 - 69.3ha @ \$432	31,500	<u>29,900</u>
Total Investment Cost	31,500	4,920,700

* Cost estimate based on a minimum rooting zone of 1 m, exclusive of the 0.5 m clay cover. The cost of spreading topsoil/subsoil is not included in these estimates.

** Adequate topsoil/subsoil available onsite.

Soil replacement costs for Site F will be extremely high and are a major constraint to rehabilitating the landfill site to an agricultural afteruse. A cost/benefit analysis for restoring Sites D and F to an agricultural afteruse is found in Appendix A. The analysis has been developed for three alternative cropping systems.

3.6 Summary

A summary of the characteristics used in assessing the feasibility of rehabilitating Sites D and F to an agricultural afteruse is presented in Table 3. There are several obvious differences between the two sites:

- o Site D is located in an area where the surrounding land use activities are primarily agriculture, whereas land use activities adjacent to Site F are primarily non-agricultural in nature.
- o Site D is located on lands with medium to high soil capability for agriculture, whereas Site F contains lands that are mostly marginal or non-productive for arable agriculture.
- o Availability of soil material for rehabilitation purposes significantly adds to the cost for Site F (Table 4). Relative rehabilitation costs for Site D,

including the cost of subsoiling and negative returns on crops, vary from \$138,300 to \$190,800 (Appendix A) depending on the crop rotation used. Large quantities of topsoil/subsoil suitable for agricultural rehabilitation must be imported for Site F. This increases the costs of rehabilitation to an estimated \$5,022,600 over the 25 year period (Table 3).

Given the foregoing, rehabilitation of Site F to an agricultural after use is not recommended.

4.0 DETAILED AGRICULTURAL REHABILITATION PROGRAM - SITE D

A series of guidelines and recommendations have been formulated to ensure that agricultural rehabilitation of Site D can be achieved. Site F is not considered in this section, since an agricultural after use is not recommended for the site. The guidelines outlined in the following sections describe aspects of soil stripping and stockpiling, reapplication of soil material, soil restoration, post-rehabilitation land management and post-rehabilitation monitoring requirements.

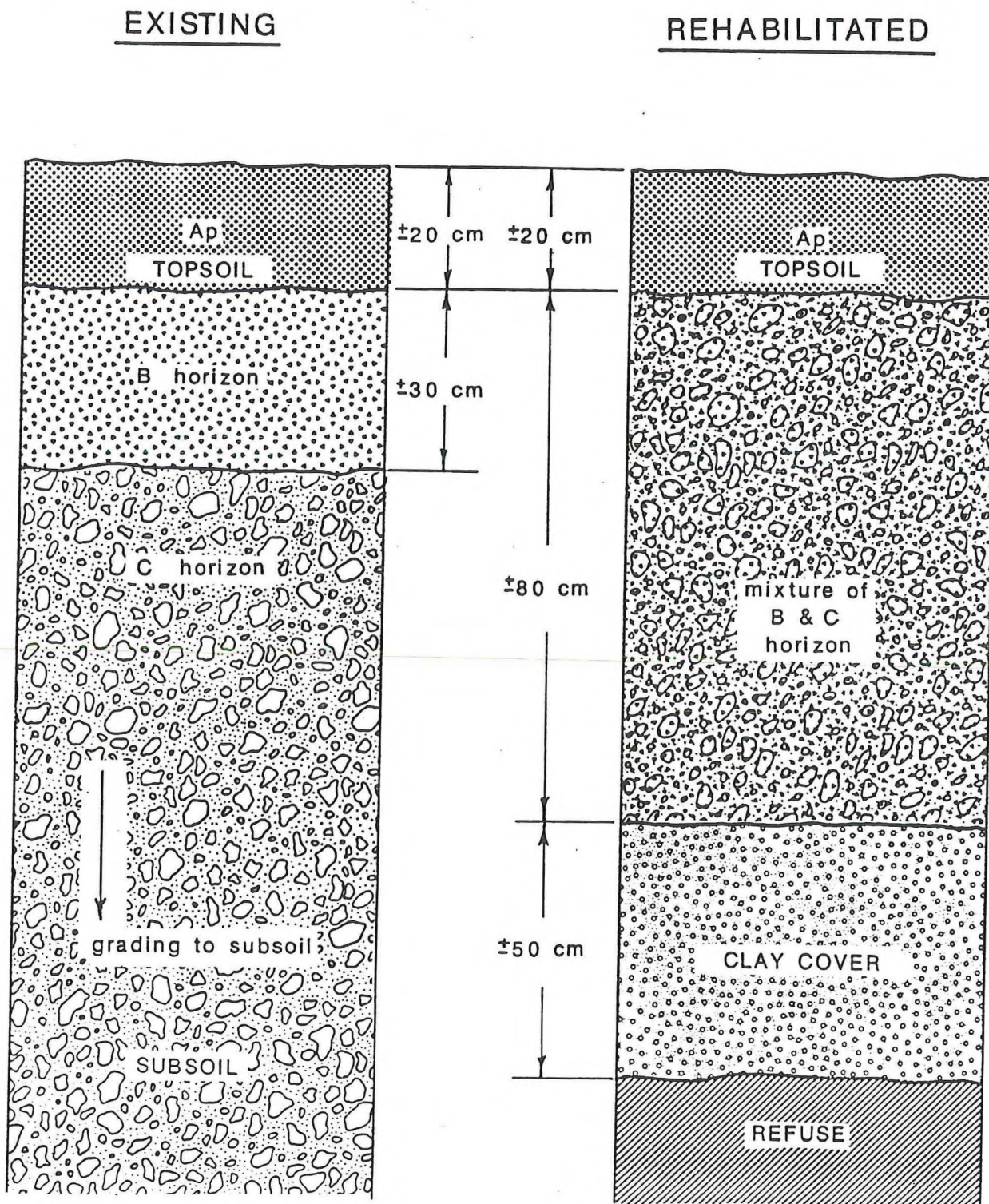
Recommendations developed for each specific section are numbered consecutively.

4.1 Soil Stripping and Stockpiling

A major concern is that sufficient quantities of topsoil and subsoil materials are stockpiled and available for reapplication during the various stages of site rehabilitation.

A minimum of 1.5 m is recommended for reapplication over the final lift of garbage (Figure 1). This should consist of 1 m of rooting medium plus 0.5 m of clay cover. All replacement material is available onsite. The 20 cm of Ap horizon (topsoil) and 80 cm of B plus C horizons should be stripped and stockpiled separately.

Figure 1 - GENERAL DESCRIPTION OF SOIL CONDITIONS
- SITE D



Specific recommendations for stripping and stockpiling include:

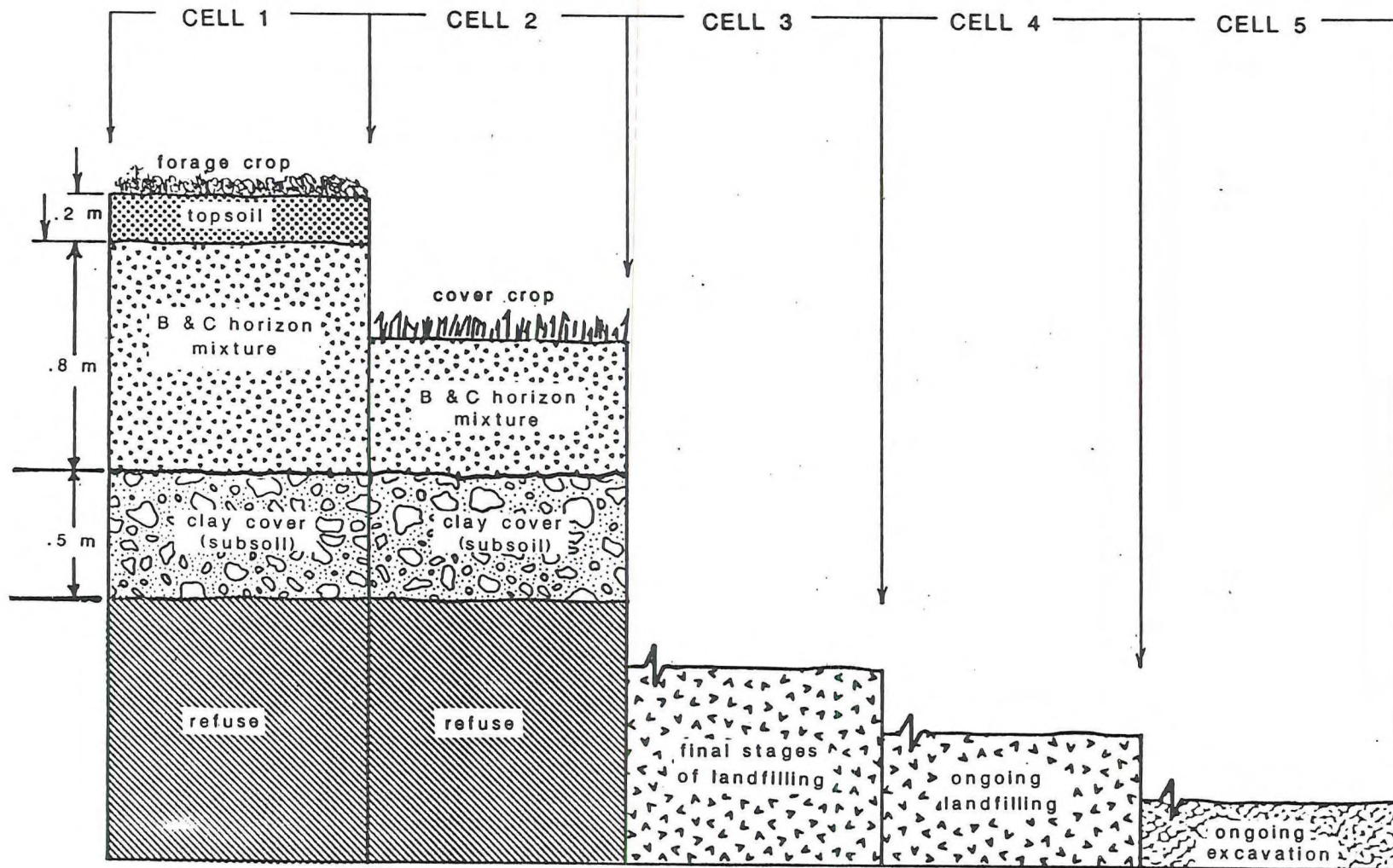
- 1) To avoid erosion and loss of materials, it is preferable that only small areas are stripped and exposed for excavation at any one time as part of an overall progressive rehabilitation program;
- 2) Stripping should be carried out in such a manner so as to ensure separation of the A horizon (topsoil) from the underlying B and C horizons;
- 3) To avoid mixing of topsoil and subsoil, topsoil should be stored in stockpiles separate from other subsoil or overburden materials. Seeding or mulching of all stockpiles should be carried out to avoid loss by soil erosion;
- 4) The initial development works will include construction of a berm. The berm could be covered with topsoil stripped from the first cell and retained for topsoil cover and reapplication on the final cell.

4.2. Reapplication of Soil Material

The degree of soil compaction can be minimized by spreading the clayey subsoil material and the topsoil when the materials are as dry as possible.

The sequence of filling (i.e. cell design), will also reduce the impact of differential settlement on rehabilitation for agricultural purposes. Final design contains 5 cells. As cell 1 is being filled with refuse, cell 2 is being excavated. Thus at the end of 3-5 years, cell 1 can be completed to near final grade with the application of 1 m or more of subsoil. Final application of subsoil and topsoil can follow at a later date, once subsidence is minimized (Figure 2).

Figure 2 - IDEALIZED REHABILITATION SEQUENCE



* minimum depth

Final surface grading should ensure adequate surface drainage without contributing to a soil water erosion hazard. The final grade on top of the landfill should contain slopes 5 percent or less.

The following recommendations refer to reapplication of soil materials:

- (5) Application and spreading of the final 1 m of cover consisting of topsoil and the B+C horizon mixture should be conducted during the dry summer months where possible.
- (6) The final grade on top of the landfill should not exceed approximately 5 percent.

Filling and rehabilitation of the cells will be progressive and final grading and reapplication of topsoil will allow for an adequate period of subsidence.

4.3 Soil Restoration

Following reapplication of topsoil/subsoil onto the clay cover, a program of tillage, organic matter additions and cropping is required to amend soil fertility and soil structure, and to return the site to full agricultural production.

The program outlined in this section is a long term venture designed to achieve several objectives:

- o to ameliorate adverse soil physical and chemical conditions;
- o to allow sufficient time for the cropping program to ameliorate adverse impacts;
- o to allow for effective management of soil erosion and drainage and correction of microrelief associated with differential settlement; and
- o to allow monitoring of progress and adjustments to the program, as required.

4.3.1 Tillage

The main limitations in establishing and maintaining agricultural production on the rehabilitated landfill site will be the physical condition of the soil reapplied to the clay cover (Figure 1).

Spreading the subsoil and topsoil over the clay cover could result in soil bulk densities of 1.6 to 1.9 gm/cm³. Existing onsite bulk densities range from 1.5 - 1.7gm/cm³ in the B and C horizons. Root penetration and growth of corn is progressively reduced at bulk densities greater than 1.4 gm/cm³ and is severely restricted at densities in excess of 1.7 gm/cm³. Good soil structural development in the B and C horizons compensates for root growth at progressively higher bulk densities. However, soil structure will be destroyed during stripping and reapplication procedures. It will be necessary, therefore, to subsoil the compacted layers to promote the development of a good rooting medium.

Subsoiling with an agricultural subsoiler will reduce soil compaction in the surface 60 cm. Shattering of compacted soils by subsoilers is most effective at soil moisture levels below field capacity.

- (7) It is recommended, therefore, that the site should be subsoiled following final grading to a depth of 60 cm during June to September, when the soil moisture levels are at or below field capacity levels.

4.3.2 Soil Structure Development

The natural sequence of soil horizons will be destroyed in the stripping and stockpiling operations. Soil structure is also destroyed, and as a result, the soils will be more susceptible to soil erosion and crusting.

- (8) The application of soil organic matter is, therefore, recommended to improve soil structure and the development of soil fertility.

Livestock manure and/or sewage sludge could be utilized. Application of sludge treatments in the soil restoration program must be carried out in compliance with the "Guidelines For Sewage Sludge Utilization On Agricultural Lands", (Ministries of Agriculture and Food, Environment, and Health, Revised January, 1986). Sufficient quantities of processed sewage sludge may be available from Municipal Water Pollution Control Plants in Halton Region, including the Oakville, Georgetown, Acton and Milton plants.

4.3.3 Interim Cropping

Cell 1 will be filled and brought to near final grade with the application of approximately 1 or more metres of subsoil (Figure 2) 3-5 years after the landfill site is opened. Similarly, cell 2 will be completed in 6-8 years and so on.

- (9) It is recommended, therefore, that as each cell is finished to near final grade, the soil should be cultivated and seeded with a forage and cover crop of oats or rye. The site should be fertilized according to soil test values.

TABLE 5: ALTERNATIVE CROP ROTATIONS FOR AGRICULTURAL
REHABILITATION OF LANDFILL SITE

<u>Year</u>	<u>INTENSIVE</u>		<u>PASSIVE</u>
	<u>Cropping System - 1</u>	<u>Cropping System - 2</u>	<u>Cropping System</u>
1	Red clover/timothy hay	Red Clover/timothy hay	Bird'sfoot Trefoil
2	"	"	"
3	"	"	"
4	"	"	"
5	Corn	Corn	"
6	Corn	Corn	"
7	Barley	Red Clover/timothy hay	"
8	Winter wheat	Red Clover/timothy hay	"
9	Red Clover/timothy hay	Corn	"
10	Red Clover/timothy hay	Corn	"
11 to 25	Repeats sequence of years 5-10	Repeats years 7-10 sequence	"

The forage/legume mixture should be seeded in the spring, if possible. Fall seeding is also suitable, but less desirable. The sod cover can be left until final grading and application of topsoil.

4.3.4 Long Term Cropping

As each cell receives the final reapplication of subsoil and topsoil and is graded, the long term cropping program can be implemented. Alternative cropping sequences which provide an opportunity for both intensive and passive agricultural after-uses have been outlined for a 25 year period (Table 5).

- (10) It is recommended that a forage (legume or legume/grass) crop should be grown on the site for the first 4-5 years following rehabilitation to add organic matter and improve soil structure and fertility. The side slope of the landfill should remain in permanent forage.

Following the initial period of forage production, several alternative crop rotation sequences can be implemented. Those shown in Table 5 are examples and they have been used as the basis for the economic analysis (Appendix A). Corn and coarse grains will be the common cash crops used in these rotations. The forage crop suggested for use in the crop rotations is a red clover/timothy hay mixture. Timothy is generally easy to establish and maintain and will grow under a wide range of environments. It is well adapted to heavier soil types and variably drained fields. Red clover (a

biennial) is useful in rotations to add nitrogen and organic matter to the soil and for breaking insect and disease cycles. A heavily branched rooting system which is usually concentrated in the top 20 cm of soil makes red clover valuable for improvement of soil structure.

4.4 Post Rehabilitation Land Management

The concept of the proposed landfill operation as an interim land use places responsibility on the Region of Halton to ensure successful completion of the proposed soil restoration and associated cropping program at Site D. Options available for management of the restoration program and subsequent agricultural enterprise, must fulfill these long term agricultural use objectives and guarantee against future land abandonment. The options available are also subject to the following constraints:

- o the soil restoration and cropping program covers a minimum time period of 25 years following closure of each stage of landfilling;
- o the first eight years of the proposed cropping program involve the initial phases of tillage and fertilizer adjustment, stringent cropping procedures, regular monitoring of progress and related specialized operations to remediate fertilization, compaction and settlement problems. Implementation is best accomplished by working in conjunction with a local farmer through a leasing or rental agreement;
- o in the first few years of the program, costs will be higher than average, while yields will be below average.

The above factors lead to the following recommendations:

- (11) The Region of Halton should retain ownership of the site, after the period of active landfilling, and for the duration of the 25 year soil restoration and cropping program.
- (12) The Region of Halton should retain the services of a local area farmer to undertake onsite agricultural activities and operations during this period.
- (13) Upon completion of 25 year program, the Region of Halton could consider options for sale of the lands for agricultural purposes or could engage in long term lease agreements with area farmers.

4.5 Post-Rehabilitation Monitoring Program

To ensure the success of the proposed landfill agricultural reclamation project, it will be necessary to monitor and supervise various stages of the program. Various references to monitoring have been made in earlier recommendations concerned with specific aspects of the program. The following recommendations deal with the monitoring and supervisory activities required to ensure successful rehabilitation:

- (14) Supervision of the agricultural rehabilitation program should be carried out under the direction of a qualified pedologist and/or agronomist.
- (15) Onsite supervision during stripping and reapplication of soil should include the following responsibilities, among others:
 - o to advise on stripping depths of A and B soil horizons and ensure maximum volume of topsoil is stripped;
 - o to ensure material reapplication is carried out when materials are as dry as possible and in such a way as to minimize compaction; and

- o to ensure adequate and consistent depths of soil are reapplied over the landfill surface and that grades are consistent with recommended guidelines for proper soil drainage and erosion control.
- (15) Onsite supervision during soil restoration should include the following responsibilities:
- o to assess post rehabilitation (base line) soil compaction and soil fertility;
 - o to monitor progress in relieving soil compaction and identify problem areas for ongoing subsoiling;
 - o to monitor site drainage, soil fertility, soil erosion and subsidence or settlement for recommendation of site specific requirements for land levelling or planing;
 - o to carry out a regular program of soil testing to ensure that sufficient levels for phosphorus and potassium are attained and maintained;
 - o to monitor crop rotation sequences and record annual crop yields;
 - o to carry out tests in zones of apparent crop injury or low yield, to determine the presence of harmful concentrations of landfill gases and/or adverse soil physical conditions; and
 - o to monitor runoff in perimeter ditches for sediment and contaminants indicative of soil erosion or leachate runoff problems.

5.0 REFERENCES CITED

- Ecological Services for Planning Ltd. 1985. Final Technical Report No. 4, Phase 1, Stage 2C, Selection of Preferred Site - Environmental Assessment of the Landfill Component of Halton's Solid Waste Management System.
- Gillespie, J.E., R.E. Wicklund and M.H. Miller. 1970. The Soils of Halton County. Report No. 43 of the Ontario Soil Survey.
- Ministries of Agriculture and Food, Environment and Health. 1986. Guidelines for Sewage Sludge Utilization on Agricultural Lands. Revised January, 1986.
- Walker, Wright, Young Associates Ltd. 1985. Final Report, Phase 2 Stage 2C, Selection of Preferred Site, Evaluation and Summary Report - Environment Assessment of the Landfill Component of Halton's Solid Waste Management System.

A P P E N D I X A

"Economic Analysis of Rehabilitating Landfill
Sites for Agricultural Production"

A Report Submitted to
Ecological Services for Planning Ltd.

by

Farm Analytics
(D. Peter Stonehouse, Ph.D.)

January, 1986

Problem Situation, Scope and Objectives

Landfill on agricultural lands is one of the more common methods of municipal waste disposal in Ontario. With appropriate treatment, landfill sites can be rendered free from environmental hazards and made suitable for a wide variety of uses in agriculture. These uses include the commonly-grown field crops, such as cereal grains, corn and pasture/forage crops, vegetable crops and any fruit crops that are shallow-rooted. Excluded would be any deep-rooted crops, such as fruit trees, other trees and alfalfa, whose root systems would be capable of penetrating the landfill cover material.

The objective of this analysis is to evaluate the longterm economics of rehabilitating and using the landfill site in an agricultural capacity only. Attention is centered on cash cropping of field crops commonly grown in Ontario. Specifically, the objectives are:

1. to compile the investment outlays necessary for initial rehabilitation of two different sites (Site D and Site F), in the first year following completion of landfill disposal of municipal wastes;
2. to estimate the present value of the future flow of annual net benefits of these two sites over an assumed Halton Region ownership horizon of 25 years, using several crop rotation alternatives;
3. to estimate the net present value (annual net benefits minus investment outlays) for each crop rotation alternative, compare them and make recommendations.

Investment Outlays for Rehabilitation

Regardless of eventual agricultural use, certain operations are required for initial restoration of each site. Additional topsoil may be needed to supplement that preserved at Site F during the landfilling process. The topsoil has to be transported and spread. Subsoiling with an agricultural subsoiler will be a necessary operation at Sites D and F for improvement of aeration and drainage in the plant rooting zones. The rehabilitation operations required for each of Sites D and F, together with their estimated costs, are shown in Table A-1.

Selection of Crop Rotational Systems

Forage crops (grasses and clovers) should be grown for the first few years following rehabilitation to improve soil structure and soil fertility. Red clover (a biennial) and timothy are recommended, with reseeding every two years. Further reliance on forage crops over a longer term horizon would no doubt engender a more complete restoration of the topsoil, so that permanent forage cropping becomes one candidate cropping system. Perennial clovers like trefoil are to be preferred over biennials such as red clover, to obviate the costs of re-seeding every two years.

Table A-1: Initial Land Restoration Investment Requirements, by Site*

	Site D	Site F
	(1985 dollars)	
Additional Topsoil	-	3,077,300
- 428,000 cu.m. @ \$7.19		
Topsoil Haulage - 725,417 tonnes @ 5c/tonne/km for 50 km	-	1,813,500
Subsoiling	31,500	
- 72.9ha @ \$432		
- 69.3ha @ \$432		29,900
Total Investment Cost	31,500	4,920,700

*as per Section 4.3.4, Table 4.

One of the principal cash crops in southern Ontario currently is grain corn. This crop should be grown only in conjunction with forage crops on a rotating basis, because of grain corn's propensity to cause structural breakdown of and net loss of organic matter in topsoils. Part of the cultural practice characterizing grain corn is the use of the broad-spectrum weed killer, atrazine, whose residual effects are typically felt for two years. Hence corn is most frequently grown for two years in succession.

Other major cash crops in southern Ontario are soybeans and cereal grains such as barley and winter wheat. A fairly typical rotation would be two years of corn followed by one year each of soybeans and winter wheat. However, soybeans do not grow well on rehabilitated clay sites. Therefore, soybeans are replaced by barley as the third-year crop in the rotation for purposes of this study. The potentially damaging effects of two years of corn on the topsoil could again be offset by two years of red clover and timothy, following the four years of other crops. The grass/clover crop can be seeded down with the winter wheat during the fourth year of this six-year rotation.

Crop Yields

Reduced crop yields can be expected during the initial years following rehabilitation due to adverse soil physical problems and

imbalances in soil nutrients. For the first year following replacement of topsoil and initial rehabilitation work, a grass-legume crop is expected to yield only 60 percent of the Halton Region average for hay crops (see Table A-2). Thereafter, yields can be expected to rise gradually through the fifth year, when 90 percent of the Halton Region average is anticipated.

Average crop yields over a number of recent years be used as a basis for assessing economic benefits and costs. With annual fluctuations in excess of 20 percent, as indicated in Table A-3, it is much safer to rely on a composite crop yield figure than on any one single year's figure, which may under- or overestimate the yield that can be reasonably expected on a long-term basis.

Crop Prices

Analogous to the case with crop yields, prices received by farmers for crops sold generally vary greatly among years. It is realistic to base economic benefits on an average of prices for a series of years and in this analysis, an average for the last five years is used (see Table A-4).

Production Costs and Gross and Net Returns

With some inflation still evident in the costs of resource inputs and services purchased by farmers, it is felt that reliance should be placed on the most recent set of crop production costs available from

Table A-2: Expected Hay Yield Profile Following Initial Restoration

Year following Initial Restoration	Percent of Halton Region Yield Expected	5-Year Average* Halton Region Hay Yield	Hay Yield on Landfill Site
		(tonnes/ha)	(tonnes/ha)
1st	60	6.63	3.98
2nd	70	"	4.64
3rd	80	"	5.30
4th	85	"	5.64
5th and Subsequent	90	"	5.97

*See Table A-3

Table A-3: Average Yields for Field Crops - Region of Halton

	Grain Corn	Barley	Winter Wheat	Hay
	(tonnes/ha)			
1980	5.27	3.28	2.56	5.58
1981	5.59	3.28	3.03	7.17
1982	4.14	3.28	2.42	6.73
1983	4.58	2.21	2.69	6.95
1984	5.52	3.50	3.70	6.73
5-Year Average	5.02	3.11	2.88	6.63
- 90% 5-Year Average	4.52	2.80	2.59	5.97

Source: Ont. Min. Agric. & Food, Publication 20, "Agricultural Statistics for Ontario". Annual.

published sources. One reliable and frequently used source is the Ontario Ministry of Agriculture and Food's (OMAF) "Crop Budgeting Aid", published annually as a guide to production costs for the most commonly produced crops in Ontario, including all the crops being considered in this study. The most recently available edition is that for 1985. The method by which the OMAF compiles its estimates of crop machinery overhead costs is based on reigning custom hire charges for the machinery, plus the full cost of wages and benefits for labour used in operating the machinery.

Table A-5 depicts all production costs for each of the crops under consideration, under the sub-headings of direct and indirect costs, in dollars per hectare. Toward the bottom of Table A-5, expected gross revenues are calculated for each crop, based on the expected crop yield data from Table A-3 and crop price data from Table A-4.

The net returns per crop are then calculated by difference, on a dollars-per-hectare basis. These net returns are in theory required to furnish compensation for the farm operator's own physical labour, management and risk inputs, plus compensation for investment in the cropland. The fact that negative net returns figures are indicated for three of the crops in Table A-5 should not be regarded with too much surprise, because only 90 percent crop yields are being expected on these landfill sites. In addition, the use of custom hire rates for machinery charges ensures that such non-cash costs as

TABLE A-4: Average Prices For Field Crops - Ontario

	Grain Corn	Barley	Winter Wheat	Hay
		(\$/tonne)		
1980	151	133	164	49
1981	115	122	157	50
1982	112	107	165	52
1983	159	140	146	56
1984	134	136	143	55
5-Year Average	134	128	155	52

Source: Ontario Ministry of Agriculture and Food, Publication 20, "Agricultural Statistics for Ontario". Annual.

TABLE A-5: Estimated Crop Production Costs, Gross Revenues and Net Returns

	Grain Corn	Barley	Winter Wheat	Red Clover/ Timothy Hay	Trefoil/ Timothy Hay
<u>Direct Costs</u>	(\$/ha)				
Materials (seed, etc.)	250	128	166	69	69
Establishment	-	-	-	78(a)	9(b)
Machinery Operating	94	64	62	98	98
Drying	79	-	-	-	-
Storage	42	12	-	-	-
Crop Insurance	17	12	15	15	15
Interest on Operating	37	12	27	16	16
Marketing	2	-	2	-	-
Subtotal Direct Costs	521	216	272	276	207
<u>Indirect Costs</u>					
Machinery Overhead	114	77	77	136	136
Miscellaneous	37	37	37	35	35
Total Costs	672	330	386	447	378
Gross Revenue (Tables 3 & 4) (Years 5 to 25)	606	358	401	310	310
Net Returns(c)	-66	28	15	-137	-68

Source: adapted from Ont. Min. Agric. & Food, "Crop Budgeting Aid, 1985".

a Amortized at 2.5% interest over 2 years.

b Amortized at 2.5% interest over 25 years.

c Net returns to Operator Labour, Land Investment, Managment & Risk.

depreciation and interest on capital investment are embodied on an "as-new" basis. Such an approach may overestimate machinery overhead charges for many farm businesses that purchase their machinery and equipment second-hand, and that have a large enough land base to reduce their overhead costs per hectare significantly.

Present Value of Investment in Agricultural Alternatives

The net returns estimates per hectare of each crop shown in Table A-5 on an average annual basis are incorporated into a 25-year profile in Table A-6, using the different crop rotational systems selected earlier for consideration in this study. In order to compare this profile of expected future annual net benefits on a realistic basis with the rehabilitation investment outlays made at the beginning of the 25-year benefits period, the annual net benefits must be transformed to present (1985) value terms. The discount rate selected for calculating the present values in this study is 2.5 percent, the rate traditionally employed by federal government departments in similar studies, and the rate generally acknowledged as representative of long-term real interest rates in Canada. The present value (discount) factors, together with the discounted annual net benefits for each crop rotation alternative, as displayed in Table A-6. For each rotation, the first four years' net benefits are shown based on clovers/grasses cropped for hay, using the gradually rising yields depicted in Table A-2. The cumulative net benefits for the 25-year horizon are also shown in Table A-6, for each rotation.

TABLE A-6: Expected Net Returns Profiles, by Crop Rotation

Year	Crop Rotation			Present Value Factor (2.5%)	Present (1985) Value		
	Corn, Barley, Wheat, Hay	Corn Hay	Continuous Trefoil Hay		Corn, Barley, Wheat, Hay	Corn, Hay	Trefoil Hay
	(\$/ha)				(\$/ha)		
1	-240 a	-240 a	-171	.9756	-234	-234	-169
2	-206 a	-206 a	-137	.9518	-196	-196	-130
3	-171 a	-171 a	-102	.9286	-159	-159	-95
4	-154 a	-154 a	-85	.9059	-140	-140	-77
5	-66	-66	-68	.8838	-58	-58	-60
6	-66	-66	-68	.8623	-57	-57	-59
7	28	-137	-68	.8413	23	-115	-57
8	15	-137	-68	.8207	12	-112	-56
9	-137	-66	-68	.8007	-110	-53	-54
10	-137	-66	-68	.7812	-107	-52	-53
11	-66	-137	-68	.7621	-50	-104	-52
12	-66	-137	-68	.7435	-49	-102	-51
13	28	-66	-68	.7254	20	-48	-49
14	15	-66	-68	.7077	11	-47	-48
15	-137	-137	-68	.6905	-95	-95	-47
16	-137	-137	-68	.6736	-92	-92	-46
17	-66	-66	-68	.6572	-43	-43	-45
18	-66	-66	-68	.6412	-42	-42	-44
19	28	-137	-68	.6244	18	-86	-43
20	15	-137	-68	.6103	9	-84	-42
21	-137	-66	-68	.5954	-82	-39	-40
22	-137	-66	-68	.5809	-80	-38	-40
23	-66	-137	-58	.5667	-37	-78	-39
24	-66	-137	-68	.5529	-36	-76	-38
25	28	-66	-68	.5394	15	-36	-37
Total					-1,559	-2,186	-1,471

a Based on Red Clover/Timothy.

Using these net benefits figures and the rehabilitation investment outlays developed in Table A-1 for each of Sites D and F, the net present value figures can be derived according to the following formula:

$$N.P.V. = -I + \sum_{t=1}^n \frac{NR_t}{(1+i)^t}$$

where NPV represents Net Present Value, in 1985 real dollars,
 -I represents the total investment outlay per Site,
 NR represents the annual net benefits for each of t years to a total of n years, where n in this case is 25 years,
 and $\frac{1}{(1+i)^t}$ represents the discount factor for each of t years with i in this case equal to 2.5 percent.

For Site D, the net present values for each rotation alternative in turn would be:

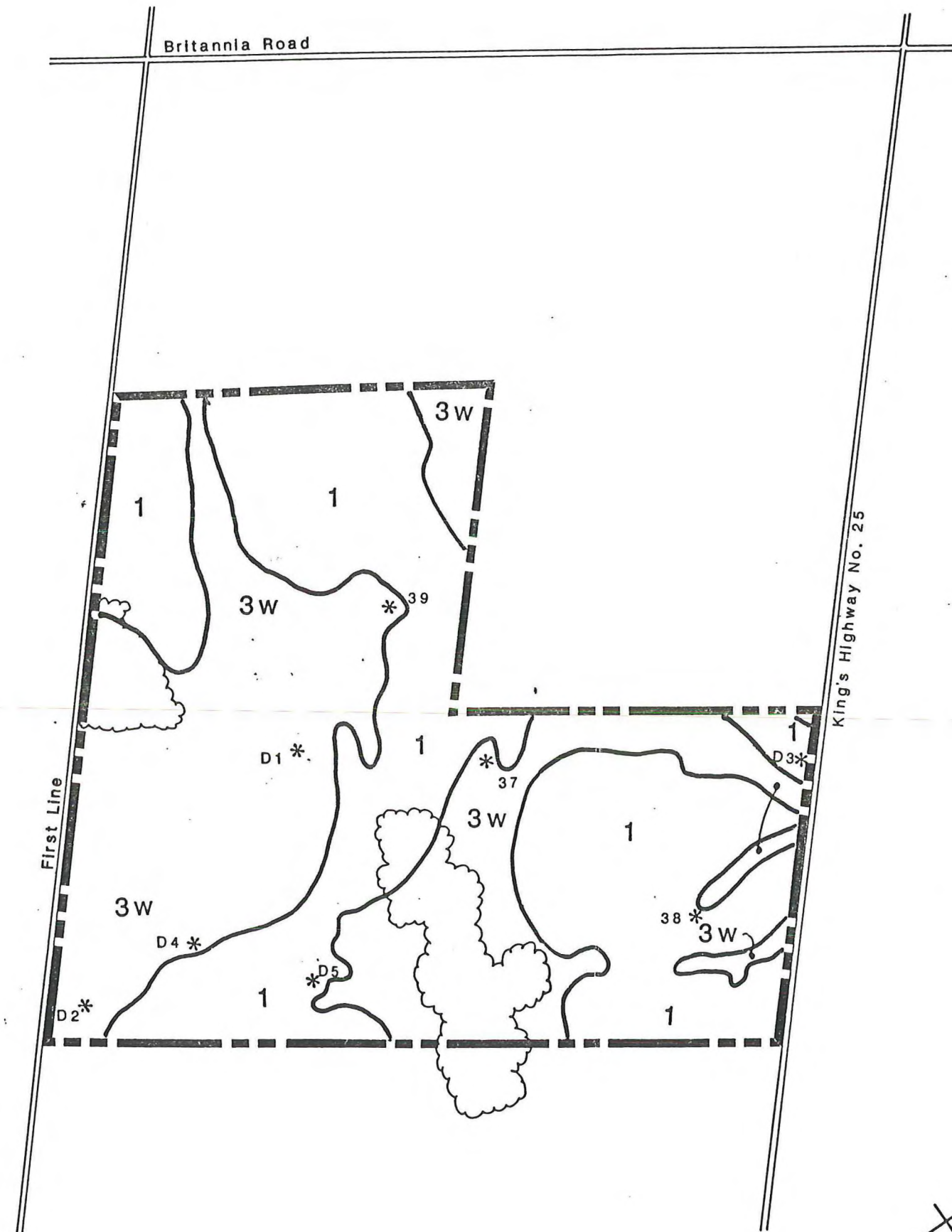
$$\begin{aligned} \text{NPV (Corn/Barley/Wheat/Hay)} &= -31,500 + (-1,559/\text{ha} \times 72.9\text{ha}) \\ &= \$145,151. \\ \text{NPV (Corn/hay)} &= -31,500 + (-2,186/\text{ha} \times 72.9\text{ha}) \\ &= \$190,859. \\ \text{NPV (Continuous Trefoil Hay)} &= -31,500 + (-1,471/\text{ha} \times 72.9\text{ha}) \\ &= \$138,736. \end{aligned}$$

For Site F, the net present value for each rotation alternative in turn would be:

$$\begin{aligned} \text{NPV (Corn/Barley/Wheat/Hay)} &= -4,920,700 + (-1,559/\text{ha} \times 69.3\text{ha}) \\ &= \$5,028,739. \\ \text{NPV (Corn/Hay)} &= -4,920,700 + (-2,186/\text{ha} \times 69.3\text{ha}) \\ &= \$5,072,290. \\ \text{NPV (Continuous Trefoil Hay)} &= -4,920,700 + (-1,471/\text{ha} \times 69.3\text{ha}) \\ &= \$5,022,640. \end{aligned}$$

APPENDIX B

SAMPLE SITE LOCATIONS



LEGEND

 site plan area
 wooded

capability class → 3W ← capability subclass

CAPABILITY SUBCLASS	LIMITATION TYPE
w	excess water

scale - 1:10,000

THE REGIONAL MUNICIPALITY
OF HALTON

Halton Region Landfill
Technical Study

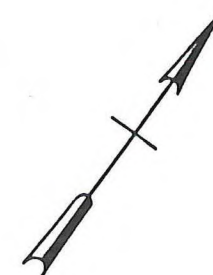
SITE D - SOIL SAMPLE POINTS
SOIL CAPABILITY
FOR AGRICULTURE



Ecological Services for Planning Ltd.

DATE: July/86
PROJECT NO.: GRH03

MAP NO.
2a



LEGEND

site plan area

wooded

capability class 7te capability subclass

CAPABILITY SUBCLASS	LIMITATION TYPE
t	topography
e	erosion damage

scale - 1:10,000

THE REGIONAL MUNICIPALITY OF HALTON

Halton Region Landfill Technical Study

SITE F - SOIL SAMPLE POINTS
SOIL CAPABILITY
FOR AGRICULTURE



Ecological Services for Planning Ltd.

DATE : July/86
PROJECT NO. : GRH03

MAP NO.
3a

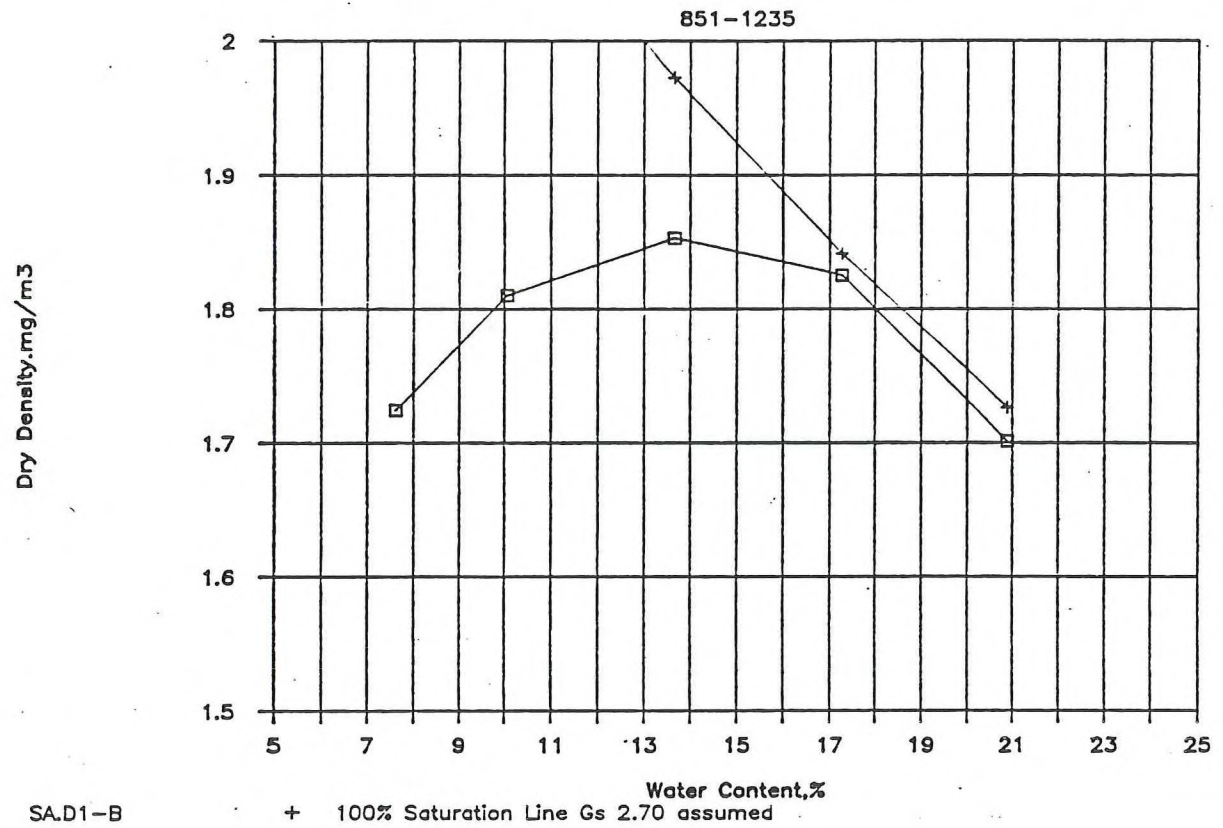
APPENDIX C

**SOIL CHEMICAL AND
PHYSICAL ANALYSES**

SUMMARY OF PHYSICAL AND CHEMICAL SOIL CHARACTERISTICS FOR SITES D AND F

Sample #	Horizon	Sand	Silt	Clay	Ph	Organic Matter (per cent)	Carbonate (per cent)	Soil Test Results			Liquid Limit %	Plastic Limit %	Maximum Dry Density mg/m ³	Bulk Density	
								Phosphorus	Potassium	Magnesium				Depth	g/cc
D1	Ap	23	46	31	6.3	2.9		14	110	230				10-15	1.57
	Btg	16	39	45	6.5			5	88	232	52	30	1.85	10-15	1.54
	CKg	16	46	38	7.5		23.51	4	68	290	38	24	1.908	45-50	1.69
D2	Ap	24	49	27	7.4	3.2		14	68	244				45-50	1.61
	Btgj	11	39	50	7.6									15-20	1.58
	CKg	10	43	47	7.8		21.99							15-20	1.50
D3	Ap	19.5	51	29.5	7.2	3.5		11	94	196				45-50	1.56
	Btgj	10.5	41	48.5	7.6									45-50	1.65
	CKgj	20.5	48	31.5	7.4		7.58							15-20	1.44
F1	Ap	19	54	27	7.4	2.6		7	68	150				45-50	1.76
	Bt ₁	9.5	39.5	51	6.9			17	100	188	57	35	1.833	45-50	1.79
	Bt ₂	8	42	50	7.2									10-15	1.62
	CK ²	15.5	46.5	38	7.8		15.17				40	25	1.925	45-50	1.62
F2	CK	—	—	—	7.8		8.34	4	344	315	26	17	2.183		
F3	Ap	19	64	17	7.3	6.8		10	274	272					
	Bt	3.5	49.5	47	6.3			17	100	272					
	CK	8	60	32	7.6		9.86	4	110	148					

MODIFIED PROCTOR TEST



Maximum Dry Density . 1.853 mg/m³

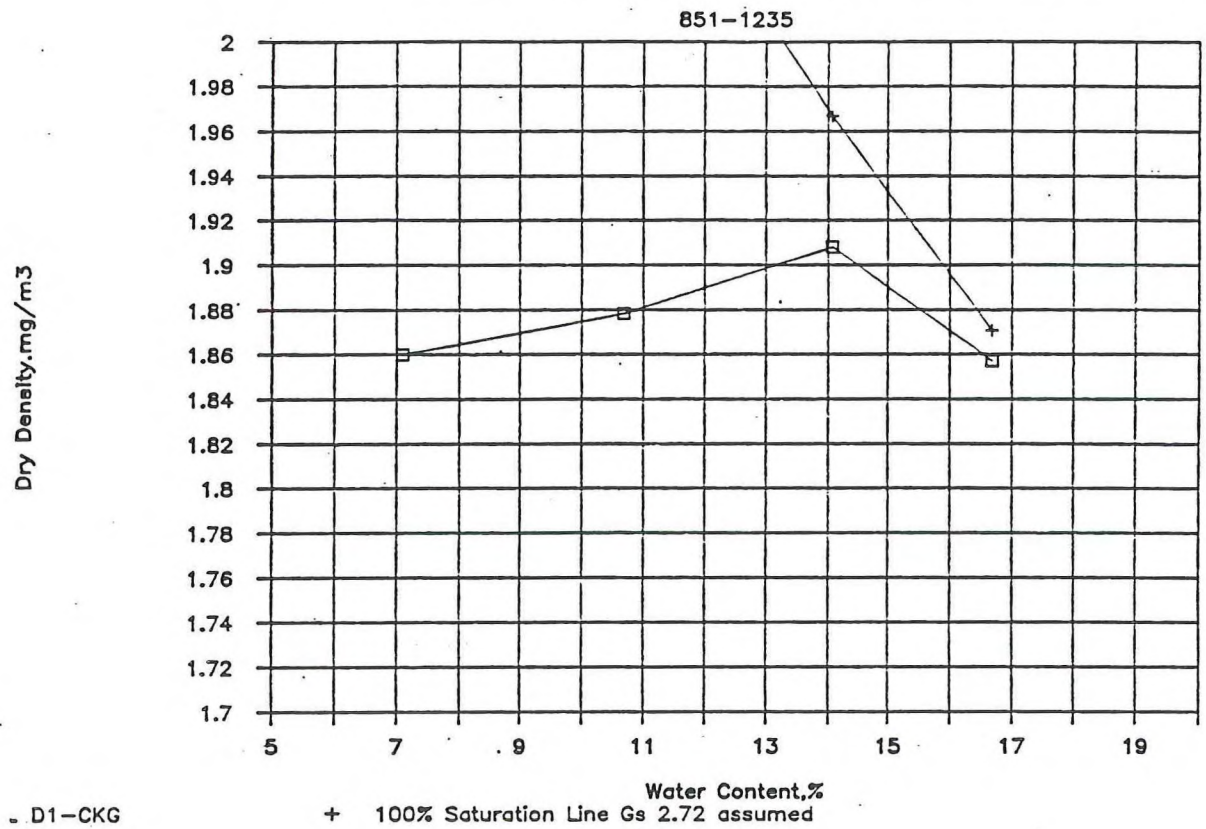
Optimum Water Content 13.7%

Natural Water Content 24.1%

Liquid Limit 52%

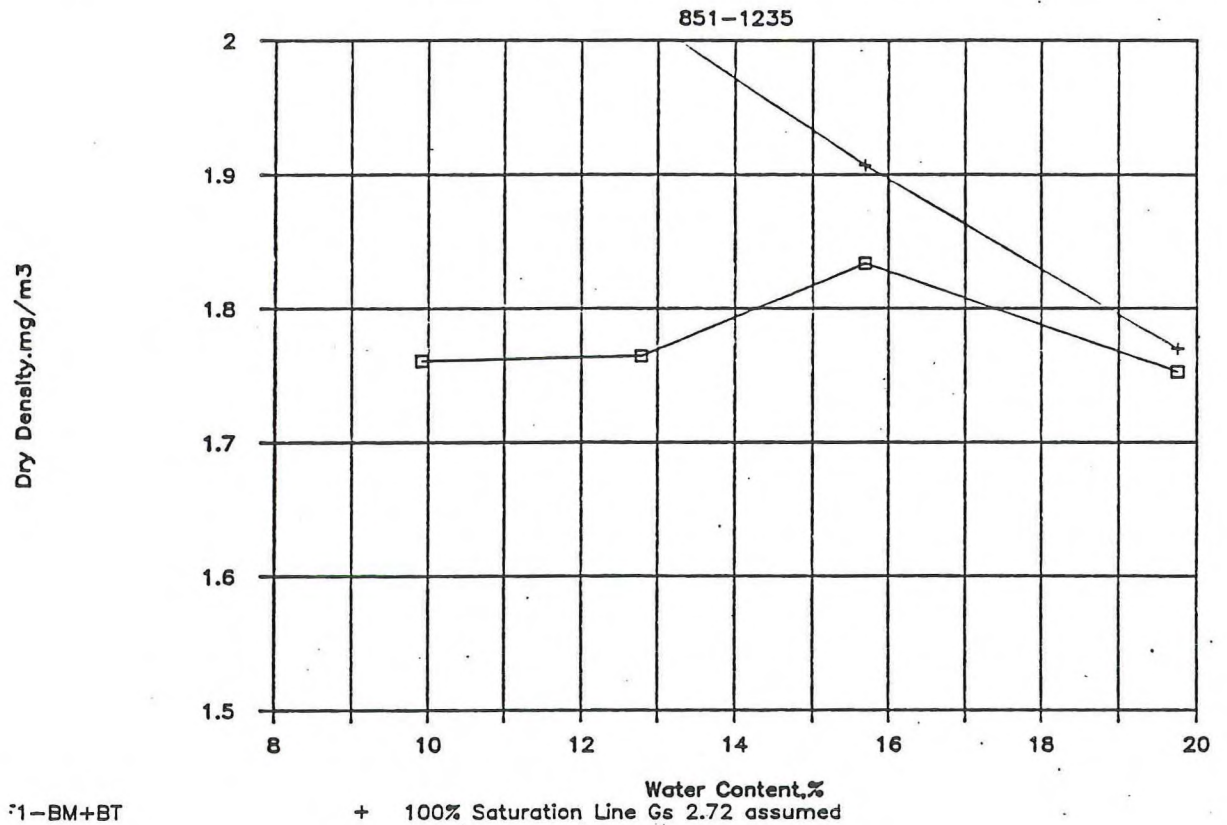
Plastic Limit 30%

MODIFIED PROCTOR TEST



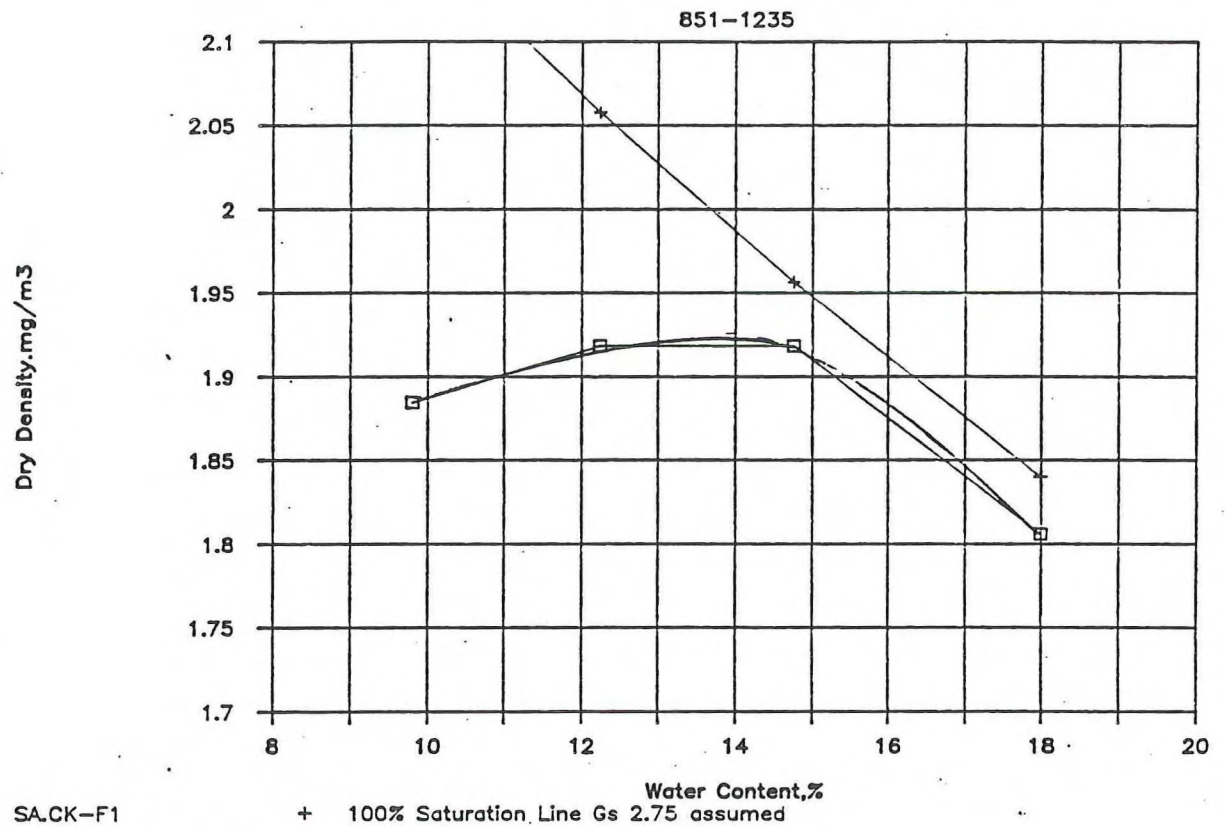
Maximum Dry Density	1.908 mg/m ³
Optimum Water Content	14.1%
Natural Water Content	18.6%
Liquid Limit	38%
Plastic Limit	24%

MODIFIED PROCTOR TEST



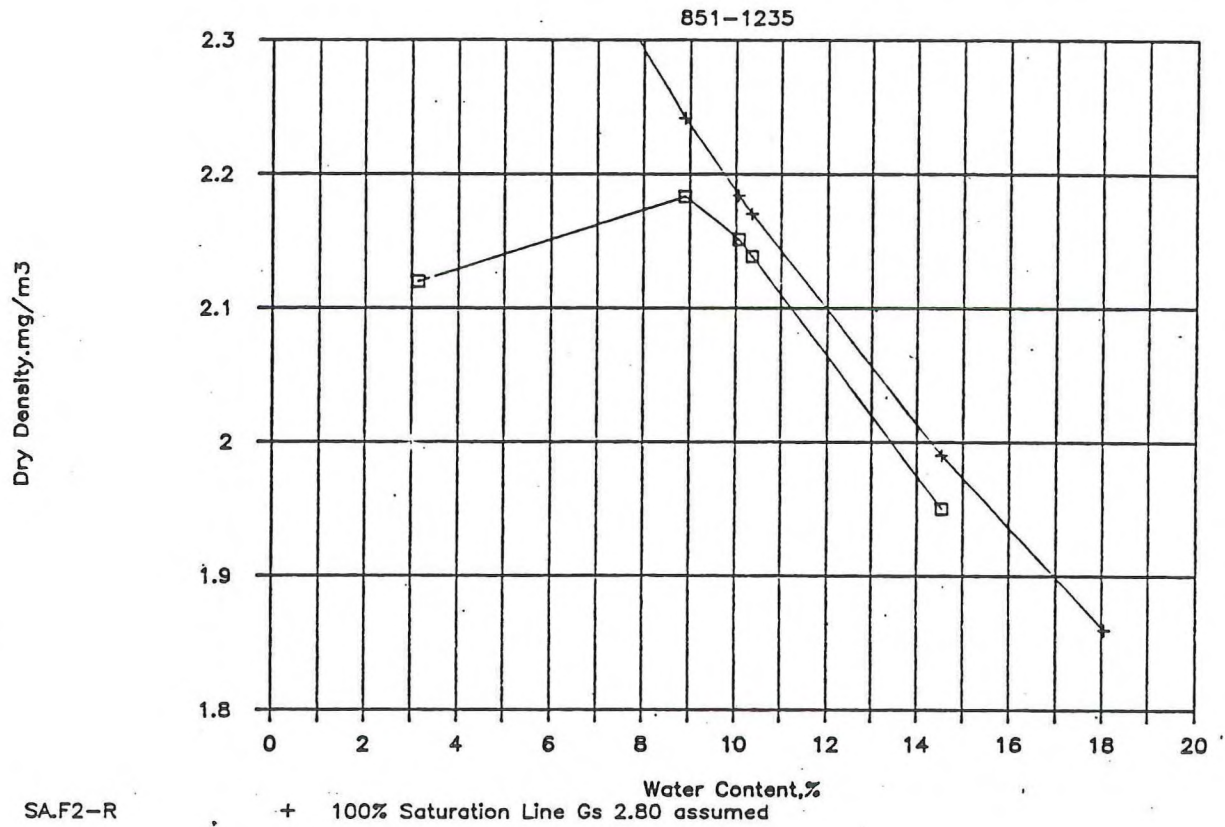
Maximum Dry Density	1.833 mg/m ³
Optimum Water Content	15.7%
Natural Water Content	15.6%
Liquid Limit	57%
Plastic Limit	35%

MODIFIED PROCTOR TEST



Maximum Dry Density	1.925 mg/m ³
Optimum Water Content	13.5%
Natural Water Content	11.5%
Liquid Limit	40%
Plastic Limit	25%

MODIFIED PROCTOR TEST



Maximum Dry Density	2.183 mg/m ³
Optimum Water Content	8.9%
Natural Water Content	2.8%
Liquid Limit	26%
Plastic Limit	17%