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Technology, Prevalence and Economics of Landfill Disposal of Solid Waste

TECHNOLOGY, PREVALENCE, AND ECONOMICS OF LANDFILL DISPOSAL OF SOLID WASTE

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FOREWORD

This report has been developed under contract number 68-01-4895 to provide information for the Office of Solid Waste to use in developing guidelines for the landfill disposal of solid waste and criteria for the classification of solid waste disposal facilities. These activities are mandated under Sections 1008 and 4004, respectively, of the Resource Conservation and Recovery Act of 1976, Public Law 94-580.

Landfill disposal of solid waste is reviewed in terms of; (1) the use of landfills for disposal; (2) techniques commonly employed for such disposal; and (3) the costs associated with landfill disposal by those techniques. This report also presents estimates of the anticipated increases in costs of landfill disposal as a result of the application of the recommended practices and procedures contained in the Guidelines.

References to the information contained in this report are found in Environmental and Economic Impact Statements (EIS) which have been developed in conjunction with the following: "Guidelines for the Landfill Disposal of Solid Waste" (40 CFR 241); and "Criteria for the Classification of Solid Waste Disposal Facilities and Practices" (40 CFR 257).

Information presented in this report is based upon an early working draft of the Guidelines and the February 6, 1978 proposed criteria (43 CFR 4942). Some information contained in the two EIS's may, therefore, appear inconsistent with this report. Any such inconsistencies should be attributed to more current information available at the time of EIS preparation or to differing assumptions in the EIS's.

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TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF TABLES
(continued)

LIST OF FIGURES

I. EXECUTIVE SUMMARY

This report evaluates the costs and economic and energy use impacts of the Guidelines for the Landfill Disposal of Solid Waste to be proposed under Section 1008 (a) of P.L. 94-580, the Resource Conservation and Recovery Act. This analysis was accomplished in six steps. Each step and the conclusions drawn from them are summarized briefly below.

First, existing data on landfill types were used to select three model landfill sizes on which to base subsequent cost, economic, and energy use considerations. The landfill sizes chosen -- 10, 100, and 300 tons per day (TPD) -- represent capacity ranges of 0 to 50, 50 to 200, and greater than 200 TPD.

Second, current landfill practices were defined in terms of the technologies and operating procedures utilized most commonly, and baseline unit costs were identified for each of the three model landfill sizes. Currently, most landfills use only ditching for surface runoff control and daily cover and clay liners for leachate control. Current disposal costs range from $2.00 to $12.00 per ton, averaging $11.15 per ton at 10 TPD landfill sites, $6.65 per ton at 100 TPD sites and $3.95 per ton at 300 TPD sites. These total unit costs represent approximately 20 to 30 per cent capital costs and 70 to 80 per cent operating expenditures.

Third, various available landfill practices which make it possible to achieve the recommendations of the Guidelines are identified and the unit costs of these alternate methods were estimated. A variety of landfill upgrading technologies were assumed. These covered waste processing, gas control, leachate control, surface runoff control, and monitoring. Leachate controls, such as impermeable daily cover (off-site source) and diking, will incur the highest landfill technology unit costs, accounting for anywhere between two-thirds and all of the total incremental costs due to the Guidelines, depending on landfill type, size, and sensitivity.

Fourth, while these Guidelines are only advisory and compliance is not mandatory the aggregate costs of application of the Guidelines were estimated. This is accomplished by (1) estimating the population of various types of landfills, (2) determining the prevalence of various environmentally sensitive site conditions, (3) determining the technologies required by the possible combinations of facility type and environmental conditions, and then (4) summing the costs for each category to arrive at an aggregate national cost. Based on a literature search and stated assumptions, the report concludes that there are 81,317 landfills in the United States, of which 81% are at privately owned industrial sites. The report further estimates that 73% of all landfills are located in environmentally sensitive areas. Application of the Guidelines would result in increased costs of $2,070.3 million, a 60 percent increase over current costs if all landfills in the Nation complied with these advisory Guidelines. The impact is greatest for small sites (0-50 TPD) located in environmentally sensitive areas.

Fifth, the economic effects of the increased costs identified previously are considered. These considerations are grouped into two categories: (1) impacts on the supply of landfills; and (2) impacts on the demand for landfill services. Briefly, the major impacts on landfill supply will be: (1) increased disposal fees for landfill users; (2) higher taxes for landfill support; (3) changes in the profits of private landfill owners; (4) changes in the profits of industries with on-site disposal; and (5) regionalization and consolidation of waste handling. Increased costs for landfill services, on the other hand, will cause the demand for landfill services to decrease in favor of increased source reduction, energy and resource recovery, other legal waste disposal methods, and illegal dumping.

Finally, current and expected landfill energy use at existing facilities as a result of Guidelines implementation was considered. Construction energy use will rise anywhere from 1 per cent for a 300 TPD pollution control residue landfill located in an environmentally non-sensitive area to 144 per cent for a 10 TPD municipal landfill sited in a sensitive area. Operating use will increase 100 per cent at most industrial and pollution control residue landfills which do not already apply impermeable daily cover.

II. INTRODUCTION

A. Scope of Work

The purpose of this report is to consider the costs, economic impacts and effects on energy use of application of the Guidelines for the Landfill Disposal of Solid Waste to be proposed under Section 1008(a) of P.L. 94-580, the Resource Conservation and Recovery Act (hereafter referred to as the Act). The Guidelines contain recommended considerations and practices for location, design, construction, operation and maintenance of solid waste landfills which if applied on a case-by-case basis should assist in complying with the "Criteria for Classification of Solid Waste Disposal Facilities" (40 CFR 257) developed in accordance with Section 4004(a) of the Act.

The Guidelines are applicable to the landfill disposal of all solid waste. They delineate recommended practices but do not contain specific requirements. The Guidelines are not mandatory. There will be no Federal enforcement of the Guidelines. Thus, for the purposes of assessing the economic impact of the Guidelines, it is assumed that all States will adopt programs which require compliance with the Guidelines.

The scope of the Guidelines covers seven areas, as follows:

Section	Topic
241.200	Site Selection
241.201	Design
241.202	Leachate Control
241.203	Gas Control
241.204	Runoff Control
241.205	Operation
241.206	Monitoring

The recommended practices in each of these areas are discussed in Section IV of this report.

As a result of the adoption of the Guidelines, significant environmental benefits are anticipated -- particularly in the protection of ground and surface-water resources. For obtaining these and other benefits, costs will be incurred as existing facilities undertake an operational upgrading program and as new facilities are sited, designed and operated. The major near-term costs associated with Guidelines application will be incurred through the upgrading of existing facilities.

The provisions contained in Sections 241.200 (site selection) and 241.201 (design) would only be applicable to new facilities. The various practices discussed under each of the remaining five sections of the Guidelines can be used individually or in combination at existing facilities to achieve environmental benefits, as dictated by site-specific conditions. It will not be possible, nor necessarily beneficial, however, for all facilities to institute all of the practices outlined in the aforementioned seven sections of the Guidelines.

B. General Methodology

1. Format. The analysis of economic and energy impacts contained in this report proceeds through six steps, each of which corresponds to a section of the report.

The first step is the selection of model landfills. Existing data on landfill types have been used to select three sizes of landfill which serve as the basis for all subsequent consideration of costs, economic impacts, and energy use.

The second step is to identify baseline costs for facilities in each of the three model sizes. Baseline costs are defined as the unit costs incurred by facilities with the mix of technologies and operating procedures currently in use.

The third step is to estimate the costs of alternate methods of compliance with the Guidelines. This section of the report first identifies the recommended practices in seven specific areas of siting, design, and operation. The report then estimates unit costs of the alternate methods in each category.

The fourth step is to estimate the aggregate costs of compliance with the Guidelines. This is accomplished by (1) estimating the population of various types of landfills, (2) determining the prevalence of various environmentally sensitive site conditions, (3) determining the technologies required by the possible combinations of facility type and environmental conditions, and then (4) summing the costs for each category to arrive at an aggregate national cost.

The fifth step is to consider the economic effects of the increased costs identified in Steps 3 and 4. Ten specific effects are considered, grouped into two major categories: (1) effects on the supply of landfills; and (2) effects on demand for landfill services, as opposed to other methods of solid waste management.

Finally, the sixth step considers current energy consumption and increased energy use as a result of Guideline implementation for the three model landfills.

2. Methods. This report was the second major deliverable under Contract No. 68-01-4895. It was the result of a concentrated effort over a very short period of time -- most of the analysis and writing having been undertaken during a four week period.

The methods used in data collection were dictated by the time constraints. Primary emphasis was placed on a review of available literature, supplemented by telephone contacts with a small number of industry associations and other persons knowledgeable in the areas of landfill prevalence and related cost data.

Because of constraints in time and in the availability of research, an incomplete picture of landfill prevalence and costs was obtained. Given the lack of hard data on many key variables, it was necessary to make numerous assumptions. For all cases, these assumptions have been clearly stated in the text along with the reasoning which led to their adoption. By adopting this approach, it was hoped that useful comments would be stimulated as to the adequacy of the assumptions, so that further revisions of the report would rest on the best available estimates.

C. Data Sources

1. Sources Utilized in the Preparation of the Draft Report. A list of sources used in preparing this report is contained in the Reference section. Fifty-nine written sources were utilized. These were supplemented by a half-dozen telephone contacts.

2. Potential Sources for Revision of this Report. Several methods of improving the data base used in this report have been discussed with the Project Officer. These discussions have focused on the prevalence of landfill types, and estimates of unit costs.

The data on prevalence of landfill types used in this report are as complete as can be obtained without undertaking a major long-term effort to conduct a national survey of landfill sites. EPA is currently undertaking such a survey under the authority of Section 4005 of RCRA, but the results will not be available until after the scheduled completion of this contract. When the survey is complete, it would seem appropriate to revise the prevalence estimates used in this report.

A second problem area relates to the adequacy of the data relating to unit costs. The cost estimates used in this report are a combination of (1) cost data reported by operating landfills and (2) engineering cost estimates. The former, while preferable because they reflect actual operating conditions, are generally not reported in sufficient detail in the available literature to provide more than an order-of-magnitude range for cost data. To be useful, cost data must specify site size, site conditions, type of waste handled, operating procedures, and type of technologies used to process waste and to minimize environmental impacts. None of the existing literature sources reported the information in such exhaustive detail.

As a result, engineering cost estimates were used to identify most of the compliance costs. These estimates were based on existing literature and personal communications. Efforts should continue to improve these estimates. One way in which they might be improved is through a detailed review of a sample of permit application files in States that require permits for solid waste disposal facilities. Such permit applications should contain detailed information on site characteristics, type and projected amount of waste handled, and technologies utilized for waste processing, leachate control, gas control, etc. This information could be correlated with cost data for the facilities to provide a more accurate picture of existing unit costs and projected impacts of the Section 1008 Guidelines.

A third problem area relates to the lack of data relating to energy use at landfill disposal sites. In general the literature does not provide energy use figures for actual construction, operation, and maintenance. Available data on energy use are generally provided only as lump sum utility expenditures.

As with the landfill prevalence and unit cost data, methodologies were developed in this study to estimate the impact of the Guidelines on energy use. A more adequate method of assessing energy impacts would require a survey of actual facilities to develop an energy data base.

III. MODEL LANDFILLS SELECTION CRITERIA

The first step in the analysis of economic and energy impacts of the Guidelines was to identify model landfills to be used as the basis of cost estimates. Three factors were considered in choosing the models: (a) prevalence of the model types; (b) differences in unit cost for the proposed models; and (c) compatibility with the models chosen by Emcon, Inc., in their Draft Environmental Impact Statement for Proposed Criteria for Classification of Solid Waste Disposal Facilities under Section 4004 of RCRA (1978). Since cost estimates for both Section 4004 Criteria and the Guidelines will require many of the same technologies and operating procedures, choosing a compatible model would make possible a comparison of these estimates. The result of this comparison would serve to reinforce and improve the estimates provided by the earlier Emcon study.

A. Prevalence

The most comprehensive data on landfill prevalence are those provided by Waste Age in its 1977 survey of U.S. disposal practices (Reference 1). These data are organized into six size categories, as shown in Table 1. Since data were presented in size categories, rather than by technology utilized, by type of waste handled, or by site conditions, this would suggest that size be the variable determining the choice of models.

B. Unit Cost

Unit cost data also suggest that size should be the key variable in the choice of model landfills, due to the fact that there are important economies of scale in landfill design and operation which lead to lower unit costs at larger sites.

Data relating unit costs to size are presented in Figures 1-4. The actual dollar values assigned as unit costs are of little concern at this stage of the analysis. What is of interest is that all of the sources show an initial steep decline in unit costs as landfill capacity increases, followed by a leveling off past some threshold. The threshold value varies in each of the sources, but in no case was it higher than 300 tons per day (TPD).

C. Compatibility with Section 4004 EIS

The final consideration in the choice of models was compatibility with the models used by Emcon, Inc., in estimating the impacts of the Section 4004 landfill criteria (Reference 6). That analysis was based on four models:

TABLE 1

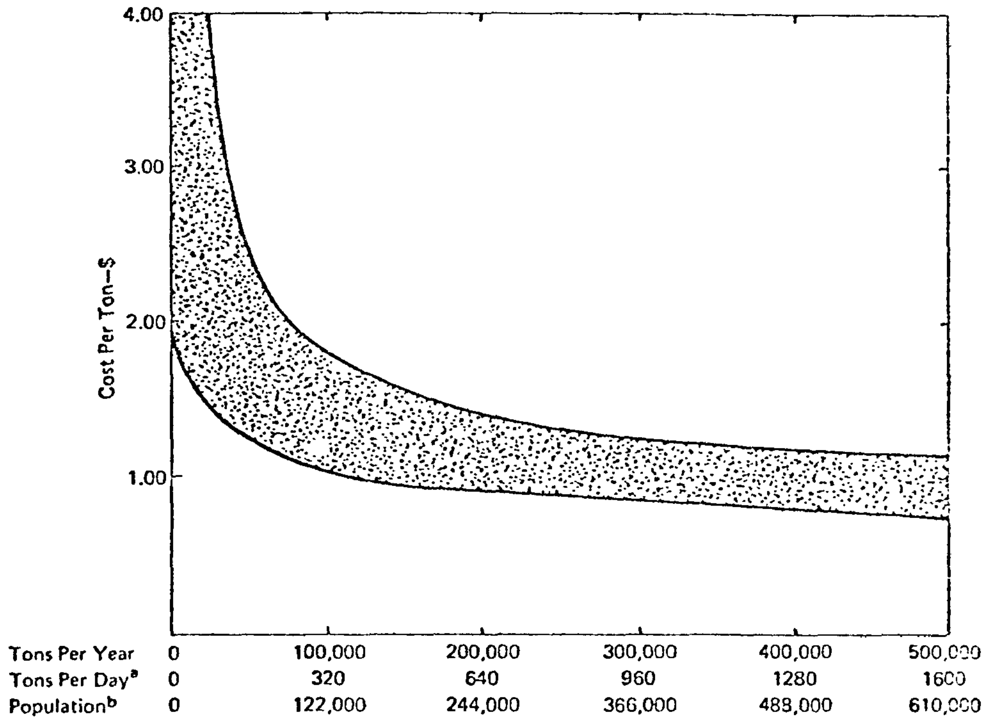
LANDFILL PREVALENCE BY SIZE CATEGORY

Size Category	Number of Landfills
0 - 50 Tons Per Day	11,165
50 - 100 Tons Per Day	1,195
100 - 200 Tons Per Day	781
200 - 500 Tons Per Day	485
500 -1,000 Tons Per Day	331
1,000+ Tons Per Day	129
Unknown	1,807

Source: Reference 1.

FIGURE 1

SANITARY LANDFILL OPERATING COSTS



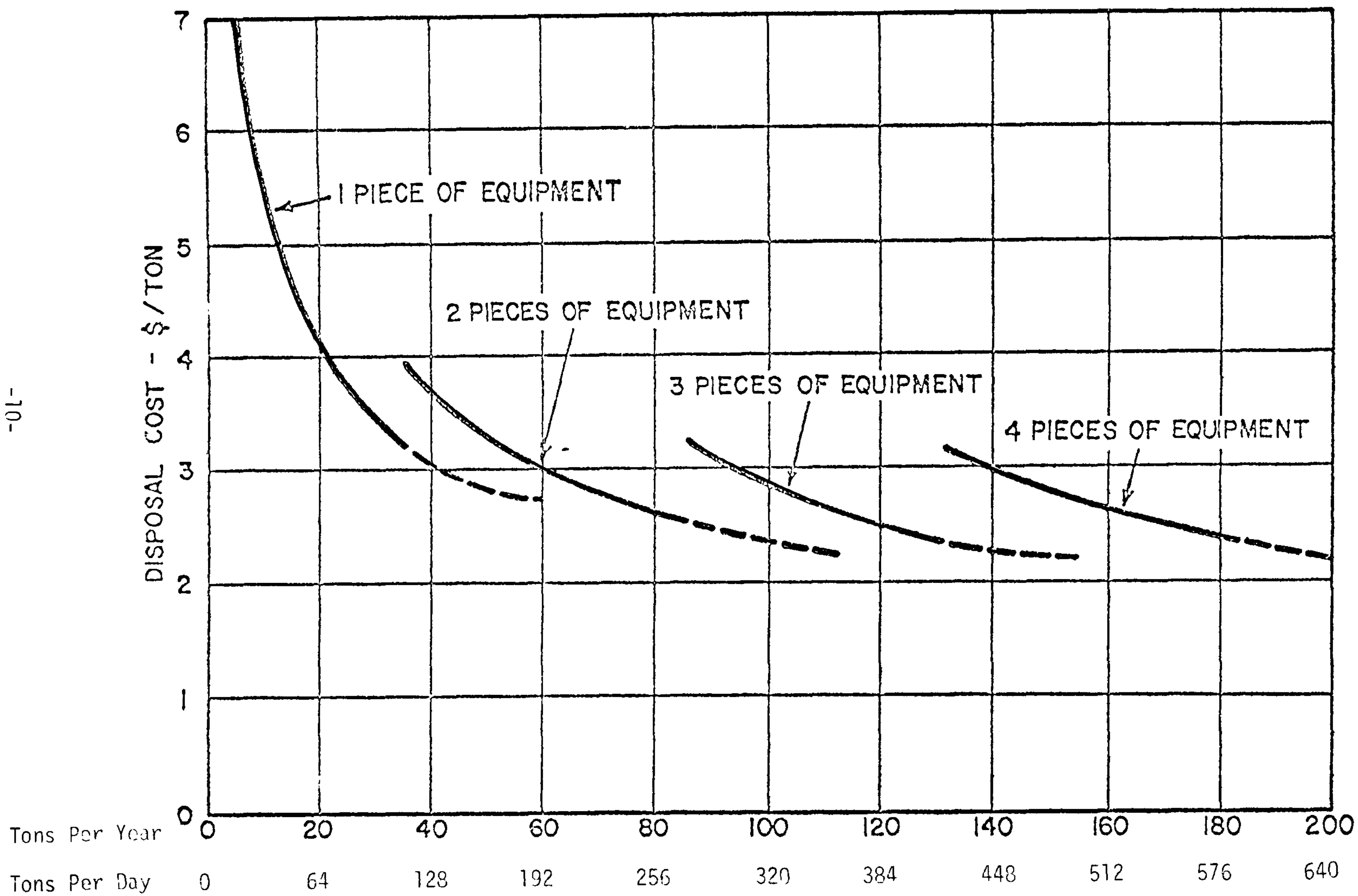
a. Based on a 6-day work week.

b. Based on national average of 4.5 lbs. per person per calendar day.

Source: Reference 2.

FIGURE 2

SANITARY LANDFILL COSTS

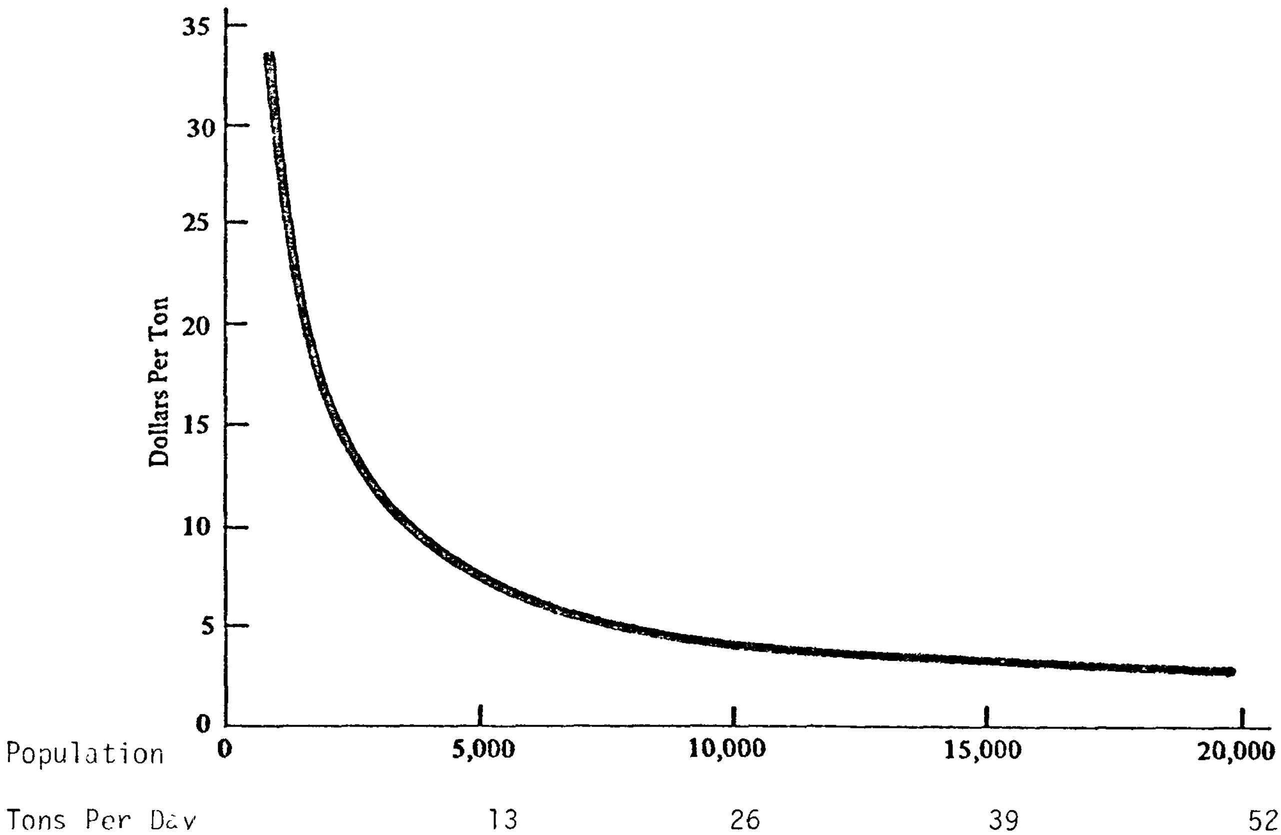


Note: The dashed portions of the curve indicate overtime or second shifts allowing the site to be operated without purchasing additional equipment.

Source: Reference 3.

FIGURE 3

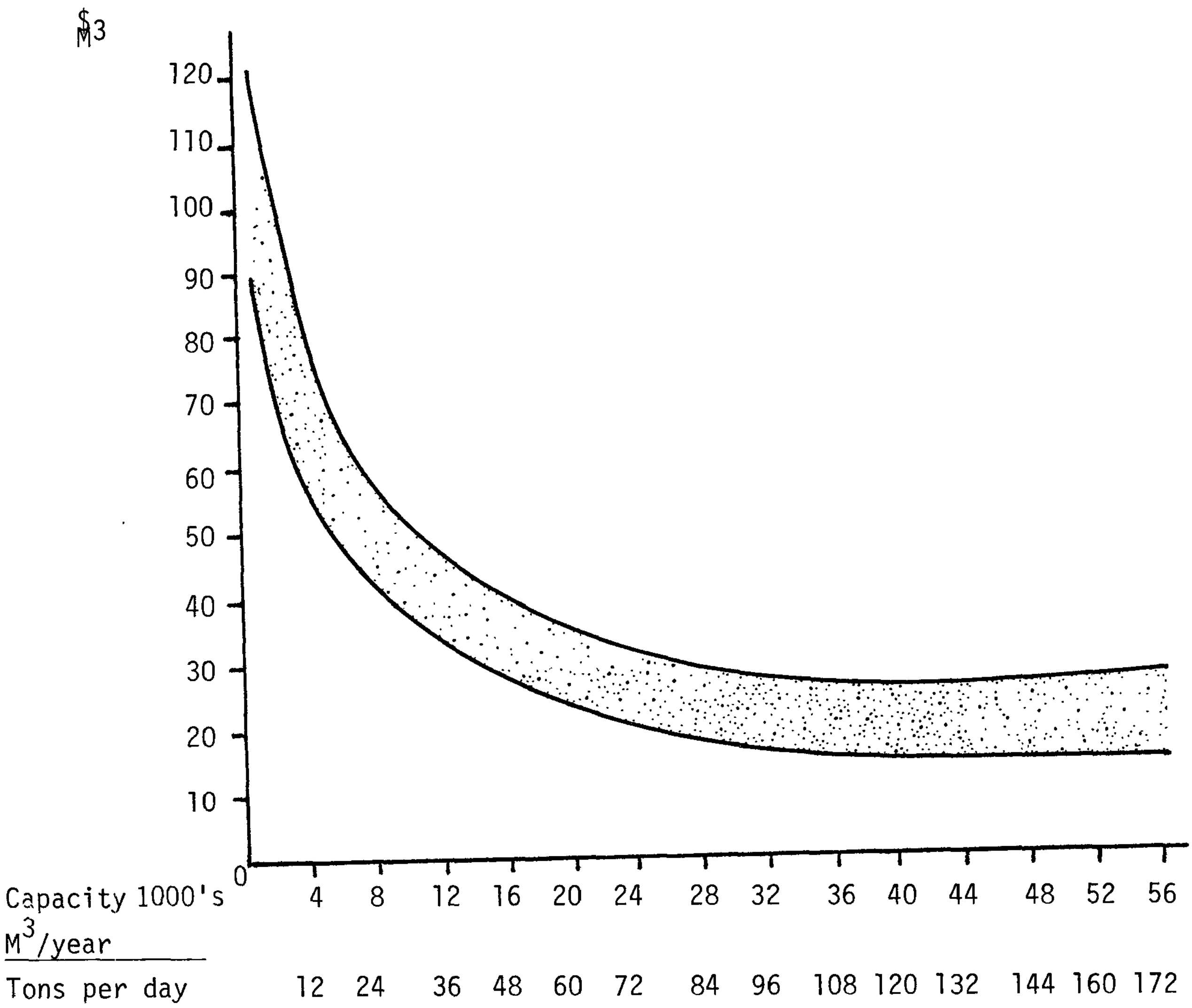
AVERAGE SANITARY LANDFILL DISPOSAL COST FOR UNDER 20,000 POPULATION



Source: Reference 4.

FIGURE 4

SCALE ECONOMIES IN LANDFILL



Note: Tons per day figure assumes that the waste has the same density as water.

Source: Reference 5.

10 TPD, 100 TPD, 300 TPD, and 700 TPD. Since there is an apparent consensus that incremental economies of scale are quite small at sites larger than 300 TPD, it was decided through discussion with the Project Officer to eliminate the largest of these models. The other three models adequately demonstrate the range of unit compliance costs at small, medium and large sites. At the same time, they were compatible with models used in the earlier study.

IV. DEVELOPMENT OF BASELINE COST DATA FOR EXISTING FACILITIES

A variety of references provide general baseline data for capital and operating and maintenance expenses for sanitary landfills. Several of these sources graphically portray this information in a cost per ton vs. daily waste tonnage chart. To estimate current landfill costs, a composite graphical approach was utilized. To accomplish this, the graphical data presented in References 2, 3, 7 and 8 were updated to 1977 dollars. Figure 5 presents the updated disposal costs per ton. For two of these studies an average modal cost curve was assumed midway between the upper and lower bounds indicated in the original reference. Appendix A presents each of the original charts. Figure 6 presents the composite curve. Data points for approximately two dozen case studies are also indicated in Figure 6 to demonstrate potential variability of costs due to site-specific conditions and variability of existing operations. Appendix B presents more specific data on the case studies.

As indicated, current disposal costs (including capital and operating expenses) range from approximately $2.00 to $12.00 per ton. Disposal costs at ten ton per day sites average $11.15 per ton ($12.29 per metric ton). One hundred ton per day sites exhibit economy of scale effects, with disposal costs averaging $6.65 per ton ($7.33 per metric ton). Similarly, three hundred ton per day sites average approximately $3.95 per ton ($4.35 per metric ton). Approximately 20 to 30 per cent of these costs represent design and construction expenses, with the remaining 70 to 80 per cent representing operating expenditures.

FIGURE 5

CURRENT SANITARY LANDFILL COSTS
(0–1000 TONS PER DAY)

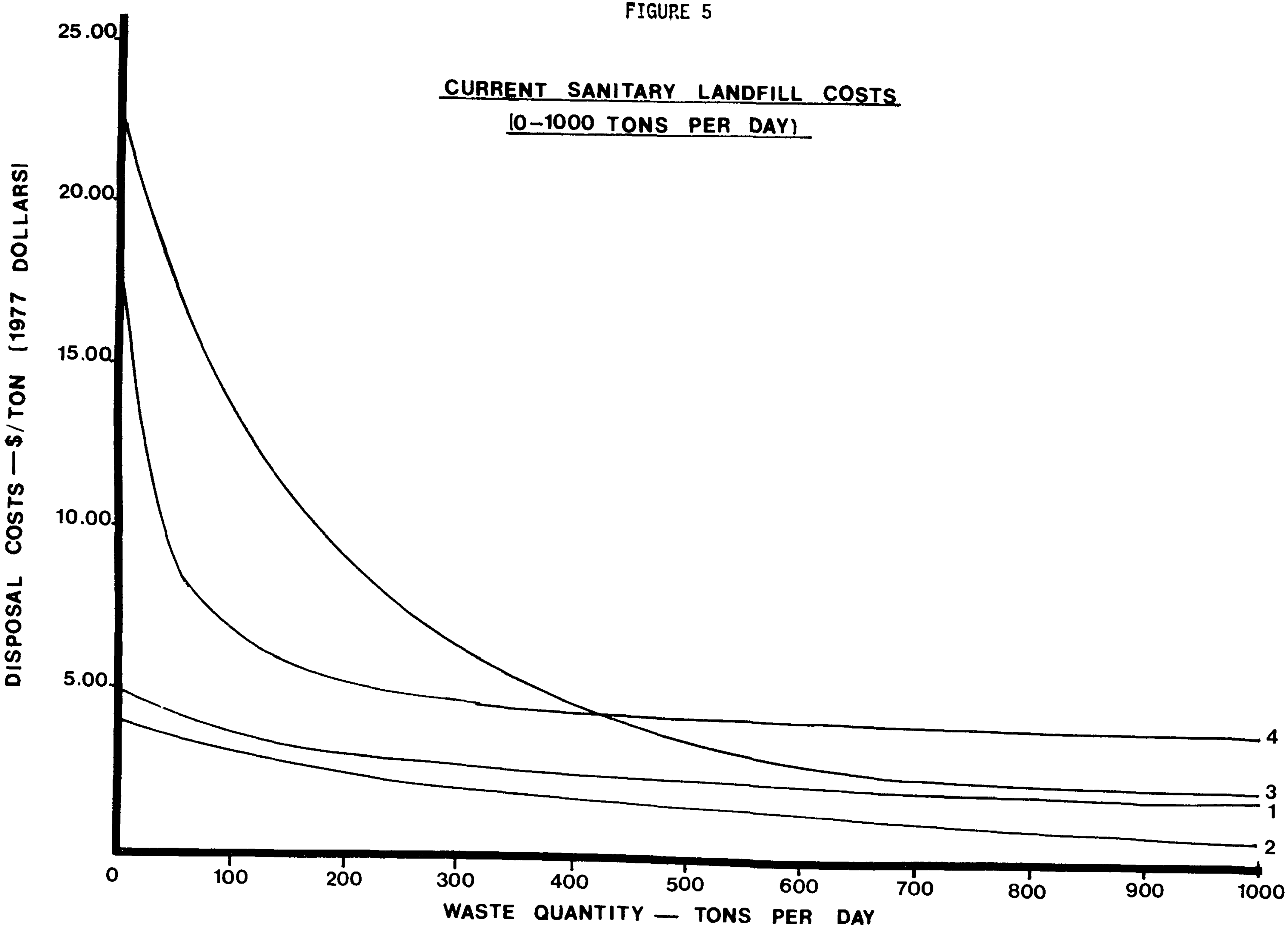
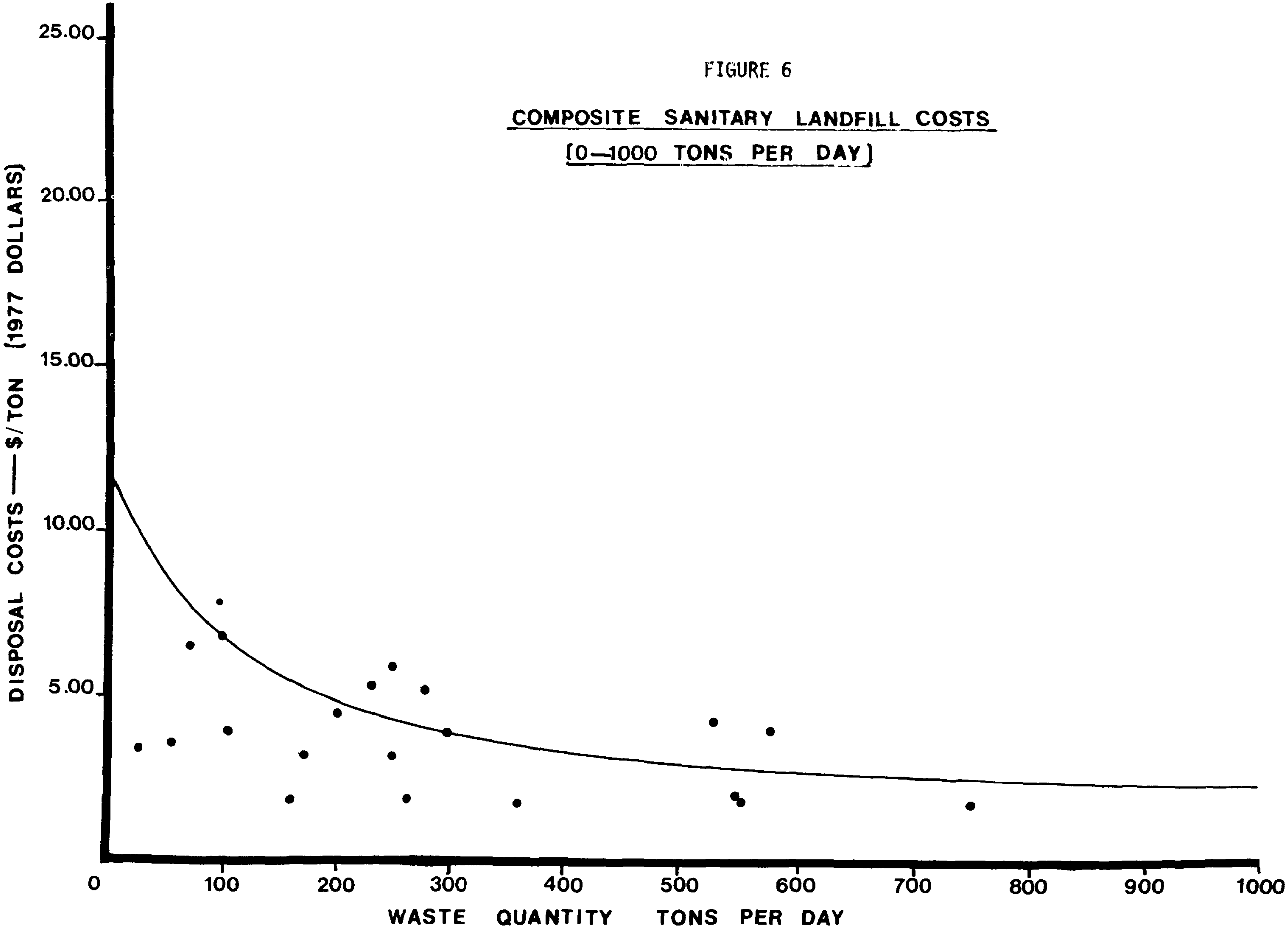


FIGURE 6

COMPOSITE SANITARY LANDFILL COSTS

(0—1000 TONS PER DAY)



V. IMPACT OF SECTION 1008 GUIDELINES ON COSTS

A. Recommended Technologies and Alternatives

The following sections summarize the alternate technologies and approaches as recommended by the Guidelines.

1. Site Selection. Section 241.200 of the Guidelines recommends avoidance of environmentally sensitive areas and areas requiring complex engineering solutions, such as locations traversed by pipes. Also recommended for incorporation in the site selection process are evaluations of the character and availability of on-site soil, potential socio-economic effects of the facility, and cost estimates, taking into account future uses of the site. The recommendations of this section are logical and should be undertaken prior to the design of any solid waste landfill.

There are no alternative procedures suggested within the text of the Guidelines. There are, however, provisions for proceeding with a feasibility assessment for the siting of a disposal facility in an environmentally sensitive area. The Guidelines do not foreclose the possibility of siting a landfill in such an area, but rather suggest that the level of study effort required in the pre-design phase should be notably greater than that required for siting a facility in a non-sensitive area.

2. Design. The Guidelines recommend that the following factors be determined in designing a landfill:

- types and quantities of waste
- current and projected ground water use
- background water quality
- direction and rate of ground water flow
- depth to water table
- potential interactions with ground and surface water
- site geology
- hydraulic conditions and soil renovative capacity
- quality, quantity, source and seasonal variation of surface water
- 100-year flood plain
- water balance
- initial and final topography
- land use and zoning

The final design, taking into consideration site-specific conditions, should provide a level of environmental protection that is compatible with the proposed Criteria and Guidelines. No specific technical alternatives are presented in this sections.

3. Leachate Control. This section of the Guidelines identifies three basic alternatives for leachate control, which may be used individually or in combination:

- control of leachate production
- control of the escape of leachate
- control of the impact of leachate on the environment.

Specific technologies that are recommended in the Guidelines, and that may be used singly or in combination, include the following:

- construction of surface runoff diversion structures to divert all of the water from a 24-hour, 25-year storm event

- construction of a dike around fills within a 100-year floodplain

- grading of fill to prevent standing surface water, but at slopes less than 30% to avoid erosion

- use of cover material with low permeability and shrink/swell potential

- vegetation of final cover

- protection of underlying ground water by liner installation (12-inch impermeable soil or 20 mil membrane)

- removal and treatment of leachate.

The leachate control section of the Guidelines also suggests that the bottom of the landfill should be substantially above the seasonal high water table and that there should be no hydraulic connection between the fill and surface water. These provisions would normally be considered in the design phase.

The selection of alternative technologies for leachate control, if required, would be performed on a case-by-case basis.

4. Gas Control. Like leachate control, gas control can be accomplished through the application of one or more alternative techniques:

- minimization of the production of gases

- control of escape of gases

- minimization of migration of gases into soils surrounding the site.

Selection of procedures for gas control should consider the waste type(s) being accepted for landfilling, and should be developed in conjunction with the leachate control plan. For example, the complete encapsulation of a site should be coupled with a venting system where gases may accumulate.

The Guidelines identify two categories of gas control technology: passive barriers and active barriers. The pros and cons for each type of barrier are also discussed. Passive barriers would consist of:

- vertical cut-off walls (clay or artificial materials) extending downward to an impervious layer below the fill

- venting system (gravel-filled trenches, perforated pipes or both)

- gravel-filled trenches in combination with cutoff walls.

Active barriers include:

- induced exhaust wells
- induced exhaust trenches
- induced recharge trenches

As in the case of leachate control, the design, construction and operation of a gas control system if required, would be considered on a case-by-case basis.

5. Runoff Control. Recommended procedures to control runoff include diversion of surface water, grading, construction of stilling basins, final cover and vegetation of final cover. Since runoff control is important to leachate control, as well as to the direct protection of surface water bodies, runoff control technologies may be incorporated as part of the leachate control approach for many sites.

6. Operation. Specific operating technologies recommended in the Guidelines include the following:

- pre-treatment of wastes (e.g., de-watering), as required;

- application of 6 inches of soil or clay daily

- application of final cover (6 inches of impermeable clay and at least 18 inches of topsoil)

- landfill compaction

- use of balers, shredders or stationary compactors at or before delivery;

- provision of safety devices and recommended practices

- eradication of vectors, if they become established

- initiation of long-term maintenance program.

7. Monitoring. The scope, frequency and duration of an environmental monitoring program is largely contingent upon the site characteristics identified during baseline studies undertaken during the design phase.

However, in general, the Guidelines recommend:

- monitoring of ground water, at least annually, at all landfills which have the potential for discharge to drinking water supply aquifers;

- monitoring of enclosed structures at landfill facilities to detect gases;

- monitoring of soils to detect gas migration.

8. Summary. It is important to emphasize that the mix of technologies to be employed in the location, design, construction, operation and maintenance of landfill disposal facilities meeting the provisions of the Section 4004 Criteria would differ widely from case-to-case. Similarly, unit costs for individual technologies would differ widely, reflecting such factors as availability of raw materials and other resources. Later sections of this report provide: (a) estimated unit costs for the specific technologies identified in the Guidelines, and the sources for those cost estimates; and (b) assumptions applied in aggregating these costs to the national level, and the rationale for those assumptions.

B. Development of Unit Costs for Upgrading Technologies

To determine the economic effects due to implementation of the Guidelines, unit costs for required upgrading technologies were developed. These upgrading technologies are identified in Table 2. The table identifies assumed technologies for waste processing, gas control, leachate control, surface runoff, and monitoring at four types of landfills (municipal, industrial, construction, and pollution control residue). The table also considers differences in current and recommended practices at sites considered to be environmentally sensitive. The term "environmentally sensitive" is defined at length in Section VI. C. of this report. It includes wetlands, floodplains, permafrost areas, critical habitats of endangered species, and recharge zones of sole source aquifers.

Table 2 identifies a set of assumptions that must be superimposed on an assessment of existing practices at landfills in order to derive aggregated national costs of implementing the proposed Guidelines. This set of assumptions is largely judgmental and identifies those technologies (or practices) which may be required in facility upgrading in order to attain or maintain status as a sanitary landfill. The basic rationale behind these judgements is as follows:

TABLE 2

EXISTING TECHNOLOGY LEVELS AND ASSUMED UPGRADING TECHNOLOGY

	Assumed Current Technology Levels	Assumed Upgrading Technologies
	MUNICIPAL LANDFILLS (in environmentally sensitive areas)	
Waste Processing:	None	-
Gas Control:	None	Vertical impermeable barriers
Leachate Control:	Clay liner Daily cover	Impermeable cover Leachate collection & treatment (new facilities only)
Surface Runoff:	Ditching	Ponding Dike construction
Monitoring:	None	Gas & leachate
	MUNICIPAL LANDFILLS (in non-sensitive areas)	
Waste Processing:	None	-
Gas Control:	None	Vertical impermeable barriers
Leachate Control:	Permeable cover	Impermeable cover
Surface Runoff:	Ditching	None
Monitoring:	None	Gas & leachate
	INDUSTRIAL LANDFILLS (in environmentally sensitive areas)	
Waste Processing:	None	-
Gas Control:	None	None
Leachate Control:	Ingrequent permeable cover	Impermeable cover Liners (new facilities only) Leachate collection & treatment (new facilities only)

TABLE 2
(continued)

Assumed Current Technology Levels		Assumed Upgrading Technologies
	INDUSTRIAL LANDFILLS (in environmentally sensitive areas) (continued)	
Surface Runoff:	None	Ponding
		Dike construction
Monitoring:	None	Leachate
	INDUSTRIAL LANDFILLS (in non-sensitive areas)	
Waste Processing:	None	-
Gas Control:	None	None
Leachate Control:	Infrequent permeable cover	Impermeable cover
		Liners (new facilities only)
Surface Runoff:	Ditching	Ponding
Monitoring:	None	Leachate
	CONSTRUCTION LANDFILLS (in environmentally sensitive areas)	
Waste Processing:	None	-
Gas Control:	None	None
Leachate Control:	None	Impermeable cover
Surface Runoff:	Ditching	Ponding
		Dike construction
Monitoring:	None	Leachate

TABLE 2
(continued)

Assumed Current Technology Levels		Assumed Upgrading Technologies
	CONSTRUCTION LANDFILLS (in non-sensitive areas)	
Waste Processing:	None	–
Gas Control:	None	None
Leachate Control:	None	None
Surface Runoff:	None	None
Monitoring:	None	None
	POLLUTION CONTROL RESIDUE LANDFILLS (in environmentally sensitive areas)	
Waste Processing:	None	-
Gas Control:	None	None
Leachate Control:	None	Impermeable cover Liner (new facilities only) Leachate collection & treatment (new facilities only)
Surface Runoff:	Ditching	Ponding Dike construction
Monitoring:	None	Leachate
	POLLUTION CONTROL RESIDUE LANDFILLS (in non-sensitive areas)	
Waste Processing:	None	-
Gas Control:	None	None
Leachate Control:	None	Impermeable cover Liner (new facilities only)
Surface Runoff:	Ditching	None
Monitoring:	None	Leachate

1. Landfill liners cannot be retrofitted. Therefore, existing unlined facilities which are adversely affecting ground water quality would be considered open dumps and closed under the authorities of Section 4004. Existing unlined facilities which are not adversely affecting ground water quality will require only minimal upgrading to assure continued protection of ground water resources.

2. New facilities will need liners plus leachate collection and treatment if they are located in sensitive areas since these areas are generally "wet" and are concentrated in the areas of the country where annual preciptation is relatively high. The exception is landfills to be used for disposal of construction wastes, which are inert and generally pose less of a leachate problem than that associated with other wastes.

3. Liners which would allow slow migration of leachate to the environment may be necessary in non-sensitive areas. However, due to the lower precipitation in these areas, leachate collection and treatment would not generally be necessary.

4. Municipal wastes are the only general category of wastes that commonly generates gases in quantities that require some control.* Alternative technologies for gas control range from simple venting systems to more complex (and costly) vertical barriers installed in combination with gravel trenches. The average fill would probably need a technology somewhere between these extremes, such as the installation of a vertical barrier or gravel trench alone. The unit cost of either would be similar to the other.

5. Most existing landfills, regardless of location, waste type and other factors have some provisions for diverting surface runoff to reduce problems in actual operation of the facility, if not for environmental protection. Substantial importance is placed on runoff control in the Guidelines. Section 241.204 deals exclusively with runoff control and Sections 241.201 (design) and 241.202 (leachate control) also incorporate recommendations for runoff control. This is also one of the few areas in which the Guidelines provide quantitative recommendations (e.g., diversion of water from a 24-hour/25-year storm event). In view of the emphasis placed on runoff control, it is considered that all fills in sensitive (wet) areas will require upgrading of current practices.

6. Monitoring is necessary to assure continued environmental protection and to measure the effectiveness of control technologies in sensitive areas. Leachate may be generated by any fill type in a wet area. Therefore, groundwater monitoring should be instituted at all facilities in sensitive areas.

7. Safety precautions record-keeping, access, and vector control are generally practiced at all landfills which would meet Section 4004 criteria. Any upgrading of such practices and consequent costs would be minimal. Therefore these items are excluded from the table.

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* Some other wastes may generate gas (e.g., the readily decomposable wastes of the food processing industry, and POTW sludges, if only partly digested). In general, however, the other categories of waste can be assumed not to be candidates for gas control.

Table 3 presents upgrading costs per ton of disposal for the identified upgrading technologies. The identified upgrading technologies represent most commonly used state-of-the-art engineering practices for achieving the objectives of the Guidelines. Table 4 presents additional unit cost estimates for alternate control technologies. The alternate technologies represent methods of compliance with the Guidelines which are either in common use already, or technologies that, when compared to those listed in Table 3, are less desirable, are more costly, do not represent current state-of-the-art, or are applicable to fewer sites. It must be emphasized, however, that the final choice of technologies will be site-specific. The Table 3 technologies simply represent those which we have assumed will be the most common methods chosen to achieve compliance.

Cost data were developed via an extensive literature search. Where data were insufficient, an engineering estimate was used. In general, total construction and operating costs were estimated for each upgrading technology and unit costs (per ton) were developed by dividing the present value of total cost by the total expected waste tonnage over an estimated ten year site life. Appendix B presents case examples and calculation assumptions for each of the upgrading technologies.

TABLE 3

UPGRADING TECHNOLOGY COSTS

Technology	10 TPD		100 TPD		300 TPD	
	Cost/Ton	(Cost/Metric Ton)	Cost/Ton	(Cost/Metric Ton)	Cost/Ton	(Cost/Metric Ton)
Vertical Impermeable Barrier	$1.30	($1.43)	$0.30	($0.33)	$0.15	($0.17)
Dike Construction	2.40	(2.65)	0.55	(0.61)	0.30	(0.33)
Impermeable Daily Cover[a] (on-site source)	0.75	(0.83)	0.35	(0.39)	0.25	(0.28)
Impermeable Daily Cover[a] (off-site source)	5.30	(5.84)	2.65	(2.92)	1.75	(1.93)
Ponding	0.10	(0.11)	0.05	(0.06)	0.04	(0.04)
Gas Monitoring	0.15	(0.17)	0.03	(0.03)	0.01	(0.01)
Groundwater Water Quality Monitoring	0.60	(0.66)	0.10	(0.11)	0.05	(0.06)
Natural Clay Liner (Off-site source)	3.20	(3.53)	1.50	(1.65)	1.35	(1.49)
Leachate Collection Facilities	0.95	(1.05)	0.40	(0.44)	0.30	(0.33)
Leachate Monitoring, Removal and Treatment	5.80	(6.39)	1.10	(1.21)	0.50	(0.55)

a. "Impermeable" refers to a cover type with relatively low permeability i.e., 1×10^{-7} cm/sec.

Source: Appendix B.

TABLE 4

ALTERNATE UPGRADING TECHNOLOGY COSTS

Technology	10 TPD Cost/Ton	10 TPD (Cost/Metric Ton)	100 TPD Cost/Ton	100 TPD (Cost/Metric Ton)	300 TPD Cost/Ton	300 TPD (Cost/Metric Ton)
Shredding	-	-	-	-	$7.00	($7.72)
Baling	-	-	-	-	5.00	(5.51)
Permeable Daily Cover (on-site source)	$0.60	($0.66)	$0.30	($0.33)	0.20	(0.22)
Permeable Daily Cover (off-site source)	1.90	(2.09)	0.95	(1.05)	0.65	(0.72)
Vertical Pipe Vents	0.90	(0.99)	0.45	(0.50)	0.40	(0.44)
Perimeter Gravel Trenches	1.60	(1.76)	0.35	(0.39)	0.20	(0.22)
Gas Collection	2.50	(2.76)	0.55	(0.61)	0.30	(0.33)
Synthetic Liner	4.00	(4.41)	1.90	(2.09)	1.65	(1.82)
Leachate Recycling (not including collection)	0.45	(0.50)	0.10	(0.11)	0.05	(0.06)
Ditching	0.15	(0.17)	0.04	(0.04)	0.02	(0.02)
Final Impermeable Cover[a] (on-site source)	0.45	(0.50)	0.20	(0.22)	0.20	(0.22)
Final Impermeable Cover[a] (off-site source)	3.20	(3.53)	1.50	(1.65)	1.35	(1.49)

a. "Impermeable" refers to a cover type with relatively low permeability, i.e., 1×10^{-7} cm/sec.

TABLE 4 (Concluded)

	10 TPD		100 TPD		300 TPD	
Technology	Cost/Ton	(Cost/Metric Ton)	Cost/Ton	(Cost/Metric Ton)	Cost/Ton	(Cost/Metric Ton)
Final Permeable Cover (on-site source)	$0.40	($0.44)	$0.15	($0.17)	$0.15	($0.17)
Final Permeable Cover (off-site source)	1.30	(1.43)	0.60	(0.66)	0.55	(0.61)
Revegetation	0.25	(0.28)	0.10	(0.11)	0.10	(0.11)
Fire Control	0.04	(0.04)	0.01	(0.01)	0.01	(0.01)
Access Control	0.90	(0.99)	0.20	(0.22)	0.10	(0.11)
Litter Control	0.05	(0.06)	0.01	(0.01)	0.01	(0.01)
Compaction	1.90	(2.09)	0.20	(0.22)	0.05	(0.06)

Source: Appendix B

VI. AGGREGATE COST OF LANDFILL GUIDELINES

A. Approach

In order to project the potential nationwide costs of implementing the Section 1008 Guidelines, it was necessary to make a number of broad assumptions based on the finite amount of information currently available. In the ensuing discussion, the information base and consequent rationale for each assumption have been identified in order to allow the reader to recognize the limitations of the data, and the categorizations and aggregation processes that were applied to those data.

It was not the intent of this study to provide a detailed economic assessment in which every case situation could be fully evaluated. Such an approach would neither be feasible nor appropriate, given the flexibility inherent in the Guidelines. The results of the aggregate cost evaluation contained herein should, thus, be viewed within the context of national scale, and with an appreciation of the limitations in sensitivity of any analysis conducted at this scale.

The enforceability and applicability of the Guidelines are a primary concern in projecting the cost of compliance. There will be no Federal enforcement of the Guidelines; however, certain recipients of Federal assistance under the provisions of RCRA must demonstrate compliance. Therefore, it is assumed that all States will enact programs requiring the adoption of procedures identified in the Guidelines. The cost of compliance would thus be State-induced.

The Guidelines are applicable to all facilities for the landfill disposal of non-hazardous solid wastes. As indicated earlier, the nearterm cost effects of the Guidelines will be incurred by existing facilities which could feasibly upgrade operational practices in order to achieve, or remain within, the Criteria for classification as sanitary landfills. Costs will also be incurred for siting, design and operation of new facilities. Finally, costs will be incurred by existing and new sanitary landfills as they undergo closure.

The general approach to assessing costs of upgrading existing facilities involves multiplying incremental cost increases associated with upgrading existing practices by the number of facilities which may be required, under State programs, to undertake various upgrading processes. Baseline and upgrading costs have been estimated in Section IV and V of this report.

The potential extent of upgrading and costs thereof, are a function of: (1) facility size; (2) waste type; (3) site characteristics; and (4) the extent of current practice of the technologies identified in the Guidelines.

1. Facility Size. Representative facility sizes are 10, 100 and 300 TPD landfills, as indicated earlier. These models are intended to represent facilities in the following ranges: 0-50 TPD, 50-200 TPD, and greater than 200 TPD.

2. Waste Type. Waste types include five broad categories: agricultural, municipal, industrial, construction and pollution control residues.

3. Site Characteristics. Site characteristics, for purposes of generalization, include environmentally sensitive areas including floodplains, wetlands, areas underlain by aquifers, and permafrost areas. All other areas are placed in the "non-sensitive" category.

4. Extent of Current Practice of the Recommended Technologies. The existing practice of Guidelines-level technologies can be broadly sorted by waste type and site characteristics. Table 2 (included in Section V) was based on an assessment of available literature and provided a checklist of environmental protection technologies currently employed by a "typical" landfill for a given type of waste in environmentally sensitive and non-sensitive areas. The indicated technologies are meant to represent the most commonly utilized technologies at the national level, and are not meant to represent the complete set of technologies in use at the various types of site. Utilizing this table, national upgrading costs can be aggregated by multiplying unit upgrading costs by the prevalence of landfills in each broad category.

It is important to point out that where existing State programs require the use of technologies equivalent to, or more stringent than those recommended in the Guidelines, upgrading costs would be attributable to those existing programs and not to State enforcement of the new Federal Guidelines. State solid waste management programs are currently being examined by another EPA contractor. That portion of total upgrading costs which may be attributable to existing programs should be subtracted from the total cost estimated here.

B. Estimating the Prevalence of Landfill Types

1. Agricultural Landfills. Agricultural wastes include wastes generated from raising and harvesting animals, grains, fruits and vegetables, and other field crops. They exclude food processing wastes which are considered industrial. Several studies have produced data on agricultural waste generation. However, a survey of EPA and other solid waste management literature and inquiries at the USDA's Soil Conservation Service produced no specific quantitative data on agricultural waste disposal practices. General information on current disposal practices indicates that essentially no single-purpose agricultural landfills exist, on-site or off-site. The large majority of agricultural waste is returned to the land on the farmsite. Manure and other livestock solid wastes from feedlot and dairy operations are normally

collected and stockpiled on-site until they can be spread on and disked into adjacent acreage. Likewise, as Table 5 indicates, most crop residues are shredded or chopped and disked or plowed back into the topsoil. Some crop residues are removed for burning and composting. (References 8, 9).

The land storage and disposal of all agricultural wastes can pose serious environmental problems, particularly with regard to water pollution. However, EPA's "Solid Waste Disposal Facilities Proposed Classification Criteria" specifically exclude from coverage solid waste storage facilities and agricultural wastes returned to the land. The disposal of pesticide wastes, which also can pose environmental problems is addressed by Subtitle C of RCRA, and, therefore is also not covered by the proposed Guidelines. On-going research, demonstration, and development of agricultural waste disposal technology also indicates that the number of future agricultural landfills will be insignificant (Reference 8). As a result of these considerations, agricultural landfills are not considered further in this report.

2. Municipal Landfills. Municipal landfills primarily handle municipal wastes, but may be privately or publicly owned or operated. These sites may also accept other types of waste, such as non-hazardous industrial wastes.

To determine the total number of municipal landfills, Fred C. Hart Associates conducted a literature search followed by telephone inquiries to update the 1977 Waste Age survey of landfills (Reference 1):

a. The literature/data base amassed by the project team was examined. This included the responses to an Office of Solid Waste (EPA Headquarters) letter, dated June 18, 1978, to the EPA Regional offices. This letter requested the Regions to secure from their respective States any information they might have that could be used to upgrade the Waste Age data base. The replies to this request were reviewed.

b. EPA Regional representatives and several State Solid Waste Rrepresentatives were contacted by telephone. Resource and time constraints, however, precluded contact with all fifty States. Therefore, only ten States, (Pennsylvania, Kentucky, New Jersey, Oregon, New York, Wisconsin, Illinois, Alabama, Washington, and California) were contacted. A criterion utilized in the selection of these particular States was the significant interest they had displayed with respect to the earlier "Criteria" EIS (Reference 6). In addition, Mr. Richard W. Eldredge, Technical Editor of Waste Age , who oversaw the Waste Age survey, was contacted.

TABLE 5

CROP RESIDUES AS A WASTE-MANAGEMENT PROBLEM

Crop	Typical yield tons/acre	Crop residue to be managed tons/acre	Nature of the residue, typical management problem
Field crops like canning tomatoes, sugar beets, potatoes	20 (wet weight)	30 (wet weight) to as little as 3 tons dry solids)	Cull fruit and all material (stems, leaves, roots) disked back into topsoil
Field crops harvested dry, like soybeans, safflower cotton	1.5	1.6	Dried plant parts; shredded and disked into topsoil
Truck crops (market vegetables)	5-30	1.5:1 to 4:1 (crop residue)	Green parts not harvested, disked back, or removed for composting
Orchard fruit	5-15 (fresh weight)	2 (prunings only)	Prunings-burned; leaves-compost on surface; cull fruit-also compost
Rice, wheat, other grains	3.0	3.5	Straw, disked or burned
Field corn	4.0	5.3	Dried stalks, usually chopped and plowed in
Cotton	0.5	1.5	Dried total plant, shredded, plowed into topsoil.
Sugar cane	60 (wet cane)	40 (burned-off)	Leaves burned before harvest, cane harvested and squeezed, then the residual (bagasse) burned at mill, field trash chopped and disked

Source: Reference 8.

The data collection efforts outlined did not significantly upgrade the data provided by the Waste Age survey, although in some cases more reliable, up-to-date data were substituted for that of Waste Age. The data cover primarily municipal landfills, but in a small number of cases it was impossible to exclude data on industrial landfills.

Based on these data collection efforts, Fred C. Hart Associates counted 14,689 municipal landfills nationwide. This figure falls approximately midway between the Waste Age 1976 estimate of 15,821 landfills and its 1977 figure of 14,126 municipal landfills. Table 6 represents the municipal landfill prevalence data.

3. Industrial Landfills. To date, the disposal practices of industries have received relatively little public attention. Consequently, very little data quantifying their waste generation and disposal practices are available. Since disposal problems are handled by the individual firms, the methods of disposal are as varied as the industries themselves. In addition, wastes are often disposed of on-site, making assessment of the disposal process more difficult to quantify. To provide a basis for aggregate cost assessment, four major questions are addressed: (1) how much industrial waste is generated; (2) what is its form and how is it disposed; (3) is it disposed on-site or off-site; and (4) what are the general disposal site characteristics?

Most of the recent studies that were examined defined industry coverage using the major groupings of the Standard Industrial Classification (SIC) Code System (see Table 7). In general, the manufacturing division represents those industries that would produce what is normally classified as industrial waste. Estimates of solid waste production per industry are usually presented for the initial two digits of the SIC Code, (SIC Groups 20 to 39). In order to remain consistent with existing studies, this study also defines industries using the SIC Code groupings.

To date, four types of waste generation data have been assembled from investigations conducted by various authorities: community average per capita industrial waste contributions; average waste generation in tonnage per employee per year (TEY); waste generation rates reported for specific points; and waste generation data for industries determined to be potential hazardous waste generators. Although none of these estimating measures is ideal, the estimates of projections of tons of waste per employee per year (TEY) provide the most reasonable method of relating waste production to the manufacture of products or commodities. The TEY method is used in this investigation to determine current industrial solid waste generation rates.

In an extensive survey of solid waste management literature, three sources were found containing TEY coefficients for each of the 20 SIC manufacturing industries (References 7, 8, 11). Tables 8 through 12 provide a range of estimates for industrial solid waste generation. The remaining tables of TEY coefficients or the equivalents (multipliers, annual waste volume per employee, or waste production rate), reveal a

TABLE 6

PREVALENCE OF MUNICIPAL LANDFILLS BY LOCATION, 1978

STATES	MUNICIPAL SITES
Region #1	
Connecticut	164
Maine	387
Massachusetts	320
New Hampshire	128
Rhode Island	25
Vermont	98
Sub-Total:	1,122
Region #2	
New Jersey	296
New York	635
Puerto Rico and Virgin Islands	5
Sub-Total:	936
Region #3	
Delaware	25
Maryland	67
Pennsylvania	365
Virginia	223
West Virginia	250
Sub-Total:	930
Region #4	
Alabama	132
Florida	330
Georgia	480
Kentucky	140(a)
Mississippi	N/A
North Carolina	170
South Carolina	211
Tennessee	148
Sub-Total:	1,611
Region #5	
Illinois	300
Indiana	149
Michigan	572
Ohio	250
Minnesota	405
Wisconsin	1,297
Sub-Total:	2,973

TABLE 6 (continued)

PREVALENCE OF MUNICIPAL LANDFILLS BY LOCATION, 1978

STATES		MUNICIPAL SITES
Region #6		
Arkansas		460
Louisiana		365
New Mexico		600
Texas		1,093(b)
Oklahoma		188
	Sub-Total:	2,706
Region #7		
Iowa		322(c)
Kansas		341(d)
Missouri		165(e)
Nebraska		449
	Sub-Total:	1,277
Region #8		
Colorado		220
Montana		227
North Dakota		135
South Dakota		300
Utah		174
Wyoming		150
	Sub-Total:	1,206
Region #9		
Arizona		187
California		605
Hawaii		35
Nevada		113
	Sub-Total:	890
Region #10		
Alaska		350
Idaho		120
Oregon		158
Washington		410
	Sub-Total:	1,038
		======
United States Total:		14,689

TABLE 6 (continued)

a. On-site industrial sites included.

b. Includes fly-ash disposal sites.

c. Includes 225 sites currently in process of being closed.

d. Includes 218 sites currently in process of being closed.

e. Includes 48 sites currently in process of being closed.

Source: Fred C. Hart Associates, Inc.

TABLE 7

STANDARD INDUSTRIAL CLASSIFICATION CODES FOR MANUFACTURING INDUSTRIES

Major Group 20.	Food and kindred products
Major Group 21.	Tobacco manufactures
Major Group 22.	Textile mill products
Major Group 23.	Apparel and other finished products made from fabrics and similar materials
Major Group 24.	Lumber and wood products, except furniture
Major Group 25.	Furniture and fixtures
Major Group 26.	Paper and allied products
Major Group 27.	Printing, publishing, and allied industries
Major Group 28.	Chemicals and allied products
Major Group 29.	Petroleum refining and related industries
Major Group 30.	Rubber and miscellaneous plastics products
Major Group 31.	Leather and leather products
Major Group 32.	Stone, clay, glass, and concrete products
Major Group 33.	Primary metal industries
Major Group 34.	Fabricated metal products, except machinery and transportation equipment
Major Group 35.	Machinery, except electrical
Major Group 36.	Electrical and electronic machinery, equipment, and supplies
Major Group 37.	Transportation equipment
Major Group 38.	Measuring, analyzing, and controlling instruments; photographic, medical and optical goods; watches and clocks
Major Group 39.	Miscellaneous manufacturing industries

Source: Reference 38

TABLE 8

WASTE GENERATION BY MANUFACTURING INDUSTRIES IN THE UNITED STATES
(in Tons per Employee per Year, TEY)

SIC Code	Industry	Data Points	Average TEY	Standard deviation	95% Confidence Limits
20	Food Processing				
	Solids	31	7.949	10.451	1.877
	Liquids	11	0.001	0.036	0.025
	Sludges	1	0.400	-	-
22	Textile-mill products				
	Solids	16	2.160	1.854	0.464
	Liquids	15	0.107	0.233	0.135
	Sludges	1	1.508	-	-
23	Apparel				
	Solids	20	2.192	6.197	1.461
	Liquids	0	-	-	-
	Sludges	0	-	-	-
24	Wood products				
	Solids	10	8.531	7.648	2.419
	Liquids	0	-	-	-
	Sludges	0	-	-	-
25	Furniture				
	Solids	7	2.783	3.578	1.352
	Liquids	0	-	-	-
	Sludges	0	-	-	-
26	Paper and allied products				
	Solids	21	3.987	8.267	1.804
	Liquids	9	0.010	0.026	0.013
	Sludges	8	0.012	0.073	0.052
27	Printing, publishing				
	Solids	24	5.835	5.958	1.242
	Liquids	12	0.013	0.000	0.000
	Sludges	0	-	-	-
28	Chemicals and allied products				
	Solids	39	8.862	7.434	1.191
	Liquids	23	2.599	4.504	1.593
	Sludges	28	2.554	5.944	2.102
29	Petroleum				
	Solids	4	1.594	2.751	1.376
	Liquids	1	0.041	-	-
	Sludges	1	0.003	-	-
30	Rubber, plastics				
	Solids	13	9.835	9.163	2.541
	Liquids	8	0.072	0.100	0.071
	Sludges	1	0.084	-	-

TABLE 8 (continued)

WASTE GENERATION BY MANUFACTURING INDUSTRIES IN THE UNITED STATES
(in Tons per Employee per Year, TEY)

SIC Code	Industry	Data Points	Average TEY	Standard deviation	95% Confidence Limits
31	Leather				
	Solids	2	8.989	6.986	4.941
	Liquids	0	-	-	-
	Sludges	0	-	-	-
32	Stone, clay				
	Solids	18	6.412	15.300	3.606
	Liquids	1	0.005	-	-
	Sludges	7	0.011	0.024	0.017
33	Primary metals				
	Solids	13	3.184	8.210	2.277
	Liquids	5	1.397	12.067	8.534
	Sludges	1	0.423	-	-
34	Fabricated metals				
	Solids	42	6.832	9.180	1.416
	Liquids	22	0.014	0.024	0.009
	Sludges	23	0.055	2.268	1.307
35	Non-electrical machinery				
	Solids	47	3.89	1.448	0.211
	Liquids	21	0.258	0.137	0.052
	Sludges	18	2.453	2.361	1.363
36	Electrical machinery				
	Solids	21	2.941	7.009	1.529
	Liquids	15	0.172	0.077	0.039
	Sludges	0	-	-	-
37	Transportation equipment				
	Solids	8	2.562	4.097	1.449
	Liquids	4	0.319	0.183	0.129
	Sludges	6	0.191	0.124	0.880
38	Professional and Sci. instruments				
	Solids	7	1.769	2.061	0.779
	Liquids	5	0.074	0.088	0.062
	Sludges	0	-	-	-
39	Miscellaneous manufacturing				
	Solids	25	1.603	1.883	0.377
	Liquids	0	-	-	-
	Sludges	0	-	-	-

Source: Reference 8

TABLE 9

WASTE GENERATION BY MANUFACTURING INDUSTRIES IN SAN JOSE, CALIFORNIA

Industry	Employment[a] July 1967	Multipliers[b] ton/ employee/ yr	Wastes ton/yr
Nondurables			
Food products			
Seasonal foods	2,200	5.56570	12,245
Other foods	11,482	4.81855	55,304
Total food products	13,682	-	-
Paper, printing and publishing	6,478	12.87060	83,376
Chemicals	1,900	8.21075	15,600
Other nondurables			
Textiles and apparel	2,193	.52575	1,153
Rubber and plastics	1,835	1.54810	2,841
Leather	355	2.49365	885
Total other nondurables	4,383		
Durables			
Stone, clay, glass, and concrete	3,708	18.11425	67,168
Primary and fabricated metals	15,250	6.7300	102,632
Electrical and nonelectric machinery	12,478	3.58040	44,676
Other durables			
Lumber and wood products	1,033	21.68805	22,404
Furniture and fixtures	1,562	20.15545	31,483
Transportation equipment	2,768	3.39330	9,393
Instruments	915	2.51700	2,303
Total other durables	6,278		
Other manufacturing	2,500	2.49365	6,234
Total manufacturing employment	66,657		457,697

[a] Basic employment data are from the State of California Department of Employment Community Labor Market Survey. Data were adjusted to exclude Union City which is not in the study area. Employment in the categories "Other Durables" and "Other Nondurables" was distributed to the relevant SIC groups by using the same proportions as existed in the 1965 employment data from ABAG.

[b] Multipliers for the manufacturing industries were developed and reported in Table VI. Comprehensive Studies of Solid Waste Management, Second Annual Report.

SOURCE: C.G. Golueke and P.H. McGauhey, Comprehensive Studies of Solid Wastes Management, Sanitary Engineering Research Laboratory, University of California, June 1970, p.53. (Reference 7)

TABLE 10

WASTE GENERATION BY LARGE FIRMS IN SAN JOSE, CALIFORNIA

Standard industrial classification	Employment[a]	Annual Wastes, vol. yd[3b]	Annual wastes per employee, yd[3b]
Ordnance and accessories	29.356	131.404	4.476
Canning and Preserving[d]	11.389	102.238	8.977
Other food processing	2.012	17.545	8.720
Tobacco	NA	NA	NA
Textiles	NA	NA	NA
Apparel	601	1.248	2.077
Lumber and Wood Products	NA	NA	NA
Furniture and fixtures	NA	NA	NA
Paper and Allied Products	250	9.360	37.440
Printing, publishing, and allied	968	7.020	7.252
Chemicals and allied	NA	NA	NA
Petroleum refining	NA	NA	NA
Rubber and plastics	481	9.069	18.854
Leather	NA	NA	NA
Stone, clay, glass, and concrete	1.258	6.617	5.260
Primary metals	NA	NA	NA
Fabricated metal products	3.565	47.078	13.206
Nonelectrical machinery	8.872	101.153	13.206
Electrical machinery	7.807	57.252	7.333
Transportation equipment	4.100	100.776	24.580
Instruments	NA	NA	NA
Miscellaneous manufacturing industries	NA	NA	NA

NA - not available

[a] Data on employment were obtained for those large firms which were surveyed and included in the wastes calculationfrom the research department of the Association of Metropolitan San Jose (Greater San Jose Chamber of Commerce).

[b] FMC report. Solid Waste Disposal System Analysis (Preliminary Report). Tables 10 and 11, 1968.

[c] Annual wastes, vol. yd^3/employment

d For canning and preserving, no individual firm data were available. The industry total developed for the country as a whole was divided by the total employment in the industry (especially tabulated) to arrive at the multiplier.

SOURCE: C.G. Goluke and P.11. McGauhey, Comprehensive Studies of Solid Wastes Management, Sanitary Engineering Research Laboratory, University of California January 1969, p.221.

Source: Reference 7.

TABLE 11

WASTE GENERATION BY SMALL FIRMS IN SAN JOSE, CALIFORNIA

Standard industrial classification	Weekly wastes, vol per firm, yd^{3}[a]	Annual wastes, vol per firm, yd^{3}[b]	Average employment per firm[c]	Annual waste, vol per employee, yd^{3}[d]
Ordnance and accessories	2.500	130.00	NA	NA
Canning and preserving	(Not surveyed)			
Other food processing	10.875	565.50	26.979	20.961
Tobacco		NA		
Textiles		NA		
Apparel	4.000	208.00	5.882	35.360
Lumber and wood products	16.083	836.33	17.247	48.492
Furniture and fixtures	23.000	1,196.00	13.767	86.877
Paper and allied products	44.650	2,321.80	35,479	65.442
Printing, publishing, and allied	6.448	335.29	13.289	25.230
Chemicals and allied	6.506	338.31	18.439	18.348
Petroleum refining	NA	NA	NA	NA
Rubber and plastics	5.275	274.30	9.596	28.583
Leather	NA	NA	NA	NA
Stone, clay, glass, and concrete	9.415	489.60	16.747	29.235
Primary metals	2.000	104.00	23.409	4.443
Fabricated metal products	5.284	274.75	12.951	21.214
Nonelectrical machinery	4.450	231.40	12.921	17.909
Electrical machinery	6.733	350.13	21.036	16.645
Transportation equipment	4.550	236.60	16.490	14.348
Instruments	3.600	187.20	20.933	8.943
Manufacturing industries	1,250	65.00	10.931	5.946

NA - not available

a Data obtained and calculated for each SIC on the basis of small firm questionnaire responses supplied by FMC.

b Weekly average in first column multiplied by 52.

c Average size of small firm estimates from the contribution of firms by employment size, supplied by the California Department of Employment (Research and Statistics), San Francisco Office.

d Annual wastes/average employment per firm.

SOURCE: C.G. Golueke and P.H. McGauhey, Comprehensive Studies of Solid Wastes Management, Sanitary Engineering Research Laboratory, University of California, January 1969, p. 221.

Source: Reference 7.

TABLE 12

WASTE GENERATION IN WISCONSIN, BY SIC GROUP

S.I.C. Group	Description	Annual Averages (1972) Waste Generation Coefficient lbs/cap/day	State Employment 1000s	Est. Waste Production tons/day (7-day week)
20-39	Manufacturing		493.6	
20	Food Products	26.7	57.7	770.3
22	Textile mill products	1.7	6.7	5.7
23	Apparel	1.3	7.0	4.6
24	Lumber & wood products, except furnitures	89.0	16.8	747.6
25	Furniture & fixtures	6.8	8.5	28.9
26	Paper & allied products	81.7	43.4	1,172.9
27	Printing & publishing	6.2	26.2	81.2
28	Chemicals	45.0	10.1	227.3
29	Petroleum refining	159.2	-	-
30	Rubber & plastics products	6.1	12.5	38.1
31	Leather & leather products	1.1	13.9	7.7
32	Stone, clay, glass & concrete products	125.0	8.3	518.8
33	Primary metals	36.8	28.1	517.1
34	Fabricated metal products	20.4	44.4	452.9
35	Machinery, except electrical	19.9	103.3	1,027.8
36	Electrical & electronic machinery	14.7	46.5	341.8
37	Transportation equipment	7.1	38.1	135.3
38	Precision instruments	1.9	8.8	8.4
39	Miscellaneous Mfg. Industries	6.6	13.0	42.9
50-51	Wholesale trade	10.3	67.9	349.7
52-59	Retail trade		278.0	
52	Retail building materials	8.7	14.1	61.3
53	Retail general merchandise	1.5	60.7	45.5
54	Retail food	11.9	45.2	268.9
55	Auto sales, service, repairs	2.5	34.3	42.9
56	Retail apparel	2.4	11.9	14.3
57	Furniture	6.4	7.9	25.3
58	Eating and drinking establishments	12.5	55.5	346.9
59	Miscellaneous retail trade	5.4	25.7	69.4
60-67	Financial operation	7.1	64.1	227.6
70-89	Services		249.5	
70	Hotels	11.8	10.6	62.5
72	Personal services	2.3	14.5	16.7
73	Business services	4.1	19.0	39.0
76	Miscellaneous repair	9.1	2.0	9.1
79	Amusements, recreation	4.0	8.1	16.2
80	Medical & health	6.9	24.6	84.9
89	Miscellaneous services	4.1	7.9	16.2
90-94	Government		279.5	

Source: Reference 11.

wide range of values for what are theoretically, the same coefficients. In part this inconsistency arises from the fact that the TEY data for each industry are based on plants with diverse production methods, which in themselves are often not reported for reasons of propriety. Another factor leading to such dispersion of data is company employment figures which often do not distinguish non-production workers who do not directly generate the wastes, from the total plant employment. Consequently, most industrial waste generation rates are based on the total employment numbers. Lastly, the sample sizes as well as the sampling regions must also be considered in evaluating coefficient differences.

For this study, coefficient values from Table 8 were chosen to estimate waste generation, since TEY coefficients in this table were broken down further into values corresponding to solid wastes, liquid wastes, and sludges. Based on the assumption that solid wastes are generally disposed of in landfills, the solid waste coefficients were utilized to calculate the total industrial waste destined for landfill disposal. Results are presented in Table 13.

Using the solid waste TEY's presented in Table 13 for each 2-digit SIC industry, one can evaluate the plant size distribution by number of employees necessary to produce 0-50, 50-200, and greater than 200 TPD of solid waste (see Table 14). Census of Manufacturers plant size categories are then reapportioned to fit the plant size distribution derived above. Once the number of plants in each waste volume generating category has been determined for each 2-digit SIC industry, a number of assumptions are made. These assumptions relied heaviliy on EPA-supported studies of industrial hazardous waste disposal practices for two reasons: first, the studies provided the most detailed industry-specific analysis of industrial waste disposal practices; and second, while the focus of the studies was hazardous waste, many of the studies noted that industry generally has not developed separate disposal facilities for hazardous and non-hazardous solid waste. Thus, the waste disposal practices described in these reports (References 5, 12-29) provide a reasonable basis for assumptions concerning solid waste disposal.

Four assumptions were made:

a. Assume the same disposal practices (method and location) for potentially hazardous and non-hazardous wastes in every industry;

b. Assume all solid wastes are landfilled unless information exists which indicates otherwise;

c. Where industrial hazardous waste practices assessments have been performed for one or more 3-digit SIC industries within a 2-digit industry, the available disposal data were averaged and the average was applied over the remainder of 3-digit SIC industries within the 2-digit SIC group;

TABLE 13

INDUSTRIAL SOLID WASTE PRODUCTION

SIC CODE	INDUSTRY	TOTAL NUMBER OF EMPLOYEES[b] (THOUSANDS)	TEY[a] (SOLIDS)	TONS OF SOLIDS/YEAR	TEY[a] (ALL WASTES)	TONS OF TOTAL WASTE/YEAR	% SOLID WASTE
20	Food Processing	1,527	7.949	12,138,000	8.350	12,750,000	95.2
21	Tobacco	76	N/A	N/A	N/A	N/A	N/A
22	Textile-Mill Products	838	2.160	1,810,080	3.775	3,163,450	57.2
23	Apparel	1,213	2.192	2,658,896	2.192	2,658,896	100.0
24	Wood Products	592	8.531	5,050,352	8.531	5,050,352	100.0
25	Furniture	398	2.783	1,107,634	2.783	1,107,634	100.0
26	Paper and Allied Products	590	3.987	2,352,330	4.009	2,365,310	99.5
27	Printing, Publishing	1,073	5.835	6,260,955	5.848	6,274,904	99.8
28	Chemicals and Allied Products	848	8.862	7,514,976	14.015	11,884,720	63.2
29	Petroleum	141	1.594	224,754	1.638	230,958	97.3
30	Rubber and Plastics	597	9.835	5,773,145	9.991	5,864,717	98.4
31	Leather	240	8.989	2,157,360	8.989	2,157,360	100.0
32	Stone, Clay	592	6.412	3,795,904	6.428	3,805,376	99.8
33	Primary Metals	1,091	3.184	3,474,744	5.004	5,459,364	63.6
34	Fabricated Metals	1,420	6.832	9,701,440	6.901	9,799,420	99.0
35	Non-Electrical Machinery	1,979	3.189	6,311,031	5.900	11,676,100	54.1
36	Electrical Machinery	1,521	2.941	4,473,261	3.113	4,734,873	94.5
37	Transportation Equipment	1,604	2.562	4,109,448	3.072	4,927,488	83.4
38	Professional and Scientific Instruments	502	1.769	888,038	1.843	925,186	96.0
39	Miscellaneous Manufacturing	394	1.603	631,582	1.603	631,582	100.0

a. Reference 8.

b. Reference 10.

TABLE 14

ESTIMATED NUMBER OF INDUSTRIAL LANDFILLS, BY SIZE CATEGORY

SIC CODE	INDUSTRY	TEY (SOLIDS)	RANGE OF PLANT SIZE GENERATING 0-50 TPD SOLID WASTE (NUMBER OF EMPLOYEES)	RANGE OF PLANT SIZE GENERATING 50-200 TPD SOLID WASTE (NUMBER OF EMPLOYEES)	NUMBER OF PLANTS GENERATING 0-50 TPD SOLID WASTE	NUMBER OF PLANTS GENERATING 50-200 TPD SOLID WASTE	% OF ALL PLANTS LANDFILLING ON-SITE	NUMBER OF ON-SITE LANDFILLS 0-50	NUMBER OF ON-SITE LANDFILLS 50-200	NUMBER OF ON-SITE LANDFILLS 200+ TPD
20	Food Processing	7.949	0-1,635	1,635 - 6,542	28,120	63	22[b]	6,186	14	0
21	Tobacco	7.949[a]	0-1,635	1,635 - 6,542	272	-	22[b]	60	0	0
22	Textile Mill Production	2.160	0-6,019	6,019 - 24,074	7,201	-	22[b]	1,584	0	0
23	Apparel	2.192	0-5,931	5,931 - 23,723	24,438	-	22[b]	5,376	0	0
24	Wood Products	8.531	0-1,524	1,524 - 6,095	33,937	12	22[b]	7,466	3	0
25	Furniture	2.783	0-4,671	4,671 - 18,685	9,233	-	22[b]	2,031	0	0
26	Paper and Allied Products	3.987	0-3,261	3,261 - 13,042	6,038	-	22[b]	1,328	0	0
27	Printing, Publishing	5.385	0-7,228	2,228 - 8,912	42,069	34	0[c]	0	0	0
28	Chemicals and Allied Products	8.862	0-1,467	1,467 - 5,868	11,317	108	40[d]	4,527	43	0
29	Petroleum	1.594	0-8,156	8,156 - 32,623	2,016	-	20[e]	403	0	0
30	Rubber and Plastics	9.835	0-1,322	1,322 - 5,287	9,168	69	0[f]	0	0	0
31	Leather	8.989	0-1,446	1,446 - 5,785	3,197	4	5[g]	160	0	0
32	Stone, Clay	6.412	0-2,027	2,027 - 8,110	15,993	22	22[b]	3,518	5	0
33	Primary Metals	3.184	0-4,083	4,083 - 16,332	6,728	64	20[h]	1,346	13	0
34	Fabricated Metals	6.832	0-1,903	1,903 - 7,611	29,450	75	22[b]	6,479	16	0
35	Non-Electrical Machinery	3.189	0-4,077	4,077 - 16,306	40,792	-	70[i]	28,554	0	0
36	Electrical Machinery	2.941	0-4,420	4,420 - 17,681	12,270	-	0[j]	0	0	0
37	Transportation Equipment	2.562	0-5,074	5,074 - 20,297	8,661	141	22[b]	1,905	31	0
38	Professional and Scientific Instruments	1.769	0-7,349	7,349 - 29,395	5,983	-	22[b]	1,316	0	0
39	Miscellaneous Manufacturing	1.603	0-8,110	8,110 - 32,440	15,187	-	22[b]	3,341	0	0
	TOTAL:							75,580	125	0

TABLE 14 (Continued)

Notes

a. TEY was unavailable for the tobacco industry. The TEY for food processing was used as a proxy.

b. Average of the "% of all Plants Landfilling On-Site" for those 2-digit SIC industries for which hazardous waste practices assessments are available.

c. Telephone Contact -- J. Grant, Director of Government Affairs, Printing Industries of America, Washington, D.C.

d. Weighted average of the "% of Plants Landfilling On-Site" for:

- inorganic chemicals SIC 281); References 12, 13, 14.
- paint and allied products (SIC 285); Reference 15.
- organic chemicals, pesticides, and explosives (SIC 286, 287); References 16, 17.

Weights based on total potentially hazardous waste volume (dry MT/Y).

e. Based on percent of total potentially hazardous waste volume (dry MT/Y) landfilling on-site; Reference 18.

f. Reference 19.

g. Based on percent of total potentially hazardous waste volume (dry MT/Y) landfilled on-site; Reference 20.

h. Reference 21.

i. Reference 22.

j. Reference 23.

d. For 2-digit SIC industries for which no hazardous waste practices assessments have been performed, the disposal data available for the other 2-digit SIC's were averaged and the average was applied.

Using the industrial hazardous waste practices assessments done for EPA, the percentage of plants landfilling on-site is determined. This percentage was applied to the numbers of plants in each waste volume generating category to yield the numbers of on-site landfills accepting 0-50, 50-200, and over 200 TPD of solid waste. The total number of 0-50 TPD industrial on-site landfills is 75,580 while the number of 50-200 TPD on-site landfills is 125 and there are essentially no on-site landfills accepting more than 200 TPD of solid waste.

In a previous EPA study (Reference 30), Fred C. Hart Associates estimated 10,558 industrial hazardous waste generators would require permits for on-site hazardous waste facility operation. Assuming most industries presently co-dispose hazardous and non-hazardous solid wastes and that 90% of the establishments landfill or open dump these wastes, 9,502 industrial on-site hazardous waste landfills must exist nationwide. Since these landfills will be covered under Subtitle C of RCRA, this figure can be subtracted from the total industry solid waste landfill figure obtained from Table 14 to yield 66,203 (or 66,094 10 TPD and 109 100 TPD) industrial on-site non-hazardous solid waste landfills nationwide which will be subject to the proposed Guidelines.

4. Construction, Demolition, and Disaster Debris Landfills. There are very few single-purpose construction, demolition or disaster debris landfills. The majority of construction wastes are used as fill material or are disposed at permitted municipal landfills. Disposal methods include separate burial, use for on-site construction such as for service roads, or burial along with the municipal solid waste. Demolition wastes normally suffer the same fate as construction wastes, except that a greater percentage is used for clean fill. The Army Corps of Engineers reports that there are no pre-planned or active disaster debris landfills. These landfills are selected on a case-by-case basis by local authorities at the time of the particular disaster. Depending on the type and amount of debris, and the availability of landfill sites, either existing municipal landfills or new single-purpose sites are selected. These are used only once, covered over, and recorded only by local authorities. The data base developed in this report does not represent national prevalence of debris fills. Refinement of that data base to include debris fills would require, at a minimum, contact with each State. Since the number of such single-purpose fills is likely to be quite small, they are not considered further in this analysis.

5. Pollution Control Residues. The waste category of pollution control residues includes: (a) flue gas desulfurization sludges (FGD sludge); (b) ash generated by combustion of coal and oil; and (c) municipal waste water treatment plant sludges. Sludges from the treatment of non-hazardous industrial wastes other than ash and FGD sludge are accounted for in the industry section. Of the three waste types in the

Pollution Control Residues (PCR) category, sludges from waste water treatment plants will not be considered further. It is estimated that 25 percent of treatment sludges are landfilled. These sludges are disposed of at permitted sites, which were identified previously in the municipal landfill category.

The remaining waste stream types are primarily generated by electric utilities. Due to the large volume of wastes generated, it can be assumed that each power plant disposes of the waste on its' own site. Scrubber sludges can be large in volume, but at the present time there are relatively few power plants with active scrubber systems. According to a recent Energy Resources Company, Inc. study (Reference 31), there were 31 non-regenerable scrubber systems (which produce waste streams rather than a saleable product). Seventeen of these facilities dispose of sludge in ponds; six units use landfills; and one unit dumps its sludge in a borrow pit. Seven units did not report on disposal practices.

The other major pollution control residue is ash. Combustion of fossil fuels, especially coal and oil, generally produces an ash residue which requires disposal. The electric power generating industry relies on coal- and oil-fired steam electric power plants to generate about 63% of the nation's electrical capacity, with coal at 38% and oil-fired plants at 25% of total capacity. The amount of ash residue generated depends upon the type of fuel and the ash content of the fuel. The disposal of the ash is a practice particular to the plant involved. We have attempted to estimate the population of combustion ash disposal sites in the manner described below.

From previous studies, the average ash generation figures per plant and per megawatt (MW) of generating capacity were derived, first for coal and then for oil-fired facilities. Per MW, coal combustion produces 300 tons of ash per year or 0.82 tons per day, based on 365 days per year of operation. The corresponding figures for ash generation at oil-fired plants are 2.5 TPY and 0.007 TPD per megawatt.

We next scaled the model landfill classes, established previously, to the MW capacity figures for each type of plant. In order for a coal-fired plant to generate from 0-50, 50-100 or 200+ tons of ash per day, its rated capacity had to fall within 3 ranges of values. These values were 0 to 61 MW, 61 to 244 MW, or 245+ MW for each of the three model landfill capacities. In the case of oil-fired plants, the MW capacity had to exceed 7,100 MW to produce more than 50 tons per day of ash. Few plants attain one tenth that size.

Table 15 lists the number of coal- and oil-fired plants in the United States, by category of ash production. Oil-fired plants fall completely within the smallest category. Coal-fired plants do not. The results, on a national level are that 729 plants (621 oil-fired, 108 coal-fired) generate enough ash to fill ponds and landfills of 0 to 50 TPD capacity; 75 plants, all coal-fired, produce 50 to 200 tons of ash per day; and 217 plants, all coal-fired, generate more than 200 tons of ash per day.

TABLE 15

NUMBER OF ASH LANDFILLS BY DAILY CAPACITY FOR STEAM ELECTRIC POWER PLANTS, BY PLANT TYPE[a]

Plant Type	Number of Plants in Ash Production Categories (TPD) 0-50	50-200	200+	Total
Oil-Fired[b]	621	-	-	621
Coal-Fired[c]	108	75	217	400
Total	729	75	217	1,021

[a]Plants in service as of December 31, 1976, according to the Federal Energy Administration.

[b]Included among oil-fired plants are some plants firing gas or coal. However, it can be assumed that all the plants generate some oil-fired ash which must be landfilled.

[c]Numbers represent plants firing coal only.

Source: Reference 32.

Data from the National Ash Association indicate that 15% of the total ash produced is used in construction and of the remaining 85% of the total, 49% is trucked to landfills and 51% is sluiced. The latter figure implies disposal in ponds or lagoons which removes this fraction from immediate consideration. However, at the conclusion of the dewatering process, this ash volume is reportedly dredged and dumped on land.

The practices of ash disposal are random; that is, they are not correlated with size of plant, with ownership, with plant location in terms of either physiography or demography, nor with plant age. Practices are solely determined by the resources of the plant in question and not of a class of plants. If 41.7% of ash is landfilled (49% trucked x 85% disposed), then the total number of landfills by capacity class, assuming a random disposal practice, is as follows:

	0-50 TPD	50-200	200+	Total
Number of landfills	304	31	90	425

C. Estimating the Prevalence of Environmentally Sensitive Areas

Wetlands, floodplains, permafrost areas, critical habitats, and recharge zones of sole source aquifers are considered as Environmentally Sensitive Areas (ESAs) by the Criteria and Guidelines. Karst terrain and active fault zones are not designated as ESAs by the Proposed Guidelines, but are listed nonetheless as areas to avoid in sanitary landfill siting, and to protect in landfill design and operation. The total U.S. area of karst terrain and active fault zones is insignificant when mapped at the gross scale used for estimating the extent of the other, more prevalent ESAs. For this reason, consideration of ESAs is limited in this report to wetlands, permafrost areas, floodplains, critical habitats, and areas overlying sole source aquifers.

1. Wetlands. The proposed Guidelines define wetlands as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." To estimate the aggregate National costs of sanitary landfilling in wetland areas, it is first necessary to map and estimate the total U.S. area of wetlands. A recent inquiry at the U.S. Fish and Wildlife Service indicates that the Federal wetland inventory is not yet complete, and that no generalized U.S. wetland map has superseded the 1956 USFWS Circular 39 map (Reference 33).

Figure 7 represents a generalized adaptation of Reference 33. Heavy concentrations of wetlands were identified by dots which represented 10,000 acres of wetlands. These were outlined to indicate generalized areas of expected concentration of wetlands. The total area of wetlands in the U.S., as reported in Reference 33 is 74 million acres. Data are still needed for Alaska, Hawaii, and the U.S. territories. The map is subjective and intended only as a rough estimate of U.S. wetlands prevalence. When the national wetland inventory is complete, a refined estimate can be made.

2. Floodplains. The proposed Guidelines define floodplains as "lowland and relatively flat areas adjoining inland and coastal waters, including flood-prone areas of offshore islands, which are inundated by the base 100-year flood." To estimate the aggregate national costs of sanitary landfilling in floodplains, it is first necessary to map and estimate the total U.S. area of 100-year floodplains.* A recent inquiry at the Federal Insurance Administration, which administers the Federal Flood Insurance Program, indicates that the Federal floodplain mapping effort is not yet complete, and that no reliable generalized U.S. floodplain map yet exists. However, in a 1978 report, the U.S. Water Resources Council (Reference 34) produced a map of existing U.S. flooding problems defined as areas (river basins) that have serious or moderate agricultural, urban and other flooding. Figure 8 shows WRC's generalized areas of serious flooding. When the Federal 100-year floodplain mapping effort is complete, a refined estimate can be made of the extent of floodprone areas.

3. Permafrost Areas. The proposed Guidelines define permafrost areas as areas of "permanently frozen subsoil." R.F. Flint's Glacial and Quaternary Geology (Reference 39) maps the present extent of continuous and discontinuous permafrost in the northern hemisphere. Figure 9 was adapted from Flint's map of continuous permafrost areas.

4. Critical Habitats. Critical habitats are those habitats which have been determined by the Secretary of the Interior to be critical to the continued existence of endangered species listed under Section 4 of the Endangered Species Act of 1973. According to K. Schreiner of the Office of Endangered Species, U.S. Fish and Wildlife Service, the ultimate total U.S. area of critical habitat will be very small compared to the total area of the other ESAs. It was therefore concluded that the identification of the known small areas of critical habitats would lack meaning in the national-scale maps used for this report. Further, many critical habitats are contained within the floodplain and wetland areas.

5. Areas Overlying Aquifers. The proposed Guidelines recommend location of landfills in areas which are not underlain by current or

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* This approach conforms with the intent of Executive Order 11988 dated May 24, 1977, concerning floodplain management.

FIGURE 7

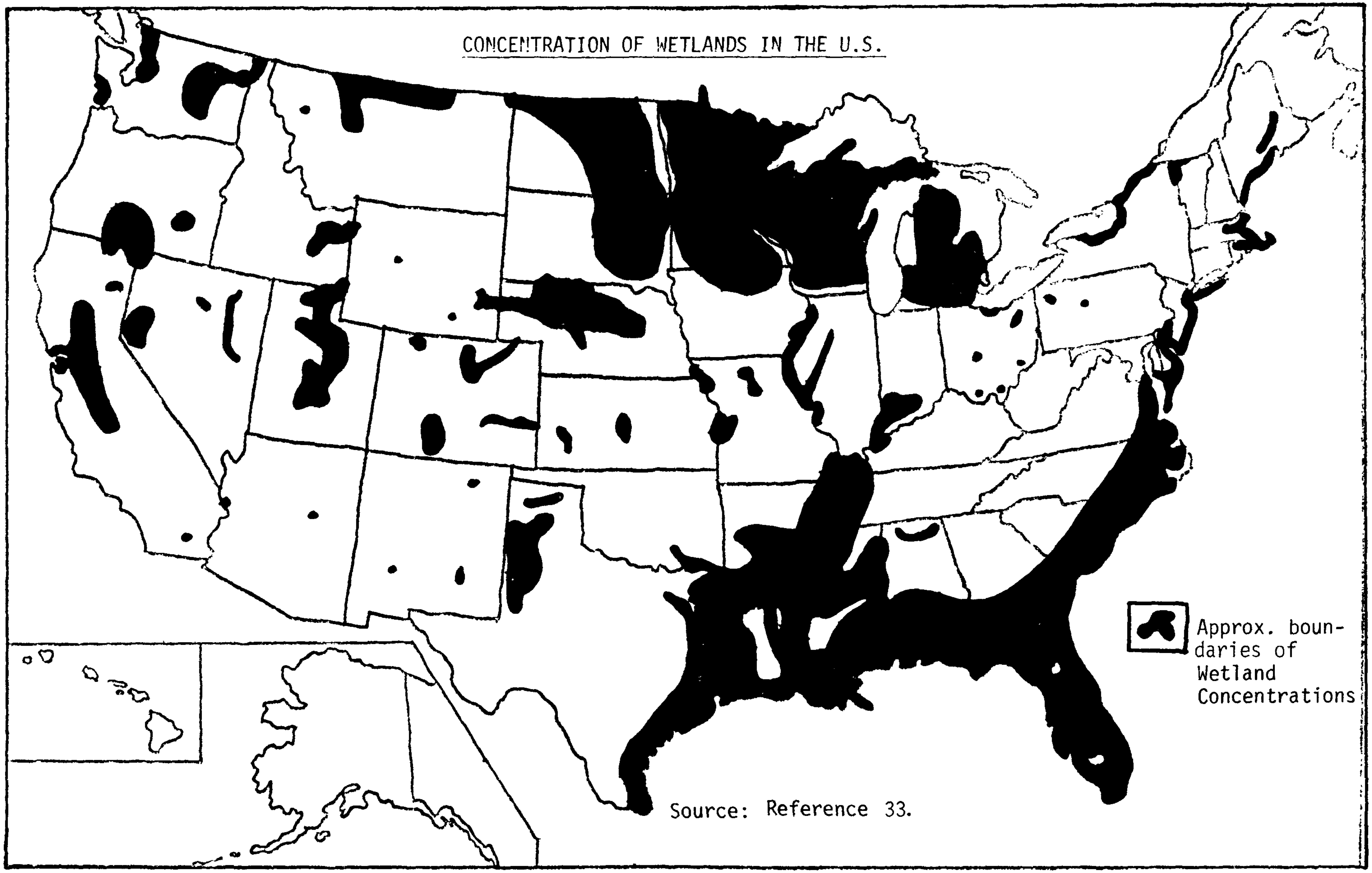
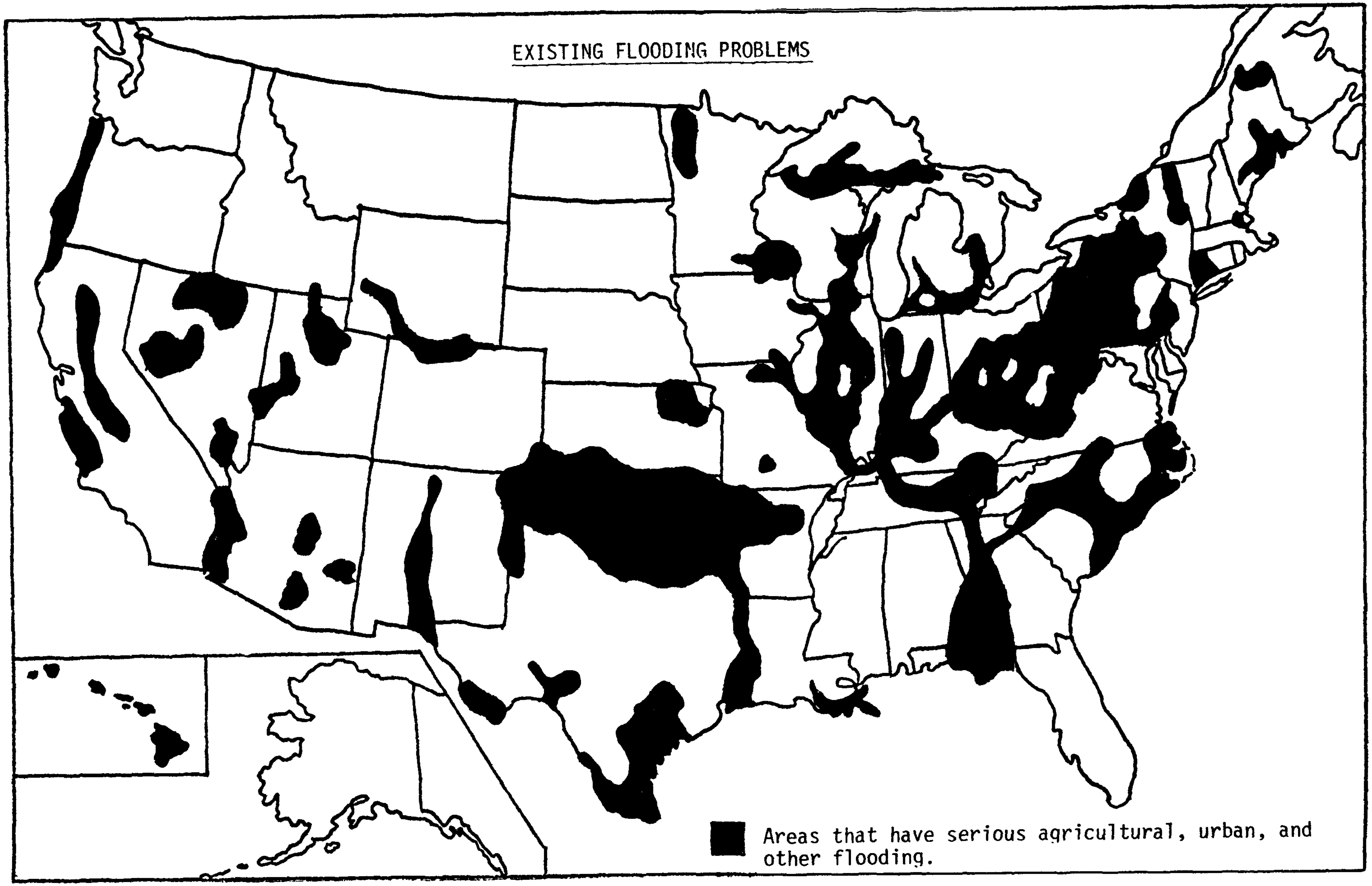

CONCENTRATION OF WETLANDS IN THE U.S.
Approx. boundaries of Wetland Concentrations
Source: Reference 33.

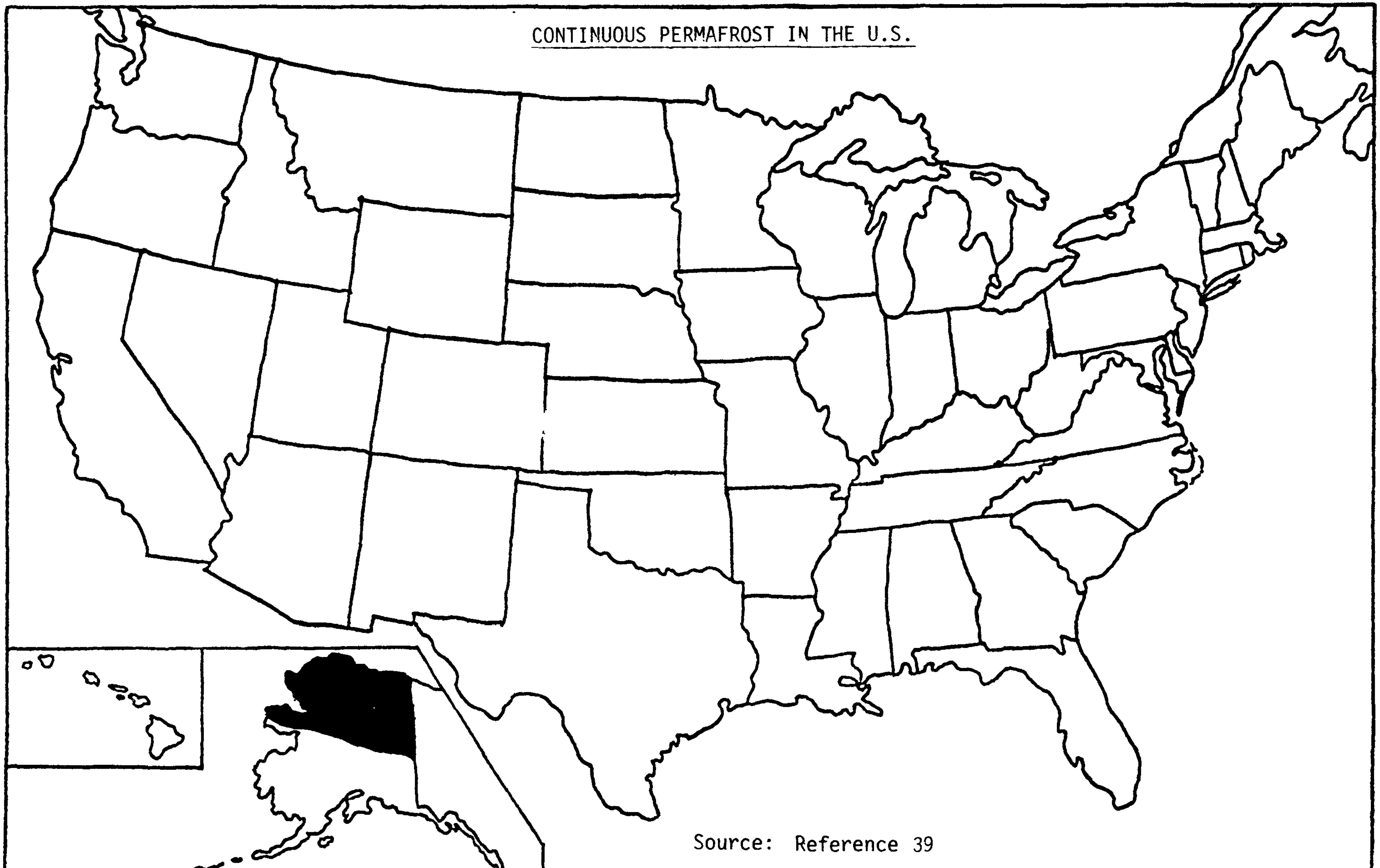
FIGURE 8



Source: Reference 34 .

FIGURE 9

CONTINUOUS PERMAFROST IN THE U.S.



Source: Reference 39

planned drinking water sources. Figure 10 shows the areas of major aquifers in the country in which municipalities rely heavily on ground water as a source of drinking water. The map was adapted from U.S. Geological Survey Hydrologic Atlas 194 (Reference 40) in consideration of municipal water use data.

6. Total Environmentally Sensitive Area. Figure 11 maps the total U.S. Environmentally Sensitive Area as defined by the Section 4004 Criteria and the proposed Guidelines. This map was produced by overlaying Figures 7 through 10 representing the four separately mapped ESAs. Figure 11 indicates that approximately 50-60% of the area of the coterminous United States is classified as environmentally sensitive.

D. Estimating the Distribution of Sanitary Landfills

For the purpose of this report, it is assumed that the distribution of sanitary landfills roughly correlates with population distribution. To determine the number of landfills in ESAs, the following methodology was used:

a. Determine which of each State's Standard Metropolitan Statistical Areas (SMSAs) lie in ESAs. This was accomplished by overlapping a map of SMSAs with the composite ESA map in Figure 11, and identifying over lapping areas. The population of SMSAs in ESAs was then summed for each State.

b. Determine the percentage of the remainder of the State (non SMSA) which lies in ESAs using the same tools as in (a) above. Subtract the State's total SMSA population from the State's total population to yield the population of the remainder of the State. Assuming an even population distribution over the remainder of the State, apply the percentage ESA area found above to the population of the remainder of the State to obtain the ESA population in the remainder of the State.

c. Add the total State SMSA population in ESAs to the population of the remainder of the State in ESAs to yield the total State population in ESAs.

d. Add all the State's total populations in ESAs together to obtain the total U.S. population in ESAs.

FIGURE 10

ESTIMATED EXTENT OF SOLE OR PRINCIPAL SOURCE AQUIFERS; COTERMINOUS UNITED STATES

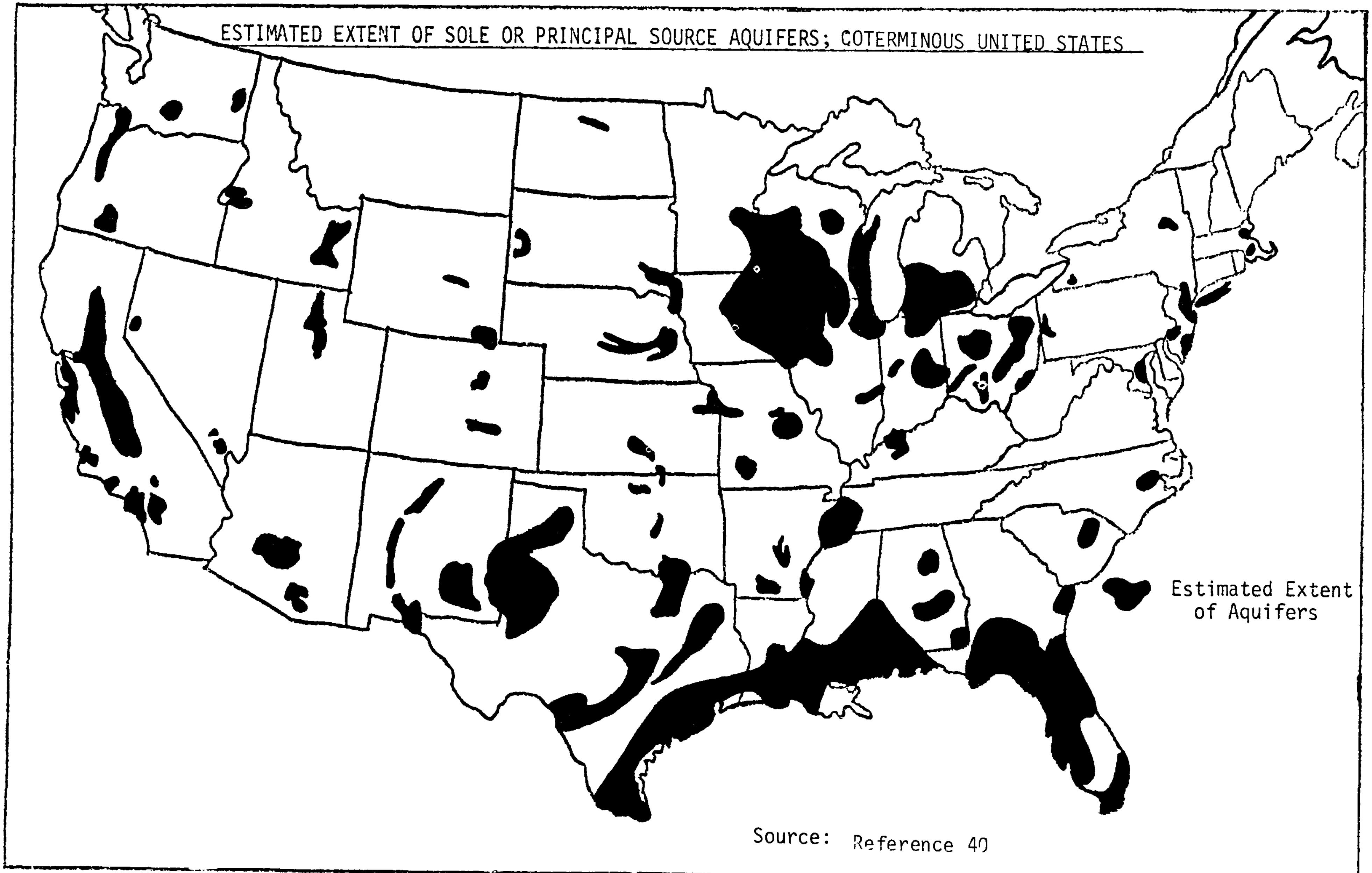
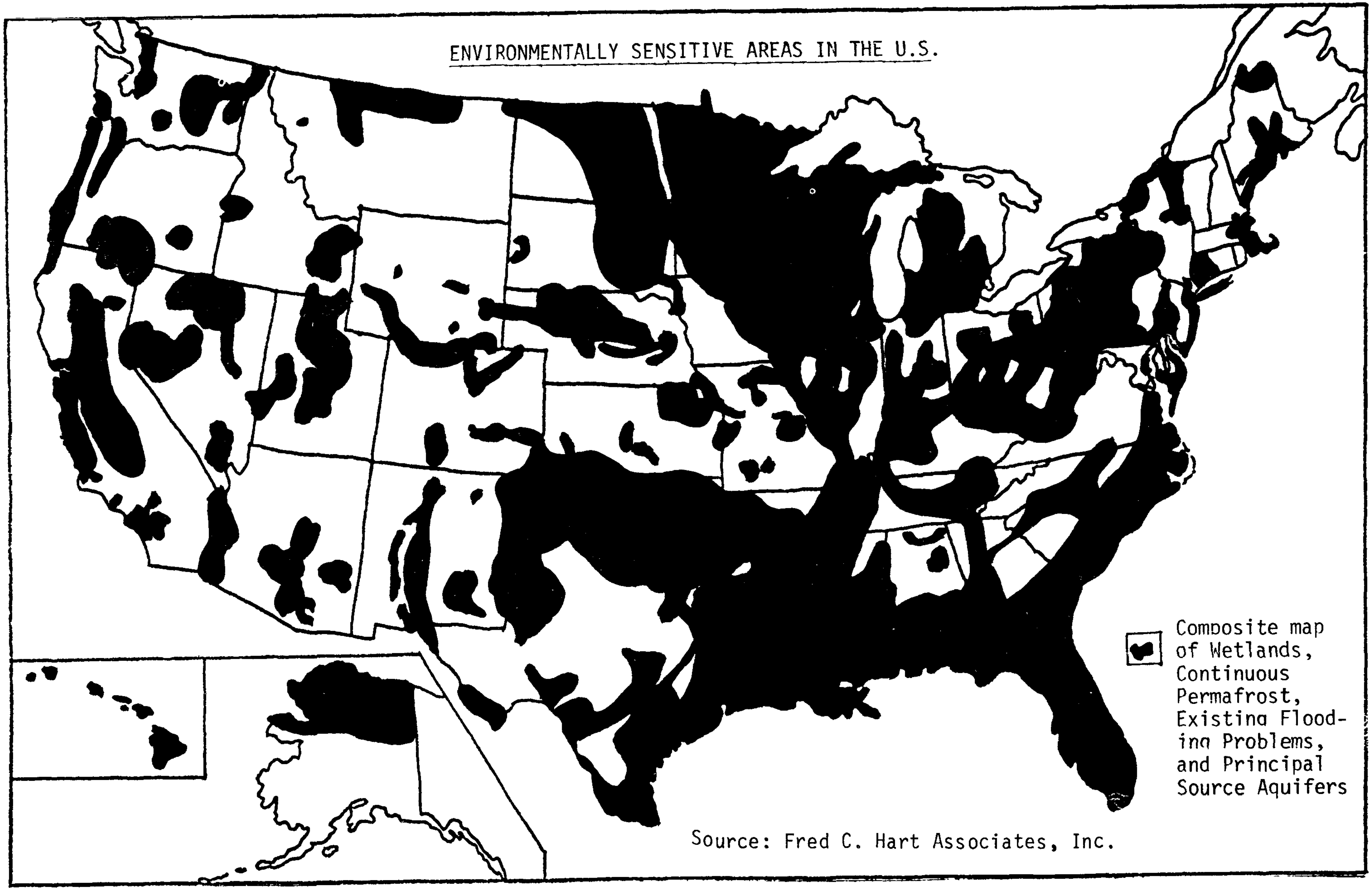


FIGURE 11

ENVIRONMENTALLY SENSITIVE AREAS IN THE U.S.



Source: Fred C. Hart Associates, Inc.

e. Determine the percentage of the total U.S. population which resides in ESAs, and apply this percentage to the total number of landfills to obtain the number of landfills in ESAs.

These data are summarized in Table 16. As the table indicates, the total U.S. population in ESAs is 154.5 million or 73.1% of the total U.S. population. If landfills are evenly distributed according to population, then 73.1% or 59,443 landfills in all, lie in ESAs.

E. Aggregate Costs

Tables 17-19 outline the potential impact of the proposed landfill Guidelines on the operating costs of various types of landfill operations. Table 20 presents the unit cost impact (i.e., costs/ton) of the Guidelines on landfill sites handling municipal, industrial, and pollution control residue waste respectively, with these operations further stratified by daily capacity (ton/day) and whether they are located in sensitive or nonsensitive areas. All of these results are then summarized in Table 21. These cost impact assessments are based on the landfill prevalence data and landfill upgrading cost estimates as developed in Sections VI.B. and V.B., respectively. The aggregate incremental cost figures in Table 21 show the amount by which these changes in unit costs would affect the average annual operating costs of each type of landfill, and the total of these Guidelines-related incremental costs for all landfills nationwide.

The factors that stand out most clearly in these tables are:

1. The potential cost impact is substantial; the national figure of $2038.0 million is approximately a 60 percent increase over the present landfill operating cost estimate of $3,539 million.

2. The incremental costs due to the Guidelines reflect the scale economy assumptions made earlier in this report for both base line and upgrading technology costs; this decreasing cost factor is the most significant for municipal solid waste sites.

3. Leachate controls, and particularly the impermeable cover requirement, represent the largest incremental cost element, while surface runoff control is the second largest factor.

4. The industrial landfill population is responsible for roughly 66 percent of the total incremental costs, with virtually all of it falling on the small (10 TPD) sites; the cost data however, show that the incremental impact per unit of waste was fairly even among the three waste categories.

TABLE 16

ESTIMATION OF U.S. POPULATION IN ENVIRONMENTALLY SENSITIVE AREAS

(1) STATE	(2) SMSAs LOCATED IN AN ESA	(3) SMSA POPULATION	(4) TOTAL SMSA POPULATION IN ESAs[a]	(5) STATE POPULATION[a]	(6) REMAINDER OF STATE POPULATION (Column 5 minus Col. 3)	(7) PERCENTAGE OF STATE AREA IN ESAs	(8) REMAINDER OF STATE POPULATION IN ESAs[a] (Column 7 Times Col. 6)	(9) TOTAL STATE POPULATION IN ESAs[a] (Column 8 Plus Col. 4)
Maine	None		0	1,047	1,047	40	419	419
New Hampshire	None		0	808	808	5	40	40
Vermont	None		0	470	470	5	24	24
Massachusetts	Boston Worcester	2,898 377	3,275	5,800	2,525	30	758	4,033
Rode Island	None		0	937	937	0	0	0
Connecticut	Bridgeport New Haven	397 415	812	3,088	2,276	40	910	1,722
New York	Albany, Schenectady, Troy Binghamton Buffalo Nassau New York City Rochester Syracuse	267[b] 151[c] 1,345 2,630 9,739 972 643	15,747	18,214	2,961	30	888	16,635

TABLE 16 (Continued)

(1) STATE	(2) SMSAs LOCATED IN AN ESA	(3) SMSA POPULATION	(4) TOTAL SMSA POPULATION IN ESAs[a]	(5) STATE POPULATION	(6) REMAINDER OF STATE POPULATION	(7) PERCENTAGE OF STATE AREA IN ESAs	(8) REMAINDER OF STATE POPULATION IN ESAs[a]	(9) TOTAL STATE POPULATION IN ESAs[a]
New Jersey	Jersey City	598						
	Long Branch	480	3,592	7,325	3,733	15	560	4,152
	Newark	2,053						
	Paterson	461						
Pennsylvania	Harrisburg	425						
	Johnstown	266						
	Lancaster	335	8,540	11,862	3,322	40	1,329	9,869
	Philadelphia	4,806						
	Pittsburgh	2,365						
	York	343						
Ohio	Akron	677						
	Canton	406						
	Cincinnati	1,383	5,529	10,737	5,208	25	1,302	6,831
	Cleveland	2,006						
	Columbus	1,057						
Indiana	Evansville	290						
	Indianapolis	1,137	1,708	5,330	3,622	40	1,449	3,157
	South Bend	281						
Illinois	Chicago	7,002						
	Peoria	351	7,624	11,131	3,507	40	1,403	9,027
	Rockford	271						
Michigan	Detroit	4,446						
	Flint	517						
	Grand Rapids	553	6,215	9,098	2,883	100	2,883	9,098
	Kalamazoo	261						
	Lansing	438						

TABLE 16 (Continued)

(1) STATE	(2) SMSAs LOCATED IN AN ESA	(3) SMSA POPULATION	(4) TOTAL SMSA POPULATION IN ESAsa	(5) STATE POPULATION	(6) REMAINDER OF STATE POPULATION	(7) PERCENTAGE OF STATE AREA IN ESAs	(8) REMAINDER OF STATE POPULATION IN ESAsa	(9) TOTAL STATE POPULATION IN ESAsa
Wisconsin	Oshkosh Madison Milwaukee	281 301 1,417	1,999	4,566	2,567	100	2,567	4,566
Minnesota	Duluth Minnesota	264 2,000	2,264	3,197	933	88	1,821	3,085
Iowa	Davenport Des Moines	365 325	690	2,855	2,165	50	1,083	1,773
Missouri	St. Louis	2,391	2,391	4,777	2,386	30	716	3,107
North Dakota	None		0	637	637	60	382	382
South Dakota	None		0	682	682	48	327	327
Nebraska	Omaha	575	575	1,543	968	28	271	846
Kansas	Kansas City	1,299	1,299	2,270	971	28	272	1,572
Delaware	None		0	573	573	0	0	0
Maryland	Baltimore	2,120	2,120	4,094	1,974	22	434	2,554
Wash., D.C.	None		0	723	723	0	0	0
Virginia	Newport Norfolk	347 745	1,092	4,908	3,816	15	572	1,664
West Virginia	Huntington	291	291	1,791	1,500	67	1,005	1,296

TABLE 16 (Continued)

(1) STATE	(2) SMSAs LOCATED IN AN ESA	(3) SMSA POPULATION	(4) TOTAL SMSA POPULATION IN ESAs[a]	(5) STATE POPULATION	(6) REMAINDER OF STATE POPULATION	(7) PERCENTAGE OF STATE AREA IN ESAs	(8) REMAINDER OF STATE POPULATION IN ESAs[a]	(9) TOTAL STATE POPULATION IN ESAs[a]
N. Carolina	Charlotte Greensboro Raleigh	588 757 458	1,803	5,363	3,560	63	2,243	4,046
S. Carolina	Columbia Greenville Charleston	349 509 352	1,210	2,784	1,574	40	630	1,840
Georgia	None		0	4,882	4,882	65	3,173	3,173
Florida	Ft. Lauderdale Jackson Lakeland Miami Orlando Pensacola Tampa W. Palm Beach	756 661 255 1,370 549 259 1,276 412	5,538	8,090	2,552	100	2,552	8,090
Kentucky	Lexington Louisville	282 886	1,168	3,357	2,189	35	766	1,934
Tennessee	Chattanooga Knoxville Memphis	389 427 863	1,679	4,129	2,450	50	1,225	2,904
Alabama	Mobile	389	389	3,357	2,968	52	1,543	1,932
Mississippi	Jackson	275	275	2,324	2,049	85	1,742	2,017
Arkansas	Little Rock	350	350	2,062	1,712	82	1,404	1,754

TABLE 16 (Continued)

(1) STATE	(2) SMSAs LOCATED IN AN ESA	(3) SMSA POPULATION	(4) TOTAL SMSA POPULATION IN ESAs[a]	(5) STATE POPULATION	(6) REMAINDER OF STATE POPULATION	(7) PERCENTAGE OF STATE AREA IN ESAs	(8) REMAINDER OF STATE POPULATION IN ESAs[a]	(9) TOTAL STATE POPULATION IN ESAs[a]
Louisiana	Baton Rouge	402						
	New Orleans	1,083	1,828	3,764	1,936	100	1,936	3,764
	Shreveport	343						
Oklahoma	Oklahoma City	750	1,322	2,709	1,387	100	1,387	2,709
	Tulsa	572						
Texas	Austin	375						
	Beaumont	102						
	Corpus Christi	298						
	Dallas	2,464	6,757	12,050	5,293	30	1,588	8,345
	El Paso	390						
	Houston	2,168						
	San Antonio	960						
Montana	None		0	735	735	15	110	110
Idaho	None		0	799	799	20	160	160
Wyoming	None		0	359	359	8	287	287
Colorado	None		0	2,496	2,496	15	374	374
New Mexico	Albaquerque	376	376	1,122	746	2[illegible]	172	548
Arizona	Phoenix	1,127	1,543	2,153	610	10	61	1,604
	Tuscon	416						
Utah	Salt Lake City	753	753	1,173	420	35	147	900
Nevada	Las Vegas	308	308	573	265	33	87	395

TABLE 16 (Continued)

(1) STATE	(2) SMSAs LOCATED IN AN ESA	(3) SMSA POPULATION	(4) TOTAL SMSA POPULATION IN ESAs[a]	(5) STATE POPULATION	(6) REMAINDER OF STATE POPULATION	(7) PERCENTAGE OF STATE AREA IN ESAs	(8) REMAINDER OF STATE POPULATION IN ESAs[a]	(9) TOTAL STATE POPULATION IN ESAs[a]
Washington	Seattle	1,383						
	Spokane	301	2,076	3,476	1,400	20	280	2,356
	Tacoma	392						
Oregon	Portland	1,062	1,062	2,266	1,204	28	337	1,399
California	Anaheim	1,597						
	Bakersfield	336						
	Fresno	435						
	Los Angeles	6,924						
	Oxnard Simi Valley	420	15,693	20,907	5,214	20	1,043	16,736
	Sacramento	864						
	Salinas	255						
	San Francisco	3,143						
	San Jose	1,157						
	Stockton	299						
	Vallejo	263						
Alaska	None		0	337	337	40	134	134
Hawaii	Honolulu	686	686	847	161	90	145	831
Total U.S. Population in Environmentally Sensitive Areas								154,545

a. In thousands.
b. One-third of total SMSA population.
c. One-half of total SMSA population.

Source: Fred C. Hart Associates, Inc.

TABLE 17

IMPACT OF GUIDELINES ON OPERATING COSTS OF MUNICIPAL SOLID WASTE LANDFILLS (COSTS/TON)

	Site Condition and Size Categories					
	10 TPD		100 TPD		300 TPD	
Required Technologies	Sensitive	Non-Sensitive	Sensitive	Non-Sensitive	Sensitive	Non-Sensitive
Gas Control						
Vertical Impermeable Barriers	$1.30	$1.30	$0.30	$0.30	$0.15	$0.15
Leachate Control						
Imper. Daily Cover (off-site source)	5.30	5.30	2.65	2.65	1.75	1.75
Dike Construction[a]	1.20	-	0.28	-	0.15	-
Surface Runoff						
Ponding	0.10	-	0.05	-	0.04	-
Dike Construction[a]	1.20	-	0.27	-	0.15	-
Monitoring						
Gas Monitoring	0.15	0.15	0.03	0.03	0.01	0.01
Ground Water Quality Monitoring	0.60	0.60	0.10	0.10	0.05	0.05
Total Incremental Costs	$9.85	$7.35	$3.68	$3.08	$2.30	$1.96
Baseline Costs	11.15	11.15	6.65	6.65	3.95	3.95
Total Post-Guidelines Costs	$21.00	$18.50	$10.33	$9.73	$6.25	$5.91
Percent Increase	88%	66%	55%	46%	58%	50%

a. Dike construction costs were divided equally between leachate and surface runoff control functions.

TABLE 18

IMPACT OF GUIDELINES ON OPERATING COSTS OF INDUSTRIAL WASTE LANDFILLS (COSTS/TON)

Required Technologies	Site Condition and Size Categories					
	10 TPD		100 TPD		300 TPD	
	Sensitive	Non-Sensitive	Sensitive	Non-Sensitive	Sensitive	Non-Sensitive
Gas Control	-	-	-	-	-	-
Leachate Control						
Imper. Daily Cover (off-site source)	$5.30	$5.30	$2.65	$2.65	-	-
Surface Runoff						
Ponding	0.10	-	0.05	-	-	-
Dike Construction	2.40	-	0.55	-	-	-
Monitoring						
Gas Monitoring	0.15	0.15	0.03	0.03	-	-
Ground Water Quality Monitoring	1.60	0.60	-.10	0.10	-	-
Total Incremental Costs Due to Guidelines	$8.55	$6.05	$3.38	$2.78	-	-
Baseline Costs	11.15	11.15	6.65	6.65	-	-
Total Post-Guidelines Costs	$19.70	$17.20	$10.03	$9.43	-	-
Percent Increase	77%	54%	51%	42%	-	-

TABLE 19

IMPACT OF GUIDELINES ON OPERATING COSTS OF POLLUTION CONTROL RESIDUE LANDFILLS (COSTS/TON)

	Site Condition and Size Categories					
	10 TPD		100 TPD		300 TPD	
Required Technologies	Sensitive	Non-Sensitive	Sensitive	Non-Sensitive	Sensitive	Non-Sensitive
Gas Control	-	-	-	-	-	-
Leachate Control	$5.30	$5.30	$2.65	$2.65	$1.75	$1.75
Imper. Daily Cover (off-site source)						
Surface Runoff						
Ponding	$0.10	-	$0.05		$0.05	-
Dike Construction	2.40	-	0.55	-	0.30	-
Monitoring						
Ground Water Quality Monitoring	0.60	0.60	0.10	0.10	0.05	0.05
Total Incremental Costs Due to Guidelines	$8.40	$5.90	$3.35	$2.75	$2.14	$1.80
Baseline Costs	11.15	11.15	6.65	6.65	3.95	3.95
Total Post-Guidelines Costs	$19.55	$17.05	$10.00	$9.40	$6.09	$5.75
Percent Increase	75%	53%	50%	41%	54%	46%

TABLE 20

SUMMARY OF IMPACT OF LANDFILL GUIDELINES ON OPERATING COSTS OF LANDFILLS (COSTS/TON)[a]

	Site Condition and Size Categories					
	10 TPD		100 TPD		300 TPD	
	Sensitive	Non-Sensitive	Sensitive	Non-Sensitive	Sensitive	Non-Sensitive
Landfill Baseline Costs	$11.15 (12.29)	$11.15 (12.29)	$6.65 (7.33)	$6.65 (7.33)	$3.95 (4.35)	$3.95 (4.35)
Waste Types						
Municipal						
Post-Guidelines Costs	21.00 (23.15)	18.50 (20.39)	10.33 (11.39)	9.73 (10.73)	6.25 (6.89)	5.91 (6.51)
Percent Increase	88%	66%	55%	46%	58%	50%
Industrial						
Post-Guidelines Costs	19.70 (21.72)	17.20 (18.96)	10.03 (11.06)	9.43 (10.39)	- -	- -
Percent Increase	77%	54%	51%	42%	-	-
Pollution Control Residues						
Post-Guidelines Costs	19.55 (21.55)	17.05 (18.80)	10.00 (11.02)	9.40 (10.36)	6.09 (6.71)	5.75 (6.39)
Percent Increase	75%	53%	50%	41%	54%	46%

a. Costs in parenthesis are costs/metric ton

TABLE 21

AGGREGATE IMPACT OF GUIDELINES ON ANNUAL LANDFILL OPERATING COSTS[a]

	Site Size Categories						
	10 TPD		100 TPD		300 TPD		
Waste Types	Sensitive	Non-sensitive	Sensitive	Non-sensitive	Sensitive	Non-sensitive	Total
Municipal							
Annual Costs/Site	$ 25,610	$ 19,110	$ 95,680	$ 80,080	$179,400	$152,880	
# Sites	(8,375)	(3,082)	(1,610)	(593)	(752)	(277)	
Total Costs ($million)	$ 214.5	$ 58.9	$ 154.0	$ 47.5	$ 134.9	$ 42.3	$ 652.1
Industrial							
Annual Cost/Site	$ 22,230	$ 15,730	$ 87,880	$ 72,280	-	-	
# Sites	(48,315)	(17,779)	(80)	(29)	-	-	
Total Costs ($million)	$ 1,074.0	$ 279.7	$ 7.0	$ 2.1	-	-	$1,362.8
Pollution Control Res.							
Annual Costs/Site	$ 21,840	$ 15,340	$ 87,100	$ 71,500	$166,920	$140,400	
# Sites	(222)	(82)	(23)	(8)	(66)	(24)	
Total Costs ($million)	$ 4.8	$ 1.3	$ 1.3	$ .6	$ 11.0	$ 3.4	$ 23.1
Total Costs							
($ million)	$1,293.3	$ 339.9	$ 163.0	$ 50.2	$ 145.9	$ 45.7	$2,038.0

A. Landfill operating year is assumed to be 260 days.

F. Sensitivity Analysis of Cost Impacts

The cost data presented here are based on numerous assumptions, all of which have been delineated in earlier sections. The results are highly sensitive to changes in some of these assumptions, while others have little or no effect on total costs. Two assumptions, one from the landfill prevalence calculations and another from the upgrading technology estimates, were tested to see how they would affect the Guidelines cost impacts outlined above:

1. the portion of the landfills that have on-site clay available for the impermeable cover process; and

2. the percentage of total landfills located in environmentally sensitive vs. non-sensitive areas.

Table 22 shows the substantial difference in the costs of the impermeable cover requirement for operations with an on-site vs. off-site clay source. The values of $5.30, $2.65, and $1.75 for 10 TPD, 100 TPD and 300 TPD sites, respectively, assumed that all sites must rely on off-site sources of clay. This assumption is reasonable since although there are extensive areas of clayey soils in the U.S., there is relatively little soil whose clay component is sufficiently impermeable (1×10^{-7} cm/sec) to be effective in meeting the Guidelines. However, if it is assumed that 20 percent of landfills have on-site sources of clay, the unit cost figures would decrease to $4.39, $2.19, and $1.45 for 10 TPD, 100 TPD, and 300 TPD sites, respectively.* If 50 percent of landfills have on-site clay, then the unit costs are even less at $3.02, $1.50 and $1.00 for 10 TPD, 100 TPD, and 300 TPD sites, respectively. All landfills are required to use this form of leachate control, so the cost impact of this change in assumptions would be fairly uniform. However, based on the substantial differences in unit costs and the technology's widespread application, the impact on overall Guidelines-induced costs would be substantial, causing a 12 percent reduction in costs assuming 20 percent of sites with clay available and a 29 percent decrease in costs assuming 50 percent of sites with clay available (see Table 22).

It is very unlikely that more than 50 percent of the sites have available surface clay; the percentage with on-site clay, based on available aggregated data on soil types, could easily be under 20 percent. Although no exact estimate can be made, it is clear that the eventual cost results are very sensitive to this factor -- a conclusion that supports the need for further work in this area.

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* The unit costs of impermeable cover for landfills with on-site sources of clay are $0.75, $0.35, and $0.25 for 10 TPD, 100 TPD, and 300 TPD sites, respectively. See Table 3.

TABLE 22

EFFECT OF CHANGE IN ON-SITE CLAY AVAILABILITY ASSUMPTION ON GUIDELINES COST IMPACTS ($ MILLIONS)

	Site Size Categories			
Assumption	10 TPD	100 TPD	300 TPD	TOTAL
0/100* (Baseline)	$1,641.7	$216.8	$211.8	$2,070.3
20/80* (% Change)	1,456.4 (-11%)	188.2 (-13%)	182.6 (-14%)	1,827.2 (-12%)
50/50* (% Change)	1,177.0 (-28%)	145.5 (-33%)	138.9 (-34%)	1,461.4 (-29%)

* 0/100 = 0% have on-site clay, etc.

The results of the second sensitivity analysis are presented in Table 23. Two alternative assumptions were substituted for the initial estimate (labeled Baseline) that 73.1 percent of all landfills were located in environmentally sensitive areas:

Alternative Assumption 1: 50% in Sensitive/50% in Non-Sensitive Areas

Alternative Assumption 2: 10% in Sensitive/90% in Non-Sensitive Areas

The second assumption is close to the value used by the authors of the Section 4004 Landfill Criteria EIS. The data in Table 23 demonstrates, however, that the impact of even large adjustments in this sensitive/non-sensitive split is rather small. A change in the on-site/off-site clay assumptions, for example, from 0%/100% to 20%/80% or 50%/50% altered total incremental costs by 12 percent and 29 percent, respectively. By comparison, an almost complete reversal of the sensitive/non-sensitive split (i.e., from 73%/27% to 10%/90%) changed total costs by only 18 per cent. Although this change is of some significance, the overall results are clearly rather insensitive to significant changes in this assumption.

TABLE 23

AGGREGATE IMPACTS OF GUIDELINES ON LANDFILL COST UNDER ALTERNATIVE SENSITIVE AREA ASSUMPTIONS
($ MILLION)

Waste Types		Site Size Category									
		10 TPD			100 TPD			300 TPD			
		Sensitive	Non-Sensitive	Total	Sensitive	Non-Sensitive	Total	Sensitive	Non-Sensitive	Total	GRAND TOTAL
Municipal											
Baseline:	73.1/26.9	$214.5	$58.9	$273.4	$154.0	$ 47.5	$201.5	$134.9	$ 42.3	$177.2	$652.1
Alt. Ass. 1:	50/50	146.7	109.4	256.1	105.4	88.2	193.6	92.3	78.7	179.7	629.4
Alt. Ass. 2:	10/90	29.3	197.0	226.3	21.1	158.8	179.9	18.5	141.6	160.1	566.3
Industrial											
Baseline:	73.1/26.9	$1,074.0	$279.7	$1,353.7	$7.0	$2.1	$9.1	-	-	-	$1,362.8
Alt. Ass. 1:	50/50	734.6	519.8	1,254.4	4.8	3.9	8.7	-	-	-	1,263.1
Alt. Ass. 2:	10/90	146.9	935.7	1,082.6	1.0	7.1	8.1	-	-	-	1,090.7
Pollution Control											
Baseline:	73.1/26.1	$11.6	$3.0	$14.6	$4.8	$1.4	$6.2	$26.5	$ 8.1	$34.6	$55.4
Alt. Ass. 1:	50/50	8.0	5.6	13.6	3.3	2.7	6.0	18.1	15.2	33.3	52.9
Alt. Ass. 2:	10/90	1.6	10.1	11.7	0.7	4.8	5.5	3.6	27.4	31.0	48.2

TOTAL GUIDELINE COSTS ($ MILLION)

Baseline:	73.1/26.9	$2,070.3	
Alt. Ass. 2:	50/50	1,945.4	(-6%)
Alt. Ass. 3:	10/90	1,705.2	(-18%)

a. The assumptions tested here deal with the percent of total landfills that are in environmentally sensitive vs. non-sensitive locations; i.e., 73.1/26.9 = 73.1% sensitive, 26.9% non-sensitive, 50/50 = 50% sensitive, 50% non-sensitive, etc.

VII. ECONOMIC EFFECTS OF INCREASED OPERATING COSTS OF LANDFILLING

A. Background

The data presented in Sections V and VI outlined the probable impact of the proposed sanitary landfill Guidelines on the per unit operating costs of such facilities. However, it is the reaction to these additional costs by those residential, commercial, industrial and government sectors directly and indirectly affected that will determine the long-run net costs and overall effectiveness of the Guidelines. When a particular business or government agency is faced with higher operating costs, it can adjust through one of the following routes:

- change operating methods or technologies to avoid the costs;
- absorb the higher costs in the form of lower profits (higher subsidies);
- shift the higher costs backward on to suppliers (e.g., lower wages);
- shift the cost forward in the form of higher rates or prices to its customers.

These four methods are of course not mutually exclusive, and typically occur in various combinations as the affected parties search for ways to minimize the burden of the added costs. In the landfill "industry" this type of situation is complicated by the fact that much of the nation's solid waste handling capacity is publicy-owned (although frequently privately-operated), so the profit element is essentially replaced by various public mandates or regulations dealing with subsidy limits, bond retirement guarantees based on user charges, and numerous other economic, financial or political constraints. Because of the multiple objectives of the public sector, an analysis of the impacts of additional costs is more difficult.

The overall incidence patterns of these costs -- i.e., who bears the burden of them -- will be determined by the particular mix of reactions outlined above. These can be roughly divided into two categories, which are discussed in the following sections:

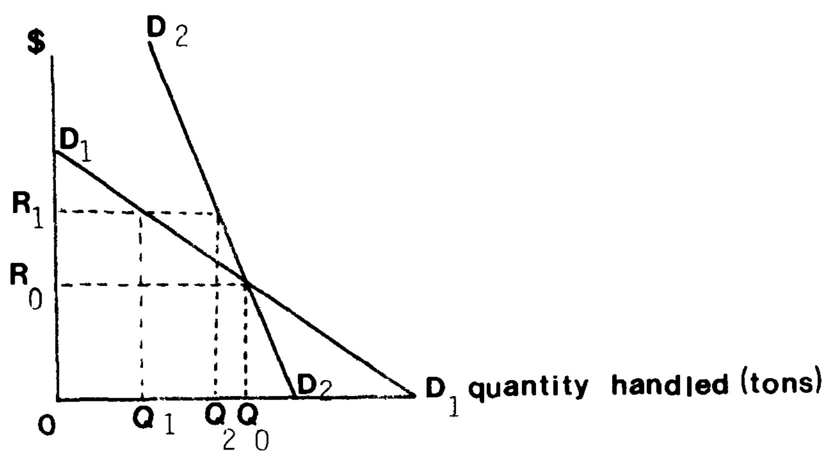
- supply effects: reactions by the suppliers of the landfill services.
- demand effects: reactions by those demanding these landfilling services (i.e., solid waste generators).

B. Supply Effects

The landfill operator faced with higher operating costs can either absorb the costs or seek out some method of avoiding them or shifting them elsewhere. The analysis of these reaction patterns is similar in nature to an analysis of the incidence of various government taxes or fees; both depend principally on the financial conditions of the firms and the characteristics of the markets in which they are involved. Any increases in business costs will eventually be borne either by (a) those who provide the various factors of production (labor , capital, equipment) or (b) those buying the business's goods or services. The only remaining alternative is to revise the technological or institutional structure of the firm (e.g., new equipment, consolidation with other firms, etc.) to avoid or minimize the impact of these costs by lowering costs in other areas. The following sections address five major market and operational effects most applicable to landfill operation.

1. Increase Disposal Fees for Landfill Users. The ability of landfill operators to pass costs forward in the form of higher user charges typically depends on the nature of the demand for their services. If the demand is very price elastic, the potential increase in revenue will be minimal as many of the landfill users will find alternative methods of meeting their waste handling needs. This is demonstrated in the figure below.

FIGURE 12



IMPACT OF HIGHER LANDFILL USER CHARGES ON DEMAND

A hypothetical landfill is used by two waste generators represented by demand D_1 and D_2 each of which dumps Q_0 tons of waste annually at the site. As the landfill raises its rates from R_0 to R_1, the more price-sensitive of the two, represented by demand curve D_1, reduces its demand from QQ_0 to QQ_1. The more price inelastic generator, represented by curve D_2 shows a more modest drop from QQ_0 to QQ_2.

The principal effect of the increase in rates is a decline in quantity disposed, and, if demand is elastic, a decline in total revenues for specific landfills. However, the problems created by a highly elastic market demand go beyond those of insufficient revenue generation. All wastes formerly handled by the landfill must either be deposited elsewhere or no longer disposed. The first of these options raises the possibility of illegal dumping as well as the increased likelihood that various landfill operators might avoid compliance, both of which are serious enforcement problems. The second option would be that generators might reduce their waste generation rates and/or expand recycling efforts. This question is covered in more detail in Section VII.C.

2. Higher Taxes for Landfill Support. A response available to public landfill operations is to pass the additional costs on to taxpayers in the form of higher subsidies for landfill operations. Some municipalities that have formerly assumed that all or a specified portion of landfill costs would be paid by landfill users may be faced with the problem of maintaining operating ratios (operating revenues/operating costs) while not wanting to provide any significant disincentives to those generators who should be using these facilities. As the portion of total costs covered by user charges drops, other public revenue sources would be required. Some private landfill operating costs could also be indirectly subsidized by taxpayers through investment, tax credits or loan guarantees for landfill upgrading or construction, research and development grants, or other forms of subsidy. The specific policy of the agencies involved, the prevailing methods used to finance everyday operating costs or retire bonds, and numerous other factors would have to be considered with the eventual reaction tending to be highly site-specific.

3. Decreases in Supplier Costs. The theoretical possibility exists that landfills could reduce their additional costs through decreases in supplier costs (e.g., lower wages, fuel costs, etc.). This possibility is raised for the sake of completeness only. It is not considered a practical possibility for most landfill operations, except as part of a regionalization and consolidation effort (covered below in Part 6).

4. Change in Profits of Private Landfill Operators. If a landfill operator cannot recover all of its additional costs through rate increases, subsidies, or decreases in supplier costs, the impact will be borne by the firm's stockholders in the form of a lower return on invested capital. Small impacts in this area will probably not cause any substantial adjustments by these firms, especially in the short-run, but the decreased profitability could reduce the level of investment in such operations and make it more difficult to raise the capital necessary to upgrade existing operations or build new ones. For those landfills that are publicly owned but privately operated (roughly seven percent of the total number of sites presented in the Waste Age survey), the situation would entail a pass-through of costs to the relevant public agency with whom the operator has contracted. The affected agency would then be

forced to either authorize higher user charges, provide alternative financial support to the operator to cover the extra operating costs, or implement a substantial revision in its operations.

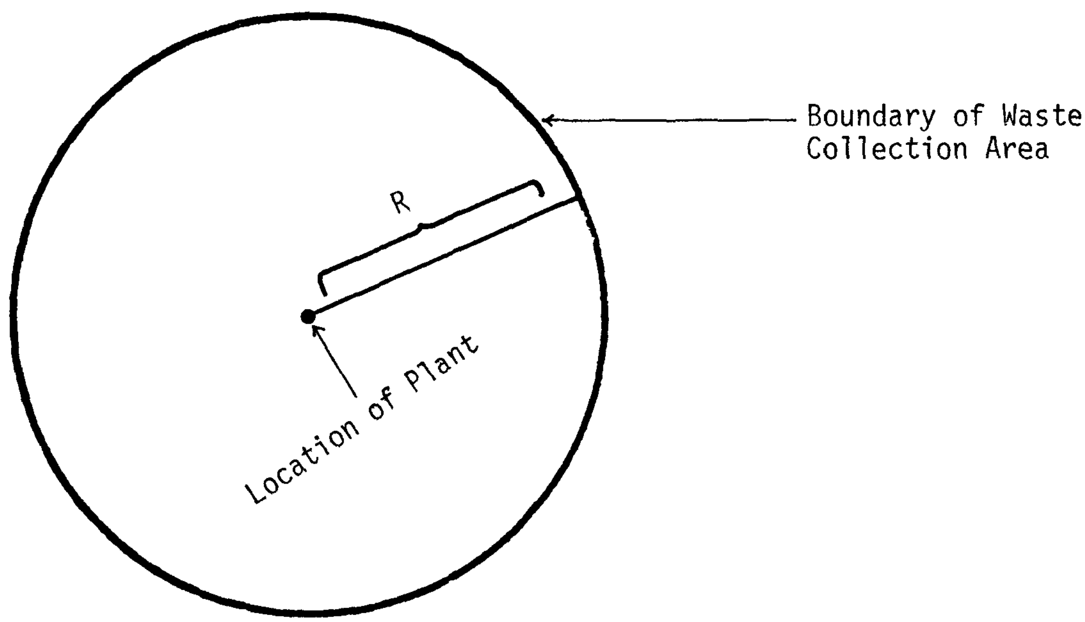
5. Change in Profits of Industries with On-Site Disposal. For those firms that handle part or all of their solid wastes at sites owned and operated by the firm, the higher disposal costs may mean a substantial financial loss if the firm has a high waste generation rate and if disposal represents a significant element in the firm's overall operating costs. Conversion from open dump operations to sanitary landfill operations could, in extreme cases, mean closure for some financially vulnerable firms. Others would be left virtually unaffected. This type of pattern has been shown to exist for the hazardous waste regulations under Subtitle C of RCRA (Reference 5): some industries (e.g., wool scouring and organic chemicals) would incur substantial cost increases and some closures, while others would either have virtually no incremental treatment costs (e.g., plastics, paints) or could pass through all of them due to an essentially price-inelastic demand (e.g., explosives). Industries that would be expected to face relatively substantial solid waste handling costs include food processing, apparel, wood products, fabricated metals and non-electrical machinery. It would be necessary to undertake detailed studies of each of these industries to determine whether they will be adversely affected by the proposed Guidelines.

6. Regionalization and Consolidation of Waste Handling. The analysis of economies of scale in landfill operations presented in Section III showed that cost savings could be realized through consolidation of smaller sites into one large landfill operation. The implementation of the RCRA landfill Criteria and Guidelines will increase the benefits of consolidation due to the lower unit disposal costs of large sites and the sharing of the initial financing burden of sanitary landfill capacity among more waste generators. The solid waste management plans of many states assume that a considerable amount of regional consolidation will occur. The New York State plan, for example, assumes that the total number of landfills will fall by over 59 percent due to the consolidation of smaller sites and the expanded use of energy and material recovery plants (Reference 35).

The major economic factors that affect the consolidation decision are (a) the potential for scale economies; (b) the density, dispersion, and total volume of the waste sources; and (c) the relevant costs of transportation. These are the essential elements of location theory that are typically applied to such problems as plant or warehouse location and market area analysis (Reference 36). A recent study of the impacts of the RCRA hazardous waste regulations outlined a hypothetical market area model that minimized unit waste disposal costs by altering market area. Figure 13 shows the location of this model facility in the center of a circular market area of radius R. Average transportation costs of 10¢/MT-mile and average haul distances of 2R were assumed. The following equation for waste handling cost was then derived:

FIGURE 13

OPTIMAL LOCATION/MARKET AREA FOR SANITARY LANDFILL



$$C_d = 20 + \frac{143,800}{(MTY)^{1.04}} \quad (\$/MT)$$

Total disposal cost then equals C_d + transporations cost:

$$C_0 = C_d + C_t$$

$$= 2(\$0.10)\ (2R/3) + 20 + \frac{143,800}{(MTY)^{1.04}}$$

C_0 was then differentiated with respect to R and this derivative was set equal to zero to find the value of R that minimized C_0. Knowing the average density of waste (wastes/yr./sq. mile), the total volume of waste in MT/year = $\pi R^2 p$, where p = annual waste generation density. Substituting this for MTY in the above equation and performing the differentiation gave the following results:

$$R_0 = \frac{78.4}{p^{0.338}}$$

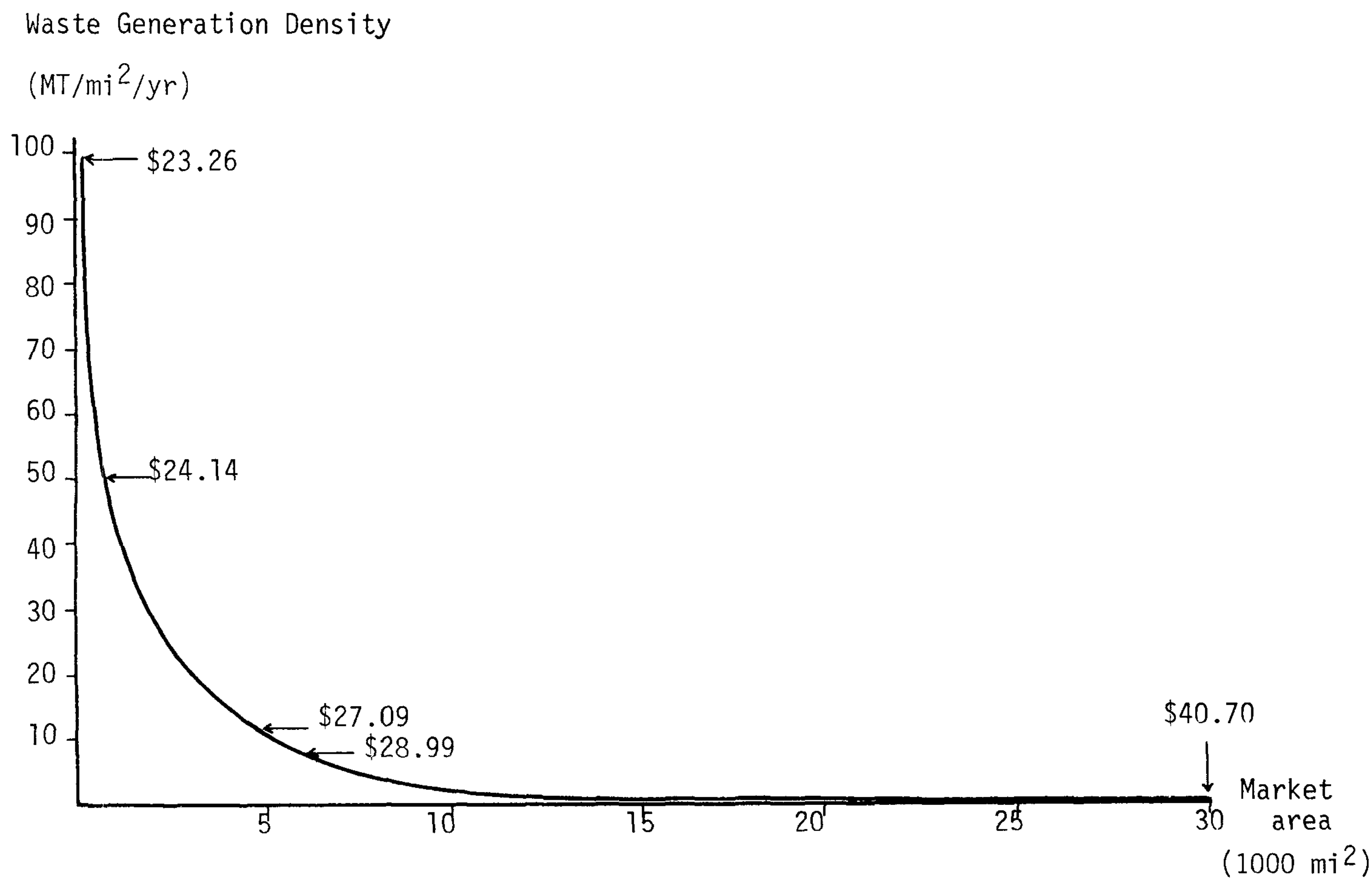
Figure 14 shows how the waste collection area decreases as the density of waste generation increases. At a waste density of 100 MTY/mi^2 (equivalent of roughly 120 persons/mi^2 generating 5 lbs/person/day), the service area is 855 mi^2 and the per unit treatment costs are \$23.26/MT; for 5 MTY/mi^2 (equivalent of 6 persons/mi^2) the area increases to 6500 mi^2, and at 1 MTY/mi^2 the area is roughly 19,400 mi^2.

Clearly there are substantial assumptions included in this type of model (e.g., the even distribution of wastes, the constant transportation costs over a wide mileage range). The transportation costs per mile would probably be considerably higher for the areas with shorter average routes, as the fixed costs of the vehicles would be spread over a smaller mileage base. If the transportation costs were doubled to 20¢/MT-mile for the highest density area, the service area would drop from 855 mi^2 to 615 mi^2, the necessary landfill capacity would fall accordingly from 85,800 MTY to 61,600 MTY, and unit costs would rise 8 percent to \$25.23 -- an increase of \$121,000 in annual disposal costs for those serviced in the revised service area.

Even with these limitations, this type of analysis does give a feel for the way in which scale economies and transportation costs can jointly determine benefits of regionalization and the optimal size and location of the waste treatment facility. The RCRA Guidelines and Criteria will force many (if not all) of the small landfill sites to consolidate their wastes in a much smaller number of large sites. The eventual impact on net disposal costs and related policy decisions will then come from the type of analyses presented above.

FIGURE 14

WASTE COLLECTION AREA FOR VARIOUS WASTE GENERATION DENSITIES



A hypothetical example showing the potential impact of the Guidelines on regionalization follows. Let us assume that the landfilling operations of states such as North Dakota were to be regionalized using the plant size/location model outlined above. The state has a land area of 69,273. sq. mi. and a population of roughly 640,000. Assuming that solid wastes suitable for landfilling are generated at a per capita rate of 4.5 lbs/day, the annual waste volume would be 525,600 tons (476,821 MT). Using the Waste Age survey number of 200 known landfills, these sites' average capacity (260 days/yr. operation) would be roughly 10 TPD (9.1 MTD). Waste density would then equal 6.88 MTY/sq. mi. Applying the equations given earlier, the ideal market area for each regional plant (assuming that the 6.88 MTY figure applies throughout the state) would be 5,243 sq. mi. , and 13 regional landfills at 36,000 MTY would replace the 200 smaller sites.

C. Demand Effects

1. Source Reduction. Part B.1. of this section showed how higher disposal costs (or rates) can reduce the demand for landfill services. Either an alternative waste disposal method will then be used (larger landfill, landspreading, illegal dumping, etc.) or the volume of the waste stream will be reduced. Adjustments in the raw materials used in production processes, changes in food packaging techniques, bottle deposit regulations and similar actions could be used to reduce the volume of waste produced from various industrial, commercial or residential activities. Part of this may occur as the disposal costs are internalized into various operations which then independently adjust their waste generation; other actions may only occur if given the impetus of State or Federal regulations. Increased disposal costs should make legislation aimed at source reduction more attractive.

2. Energy and Resource Recovery. The combined forces of higher waste disposal costs, increased petroleum cost, and concern over possible disruptions in energy supplies have improved the cost-effectiveness of many resource and energy recovery systems and approaches. The number of existing, under construction, or planned recovery plants across the country has increased substantially in recent years, as the data in Table 24 show.

TABLE 24

TREND IN MIXED-WASTE RESOURCE RECOVERY FACILITIES IMPLEMENTATION

Facility Status	1974	1975	1976
Operational	15	19	21
Under Construction	7	8	10
Advanced Planning[a]	23	30	33
Feasibility Studies[b]	25	37	54
Total:	70	94	118

a. Advanced planning = request for proposals issued, final design underway and/or funding authorized.

b. Feasibility studies = expressed interest in or undertaken informal studies.

Source: Reference 37.

The 21 operational sites used the following range of conversion/recovery processes:

TABLE 25

CONVERSION TECHNOLOGIES AT EXISTING RECOVERY FACILITIES, 1976

Process	No. of Sites	Average Capacity/ Site (tons/day)
. Waste→Steam via Combustion	13	645
. Waste→Refuse Derived Fuel	4	235
. Materials or Gas Recovery	2	150[a]
. Compost→Humus	1	200
. Waste→Gas via Pyrolysis	1	200

a. Materials recovery plant only; methane recovery plant operated at existing landfills and therefore had no tons/day figure.

Source: Reference 37.

The average capacity figure for the steam-generating plants is artificially lowered by demonstration-size plants (in the 20-50 TPD range); the average value for the 6 largest sites is 910 tons/day with 3 sites in the 1,200 - 1,600 TPD range. Plants in the 1,200 TPD range are all located within metropolitan areas. Such facilities need a service area population of about 500,000 in order to maintain that average flow figure. The average size of plants under construction and in advanced planning is even larger. A higher portion of these facilities will be using RDF technologies, generally in combination with metal and glass recovery, while the generation of steam via combustion is still frequently applied.

The capital costs of many of these plants are rather high -- up to $50,000 per daily ton of capacity for plants completed in the 1974-1976 period. Although additional experience in using these technologies in large-scale (vs. pilot) operations may lower these costs, the cost of such plants will still imply a long-term commitment. Nevertheless, many public and private sector observers feel that material and energy recovery will become a self-sufficient reality in the United States. Their conclusions are based on the long history of successful operation of such facilities in Europe and elsewhere, and the fact that private investment has begun to occur in the field.

The added costs of RCRA will encourage this trend, especially in or near large urban areas where suitable landfill sites are scarce and expensive and the waste density exists that is necessary for large scale recovery plants. Much of this same type of activity will, of course, occur in the industrial sectors that also face similar disposal cost increases. In combination with waste reduction, energy and material recovery techniques will be applied more frequently, depending on (a) the market for the recovered materials, within or outside the firm, (b) the incremental production costs of the recovery processes, and (c) the regional costs of electricity and other energy forms.

3. Other Legal Waste Disposal Methods. Other legal disposal methods that will continue to exist after implementation of the Guidelines are volume reduction (with disposal of residues), surface impoundment, and landspreading. The costs of the latter two will also be affected by RCRA, as Guidelines for surface impoundments and landspreading are issued under Section 1008. Decisions concerning waste disposal options by industry and municipalities will change to reflect the costs of these options after all the Guidelines are issued. Since the costs of future surface impoundment and landspreading activities are not yet determined, it is impossible to say how the increases in the cost of landfilling identified in this report will affect the choice of these other legal disposal options.

4. Illegal Dumping. One option that is unfortunately available to generators and landfill operators is the continued use or operation of illegal open dumps. The enforcement problem will be most severe for the thousands of very small sites in rural areas that would face very large increases in disposal costs under the RCRA Guidelines, even if

they were to implement the most cost-effective combination of site and collection consolidation. The enforcement costs for such operations, due to their geographic dispersion, small sites, and overall detection difficulty, will be rather high as well, forcing agencies to concentrate only on large sites. An enforcement management system would have to be developed that could maximize the return on resources spent on enforcement by taking into account such considerations as ground water conditions, landfill size, waste types handled, and enforcement staff constraints.

VIII. IMPACT OF THE GUIDELINES ON ENERGY USE

A. Background

Guidelines implementation will result in increased energy consumption for both the construction (involved in upgrading) and operating phases of landfill operations. Construction energy use will increase due to the requirements for improved levels of environmental protection with the concommittant use of more complex technologies such as liner installation, gas venting and collection systems, leachate collection and treatment systems, etc. Similarly, energy use associated with the operating phase will increase due to energy requirements for leachate pumping, more frequent cover application, etc. As previously referenced, Table 2 presents those technologies which have been defined as required upgrading technologies for existing landfills and which will result in increased construction energy use. Similarly, Table 26 indicates those technologies which will result in increased energy use associated with landfill operation.

B. Estimating Construction Energy Impacts

Data detailing construction energy use (gasoline, oil, diesel fuel, electricity) for construction of landfills are currently unavailable. To estimate the potential increase in construction energy use, the assumption has been made that increased energy use is directly proportional to increased capital expenditure. The baseline costs for existing landfill operations, as previously developed in Section III are $11.15, $6.65 and $3.95 per ton for 10 TPD, 100 TPD and 300 TPD facilities, respectively. Approximately 25 percent of those costs are attributable to construction costs, as follows: 10 TPD - $2.78; 100 TPD - $1.66; 300 TPD - $0.99.

By utilizing capital upgrading costs for the technologies identified in Table 2, total upgrading capital costs can be determined. Table B-1 (see Appendix B) presents the capital costs for those upgrading technologies to be incorporated into existing facilities. Table 27 converts the total upgrading technology capital costs developed in Appendix B to unit costs, and sums the unit costs of the appropriate technologies by landfill type, size, and site sensitivity. This yields increased capital costs per ton. Increased construction energy use has been assumed to be proportional to increased capital costs of the required upgrading technologies. Table 27 also shows the per cent increase in construction energy use for upgraded facilities. Consumption use is expected to be primarily in the form of gasoline, oil, and diesel fuel utilization.

TABLE 26

UPGRADING TECHNOLOGIES RESULTING IN INCREASED ENERGY OPERATING COSTS

Municipal[a]	Industrial	Pollution Control Residues
SENSITIVE FACILITIES		
Groundwater Water Quality Monitoring	Impermeable Daily Cover	Impermeable Daily Cover
Gas Monitoring	Groundwater Water Quality Monitoring	Groundwater Water Quality Monitoring
NONSENSITIVE FACILITIES		
Groundwater Water Quality Monitoring	Impermeable Daily Cover	Impermeable Daily Cover
Gas Monitoring	Groundwater Water Quality Monitoring	Groundwater Water Quality Monitoring

a. Daily cover assumed as existing technology; no increased energy use.

TABLE 27

TOTAL INCREASED CAPITAL COSTS PER TON AND PERCENT INCREASE IN CONSTRUCTION ENERGY USE FOR UPGRADED FACILITIES

	10 TPD		100 TPD		300 TPD	
	Increased Capital Cost/Ton	% Increase[a]	Increased Capital Cost/Ton	% Increase[a]	Increased Capital Cost/Ton	% Increase[a]
Municipal						
Sensitive	$3.99	144%	$0.93	56%	$0.51	52%
Nonsensitive	1.49	54%	0.33	20%	0.17	17%
Industrial						
Sensitive	2.62	94%	0.62	37%	0.35	35%
Nonsensitive	0.22	8%	0.07	4%	0.05	5%
Pollution Control Residues						
Sensitive	2.62	94%	0.62	37%	0.35	35%
Nonsensitive	0.12	8%	0.02	1%	0.01	1%

a. Baseline construction costs: 10 TPD, $2.78; 100 TPD, $1.66; 300 TPD, $0.99

C. Estimating Operating Energy Impacts

Table 26 lists upgrading technologies which will result in increased energy use during landfill operation. For existing facilities the primary energy consuming technology is that of impermeable cover. It has been assumed that municipal facilities for both sensitive and nonsensitive areas apply daily cover. Consequently, energy costs will not increase. For the remainder of the waste types, it has been assumed that daily cover is not a common practice and that impermeable cover application is energy intensive. A 100% increase in energy requirements for those sites which currently do not apply daily cover might be a reasonable estimate. Consumption is primarily in the area of gasoline and diesel fuel.

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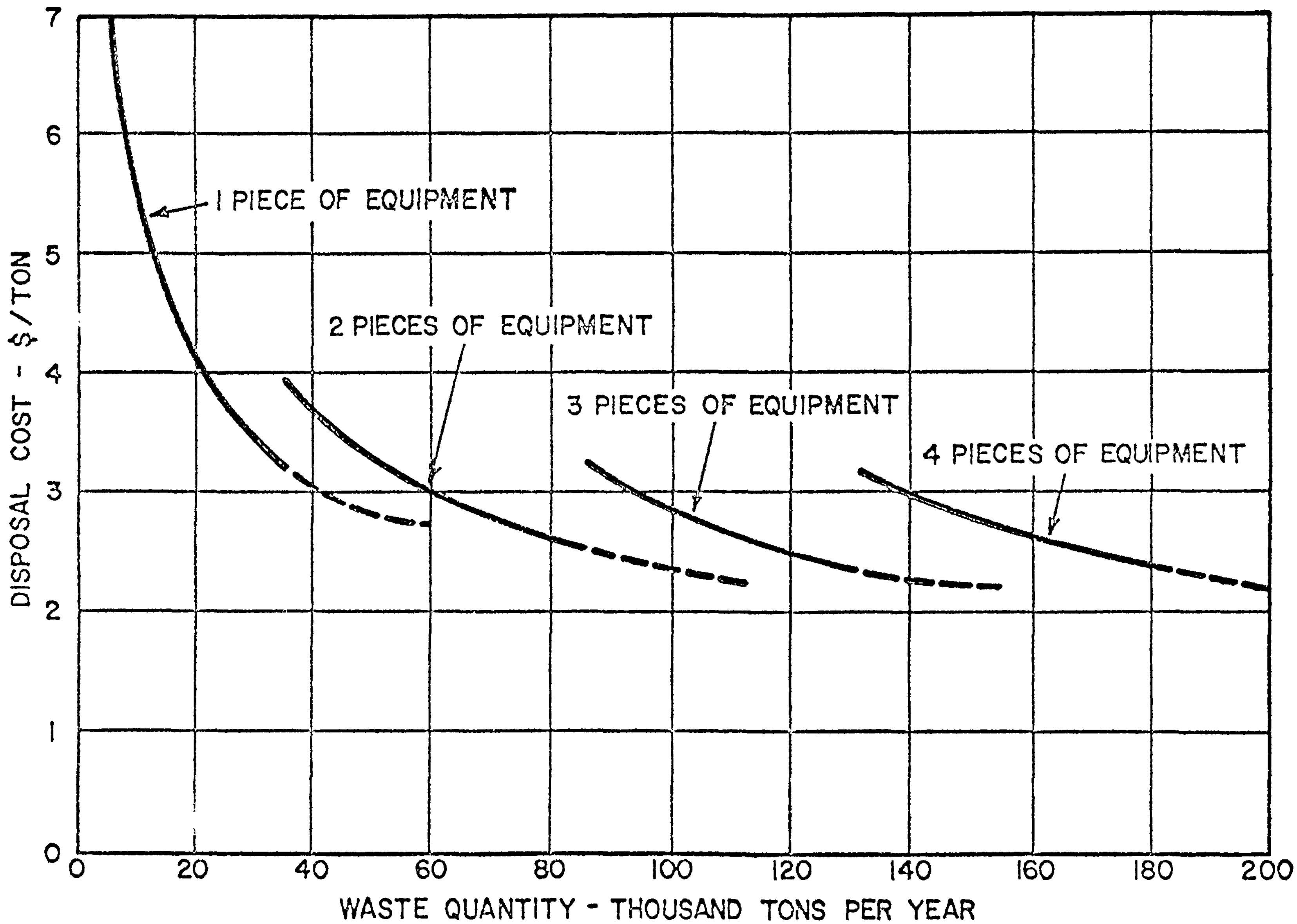
APPENDIX A

SAMPLE BASELINE COST CURVES

FIGURE A1

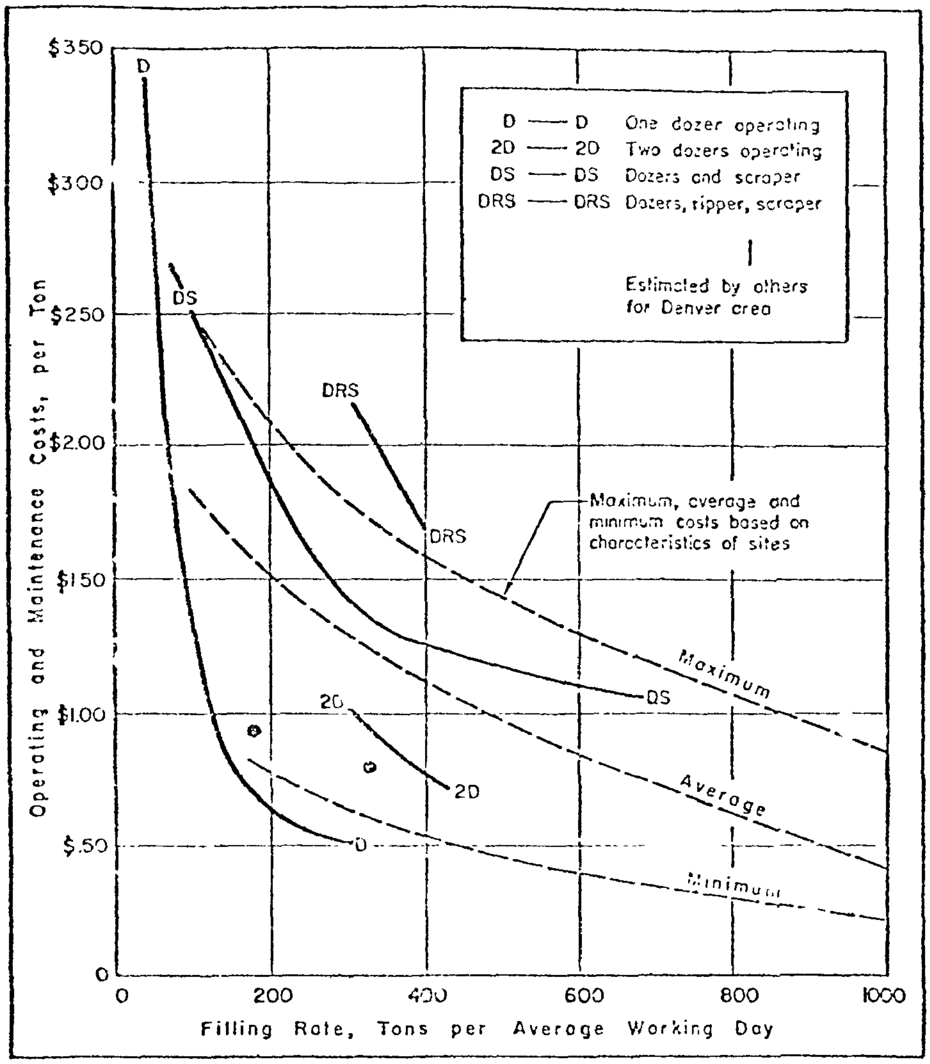
SANITARY LANDFILL COSTS



Source: Reference 3.

FIGURE A2

ESTIMATED SANITARY LANDFILL OPERATION AND MAINTENANCE COSTS

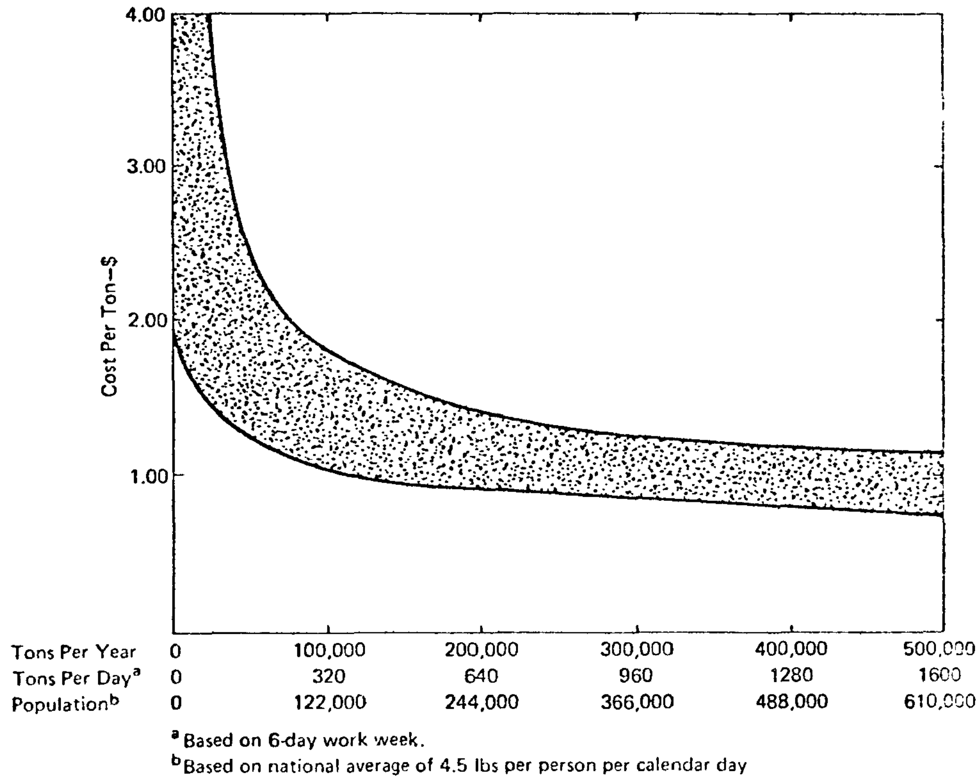


Note : Chart shows how cost of ownership and operation of equipment relates to the required filling rate.

Source: Reference 7.

FIGURE A3

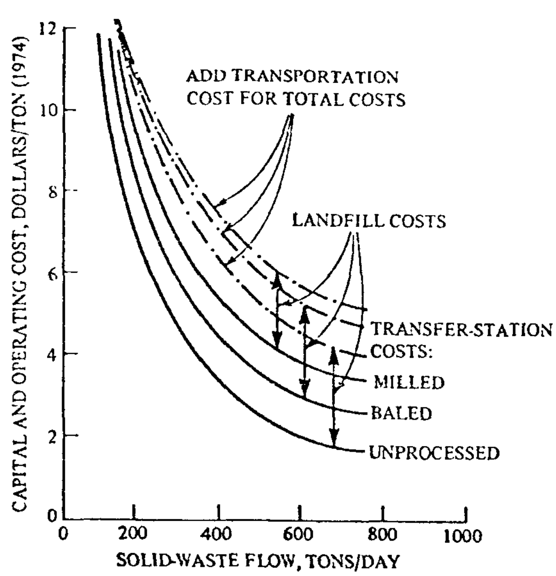
TYPICAL LANDFILL COSTS



Source: Reference 2.

FIGURE A4

SANITARY LANDFILL OPERATING COSTS



Source: Reference 8.

APPENDIX B

UNIT COST CALCULATIONS AND ASSUMPTIONS

For the purposes of developing final upgrading unit costs a calculation methodology was adopted which was similar in approach to the "Draft Environmental Impact Statement Criteria for Classification of Solid Waste Disposal Facilities." Major assumptions are as follows:

- Utilization of 10 TPD, 100 TPD, and 300 TPD sites
- Corresponding total acreages of 6 acres, 28 acres and 75 acres respectively
- Corresponding total perimeter lengths of 2,000 ft., 4,400 ft. and 7,200 ft. respectively
- 260 days operation per year
- In place refuse to soil cover rations of 1:1, 2:1 and 3:1 respectively
- 26,000, 260,000 and 780,000 total ten year life capacity for 10 TPD, 100 TPD and 300 TPD facilities respectively

More detailed assumptions for the selected and alternative upgrading technologies are as follows:

VERTICAL IMPERMEABLE BARRIER

- 20' depth, 60 cu. ft./ft. perimeter installation
- excavation @ $0.50/cu. yd., clay material @ $3.00/cu. yd., placement @ $0.30/cu. yd.
- total unit cost $17.00/ft. ($55.76/meter)

DIKE CONSTRUCTION

- 10' depth, 567 cu. ft./ft.
- 3:1 slopes
- materials and placement @ 1.50 cu. yd.
- total unit cost $31.50/ft. ($103.32/meter)

IMPERMEABLE DAILY COVER (ON-SITE SOURCE)

- total unit cost $0.60/cu. yd. ($0.78/cu. meter)

IMPERMEABLE DAILY COVER (OFF-SITE SOURCE)

- transport @ $1.00/cu. yd., clay material @ $3.00/cu. yd. placement @ $0.30 cu. yd.
- 2 mile average transport distance
- total unit cost $4.30/cu. yd. ($5.62/cu. meter)

PONDING

- 2" 24 hr. rainfall event
- runoff storage required for twice the site landfill area
- excavation @ $0.50/cu. yd. (0.65/cu. meter) land @ $3,000/acre ($7,410/hectare)
- 10 TPD, 0.4 acres, 5' depth; 100 TPD, 1.85 acres, 5' depth; 300 TPD, 2.5 acres, 10' depth

PERIMETER GRAVEL TRENCHES

- 20' depth, 60 cu. ft/ft, perimeter installation
- excavation @ $0.50/cu. yd., gravel material @ $4.00/cu. yd, placement @ $0.30/cu. yd.
- total unit cost $21.00/ft. ($68.88/meter)

GAS COLLECTION

- perimeter installation
- total unit cost @ $20.00/ft for 10 TPD and 100 TPD sites, $15.00/ft for 300 TPD sites ($65.60/meter, $65.60/meter, $49.20/meter respectively
- Annual operating costs for 10 TPD, $4,000; 100 TPD, $8,800; 300 TPD, $10,800

SYNTHETIC LINER

- total unit costs including site preparation and earth cover $3.60/sq. yd. ($4.31/sq. meter)

LEACHATE RECYCLING

- 30" infiltration/year.
- 10 TPD, $6,000 piping, $2,000 pump station, $500 annual costs; 100 TPD, $13,200 piping, $4,000 pump station, $1,000 annual costs; 300 TPD, $21,600 piping, $10,000 pump station, $2,000 annual costs

DITCHING

- total unit cost $2.25/ft. ($7.38/meter)

FINAL IMPERMEABLE COVER (ON-SITE SOURCE)

- unit cost $0.60/cu. yd. @ 2' depth ($5.62/cu. meter)

FINAL PERMEABLE COVER (ON-SITE SOURCE)

- unit cost $0.50/cu. yd. @ 2' depth ($0.65/cu. meter)

FINAL PERMEABLE COVER (OFF-SITE SOURCE)

- unit cost $1.75/cu. yd. @ 2' depth ($2.29/cu. meter)

REVEGETATION

- total unit cost $1,000/acre ($2,471/hectare)

The following table presents the development of technology unit costs in more detail:

GAS MONITORING

- 10 TPD, 4 wells; 100 TPD, 8 wells; 300 TPD, 12 wells
- wells @ $200/each, labor @ $100/day
- sampling labor for 10 TPD, 4 man-days/year; 100 TPD 8 man-days/year; 300 TPD, 12 man-days/year
- $1,000 monitoring equipment

GROUNDWATER WATER QUALITY MONITORING

- 10 TPD, 3 wells; 100 TPD, 4 wells; 300 TPD, 7 wells
- quarterly sampling @ $150/sample, $1,000/well
- sampling labor for 10 TPD, 3 man-days/year; 100 TPD, 4 man-days/year; 300 TPD, 7 man-days/year @ $100/day

NATURAL CLAY LINER (OFF-SITE SOURCE)

- transport @ $1.00/cu. yd., clay material @ $3.00/cu. yd., placement @ $0.30/cu. yd.
- 2-foot depth clay material
- 2-mile average transport distance
- total unit cost @ $4.30/cu. yd. ($5.89/cu. meter)

LEACHATE COLLECTION FACILITIES

- 10 TPD, 3,500' collector pipe; 100 TPD, 14,300' collector pipe; 300 TPD, 36,000' collector pipe
- 100' collector pipe spacing plus perimeter
- total unit cost @ $7.00/ft. ($22.96/meter)

LEACHATE MONITORING, REMOVAL AND TREATMENT

- 6" infiltration/year, 450 gal/day/acre
- 10 TPD, 2,700 gal/day, 2.5¢/gal; 100 TPD, 12,600 gal/day, 1¢/gal; 300 TPD, 33,750 gal/day, 0.5¢/gal (18.7¢/cu. ft., 7.5¢/cu. ft., 3.7¢/cu. ft. respectively

PERMEABLE DAILY COVER (ON-SITE SOURCE)

- total unit cost $0.50/cu. yd. ($0.65/cu. meter)

PERMEABLE DAILY COVER (OFF-SITE SOURCE)

- transport @ $0.75/cu. yd, material @ $0.30/cu. yd, placement @ $0.50/cu. yd.
- 1-mile average transport distance
- total unit cost $1.55/cu. yd. ($2.03/cu. meter)

VERTICAL PIPE VENTS

- 2 per acre @ $2,000/vent

FIRE CONTROL

- one fire truck unit @ $1,000, $2,000, and $10,000 per site for 10 TPD, 100 TPD and 300 TPD sites respectively

ACCESS CONTROL

- perimeter installation
- total unit cost @ $12.00/ft. ($39.36/meter)

LITTER CONTROL

- litter control fencing, 130 ft., 280 ft. and 450 ft. per 10 TPD, 100 TPD and 300 TPD sites respectively @ $10.00/ft. ($32.80/meter)

COMPACTION

- one machine @ $50,000

TABLE B1
UNIT COSTS OF CONTROL TECHNOLOGIES

		Capital Costs			O & M COSTS				
Technology	Site Size	Unit Costs	Quantity	Total	Unit Cost	Quantity	Yearly Costs	Present Worth	Total Costs/Ton (1977 dollars)
Vertical Impermeable Barrier	10 TPD	$17.00/ft.	2,000'	$ 34,000	-	-	-	-	$ 1.30
	100 TPD	"	4,400'	74,800	-	-	-	-	0.30
	300 TPD	"	7,200'	122,400	-	-	-	-	0.15
Dike Construction	10 TPD	$31.50/ft.	2,000'	$ 63,000	-	-	-	-	$ 2.40
	100 TPD	"	4,400'	138,000	-	-	-	-	0.55
	300 TPD	"	7,200'	226,800	-	-	-	-	0.30
Impermeable Daily Cover (on-site source)	10 TPD	-	-	-	$0.60/cu. yd.	5,200 cu. yd.	$ 3,120	$ 19,200	$ 0.75
	100 TPD	-	-	-	"	26,000 cu. yd.	15,600	95,800	0.35
	300 TPD	-	-	-	"	52,000 cu. yd.	31,200	191,600	0.25
Impermeable Daily Cover (off-site source)	10 TPD	-	-	-	$4.30/cu. yd.	5,200 cu. yd.	$ 22,400	$ 137,300	$ 5.30
	100 TPD	-	-	-	"	26,000 cu. yd.	111,800	686,500	2.65
	300 TPD	-	-	-	"	52,000 cu. yd.	223,600	1,372,900	1.75
Ponding	10 TPD	$ 0.50/cu. yd.	3,200 cu. yd.	$ 2,800*	-	-	-	-	$ 0.10
	100 TPD	"	15,000 cu. yd.	13,000*	-	-	-	-	0.05
	300 TPD	"	40,200 cu. yd.	27,500*	-	-	-	-	0.04
Gas Monitoring	10 TPD	$200/well	4	$ 1,800**	$100/day	4 days/year***	$ 400	$2,400	$ 0.15
	100 TPD	"	8	2,600**	"	8 days/year***	800	4,900	0.03
	300 TPD	"	12	3,400**	"	12 days/year***	1,200	7,400	0.01
Groundwater Water Quality Monitoring	10 TPD	$1,000/well	3	$ 3,000	$150/sample	3 days/year****	$2,100	$ 12,900	$ 0.60
	100 TPD	"	4	4,000	"	4 days/year****	2,800	17,200	0.10
	300 TPD	"	7	7,000	"	7 days/year****	4,900	30,100	0.05
Gas Collection Facilities	10 TPD	$ 20/ft.	2,000'	$ 40,000	-	-	$ 4,000	$ 24,600	$ 2.50
	100 TPD	"	4,400'	88,000	-	-	8,800	54,000	0.55
	300 TPD	"	7,200'	144,000	-	-	14,400	88,400	0.30

* includes land costs
** includes equipment costs at $1,000
*** 8 samples/well/year
**** 4 samples/well/year

Technology	Site Size	Capital Costs: Unit Costs	Capital Costs: Quantity	Capital Costs: Total	O & M COSTS: Unit Cost	O & M COSTS: Quantity	O & M COSTS: Yearly Costs	O & M COSTS: Present Worth	Total Costs/Ton (1977 dollars)
Natural Clay Liner	10 TPD	$4.30/cu. yd.	19,350 cu. yd.	$ 83,200	-	-	-	-	$ 3.20
	100 TPD	"	90,340 cu. yd.	388,500	-	-	-	-	1.50
	300 TPD	"	242,000 cu. yd.	1,040,600	-	-	-	-	1.35
Leachate Collection	10 TPD	$7.00/ft.	3,500'	$ 24,500	-	-	-	-	$ 0.95
	100 TPD	"	14,300'	100,100	-	-	-	-	0.40
	300 TPD	"	36,000'	252,000	-	-	-	-	0.30
Leachate Treatment	10 TPD	-	-	-	2.5¢/gal.	2,700 gal/day	$24,600*	$151,300	$ 5.80
	100 TPD	-	-	-	1.0¢/gal.	12,600 gal.day	46,000*	282,400	1.10
	300 TPD	-	-	-	0.5¢/gal.	33,750 gal/day	61,600*	378,200	0.50
Permeable Daily Cover (on-site source)	10 TPD	-	-	-	$0.50/cu. yd.	5,200 cu. yd.	$ 2,600	$ 16,000	$ 0.60
	100 TPD	-	-	-	"	26,000 cu. yd.	13,000	79,800	0.30
	300 TPD	-	-	-	"	52,000 cu. yd.	26,000	159,600	0.20
Permeable Daily Cover (off-site source)	10 TPD	-	-	-	$1.55/cu. yd.	5,200 cu. yd.	$ 8,100	$ 49,500	$ 1.90
	100 TPD	-	-	-	"	26,000 cu. yd.	40,300	247,400	0.95
	300 TPD	-	-	-	"	52,000 cu. yd.	80,600	494,900	0.65
Vertical Pipe Vents	10 TPD	$2000 per	12	$ 24,000	-	-	-	-	$ 0.90
	100 TPD	"	56	112,000	-	-	-	-	0.45
	300 TPD	"	150	300,000	-	-	-	-	0.40
Perimeter Gravel Trenches	10 TPD	$21.00/ft.	2,000'	$ 42,000	-	-	-	-	$ 1.60
	100 TPD	"	4,400'	92,400	-	-	-	-	0.35
	300 TPD	"	7,200'	151,200	-	-	-	-	0.20

* treatment 7 days/week

TABLE B1 (CONTINUED)

Technology	Site Size	Capital Costs			O & M COSTS				Total Costs/Ton (1977 dollars)
		Unit Costs	Quantity	Total	Unit Cost	Quantity	Yearly Costs	Present Worth	
Synthetic Liner	10 TPD	$ 3.60/sq. yd.	29,040 sq. yd.	$ 104,500	-	-	-	-	$ 4.00
	100 TPD	"	135,520 sq. yd.	487,900	-	-	-	-	1.90
	300 TPD	"	363,000 sq. yd.	1,306,800	-	-	-	-	1.65
Leachate Recycling	10 TPD	$ 3.00/ft.	2,000'	$ 8,000*	-	-	$ 500	$ 3,100	$ 0.45
	100 TPD	"	4,400'	17,200*	-	-	1,000	6,100	0.10
	300 TPD	"	7,200'	31,600*	-	-	2,000	12,300	0.05
Ditching	10 TPD	$ 2.25/ft.	2,000'	$ 4,500	-	-	-	-	$ 0.15
	100 TPD	"	4,400'	9,900	-	-	-	-	0.04
	300 TPD	"	7,200'	16,200	-	-	-	-	0.02
Final Impermeable Cover (on-site source)	10 TPD	$ 0.60/cu. yd.	19,360 cu. yd.	$ 11,600	-	-	-	-	$ 0.45
	100 TPD	"	90,340 cu. yd.	54,200	-	-	-	-	0.20
	300 TPD	"	242,000 cu. yd.	145,200	-	-	-	-	0.20
Final Impermeable Cover (off-site source)	10 TPD	$ 4.30/cu. yd.	19,360 cu. yd.	$ 83,200	-	-	-	-	$ 3.20
	100 TPD	"	90,340 cu. yd.	388,500	-	-	-	-	1.50
	300 TPD	"	242,000 cu. yd.	1,040,600	-	-	-	-	1.35
Final Permeable Cover (on-site source)	10 TPD	$ 0.50/cu. yd.	19,360 cu. yd.	$ 9,700	-	-	-	-	$ 0.40
	100 TPD	"	90,340 cu. yd.	45,200	-	-	-	-	0.15
	300 TPD	"	242,000 cu. yd.	121,000	-	-	-	-	0.15
Final Permeable Cover (off-site source)	10 TPD	$ 1.75/cu. yd.	19,360 cu. yd.	$ 33,900	-	-	-	-	$ 1.80
	100 TPD	"	90,340 cu. yd.	159,000	-	-	-	-	0.60
	300 TPD	"	242,000 cu. yd.	423,500	-	-	-	-	0.55
Revegetation	10 TPD	$1,000/acre	6 acres	$ 6,000	-	-	-	-	$ 0.25
	100 TPD	"	28 acres	28,000	-	-	-	-	0.10
	300 TPD	"	75 acres	75,000	-	-	-	-	0.10

* includes pump station

		Capital Costs			O & M COSTS				
Technology	Site Size	Unit Costs	Quantity	Total	Unit Cost	Quantity	Yearly Costs	Present Worth	Total Costs/Ton (1977 dollars)
Fire Control	10 TPD	-	1	$ 1,000	-	-	-	-	$ 0.04
	100 TPD	-	1	2,000	-	-	-	-	0.01
	300 TPD	-	1	10,000	-	-	-	-	0.01
Access Control	10 TPD	$ 12.00/ft.	2,000'	$24,000	-	-	-	-	$ 0.90
	100 TPD	"	4,400'	52,800	-	-	-	-	0.20
	300 TPD	"	7,200'	86,400	-	-	-	-	0.10
Litter Control	10 TPD	$ 10.00/ft.	130'	$ 1,300	-	-	-	-	$ 0.05
	100 TPD	"	280'	2,800	-	-	-	-	0.01
	300 TPD	"	450'	4,500	-	-	-	-	0.01
Compaction	10 TPD	-	1	$50,000	-	-	-	-	$ 1.90
	100 TPD	-	1	50,000	-	-	-	-	0.20
	300 TPD	-	1	50,000	-	-	-	-	0.05

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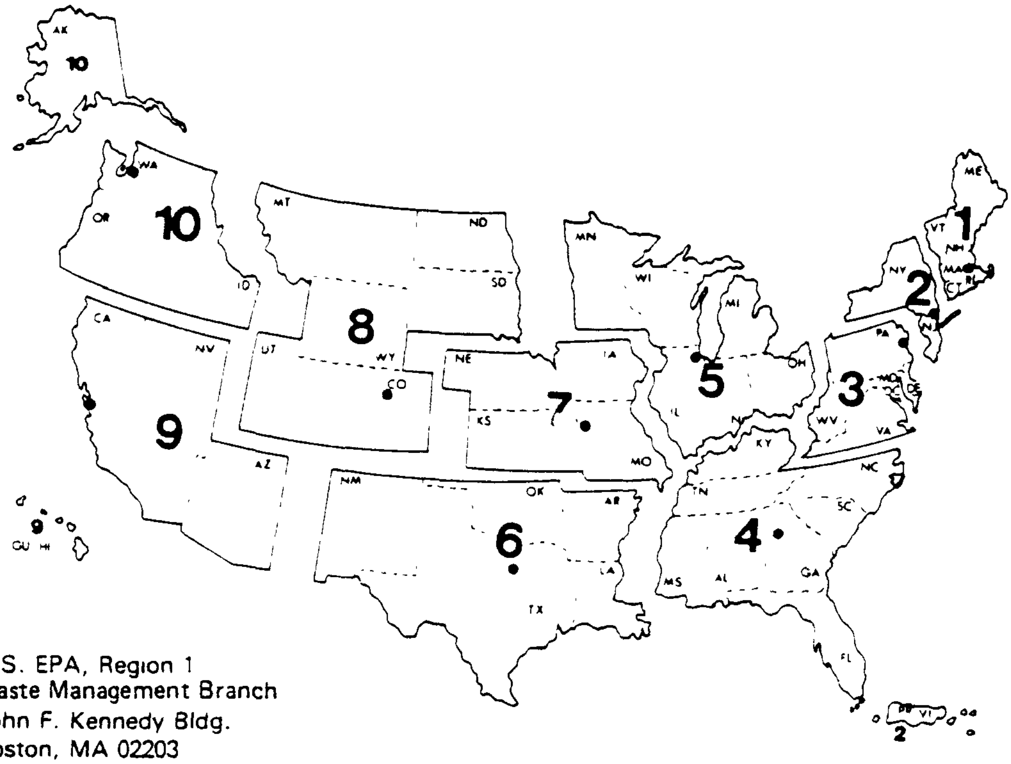
EPA REGIONS



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