United States Environmental Protection Agency

Office of Solid Waste and Emergency Response

EPA

DIRECTIVE NUMBER: 9523.00-5

TITLE: Permit Applicant's Guidance Manual for Hazardous Waste Land Treatment, Storage, and Disposal Facilities

APPROVAL DATE: 7/1/86

EFFECTIVE DATE: 7/1/86

ORIGINATING OFFICE: OSW

☒ **FINAL**

☐ **DRAFT**

STATUS:
[ ] A- Pending OMB approval
[ ] B- Pending AA-OSWER approval
[ ] C- For review &/or comment
[ ] D- In development or circulating headquarters

REFERENCE (other documents):

OSWER OSWER OSWER

E DIRECTIVE DIRECTIVE

EPA

Washington, DC 20460

OSWER Directive Initiation Request

Directive Number: 9523.00-5

Originator Information

Name of Contact Person	Mail Code - Branch	Telephone Number
Art Day	PSPD	382-4680

Lead Office: ☐ OERR ☐ OSW ☐ OUST ☐ OWPE ☐ AA-OSWER

Approved for Review

Signature of Office Director | Date

Title: Permit Applicant's Guidance Manual for Hazardous Waste Land Treatment, Storage, and Disposal Facilities

Summary of Directive

SUMMARY

To provide guidance for preparation of Part A and Part B permit applications for hazardous waste land treatment, storage and disposal facilities regulated under RCRA 1976. Some of the standards in effect when the Manual was published have been replaced, i.e., some guidelines are obsolete while others remain current.

Key Words:
Permit, Treatment, Storage, Disposal, Landfill, Groundwater Monitoring

Type of Directive *(Manual, Policy Directive, Announcement, etc.)*

Status: ☐ Draft ☐ Final ☐ New ☐ Revision

Does this Directive Supersede Previous Directive(s)? ☐ Yes ☐ No Does It Supplement Previous Directive(s)? ☐ Yes ☐ No

If "Yes" to Either Question, What Directive *(number, title)*

Review Plan

☐ AA-OSWER ☐ OERR ☐ OSW ☐ OUST ☐ OWPE ☐ Regions ☐ OECM ☐ OGC ☐ OPPE ☐ Other *(Specify)*

This Request Meets OSWER Directives System Format

Signature of Lead Office Directives Officer | Date

Signature of OSWER Directives Officer | Date

United States
Environmental Protection
Agency

Office of Solid Waste
and Emergency Response
Washington DC 20460

October 1983

Solid Waste

EPA

Draft

Permit Writers' Guidance Manual for Hazardous Waste Land Treatment, Storage, and Disposal Facilities

Volume 2

For Internal Use Only

OSWER -

9523

PERMIT WRITER'S GUIDANCE MANUAL FOR HAZARDOUS WASTE LAND TREATMENT, STORAGE, AND DISPOSAL FACILITIES

Volume 2

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Project Officer

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OFFICE OF SOLID WASTE AND
EMERGENCY RESPONSE
U. S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DISCLAIMER

This Draft Final Report was furnished to the Environmental Protection Agency by the GCA Corporation, GCA/Technology Division, Bedford, Massachusetts 01730, in fulfillment of Contract No. 68-02-3168, Assignment No. 87-(3). The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Environmental Protection Agency or the cooperating agencies. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

ACKNOWLEDGMENTS

The authors express their appreciation to the staff of the Office of Solid Waste, Land Disposal Branch, including Mr. Jon Perry, the EPA Project Officer, and Messrs. Art Day and Mike Flynn, for their assistance and helpful guidance throughout this program. We also acknowledge the collective group of authors whose work is cited throughout this document including researchers associated with the EPA Municipal Environmental Research Laboratory in Cincinnati, and organizations such as K. W. Brown and Associates, Inc., GeoTrans, Inc., and Matrecon, Inc.

This manual was prepared by the GCA/Technology Division of GCA Corporation, Bedford, MA. The principal authors were Charles W. Young, Peter H. Anderson, Stephen V. Capone, John P. Patinskas, Ronald K. Bell, Lisa A. Baci, Nancy H. Krusell, and Pablo Huidobro. We thank other GCA staff members who contributed to this document, including Messrs. Thomas J. Nunno, Daniel J. Goode, and Michael R. Jasinski. We also extend our appreciation to the staff of the GCA Technical Publications Department, managed by Ms. Sharon Pleskowicz, for their dedicated assistance in preparing this document.

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SECTION 8.0

LAND TREATMENT

This Section presents guidance on evaluating application information submitted in support of the land treatment facility standards specified in Subpart M of Part 264. The federal requirements are reproduced and the application information requested by the Part B Permit Applicants' manual is summarized. This Section is subdivided into the following seven major subject areas:

8.1 Treatment Demonstration

8.2 Land Treatment Program

8.3 Design and Operating Requirements

8.4 Food-Chain Crop Requirements

8.5 Closure and Post-Closure Care

8.6 Special Requirements for Ignitable or Reactive Wastes

8.7 Special Requirements for Incompatible Wastes

A Technical Adequacy Checklist is provided at the end of the Section in subsection 8.8. References cited in each of the first seven subsections are listed at the end of the subsections.

The information requirements of §270.20 are reprinted* below to provide an overview of the issues to be considered in reviewing a land treatment permit application.

> §270.20 Specific Part B Information Requirements for Land Treatment Facilities
>
> "Except as otherwise provided in §264.1, owners and operators of facilities that use land treatment to dispose of hazardous waste must provide the following additional information:
>
> (a) A description of plans to conduct a treatment demonstration as required under §264.272. The description must include the following information:

---

*All regulatory citations are reproduced or quoted from the Federal Register.

(1) The wastes for which the demonstration will be made and the potential hazardous constituents in the waste;

(2) The data sources to be used to make the demonstration (e.g., literature, laboratory data, field data, or operating data);

(3) Any specific laboratory or field test that will be conducted, including:

(i) The type of test (e.g., column leaching, degradation);

(ii) Materials and methods, including analytical procedures;

(iii) Expected time for completion;

(iv) Characteristics of the unit that will be simulated in the demonstration, including treatment zone characteristics, climatic conditions, and operating practices.

(b) A description of a land treatment program, as required under §264.271. This information must be submitted with the plans for the treatment demonstration, and updated following the treatment demonstration. The land treatment program must address the following items:

(1) The wastes to be land treated;

(2) Design measures and operating practices necessary to maximize treatment in accordance with §264.273(a) including:

(i) Waste application method and rate;

(ii) Measures to control soil pH;

(iii) Enhancement of microbial or chemical reactions;

(iv) Control of moisture content;

(3) Provisions for unsaturated zone monitoring, including:

(i) Sampling equipment, procedures, and frequency;

(ii) Procedures for selecting sampling locations;

(iii) Analytical procedures;

(iv) Chain of custody control;

(v) Procedures for establishing background values;

(vi) Statistical methods for interpreting results;

(vii) The justification for any hazardous constituents recommended for selection as principal hazardous constituents, in accordance with the criteria for such selection in §264.278(a);

(4) A list of hazardous constituents reasonably expected to be in, or derived from, the wastes to be land treated based on waste analysis performed pursuant to §264.13;

(5) The proposed dimensions of the treatment zone;

(c) A description of how the unit is or will be designed, constructed, operated, and maintained in order to meet the requirements of §264.273. This submission must address the following items:

(1) Control of run-on;

(2) Collection and control of run-off;

(3) Minimization of run-off of hazardous constituents from the treatment zone;

(4) Management of collection and holding facilities associated with run-on and run-off control systems;

(5) Periodic inspection of the unit. This information should be included in the inspection plan submitted under §270.14(b)(5);

(6) Control of wind dispersal of particulate matter, if applicable;

(d) If food-chain crops are to be grown in or on the treatment zone of the land treatment unit, a description of how the demonstration required under §264.276(a) will be conducted including

(1) Characteristics of the food-chain crop for which the demonstration will be made.

(2) Characteristics of the waste, treatment zone, and waste application method and rate to be used in the demonstration;

(3) Procedures for crop growth, sample collection, sample analysis, and data evaluation;

(4) Characteristics of the comparison crop including the location and conditions under which it was or will be grown;

(e) If food-chain crops are to be grown, and cadmium is present in the land-treated waste, a description of how the requirements of §264.276(b) will be complied with;

(f) A description of the vegetative cover to be applied to closed portions of the facility, and a plan for maintaining such cover during the post-closure care period, as required under §264.280(a)(8) and §264.280(c)(2). This information should be included in the closure plan and, where applicable, the post-closure care plan submitted under §270.14(b)(13);

(g) If ignitable or reactive wastes will be placed in or on the treatment zone, an explanation of how the requirements of §264.281 will be complied with;

(h) If incompatible wastes, or incompatible wastes and materials, will be placed in or on the same treatment zone, an explanation of how §264.282 will be complied with."

In using this manual to evaluate permit applications it is important to recognize that the recommended specifications and techniques presented are guidance, not regulations. During the permitting process there will be considerable negotiation to determine best facility design and operating practices for a subject land treatment unit. Owners and operators may design and/or operate their facilities differently than the methods recommended herein, which is acceptable as long as sufficient information is presented in the permit application to demonstrate compliance with specified performance requirements.

8.1 TREATMENT DEMONSTRATION

8.1.1 Federal Requirement

Plans for conducting a treatment demonstration and presenting complete demonstration results, unless applying for a two-phase permit, must be included in the Part B permit application for facilities that use land treatment to dispose of hazardous waste. Section 270.20(a) states that the Part B application must include:

"(a) A description of plans to conduct a treatment demonstration as required under §264.272. The description must include the following information:

(1) The wastes for which the demonstration will be made and the potential hazardous constituents in the waste;

(2) The data sources to be used to make the demonstration (e.g., literature, laboratory data, field data, or operating data);

(3) Any specific laboratory or field test that will be conducted, including:

(i) The type of test (e.g., column leaching, degradation);

(ii) Materials and methods, including analytical procedures;

(iii) Expected time for completion;

(iv) Characteristics of the unit that will be simulated in the demonstration, including treatment zone characteristics, climatic conditions, and operating practices."

Applicants who use existing available data to complete the treatment demonstration or who are issued short-term demonstration permits must submit the demonstration results with the Part B permit application. Applicants who are issued a two-phase permit are required to submit the demonstration results upon completion of testing. The following discussion addresses short-term and two-phase permits.

The technical standards of Part 264 for the treatment demonstration, covered under §264.272(a), (b), and (c), are as follows:

"(a) For each waste that will be applied to the treatment zone, the owner or operator must demonstrate, prior to application of the waste, that hazardous constituents in the waste can be completely degraded, transformed, or immobilized in the treatment zone.

(b) In making this demonstration, the owner or operator may use field tests, laboratory analyses, available data, or, in the case of existing units, operating data. If the owner or operator intends to conduct field tests or laboratory analyses in order to make the demonstration required under paragraph (a) of this section, he must obtain a treatment or disposal permit under §270.63. The Regional Administrator will specify in this permit the testing, analytical, design, and operating requirements (including the duration of the tests and analyses, and, in the case of field tests, the horizontal and vertical dimensions of the treatment zone, monitoring procedures, closure and clean-up activities) necessary to meet the requirements in paragraph (c) of this section.

(c) Any field test or laboratory analysis conducted in order to make a demonstration under paragraph (a) of this section must:

(1) Accurately simulate the characteristics and operating conditions for the proposed land treatment unit including:

(i) The characteristics of the waste (including the presence of Appendix VIII of Part 261 of this chapter constituents);

(ii) The climate in the area;

(iii) The topography of the surrounding area;

(iv) The characteristics of the soil in the treatment zone (including depth); and

(v) The operating practices to be used at the unit.

(2) Be likely to show that hazardous constituents in the waste to be tested will be completely degraded, transformed, or immobilized in the treeatment zone of the proposed land treatment unit; and

(3) Be conducted in a manner that protects human health and the environment considering:

(i) The characteristics of the waste to be tested;

(ii) The operating and monitoring measures taken during the course of the test;

(iii) The duration of the test;

(iv) The volume of waste used in the test;

(v) In the case of field tests, the potential for migration of hazardous constituents to ground water or surface water."

When the applicant intends to conduct field or laboratory analyses to make the treatment demonstration, the owner or operator must first obtain a treatment or disposal permit. Under such conditions, a short-term permit covering only field testing and/or laboratory analyses may be issued, or a two-phase facility permit may be issued covering the treatment demonstration and facility design, construction, operation, and maintenance. Section 270.63, presented below, defines the nature of these permits and the conditions under which they should be issued.

Section 270.63, Permits for land treatment demonstrations using field test or laboratory analyses, states:

"(a) For the purpose of allowing an owner or operator to meet the treatment demonstration requirements of §264.272 of this Chapter, the Director may issue a treatment demonstration permit. The permit must contain only those requirements necessary to meet the standards in §264.272(c). The permit may be issued either as a treatment or disposal permit covering only the field test or laboratory analyses, or as a two-phase facility permit covering the field tests, or laboratory analyses, and design, construction, operation, and maintenance of the land treatment unit.

(1) The Director may issue a two-phase facility permit if he finds that, based on information submitted in Part B of the application, substantial, although incomplete or inconclusive, information already exists upon which to base the issuance of a facility permit.

(2) If the Director finds that not enough information exists upon which he can establish permit conditions to attempt to provide for compliance with all of the requirements of Subpart M, he must issue a treatment demonstration permit covering only the field test or laboratory analyses.

(b) If the Director finds that a phased permit may be issued, he will establish, as requirements in the first phase of the facility permit, conditions for conducting the field tests or laboratory analyses. These permit conditions will include design and operating parameters (including the duration of the tests or analyses and, in the case of field tests, the horizontal and vertical dimensions of the treatment zone), monitoring procedures, post-demonstration clean-up activities, and any other conditions which the director finds may be necessary under §264.272(c). The Director will include conditions in the second phase of the facility permit to attempt to meet all Subpart M requirements pertaining to

unit design, construction, operation, and maintenance. The Director will establish these conditions in the second phase of the permit based upon the substantial but incomplete or inconclusive information contained in the Part B application.

(1) The first phase of the permit will be effective as provided in §124.15(b) of this Chapter.

(2) The second phase of the permit will be effective as provided in paragraph (d) of this Section.

(c) When the owner or operator who has been issued a two-phase permit has completed the treatment demonstration, he must submit to the Director a certification, signed by a person authorized to sign a permit application or report under §270.11, that the field tests or laboratory analyses have been carried out in accordance with the conditions specified in phase one of the permit for conducting such tests or analyses. The owner or operator must also submit all data collected during the field tests or laboratory analyses within 90 days of completion of those tests or analyses unless the Director approves a later date.

(d) If the Director determines that the results of the field tests or laboratory analyses meet the requirements of §264.272 of this Chapter, he will modify the second phase of the permit to incorporate any requirements necessary for operation of the facility in compliance with Part 264, Subpart M, of this Chapter, based upon the results of the field tests or laboratory analyses.

(1) This permit modification may proceed as a minor modification under §270.42, provided any such change is minor, or otherwise will proceed as a modification under §270.41(a)(2).

(2) If no modifications of the second phase of the permit are necessary, or if only minor modifications are necessary and have been made, the Director will give notice of his final decision to the permit applicant and to each person who submitted written comments on the phased permit or who requested notice of the final decision on the second phase of the permit. The second phase of the permit then will become effective as specified in §124.15(b).

(3) If modifications under §270.41(a)(2) are necessary, the second phase of the permit will become effective only after those modifications have been made."

8.1.2 Summary of Necessary Application Information

The following summarizes the information to be submitted in the Part B permit application for land treatment facilities. Information requirements identified are those presented in EPA's Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities.[1] The applicant is required to submit a treatment demonstration plan that describes how hazardous constituents contained in or derived from wastes to be disposed of at the facility will be degraded, transformed, or immobilized in the treatment zone. This applies to both new and existing facilities. All treatment demonstrations should contain two components; a plan and the results.

8.1.2.1 Treatment Demonstration Plan--

Items to be included in the plan are: (1) description of wastes for treatment demonstration, (2) data sources to make demonstration, and (3) when used, a description of laboratory and field test designs.

8.1.2.1.1 Wastes for Treatment Demonstration Plan--

Part 1 - The applicant must list the hazardous wastes that will be land treated. In addition, nonhazardous wastes that will be applied to the same treatment zone or plot as the hazardous waste(s) should also be listed. The Permit Applicant's Guidance Manual recommends that wastes be listed in the format shown in Table 8.1.1.

TABLE 8.1.1. EXAMPLE FORMAT FOR LISTING WASTES THAT WILL BE TREATED IN THE HWLT UNIT

Name of waste	Generating process or source	Monthly or annual quantity	EPA hazardous waste ID number
Oil/Water Separator Sludge	Crude Topping Unit	50 m Ton/Mo	K051
Leaded Tank Bottoms	Leaded Gasoline Storage	100 m Ton/Yr	K052
Treated Wastewater	Refinery Wastewater Treatment Plant	50,000 m Ton/Mo	Nonhazardous

Part 2 - List hazardous constituents (see Appendix VIII, Part 261) present in or expected to be derived from each hazardous waste to be land treated and pertinent nonhazardous constituents of wastes to be applied to same portion of the treatment zone. "Pertinent" nonhazardous constituents means any nonhazardous constituent that will likely affect the degradation, transformation, or immobilization of hazardous constituents.

Part 3 - For each waste identified in Part 1 above, the following information should be included in the application:

- concentration of each hazardous and pertinent nonhazardous constituent,
- concentration of volatile hazardous constituents,
- percent water content,
- specific gravity or bulk density,

- pH,
- electrical conductivity,
- total acidity or alkalinity, and
- total organic carbon.

8.1.2.1.2 Data Sources for Treatment Demonstration--Published literature, laboratory studies, field tests, and existing operating data may be used to make the treatment demonstration. The applicant should explain which data source will be used to make the treatment demonstration and expected results.

8.1.2.1.3 Laboratory and Field Test Design--If laboratory and/or field tests are used to make the treatment demonstration, the following information should be provided, respectively.

Part 1 - An explanation covering the following information should be provided for each laboratory test performed:

- name of test,
- objective of test,
- materials and methods,
- schedule of completion,
- list of experimental conditions, and
- description of data reduction, analysis, and presentation.

Part 2 - When field tests are to be used to make the treatment demonstration the applicant should prepare a written description containing the following:

- objectives of test,
- scale drawings delineating number and size of plots,
- statistical design of the test(s),
- dimensions of each plot treatment zone,
- test plot preparation,
- waste application rate and method on each plot,
- irrigation methods and scheduling,
- methods for establishing and maintaining vegetation (if vegetated),
- meteorological data collection and recording techniques,

- procedures for monitoring soil, soil pore liquid, run-off, vegetation, ground water, and ambient air, as applicable,
- schedule of daily events and activities,
- rationale for design and management of field tests,
- expected test results and data presentation, and
- clean-up procedures upon completion of field tests.

8.1.2.2 Treatment Demonstration Results--

Results obtained from the treatment demonstration should be submitted with the Part B permit application. This applies to both single-phase and two-phase permits, with submittal of results upon completion of testing for the latter.

8.1.2.2.1 Wastes and Waste Composition--If wastes used in treatment demonstration differ from those submitted in treatment demonstration plan, the applicant should identify these wastes and provide physical and chemical characterizations of each. Pretreatment or mixing of wastes should also be noted.

8.1.2.2.2 Degradation/Transformation--The applicant should provide the results of any literature review, existing operating data, laboratory tests, and/or field tests demonstrating the rate (time) and extent (percentage) of specific organic hazardous constituent and bulk organic fraction degradation.

Part 1 - Review of existing literature - The applicant should provide a concise discussion of how data contained in the literature are appropriate to use to make the treatment demonstration. Most important factors to be discussed are representativeness of data to proposed treatment facility.

Part 2 - Existing Operating Data - Applicant should submit the following operating information as appropriate to make the treatment demonstration for the proposed new or existing land treatment facility:

- description of existing facility,
- operational records,
- waste composition,
- waste application rate and methods, and
- data demonstrating degradation of hazardous constituents and/or bulk organics.

Part 3 - Laboratory Test Results - Applicant should submit the following information when laboratory tests are used to demonstrate organic hazardous constituent degradation:

- name of test,

- objective of test,
- test methods and materials and experimental conditions,
- test results (including visual presentations, i.e., graphs, figures, and tables), and
- accompanying discussion to aid interpretation of results.

Part 4 - Field Test Results - When field tests are conducted to demonstrate hazardous organic constituent or bulk organic degradation or transformation, the applicant should submit the following information:

- objective and test(s),
- description of experimental design and procedures (applicant is directed to present information contained in Table 8.1.2),
- test results (including visual presentations, i.e., graphs, figures, and tables), and
- accompanying discussion to aid interpretation of results.

TABLE 8.1.2. GENERAL INFORMATION TO BE INCLUDED IN FIELD TEST DESCRIPTIONS

Location of test plots relative to the land treatment unit.	Method of waste application and soil incorporation techniques.
Number and size of test plots.	Irrigation methods and frequency.
Dimensions of treatment zone for field test plots.	Rainfall and temperature data collected during the test.
Preparation of field test plots.	Sampling schedule and procedures.
Soil properties.	Analytical methods.
Waste application rate on each plot.	Statistical methods.
	Photographs of test plots.

8.1.2.2.3 Immobilization--The applicant should submit results from any literature review, existing operating data, laboratory tests, and/or field studies that demonstrate organic (for persistent compounds) and inorganic hazardous constituent immobilization in the treatment zone.

Part 1 - Review of existing literature - If the applicant elects to demonstrate constituent immobilization using data reported in the literature, a concise written analysis should be presented explaining similarities between cited work and proposed treatment facility and expected constituent immobilization under actual operating conditions.

Part 2 - Existing operating data - When these data are used, the following information should be submitted along with an explanation of the representativeness of the existing data to proposed facility:

- description of existing facility,
- operation records,
- waste composition,
- waste application rate and method, and
- data demonstrating immobilization of subject organic and/or inorganic constituents.

Part 3 - Laboratory test results - Applicant should submit the following information when laboratory tests are used to demonstrate hazardous constituent immobilization:

- name of test,
- objective of test,
- test methods and materials,
- test results (including visual presentation, i.e., graphs, figures, and tables), and
- accompanying discussion to aid interpretation of results.

Part 4 - Field test results - When field studies are conducted to demonstrate hazardous constituent immobilization, the applicant should submit a description of the following:

- field test objectives,
- field test procedures, including the information identified in Table 8.1.2, and
- field test results, including visual presentation of data (i.e. graphs, figures, and tables).

8.1.2.2.4 Volatilization--As part of the treatment demonstration, the applicant should address gaseous losses of hazardous constituents from the land treatment unit. Volatilization is not a form of hazardous constituent

degradation, transformation, or immobilization. Because it can result in the release of untreated hazardous constituents, the extent of organic compound volatilization must be examined to verify actual constituent treatment.

The applicant should submit the vapor pressure (mm of Hg) of each organic hazardous constituent present in the waste to be land treated. Estimates or test results of gaseous losses should be expressed as the mass or concentration of volatilized compound per unit area of soil as a function of time. Data sources for estimating volatilization include published literature, existing operating data, laboratory tests, and field studies.

Part 1- Published literature - If existing literature is used to estimate volatilization losses, the applicant should submit support materials, such as tables or figures, any calculations, description of assumptions and their rationale, and a discussion of data representativeness.

Part 2 - Operating data - The applicant should submit the following when existing operating data are used to estimate hazardous constituent gaseous losses:

- description of the facility,
- pertinent operational records,
- waste composition,
- waste application rates, and
- results of hazardous constituent volatilization.

Part 3 - Laboratory tests - The following information should be provided in the application if laboratory tests are used to estimate hazardous constituent vaporization:

- name of test,
- test methods and materials, including experimental design,
- test results, including visual presentation, i.e., graphs, figures, and tables, and
- accompanying discussion, as needed, to interpret results

Part 4 - Field tests - When field tests are conducted, the applicant should submit a description of the following information:

- test objectives,
- test methods and materials, including experimental design,
- test results, including visual presentations, i.e., graphs, figures, and tables, and

- accompanying discussion, as needed, to interpret results.

The information identified in Table 8.1.2 should be presented with the discussion on test procedures.

8.1.2.2.5 Toxicity--

(a) Microbial Toxicity - Biological degradation and transformation are fundamental processes of the treatment facility. These processes are carried out by soil microbes. Microbial toxicity of the waste and hazardous constituents must be determined to assess the extent of waste treatment. If a waste is highly toxic to the microbial population, the waste will not be biodegraded unless it is applied to the soil at a rate below the thresnold of toxic effects. Data sources that can be used to determine microbial toxicity are published literature, existing operating data, laboratory tests, and/or field studies.

Part 1 - Published literature - The applicant should submit an analysis of the scientific literature or previous studies that contain information concerning the toxicity of the waste or hazardous constituents to soil microbes.

Part 2 - Existing operating data - For this data source, the applicant should provide the following:

- a description of the existing facility,
- operational records,
- waste composition,
- waste application rates, and
- data assessing toxicity of the waste.

Part 3 - Laboratory tests - The applicant should submit the following information when laboratory tests are conducted to evaluate microbial toxicity:

- name of test,
- test methods and materials, including experimental design,
- test results, and
- accompanying discussion, as needed, to interpret data.

Part 4 - Field test - If field tests are conducted to determine whether the hazardous constituents of the waste will be toxic to soil microbes, the following information should be provided:

- statement of test objective,

- test methods and materials, including the information identified in Table 8.1.2, and

- test results, including visual presentations, i.e., graphs, figures, and tables.

(b) Phytotoxicity - If plants are to be grown on or in the treatment zone during its active life, the applicant should submit data addressing the phytotoxicity of nondegradable organics or immobilized inorganics to planted crops.

Part 1 - Review of existing literature - A concise summary of the literature review, including a description of specific plant species grown, waste application rates and methods, waste composition, soil type, and test procedures should be submitted by the applicant.

Part 2 - Existing operating data - For this data source, the applicant should provide the following information:

- a description of the existing facility,

- operational records,

- waste application rates and methods, and

- data assessing toxicity of the waste.

Part 3 - Greenhouse test results - If greenhouse studies are conducted to assess phytotoxicity, the applicant should provide the following:

- test results (identifying concentrations causing a decrease in plant growth),

- description of test methods and materials,

- experimental design,

- waste application rates and methods,

- waste application schedule, and

- plant species tested.

Part 4 - Field test results - When field tests are performed to determine phytotoxic levels, test results identifying hazardous constituent concentrations that inhibit plant growth should be submitted. A description of the field test(s) addressing the issues identified in Table 8.1.2 should also be included in the written submittal, as well as a statement of test objectives and an accompanying discussion, as needed, to interpret test results.

8.1.3 Guidance on Evaluating Application Information

The owner or operator of the land treatment unit must demonstrate that hazardous constituents in or derived from the waste(s) applied on or in the treatment zone soil will be completely degraded, transformed, or immobilized. Land treatment of the hazardous constituents relies on the dynamic physical, chemical, and biological processes occurring in the soil of the treatment zone. Table 8.1.3 identifies the components of the treatment demonstration that should be included in the permit application.

TABLE 8.1.3. REQUIRED INFORMATION FOR TREATMENT DEMONSTRATION

Treatment demonstration plan	Treatment demonstration results
• Wastes for treatment demonstration	• Wastes and waste composition
• Data sources for treatment demonstration	• Degradation/transformation
• Laboratory and field test design	• Immobilization
	• Volatilization
	• Toxicity: Soil Microbes Plants

8.1.3.1 Wastes for Treatment Demonstration Plan--

Part 1 - List of hazardous wastes - The treatment demonstration must be made for wastes that are representative of those that will be land treated at the proposed disposal site. The applicant should identify the type and name of the waste, process or source generating the waste, monthly or annual quanities expected to be handled, and EPA Hazardous Waste ID number. The list presented by the applicant should be compared with the hazardous wastes identified in Part 261, Subpart D, §§261.30 through 261.33; Appendix VII of Part 261; and any applicable state hazardous waste regulation.

Hazardous wastes will contain organic and inorganic compounds. In general, land treatment should be confined to wastes that are principally organic. These wastes are more readily treated by the primary soil processes of biological degradation and chemical transformation. Inorganic compounds and heavy metals are unaffected or slowly affected by the degradation and transformation processes. These constituents must be immobilized in the treatment zone. With respect to persistent hazardous organic constituents, these compounds must be immobilized in the treatment zone to enable complete degradation. Table 8.1.4 summarizes the processes involved in land treatment of hazardous constituents, while Table 8.1.5 describes qualitatively the treatability of major hazardous material groups.

TABLE 8.1.4. TREATMENT OF HAZARDOUS CONSTITUENTS BY LAND TREATMENT PROCESSES

Hazardous constituent	Degradation[a]/ transformation	Immobilization		Plant uptake[b]
		Adsorption/ precipitation	Ion exchange	
Organics	X	X		X
Metals		X	X	X
Inorganic Cations		X	X	X
Inorganic Anions		X		X

[a]Includes biological, chemical, and photochemical degradation.

[b]Removal by crop harvesting.

TABLE 8.1.5. QUALITATIVE ASSESSMENT OF THE LAND TREATABILITY[a] OF HAZARDOUS MATERIAL GROUPS[3]

Hazardous material group	Land treatability potential
Solvents and related organics such as trichloroethylene, chloroform, and toluene	High
PCBs and PBBs	Limited
Pesticides	High
Inorganic chemicals such as ammonia, cyanide, acids, and bases	Limited
Heavy metals	Limited
Waste oils and greases	High

[a]High land treatability does not infer immunity from environmental damage. Only through proper design and management of a land treatment unit can the desired level of treatment be obtained and the migration of hazardous materials be prevented.

In addition to listing hazardous wastes, the applicant should identify nonhazardous wastes that will be treated in the same land treatment plot as the hazardous waste. Although a treatment demonstration is not required for the nonhazardous waste, the presence of these wastes in the same plot may affect hazardous constituent degradation, transformation, and/or immobilization.

Part 2 - List of hazardous constituents - The applicant should identify the hazardous constituents present in the waste. This list should be based on the results of a complete analysis of the wastes to be land treated at the facility. Analytical procedures described in Test Methods for Evaluating Solid Waste[4] should be followed for determining the presence of hazardous constituents. Appendix VIII of Part 261 identifies constituents that EPA has determined to be hazardous.

To verify the list of hazardous constituents identified by the applicant, the reviewer should consult the Hazardous Waste Land Treatment (HWLT) manual[5] and Characteristics of Hazardous Waste Streams[6] which provide lengthy discussions of the general characteristics of various industrial waste streams. Table 8.1.6 lists the waste streams described in the referenced documents. Appendix A of the HWLT manual[5] presents the results of a survey of existing hazardous waste land treatment facilities in the United States. Table 8.1.7 summarized industry groups currently operating land treatment units.

The applicant should also provide information on the presence of pertinent nonhazardous constituents in the wastes to be applied at the treatment unit. As previously described, pertinent nonhazardous constituents can be any compounds or substance that may affect the degradation, transformation, or immobilization of hazardous constituents. Table 8.1.8 lists the more common pertinent nonhazardous constituents or substances and the impact they might have on hazardous constituent degradation, transformation, or immobilization. Section 6 of the HWLT manual[5] identifies waste streams that contain the pertinent nonhazardous constituents listed in Table 8.1.8. Worksheets for evaluating the adequacy of listing hazardous constituents to be land treated are presented in Figures 8.1.1 and 3.1.2 for existing and new facilities, respectively.

Part 3 - Waste characterization - Analytical methods to determine the waste characteristics identified in Section 8.1.2.1.1, Part 3 are described in Section 5 of the HWLT manual[5] and Test Methods for Evaluating Solid Waste.[4] The applicant should identify the specific test used to determine each waste characteristic as well as sample collection and preparation techniques. The values reported for each characteristic will aid in determining application rates and frequencies and whether soil conditioning (e.g., pH control, soil moisture control) prior to and subsequent to waste application will be required.

8.1.3.1.1 Data Sources for Treatment Demonstration--Treatment demonstrations can be made using information derived from published literature, laboratory tests, field studies or existing operating data. Applicants will frequently make the treatment demonstration using data obtained from a combination of

TABLE 8.1.6. SOURCES OF INDUSTRIAL HAZARDOUS WASTE STREAMS[6]

Specific sources of hazardous waste	Nonspecific sources of hazardous waste
Textile Mills	Solvent Bearing Wastes
Lumber	Solvent Use in Degreasing Operations
Paper	Solvent Use in Product Formulation and Synthesis
Printing	Solvent Use in Dry Cleaning Plants
Inorganic Chemicals	Paint Bearing Wastes
Alkalies and Chloride	Heavy Metal and Cyanide Bearing Wastes
Inorganic Gases	Electroplating Operations
Inorganic Pigments	Metal Heat Treating
Other Inorganic Chemicals	Metal Recovery
Organic Chemicals	Scrubber Sludges from Blast Furnaces and Coke Ovens
Plastics	
Synthetic Rubber	
Synthetic Fibers	
Pharmaceuticals	
Soaps, Detergents, and Cosmetics	
Paint Formulation	
Gum and Wood Chemicals	
Cyclic Crudes and Intermediaries	
Cyclic (benzenoid) Intermediates	
Synthetic Organic Dyes	
Synthetic Organic Pigment	
Cyclic Crudes	
Other Organic Chemicals	
Pesticides	
Adhesives	
Explosives	
Inks	
Petroleum Products	
Petroleum Refining	
Petroleum Re-refining	
Syncrudes	
Rubber Products	
Leather Tanning and Finishing	
Stone, Clay, and Glass	
Metal Smelting and Refining	
Metal Finishing Industries	
Electroplating	
Metal Heat Treating	
Coating	
Solvent Degreasing	
Machinery	
Electronic Components	
Batteries	
Electric Utilities	

TABLE 8.1.7. INDUSTRY GROUPS CURRENTLY OPERATING HAZARDOUS WASTE LAND TREATMENT UNITS[5]

SIC Code[a]	Description	Number of units
29	Petroleum refining and related industries	105
28	Chemicals and allied products	30
49	Electric, gas, and sanitary services	16
34	Fabricated metal products, except machinery and transportation equipment	12
97	National security and international affairs	9
24	Lumber and wood products, except furniture	7
36	Electrical and electronic machinery, equipment, and supplies	5
20	Food and kindred products	4
22	Textile mill products	4
39	Miscellaneous manufacturing industries	3
35	Machinery, except electrical	3
26	Paper and allied products	3
13	Oil and gas extraction	2
44	Water transportation	2
76	Miscellaneous repair services	2
02	Agricultural production - livestock	1
30	Rubber and miscellaneous plastics products	1
33	Primary metal industries	1
37	Transportation equipment	1
51	Wholesale trade - nondurable goods	1
82	Educational services	1

[a]Standard industrial classification code.

TABLE 8.1.8. LIST OF PERTINENT NONHAZARDOUS CONSTITUENTS OR SUBSTANCES

Constituent or substance	Potential impact
Organic Matter	High organic content in waste stimulates microbial activity, resulting in nutrient depletion if soil is not fertilized periodically Also increasing organic content of soil increases water holding capacity which may lead to prolonged periods and anaerobic conditions during wet weather
Water	Excess water can create anaerobic conditions resulting in reduced degradation Also addition of excess water may result in constituent leaching and/or increased surface runoff
Inorganic Nutrients (Nitrogen, phosphorus, boron, and sulfur)	Wastes devoid of inorganic nutrients accelerate nutrient depletion and must be countered by increased soil fertilization Alternatively, excessive concentrations in waste applied may have detrimental effects on soil microbes and plants and also may damage physical properties of soils
Inorganic Acids and Bases	Additions of these constituents upset soil pH balance such that pH management must be intensified
Inorganic Salts	Soil accumulation of inorganic salts and halides may retard microbial activity or inhibit plant growth during active period Also, salt accumulation will alter physical and chemical characteristics of soil
Halides (Fluorine, chlorine, bromine, iodine)	Halide accumulation due to application of excessive concentrations can be toxic to soil microbes and cover crops
Nonhazardous[a] Metals (Cobalt, copper, lithium, managanese, palladium, zinc)	Elevated soil metal concentrations can retard microbial activity or inhibit plant growth

[a]Nonhazardous means metal is not listed in Appendix VIII of Part 261.

LISTING OF HAZARDOUS WASTES AND CONSTITUENTS--EXISTING FACILITY

Has this part of the applicant's submittal been reviewed and evaluated?	Yes	No	Date
Does the Part B information agree completely with the information provided previously in the Part A application?	Yes	No	
Are waste names and EPA ID numbers identified?	Yes	No	
Are locations identified showing where wastes are or will be applied within the land treatment unit?	Yes	No	

If all answers are yes, this part of the applicant's submittal is adequate. However, if any differences exist between the Part A and Part B applications continue below--

Are only subsets of the wastes listed in the Part A application going to be land treated?	Yes	No
Are previously identified wastes (in Part A) treated or somehow transformed before land treatment?	Yes	No
Have any of the wastes been delisted?	Yes	No
Have any of the treatment zones or portions thereof been closed?	Yes	No
Are all apparent discrepancies explained in the Part B application?	Yes	No
Has the applicant submitted a revised Part A application?	Yes	No

Describe any deficiencies in the applicant's submittal, if they exist.

_____

_____

_____

Figure 8.1.1. Worksheet for evaluating the adequacy of listing hazardous wastes and constituents being or to be land treated at existing facilities.

LISTING OF HAZARDOUS WASTES AND CONSTITUENTS--NEW FACILITY

	Yes	No	Date
Has this part of the applicant's submittal been reviewed and evaluated?	_____	_____	_____
Have both Part A and Part B applications been submitted?	_____ Yes	_____ No	
Are waste names and EPA ID numbers identified?	_____ Yes	_____ No	
Are locations identified showing where wastes will be applied within the land treatment unit?	_____ Yes	_____ No	
Are there any apparent discrepancies in the information provided in the Part A and B applications?	_____ Yes	_____ No	
Will only subsets of the wastes listed in the Part A application be land treated?	_____ Yes	_____ No	
Will any wastes listed in the Part A application be treated or transformed prior to land treatment?	_____ Yes	_____ No	

Describe any deficiencies in the applicant's submittal, if they exist.

_____

_____

_____

_____

Figure 8.1.2. Worksheet for evaluating the adequacy of listing hazardous wastes and constituents to be land treated at new facilities.

these sources. Table 8.1.9 identifies the advantages and disadvantages associated with the types of data sources to be used to make a treatment demonstration.

Laboratory tests or field studies conducted to demonstrate the treatability of specific hazardous constituents must be performed under conditions similar to those present or expected at the land treatment unit. Also, if existing literature is used, data obtained from published documents must be representative of conditions at the treatment facility. The following conditions/characteristics of the proposed or existing land treatment unit must be described in the application if published literature is used or simulated if tests are performed:

(i) characteristics of wastes to be land-treated (see Part 3 of Section 8.1.2.1.1 above),

(ii) characteristics of the treatment zone, including depth, soil texture, pH, cation exchange capacity, organic matter content, moisture content, and depth to seasonal high water table,

(iii) topography of the treatment zone including slope,

(iv) local climate, including monthly temperature, precipitation, evaporation, and wind pattern data, and

(v) operating practices, including waste application method and rate, tilling depth and frequency, and soil conditioning practices (e.g., pH adjustment, fertilization, soil water regulation).

The permit reviewer should verify that each of these items are addressed in the treatment demonstration. Figure 8.1.3 provides a worksheet to aid in the review of these permit application information requirements. In addition to determining that the data used to make the treatment demonstration are generated under conditions that are similar or representative of those present or expected at the land treatment unit, the reviewer should confirm that all activities described in the treatment demonstration are going to be implemented under the land treatment program. This check is to ensure completeness of the application and to verify consistency between theoretical/experimental operation and actual operation of the land treatment facility.

Literature Data Sources

When treatment demonstration schemes are based on literature reviews, the permit reviewer must confirm that the information is representative and directly applicable to the proposed facility. Treatment demonstrations based on studies reported in the literature must be carefully examined to ensure that climate, soil characteristics, waste types, and application rates associated with the proposed facility are similar to those reported in the literature. It is essential that the literature data be representative of the proposed site characteristics. Also, the information used to make the

TABLE 8.1.9. UTILITY OF DATA SOURCES FOR MAKING TREATMENT DEMONSTRATION

Data source	Advantage	Disadvantage
Literature	When available, existing literature is readily obtained and inexpensive.	Very little documentation/ test results are presently available. Also, information that is available may not be specific to waste(s) to be treated, generalizations have to be made to make extrapolations.
Laboratory Test	Can be well controlled; can simulate specific interactions at microcosm level.	Small scale and generally unidimensional; one or two factor analysis limits utility.
Field Tests	Provides more holistic approach than laboratory studies, can closely simulate actual land treatment unit conditions.	Time consuming to obtain, environmental factors (e.g., precipitation, temperature) uncontrollable.
Operating Data	Closest approximation of actual conditions. Excellent for existing facilities.	Not usually well documented, very site specific. Therefore, utility is limited for other sites.

	Simulated in Demonstration		Comments
	Yes	No	
Waste Characteristics:			
Concentration of hazardous constituents and pertinent nonhazardous constituents			
Concentration of volatile hazardous constituents			
Water content			
Specific gravity or bulk density			
pH of waste			
Electrical conductivity			
Total acidity or alkalinity			
Total organic carbon			
Treatment Zone Characteristics.			
Depth of zone			
Soil texture			
Soil pH			
Cation exchange capacity			
Organic matter content			
Moisture content			
Depth to seasonal high groundwater table			
Surface slope of treatment zone			
Local Climate:			
Temperature range (monthly)			
Precipitation			
Evaporation			
Wind patterns			
Operating Practices:			
Application rate			
Application method			
Tilling frequency and depth			
Soil conditioning			
pH adjustment			
fertilization			
soil water control			

Figure 8.1.3. Worksheet for items to be simulated by treatment demonstration tests/evaluation.

demonstration should be derived from well designed scientific studies where replicated experiments, employing representative sampling and experimental controls, were conducted. All statements and conclusions made within the application should be documented with citations in the text and bibliography.

In addition to providing information on hazardous constituent degradation, transformation, or immobilization, published literature can be used (and is recommended) to design laboratory and field experiments. Literature sources used to make portions of the treatment demonstration should have been subjected to a thorough peer review.

References providing relevant information on the principles and fundamentals of land treatment of industrial and municipal wastes are identified in Table 8.1.10. Information presented in the cited references may not provide specific answers for a particular application. However, key design and operating principles, measurement techniques, and various waste characteristics are described that can be applied, through engineering and scientific knowledge and professional experience, to determine the technical adequacy of most permit applications to be reviewed.

Because the land treatment of hazardous waste is an emerging field, results of laboratory and field tests identifying chemical constituents that are resistant to degradation or immobilization generally are not well documented in the literature. Therefore, pilot studies conducted in the laboratory or field should be encouraged at the preapplication meeting, particularly when dealing with unknown or uncommon wastes or hazardous constituents. During the preapplication meeting it should be made clear that field tests or laboratory experiments be performed not only to identify optimum operating conditions but also to define the upper or lower values for all factors that limit waste degradation, transformation, and immobilization.

Existing Operating Data

When available, existing operating data provide an effective means of making the treatment demonstration. Because many of the initial Part B applications are going to be submitted for existing land treatment units, existing operating data will likely be used to demonstrate waste treatment. Existing data presented in the application must include results from soil-core (including treatment zone), soil-pore liquid, ground water, run-off, and air monitoring. The monitoring data submitted must be comprehensive and clearly demonstrate hazardous constituent degradation, transformation, or immobilization within the treatment zone. It should be recognized that the monitoring data can be used to demonstrate the treatability of wastes that are similar to those previously disposed at the treatment unit. Additional documentation will be required to demonstrate the treatability of new and different wastes planned for disposal at the unit. Such demonstrations will likely involve laboratory and field studies, which are discussed below.

8.1.3.1.2 Laboratory and Field Test Design--Laboratory tests, field studies, or greenhouse tests conducted by the applicant must be evaluated to determine that they will be properly performed, conducted under conditions that are

TABLE 8.1.10. KEY LAND TREATMENT REFERENCE SOURCES

Title	Citation	Report synopsis
Hazardous Waste Land Treatment	Brown, K. W. et al. Prepared by K. W. Brown and Associates, Inc. for U.S. EPA, Report No. SW-874. February 1983.	An extensive treatise of the disposal of Hazardous Waste by Land Treatment. Topics covered: site selection, site design and operation, soil-waste interactions, industrial hazardous waste streams, laboratory and field testing, environmental monitoring, site management and closure.
Land Cultivation of Industrial Wastes and Municipal Solid Wastes Volume 1 - Technical Summary and Literature Review Volume 2 - Field Investigations and Case Studies	Phung, T. et al. Prepared by SCS Engineers for U.S. EPA, Report Nos. EPA-600/2-78-140a and EPA-600/2-78-140b. August 1978.	Summary of extensive literature review of land cultivation of industrial and municipal wastes. Topics covered: cultivation practices, waste characteristics, mechanisms of waste degradation, application rates and effects on soil properties and plant uptake, site operational and monitoring considerations, and case studies.
Proceedings of the International Conference on Land for Waste Management	Tomlinson, S., ed. Ottawa, Canada, Conference held October 1973. Report published 1974.	An overview of waste disposal and its interaction with soils with particular emphasis on northern areas.
Land Treatment and Disposal of Municipal and Industrial Wastewater	Sanks, R. L. and T. Asano, eds. Ann Arbor Science, Ann Arbor, MI. 1976.	A compilation of thirteen technical reports that address pertinent issues concerning land treatment technologies. Topics covered: soil-vegetation recycling, land treatment processes, acceptability of wastewater by soils, hydrogeological considerations of land treatment, infiltration-percolation, engineering design and operating aspects.
Design of Land Treatment Systems for Industrial Wastes, Theory and Practice	Overcash, M. R. and D. Pal. Ann Arbor Science, Ann Arbor, MI. Second Printing, 1981.	Detailed discussion of the land treatment of both hazardous and nonhazardous industrial wastewaters. Topics covered: facility design and operation, substance degradation and immobilization, limiting constituent analysis, application methods, site management.
Decomposition of Toxic and Nontoxic Organic Compounds in Soils	Overcash, M. R., ed. Ann Arbor Science, Ann Arbor, MI. 1981.	A collection of research papers concerning degradation of various organic compounds in soils. Classes of compounds covered: chlorinated organics, agricultural chemicals, phenols and related compounds, aromatics and polynuclear aromatics, urea resins, and surfactants.

(continued)

TABLE 8.1.10 (continued)

Title	Citation	Report synopsis
Land Treatment of Hazardous Wastes	Parr, J. F. et al. Noyes Data Corporation, Park Ridge, NJ. 1983.	An extensive treatise of the land treatment of hazardous wastes. Topics covered: soil/waste interactions, factors affecting degradation, fate of hazardous constituents, effects on food-chain, bioassay for toxicity, and specific land treatment experiences.
Test Methods for Evaluating Solid Wastes, Physical/Chemicl Methods	U.S. EPA, Office of Solid Waste, Report No. SW 846. July 1982.	Technical Guidance document describing methods that will be used by EPA in conducting investigations and determining acceptability of sources operated under Sections 3004, 3007 and 3008 of RCRA. Topics covered. methodologies for collecting representative samples and for determining waste composition, ignitability, corrosivity, reactivity, and extraction procedure (EP) toxicity.
Supplementary References		
Soils for Management of Organic Wastes and Waste Waters	Elliott, E. F. and F. J. Stevenson, eds. American Society of Agronomy, Madison, WI 1977.	A collection of papers dealing mainly with municipal and agricultural waste.
Land as a Wastewater Management Alternative	Loehr, R. C., ed. Ann Arbor Science, Ann Arbor, MI. 1976.	Proceedings of a symposium which dealt mainly with municipal and animal waste disposal.
Land Disposal of Hazardous Waste, Proceedings of the 8th Annual Research Symposium	Shultz, D. W., ed. Prepared by Southwest Research Institute for U.S. EPA, Report No. EPA-600/9-82 002. March 1982.	Proceedings of symposium. Relevant topics covered composition of hazardous waste leachate, soil column tests, subsurface effects of long-term land treatment.
Managing the Heavy Metals on the Land	Leeper, G. W. Marcel Dekker, Inc., New York. 1978.	A summary of the movement and accumulation of soil-applied metals.
Sludge Disposal by Landspreading Techniques	Torrey, ed. Noyes Data Corporation, Park Ridge, NJ. 1979.	A collection of a group of government-sponsored research projects dealing with sewage sludge disposal.

similar or can be reasonably correlated to those present at the land treatment unit, and clearly demonstrate hazardous constituent degradation, transformation, or immobilization.

Table 8.1.11 identifies various test methods for assessing specific waste-site interactions involving constituent degradation, transformation, or immobilization. Also identified in the table are the sections of the HWLT manual that describe each test. Note that the applicant is not required to use these tests to make the treatment demonstration. Although these test methods have been recommended to the applicant in the Permit Applicants' Guidance Manual,[1] other test methods can be used as long as they are fully described and sufficiently documented by the applicant and satisfy the same objectives.

Soils in which laboratory, field test, or greenhouse studies are performed should be similar to the soil of the actual or proposed treatment zone. In general, a soil series classification, including a description of the "A" horizon, will usually adequately define the necessary similarities of soils. A soil series is a subdivision of a soil family. The series identifies a group of soils having similar thickness, texture, structure, color, organic content, and reaction (acid, neutral, or alkaline).[7]

The "A" horizon of a soil is the top mineral layer located at or adjacent to the surface, just below the organic horizon. The characteristics of the "A" horizon within and among soil series can vary (see Appendix C of HWLT manual). Therefore, treatment demonstration tests should be performed in soils that have characteristics similar to the "A" horizon of the treatment zone soil. The characteristics of the "A" horizon can be determined from a local Soil Conservation Service (SCS), Soil Survey Report or consultation with a SCS soil scientist.

It is important to recognize that extrapolation of field test results must be made with discretion because they are limited to the environmental conditions existing during testing. Testing should be performed under a wide range of conditions that are expected at the units. This includes seasonal variations, where applicable. Also, replicate sampling to statistically verify test results should be conducted. However, uncontrollable variables such as temperature, precipitation, and wind speed and direction make testing under reproducible conditions difficult, as well as data interpretation.

Although it is not required, tests should be conducted or extrapolations made to determine the limitations of the treatment unit. Once the limits have been identified, contingency plans can be developed to accommodate expected or unexpected phenomena when they occur. Examples of situations requiring a contingency course of action include: continued periods of heavy rainfall, increasing surface ponding and run-off; ground freezing during winter months, slowing or stopping waste degradation; or ice cover formation, resulting in anaerobic soil conditions (note that when the ice cover melts an odor problem can result due to anaerobic decomposition under reducing conditions).

TABLE 8.1.11. TEST METHODS FOR ASSESSING SPECIFIC WASTE-SITE INTERACTIONS (FROM HWLT MANUAL[5])

Waste-site interactions	Test method	HWLT manual section
Degradation of waste	Respirometry	7.2.1.1
	Field studies by soil testing	7.4.1
Accumulation in soil of nondegradables	Waste analysis (inorganics)	5.3.2.3.1
	Respirometry (organics)	7.2.1.1
Leaching hazards	Soil thin layer chromatography	7.2.2.1
	Soil leaching columns	7.2.2.2
	Field soil leachate testing	7.4.2
Volatilization hazards	Environmental chamber	7.2.3
	Field air testing	7.4.4
Acute toxicity	Respirometry (soil biota)	7.2.1.1
	Beckman Microtex™ System	7.2.4.1.1
	Greenhouse studies (plants)	7.3.2
Chronic toxicity	Microbiological mutagenicity assays	5.3.2.4
Plant uptake	Greenhouse studies	7.3
Pretreatment	Assessment of processes generating waste	5.2

In addition to demonstrating complete hazardous constituent degradation, transformation, or immobilization, the treatment demonstration will aid in defining site management activities such as waste application methods and rates, soil pH and moisture control, fertilization needs, and soil aeration.

To assess the impact of waste applications on the test soil, it is suggested that the parameters identified in Table 8.1.12 be measured prior to and after each or a series of waste applications. A detailed discussion of the importance of measuring each of the parameters identified and their impact on the soil processes involved in the treatment of hazardous waste is presented in the references cited in the last column of the table. A general interpretation of some of the more important soil chemical tests is presented in Table 8.1.13. Analytical methods to determine each soil parameter identified are presented in Test Methods for Evaluating Solid Waste[4] and Methods of Soil Analysis.[10,11]

In addition to assessing the parameters identified in Table 8.1.12, which are primarily chemical components, soil texture should also be evaluated. Section 3 of the HWLT manual provides a discussion of the suitability of various textured soils for land treatment of hazardous industrial wastes. Table 8.1.14 (reprinted from the HWLT manual) identifies the advantages and disadvantages of applying hazardous waste to several soil texture classes. This information can be used to identify operational concerns that should be addressed by the facility design (see subsection 8.3).

8.1.3.2 Treatment Demonstration Results--

The applicant must submit the results of any tests conducted to make the treatment demonstration. The following discussion provides guidance for evaluating the data submitted to show hazardous constituent degradation, transformation, or immobilization. To ensure that each hazardous waste and hazardous constituent identified in the Part B permit application have been addressed by the treatment demonstration, a checklist should be prepared that identifies how each hazardous constituent will be degraded, transformed, or immobilized in the treatment zone. Table 8.1.15 presents an example checklist to be developed during the treatment demonstration review process. Completion of such a checklist will provide an accounting of how each hazardous waste and hazardous constituent will be treated at the unit. Emphasis should be placed on documenting the degradation, transformation, or immobilization of highly water soluble hazardous constituents that are leachable and compounds with high vapor pressures that may be lost through volatilization.

8.1.3.2.1 Wastes and Waste Composition--If for any reason the wastes used in the treatment demonstration differ or have been pretreated or mixed, the applicant should have provided the same information outlined in Section 8.1.2.1.1. In some cases, the applicant may pretreat the waste as part of the treatment demonstration to try to: (1) improve treatability, (2) reduce waste volume, (3) add soil amendments, or (4) eliminate untreatable or unacceptable waste constituents. Pretreatment can be accomplished by physical, chemical, or biological processes. The reviewer is referred to the HWLT manual and references therein cited for a discussion of waste pretreatment. Table 8.1.16 provides a synopsis of various pretreatment techniques as they relate to waste amendment prior to land treatment.

TABLE 8.1.12. SUGGESTED SOIL PARAMETERS TO MONITOR PRIOR TO AND AFTER WASTE APPLICATION[a]

Parameter	Prior to application	After one or series of applications	References for discussion of parameter
pH	Yes	Yes, after series	2,5,7,8,9
Cation exchange capacity	Yes	Yes, after series	2,5,7,8,9
Organic matter	Yes	Yes, after series	2,5,7,8,9
Soluble salts (TDS or EC)[b]	Yes	Yes, after each	2,5,7,8,9
Soil moisture content	Yes	Yes, after each	2,5,7,8,9
Soil fertility (N,P,K)[c]	Yes	Yes, after series	2,5,7,8,9

[a]Adapted from Reference 3.

[b]TDS--total dissolved solids, EC--electrical conductivity.

[c]Nitrogen, phosphorus, potassium.

TABLE 8.1.13. INTERPRETATION OF SOIL CHEMICAL TESTS[a]

Test result	Interpretation
pH of saturated soil paste	
<4.2	Too acid for most soil microbes and plants to do well
4.2-5.5	Suitable for acid-tolerant soil microbes and plants
5.5-8.4	Suitable for most soil microbes and plants
>8.4	Too alkaline for most soil microbes and plants, indicates a possible sodium problem
Cation exchange capacity (CEC), meq/100 g	
1-10	Sandy soils (limited adsorption)
12-20	Silt loam (moderate adsorption)
>20	Clay and organic soils (high adsorption)
Electrical conductivity (EC_e), mmhos/cm at 25°C, of saturation extract	
2	No salinity problems
2-4	Restricts growth of very salt-sensitive crops
4-8	Restricts growth of many crops
8-16	Restricts growth of all but salt-tolerant crops
>16	Only a few very salt-tolerant crops make satisfactory yields

[a]Adapted from Process Design Manual for Land Treatment of Municipal Wastewater, U.S. EPA, Report No. 625/1-77-008, October 1977.

TABLE 8.1.14. SUITABILITY OF VARIOUS TEXTURED SOILS FOR LAND TREATMENT OF HAZARDOUS INDUSTRIAL WASTES[5]

Texture[a]	Advantages	Disadvantages
Sand	Very rapid infiltration Usually oxidized and dry Low runoff potential	Very low cation exchange capacity (CEC) Very high hydraulic conductivity rate Low available water Little soil structure
Loamy sand	High infiltration Low to medium runoff	Low CEC Moderate to high hydraulic conductivity rate Low to medium available water
Loam	Moderate infiltration Fair oxidation Moderate runoff potential Generally accessible Good CEC	Fair structure
Silt loam	Moderate infiltration Fair oxidation Moderate runoff potential Generally accessible Good CEC	Some crusting Fair to poor structure
Silt	Low infiltration Fair to poor oxidation Poor CEC Good available water	High crusting potential Poor structure High runoff
Silty clay loam	Medium to low percolation Fair structure High CEC	Medium to low infiltration Some crusting potential
Silty clay	Good to high available water	Moderate runoff Often wet Fair oxidation
Clay loam	Medium to low percolation Good structure Medium to poor aeration High CEC High available water	Medium to low infiltration Moderate to high runoff Often wet

(continued)

TABLE 8.1.14 (continued)

Texture[a]	Advantages	Disadvantages
Clay	Low percolation High CEC High available water	Low infiltration Often massive structure High runoff Sometimes low aeration
Sandy clay	Medium to low percolation Medium to high CEC	Fair structure Moderate to high runoff
Sandy clay loam	Medium to high available water Good aeration	Medium infiltration

[a]Based on U.S.D.A. textural classification scheme.

TABLE 8.1.15. EXAMPLE HAZARDOUS WASTE AND HAZARDOUS CONSTITUENT TREATMENT DEMONSTRATION CHECKLIST

Constituent	Treatment process	Data source
Phenol	Biodegradation	Soil respirometer tests
Hexachloroethane	Adsorption by soil colloids	Extractability tests
Cadmium	Adsorption	Laboratory soil column leaching test
Chromium	Ion exchange	Literature review

TABLE 8.1.16. PRETREATMENT METHODS FOR HAZARDOUS WASTES[5]

Pretreatment Method	Heavy Metal Removal	Organic Removal	Organic Destruction	Waste Volume Reduction	Comments	Physical Form Treated
Activated sludge	Yes	Yes	Yes	Yes	Waste must have heavy metal content less than 1%	Liquid, slurry, sludge
Aerated lagoons	No	Yes	Yes	Yes	Used in temperate climates	Liquid, slurry, sludge
Anaerobic digestion	No	Yes	Yes	Yes	Very sensitive to toxic compounds	
Composting	No	Yes	Yes	Yes	Least sensitive method of biological treatment	Slurry, sludge, liquid
Enzymatic biological treatment	No	Yes	Yes	No	Only works for specific chemicals	Liquid, slurry, sludge
Trickling filters	No	Yes	Yes	Yes	Low efficiency for organic removal	Liquid, slurry, sludge
Waste stabilization ponds	No	Yes	Yes	Yes	Waste must have dilute concentrations of organic and inorganics	Liquid, slurry, sludge
Carbon adsorption	Yes	Yes	No	No	Efficient for wastes with less than 1% organics	Liquid
Resin adsorption	Possible	Yes	No	No	Extracts and recovers mainly organics ganics solutes from aqueous waste	Liquid
Calcination	Possible	No	Yes	Yes	Will require volume of nonorganics and convert them into a form of low leachability	Liquid, slurry, sludge
Catalysis	No	No	Yes	No		Liquid
Centrifugation	Yes	No	No	Yes	Primarily used for dewatering sludge	Slurry
Chlorinolysis	No	No	Yes	Yes	Conversion of chlorinated hydrocarbons to carbon tetrachloride	Liquid
Dialysis	Yes	No	No	No	Separation of salts from aqueous	Liquid
Dissolution	Yes	No	No	No	Removal of heavy metals from fly ashes	Liquid, slurry, sludge
Distillation	No	Yes	No	Yes	Recovery of organic solvents	Liquid, slurry, sludge
Electrolysis	Yes	No	No	No	Removal of heavy metals from concentrated aqueous solution	Liquid

--continued--

TABLE 8.1.16 (continued)

Pretreatment Method	Heavy Metal Removal	Organic Removal	Organic Destruction	Waste Volume Reduction	Comments	Physical Form Treated
Electrodialysis	Possible	No	No	No	Recovery of inorganic salts	Liquid
Evaporation	No	Possible	No	Yes	Recovery of inorganic salts	Liquid
Filtration	Yes	No	No	Yes	Removal of metal precipitates	Slurry
Precipitation, flocculation, sedimentation	Yes	Yes	No	Yes	Removal or recovery of solids from aqueous solution	Liquid, slurry
Flotation-biological	Yes	No	No	No	Separation of solid particles suspended in a liquid medium	Slurry
Freeze crystallization	Yes	Yes	No	Yes	Desalination of water	Liquid, slurry, sludge
Freeze drying	No	No	No	Yes	Separation of pure water from solids	Liquid, slurry
Suspension freezing	Yes	No	No	Yes	Separation of suspended particles magnetic particles from liquids	Liquid
Hydrolysis	No	No	Yes	No	May increase toxicity of waste	Liquid, slurry, sludge
Ion exchange	Yes	Yes	No	No	Selective removal of heavy metals and hazardous anions	Liquids
Liquid ion exchange	Yes	No	No	No	Selective removal and/or separation of free and complexed metal ions in high concentrations	Liquid, slurry, sludge
Liquid-liquid extraction of organics	No	Yes	No	No	Solvent recovery	Liquid
Microwave discharge	No	Possible	Yes	Yes	Developmental stages; primarily for small quantities of toxic compounds	Liquid
Neutralization	No	No	No	No	Renders waste treatable by other	Liquid, slurry, sludge
Chemical oxidation	Possible	No	Yes	No	Detoxification of hazardous materials	Liquid
Ozonolysis	No	No	Yes	No	May be used to make toxic wastes more susceptible to biological action, especially chlorinated hydrocarbons	Liquid

--continued--

TABLE 8.1.16 (continued)

Pretreatment Method	Heavy Metal Removal	Organic Removal	Organic Destruction	Waste Volume Reduction	Comments	Physical Form Treated
Photolysis	No	No	Yes	No	Degradation of aromatic and chlorinated hydrocarbons	Liquid
Chemical reduction	Possible	No	No	No	Detoxification of hazardous materials	Liquid
Reverse osmosis	Yes	Yes	No	Yes	Purification dilute wastewaters	Liquid
Size reduction	No	No	No	No	For spill debris such as contaminated pallets and lumber	Solid
Soil mixing	No	No	No	No	Volume of waste will increase, this technique applies to stick or tarry waste	
Steam distillation	No	Yes	No	Yes	Solvent recovery	Liquid, slurry, sludge
Air stripping	No	Possible	No	No	Recovery of volatile compounds from aqueous solutions	Liquid, slurry
Steam stripping	No	Yes	No	No	Recovery of volatile compounds from aqueous solutions	Liquid, slurry
Ultra filtration	Yes	Yes	No	No	Separation of dissolved or suspended particles from a liquid stream	Liquid
Zone refining	Yes	Yes	No	No	Purification technique for obtaining high-purity organic and inorganic materials	Liquid

(As adopted from DeRenzo, D. J. 1978. Unit Operations for Treatment of Hazardous Industrial Wastes. Noyes Data Corporation, Park Ridge, New Jersey.)

Hazardous constituents contained in wastes to be land treated should be carefully evaluated to assure treatability. Because biodegradation is the principal treatment mechanism, wastes containing significant quantities of halogenated organic compounds, inorganic acids, bases, salts, and heavy metals are not well suited for land treatment. Wastes containing these types of constituents are not readily biodegraded and will accumulate in the soil, limiting a facility's service life and increasing the potential for ground water contamination due to leaching. The following discussion addresses the various treatment methods and major environmental concerns associated with the operation of a hazardous waste land treatment facility.

8.1.3.2.2 Degradation/Transformation--Organic hazardous constituents applied in or on the treatment zone may be degraded by biological, chemical, or photochemical processes. Biodegradation, however, is the principal treatment mechanism. Biodegradation is accomplished by soil microbes, and when a vegetative cover is present by plant metabolism.

Chemical degradation or transformation of hazardous constituents results from compound oxidation, reduction, hydrolysis, isomerization, and polymerization. Phung, T. et al.[8] provide a discussion of the factors affecting chemical transformation and cite references for additional information.

Photochemical degradation is generally a minor component of land treatment of hazardous wastes because the waste is usually incorporated into the soil. Photochemical degradation occurs only at the soil surface where wastes that have been surface spread are directly exposed to incident radiation. Chemical reactions, primarily altering organic compounds, are induced by solar radiation. For a more detailed discussion of photochemical degradation see Phung, T. et al.[8] and references cited therein.

Because chemical and photochemical degradation play minor roles in hazardous constituent degradation, these processes will only be briefly addressed in the following discussion. Principal determinations to be made by the treatment demonstration are the rate and extent of organic hazardous constituent degradation or transformation in the treatment zone. The extent of degradation will determine whether land treatment is an acceptable means of disposal, whereas the rate of degradation will determine frequency of waste application.

Part 1 - Existing literature - The reviewer should consult the literature and possibly other (Federal, State, and local) regulatory agency personnel to gain an understanding of potential problem waste constituents that resist degradation or are difficult to immobilize. Section 6 of the HWLT manual and the Design of Land Treatment Systems for Industrial Wastes - Theory and Practice[9] provide useful information on microbial degradation rates of various classes of organic compounds (e.g. phenols, substituted biphenyls, polynuclear aromatics, solvents, and alcohols) and the mobility of various metals in soil. The following discussion highlights pertinent information presented in the references (refer to the texts themselves, however, for a more detailed explanation).

Table 8.1.17 presents a compilation of research results showing rates of degradation of phenol and phenolic compounds. The results are expressed in terms of percent degradation occurring in a certain number of days. Application rates are also shown. Although the information provided is based on small scale analyses, it can provide a starting point for estimating and evaluating rates of degradation and application loadings more precisely.

TABLE 8.1.17. RATES OF DEGRADATION OF PHENOL AND PHENOLIC COMPOUNDS (ADOPTED FROM REFERENCE 9)

Compound	Application rate	Degradation rate
Phenol	0.05% of soil weight	100% in 6 days
o-Cresol	0.05% of soil weight	100% in 8 days
m-Cresol	0.05%	100% in 11 days
p-Cresol	0.05%	100% in 7 days
2,4-xylenol	0.05%	100% in 4 days
2,5-xylenol	0.05%	100% in 14 days
3,4-xylenol	0.05%	100% in 9 days
3,5-xylenol	0.05%	100% in 11 days
Thymol	0.05%	100% in 3 days
Pyrocatechin	0.05%	100% in 1 day
Resorcinol	0.05%	100% in 2 days
Hydroquinone	0.05%	100% in 1 day
α-Naphthol	0.05%	100% in 5 days
ß-Naphthol	0.05%	Very little in 90 days
1,4-Naphthoquinone	0.05%	100% in 9 days

It is noted that phenol rate of application reportedly has a strong influence on microbial activity.[9] Phenol application rates equivalent to 0.01 to 0.1 percent of the soil weight have actually caused an increase in microbial activity, resulting in complete degradation of the organic compound. As the loading is increased to 0.1 to 1.0 percent of soil weight, however, an increasingly strong inhibitory effect has been recorded. Consequently, treatment demonstration tests should be performed to assess the impact of organic concentrations on soil organisms. Organic hazardous constituent concentrations similar to those expected in the waste to be applied at the land treatment facility should be used during testing.

Tables 8.1.18 and 8.1.19 identify relations between microbial activity and application of various solvents and alcohols, respectively. The phrase 'critical soil level' identified in the tables is the dose that causes a reduction in microbial numbers and diversity. Doses above critical levels result in long-term adverse soil response. Application rates below the critical level have little or no effect, and microbial populations are actually stimulated by the addition.

TABLE 8.1.18. RESPONSE OF SOIL MICROBIAL POPULATIONS TO APPLICATION OF VARIOUS SOLVENTS (ADOPTED FROM REFERENCE 9)

Solvent	Critical soil level (ppm)	Time period for recovery at critical dose
Cyclohexane	840	Within 37 days
Hexane	430	Within 19 days
Heptane	10,000	Within 24-63 days
Pentane	7,000	Within 30-53 days
Formaldehyde	150-300	Within 22 days
Chloroform	590	Within 12 days
Ether	7,400	Within 14 days
Acetone	58,000	Within 12 days
Pyridine	7,900	Within 16-30 days

TABLE 8.1.19. RESPONSE OF SOIL MICROBIAL POPULATIONS TO APPLICATION OF VARIOUS ALCOHOLS (ADOPTED FROM REFERENCE 9)

Alcohol	Critical soil level (ppm)	Time period for recovery at critical dose
Methanol	32,000	Within 12 days
Ethanol	46,000	Within 11 days
1-propanol	12,000	Within 21 days
2-propanol	12,000	--

With respect to organic acids degradation, Table 8.1.20 presents the percentage decomposition of various carboxylic acids. Doses of 1000 ppm were applied to loamy sand. The highest and lowest percent loss are shown after 7 days and after 84 days.

TABLE 8.1.20. DECOMPOSITION OF CARBOXYLIC ACIDS IN SOILS (ADOPTED FROM REFERENCE 9)

Compound	Percentage decomposition	Time required (days)
Acetic acid	52-76	7
Acetic acid	71-87	84
Pyruvic	47-83	7
Pyruvic	70-93	84
Succinic acid	52-89	7
Succinic acid	71-95	84
Glucose	75	7
Glucose	87	84

In general, organic compound groups may be ordered as follows based on increasing ease of biodegradation:

Halogenated Hydrocarbons (e.g., pesticides)
Aromatics (e.g., polynuclear aromatics, PNA)
Alkanes, carboxylic acids
Alcohols

Part 2 - Operating data - Demonstration of hazardous constituent degradation using existing operating data will likely be based on analysis of soil-core and soil-pore liquid samples. Test results presented in the application should identify the rate and extent of degradation of the organic hazardous constituents present in the waste being land treated. This means of making the treatment demonstration will very likely be exercised by existing hazardous waste land treatment facilities that have been collecting such information since startup.

Part 3 - Laboratory tests - Waste degradation is principally accomplished by aerobic microbial decomposition. One method of assessing biodegradation is to monitor microbial activity following waste application and measure waste decomposition products. A soil respirometer is one technique available to

evaluate the degradation of organic compounds in a waste-soil mixture. A soil respirometer can be used to indicate microbial activity and relative waste decomposition based on the rate of CO_2 evolution. Figure 8.1.4 displays a decision making process to determine hazardous waste treatability based on soil respirometry studies. Other methods to determine organic material degradation are infrared gas analysis, and gas chromatography.[12] Results obtained from these analyses can be used to gauge application rate and frequency, rate of required nutrient (fertilizer) addition, and rate of waste degradation in different soil types or temperatures. The time required for aerobic decomposition is primarily a function of waste composition and loading and soil characteristics.[8] More detailed explanations of biodegradation, including soil respirometry and its methodology, are provided in the HWLT manual.

Laboratory tests allow the examination of soil treatment processes under several different environmental conditions within a reasonable time period. Although laboratory tests can be designed to simulate actual conditions, they are somewhat one dimensional and do not reflect the complex interactions that occur in the field. As a result, field studies may be necessary to verify certain laboratory generated data.

Laboratory results should be clearly presented. Data should show rate of degradation, i.e., amount of orgnic decomposition over time, and extent of degradation, i.e., percent degradation as a function of time (see Figure 8.1.5 as example). Laboratory tests should determine the extent and rate of degradation for all organic hazardous constituents, focusing on those constituents which are less susceptible to degradation. In addition, the half-lives of each organic hazardous constituent should be determined, as discussed below.

Two basic techniques are used to assess organic constituent degradation. They involve: (1) measuring CO_2 evolution from the soil incubated in a chamber and, (2) analyzing soil samples for organic constituents. The former, which is not constituent specific, is used to determine the rate of degradation of the bulk organic fraction of the waste applied to the soil. The latter technique can be used to determine specific constituent degradation by chemical analysis of a soil extract. Sections 5 and 7 of the HWLT manual describe the analytical techniques and calculation methods for assessing organic hazardous constituent degradation.

To assess the amount of constituent that will accumulate due to repeated applications, it is important to determine the half-life of each organic hazardous constituent to be applied at the treatment unit. Half-life is defined as the time required to degrade 50 percent of the waste constituent. Half-life values should be used to determine acceptable yearly waste loading rates. The organic hazardous constituent with the longest half-life should be used to calculate site loading rates. Section 7 of the HWLT manual presents a detailed discussion of the techniques used to determine organic hazardous constituent half-lives.

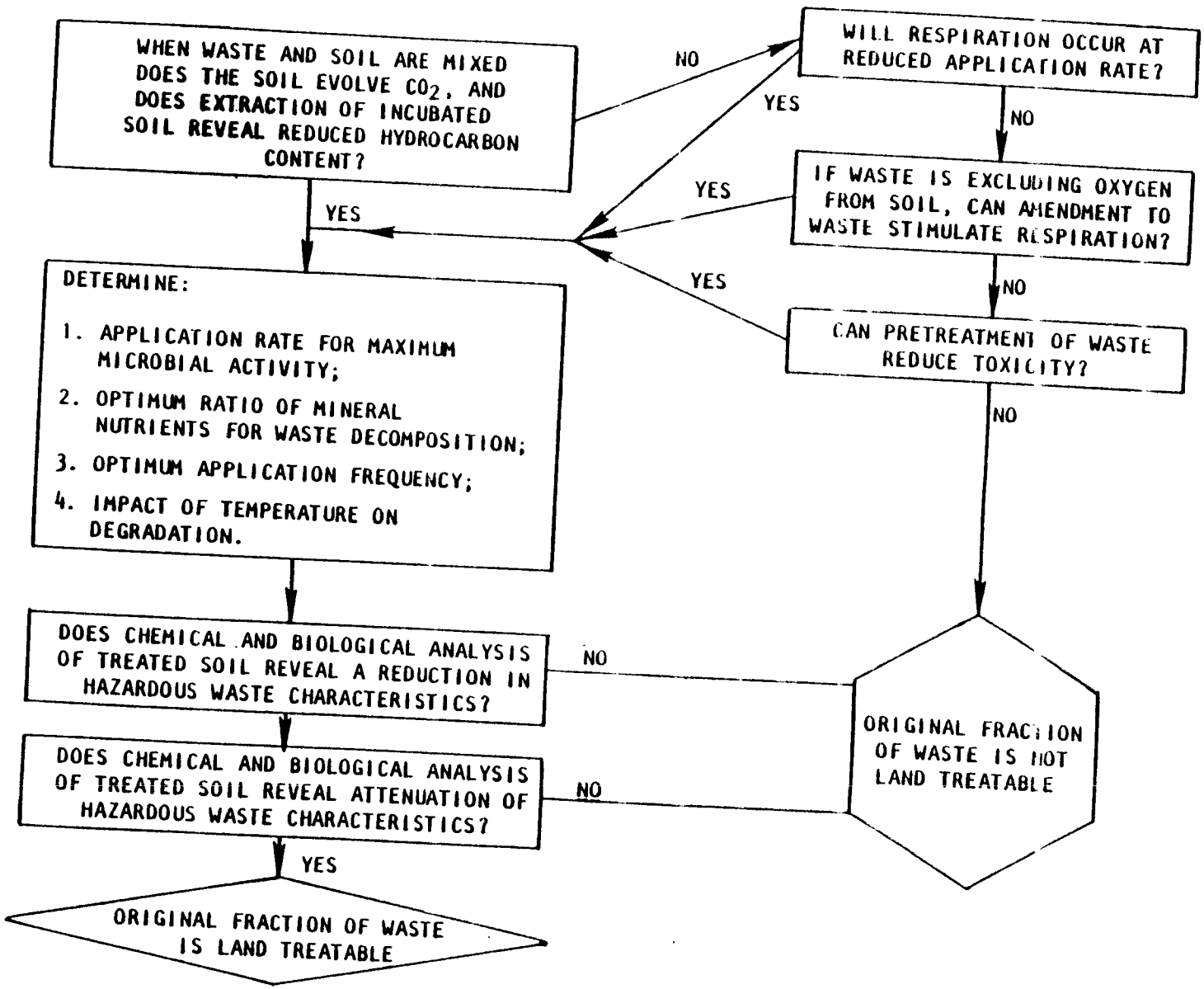

Figure 8.1.4. Decision chart to determine treatability of hazardous organic constituents--based on soil respiration studies.

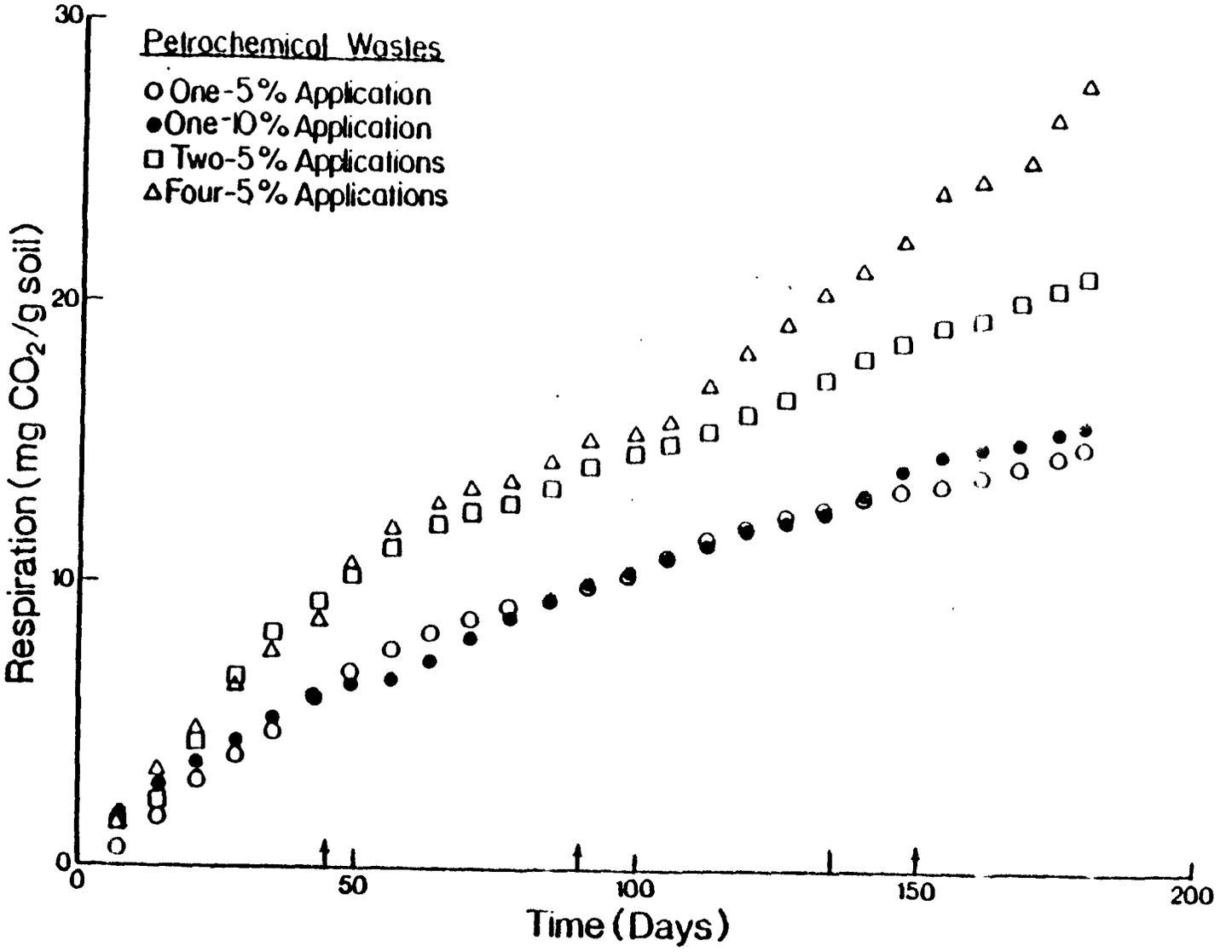

Figure 8.1.5. Effect of treatment frequency on the evolution of CO_2 from Norwood soil amended with petrochemical sludge and incubated for 180 days at 30°C and 18 percent moisture (adopted from HWLT manual[5]).

In general, application rates for hazardous constituents with half-lives of no more than 1 year can be twice the amount applied annually so long as the applications are separated in time equal to one half-life for the constituent. Table 8.1.21 presents estimates of the percent degradation of organic constituents with various half-lives after 10, 20, and 30 years. Note that constituents with half-lives of 1 year or less are degraded by more than 99 percent after 10 years. Although the information presented in Table 8.1.21 is very general and not constituent or soil-specific, it illustrates how to evaluate half-life degradation data submitted by the applicant.

Table 8.1.22 presents values of selected soil factors that are generally considered optimal for biodegradation. Note that these conditions are for a generic class of organic wastes, under an aerobic environment. Other conditions or values, as determined by the treatment demonstration, may be more effective to treat the hazardous constituents applied. Each land treatment facility should be evaluated on a case-by-case basis.

Part 4 - Field studies - Field studies may be necessary to confirm test results obtained under laboratory conditions. Field tests should be conducted to determine bulk organic fraction degradation. In addition, field tests should be performed to assess the degradation of any persistent compounds identified by a laboratory test or literature search. Recommended soil sampling and analytical procedures to be employed as part of the field tests are discussed in Sections 5 and 7 of the HWLT manual.

Field test plots should be as small as possible, generally no more than 500 m^2. Larger plots may be necessary, however, to accommodate specialized waste application equipment or other machinery as required to conduct the field tests.

Figure 8.1.6 presents a worksheet that can be used for evaluating field test designs submitted by the applicant. Completion of the worksheet will provide an assessment of the completeness and appropriateness of the applicant's selected field tests to demonstrate hazardous organic constituent degradation. Test results provided by the applicant should include the percent degradation or transformation as a function of time for each waste application treatment. Section 7 of the HWLT manual provides a lengthy discussion of how to interpret degradability results obtained from laboratory and field tests.

8.1.3.2.3 Immobilization--Inorganic hazardous constituents and organic hazardous constituents that are resistant to degradation must be immobilized in the treatment zone. Even organic hazardous compounds that are readily biodegraded must be retained in the treatment zone long enough to allow complete decomposition. Substance mobility in the treatment zone depends on compound solubility and certain characteristics of the soil, primarily soil pH, organic matter content, and the types and amounts of clay. With respect to metals, most species are insoluble above soil pH of 7. In addition to insolubility, metals are immobilized by adsorption, precipitation, and chelation and metal-organic complex formation. The following identifies the relative mobility of certain metals based on soil clay and mineral surface adsorption:

TABLE 8.1.21. PERCENT DEGRADATION AFTER 10, 20, AND 30 YEARS FOR ORGANIC CONSTITUENTS WITH VARIOUS HALF-LIVES IN SOIL (ADOPTED FROM HWLT MANUAL[5])

Half-life in soil	Percentage of substance degraded		
	After 10 years	After 20 years	After 30 years
3 months	100		
6 months	99.9999	100	
1 year	99.90	99.9999	100
2 years	96.88	99.90	99.9999
3 years	89.56	98.96	99.90
4 years	81.25	96.88	99.39
5 years	75.0	93.75	98.44
10 years	50.0	75.0	87.5
20 years	25.0	50.0	62.5
30 years	16.6	33.3	50.0

TABLE 8.1.22. OPTIMUM VALUES OF SELECTED SOIL FACTORS FOR BIODEGRADATION

Soil factor	Range of values or types
Texture	Sandy clay, silt loam, or sandy clay loam soils
Temperature	10° to 30°C (ca 40° to 85°F)
Moisture content	Between wilting coefficient and field capacity
Aeration	Periodic tilling will be adequate to promote soil aeration
pH	6 to 7 pH
Microbes	Natural populations in undistributed soils appear to be adequate; microbial inoculations may be required

FIELD TEST DESCRIPTION FOR TREATMENT DEMONSTRATION

Does the field test description state the test objective?	yes	no
Has the applicant provided a scale drawing showing the location of test plots relative to the proposed land treatment unit?	yes	no
Are the number and size of the test plots indicated?	yes	no
Is the statistical design of the test stated?	yes	no
Are the horizontal and vertical dimensions of the treatment zone of the test plot(s) provided?	yes	no
Has the applicant described how the test plots will be prepared (e.g., tillage, liming, fertilizer, installation of monitoring equipment, surface water control)?	yes	no
Are waste application rates, methods of application, and soil incorporation techniques described?	yes	no
If used, are irrigation methods and scheduling described?	yes	no
If plots will be vegetated, are methods for establishing and maintaining vegetation stated?	yes	no
Are methods for measuring and recording daily meteorological data presented?	yes	no
Has the applicant described procedures for monitoring soil, soil-pore liquid, runoff, vegetation, groundwater, and ambient air, as applicable?	yes	no
Has a schedule of daily events and activities been presented?	yes	no
Has the applicant described a design and management rationale to preclude the migration of hazardous constituents to ground or surface water?	yes	no
Are expected test results and data presentation described?	yes	no
Has the applicant described the clean-up procedures to be implemented upon completion of field tests?	yes	no

Figure 8.1.6. Worksheet for evaluating the adequacy of field tests for demonstrating hazardous constituent treatment.

Most Mobile:	Pb and Cd
Less Mobile:	Mn, Zn, Cu, Co, Ni, and Cr
Least Mobile:	Al, Fe, and Mg

Metal precipitation occurs when concentrations of cations and anions in the soil solution become sufficiently high whereby specific types will associate to form solid chemical compounds with limited solubility. Concentration levels at which precipitation occurs is compound-specific. Insolubilization of the precipitates leads to metal immobilization.

Metals fixation based on chelation and metal-organic complex formation may be generally ordered as follows:

Order of chelate stability: Hg > Cu > Ni > Pb > Co > Zn > Cd > Fe > Mn > Mg > Ca

Decreasing order for organic bonding: Cu > Fe > Zn > Ca

To ensure complete degradation or immobilization by adsorption or complexation, the hazardous constituent must remain in the treatment zone. With respect to organic hazardous constituents, the liquid infiltration rate and soil permeability must be determined to assess whether these compounds move through the treatment zone too quickly to allow complete degradation. Once an organic compound has leached below the zone of aeration where microbial degradation is most active, subsequent degradation in the lower soil horizons is markedly reduced. Incompletely degraded organic compounds reaching these zones can be leached from the treatment zone and enter the ground water system. For purpose of application evaluation, Table 8.1.14 provides a qualitative assessment of the infiltration and percolation rates of various textured soils. The applicant's submittal should be reviewed to compare soils of the existing or proposed treatment zone with the information presented in Table 8.1.14. If the treatment zone soils are of the type that have relatively high or low infiltration or percolation rates, the reviewer must be assured that treatment of the hazardous constituents applied in or on the treatment zone will not be precluded.

Hazardous constituents, including hazardous organic compounds, that are not degraded or transformed must be immobilized in the treatment zone. Studies have shown that the soil adsorption capacity is directly related to soil colloidal content.[8,9] Non-ionic compounds are thought to be adsorbed by the soil organic matter, whereas the polar constituents are considered immobilized by the mineral component of soils. Precipitation of the less soluble constituents and complexation also attenuate substances.

Part 1 - Existing literature - Because there is little specific information in the literature on hazardous constituent immobilization, treatability tests performed under laboratory or field conditions should be conducted to determine the mobility of a given inorganic or organic constituent in a soil environment similar to that of the existing or planned land treatment unit.

Part 2 - Existing operating data - Section 8.1.2.2.3 identifies the data elements to be submitted by the applicant who elects to demonstrate immobilization of hazardous constituents using existing operating data. Important data to be compared are analytical results of collected leachate and composition of wastes applied. Analytical techniques selected by the applicant should be capable of detecting known hazardous constituents of the waste applied and any hazardous constituent expected to be derived from the waste as a result of treatment. Concentrations of any hazardous constituent detected in the collected leachate should be compared with background levels to determine any significant difference. Section 9 of the HWLT manual provides a discussion of various sampling techniques employed in monitoring the soil-pore liquid. Sampling and analytical techniques used by the applicant should be evaluated by reviewing Section 5 of the HWLT manual and Test Methods for Evaluating Solid Waste Physical/Chemical Methods.[4]

Part 3 - Laboratory tests - Laboratory tests to assess constituent mobility or potential leachability include soil thin-layer chromatography and column leaching. Soil thin-layer chromatography is a technique used to assess the relative mobility of a substance by comparing the distance traversed by a given compound to the distance traversed by the wetting front. Column leaching is a laboratory or field measurement technique used to assess relative pollutant mobility under saturated soil conditions. If the soil profile of the treatment zone is nonuniform, laboratory mobility tests should be performed under conditions reflecting the expected multilayered soil profile.

Part 4 - Field tests - Demonstration of hazardous constituent immobilization can be accomplished by studies performed on field test plots. A description of the field studies should be included in the application that contains the information identified in Table 8.1.2. Specific field tests to make this (immobilization) demonstration are discussed in Section 7 of the HWLT manual. Results submitted by the applicant should clearly show the following:

- the concentration of hazrdous constituents in the soil as a function of depth at various times during the field test,
- the concentration of hazardous constituents in the soil-pore liquid at various depths, over time,
- the concentration of hazardous constituents in rainfall run-off as a function of the depth of rainfall, and
- the concentration of hazardous constituents in the ground water underlying the field test plots.

Submittal of these results will provide an accounting of the migration of hazardous constituents through and out of the treatment zone.

Figure 8.1.6 presents a worksheet that can be used for evaluating field test designs submitted by the applicant. Completion of the worksheet will reveal the completeness and appropriateness of the applicant's selected field

tests to demonstrate hazardous constituent immobilization. Section 7 of the HWLT manual provides a discussion of the interpretation of hazardous constituent immobilization studies performed in the laboratory or field.

8.1.3.2.4 Volatilization--Volatilization of hazardous compounds can occur during waste application and subsequent cultivation when underlying soil layers are exposed to the atmosphere. Surface spreading and subsurface injection are two common waste application techniques. Studies have shown that air emission releases are greater when wastes are spread on the surface than when injected into the top soil layer. During surface spreading, volatilization is a gas-phase resistance phenomenon, whereas when wastes are injected below the soil surface, vaporization is governed by liquid-phase and gaseous-phase resistance and diffusion through the porous soil.

Experience gained from the land treatment of refinery oily sludges,[13] which presently is one of the most common waste types land treated, indicates that hydrocarbon emissions are released in proportion to the quantity of their volatile hydrocarbon content. It has also been learned that volatilization is minimized by delaying tilling after subsurface injection. Figure 8.1.7 displays test data revealing a marked decrease in atmospheric emissions by delaying tilling 2 days, from 4 to 6 days after soil injection.

Simulated laboratory tests should investigate the following factors as they affect volatilization of the wastes applied:

- Volatility of waste (the most important parameter affecting emissions),
- Application method (subsurface injection results in lower air emission release),
- Application rate (loading rate is inversely related to emission release, especially when waste contains high moisture content),
- Air temperature (emission release will increase as temperature increases),
- Soil temperature (same as air temperature),
- Soil type (relationship to emissions not clearly defined, but differing release rates from same waste applied to different soils have been recorded),
- Soil moisture (emission release tends to increase with soil moisture),
- Air moisture (direct relationship between relative humidity and emission release),
- Air flow (emission release directly related to air velocity).

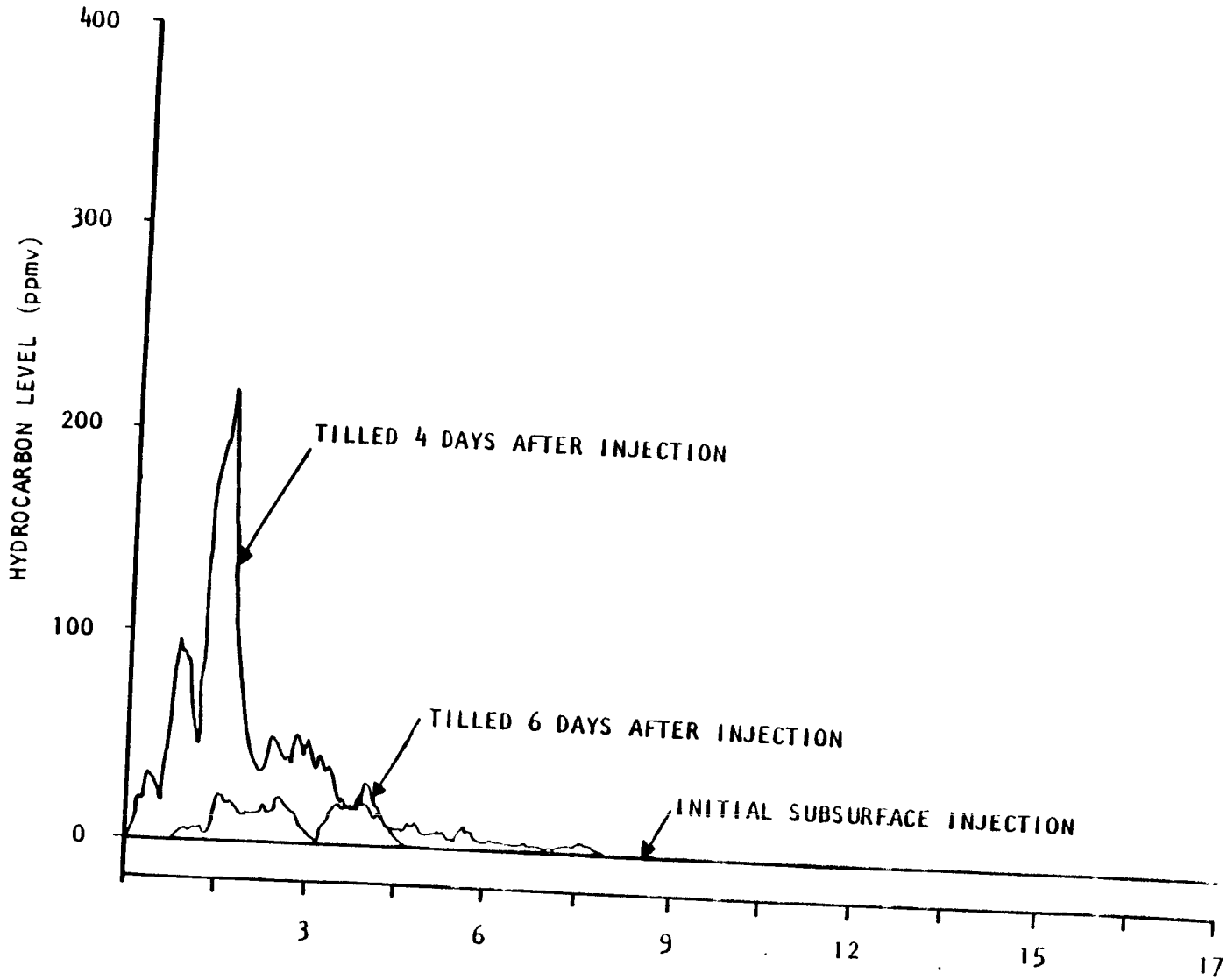

Figure 8.1./. Effect of resting time before tilling on emissions after subsurface injection.13

All laboratory experiments to be performed as part of the treatment demonstration should be conducted under carefully controlled conditions using an environmental chamber that assures quantitative sampling and exclusion of outside interferences. The experimental apparatus should include equipment to regulate air flow, temperature, and moisture, and soil temperature and moisture.

Monitoring equipment and analyzers must be employed to record hydrocarbon emissions (qualitatively and quantitatively), soil temperature and moisture, and air flow, temperature, and relative humidity. Table 8.1.23 presents an example matrix of experimental conditions for land treatment simulation tests. Replicate testing should be performed to determine statistical variations and representativeness of data generated. Section 9 of the HWLT manual provides a brief discussion of air monitoring at hazardous waste land treatment facilities. For a more detailed discussion, refer to references 13 through 17. Beyond actual testing, theoretical equations have been derived to estimate air emission release rates from land treatment facilities. Discussion of these estimation techniques are provided in references 14 and 18. The Office of Solid Waste, Land Disposal Branch, is currently researching the viability and accuracy of using mathematical equations to estimate air emission release rates.

Table 8.1.24 lists the vapor pressure of chemicals that are contained in hazardous wastes representing 95 percent of the total U.S. hazardous waste disposal volume. The chemical listing resulted from a compilation of wastes identified in EPA's RCRA Part A permit application data base. Wastes disposed of in amounts greater than 10,000 metric tons were reviewed with respect to their chemical constituents and associated chemical, physical, and toxicological characteristics. The vapor hazard ratio (VHR) presented in the table is useful for comparing the relative air hazards imposed by different chemicals. The VHR is defined as the ratio (ppm/ppm) of a chemical's equilibrium vapor concentration at 25°C (computed from vapor pressure data) to its Threshold Limit Value (TLV); the lower the ratio, the lower the potential hazard. For example, if judged on the basis of TLV alone, ethyl ether, with a TLV of 400 ppm, might be deemed safer than 1,2-trans-dichloroethylene, with a TLV of 200 ppm. When volatility is taken into account, it is apparent that 1,2-trans-dichloroethylene, with a VHR of 2072, represents more of a potential air hazard than ethyl ether, with a VHR of 1711.

Presentation of these data should not be interpreted to mean that VHRs have to be determined for the wastes to be land treated. The information provided in the table is for reference only. The primary purpose here is to list the vapor pressure of hazardous constituents frequently handled.

8.1.3.2.5 Toxicity--When biodegradation is relied on to treat wastes and/or a vegetative cover is established during the active portion of the unit, waste application rates and frequency must be carefully evaluated to prevent acute and/or chronic toxicity of soil microbes and plant populations. It should be recognized, however, that high intensity applications of inorganic constituents or organic constituents that resist degradation may be applied to the soil. Under these circumstances, treatment is based almost completely on substance immobilization. Under such conditions, the toxic effects of the constituents on soil microbes and vegetative cover are disregarded.

TABLE 8.1.23. MATRIX OF EXPERIMENTAL CONDITIONS FOR LAND TREATMENT SIMULATION RUN

Run No.	Waste material	Waste loading (lb/ft^2)	Soil type	Soil moisture (wt%)	Soil/Air temperature (°F/°F)	Air velocity (mph)	Relative humidity (%)	Spreading mechanism	Remarks
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
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16									
17									
18									
19									
20									
21									
22									
23									
24									
25									

TABLE 8.1.24. RELATIVE RANKING OF CHEMICALS POTENTIALLY RELEASED FROM HAZARDOUS WASTE TREATMENT, STORAGE AND DISPOSAL FACILITIES BY VAPOR HAZARD RATIO (VHR)[a]

Rank	Chemical name	Vapor pressure (mmHg@25°C) approximate	TLV (ppm)	Vapor hazard ratio[a] (ppm/ppm)
1	**Formaldehyde**	3,500	2	2.3×10^6
2	**Hydrogen sulfide**	15,200	10	2.0×10^6
3	**Vinyl chloride**	2,600	5	684,211
4	**Hydrofluoric acid**	900	3	394,737
5	**Dimethylamine**	1,500	10	197,368
6	**Hydrocyanic acid**	760	10	100,000
7	**Methyl chloride**	3,700	50	97,368
8	**Vinylidene chloride**	600	10	78,947
9	**Chloroacetaldehyde**	60	1	78,947
10	**Acrylonitrile**	100	2	65,789
11	**Tetraethyl lead**	0.35	0.0076	60,596
12	**Carbon disulfide**	350	10	46,053
13	**Carbon tetrachloride**	100	5	26,316
14	**Chloroform**	200	10	26,316
15	**Toluene diisocyanate**	0.08	0.005	21,053
16	**Benzene**	100	10	13,158
17	**1,1,2,2-tetrachloroethane**	9	1	11,842
18	**Epichlorohydrin**	17	2	11,184
19	**Ethylene dichloride**	85	10	11,184
20	**Formic acid**	40	5	10,526
21	**Ethyl acrylate**	40	5	10,526

TABLE 8.1.24 (continued)

Rank	Chemical name	Vapor pressure (mmHg@25°C) approximate	TLV (ppm)	Vapor hazard ratio[a] (ppm/ppm)
22	Acetaldehyde	760	100	10,000
23	Pyridine	20	5	5,263
24	Methylene chloride	400	100	5,263
25	1,1,2-trichloroethane	25	10	3,289
26	Acetonitrile	90	40	2,961
27	Trichloroethylene	90	50	2,368
28	1,2-trans-dichloroethylene	315	200	2,072
29	Ethyl ether	520	400	1,711
30	Maleic anhydride	0.3	0.25	1,579
31	Ethylidene chloride	230	200	1,513
32	Benzyl chloride	1	1	1,316
33	Trichlorofluoromethane	760	1000	1,000
34	Methyl alcohol	120	200	789
35	Tetrachloroethylene	25	50	658
36	Methyl ethyl ketone	100	200	658
37	Aniline	0.75	2	493
38	Acetone	266	750	467
39	1,1,1-trichloroethane	120	350	451
40	1,1,2-trichloro-1,2,2-trifluoroethane	300	1000	395
41	Toluene	30	100	395
42	Nitrobenzene	0.3	1	395

(Continued)

TABLE 8.1.24 (continued)

Rank	Chemical name	Vapor pressure (mmHg@25°C) approximate	TLV (ppm)	Vapor hazard ratio[a] (ppm/ppm)
43	Ethyl acetate	100	400	329
44	Isobutyl alcohol	12	50	316
45	Cyclohexanone	4.8	25	253
46	Cumene	9.0	50	237
47	Chlorobenzene	12	75	211
48	Methyl isobutyl ketone	7.5	50	197
49	n-Butyl alcohol	7.0	50	184
50	Ethyl benzene	10	100	132
51	Phenol	0.5	5	132
52	1,2,3-trichloropropane	4.4	50	116
53	Xylene	8.5	100	112
54	Cresols	0.4	5	105
55	Acrylamide	0.007	0.1	92
56	Hexachloroethane	0.65	10	86
57	Cresylic acid	0.3	5	79
58	Acrylic acid	0.45	10	59
59	Phthalic anhydride	0.03	1	39
60	o-Dichlorobenzene	1.4	50	37
61	Naphthalene	0.15	10	20
62	p-Dichlorobenzene	0.8	75	14

[a]Vapor hazard ratio is defined as the ratio (ppm/ppm) of the chemical's equilibrium vapor concentration at 25°C (continued)

(a) Microbial Toxicity - The likelihood of acute toxicity occurring can be evaluated by a review of the literature or laboratory testing, the latter involving soil respiration experiments to demonstrate the effect of various concentrations of toxic compounds on indigenous soil microbes. Potential chronic effects imparted by long-term waste application and hazardous substance soil accumulation must also be investigated. Determination of chronic toxicity effects by laboratory tests is very time consuming. Consequently, the applicant may refer to the literature to discover the effects of long-term exposure to toxic compounds on soil microbes. Section 7 of the Hazardous Waste Land Treatment manual provides informative discussions of laboratory tests that can be used to determine the effects of acute exposure to hazardous substances and techniques for assessing chronic effects. Note that the microbial toxicity assessment can be made simultaneously with the hazardous constituent degradation/transformation demonstration.

(b) Phytotoxicity - If plants, food-chain or nonfood-chain crops, are to be grown in or on the treatment zone of the land treatment unit during its active life, the permit application should include a demonstration of the effects of waste additions on seed germination and plant establishment and yield. Establishment of a vegetative cover may be part of the unit design to immobilize or transform hazard waste constituents or to control soil moisture content and wind dispersal of particulate matter. Demonstration of the effectiveness of this treatment technique may be based on an analysis of the literature, laboratory or greenhouse studies, field tests, and operating data. In addition to demonstrating adequate treatment, the applicant must provide an analysis of plant viability in or on the treatment zone. Greenhouse studies investigating seed germination, root development, and above ground growth can be used to determine acute toxicity effects of plants to be grown during the active period of the treatment unit or following closure. Section 7 of the HWLT manual provides guidance on acceptable experimental procedures and methods of assessing plant viability and potential phytotoxicity.

Figure 8.1.6 provides a worksheet that can be used by the permit writer to evaluate the applicant's field test plan to assess whether waste applications will have a toxic effect on soil microbes or vegetative cover.

8.1.4 Draft Permit Preparation

If the owner or operator intends to conduct field tests or laboratory analyses to make the treatment demonstration required under §264.272(a), he or she must obtain a treatment or disposal permit under §270.63. This subsection describes the items to be included in the draft permit as they pertain to the treatment demonstration. Section 4 of this manual presents the Permit Module (XIV) for Land Treatment Facilities which should be used in conjunction with Permit Module (XIII) for the Land Treatment Demonstration to prepare the draft permit for the entire complex.

The Treatment Demonstration component (see Module XIII in Section 4) of the draft permit is comprised of the following three conditions: Waste Identification (Condition A), Design and Operating Requirements (Condition B),

and Testing and Analytical Procedures (Condition C). Condition A of the Permit Module specifies that the Treatment Demonstration must be made for the wastes and potential hazardous constituents in or derived from the wastes to be treated, as identified by the applicant. Note that only those wastes for which it will be demonstrated are completely degraded, transformed, or immobilized are allowed to be treated at the site. If the owner or operator plans to treat wastes not listed in the application, he or she will have to obtain another permit to demonstrate that they also can be completely degraded, transformed, or immobilized by the land treatment unit.

Condition A reads as follows:

> Waste Identification. The Permittee must conduct a land treatment demonstration in accordance with the requirements of 40 CFR 264.272 for the wastes listed in Attachment_____. Any field test or laboratory analysis conducted in order to make this demonstration must be likely to show that the hazardous constituents listed in Attachment_____ will be completely degraded, transformed or immobilized in the treatment zone of the existing or proposed land treatment unit.

Condition B of the Treatment Demonstration Permit Module XIII stipulates treatment demonstration design and operating requirements when any field test or laboratory analyses are conducted. The draft permit should specify, at a minimum, the following:

- the horizontal and vertical dimensions of the treatment zone,
- monitoring procedures,
- closure and clean-up activities, and
- description of conditions that accurately simulate the characteristics and operating conditions for the proposed land treatment unit.

Condition B of Permit Module XIII reads as follows:

> Design and Operating Requirements. The Permittee shall conduct the demonstration in accordance with the requirements of 40 CFR 264.272(c) as specified in the attached plans and specifications.

Condition C of the Treatment Demonstration Permit Module specifies testing and analytical procedures. The condition can be implemented by reference to the applicant's proposed testing and analytical program. To be acceptable for substitution as a written permit condition, the referenced portion of the applicant's submittal should specify the following:

- type of test(s), including duration,

- materials and methods, including analytical procedures, and
- expected time for completion of tests and analyses.

Condition C of Permit Module XIII reads as follows:

> Testing and Analytical Procedures. The Permittee shall conduct the demonstration using the testing and analytical procedures and data sources specified in Attachment _____ in accordance with requirements of 40 CFR 264.272(c).

3.1.5 References

1. U.S. Environmental Protection Agency. Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Draft Report. Office of Solid Waste, Land Disposal Branch. Washington, D.C. March 1983.

2. Spyridakis, D. E., and E. B. Welch. Treatment Processes and Environmental Impacts of Waste Effluent Disposal on Land. In Land Treatment and Disposal of Municipal and Industrial Wastewater, pp. 45-83. Edited by R. L. Sanks and T. Asano. Ann Arbor Science, Ann Arbor, MI. 1976.

3. U.S. Environmental Protection Agency. Damages and Threats Caused by Hazardous Material Sites. Oil and Special Materials Control Division. Washington, D.C. EPA Report 430/9-80-004, 1980.

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13. Minear, R. A., et al. Atmospheric Hydrocarbon Emissions from Land Treatment of Refinery Oily Sludges. Prepared by Radian Corporation for the American Petroleum Institute, Washington, DC. May 1981.

14. Thibodeaux, L. J., and S. T. Hwang. Landfarming of Petroleum Wastes--Modeling the Air Emission Problem. Envir. Prog. Vol. 1, No. 1, February 1982. pp. 42-46.

15. Hwang, S. T. Toxic Emissions from Land Disposal Facilities. Envir. Progr. Vol. No. 1. February 1982. pp. 46-52.

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17. Sunoco Corporation, Summary of Results from the Toledo, Ohio Refinery Landfarm Tests. SUNTECH Environmental Group, Marcus Hook, PA. pp. 9-49, undated.

18. Farino, W., et al. Evaluation and Selection of Models for Estimating Air Emissions from Hazardous Waste Treatment, Storage, and Disposal Facilities. Draft Final Report. Prepared by GCA/Technology Division for U.S. Environmental Protection Agency, Office of Solid Waste, Land Disposal Branch, Washington, D.C. October 1982.

8.2 LAND TREATMENT PROGRAM

8.2.1 Federal Requirement

As required by §270.20(b), the Part B permit application must include:

> "(b) A description of a land treatment program, as required under §264.271. This information must be submitted with the plans for the treatment demonstration, and updated following the treatment demonstration. The land treatment program must address the following items:
>
> (1) The wastes to be land treated;
>
> (2) Design measures and operating practices necessary to maximize treatment in accordance with §264.273(a) including:
>
> (i) Waste application method and rate;
>
> (ii) Measures to control soil pH;
>
> (iii) Enhancement of microbial or chemical reactions;
>
> (iv) Control of moisture content;
>
> (3) Provisions for unsaturated zone monitoring, including:
>
> (i) Sampling equipment, procedures, and frequency;
>
> (ii) Procedures for selecting sampling locations;
>
> (iii) Analytical procedures;
>
> (iv) Chain of custody control;
>
> (v) Procedures for establishing background values;
>
> (vi) Statistical methods for interpreting results;
>
> (vii) The justification for any hazardous constituents recommended for selection as principal hazardous constituents, in accordance with the criteria for such selection in §264.278(a);
>
> (4) A list of hazardous constituents reasonably expected to be in, or derived from, the wastes to be land treated based on waste analysis performed pursuant to §264.13;
>
> (5) The proposed dimensions of the treatment zone."

Fulfillment of the requirements of §270.20(b) necessitates compliance with several Part 264 standards. As identified above, §264.271 is the specific technical standard for the land treatment program. The standard is as follows:

> "(a) An owner or operator subject to this subpart must establish a land treatment program that is designed to ensure that hazardous constituents placed in or on the treatment zone are degraded, transformed, or immobilized within the treatment zone. The Regional Administrator will specify in the facility permit the elements of the treatment program, including:
>
> (1) The wastes that are capable of being treated at the unit based on a demonstration under §264.272;
>
> (2) Design measures and operating practices necessary to maximize the success of degradation, transformation, and immobilization processes in the treatment zone in accordance with §264.273(a); and
>
> (3) Unsaturated zone monitoring provisions meeting the requirements of §264.278.

(b) The Regional Administrator will specify in the facility permit the hazardous constituents that must be degraded, transformed, or immobilized under this subpart. Hazardous constituents are constituents identified in Appendix VIII of Part 261 of this chapter that are reasonably expected to be in, or derived from, waste placed in or on the treatment zone.

(c) The Regional Administrator will specify the vertical and horizontal dimensions of the treatment zone in the facility permit. The treatment zone is the portion of the unsaturated zone below and including the land surface in which the owner or operator intends to maintain the conditions necessary for effective degradation, transformation, or immobilization of hazardous constituents. The maximum depth of the treatment zone must be:

(1) No more than 1.5 meters (5 feet) from the initial soil surface; and

(2) More than 1 meter (3 feet) above the seasonal high water table."

Section 264.271(a)(2) states that the owner or operator must design and operate the land treatment unit to maximize treatment in accordance with §264.273(a), which states:

"(a) The owner or operator must design, construct, operate, and maintain the unit to maximize the degradation, transformation, and immobilization of hazardous constituents in the treatment zone. The owner or operator must design, construct, operate, and maintain the unit in accord with all design and operating conditions that were used in the treatment demonstration under §264.272. At a minimum, the Regional Administrator will specify the following in the facility permit:

(1) The rate and method of waste application to the treatment zone;

(2) Measures to control soil pH;

(3) Measures to enhance microbial or chemical reactions (e.g., fertilization, tilling); and

(4) Measures to control the moisture content of the treatment zone."

Section 264.271(a)(3) states that the owner or operator must meet the unsaturated zone monitoring requirements of §264.278. This section requires that:

"(a) The owner or operator must monitor the soil and soil-pore liquid to determine whether hazardous constituents migrate out of the treatment zone.

(1) The Regional Administrator will specify the hazardous constituents to be monitored in the facility permit. The hazardous constituents to be monitored are those specified under §264.271(b).

(2) The Regional Administrator may require monitoring for principal hazardous constituents (PHCs) in lieu of the constituents specified under §264.271(b). PHCs are hazardous constituents contained in the wastes to be applied at the unit that are the most

difficult to treat considering the combined effects of degradation, transformation, and immobilization. The Regional Administrator will establish PHCs if he finds, based on waste analyses, treatment demonstrations, or other data, that effective degradation, transformation, or immobilization of the PHCs will assure treatment at at least equivalent levels for the other hazardous constituents in the wsates.

(b) The owner or operator must install an unsaturated zone monitoring system that includes soil monitoring using soil cores and soil-pore liquid monitoring using devices such as lysimeters. The unsaturated zone monitoring system must consist of a sufficient number of sampling points at appropriate locations and depths to yield samples that:

(1) Represent the quality of background soil-pore liquid quality and the chemical make-up of soil that has not been affected by leakage from the treatment zone; and

(2) Indicate the quality of soil-pore liquid and the chemical make-up of the soil below the treatment zone.

(c) The owner or operator must establish a background value for each hazardous constituent to be monitored under paragraph (a) of this section. The permit will specify the background values for each constituent or specify the procedures to be used to calculate the background values.

(1) Background soil values may be based on a one-time sampling at a background plot having characteristics similar to those of the treatment zone.

(2) Background soil-pore liquid values must be based on at least quarterly sampling for one year at a background plot having characteristics similar to those of the treatment zone.

(3) The owner or operator must express all background values in a form necessary for the determination of statistically significant increases under paragraph (f) of this section.

(4) In taking samples used in the determination of all background values, the owner or operator must use an unsaturated zone monitoring system that complies with paragraph (b)(1) of this section.

(d) The owner or operator must conduct soil monitoring and soil-pore liquid monitoring immediately below the treatment zone. The Regional Administrator will specify the frequency and timing of soil and soil-pore liquid monitoring in the facility permit after considering the frequency, timing, and rate of waste application, and the soil permeability. The owner or operator must express the results of soil and soil-pore liquid monitoring in a form necessary for the determination of statistically significant increases under paragraph (f) of this section.

(e) The owner or operator must use consistent sampling and analysis procedures that are designed to ensure sampling results that provide a reliable indication of soil-pore liquid quality and the chemical make-up of the soil below the treatment zone. At a minimum, the owner or operator must implement procedures and techniques for:

(1) Sample collection;
(2) Sample preservation and shipment;
(3) Analytical procedures; and
(4) Chain of custody control.

(f) The owner or operator must determine whether there is a statistically significant change over background values for any hazardous constituent to be monitored under paragraph (a) of this section below the treatment zone each time he conducts soil monitoring and soil-pore liquid monitoring under paragraph (d) of this section.

(1) In determining whether a statistically significant increase has occurred, the owner or operator must compare the value of each constituent, as determined under paragraph (d) of this section, to the background value for that constituent according to the statistical procedure specified in the facility permit under this paragraph.

(2) The owner or operator must determine whether there has been a statistically significant increase below the treatment zone within a reasonable time period after completion of sampling. The Regional Administrator will specify that time period in the facility permit after considering the complexity of the statistical test and the availability of laboratory facilities to perform the analysis of soil and soil-pore liquid samples.

(3) The owner or operator must determine whether there is a statistically significant increase below the treatment zone using a statistical procedure that provides reasonable confidence that migration from the treatment zone will be identified. The Regional Administrator will specify a statistical procedure in the facility permit that he finds:

(i) Is appropriate for the distribution of the data used to establish background values; and

(ii) Provides a reasonable balance between the probability of falsely identifying migration from the treatment zone and the probability of failing to identify real migration from the treatment zone.

(g) If the owner or operator determines, pursuant to paragraph (f) of this section, that there is a statistically significant increase of hazardous constituents below the treatment zone, he must:

(1) Notify the Regional Administrator of this finding in writing within seven days. The notification must indicate what constituents have shown statistically significant increases.

(2) Within 90 days, submit to the Regional Administrator an application for a permit modification to modify the operating practices at the facility in order to maximize the success of degradation, transformation, or immobilization processes in the treatment zone.

(h) If the owner or operator determines, pursuant to paragraph (f) of this section, that there is a statistically significant increase of hazardous constituents below the treatment zone, he may demonstrate that a source other than regulated units caused the increase or that the increase resulted from an error in

sampling, analysis, or evaluation. While the owner or operator m make a demonstration under this paragraph in addition to, or in l of, submitting a permit modification application under paragraph (g)(2) of this section, he is not relieved of the requirement to submit a permit modification application within the time specified in paragraph (g)(2) or this section unless the demonstration made under this paragraph successfully shows that a source other than regulated units caused the increase or that the increase resulted from an error in sampling, analysis, or evaluation. In making a demonstration under this paragraph, the owner or operator must:

(1) Notify the Regional Administrator in writing within seve days of determining a statistically significant increase below the treatment zone that he intends to make a determination under this paragraph;

(2) Within 90 days, submit a report to the Regional Administrator demonstrating that a source other than the regulated units caused the increase or that the increase resulted from error in sampling, analysis, or evaluation;

(3) Within 90 days, submit to the Regional Administrator an application for a permit modification to make any appropriate changes to the unsaturated zone monitoring program at the facility; and

(4) Continue to monitor in accordance with the unsaturated zone monitoring program established under this section."

8.2.2 Summary of Necessary Application Information

8.2.2.1 Wastes for Land Treatment Program--

The application should contain a listing of all hazardous wastes, hazardous constituents, and pertinent nonhazardous constituents that will be or currently are (for existing facilities) applied in or on the treatment zone(s) of the subject land treatment facility.

8.2.2.2 Waste Application Rates and Methods--

Part 1 - For each waste constituent listed in Section 8.2.2.1, the applicant should assess its application limit (AL), rate limit (RL), and capacity limit (CL). EPA's Permit Applicants' Guidance Manual[1] recommends that this information be presented in the format provided in Table 8.2.1.

Part 2 - For each waste constituent identified in Section 8.2.2.1, list respective waste concentrations and quantity required (as per hectare basis) to reach each constituent's AL, RL, and CL. Table 8.2.2 shows the recommended format for presenting this information. An asterisk or other footnote should be used to identify application limiting constituent (ALC), rate limiting constituent (RLC), and capacity limiting constituent (CLC).

Part 3 - The application should include a monthly application schedule based on the following:

- application limiting constituent,

TABLE 8.2.1. FORMAT FOR REPORTING APPLICATION, RATE, AND CAPACITY LIMITING CONSTITUENTS

Waste Constituent	Limit	Value	Discussion
Phenol	AL	1.1×10^3 kg/ha	Concentration $\geq$500 mg/kg soil are phytotoxic and inhibit microbial activity
	RL	70 kg/ha/yr	Optimum degradation rate is 70 kg/ha/yr
Lead	AL	None	
	RL	None	
	CL	2.2×10^3 kg/ha	Not to exceed 1000 mg/kg

TABLE 8.2.2. FORMAT FOR IDENTIFYING LIMITING CONSTITUENTS (ALCs, RLCs, AND CLCs ARE MARKED WITH AN ASTERISK)

Waste Constituent	Concentration in Waste (mg/kg)	Amount of Waste to Reach AL kg/ha/Application	Amount of Waste to Reach RL kg/ha/yr	Amount of Waste to Reach CL kg/ha
1. Water[-]	8.5×10^5		3.53×10^6	N/A
2. Phenol	200	5.6×10^6*	3.5×10^5*	N/A
3. Lead	500	N/A	N/A	4.5×10^3*

N/A, not applicable.

[-]Pertinent nonhazardous substance.

- rate limiting constituent,
- capacity limiting constituent,
- waste generation rate,
- seasonal restrictions on application,
- expected life span of unit, and
- waste application method.

Table 8.2.3 shows the recommended format for presenting the waste application schedule.

Part 3 - The application should contain a description of waste handling and application methods that includes the following:

- methods and frequency of waste collection and transport,
- location, type, and capacity of onsite storage containers,
- waste application equipment,
- application restrictions (e.g. weather, rate of degradation), and
- plot configuration (plot rotation).

8.2.2.3 Measures to Control Soil pH--

The following information addressing the control of treatment zone soil pH should be presented in the permit application:

- current or antecedent soil pH (mean and range) of treatment zone,
- minimum and maximum treatment zone soil pH values that promote maximum degradation, transformation, or immobilization, and
- description of soil monitoring scheme and amendment procedures to control treatment zone soil pH at optimum levels.

8.2.2.4 Measures to Enhance Microbial or Chemical Reactions--

The applicant should describe how the treatment zone(s) will be conditioned to enhance microbial or chemical degradation, transformation, or immobilization of hazardous constituents applied with or derived from wastes placed in the land treatment unit.

8.2.2.5 Measures to Control Soil Moisture in the Treatment Zone--

Estimates of expected monthly waste gains and losses at the land treatment unit should be included in the application. Procedures for estimating or data sources for each of the following should be described in

TABLE 8.2.3. EXAMPLE WASTE APPLICATION SCHEDULE

Month	Monthly Waste Generation Rate kg/month	Number of Hectares (ha) Receive Waste Applications ha	Application Rate kg/ha/month
January			
February			
March			
April			
May			
June			
July			
August			
September			
October			
November			
December			
TOTALS	kg/yr	ha	kg/ha/year

Total Amount of Available Land: _____ ha
Expected Life Span of the Unit: _____ years
Expected total Quantity of Waste Applied per ha: _____ kg/ha

the application: precipitation, evapotranspiration, run-off, percolation, irrigation needs, and storage requirements. All support calculations and assumptions should be included in the application.

8.2.2.6 Unsaturated Zone Monitoring--

Under §270.20(b)(3) the applicant is required to submit an unsaturated zone monitoring plan that will demonstrate compliance with the requirements of §264.278. At a minimum, the plan should address the following nine parts. Unsaturated zone monitoring is required for each plot placed in service.

Part 1 - Sampling location - On a scale drawing of the land treatment unit, the applicant should show the location and depth of soil-pore liquid sampling devices and locations and depths for taking soil samples.

Part 2 - Sampling frequency - A schedule identifying the sampling frequency of the soil-pore liquid and soil below the treatment zone should be included in the permit application. Factors affecting sampling frequency such as waste application rate, waste application schedule, climatic factors, and the hydraulic conductivity of the treatment zone should be addressed by the applicant.

Part 3 - Sampling equipment - The applicant should identify and describe the equipment (including procedures and materials) that will be used to obtain both soil core samples and soil-pore liquid samples.

Part 4 - Equipment installation - A step-by-step description of the procedure used for installing soil-pore liquid monitoring devices should be included in unsaturated zone monitoring plan.

Part 5 - Sampling procedures - Explain in a step-by-step fashion how samples of soil-pore liquid and soil will be obtained using the equipment described above. The number of samples taken at each sampling event, as well as compositing procedures, if used, should be described.

Part 6 - Analytical procedures - Analytical procedures that will be used to determine the concentration of each hazardous constituent in collected samples and the name of the laboratory that will perform the analyses should be identified in the application.

Part 7 - Chain-of-custody control - The applicant should explain in a step-by-step fashion the plan for maintaining chain-of-custody control throughout sampling, transportation, analysis, and reporting.

Part 8 - Background - A detailed description of the procedures for determining both soil background and soil-pore liquid background values, including the location and depth of background samples, sampling procedures, analytical methods, and results should be contained in the application.

Part 9 - Statistical methods - The statistical methods that will be used to determine a significant difference between background sample concentration and monitoring sample concentrations for both soil and soil-pore liquids must be included in the unsaturated zone monitoring plan.

(a) Time Period for Determining Increases Over Background - In accordance wth §264.278(f)(3), the applicant must submit results that show a significant increase over background values within a reasonable time frame.

(b) Principal Hazardous Constituents - The applicant can elect to monitor only principal hazardous constituents (PHCs) instead of all hazardous constituents listed in Section 8.2.2.1. If this is the case, the application should identify the PHCs and supporting justifying documentation.

8.2.2.7 Treatment Zone Description--

A description of the dimensions and soils of the treatment zone including each of the following four Parts should be submitted in the permit application.

Part 1 - Soil survey - A map or plot plan of the land treatment unit that delineates the horizontal boundaries of the treatment zone(s) and labels the series classification of the soils contained therein should be included in the application.

Part 2 - Series descriptions - Soil series descriptions should be submitted that include the following information (this applies to undisturbed native soils, disturbed soils, fill materials, or previously waste-treated soil):

- soil profile description,
- physical setting with slope and climatic data,
- mineralogy,
- land use and vegetation cover,
- estimated soil properties including:

USDA texture	shrink-swell potential
Atterburg limits	erosion factors
permeability	flood frequency and duration
available water capacity	depth of seasonal high water table
pH	
salinity	frost action potential

Part 3 - Results of soil sampling and analysis - The applicant should submit the results of analyses of the soils within the treatment zone. The submittal should also include sample location, collection and preparation, and analytical methods. Table 8.2.4 presents the recommended format for reporting results of soil sampling and analysis.

Part 4 - Depth of treatment zone - For each plot of the treatment unit, the applicant must specify the dimensions of its treatment zone. Vertical dimensions should be expressed in meters below the initial soil surface and meters above the seasonal high water table.

TABLE 8.2.4. FORMAT FOR REPORTING THE RESULTS OF SOIL SAMPLING AND ANALYSIS

Series Name: _____ Date of Sampling: _____

Horizon	Parameters	Analytical Methods*	Value	Units
A (0-X cm)	pH	1:1 Glass Electrode	___	Standard pH Units
	Particle Size Distribution	Hydrometer Method	Sand ___	Dry Weight %
			Silt ___	Dry Weight %
			Clay ___	Dry Weight %
	Electrical Conductivity	Saturated Paste Extract - Wheatstone Bridge	___	mmhos/cm
	Total Organic Carbon	Dichromate Wet Oxidation Method	___	Dry Weight %
	Cation Exchange Capacity	Ammonium Saturation Method	___	meq/100 g soil
	Lime Requirement for pH = 6.5	$BaCl_2$ TEA Method	___	meq/100 g
B (X-Y cm)	pH	1:1 Glass Electrode	___	Standard pH Units
	Particle Size Distribution	Hydrometer Method	Sand ___	Weight %
			Silt ___	Weight %
			Clay ___	Weight %
	Cation Exchange Capacity	Ammonium Saturation Method	___	meq/100 g soil
	Electrical Conductivity	Saturated Paste Extract - Wheatstone Bridge	___	mmhos/cm
	Total Organic Carbon	Dichromate Wet Oxidation Method	___	Dry Weight %
C (Y-Z cm)	pH	1:1 Glass Electrode	___	Standard pH Units
	Particle Size Distribution	Hydrometer Method	Sand ___	Weight %
			Silt ___	Weight %
			Clay ___	Weight %

*Recommended methods for soil analysis are discussed in Hazardous Waste Land Treatment manual (2) and Methods of Soil Analysis (3).

8.2.3 Guidance on Evaluating Application Information

The applicant must develop a land treatment program that is designed to ensure that hazardous constituents placed in or on the treatment zone are degraded, transformed, or immobilized in the treatment zone. Figure 8.2.1 identifies the required components of the land treatment program. Establishment of operating conditions and work practices should be based on results obtained from the treatment demonstration.

8.2.3.1 Wastes for Land Treatment Program--

Evaluation of the waste(s) capable of being treated by the land treatment unit should be based on the results of the treatment demonstration. Wastes containing hazardous constituents that have been shown to be completely degraded, transformed, or immobilized under the treatment demonstration can be disposed of at the proposed or existing unit, as the case may be. If the owner or operator demonstrates similarities, specifically with respect to hazardous constituents between broad classes of waste, it may not be necessary to require analysis of each batch of waste that might be handled at the unit.

Figure 8.2.2 presents a worksheet to assess the completeness of the information provided by applicant with respect to wastes that are or will be treated at the facility.

8.2.3.2 Waste Application Rates and Methods--

Determination of waste loading rates should be based on three factors. These factors are the rate limiting constituent (RLC), application limiting constitutent (ALC), and capacity limiting constituent (CLC). The rate limiting constituent is the chemical substance or compound that controls yearly loading rates. The application limiting constituent is the substance that restricts the amount of waste that can be spread in a single application, although it may be rapidly degraded, transformed, or immobilized. The third restricting factor, capacity limiting constituent, is an accumulating substance, such as a heavy metal, that sets the upper boundary for the total quantity of waste that can be applied at the site. The CLC controls the maximum design life of the treatment unit.

Section 7 of the HWLT manual[2] provides an informative discussion on how these three factors are determined based on the composition of the wastes to be applied. Appendix E of the HWLT manual provides sample calculations to determine each value for a given waste. Table 8.2.5 categorizes primary waste constituents with respect to their potential application, rate, and capacity limiting characteristics.

The HWLT manual also provides a technique for assessing constituent degradability as it relates to limiting application rates and frequency. Two management scenarios are discussed, one involving the maintenance of a plant cover over the active treatment zone, and the second addressing systems designed to function without a vegetative cover. Table 8.2.6 presents the computations that are required to determine the number of applications that are acceptable under either scenario, based on the expected degradability of the most persistent constituent.

LAND TREATMENT PROGRAM

- Waste for Land Treatment Program
- Waste Application Rates and Methods
- Measures to Control Soil pH
- Measures to Enhance Microbial or Chemical Reactions
- Measures to Control Soil Moisture in Treatment Zone
- Unsaturated Zone Monitoring
- Treatment Zone Description

Figure 8.2.1. Components of the Land Treatment Program.

WASTES FOR LAND TREATMENT PROGRAM

Is the following information provided for <u>each</u> waste being or to be land treated?

		YES	NO
Part 1	Waste Name	____	____
	Waste Generating Process or Source	____	____
	Monthly or Annual Quantity Handled	____	____
	EPA Hazardous Waste ID Number (if applicable)	____	____
Part 2	Name(s) of Pertinent Hazardous Constituents	____	____
	Name(s) of Pertinent Nonnazardous Constituents	____	____
Part 3	Concentration of Each Hazardous Constituent	____	____
	Volatility of Each Hazardous Constituent	____	____
	Percent Water	____	____
	Specific Gravity or Bulk Density	____	____
	pH	____	____
	Electrical Conductivity	____	____
	Total Acidity or Alkalinity	____	____
	Total Organic Carbon	____	____

Figure 8.2.2. Worksheet for evaluating completeness of description of wastes for land treatment program.

TABLE 8.2.5. WASTE COMPONENTS TO BE COMPARED IN DETERMINING APPLICATIO RATE, AND CAPACITY LIMITING CONSTITUENTS[a](2)

Constituent	Potential ALC[b]	Potential RLC	Potenti CLC
Organics	X	X	
- Volatilization	X		
- Leaching	X	X	
- Degradation		X	X
Water[c]	X	X	
Metals		X[d]	X
Nitrogen[c]	X	X	
Phosphorus[c]			X
Inorganic Acids, Bases, and Salts		X	X
Halides		X	

[a]The actual comparison should be tabulated similarly, but using calculated loading rates and capacities in place of the X's. The lowest value under ea category corresponds to the respective limiting constituent.

[b]Depending upon prevailing site conditions, the ALC may vary seasonal.y.

[c]Although these constituents are not considered hazardous, they may be the ALC, RLC, or CLC for the treatment unit.

[d]Metals may be the RLC when biodegradation is relied on for waste treatment and/or when a vegetative cover is maintained during active life. Elevated metal concentrations may be toxic to soil microbes and plants.

TABLE 8.2.6. COMPUTATION OF NUMBER OF APPLICATIONS PER YEAR BASED ON ORGANIC CONSTITUENT DEGRADATION (ADOPTED FROM REFERENCE 2)

Scenario A

When vegetation is a part of operational management, toxic organics may limit the loading rate. Loading rates must be constant so that the design facility area is adequate to handle each year's waste production. The following equation applies:

$$C_{yr} = \frac{1/2\ C_{crit}}{t_{1/2}} \quad (1)$$

where C_{yr} = the rate of application of the compound or fraction of interest to soil (kg/ha/yr);

C_{crit} = the critical concentration of the compound or fraction in soil at which yield reductions occur (kg/ha); and

$t_{1/2}$ = half-life (yr).

$$\text{Then } LR = \frac{C_{yr}}{C_w} \quad (2)$$

where LR = loading rate (kg/ha/yr) and

C_w = concentration of the compound or fraction of interest in the bulk waste (kg/kg).

If $t_{1/2}$ is less than one year, then the year's loading rate should be applied in more than a single dose as follows:

$$\text{Let } 1/t_{1/2} = \text{the smallest integer} \quad 1/t_{1/2} \quad (3)$$

Then $NA = 1/t_{1/2}$

where NA = number of applications per year

Scenario B

When a vegetation cover is desired only after site closure begins, then applications of waste may greatly exceed the toxicity threshold value. The only constraint would be that the site must have a final vegetative cover after a given number of years following the beginning of closure. Calculations are as follows:

$$C_{max} = C_{crit} 2^{n/t_{1/2}} \quad (4)$$

where C_{max} = maximum allowable concentration of the compound or fraction of interest applied to the soil (kg/ha);

n = number of years between final waste application and crop establishment (yr); and

$t_{1/2}$ = half-life (yr).

Substituting C_{max} for C_{crit} in equation 1, the loading rate can be calculated using equation 2.

Figure 8.2.3 presents a worksheet that can be used to assess whether all of the information requested under Section 8.2.2.2 has been submitted in the application.

Table 8.2.7 identifies the advantages and disadvantages of various waste application methods. Method of application should be thoroughly reviewed to determine that all disadvantages associated with the application technique to be employed have been addressed by the applicant and ways to minimize their negative impact (e.g. potential increased run-off) on the operation of the unit will be instituted.

Climatic conditions and geographical latitude will affect the rate of degradation and thus application rates and frequency. During the winter months and periods of excessive rainfall, the rate of biological degradation will slow down. Also, application rates are expected to be lower in the northern climates compared to southern latitudes. Figure 8.2.4 can be used to make a preliminary estimate of the number of days that waste application should be suspended based on geographical location.

Contingency arrangements should be made for waste storage when waste application is suspended. Storage facilities will also be necessary when equipment breakdown occurs. The permit application should contain a description of the waste handling activities to be performed when waste disposal is suspended or interrupted. Note that storage of hazardous wastes in containers or tanks are subject to the permit requirements of Part 270 and technical standards of subparts I and J of Part 264, respectively. If storage of the waste is not feasible, alternate disposal methods such as placement in waste piles, surface impoundments, or a landfill may be practiced. Disposal in any of these alternate facilities mandates conformance with the requirements of the applicable subpart of Part 264.

Another concern associated with the land treatment involves sustaining a microorganism population for biodegradation of hazardous wastes. Soil organisms are sensitive to both rapid and long term environmental changes. Consequently, waste application methods and rates must be well regulated to avoid irreparable damage to the soil ecosystem. Application rates should not exceed the assimilative capacity of the soil or crops, when grown in or on the treatment zone. In addition, it is good practice to suspend waste applications during periods of heavy rainfall, when the ground is frozen, or when soils are saturated.

Table 8.2.8 summarizes some recent land treatment experiences in the hydrocarbon processing industry. It should be recognized that each treatment facility will be different and application rates will vary depending on waste type, soil treatability, and climatic factors. Although the information presented in the table is specific to a few sites, it is useful to review in that it provides actual field data illustrating application rates and methods.

Section 7.5.4 of the HWLT manual describes how RLC, ALC, and CLC constituents are used to determine the required land area, number of applications per year, and unit's service life. The following presents example calculations to determine each of these items.

RATE AND METHODS OF WASTE APPLICATION

Has the applicant listed respective rate limiting, application limiting, and capacity limiting concentrations for each hazardous constituent?	Yes	No
Has the rationale for determining each limit been provided?	Yes	No
Has the necessary quantity of waste applied per hectare to reach constituents respective RL, AL, and CL been submitted?	Yes	No
Has the applicant submitted a monthly waste application schedule?	Yes	No
Are the methods and frequency of waste collection and transport described?	Yes	No
Has the applicant described the location, type, and capacity of waste storage units associated with the land treatment unit?	Yes	No
Is waste application equipment described?	Yes	No
Have restrictions on waste application been described?	Yes	No
Has the applicant described the planned plot configuration?	Yes	No

Figure 8.2.3. Worksheet for assessing completeness of applicant's waste application rate and methods.

TABLE 8.2.7. ADVANTAGES AND DISADVANTAGES OF VARIOUS SYSTEMS OF WASTE APPLICATION[a]

Advantages	Disadvantages
I. Surface application	
a) spraying	
low labor requirement, low land preparation, wide selection of equipment, operates on rough or wet land	clogging of nozzles, power for pumps, aerosol pollution, must flush pipe when stopping application
b) overland flow or controlled flooding	
low labor, low land preparation, operates on wet land	clogging of pipes and perforations, poor distribution over a given area or field due to slope and % solid in sludge, limited reapplication, potential odor, must flush pipes when stopping application
c) ridge and furrow	
rather simple system with low capital outlay, reasonably flexible, low energy requirement	can only use sludges with 4% solids or less, only limited reapplication possible, solids settle out at heads of furrows, needs well prepared site with slope of only 1/2 to 1-1/2% ponding and odor problems, deteriorates soil structure, not good under wet soil conditions
d) tank truck surface spreading	
low overhead, flexible, easily regulated application rate	limited in wet weather - need storage or alternate application system, damages soil structure resulting in compaction, high bulk density, and low infiltration
II. Subsurface application	
immediate mixing of sludge and soil, low odor and ponding problems, less chance of runoff contamination	complex management, requires specialized equipment, cannot be used in wet soil
III. Surface spreading and mixing of dewatered sludge	
Can use conventional equipment, can apply at higher rates, does not cause flooding and ponding and associated problems	high energy cost to dry the sludge, high operational costs to dry and apply, difficult to achieve uniform application

[a](Adapted from HWLI manual, U.S. EPA, EPA Report SW-874, (2)).

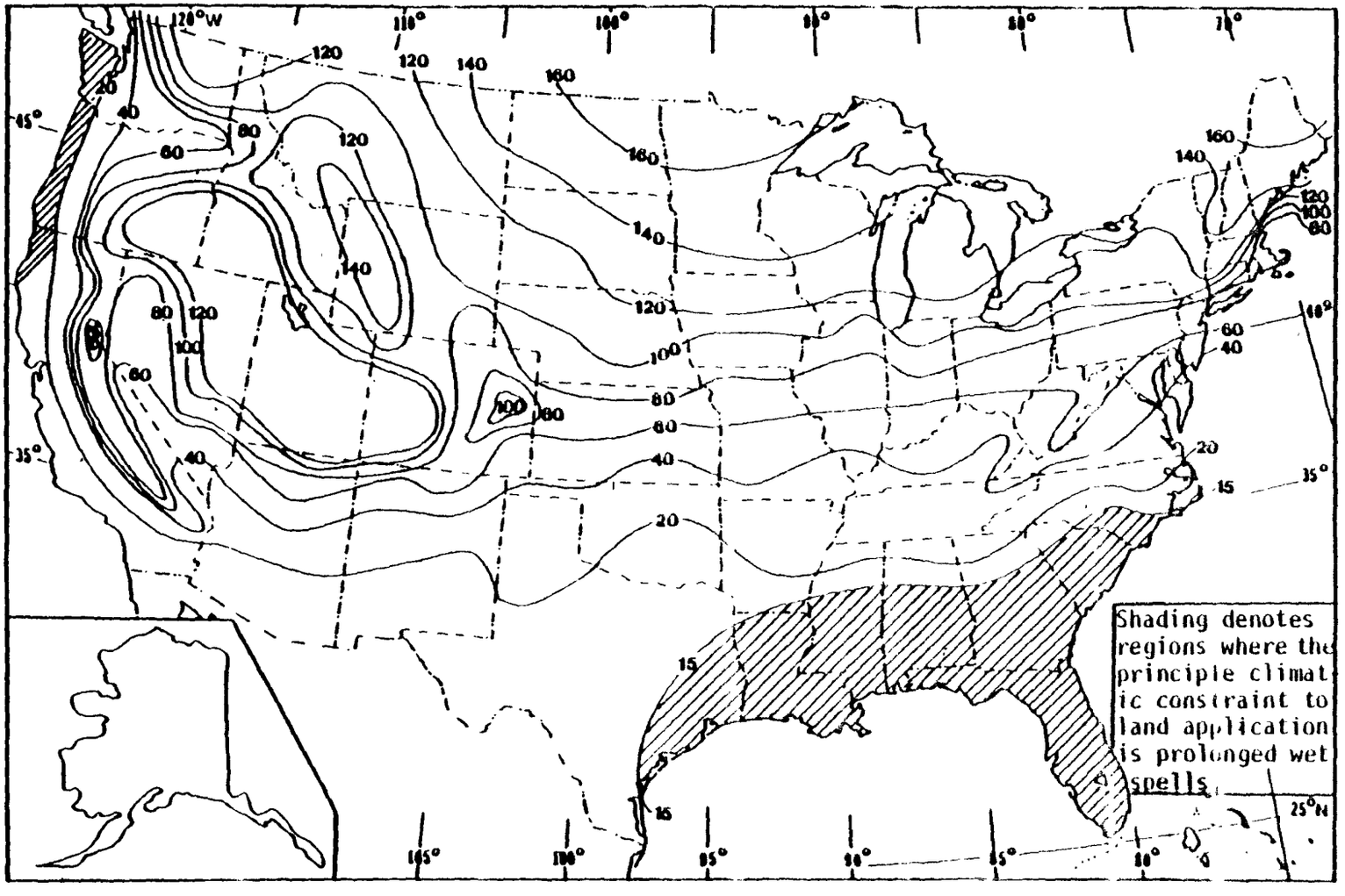

Figure 8.2.4. Estimated storage days based only on climatic factors.[4]

TABLE 3.2.8. SUMMARY OF LAND TREATMENT EXPERIENCES IN THE HYDROCARBON PROCESSING INDUSTRY (5,6).

Waste Applied:	Oily sludge including API separator sludge, DAF float, biosludge, and tank bottoms
Application Method:	surface spreading or subsurface injection (15-20 cm)
Application rates:	100 to 120 barrels/acre/application, with a maximum of 200 barrels under optimum conditions (e.g. climate, soil moisture, degradation)
Frequency of application:	monthly, up to a total of eight times per year
Percent oil in soil following application:	5 to 10, with a maximum of 20
Optimum soil moisure content:	15 to 20 percent
Run-off collection and handling:	analysis of collected runoff reveals high oil and grease content such that liquid must be treated prior to discharge or can be reapplied to treatment zone during dry periods

The amount of land area required for a site can be calculated as follows:

$$\text{Required treatment area (Ha)} = \frac{PR}{LR_{RLC}}$$

Where PR = waste production or handling rate (kg/yr); and

LR_{RLC} = waste loading rate based on the rate limiting constituent RLC (kg/ha/yr)

$$\text{Example: } \frac{1,056,000 \text{ (kg/yr)}}{26,400 \text{ (kg/ha/yr)}} = 40 \text{ ha}$$

If the required land area is greater than the area available for treatment, then the proposed facility cannot accommodate all of the waste that is produced or expected to be handled by the site.

The maximum number of annual applications is based on the rate limiting constituent (RLC) and the application limiting constituent (ALC), and is computed as follows:

$$\text{Annual number of applications} = \frac{LR_{RLC}}{AL} = \text{the smallest integer } _ \frac{LR}{AL}$$

Where LR_{RLC} = waste loading rate based on the RLC (kg/ha/yr); and

AL = application limit based on the ALC (kg/ha/application).

$$\text{Example: } \frac{26,400 \text{ (kg/ha/yr)}}{5,280 \text{ (kg/ha/app)}} = 5 \text{ applications per year}$$

Determination of facility life is based on accumulation of the capacity limiting constituent (CLC) and loading rate of the rate limiting constituent (RLC). Expected facility life can be calculated as follows:

$$\text{Facility life (years)} = \frac{LCAP_{CLC}}{LR_{RLC}}$$

where $LCAP_{CLC}$ = waste loading capacity beyond which the CLC will exceed allowable accumulations (kg/ha); and

LR = waste loading rate based on the RLC (kg/ha/yr).

$$\text{Example: } \frac{264,000 \text{ (kg/ha)}}{26,400 \text{ (kg/ha/yr)}} = 10 \text{ years}$$

If the RLC is also the CLC, then the facility life is 1 year. To increase facility life the applicant must increase the available land area proportionately.

It should be recognized that waste application methods and rates employed by facilities maintaining a vegetative cover during the unit's active life will differ considerably from land treatment units choosing not to establish a plant cover. Factors influencing the selection of the waste application method are:

- plant tolerance to physical disturbance,
- detrimental effect of waste applied on exposed vegetative matter, and
- impact on plant root system.

The decision to establish a plant cover (e.g., food-chain crops) may be based on two separate functions or a combination of both. Vegetative cover can serve to 1) protect the surface soil from erosion, or 2) cycle and treat the waste material applied to the treatment zone. Table 8.2.9 identifies the specific functions a vegetative cover can provide and alternative management techniques that can be instituted in cases when it would be inappropriate to maintain a vegetative cover. The HWLT manual has identified the following concerns which may preclude establishment of a vegetative cover:

(1) Maintaining concentrations of waste in soil which are not phytotoxic may limit the allowable waste application rates to levels far below the soil's capacity to treat the waste, thus underutilizing the treatment capacity of the site.

(2) Where wastes are applied by spray irrigation, hazardous constituents may adhere to vegetative surfaces.

(3) A crop cover may filter ultraviolet radiation which could have aided in the photochemical decomposition of certain compounds.

Many factors will affect the successful establishment of a vegetative cover. These factors are essentially the same as those to enhance of microbial activity (see Section 8.2.3.4). However, the principal concern with respect to growth in or on the treatment zone is phytotoxicity, primarily resulting from heavy metal accumulation. Table 8.2.10 provides a limited compilation of the normal range of trace element concentrations found in plant leaves and identifies levels that are toxic. The information presented or similar data obtained from other sources should be used together with a review of the type and rate of hazardous constituents to be land treated at the proposed site to identify potentially phytotoxic conditions.

Plant species selection will depend on existing and altered soil conditions, local climate, and intended function of vegetative cover. Plant species selected by the applicant should be evaluated with respect to growth potential and ease of maintenance. This is best accomplished by consulting regional agronomists from the State Agricultural Extension Service of the U.S. Department of Agriculture or the agronomy department of nearby college or universities.

TABLE 8.2.9. ALTERNATIVE MANAGEMENT TECHNIQUES TO REPLACE THE ROLE OF CROP COVER IN A LAND TREATMENT SYSTEM[a]

Plant function	Alternative management
Protective:	
Wind erosion	Maintain a moist soil surface.
	Wastes often provide the necessary stability when mixed with the soil.
Water erosion	Minimize slopes and use proper contouring to reduce water flow velocities.
	Some wastes, such as oily sludges, repel water and stabilize the soil against water effects.
	Design run-off catchments to account for increased sediment load.
	Run-off water may need some form of treatment before release into waterways.
Cycling:	
Transpiration	Dewater the waste.
	Control applications of wastewater to a lower level.
Removal	Plants have only a very minor role in this respect; for organics, manage for enhanced degradation; for inorganics, reduce loading rates.

[a]Adapted from HWLT manual(2).

TABLE 8.2.10. NORMAL RANGE AND TOXIC CONCENTRATION OF TRACE ELEMENTS IN PLANTS[a]

Concentrations of Elements in Plant Leaves (ppm Dry Weight)		
Element	Range	Toxic
As	0.01 - 1.0	>10
B	5 - 30	>75
Ba	10 - 100	--
Be	1 - 40	>40
Cd	0.2 - 0.8	5 - 700
Co	0.01 - 0.30	200
Cr	0.1 - 1.0	10 - 20
Cu	4 - 15	>20
F	2 - 20	20 - 1500
Fe	20 - 300	--
Hg	0.001 - 0.01	>10
I	0.1 - 0.5	>10
Li	0.2 - 1.0	50 - 700
Mn	15 - 150	500 - 2000
Mo	1 - 100	>1000
Ni	0.1 - 1.0	50 - 200
Pb	0.1 - 5.0	Low plant uptake
Se	0.02 - 2.0	50 - 100
V	0.1 - 10.0	>10
Zn	15 - 150	500

[a]Adopted from HWLT manual (2) (see Reference 2 for original citations).

8.2.3.3 Measures to Control Soil pH--

Soil pH is a controlling factor in determining the mobility and solubility of many hazardous constituents and plant nutrients and will influence soil microbial activity. The pH value expresses the degree of acidity or alkalinity of a soil. The Soil Conservation Service has classified soil pH values as follows:

Extremely acid	Below 4.5
Very strongly acid	4.5-5.0
Strongly acid	5.1-5.5
Medium acid	5.6-6.0
Slightly acid	6.1-6.5
Neutral	6.6-7.3
Mildly alkaline	7.4-7.8
Moderately alkaline	7.9-8.4
Strongly alkaline	8.5-9.0
Very strongly alkaline	9.1 and higher

A soil pH in the range of 6.0 to 8.0 is considered optimal for organic compound biodegradation and heavy metal precipitation with subsequent colloid adsorption (7-11). It is noted that certain hazardous constituents (e.g., selenium) are more available to plants in neutral pH soils than in acids soils. Consequently, the availability and mobility of hazardous constituents to be treated should be evaluated under various soil pH conditions prior to actual application. This determination should be made under the treatment demonstration. Management of soil pH consists of three components:

- Initial determination of antecedent soil
- Periodic monitoring
- Addition of soil amendments to maintain optimum pH range

Soil sampling and analysis should be performed periodically to monitor changes in soil pH and to predict the need for conditioning. Section 8 of the HWLT manual provides a discussion on the management of soil pH. The manual identifies three common methods for measuring soil pH. They are:

(1) Titration with base or equilibration with lime,

(2) Leaching with a buffered solution followed by analysis of the leachate for the amount of base consumed by reaction with the soil, and

(3) Subtracting the sum of exchangeable bases from the cation exchange capacity (CEC).

The EPA TRD (SW-846) Tests Methods for Evaluating Solid Waste-Physical/Chemical Methods[12] should also be reviewed to evaluate the applicant's sampling and analysis protocol.

The following discussion identifies methods of controlling soil pH. The most frequently encountered situation will be to reduce soil acidity.

Reduction of Soil Acidity

The most common method of raising the pH of an acidic soil to the neutral level is liming. Liming is a comprehensive term which includes the addition of oxides, hydroxides, or carbonates of calcium or magnesium. Lime application rates will vary depending on the kind of lime to be used. The relative effectiveness of the three forms in raising soil pH are roughly in the ratio 1 ton of representative finely ground limestone to 0.7 ton of commercial hydroxide to a little over 0.5 ton of representative oxide. It is important to note that initial applications will be the heaviest. Once the desired pH level has been achieved, periodic liming at reduced loadings will be required to maintain a neutral medium. The frequency of liming will increase in regions where water percolation is high such as in humid Eastern sections of the U.S. and in arid locations that will require frequent irrigation to control soil moisture content. In both of these environments calcium and magnesium are leached from the soil, increasing its acidity.

Although derived from agricultural experiences, Figure 8.2.5 provides a general guide to determine the amount of lime to apply to raise a soil pH to a desired value. The data presented are for the plow zone (15 to 23 cm). When the entire depth of the treatment zone, up to 1.5 meters, will be used to treat the wastes, the applicant must employ techniques that will ensure the maintenance of proper soil pH levels throughout the entire depth of the treatment zone. This will require the incorporation of lime at depths lower than the conventional plow zone. Techniques that may be used include surface liming with subsequent deep plowing to a depth greater than the conventional 23 cm plow depth or for small plots possibly excavating the top surface layer and applying a layer of lime well within the treatment zone itself. The U.S. Soil Conservation Service or the local agricultural extension service should be consulted for specific assistance in evaluating an applicant's soil pH management program.

Intensification of Soil Acidity

Although the need to intensify soil acidity will not occur often, there may be situations where it will be required. The reduction of soil pH or increase in acidity can be accomplished by:

1. addition of acid organic matter to the treatment zone soil,

2. addition of chemicals, or

3. application of acidic but compatible waste(s).

Note that records should be kept of all soil additions to ensure that the assimilative capacity of the soil will not be altered or diminished.

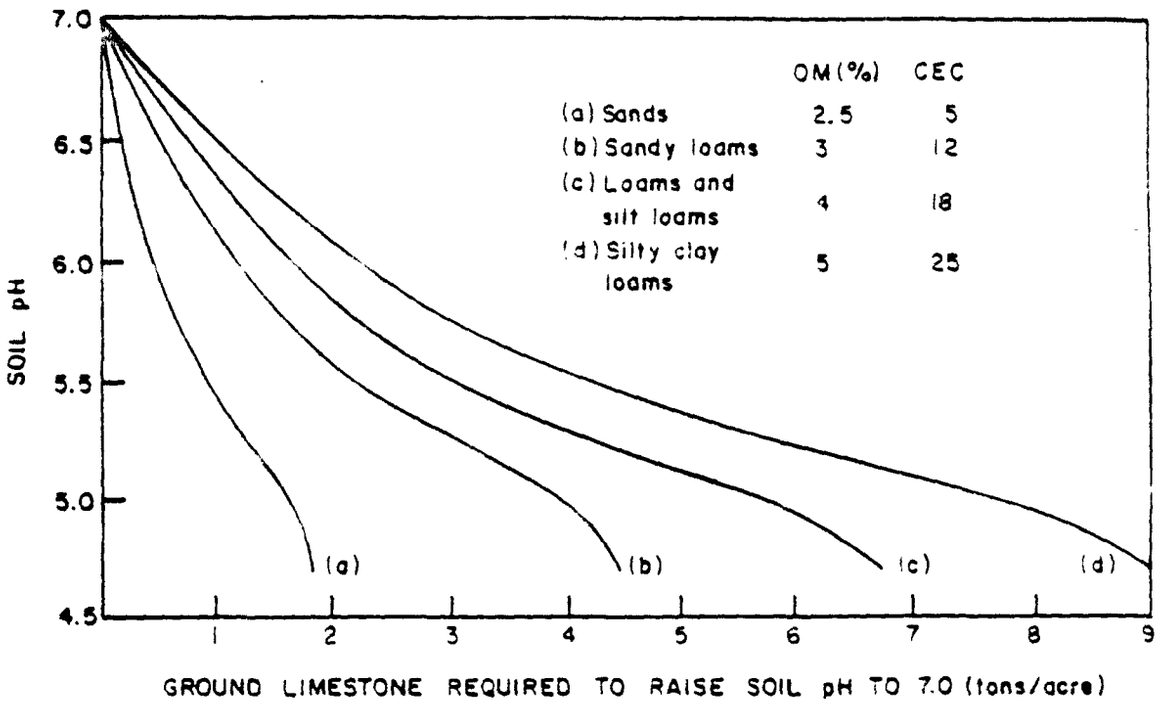

Figure 8.2.5. Relationship between soil texture and the amount of limestone required to raise the pH of New York soils to 7.0. Representative organic matter (OM) and cation exchange capacity (CEC) levels are shown. Note that pH refers to conventional plow zone soil (15 to 23 cm). [Adopted from Reference 7.]

Use of Acid Organic Matter

The decomposition of soil organic matter forms both organic and inorganic acids. The presence of organic acids, such as carbonic acid (H_2CO_3), causes the dissolution of limestone or calcium carbonate resulting in the removal of the bases by solution and leaching. Inorganic acids formed, such as H_2SO_4 and HNO_3, are sources of hydrogen ions which increase soil acidity. Sources of acidic organic matter are pine needles, tanbark, sawdust, and peat. Sewage sludge is another source of organic matter.

Use of Chemicals

When use of acid organic matter is not acceptable, chemicals such as ferrous sulfate, aluminum sulfate, or other salts may be used to lower soil pH. The salt is hydrolyzed in the soil to form a strong acid (e.g. sulfuric acid) which drastically lowers the pH. Another compound used to lower pH in agricultural environments is flowers of sulfur (a form of elemental sulfur). The sulfur compound is oxidized by soil microbes producing sulfuric acid. At equivalent concentrations, microbial oxidation of the flowers of sulfur is reportedly four or five times more effective in developing acidity than ferrous sulfate.[7]

No specific recommendation can be made as to amounts of ferrous sulfate or sulfur that should be applied because sources of soil pH are so variable. Brady[7] reports that for certain plant species, 0.45 to 0.90 kilograms (1 to 2 pounds) of sulfur per 9.3 square meters (100 square feet) is required to lower the pH 1/2 unit for a medium textured soil (e.g. loam, silt-loam, silt).

Use of Acidic Wastes

When compatible with other wastes being applied, incorporation of acidic wastes into the treatment zone can be an effective method of reducing soil pH. Table 8.2.11 identifies organic compounds that hydrolyze in the presence of water (e.g., soil water) to form strong acids. The safe use of acidic wastes for this purpose must be demonstrated prior to any application under normal operating conditions.

8.2.3.4 Measures to Enhance Microbial or Chemical Reactions--

Measures to enhance waste treatment include incorporating the waste in the soil, soil aeration, microbial innoculations, fertilizer applications, and establishment of a vegetative cover.

Waste/Soil Contact

Generally, as the surface area of waste particles increases and the amount of physical contact with the soil increases, biodegradation increases. For liquid waste applications proper soil/waste mixing can be accomplished by regularly scheduled tillage. In caes where solid or semisolid wastes will be applied to the treatment zone, material shredding or pulverization prior to application will maximize the contacting surface area.

TABLE 8.2.11. SOME ORGANICS THAT BECOME ACIDIC WHEN WET[13,14]

Acetyl chloride - FL[a]	Dichlorodifluoromethane
Acetylene tetrachloride	Diethyl ether - CL
Allyl chloride - FL	Dimethyl sulfate - CM
Ammonium citrate	Dinitrochlorobenzene - Poison B
Ammonium oxalate	Ethyl chloride - FL
Amyl chloride - FL	Ethylene dichloride - FL
Amyl propionate	Ethyl mercaptan - FL
Benzaldehyde - CL	Hexachlorobutadiene
Benzotrichloride	Hexachloroethane
Benzene hexachloride	Hexaethyl tetraphosphate - Poison B
Benzene sulfonic acid	Lead acetate
Benzyl chloride - CM	Methylene chloride
Butyl chloride - FL	Nitrophenols
Carbon tetrachloride	Potassium oxalate
Chloroform	n-Propyl nitrate
Chlorophenol	Trimethyl phosphite
Chlorosulfonic acid - CM	Vinyl chloride - FG
Citric acid	

[a]Department of Transportation Hazardous Material classification:
FL - Flammable liquid
CL - Combustible liquid
CM - Corrosive material
FG - Flammable gas

The treatment zone surface should be cultivated by disking, plowing, or rototilling just prior to and subsequent to waste application. As one example, experience in land treating oil refinery production wastes has shown that six cultivations are required to adequately blend the waste and soil between applications.[5,6]

Soil Aeration

The presence of adequate free oxygen in the soil is essential to maintain biodegradation and drive chemical reactions. Soil conditioning involving creation of good drainage, periodic cultivation, and proper waste loadings will promote aerobic soil conditions. It should be noted that under certain conditions, some wastes, particularly nitrogenous wastes, will be degraded only under anaerobic conditions. Therefore, conditions that are most conductive to waste degradation or transformation should be established and maintained.

Microbial Innoculations

Although not always necessary, biodegradation may be improved by innoculating the treatment zone with soil microbes. This involves amending the soil with cultured soil microorganisms indigenous to the region.

Soil Fertility

Inorganic nutrients must be available in sufficient quantities to sustain microbial populations. The amounts required are dependent on the levels and availability of nutrients in the waste, biodegradation rates, waste application rates, and persistence of added fertilizer in the treatment zone. The availability of nutrients from a waste applied to the treatment zone, as an example, nitrogen in certain cases, is expected to be low. Consequently, nitrogen or some other nutrient deficiency may occur as a result of the waste application. The addition of a fertilizer to the waste-treated soil will be required to increase microbial activity.

Vegetation

Establishment of a vegetative cover crop can serve to cycle and treat certain hazardous constituents. Treatment functions performed by plants may include translocation of substances from the soil to vegetative matter and transformations within the plant. It should be noted that unless the plants are harvested or substance transformation performed by the plant results in a nonhazardous compound, the hazardous constituent taken up by the plant will be returned to the soil following death and decay. Under these conditions, treatment is only in the form of temporary storage. Area agronomists from the State Agricultural Extension Service of the U.S. Department of Agriculture or the agronomy department of nearby universities should be consulted to obtain information on local cultivation practices that will be necessary to properly evaluate the permit application.

When a vegetative cover is established, the owner or operator should address the impact of growing crops during the active years of the treatment unit. Factors to be evaluated include nutrient depletion, water balance impact, and effect of increased soil organic matter (i.e., root system and stubble).

The mechanisms associated with chemical degradation, transformation, and immobilization are complex and multifaceted. They cannot be adequately summarized for inclusion in this document. However, soil conditioning to improve microbial activity generally will also enhance soil chemical reactions. Explanations of the chemical reactions occurring in soils and environmental factors that affect them are provided in references 2, 7, and 8.

8.2.3.5 Measures to Control Soil Moisture in the Treatment Zone--

Section 8 of the HWLT manual presents a detailed discussion of water control and management at hazardous waste land treatment facilities. In addition, sample water balance calculations are provided in Appendix E of the manual. Given that this information is well explained in the HWLT manual, it is not repeated here.

The primary purpose for preparing a water balance is to determine whether moisture control problems will occur at the site. The principal factor of concern is saturation of the treatment zone soil. Under saturated conditions, aerobic waste degradation will decrease, if not be halted, and the likelihood for hazardous constituent leaching will increase. Even if a soil is normally well drained, soil saturation can occur if the rate of water supply to the soil surface is sufficiently rapid. Saturation of the soil results in poor aeration. Techniques to prevent this condition from occurring include removal of excess water by either land drainage or controlled run-off. In order to determine what measures must be taken, if any, to prevent prolonged soil saturation, a site specific water balance should be conducted. Variables to be evaluated by the applicant and assessed in the permit application submitted are local precipitation and evapotranspiration rates, surface run-off, percolation rates, irrigation needs, and storage requirements. Results obtained from the water balance calculation will determine site design criteria such as the installation of a subsurface drainage system or a controlled surface run-off network.

A secondary concern, which is more prevalent in arid regions of the country, is low soil moisture due to water losses. Soil moisture losses result from evaporation, transpiration from plant surfaces, surface run-off, and percolation. Evaporation and transpiration are vapor losses, whereas surface run-off and percolation are liquid losses. Environmental factors affecting vapor losses are temperature and wind. Temperature cannot be controlled but wind effects can be minimized using shelter belts and windbreaks.

Liquid losses can be reduced by minimizing surface run-off and increasing the water holding capacity of the soil. Run-off control is discussed in Section 8.3.3.1. The water holding capacity of soils can be increased by amending the soil with organic matter and clays.

Measurement of Soil Moisture

Soil moisture content can be measured directly or indirectly. Indirect techniques involve collecting a soil sample in an air tight container and transferring it to a laboratory where the sample is oven dried. The weight loss by heating represents the moisture content of the soil sample taken in the field and is expressed as a percentage of the oven dry weight of the soil. This gravimetric technique is one of the most common methods used to determine soil moisture content on a weight percentage basis.[7]

Direct techniques measure the moisture content of the soil in the field. Two methods for measuring soil moisture directly are electrical resistance and neutron scattering. These methods are described in The Nature and Properties of Soils.[7] These techniques allow the operator to leave sampling devices in the soil for extended periods of time. This reduces the time required to determine soil moisture content considerably. These techniques are not as accurate as the gravimetric method, but they will provide the necessary information on a relative basis.

8.2.3.6 Unsaturated Zone Monitoring--

The purpose of unsaturated zone monitoring is to provide prompt feed back on the success of treatment in the treatment zone. Feedback information should be used to adjust the unit operating conditions to maximize hazardous constituents degradation, transformation, and immobilization. With respect to Part 264 requirements, the unsaturated zone refers to the layer of soil or parent material separating the bottom of the treatment zone and the seasonal high water table or ground water table. This soil layer is usually found to have a moisture content of less than saturation.

To avoid confusion, it is important to note that unsaturated zone monitoring and ground water monitoring are both required at a land treatment facility. The distinction between the two is that ground water monitoring is designed to determine the effect of hazardous waste leachate on the ground water, whereby unsaturated zone monitoring is performed to provide an indication of whether hazardous constituents are migrating out of the treatment zone.

Identification of hazardous constituents to be monitored should be based on the results of the comprehensive waste analysis performed in accordance with §264.13. Recommended analytical methods that can be used to verify analyses performed by the applicant are presented in Test Methods for Evaluating Solid Waste.[12]

Hazardous constituents to be monitored include those contained in the waste and those derived following waste application. Identification of hazardous constituents that may be derived from the waste following soil incorporation should have been performed as part of the treatment demonstration. Analysis of leachate and soil collected from soil column tests performed in the laboratory or field tests using a lysimeter or other similar device should have been conducted to determine whether hazardous constituents will be derived from the waste(s) to be land treated.

It is noted that a provision of the regulation states that upon approval following sufficient documentation, principal hazardous constituents (PHC), which are hazardous constituents contained in or derived from the wastes to be applied that are the most difficult to degrade, transform, or immobilize, may be designated (as indicators) for unsaturated zone monitoring purposes in lieu of monitoring for all hazardous constituents contained in or derived from the waste. A methodology for determining PHCs is provided in U.S. EPA's RCRA Guidance Document for Land Treatment.[15] At a minimum, a PHC must be one of the most mobile and/or most concentrated and persistent constituents in the treatment zone. Meeting these criteria will assure that the constituents provide a reliable indication of the success of treatment or conversely forewarning of incomplete or ineffective treatment.

The applicant must provide a description of how the soil and soil-pore liquid below the treatment zone will be monitored to determine whether hazardous constituents migrate from the treatment unit. The description provided in the application should include the following:

- constituents to be monitored,
- installation of monitoring system (equipment and locations),
- determination of background levels,
- implementation of monitoring programs,
  - frequency
  - sampling procedures
  - analytical techniques
- determination of significant migration from treatment zone,
- notification of any significant migration,
  - due to facility operation
  - due to other source(s).

Figure 8.2.6 presents a worksheet that can be used to help the permit writer evaluate the applicant's description of the unsaturated zone monitoring program.

A fundamental concept of a land treatment facility is that it is a dynamic system. Several parameters must be monitored periodically to ensure optimization of hazardous constituent degradation, transformation, and immobilization. Operation of the treatment unit will be modified over time as monitoring data indicate the need for adjustments.

The applicant must document conditions existing (background) prior to the application of waste to the treatment zone. Collection of the background data provides a bench mark for comparison with subsequent monitoring results. For existing facilities, background levels can be determined by monitoring background or control plots operated near the treatment units. To the extent

UNSATURATED ZONE MONITORING

Has the applicant identified, schematically, soil-pore liquid and soil core sampling locations and depths?	Yes	No
Has the applicant provided a rationale and statistical assessment for sampling locations?	Yes	No
Are sampling frequencies, taking into consideration site operating conditions and climatic factors, stated?	Yes	No
Has the applicant described the equipment to be used to take soil-pore liquid and soil core samples?	Yes	No
Are the procedures for installing soil-pore liquid monitoring devices described?	Yes	No
Has the applicant described how soil samples will be taken, including sample collection, preparation, preservation, and transport?	Yes	No
Are analytical procedures specified?	Yes	No
Are the chain-of-custody procedures specified?	Yes	No
Has the applicant described how soil core and soil-pore liquid background values will be determined?	Yes	No
Are statistical methods to be used to determine whether significant increases in hazardous constituent concentrations occur described?	Yes	No
Has the applicant identified the time period following sampling to determine whether a significant increase in constituent concentration has occurred?	Yes	No
Has the applicant identified the hazardous constituents to be monitored?	Yes	No
If the applicant has elected to monitor only principal hazardous constituents (PHCs), has he or she provided a satisfactory explanation for doing so?	Yes	No

Figure 8.2.6. Worksheet for evaluating applicant's unsaturated zone monitoring plan.

possible, the soils of the control plots monitored should be similar to those of the unsaturated layer immediately below the subject treatment zone. In addition, samples obtained to determine background levels and unsaturated zone concentrations should be taken at similar soil depths.

For new facilities, background levels can be determined by sampling the unsaturated zone prior to any waste application. Unsaturated zone monitoring involves taking and analyzing soil-core and soil-pore liquid samples for the presence of hazardous constituents contained in or derived from the waste applied. These two samples are taken to complement one another. Analysis of soil-core samples will provide information on the movement of slow migrating constituents while soil-pore liquid results will provide complementary data on the movement of the more mobile hazardous constituents.

Soil core and soil-pore liquid sampling should be random within a given uniform area. A uniform area generally refers to an area of the active portion of a land treatment unit that is composed of soils of a similar soil series (including similar "A" horizons) and to which similar wastes or waste mixtures are applied at similar rates.

The HWLT manual (Section 9) and RCRA Guidance Document for Land Treatment[15] provide informative discussions on unsaturated zone monitoring. Table 8.2.12 presents a matrix indentifying recommended soil core and soil-pore liquid sample locations, frequencies, depths, and numbers. The concepts of sample compositing and uniform area sampling are proposed by EPA as an attempt to minimize sampling and analytical costs and to assure statistically reliable results.

The frequency of soil core and soil-pore liquid sampling should be based on waste application rates and frequency, soil permeability, and amount and frequency of precipitation. Sample preservation and shipment, and hazardous constituent (or Principal Hazardous Constituents, PHCs) analysis should be performed in accordance with the procedures included in Test Methods for Evaluating Solid Waste.[12] For each soil series or uniform area, as applicable, an arithmetic mean and variance for each hazardous constituent (or PHC) should be determined by pooling all composite measurements.

As previously stated, one of the purposes for monitoring the unsaturated layer beneath the treatment zone is to be able to detect pollution migration. Hazardous constituent migration out of the treatment zone may result from improper design or operating practices that can be altered to impede or halt additional or continued pollutant movement. Table 8.2.13 presents, as examples, a couple of different scenarios where constituent increases were recorded and what possible adjustments can be made. Section 9 of the HWLT manual identifies the following modifications to unit operations that should be considered to maximize treatment within the treatment zone:

1. alter the waste characteristics;

2. reduce waste application rate;

3. alter the method or timing of waste applications;

TABLE 8.2.12. SUGGESTED UNSATURATED ZONE MONITORING SAMPLING SCHEME (2,15).

	Number of samples[a] (for each soil series)[b]	Location	Depth	Frequency	Compositing
Soil Core Sample					
Background:[c]	8	Immediately Below treatment zone	30 cm below treatment zone lower boundary	One time	Randomly composite two samples to form one composite sample, since eight core samples per soil series were taken, a total of four composite samples will be formed for analysis
Active Portion	6 (per uniform area)[d]	Immediately Below treatment zone	30 cm below treatment zone lower boundary	Quarterly	For each uniform area composite two samples to form three composite samples for analysis, if uniform area is greater than 5 hectares, a minimum of one composite sample per 1.5 hectares should be formed
Soil Pore Liquid Sample					
Background:[e]	two sampling points[e] per soil series	Immediately Below treatment zone	30 cm below treatment zone lower boundary	Quarterly for one year[f]	Composite the two quarterly samples taken from each device (e.g. lysimeter) to form one composite for analysis each quarter
Active Portion.	Six sampling points[e] per uniform area[d] (randomly located)	Immediately Below treatment zone	30 cm below treatment zone lower boundary	Quarterly[g] (or less depending on frequency of application)	Composite samples from each uniform area in pairs to form three samples for analysis. If a uniform area is greater than 5 hectares, a minimum of one composite per 1.5 hectares should be formed

[a]Randomly selected.

[b]It is important not to composite samples taken from different soil series

[c]Sample taken from soil where waste has not been applied.

[d]If a uniform area is greater than 5 hectares (12 acres) at least two randomly selected samples per 1.5 hectares (4 acres) should be taken semi annually.

[e]Each sample is taken using a liquid monitoring device installed in soil.

[f]If liquid is not present at regularly scheduled sampling time, a sample should be collected as soon as liquid is present.

[g]If liquid is not present at a regularly scheduled sampling event, the monitoring device should be checked within 24 hours of each following significant waste application or rainfall event, and a sample drawn when sufficient liquid is present.

TABLE 8.2.13. EXAMPLES OF POSSIBLE RESPONSES TO THE DETECTION OF HAZARDOUS CONSTITUENT MIGRATION (2)

Detected Constituent Increase	Possible Adjustments		
	Operating Practices	Soil Amendments	Treatment Mechanism to be Adjusted
Organic Compounds			
Readily Degraded	Postpone next application, increase tillage	Adjust soil pH, fertilize, irrigate	Degradation
Persistent	Postpone next application	Adjust soil pH, add organic matter	Degradation/ immobilization
Inorganic Compounds			
Salts	Postpone next application	Irrigate	Transformation/ immobilization
Metals	Postpone next application, postpone irrigation	Adjust soil pH, add organic matter to increase Cation Exchange Capacity (CEC)	Immobilization

4. cease application of one or more particular waste(s) at the unit;

5. revise cultivation or management practices; and/or

6. alter the characteristics of the treatment zone, particularly soil pH or organic matter content.

It is recommended that responses to detection of pollutant movement below the treatment zone be discussed during preapplication conferences.

8.2.3.7 Treatment Zone Description--

The treatment zone refers to a defined layer of surface and subsurface soils used to degrade, transform, or immobilize hazardous constituents contained in or derived from the waste applied or the leachate passing through the zone.

Although the original treatment zone design will be made by the owner or operator, the reviewing authority will specify the vertical and horizontal dimensions of the treatment zone in the facility permit. The depth of the treatment zone must be:

- No more than 1.5 meters (5 feet) from the initial soil surface, and
- More than 1 meter (3 feet) above the seasonal high water table.

Data sources available to evaluate whether these conditions are met are identified below.

Soils	• United States Department of Agriculture (USDA), Soil Conservation Service (SCS), Local Extension Service • United States Geological Survey (USGS) reports • Geology or Agriculture department of local university or college
Bedrock	• USGS reports • State Geological Survey reports • Professional geologists in the area • Geology department of local university or college
Ground water	• USGS water supply papers • State or regional water quality agencies • USDA, SCS • State or Federal water resources agencies • Local health department

Section 8.2.2.7 identified specific items that the applicant should include in the permit application. Sections 3 and 4 of the HWLT manual provide explanation of each item and, in some cases, typical ranges of values. Soil survey (Part 1) and series description (Part 2) information (see

Section 8.2.2.7) to be included in the application may be obtained from USDA Soil Conservation Service County Soil Surveys. For soils that have not been surveyed, the permit writer should contact a soil scientist of the regional Soil Conservation Service office to obtain assistance in evaluating information submitted by the applicant. The following provides an explanation of the treatment zone soil characteristics (Part 2) to be included in the applicant's description of the treatment zone. Table 8.2.14 presents, as an example, relevant soil characteristics of five soils found in Connecticut. The information provided in the table is presented as it typically appears in SCS County Soil Survey reports.

Profile Description

Horizonation--Horizonation refers to the sequence of soil layers of the soil profile. Soils are characterized by the sequence and composition of their soil horizons. Specific properties that need to be described include depth of each horizon and changes in textural properties. In general, soils have horizons of contrasting properties within the upper 1.5 to 1.8 meters (5 or 6 feet). The application should include a description of the depth to the upper and lower boundaries of each horizon and note changes in textural properties. Textural properties of each horizon should be evaluated for their suitability as the treatment medium (see Table 8.1.14 of Section 8.1.3).

Relief

The slope gradient, aspect, and elevation of each treatment plot should be submitted in the application. These characteristics influence surface drainage of the unit.

Climatic Data

Monthly temperature and precipitation data should be submitted with the permit application. These are the two most important climatic factors affecting the treatment zone soil. Ambient air temperature will influence the extent and rate of hazardous constituent degradation, plants growing season, and extent of frost action. Precipitation will affect aerobic soil conditions, the rate soluble chemicals are leached from the soil, and the amount of surface water run-on and run-off. Tables 8.2.15, 8.2.16, and 8.2.17 provide examples of temperature and precipitation data supplied by the SCS Soil Survey reports. This information should be used to help determine application methods and frequencies, plant species selection, and design site run-on and run-off control systems.

Mineralogy

Soil mineralogy is closely aligned with soil texture. Figure 8.2.7, adopted from Brady,[7] presents the general relationship between particle size and kinds of minerals present. Quartz dominates the sand and coarse silt fractions. Primary silicates such as the feldspars, hornblende, and micas are present in the sands but tend to disappear as one moves to the silt fraction.

TABLE 8.2.14. EXAMPLE OF SOIL CHARACTERISTICS TO BE INCLUDED IN APPLICANT'S TREATMENT ZONE DESCRIPTION

Soil name	Horizon depth	USDA texture	Liquid limit	Plasticity index	Permeability	Available water capacity	Soil reaction	Shrink swell potential	Erosion factors		Flooding			High water table			Bedrock	Potential frost action
									K	T	Frequency	Duration	Months	Depth	Kind	Months	Depth	
	In		Pct		In/hr	In/in	pH							Ft			In	
Cheshire	0-8	Very stony silt loam.	25	NP-5	0.6-6.0	0.11-0.28	4.5-6.0	Low	0.20	3	None	-	--	6.0	----	- -	60	Moderate
	8-26	Fine sandy loam, loam, silt loam.	25	NP-3	0.6-6.0	0.08-0.24	4.5-6.0	Low	0.43	-								
	26-60	Fine sandy loam, gravelly fine sandy loam, gravelly sandy loam.	---	NP	0.6-6.0	0.05-0.15	4.5-6.0	Low	0.43	-								
Mulyuke	0-4	Silt loam.	25	NP-5	0.6-2.0	0.12-0.22	3.6-6.0	Low	0.24	2	None	-	--	0.0	----	---	10-20	Moderate
	4-13	Silt loam, loam, gravelly fine sandy loam.	25	NP-3	0.6-2.0	0.11-0.22	3.6-6.0	Low	0.43	-								
	13	Unweathered bedrock.	---	--	---	---	---	---	----	-								
Ellington	0-6	Fine sandy loam.	35	NP-7	0.6-2.0	0.15-0.22	4.5-6.0	Low	0.24	3	None	-	--	1.5-3.5	Apparent	Nov-Apr	60	High
	6-29	Silt loam, loam, fine sandy loam.	25	NP-5	0.6-2.0	0.13-0.22	4.5-6.0	Low	0.64	-								
	29-60	Gravelly sand, very gravelly sand, loamy sand.	---	NP	6.0	0.01-0.06	4.5-6.0	Low	0.17	-								
Hartford	0-9	Sandy loam.	25	NP-3	2.0-6.0	0.08-0.25	4.5-6.0	Low	0.17	3	None	--	--	6.0	----	---	60	Low
	9-24	Silt loam, loamy sand, gravelly sandy loam.	---	NP	2.0-6.0	0.07-0.17	4.5-6.0	Low	0.28	-								
	24-60	Gravelly sand, very gravelly sand.	---	NP	6.0	0.01-0.06	4.5-6.0	Low	0.17	-								
Hinckley	0-8	Gravelly sandy loam.	---	NP	6.0-20	0.03-0.23	3.6-6.0	Low	0.17	3	None	-	--	6.0	--	---	60	Low
	8-20	Gravelly loamy sand, loamy fine sand, gravelly loamy coarse sand.	---	NP	6.0-20	0.01-0.11	3.6-6.0	Low	0.17	-								
	20-60	Stratified gravelly loamy fine sand to very cobbly coarse sand	---	NP	20	0.01-0.06	3.6-6.0	Low	0.15	-								

Source: Soil Survey of Middlesex County Connecticut, U.S D.A., Soil Conservation Service, 1979.

TABLE 8.2.15. TEMPERATURE AND PRECIPITATION DATA[a]

Month	Temperature[b]						Precipitation[b]				
	Average daily maximum	Average daily minimum	Average daily	2 years in 10 will have-- Maximum temperature higher than--	2 years in 10 will have-- Minimum temperature lower than--	Average number of growing degree days[c]	Average	2 years in 10 will have-- Less than--	2 years in 10 will have-- More than--	Average number of days with 0.10 inch or more	Average snowfall
	°F	°F	°F	°F	°F	Units	In	In	In		In
January	35.2	19.9	27.6	57	-5	15	3.26	1.67	4.55	6	9.9
February	37.6	21.7	29.7	57	-5	18	3.66	2.49	4.73	6	10.6
March	45.1	28.8	37.0	68	9	56	4.36	2.83	5.74	7	9.5
April	58.5	38.5	48.5	81	22	269	4.35	2.53	5.64	8	1.2
May	68.8	47.4	58.1	88	32	561	3.93	2.93	5.37	8	.0
June	78.1	57.1	67.6	94	40	828	3.62	1.76	5.14	7	.0
July	82.6	62.6	72.6	95	48	1,001	3.66	2.17	4.99	6	.0
August	80.2	61.2	70.7	92	44	952	4.02	2.09	5.60	6	.0
September	72.8	54.0	63.4	90	32	702	4.29	2.39	5.84	6	.0
October	62.9	44.4	53.7	81	25	425	3.82	1.61	5.60	5	.1
November	51.1	35.2	43.2	68	16	129	4.74	3.07	6.24	8	1.5
December	39.2	24.7	32.0	61	2	2	4.78	2.66	6.51	8	7.4
YEAR	59.3	41.3	50.3	96	-8	5,006	48.49	42.23	54.56	81	40.2

[a]Source: Soil Survey of Middlesex County Connecticut, U.S.D.A., Soil Conservation Service, 1979.

[b]Recorded in the period 1951-73 at Middletown, CT.

[c]A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minimum daily temperature, dividing the sum by 2, and subtracting the temperature below which growth is minimal for the principal crops in the area (40°F in this case).

TABLE 8.2.16. FREEZE DATES IN SPRING AND FALL[a]

Probability	Temperature[b] 24°F or lower	28°F or lower	32°F or lower
Last freezing temperature in spring:			
1 year in 10 later than--	April 8	April 19	May 12
2 years in 10 later than--	April 4	April 15	May 5
5 years in 10 later than--	March 28	April 6	April 22
First freezing temperature in fall:			
1 year in 10 earlier than--	October 31	October 10	September 27
2 years in 10 earlier than--	November 6	October 16	October 3
5 years in 10 earlier than--	November 17	October 28	October 15

[a]Source: Soil Survey of Middlesex County Connecticut, U.S.D.A., Soil Conservation Service, 1979.

[b]Recorded in the period 1951-73 at Middletown, CT.

TABLE 8.2.17. GROWING SEASON LENGTH[a]

Probability	Daily minimum temperature during growing season[b]		
	Higher than 24°F	Higher than 28°F	Higher than 32°F
	Days	Days	Days
9 years in 10	212	183	147
8 years in 10	219	190	156
5 years in 10	233	204	174
2 years in 10	247	218	192
1 year in 10	255	225	202

[a]Source: Soil Survey of Middlesex County Connecticut, U.S.D.A., Soil Conservation Service, 1979.

[b]Recorded in the period 1951-73 at Middletown, CT.

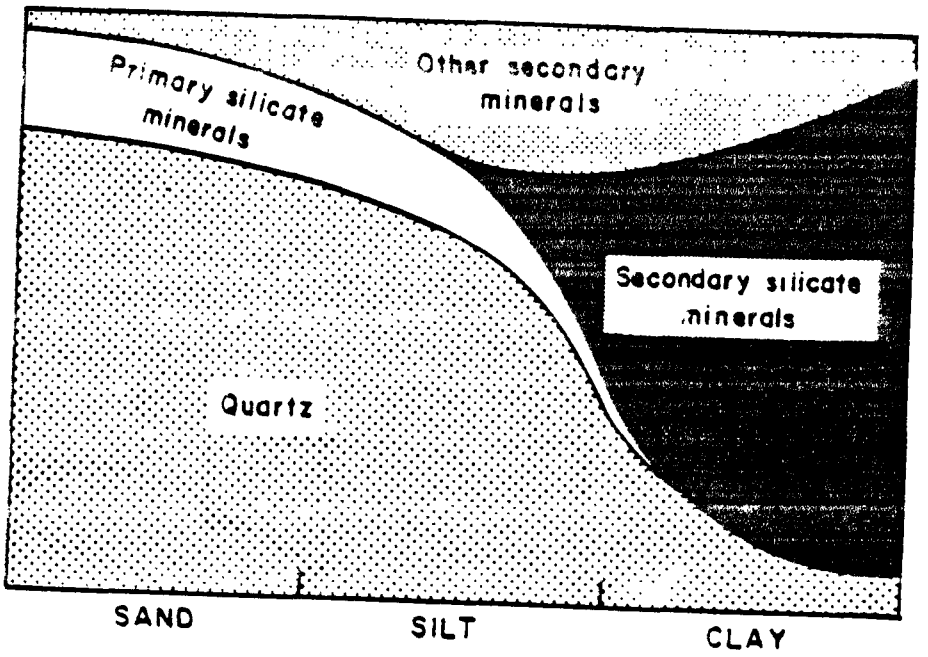

Figure 8.2.7. General relationship between soil particle size and minerals content.

Secondary silicates dominate the fine colloidal clay. Other secondary minerals, such as the oxides of iron and aluminum, are prominent in the fine silt and coarse clay fractions.

Land Use and Vegetation--Soil Surveys describe soils with respect to land use and suitability for crop cultivation. The more important factor of the two to evaluate is the suitability of soils to support vegetation. In addition to existing Soil Survey reports, local offices of the Soil Conservation Service and the Cooperative Extension Service can be contacted to provide information about vegetative management concerns, growing season length, and productivity of the soils under review.

Soil Texture

Soil texture refers to the percentages of sand, silt, and clay in the soil material that are less than 2 millimeters in diameter. If a soil contains gravel or other particles coarser than sand, a modifier, for example gravelly loam, is added. Table 8.2.18 lists USDA soil texture classifications. Soil texture can be determined by laboratory means or simply by touch for the experienced soil scientist. Guidance for determining the suitability of various soil textures as the treatment medium is presented in Table 8.1.14 (see Section 8.1.3).

Atterburg Limits

Atterburg limits refer to the effect of water on soil strength and consistency. Three states of consistency are defined based on the water content of the soil. The term consistency refers to the degree of firmness (e.g., soft, medium, firm). The three states are the shrinkage limit, plastic limit, and liquid limit. These three limits correspond to the transition points that occur when the water content of the soil increases such that the soil passes from a solid state to a semisolid state, to a plastic state, and finally to a liquid state. Figure 8.2.8 graphically displays the Atterburg limits. Atterburg limits are determined in the laboratory using standard test methods, such as ASTM D-423, D-424, and D-427 for the liquid, plastic, and shrinkage limits, respectively.

Permeability

Permeability refers to the rate at which a liquid penetrates or passes through a bulk mass or layer of soil. Permeability should be determined to provide an indication of the length of time mobile constituents applied to the treatment zone will reside in the soil. The treatment zone soil should be permeable enough to minimize surface run-off but not so permeable that the waste constituents percolate through the soil before adequate treatment. Table 8.1.14 (see Section 8.1.3) describes the suitability of various textured soils for land treatment of hazardous industrial wastes. The information presented should only be used as a preliminary step to determine waste application suitability. A more detailed analysis of soil permeability of the proposed unit is recommended. EPA's RCRA Land Treatment Guidance Document[15] suggests that the treatment zone contain soils having one or more of the following textures (USDA classification scheme): loam, silt loam, sandy clay

TABLE 8.2.18. UNITED STATES DEPARTMENT OF AGRICULATURE (USDA) SOIL TEXTURES

1.	Gravel, very gravelly loamy sand
2.	Sand, coarse sand, fine sand
3.	Loamy gravel, very gravelly sandy loam, very gravelly loam
4.	Loamy sand, gravelly loamy sand, very fine sand
5.	Gravelly loam, gravelly sandy clay loam
6.	Sandy loam, fine sandy loam, loamy very fine sand, gravelly sandy loam
7.	Silt loam, very fine sandy clay loam
8.	Loam, sandy clay loam
9.	Silty clay loam, clay loam
10.	Sandy clay, gravelly clay loam, gravelly clay
11.	Very gravelly clay loam, very gravelly sandy clay loam, very gravelly silty clay loam, very gravelly silty clay and clay
12.	Silty clay, clay
13.	Muck and peat

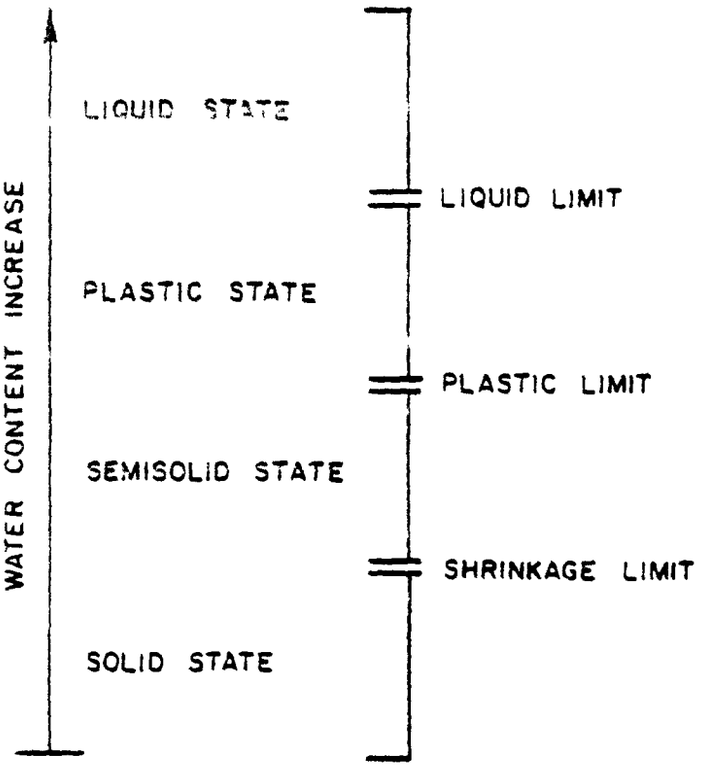

Figure 8.2.8. Atterberg limits. (16)

loam, sandy loam, silty clay loam, or clay loam. Three soil textural classes into or onto which hazardous waste(s) should not be applied are sands, clays, and silts. Sandy soils have rapid infiltration and percolation potentials that could easily lead to ground water contamination. Conversely, clay soils have extremely slow infiltration rates. This condition would increase the likelihood of surface water contamination due to water and wind erosion. Silty soils, which upon drying have a severe surface crusting problem, would have similar surface erosion concerns.

Because wide variations in permeability are common even in a small area, several soil samples and infiltration and permeability tests should be conducted to characterize the treatment zone. Section 4.1.1.5 of the HWLT manual describes methods for determining soil permeability. Note that permeability should be determined for each soil horizon.

Available Water Capacity

This is a characteristic of the soil relating to its ability to hold water and make it available to plants. Available water holding capacity is a measure of the amount of water held in the soil against the pull of gravity. Section 3.4.3 of the HWLT manual describes differences in water holding capacities and their impact on the function of the treatment zone. In general, the higher the water holding capacity, the lower the likelihood of constituent leaching.

Soil pH

Soil pH, which is the degree of acidity or alkalinity of a soil, has been discussed in Section 8.2.2.3. Table 8.2.19 presents a general guide for interpreting soil pH test results as they pertain to the viability of soil microbes and plants.

Salinity

Salinity generally refers to the electrical conductivity (EC) of a soil. It is a measure of a soil solution salt content. Section 4.1.2.6 of the HWLT manual discusses the importance of determining soil salinity and describes test methods. Table 8.2.19 provides guidance on interpreting EC results as they relate to establishing a vegetative cover during the active years or at closure.

Shrink-Swell Potential

This soil characteristic is influenced by the amount and kind of clay in the soil. Soils with a high shrink-swell potential can increase constituent leaching due to the formation of deep cracks in the soil during extended periods of dry weather. Obviously, soils with low shrink-swell potentials are preferred for hazardous waste land treatment. The measurement of shrink-swell potential can be made in the laboratory using undisturbed bulk samples or estimated by soil scientists based on the kind and amount of clay in the soil and extrapolation of tests performed on similar soils.

TABLE 8.2.19. INTERPRETATION OF SOIL CHEMICAL TESTS[17]

Test Result	Interpretation
pH of saturated soil paste	
<4.2	Too acid for most soil microbes and plants to do well
4.2-5.5	Suitable for acid-tolerant soil microbes and plants
5.5-8.4	Suitable for most soil microbes and plants
>8.4	Too alkaline for most soil microbes and plants, indicates a possible sodium problem
Cation Exchange Capacity (CEC), meq/100 g	
1-10	Sandy soils (limited adsorption)
12-20	Silt loam (moderate adsorption)
>20	Clay and organic soils (high adsorption)
Electrical Conductivity (EC), mmhos/cm at 25°C of saturation extract	
2	No salinity problems
2-4	Restricts growth of very salt-sensitive crops
4-8	Restricts growth of many crops
8-16	Restricts growth of all but salt-tolerant crops
>16	Only a few very salt-tolerant crops make satisfactory yields

Erosion Factors

Soil losses due to erosion should be evaluated to assess the potential for hazardous constituent release from the site. Section 8.3.3.2 describes the Universal Soil Loss Equation technique for determining soil losses per unit area of land.

Flood Potential

The proposed site should be evaluated to assess the likelihood of flooding. Soil surveys conducted by the Soil Conservation Service will identify flood-prone areas. Flooding is rated in general terms that describe the frequency and duration of flooding and the time of year such flooding is most likely. Table 8.2.14 presents an example of this site characteristic for some soils found in Connecticut.

Water Table Depth

In general, water tables are deeper in arid regions than humid regions. Water table depths also tend to follow surface topography; deeper beneath interstream areas and shallower in lowlands.[3] In addition, the water table generally coincides with the surface of perennial streams. Furthermore, water tables are usually shallower in relatively impermeable soils (e.g., clays) than in relatively permeable soils (e.g., coarse sand).[8]

The applicant should identify for the treatment zone, the depth to seasonally high water table. The Soil Conservation Service defines high water table as the highest level of a saturated zone more than 15 centimeters (6 inches) thick for a continuous period of more than 2 weeks during most years. Estimates of depth to seasonally high water table are based mainly the relationship between grayish colors or mottles in the soil horizon and the depth to free water observed. Information on depth to seasonal high water table may be obtained from regional offices of the Soil Conservation Service, U.S. Geological Survey, Water Resources Branch of U.S. Department of the Interior.

Frost Action Potential

The Soil Conservation Service states that the freezing and thawing action accompanying frost affects soil structure and increases aggregate formation. The resultant increase in particle size increases the rate of water movement through the soils of the frost zone thereby increasing the likelihood of soluble chemical leaching. Frost action potentials are typically provided in SCS County Soil Survey reports (see Table 8.2.14 as an example).

8.2.4 Draft Permit Preparation

Condition A of the Land Treatment Permit Module XIV contains three components. The three parts, (1) list of wastes to be treated, (2) treatment zone operating conditions, and (3) treatment zone design can be stipulated by reference to segments of the applicant's submittal. The first component of

Condition A requires that the permit contain the list of wastes to be treated that have been demonstrated under §264.272 as being completely degraded, transformed, or immobilized in the treatment zone.

Part 2 of Condition A stipulates that the permit must specify the following, which can be incorporated into the draft permit by reference to that applicable part of the application:

- rate and method of waste application
- measures to control soil pH
- procedures to enhance microbial or chemical reactions
- measures to control moisture content

Part 3 of Condition A requires that the permit specify the vertical and horizontal dimensions of the treatment zone.

The three parts of Condition A of Permit Module XIV are as follows:

1. The Permittee shall establish a treatment program for the wastes listed in Table XIV-1 as required by 40 CFR 264.271(a). The treatment program must include the design measures and operating practices specified in condition XIV.B and the unsaturated zone monitoring provisions specified in XIV.E. The treatment program must be capable of degrading, transforming, or immobilizing the hazardous constituents listed in Attachment __.

2. The Permittee shall design, construct, operate, and maintain the treatment unit in accordance with the requirements of 40 CFR 264.273(a), as specified in the attached plans and specifications.

3. The Permittee shall construct the treatment zone as specified in Attachment __.

In addition to specifying the provisions of Condition A of Module XIV, the permit writer must also stipulate unsaturated zone monitoring conditions (see Condition D of Module XIV, as presented in Section 4). These conditions outlined below, may be incorporated into the permit by reference to applicable parts of the Part B permit application submittal.

1. The Permittee shall establish an unsaturated zone monitoring program for the hazardous constituents listed in Attachment __, as required by 40 CFR 264.278.

[Note: Unless the Regional Administrator requires monitoring for principal hazardous constituents (PHCs) in accordance with the provisions of §264.278(a)(2), this list of hazardous constituents should be the same as the one specified in condition A of Permit Module XIV.7.]

2. The Permittee shall install an unsaturated zone monitoring system as required by 40 CFR 264.278(b); as specified in the attached plans and specifications.

[Note: The attached plans and specifications should demonstrate compliance with the requirements of §264.278(b). At a minimum, these plans should contain the information required by §270.20(b)(3) including sampling equipment, procedures, and frequency, and procedures for selecting sampling locations.]

3. The Permittee shall establish a background value for each hazardous constituent to be monitored under Condition XIV.E.1 as required by 40 CFR 264.278(c), as specified in Attachment __.

[Note: The Attachment should demonstrate how the Permittee will comply with the requirements of §264.278(c).]

4. The Permittee shall conduct soil monitoring and soil-pore liquid monitoring as required by 40 CFR 264.278(d), as specified in Attachment __.

[Note: The Attachment should demonstrate how the Permittee will comply with the requirements of §264.278(d). The permit should specify the frequency and timing of this monitoring in accordance with the conditions outlined in §264.278(d).]

5. The Permittee shall follow the sampling and analysis procedures specified in Attachment __ as required by 40 CFR 264.278(c).

[Note: This Attachment should demonstrate compliance with §264.278(e).]

6. The Permittee shall determine whether there is a statistically significant change over background values for any hazardous constituent to be monitored under Condition XIV.E.1 each time the monitoring required by Condition XIV.E.4 is conducted, as required by 40 CFR 264.278(f). This determination shall be made using the statistical procedures outlined in Attachment __.

[Note: This Attachment should demonstrate compliance with the requirements of 40 CFR 264.278(f). The permit writer should specify the time period for making the determination in accordance with §264.278(f)(2).]

7. If the Permittee determines, pursuant to Condition XIV.E.6, that there is a statistically significant increase of hazardous constituents below the treatment zone, he shall notify the Regional Administrator of this finding and apply for a permit modification in accordance with the provisions of 40 CFR 264.278(g).

8. The Permittee need not submit the application required by Condition XIV.E.7 if he successfully demonstrates that a source other than the regulated unit caused the increase or that the increase resulted from an error in sampling, analysis, or evaluation as specified by 40 CFR 264.278(h).

8.2.5 References

1. U.S. Environmental Protection Agency. Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Draft Report. Office of Solid Waste, Land Disposal Branch. Washington, D.C. March 1983.

2. U.S. Environmental Protection Agency. Hazardous Waste Land Treatment, prepared by K. W. Brown and Associates, Inc., for U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Solid and Hazardous Waste Research Division, Cincinnati, OH. Report No. SW-874. 1983.

3. Black, C. A., ed. Methods of Soil Analysis, Parts 1 and 2, The American Society of Agronomy, Inc., Madison, Wisconsin. 1965.

4. Whiting, D. M. Use of Climatic Data in Estimating Storage Days for Soil Treatment Systems. Environmental Protection Agency, Office of Research and Development. EPA-IAG-D5-F694. 1976.

5. Huddleston, R. L. Solid Waste Disposal: Landfarming. Chemical Engineering, February 26, 1979. pp. 119-124.

6. Landfarming Fills an HPI Need. Hydrocarbon Processing, June 1980. pp. 97-103.

7. Brady, N. C. The Nature and Properties of Soils. 8th Ed. MacMillan Publishing Company, Inc. New York, NY. 1974.

8. Phung, T., et al. Land Cultivation of Industrial Wastes and Municipal Solid Wastes: State-of-the-Art Study. Volume I, Technical Summary and Literature Review. Prepared by SCS Engineers for U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, OH. EPA-600/2-78-140a. August 1978.

9. Page, A. L. Fate and Effects of Trace Elements in Sewage Sludge When Applied to Agricultural Lands. A Literature Review Study. EPA-670/2-74-005. U.S. Environmental Protection Agency. January 1974.

10. Dowdy, R. H., and W. E. Larson. The Availability of Sludge-borne Metals to Various Vegetable Crops. J. of Env. Quality, 4: 278-282. 1975.

11. Chaney, R. L., P. T. Hundemann, W. T. Palmer, R. J. Small, M. C. White, and A. M. Decker. Plant Accumulation of Heavy Metals and Phytotoxicity Resulting from Utilization of Sewage Sludge and Sludge Composts on Cropland, pp. 86-97. In: Proc. Nat'l Conf., Composting Municipal Residues and Sludges. Information Transfer Inc., Rockville, MD. 1978.

12. U.S. Environmental Protection Agency. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods. U.S. Environmental Protection Agency, Office of Solid Waste. Report No. SW-846. July 1982.

13. Kirby, G. N. Corrosion Performance of Carbon Steel. Chemical Engineering, March 12, 1979.

14. Farino, W. J. and C. W. Young. Suitable Methods for Drum Disposal at Hazardous Waste Landfills, prepared by GCA/Technology Division for Office of Solid Waste, Hazardous Waste Management Division. January 1983.

15. U.S. Environmental Protection Agency. RCRA Guidance Document Land Treatment, Draft Report. Office of Solid Waste, Washington, DC. January 1983.

16. Cernica, J. N. Geotechnical Engineering. CBS College Publishing. 1982.

17. U.S. Environmental Protection Agency. Process Design Manual for Land Treatment of Municipal Wastewater. EPA-625/1-77-008. October 1977.

8.3 DESIGN AND OPERATING REQUIREMENTS

8.3.1 Federal Requirement

Section 270.20(c) requires the applicant to provide:

> "(c) A description of how the unit is or will be designed, constructed, operated, and maintained in order to meet the requirements of §264.273. This submission must address the following items:
>
> (1) Control of run-on;
>
> (2) Collection and control of run-off;
>
> (3) Minimization of run-off of hazardous constituents from the treatment zone;
>
> (4) Management of collection and holding facilities associated with run-on and run-off control systems;
>
> (5) Periodic inspection of the unit. This information should be included in the inspection plan submitted under §270.14(b)(5);
>
> (6) Control of wind dispersal of particulate matter, if applicable."

The corresponding Part 264 standards, which are contained in §264.273(b) through (g), stipulate that:

> "(b) The owner or operator must design, construct, operate, and maintain the treatment zone to minimize run-off of hazardous constituents during the active life of the land treatment unit.
>
> (c) The owner or operator must design, construct, operate, and maintain a run-on control system capable of preventing flow onto the treatment zone during peak discharge from at least a 25-year storm.
>
> (d) The owner or operator must design, construct, operate, and maintain a run-off management system to collect and control at least the water volume resulting from a 24-hour, 25-year storm.
>
> (e) Collection and holding facilities (e.g., tanks or basins) associated with run-on and run-off control systems must be emptied or otherwise managed expeditiously after storms to maintain the design capacity of the system.
>
> (f) If the treatment zone contains particulate matter which may be subject to wind dispersal, the owner or operator must manage the unit to control wind dispersal.
>
> (g) The owner or operator must inspect the unit weekly and after storms to detect evidence of:
>
> (1) Deterioration, malfunctions, or improper operation of run-on and run-off control systems; and
>
> (2) Improper functioning of wind dispersal control measures."

8.3.2 Summary of Necessary Application Information

8.3.2.1 Surface Water Control Plans--

A scale drawing of the land treatment unit depicting the location of surface water and/or soil erosion control structures that will be used to control run-on and run-off should be included in the permit application.

Equipment design features and specifications should be submitted along with calculations for sizing surface water control structures based on specified (see §264.273(c) and (d)) storm frequency, duration, and intensity.

8.3.2.2 Minimizing Run-off of Hazardous Constituents--

Specific measures to minimize the concentration of hazardous constituents in surface water run-off from the treatment zone should be identified in permit application.

8.3.2.3 Management of Accumulated Run-off and Run-on--

The applicant should submit a monthly tabulation of run-off and run-on storage requirements and a concise explanation of how the collected liquid will be managed for disposal. Note that the applicant must determine whether the collected liquid is a hazardous waste or not according to the criteria of Part 261.

8.3.2.4 Control of Wind Dispersal--

A wind erosion control plan designed to minimize the wind dispersal of soil, soil-waste mixture, or waste particulate matter must be included in the application.

8.3.2.5. Inspection of Land Treatment Unit--

The applicant should submit a schedule for periodic inspections of the land treatment unit to determine the adequacy of surface water control and wind erosion control measures. The name or title of the person(s) responsible for conducting inspections, a list of items to be inspected, procedures for responding to observed inadequacies, and records for inspection results should also be included in the application.

8.3.3 Guidance on Evaluating Application Information

To satisfy the facility design, construction, operation, and maintenance requirements, the applicant must provide a description of the following:

- Surface water control plans, addressing:
  - Facility surface run-on control system
  - Facility surface run-off control and collection systems
- Minimizing run-off of hazardous constituents
- Management of accumulated run-off (and run-on)
- Control of wind dispersal
- Inspection of land treatment unit

Where applicable, facility design and operating parameters should be based on the results of the treatment demonstration. Examples would include surface water run-on and run-off experiences gained from field studies or

existing units; effectiveness of wind dispersal controls implemented during field tests or at existing units; and procedures tested under field studies to minimize run-off hazardous constituents.

8.3.3.1 Surface Water Control Plans--

Because of their interrelationship, evaluation of run-on and run-off control systems are discussed together. Water is the primary conduit for hazardous constituent release from the treatment zone. Therefore, the design and operation of surface water control systems are essential in limiting ground water or nearby surface water contamination.

The land treatment unit must be designed to prevent run-on of surface water during periods of intense rainfall. The primary purpose for controlling run-on is to prevent excess water from entering the treatment zone. Excess water, resulting in soil saturation, will create anaerobic conditions that will reduce microbial degradation, hinder waste application and tilling operations, and increase the likelihood of hazardous constituent leaching from the unit.

Just as important as controlling run-on, the land treatment unit must be designed and operated to control run-off. Uncontrolled run-off released from the site can, if it contains unacceptable levels of hazardous constituents, result in contamination of nearby soils and surface waters. The RCRA Land Treatment Guidance document[1] and Chapter 8 of the HWLT manual[2] provide guidance on the design, operation, and maintenance of run-on and run-off control systems for hazardous waste land treatment units.

As required under Part 264, the land treatment facility operator or owner must design, construct, operate, and maintain a run-on control system capable of preventing flow onto the treatment zone during peak discharge from at least a 25-year storm. The amount of run-on, and also run-off, expected as a result of precipitation will depend on:

- soil cover (vegetated or nonvegetated),
- watershed surface slope,
- soil permeability,
- antecedent soil moisture content, and
- seasonal temperatures (e.g., soil freezing).

The relationship between run-on or run-off and these factors are covered in the HWLT manual and introductory hydrology text books.[3,4]

Surface run-on can be effectively controlled by contour grading surrounding land to divert surface overland flow away from the treatment zone. Diversion of potential surface run-on will reduce excess infiltration through the treatment zone, thus minimizing leaching during periods of precipitation.

Surface run-on diversion involves creating earth berms and excavating diversion ditches along the upslope side of the treatment zone that direct flow toward natural drainageways downslope from the unit. Diversion ditches must be designed to accommodate the characteristics of the contributing

watershed such as area, annual rainfall, land use, soil type, and topography. As required, they must be designed to handle the 25-year storm intensity. Determination of peak discharge should be determined on a unit-specific basis, taking into consideration local rainfall intensity and the size and terrain of surrounding watershed. The amount of rainfall expected from a local or regional 25-year storm event can be obtained from the National Oceanic and Atmospheric Administration or local Agricultural Extension Service.

The permit writer's worksheet for assessing the adequacy of the applicant's determination of storm magnitude is present in Figure 8.3.1.

Two methods commonly used to calculate the volume of run-on or run-off during and after rainfall are the "rational method" and the Soil Conservation Service (SCS) method.

The Rational Method

The rational method calculates peak run-off based on the following expression:

$$Q = cia$$

where Q = peak run-off rate in cubic feet per second (CFS)

c = run-off coefficient which is actually the ratio of the peak run-off rate to the average rainfall rate for a period known as the time of concentration

i = average rainfall intensity in inches per hour for a period equal to the time of concentration

a = drainage area in acres

Use of the rational method for determination of design run-on quantity is appropriate since the Part 264 regulations require control of the peak discharge rate. Q, as calculated using the rational method, is defined as the peak discharge rate associated with the selected storm event.

The rational method formula is based on the following assumptions:[3]

(1) the maximum run-off rate is a function of the average rate of rainfall during the time of concentration,

(2) the maximum rate of rainfall occurs during the time of concentration, and

(3) the variability of the storm pattern is not taken into consideration.

The time of concentration (t_c) is defined as the flow time from the most remote point in the drainage area to the point in question. The time of concentration is calculated as follows:

Determination of Magnitude of the 25-year Storm Event

- Has this part of the applicant's submittal been read and evaluated?

  _____ Yes _____ No

- What storm magnitude was selected by the applicant? _____

- What depth of rainfall is this storm event equivalent to? _____ inches

  - based on what references? _____

    _____

Independent Check

- What is the local rainfall depth associated with the 25-year storm? _____ inches

  - based on what reference? _____

- Is the rainfall depth established by the applicant at least as great as this determination?

  _____ Yes _____ No

Then, likewise, this aspect of the applicant's submittal is or is not acceptable

_____ is acceptable _____ is not acceptable

Figure 8.3.1. Worksheet for determination of the magnitude of the 25-year storm event.

$$t_c = \frac{41b\ L_o^{1/3}}{(ci)^{2/3}} \qquad (1)$$

where t_c = time of concentration in minutes

b = coefficient

L_o = overland flow length in feet

c = run-off coefficient (see Table 8.3.1)

i = rainfall intensity in inches per hour during time of concentration

The equation is valid only for laminar flow conditions where the product iL_o is less than 500. The coefficient b is found as follows:

$$b = \frac{0.0007i + C_r}{S_o^{1/3}} \qquad (2)$$

where S_o = surface slope

C_r = a coefficient of retardance

Values of C_r, are given in Table 8.3.2.

The runoff coefficient (C) is influenced by a number of variables, such as infiltration capacity, interception by vegetation, and depression storage.[3] As used in the rational method, the coefficient C represents a fixed ratio of run-off to rainfall, while in actuality it is not fixed and may vary for a specific drainage basin with time during a particular storm, from storm to storm, and with change in season. Table 8.3.1 lists some values of the run-off coefficient for various soils and surface covers.

The rainfall intensity (i) is derived from the average intensity (in/hr) of a storm for a given frequency (25-year in this case) for the time of concentration. Following determination of t_c, the rainfall intensity is usually obtained by making use of a set of rainfall intensity-duration-frequency curves such as shown in Figure 8.3.2. Drawing a line from the abscissa at the appropriate value of t_c and then projecting upward to intersect the desired frequency curve, i can be found by projecting this intersection point horizontally to intercept the ordinate.[3] If an adequate number of years of local rainfall records is available, curves similar to Figure 8.3.2 may be developed. Otherwise, data compiled by the National Oceanic and Atmospheric Administration, the Department of Agriculture, or other local government agencies can be used.

A more indepth discussion of surface run-on and run-off computations using the rational method is presented in References 3 and 4.

TABLE 8.3.1. VALUES OF RUN-OFF COEFFICIENT[3]

Earth Surface	Cover	Min.	Max.
Sand, from uniform grain size, no fines, to well graded, some clay or silt	Bare	0.15	0.50
	Light Vegetation	0.10	0.40
	Dense Vegetation	0.05	0.30
Loam, from sandy or gravelly to clayey	Bare	0.20	0.60
	Light Vegetation	0.10	0.45
	Dense Vegetation	0.05	0.35
Gravel, from clean gravel and gravel sand mixtures, no silt or clay to high clay or silt content	Bare	0.25	0.65
	Light Vegetation	0.15	0.50
	Dense Vegetation	0.10	0.40
Clay, from coarse sandy or silty to pure colloidal clays	Bare	0.30	0.75
	Light Vegetation	0.20	0.60
	Dense Vegetation	0.15	0.50

NOTE: Values of C for earth surfaces are further varied by degree of saturation, compaction, surface irregularity and slope, by character of subsoil, and by presence of frost or glazed snow or ice.

TABLE 8.3.2. RETARDANCE COEFFICIENT C_r (3)

Surface	C_r
Smooth asphalt	0.007
Concrete paving	0.012
Tar and gravel paving	0.017
Closely clipped sod	0.046
Dense bluegrass turf	0.060

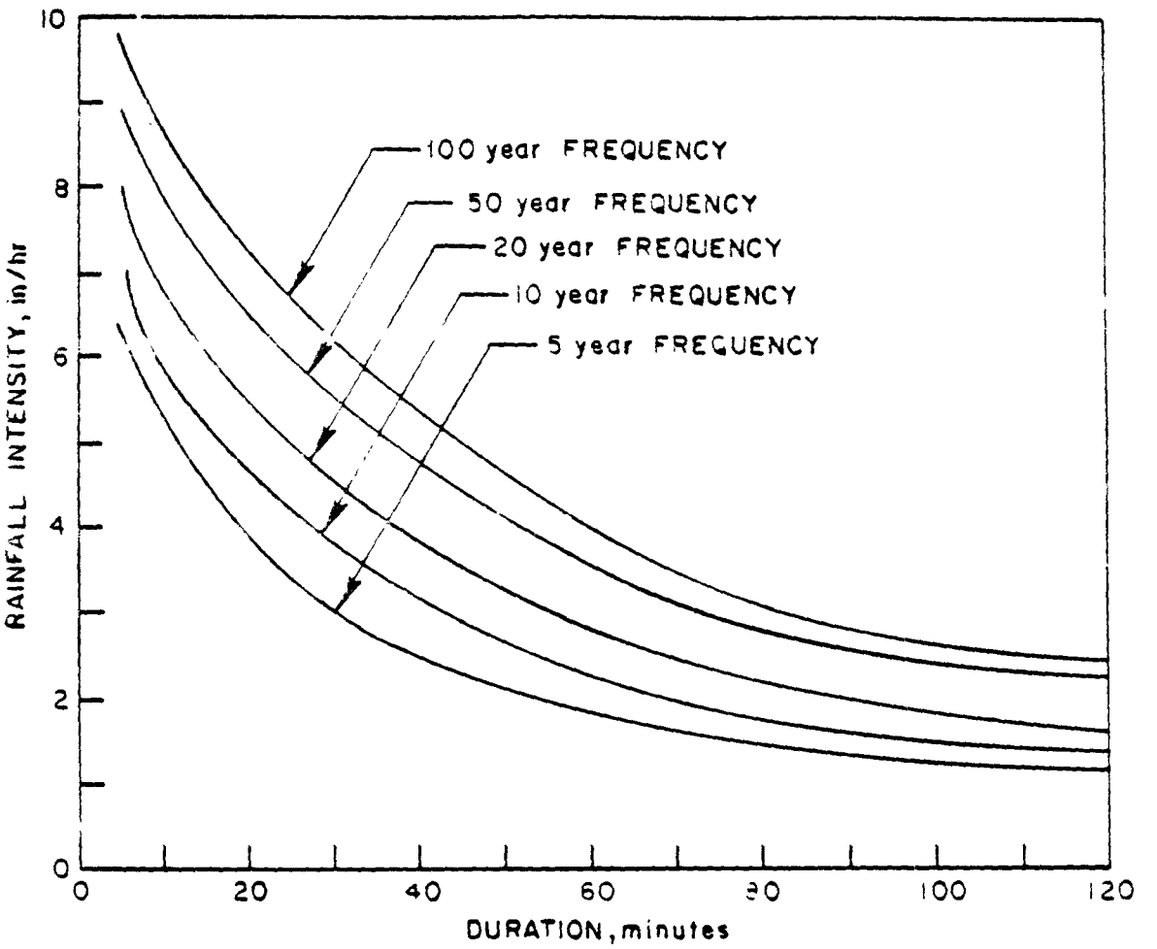

Figure 8.3.2. Typical intensity-duration-frequency curves.[3]

The SCS Method

The SCS run-off equation is a method of estimating direct run-off from storm rainfall of a duration of 1 day or less.

The equation is:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \quad (3)$$

where Q = accumulated direct run-off

P = accumulated rainfall (potential maximum run-off)

I_a = initial abstraction including surface storage, interception, and infiltration prior to run-off

S = potential maximum retention

To simplify use of the equation, the following empirical relationship is often used in the SCS run-off equation:

$$I_a = 0.2S \quad (4)$$

Substituting 0.2S for I_a, the equation becomes:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad (5)$$

and is the rainfall run-off equation used for estimating direct run-off from storm rainfall.

S values have been transformed into curve numbers (CN) to allow for graphical solution of run-off. Figure 8.3.3, reprinted from Reference 6 (USDA, Soil Conservation Service, 1973), provides the graphical solution using the curve number method. Research has been conducted to correlate curve numbers with various hydrologic soil cover complexes, as illustrated in Table 8.3.3, also reprinted from Reference 6. The information in the table is useful in determining run-off from a vegetated unit or closed facility, but not from an unvegetated active land treatment unit. In that case, an estimate of S is necessary to determine the appropriate curve number, from the equation:

$$CN = \frac{1000}{S + 10} \quad (6)$$

The Part 264 regulations for run-on control require that the system be "capable of preventing flow onto the active portion of the landfill during peak discharge from at least a 25-year storm." The SCS has developed the following equation to estimate peak discharge:

$$q_p = (KAQ)/T_p \quad (7)$$

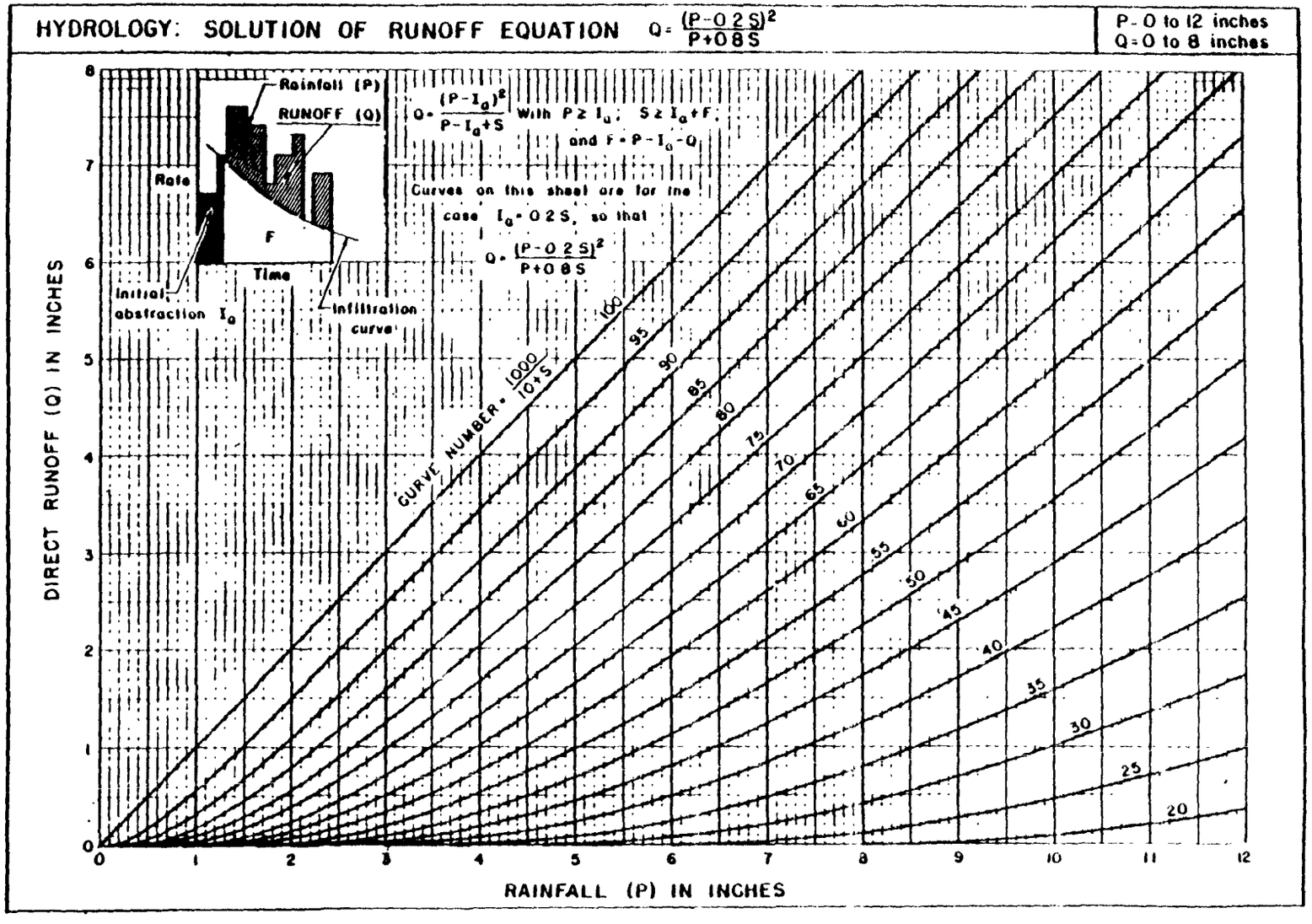

Figure 8.3.3. Solution of the SCS runoff equation.[6]

TABLE 8.3.3. RUNOFF CURVE NUMBERS FOR HYDROLOGIC SOIL-COVER COMPLEXES (ANTECEDENT MOISTURE CONDITION II, AND $I_a = 0.2\ S$)[b]

Land use and treatment or practice	Hydrologic condition	Hydrologic soil group			
		A	B	C	D
Fallow					
Straight row	----	77	86	91	94
Row crops					
Straight row	Poor	72	81	88	91
Straight row	Good	67	78	85	89
Contoured	Poor	70	79	84	88
Contoured	Good	65	75	82	86
Contoured and terraced	Poor	66	74	80	82
Contoured and terraced	Good	62	71	78	81
Small grain					
Straight row	Poor	65	76	84	88
Straight row	Good	63	75	83	87
Contoured	Poor	63	74	82	85
Contoured	Good	61	73	81	84
Contoured and terraced	Poor	61	72	79	82
Contoured and terraced	Good	59	70	78	81
Close-seeded legumes or rotation meadow					
Straight row	Poor	66	77	85	89
Straight row	Good	58	72	81	85
Contoured	Poor	64	75	83	85
Contoured	Good	55	69	78	83
Contoured and terraced	Poor	63	73	80	83
Contoured and terraced	Good	51	67	76	80
Pasture or range					
No mechanical treatment	Poor	68	79	86	89
No mechanical treatment	Fair	49	69	79	84
No mechanical treatment	Good	39	61	74	80
Contoured	Poor	47	67	81	88
Contoured	Fair	25	59	75	83
Contoured	Good	6	35	70	79
Meadow	Good	30	58	71	78
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	25	55	70	77
Farmsteads	----	59	74	82	86
Roads[a]					
Dirt	----	72	82	87	89
Hard surface	----	74	84	90	92

[a]Including rights-of-way.

where q_p = peak rate of discharge

A = drainage area

Q = storm run-off (as determined from Figure 8.3.3)

K = a constant, and

T_p is the time to peak flow and is calculated as:

$$T_p = \frac{D}{2} + L \qquad (8)$$

where D = storm duration, and

L = drainage area lag

The value of q_p can be approximated by making some simplifying assumptions. For instance, the value of q_p is maximized as T_p is minimized. For a given storm event, say the 25-year storm, T_p is minimized if L, the lag time, is arbitrarily set equal to zero. Substituting a value of 484 for K will then provide the estimate of the upper bound on peak run-on discharge rate. If the applicant's calculation of peak discharge is at least as great using any procedure, the estimate should be conservative. In other cases, the permit writer will have to exercise judgment, or follow the exact computation procedure proposed by SCS for estimating peak discharge rate. In the latter case, it is recommended that the permit writer refer to References 6 (Kent, 1973) or 7 (Mockus, 1969).

The permit writer's worksheet for evaluating the applicant's calculation of peak run-on rate is presented in Figure 8.3.4.

Erosion Control

Erosion control is an important part of the surface water control plan. Vegetation planted near and on the sides of diversion ditches will stabilize the soil, securing their structural integrity. However, vegetation can take between 1 and 2 years to become firmly established. During that period, mulch and hay bales should be used to stabilize these areas. Mulch can be pegged in place on steeper slopes. Erosion control also prevents siltation that can clog diversion ditches, resulting in surface ponding which should be avoided.

References 8 through 11 listed in subsection 8.3.5 should be reviewed to obtain a more thorough understanding of the erosion control techniques described above.

8.3.3.2 Minimizing Run-off of Hazardous Constituents--

Surface run-off must be controlled to minimize the release of hazardous constituents from the unit. Surface run-off from the treatment zone can occur during waste application, periods of heavy rainfall, or following a moderate to heavy snowfall with subsequent rapid melting. Under normal conditions, surface run-off should not occur during waste application. Approaches to minimize surface water run-off include proper facility siting and design and

Calculation of peak run-on rate for design storm event

- Has this part of the applicant's submittal been read and evaluated? _____ Yes _____ N
- What technique was used to calculate the peak run-on rate? _____
- Using this technique, what quantity (note units) or rate and duration of run-on is the proposed system designed to handle? _____
- **Independent Check Using the Rational Method**
- Define Necessary Parameter Values -

1. Surface slope, S_o = _____
2. Retardance coefficient, Cr = _____
3. Rainfall intensity during time of concentration, i = _____ in./hr (note data source)

} Calculate the value of b from Eq. 2; b = _____

4. Maximum overland flow length, L_o = _____ ft.
5. Run-off coefficient, C = _____ (from Table 8.3.1)

→ Calculate time of concentration, t_c from Eq. 1; t_c = _____ min

Is the value of t_c calculated from the value used in 3. to determine i? _____ Yes _____ No

If yes, recalculate i, b, and t_c

6. Drainage area, a = _____ acres

→ Calculate peak run-on rate, Q = Cia = _____ cfs

Figure 8.3.4. Worksheet for determination of peak run-on discharge rate for evaluation of run-on control.

implementation of good management practices, such as application scheduling and periodic cultivation. Note that management practices complement a facility design and should not be considered as an alternative or substitute. The success of minimizing surface run-off from the unit is predicated on a carefully thought-out facility design.

The land treatment unit should be designed such that liquids contained in the waste applied infiltrate the soil before moving laterally (overland flow) to the perimeter of the site. In addition, the unit should be managed whereby loading rates and frequency of application are scheduled such that:

- waste is not applied during periods when the soil is saturated,
- waste is not applied to the treatment zone when the surface soil is frozen, or
- waste is not applied during periods of heavy precipitation.

Surface run-off resulting from excessive precipitation can be minimized by maintaining a relatively level treatment zone surface and periodic cultivation. It is recommended that the surface slope be less than 5 percent. Grades greater than 5 percent will significantly increase overland flow velocities with a subsequent increase in soil erosion. However, it is also important to avoid water and waste ponding. Standing water can create anaerobic conditions and/or excessive leaching of waste constituents. In most cases, a 1-percent grade should be sufficient to ensure noneroding run-off and prevent water and waste ponding.

With respect to cultivation, contour tillage across the slope rather than with it is preferred. Cultivation improves soil granulation, which maintains porosity, aids infiltration, and prevents surface crusting. Tillage also improves waste degradation by aerating the soil and increasing waste/soil contacting.

In addition to surface water run-off, hazardous constituents adsorbed to soil particles or particles of the waste material themselves can be released from the treatment zone by soil erosion losses. Soil loss per unit area due to water erosion can be calcuated using the Universal Soil Loss Equation. The equation is:

$$A = R K L S C P$$

where A, the computed soil loss per unit area, is the product of the following factors:

R = rainfall and run-off erosivity index

K = soil erodibility factor, tons/acre

L = slope-length factor

S = slope gradient (steepness) factor

C = crop management (vegetative cover) factor

P = erosion-control practice

Input values for each factor and sample calculations are presented in Evaluating Cover Systems for Solid and Hazardous Waste.[12]

8.3.3.3 Management of Accumulated Run-off and Run-on--

To avoid migration of contaminated run-off, land treatment facilities must be designed and operated to collect and subsequently manage surface run-off from the treatment unit. It should be noted that the run-off standards do not distinguish between active areas, undeveloped areas (surrounding land), or closed areas of the land treatment facility. Run-off, as defined under §260.10, means any rainwater, leachate, or other liquid that drains over land from any part of a facility. A facility, as defined under §260.10 means all land and structures used for treating, storing, and disposing of hazardous waste.

Concerning the collection of run-off as required under §264.273(d), the Agency proposes the following:[13]

- Active area run-off should definitely be collected and managed as a hazardous waste, as explained in the Permit Applicants' manual.[14]
- Run-off from closed areas should also be collected, although it need not be assumed to be a hazardous waste.
- Run-off from access roads and building roofs need not be collected.

The technical issues associated with the management of accumulated run-off are identified in Figure 8.3.5.

Magnitude of the 24-Hour, 25-Year Storm Event

Facilities must be designed to handle the run-off volume associated with at least the 24-hour, 25-year storm. Figure 8.3.6 indicates the depth of rainfall for this event throughout the United States. The permit writer's worksheet for evaluating the magnitude of the selected storm event is presented in Figure 8.3.7.

Calculation of Run-off Volume

The volume of run-off expected for this storm event can be calculated using the SCS Method or the Rational Method, as described in subsection 8.3.3.1.

The Part 264 regulations for run-off require that the run-off management system "collect and control at least the water volume resulting from a 24-hour, 25-year storm." Because the rational method only calculates peak discharge, use of the SCS method may provide a more straightforward approach to calculating the total run-off water volume associated with the design storm event. First, Q is estimated using the graphical method shown in Figure 8.3.3. Then the total run-off volume associated with the storm event is approximated as:

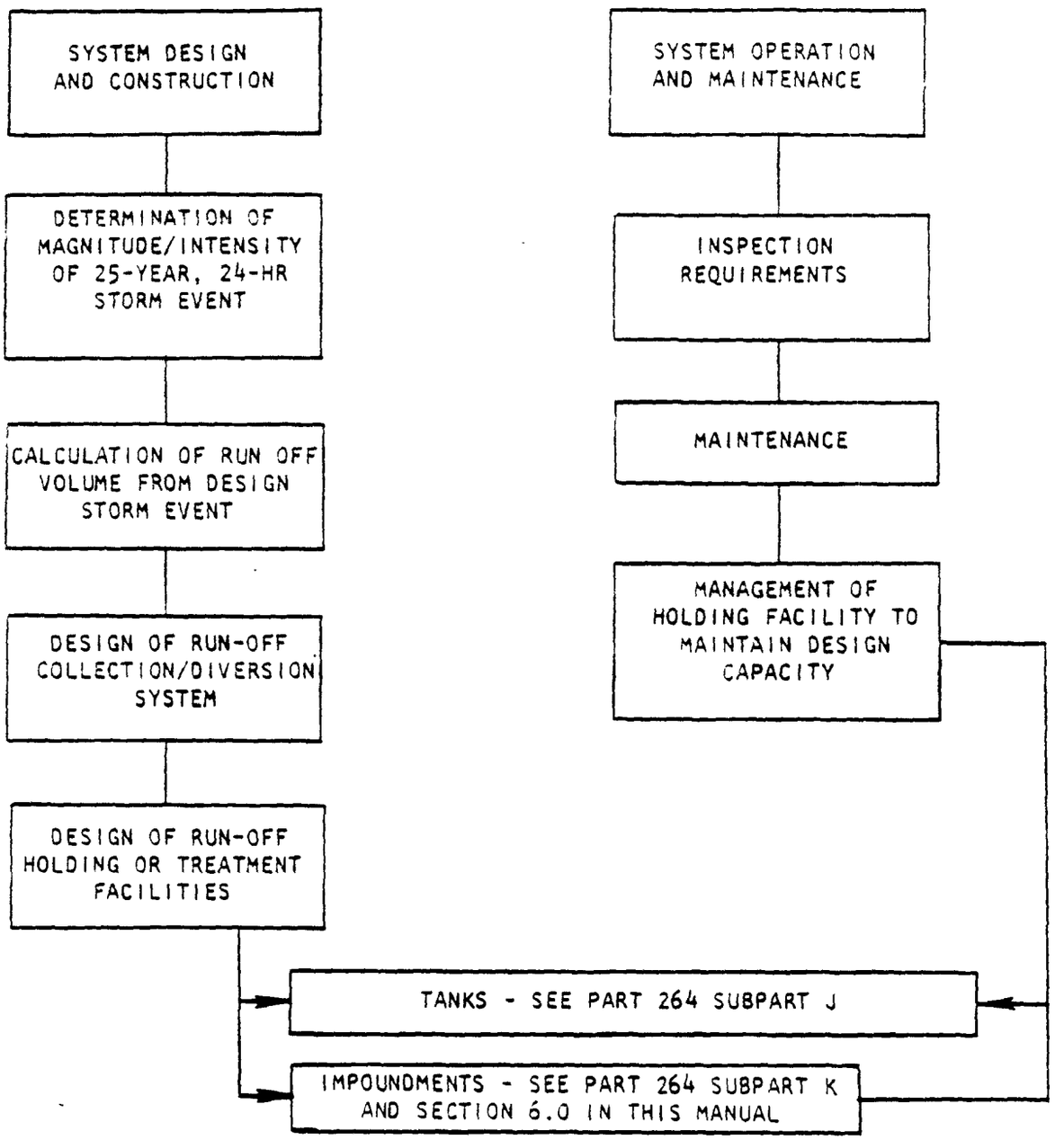

Figure 8.3.5. Technical issues associated with run-off control.

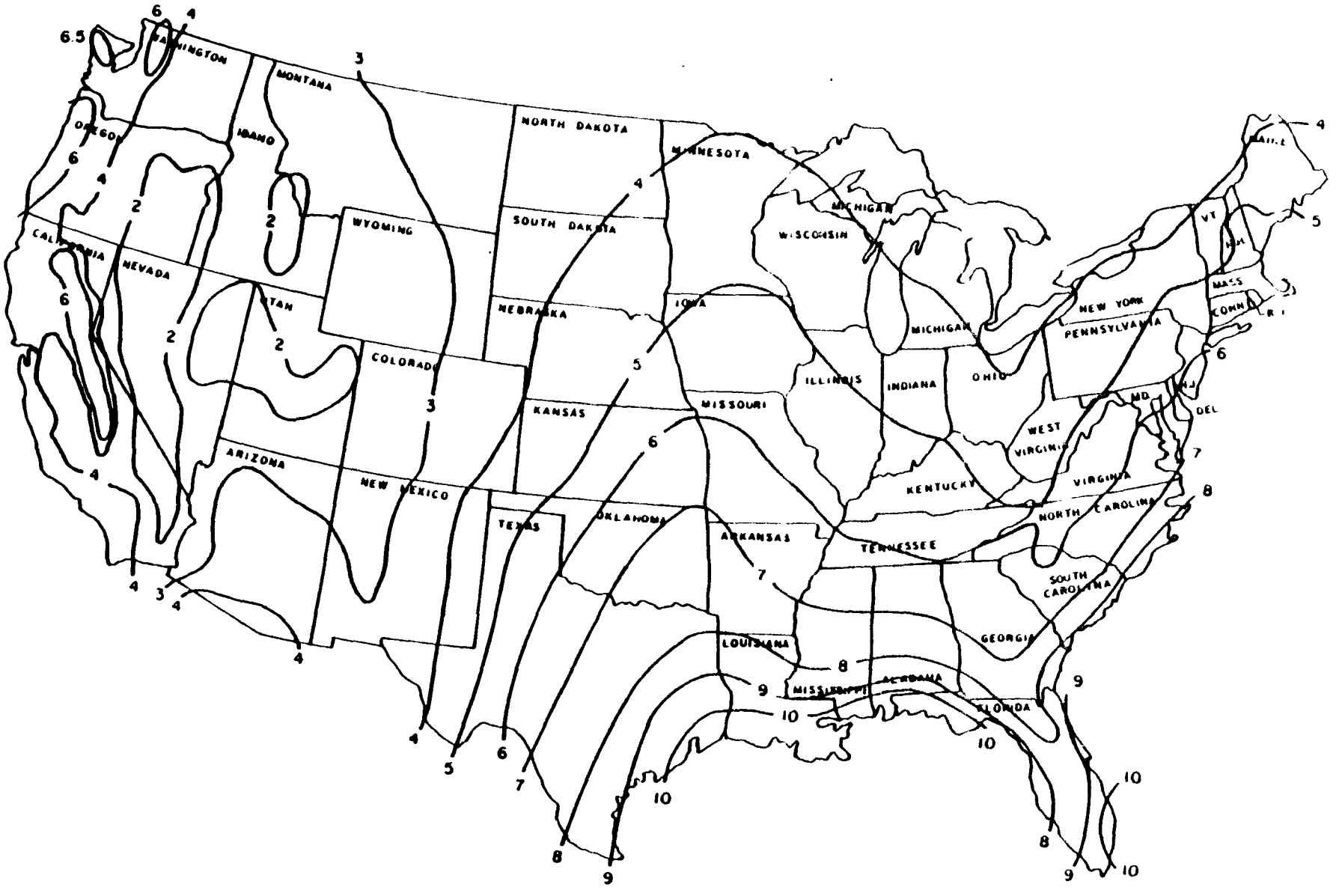

Figure 8.3.6. 24-hour 25-year rainfall event (inches).[15]

Determination of Magnitude/Intensity of 24-hr, 25-year storm event

- Has this part of the applicant's submittal been read and evaluated?

  _____ Yes _____ No

- What storm magnitude was selected by the applicant? _____

- What depth of rainfall is this storm event equivalent to? _____ inches

  - based on what references _____

Independent Check

- What is the rainfall depth associated with the 24-hr, 25-year storm _____ inches

  - based on what reference _____

- Is the rainfall depth established by the applicant at least as great as this determination?

  _____ Yes _____ No

Then, likewise, this aspect of the applicant's submittal is or is not acceptable

_____ is acceptable _____ is not acceptable

Figure 8.3.7. Worksheet for evaluating the magnitude of the selected storm event.

$$V = \frac{QA}{12}$$

where V is in ft^3, and

A = area of the active land treatment unit in square feet

The average flow rate can be approximated by assuming that this quantity of run-off flows for a duration of 24 hours. If peak discharge is of concern or used as a design basis in the applicant's presentation, then the computation techniques specified for determining peak run-on rate would be applicable.

The permit writer's worksheet for evaluating run-off volume computations is presented in Figure 8.3.8.

Design of Run-off Collection/Diversion System

This design will be site-specific depending on topography, site layout, and other factors. The design may include an open channel with an impervious floor flowing by gravity to a collection or storage basin. Alternatively, if the topography is less favorable, collected run-off may have to be pumped at some point where continued gravity flow is not longer possible to lift the collected run-off into a storage tank or impoundment. Such storage is envisioned to be necessary to allow for determination of whether the collected run-off is hazardous. A discussion of the management of these storage facilities follows.

If the applicant proposes to divert and collect stormwater run-off by installation of an open channel or culvert, it will be necessary to check the proposed dimensions to assure that the design run-off volume can be carried without overtopping of the channel. Open channel flow can be calculated using the Manning formula, wherein:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

where n = Manning's roughness coefficient

A = cross-sectional area of flow

R = A/WP, the hydraulic radius (where WP = the wetter perimeter), and

S = the channel slope.

Values of n for a variety of surface materials area listed in Table 8.3.4.

The applicant is required to provide an explanation of how collected liquid will be managed for disposal. As part of the submittal, the time required to empty the facilities must be estimated and the method of disposal of collected run-off (i.e., treatment, evaporation) must be described.

Calculation of run-off volume from design storm event

- Has this part of the applicant's submittal been read and evaluated?

  Yes ____ No ____

- What technique was used to calculate run-off ____

- Using this technique, what quantity (note units) or rate and duration of runoff is the proposed system designed to handle ____

- Is the run-off volume presented in terms consistent with the regulation, i.e., the run-off volume associated with the 24-hour, 25-year storm?

  Yes ____ No ____

Independent Check Using the SCS Method

- Define parameter values:
  - Select a value of S ____
  - Calculate CN from $CN = \frac{1000}{10 + S}$ ____
  - Interpolate Q from Figure 8.3.3 ____ inches
- Calculate V, volume of run-off:
  - A = active portion area = ____ sq.ft.
  - V = QA/12 = ____ cu.ft.
- Is the volume of runoff used as the design basis at least as great?

  Yes ____ No ____

Figure 8.3.8. Worksheet for evaluating run-off volume computations.

TABLE 8.3.4. REPRESENTATIVE VALUES OF n, MANNING'S ROUGHNESS COEFFICIENT[16]

Nature of surface	n	
	Min	Max
Neat cement surface	0.010	0.013
Wood-stave pipe	0.010	0.013
Plank flumes, planed	0.010	0.014
Vitrified sewer pipe	0.010	0.017
Metal flumes, smooth	0.011	0.015
Concrete, precast	0.011	0.013
Cement mortar surfaces	0.011	0.015
Plank flumes, unplaned	0.011	0.015
Common-clay drainage tile	0.011	0.017
Concrete, monolithic	0.012	0.016
Brick with cement mortar	0.012	0.017
Cast iron	0.013	0.017
Cement rubble surfaces	0.017	0.030
Riveted steel	0.017	0.020
Canals and ditches, smooth earth	0.017	0.025
Metal flumes, corrugated	0.022	0.030
Canals:		
Dredged in earth, smooth	0.025	0.033
In rock cuts, smooth	0.025	0.035
Rough beds and weeds on sides	0.025	0.040
Rock cuts, jagged and irregular	0.035	0.045

Run-off collected from the active portion of a landfill must be analyzed to determine the presence and concentration of hazardous constituents. If collected run-off proves hazardous, as defined in Part 261, it must be managed as a hazardous waste. To do so will often require storage of the collected run-off in a tank, container, or surface impoundment. If so, these facilities must be designed, constructed, and operated in conformance with the Standards of Part 264. The permit applicant must adequately demonstrate his proposed method of emptying or otherwise managing run-off collection facilities after storms to maintain the design capacity of these systems.

The regulations require diversion of run-on as opposed to collection. Therefore, an adequate monitoring and inspection plan for run-on facilities will often be adequate to demonstrate proper management of these systems. However, some part of the applicant's submittal should designate how the system will be maintained if problems are found during inspection. The permit applicant should also identify what actions will be taken when systems are found to be operating incorrectly or not at all. In addition, preventive procedures to be implemented, such as routine maintenance, should be described. Figure 8.3.9 provides a worksheet to assess the management practices associated with the land treatment run-on and run-off control systems.

8.3.3.4 Wind Dispersal Control Measures--

The land treatment unit must be designed and operated to prevent wind dispersal of particulate matter from the site that might contain hazardous constituents. Note that control of wind dispersal also applied during closure and post-closure care, as required by §§264.280(a)(8) and 264.280(c)(2). This concern arises because hazardous waste will generally be placed on or just below the soil surface. Measures to control wind dispersal of particulate matter include:

- timing of waste applications,
- maintenance of surface soil moisture content,
- use of chemical soil stabilizing agents,
- use of wind breaks, and/or
- establishment of a vegetative cover.

Factors that affect particulate matter dispersal are local prevailing wind direction, type of waste to be disposed, and operating techniques being or to be employed at the site. Familiarization with each of these will enable proper steps to be taken to minimize the effects of wind dispersal.

Scheduling of applications to avoid periods of excessive wind speed and turbulence will minimize wind dispersal of particulate matter. Also, disking of the surface soil should be timed to avoid periods of high wind. The applicant should demonstrate the ability to accommodate delays in waste application or cultivation. This may include extra storage capacity for wastes, flexible staff hours, and/or availability of application and tilling equipment.

MANAGEMENT OF UNITS ASSOCIATED WITH RUN-ON AND RUN-OFF CONTROL SYSTEMS

Has this part of the applicant's submittal been read and evaluated?	yes	no
Are the provisions for maintaining the run-off design capacity described?	yes	no
Are automatic control and/or alarm systems used to initiate emptying procedures and alert personnel to potential problems?	yes	no
Does the run-off management plan include provisions for testing run-off collected from active portions of the site for hazardous constituents?	yes	no
Does the application describe how run-off found to be hazardous will be treated or disposed?	yes	no
Does the application describe how non-hazardous run-off will be disposed of or discharged?	yes	no

Figure 8.3.9. Worksheet for evaluating management of unit's run-on and run-off control systems.

In addition to implementing good management techniques, the soil should be stabilized using either water to wet the surface or chemical soil stabilizing agents. Information about surface soil stabilizing techniques using water or chemical agents is presented in references 1 and 17.

One method of maintaining soil moisture content at effective levels, is to apply accumulated run-off. If chemical stabilizing agents are applied to the treatment zone, they should be carefully evaluated to determine that they do not adversely affect the treatment process or cause environmental damage.

Figure 8.3.10 presents a worksheet to aid in the evaluation of the applicant's proposed wind dispersal control measures.

8.3.3.5 Inspection of Land Treatment Unit--

As part of the inspection plan required under §270.14(b)(5), the owner or operator of a land treatment unit must submit a schedule for periodic inspection of the facility to determine the adequacy of surface water and wind dispersal control measures. In addition to the general inspection requirements specified in §270.14(b)(5), the inspection plan for land treatment facilities must include provisions whereby the unit will be inspected weekly and after storms to detect evidence of the following:

1. deterioration, malfunctions, or improper operation of run-on and run-off control systems, and

2. improper functioning of wind dispersal control measures.

The weekly inspection procedures should be specific. The applicant should describe what, how, and where the control systems will be checked. Specific criteria that will be used to evaluate the proper operation of these systems should be stated. The use of a form requiring written completion by the person conducting the inspection should be included in the application for review. Also, any employee responsible for inspections should be identified by name or title.

8.3.3.5.1 Run-on and Run-off Control Systems--Inspections of run-on and run-off control systems will vary in complexity in relation to the complexity of the systems' designs. In general, run-on control systems are simply intended to divert the surface water flow around/away from the treatment unit. In most cases, it will consist of trenches that may or may not be lined. Alternatively, the run-off control system is primarily designed to collect and contain all liquid overland flow from the active portion of the treatment unit and deliver it to some type of holding or treatment facility prior to disposal or reapplication. A run-off control system is likely to be of a more sophisticated design than a run-on control system since it will be handling liquid that has been in contact with the hazardous waste. The following two basic concerns should be investigated during any inspection:

- The physical integrity of the system with respect to original construction, and

- The capacity of the system compared to original design.

CONTROL OF WIND DISPERSAL

Has this part of the applicant's submittal been read and evaluated?	yes	no
Are the methods to control wind dispersal described?	yes	no
Are waste applications and subsequent disking going to be scheduled to minimize wind dispersal of particulate matter?	yes	no
If wind breaks are going to be used, has the applicant described what they are, where they will be located, and how maintained?	yes	no
If a vegetative cover is going to be established, has the type of cover and associated maintenance been described?	yes	no
If soil moisture control will be implemented to minimize wind dispersal, has the applicant described the frequency of irrigation and water supply source?	yes	no
If chemical agents will be used to stabilize the soil, has the applicant identified what they are, what impact they may have on the treatment process and application schedule?	yes	no
Has the applicant identified what actions will be taken when control systems are found not to be operating as intended?	yes	no
Has the applicant provided a description of what preventive measures will be implemented, such as routine maintenance, to minimize or reduce the likelihood of malfunctions?	yes	no

Figure 8.3.10. Worksheet for evaluating wind dispersal control measures.

For either run-on or run-off control systems, inspections of physical integrity should address:

- The liquid collection trench, the slope of culverts or piping, breaches, and tight joints.
- If the conveyance system is lined, the liner material should be checked for adhesion to substrate, holes, wear points, and cracks.
- If mechanical equipment are part of the system (e.g., pumps, valves, gates) they should be checked for leaks, malfunction, or other damage.

For run-on control systems, inspections to confirm continuance of design capacity should address:

- The presence of sedimentation, debris, or other materials that could inhibit system flow.
- The condition of terrain downgradient from the system exit that could cause liquids to back up into the system.

For run-off control systems, inspections to confirm continuance of design capacity should investigate:

- The presence of sedimentation, or encrustation in the system.
- The operation of mechanical equipment in the system.
- The status (full/empty) of holding or treatment systems downstream of the run-off control system.

To the extent that the holding/treatment equipment associated with a run-off control system are identified as storage, treatment, or disposal facilities under Part 264, they too must have an inspection plan as required by §270.14(b)(5) and §264.15.

8.3.3.5.2 Wind Dispersal Control Systems--As previously discussed, there are various options to control wind dispersal of particulate matter at a land treatment facility. In some cases, a combination of methods will be implemented. At a minimum, inspection procedures should include close visual observation of all wind dispersal control systems on a weekly basis. During periods of high winds or when wastes are very susceptible to wind dispersal, the frequency of inspection should be increased. Any individual assigned to inspect the facility should have the authority to require immediate repair or cleaning of wind dispersal control systems. Cleaning would be necessary where fences or burlap screens are installed to catch wind blown material. Figure 8.3.11 provides a worksheet for assessing the adequacy of the inspection plan, as it relates to the referenced two control measures.

INSPECTION REQUIREMENTS

Has this part of the applicant's submittal been reviewed and evaluated?	yes	no
Does the application include a schedule identifying when the unit will be inspected to determine the adequacy of surface water control and wind dispersal control measures?	yes	no
Are individuals responsible for conducting the inspections identified?	yes	no
Are the items to be inspected listed?	yes	no
Does the application describe the procedures for responding to observed inadequacies?	yes	no
Are recordkeeping procedures described?	yes	no
Do weekly and post storm run-on and run-off inspection procedures address:		
1. Inspection of liquid collection trenches, culverts or piping systems for proper slope, breaches and tight joints?	yes	no
2. Inspection of lined conveyance systems for adhesion to substrate, holes, wear points, and cracks?	yes	no
3. Inspection of mechanical equipment for leaks, malfunction, or other damage?	yes	no
Do run-on control system inspection procedures include:		
1. Inspection for the presence of sedimentation, debris, and other material that could inhibit flow?	yes	no
2. Inspection of the downgradient terrain to identify potential causes of liquid backup?	yes	no
Do run-off control system inspection procedures include:		
1. Inspection for the presence of sedimentation or encrustation?	yes	no
2. Inspections to determine the proper operation of mechanical equipment?	yes	no
3. Inspections to determine the status (full/empty) of holding or treatment systems?	yes	no
Wind Dispersal Control Systems:		
1. Does the inspection plan include procedures for weekly visual inspections of wind dispersal control systems?	yes	no
2. Does the frequency of inspection increase during periods of high winds?	yes	no

Figure 8.3.11. Worksheet for evaluating the applicant's inspection program.

Although specific requirements are not specified in Part 270 or 264, the owner or operator of the unit should, at a minimum, initiate the following response when surface water control or wind dispersal control measures fail:

1. suspend waste application,

2. institute backup system or control measures,

3. contact local authorities (state Hazardous Waste Agency or Coordinator, and fire and police departments, as necessary),

4. once the problem is under control determine the reason for failure and take corrective action.

8.3.4 Draft Permit Preparation

Condition B of the Permit Module XIV (see Section 4) addresses design and operating requirements of the land treatment facility. Condition B is comprised of six components that address: (1) minimization of run-off of hazardous constituents during the active life of the land treatment unit, (2) control of surface water run-on, (3) control and management of run-off, (4) management of run-on and run-off collection and handling systems, (5) control of wind dispersal, and (6) plans to inspect site at regular intervals. The components of Condition B may be implemented as permit requirements by reference to a permit attachment that includes the design and operating plans and specifications proposed in the permit application.

To be suitable for substitution in the permit condition attachment, the submitted application information should include the following for each of the six components:

- Minimization of run-off of hazardous constituents:

  - plans to delay waste application when treatment zone soil is saturated

  - plans to suspend application when surface soil is frozen

  - plans to suspend application during periods of heavy precipitation

  - schedule of surface soil tillage or establishment of a vegetative cover

  [Note: The attached plans and specifications should demonstrate that the treatment zone will be designed, constructed, operated, and maintained to minimize run-off of hazardous constituents during the active life of the land treatment unit.]

- Control of surface water run-on:

  - designs for contour grading surrounding land

  - construction of diversion terms or ditches

  - all calculations of peak rate of discharge

  [Note: The attached plans and specifications should demonstrate that the control system is capable of preventing flow onto the treatment zone during peak discharge from at least a 25-year storm.]

- Control and management of run-off:

  - designs for minimizing run-off

  - all calculations of peak run-off volume

  - engineering plans for controlling run-off

  [Note: The attached plans and specifications should demonstrate the run-off management system will collect and control at least the water volume resulting from a 24-hour, 25-year storm.]

- Management of run-on and run-off:

  - all calculations supporting the design and sizing of run-off collection facilities

  - management plans for holding or treatment facilities

  - procedures for assessing whether run-off is a hazardous waste that must be handled accordingly

  [Note: The Attachment must demonstrate how the Permittee will comply with §264.273(e).]

- Control of Wind Dispersal:

  - plans for timing of applications

  - measures to maintain soil moisture content

  - plans to use soil stabilizing agents or vegetative cover

  - design and construction of wind breaks

  [Note: This condition only applies if the treatment zone contains particulate matter which may be subject to wind dispersal. The Attachment must demonstrate how the Permittee will comply with §264.273(f).]

- Inspection of Land Treatment Unit:

  - plans to inspect the unit weekly and after storms

  [**Note:** §270.14 requires the general inspection schedule submitted under §264.15(b) to address the requirements of §264.273(g). The Attachment should demonstrate compliance with §264.273(g). Permit condition VI.E (see Module II) requires the Permittee to remedy any deterioration or malfunction discovered during an inspection and to keep records of inspections.]

8.3.5 References

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5. Seelye, E. E. Data Book for Civil Engineers Design, John Wiley and Sons, Inc. New York, NY. 1960.

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8. U.S. EPA, Erosion and Sediment Control, Surface Mining in the Eastern U.S., Part 2, Design. EPA Report 625/3-76-006. October 1976.

9. U.S. EPA, Design and Construction of Covers for Solid Waste Landfills. Municipal Environmental Research Laboratory, EPA Report 600/2-79-165. August 1979.

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16. Daugherty, R. L., and J. B. Franzini. Fluid Mechanics and Engineering Applications, 6th Edition, McGraw-Hill Book Company, New York. 1965.

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8.4 FOOD-CHAIN CROPS REQUIREMENTS

8.4.1 Federal Requirement

Sections 270.20(d) and (e) state that:

> "(d) If food-chain crops are to be grown in or on the treatment zone of the land treatment unit, a description of how the demonstration required under §264.276(a) will be conducted including:
>
> (1) Characteristics of the food-chain crop for which the demonstration will be made.
>
> (2) Characteristics of the waste, treatment zone, and waste application method and rate to be used in the demonstration;
>
> (3) Procedures for crop growth, sample collection, sample analysis, and data evaluation;
>
> (4) Characteristics of the comparison crop including the location and conditions under which it was or will be grown;
>
> (e) If food-chain crops are to be grown, and cadmium is present in the land-treated waste, a description of how the requirements of §264.276(b) will be complied with."

The corresponding Part 264 standards, covered under §264.276, state that:

> "The Regional Administrator may allow the growth of food-chain crops in or on the treatment zone only if the owner or operator satisfies the conditions of this section. The Regional Administrator will specify in the facility permit the specific food-chain crops which may be grown.
>
> (a)(1) The owner or operator must demonstrate that there is no substantial risk to human health caused by the growth of such crops in or on the treatment zone by demonstrating, prior to the planting of such crops, that hazardous constituents other than cadmium:
>
> (i) Will not be transferred to the food or feed portions of the crop by plant uptake or direct contact, and will not otherwise be ingested by food-chain animals (e.g., by grazing); or
>
> (ii) Will not occur in greater concentrations in or on the food or feed portions of crops grown on the treatment zone than in or on identical portions of the same crops grown on untreated soils under similar conditions in the same region.
>
> (2) The owner or operator must make the demonstration required under this paragraph prior to the planting of crops at the facility for all constituents identified in Appendix VIII of Part 261 of this chapter that are reasonably expected to be in, or derived from, waste placed in or on the treatment zone.
>
> (3) In making a demonstration under this paragraph, the owner or operator may use field tests, greenhouse studies, available data, or, in the case of existing units, operating data, and must:
>
> (i) Base the demonstration on conditions similar to those present in the treatment zone, including soil characteristics (e.g., pH, cation exchange capacity), specific wastes, application rates, application methods, and crops to be grown; and

(ii) Describe the procedures used in conducting any tests, including the sample selection criteria, sample size, analytical methods, and statistical procedures.

(4) If the owner or operator intends to conduct field tests or greenhouse studies in order to make the demonstration required under this paragraph, he must obtain a permit for conducting such activities.

(b) The owner or operator must comply with the following conditions if cadmium is contained in wastes applied to the treatment zone:

(1)(i) The pH of the waste and soil mixture must be 6.5 or greater at the time of each waste application, except for waste containing cadmium at concentrations of 2 mg/kg (dry weight) or less;

(ii) The annual application of cadmium from waste must not exceed 0.5 kilograms per hectare (kg/ha) on land used for production of tobacco, leafy vegetables, or root crops grown for human consumption. For other food-chain crops, the annual cadmium application rate must not exceed:

Time period	Annual Cd application rate (kilograms per hectare)
Present to June 30, 1984	2.0
July 1, 1984 to Dec. 31, 1986	1.25
Beginning Jan. 1, 1987	0.5

(iii) The cumulative application of cadmium from waste must not exceed 5 kg/ha if the waste and soil mixture has a pH of less than 6.5; and

(iv) If the waste and soil mixture has a pH of 6.5 or greater or is maintained at a pH of 6.5 or greater during crop growth, the cumulative application of cadmium from waste must not exceed: 5 kg/ha if soil cation exchange capacity (CEC) is less than 5 meq/100g; 10 kg/ha if soil CEC is 5-15 meq/100g; and 20 kg/ha if soil CEC is greater than 15 meq/100g; or

(2)(i) Animal feed must be the only food-chain crop produced;

(ii) The pH of the waste and soil mixture must be 6.5 or greater at the time of waste application or at the time the crop is planted, whichever occurs later, and this pH level must be maintained whenever food-chain crops are grown;

(iii) There must be an operating plan which demonstrates how the animal feed will be distributed to preclude ingestion by humans. The operating plan must describe the measures to be taken to safeguard against possible health hazards from cadmium entering the food chain, which may result from alternative land uses; and

(iv) Future property owners must be notified by a stipulation in the land record or property deed which states that the property has received waste at high cadmium application rates and that food-chain crops must not be grown except in compliance with paragraph (b)(2) of this section."

8.4.2 Summary of Necessary Application Information

8.4.2.1 Food-Chain Crop Demonstration--

If food-chain crops are to be grown during the active life of the treatment unit, the applicant must demonstrate that hazardous constituents will not be transferred to food or feed portions of the crop, or that hazardous constituents will not occur in greater concentrations in or on the food or feed portions of crops grown on the treatment zone than in or on identical portion of the same crops grown on untreated soils under similar conditions in the same region. Under either option, the owner or operator must address all potential food-chain contamination pathways including crop uptake, physical adherence to crop, and direct ingestion of contaminated crops by grazing animals.

The application should contain a description of how the food-chain crop demonstration will be made using information available from the literature, greenhouse tests, field studies, or in the case of existing units, operating data. Note that any tests conducted to measure crop uptake must be based on specific waste and application rates used or expected to be used at the unit. The owner or operator must obtain a permit prior to conducting any field tests or greenhouse studies.

Part 1 - Existing literature - When published literature is used to make the food-chain crop demonstration, the applicant should explain how the reported data relates to the treatment facility and can be extrapolated to make the demonstration.

Part 2 - Greenhouse tests - The following issues should be submitted by the applicant if greenhouse tests are to be conducted to make the food-chain crop demonstration:

Crop characteristics - The common and scientific name of the crop or crops to be grown should be identified along with the potential food or feed portions of the plant.

Waste characteristics - If not previously submitted (see Sections 8.1.2.1.1. or 8.2.2.1), the applicant should list hazardous constituents in the waste and their respective concentration.

Assessment of potential crop uptake - The applicant should explain how the potential for crop uptake will be assessed. If existing information from the literature will be used, the applicant should state and describe the data sources. If greenhouse or field tests will be used to evaluate plant uptake, a description of proposed test procedures addressing the following should be submitted:

- test location;
- test schedule;
- number and size of pots or containers;

- number of treatment replications;
- number of treatments;
- rate of waste application;
- soil characteristics;
- soil preparation;
- sampling and sample preparation methods;
- analytical methods;
- data interpretation methods; and
- method of data presentation.

Potential for external contamination - The application should contain an explanation of how external (surface) contamination of the food or feed portion of the crop will be precluded and how this will be substantiated in the demonstration.

Potential for ingestion by food-chain animals - A description of how food chain animals will be prevented from ingesting hazardous constituents and how this will be substantiated in the demonstration should be submitted by the applicant.

Part 4 - Field tests - If field tests will be used in the food chain crop demonstration, the applicant should describe how each test will be designed and conducted, including the information described below:

Plot configuration - A scale drawing showing the test plot layout, location, and dimensions should be presented.

Crop characteristics - The applicant should identify the plant species and variety of the crop, the edible portion of the crop, and existing information concerning plant uptake of the hazardous constituents present in the waste by the crop being tested or by similar crops.

Waste characteristics - The following information should be provided for each hazardous constituent present in the waste to be used during the demonstration (note that wastes used to make the demonstration should be similar to those proposed to be land treated):

- concentration,
- volatility,
- water solubility, and
- persistence.

Treatment zone characteristics - An evaluation of the effect of the following soil properties have on plant uptake of hazardous constituents should be made and presented in the application:

- soil pH,
- soil organic matter,
- soil texture, and
- soil cation exchange capacity.

Waste application rate and method - Application rates and method that will be used in the food-chain crop demonstration should be described in the application.

Sample collection procedures - The following sampling procedures should be described by the applicant: harvest or sample collection, method of collection, quantity of sample collected, methods for obtaining representative samples, and sample preservation and transport.

Analytical procedures - A detailed explanation of analytical methods, chain-of-custody control, and expected detection levels of the constituents being analyzed should be submitted as part of the demonstration program.

Data evaluation methods - The following factors should be evaluated and results presented as part of the food-chain crop demonstration:

- dilution effects due to growth,
- variability between individual plants,
- variability between waste application rate,
- bioconcentration through plant uptake,
- quantity taken up by crops,
- persistence of hazardous constituents in plant tissues, and
- concentration of hazardous constituents in edible portions.

8.4.2.2 Wastes Containing Cadmium--

Part 1 - If cadmium is contained in the wastes to be land treated on plots growing food chain crops, the applicant must submit the information presented in Table 8.4.1.

TABLE 8.4.1. EXAMPLE CADMIUM LOADING RATE TABLE

Waste name and EPA ID No.	Cd in waste mg/kg	Annual waste application rate kg/ha	Annual cadmium loading kg/ha
1.			
2.			
3.			

Part 2 - The applicant should submit the following if animal feed is the only food-chain crop to be grown:

- plant species and variety to be grown,
- antecedent or native soil pH,
- methods and frequency of soil pH adjustments (when required),
- management plan to control cadmium release from unit, and
- notice in land deed that soil has received cadmium-containing wastes.

The following should be submitted if animal feed will not be the only food chain crop grown:

- plant species and variety to be grown,
- antecedent or native soil pH,
- methods and frequency of soil pH adjustments (when required), and
- an operating plan for controlling applications of cadmium-containing waste(s).

8.4.3 Guidance on Evaluating Application Information

8.4.3.1 Food-Chain Crop Demonstration--

If food-chain crops, which include tobacco, crops grown for human consumption, and crops grown for animals whose products are consumed by humans, are to be grown, the reviewer should first determine whether the owner or operator plans to demonstrate: (1) that hazardous constituents will not be transferred to food or feed portions of the crop, or (2) that hazardous constituents will not occur in greater concentrations in or on the food or feed portions of crops grown on the treatment zone than in or on identical portions of the same crops grown on untreated soils under similar conditions

in the same region. [Note that growth of food-chain crops during the active years is optional.] As described in 8.4.2, the applicant may make the demonstration using field tests, greenhouse studies, available literature, or in the case of existing units, operating data. It is noted, however, that in most cases, field testing or operating data will be required to make the second demonstration option identified above.

In evaluating the demonstration, it is particularly important to verify that test conditions simulate actual or expected site operating conditions. Consequently, the permit reviewer should compare the site design and operating conditions described in Section 8.3 and the conditions under which greenhouse or field studies to make the food-chain crop demonstration will be performed. Detailed discussions of greenhouse and field test experimental designs are presented in Greenhouse Techniques for Soil-Plant-Fertilizer Research[1] and the Hazardous Waste Land Treatment manual[2], respectively. In addition, a qualified agronomist should be consulted to help evaluate experimental designs and plant species selection. Agronomists may be found at local colleges or universities or state agricultural experiment stations or extension service offices. Results obtained from the demonstration must be statistically valid to ensure that the demonstration was thorough and adequate to confirm that there will be no substantial risk to human health caused by the growth of food-chain crops in or on the treatment zone.

Part 270 requires that the owner or operator obtain a permit under §270.63 for conducting the food-chain crop demonstration. [See Section 8.1 for specific requirements for obtaining the demonstration permit.] The demonstration must be made for all hazardous constituents (i.e., constituents listed in Appendix VIII of Part 264) that are reasonably expected to be in or derived from the waste being or to be land treated.

As stated above, any greenhouse study or field test performed to make the required demonstration must simulate conditions that are representative of the geographical location of the proposed or existing land treatment unit. For existing units, it is likely that operating data will be used to make the required demonstration. The following sources may be consulted to obtain representative values of the environmental parameters to be simulated and to gain an understanding of the effects of waste application on plant growth and constituent uptake: Soil Conservation Service, Agricultural Extension Service and Experiment Stations; U.S. Weather Bureau; and local colleges and universities. In addition, information on plant uptake of various substances can be found in the literature (1,2,3,4,5,6), as required under §270.20(d)(1).

The applicant must provide a description of the plant species and varieties to be grown at the site. The description should include an explanation of the following for each plant species identified:

- translocation of hazardous constituents,
- growth season, and
- harvesting techniques and ultimate disposal.

Table 8.4.2 provides, for illustrative purposes, a brief listing of plant uptake mechanisms involved in the translocation of pesticides from soils. Similar information should be presented by the applicant. If the hazardous constituent is translocation within the plant, the applicant should document where and how the constituent will be transformed to a nonhazardous form, or if not, how it will be prevented from entering the food-chain such that it will not cause a substantial risk to human health.

If the owner or operator elects to demonstrate that the concentration of hazardous constituent(s) in or on the food or feed portions of crops grown in or on the treatment zone will not be greater than corresponding portions of identical crops grown on untreated soils under similar conditions in the same region, they must fully describe the characteristics of the comparison crop(s). The comparison crop essentially reflects the control group of a basic experimental design. The comparison crop serves as the base condition whereby any significant deviation from it would constitute a statistically meaningful change.

Growth of the comparison crop(s) under field or greenhouse conditions should be identical to the growth of the demonstration crop(s) with the exception that the hazardous waste(s) under review is not applied to the soil. The worksheet presented in Figure 8.4.1 or similar list developed by the reviewer, should be used to systematically determine that both groups of plants are grown under identical conditions, except for the difference of treated and untreated soils.

Figure 8.4.2 and 8.4.3 present worksheets that can be used to evaluate the adequacy of the permit application with regard to the information required for greenhouse tests and field tests performed to make the food-chain crop demonstrations, respectively.

With respect to identifying potential consumers or uses of particular crops, the following sources should be consulted:

- Local Agriculatural Extension Service
- State Department of Agriculture
- State University Agriculture Department
- Buyers such as grain dealers and co-operatives
- Local farmers

8.4.3.2 Wastes Containing Cadmium--

Special interest is paid to cadmium because of its potential transfer through the food chain and adverse human health effects. Land treatment of cadmium-containing municipal and industrial wastes can result in an accumulation of cadmium in the soil.

TABLE 8.4.2. PLANT UPTAKE AND TRANSLOCATION OF PESTICIDES FROM SOILS

Insecticide	Absorbed by root	Translocated from root	Compounds found after translocation	
			Parent	Metabolites
Aldrin	Yes	Yes	Yes	Yes
Dieldrin	Yes	Yes	Yes	Probable
Isodrin	Yes	Probable	Improbable	Yes
Endrin	Yes	Yes	Yes	Yes
Heptachlor	Yes	Yes	Yes	Yes
Heptachlor epoxide	Yes	Yes	Yes	Unknown
Chlordane	Yes	Improbable	Unknown*	Unknown
Endosulfan	Yes	Yes	Yes	Unknown
Toxaphene	Probable	Improbable	Unknown*	Unknown
BHC	Yes	Yes	Yes	Yes
Lindane	Yes	Yes	Yes	Yes
DDT	Yes	Probable	Probable	Yes
Diazinon	Yes	Yes	Yes	Probable
Dimethoate	Yes	Probable	Unknown	Probable
Disulfoton	Yes	Yes	Yes	Yes
Phorate	Yes	Yes	Yes	Yes
Parathion	Yes	Probable	Probable	Unknown
Chloroneb	Yes	Yes	Yes	Yes
Arsenic	Yes	Yes	Yes	---
Lead	Yes	Yes	Yes	---

*None, or has never been investigated.

Adapted from Phung et al. (3).

Untreated Soil Case	Environmental Parameter/Condition	Treated Soil Case
_____	Plant Species	_____
_____		_____
_____		_____
_____		_____
_____	Air Temperature	_____
_____	Air Humidity	_____
_____	Soil Temperature	_____
_____	Soil Moisture	_____
_____	Soil pH	_____
	Soil Fertility:	
_____	Nitrogen	_____
_____	Phosphorous	_____
_____	Potassium	_____
_____	Soil Texture	_____
_____	Cation Exchange Capacity	_____
_____	Soil Depth	_____
_____	Insolation (hours daily)	_____

Figure 8.4.1. Worksheet to evaluate similarities of conditions under which food-chain crop demonstrations are made.

Has the applicant identified the crops, including potential food or feed portions, to be grown to make demonstration?

yes n

Are the hazardous constituents of the waste and respective concentrations identified?

yes no

Does the application provide an explanation of how the potential for crop uptake will be assessed and describe proposed test procedures (see specific requirements outlined in 8.4.2.1 Part 2)?

yes no

Has the applicant described how external contamination of the food or feed portion of the crop will be precluded?

yes no

Does the application contain a description of how food-chain animals will be prevented from ingesting hazardous constituents?

yes no

Figure 8.4.2. Worksheet to assess food-chain crop demonstration made by greenhouse tests.

Has the applicant presented the layout, location, and dimensions of test plots on a scale drawing?	yes	no
Does the application identify the species and variety of the crop, the edible portion of the crop, and previous information concerning hazardous constituent uptake?	yes	no
Are the concentration of hazardous constituents in the waste, the volatility, and water solubility of the hazardous constituents, and the persistence of these constituents in soil described in the application?	yes	no
Has the applicant presented an evaluation of the soil properties that will affect plant uptake of hazardous constituents?	yes	no
Has the applicant described waste application rates and methods of application?	yes	no
Does the application contain a description of all sample collection procedures associated with the demonstration?	yes	no
Are analytical procedures and sensitivities described in the application?	yes	no
Has the applicant provided an explanation of the statistical methods to be used to evaluate results and identified how results will be presented?	yes	no

Figure 8.4.3. Worksheet to assess food-chain crop demonstration made by field tests.

The presence of cadmium in the waste to be applied will have been determined by the waste analysis required under the Treatment Demonstration (see subsection 8.1). If cadmium will not be present in the waste to be land treated, proceed to subsection 8.5. However, if cadmium is present in the waste continue with the review under this section.

The owner or operator must comply with certain management practices that are designed to limit the entry of cadmium into the food chain. The specific requirements of §264.276(b) that must be compiled with (if the waste to be applied contains cadmium) are presented above. To demonstrate compliance with the requirements of §264.276(b), the owner or operator must describe how he will maintain soil pH and cation exhange capacity at prescribed levels. Section 8.2.3 provides information on evaluating these two parameters. An informative discussion of the relationship between food-chain crops and cadmium is presented in the Office of Solid Waste's Guidance Manual for the Classification of Solid Waste Disposal Facilities[7] and U.S. EPA's Process Design Manual for Land Treatment of Municipal Wastewater.[8]

One of the more important concerns at a site where cadmium is contained in the waste to be treated is the facility operating plan. The operating plan designed to preclude ingestion by humans and prevent possible health hazards resulting from alternative future uses of the land should be reviewed to determine the chain of possession of the crop after harvest. The distribution of any food-chain crop grown at the land treatment unit must be carried out such that there is no chance of ingestion by humans (e.g., it could be sold directly to a dairy farm or feed lot where it would be fed to cattle).

Concerning possible health hazards from cadmium entering the food-chain as a result of alternative future land uses, the site should not be used as vegetable farms or home vegetable gardens that could result in significant dietary increase of cadmium. Acceptable provisions in the facility operating plan could include dedication of the site as a public park following closure or removal of the contaminanted soil. Figure 8.4.4. presents a worksheet that can be used to evaluate the adequacy of permit applications for land treatment units that will or are handling cadmium-containing waste.

8.4.4 Draft Permit Preparation

Condition C of Module XIV (see Section 4) outlines the conditions to be specified in the permit. Foremost in permit preparation is the requirement that the permit writer specify that only those food-chain crops the owner or operator has demonstrated will not have contaminated levels above those found in similar crops grown on untreated soils under similar circumstances in the same region may be grown at the land treatment facility. Conditions of the permit relating to food-chain crops may be stipulated in the permit by reference to portions of the permit application. This pertains specifically to information describing:

- plant species,
- waste characteristics,

Has the applicant specified the concentration of cadmium in wastes to be applied, annual application rates, and soil loading of cadmium resulting from the application rates used?	yes	no
Does the application provide a description of the following:		
Species and variety of crop to be grown?	yes	no
Initial or native soil pH?	yes	no
Methods and frequency for adjusting soil pH (if necessary)?	yes	no
If animal feed is the only food-chain crop produced, has the applicant provided a description of an operating plan for preventing direct human consumption of produced animal feed and a plan to safeguard against cadmium entering the human food-chain resulting from future alternative land use?	yes	no
Also, has the owner or operator identified that the land deed will be changed to indicate that the site has received elevated applications of cadmium and that food-chain crops should not be grown except in accordance with §264.276(b)(2)?	yes	no
If animal feed will not be the only food-chain crop produced, does the application include an operating plan for controlling applications of cadmium to the soil?	yes	no

Figure 8.4.4. Worksheet for evaluating adequacy of permit application where waste(s) containing cadmium will be or are being treated.

- assessment of potential crop uptake,
- potential for external human contamination and ingestion by food-chain animals,
- sampling and analytical procedures, and
- treatment zone characteristics (if field study).

Under the food-chain crop provisions, the permit must specify how the site will be managed to limit the entry of cadmium, when contained in the waste, applied into the food chain. The permit should specify loading rates to prevent the build up of cadmium in the treatment zone soil. As with the food-chain permit conditions, portions of the Part B permit application may be referenced in the permit to stipulate conditions for controlling applications of cadmium-containing waste.

Condition C of Module XIV states that:

> If the Permittee has successfully demonstrated in accordance with 40 CFR 264.276(a) and (b) that there is no substantial risk to human health from the growth of food-chain crops in or on the treatment zone, the permit writer may allow the growth of such crops. This decision should be documented in the administrative record. When cadmium is contained in wastes applied to the treatment zone, the permit writer should include a condition that requires compliance with §264.276(b). This condition should reference the Attachment required by §270.20 which must demonstrate how the requirements of §264.276(b) will be complied with.

8.4.5 References

1. Allen, S. E., et al. Greenhouse Techniques for Soil-Plant-Fertilizer Research. Bulletin Y-104, National Fertilizer Development Center, Tennessee Valley Authority, Muscle Shoals. Alabama. May 1976.

2. Brown, K. W., et al. Hazardous Waste Land Treatment. Prepared by K. W. Brown and Associates, Inc. for U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory. Solid and Hazardous Waste Research Division. Cincinnati, OH. Report No. SW-874. February 1983.

3. Phung, T., et al. Land Cultivation of Industrial Wastes and Municipal Solid Wastes: State-of-the-Art Study. Volume I, Technical Summary and Literature Review. Prepared by SCS Engineers for U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, OH. EPA-600/2-78-140a. August 1978.

4. Sanks, R. L., and T. Asano, eds. Land Treatment and Disposal of Municipal and Industrial Wastewater. Ann Arbor Science, Ann Arbor, Michigan. 1976.

5. Overcash, M. R., and D. Pal. Design of Land Treatment Systems for Industrial Wastes - Theo nd Practice, Ann Arbor Science, Ann Arbor, Michigan. 1981.

6. Sidle, R. C., et al. Heavy Metals Application and Plant Uptake in a Land Disposal System for Wastewater. J. Environ. Qual., Vol. 5, No. 1. 1976. pp. 97-102.

7. U.S. Environmental Protection Agency. Guidance Manual for the Classification of Solid Waste Disposal Facilities. Office of Solid Waste. Washington, D.C. November 1979.

8. U.S. Environmental Protection Agency. Process Design Manual for Land Treatment of Municipal Wastewater. EPA Report-625/1-77-008. October 1977.

8.5 ESTABLISHMENT OF VEGETATIVE COVER AT CLOSURE

8.5.1 Federal Requirement

Section 270.20(f) requires the owner or operator to include in the permit application (as part of the facility closure plan):

> "A description of the vegetative cover to be applied to closed portions of the facility, and a plan for maintaning such cover during the post-closure care period, as required under §264.280(a)(8) and §264.280(c)(2). This information should be included in the closure plan and, where applicable, the post-closure care plan submitted under §270.14(b)(13)."

The corresponding Part 264 standards, §264.280(a)(8) and §264.280(c)(2), require that the owner or operator:

§264.280(a)

> "(8) Establish a vegetative cover on the portion of the facility being closed at such time that the cover will not substantially impede degradation, transformation, or immobilization of hazardous constituents in the treatment zone. The vegetative cover must be capable of maintaining growth without extensive maintenance."

and,

§264.280(c)

> "(2) Maintain a vegetative cover over closed portions of the facility;"

8.5.2 Summary of Necessary Application Information

[Note: This item should also be included in the closure and post-closure care plans described in Sections IV 2(c) and (d) of this document]. In addition to providing the following information, the applicant should submit a written description of procedures employed to establish and maintain a vegetative cover on closed portions of the land treatment unit:

- common and scientific name and species and variety of plants to be established as the cover crop,
- documentation of selected plant species viability, and
- identification of minimum percentage of cover that will be maintained.

8.5.3 Guidance on Evaluating Application Information

The primary purpose of establishing a vegetative cover at closure is to minimize wind and water erosion. Plant root systems stabilize the surface soil, minimizing erosion. Secondarily, the plant cover can aid in the treatment of hazardous constituents.

Section 264.280(a)(8) requires the owner or operator to establish a vegetative cover at such time that the cover will not substantially impede degradation, transformation, or immobilization of hazardous constituents. Because certain operating practices to maximize treatment, such as tilling, cannot be performed without damaging or destroying the vegetative cover, the owner or operator must postpone seeding until sufficient waste treatment has occurred following the last application. Results from unsaturated zone monitoring, treatment zone analyses, and data on run-off liquid quality, should be used in judging the degree of treatment achieved. Correspondingly, once the cover is established, operating practices to enhance waste treatment that are inconsistent (e.g., tilling) with establishment and maintenance of the vegetative cover should be discontinued.

It is important to note that the owner or operator can be exempted from the vegetative cover closure requirement of §264.280(a)(8) and post-closure care requirements of §264.280(c)(2) if it is demonstrated that the level of hazardous constituents within the treatment zone is not significantly greater than background values. Procedures to make this demonstration are similar to corresponding standards used for unsaturated zone monitoring under §264.278 (see Section 8.2.3.6). However, only soil core monitoring is necessary, not soil-pore liquid monitoring.

The RCRA Guidance Document for Land Treatment[1] describes a scheme for demonstrating that no statistically significant increases in hazardous constituents over background levels exist in the entire treatment zone. The document also describes the sampling protocol for unsaturated zone monitoring during the post-closure care period. The suggested scenario, for soil-core monitoring, involves a geometrically progressive sampling schedule at 1/2, 1, 2, 4, 8, 16, and 30 years after the post-closure care period begins.

Soil core samples should be taken at various depth increments within the treatment zone, rather than just below the treatment zone as required for unsaturated zone monitoring during the active years. Concerning soil-pore liquid monitoring, which only continues for 90 days after the last waste application, at least two sampling events should occur. The reason for this latter condition is that the Agency expects that the fast-moving constituents that the soil pore liquid monitoring system is designed to detect should migrate out of the land treatment zone soon after these constituents are applied if they are to migrate at all.

The owner or operator of the land treatment unit may be exempted from Subpart F requirements (see Section 5) if he or she can demonstrate the following:

1. that hazardous constituents are no longer present in the treatment zone at statistically significant amounts, and

2. that no hazardous constituents (or PHCs) have migrated below the treatment zone during the active life of the land treatment unit.

As mentioned above, results from unsaturated zone monitoring and treatment zone analyses may be used to document these conditional requirements.

Although §270.20(f) only specifically calls for information on the establishment and maintenance of a vegetative cover, the applicant must also submit information on all of the other closure and post-closure requirements of §264.280(a) for closure and §264.280(c) for post-closure. The application should contain a description of how these requirements will be complied with. In general, these requirements simply specify that design and operational activities performed during the facility's active years be continued or maintained during closure and post-closure care periods. Briefly, the operations, other than establishment and maintenance of a vegetative cover, to continue are:

Closure	Post-Closure
• Sustain waste degradation transformation, and immobilization*	• Sustain waste degradation, transformation, and immobilization*
• Continue to minimize run-off	• Maintain run-on control system
• Maintain run-on control system	• Maintain run-off management system
• Maintain run-off management system	• Maintain wind dispersal controls (if needed)
• Continue to control wind dispersal (if needed)	• Continue food-chain crop management
• Continue food-chain crop management	• Continue unsaturated zone monitoring‡
• Continue unsaturated zone monitoring‡	

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*Except to the extent that such operations are inconsistent with the establishment of a vegetation cover. Operations include tilling of the soil, control of soil pH and moisture content, and fertilization.

‡Soil-pore liquid monitoring may be terminated 90 days after the last waste application.

Owners or operators of land treatment facilities must also comply with the general closure requirements provided under Subpart G. These requirements address the closure performance standard (§264.111), the closure plan (§264.112), time allowed for closure (§264.113), disposal or decontamination of equipment (§264.114), certification of closure (§264.115), post-closure care period (§264.117), post-closure plan (§264.118), and notices (§264.119 and §264.120). In addition, the applicant must also comply with the applicable general information requirements of §270.14(b)(13).

Even though the exemptions identified above may be implemented, establishment of a vegetative cover is a good management practice. A vegetative cover will control wind dispersal of particulate matter and provide soil stabilization which will minimize erosion.

The purposes of establishing and maintaining a vegetative cover are to:

- physically stabilize the soil,
- reduce infiltration of precipitation,*
- retard surface run-off,
- minimize wind and water soil erosion, and
- enhances site appearance.

The success of establishing a vegetative cover hinges on selecting plant species that have good seed germination and growth characteristics and are indigneous to the area. In order to ensure continued compliance with the post-closure requirement, plant species selected must also be easily maintained without extensive maintenance (e.g., frequent fertilization, liming, and watering).

To provide an opportunity for plant species to become established, the top soil layer comprising the root zone must be conditioned both physically and chemically to ensure a high success rate of seed germination and vigorous growth. The soil must provide adequate moisture, nutrients, and aeration. Many treatment zone soils may require conditioning prior to seeding and some level of periodic maintenance following germination. Soil conditioning includes:

- addition of organic matter,
- periodic cultivation,
- chemical nutrient addition, and
- soil pH and moisture control.

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*Infiltration is seasonally reduced by intercepting and evapotranspiring some of the precipitation.

In cases where the treatment zone soil is not acceptable, even after conditioning, for vegetative growth, it may be amended by the addition of clean top soil. Actually, in some situations, factors promoting plant growth and thus improve the likelihood for the establishment of a vegetation cover will be enhanced by the waste applications. For example, the following benefits can result from the waste disposal activity: an increase in soil organic matter content, soil pH, and potassium, calcium, magnesium, and zinc levels.

In order to determine types of vegetation that would be suitable for a particular site, soils analyses must be conducted. Investigations should be made to determine pH and fertility of the treatment zone surface soil (down to 5 to 10 cm) or soil brought into be used for cover. Methods for performing these analyses are generally available from county offices of the Soil Conservation Service.

Experiences gained with the land cultivation of municipal solid waste and industrial wastewater and sludges have revealed that nitrogen and phosphorus deficiencies can occur in the soil which will adversely affect seed germination, growth, and metal uptake by plants.[2,3,4,5] In order to establish and maintain the vegetative cover required, soil amendments using chemical or natural fertilizers will likely be necessary.

Chapter 8 of the Hazardous Waste Land Treatment Manual[2] presents an in-depth discussion on the establishment of a vegetative cover at closure. Issues addressed in the manual include management objectives, species selection, seedbed preparation, seeding and plant establishment, and soil fertility.

To ensure successful establishment and ease of maintenance, plant species selection should be based on suitability with local climatic (seasonal) and soil conditions. Information regarding plant species selection and cultivation practices can be obtained from agronomists of the State Agricultural Extension Service, U.S.D.A. or plant science professors at nearby colleges and universities.

As discussed in the RCRA Guidance Document,[1] the Agency believes that, in many cases, the closure activities at land treatment units and establishment of a vegetative cover may be accomplished within 180 days. However, each facility will be unique and should be evaluated on a case-by-case basis.

A key concern when establishing the vegetation is to assure adequate cover. The surface soil should be completely covered to avoid bare spots that may initiate soil erosion which could expand to the extent that widespread erosion and elimination of portions of the vegetative cover results.

The first steps to assuring adequate cover are seeding rate and timing. The seeding rate, that is the quantity of seed applied per arce, depends on the seed species, method of seeding, and surface soil conditions at the time of closure. The current practice for calculating seeding rates is based on the quantity (pounds) of seed required to produce 20 live seeds per foot.[2]

Other seeding rates may be acceptable, however. The reviewer should contact the local agricultural extension service office or Soil Conservation Service for information on proven seeding rates for the region.

The timing of seeding will depend on whether the plant species selected is a cool or warm season species. Cool season species do best when planted in late summer or early fall. Warm season species are generally planted during late winter or early spring.[2]

The chosen mixture of seeds and soil amendments can be hydroseeded, that is, sprayed onto the land surface in a water mixture. Hydroseeding is one of the least expensive and the most cost-effective method of seeding a landfill. Following seeding, a mulch consisting of hay, straw, or wood chips can be blown onto the surface to stabilize it while the seeds germinate. On steeper slopes, netting or pegging may be necessary to hold the seeds, soil, and mulch in place until growth is established (approximately 1 to 2 years).[6]

Once a cover of vegetation is started and a stable, extensive root system develops, organic matter and decomposition processes develop a layer of humus capable of perpetuating the cover vegetation.[7] However, erosion forces, burrowing animals, and maintenance equipment may damage parts of this cover of soil and vegetation. The application should include a description of the provisions for maintenance, specifically for transplanting grass sods, planting new seeds or shrubs, and replacing eroded soil during the post-closure care period.

Plant species selected should be easily established and maintained, and relatively tolerant of potentially phytotoxic waste constituents. Discussions of the phytotoxicity of various waste constituents are presented in the literature.[2,3,4,5,8,9,10] Disease and insect resistance should also be considered during vegetation selection.

Although it is not a specific requirement, field studies investigating seed germination, root development, vegetative growth, and plant viability should be conducted on small plots of the treatment zone during its active life. Results obtained from such studies will be valuable for the selection of the best vegetative cover to establish during closure. It is suggested that this topic be discussed during the pre-application meeting.

EPA has developed a 39-step approach for evaluating the adequacy of closure and post-closure plans and engineering reports with respect to hazardous waste landfills.[11] The review procedure is specifically intended for use by staff members in the Regional EPA offices and state offices. Although the cover evaluation procedures are directed towards landfills, certain aspects relate directly to the closure of land treatment facilities. Specifically, these include steps 25 through 39, described as follows:

Closure:
- Step 25. Evaluate Soil
- Step 26. Evalute pH Level
- Step 27. Evaluate Nitrogen and Organic Matter
- Step 28. Evaluate Other Nutrients
- Step 29. Evaluate Species Selection

Step 30. Evaluate Shrubs and Trees
Step 31. Evaluate Time of Seeding
Step 32. Evaluate Seed and Surface Protection

Post-Closure: Step 33. Evaluate Design/Maintenance
Step 34. Evaluate Maintenance of Vegetation
Step 35. Evaluate Provisions for Condition Surveys
Step 36. Evaluate Plan for Erosion Damage Repair
Step 37. Evaluate Plan for Vegetation Repair
Step 38. Evaluate Plan for Drainage Renovation
Step 39. Evaluate Plan for Other Cover Deterioration

Evaluate vegetation (Steps 25-32) - Establishment and maintenance of vegetation requries an evaluation of soil type, nutrient and pH levels, climate, species selection, mulching, and seeding time. Species should be selected on the basis of environmental and biological strengths and limitations.

Evaluate maintenance procedure (Steps 33-35) - Regular maintenance intervals should be planned to repair erosion damage and to maintain the vegetative cover. Provisions should also be made for site monitoring by a qualified individual to periodically inspect the cover condition.

Evalute contingency plan (Steps 36-39) - A contingency plan should be established to deal with future unforeseen problems such as excessive wind and water erosion, loss of vegetation, and drainage system failures. The permit reviewer should evaluate the effectiveness of the applicant's post-closure plan to address such problems in a timely manner.

8.5.3 Draft Permit Preparation

In addition to compliance with the closure plan requirements of §264.112, the permit issued must specify that the land treatment unit be closed in accordance with 40 CFR §264.280. If the Permittee successfully demonstrates in accordance with §264.280(d) that the level of hazardous constituents in the treatment zone soil does not exceed the background value of those constituents by a statistically significant amount, he is not subject to regulation under §§264.280(a)(8) and (c). The Permittee who satisfies the requirements of §264.280(d) is also not subject to regulation under Subpart F, if the monitoring program established under Condition E of Permit Module XIV indicates that hazardous constituents have not migrated beyond the treatment zone during the active life of the land treatment unit. Condition M of Permit Module II outlines general facility closure requirements.

Conditions of the permit, which can be implemented by reference to portions of the Part B permit application, should specify the following:

- plant species to be grown,
- procedures to ensure vegetative establishment, and
- techniques to maintain the cover during the post-closure care period.

Depending on the site and hazardous constituents applied, particularly persistent organic compounds, the permit writer may wish to state in the facility permit, the level of treatment, specifically degradation or transformation, required prior to start of post-closure care. The degree of treatment achieved may be determined from unsaturated zone monitoring results, treatment zone analyses, and run-off liquid quality data.

8.5.5 References

1. U.S. Environmental Protection Agency. RCRA Guidance Document, Land Treatment. Draft Report. Office of Solid Waste. January 1983.

2. U.S. Environmental Protection Agency. Hazardous Waste Land Treatment. Prepared by K. W. Brown and Associates, Inc., for U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Solid and Hazardous Waste Research Division. Cincinnati, OH. Report No. SW-874. 1983.

3. Phung, T., et al. Land Cultivation of Industrial Wastes and Municipal Solid Wastes: State-of-the-Art Study. Volume I. Technical Summary and Literature Review. Prepared by SCS Engineers for U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, OH. EPA-600/2-78-140a. August 1978.

4. Overcash, M. R., and D. Pal. Design of Land Treatment Systems for Industrial Wastes, Theory and Practice, Ann Arbor Science. Ann Arbor, Michigan. 1979.

5. Parr, J. F., et al. Land Treatment of Hazardous Wastes, Noyes Data Corporation, Park Ridge, New Jersey. 1983.

6. Tolman, A. L., et al. Guidance Manual for Minimizing Pollution from Waste Disposal Sites. Prepared by A. W. Martin, Associates, Inc. for U.S. Environmental Protection Agency, Municipal Environmetal Research Laboratory, Cincinnati, OH. EPA Report No. EPA-600/2-78-142. August 1978.

7. Lutton, R. J. Evaluating Cover Systems for Solid and Hazardous Waste, Prepared by U.S. Army Engineer Waterways Experiment Station for U.S. Environmental Protection Agency, Solid and Hazardous Waste Research Division, Cincinnati, OH. EPA Report SW-867. September 1982.

8. Page, A. L. Fate and Effects of Trace Elements in Sewage Sludge when Applied to Agriculatural Lands. A Literature Review Study. U.S. Environmental Protection Agency, EPA-670/2-74-005. January 1974.

9. Allaway, W. H. Agronomic Control Over Environmental Cycling of Trace Elements, Adv. Agron. 20:235-274. 1968.

10. Chaney, R. L., and P. M. Giordano. Microelements as related to plant deficiencies at toxicities. pp. 234-279. In: L. F. Elliot and R. J. Stevenson (ed.) Soils for Management of Organic Wastes and Waste Waters. American Society of Agronomy, Madison, WI. 1977.

11. U.S. Environmental Protection Agency. Evaluating Cover Systems for Solid and Hazardous Waste, Second Edition. EPA Report No. SW-867. September 1982.

8.6 SPECIAL REQUIREMENTS FOR IGNITABLE OR REACTIVE WASTES

8.6.1 Federal Requirement

Section 270.20(g) states:

> "If ignitable or reactive wastes will be placed in or on the treatment zone, an explanation of how the requirements of §264.281 will be complied with."

The corresponding Part 264 standards, §264.281 states that the owner or operator must not apply ignitable or reactive waste to the treatment zone unless:

> "(a) The waste is immediately incorporated into the soil so that:
> (1) The resulting waste, mixture, or dissolution of material no longer meets the definition of ignitable or reactive waste under §§261.21 or 261.23 of this chapter; and
> (2) Section 264.17(b) is complied with; or
> (b) The waste is managed in such a way that it is protected from any material or conditions which may cause it to ignite or react."

Section 261.21 states:

> "(a) A solid waste exhibits the characteristic of ignitability if a representative sample of the waste has any of the following properties:
> (1) It is a liquid, other than an aqueous solution containing less than 24 percent alcohol by volume and has flash point less than 60°C (140°F), as determined by a Pensky-Martens Closed Cup Tester, using the test method specified in ASTM Standard D-93-79 or D-93-80 (incorporated by reference, see §260.11), or a Setaflash Closed Cup Tester, using the test method specified in ASTM Standard D-3278-78 (incorporated by reference, see §260.11), or as determined by an equivalent test method approved by the Administrator under procedures set forth in §§260.20 and 260.21.
> [261.21(a)(1) amended by 46 FR 35247, July 7, 1981]
> (2) It is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard.
> (3) It is an ignitable compressed gas as defined in 49 CFR 173.300 and as determined by the test methods described in that regulation or equivalent test methods approved by the Administrator under§§260.20 and 260.21.
> (4) It is an oxidizer as defined in 49 CFR 173.151.
> (b) A solid waste that exhibits the characteristic of ignitability, but is not listed as a hazardous waste in Subpart D, has the EPA Hazardous Waste Number of D001."

Section 261.23 states:

"(a) A solid waste exhibits the characteristic of reactivity if a representative sample of the waste has any of the following properties:

(1) It is normally unstable and readily undergoes violent change without detonating.

(2) It reacts violently with water.

(3) It forms potentially explosive mixtures with water.

(4) When mixed with water, it generates toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment.

(5) It is a cyanide or sulfide bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment.

(6) It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement.

(7) It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.

(8) It is a forbidden explosive as defined in 49 CFR 173.51, or a Class A explosive as defined in 49 CFR 173.53 or a Class B explosive as defined in 49 CFR 173.88.

(b) A solid waste that exhibits the characteristic of reactivity, but is not listed as a hazardous waste in Subpart D, has the EPA Hazardous Waste Number of D003."

Section 264.17(b) states:

"(b) Where specifically required by other Sections of this Part, the owner or operator of a facility that treats, stores or disposes ignitable or reactive waste, or mixes incompatible waste or incompatible wastes and other materials, must take precautions to prevent reactions which:

(1) Generate extreme heat or pressure, fire or explosions, or violent reactions;

(2) Produce uncontrolled toxic mists, fumes, dusts, or gases in sufficient quantities to threaten human health or the environment;

(3) Produce uncontrolled flammable fumes or gases in sufficient quantities to pose a risk of fire or explosions;

(4) Damage the structural integrity of the device or facility;

(5) Through other like means threaten human health or the environment.

(c) When required to comply with paragraphs (a) or (b) of this Section, the owner or operator must document that compliance. This documentation may be based on references to published scientific or engineering literature, data from trial tests (e.g., bench scale or pilot scale tests), waste analyses (as specified in §264.13), or the results of the treatment of similar wastes by similar treatment processes and under similar operating conditions."

8.6.2 Summary of Necessary Application Information

The applicant should submit a detailed written plan for managing ignitable or reactive wastes that will be placed in or on the treatment zone. The plan should include:

- name and chemical composition of waste,
- provisions for immediate soil incorporation of waste,
- test results showing that wastes are no longer ignitable or reactive following soil incorporation, and
- handling procedures and safety precautions for preventing conditions which may cause the waste to ignite or react.

8.6.3 Guidance on Evaluating Application Information

The provisions of §264.281 require good operating practice to ensure the safe handling of any ignitable or reactive wastes that might be applied to the land treatment unit. As stated in the Part 264 standard, the owner or operator must handle such waste such that it is incorporated into the soil immediately, or managed in a way such that the material will not ignite or react. The management techniques to meet the latter condition will vary depending on specific waste types.

If an applicant provides information that none of the wastes intended for land treatment are reactive or ignitable, the provisions discussed in this section do not apply. Information that would be acceptable includes the results of tests or analyses conducted on the wastes by the land treatment facility owner or operator, or the waste generator. Documentation based on information or data in the scientific or engineering literature is also acceptable. If the applicant has demonstrated that all wastes are neither ignitable nor reactive, the permit writer must indicate in the permit that ignitable or reactive wastes are not permitted for receipt or application at the land treatment facility.

The characteristic of ignitability is exhibited by a solid waste if it has any of the four properties listed in §261.21(a) (see Section 8.6.1 above). Specifically, §261.21(a)(1) addresses liquids, §261.21(a)(2) addresses nonliquids, §261.21(a)(3) addresses compressed gases, and §261.21(a)(4) addresses oxidizers. The provisions of §261.21(a)(1) identify three ASTM standard methods that can be used to determine ignitability. They are:

- ASTM Standard D-93-79
- ASTM Standard D-93-80
- ASTM Standard D-3278-78

These methods are also described in Section 2.1.1 of Test Methods for Evaluating Solid Waste, Physical/Chemical Methods.[1] Descriptions and test methods for ignitable compressed gases and oxidizers are also described in Section 2.1.1 of the referenced report.

The characteristic of reactivity is exhibited by a solid waste if it has any of the eight properties listed in §261.23(a) (see Section 8.6.1 above). Those properties are based largely on the definition employed by the National Fire Protection Association. The NFPA's headquarters are in Batterymarch Park, Quincy, MA 02269 and there is also a Washington, D.C. Office. Telephone numbers are:

General and Executive Offices	(617) 328-9290
Publication Sales	(617) 770-3002
Washington, D.C. Office	(202) 484-8200

Detailed information on identification and testing of reactive wastes is provided in Section 2.1.3 of Test Methods for Evaluating Solid Waste, Physical/Chemical Methods.

In addition to using the methods referenced in the regulations, the permit applicant may use other methods to determine ignitability or reactivity if he has petitioned and received approval from the Administrator, as allowed under §260.20 and §260.21. If the permit reviewer encounters methodologies whose acceptability can not be determined, the Manager of the Waste Analysis Program (WH-565), Waste Characterization Branch, Office of Solid Waste, Washington, D.C. 20460 (202) 755-9187 should be contacted for assistance.

Documentation that the precautions of §264.17(b) will be effective is required by §264.17(c). Specifically, §264.17(c) requires that;

> "When required to comply with paragraphs (a) or (b) of the Section, the owner or operator must document that compliance. This documentation may be based on references to published scientific or engineering literature, data from trial tests (e.g., bench scale or pilot scale tests), waste analyses (as specified in §264.13), or the results of the treatment of similar wastes by similar treatment processes and under similar operating conditions."

The owner or operator of a land treatment facility who is treating ignitable or reactive wastes must document that the treatment employed will not itself be hazardous. The permit application may be judged deficient if the required documentation is not submitted or if it is judged to be inadequate.

Figure 8.6.1 presents the major topics that are discussed in this section. The permit reviewer should first determine which of the technical topics are applicable to the facility and operation of concern. For instance, if the applicant proposes to manage the waste in conformance with the requirements of §264.281(b), than the discussion about treating, rendering, or

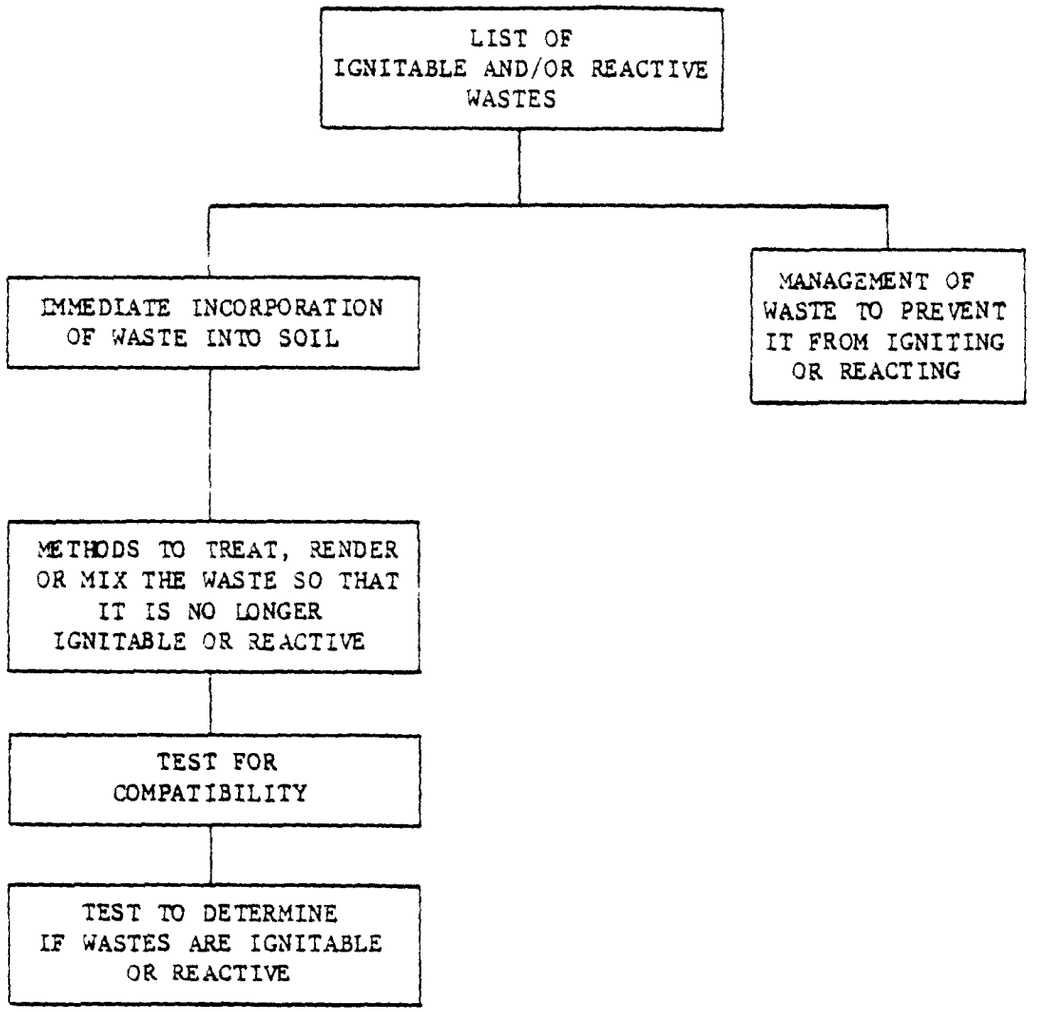

Figure 8.6.1. Flow diagram for evaluating the tecnnical adequacy of the application for disposal of ignitable or reactive waste.

mixing the waste so that it is no longer ignitable does not apply. If any of the associated topics are not adequately addressed by the applicant, the application and the proposed disposal methods may be technically deficient.

8.6.3.1 Lists of Ignitable and Reactive Wastes--

In Part 261, Subpart D, [Lists of Hazardous Wastes], ignitable wastes are denoted by an "(I)" and reactive wastes are denoted with an "(R)". Table 8.6.1 lists the hazardous wastes, by EPA Hazardous Waste number, that are identified in Subpart D as being ignitable. Table 8.6.2 lists the hazardous wastes, by EPA Hazardous Waste number, that are identified in Subpart D as being reactive. At a minimum, if the applicant indicates that any of these wastes will be treated at the facility, he must document how compliance with §264.281 will be achieved.

The permit reviewer should refer to A Method for Determining the Compatibility of Hazardous Wastes[2] for assistance in evaluating the application. This reference provides a list of 174 chemicals which are extremely reactive and therefore should not be mixed with water, or other chemicals or waste materials. If these "extremely reactive" compounds are mixed with water or most other compounds, heat may be generated, or toxic and/or flammable gases may be produced. In addition, explosions may occur, or highly unstable mixtures may result.

If the following materials are mixed with water, flammable gas will be generated:

- Metals, such as sodium and potassium
- Nitrides
- Sulfides, Inorganic
- Strong Reducing Agents

Reference 2 also provides a list of materials which are combustible and flammable and a list of materials which are explosive.

8.6.3.2 Methods to Treat, Render, or Mix Waste so that it is no longer Ignitable or Reactive--

There are a number of methods available to treat, render, or mix wastes so that they are no longer ignitable or reactive. Several treatment processes which previously were only used in the organic or inorganic chemical industry are being considered for broader applications in the treatment of hazardous waste. Over 50 processes have been demonstrated to be applicable to hazardous waste treatment, although the technical and economic feasbility of a number of these processes has not been demonstrated on a commercial scale. Table 8.6.3 identifies several of the most promising nonbiological treatment methods along with general information regarding feed stream requirements, output streams, and the current state of technology.[3-8] The applicant may propose to employ one or a combination of these methods to treat ignitable or reactive wastes prior to application.

TABLE 8.6.1. IGNITABLE WASTES

EPA hazardous waste No.	Hazardous waste
F003	Spent nonhalogenated solvents
F005	Spent nonhalogenated solvents
U001	Acetaldehyde
U112	Acetic acid, ethyl ester
U002	Acetone
U003	Acetonitrile
U008	Acrylic acid
U012	Aniline
U012	Benzenamine
U019	Benzene
U239	Benzene, dimethyl-
U056	Benzene, hexahydro-
U055	Benzene, (1-methylethyl),
U169	Benzene, nitro-
U085	2,2-bioxizane
U031	t-butanol
U159	2-butanone
U074	2-butene, 1,4-dichloro-
U031	n-butyl alcohol
U156	Carbonochloridic acid, methyl ester
U055	Cumnene
U056	Cyclohexane
U057	Cyclohexanone
U074	1,4-dichloro-2-butene
U085	1,2:3,4-diepoxybutane
U092	Dimethylamine
U110	Dipropylamine

(continued)

TABLE 8.6.1 (continued)

EPA hazardous waste No.	Hazardous waste
U001	Ethanol
U008	Ethanenitrile
U117	Ethane, 1,1-oxybis
U112	Ethyl acetate
U113	Ethyl acrylate
U115	Ethlene oxide
U117	Ethyl ether
U125	2-furancarboxaldehyde
U213	Furan, tetrahydro-
U125	Furtural
U124	Furfuran
U140	Isobutyl alcohol
152	Methacrytonitrile
U092	Methanamide, N-methyl
U045	Methane, cnloro-
U153	Methanethiol
U154	Methanol
U154	Metnyl alcohol
U186	1-methyl butadiene
U045	Methyl chloride
U156	Methyl chlorocarbonate
U159	Methyl ethyl ketone
U161	Methyl isobutyl ketone
U162	Methyl methacrylate
U161	4-methyl-2-pentanone
U169	Nitrobenzene
U171	2-nitropropane

(continued)

TABLE 8.6.1 (continued)

EPA hazardous waste No.	Hazardous waste
U115	Oxirane
U186	1,3-pentadiene
U194	1-propanamine
U110	1-propanamine
U171	Propane, 2-nitro
U140	1-propanol, 2-methyl-
U002	2-propanone
U152	2-propenenitrile, 2-methyl
U008	2-propenoic acid
U113	2-propenoic acid, ethyl ester
U162	2-propenoic acid, 2-methyl-, methyl ester
U194	n-propylamine
U213	Tetrahydrofuran
U153	Thiomethanol
U239	Xylene

TABLE 8.6.2. REACTIVE WASTES

EPA hazardous waste number	Hazardous waste
F007	Spent cyanide plating bath solutions ...
F008	Plating bath sludges ...
F009	Spent stripping and cleaning bath solutions ...
F010	Quenching bath sludge ...
F011	Spent cyanide solutions from salt bath ...
K011	Bottom stream from wastewater ... acrylonitrile
K013	Bottom stream from the acetonitrile column ...
K027	Centrifuge and distillation residues from toluene diisocyanate production
K044	Wastewater treatment sludges from the manufacturing and processing of explosives
K045	Spent carbon from the treatment of wastewater containing explosives
K047	Pink/red water from TNT operations
P009	Ammonium picrate
P065	Mercury fulminate
P112	Methane, tetranitro-
P081	Nitroglycerine
P009	Phenol, 2,4,6-trinitro-, ammonium salt
P112	Tetranitromethane
P112	Zinc phosphide

(continued)

TABLE 8.6.2 (continued)

EPA hazardous waste number	Hazardous waste
U006	Acetyl chloride
U223	Benzene, 1,3-diisocyanatomethyl
U020	Benzenesulfonyl chloride
U023	Benzene, (trichloromethyl)
U024	Benzene, 1,3,5-trinitro-
U023	Benzotrichloride
U160	2-butanone peroxide
U033	Carbon oxyfluoride
U033	Carbonyl fluoride
U133	Examine
U096	Alpha, alpna-dimethylbenzylhydroperoxide
U006	Ethanoyl chloride
U133	Hydrazine
U086	Hydroperoxide, 1-methyl-1-phenyethyl-
U189	Phosphorous sulfide
U205	Selenium disulfide
U189	Sulfur phosphide
U205	Sulfur selenide
U223	Toluene diisocyanate
U234	Sym-trinitrobenzene

TABLE 8.6.3. OVERVIEW OF HAZARDOUS WASTE TREATMENT PROCESSES
SOURCE: REFERENCES 3 THROUGH 8

Process	Description	Feed requirements/preferences	Output streams	Technology status
Carbon Adsorption	Waste stream is contacted with carbon to selectively adsorb hazardous organic materials. When carbon reaches its capacity for adsorption it must be disposed of or regenerated.	• Used for liquid organic or nonmetal anion wastes • More amenable to treatment of compounds with low polarity, and low degree of ionization • Treats organic concentrations of up to about 1% • Oil and grease should be less than 10 ppm.	• 'Purified' stream containing unadsorbed compounds • Carbon which must be thermally regenerated (or disposed of).	• Widely used for treatment of segregated waste streams containing phenols, cyanide wastes, refinery wastes, TNT, toluene, p-chlorobenzene and others.
Distillation	Boiling of liquid solution and condensation of vapor for purposes of separating waste stream components.	• Organic containing slurries and sludges • High organic concentrations; avoid compounds which polymerize or are nonvolatile • Tarry, viscous streams may require pretreatment.	Recovered solvent, still bottoms, sludge.	• Technology well established • Widely used for solvent recovery and fractionation of petroleum compounds
Electrolysis	Process oxidizes or reduces waste components at the surface of conductive electrodes immersed in an electrolyte.	Aqueous solutions containing <10% metals or nonmetal anions.	Recovered metals; solution with 2-10 ppm metals.	Technology is well established in industry, but application to hazardous waste treatment has been limited; use in electroplating and electrometallurgy.
Hydrolysis	Refers to degradation reactions of the following form: $KY + H_2O \rightarrow HY + XOH$. Generally carried out at elevated temerature and pressure in the presence of a catalyst.	• Treats organic liquid, slurry, sludge or solid wastes • No concentration limit • Hydrolyzable organics include esters, ethers, nitriles, organiphosphorus pesticides, halogenated compounds, amides, etc.	• Hydrolysis products which in some cases are more toxic • High temperature hydrolysis may yield vapor products.	• Process is widely used by organic chemical industry but requires further research for applications to hazardous wastes • Process has been used in pesticide degradation and in treatment of acid sludge from petroleum industry.

(continued)

TABLE 8.6.3 (continued)

Process	Description	Feed requirements/preferences	Output streams	Technology status
Ion Exchange	Interchange of ions between an aqueous solution and a solid material.	• Aqueous solutions of metals, nonmetal anions and water soluble, ionic organics • Concentrations should be less than 2500 ppm (because of regeneration requirements) although concentrations up to 4000 ppm may be acceptable • Sensitive to suspended matter, oxidants, and some organics, especially aromatics.	• Purified product stream • Small, concentrated stream with spent regenerant and high concentrations of pollutant.	Used in several areas of hazardous waste treatment; • Electroplating wastewaters • Metal finishing wastes • "Sour water" condensate from petroleum refining. • Recovery of chromium. • Removal of cyanides.
Liquid Ion Exchange	Involves transfer of waste component into an immiscible organic phase.	• Treats mainly aqueous streams containing free or complexed metal ions, and other inorganic species • Volume of extractants required places a practical upper limit of 10 g/l • Sensitive to oxidants, surfactants, and suspended solids.	Cleaned streams and stripping liquors which contain small amounts of extraction solvent.	Many possible applications in pilot scale stage; some commercial applications: • Metal pickling liquors • Copper recovery from Echants solutions • Removal of zinc and cyanide from electroplating rinsewater.
Liquid/Liquid Organic Extraction	Separation of a liquid from solution by contact with an immiscible liquid.	Aqueous streams low in suspended solids; solute concentration in excess of 10% may make process impractical; favors extraction of hydrophobic compounds.	Purified stream containing low levels of contaminants; solute stream which is usually recycled.	Currently has limited use in treatment of phenols and related compounds, solvent recovery and separation, deoiling of quench water, and acetic acid recovery.
Neutralization	Chemical reaction between an acid and base to obtain a neutral solution.	Usually aqueous streams with strong acid or bases; but also sludges and solids.	Stream of altered pH.	Widely practiced.
Chemical Oxidation	Conversion of a waste to a higher oxidation state for purposes of detoxification.	Low to moderate concentrations of oxidizable materials (few 1000 ppm); nonmetal anion or organic waste liquid slurry, or sludge.	Waste with oxidized compounds and oxidizing agents; waste stream is lower in COD than feed stream.	Current applications for hazardous wastes include: • Oxidation of cyanide in metal finishing wastes • Oxidation of phenol • Oxidation of organic residues of benzidine, aldehydes, mercaptans and unsaturated acids in wastewater.

(continued)

TABLE 8.6.3 (continued)

Process	Description	Feed requirements/preferences	Output streams	Technology status
Precipitation/ Sedimentation	Physiochemical process for removal of precipitable soluble substances and/or suspended particles from solution.	Aqueous or low viscosity non-aqueous solutions of metals; no upper concentration limit.	Metal sulfides, hydroxides or oxides, total dissolved solid concentrations governed by solubility product of precipitates.	Widely used.
Chemical Reduction	Lowering of oxidation state for detoxification.	Low to moderate concentrations of liquid, slurry or sludges (<1%) which can be reduced.	Reduced compounds and reducing agents.	Used or demonstrated in several waste treatment applications: • Reduction of Cr(VI) to Cr(III) • Removal of dissolved lead compounds • Removal of silver, mercury and other metals.
Steam Stripping	A form of fractional distillation used to remove volatile components from aqueous streams.	Dilute liquid or slurry wastes with volatile organics.	Treated stream with traces of organics, and a concentrated vapor or liquid of volatile organics.	Technology is well demonstrated, uses include: • Ammonia stripping from coke oven gas and sour water • Phenol stripping • Stripping of low-molecular-weight chlorinated hydrocarbons is under study.
Ultraviolet/ Ozone Destruction	Oxidation of organics activated with UV radiation by ozone.	Aqueous wastes with low concentrations (<1%) of oxidizable compounds.	Oxidized wastes, often completely mineralized to CO_2.	Shown to be effective for PCBs, TCDD, nitrobenzene, hydrazines.
Wet Air Oxidation (Catalyzed)	Catalytic (bromide-nitrate-manganese catalyst) oxidation of organics at elevated temperature and pressure.	Liquid, slurry or sludge containing oxidizable compounds.	Oxidized compounds, some completely mineralized to CO_2; used catalyst.	Although wet air oxidation is fully developed commercially, the catalyzed process is not yet commercial. Demonstrated for PAHs, phenols, a number of halogenated compounds, malethion, nitrobenzene, acetonitrile, etc.

The applicant may propose to render ignitable or reactive compounds nonignitable or nonreactive by diluting the waste with other compatible material. However, dilution has the obvious disadvantage in that hazardous reactions may result if the materials being mixed are incompatible. In addition, dilution with liquids is undesirable because of added liquids to the land treatment unit and greater attendant leachate generation. If other than a small quantity of waste requires dilution, the reviewer may elect to require an alternative treatment process to minimize the application of liquids that might affect the units water balance.

There are a number of data sources which may assist the reviewer in evaluating an applicant's proposed method of waste treatment, when required, including references 3 through 17 listed in subsection 8.6.5. The reviewer should refer to Chapters 8 and 9 of Metry[9] which lists an additional 200 references on physical and chemical treatment of hazardous waste.

8.6.3.3 Test for Compatibility--

The permit reviewer should refer to A Method for Determining the Compatibility of Hazardous Waste[2] which addresses hazardous waste compatibility. A hazardous waste compatibility chart (see subsection 8.7.3 of this manual) is presented which illustrates the compatibility of 41 binary combinations of hazardous chemical wastes. The reason for incompatibility is also noted for each combination. Further discussion of incompatible wastes is presented in subsection 8.7.3.

8.6.3.4 Testing of Ignitable and Reactive Waste--

After a treatment process has been employed, the applicant must test or document by some other means that the waste is no longer ignitable or reactive. If testing is to be employed, the applicant must specify what testing procedures he will use. Available methods to test for ignitability are set forth in §261.21. Two test methods are acceptable for determining the flash point: Pensky-Martens Closed Cup Tester using the test method specified in ASTM standard D-93-79 or D-93-80, or a Setaflash Closed Cup Tester, using the test method specified in ASTM Standard D-3278-78.

To test if a treated waste has the characteristics of reactivity, the applicant should base his demonstration on tests for: water reactivity, flash point/flamability, oxidation/reduction potential, pH, and the presence of cyanide or sulfide. The testing procedures employed should conform with the ASTM standards and test methods incorporated in Test Methods for Evaluating Solid Waste.[1]

8.6.3.5 Site Management to Prevent Ignition--

The applicant must specify handling methods to avoid heat, sparks, rupture, or any other condition that might cause ignition of the waste. The applicant should specify the types of handling equipment and management procedures that will be employed. All equipment should be constucted of nonsparking materials.

If an applicant proposes to place an ignitable waste in the same treatment unit with another waste type, it must be determined whether this other waste type may react exothermically with water and generate sufficient heat to cause ignition. However, wastes which are reactive with water should not be treated at the unit. Section 264.281(a) requires that any reactive waste be incorporated into the soil immediately after application so that the resulting waste, mixture or dissolution of material no longer meets the definition of ignitable or reactive waste under §261.21 or §261.23. Nonetheless, the reviewer should check to be certain that any wastes which are to be co-disposed with an ignitable waste are nonreactive. In Part 261, Subpart D - Lists of Hazardous Wastes, the wastes that are reactive are designated by an "(R)" hazard code. Also, any waste which has an EPA hazardous waste number of D003 exhibits the characteristics of reactivity. The reviewer should cross-check those wastes which will be co-disposed with an ignitable waste with the wastes in the Subpart D list which are reactive (listed in Table 8.6.1 of this section). However, not all of the waste in the Subpart D list which are designated to be reactive, will react exothermically with water. A waste is reactive if it exhibits any of the eight properties listed in §261.23.

Figure 8.6.2 presents a worksheet that can be used to evaluate the applicant's plan to properly handle ignitable or reactive wastes to be disposed of at the land treatment unit.

8.6.4 Draft Permit Preparation

Condition G of Permit Module XIV (see Section 4) covers the special requirements for ignitable or reactive wastes, if they are to be handled at the land treatment facility. Permit conditions to be specified may be implemented by reference to applicable sections of the Part B permit application. Items covered by Condition G are as follows:

G.1. The Permittee shall not place ignitable or reactive waste in a land treatment unit unless the practice described in Attachment _ are followed, as required by 40 CFR 264.281.

[Note: The attachment must demonstrate how the facility will handle ignitable and reactive wastes as required by 40 CFR 264.281. If the application does not address this, the permit writer should write specific conditions to implement this provision or should condition the permit so as not to allow this practice.]

G.2. The Permittee shall document compliance with Condition G of Permit Module XIV as required by 40 CFR 264.17(c) and place this documentation in the operating record (see Module II, Condition E.1.

[Note: Condition G of Module XIV applies only to facilities that store ignitable or reactive waste in land treatment units.]

SPECIAL REQUIREMENTS FOR IGNITABLE OR REACTIVE WASTES

Are any wastes to be land treated ignitable or reactive?	yes	no
If ignitable or reactive wastes are going to be treated, has the applicant provided a description of how the waste will be incorporated into the soil and how the waste/soil mixture will be tested to determine that it is no longer ignitable or reactive?	yes	no
Does the application provide a description of how the requirements of §264.17(b) will be met?	yes	no
If the owner or operator elects to comply with §264.281(b), does the application describe how the site will be managed to prevent the waste applied from igniting or reacting?	yes	no

Figure 8.6.2. Worksheet to evaluate applicant's plan for handling ignitable or reactive wastes.

8.6.5 References

1. U.S. Environmental Protection Agency. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods. U.S. EPA, Office of Solid Waste. Second Edition. SW-846. July 1982.

2. Hatayama, H. K., et. al., A Method for Determining the Compatability of Hazardous Wastes. U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, Ohio, EPA-600/2-80-076. April 1980.

3. GRB Associates, Inc., Techniques for Evaluating Environmental Processes Associated with the Land Disposal of Specific Hazardous Materials, Volume I: Fundamentals. EPA Contract No. 68-01-5052, March 31, 1982.

4. DeRenzo, D. J., Unit Operations for Treatment of Hazardous Industrial Wastes. Noyes Data Corp., 1978.

5. Schalit, L. and G. Staples, Fostering Industrial Innovative Technology to Attain Agency Goals: Technological Opportunities, Volume II, Prepared for Office of Research and Development, U.S. Environmental Protection Agency. Science Applications Inc., (SAI - 0/2-80-523-LJ), 1980.

6. Pytlewski, L. L., et al., The Reaction of PCBs with Sodium, Oxygen, and Polyethylene Glycol. In: Proceedings of the Sixth Annual Research Symposium on Treatment of Hazardous Wastes, March 17-20, 1980, Chicago, Illinois, U.S. EPA--Municipal Environmental Research Laboratory. EPA-600/9-80-011.

7. Edward, B. H., et al. Emerging Technologies for the Destruction of Hazardous Waste. Ultraviolet 10 Zone Destruction. In: Proceedings of the Seventh Annual Research Symposium on Land Disposal of Hazardous Wastes. Philadelphia. U.S. EPA--Municipal Environmental Research Laboratory. (EPA-600/9-81-002b), 1981.

8. Miller, R. A., et al., Evaluation of Catalytic Wet Oxidation for Treatment of Hazardous Wastes. In: Proceedings of Seventh Annual Research Symposium on Land Disposal of Hazardous Wastes. Philadelphia. U.S. EPA--Municipal Environmental Research Laboratory. (EPA-600/9-81-002b), 1981.

9. Metry, Amir, A., The Handbook of Hazardous Waste Management. Technomic Publishing Company, Inc., Westport, CT., 1980.

10. TRW Systems, Inc. Recommended Methods of Reduction, Neutralization, Recovery, or Disposal of Hazardous Waste. Volume I-XVI. U.S. Environmental Protection Agency, Washington, D.C., 1973.

11. EPA-600/2-82-001c, Treatability Manual. Volumes I-IV. U.S. Environmental Protection Agency, Washington, D.C., Sept. 1981.

12. Battelle Memorial Institute. Program for the Management of Hazardous Waste. Volumes 1 and 2. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Washington, D.C., 1974.

13. Booz-Allen Applied Research, Inc. A Study of Hazardous Effects and Disposal Methods. U.S. Environmental Protection Agency. Cincinnati, OH, 1972.

14. Bretherick, L., Handbook of Reactive Chemical Hazards. CRL Press, Inc., Cleveland, OH, 1975.

15. Fire Protection Guide on Hazardous Materials. Sixth Edition. National Fire Protection Association, Boston, Massachusetts, 1975.

16. Nermerow, N.L., Liquid Waste of Industry: Theories, Practice, and Treatment. Addison-Wesley Publishing Co., Reading, MA, 1972.

17. Toxic and Hazardous Industrial Chemicals Safety Manual for Handling and Disposal, with Toxicity and Hazard Data. The International Technical Information Institute, Torahomon-Tachikawa Bldg. 6-5, 1 Chome, Nishi-Shimbashi, Minato-KW, Tokyo, Japan, 1975.

8.7 SPECIAL REQUIREMENTS FOR INCOMPATIBLE WASTES

8.7.1 Federal Requirement

Section 270.20(h) states:

> "If incompatible wastes, or incompatible wastes and materials will be placed in or on the same treatment zone, an explanation of how §264.282 will be complied with."

Section 264.282 states:

> "The owner or operator must not place incompatible wastes, or incompatible wastes and materials (see Appendix V of this part for examples), in or on the same treatment zone, unless §264.17(b) is complied with."

Section 264.17(b) states:

> "(b) Where specifically required by other Sections of this Part, the owner or operator of a facility that treats, stores or disposes ignitable or reactive waste, or mixes incompatible waste or incompatible wastes and other materials, must take precautions to prevent reactions which:
>
> (1) Generate extreme heat or pressure, fire or explosions, or violent reactions;
>
> (2) Produce uncontrolled toxic mists, fumes, dusts, or gases in sufficient quantities to threaten human health or the environment;
>
> (3) Produce uncontrolled flammable fumes or gases in sufficient quantities to pose a risk of fire or explosions;
>
> (4) Damage the structural integrity of the device or facility;
>
> (5) Through other like means threaten human health or the environment.
>
> (c) When required to comply with paragraphs (a) or (b) of this Section, the owner or operator must document that compliance. This documentation may be based on references to published scientific or engineering literature, data from trial tests (e.g., bench scale or pilot scale tests), waste analyses (as specified in §264.13), or the results of the treatment of similar wastes by similar treatment processes and under similar operating conditions."

8.7.2 Summary of Necessary Application Information

The application must include a written plan that explains the procedures and precautions for handling incompatible wastes and materials if such wastes will be placed in or on the same treatment zone. The plan must contain the following information:

- name of incompatible materials or wastes,
- explanation of incompatibility,

- composition of incompatible materials and waste,
- rate and schedule of incompatible waste or material applications to the treatment zone,
- step-by-step procedures for managing incompatible wastes or materials to prevent undesirable reactions or effects, and
- laboratory or field data demonstrating that incompatible wastes can be safely managed at the land treatment unit using the proposed procedures.

8.7.3 Guidance on Evaluating Application Information

If wastes from different waste streams are to be applied to the same treatment zone, the owner or operator must demonstrate prior to application that the waste from different streams are compatible. Table 8.7.1, adapted from Appendix V of Part 264, presents a partial listing of potentially incompatible wastes, waste components, and materials, along with the harmful consequences which result from mixing materials in one group with materials in another group.

The potential consequences identified may result from mixing of an A material with a B material within the same Group number. Under certain conditions, waste identified as being incompatible may be applied to the same treatment zone. For example:

- adding acid to water, then water to acid, or
- a strong acid mixed with a strong base.

Characterization of wastes to be land treated is required of the applicant under §264.13. Waste analysis methods employed by the applicant can be verified using Test Methods for Evaluating Solid Waste.[1]

Published scientific or engineering literature, data from actual testing, or results from the treatment of similar waste by similar treatment processes and under similar operating conditions can be used to determine that the applicant will comply with the requirements of §264.17(b).

There is no characterization of incompatibility in 40 CFR 261. Rather, Appendix V of Part 264 presents examples of potentially incompatible wastes. A definition of incompatible wastes is provided in §260.10 of Subpart B of Part 260. Technical references are also available that identify incompatible waste combinations, as discussed below.

It is the responsibility of the land treatment owner or operator to identify whether or not wastes are compatible. For commercial off-site land treatment facilities, the variety of wastes received will likely result in

TABLE 8.7.1. LISTING OF KNOWN INCOMPATIBLE WASTE OR WASTE COMPONENTS

GROUP 1-A

Acetylene sludge
Alkaline caustic liquids
Alkaline cleaner
Alkaline corrosive liquids
Alkaline corrosive battery fluid
Caustic wastewater
Lime sludge and other corrosive alkalies
Lime wastewater
Lime and water
Spent caustic

Potential consequences: Heat generation; violent reaction.

GROUP 1-B

Acid sludge
Acid and water
Battery acid
Chemical cleaners
Electrolyte, acid
Etching acid liquid or solvent
Pickling liquor and other corrosive acids
Spent acid
Spent mixed acid
Spent sulfuric acid

GROUP 2-A

Aluminum
Beryllium
Calcium
Lithium
Magnesium
Potassium
Sodium
Zinc powder
Other reactive metals and metal hydrides

Potential consequences: Fire or explosion; generation of flammable-hydrogen gas

GROUP 2-B

Any waste in Group 1-A or 1-B

GROUP 3-A

Alcohols
Water

Potential consequences: Fire, explosion, or heat generation, generation of flammable or toxic gases.

GROUP 3-B

Any concentrated waste in Groups 1-A or 1-B
Calcium
Lithium
Metal hydrides
Potassium
SO_2Cl_2, $SOCl_2$, PCl_3, CH_3SiCl_3
Other water-reactive waste

GROUP 4-A

Alcohols
Aldehydes
Halogenated hydrocarbons
Nitrated hydrocarbons
Unsaturated hydrocarbons
Other reactive organic compounds and solvents

Potential consequences. Fire, explosion, or violent reaction.

GROUP 4-B

Concentrated Group 1-A or 1-B wastes
Group 2-A wastes

GROUP 5-A

Spent cyanide and sulfide solutions

Potential consequences: Generation of toxic hydrogen cyanide or hydrogen sulfide gas.

GROUP 5-B

Group 1-B wastes

GROUP 6-A

Chlorates
Chlorine
Chlorites
Chromic acid
Hypochlorites
Nitrates
Nitric acid, fuming
Perchlorates
Permanganates
Peroxides
Other strong oxiders

Potential consequences. Fire, explosion, or violent reaction.

GROUP 6-B

Acetic acid and other organic acids
Concentrated mineral acids
Group 2 A wastes
Group 4-A wastes
Other flammable and combustible wastes

Source: "Law, Regulations, and Guidelines for Handling of Hazardous Waste." California Department of Health, February 1975.

some cases of incompatibility. For on-site land treatment facilities, those operated by the waste generator, it is more likely that the wastes will be compatible. If it is shown that all wastes are compatible with each other and with other materials treated at the site, the permit application is sufficient with respect to the requirements of §264.282.

Based on a literal interpretation of the regulations, only a waste that has already been identified as a hazardous waste can be further identified as an incompatible waste. Specifically, the §260.10 definition states than an incompatible waste "means a hazardous waste which..." and Appendix V of Part 264 states "Many hazardous wastes, when mixed with...." The intent of the regulations is fairly clear, however, if any two (or more) materials or wastes cannot be formed into a homogeneous mixture that neither separates nor is altered by chemical interaction (Webster), they are incompatible and must not be placed in or on the same treatment zone, unless the requirements of §264.17(b) are met. Thus, it is the responsibility of the permit applicant to compare each waste (hazardous and nonhazardous) to be treated at the facility for compatibility with each other.

Documentation that the precautions of §264.17(b) will be effective is required by §264.17(c). Specifically, §264.17(c) requires that:

> "When required to comply with paragraphs (a) or (b) of this Section, the owner or operator must document that compliance. This documentation may be based on references to published scientific or engineering literature, data from trial tests (e.g., bench scale or pilot scale tests), waste analyses (as specified in §264.13), or the results of the treatment of similar wastes by similar treatment processes and under similar operating conditions."

The owner or operator of the land treatment facility must supply documentation that the procedures employed will not allow incompatible wastes to be placed in or on the same treatment zone. The permit application is deficient if the required documentation is not submitted or if it is judged to be inadequate. If the application indicates that incompatible wastes will not be placed in or on the same treatment zone, then procedures to insure that they will not should be stated. Also, if an application indicates that a waste will be treated so that it is no longer incompatible prior to application, documentation that the treatment complies with §264.17(b) is required.

To augment the information on incompatible wastes presented in Appendix V of Part 264, the permit application reviewer is referred to two additional technical reports to determine if the applicant has correctly investigated the compatibility of the materials and wastes to be handled. These documents are identified below, and a brief description of the contents of each is provided.

A Method for Determining the Compatibility of Hazardous Wastes (EPA-600/2-80-076, April 1980)[2] was prepared for the EPA's Municipal Environmental Research Laboratory by researchers at the California Department of Health Services. The abstract of the report states:

"This report describes a method for determining the compatibility of the binary combinations of hazardous wastes. The method consists of two main parts, namely: (1) the step-by-step compatibility analysis procedures, and (2) the hazardous wastes compatibility chart. The key element in the use of the method is the compatibility chart. Wastes to be combined are first subjected through the compatibility procedures for idnetification and classification, and the chart is used to predict the compatibility of the wastes on mixing.

The chart consists of 41 reactivity groups of hazardous wastes designated by Reactivity Group Numbers (RGN). The RGN are displayed in binary combinations on the chart, and the compatibility of the combinations is designated by Reaction Code (RC).

The method is applicable to four categories of wastes based on available compositional information: (1) compositions known specifically, (2) compositions known nonspecifically by chemical classes or reactivities, (3) compositions known nonspecifically by common or generic names of wastes, and (4) compositions unknown requiring chemical analysis."

The 79 references and 5 appendices provide a significant amount of data on the compatibility of various chemical wastes.

The other document, Techniques for Evaluating Environmental Processes Associated with Land Disposal of Specific Hazardous Materials, Volume II, Incompatible Wastes,[3] March 31, 1982, was prepared for the EPA Office of Solid Waste by JRB Associates, Inc., McLean, Virginia. This document discusses processes that enhance pollutant migration potential through the liquid phase in soils. Three general processes were identified. They are:

- direct solubility effects between waste constituents,
- chemical reactions between waste constituents which generate reaction products which are more mobile than the original waste constituents, and
- processes whereby waste interactions with the environment decrease the soil's ability to attenuate pollutant migration.

Conclusions and 18 references are included.

Hazardous Waste Compatibility

Because many types of hazardous wastes are extremely reactive, the compatibility of hazardous wastes to be combined must be thoroughly evaluated. Combining wastes which are incompatible may result in:[3] (1) heat generation, (2) fire, (3) toxic gases, such as HCN or H_2S, (4) flammable gases, such as H_2 or C_2H_2, (5) explosion due to extremely vigorous reactions or reactions producing enough heat to detonate unstable reactants or reaction products, (6) violent polymerization resulting in generation of extreme heat and flammable gases, and (7) solubilization of

toxic substances including metals. Consequently, the applicant must identify the methods he will employ for estimating the potential consequences of mixing different classes of wastes.

Insufficient or inaccurate information about a waste or wastes is the primary cause of inadvertently combining incompatible wastes. Regardless of efforts to adequately characterize wastes via the waste analysis plan, properties of some wastes may change with time and temperature, thereby producing more or different hazardous components.[3] A second cause of accidents is indiscriminate handling of waste, such as haulers "topping off" their load on the way to the disposal site.

As previously mentioned, A Method for Determining the Compatibility of Hazardous Wastes[2] is a valuable resource document for determining the compatibility of binary waste combinations.

The method provided in this report consists of two main parts: (1) stepwise compatibility analysis procedures, and (2) use of a hazardous waste compatibility chart. Wastes under consideration are first identified and classified and then the compatibility chart is used to assess the compatibility of the wastes upon mixing. The remainder of this section provides background information for employing the compatibility analysis presented in the cited reference (2). The five general steps necessary to determine the compatibility of two waste types are summarized below. Discussion of implementation of these steps is as reported by Hatayama, et al.[4] Figure 8.7.1 summarizes the steps to be taken to determine hazardous waste compatibility.

Step 1: Waste Characterization

The first step in determining the compatibility of two different waste types is to accurately characterize the wastes. The applicant should provide as much information as possible about waste composition as required for compliance with §264.13 (Waste Analysis Plan) and as part of the list of hazardous wastes incorporated in the application [§270.20(a)(1) and (b)(1)].

Step 2:* List Name of Compounds or Classes of Compounds or Generic Name of Waste

"Starting with one waste, Waste A, list the names of or the classes of compounds found in the wastes, or list its generic name on the vertical axis of the Worksheet for Determination of Hazardous Waste Compatibility (Figure 8.7.2). The composition of a waste is Known Specifically when the constituents are listed by chemical names such as ethylene glycol, sodium nitrate, etc. The composition is Known Nonspecifically by Classes when the constituents are identified only by chemical classes or reactivities such as alcohols, caustics, mercaptans, etc. The composition is Known Nonspecifically by Generic Name when the waste is classified as spent caustic, tanning sludge, copper plating waste, etc."

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*Quoted from Hatayama, H. K., et al. EPA-600/9-80-010, March 1980. (Reference 4.)

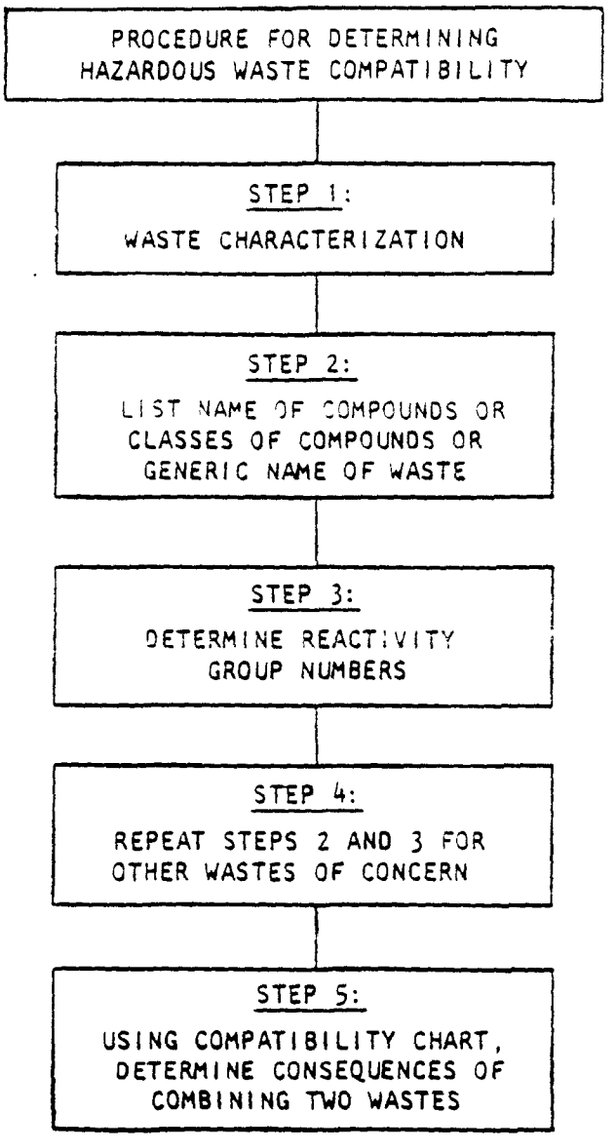

Figure 8.7.1. Flow diagram for assessing the compatibility of hazardous waste using procedures specified in A Method for Determining the Compatibility of Hazardous Wastes. (Reference 2)

Waste A _____ Source _____

Waste B _____ Source _____

Name of Waste Evaluation _____ Date _____

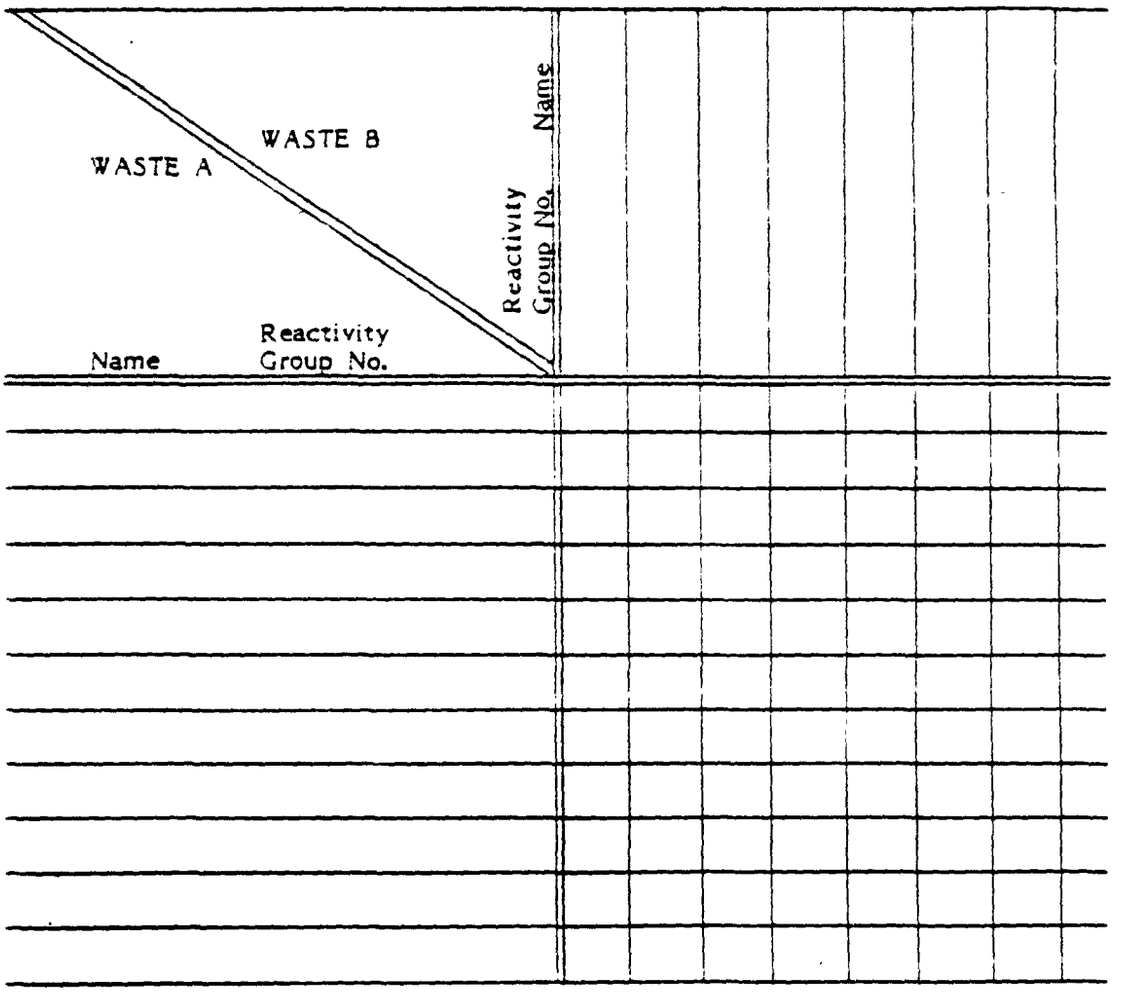

Figure 8.7.2. Worksheet for determination of hazardous waste compatibility.

Source: Reference 2

Step 3:* Determine Reactivity Group Numbers

"When the composition of Waste A is Known Specifically by chemical names, consult the List of Chemical Names [in Appendix I of Reference 2] to obtain the Reactivity Group Number (RGN) for each chemical constituent. The RGNs are then noted on the Worksheet. If a compound is not on the list, a synonym can be found in various chemical references (Merck,[5] Hawley[6]). When a suitable synonym cannot be found, the RGN of the component may alternatively be determined based on its chemical class or reactivity.

When the composition of the waste is Known Specifically by Classes, consult the List of Waste Constituents by Chemical Class and Reactivity [in Appendix II of Reference 2] to determine the corresponding RGN.

When the composition of the waste is Known Nonspecifically by Generic Name, go to the Industry Index and List of Generic Names of Wastes [in Appendix III of Reference 2] to obtain the corresponding RGN and note it on the worksheet."

Step 4:* Repeat Steps 2 and 3 for Other Waste(s) of Concern

"Repeat Steps 2 and 3 for the second waste, Waste B, and note the information on the horizontal axis of the Worksheet."

Step 5:* Using Compatibility Chart, Determine Consequences of Combining Two Wastes

"Consult the Hazardous Waste Compatibility Chart (Figure 8.7.3) and note the Reaction Codes (RC) between all binary combinations of RGN of Waste A and Waste B. If any RC corresponds to any binary combination of RGN between Wastes A and B, then Wastes A and B are incompatible and should not be mixed."

Limitations of the Method

Although this procedure should provide a useful aid in determining the compatibility of hazardous waste, the method must be used with caution because there are numerous factors which will influence waste component reactions. Among these are temperature, catalytic effects of dissolved or particulate metals, soil reactions, and reactions between the waste and surfaces it may be in contact with.[3] Consequently, the reviewer may elect to require that the applicant perform laboratory compatibility analysis prior to actual co-disposal of wastes.

Compatibility with Treatment Zone Processes

In addition to assessing the compatibility of wastes to be applied at the treatment facility, it is important to evaluate the impact of wastes applied on the soil processes responsible for hazardous constituent degradation,

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*Quoted from Hatayama, H. K., et al. EPA-600/9-80-010, March 1980. (Reference 4.)

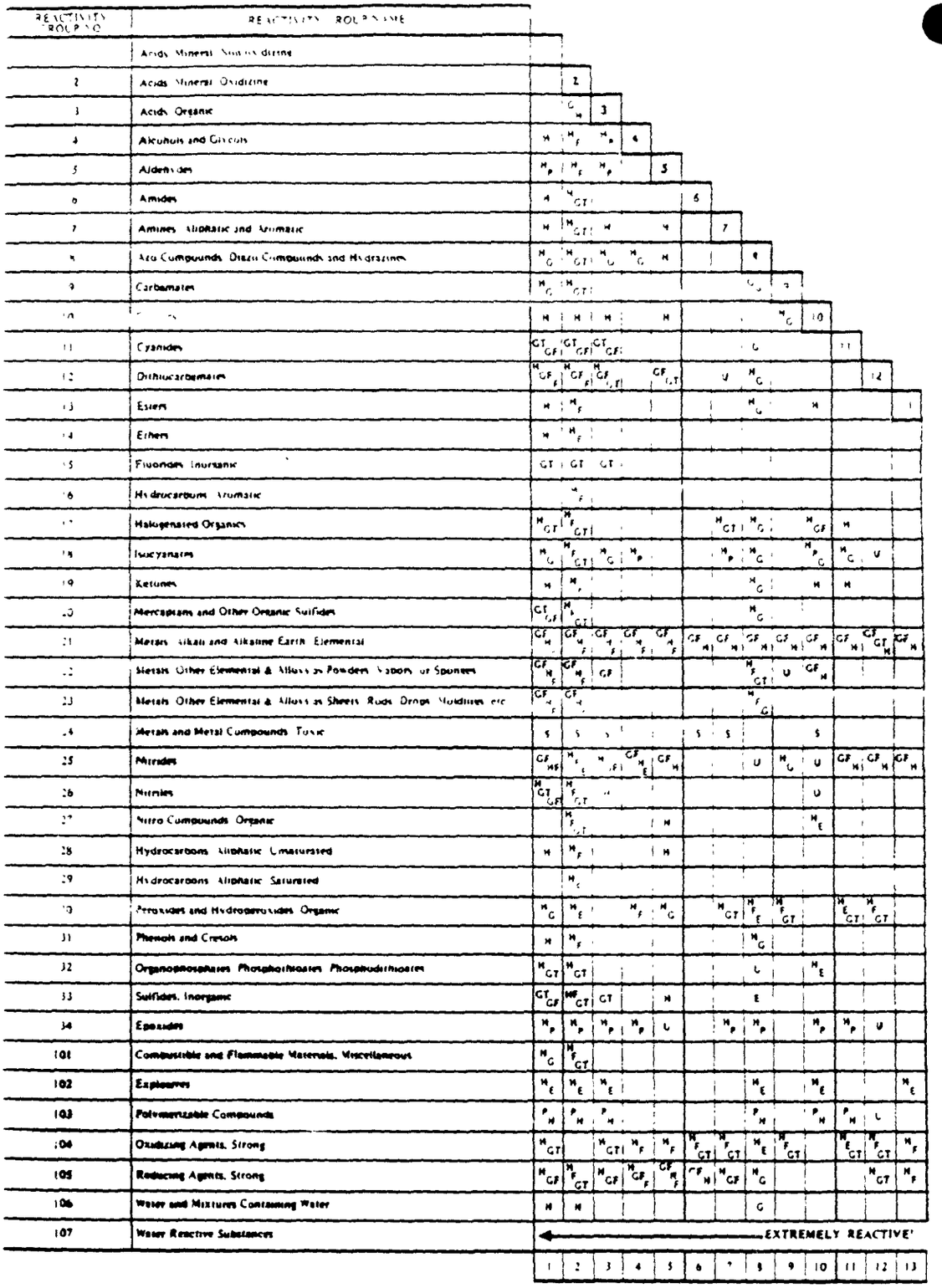


Figure 8.7.3. Hazardous waste compatibility chart.

Source: Reference 1

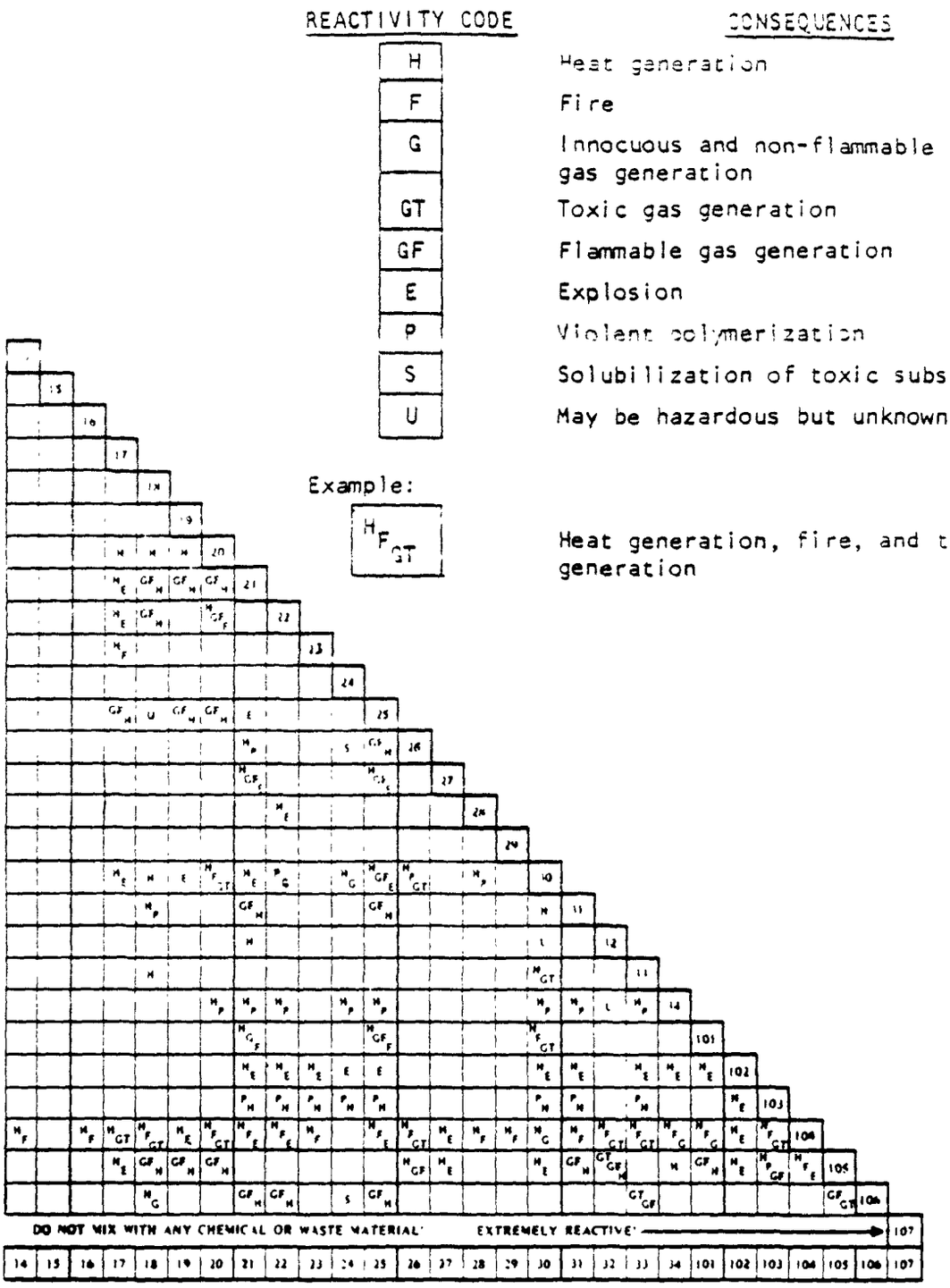


Figure 8.7.3. (continued).

transformation, and immobilization. Although this consideration should be addressed under the Treatment Demonstration (see subsection 8.1), it is mentioned here because it must be considered when assessing the compatibility of wastes to be handled at the land treatment facility.

Issues to be addressed include the effect of co-disposal of wastes on soil microbes, soil pH, soil fertility, adsorption properties (e.g., CEC) of treatment zone soil, and increased volatilization of organic constituents.

Reactions between different waste types may result in increased soil acidity, decreased soil fertility, increased soil temperature, and possibly destruction of soil microbe populations. All of these concerns should be addressed by the hazardous waste treatment demonstration conducted in accordance with §264.272.

Figure 8.7.4 presents a worksheet to be used by the permit writer for evaluating an applicant's submittal for meeting special requirements for incompatible wastes.

8.7.4 Draft Permit Preparation

Condition H of Permit Module XIV (see Section 4) addresses the special requirements for incompatible wastes if they are to be treated at the land treatment facility. Permit conditions to be specified may be implemented by reference to applicable portions of the Part B permit application. Items covered by Condition H are as follows:

H.1 The Permittee shall not place incompatible wastes, or incompatible wastes and material, in or on the same treatment zone unless the procedures specified in Attachment __ are followed, as required by 40 CFR 264.17(b).

[Note: The attachment must specify how the Permittee will handle incompatible wastes so as to comply with 40 CFR 264.17(b). If the application does not address this, the permit writer should write specific conditions to implement this provision or should condition the permit so as not to allow this practice.]

H.2 The Permittee shall document compliance with Condition H.1 of Permit Module XIV as required in 40 CFR 264.17(c) and place this documentation in the operating record (see Module II, Condition L.1).

[Note: Condition H of Module XIV applies only to facilities that store incompatible wastes in land treatment units.]

SPECIAL REQUIREMENTS FOR INCOMPATIBLE WASTES

Have acceptable procedures been used to accurately characterize the wastes?	yes	no
Were wastes properly catagorized by reactivity group numbers?	yes	no
Was waste compatibility identified using the Reference 2 compatability chart or other acceptable means?	yes	no
Does the compatibility assessment include all wastes identified in Section 8.1?	yes	no
If wastes are incompatible and will be placed in or on the same treatment zone, will the requirements of §264.17(b) be met?	yes	no

Figure 8.7.4. Worksheet for evaluating applicant's submittal for meeting special requirements for incompatible wastes.

8.7.5 References

1. U.S. Environmental Protection Agency. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods. U.S. Environmental Protection Agency, Office of Solid Waste, EPA Report SW-846. July 1982.

2. Hatayama, H. K., et al. A Method for Determining the Compatibility of Hazardous Wastes. EPA-600-2-80-076. April 1980.

3. JRB Associates, Inc. Techniques for Evaluating Environmental Processes Associated with Land Disposal of Specific Hazardous Materials, Volume II, Incompatible Wastes. Prepared for the U.S. EPA Office of Solid Waste. March 31, 1982.

4. Hatayama, H. K., et al. Hazardous Waste Compatibility. Presented in Disposal of Hazardous Waste, Proceedings of the Sixth Annual Research Symposium. EPA-600/9-80-010. March 1980.

5. Merck and Company, Inc. 1976. The Merck Index. 9th Edition, Rahway, NJ.

6. Hawley, G. G. 1971. The Condensed Chemical Dictionary. 8th Edition. Van Nostrand Reinhold Company, New York, Cincinnati, Toronto, London, Melbourne.

8.8 TECHNICAL ADEQUACY CHECKLIST

The technical adequacy checklist presented in Table 8.8.1 provides a summary of the basic information needed to determine the completeness and merit of Part B permit applications submitted for new and existing land treatment facilities. The checklist is organized according to the Part 270 permit requirements. Completion of the checklist will enable determination of application deficiencies, where they may exist. Deficiencies should be noted and identified in the Notice of Deficiency (NOD) to be issued to the applicant pursuant to §124.3(c).

TABLE 8.8.1. TECHNICAL ADEQUACY CHECKLIST FOR REVIEWING PART B LAND TREATMENT PERMIT APPLICATIONS

Permit requirement	Is requirement applicable to facility	Is the requirement addressed	Has application been evaluated for completeness and adequacy	Is further action required	Comments
I. Treatment Demonstration					
I.1. Treatment Demonstration Plan					
I.1.A. List of Wastes for Demonstration					
- List of Wastes					
List of Hazardous Constituents					
- Specific Waste Characteristics					
I.1.B. Data Sources for the Demonstration					
- Literature					
Operating Data					
- Laboratory Studies (including specific conditions)					
- Field Tests (including specific conditions)					
I.2. Treatment Demonstration Results					
I.2.A. Wastes and Waste Composition					
I.2.B. Degradation/Transformation					
I.2.C. Immobilization					
I.2.D. Volatilization					
I.2.E. Toxicity					
II. Land Treatment Program					
II.1. Wastes for Land Treatment Program					

(continued)

TABLE 8.8.1 (continued)

Permit requirement	Is requirement applicable to facility	Is the requirement addressed	Has application been evaluated for completeness and adequacy	Is further action required	Comments
II.2. Waste Application Rates and Methods					
- Identification of Application, Rate, and Capacity Limiting Constituents					
- Application Method					
II.3. Measures to Control Soil pH					
II.4. Measures to Enhance Microbial or Chemical Reactions					
II.5. Measures to Control Soil Moisture in the Treatment Zone					
II.6. Unsaturated Zone Monitoring					
- Sampling Location					
- Sampling Frequency					
- Sampling Equipment					
- Equipment Installation					
- Sampling Procedures					
- Analytical Procedures					
- Sample Handling (Chain-of-custody)					
- Determination of Background Levels					
- Statistical Methods to be Used					
- Use of principal hazardous constituents					

(continued)

TABLE 8.8.1 (continued)

Permit requirement	Is requirement applicable to facility	Is the requirement addressed	Has application been evaluated for completeness and adequacy	Is further action required	Comments
II.7. Treatment Zone Description					
- Soil Survey					
- Soil Series Description					
Soil Analyses					
- Zone Dimensions					
III. Design, Construction, Operation, and Maintenance					
III.1. Run-On Control					
- Determination of Magnitude of 25-year Storm Event					
- Calculation of Peak Run-on Rate for Design Storm Event					
III.2. Run-Off Control					
- Determination of Magnitude and Intensity of 24-hour, 25-year Storm Event					
- Calculation of Run-off Volume from Design Storm Event					
III.3. Minimization of Run-Off of Hazardous Constituents					
- Timing of Applications					
- Conditioning of Surface Soil (Tillage)					
- Establishment of Vegetative Cover					

(continued)

TABLE 8.8.1 (continued)

Permit requirement	Is requirement applicable to facility	Is the requirement addressed	Has application been evaluated for completeness and adequacy	Is further action required	Comments
III.4. Management of Run-Off, Run-On, Collection and Holding Facilities					
- Run-Off Control					
- Run-On Control					
III.5. Wind Dispersal Control					
- Timing of Application					
- Maintenance of Soil Moisture Content					
- Use of Soil Stabilizers/ Wind Breaks					
- Establishment of Vegetative Cover					
III.6. Unit Inspection					
- Planned Weekly Schedule					
- After Storms					
IV. Food-Chain Crops Requirements					
IV.1. Food-Chain Crop Demonstration					
- Data Sources					
- Crop Characteristics					
- Waste Characteristics					
- Assessment of Potential Crop Uptake					
- Potential for External Contamination					
- Potential for Ingestion by Food-Chain Animals					

(continued)

TABLE 8.8.1 (continued)

Permit requirement	Is requirement applicable to facility	Is the requirement addressed	Has application been evaluated for completeness and adequacy	Is further action required	Comments
In addition for Field Tests					
- Plot Configuration					
- Treatment Zone Characteristics					
- Waste Application Rates					
- Sampling and Analysis Procedures					
IV.2. Wastes Containing Cadmium					
- Amounts Applied					
- Soil Monitoring/Conditioning (soil pH, CEC)					
V. Vegetative Cover at Closure and Post-Closure					
V.1. Establishment of Cover					
- Plant species					
- Plant Viability					
- Maintenance of Vegetation, Minimum Percentage Cover					
V.2. Exemptions for Vegetative Cover					
VI. Special Requirements for Ignitable or Reactive Wastes					
- Waste Assessment					
- Procedures for Handling					
VII. Special Requirements for Incompatible Wastes					
- Waste Assessment					
- Procedures for Handling					

SECTION 9.0

LANDFILLS

This Section presents guidance on evaluating application information submitted in support of the landfill standards specified in Subpart N of Part 264. The federal requirements are reproduced and the application information requested by the Part B Permit Applicants' Manual is summarized. This Section is subdivided into 8 major subject areas, as follows:

9.1 Waste Description

9.2 Design and Operating Requirements

9.3 Monitoring and Inspection

9.4 Closure and Post-Closure

9.5 Special Requirements for Ignitable or Reactive Wastes

9.6 Special Requirements for Incompatible Wastes

9.7 Liquid Wastes

9.8 Containerized Wastes

A Technical Adequacy Checklist is provided at the end of the Section in subsection 9.9. References cited in each of the first eight subsections are listed at the end of each of those subsections. Subsection 9.2, Facility Design and Operation, includes guidance on evaluating the applicant's submittal if he is requesting an exemption from the Subpart F requirements for ground water protection or from the liner and leachate collection system requirements.

The information requirements of §270.21 are reprinted* below to provide an overview of the topics and proposals that may have to be considered in reviewing a landfill application.

---

*All regulatory citations are quoted from the Federal Register.

"§270.21 Specific Part B Information Requirements for Landfills Except as otherwise provided in §264.1, owners and operators of facilities that dispose of hazardous waste in landfills must provide the following additional information:

(a) A list of the hazardous wastes placed or to be placed in each landfill or landfill cell;

(b) Detailed plans and an engineering report describing how the landfill is or will be designed, constructed, operated and maintained to comply with the requirements of §264.301. This submission must address the following items as specified in §264.301:

(1) The liner system and leachate collection and removal system (except for an existing portion of a landfill). If an exemption from the requirements for a liner and a leachate collection and removal system is sought as provided by §264.301(b), submit detailed plans and engineering and hydrogeologic reports, as appropriate, describing alternate design and operating practices that will, in conjunction with location aspects, prevent the migration of any hazardous constituent into the ground water or surface water at any future time;

(2) Control of run-on;

(3) Control of run-off;

(4) Management of collection and holding facilities associated with run-on and run-off control systems; and

(5) Control of wind dispersal of particulate matter, where applicable;

(c) If an exemption from Subpart F of Part 264 is sought, as provided by §264.302(a), the owner or operator must submit detailed plans and an engineering report explaining the location of the saturated zone in relation to the landfill, the design of a double-liner system that incorporates a leak detection system between the liners, and a leachate collection and removal system above the liners;

(d) A description of how each landfill, including the liner and cover systems, will be inspected in order to meet the requirements of §264.303 (a) and (b). This information should be included in the inspection plan submitted under §270.14(b)(5).

(e) Detailed plans and an engineering report describing the final cover which will be applied to each landfill or landfill cell at closure in accordance with §264.310(a), and a description of how each landfill will be maintained and monitored after closure in accordance with §264.310(b). This information should be included in the closure and post-closure plans submitted under §270.14(b)(13).

(f) If ignitable or reactive wastes will be landfilled, an explanation of how the standards of §264.312 will be complied with;

(g) If incompatible wastes, or incompatible wastes and materials will be landfilled, an explanation of how §264.313 will be complied with;

(h) If bulk or noncontainerized liquid waste or wastes containing free liquids is to be landfilled, an explanation of how the requirements of §264.314 will be complied with;

(i) If containers of hazardous waste are to be landfilled, an explanation of how the requirements of §264.315 or §264.316, as applicable, will be complied with."

9.1 WASTE DESCRIPTION

9.1.1 The Federal Requirement

The Part 270 information requirements are:

> §270.21 "Except as otherwise provided in §264.1, owners and operators of facilities that dispose of hazardous waste in landfills must provide the following additional information: (a) A list of the hazardous wastes placed or to be placed in each landfill or landfill cell"

Subpart N, Landfills (§§264.300-264.339) of Part 264 does not contain specific requirements for waste identification. However, in Subpart B, General Facility Standards, the provisions of §264.13, General Waste Analysis, require owners and operators of all waste facilities to identify all wastes handled. Specifically, the requirements of §264.13(a), (b), and (c) apply to landfills and those requirements are:

> §264.13 General waste analysis
>
> "(a)(1) Before an owner or operator treats, stores, or disposes of any hazardous waste, he must obtain a detailed chemical and physical analysis of a representative sample of the waste. At a minimum, this analysis must contain all the information which must be known to treat, store, or dispose of the waste in accordance with the requirements of this Part or with the conditions of a permit issued under Part 270, and Part 124 of this Chapter.
>
> (2) The analysis may include data developed under Part 261 of this Chapter, and existing published or documented data on the hazardous waste or on hazardous waste generated from similar processes.
>
> (3) The analysis must be repeated as necessary to ensure that it is accurate and up to date. At a minimum, the analysis must be repeated:
>
> (i) When the owner or operator is notified, or has reason to believe, that the process or operation generating the hazardous waste has changed; and
>
> (ii) For off-site facilities, when the results of the inspection required in paragraph (a)(4) of this Section indicate that the hazardous waste received at the facility does not match the waste designated on the accompanying manifest or shipping paper.
>
> (4) The owner or operator of an off-site facility must inspect and, if necessary, analyze each hazardous waste movement received at the facility to determine whether it matches the identity of the waste specified on the accompanying manifest or shipping paper.

(b) The owner or operator must develop and follow a written waste analysis plan which describes the procedures which he will carry out to comply with paragraph (a) of this Section. He must keep this plan at the facility. At a minimum, the plan must specify:

(1) The parameters for which each hazardous waste will be analyzed and the rationale for the selection of these parameters (i.e., how analysis for these parameters will provide sufficient information on the waste's properties to comply with paragraph (a) of this Section;

(2) The test methods which will be used to test for these parameters;

(3) The sampling method which will be used to obtain a representative sample of the waste to be analyzed. A representative sample may be obtained using either:

(i) One of the sampling methods described in Appendix I of Part 261 of this Chapter; or

(ii) An equivalent sampling method.

(4) The frequency with which the initial analysis of the waste will be reviewed or repeated to ensure that the analysis is accurate and up to date; and

(5) For off-site facilities, the waste analyses that hazardous waste generators have agreed to supply.

(6) Where applicable, the methods which will be used to meet the additional waste analysis requirements for specific waste management methods as specified in §§264.17 and 264.341.

(c) For off-site facilities, the waste analysis plan required in paragraph (b) of this Section must also specify the procedures which will be used to inspect and, if necessary, analyze each movement of hazardous waste received at the facility to ensure that it matches the identity of the waste designated on the accompanying manifest or shipping paper. At a minimum, the plan must describe:

(1) The procedures which will be used to determine the identity of each movement of waste managed at the facility; and

(2) The sampling method which will be used to obtain a representative sample of the waste to be identified, if the identification method includes sampling."

9.1.2 Summary of Necessary Application Information

The Part B Permit Applicants' Manual[1] instructs the applicant to submit a list of all hazardous waste that will be disposed of in the landfill, including:

- Name of the waste
- EPA hazardous waste ID number
- Location(s) within the landfill where waste is or will be disposed of (e.g., cell number)

The applicant is advised that waste analysis information is required in the Part A application (under §270.13(j)) and in response to the general facility information requirements (under §270.14(b)(2)). The Part A application must include:

- Specification of the hazardous wastes to be disposed of
- Quantity of wastes to be disposed at the facility
- Quantity of wastes to be disposed annually
- General description of processes to be used for such wastes

If an existing facility with interim status submits a Part B application which indicates a different listing than in the original Part A application, a revised Part A application is also required. In this case, the Part B application should note the changes.

9.1.3 Guidance on Evaluating Application Information

The requirement for a waste description is applicable to existing and new landfills and is intended to assure that the facility can adequately dispose of the proposed waste materials.

For existing facilities operating under interim status, the list of current and expected wastes should include all the wastes shown on the previously submitted Part A of the permit application. If the list shows fewer wastes than the Part A, then either the waste must have been specifically delisted since the Part A was submitted or the applicant must state in the application that the waste will no longer be accepted for disposal at the landfill. The list should be judged inadequate if neither of these criteria are met. For existing facilities operating under interim status, if the list contains more wastes than indicated on the previously submitted Part A, then the application must include a revised Part A. The application is incomplete if the revised Part A is not included.

If the landfill is a unit of a larger facility, the Part A application will incorporate a listing of all wastes handled in all portions of the facility by EPA ID number. The wastes to be landfilled may be a subset of this list, or may result from processing or treatment of the noted wastes. Consequently, some or all of the wastes to be landfilled may not have an EPA ID number.

An applicant could have difficulty supplying a detailed list of wastes that have been placed in areas of an existing facility that have been inactive for long periods of time. (If such a facility portion is closed before January 26, 1983, it is not a regulated unit and, therefore, the information requirement is not applicable unless ground water contamination is evident.) For existing active portions, the applicant should be expected to indicate whether the wastes were bulk or containerized, solid or liquid. The owner's records may also indicate the type of waste (e.g., empty raw materials packages) or the type of process or operation that generated the waste (e.g,

distillation column bottoms). In some cases, the landfill may still be disposing of wastes from the same company or processes and the owner or operator can use that current information to help identify and characterize the wastes placed in inactive areas of the facility.

Experience in the review of historical records indicates that a disposer's records will typically contain enough information to determine the physical characteristics of wastes disposed and a generic description of the waste. However, records do not usually supply much information on where at the site a specific waste was buried or information that would allow a definitive hazardous/nonhazardous determination.[2] Thus, a judgement on the adequacy of a list of wastes previously disposed of at a facility may have to be made on a case-by-case basis after discussions with the owner or operator.

New facilities must submit a Part A application with their Part B permit application. The information on waste types and quantities contained in the Part A will generally be sufficient to meet the listing criteria for Part B. However, unless the permit application for a new facility includes both a Part A and a Part B, the submittal must be judged incomplete.

The regulations require a list of only the hazardous wastes. However, in some cases it may be advantageous to have information on the nonhazardous wastes that will be disposed. This is especially important if hazardous and nonhazardous wastes are to be intermingled, because a showing of compatibility must be provided in the permit application.

The most frequent reasons for listing a waste as hazardous will be that the waste exhibits a characteristic identified in Subpart C of Part 261, that it is specifically listed in Subpart D of Part 261, or that it contains a compound listed in Appendix VIII of Part 261. However, the applicant may list a waste as hazardous based on his knowledge of the waste or on the generator's knowledge of the waste, even if it does not meet any of the criteria in Part 261 that would require it to be listed. Sampling and analytical procedures recommended for hazardous waste characterization are presented in SW-846--Test Methods for Evaluating Solid Waste.[3]

For wastes placed in portions of a facility that have long been inactive, the applicant may be unable to identify hazardous constituents in that waste. Because the information on hazardous constituents is used to determine the adequacy of other parts of the permit application (especially ground water monitoring), the permit application reviewer will have to make case-by-case judgements of adequacy whenever such situations are encountered.

Worksheets for evaluating the technical adequacy of the applicant's waste listings are presented for existing facilities and new facilities in Figures 9.1.1 and 9.1.2, respectively. Completion of these worksheets will allow the permit application reviewer to proceed through the first part of the Technical Adequacy Checklist provided in subsection 9.9.

LISTING OF HAZARDOUS WASTES--EXISTING FACILITY

	Yes	No	Date
Has this part of the applicant's submittal been reviewed and evaluated?			
Does the Part B information agree completely with the listing information provided previously in the Part A application?	Yes	No	
Are waste names and EPA ID numbers identified?	Yes	No	
Are locations identified within the landfill to show where wastes are or will be disposed of?	Yes	No	

If all answers are yes, this part of the applicant's submittal is adequate. However, if any differences exist between the Part A and Part B applications--

Are only a subset of the wastes listed in Part A to be landfilled?	Yes	No
Are one or more of the previously identified wastes (in Part A) to be treated or somehow transformed before landfilling?	Yes	No
Have any of the wastes been delisted?	Yes	No
Have any of the subject landfill portions been closed?	Yes	No
Is the apparent discrepancy explained in the Part B application?	Yes	No
Has the applicant submitted a revised Part A application?	Yes	No

Describe any deficiencies in the applicant's submittal, if they exist.

Figure 9.1.1. Worksheet for evaluating the adequacy of the listing of hazardous wastes for existing facilities.

LISTING OF HAZARDOUS WASTES--NEW FACILITY

Has this part of the applicant's submittal been reviewed and evaluated?	Yes	No	Date
Have both Part A and Part B applications been submitted?	Yes	No	
Are waste names and EPA ID numbers identified?	Yes	No	
Are locations identified within the landfill to show where wastes are or will be disposed of?	Yes	No	
Are there any apparent discrepancies in information provided in Parts A and B?	Yes	No	
Are only a subset of the wastes listed in Part A to be landfilled?	Yes	No	
Will any wastes listed in Part A be treated or transformed to different wastes that will ultimately be landfilled?	Yes	No	

Describe any deficiencies in the applicant's submittal, if they exist.

_____

_____

_____

_____

Figure 9.1.2. Worksheet for evaluating the adequacy of the listing of hazardous wastes for new facilities.

9.1.4 Draft Permit Preparation

As noted in Module XV, Condition A, the permit writer must specify the wastes that can be disposed of in given landfill units at the applicant's facility. In the body of the permit, rather than by attachment, the wastes or classes of wastes that are allowed for disposal must be stipulated. If any of these wastes are currently identified by EPA identification numbers, these numbers should be included in the listing of wastes.

If any special requirements are attendant with the noted wastes because of reactivity, ignitability, incompatibility, or other concerns, applicable permit conditions or attachments should be cross-referenced at condition A. Permit condition B and attachments related to liner selection based on waste/chemical resistance should also be referenced at permit condition A.

The fact sheet (or statement of basis) accompanying the draft permit should include a paragraph at the beginning to summarize the waste description or list incorporated as condition A in permit module XV. Other information which may be appropriate to explain briefly at this point in the fact sheet is the amount of waste expected to be handled on an annual basis.

9.1.5 References

1. U.S. Environmental Protection Agency. Permit Applicant's Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Volume 1, Office of Solid Waste, Washington, D.C., 1983.

2. Telephone conversation. J. McNeish, Intera Environmental Consultants, Inc., and S. Capone, GCA/Technology Division. February 7, 1983.

3. U.S. Environmental Protection Agency. Test Methods for Evaluating Solid Waste--Physical/Chemical Methods. SW-846. Second Edition. July, 1982.

9.2 DESIGN AND OPERATING REQUIREMENTS

Section 264.301 specifies design and operating standards for landfill components such as liners, leachate collection facilities, run-on and run-off control facilities, and wind dispersal control systems. Because of the broad coverage of the design and operating standards, the forthcoming discussion is subdivided to address each of these system components. The remainder of this subsection is presented in the following manner:

9.2.1 Liner System Design

9.2.2 Leachate Collection and Removal System

9.2.3 Liner and Leachate Collection and Removal System Exemption

9.2.4 Control of Run-on

9.2.5 Control of Run-off

9.2.6 Management of Units Associated with Run-on and Run-off Control Systems

9.2.7 Management of Wind Dispersal

9.2.8 Subpart F Exemption

The following subsections are incorporated under each of these sections:

9.2._.1 The Federal Requirement

9.2._.2 Summary of Necessary Application Information

9.2._.3 Guidance on Evaluating Application Information

9.2._.4 Draft Permit Preparation

9.2._.5 References

The third subsection of each of the first eight sections provides guidance on evaluating the technical adequacy of the application and includes worksheets for making this determination. The fourth subsection incorporates guidance on preparing the draft permit based on the submitted application information and model permit modules presented in Section 4 of this manual.

9.2.1 Liner System Design

9.2.1.1 The Federal Requirement--

Paragraph(b) of §270.21 requires that the applicant's plans and/or engineering report on landfill design, construction, operation, and maintenance must address:

"(1) The liner system. . ."

The liner standards of §264.301 state that:

> "(a) A landfill (except for an existing portion of a landfill) must have:
> (1) A liner that is designed, constructed, and installed to prevent any migration of wastes out of the landfill to the adjacent subsurface soil or ground water or surface water at anytime during the active life (including the closure period) of the landfill. The liner must be constructed of materials that prevent wastes from passing into the liner during the active life of the facility. The liner must be:
> (i) Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients (including static head and external hydrogeologic forces), physical contact with the waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation;
> (ii) Placed upon a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression, or uplift; and
> (iii) Installed to cover all surrounding earth likely to be in contact with the waste or leachate; ..."

9.2.1.2 Summary of Necessary Application Information--

The Part B Permit Applicants' Manual[1] directs the applicant to provide the following information on liner system design:

(a) Hydrogeologic Data, including:

- the location of the landfill bottom with respect to the water table
- data showing seasonal variation and highest recorded level of the water table

(b) Material of Construction

(c) Chemical Properties of Liner

(d) Physical Strength and Thickness

(e) Foundation Design/Integrity, including:

- regional and site geologic data
- summary of seismic conditions at the site
- hydrogeological data describing aquifers at the site

- an evaluation of surface water run-on and run-off
- geotechnical data on foundation soils
- a summary report, including:
  - Detailed boring logs
  - Typical soil profiles
  - Site and regional geology
  - Fault map
  - Results of analyses and description of methods
  - Solution cavity potential
  - Sinkhole potential
  - Liquefaction potential
  - Uplift potential
- description of liner bedding material

(f) Areal Extent of Liner

(g) Liner System Integrity, considering:

- waste/liner compatibility
- internal/external pressure gradients
- climatic conditions
- installation stresses
- daily operational stresses.

The foundation investigation is expected to incorporate subsurface exploration by means of test borings, trenches, or geophysical surveys. Other field testing may also be appropriate, such as pumping, permeability testing, and tests for density, shear strength, and bearing capacity. Soil testing in the laboratory is appropriate to classify the soil and establish index and engineering properties such as Atterberg limits, grain size distribution, and soil compressibility. Settlement analyses should be conducted and reported to demonstrate total and differential settlement, primary and secondary consolidation, creep, and liquefaction. This foundation analysis is expected to be prepared by a local foundation expert (e.g., civil or geotechnical engineer).

To illustrate liner system integrity, the applicant is asked to submit compatibility testing results. This information should include the test method, description of procedures, chemical and physical waste characteristics, raw test results, and interpretation of results. Perspective is provided in the Part B Manual on primary and secondary leachates and physical classes of wastes. These latter factors influence the selection of a method for collecting representative samples of leachates and wastes. The

Agency has developed Test Method 9090 for assessment of waste/synthetic liner compatibility. A copy of the procedure is included as an Appendix to the RCRA Technical Guidance Document for Landfills[2].

A detailed engineering report is requested in the Part B Manual to illustrate the proposed liner system's ability to withstand internal and external pressure gradients during the active life of the landfill. To demonstrate adequate strength and thickness, the applicant is asked to consider waste/liner compatibility, bottom heave or blow out, slope stability and creep, strength loss due to several factors, possible puncturing or tearing of the liner, and live loads on the liner.

Finally, if the facility has a projected active life of greater than 30 years, the applicant is asked to provide information on the soil liner proposed below the synthetic liner (in keeping with guidance in the RCRA Technical Guidance Document[2]). In this case, the application information requirements are as stated for clay liners in Section 6.0, Surface Impoundments.

It is recommended that the permit writer review subsection 2.1.3 of the landfill chapter of the Part B Permit Applicants' Manual[1] because the Agency has requested extensive information on liner system design.

9.2.1.3 Guidance on Evaluating Application Information--

9.2.1.3.1 Introduction--Figure 9.2.1 is a flow chart that indicates the applicability of the Part 264 requirements to the design of liner systems. This section provides technical guidance to assist in answering the major questions posed in the chart. An overview of the related subject matter addressed in this section is presented in Figure 9.2.2. Each topic presented in Figure 9.2.2 is discussed to provide a general understanding of liner design, installation, and performance factors which must be considered in evaluating the technical adequacy of an applicant's proposed liner system. Synthetic liners are emphasized because, if properly selected and installed, they will minimize the volume of waste which passes into the liner during the active life and, therefore, will promote leachate collection and removal through the leachate collection system. The reader is referred to the Technical Resource Document (TRD) on "Lining of Waste Impoundment and Disposal Facilities" (SW-870)[3] which provides a comprehensive treatment of this subject. Much of the following text is based on information from the TRD.

9.2.1.3.2 Seasonal Variation of Water Table and Maximum Recorded Height-Information Requirement (a)--Several basic ground water hydrology references are available which discuss the concept of the ground water table and seasonal variation in ground water table elevation. These include Chow (1964),[4] Bouwer (1978),[5] and Freeze and Cherry (1979).[6]

The ground water table is the location of transition from the unsaturated zone near the ground surface to the saturated zone at depth. Since a capillary fringe often exists at this location, the water table is best defined as the surface at which fluid pore pressure is equal to atmospheric pressure.

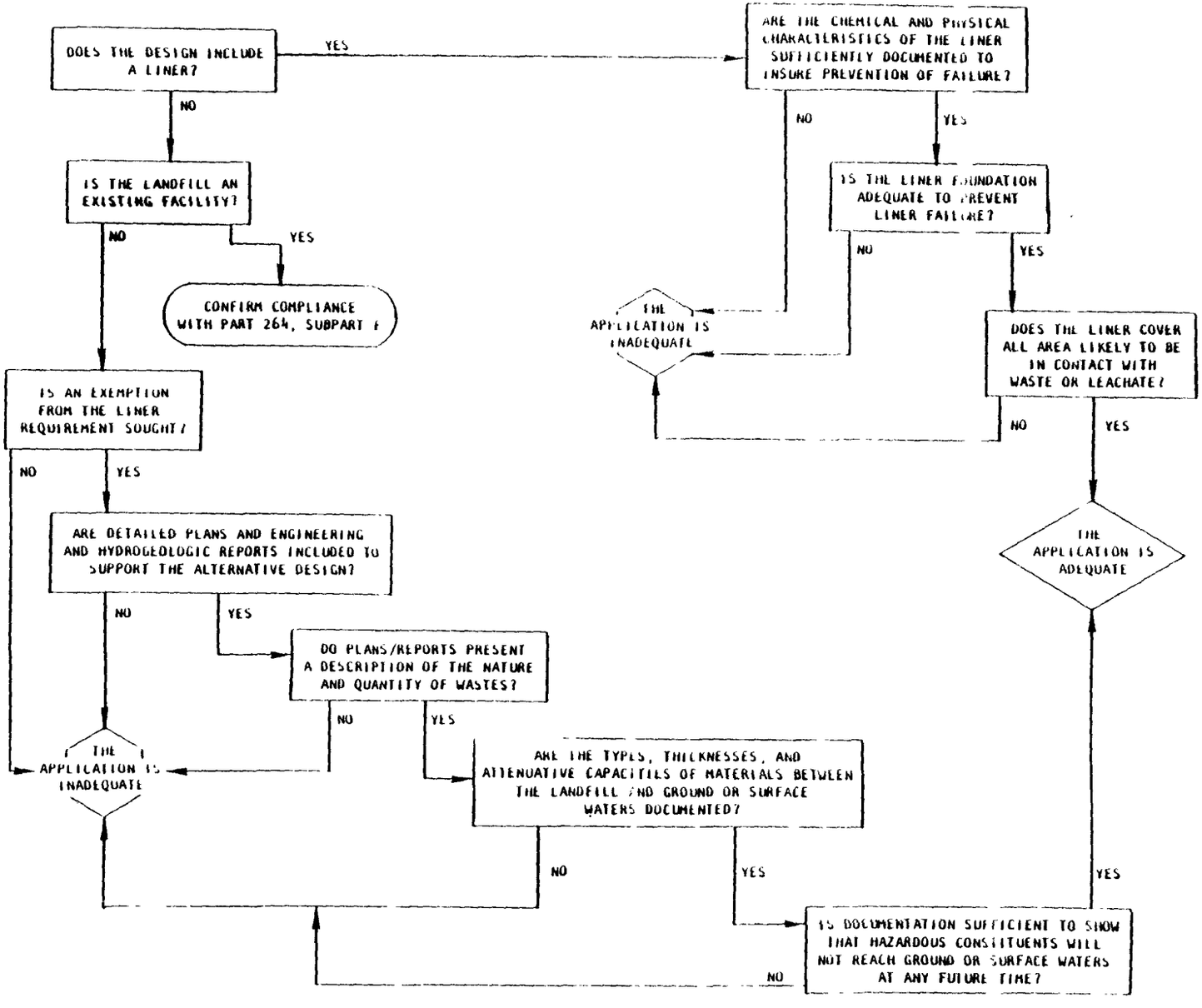


Figure 9.2.1. Applicability of Part 264 requirements to liner system.

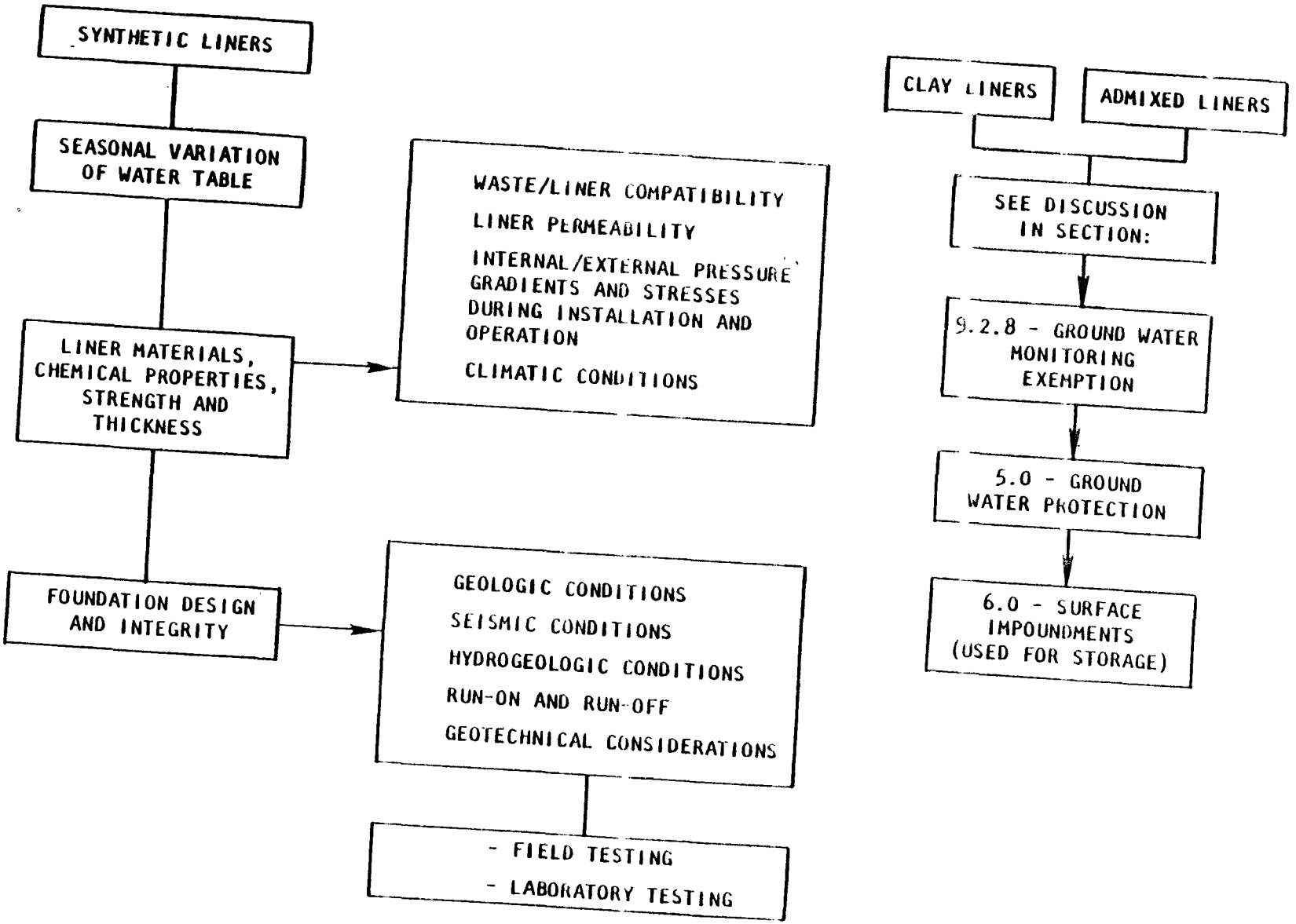


Figure 9.2.2. Evaluation of proposed liner systems.

Water table location is assessed based on well level measurements. State water resource departments are the best source of historical records for ground water elevations in localized areas. These agencies may be affiliated with the U.S.G.S. or state environmental departments. Often, conservation commissions may keep such records for their city or town. State water resource departments install and maintain monitoring wells to collect ground water table elevation data. In some states, records may cover as many as 100 years of measurements. In most states, measurements are made on a monthly basis.

These information sources should be used as the basis for the applicant's demonstration of maximum recorded water table elevation, as well as seasonal water table variation.

9.2.1.3.3 Liner Materials, Chemical Properties, Strength and Thickness - Information Requirements (b), (c), (d), (f), and (g)--Topics grouped under this heading are discussed together because of strong interrelationships which exist among them. The chemical makeup of the liner is a determining factor in waste/liner compatibility. Incompatibility between the liner and waste or leachate may manifest itself as a reduction in liner strength, or as an increase in liner permeability. The strength of a synthetic liner may also be influenced by internal or external pressure gradients, stresses during installation and operation, or climatic conditions. These topics and associated evaluation methods are addressed in the next 4 subsections.

Waste/Liner Compatibility

Use of synthetic membrane liners for containment of hazardous wastes in landfills is an emerging technology. In past applications, synthetic liners have been used for lining of surface impoundments holding relatively homogenesous wastes in comparison to the range of wastes and leachates that could be generated in a landfill cell. Manufacturer's compatibility data may be adequate for single wastes and specific synthetic material blends, but will be of little value in evaluating the compatibility of a given liner with several different waste types or leachates generated from mixing of several different wastes.

In recognition of the fact that selection of synthetic liners for hazardous waste landfill applications is tenuous based on currently documented data, the EPA has established a laboratory test method for assessing waste/liner compatibility. Test Method 9090, currently in draft form and subject to revision, is incorporated as an Appendix to the RCRA Technical Guidance Document for Landfills.[2] As stated there, the EPA prefers chemical testing of liners using this method to account for the possible interaction of many waste or leachate types with the liner. Therefore, in all cases, except the most straightforward applications, it is incumbent upon the owner/operator to conduct such testing to provide evidence of waste/liner compatibility. Applicants will often require expert assistance in conducting this testing and in evaluating the results to assure that a proposed liner can be used with success.

Test Method 9090--In this test, a sample of the liner material is exposed to the expected chemical environment for a period of 120 days and physical properties, tested before and after liner exposure, are compared. The physical parameters tested include tear resistance, puncture resistance, tensile strength, hardness, and elongation at break. Appendix VIII of the Liner TRD (SW-870) incorporates tabulations of ASTM test methods used to measure all physical properties specified in method 9090. Any significant change in these properties after sample exposure is considered to be indicative of incompatibility between the waste and liner.

An important aspect of the test is collection and use of a representative sample of the waste or leachate. Collection of a representative sample will be difficult in the case of a new facility where the owner/operator plans to combine several wastes in the same cell. In this case, the permit reviewer should carefully evaluate the owner/operator's proposal for generation of a representative sample of waste or leachate. In the case of an interim status facility with existing units, leachate collected from an existing unit may be representative of leachate generated in a unit to be opened if waste types to be accepted are documented as similar.

Tear resistance measures the force required to tear a specimen of the liner with or without a controlled flaw, and serves as an indication of the mechanical strength of the sheeting. Puncture resistance measures the force required to puncture the liner sheet with a standard probe. It is intended to indicate the susceptibility to puncture from poorly graded materials above and below the liner. Hardness is a measure of the ability of the liner to resist indentation by a small probe of specified shape and dimensions.

Tests of tensile strength and related properties may include the following measurements, depending on the type of polymeric sheeting tested:

- tensile strength at fabric break (if fabric-reinforced),
- elongation at fabric break (if fabric reinforced),
- tensile strength at yield (if a crystalline liner),
- elongation at yield (if a crystalline liner),
- tensile strength at break of sheeting,
- elongation at break of sheeting,
- modulus of elasticity at specified elongations, e.g., 100 percent and 200 percent.

These tests are performed according to ASTM and FTMS protocols (see Appendix VIII and Table 3-7 in SW-870). Results are plotted over the time period 0 to 120 days. Submitted data should include raw, tabulated, and plotted results. Raw data are particularly important to allow the permit reviewer to assess the validity of the applicant's interpretation of results.

Discussions in the RCRA Technical Guidance Document for Landfills[2] suggest that any significant deterioration in any of these measured properties should be considered as evidence of incompatibility unless a convincing demonstration is made to show that deterioration exhibited by the test results will not impair liner integrity over the facility's life. The cumulative effects of possible deterioration should be extrapolated over the facility's operating life in any determination such as this.

Existing Compatibility Test Results--The liner TRD (SW-870) reports test results for liner exposure and immersion in hazardous wastes. In one series of tests, liners were exposed to strong acid wastes, a strong alkali waste, an oil refinery tank bottom waste, a lead waste from gasoline, saturated and unsaturated hydrocarbon wastes, and a pesticide waste.

Significant changes in ultimate elongation of butyl rubber (see Table 4-21 in SW-870) were found after 3 years of exposure to strong acids or caustic. Minor changes were noted for all waste/liner combinations although the statistical significance of the changes is uncertain. The S-100 modulus was noted to change for CPE and CSPE liner specimens exposed to caustic solution. Deterioration was also noted for other combinations.

Several physical properties were tested to determine the compatibility of several liner types with a dilute aqueous organic waste (0.1 percent tributyl phosphate in deionized water). Those results are worth noting here because they reflect the type of data that would be reported in performing Test Method 9090 (although the test period is longer than required under Method 9090). Table 9.2.1 reprints information from Table 4-28 of the Liner TRD. Some fairly significant changes in physical properties are evident. The tear resistance of all liner types suffered significantly. Tensile strength and elasticity are also noted to have deteriorated. These results would indicate that use of CPE, CSPE, or PVC with this waste would be unacceptable considering the significant changes in physical properties noted. Even use of butyl rubber or HDPE would be uncertain based on these test results, for the specific liner/waste combination considered.

Factors Affecting Liner Deterioration--Liner deterioration is most often caused or associated with one or more of the following:[7]

- Swelling of the coating compound used on the liner,
- Degradation of the polymer used in the liner fabrication,
- Crosslinking of the polymer in the coating.

Swelling of the liner compound may lead to softening, a reduction in tensile strength, a loss of elasticity or possible elongation, and an increase in permeability. Degradation of the membrane polymer can increase swelling. Crosslinking of the polymer causes stiffening, usually loss of tear strength, and sometimes loss of tensile strength as well. Although fabric reinforcement may enhance liner tensile strength, the reinforcement may be affected by wastes which can permeate the coating.

TABLE 9.2.1. EFFECTS OF EXPOSURE ON SELECTED POLYMERIC MEMBRANE LINERS IN WATER CONTAINING A LOW CONCENTRATION OF A DISSOLVED ORGANIC CHEMICAL[a] FOR 17.2 MONTHS
SOURCE: TABLE 4-28 OF SW-870[3]

Polymer	Butyl	CPE[d]	CPE[d]	CSPE[d]	PVC[d]	HDPE[d]
Type of compound[b]	XL	TP	XL	TP	TP	CX
Liner number	44	77	100	55	59	105
Initial thickness, mil	63.0	30.0	35.8	33.1	33.1	31.9
Analytical properties:						
Weight gain, %	21.9	107.2	34.4	31.6	46.2	0.56
Physical properties:[c]						
Final thickness, mil	64	48	41	38	36	31.5
Change, %	+2	+60	+15	+15	+9	-1
Tensile strength, % retention	107	10	63	48	31	88
Elongation at break, % retention	115	155	79	79	89	101
Stress at 100% elongation, % retention	74	6	46	30	28	92
Tear resistance, % retention	...	14	29	39	23	81
Hardness change, Durometer points	-2A	-60A	-20A	-14A	-33A	-1A
Puncture test:						
Stress, % retention	73	20	85	112	48	101
Elongation, % retention	126	127	125	131	133	107

[a] 0.1% Tributyl phosphate in deionized water.

[b] TP=thermoplastic, XL=crosslinked, CX=partially crystalline thermoplastic.

[c] Data for tensile, elongation, S-100, and tear are the averages of measurements made in both machine and transverse directions.

[d] CPE - chlorinated polyethylene
CSPE - chlorosulfonated polyethylene
PVC - polyvinyl chloride
HDPE - high-density polyethylene

Preliminary Selection of Synthetic Liner Materials--Given the emerging status of synthetic liner use for hazardous waste management, a comprehensive and reliable guide on waste/liner compatibility is not currently available. However, some existing knowledge can be summarized to provide some general information on liner selection. To date, quite a bit of data has been compiled on liner swelling (i.e., weight gain) after immersion or exposure to wastes. Table 9.2.2 provides a summary of some of this information (based on References 3, 8, and 9) and indicates waste/liner combinations of high, medium, or low resistivity. The results from Reference 3 are based on immersion tests (of up to 81 days) using reagent grade chemical baths according to the ASTM D471 Immersion Method. Resistivity ratings presented in the table were defined on the following basis:

Resistivity Rating	% Weight Loss or Gain
High	0.1 - 11.5
Moderate	7.0 - 23.0
Low	20.0 - 250+, and dissolution or deterioration

Qualitative rankings (good, fair, poor) of waste/liner compatibility are presented for generic industrial waste types (caustic petroleum sludge, acidic steel-pickling waste, etc.) in the Liner TRD (SW-870). Rankings for synthetic liner/generic waste combinations are reproduced here in Table 9.2.3. This information is presented for general guidance only. If a situation arises which is apparently covered by one of the ratings, it should not relieve the applicant of conducting laboratory testing.

Compatibility information is available through the flexible membrane liner industry. Considerable data on the use of polymeric materials has been collected. Generally, however, this information is representative of situations which are not as complex as those that may arise in permitting situations. Generally, the compatibility of the liner and one constituent are considered in manufacturer's information. However, some liner fabricators may be willing to share previous experience or case history information which they have on file.

Manufacturer's waste/liner compatibility data have been summarized and statistically evaluated by A. T. Kearney[10] for the EPA Office of Solid Waste. Liner ratings provided by manufacturers were converted to numerical scores and were also ranked using a pass-fail system.

EPA is continuing research of liner characteristics and will issue updates on existing data as information becomes available. The RCRA Technical Guidance Manual "Landfill Design - Liner Systems and Final Cover" should be consulted in addition to SW-870, the Liner TRD.

Additional information sources that may be of value in assessing waste/liner compatibility are listed in subsection 9.2.1.5, References, numbers 11 through 15.

TABLE 9.2.2. CHEMICAL RESISTIVITY OF SYNTHETIC LINER MATERIALS

Liner material	Chemical waste component													Comments	References
	Acids	Alkalis	Aliphatic solvents	Aromatic solvents	Halogenated solvents	Oxidizing solvents	Silicates	Phosphates	Brines	Pesticides	Petroleum bottoms	Pharmaceutical wastes	Rubber and plastics		
Butyl	H	H	L	L	L	M	M	M	M	M	L	M	M	High ozone, UV resistance	3,8,9
EPDM	H	H	L	L	L	M	M	M	M	M	L	M	M	High UV resistance	3,8
Hypalon	M	M	M	M	M	M			M	M	L	M	M	High ozone, UV resistance Low resistance to oils	3,8,9
CPE	M	M	L-M	L	L	L			M	M	L	M	M	High ozone resistance. Can be formulated to withstand intermittent contact with aliphatics, oils	3,8,9
Neoprene		M	M				M	M	M					High ozone, UV resistance Resistant to water with trace hydrocarbons, also to mixtures of oils and acids	3,8
PVC	M	M	L-M	L-M	L-M	M			M	M	L	M	M	Poor UV resistance. Susceptible to sulfides. Can exhibit plasticizer loss through volatilization	3,8,9
Polyethylene	H	H	H-M	H-M	M	M				M	M	H	H	Resistive capabilities are a strong function of crystallinity and density type	3,8,9
Polypropylene	H	H	H	H	M	L								Poor ozone, UV resistance	8,9
Elasticized Polyolefin	H	H		L	L						L			Poor resistance to oils	3
Epichlorohydrin Rubber			M	H	H						H			High ozone resistance	3
Nylon	L	M	H	H	H										9

RESISTIVITY RATING CODE: L - Low, M - Moderate, H - High (see text for numerical values).

TABLE 9.2.3. SYNTHETIC LINER-INDUSTRIAL WASTE COMPATIBILITIES[a]

Liner material	Petroleum sludge	Caustic pickling waste	Acidic steel-plating sludge	Toxic pesticide formulations	Oil refinery sludge	Toxic pharmaceutical waste	Rubber and plastic
Polymeric membranes:							
Butyl rubber	G	G	G	F	P	F	G
Chlorinated polyethylene	G	F	F	F	P	F	G
Chlorosulfonated polyethylene	G	G	G	F	P	F	G
Ethylene propylene rubber	G	G	G	F	P	F	G
Polyethylene (low density)	G	F	F	G	F	G	G
Polyvinyl chloride	G	F	F	G	G	G	G

G = Good, F = Fair, P = Poor.

Source: Reference 3, which cites Stewart, W. S. State-of-the-Art Study of Land Impoundment Techniques. EPA-600/2-78-196.

Synthetic Liner Permeability

The regulations require use of a liner that prevents wastes from passing into the liner during the active life of the facility. Synthetic liners come closest to meeting the condition of impermeability, although none have been identified which are completely impermeable.

A review of manufacturer's literature indicates that liner permeability is rarely specified. In some cases, the percent water absorption is specified but the associated test period is not.

The TRD on liners (SW-870)[3] reports a variety of test results for synthetic membrane liners exposed to hazardous waste leachates which are indicative of liner susceptibility to waste or leachate permeation. These tests were designed, in part, to measure changes in volatile and extractable content of exposed liners, changes in weight, and changes in other measured parameters, as discussed below.

In these experiments, membrane liner samples were exposed to hazardous waste leachate in immersion tests, pouch tests, and tub tests. The wastes included two strong acid wastes, a strong alkali waste, an oil refinery tank bottom waste, a lead waste from gasoline, saturated and unsaturated hydrocarbon wastes, and a pesticide waste.

As part of the immersion tests, eight membrane liners were exposed below 1 foot of waste. After 1 year and 3.5 years of exposure, the membrane samples were analyzed for volatiles and extractables (i.e., the higher the percentage of extractables and volatiles, the greater the membrane permeability). The results of this testing showed that butyl rubber, elasticized polyolefin, polyester and polyvinyl chloride contained a lower percentage of volatiles (2.9-4.8 percent) than chlorinated polyethylene, chlorosulfonated polyethylene, ethylene propylene rubber, and neoprene (6.3-13.6 percent) when exposed to a pesticide waste. Exposure to other wastes produced similar results.

Concurrent with these tests, supplemental liners were hung in the wastes and the effects of exposure were evaluated by determining the increase in weight, analyzing the exposed specimen, and measuring selected physical properties. The amount of pesticide waste absorbed by butyl rubber, elasticized polyolefin, fabric reinforced ethylene propylene rubber, polyester, and PVC was less than 5.1 percent. Chlorinated polyethylene, chlorosulfonated polyethylene, non-fabric reinforced elasticized polyolefin, and neoprene showed significantly higher absorption of pesticide waste, ranging from 11.4 to 20.4 percent. Absorption rates were similar for other wastes with some exceptions. One notable exception was the butyl membrane. This membrane exhibited low absorption for the pesticide, acidic, and caustic wastes but a high absorption capacity for the oil wastes. In the immersion tests, measurement of the volatile content of the membranes were analogous to the results of the absorption test.

In a pouch test, small pouches were fabricated out of chlorinated polyethylene, chlorosulfonated polyethylene, elasticized polyolefin, polybutylene and polyvinyl chloride. (At the present time, only pouches made of thermoplastic and crystalline sheetings have been successfully fabricated into pouches and tested.) These pouches were filled with wastes and other test fluids and then sealed and immersed in deionized water. The permeabilities of the membranes to water and to pollutants were determined by observing, respectively, the change in weights of the bags and the pH and electrical conductivity of the deionized water. After 552 days of testing, measurements of the electrical conductivity and average flux showed that PVC lining materials had the greatest permeability of the membranes tested. Chlorinated polyethylene and chlorosulfonated polyethylene were found to have less permeability than PVC but greater permeability than ethylene propylene rubber and polybutylene. An analysis of the physical properties of the pouch wall materials after 1150 days of exposure confirm the above conclusions.

As part of the tub tests, two samples of polyolefin liner were exposed to an oily waste; failure occurred by cracking at the folds of the sheet. In a preliminary immersion test, this liner had appeared to perform satisfactorily with the waste, although the manufacturer had not recommended the liner for use in waste oil impoundments. Performance was noted to vary significantly depending on location of the liner specimen in the tub. The worst performance was noted when the sample was located at the waste - air interface. The unexposed sample retained its properties during the 43-month exposure period.

Based on all testing reported in the TRD (SW-870), the following general conclusions are noted regarding relative permeability of membrane liners. PVC liners exhibit relatively high permeability in the presence of some hazardous wastes in spite of the fact that they have shown low permeability in the presence of sanitary wastes. PVC membranes are attacked by many organic chemicals including hydrocarbons, solvents, and oils. Other liners which appear to have a relatively high permeability are chlorinated polyethylene and chlorosulfonated polyethylene. Ethylene propylene rubber, polybutylene, polyester, and butyl rubber appear to be the least permeable of the membranes tested. Neoprene and elasticized polyolefin appear to have a medium level of permeability. These results are summarized in Table 9.2.4. Because they are general in nature, they should not be used as the basis for accepting or rejecting a liner proposed for use in containing a particular waste.

Resistance to Pressure Gradients and Stresses During Installation and Operation

EPA believes (RCRA Technical Guidance Document on landfills)[2] that synthetic membrane liners should be at least 30 mils thick; thinner liners are reported to be readily damaged. One of the primary reasons for failure is tearing, puncture, or stretching during installation or operation.

In general, damage may result from physical, biological, or chemical failure, as presented in Table 9.2.5, from section 4.6 of the liner TRD. The following discussion briefly describes each category and provides recommendations on how to avoid such failure. Additional information may be found in SW-870[3] and the RCRA Technical Guidance Document.[2] The previous discussion of waste/liner compatibility can be referenced for guidance on chemical damage.

TABLE 9.2.4. RELATIVE MEMBRANE LINER PERMEABILITY BASED ON TESTING[a] WITH HAZARDOUS WASTES
SOURCE: REFERENCE 3.

Liner material	Hazardous wastes tested	Relative permeability
PVC	Pesticides, acid, alkali, oil,[b] lead, saturated and unsaturated hydrocarbons, HNO_3, spent caustic, slopwater[c]	High
CPE	Pesticides, slopwater	High
CSPE	Pesticides, slopwater	High
Neoprene	Pesticides, hydrocarbons	Medium
ELPO--Elasticized polyolefin	Pesticides, slopwater	Medium
Ethylene propylene rubber (fabric reinforced)	As listed for the PVC liner	Low
Polybutylene	HNO_3, spent caustic, slopwater	Low
Polyester	Pesticides, hydrocarbons	Low
Butyl rubber	Pesticides, hydrocarbons	Low

[a]The generalizations reported in this table are based mainly on measurements of liner swelling.

[b]Oil is a category covering three separate oil tests: oil 104, aromatic oil, and weed oil.

[c]"Slopwater" was an alkaline waste (see Table 4-18 in SW-870).

TABLE 9.2.5. FAILURE CATEGORIES

Physical	Biological	Chemical
Puncture	Microbial attack	Ultraviolet attack
Tear		Ozone attack
Creep		Hydrolysis
Freeze-thaw cracking		Ionic species attack
Wet-dry cracking		Extraction
Differential settling		Ionic species incompatibility
Thermal stress		Solvents
Hydrostatic pressure		
Abrasion		

Source: Reference 3 (SW-870).

Physical failures, especially puncture, are more prevalent problems for landfills than for other types of waste storage or disposal facilities because of the nature of the wastes and methods of waste placement (dropping of waste containers, driving vehicles above the liner, etc.) Puncture, tearing, or abrasion may result when run-off containing branches, rocks, or other debris comes in contact with the liner. In addition, puncture failure can be caused by burrowing or hoofed animals.

EPA recommends protecting synthetic liners from above and below by a minimum of 6 inches of bedding material. (The top bedding layer also acts to protect the membrane from damage due to exposure to sunlight and wind while the cell is in operation). However, membrane liners can be punctured by angular rocks in the bedding material that become exposed during installation. For this reason, the bedding layer should consist of materials which are no coarser than sand (SP) as defined by the Uniform Soil Classification System (USCS). The bedding material does not necessarily have to be a separate layer; natural soils or the leachate collection system media may meet the necessary criteria. However, due to the possibility of puncture from plant growth, application of herbicides on such soil may be appropriate.

Tear failure may occur as a result of the same mechanisms which cause puncture failure. In addition to the effects of landfill operations and burrowing animals, stress-relaxation-stress cycles may lead to tear failure. Proper design of liner bedding and care in operation will decrease the chances of this occurrence.

Creep failure arises with increasing deformation of the membrane under a sustained load. Material microstructure, stress level, and temperature all influence creep, and as a result, it is difficult to detect and control.

Thermal stress results from the occurrence of differential temperatures throughout the liner material or temperature changes which are great enough to cause a phase change in the material. Phase changes in membranes can cause volume changes by expansion or contraction. It can also be significant in composite materials as the various components may have different thermal reaction rates.

Freeze-thaw cracking and wet-dry cracking are cyclic occurrences causing repeated expansion and shrinkage of the liner material. Freeze-thaw is a more important concern for buried membrane liners. It acts to increase pore space volume and, therefore, the accessibility of liquids to this pore space. Freeze-thaw cracking may affect the entire expanse of liner rather than a localized section. Therefore, it is important to guard against it. Liner shrinkage and expansion will generally not be equal. Expansion takes place in the calender direction, transverse to the seams. Studies of HDPE, in particular, show this type of movement. It is imperative to design for control of thermal stress by allowing for expansion and contraction. In addition, expansion and contraction of pipes entering the landfill should be considered to assess their potential effect on the liner material.

Differential settling of the liner base will induce liner stresses that may cause elongation, tearing, or a change in liner elasticity. This problem can be minimized with proper geologic analysis prior to site selection and careful design and construction of the subgrade.

Liner resistance to internal and external pressure gradients is an important consideration. Liners are subjected to pressure due to swelling and cracking from within and pressure due to waste and equipment loading from above. Hydrostatic pressure failure is of concern when the structural integrity of the subgrade or base material is lost (due to sinkholes, oxidation of organic materials, etc.)

Finally, abrasion, or wearing of the liner, may be caused by wind or run-off. If blowing sand particles are a concern in the region in which the landfill is constructed, it should be designed with an abrasion-resistant liner or protective cover over all areas of the liner.

Biological failures due to microbial attack, particularly of the plasticizers used in some polymer compounds, are most often prevented with the addition of bactericides during liner manufacture.

Experience indicates that vegetation can penetrate liners of 40 mils thickness.[16] Therefore, the owner/operator should consider the use of sterilants or herbicides in the liner bedding proposed for the landfill liner system or cap.

Swelling of the liner is a chemical failure mechanism which can cause softening, loss of tensile and mechanical strength, elongation, creep and flow, and loss of puncture resistance. Adequate waste/liner compatibility studies and placement of the liner using recommended bedding layers will aid in preventing such failure. Extraction of plasticizers from liner materials such as PVC can result in shrinkage, embrittlement, and breaks in the liner material.

Atmospheric ozone is another source of chemical failure which can cause cracking of many polymers, particularly those which are partly unsaturated. Failures such as this are likely, especially in situations where the membrane is stretched. More detailed information may be found in Reference 17 (A. G. Strong, 1980), as recommended in the Liner TRD.

Climatic conditions which affect performance are temperature, rainfall, and wind direction and velocity. As such, performance of a given liner type will vary with geographic location. Exposure to sunlight or ultraviolet light will affect certain types of synthetic liners.

Ambient temperature, temperature extremes, and the duration of such extremes may be of particular significance in the liner selection process. Liner materials exhibiting superior low temperature resistance to cracking may not be able to withstand high temperature effects. If temperatures are low enough to cause icing or freezing, this may affect the structural integrity of the liner and/or the subgrade. Depending on the type of liner, low temperatures can cause stiffening, causing the liner to become brittle. When

warmed again, the time required for softening varies. ASTM tests are available to predict these properties. On the other hand, high temperatures may cause some liner materials to creep, elongating to failure during high temperature cycles.

Rolled or folded panels of thermoplastic liner material can block or stick together if exposed to the sun's heat during installation. As these panels are unfolded, coated sheets may split and unsupported sheets may tear. Black sheeting has been reported[13] to reach temperatures of 220°F at the surface during installation. At this temperature, tensile and tear strength can be significantly lower than at normal test temperatures. To minimize liner temperature effects during installation, at least one material (Hypalon™) is available in white. Liner burial abates temperature extremes because of temperature stability below ground. However, recent studies (at sanitary landfills) indicate that sustained temperatures as low as 60°F below ground or inside the landfill may be detrimental over time because these conditions are suitable for methane generation.[19] If gas venting is not provided, liner uplift or rupture may occur.

Recommended temperature for liner installation is approximately 50°F, although liner manufacturers report an allowable range of 4-95°F.[16,20]

Rainfall will affect liner service life. Although no specific studies are available testing rainwater, studies have been conducted to assess the effect of water on synthetic liners. For example, one liner fabricator has performed tests on Hypalon liners using both distilled and cold tap water. Weight gains from water exposure with one grade of hypalon were lessened significantly with addition of lead salts, formulating another grade of Hypalon liner.[21] Commentary on the effects of rainfall on liner system performance is also provided in the subsection on landfill foundation design and integrity. As noted in subsection 9.3, Monitoring and Inspection, liners should not be installed during wet weather conditions.

Wind is a factor that must be considered during liner installation and in accepting the final installation. Liner abrasion may occur during installation as a result of the impact of windborne sand particles, especially in arid regions. If liner ends are left exposed on slopes at the top of a landfill cell, whipping or repeated lifting of the exposed material can lead to tearing or cracking. To avoid this, some form of ballast should be used to hold down any exposed section of liner. Ideally, all sections of liner material should be covered with soil.

Certain liner materials are affected by exposure to sunlight. For example, CSPE is an exposable liner (sides, slopes) whereas PVC is normally used in situations where it will be covered to avoid exposure to ultraviolet light. Unprotected, clear polyethylene has an instant thermal reaction upon exposure to sunlight and degrades rapidly. However, the addition of 2 to 3 percent carbon black improves its resistance to ultraviolet light. Some liners have also been found to be sensitive to infrared light.

Table 9.2.6 is provided to summarize the effect of weathering on synthetic liners and is based on information presented in SW-870.

TABLE 9.2.6. POLYMERIC MEMBRANE LINER RESISTANCE TO NATURAL ELEMENTS
Source: SW-870.

Liner type	Resistance to: Temperature	Weathering	Sunlight	Ozone
Butyl rubber	High tolerance for extremes in temperature	Good	-	Good
CPE	-	Good	-	Poor
CSPE	Good heat resistance	Good	Tends to shrink; some also tends to harden on aging due to cross-linking by ultraviolet radiation[a]	Good
Elasticized polyolefin	Some difficulties in low temperature and high wind	Excellent	-	-
Epichlorohydrin rubbers (CO and ECO)	Good thermal stability--high tolerance for temperature extremes	Good	-	Good
Ethylene propylene rubber (EPDM)	Tolerates extremes of temperature	Excellent	Excellent resistance to ultraviolet radiation	Excellent
Polyethylene (HDPE, LDPE)	-	-	[b]	-
PVC	-	Poor	Poor[c]	-

[a]Fabric reinforcement reportedly reduces distortion resulting from shrinkage when exposed to the heat of the sun.

[b]Unprotected clear polyethylene degrades readily with outdoor exposure, but the addition of 2 to 3 percent carbon black can improve ultraviolet light protection.

[c]The PVC polymer is affected by ultraviolet exposure. The sun's heat volatilizes the plasticizer; although the addition of carbon black prevents deterioration from exposure to ultraviolet light, it causes increased absorption of solar energy, thus vaporizing more of the plasticizer. Soil or other cover materials may be used to bury the liner and protect it from ultraviolet exposure.

9.2.1.3.4 Foundation Design and Integrity - Information Requirement (e)--Following confirmation of waste/liner compatibility and inherent liner strength, acceptance of the proposed liner system will rest on evaluation of the foundation design and analysis. Since compression, settlement, or uplift of the foundation could cause liner damage, the applicant must establish the long term stability of the liner foundation. This section addresses essential factors in this analysis, including:

- regional and site specific geologic conditions
- seismic conditions, location of faults
- hydrogeologic conditions, description of aquifers
- evaluation of surface run-on or run-off
- geotechnical engineering, classification, and characterization of foundation soils

Geologic Conditions

Regional and site-specific geologic data submitted with the application should include:

- geologic setting
- type(s) of bedrock and depth(s)
- subsidence history, and
- potential for sinkholes.

Information on geologic setting and bedrock characteristics will likely be presented in the form of geologic maps as well as aerial photographs and descriptions. Subsidence history could be shown by a historical map sequence or through research. The potential for sinkholes is partially derived based on the type of bedrock underlying the area in conjunction with other site specific conditions such as surface water characteristics, soil types, rainfall, wells and ground water consumption, etc.

The scope of technical information expected to be submitted in support of this information requirement is reviewed here. Various considerations, such as data quality and data interpretation are noted. It is recommended that the permit reviewer refer to the basic references sited in this discussion for more detailed information.

Geologic Setting and Bedrock Description--A detailed discussion of applicable information on geologic setting is provided as part of the ground water section of this document (see Section 5.0). Specific technical information which pertains to foundation design and integrity is summarized.

Geologic maps should be included in the application to indicate bedrock and surficial geology of the area. In addition, the applicant should have consulted with a certified geologist concerning local conditions which might not appear on a general map, or which might appear in a different location. The application should include as much site specific geologic information as possible.

Bedrock information provided should include:

- the physiographic province in which the bedrock is located (Coastal Plain, Appalachian Highlands, etc.),
- rock name, group, and type (for example, limestone is in the carbonate rock group which falls into the sedimentary rock type, granite is an igneous rock type in the granite-granodiorite family),
- formation name,
- age (the era, period, or epoch which best describes the age of the rock),
- thickness of each type of bedrock unit,
- texture--size and shape characteristics, such as fine, sub-rounded, angular, etc. Also, the fabric/matrix make-up (elastic, sorted, fissile, shaley, etc.),
- structural features of note, such as geomorphologic characteristics (faults, joints, salt domes, geosynclines, karst, caves, etc.) and petrologic characteristics for igneous and metamorphic rocks: lava, dikes, veins, cones, craters, batholiths, plutons, etc.). For sedimentary structures this would include: dunes, clastic dikes, cross-bedding, deformation, etc.; and
- Orientation--the altitude and direction of the formation in terms of strike and dip.

Surficial information should include:

- The soil type designated according to the unified soil classification system notation (for example "GW" represents well-graded gravels and gravel-sand mixtures with little or no fines; "SC" represents clayey sands or poorly graded sand-clay mixtures). Sediments may also be classified into several sediment groups, for example, alluvium is in the group comprised of terrigenous clastics,
- The physical characteristics of the soil (i.e., is it dry, moist, compacted, cemented, man-made, etc.),
- Formation name for the soil deposit,
- Depth of surficial deposits,

- Age of the soil,
- Thickness of the deposit,
- Texture of the deposit,
- Genesis of the surficial deposits should be noted, such as whether it was organic in origin, volcanic, glacial, eolian, evaporitic, chemically precipitated, detrital, etc.; and
- The environment in which the soil formed should be defined: fluvial, lacustrine, glacial, marine, eolian, evaporitic, deltaic, estuarine, alluvial fan, etc.

This information, along with mapping of the geologic units (both bedrock and surficial deposits), will enable the applicant's geologist to assess the geologic setting for the landfill. Specific characteristics of the area's soils and bedrock, such as permeability and ability to hold water, should be assessed in the application.

Subsidence History--Subsidence of an area may be linked to various geologic features as well as human activity. Therefore, both geologic and human influence should be carefully evaluated for each site. For landfills, the permit reviewer should be concerned with possible subsidence resulting from several causes, as discussed later in this subsection under Foundation Analysis. Subsidence directly related to human activity and geohydrologic conditions may occur in an aquifer system inter-layered with plastic clays if the aquifer system is developed to the extent that the ground water table is significantly lowered.

Subsidence will also be dependent on the existing and potential amounts of water withdrawn for the area. This will depend on the size and capacity of the aquifer, its potability or suitability for industrial uses, and potential future uses.

Although subsidence potential is site-specific, there are certain areas in which the phenomenon of subsidence has been demonstrated in rather extreme fashion. These include Long Beach, California; the San Joaquin Valley in California; and Mexico City, Mexico. In these instances, subsidence has been shown to occur at rates of almost 1 meter every three years. These situations involved aquifer systems containing layers of soft clay, silt, or peat. Upon development of the aquifer systems, the cohesive layers compacted causing the ground to sink. Subsidence cannot be avoided if the water table is continually lowered in areas containing compressible, cohesive soils. Consequently, landfills should not be located in such areas. Figure 9.2.3 illustrates the degree of subsidence which occurred due to ground water withdrawal over a period of 36 years in an area of California.[22]

Potential for Sinkholes--Sinkholes occur in areas referred to as karst topography. They are formed as depressions on the ground surface overlying soluble rock material which has collapsed or dissolved. In some cases, limestone immediately below the soil may be dissolved due to seepage of

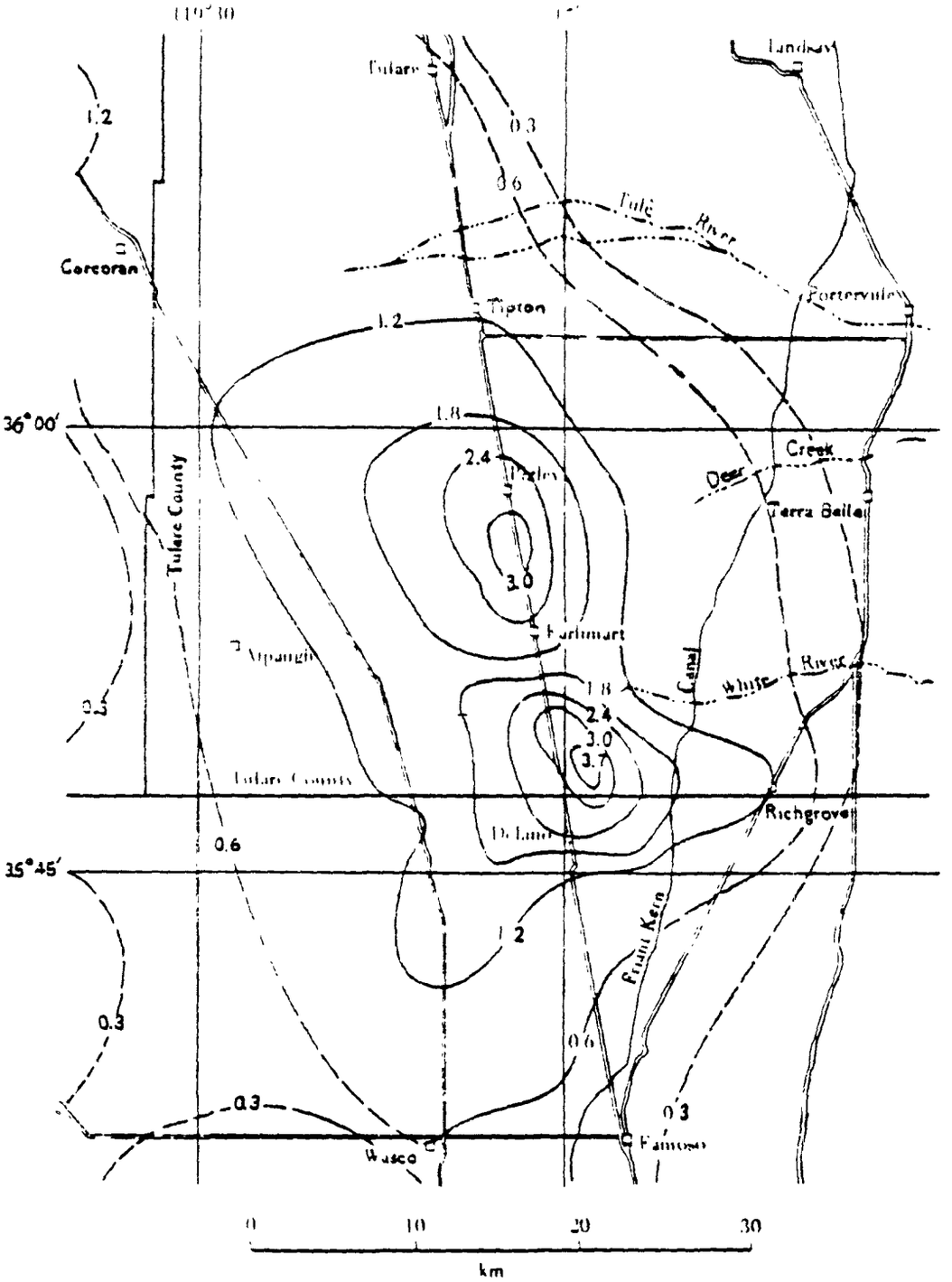


Figure 9.2.3. Land subsidence in the Tulare-Wasco area, California, 1926-1962, due to withdrawal of ground water. Lines show equal subsidence in meters and are dashed where approximate.

Source: Reference 22.

water. This process may be accelerated by local factors such as abundant rainfall or limestone solubility. More commonly, sinkholes form when the surface collapses into a large cavity below. Surface water may drain through the sinkholes to the ground water table. Lakes may be formed when subterranean outlets become clogged or if the sinkhole forms in an area with a high ground water table. The most notable karst areas are in regions where limestone deposits underlie the surface. However, in some localities, dolomites or dolomitic limestones, gypsum and rock salt of limited areal extent may also develop such features. Because limestone deposits are abundant in nature, it might be expected that karst topography is widespread. In actuality, however, only a relatively small number of localities experience full development of karst.

Four conditions that contribute to the development of karst should be examined by the permit reviewer. They are:[23]

1. The presence of soluble rock near the surface, such as limestone;

2. Soluble rock which is dense, highly jointed, and thinly bedded;

3. Areas where entrenched major valleys exist below uplands which are underlain by soluble, well-jointed rock; and

4. Areas with at least a moderate amount of rainfall.

By far the most common and widespread topographic form in a karst region is the sinkhole (other names which might be used for associated forms of sinkholes include solution pans, uvalas, poljes). Often, such sinkholes may be present in great numbers and may vary greatly in size. In fact, thousands of sinkholes exist in the karst terrain of southern Indiana, Florida, and other states.[23]

Lowering of the ground water table due to development of aquifer systems has been known to cause rapid subsidence which may result in sinkholes. In one example, an area underlain by dolomite covered with a thick layer of weathered material developed sinkholes after lowering of the water table as part of a mining program. These sinkholes developed over zones where the surface of the dolomite was irregular and characterized by pinnacles of unweathered rock separated by accumulations of weathered material and debris from mining. Sinkholes started to form with the development of large voids between the pinnacles. This was due partly to drying of the debris resulting from lowering of the water table. In addition, the debris was washed into the dolomite openings at deeper levels.

Because sinkholes form in karst topography, locations in such areas should be carefully evaluated. Locations where sinkhole formation is of concern are those which have humid climate, limestone bedrock, and ground or surface waters which contain carbon dioxide from vegetative soures or are under pressure. These locations include Florida, the Great Valley area of Virginia and Tennessee, southern Indiana, west-central Kentucky, and

north-central Tennessee. Aerial photographs may be checked to assist in evaluating the sinkhole potential of a site. Additional information on evaluating the potential for sinkholes can be found in References 23 and 24.

Seismic Conditions

The applicant must provide data and interpretative discussion concerning the potential for ground shaking and surface rupture at the site. A map showing fault areas should be submitted, especially for sites located in areas listed in Appendix VI to Part 264 (Political Jurisdications in which Compliance with the Seismic Standard must be Demonstrated). Such a map may be compiled using aerial photographs of the site, published information, a walking tour of the site, and/or a subsurface investigation of the site. These techniques are briefly described in this section.

The submitted map should show distances to known faults and summarize seismic activity to date. Activity occuring in Holocene time is especially important (approximately the last 11,000 years). The application should demonstrate the location of faults with respect to the site in question; most importantly, if faults are located within 3,000 feet of the site. Permit reviewers should evaluate the existence of faults based on the most conservative interpretation of the information presented.

Permit applications covering sites in areas where seismic activity is of concern may include aerial photos or they may be requested as additional data needed for sufficient review. Aerial photo analysis should be performed by one trained in aerial photographic interpretation. Because aerial photos vary with season of flight, type of film, photo scale, cloud cover, etc., review will necessitate analysis of such factors. Aerial photos will be most useful if they cover a 5 mile radius around the site.

Published information which would aid in seismic interpretation should also be included in the application and should have been interpretated by one skilled in seismic studies. Sources of data should be noted and referenced in the application. If there is doubt in regard to data quality or seismic evaluation techniques, a site tour should be recommended.

Applicants with sites which appear to be within 3,000 feet of a fault must provide information showing that no faults (or lineations) pass within 200 feet of portions of the facility where treatment, storage, or disposal of hazardous waste will be conducted. Such evidence might be available from a comprehensive geologic analysis which would likely include a seismic survey. If this is not conclusive, a subsurface investigation should be conducted. A comprehensive geologic analysis entails surface geophysical surveys, evaluation of borehole records, ground-penetrating radar, seismic refraction techniques, and other methods to determine exact fault location. A map should be included in the application showing results of the study. Seismic surveys can provide elevations and thickness of hydrogeologic units, as well as fault/lineation location. Such information is useful in the geologic analysis as well.

Boreholes may be installed by the applicant to supplement knowledge of site geology gained from the comprehensive geologic analysis. In addition, some sort of digging, such as trenching, may provide necessary information. Trenching may be required in cases where the comprehensive geologic analysis or borehole logs do not provide conclusive evidence of the absence of faults within 200 feet of the portions of the facility where treatment, storage, or disposal of hazardous waste is proposed. The permit reviewer should check trenching maps to verify that trenching has been performed perpendicular to known faults that were found to pass within 3,000 feet of such portions of the facility.

In evaluating seismic data, the permit writer should be aware that such data also pertain to geologic and hydrologic considerations. Therefore, as an indication of application integrity, the application should document that seismic data were evaluated by a geologist familiar with the area and with seismic analysis. References 25 through 30 contain data which may aid in the application review process for seismic conditions.

Hydrogeologic Conditions

The application information should present definitive characterization of aquifers directly below the site and within proximity of the site. Through the use and presentation of test borings, trenching results, geophysical surveys, and published information, the applicant should be expected to define potentially impacted aquifers to the following extent:

- Aquifer dimensions
- Aquifer elevation and seasonal fluctuations
- Aquifer flow characteristics including velocity, volume and directions
- Ground water uses and potential uses (e.g., drinking or industrial consumption)
- Relative locations and permeability of confining strata
- Test data such as pump tests, drawdown curves, hydraulic conductivity, transmissivity, hydraulic gradient determinations, etc.

The information submitted to establish ground water monitoring plans under Subpart F should be comprehensive enough to support this information requirement.

Surface Water Run-on and Run-off

Characterization of overland flow patterns is an important consideration in the foundation anaysis to account for the potential liner damage resulting from foundation erosion. The permit applicant should conduct a hydrologic study to evaluate run-off quantities and patterns upgradient of and within the

site boundaries. Such factors as precipitation, infiltration capacity, area of the drainage basin, overland flow length, and drainage basin gradient are used to calculate overland flow.

The peak rate of overland flow across the landfill can be estimated using the Rational Method or the Soil Conservation Service (SCS) method. A detailed discussion on applying these techniques is provided in subsection 9.2.4.3 to address the regulatory requirements of §264.301(c) and §264.301(d) for run-on and run-off management, respectively.

Geotechnical Evaluation

The permit application reviewer should evaluate the applicant's geotechnical data submitted to demonstrate the stability of the liner foundation and subgrade (or liner bedding material). Information provided on soil classification, soil engineering properties, solution cavity potential, sinkhole potential, liquefaction potential, and uplift potential must be evaluated.

References 31 through 35 are valuable basic reference sources on soil mechanics and geotechnical engineering. They should be reviewed for a more thorough understanding of the subject matter presented here.

The permit applicant should conduct sufficient testing to classify foundation soils and characterize the engineering properties of the soil. Index properties that should be evaluated include grain size distribution, Atterberg limits, specific gravity, density, and moisture content. Engineering properties that should be evaluated include strength, permeability, compressibility and others. A settlement analysis is required to estimate total and differential settlement, immediate settlement, primary and secondary consolidation, creep, and liquefaction. Bearing capacity and stability of foundation soils can then be assessed based on this information.

Index Properties--

A sieve or mechanical analysis is performed to determine the grain size distribution of a soil. A typical grain size analysis is plotted in Figure 9.2.4, reprinted from the SCS Engineering Field Manual.[33] Information which can be obtained from this chart includes the total percentage of a given size, the total percentage larger or finer than a given size, and the uniformity or range in size of a given soil.

Soils are classified as coarse or fine based on the amount of material passing a number 200 sieve (0.074 mm opening). A material is coarse if more than 50 percent (dry) is retained on the #200 sieve; fine if more than 50 percent passes the sieve. Coarse materials consist of sand and gravel and possibly some small portion of fines. If the fines content is less than 5 percent, the engineering properties will be a function of the coarse materials only.

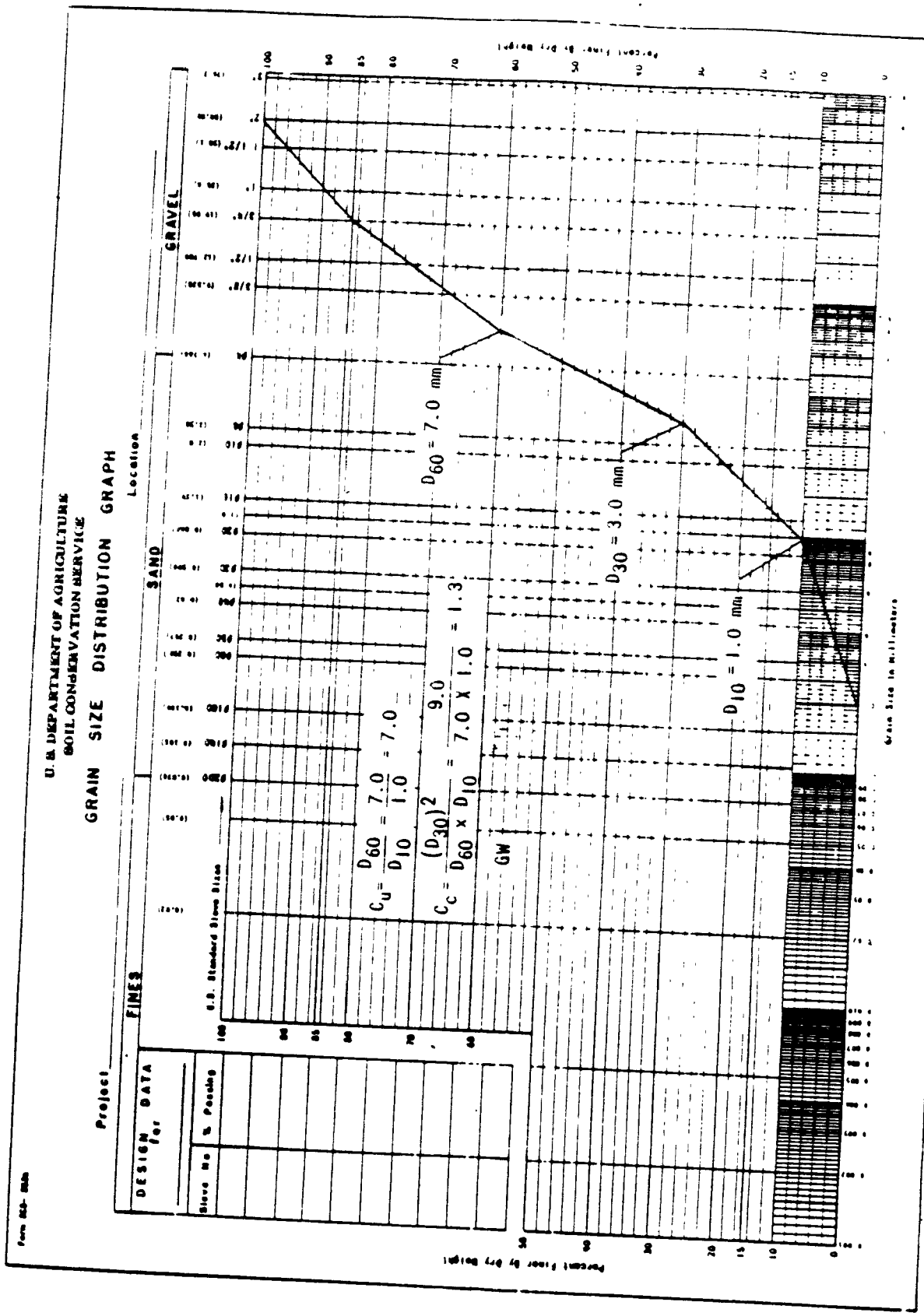


Figure 9.2.4. Example soil grain size analysis.

Source: Reference 33.

Soil classification systems that have been developed and have found most widespread use include the AASHTO (American Association of State Highway and Transportation Officials) system and the Unified Soil Classification System, These and others and their definition by grain size fractions are illustrated in Figure 9.2.5, after Cernica (1982).[34]

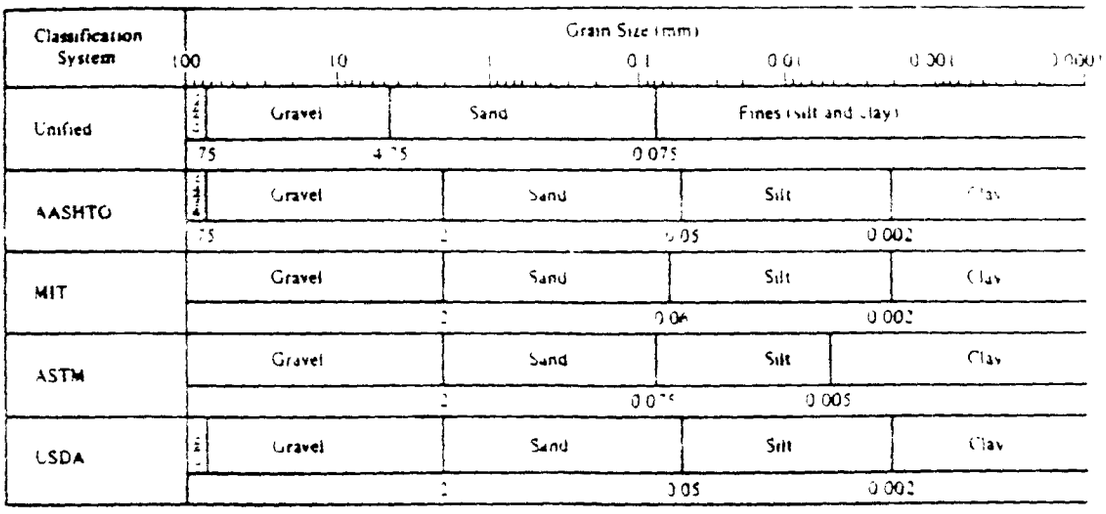


Figure 9.2.5. Soil classification based on grain size.
Source: Reference 34 (Cernica)

Coarse grained soils are generally cohesionless and possess properties remarkably different from fine grained cohesive soils. For instance, the strength of coarse grained soils is a function of interparticle stresses and density, whereas the strength and stability of fine grained clayey soils is a strong function of water content. These factors are discussed in more detail in the subsection - Engineering Properties.

Soil Void Ratio--The void volume of a soil may be filled with air or water. Therefore, the soil volume is a combination of soil, water, and air, whereas the soil weight is a function of the soil and water content only. The void ratio, e, is expressed as:

$$e = \frac{V_v}{V_s} \text{ (dimensionless)} \qquad (1)$$

where V_v = volume of voids

V_s = volume of solids

Porosity, n, is related to the void ratio and is defined as the ratio of the volume of voids to the total volume of the mass (V), or:

$$n = \frac{V_v}{V} \times 100 \text{ (expressed as a percentage)} \qquad (2)$$

The void ratio changes as a function of the volume of voids because the volume of solids is generally assumed to remain constant. The void ratio may range from 0.5 to 0.9 for sands or gravel and between 0.5 to 1.5 for clays, although higher values can be encountered for clays.

Soil Moisture Content--The water or moisture content, w, is defined as the ratio of the weight of water (W_w) to the weight of soil (W_s), or:

$$w = \frac{W_w}{W_s} \times 100 \text{ (expressed as a percentage)} \qquad (3)$$

The degree of saturation, S, is defined as the ratio of the volume of water (V_w) to the volume of voids (V_v), or:

$$S = \frac{V_w}{V_v} \times 100 \text{ (expressed as a percentage)} \qquad (4)$$

A soil will never be fully saturated, even if submerged, because a certain amount of air will remain within the soil mass. However, the water content can exceed 100 percent, especially for fine grained soils and will have a significant effect on the engineering properties of clays. The optimum moisture content is the value of w where the soil reaches maximum density under a given compactive force.

Soil Density--Relative Density, D_R, is defined as:

$$D_R = \frac{\gamma_{max}}{\gamma} \times \frac{\gamma - \gamma_{min}}{\gamma_{max} - \gamma_{min}} \times 100 \qquad (5)$$

where γ_{max} = dry unit weight of soil in densest state

γ_{min} = dry unit weight of soil in loosest state

The relative density may be considered as an indication of the stability of a soil. For instance, a granular soil with low density may be subject to settlement upon vibration. In the field, density is characterized using the Standard Penetration Test described later. Cernica (1982) presents the following relationships for soil density:

D_R (%)	Soil Designation
0 - 15	very loose
15 - 35	loose
35 - 70	medium dense
70 - 85	dense
85 - 100	very dense

Specific Gravity--The specific gravity, G, is the ratio of the unit weight (γ) of the soil to the unit weight of water (γ_w) at 4°C. Most soil particles have specific gravities ranging from 2.6 to 2.8. Organic soils (silts) may have a lower specific gravity.

Atterberg Limits--The Atterberg Limits provide a great deal of information for cohesive soils. The concept was introduced by A. Atterberg and modified and amplified by Terzaghi and Casagrande. As water is added to a dry clay, it will be transformed from a solid or semisolid state to a plastic state and then to a liquid state. The water contents at these points of change are termed the shrinkage limit (SL), plastic limit (PL), and liquid limit (LL) (e.g., the Atterberg limits) as demonstrated in Figure 9.2.6.

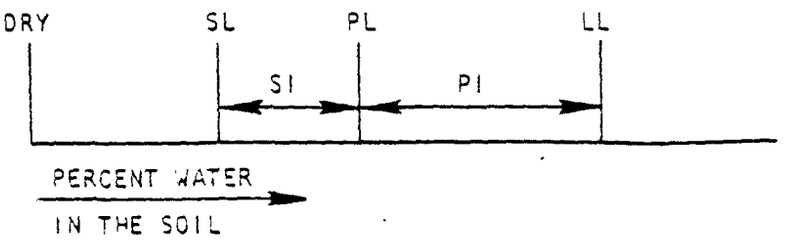


Figure 9.2.6. Atterberg limits.

The shrinkage limit is the maximum water content at which a reduction in water content will not cause a decrease in the volume of the soil mass. The plastic limit is the water content at which a soil will begin to crumble when rolled into a thread approximately 1/8 inch in diamter. The liquid limit is the water content at which a pat of soil, cut by a groove of standard dimensions, will flow together over a distance of 1/2 inch under the impact of 25 blows in a standard liquid limit apparatus.

The Shrinkage Index (SI) is the difference between the plastic and shrinkage limits, or:

$$SI = PL - SL \tag{6}$$

The Plasticity Index is the difference between the liquid and plastic limits.

$$PI = LL - PL \tag{7}$$

and indicates the range of water content over which the soil will remain plastic.

Engineering Properties--It will be important to evaluate the applicant's assessment of soil engineering properties to ensure the acceptability of the liner foundation and subgrade materials. The soil index properties should be reported, especially Atterberg limits and moisture content for cohesive soils that may be part of foundation soils. The liner subgrade will generally be a cohesionless soil such as sand and the grain size distribution should be

reported. In general, the engineering properties of the in-situ or implaced foundation soils below the subgrade will be the most important to the stability of the liner system. Therefore, most of the remaining discussion addresses these types of foundation soils.

This discussion of soil properties and their affect on the engineering behavior of soils is based on information presented in:

Engineering Field Manual for Conservation Practices. U.S. Department of Agriculture, Soil Conservation Service. April, 1975.[33]

If the soil is coarse (either sand or gravel) but has a fines content of from 12 to 50 percent, the behavior characteristics of the portion smaller than the #40 sieve will determine the secondary characteristics of the material. If this portion of the material is clayey, the material is coarse grained with clayey fines. If not, it is coarse grained with silty fines. To determine whether the material is classed as clay or silt, the plastic limit and liquid limit are measured.

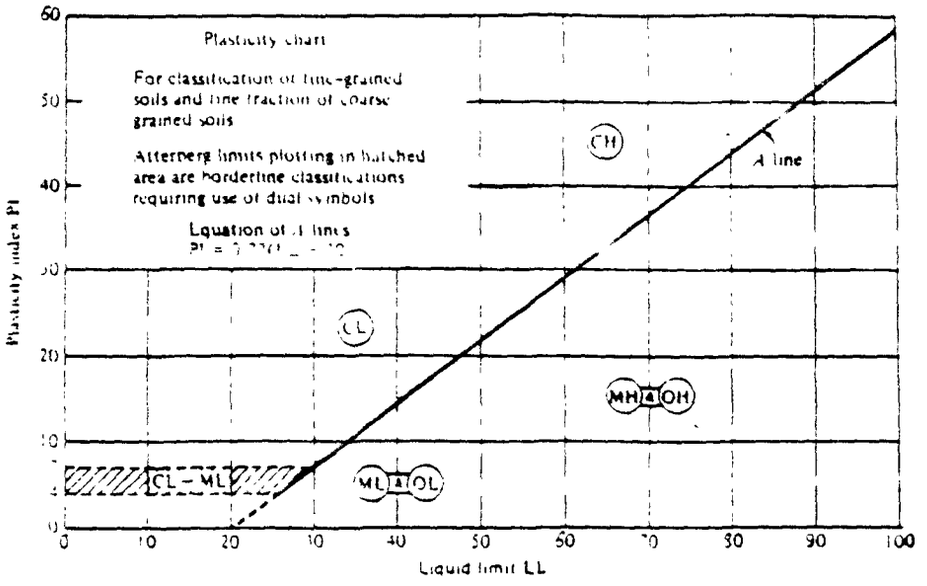
A Plasticity Chart, Figure 9.2.7 from Cernica (1982)[34], is made with the LL as the abscissa and PI as the ordinate. A line known as the "A" line originates at PI = 4, LL = about 25, and lies approximately parallel to the plot of many basic geologic materials. For purposes of classification, all materials that fall above this line are designated as clay and all that fall below as silt. A small (cross hatched) area having a PI between 4 and 7 percent extending from the "A" line toward zero percent LL has a special dual designation and may be considered as an extension of the "A" line in separating materials.

There are four classifications of coarse materials where the percent of fines is over 12 percent. They are gravels with clayey fines (GC), gravels with silty fines (GM), sands with clayey fines (SC), and sands with silty fines (SM).

Coarse materials with a fines content between 5 and 12 percent do not have separate classification breakdowns. They have a dual classification which consists of groupings of zero to 5 percent fines and over 12 percent fines. The materials are considered to be borderline exhibiting characteristics of both cohesionless and cohesive soils.

Plasticity is most important in fine grained soils. Soils with higher plasticity generally have higher cohesion and resistance to piping, erosion, and settlement cracks than soils with lower plasticity.

The density of a soil mass is an important determinant of the engineering behavior of soils. Soil strength generally increases while permeability and compressibility generally decrease with increased density. Density can be increased by compaction and by consolidation under static loads.



KEY

CH Inorganic clays of high plasticity, fat clays

CL Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays

MH Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts

ML Inorganic silts, very fine sands, rock flour, silty or clayey fine sands

OH Organic clays of medium to high plasticity

OL Organic silts and organic silty clays of low plasticity

Figure 9.2.7. Casagrande's plasticity chart showing several representative soil types.

Source: Cernica (1982), Reference 34.

Shear strength of soil depends on two elements, friction and cohesion. Friction is the resistance to sliding of one block of nonplastic soil against another. The friction in soil is complicated by such factors as the irregulatiry of the planes, interlocking of opposite particles, and size and shape of the soil grains.

Cohesion is the result of the magnetic-like attraction of particles that manifests itself as the plasticity and stickiness of soils. It resists one particle of soil sliding on another, but cohesion resistance does not increase with increased load. Both friction and cohesion of soils increase with increased density.

Resistance to internal erosion or piping is correlated with resistance to surface erosion. Soils with a high susceptibility to sheet erosion also have a high piping potential and, therefore, are critical to earth structure safety. In contrast, soils with a low susceptibility to surface erosion such as the more plastic soils do not present an internal erosion problem.

Cracking may be caused by dewatering of a soil. As the soil dries, it shrinks and develops cracks. The finest materials have the highest cracking potential. Plasticity is only an indirect indicator of cracking potential because higher plasticity means finer material. If nonplastic materials have the same grain size as plastic materials their cracking potential is essentially equal.

Cracking due to movement of embankments is a result of both the amount of movement and the deformability of the material. Deformability of embankments is a result of both the plasticity of the material and the water content at which the embankment is built. Generally, the lower the water content when compacted, the more brittle the embankment and the higher the cracking potential.

Permeability depends on both the size and volume of pores in a soil. Hence, it increases as grain size increases and decreases as density increases.

Compressibility of a soil is a measure of decrease in volume when subjected to load. Compressibility depends on the volume of voids in the soil, and increases with decreasing density. The amount of settlement that will occur in a soil depends on its compressibility and on the magnitude of the load to be placed on it. Because of grain-to-grain contacts, coarse grained soils may be nearly incompressible under static loads but may settle from shock or vibration. The finer grained soils are susceptible to settlement if dewatered.

Highly plastic soils may swell under low loads if moisture content increases. The swelling capacity may be estimated from the plasticity index of a soil. Soils with a plasticity index of more than 20 usually have a medium to high swell potential; those with a plasticity index more than 35 normally fall in the very high swell category. The strength of soils after swelling is greatly reduced.

Upon drying from saturation to the shrinkage limit, soils with a low shrinkage limit will shrink more than those with a high shrinkage limit.

If possible, the placement of soils with a high shrink-swell potential should be restricted to zones where moisture content will remain fairly constant.

The ultimate bearing capacity of a soil is the average load per unit area required to produce failure by rupture of a supporting soil mass. Bearing capacity is important in evaluating the ability of the foundation to successfully support the liner, wastes, and cover materials at closure.

Soils Testing--The applicant will conduct an engineering analysis based on laboratory or field testing of soils. Laboratory tests are necessary to determine soil index properties and include:

Test	ASTM Designation	Purpose of Test
Grain Size Analysis	D421, D422 D2217 D1140	Soil classification
Atterberg Limits	D423 D424 D427 D2217	Determine the plasticity and shrink-swell characteristics. Assess sensitivity to changes in moisture content. Results may be considered as part of all engineering analyses.
Water Content	D2216, D2974	Measure water content
Compaction	D698 D1557	Identify the characteristic moisture/density relationship for the soil.
Unconfined Compressive Strength	D2166	Measure cohesive soil shear strength
Triaxial Compressive Strength	D2850	Measure characteristic stress-strain relationship for soil
Direct Shear	D3080	Measure soil shear resistance

In-situ or field tests that the applicant may conduct during performance of borings or excavation of test pits and trenches include:

Test	ASTM Designation	Purpose of Test
Standard Penetration	D1586	Measure relative soil density; indicate bearing capacity
Vane Shear	D2573	Measure shear strength of cohesive soils; sensitivity to remolding
Pressuremeter	Not currently specified	Measure stress-strain, Young's Modulus, cohesive strength
Saturated Hydraulic Conductivity	Several - See Method 9100, Appendix to RCRA Technical Guidance Documents	Measure saturated hydraulic conductivity
Plate Load	D1194	Measure bearing capacity
Cone Penetration		Soil classification, strength, compressibility, and bearing capacity.

Foundation Analysis--The permit applicant must conduct a settlement analysis to estimate primary and secondary consolidation, creep, and differential settlement.

Consolidation occurs when a load is imposed on a highly compressible porous saturated soil (e.g., clay) forcing excess water to drain from the soil. Primary consolidation is governed by soil permeability which controls the flow of draining water. Secondary consolidation is believed to result from slippage between grains bonded by adsorbed water.

Settlement due to consolidation can be calculated from the relationships illustrated in Figure 9.2.8, a phase diagram from Holtz (1981).

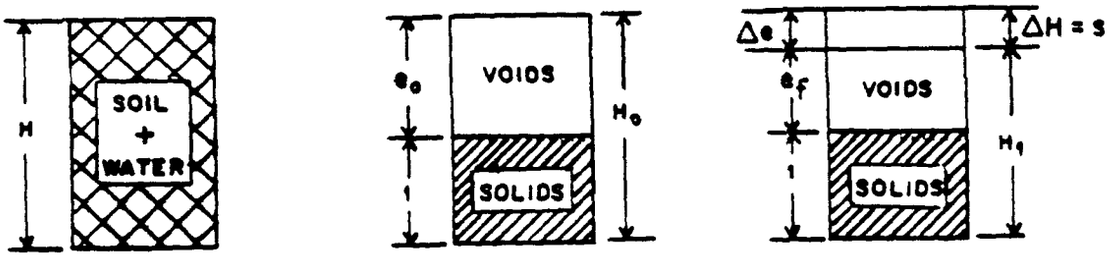


Figure 9.2.8. Calculation of settlement from the phase diagram. Source: Reference 35.

At the initial time condition (middle of figure), the volume of solids, V_s, is equal to 1 (and remains 1 at the end of consolidation). The volume of voids changes from the initial value, e_o, by the amount e, to e_f, the final volume of voids. It can be demonstrated that the settlement, S, is equal to:

$$S = \frac{\Delta e}{1 + e_o} H_o = \epsilon_v H_o \qquad (8)$$

The stresses, changes in void ratio, percentage of settlement, or amount of settlement must be computed for each compressible stratum. The sum of the estimated settlements for each stratum is equal to the total settlement for the soil depth of concern. The confined compressibility test is the laboratory method used to evaluate consolidation.[31]

Creep is a term used to define deformation of clay soils in response to shearing stress. The creep strength identifies the sheering stress which will result in continuous progressive deformation. Shear tests should be used to evaluate the potential for creep.

Differential settlement in cohesive soil can be attributed to consolidation as discussed above. Differential settlement of cohesive soils can also result from distortion in which a load on the soil causes the soil mass to deflect downward and bulge laterally, as shown in Figure 9.2.9. The shape of the curve can be computed by methods of elasticity.[36]

Differential settlement of cohesionless soils by distortion results in a downward deflection curve as shown in Figure 9.2.10. The soil near the edge of the loaded area is unconfined laterally and is pushed aside by the lateral pressure of the sand nearer the center of the area. Methods for calculating the slope of the settlement curve are not available. However, experiments show that the wider the loaded area, the flatter the curve at the center.

Cohesionless soils are also susceptible to excessive settlement if the soil is subject to vibrations. The greatest settlement will occur from a pulsating frequency between 500 and 2500 impulses per minute.[31] The frequency of unbalanced forces in many types of machinery, such as steam turbines, diesel power trim units, and air and gas compressors lie within this range. Ordinarily the settlement will be small if the relative density is greater than 70 percent, but if the vibration is severe, settlement can occur until the relative density is nearly 90 percent.[36] The potential for settlement should be carefully evaluated using density determination techniques previously described in this section. Vibration compaction techniques can be used during installation to minimize the potential for later settlement during facility operation.

Other causes of settlement include shrinkage due to drying, consolidation due to lowering of the water table, structural collapse, erosion into openings and cavities, biochemical and chemical attack, mass collapse of drainage systems, and expansion due to frost and clay expansion. Predictive models for

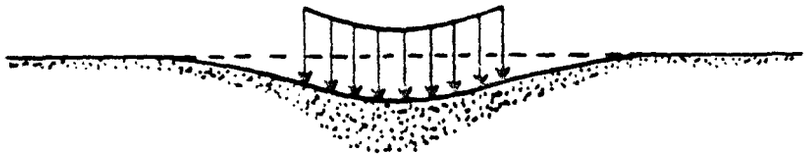


Figure 9.2.9. Profile of distortion settlement of a uniformly loaded flexible foundation on an elastic solid such as a saturated clay.

Source: Reference 36.

Figure 9.2.10. Profile of distortion settlement of a uniformly loaded flexible foundation on a cohesionless soil.

Source: Reference 36.

determining the amount of settlement are generally unavailable. However, standard foundation and geotechnical analyses can be used to estimate the susceptibility to settlement from such causes.

The technical adequacy worksheet for evaluating the suitability of the liner system design is presented in Figure 9.2.11. The worksheet should be completed before addressing the technical adequacy checklist in subsection 9.9.

9.2.1.4 Draft Permit Preparation--

Condition B.1 of Permit Module XV addresses design, construction and installation of the liner system for new portions of the landfill. The condition is implemented through reference to a permit attachment that includes plans and specifications for the proposed liner system. The submitted application information can be inserted as the permit condition attachment provided the applicant has adequately addressed the following:

- Hydrologic data
- Construction materials
- Liner chemical properties
- Physical strength and thickness
- Foundation analysis
- Liner system integrity considerations

The attachment should demonstrate that the wastes will be prevented from entering the liner throughout the active life of the facility.

9.2.1.5 References--

1. U.S. Environmental Protection Agency. Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Office of Solid Waste, Washington, DC. Volume I. 1983.

2. U.S. Environmental Protection Agency. RCRA Technical Guidance Document. Landfill Design: Liner Systems and Final Cover. July 1982.

3. U.S. Environmental Protection Agency. Lining of Waste Impoundment and Disposal Facilities. Prepared by Matrecon for the U.S. EPA. Second Edition. SW-870. September 1982.

4. Chow, V. T. Handbook of Applied Hydrology. McGraw-Hill, New York. 1964.

5. Bouwer, H. Ground Water Hydrology. McGraw-Hill, New York. 1978.

Liner Location Versus Water Table Elevation

Has this part of the applicant's submittal been reviewed and evaluated? ____ Yes ____ No ____ Date

Did the applicant address:

- Seasonal variation in the water table height? ____ Yes ____ No
- Maximum water table height? ____ Yes ____ No
- Liner location in relation to water table? ____ Yes ____ No

Were onsite monitoring wells used to identify ground water levels? ____ Yes ____ No

Was water table information obtained from state and local agencies? ____ Yes ____ No
and, if so:
How do these data compare with onsite monitoring data? _____

What is the minimum distance expected between the liner and the water table?

Does this distance insure that damage will not occur through uplift? ____ Yes ____ No

Figure 9.2.11. Worksheet for evaluating design of liner systems.

Synthetic Liner/Waste Compatibility

Was EPA Test Method 9090 used to evaluate compatibility? ____ Yes ____ No

What steps were taken to insure representativeness of the waste(s) and leachate(s) tested? _____

_____

Were the measures adequate? ____ Yes ____ No

What lab(s) performed the test(s)? _____

_____

Was liner manufacturer compatibility data used in place of laboratory test data? ____ Yes ____ No

If yes, is the landfill intended for only one type of waste? ____ Yes ____ No

Was liner manufacturer compatibility data compared to laboratory test results? ____ Yes ____ No

Was compatibility evaluated in terms of:

- Tear resistance? ____ Yes ____ No
- Puncture resistance? ____ Yes ____ No
- Tensile strength? ____ Yes ____ No
- Hardness? ____ Yes ____ No
- Elongation? ____ Yes ____ No

Describe any differences in liner properties listed above resulting from exposure to waste or leachate. _____

_____

_____

Figure 9.2.11 (continued)

If deterioration is indicated, the liner should be judged inadequate unless the applicant can demonstrate that the deterioration will not affect liner integrity.

Synthetic Liner Permeability

Did the applicant address synthetic liner permeability? _____ Yes _____ No

What laboratory test procedures and/or data sources were used? _____

_____

Describe any properties identified that indicate susceptibility to waste or leachate penetration (e.g., changes in volatile or extractable liner materials, swelling, changes in weight, etc.). _____

_____

_____

Are data supplied by the applicant consistent with permeability data contained in SW-870? _____ Yes _____ No

Figure 9.2.11 (continued)

Resistance of Synthetic Liners to Pressure Gradients Stresses, and Environmental Factors During Installation and Operation

Is the liner at least 30 mils thick?	Yes	No
Is the liner protected from physical failure by at least 6 inches of bedding material above and below the liner?	Yes	No
Did the applicant document that the bedding material is no coarser than sand?	Yes	No
Were herbicides proposed for use to prevent possible puncture from plant growth?	Yes	No
Does the liner design allow for shrinkage and expansion due to freeze-thaw and wet-dry cracking?	Yes	No
Did the applicant address liner abrasion wear?	Yes	No
Does the liner material contain a bactericide to prevent microbial attack?	Yes	No
Did the applicant address liner exposure to sunlight or ultraviolet light?	Yes	No
Are any steps taken to minimize any potentially harmful effects of temperature extremes?	Yes	No
Are there any techniques used to prevent liner abrasion from windblown particles?	Yes	No
Are exposed liner ends securely held in place to prevent wind damage?	Yes	No

Describe any data gaps relating to the questions listed above. _____

Figure 9.2.11 (continued)

Foundation Design and Integrity

Did the applicant define the following index properties for liner foundation materials? Yes ____ No ____

- Grain size distribution? Yes ____ No ____
- Atterberg limits (for cohesive soils)? Yes ____ No ____
- Specific gravity? Yes ____ No ____
- Density? Yes ____ No ____
- Moisture content? Yes ____ No ____

Has the applicant addressed the following engineering properties:

- Bearing capacity? Yes ____ No ____
- Shear strength? Yes ____ No ____
- Cohesion? Yes ____ No ____
- Permeability? Yes ____ No ____
- Compressibility? Yes ____ No ____

Did the foundation analysis provide an adequate evaluation of:

- Erosion potential? Yes ____ No ____
- Cracking potential? Yes ____ No ____
- Secondary consolidation? Yes ____ No ____

Figure 9.2.11 (continued)

- Creep? ____ Yes ____ No

- Differential settlement? ____ Yes ____ No

Did the applicant address:

- Solution cavity potential? ____ Yes ____ No

- Sinkhole potential? ____ Yes ____ No

- Uplift potential? ____ Yes ____ No

- Liquefaction potential? ____ Yes ____ No

Did the applicant's foundation analysis include an estimation of:

- Consolidation? ____ Yes ____ No

- Creep? ____ Yes ____ No

- Differential settlement? ____ Yes ____ No

Describe any data inadequacies relating to the questions listed above. _____

_____

_____

Figure 9.2.11 (continued)

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7. Letter Correspondence from Mr. Henry Haxo (Matrecon) to Mr. Arthur Day (EPA Office of Solid Waste). February 18, 1983.

8. Lee, J., Selecting Membrane Pond Liners, Pollution Engineering, January, 1974.

9. Kumar, J., and J. A. Jedlicka. Selecting and Installing Synthetic Pond-Linings. Chemical Engineering, February 5, 1973.

10. Kearney Management Consultants. Chemical Property Data and Liner/Waste Compatibility Data. Work Assignment #00-008, EPA Contract No. 68-01-6515.

11. Haxo, Henry E., Jr. "Testing of Materials for Use in the Lining of Waste Disposal Facilities," ASTM, 1982. Special Technical Publication 760.

12. Haxo, Henry E., Jr. "Chemical Compatibility of Lining Materials With Different Waste Fluids," Colloque "Etancnéité Superficielle," 1983, Paris, p. 13-19, Session 1.

13. Landreth, Robert E., U.S. EPA. "Liners for Waste Impoundments and Disposal Facilities." Colloque "Etanchéité Superficielle," 1983, Paris, p. 17-20, Session 1.

14. Haxo, H., R. White, P. Haxo, M. and Fong. Liner Materials Exposed to Municipal Solid Waste Leachate. U.S. EPA, Cincinnati, Ohio, 1976.

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17. Strong, A. G. The Deterioration of Rubber and Plastic Linings on Outdoor Exposure - Factors Influencing Their Longeivity. 1980.

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9.2.2 Leachate Collection and Removal System

9.2.2.1 The Federal Requirement--

Paragraph(b) of §270.21 requires that the applicant's plans and/or engineering report on landfill design, construction, operation, and maintenance must address:

"(1) The ... leachate collection and removal system ..."

The landfill standards of Part 264 state that:

"(a) A landfill (except for an existing portion of a landfill) must have:

(1) . . . .

(2) A leachate collection and removal system immediately above the liner that is designed, constructed, maintained, and operated to collect and remove leachate from the landfill. The Regional Administrator will specify design and operating conditions in the permit to ensure that the leachate depth over the liner does not exceed 30 cm (one foot). The leachate collection and removal system must be:

(i) Constructed of materials that are:

(A) Chemically resistant to the waste managed in the landfill and the leachate expected to be generated; and

(B) Of sufficient strength and thickness to prevent collapse under the pressures exerted by overlying wastes, waste cover materials, and by any equipment used at the landfill; and

(ii) Designed and operated to function without clogging through the scheduled closure of the landfill."

9.2.2.2 Summary of Necessary Application Information--

The Part B Manual[1] instructs the applicant to submit engineering reports and detailed drawings to support the proposed design of the leachate collection and removal system. Specific information requested includes:

(a) System design and materials of construction

- detailed drawings; facility layout, slope, spacing, design of sumps
- type of collection pipes
- calculations illustrating maintenance of less than 1 foot of leachate head except during storm periods.

(b) Chemical resistance

- compatibility of pipes and sumps with leachate and wastes

(c) Strength and thickness

- demonstrate that the system can withstand incurred live and dead loads, accounting for pipe perforations or slots.
- account for pipe deflection, buckling, and compression

(d) Prevention of clogging

- engineering design calculations to assure functioning without clogging through closure.

9.2.2.3 Guidance on Evaluating Application Information--

Figure 9.2.12 is a flow chart which indicates the applicability of the Part 264 requirements to leachate collection and removal systems. The guidance which follows on evaluating the technical adequacy of the applicant's proposed leachate collection system addresses the major regulatory requirements identified in the flow chart. Subsection 9.2.3 provides guidance on evaluating an applicant's submittal in cases where an exemption from the leachate collection system requirement is sought.

At least four aspects of leachate collection system design and operation will be addressed by the applicant and should be rigorously reviewed by the permit writer. These include:

- System design and materials of construction
  - design drawings
  - pipe materials
  - calculation of leachate head above the bottom liner
- chemical resistance of system materials
- strength and thickness of materials, and
- leachate collection system clogging

Figure 9.2.13 presents a summary of technical topics addressed in the remainder of this section to assist the permit reviewer in evaluating the applicant's proposed design.

9.2.2.3.1 Leachate Collection System Design and Materials of Construction--

System Design

The applicant should have submitted engineering drawings illustrating the full areal extent of the leachate collection system and profiles of all piping and appurtenant structures such as manholes or cleanouts. The inside diameter

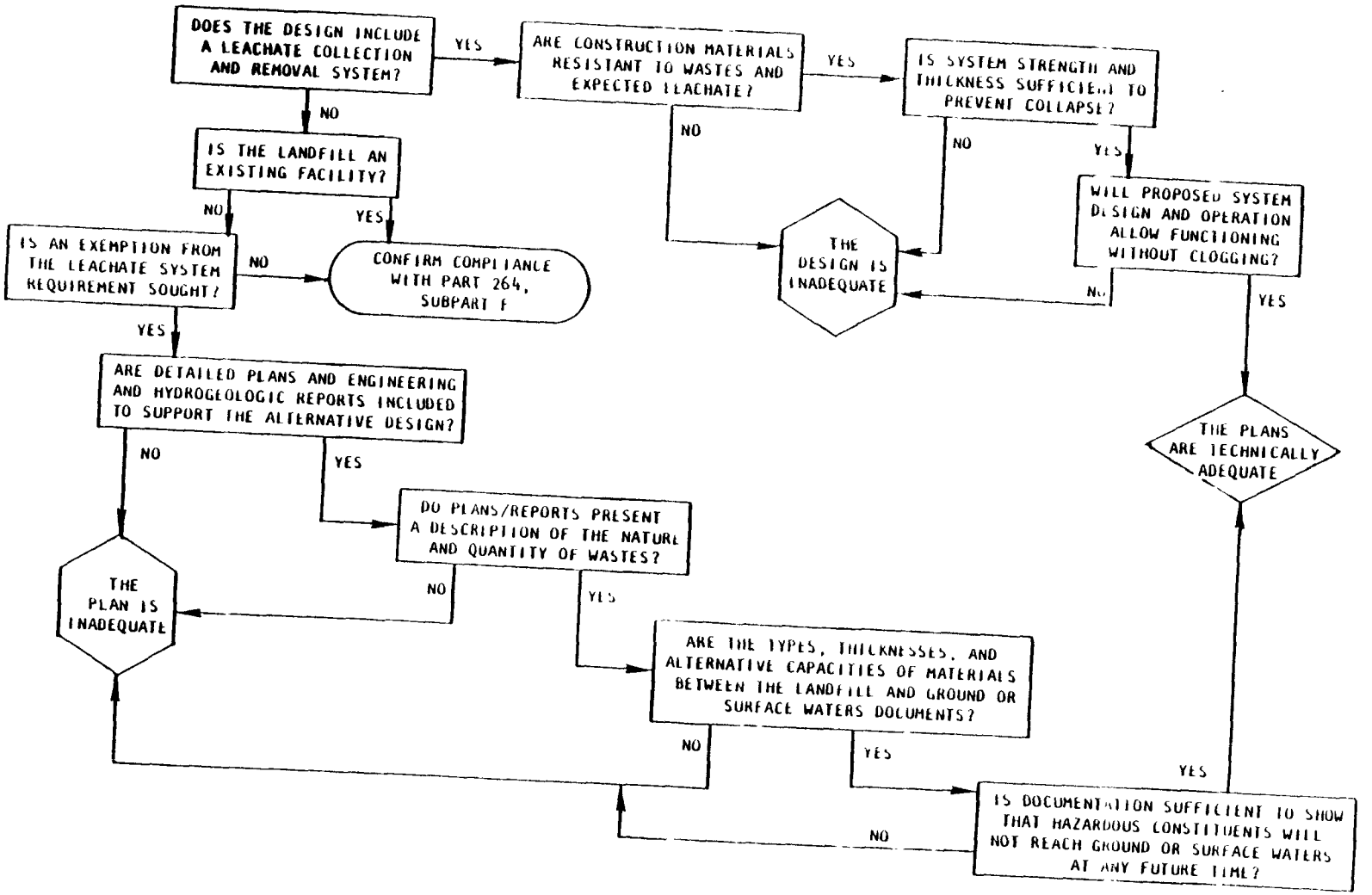

Figure 9.2.12. Applicability of Part 264 requirements to leachate collection and removal systems.

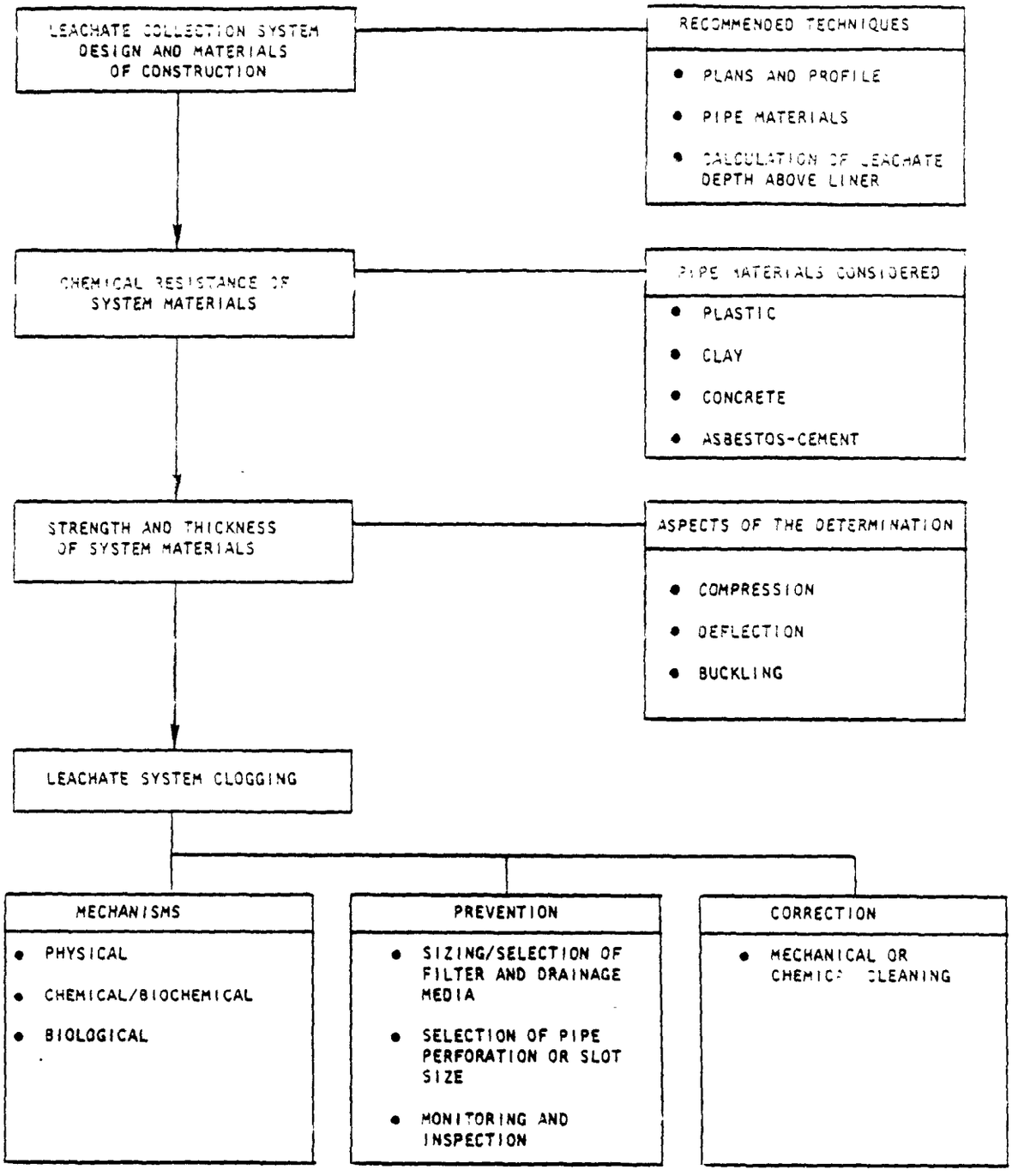

Figure 9.2.13. Evaluation of leachate collection and removal system design.

of the pipe should be indicated along with slot or perforation size. These plans and profiles should be drawn to scale, such as 1" = 20' or 40', so that the details of the design are clear. The profiles should indicate the location, depth, and thickness of foundation, subgrade, filter, and drainage layers, and the orientation of collection pipes with respect to the synthetic liner. The slope of all piping should be indicated in terms of percent slope (rise/run x 100) or inches of rise or fall for each foot of pipe length. References 2 (Metcalf and Eddy) and 3 (ASCE Manual of Practice 37) provide detailed information on design of subsurface piped drainage systems.

The spacing of all pipe laterals and interceptor piping should be visible from the plans and/or profile drawings, whichever provides a more straightforward view. The vertical extent of wastes and soils to be placed above the collection system should be indicated on the profile drawings.

Calculations should be provided that illustrate that the flow capacity of the collection system is capable of handling expected leachate flows over the life of the facility. Appendix V of the Liner TRD (SW-870)[4] presents a method of designing or evaluating the capacity of leachate collection systems. Selection of the design leachate flow rate should demonstrate consistency with the storm event selected for designing the run-off collection system facilities.

Pipe Materials

The selected pipe materials should be indicated, preferably on the plans and drawings. Possible materials include clay, PVC and other plastics, asbestos-cement, concrete, and others. The pipe class and wall thickness and bedding materials should be indicated so that pipe strength can be evaluated. If additives or special treatments or coatings will be used in pipe manufacture, these factors should also be specified.

Leachate Depth Above the Bottom Liner

The RCRA Technical Guidance Document for landfills[5] expresses the Agency's perception that "a [leachate collection system] design incorporating 4-inch diameter tiles on 50 to 200 foot (15 to 60 meter) centers will effectively minimize head on the liner system." However, the guidance manual recommends that the owner/operator incorporate design calculations in his application to demonstrate that no more than 1 foot of head will exist above the liner at any time, except during storm periods.

The EPA TRD (SW-868), Hydrologic Simulation On Solid Waste Disposal Sites,[6] provides a procedure for estimating the amount of moisture percolation through different types of landfill covers and, therefore, is only applicable for determining leachate depths after landfill closure. The EPA TRD (SW-869),[7] Landfill and Surface Impoundment Performance Evaluation, provides an analytical technique for determining the flow capacity of sand or gravel drainage layers.

Procedures recommended in SW-869--Moore (SW-869) presents the two drainage system configurations shown in Figure 9.2.14 and provides analytical methods for determining maximum leachate depth for the case of a flat liner or a sloping liner, where α is the liner slope in degrees. The figure shows a high permeability drainage layer overlying a low permeability layer (the purpose of which is to maximize horizontal flow in the drainage layer). In either configuration leachate travels to drains spaced a distance L apart. The source of liquid intercepted by the drain system is waste leachate or rainfall percolation.

In the case of a flat drainage layer, α=0, the shape of the leachate mound that forms in the drainage layer is presented by Harr in SW-869 as:

$$h = \left[\frac{e}{k_s} (L-X)\, X \right]^{1/2}$$

where,

h = the leachate depth at point x, (m),

e = the liquid impingement rate (m/sec),

k_s = the saturated permeability of the drainage layer, (m/sec), and

x = the distance to the point in question along the length L, (m)

H_{max} for the case of a flat liner occurs at the point where x = L/2. Substituting:

$$h_{max} = \left[\frac{e\, L^2}{4\, k_s} \right]^{1/2} \qquad (10)$$

In the case where α is greater than zero (i.e., the drainage layer slopes), leachate will tend to migrate out of the system at a more rapid rate because t gradient toward th drain pipe is higher.

To determine h_{max} for this situation, Moore presents the following:

$$h_{max} = \frac{L\sqrt{c}}{2} \left[\frac{\tan^2\alpha}{c} + 1 - \frac{\tan\alpha}{c}\sqrt{\tan^2\alpha + c} \right] \qquad (11)$$

where,

$$c = e/k_s$$

Figure 9.2.15 demonstrates the relationship between h_{max}/L and c as a function of bottom slope.[7] Clearly, bottom slope has little influence at slope greater than 5 or 6 percent, but such slopes are expected to be

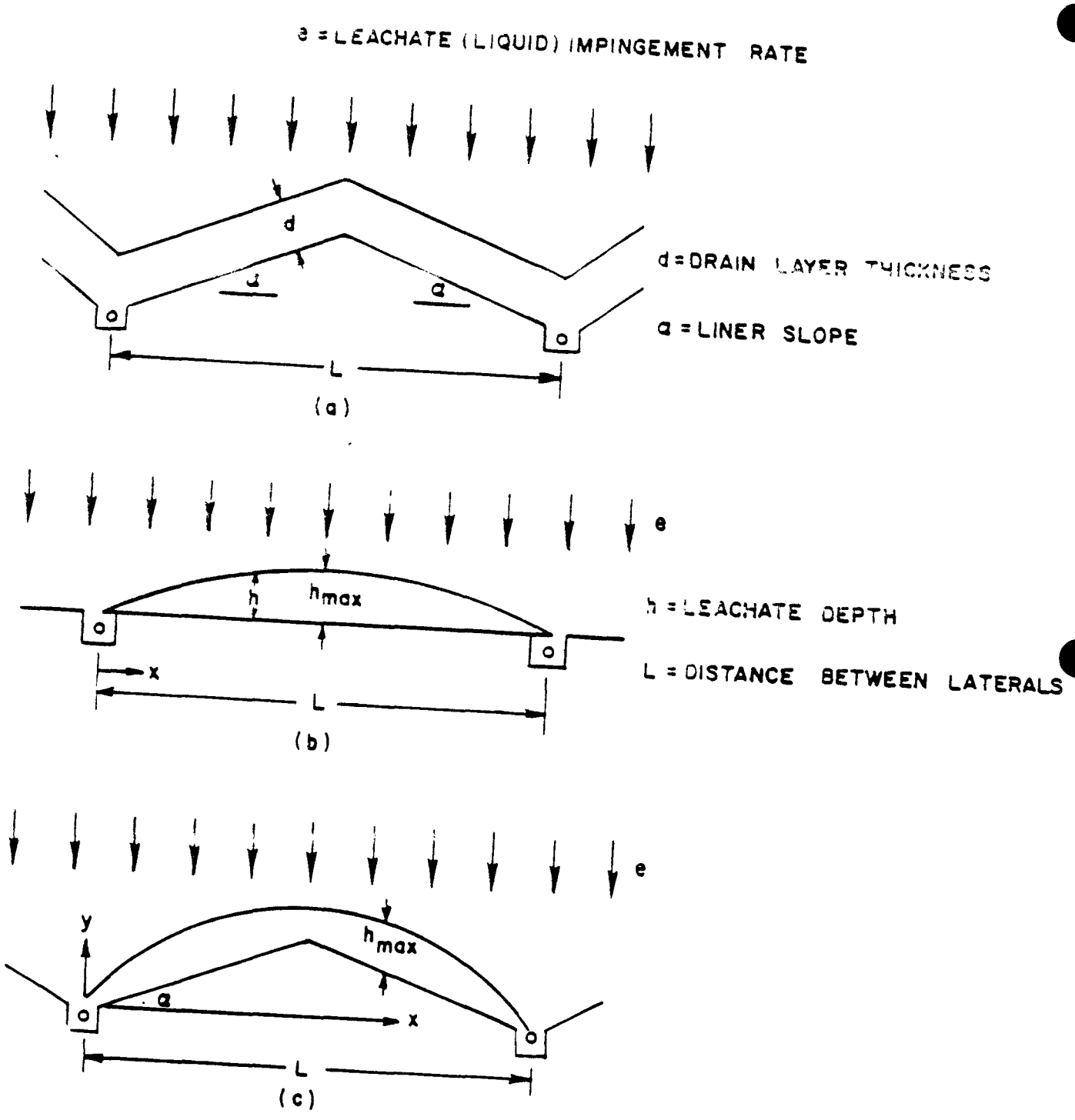

Figure 9.2.14. Alternative drainage system orientations considered in solving for maximum leachate depth.

Source: Reference 7.

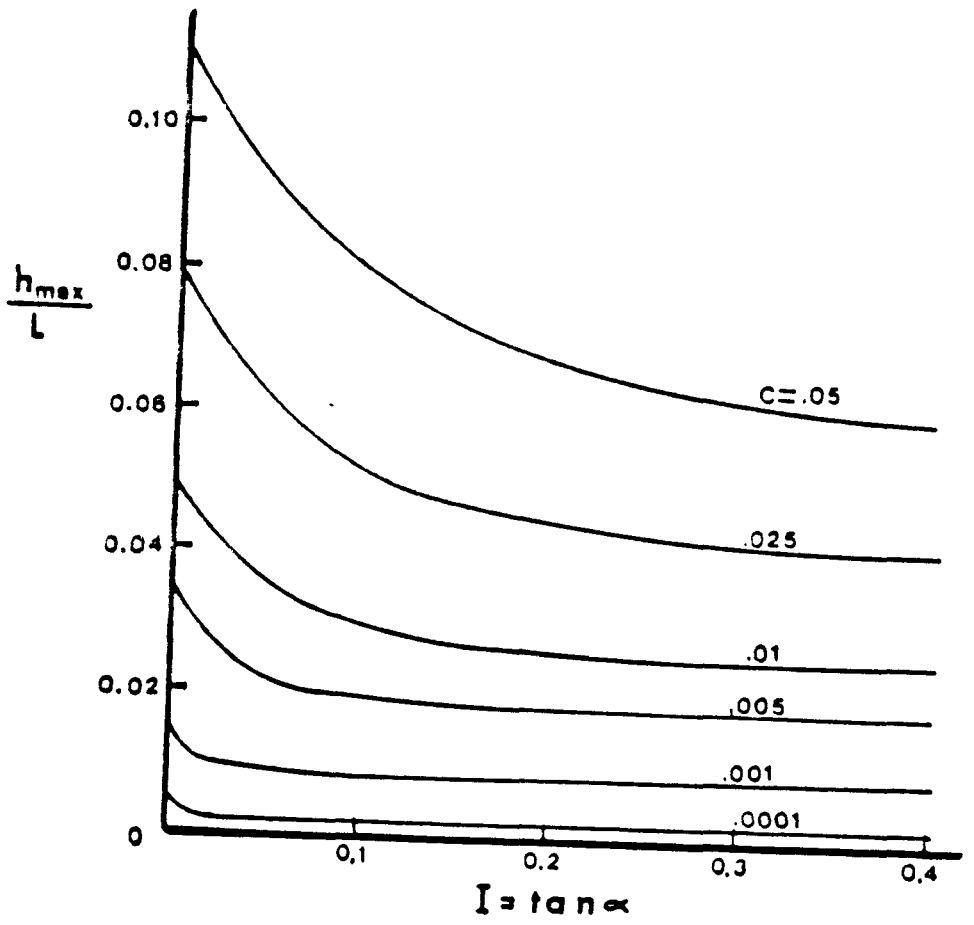

Figure 9.2.15. Relationship between h_{max}/L and $c = e/k_s$.

Source: Reference 7.

uncommon. At slopes expected in practice of 1 to 2 percent, h_{max}/L will be sensitive to minor changes in slope and will increase as the impingement rate, e, increases or as the permeability, k_s, decreases.

In applying these equations, SW-869 assumes steady state liquid impingement over 1 year's time. The permit reviewer should recognize that the worst case may be represented by estimating h_{max} attendant with a rare storm event (say 25 or 50 years) over a 24-hour period. The applicant should estimate short term leachate depths expected in such instances so that the adequacy of the system design can be better evaluated. If unacceptably high leachate depths are shown to occur in such instances, the permit reviewer should request resolution of the problem, possibly by requesting installation of a more permeable drainage layer or closer positioning of the lateral drainage pipes. The permit reviewer should also closely consider the applicant's assumptions regarding the fraction of rainfall which infiltrates to the drainage layer or rainfall losses attributed to evapotranspiration.

Underestimation of the leachate production rate (e) could result from the following:

- Failure to account for drainage of sludges placed in the facility.
- Poor maintenance and operation of the run-on and run-off control system during the active phase of operation.
- Failure of the impervious cap after closure.

In addition, the impingement rate could be altered locally (in one cell for example) by the propagation of channels through the waste materials which might deliver the leachate to one area of the leachate collection system and overload it.

Since observation of hydrostatic head is the criterion by which clogging of the collection system is determined, it is critical that these factors are accurately assessed in the initial design phase.

HELP - The Hydrologic Evaluation of Landfill Performance Model--The following discussion is based on two documents which present documentation and a user's guide for the HELP model. Both are currently in draft form and were prepared at the U.S. Army Corps of Engineers Waterways Experiment Station by:

- Walski, T. M., et al. - User Guide for the HELP Model[8]
- Schroeder, P. R., et al. - Documentation for the HELP Model[9]

The presentation provided here is intended as an introduction and overview only. If the permit applicant has used the HELP model or if the application reviewer chooses to use it as an independent check on the applicant's calculations, then it is strongly recommended that the permit application reviewer obtain copies of the User Guide and the Documentation.

The hydrologic evaluation of landfill performance (HELP) computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills. The model uses climatologic, soil, and landfill design data and incorporates a solution technique which accounts for the effects of surface storage, run-off, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage. The program estimates run-off drainage and leachate expected to result from a wide variety of landfill designs, including open, partially open, and closed landfill cells. Most importantly, in consideration of this topic, the model can be used to estimate the buildup of leachate above the bottom liner of the landfill. The following discussion is from Reference 9:

> "The HELP model performs a sequential daily analysis to determine run-off, evapotranspiration, percolation, and lateral drainage for the landfill (cap, cell, leachate collection system, and liner) and obtain daily, monthly, and annual water budgets. The model does not account for lateral inflow and surface run-on.
>
> "The HELP model requires climatologic data, soil characteristics, and design specifications to perform the analysis. Climatologic input data consist of daily precipitation values, mean monthly temperatures, mean monthly solar radiation values, leaf area indices, root zone or evaporative zone depths, and winter cover factors. Soil characteristics include porosity, field capacity, wilting point, hydraulic conductivity, water transmissivity evaporation coefficient and Soil Conservation Service (SCS) run-off curve number for antecedent moisture condition II. Design specifications consist of the number of layers and their descriptions including type, thickness, slope, and maximum lateral distance to a drain, if applicable, and whether synthetic membrances are to be used in the cover and/or liner. The HELP model maintains five years of default climatologic data for 102 cities throughout the United States. Any of seven default options for vegetation may be specified. The model also stores default soil characteristics for 21 soil types for use when measurements or site specific estimates are not available.
>
> "The model is ordinarily used in the conversational mode. This enables users to interact directly with the program and receive output through the terminal immediately. Use of the model does not require prior experience with computer programming; though, some experience would assist the user in logging on the computer system and manipulating data files. The model can also be run in the batch mode; however, this requires more computer programming experience and extreme care in preparation of input data files."

Figure 9.2.16 illustrates the landfill layers and profiles that can be considered in applying HELP.[9] In the current case, the evaluation is concerned with open, active landfill portions. If the topmost layer is identified as a waste layer, the program assumes that the landfill is open. For this case, an SCS run-off curve number* must be specified as well as the fraction of the potential surface run-off that is collected and removed from the landfill surface.

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*The SCS method for calculating run-off is discussed in subsection 9.2.5.

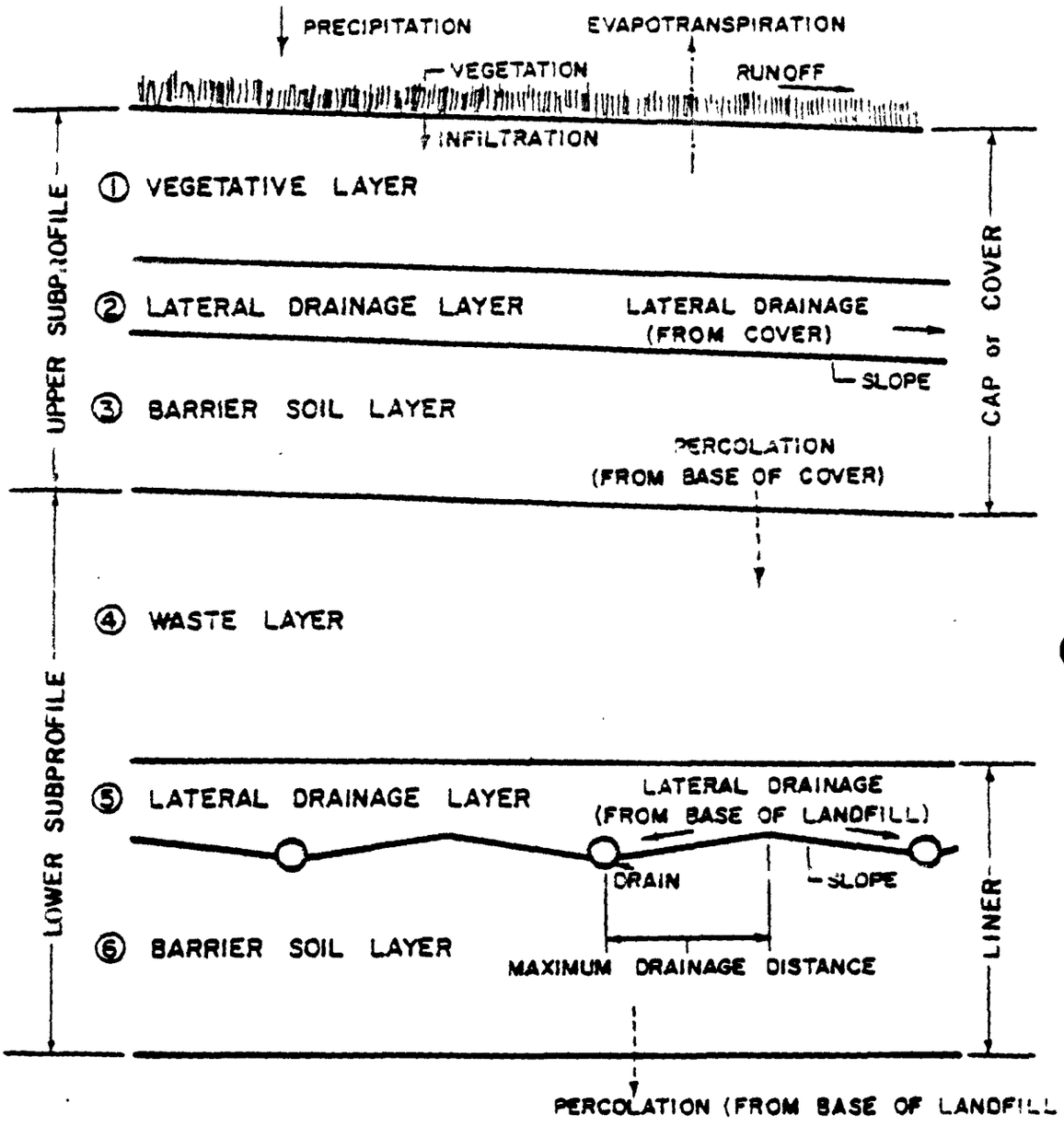


Figure 9.2.16. Hazardous waste landfill profile simulated using HELP.

Source: Reference 9.

The HELP model performs a daily sequential analysis to compute all output data. As many as 9 soil or waste layers can be simulated throughout a time period from 2 to 20 years. The model incorporates a lateral drainage equation which was developed to cover a wide range of landfill bottom design specifications, namely, slopes from 0 to 10 percent, drainage layer lengths from 25 to 200 feet, and SCS run-off curve numbers from 20 to 100 (see subsection 9.2.4.3.2). The liner leakage fraction and the fraction of run-off from open sites can vary from 0 to 1.

Optional forms of input and output are possible using the HELP program. Input climatological and soil data can be formulated by the user or default values can be used. Leachate system design data must be specified by the program user.

Output can be obtained in the form of daily values or monthly totals, each with a summary of the simulation. To obtain results indicating the head of leachate above the bottom liner, output must be formulated in terms of daily values. The accompanying simulation summary prints annual totals, monthly and annual averages, and peak daily values.

In summary, the HELP program can be used to estimate the depth of leachate above the bottom liner for a variety of landfill designs, time averages, and storm events. The results may be used to compare designs or to design leachate drainage and collection facilities. Review of the two referenced documents is recommended.

Assistance in running the program can be received from the developers at the Waterways Experiment Station. They can be reached by commercial telephone at (601) 634-3710 or via the FTS system at 542-3710.

The DRAINFIL Model--The DRAINFIL model is a landfill water balance technique developed by Wayne Skaggs at North Carolina State University.[10] Calculations conducted by EPA illustrate close comparison in results between DRAINFIL and HELP.[11] DRAINFIL can be used to determine leachate depth above the bottom liner of the landfill cell.

9.2.2.3.2 Chemical Resistance of System Materials--The components of the leachate collection system which should be evaluted for their resistance to chemicals in the landfill are the bottom liner and drainage tiles or pipes. The chemical resistance of liners is discussed in subsection 9.2.1.3. Chemical resistance of drainage conduit is discussed below.

The following types of pipe are commercially available for collection system drain construction.[12]

- vitrified clay
  - Clay drain tile
  - Clay pipe (standard and extra-strength perforated)

- Concrete (bell and spigot or tongue and groove joint)
  - Perforated concrete
- Asbestos-cement
  - Perforated sealed joint
- Plastic
  - Acrylonitrile-Butadiene-Styrene (ABS)
  - Polyvinyl chloride (PVC)
  - Styrene-rubber (SR)
  - Polyethylene (PE), straight wall or corrugated

Vitrified Clay

Vitrified clay tile or pipe is an excellent choice for leachate collection systems due to its resistance to chemical attack. Vitrified clay is resistant to internal and external attack from gases, solvents, and alkalies. This type of pipe has demonstrated long service life in both sewage conveyance and drainage collection applications. It should be noted, however, that some mineral components of clay pipe may be attacked under acid conditions. To evaluate resistance to acid attack, representative sample of pipe material could be tested by the applicant using a method such as the acid-soluble extraction technique specified by ASTM 301-79.

Asbestos-Cement and Concrete Pipes[3]

Asbestos-cement and concrete pipes are susceptible to corrosion under acid conditions. Although some corrosion is acceptable, excessive acidity can result in premature failure of the pipe. There are three possible methods of avoiding corrosion failure when asbestos-cement or concrete pipe are planned for use:

- Alter the composition of the pipe materials
- Apply acid resistant barriers
- Increase the wall thickness.

Type II Portland cement is superior to Type I in resisting sulfate attack in sewer systems. However, the type of cement does not seem to be a factor in the resistance of concrete pipe to acid attack.

For concrete pipe, extra wall thickness can be used to increase pipe life under acidic conditions. Another method is to use limestone or dolomite aggregate to increase the amount of acid soluble material in the concrete, thereby prolonging the life of the pipe in corrosive environments. The

corrosion rate of dolomite or limestone aggregate can be expected to be approximately one-fifth as great as granite aggregate. The practicability of using limestone or dolomite aggregate in pipe varies with the acidity of the leachate and the availability and alkalinity of the aggregate.

Protective barriers have been used on concrete and asbestos-cement pipe with varying success. Available coating and lining materials include bituminous and coal tar products, vinyl and epoxy resins, and paints. The linings must be applied such that the pipes are completely sealed. Any acid seepage or diffusion through the lining at any point, even through a pinhole, will react with the cement, thereby destroying the effectiveness of the liner. In leachate collection systems designed with cement and concrete pipe, linings may have to be applied to both the inner and outer surfaces.

Plastic Pipe[13,14]

Plastic pipe is well established in the drainage industry primarily due to low cost and ease of installation. In addition, quality control of joint construction is usually better than for other materials. In general, plastics have excellent resistance to weak mineral acids and are unaffected by inorganic salt solutions. Since plastics do not corrode in the electrochemical sense, they are not affected by slight changes in pH, minor impurities, or oxygen content. Table 9.2.7, from Reference 13, identifies the chemical resistance of ABS, PVC, and PE to selected chemicals.

Acrylonitrile butadiene styrene polymers (ABS) have good resistance to weak acids but are not satisfactory with oxidizing acids. They should not be used with chlorinated hydrocarbons but have good resistance to aliphatic hydrocarbons.

Polyvinyl chlorides have excellent resistance to non-oxidizing and weak acids, but should not be used with oxidizing acids. Resistance is also good to weak and strong alkaline materials. PVC has poor resistance to chlorinated hydrocarbons.

Styrene rubber is resistant to attack by ozone, sunlight, oils, gasoline, and aromatic and halogenated solvents. Styrene rubber can be attacked by benzene and ketones.

Polyethylene is the lowest cost plastic commercially available. Mechanical properties are relatively poor and such pipe must be fully supported. Carbon-filled grades are the most resistant to sunlight and weathering. Polyethylene has excellent resistance to acids and bases. However, it is readily attacked by aromatics and derivatives), alcohols, ketones, and hydrocarbons.

9.2.2.3.3 Strength and Thickness of Leachate Collection System Materials--The leachate collection system design must recognize that the drainage pipe may be the weakest structural component of the overall system. Therefore, materials selection and wall thickness design must account for expected dead and live loads above the pipe.

TABLE 9.2.7. CHEMICAL RESISTANCE OF PLASTICS USED FOR PIPING[a]
Source: Reference 13.

	ABS[b]	PVC[c]	Polypropylene polyethylene
10% H_2SO_4	Excellent	Excellent	Excellent
50% H_2SO_4	Excellent	Excellent	Excellent
10% HCl	Excellent	Excellent	Excellent
10% HNO_3	Good	Excellent	Excellent
10% Acetic	Excellent	Excellent	Excellent
10% NaOH	Excellent	Good	Excellent
50% NaOH	Excellent	Excellent	Excellent
NH_4OH	Excellent	Excellent	Excellent
NaCl	Excellent	Excellent	Excellent
$FeCl_3$	Excellent	Excellent	Excellent
$CuSO_4$	Excellent	Excellent	Excellent
NH_4NO_3	Excellent	Excellent	Excellent
Wet H_2S	Excellent	Excellent	Excellent
Wet Cl_2	Excellent	Good	Poor
Wet SO_2	Excellent	Excellent	Excellent
Gasoline	Excellent	Excellent	Poor
Benzene	Poor	Poor	Poor
CCl_4	Poor	Fair	Poor
Acetone	Poor	Poor	Poor
Alcohol	Excellent	Excellent	Poor

[a]Ratings are for long-term exposures at ambient temperatures (less than 100°F).

[b]Acrylonitrile butadiene styrene polymer.

[c]Polyvinyl chloride, type I.

EPA TRD SW-870[14] provides a comprehensive summary of design criteria for collection pipes considering loads from overlying waste fill. The following discussion is based on that reference, ASCE MOP 37,[2] information presented in "Clogging of Leachate Collection Systems Used in Hazardous Waste Land Disposal Facilities",[15] the Clay Pipe Engineering Manual,[16] and manufacturer's literature.[17,18]

In the analysis of structural stability under an imposed loading, the pipe is considered to be either rigid or flexible. Examples of rigid pipe include clay and concrete. Plastic and fiber glass are examples of flexible pipe construction material. For rigid pipe, compressive strength is the overriding design loading criterion. Deflection and buckling of pipe walls are more important considerations for flexible pipe.

Loads are generally determined from one or two conditions: a trench condition or a positive projection condition. Trench conditions exist when the pipe is installed in a relatively narrow trench cut in undisturbed ground and covered with earth backfill to the original ground surface. Projecting conditions exist when the pipe is covered with fill above the original surface or when a trench is so wide that trench wall friction does not affect the load on the pipe.

The pipe stability analysis must consider both dead loads imposed by the backfill and the waste and live loads imposed by vehicular traffic.

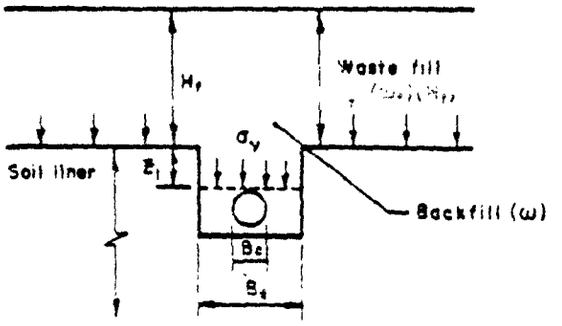
Pipe Loading Conditions

Typical trench and positive projection installations are illustrated in Figure 9.2.17. For trench conditions, backfill between the trench wall and the pipe is prevented from settling to the maximum density by the action of a frictional force along the sides of the pipe. This increases the load that can be supported by the pipe. As the trench width increases, the load which the pipe can support decreases until the "transition width" is reached. The transition width is the trench width at which further widening will have no effect on the load on the pipe. The pipe load should be calculated as a projecting condition whenever the transition width is exceeded. Worst case loading conditions exist under positive projecting conditions. Transition widths for various pipe diameters and trench widths can be obtained from design manuals such as the Clay Pipe Engineering Manual (Reference 16) and by consulting with pipe manufacturers. Transition widths for 6- and 8-inch diameter pipes buried in sand and gravel are provided in Table 9.2.8.

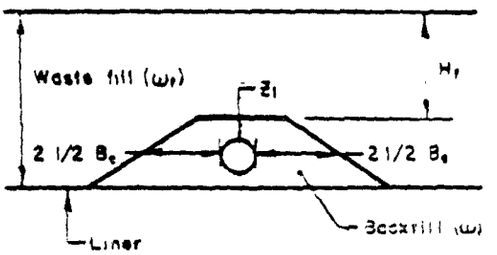
Pipe Strength Determination Procedures

Methods for determining the vertical load on buried pipes have been developed by Marston. These methods are based on theory and experimentation and have achieved acceptance as being the most useful and reliable. The general form of Marston's equation is:

$$W = C_w B^2 \qquad (13)$$



a) TRENCH CONDITION



b) PROJECTING CONDITION

Figure 9.2.17. Pipe installation - conditions and loading.

Source: Reference 4 (SW-870)

TABLE 9.2.8. TRANSITION WIDTHS FOR 6-INCH AND 8-INCH PIPE INSTALLED IN SAND AND GRAVEL

Depth of backfill (ft)	Transition width (ft)	
	6-inch pipe	8-inch pipe
5	1.59	1.93
6	1.69	2.03
8	1.86	2.22
10	2.02	2.40
12	2.17	2.56
14	2.31	2.71
16	2.44	2.86
18	2.56	3.00
20	2.68	3.13
22	2.80	3.26
24	2.91	3.38
26	3.01	3.50
28	3.12	3.62
30	3.22	3.73

where: W = vertical load per unit length acting on the pipe due to gravity earth loads in lb/ft

w = unit weight of earth per unit volume in lb/ft^3

B = Trench width or pipe width, depending on installation conditions, in ft

C = Dimensionless coefficient to account for:

(1) Ratio of the fill height to the width of the trench or conduit.
(2) Shearing forces between the earth prism directly above the pipe and adjacent prisms.
(3) Direction and amount of relative settlement between interior and adjacent earth prisms.

Allowable Load for Rigid Pipes

Loads must be calculated for either trench or projecting conditions. Marston's formula for calculating loads on rigid pipe in trench conditions is:

$$W = C_d \, w \, B_d^2 \tag{14}$$

where: W and w are previously defined

B_d = Trench width at the top of the pipe in ft

C_d = Dimensionless coefficient that is a function of the ratio of fill height to the width of the trench and of the friction coefficient between the backfill and the sides of the trench. C_d is computed as:

$$C_d = \frac{[1 - e^{-2K\mu(Z/B_d)}]}{2K\mu} \tag{15}$$

where: e is the base of natural logarithms

K = Rankines ratio of lateral pressure to vertical pressure

Z = height of backfill above pipe (see Figure 9.2.17)

μ = coefficient of friction between backfill material and sides of the trench

In land based hazardous waste management applications, the pipe load is caused by both the waste fill and the trench backfill. (Live loads are discussed later.) These two components of the total vertical pressure are computed separately and then added to obtain the total vertical pressure acting on the pipe. The modified Marston's equation used is:

$$W = B_d \, w \, C_d + w_f \, H_f \, C_{us} \quad (16)$$

where: W, B_d, w, and C_d are previously defined

w_f = unit weight of waste fill (values range from 45 to 65 lb/ft^3 for municipal waste with soil cover)

H_f = height of waste fill, ft, and

$$C_{us} = e^{-2K\mu(2/B_d)} \quad (17)$$

The term C_{us}, a load coefficient, is a function of the ratio of the depth of the trench, Z, to the width of the trench, B_d (see Figure 9.2.17), and the friction between the backfill and the sides of the trench.

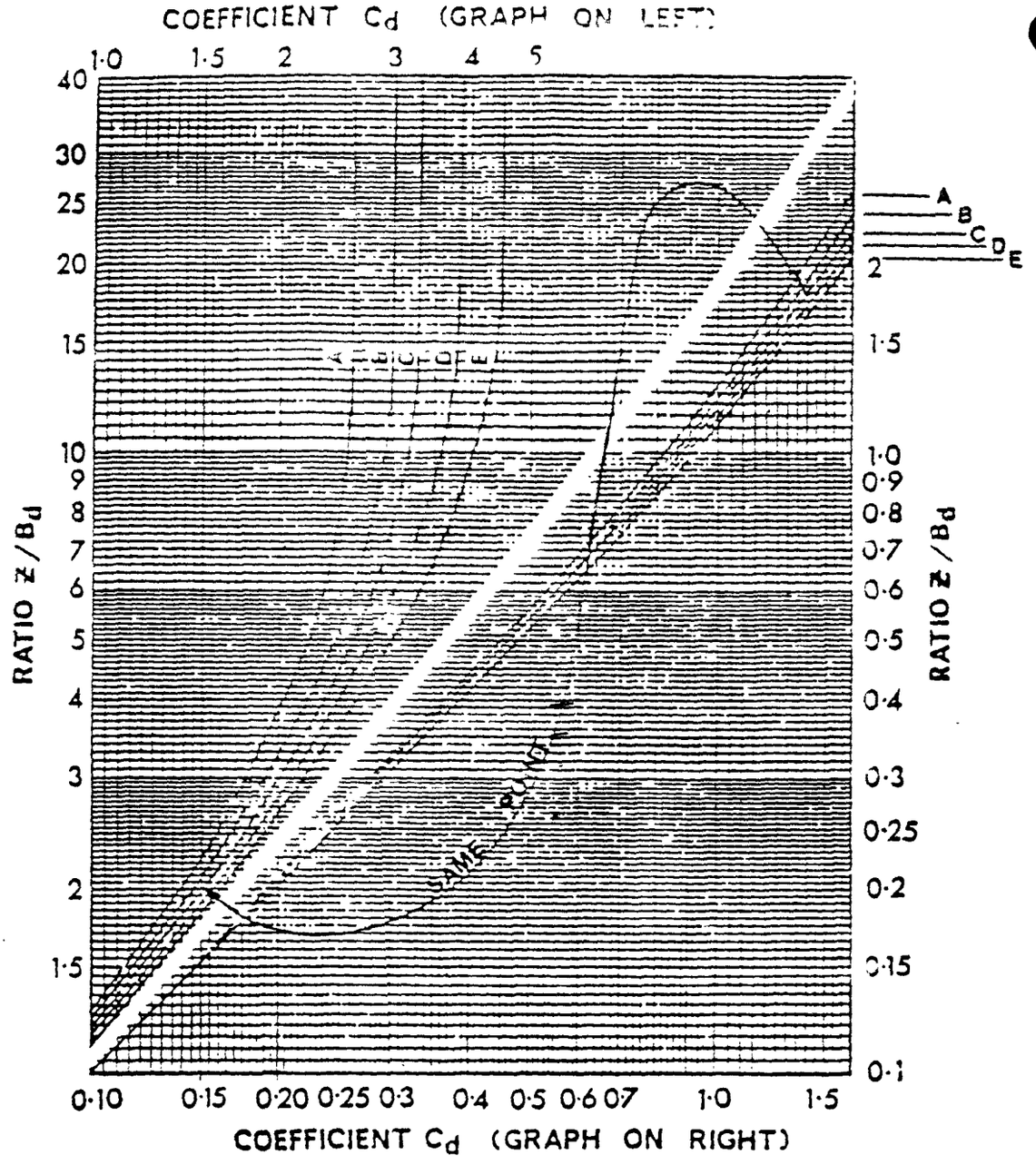
With the exception of coefficients K and μ, terms used in Equation 15 are identified by the density of the cover materials and by the dimensions of the installation. The coefficients K and μ, used in determining C_d and C_{us}, are dependent on the type of backfill materials used. Typical values of the product $K\mu$ are:

- 0.19 - granular materials without cohesion
- 0.165 - sand and gravel
- 0.13 - unsaturated clay
- 0.11 - saturated clay
- 0.15 - saturated topsoil

To expedite the calculation of pipe loads under trench conditions, graphical techniques can be used to determine C_d and C_{us}. Working graphs for calculating C_d and C_{us} are provided in Figure 9.2.13 and Figure 9.2.19, respectively. Load can then be determined using the modified Marston equation.

Projecting conditions exist whenever the pipe is covered with fill above the ground surface or when the trench width is wider than the "transition width." Under projecting conditions, the load can be calculated using the modified Marston equation by assuming the trench width, B_d, to be equal to the transition width.

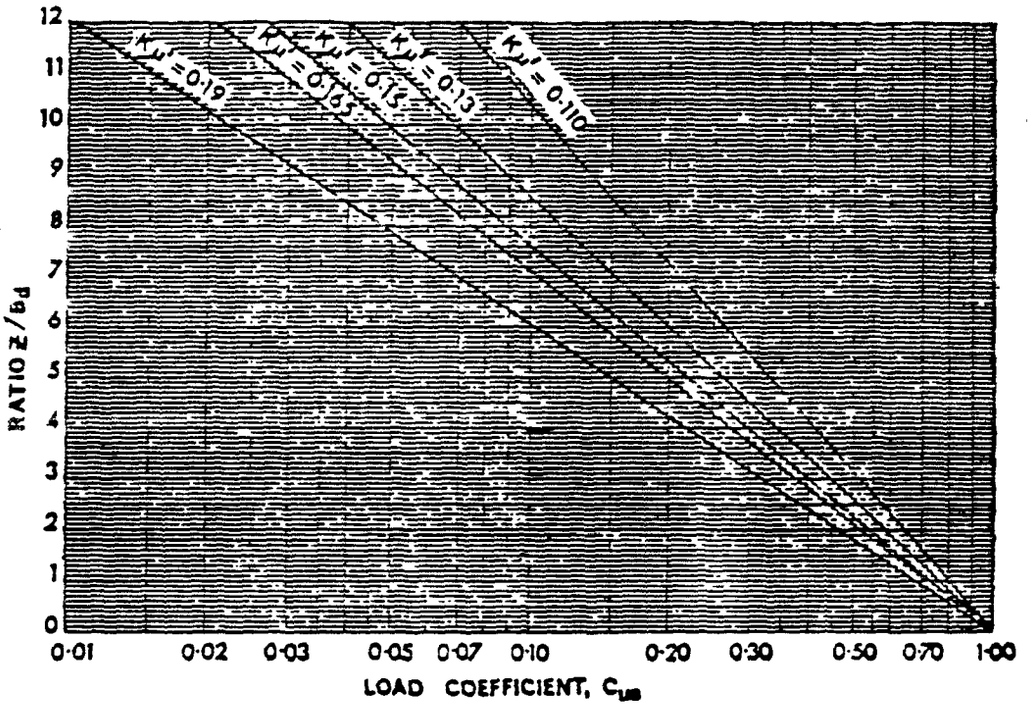
After calculating the load on the pipe, the next step is to determine the adequacy of the pipe in bearing the load. The ability of rigid pipe to safely resist the calculated load depends on its inherent strength, the distribution of the vertical load, the type of bedding material used, and the lateral pressure acting against the sides of the pipe. Compressive strength is the primary loading design parameter for rigid pipe.



Curve

A—C_d for $K\mu' = 0.19$ for granular materials without cohesion
B—C_d for $K\mu' = 0.165$ max. for sand and gravel
C—C_d for $K\mu' = 0.150$ max. for saturated top soil
D—C_d for $K\mu' = 0.130$ ordinary max. for clay
E—C_d for $K\mu' = 0.110$ max. for saturated clay

Figure 9.2.18. Trench condition - pipe load coefficient.
Source: SW-870.



Values of load coefficient C_{us} (trench uniform surcharge)

Figure 9.2.19. Projecting condition - pipe load coefficient.
Source: SW-870.

Rigid pipe has an inherent crushing strength measured by the three edge bearing test (ASTM Method C301). Minimum crushing strength for standard and extra strength perforated and nonperforated vitrified clay pipe is provided in Table 9.2.9. To represent actual field conditions, a "load factor" is used to convert minimum crushing strength to field support strength. The load factor is dependent on the pipe bedding material. Recommended load factor values are (Reference 16 (Clay Pipe Manual)):

Class A-1 (plain concrete = 2.8

Class A-1 (reinforced concrete) = 3.4

Class A-11 (reinforced concrete, p = 0.4 percent) = 3.4

Class A-11 (reinforced concrete, p = 1.0 percent) = 4.8

Crushed stone encasement = 2.2

Class B = 1.9

Class C = 1.5

Class D = 1.1

The field supporting strength is calculated as:

$$\text{Field supporting strength} = \text{minimum crushing strength} \times \text{load factor} \qquad (18)$$

Because of limitations in the 3-edge bearing test in simulating actual field conditions, a factor of safety must be applied to the field supporting strength to calculate a safe supporting strength. The safe supporting strength is calculated as:

$$\text{Safe supporting strength} = \frac{\text{Field supporting strength}}{\text{Factor of safety}} \qquad (19)$$

ASTM Designation C12-82 recommends using a safety factor of between 1.0 and 1.5.

Allowable Load for Flexible Pipe

The load on flexible pipe is also calculated by a version of Marston's equation. The flexible pipe load differs from the load imposed on rigid pipes in that the soil at the sides of the pipe is compacted to the extent that it will deform under the vertical load imposed on the pipe itself. Therefore, the side fills can be expected to carry a proportional share of the total load. Under these circumstances, the trench load formula may be modified to:

$$W = B_c \left(B_d \, w \, C_d + w_f \, H_f \, C_{ts}\right) \qquad (20)$$

TABLE 9.2.9. MINIMUM CRUSHING STRENGTH (3-EDGE BEARING STRENGTH)
Source: Reference 16

Nominal size, in.	Extra strength vitrified clay pipe		Standard strength vitrified clay pipe		Perforated vitrified clay pipe			
					Extra strength		Standard strength	
	lbf/linear ft	kN/linear m	lbf/linear ft	kN/linear m	lbf/linear ft	kN/linear m	lbf/linear ft	kN/linear m
3	2,000	29.2						
4	2,000	29.2	1,200	17.5	1,250	18.2	1,000	14.6
6	2,000	29.2	1,200	17.5	1,600	23.4	1,000	14.6
8	2,200	32.1	1,400	20.4	1,600	23.4	1,000	14.6
10	2,400	35.0	1,600	23.4	1,600	23.4	1,100	16.1
12	2,600	37.9	1,800	26.3	1,800	26.3	1,200	17.5
15	2,900	42.3	2,000	29.2	2,200	32.1	1,400	20.4
18	3,300	48.2	2,200	32.1	2,640	38.5	1,700	24.8
21	3,850	56.2	2,400	35.0	3,100	45.2	2,000	29.2
24	4,400	64.2	2,600	37.9	3,520	51.4	2,400	35.0
27	4,700	68.6	2,800	40.9	---	---	---	---
30	5,000	73.0	3,300	48.2	---	---	---	---
33	5,500	80.3	3,600	52.5	---	---	---	---
36	6,000	87.6	4,000	58.4	---	---	---	---
39	6,600	96.3	---	---	---	---	---	---
42	7,000	102.2	---	---	---	---	---	---

where: w, B_d, w, w_f, H_f and C_{cs} are previously defined

B_c = Outside diameter of pipe, ft, (see Figure 9.2.17)

As with rigid pipes, the coefficients C_d and C_{cs} may be calculated using working graphs provided in Figures 9.2.18 and 9.2.19.

Under projecting conditions, the load on flexible pipe can be assumed to be equal to the weight of a prism of overlying waste fill with a width B_c and a height, H_f, plus the weight of a similar prism of gravel above the pipe (see Figure 9.2.17). The following equation can be used to determine the load:

$$W = (w_f H_f + w Z) \qquad (21)$$

where: W, w_f, H_f, w and Z are previously defined

After calculating the load, it must be determined whether excessive deflection will occur. Flexible pipe derives its ability to support a load from its inherent strength plus the passive resistance pressure of the soil at the sides as the pipe deflects and moves outward against the side fills. This type of pipe fails by excessive deflection and collapse or buckling, rather than by rupture as is the case with rigid pipes.

Flexible pipes must be designed to withstand vertical pressure at the top of the pipe without excessive deflection. The Iowa formula is a well-accepted equation for calculating flexible pipe deflection under earth loading and is given as:

$$\Delta y = D_e \frac{KWr^3}{EI + 0.061\ E'r^3} \qquad (22)$$

where: Δy = horizontal and vertical deflection of the pipe (in.). A maximum long term deflection of between 5 and 10 percent is recommended

D_e = a factor, generally taken at a conservative value of 1.5, compensating for the lag or time dependent behavior of the soil/pipe system (dimensionless)

W = vertical load acting on the pipe per unit of pipe length (lb/in.)

r = mean radius of the pipe (in.)

E = modulus of elasticity of the pipe materials (psi)

E' = modulus of passive soil resistance (psi) (normally estimated to be 300 psi for soils with Proctor density of 65 percent, and 700 psi for soils with Proctor density of at least 90 percent)

K = bedding constant, reflecting the support the pipe receives from the bottom of the trench (dimensionless, a conservative value of 0.10 is normally assigned)

I = moment of inertial of pipe wall per unit of length (in.^{4}/in.); for any round pipe, $I=t^3/12$ where t is the average thickness (in.)

The first term in the denominator of Equation 22, EI, reflects the influence of the inherent strength of the pipe on deflection. The second term, $0.061\ E'r^3$, reflects the influence of the passive soil pressure on the sides of the pipe. It is recommended that the value of EI should never be less than 10 to 15 percent of $0.061\ E'r^3$. Due to the variety of flexible pipes available, manufacturers should be consulted for data on pipe strength. Example values of EI for 4 types of pipe are as follows:

4-inch Schedule 40, EI = 16.2
4-inch Schedule 80, EI = 47.4
6-inch Schedule 40, EI = 28.4
6-inch Schedule 80, EI = 105.3

Reference 4 presents a graphical technique which can be used to evaluate deflection in flexible pipe. Several examples are also provided. Manufacturers often provide tabulated data to give the design engineer a quick indication of the adequacy and applicability of flexible pipe. Table 9.2.10 illustrates the capability of PVC pipe with a stiffness of 46 psi under projection conditions. The table illustrates that deflection will be less than 7.5 percent for depths up to 12 feet. At greater depths, greater defleciton is possible depending on soil type.

The capacity of flexible pipe to support vertical stresses may in some cases be limited by buckling. In most cases, the allowable deflection will be exceeded before buckling becomes the limiting factor. In some cases, buckling modulus of passive soil resistance. Specific information on buckling characteristics should be obtained from the pipe manufacturer.

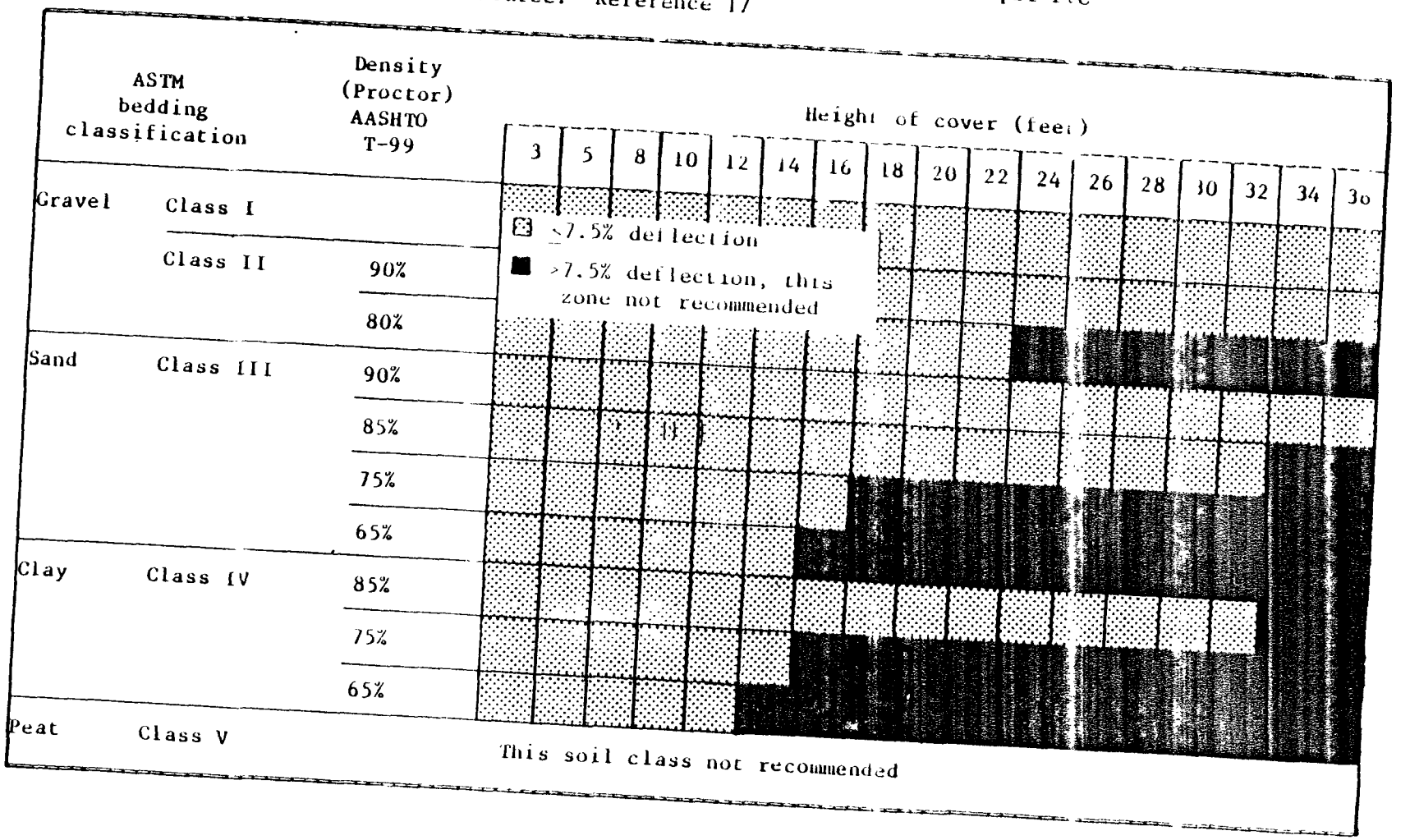
Perforated Pipe

Perforations reduce the ability of rigid and flexible pipe to carry load and resist deflection under both trench and positive projection conditions. This effect can be accounted for by assuming and using an increased load per unit length of pipe. The following equation is recommended:[3]

$$\text{Design load} = \frac{12}{12 - L_p} \times \text{Actual load} \qquad (23)$$

where: L_p = Cumulative length of perforations in inches per foot

TABLE 9.2.10. MAXIMUM LONG-TERM DEFLECTION OF F/AY 46 psi PVC
Source: Reference 17



Working or Moving Live Loads

Live loads due to construction equipment are a key consideration in leachate collection system design. Discussions with landfill operators and designers suggest that failures of many leachate collection systems may result from construction equipment loading. EPA TRD SW-870 suggests a minimum vertical separation of 4 feet between the loaded surface and the top of the pipe. Concentrated live loads such as a truck wheel load can be calculated as follows:[16]

$$W_{sc} = C_s \frac{P\ F}{L} \qquad (24)$$

where: W_{sc} = load on the pipe in pounds per linear foot

P = concentrated load in lbs

F = impact factor; a minimum value of 1.5 is recommended

L = effective length of pipe, ft. It is recommended that an effective length of 3 feet be used for pipe greater than 3 feet long, and actual length for pipe shorter than 3 feet

C_s = load coefficient; the load coefficient is a function of pipe width, effective pipe length, and fill height

The load coefficient, C_s, is a function of $B_c/2H$ and $L/2H$. Load coefficient values can be obtained from Table 9.2.11 for several combinations of pipe size and depth. However, C_s cannot be obtained from this table for small pipe (6 to 8 inch diameter) at depths greater than 3 or 4 feet. For depths up to 8 feet the live load can be approximated from the data presented in Table 9.2.12. The wheel load must first be determined and then the percentage of that load applied to a unit length of pipe is obtained from Table 9.2.12. This load must then be corrected using an impact factor of 1.5 or greater. Based on the information presented in these tables and an impact factor of 1.5, the live loads calculated for 6-inch and 8-inch diameter pipe under a 20-ton truck are presented below:

Depth (ft)	Pipe load, lbs/linear foot	
	6-inch pipe	8-inch pipe
1	3070	3600
2	1370	1680
3	700	860
4	400	500
5	290	340
6	200	240
7	120	170
8	100	120

TABLE 9.2.11. VALUES OF LOAD COEFFICIENTS, C_s, FOR CONCENTRATED LOADS VERTICALLY CENTERED OVER CONDUIT
Source: Reference 16

$\frac{B_c}{2H}$	$\frac{L}{2H}$													
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	5.0
0.1	0.019	0.037	0.053	0.067	0.079	0.089	0.097	0.103	0.108	0.112	0.117	0.121	0.124	0.128
0.2	0.037	0.072	0.103	0.131	0.155	0.174	0.189	0.202	0.211	0.219	0.229	0.238	0.244	0.248
0.3	0.053	0.103	0.149	0.190	0.224	0.252	0.274	0.292	0.306	0.318	0.333	0.345	0.355	0.360
0.4	0.067	0.131	0.190	0.241	0.284	0.320	0.349	0.373	0.391	0.405	0.425	0.440	0.454	0.460
0.5	0.079	0.155	0.224	0.284	0.336	0.379	0.414	0.441	0.463	0.481	0.505	0.525	0.540	0.548
0.6	0.089	0.174	0.252	0.320	0.379	0.428	0.467	0.499	0.524	0.544	0.572	0.596	0.613	0.624
0.7	0.097	0.189	0.274	0.349	0.414	0.467	0.511	0.546	0.584	0.597	0.628	0.650	0.674	0.688
0.8	0.103	0.202	0.292	0.373	0.441	0.499	0.546	0.584	0.615	0.639	0.674	0.703	0.725	0.740
0.9	0.108	0.211	0.306	0.391	0.463	0.524	0.574	0.615	0.647	0.673	0.711	0.742	0.766	0.784
1.0	0.112	0.219	0.318	0.405	0.481	0.544	0.597	0.639	0.673	0.701	0.740	0.774	0.800	0.816
1.2	0.117	0.229	0.333	0.425	0.505	0.572	0.628	0.674	0.711	0.740	0.783	0.820	0.849	0.868
1.5	0.121	0.238	0.345	0.440	0.525	0.596	0.650	0.703	0.742	0.774	0.820	0.861	0.894	0.916
2.0	0.124	0.244	0.355	0.454	0.540	0.613	0.674	0.725	0.766	0.800	0.849	0.894	0.930	0.956

TABLE 9.2.12. PERCENTAGE OF WHEEL LOADS TRANSMITTED TO UNDERGROUND PIPES[a]
Source: Reference 16

Depth of Backfill Over Top of Pipe in Feet	Pipe Size	9"	12"	15"	18"	21"	24"	27"	30"	33"	36"	39"	42"
	Outside Diam of Pipe in Feet (Approx)	.64	.81	1.0	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.5	3.9	4.2
1		12.8	15.0	17.3	20.0	22.6	24.8	26.4	27.2	28.0	28.6	29.0	29.4	29.8	29.9
2		5.7	7.0	8.3	9.6	11.5	13.2	15.0	15.6	16.8	17.8	18.7	19.5	20.0	20.5
3		2.9	3.6	4.3	5.2	6.4	7.5	8.6	9.3	10.2	11.1	11.8	12.5	12.9	13.5
4		1.7	2.1	2.5	3.1	3.9	4.6	5.3	5.8	6.5	7.2	7.9	8.5	8.8	9.2
5		1.2	1.4	1.7	2.1	2.6	3.1	3.6	3.9	4.4	4.9	5.3	5.8	6.1	6.4
6		0.8	1.0	1.1	1.4	1.8	2.1	2.5	2.8	3.1	3.5	3.8	4.2	4.3	4.4
7		0.5	0.7	0.8	1.0	1.3	1.6	1.9	2.1	2.3	2.6	2.9	3.2	3.3	3.5
8		0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.3	2.5	2.6

[a]Tabulated figures show percentage of wheel load applied to one linear foot of pipe, but make no allowance for impact factor.

These loads are calculated assuming 50 percent of the 20-ton load is distributed over the rear axle, each rear wheel carrying one-half this load or 16,000 pounds. From these data, it is evident that increasing depths of cover substantially reduce the live load.

The technjnical adequacy worksheet for evaluating the calculations of load bearing capacity for the leachate collection system piping is presented in Figure 9.2.20. The worksheet should be completed before addressing the technical adequacy checklist provided in Section 9.9.

9.2.2.3.4 Leachate Collection System Clogging--The following text identifies physical, chemical, and biological phenomena which can cause clogging of leachate collection facilities. Such clogging could result in leachate depths greater than 1 foot above the bottom liner, the limit specified in the regulations (§264.301(a)(2)). Leachate build-up, in combination with a bottom liner failure, could lead to extensive contaminant exfiltration. The discussion which follows is taken from Reference 15, "Clogging of Leachate Collection Systems Used in Hazardous Waste Land Disposal Facilities."

Clogging Mechanisms

Physical Clogging Mechanisms--Pipe drainage system failures, or partial failures, due to physical causes are usually associated with unstable soil conditions which cause shifts in pipe alignment and grade, collapsed tubing, pulled joints, and plugging, according to the Bureau of Reclamation. Other failure mechanisms which may be more common to land disposal operations include crushing of pipe due to equipment loads, damage due to frost action or hydrostratic uplift, or migration of fine grained soils into and through the drainage filter envelope surrounding the pipe.

The failure of drains due to clogging by soil sediment deposits is a common problem and will depend on the nature of the soil surrounding the drain. Such sedimentation may occur in noncohesive soils or soils with a high content of silt and fine sand.

The effects of undesirable soil types which may be adjacent to or within the leachate collection system can be mitigated by: (1) proper selection of the filter and drainage layer soil particle size gradations to exclude the smaller mobile particle sizes; and (2) incorporation of adequate facilities for cleanout of the system if it becomes clogged. Procedures for the selection of filter and drainage envelope particle size gradations are discussed in a following subsection. However, in some cases, especially immediately after construction, some fine particles may wash out of the filter envelope if fines are not kept to a minimum. Thus, the design of cleanout facilities, also discussed later, is recommended as a precautionary measure.

Chemical and Biochemical Clogging Mechanisms--The potential or probability for clogging of leachate collection systems is difficult to quantify because of widely variable site specific waste, soil, and operating conditions. Therefore, the clogging mechanisms discussed below may act only in limited cases depending on conditions at the site. The clogging agents discussed

LEACHATE COLLECTION SYSTEM/LOAD BEARING CAPACITY

Has this part of the applicants submittal been read and evaluated?

_____ Yes _____ No

Has the applicant addressed this issue?

_____ Yes _____ No

What source of information has the applicant used to assess the structural strength of the leachate collection system?_____

What is the anticipated dead load?_____ lb/ft

What is the anticipated live load?_____ lb/ft

What are the proposed pipe trench conditions; trench or projecting? _____

Based on independent calculations, will the piping withstand the anticipated total load?

_____ Yes _____ No

Figure 9.2.20. Worksheet for calculation of load bearing capacity of underground leachate collection system piping.

include calcium and manganese carbonate, various iron precipitates, and biochemically generated ferric and manganese hydroxides (ochre).

Calcium carbonate precipitates have been found to cause plugging problems around well screens, in drainage layers, and within pipes.[19,20] Incrustation occurs when the concentrations of both the calcium and bicarbonate ions are present in excess of their equilibrium concentrations.[20] In wells, during normal pumping periods, pressure changes accelerate the conversion of the bicarbonate ion to the carbonate ion by permitting escape of carbon dioxide from solution.[20] The carbonate combines with calcium to form calcium carbonate precipitate. These mechanisms are shown by the following reaction scheme.[20]

$$Ca^{++} + 2HCO_3^- \longrightarrow CaCO_3 \text{ (solid)} + CO_2 \text{ (gas)} + H_2O \qquad (25)$$

Investigators have formulated an expression to determine the likelihood that incrustation of calcium carbonate will occur on a site-specific basis. The resultant formula relates pH, total alkalinity (T.A.) or bicarbonate alkalinity, and calcium hardness as follows:[20]

$$\text{Incrustation Potential Ratio (I.P.R.)} = \frac{(\text{T.A. as ppm } CaCO_3)(\text{calcium hardness as ppm } CaCO_3)}{10.3 \times 10^{11}\ (H^+)} \qquad (26)$$

If the resultant I.P.R. value is less than 1, no calcium carbonate problem should exist. On the other hand, if the I.P.R. value equals 1 or more, calcium carbonate incrustation is a potential problem.

Manganese has also been shown to form chemical precipitates (manganese carbonates) responsible for clogging. Manganese forms carbonates (rhodochrosite), sulfides, and silicates that are fairly insoluble in neutral and basic solutions. Precipitation may occur whenever the pH increases, provided carbonate is present in sufficient concentrations.

Research performed on well systems and subsurface drains used for agricultural land drainage indicates that a predominant clogging phenomenon experienced worldwide is the formation of iron deposits. Observations of iron incrustation in drain pipes has been reported as far back as 1937 (Germany).[21]

Geological investigations and experience with subsurface wastewater treatment systems indicate that insoluble iron and manganese compounds are transformed under anaerobic or reducing conditions into more soluble ferrous and manganous forms. If the soil drains and these compounds are exposed to oxygen, insoluble compounds are formed and precipitate out of solution. These colored precipitates are referred to as soil mottles.

Discussions with Dr. Ron Lavigne[22] also indicated that formation of iron precipitates in leachate collection systems is likely when oxygen is brought into contact with leachate. Dr. Lavigne noted that leachate drawn

from piezometer caps located in the anaerobic zone of a pilot leachate collection system in Barre, Massachusetts was clear in color upon withdrawal. When the clear leachate was exposed to air a "rust" precipitate began to form. Dr. Lavigne indicated that problems with passing the precipitate would occur if air were not excluded from the collection system.

Reduced soluble forms of iron and manganese are metabolized by aerobic iron bacteria as an energy source producing large quantities of ferric and manganese hydroxides which entwine and biologically precipitate within and at the water entry slots of drains. In the absence of these autotrophic (self-sufficient) bacteria, chemically-precipitated $Fe(OH)_3$ is found to be porous and less of a clogging agent unless it is clumped in large particles.[19,23,24]

Iron sulfide deposits (FeS) produced from available Fe^{+2}, are known to adhere to organic soil matter forming a relatively impervious mat within drain envelopes, and have been found capable of clogging the entry slots in corrugated plastic tubing.[25]

Other research indicates that the presence of certain complexing agents in association with iron (Fe^{+2}) can influence the production of ochre. These organic complexing agents; i.e., tannins, humic acids, and certain aromatic hydroxyl compounds such as phenols, are known to complex iron and reduce ochre development when the Fe^{+2} content is >4 ppm.[25] However, these compounds have also been found to form colloidal iron complexes in water, free of iron bacteria, that may adhere to drains and act as sites for additional accumulation of ferric (Fe^{+3}) compounds and subsequent trapping of particulate matter such as sand grains.[19] The iron complexation problem is particularly severe when the pH is between 7.0 and 7.8.[23,24] In studies using iodine as a biocide to control these clogging agents, iodine was also found to complex with iron and form a clogging agent.[19]

Soil types have a predominant influence on the potential for clogging due to these biochemical mechanisms. Studies conducted in Florida have indicated that the types of soils showing the most potential for ochre formation are:[26,27] fine sands and silty sands, organic soils and organic pans, mixed profiles containing organic matter, gullies, flood plains of rivers, and depressions containing organic residues. Soils with the least potential for ochre formation are silty clay loams that are deficient in Fe^{+2} in the soil solution because of the high amount of energy required to reduce the iron present. Additionally, soils containing glauconite, iron oxide or magnesium oxide are known to seal over drain joints or perforations due to the various chemical actions that may take place within these soils.[28]

Biological Clogging Mechanisms--Research efforts and operational experience with microbial removal of hazardous waste compounds, porous media wastewater treatment, wastewater tile fields, soil absorption beds, and agricultural drainage and irrigation systems are indicative of biological clogging mechanisms that may be encountered in leachate collection systems.

In studies of low volume irrigation systems by Ford, a filamentous slime forming organism identified as Vitreoscilla and a common, universally distributed soil bacteria called Pseudomonas (specifically, its associated polysaccharide slimes) were shown to act as clogging agents in the absence of iron.[19] Additionally, Ford has suggested that a clear jelly-like slime, dominated by bacteria of the genus Enterobacter, may contribute to an increase in drain entry resistance by clogging the zone abutting the drain envelope.[24]

Extensive investigations by Kobayashi and Rittmann[3] have indicated that numerous microorganisms have the ability to metabolize various anthropogenic (hazardous waste) compounds and, in turn, remove these substances from the environment. Pseudomonas species appear to be the most ubiquitous microorganisms and are able to metabolize many different anthropogenic compounds. Microorganisms, such as Pseudomonas, can persist within a hazardous waste disposal site and are also associated with biological slime clogging of drainage systems.

Prevention of Clogging

To prevent clogging of leachate drainage layers and piping, filter and drainage layer size gradations should be designed using criteria established by Cedergren and/or the Army Corps of Engineers (as discussed below). Drainage layers should be designed to have adequate hydraulic conductivity; i.e., greater than 1×10^{-3} cm/sec. Drainage media should be washed before installation to minimize fines. If drain pipe is used, it should be slotted or perforated with a minimum inside diameter of 6 inches to allow for cleaning. Protective bedding should be placed under and around piping to help withstand overburden loads.

Selection and Sizing of Filter and Drainage Media--To prevent piping in a drainage system the pore spaces between the filter particles should be small enough to hold some of the larger particles of the protected materials in place. Soils and aggregates are composed of ranges of particle sizes, and if the pore spaces in filters are small enough to hold the 85 percent size (D_{85}) of adjacent soils (upgradient from the filter) in place the finer soil particles will also remain in place.[30] This phenomenon is graphically illustrated in Figure 9.2.21 (after Cedergren[30]) demonstrating the relationship in size among protected soil, filter media, and drainage layer media.

Two criteria are suggested for use in design of drainage and filter layers for tile drain systems.[30] These criteria are:

> Criterion 1. The 15 percent size (D_{15}) of a filter material must be not more than four or five times the 85 percent size (D_{85}) of a protected soil. The ratio of D_{15} of a filter to D_{85} of a protected soil is called the piping ratio.

$$\frac{D_{15}\ \text{(of a filter)}}{D_{85}\ \text{(of soil)}} < 4 \text{ to } 5 \qquad (27)$$

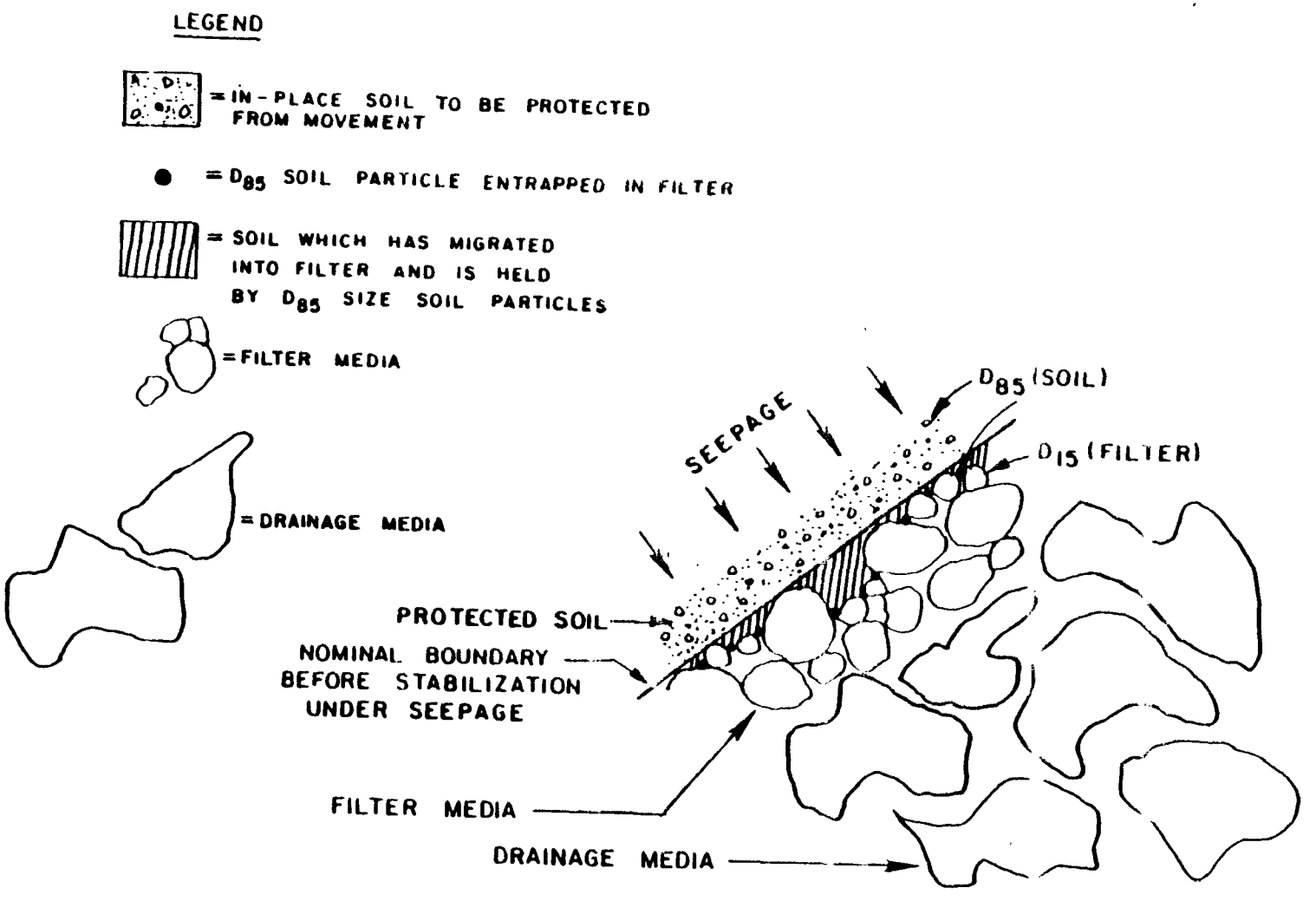


Figure 9.2.21. Illustration of prevention of piping by graded filters.

Reference: 30, after Cedergren.

Criterion 2. The 15 percent size (D_{15}) of a filter material should be at least four or five times the 15 percent size (D_{15}) of a protected soil.

$$\frac{D_{15}\ \text{(of filter)}}{D_{15}\ \text{(of soil)}} > 4 \text{ to } 5 \qquad (28)$$

The first criterion is for the control of piping (hydraulic failure) of soil into the filter layer and the drainage system, while the second criterion is meant to guarantee sufficient permeability to prevent the buildup of large seepage forces and hydrostatic pressure in filters and drainage layers.

Other criteria can be specified in addition to or in lieu of those noted above. The U.S. Army Corps of Engineers[31] recommends the following for protecting nonplastic soils:

$$\frac{D_{15}\ \text{size of filter material}}{D_{85}\ \text{size of protected soil}} \leq 5 \qquad (29)$$

$$\frac{D_{50}\ \text{size of filter material}}{D_{50}\ \text{size of protected soil}} \leq 25 \qquad (30)$$

These criteria are based on experience with and design of dams and other earthworks that require slope stability, and design of underground drainage systems.

The U.S. Army Corps of Engineers[31] also allows a relaxation of the above criteria for medium to highly plastic clays without sand or silt lenses, which would require multiple stage filters by the above criteria. These criteria state that for these clay soils, the D_{15} size of the filter may be as great as 0.4 mm and the above D_{50} criterion may be disregarded. This relaxation in criteria for protecting medium to highly plastic clays will allow the use of a one-stage filter system; however, the filter material must be well graded, and to ensure nonsegregation of the filter material, a coefficient of uniformity (ratio of D_{60} to D_{10}) of not greater than 20 is required.

In contrast to the Corps criteria stated above, Sherard et al.[32] note that certain types of clay may erode by a process called "dispersion" or "deflocculation." Cedergren[30] indicates that the chance of piping failure of drainage systems using dispersive clays can be greatly reduced by providing adequate filters to retain erodible soils. In some cases two or three filter layers may be required for such systems. Field tests of soils should be performed to establish safe piping ratios (D_{15} filter/D_{85} soil) for systems using dispersive clays.

The U.S. Bureau of Reclamation[33] has also developed filter grading criteria for high head-rapid pressure dissipation applications. These criteria address piping and permeability in a manner similar to those

mentioned above. In addition, the Bureau recommends separate criteria for uniform grain size filters and differentiates between angular and rounded graded filter media. Bureau criteria also suggest that all filter materials pass a 3-inch screen to minimize particle segregation and bridging during placement.

A key consideration in using all the above criteria is that the grain-size curves of filter and protected layers be somewhat parallel. This objective is expressed by the relationship given in equation 10 of the Corps criteria.[31]

The technical adequacy worksheet for evaluating the suitability of drainage and filter layer design using natural materials (gravel, stone, sand, etc.) is presented in Figure 9.2.22. The worksheet should be completed before addressing the technical adequacy checklist in subsection 9.9.

Use of Filter Fabrics--When filter fabrics (geotextiles) are used in place of graded filters, the protective filter may only be about 1 mm in thickness. Caution should be exercised to ensure that no holes, tears, or gaps are permitted to form in the fabric. Cedergren[30] suggests that if the D_{85} of a soil is larger than the near maximum opening size of the fabric (D_{85} fabric), little soil should move through the fabric mesh.

Demery[34] has shown that if the permeability of the protected soil is less than the permeability of the filter fabric, the soil controls the hydraulic response of the system. Willardson indicates that it is wise to maintain the ratio of filter permeability to soil permeability (k filter/k soil) greater than 1.0 to minimize the hydraulic gradient at the interface.[35] In general, the permeability of synthetic filter fabrics lies in the range of 5×10^{-4} to 10^{-1} cm/sec. Thus, in most cases a ratio of k filter/k soil greater than 1.0 can be easily achieved.

The advantages to using synthetic fabric filters in place of granular filters are cost, durability, and consistency. With increases in costs of graded aggregate and its installation, synthetic filters are competitive with graded filters. Probably the most important advantage to fabric filters is quality control during construction. The properties of fabric filters will remain practically constant independent of construction practices, whereas graded filters can become segregated during placement.

Although synthetic filters do have certain advantages they are not problem free. Benz et al,[36] indicated in studies of drainage envelopes that some synthetic fabric envelopes did tear under test. Broughton et al.[37] indicated that Remay filters (27 g/m^2) suffered considerable abrasion damage in transport and field handling requiring patching of the filter. In other cases[37] drainage pipes (tiles) were found blocked by sand deposits which apparently entered through the joint between two sheets of filter material. In addition, bacterial plugging (iron bacteria) of synthetic filters has been noted by Demery.[4] Compatability of filter materials and leachate will also be a subject of concern in specific cases, and should be accounted for during system design.

- Has this part of the applicants submittal been read and evaluated? ____ Yes ____ No
- Are soils and/or stone media proposed for adjacent filter and drain layers? (If filter fabrics are proposed, see Figure __) ____ Yes ____ No
- Are the size gradations characterizing these soil layers presented by the applicant? ____ Yes ____ No
- What criteria or equations has the applicant used to demonstrate that movement of fines (and media clogging) will not occur? _____

  _____
- Have equations recommended by EPA been used to assure acceptability of adjacent layers? ____ Yes ____ No
- If no, conduct an independent check using those relationships

Independent Check

a. D_{15} filter/D_{85} soil = _____ $\leq$ 5? ____ Yes ____ No

b. D_{15} filter/D_{15} soil = _____ $\geq$ 5? ____ Yes ____ No

c. D_{50} filter/D_{50} soil = _____ = 25? ____ Yes ____ No

- Is the applicants proposal acceptable in preventing drainage media clogging by fines? ____ Yes ____ No

Figure 9.2.22. Worksheet to determine adequacy of design of drainage and filter layers.

The technical adequacy worksheet for determining the suitability of geotextile filter materials is presented in Figure 9.2.23.

Selection of Pipe Perforation or Slot Size--When drainage systems are embedded in filter and drainage layers, no unplugged ends should be allowed and the filter materials in contact with the pipes must be coarse enough to be excluded from joints, holes, or slots.[30] The U.S. Army Corps of Engineers[31] use the following criteria for gradation of filter materials in relation to pipe openings.

For slots:

$$\frac{D_{85} \text{ filter material}}{\text{slot width}} = 1.2 \qquad (31)$$

For circular holes:

$$\frac{D_{85} \text{ filter material}}{\text{hole diameter}} = 1.0 \qquad (32)$$

The U.S. Bureau of Reclamation[33] uses the following criterion for grain size of filter materials in relation to openings in pipes:

$$\frac{D_{85} \text{ of the filter nearest the pipe}}{\text{maximum opening of pipe drain}} \geq 2 \qquad (33)$$

Cedergren[30] suggests that these equations represent a reasonable range over which satisfactory performance can be expected.

The U.S. Bureau of Reclamation[38] additionally recommends that the maximum opening in pipes not exceed 1/8 in. (3 mm). Control of opening size is difficult in open joint construction practice, thus making perforated pipes more reliable. Modern trenchers often employ double hydraulic rams to maintain pressure on pipe ends during placement and spacing lugs are required. However, even with this modification, pulled joints still occasionally occur so that the additional precaution of covering the top half of the pipe with a plastic cover is recommended.[38] Other solutions to this problem include wrapping open joints in synthetic filter fabrics.

The technical adequacy worksheet for determining the suitability of the applicant's design for pipe slot or perforation size is presented in Figure 9.2.24.

Correction of Clogging

It is likely that proper engineering design and careful operation of a leachate collection system can significantly reduce the risk of clogging and allow for repair if clogging occurs. Recommended engineering components or methods for system maintenance, cleaning, and repair include:

ACCEPTABILITY OF FILTER FABRICS (GEOTEXTILES)

- Have the filter fabrics proposed by the applicant been evaluated? _____ Yes _____ No
- Has the applicant demonstrated a suitable inspection plan to assure that the filter will be free of holes, tears, or gaps before and after installation? _____ Yes _____ No
- Has the applicant noted the maximum opening size of the fabric, and if so what is it? _____
- What is the D_{85} of the adjacent protected soil? _____
- Is D_{85} soil greater than the maximum opening of the fabric, thus preventing movement of soil into the fabric? _____ Yes _____ No
- If the filter permeability is known, what is the reported value? _____
- If the adjacent soil permeability is known, what is the reported value? _____
- Is the ratio $k_{filter}/k_{soil} \geq 1$? _____ Yes _____ No

Figure 9.2.23. Worksheet for determining the adequacy of filter fabrics proposed by the applicant.

LEACHATE COLLECTION SYSTEMS--SELECTION OF PIPE PERFORATION OR SLOT SIZE

- Has this part of the applicants submittal been read and evaluated? Yes / No

- Has the applicant addressed this topic to assure that the leachate collection pipe openings will not clog? Yes / No

Independent Check

- What is the proposed slot width or hole diameter? _____

- What is the D_{85} of the adjacent filter material: _____

- Are the criteria of equations 31, 32, and 33 satisfied?

  D_{85} filter/slot width = 1.2? Yes / No

  D_{85} filter/hole diameter = 1.0? Yes / No

  D_{85} filter/max. pipe drain opening $\geq$ 2.0? Yes / No

- Is the applicant's proposal acceptable? Yes / No

Figure 9.2.24. Worksheet for determining the adequacy of pipe perforation or slot design.

- perforated drainage pipes (e.g., [illegible] concrete, or PVC), with sealed joints of a minimum diameter of 6 in. to facilitate mechanical or chemical cleaning,

- manholes located at major pipe intersections or bends to allow for access, inspection, and mechanical or chemical cleaning,

- incorporation of valving, ports, or other appurtenances necessary to introduce biocides and/or cleaning solutions, and

- automatic leachate level monitors and (possibly) alarm systems.

Following construction, scheduled periodic maintenance is recommended. After the initial lift of waste has been placed, the drainage system should be inspected, cleaned and tested, and repaired if necessary. Subsequently, periodic testing and cleaning should be conducted, possibly once per year. In addition, leachate levels and flow rates should be continuously monitored and correlated with rainfall so that inconsistencies indicating clogging can be immediately investigated.

Clogged drainpipes can be restored to a free flowing condition by physical or chemical cleaning except in cases where blockage is due to crushing of the drain. In this case, drain replacement would be required. Also, except under unusual circumstances, it would not be feasible to clean large areas of drainage layers which had become clogged.

Of the two physical methods of drain cleaning, hydraulic jets have generally been considered superior to mechanical cleaning systems (e.g., Roto-rooters) which are often used with success in the cleaning of sanitary sewer lines, or mechanical "pigs" which are used for cleaning water mains.

Physical methods for removal of ochre and other associated iron clogging agents within drains have been extensively used in Europe, and to some degree in the United States. These methods employ a high or low pressure jet cleaning system placed within the drains.[39] In Europe, the high pressure system is used for the more seriously clogged drains while low pressure units are restricted to removing silt and iron deposits.[39]

Preliminary tests by Ford, using a high pressure (1100 to 1300 psi at the pump) system, found that condiserable damage to the sand-gravel envelope surrounding the drains and subsequent deposition of sand and gravel within the drains was occurring.[39] These observations prompted interest in a low pressure system for ochre removal in Florida. From a group of 21 low pressure nozzle types, two nozzles (as shown in Figure 9.2.25) were rated highest on the basis of propelling distance, cleaning efficiency, water requirements, and ease of construction.[39]

The overall performance of these low pressure nozzle cleaning systems was found to be adequate in removing deposits which primarily consisted of ochre and FeS within 4 to 5 inch plastic drains of up to 550 ft in length.[39] It was noted that jetting should be performed at a slow entry rate and with a

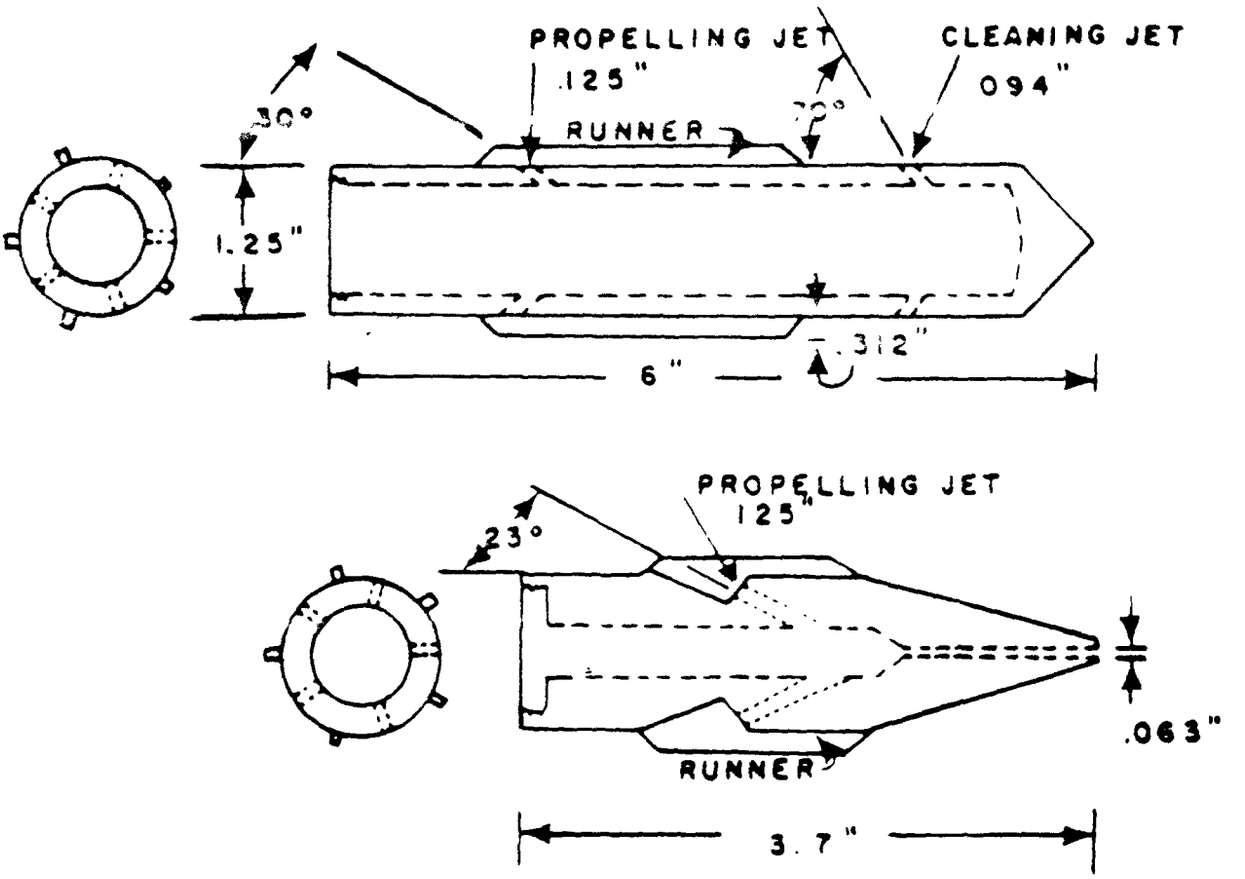


Figure 9.2.25. General purpose nozzle (top) and penetrator nozzle (bottom). Source: Reference 39.

hydraulic head above the drain.[39] However, low pressure jetting was not totally effective in removing large accumulations of FeS on organic matter abutting the drain envelope.[39] Subsequent testing with high pressure systems has shown that removal of the more mature ochre deposits is not entirely possible.[40] Recent tests in Wisconsin indicate that water jets can be used to effectively clean drain pipes which, for test purposes, were filled completely with silt and clay.[41]

For deposits which are not readily removed by water jets or other mechanical means, chemical cleaning techniques have been tested. These methods fall into two broad classifications: (1) chemically dissolving the accumulated material, or (2) controlling the iron bacteria responsible for these deposits.

Chemically dissolving the accumulated material appears to be a function of several variables. Calcium and magnesium carbonate deposits have been known to dissolve readily in well systems using hydrochloric (muriatic) acid.[42] However, these same deposits have been shown to react with sulfuric acid treatments producing only slightly soluble sulfates in water.[42]

Hydrochloric acid has also proved effective for removal of iron and manganese hydroxide and oxide deposits from well systems and irrigation systems (although these deposits will precipitate from solution if the pH goes above 3).[19,42] Apparently, in the treatment of these hydroxide or oxide accumulations, the chlorine (either as a hypochlorite-Cl_2 dissolved in $Ca(OH)_2$ or NaOH, or as the gas-Cl_2) effectively kills the bacteria associated with these deposits, and also oxidizes Fe (II).[19] In a study of recovery wells around the Army Creek Landfill in New Castle County, Delaware, which were clogged by ochre deposits, a polyphosphate solution containing 100 pounds of activated carbon (Calgon™) and 5 pounds of granular dry chlorine gave good results in rehabilitating these wells.[43]

Additional effective treatment methods for ochre deposits within subsurface agricultural drains include the use of gaseous sulfur dioxide, sulfuric acid, and sulfamic acid.[23,40,42,44,45] Experimental research with sulfuric acid has shown that several factors may affect the eventual removal of ochre from drain lines; i.e., the organic matter content, the amount of acid solution in relation to the amount of ochre, and the concentration of the acid.[40] Generally, at higher organic contents, more acid is required for successful removal of ochre.[40] Additionally, a drawback in the use of gaseous SO_2 and sulfuric acid is the inherent problem of handling these materials.

Studies by Lidster and Ford[40] using dry pelletized sulfamic acid (at concentrations equivalent to that of sulfuric acid) have shown good results in attempts at dissolving ochre into solution. Sulfamic acid is inactive in its dry form and, thus, easier to handle than sulfuric or hydrochloric acids.

The second alternative method of chemical cleaning is direct control of iron bacteria through the use of biocides. Compounds tested experimentally in the field include:[19] (1) acrolein, a three carbon aldehyde which is

identified as a hazardous waste and, therefore, could be inappropriate, (2) quarternary ammonium salts, a nonoxidizing biocide which killed the bacteria but also had to be limited to certain types of problems because these salts form undesirable complexes, (3) iodine which was a good biocide, but which forms complexes with iron that may clog, and (4) hydrogen peroxide (H_2O_2), which when combined with Fe forms a superoxide radical which was found to be a good biocide. Otherwise, H_2O_2 was a poor biocide for sulfur slime and other slimes that did not contain Fe.

In summary, numerous methods for reclaiming drainage systems have been attempted. Some have shown great success with certain clogging agents, while others are not as effective or are dangerous to handle. As indicated by Ford,[19] prevention is the best method for controlling chemical-microbiological slimes and associated clogging problems.

9.2.2.4 Draft Permit Preparation--

Condition B.2 of Permit Module XV (see Section 4) addresses design and operation of leachate collection and removal systems. The condition is implemented through reference to a permit attachment that includes plans and specifications for the proposed leachate collection system. To be suitable for substitution in the permit condition attachment, the submitted application information should include the following:

- engineering plans which show the full extent of the leachate collection system in plan and profile views,
- all calculations and results demonstrating the depth of leachate above the bottom liner,
- all calculations supporting selection of pipe of sufficient strength to withstand overburden live and dead loads,
- all conclusions and associated documentation illustrating the resistance of leachate collection system materials to wastes,
- all calculations, assertions, and drawings necessary to illustrate design procedures to prevent leachate system clogging and allow for correction of clogging if it occurs.

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9.2.3 Liner and Leachate Collection and Removal System Exemption

9.2.3.1 The Federal Requirement--

Part 270 requires the following application information if an exemption is sought:

> §270.21(b)(1) "... If an exemption from the requirements for a liner and a leachate collection and removal system is sought as provided by §264.301(b), submit detailed plans and engineering and hydrogeologic reports, as appropriate, describing alternate design and operating practices that will, in conjunction with location aspects, prevent the migration of any hazardous constituent into the ground water or surface water at any future time."

The Part 264 standards incorporate the following exemption criteria:

> "(b) The owner or operator will be exempted from the requirements of paragraph (a) of this section if the Regional Administrator finds, based on a demonstration by the owner or operator, that alternative design and operating practices, together with location characteristics, will prevent the migration of any hazardous constituents (see §264.93) into the ground water or surface water at any future time. In deciding whether to grant an exemption, the Regional Administrator will consider:
>
> (1) The nature and quantity of the wastes;
>
> (2) The proposed alternate design and operation;
>
> (3) The hydrogeologic setting of the facility, including the attenuative capacity and thickness of the liners and soils present between the landfill and ground water or surface water; and
>
> (4) All other factors which would influence the quality and mobility of the leachate produced and the potential for it to migrate to ground water or surface water."

9.2.3.2 Summary of Necessary Application Information--

The Part B Permit Applicants' Manual[1] specifies the following information requirements for new units:

- location information relevant to assessing the potential for leachate migration, i.e., soil permeability, attenuation capacity, geology, and geohydrology, and

- a description of the alternative design and operating practices and a demonstration that the proposal will prevent contamination of surface and ground water at any future time.

9.2.3.3 Guidance on Evaluating Application Information--

It is not expected that many applicants will apply for this exemption. Additionally, it is not expected that many, if any, locations exist where such a demonstration could be adequately made. By definition, the site would first have to be located well above the existing water table in the unsaturated zone. The intermediate soil would have to be a dense cohesive fine grained material (clay) with extremely low permeability. Given the low water content and low void ratio, it is expected that high suction pressures would exist. Suction forces of this magnitude could provide a driving force for leachate migration which is one to two orders of magnitude greater than any attendant hydrostatic driving force. Although the volume of leachate that would migrate under these conditions is less than the amount that would migrate in saturated soils according to Darcy's Law, the velocity of movement of the wetting front could be several times greater.

As detailed in References 2 through 12, a great deal of information exists in this subject area. For instance, Moore notes a linearized solution to the unsaturated flow equations in the TRD on Hydrologic Simulation (SW-869).[2] Of most relevance is a guidance manual (GCA-1983)[3] which illustrates the use of numerical modeling to simulate leachate flow through clay liners. Although the manual is intended for use in designing liners for storage surface impoundments, the technique could be applied to determine the time of travel of the leachate from the unit to the nearest ground water or surface water resource. Given the physics of the situation and the available solution techniques, it seems improbable that an applicant could illustrate with validity that leachate would never reach any ground water or surface water at any future time.

The guidance manual on numerical modeling incorporates a bibliography of related scientific literature. The references listed in subsection 9.2.3.5 should provide for further understanding of this topic.

The technical adequacy worksheet for determining the suitability of the applicant's alternative to the liner and leachate collection system is presented in Figure 9.2.26.

9.2.3.4 Draft Permit Preparation--

Liner and leachate collection system exemptions are discussed in Condition B.2 of Module XV. The condition is implemented through reference to a permit attachment that provides plans and specifications for an alternative design. The permit application may be used as the attachment provided it includes an adequate description of the alternative design and operating practices and demonstrates that the design and operating practices, in combination with location characteristics, will prevent any hazardous constituents from entering the ground water or surface water at any future time. Successfully demonstrated alternative plans should also be documented in the administrative record.

LINER AND LEACHATE COLLECTION SYSTEM EXEMPTION

Has the applicant applied for a liner and leachate collection system exemption?	Yes	No
Has this part of the applicant's submittal been reviewed and evaluated?	Yes	No
Are any of the hazardous materials leachable?	Yes	No
Will significant quantities of leachable hazardous waste be disposed in the landfill?	Yes	No
Is the site located well above the existing water table?	Yes	No
Has the applicant demonstrated (using engineering and hydrologic reports) that the intermediate soil layer has an extremely low permeability?	Yes	No
Has an accepted numerical or analytical model been used to simulate leachate flow?	Yes	No
Does the simulation conclude that leachate will never reach ground water or surface water?	Yes	No

How do the results compare with your independent evaluation using techniques presented in SW-869 or a numerical model? _____

_____

_____

Figure 9.2.26. Worksheet for determining the adequacy of the applicant's submittal for a liner and leachate collection system exemption.

9.2.3.3 References--

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9.2.4 Control of Run-On

9.2.4.1 The Federal Requirement--

As part of the applicant's detailed plans and engineering report, §270.21(b)(2) requires the submission to address "control of run-on."

The Part 264 standards for run-on control specify in §264.301(c) that:

> "The owner or operator must design, construct, operate, and maintain a run-on control system capable of preventing flow onto the active portion of the landfill during peak discharge from at least a 25-year storm."

9.2.4.2 Summary of Necessary Application Information--

The Part B Permit Applicants' Manual[1] instructs the applicant to:

- Determine the peak flow from the upstream watershed area during the 25-year storm event,
- Size and design run-on control facilities to accommodate the peak flow rate, and
- Devise a plan for run-on system maintenance, restoration, and repair.

9.2.4.3 Guidance on Evaluating Application Information--

A flow chart indicating the applicability of the Part 264 requirements to run-on control is provided in Figure 9.2.27. The flow chart is also applicable to run-off control and management of run-on and run-off control units, as discussed in subsections 9.2.5 and 9.2.6.

The landfill owner/operator must design, construct, operate, and maintain a run-on control system capable of preventing flow onto the active portion of the landfill during peak discharge from at least a 25-year storm. The technical issues which must be considered in evaluating the application information are presented in Figure 9.2.28.

The amount of run-on (or runoff, as discussed in subsection 9.2.5) expected as a result of precipitation will depend on:

- soil cover (vegetated or nonvegetated),
- upstream watershed surface slope,
- soil permeability,
- antecedent soil moisture content, and
- seasonal temperatures (e.g., soil freezing).

The relationships between run-on or run-off production and these factors are covered in introductory hydrology textbooks (see Reference 2 and Reference 3).

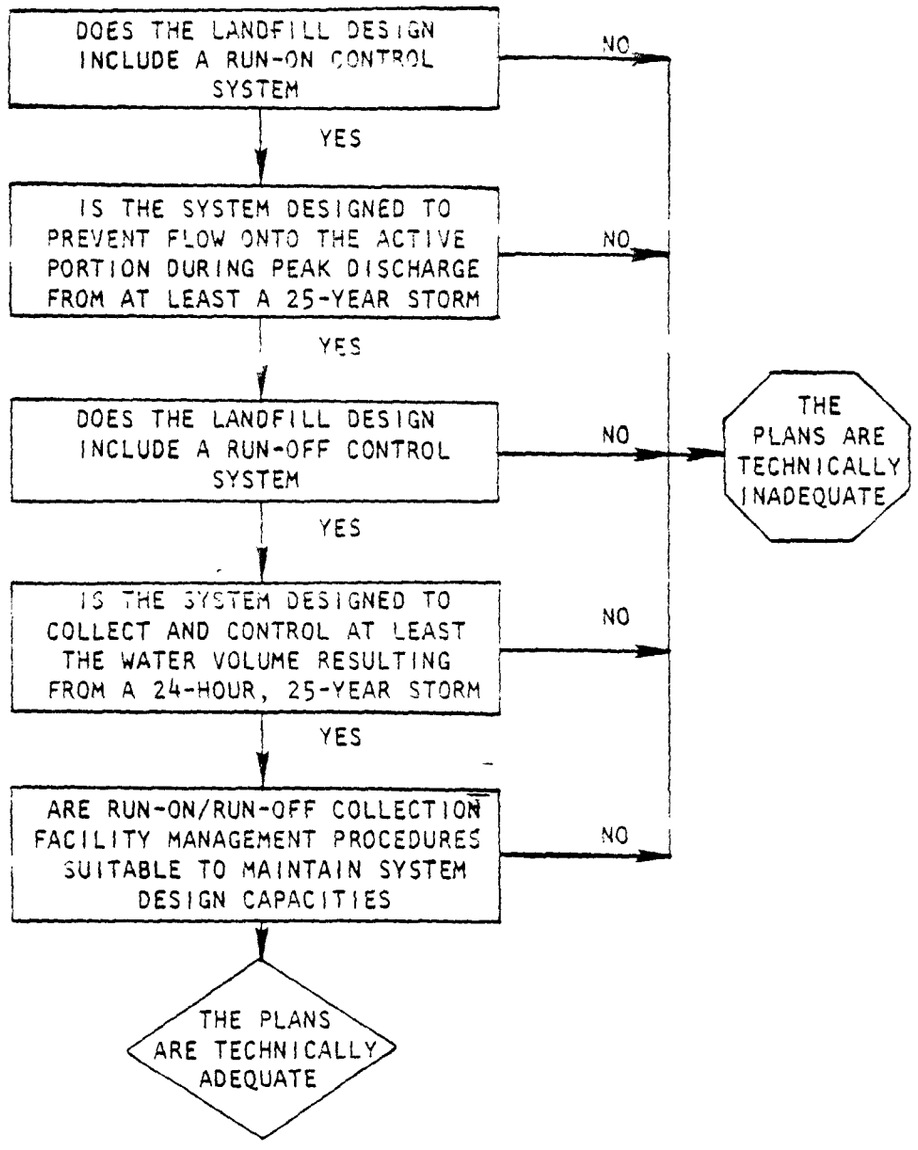


Figure 9.2.27. Regulations applicable to the control of run-on and run-off at hazardous waste landfills.

RUN-ON CONTROL

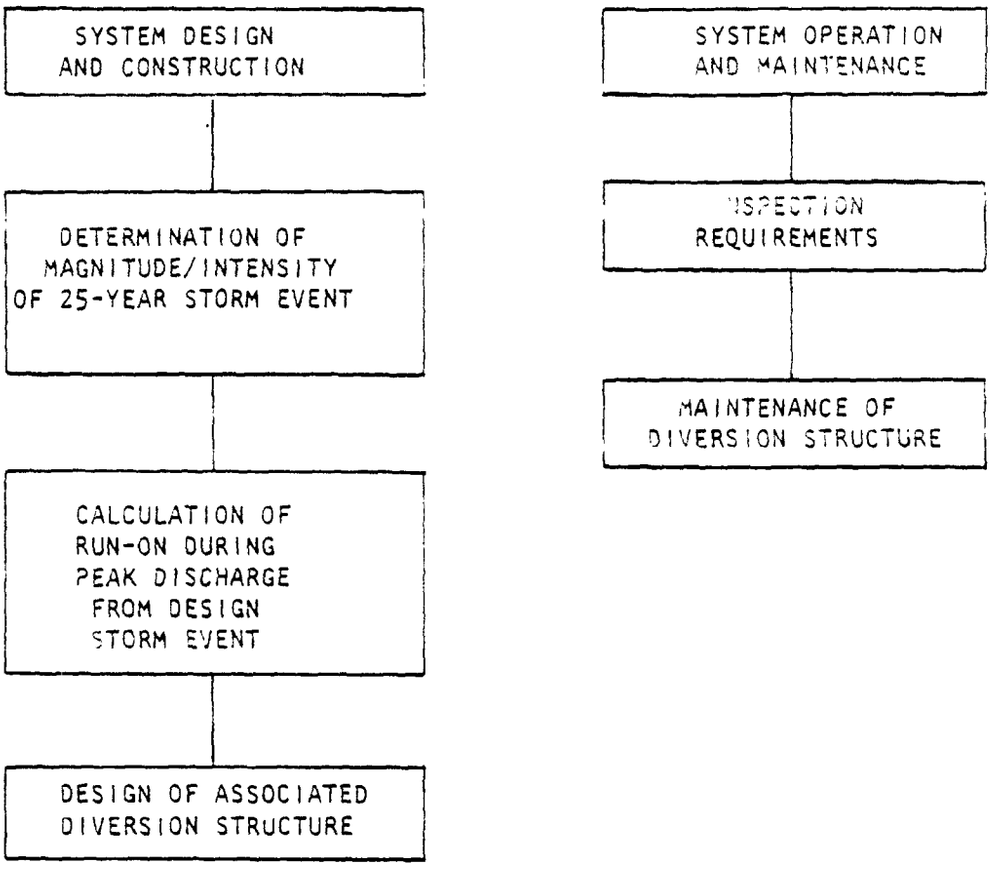


Figure 9.2.28. Technical topics addressed for run-on control.

Rainfall run-on can be diverted by constructing earth berms or diversion ditches along the upslope side of the facility to direct flow toward natural drainageways downslope from the unit. Such diversion ditches or berms must be designed to accommodate, at a minimum, the peak flow associated with the 25-year storm, as required by the Part 264 regulations.

9.2.4.3.1 Magnitude of the 25-Year Storm Event--The amount of rainfall expected from a local or regional 25-year storm event can be obtained from the National Oceanic and Atmospheric Administration or local Agricultural Extension Service. A worksheet for assessing the adequacy of the applicant's determination of storm magnitude is presented in Figure 9.2.29.

9.2.4.3.2 Calculation of Peak Run-on Discharge Rate--Two methods commonly used to calculate the volume of run-on or run-off during and after rainfall are the "rational method" and the Soil Conservation Service (SCS) method.

The Rational Method

The rational method calculates peak runoff production based on the following expression:

$$Q = CiA \qquad (34)$$

where Q = peak run-off rate in cubic feet per second (cfs)
c = run-off coefficient which is actually the ratio of the peak run-off rate to the average rainfall rate for a period known as the time of concentration
i = average rainfall intensity in inches per hour for a period equal to the time of concentration
a = drainage area in acres

Use of the rational method for determination of design run-on quantity is appropriate since the Part 264 regulations require control of the peak discharge rate. Q, as calculated using the rational method, is defined as the peak discharge rate associated with the selected storm event.

The rational method formula is based on the following assumptions:[2]

(1) the maximum run-off rate is a function of the average rate of rainfall during the time of concentration,

(2) the maximum rate of rainfall occurs during the time of concentration, and

(3) the variability of the storm pattern is not taken into consideration.

The time of concentration (t_c) is defined as the flow time from the most remote point in the drainage area to the point in question. The time of concentration is calculated as follows:

$$t_c = \frac{41b\ L_o^{1/3}}{(ci)^{2/3}} \qquad (35)$$

RUN-ON CONTROL

Determination of Magnitude of the 25-year Storm Event

- Has this part of the applicant's submittal been read and evaluated? ____ Yes ____ No
- What storm magnitude was selected by the applicant? _____
- What depth of rainfall is this storm event equivalent to? _____ inches
  - based on what references? _____

Independent Check

- What is the rainfall depth associated with the 25-year storm? _____ inches
  - based on what reference? _____
- Is the rainfall depth established by the applicant at least as great as this determination? ____ Yes ____ No

Then, likewise, this aspect of the applicant's submittal is or is not acceptable

_____ is acceptable _____ is not acceptable

Figure 9.2.29. Worksheet for determination of the magnitude of the 25-year storm event for evaluation of run-on control.

where t_c = time of concentration in minutes
b = coefficient
L_o = overland flow length in feet
C = run-off coefficient (see Table 9.2.13)
i = rainfall intensity in inches per hour during time of concentration

The equation is valid only for laminar flow conditions where the product iL_o is less than 500. The coefficient b is found as follows:

$$b = \frac{0.0007i + C_r}{S_o^{1/3}} \tag{36}$$

where S_o = surface slope
C_r = a coefficient of retardance
Values of C_r, are given in Table 9.2.14.

The run-off coefficient (C) is influenced by a number of variables, such as infiltration capacity, interception by vegetation, and depression storage.[2] As used in the rational method, the coefficient C represents a fixed ratio of run-off to rainfall, while in actuality it is not fixed and may vary for a specific drainage basin with time during a particular storm, from storm to storm, and with change in season. Table 9.2.12 lists some values of the run-off coefficient for various soils and surface covers.

The rainfall intensity (i) is derived from the average intensity (in/hr) of a storm for a given frequency (25-year in this case) for the time of concentration. Following determination of t_c, the rainfall intensity is usually obtained by making use of a set of rainfall intensity-duration-frequency curves such as shown in Figure 9.2.32. Drawing a line from the abscissa at the appropriate value of t_c and then projecting upward to intersect the desired frequency curve, i can be found by projecting this intersection point horizontally to intercept the ordinate. If an adequate number of years of local rainfall records is available, curves similar to Figure 9.2.30 may be developed. Otherwise, data compiled by the National Oceanic and Atmospheric Administration, the Department of Agriculture, or other local government agencies can be used.

A more in-depth discussion of surface water run-on and run-off computations using the rational method is presented in References 2 and 3.

The SCS Method

The SCS run-off equation is a method of estimating direct run-off from storm rainfall of a duration of 1 day or less.

The equation is:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \tag{37}$$

TABLE 9.2.13. VALUES OF RUN-OFF COEFFICIENT, C
Source: Reference 4.

Earth Surface	Cover	Min.	Max.
Sand, from uniform grain size, no fines, to well graded, some clay or silt	Bare	0.15	0.50
	Light Vegetation	0.10	0.40
	Dense Vegetation	0.05	0.30
Loam, from sandy or gravelly to clayey	Bare	0.20	0.60
	Light Vegetation	0.10	0.45
	Dense Vegetation	0.05	0.35
Gravel, from clean gravel and gravel sand mixtures, no silt or clay to high clay or silt content	Bare	0.25	0.65
	Light Vegetation	0.15	0.50
	Dense Vegetation	0.10	0.40
Clay, from coarse sandy or silty to pure colloidal clays	Bare	0.30	0.75
	Light Vegetation	0.20	0.60
	Dense Vegetation	0.15	0.50

NOTE: Values of C for earth surfaces are further varied by degree of saturation, compaction, surface irregularity and slope, by character of subsoil, and by presence of frost or glazed snow or ice.

TABLE 9.2.14. RETARDANCE COEFFICIENT, C_r
Source: Reference 2

Surface type	C_r
Smooth asphalt	0.007
Concrete paving	0.012
Tar and gravel paving	0.017
Closely clipped sod	0.046
Dense bluegrass turf	0.060

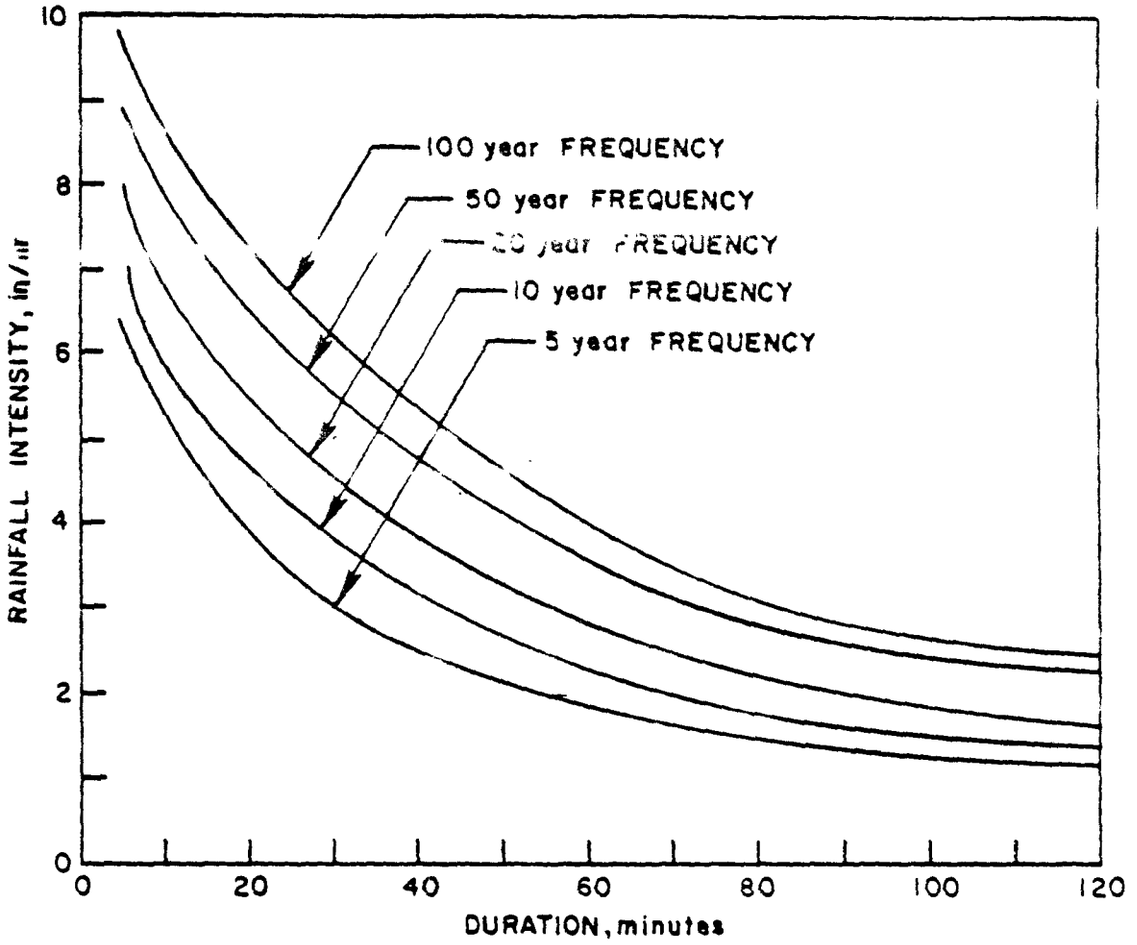


Figure 9.2.30. Typical intensity-duration-frequency curves.
Source: Reference 2.

where Q = accumulated direct run-off (in inches)

P = accumulated rainfall (potential maximum run-off).

I_a = initial abstraction including surface storage, interception, and infiltration prior to run-off.

S = potential maximum retention.

To simplify use of the equation, the following empirical relationship is often used in the SCS run-off equation:

$$I_a = 0.2S \tag{38}$$

Substituting 0.2S for I_a, the equation becomes:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{39}$$

and is the rainfall run-off equation used for estimating direct run-off from storm rainfall.

S values have been transformed into curve numbers (CN) to allow for graphical solution of runoff. Figure 9.2.31, reprinted from Reference 5 (U.S.D.A. Soil Conservation Service, 1973) provides the graphical solution using the curve number method. Research has been conducted to correlate curve numbers with various hydrologic soil cover complexes, as illustrated in Table 9.2.15, also reprinted from Reference 5. If the soil cover complex is not represented in the table, S must be estimated to determine the appropriate curve number, using the equation:

$$CN = \frac{1000}{S + 10} \tag{40}$$

The regulations for run-on control require that the system be "capable of preventing flow onto the active portion of the landfill during peak discharge from at least a 25-year storm." The SCS has developed the following equation to estimate peak discharge:

$$q_p = (KAQ)/T_p \tag{41}$$

where: q_p = peak rate of discharge

A = drainage area

Q = storm runoff (as determined from Figure 9.2.31)

K = a constant, and

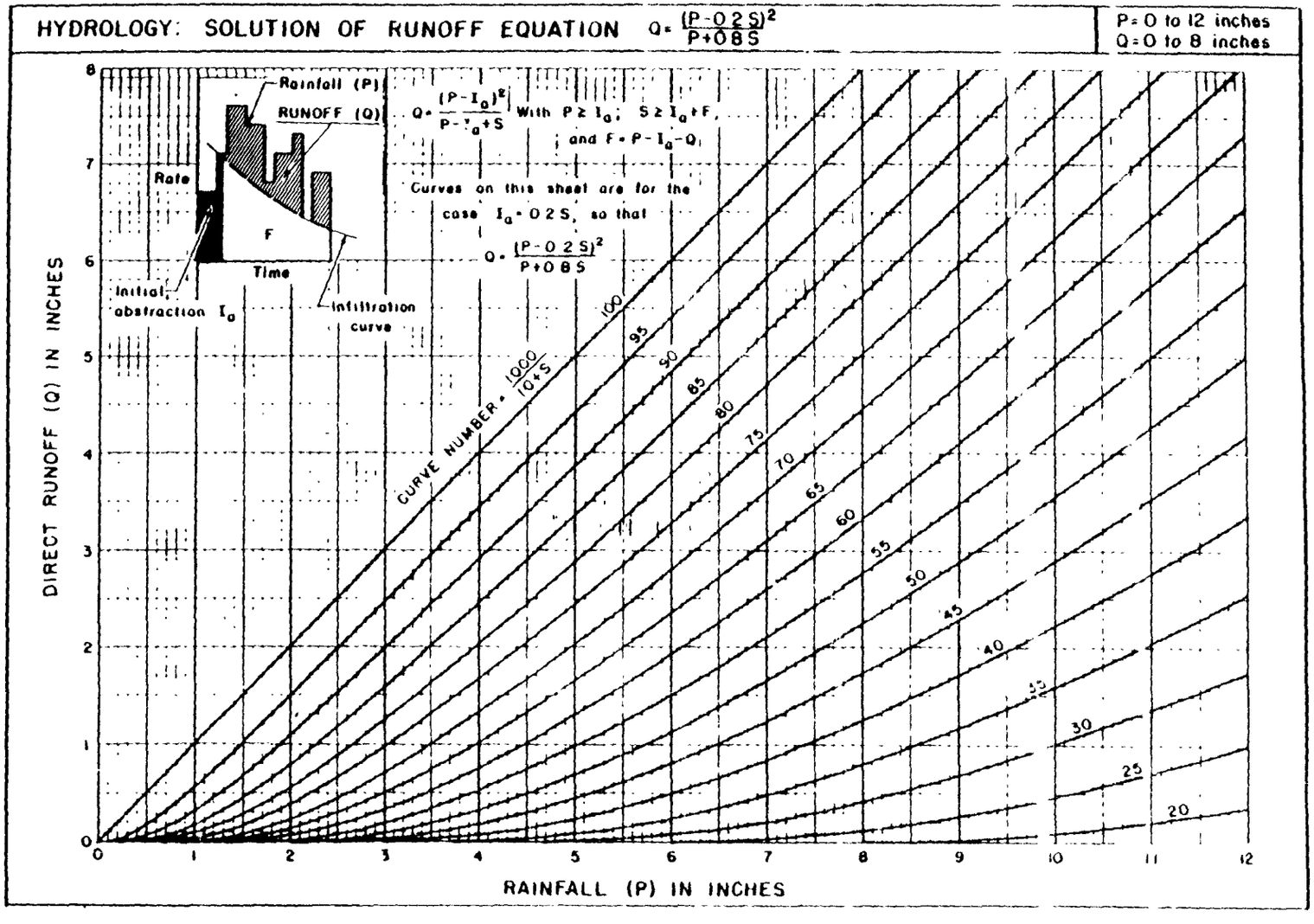


Figure 9.2.31. Solution of the SCS run-off equation.

Source: Reference 5.

TABLE 9.2.15. RUN-OFF CURVE NUMBERS FOR HYDROLOGIC SOIL-COVER COMPLEXES (ANTECEDENT MOISTURE CONDITION II, AND $I_a = 0.2\ S$)
Source: Reference 5

Land use and treatment or practice	Hydrologic condition	Hydrologic soil group			
		A	B	C	D
Fallow					
Straight row	----	77	86	91	94
Row crops					
Straight row	Poor	72	81	88	91
Straight row	Good	67	78	85	89
Contoured	Poor	70	79	84	88
Contoured	Good	65	75	82	86
Contoured and terraced	Poor	66	74	80	82
Contoured and terraced	Good	62	71	78	81
Small grain					
Straight row	Poor	65	76	84	88
Straight row	Good	63	75	83	87
Contoured	Poor	63	74	82	85
Contoured	Good	61	73	81	84
Contoured and terraced	Poor	61	72	79	82
Contoured and terraced	Good	59	70	78	81
Close-seeded legumes or rotation meadow					
Straight row	Poor	66	77	85	89
Straight row	Good	58	72	81	85
Contoured	Poor	64	75	83	85
Contoured	Good	55	69	78	83
Contoured and terraced	Poor	63	73	80	83
Contoured and terraced	Good	51	67	76	80
Pasture or range					
No mechanical treatment	Poor	68	79	86	89
No mechanical treatment	Fair	49	69	79	84
No mechanical treatment	Good	39	61	74	80
Contoured	Poor	47	67	81	88
Contoured	Fair	25	59	75	83
Contoured	Good	6	35	70	79
Meadow	Good	30	58	71	78
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	25	55	70	77
Farmsteads	----	59	74	82	86
Roads[a]					
Dirt	----	72	82	87	89
Hard surface	----	74	84	90	92

[a] Including rights-of-way.

T_p is the time to peak flow and is calculated as:

$$T_p = \frac{D}{2} + L \qquad (42)$$

where: D = storm duration, and
L = drainage area lag

The value of q_p can be approximated by making some simplifying assumptions. For instance, the value of q_p is maximized as T_p is minimized. For a given storm event, say the 25-year storm, T_p is minimized if L, the lag time, is arbitrarily set equal to zero. Substituting a value of 484 for K will then provide the estimate of the upper bound on peak run-on discharge rate. If the applicant's calculation of peak discharge is at least as great using any procedure, the estimate should be conservative. In other cases, the permit writer will have to exercise judgment, or follow the exact computation procedure proposed by SCS for estimating peak discharge rate. In the latter case, it is recommended that the permit writer refer to Reference 5 (Kent - 1973) or 6 (Mockus - 1969).

A worksheet for evaluating the applicant's calculation of peak run-on rate is presented in Figure 9.2.32.

Erosion Control

Erosion control is an important part of surface water diversion. Vegetation planted near and on the sides of diversion ditches will stabilize the soil. However, vegetation can take between 1 to 2 years to become firmly established. During that period, mulch and hay bales should be used to stabilize these areas. Mulch can be pegged in place on steeper slopes. Erosion control also prevents siltation that can clog diversion ditches, resulting in surface ponding which should be avoided.

References 7 through 11 listed in subsection 9.2.4.5 may be consulted to obtain a more thorough understanding of the erosion control techniques noted above.

9.2.4.4 Draft Permit Preparation--

Condition B.3 of Permit Module XV addresses design and operation of run-on control systems. The condition is implemented through reference to a permit attachment that includes plans and specifications prepared for the run-on control system. To be suitable for substitution in the permit condition attachment, the submitted application information should include the following:

- Documented hydrologic data identifying peak flow from the upstream watershed area resulting from the 25-year storm event.
- All calculations and results supporting the design of the run-on control facilities to accommodate the peak flow rate.

Calculation of peak run-on rate for design storm event

- Has this part of the applicant's submittal been read and evaluated? ____ Yes ____ No
- What technique was used to calculate the peak run-on rate _____
- Using this technique, what quantity (note units) or rate and duration of run-on is the proposed system designed to handle _____

Independent Check Using the Rational Method

Define Necessary Parameter Values -

1. Surface slope, S_c = _____
2. Retardance coefficient, Cr = _____
3. Rainfall intensity during time of concentration, i = _____ in./hr (note data source)

} Calculate the value of b from Eq. 36; b = _____

4. Maximum overland flow length, L_o = _____ ft.
5. Run-off coefficient, C = _____ (from Table __)

→ Calculate time of concentration, t_c from Eq. 35; t_c = _____ min

Is the value of t_c calculated different from the value used in 3. to determine i? ____ Yes ____ No

If yes, recalculate i, b, and t_c

6. Drainage area, a = _____ acres

→ Calculate peak run-on rate, Q = Cia = _____ cfs

Figure 9.2.32. Worksheet for evaluation of calculated peak run-on discharge rate.

- All calculations and supporting data that demonstrate the effectiveness of proposed run-on control system maintenance, and repair procedures.

9.2.4.5 References--

1. U.S. EPA. Permit Applicant's Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Volume I. Office of Solid Waste, Washington, D.C. 1983.

2. Clark, J. W., et al. Water Supply and Pollution Control. Second Edition. International Textbook Company. Scranton. PA. 1971.

3. Viessman, W., Jr., et al. Introduction to Hydrology. Intext Educational Publishers, New York. 1972.

4. Seelye, E. E. Data Book for Civil Engineers-Design. John Wiley and Sons, Inc. New York, NY. 1960.

5. Kent, K. M. A Method for Estimating Volume and Rate of Runoff in Small Watersheds. U.S. Department of Agriculture, Soil Conservation Service. SCS-TP-149. Revised April 1973.

6. Mockus, V. National Engineering Handbook. Section 4 - Hydrology. Chapter 10. Estimation of Direct Runoff From Storm Rainfall. U.S. Department of Agriculture, Soil Conservation Service. Reprinted with Minor Revisions, 1969.

7. U.S. EPA, Erosion and Sediment Control, Surface Mining in the Eastern U.S., Part 2, Design.. EPA Report 625/3-76-006. October 1976.

8. U.S. EPA, Design and Construction of Covers for Solid Waste Landfills. Municipal Environmental Research laboratory, EPA Report 600/2-79-165. August 1979.

9. Brown, K. W. and Assoc., Inc. Hazardous Waste Land Treatment. Prepared for the U.S. EPA, Municipal Environmental Research Laboratory. Second Edition. SW-874. February 1983.

10. U.S. EPA, Process Design Manual for Land Treatment of Municipal Wastewater, EPA Technology Transfer Series, EPA Report 625/1-77-008, October 1977.

11. Brady, N. C., The Nature and Properties of Soils - 8th Ed. McMillan Publishing Company, N.Y., 1974.

9.2.5 Control of Run-off

9.2.5.1 The Federal Requirement--
As part of the applicant's detailed plans and engineering report, §270.21(b)(3) requires the submission to address "control of run-off."

The Part 264 standards for run-off control specify in §264.301(d) that:

> "The owner or operator must design, construct, operate, and maintain a run-off management system to collect and control at least the water volume resulting from a 24-hour, 25-year storm."

9.2.5.2 Summary of Necessary Application Information--
The Part B Manual[1] instructs the applicant to conduct the following procedures and submit the results in the application:

- Determine the peak flow rate and run-off volume associated with at least a 24-hour, 25-year storm over the landfill,
- Size and design run-off collection facilities to collect at least this water volume,
- Size and design run-off storage facilities to accommodate the calculated runoff volume
- Devise a plan for run-off system maintenance, restoration, and repair.

9.2.5.3 Guidance on Evaluating Application Information--
To avoid migration of contaminated run-off, facilities must be designed and operated to collect and control surface run-off from the active portion of the landfill. The technical issues of concern are presented in Figure 9.2.33.

9.2.5.3.1 Magnitude of the 24-Hour, 25-Year Storm Event--Facilities must be designed to handle the run-off volume associated with at least the 24-hour, 25-year storm. Figure 9.2.34 indicates the depth of rainfall for this event throughout the United States.[2] A worksheet for evaluating the magnitude of the selected storm event is presented in Figure 9.2.35.

9.2.5.3.2 Calculation of Run-off Volume--The volume of runoff expected for this storm event can be calculated using the SCS Method or the Rational Method, as described in subsection 9.2.4.3.

The Part 264 regulations for run-off require that the run-off management system "collect and control at least the water volume resulting from a 24-hour, 25-year storm." Since the rational method calculates peak discharge, use of the SCS method may provide a more straightforward approach to calculating the total run-off water volume associated with the design storm event. First, Q is estimated using the graphical method shown earlier in Figure 9.2.31. Then, the total run-off volume associated with the storm event is approximated as:

$$V = \frac{QA}{12} \qquad (43)$$

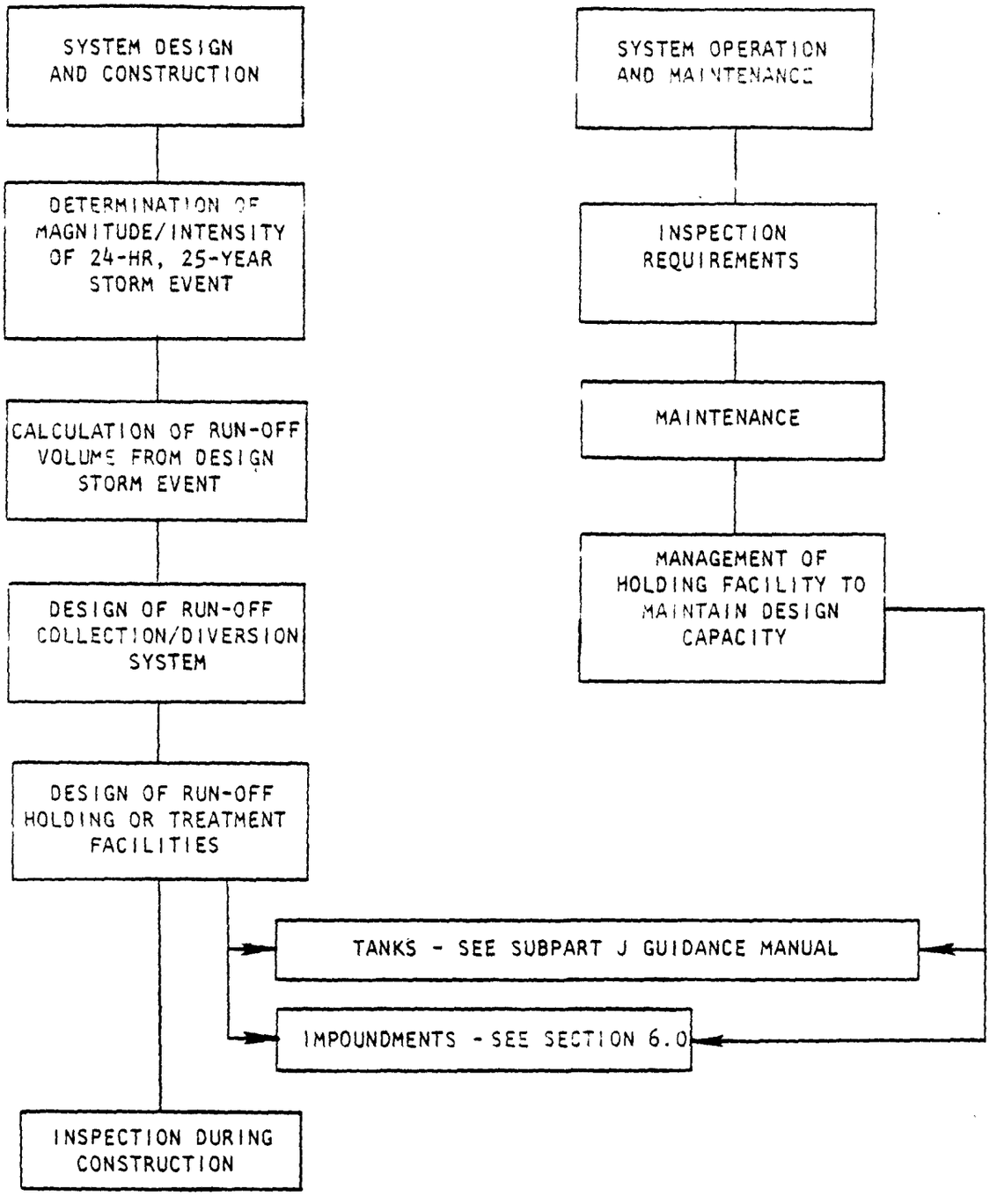


Figure 9.2.33. Technical issues associated with run-off control.

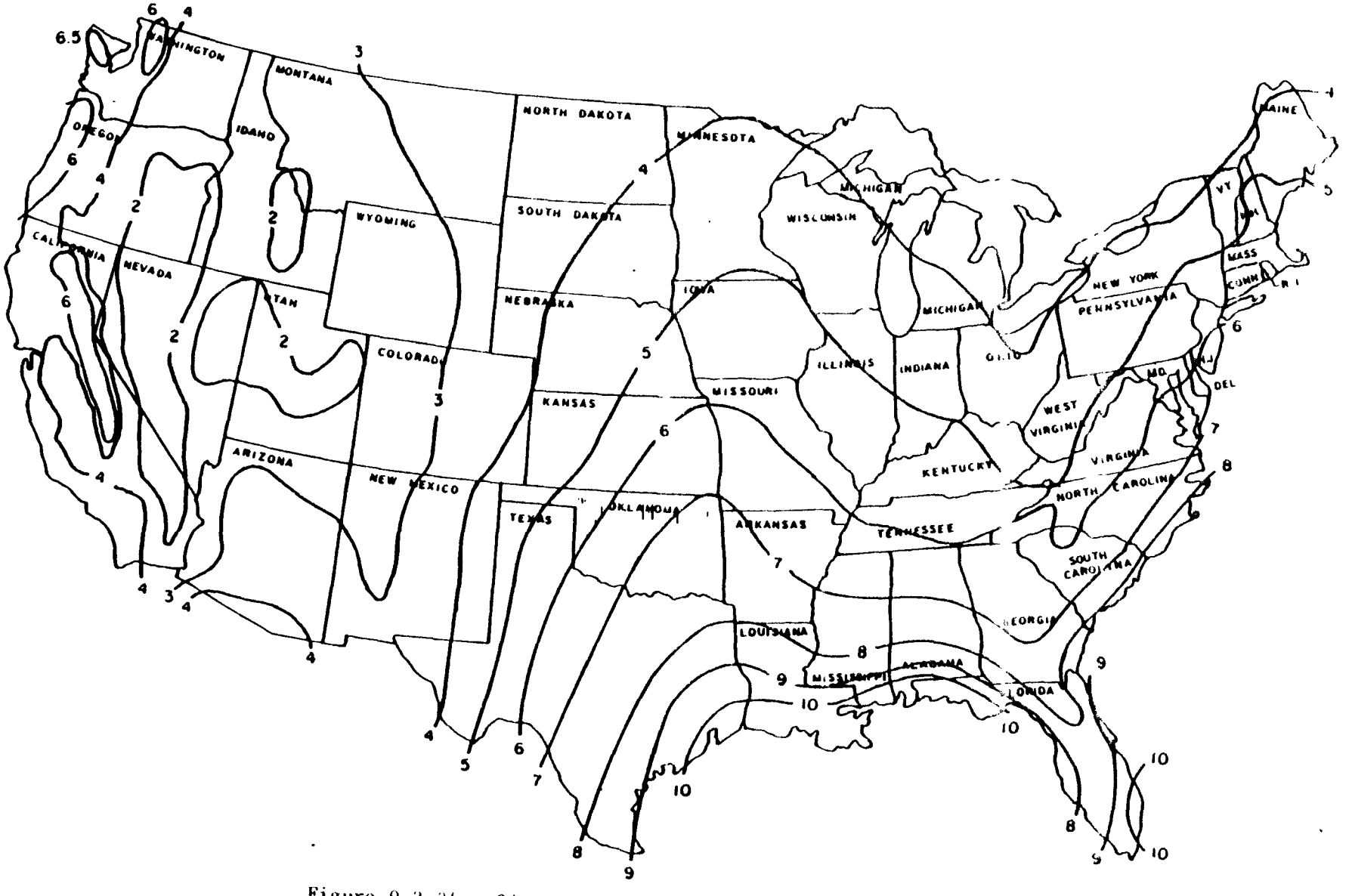


Figure 9.2.34. 24-hour, 25-year rainfall event (inches).

Source: U.S. Weather Bureau (Reference 2).

RUN-OFF CONTROL

Determination of Magnitude/Intensity of 24-hr, 25-year storm event

- Has this part of the applicant's submittal been read and evaluated?

  _____ Yes _____ No

- What storm magnitude was selected by the applicant? _____

- What depth of rainfall is this storm event equivalent to? _____ inches

  - based on what reference(s) _____

Independent Check

- What is the rainfall depth associated with the 24-hr, 25-year storm _____ inches

  - based on what reference _____

- Is the rainfall depth established by the applicant at least as great as this determination?

  _____ Yes _____ No

  Then, likewise, this aspect of the applicant's submittal is or is not acceptable

  _____ is acceptable _____ is not acceptable

Figure 9.2.35. Worksheet for evaluating the magnitude of the selected storm event.

where: V is in ft^3, and

A = area of the active landfill portion in square feet

The average flow rate can be approximated by assuming that this quantity of run-off flows for a duration of 24 hours. If peak discharge is of concern or used as a design basis in the applicant's presentation, then the computation techniques specified for determining peak run-on rate would be applicable.

A worksheet for evaluating run-off volume computations is presented in Figure 9.2.36.

9.2.5.3.2 Design of Run-off Collection/Diversion System--This design will be site specific depending on topography, site layout, and other factors. These facilities may include an open channel with an impervious floor flowing by gravity to a collection or storage basin. Alternatively, if the topography is less favorable, collected run-off may have to be pumped at some point where continued gravity flow is no longer possible to lift the collected run-off into a storage tank or impoundment. Such storage is envisioned to be necessary to allow for determination of whether the collected run-off is hazardous. The management of these storage facilities is discussed in Section 9.2.6 which follows.

If the applicant proposes to divert and collect stormwater run-off by installation of an open channel or culvert, it will be necessary to check the proposed dimensions to assure that the design run-off volume can be carried without overtopping of the channel. Further, since run-off from the active area is considered hazardous, this channel will have to be considered as an extension of the surface impoundment or tank accepting the flow, and designed in accordance with the Part 264 regulations for such facilities.

Open channel flow can be calculated using the Manning formula, wherein:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2} \qquad (44)$$

where: n = Manning's roughness coefficient

A = cross-sectional area of flow

R = A/WP, the hydraulic radius (where WP = the wetted perimeter), and

S = the channel slope.

Values of n for a variety of surface materials are listed in Table 9.2.16, from Reference 3.

Calculation of run-off volume from design storm event

- Has this part of the applicant's submittal been read and evaluated?

  _____ Yes _____ No

- What technique was used to calculate run-off? _____

- Using this technique, what quantity (note units) or rate and duration of run-off is the proposed system designed to handle? _____

- Is the run-off volume presented in terms consistent with the regulation, i.e., the run-off volume associated with the 24-hour, 25-year storm?

  _____ Yes _____ No

Independent Check Using the SCS Method

- Define parameter values:
  - Select a value of S _____
  - Calculate CN from $CN = \frac{1000}{10 + S}$ _____
  - Interpolate Q from Figure 9.2.33 _____ inches
- Calculate V, volume of run-off:
  - A = active portion area = _____ sq.ft.
  - V = QA/12 = _____ cu.ft.
- Is the volume of run-off used as the design basis at least as great?

  _____ Yes _____ No

Figure 9.2.36. Worksheet for evaluating run-off volume computations.

TABLE 9.2.16. REPRESENTATIVE VALUES FOR MANNING'S ROUGHNESS COEFFICIENT
Source: Reference 2

Nature of surface	n	
	Min	Max
Neat cement surface	0.010	0.013
Wood-stave pipe	0.010	0.013
Plank flumes, planed	0.010	0.014
Vitrified sewer pipe	0.010	0.017
Metal flumes, smooth	0.011	0.015
Concrete, precast	0.011	0.013
Cement mortar surfaces	0.011	0.015
Plank flumes, unplaned	0.011	0.015
Common-clay drainage tile	0.011	0.017
Concrete, monolithic	0.012	0.016
Brick with cement mortar	0.012	0.017
Cast iron	0.013	0.017
Cement rubble surfaces	0.017	0.030
Riveted steel	0.017	0.020
Canals and ditches, smooth earth	0.017	0.025
Metal flumes, corrugated	0.022	0.030
Canals:		
Dredged in earth, smooth	0.025	0.033
In rock cuts, smooth	0.025	0.035
Rough beds and weeds on sides	0.025	0.040
Rock cuts, jagged and irregular	0.035	0.045

9.2.5.4 Draft Permit Preparation--

Design and operation of run-off control systems are discussed in Permit Modules XV, Condition B.3. The condition is implemented through reference to a permit attachment that includes plans and specifications for the proposed run-off control system. To be suitable for substitution in the permit condition attachment, the submitted application information should include the following:

- Local weather service data that identify the magnitude (inches) of the 24-hour, 25-year event.
- All final calculations identifying he peak flow rate and run-off volume associated with the 24-hour, 25-year event.
- All final calculations demonstrating the adequacy of the storage facilities to accommodate the calculated run-off volume.
- All final calculations and supporting data that demonstrate the effectiveness of the run-off control system maintenance, restoration, and repair plan.

9.2.5.5 References

1. U.S. EPA. Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Volume I. Office of Solid Waste, Washington, D.C. 1983.

2. U.S. Weather Bureau, 1961b, Rainfall-frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years, Tech. Paper 40.

3. Daugherty, R. L., and J. B. Franzini. Fluid Mechanics with Engineering Applications. Sixth Edition. McGraw-Hill Book Company. New York. 1965.

9.2.6 Management of Units Associated with Run-On and Run-Off Control Systems

9.2.6.1 The Federal Requirement--

According to §270.21(b)(4), the applicant's submitted information must explain his intended methods of:

> "Management of collection and holding facilities associated with run-on and run-off control systems"

The standards of §264.301(e) require that:

> "Collection and holding facilities (e.g., tanks or basins) associated with run-on and run-off control systems must be emptied or otherwise managed expeditiously after storms to maintain design capacity of the system."

9.2.6.2 Summary of Necessary Application Information--

The applicant must prepare a plan for dewatering of collection or holding facilities associated with run-on and run-off management systems to assure maintenance of system capacity. The time required to empty the facilities must be estimated and the method of disposal of collected run-off (i.e., treatment, evaporation) must be described.

9.2.6.3 Guidance on Evaluating Application Information--

Run-off from the active landfill area must be assumed to be hazardous because it may have leached hazardous constituents from the waste or it may incorporate hazardous leachate. To manage the run-off properly, it will be necessary to store the collected run-off in a tank, container, or surface impoundment to allow for treatment or to allow for testing to determine if the collected run-off is not hazardous. To provide for either circumstance, these facilities must be designed, constructed, and operated in conformance with the Standards of Part 264. The permit applicant must adequately demonstrate his proposed method of emptying or otherwise managing run-off collection facilities after storms to maintain the design capacity of these systems.

Run-off facilities must be sized to store the run-off expected from the 25-year, 24-hour storm. There are two general approaches for meeting this requirement. One approach is to design the impoundment to contain rainfall run-off collected from previous storms as well as the specified event. The impoundment is managed such that there is no net change in the volume of run-off stored on a long-term basis.

A second alternative is to size an impoundment for the run-off expected from the specified storm and keep the impoundment empty. During and/or following a storm, the impoundment contents are drained to a second impoundment designed for long-term storage. In order to minimize the potential for overflow, the first impoundment must be dewatered as quickly as is practicable. In demonstrating the emptying procedure, the applicant should identify and describe the function of any level sensing devices and automatic and manually operated controls. Level sensing devices generally incorporate floats or electronic or pressure sensitive probes. The sensors can be used to automatically activate pumps and/or valves used in dewatering the impoundment. Level sensors can also be wired into an alarm system which will alert plant personnel when the water level reaches a predetermined height.

The management plan must account for sediment buildup in the impoundment(s). Periodic dredging may be necessary to maintain the design capacity. Therefore, the applicant should indicate the dredging equipment to be used and the expected dredging schedule.

The applicant must describe the treatment/disposal method(s) to be used for collected run-off. Several options are available. Run-off can either be treated and released via a National Pollutant Discharge Elimination System (NPDES) Permit, or treated in a zero discharge system.

The regulations require diversion of run-on as opposed to collection. Therefore, an adequate monitoring and inspection plan for run-on facilities

will often be adequate to demonstrate proper management of these systems. However, some part of the applicant s submittal should designate how the system will be maintained if problems are found during inspection.

The permit application should contain a description of the inspection program to be implemented for run-on and run-off handling facilities. This description should be included in the inspection plan submitted as required under §270.14(b)(5). At a minimum, the program must include provisions for inspecting weekly and after storms to detect evidence of deterioration, malfunctions, or improper operation of the run-on and run-off control systems.

The permit applicant should identify what actions will be taken when systems are found to be operating incorrectly or not at all. Also, preventive procedures to be implemented, such as routine maintenance, should be described. A worksheet for evaluating management procedures for run-on and run-off control systems is presented in Figure 9.2.37.

9.2.6.4 Draft Permit Preparation--

Management of run-on and run-off collection and holding facilities is addressed in Permit Module XV, Condition B.4. The condition is implemented through reference to a permit attachment that specifies design and operating practices for the management system. The submitted permit application information is suitable for substitution in the permit condition if it contains the following:

- A description of methods used to store, treat, or dispose of the collected run-off.
- All final calculations indicating the time required to empty the collection facilities. Such calculations, together with supporting data, must demonstrate that the collection system design capacity will not be exceeded.

9.2.7 Management of Wind Dispersal

9.2.7.1 The Federal Requirement--

As part of the applicant's submitted plans and/or engineering report, §270.21(b)(5) requires that information be included on:

> "Control of wind dispersal of particulate matter, where applicable"

The standards of §264.301(f) require that:

> "If the landfill contains any particulate matter which may be subject to wind dispersal, the owner or operator must cover or otherwise manage the landfill to control wind dispersal."

9.2.7.2 Summary of Necessary Application Information--

The applicant must provide plans for controlling wind dispersal of landfilled waste materials or soil from landfill covers as well as fugitive

MANAGEMENT OF UNITS ASSOCIATED WITH RUN-ON AND RUN-OFF CONTROL SYSTEMS

Has this part of the applicant's submittal been read and evaluated?	yes	no
Is an inspection schedule provided for identifying and correcting run-on or run-off collection system problems?	yes	no
Are provisions made for maintaining the capacity of the run-on and run-off collection systems?	yes	no
Does the application describe how run-off will be stored, treated, or disposed?	yes	no
Are automatic controls and/or alarm systems used to initiate emptying procedures and alert personnel to potential problems?	yes	no
Does the run-off management plan include provisions for testing run-off for hazardous components?	yes	no
Does the application describe how run-off found to be hazardous will be managed?	yes	no

Figure 9.2.37. Worksheet for determining the adequacy of the applicant's plan to manage units associated with run-on and run-off control.

dust from unpaved haul roads and excavation activities. The applicant should describe methods of control, such as chemical stabilizers, vegetative covers, or wet suppression, and should estimate the efficiency of the proposed wind dispersal control method.

9.2.7.3 Guidance on Evaluating Application Information--

Particulate matter entrainment due to wind dispersal must be controlled during the active life of the facility and during the closure and post-closure care periods. A flow chart indicating the applicability of the part 264 requirements is presented in Figure 9.2.38.

Several options are available to control wind dispersal of particulate matter, as illustrated in Figure 9.2.39. Options listed below may be implemented individually or in combination as required to prevent fugitive dust emissions.

(a) reduction of wind-speed (wind breaks),

(b) use of dust suppressant (chemical or water-amended spray application),

(c) establishment and maintenance of a vegetative cover,

(d) maintenance of soil moisture (periodic irrigation).

Susceptibility to wind dispersal is directly related to the moisture content of soils. Keeping the soil moist reduces the potential for wind dispersal of particulate matter. In addition, by rougning the soil surface, the wind velocity can be decreased and some moving particles trapped. Barriers such as tree shelterbeds are effective in reducing wind velocities for short distances and for trapping drifting soil. Picket fences and burlap screens, while less efficient as windbreaks than trees, are often preferred because they can be moved from place to place as portions of the facility open and close.

Other factors that will affect particulate matter dispersal are local prevailing wind direction, type of waste to be disposed, and operating techniques to be employed at the site. Familiarization with each of these will enable proper steps to be taken to minimize the effects of wind dispersal. Establishing a wind break at the edge of the site, perpendicular to the prevailing wind direction will lessen wind speeds across the unit. Use of a dust suppressant, such as water, on dry, powdery wastes will help control dust generation during waste disposal. Also, scheduling disposal activities to avoid periods of excessive wind speed and turbulence and atmospheric instability will control wind dispersal.

The technical adequacy worksheet for determining the suitability of the applicant's plan for controlling wind dispersal is presented in Figure 9.2.40.

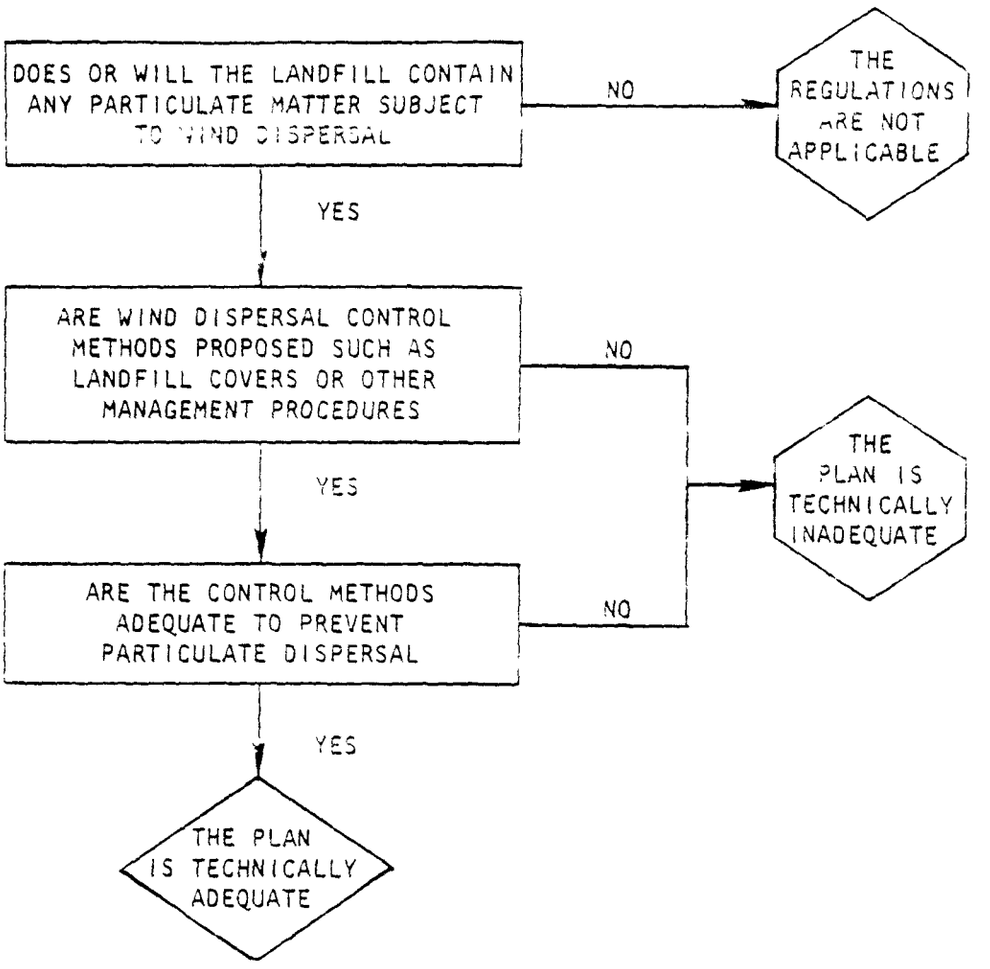


Figure 9.2.38. Regulations applicable to the control of wind dispersal of particulate matter at hazardous waste landfills.

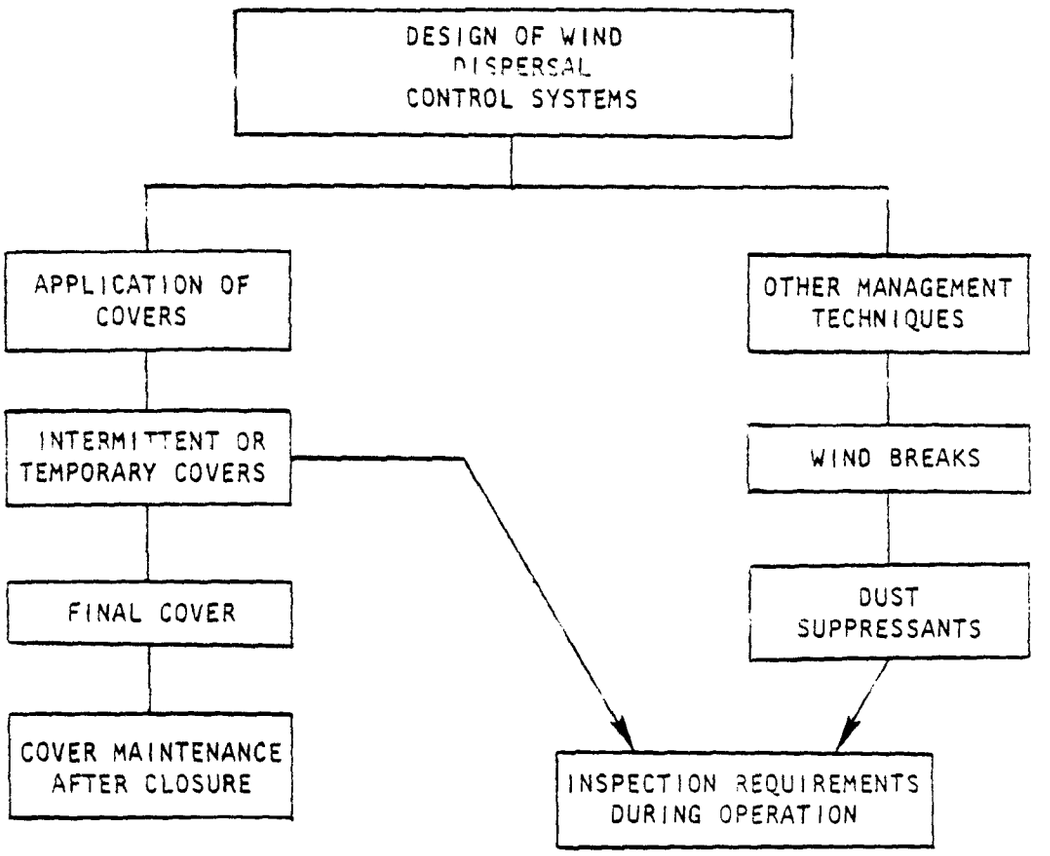


Figure 9.2.39. Wind dispersal control options.

MANAGEMENT OF WIND DISPERSAL

Has this part of the applicant's submittal been read and evaluated?	yes	no
Is erosion potential addressed for:		
Waste materials?	yes	no
Landfill cover?	yes	no
Unpaved haul roads?	yes	no
Excavation activities?	yes	no
Are control methods described (e.g., chemical stabilization, vegetative covers, wet suppression, wind breaks, etc.)?	yes	no
Is particulate control efficiency estimated for each control method?	yes	no
Are waste disposal operations suspended during excessively high winds?	yes	no

Figure 9.2.40. Worksheet for evaluating the adequacy of wind dispersal control measures.

9.2.7.2 Draft Permit Preparation--

As noted in Module XV, Condition B.5, the permit should specify methods for controlling wind dispersal if the landfill contains particulate matter which may be subject to wind dispersal. This condition is implemented through reference to a permit attachment that includes plans and specifications for the proposed wind dispersal control measures. Submitted application information suitable for substitution in the permit condition attachment should include the following:

- A description of areas where wind dispersal controls are applicable.
- A description of methods used for wind dispersal control.
- Wind dispersal control efficiency estimates, along with calculations and supporting data.

9.2.8 Subpart F Exemption

9.2.8.1 The Federal Requirement--

The Part 270 information requirements state in §270.21(c) that:

> "If an exemption from Subpart F of Part 264 is sought, as provided by §264.302(a), the owner or operator must submit detailed plans and an engineering report explaining the location of the saturated zone in relation to the landfill, the design of a double-liner system that incorporates a leak detection system between the liners, and a leachate collection and removal system above the liners."

The text of §264.302 specifies the requirements for double-lined landfills designed for exemption from Subpart F ground water protection requirements. This section of the regulation states that:

> "(a) The owner or operator of a double-lined landfill is not subject to regulation under Subpart F of this part if the following conditions are met;
>
> (1) The landfill (including its underlying liners) must be located entirely above the seasonal high water table.
>
> (2) The landfill must be underlain by two liners which are designed and constructed in a manner to prevent the migration of liquids into or out of the space between the liners. Both liners must meet all the specifications of §264.301(a)(1).
>
> (3) A leak detection system must be designed, constructed, maintained, and operated between the liners to detect any migration of liquid into the space between the liners.
>
> (4) The landfill must have a leachate collection and removal system above the top liner that is designed, constructed, maintained, and operated in accordance with §264.301(a)(2).
>
> (b) If liquid leaks into the leak detection system, the owner or operator must:

(1) Notify the Regional Administrator of the leak in writing within seven days after detecting the leak; and

(2)(i) Within a period of time specified in the permit, remove accumulated liquid, repair or replace the liner which is leaking to prevent the migration of liquids through the liner, and obtain a certification from a qualified engineer that, to the best of his knowledge and opinion, the leak has been stopped; or

(ii) If a detection monitoring program pursuant to §264.98 has already been established in the permit (to be complied with only if a leak occurs), begin to comply with that program and any other applicable requirements of Subpart F of this part within a period of time specified in the permit.

(c) The Regional Administrator will specify in the permit all design and operating practices that are necessary to ensure that the requirements of this section are satisfied."

9.2.8.2 Summary of Necessary Application Information--

The Part B Permit Applicants' Manual[1] instructs the applicant to submit hydrogeologic data and design specifications for the liner system, leak detection system, and the leachate collection and removal system. Specific information required includes:

- hydrogeologic data - location of liners above the saturated zone; maximum recorded height and seasonal variation of the water table

- liner system design - all information specified earlier in subsection 9.2.1.2 must be submitted for the liner design. This includes:

  - liner materials
  - liner chemical properties and waste/liner compatibility
  - liner strength and thickness
  - foundation design and integrity
  - area extent of the liners, and
  - liner system integrity

- leak detection system - information items requested are the same as those requested for the leachate collection system design, as summarized in subsection 9.2.2.2. This includes information on:

  - system design and construction materials
  - chemical resistance
  - strength and thickness, and
  - prevention of clogging

- leachate collection system - the information requirements are the same as those specified in subsection 9.2.2.2.

9.2.8.3 Guidance on Evaluating Application Information--

Figure 9.2.41 is a flow chart which indicates the applicability of the part 264 requirements to the Subpart F exemption. The permit reviewer is

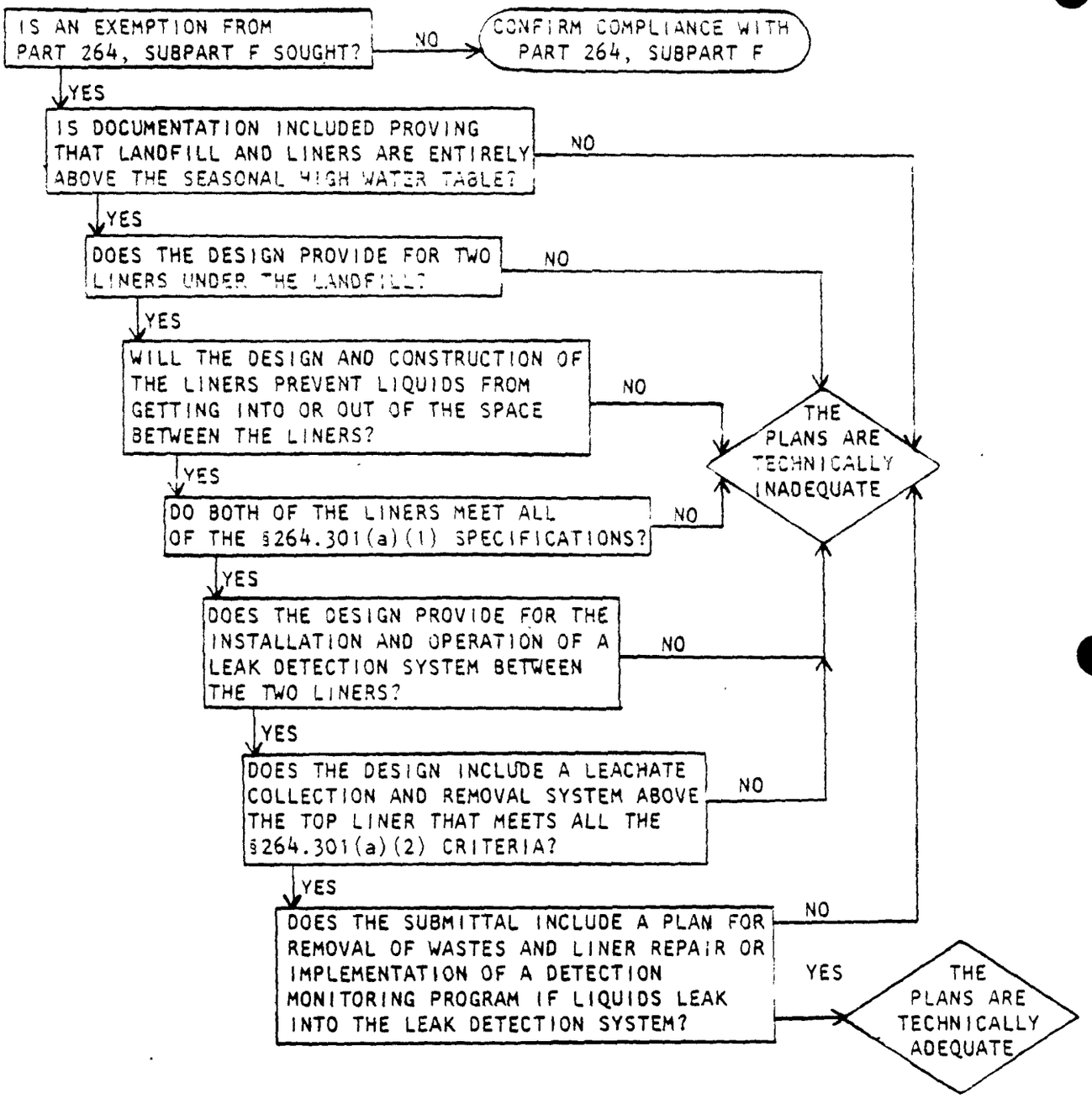


Figure 9.2.41. Applicability of Part 264 requirements to the Subpart F exemption.

referred to the guidance provided in subsection 9.2.1.3.2 for evaluation of information on water table elevation and to subsection 9.2.1.3.3 for guidance on liner materials, chemical properties, and liner strength and thickness. To evaluate the adequacy of the leak detection system and/or the leachate collection system, the permit reviewer is referred to subsection 9.2.2.3 which provides guidance on system design and materials, chemical resistance, pipe strength and thickness, and media/pipe clogging. Although resistivity probes could be used for leak detection systems, the Agency strongly recommends that drainage media and piping be designed into the system as for leachate collection systems. If leakage occurs, then a system will be in place for leachate collection and removal.

The technical adequacy worksheet for determining the suitability of the applicant's plan for an exemption from Subpart F is presented in Figure 9.2.42. Worksheets incorporated in subsections 9.2.1.3 and 9.2.2.3 should be used first to assess the adequacy of liners, leak detection systems, and leachate collection systems.

9.2.8.4 Draft Permit Preparation--

As noted in Condition C of Permit Module XV, permit applications that satisfy the exemption requirements should be documented in the administrative record. The permit should include, by attachment, design and operating conditions for double liners, leachate collection and removal systems, and leak detection systems. Design and operating conditions pertinent to leak detection and subsequent required actions should be highlighted in the body of the permit.

9.2.8.5 References--

1. U.S. EPA. Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment and Disposal Facilities. Volume I. Office of Solid Waste. Washington, D.C. 1983.

SUBPART F EXEMPTION

Has this part of the applicant's submittal been read and evaluated?	Yes	No
Is hydrologic data provided which indicates the location of the seasonally high ground water table relative to the landfill?	Yes	No
Is the landfill and liner system completely above the high water table at all times?	Yes	No
Does the liner system design prove suitable based on use of the evaluation procedures and worksheets incorporated in subsection 9.2.1.2?	Yes	No
Do the leak detection and leachate collection system designs prove suitable based on use of the evaluation procedures and worksheets incorporated in subsection 9.2.2.2?	Yes	No

Figure 9.2.42. Worksheet for determining adequacy of applicant's submittal for an exemption from Subpart F.

9.3 INSPECTION REQUIREMENTS

9.3.1 The Federal Requirements

Part 270 requires the applicant to provide the following information on landfill inspection.

> "270.21(d) A description of how each landfill, including the liner and cover systems, will be inspected in order to meet the requirements of §264.303(a) and (b). This information should be included in the inspection plan submitted under §270.14(b)(5)."

The relevant standards of §264.303 specify:

> "(a) During construction or installation, liners (except in the case of existing portions of landfills exempt from §264.301(a) and cover systems (e.g., membranes, sheets, or coatings) must be inspected for uniformity, damage, and imperfections (e.g., holes, cracks, thin spots, or foreign materials). Immediately after construction or installation:
>
> (1) Synthetic liners and covers must be inspected to ensure tight seams and joints and the absence of tears, punctures, or blisters; and
>
> (2) Soil-based and admixed liners and covers must be inspected for imperfections including lenses, cracks, channels, root holes, or other structural non-uniformities that may cause an increase in the permeability of the liner cover."

§264.303(b) states:

> "(b) While a landfill is in operation, it must be inspected weekly and after storms to detect evidence of any of the following:
>
> (1) Deterioration, malfunctions, or improper operation of run-on and run-off control systems;
>
> (2) The presence of liquids in leak detection systems, where installed to comply with §264.302;
>
> (3) Proper functioning of wind dispersal control systems, where present, and
>
> (4) The presence of leachate in and proper functioning of leachate collection and removal systems, where present."

9.3.2 Summary of Necessary Application Information

The Part B Permit Applicants' Manual[1] instructs the applicant to develop and submit with the application a detailed written inspection schedule. The applicant is referenced to the Permit Applicants' Guidance Manual on the General Facility Standards for instruction on preparation of the inspection plan. The latter manual recommends that the applicant submit the actual inspection log that he proposes to use for day to day inspection activities.

9.3.3 Guidance on Evaluating Application Information

Figure 9.3.1 presents a flow chart identifying standards applicable to inspection of the landfill.

9.3.3.1 Introduction--

The requirements of §264.303 identify specific inspections relevant to landfills that must be included, in addition to the general inspection requirements, as part of the overall inspection plan required by §270.14(b)(5) and §264.15. The inspection procedures submitted to comply with §264.303 requirements should address inspections conducted during three time periods.

- before/during construction
- after construction
- during operation

The first sentence of §264.303(a) requires inspection during construction or installation of liner and cover materials that will be placed in a new landfill. The intent is to prevent the liner or cover from failure caused from improper installation or use of poor quality materials (see subsection 9.3.3.3). Inspection after installation is also required by §264.303(a)(1) and (2) (see subsections 9.3.3.4 and 9.3.3.5). The intent is to insure that the quality of construction is sufficient to avoid liner or cover failure.

Although not specifically stated, the intent of §264.303 is to allow for rejection or repair of the liner or cover system materials before or after they are installed if they do not conform to specifications. Therefore, in addition to describing the inspection methods, the permit application should include a description of actions that will be taken if the materials are found to be damaged or imperfect, or if the construction techniques or installation procedures prove to be unacceptable.

As part of an overall inspection plan, the owners or operators should identify, by name or title, a qualified person who will be responsible for conducting the inspection. The various materials manufacturers/suppliers and installation contractors involved in the construction of a landfill will typically conduct various QA/QC and inspection procedures established as a result of their experience. However, the owners or operators should indicate the presence onsite of at least one qualified inspector who represents only their interests and from whom approval of procedures or inspection results must be obtained before construction activities can proceed, or the installed facilities can be accepted for operation.

During evaluation of the application, the permit application reviewer should ask the following questions to determine the adequacy of proposed inspection procedures.

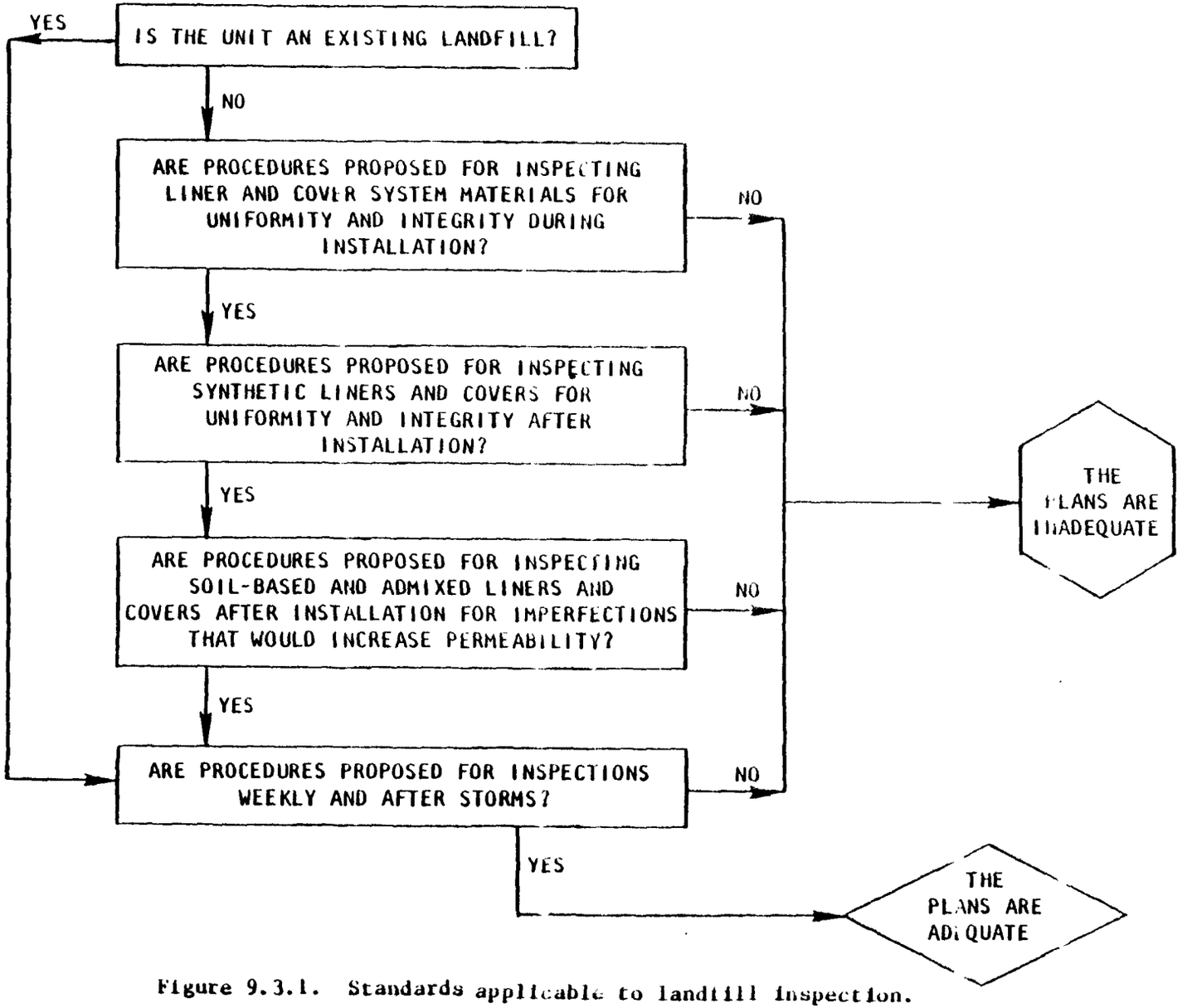


Figure 9.3.1. Standards applicable to landfill inspection.

Do the inspection procedures indicate;

(1) When (i.e., at what stage of construction) prior to the first addition of waste, the specific procedures will be implemented?

(2) Why the procedures will be implemented?

(3) What specific items will be inspected?

(4) How the items identified will be inspected?

(5) What constitutes failure as a result of inspection?

(6) What corrective actions will be instituted upon failure?

(7) What records of the inspections will be maintained?

In §264.303(a), the term "liners ... and cover systems" is used to identify what is intended for inspection. At a landfill, these "systems" may consist of multiple layers of soil and nonsoil materials. It is the intent of the regulation that all materials used to construct the various layers of liners or covers be inspected during and after installation. The remainder of this section addresses the procedures that should be included in an inspection plan to adequately comply with the intentions of §264.303(a) regarding inspection of liner and cover layers.

9.3.3.2 Is the unit an existing landfill?--

A definition of "existing portion" can be found in §260.10. Any portion of a landfill which does not meet the criteria for existing is new and must be inspected during and after construction of liner and leachate collection systems (see subsections 9.3.3.3 through 9.3.3.5). Existing portions are not required to have liners but must still be inspected on a regular basis during operation (see subsection 9.3.3.6).

The definitions in §260.10 for "active portion," "closed portion," "existing hazardous waste management facility," "facility," "inactive portion," "landfill," "landfill cell," and "partial closure" may aid the permit application reviewer in confirming the identification of new and existing portions of a landfill.

A worksheet for evaluating the applicant's submittal in terms of general inspection information requirements is provided in Figure 9.3.2.

9.3.3.3 Does the application contain a description of procedures for inspecting liner and cover system materials for uniformity and integrity during installation?--

9.3.3.3.1 Introduction--Figure 9.3.3 is a chart of topics presented in this part. The topics address each of the various layers that could typically be a part of any liner or cover system at a landfill.

INSPECTION REQUIREMENTS

Has this part of the applicant's submittal been reviewed and evaluated?	Yes	No
Does the application include a detailed, written inspection schedule?	Yes	No
Was a copy of the actual inspection log submitted?	Yes	No
Does the application include inspection procedures for the time period:		
• Before and during construction?	Yes	No
• After construction?	Yes	No
• During operation?	Yes	No
Does the inspection plan indicate actions to be taken if materials are found to be damaged or imperfect?	Yes	No
Does the inspection plan name a qualified person for conducting the established inspection procedures?	Yes	No
If the liner and cover systems are composed of multiple layers, do inspection procedures provide for inspecting each layer during and after installation?	Yes	No
Does the plan call for inspection of existing portions of the landfill as well as new areas?	Yes	No

Figure 9.3.2. Worksheet for determining the adequacy of general inspection information.

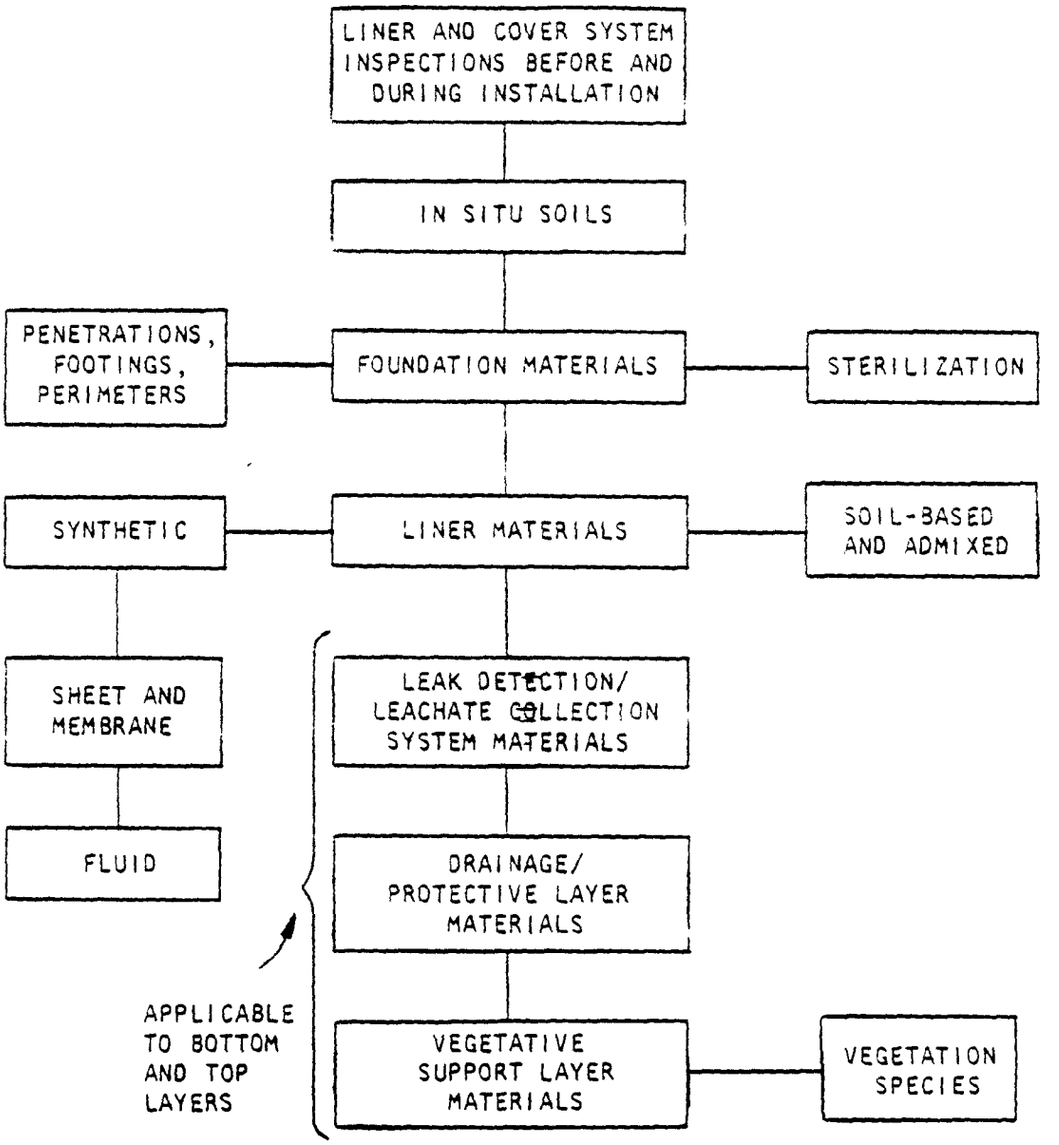


Figure 9.3.3. Inspection of liner and cover system materials before and during installation.

A single liner landfill will consist of the following layers:

- In-situ soils
- Foundation materials
- Liner materials
- Leachate collection system materials
- Drainage/protective layer materials

A double lined landfill will have the following additional layers;

- Leak detection system materials
- Drainage/foundation layer materials

These additional layers would be installed above the foundation materials and below the liner materials of a single liner landfill.

A cover system designed as a final cap for a landfill will consist of the following layers;

- Vegetative support layer materials
- Filter layer materials
- Drainage layer materials
- Bedding layer materials
- Synthetic membrane layer materials
- Low conductivity clay layer

In some cases the filter and bedding layers may be omitted. In other cases a bedding layer must also be included between the synthetic and underlying clay layers. The low conductivity clay layer will typically be placed directly over the waste materials at closure.

The construction materials and inspection procedures for liner systems and cover systems will be very similar (if not identical) at many landfills. The guidance here on inspection procedures is organized according to the materials of each layer in a liner system. The inspections that should be implemented before and during installation of a layer are identical regardless of whether the layer is in a liner or a cover system. (Inspections after installation are discussed in subsections 9.3.3.4 and 9.3.3.5.) The correspondence between liner system layers and cover system layers is shown in Table 9.3.1.

TABLE 9.3.1. EQUIVALENCE OF LINER AND COVER SYSTEM LAYERS IN CONSIDERATION OF INSPECTION REQUIREMENTS

Liner system layers	Cover system layers
In-situ soils	No equivalent
Foundation materials	Bedding materials
Lower liner materials in a double lined landfill	Impermeable materials
Leak detection system materials	No equivalent
Upper liner materials in a double lined landfill	Synthetic membrane materials
Liner materials in a single lined landfill	Synthetic membrane materials
Leachate collection system materials	No equivalent
Drainage/protective material[a]	Filter and drainage materials
No equivalent	Vegetative support material

[a]Installed above any liner

Where equivalency is indicated, the inspection procedures discussed here are applicable to both the liner and cover layers identified.

9.3.3.3.2 In-Situ Soils--Preparation of the existing land surface before construction of a landfill cell does not typically require complex procedures. However, inspection during construction should be conducted. These inspection procedures should confirm that:

- The in-situ soils have been properly graded and all large irregularities and rocks have been removed.
- The finished surface is not closer to the water table than presented in the original plans.
- The horizontal dimensions of the prepared surface agree with the original plans.
- There is no water or other liquid, not previously anticipated, on the finished surface.
- There are no previously unidentified strata or geologic formations present that would jeopardize the function of the liner system.

It is important to determine the moisture content of the layer before it is covered by an overlaying layer. This is especially true in areas where the layer will be exposed to freeze/thaw cycles. The inspection procedures should provide for postponement of construction when precipitation occurs. Any standing water or dampness should be removed before construction continues.[3]

Other important concerns are the presence of organic materials, gas pockets, or soluble soils.[3] If any of these are present in the in-situ materials, they can have a detrimental effect on all overlying layers. Thus, the inspection procedures should provide that the inspector will either conduct or observe tests to confirm that organic materials, gas pockets, or soluble gas are not present at or near the surface of the in-situ materials. The corrective actions to be taken if these materials are identified should be described.

9.3.3.3.3 Foundation Materials--Once the bottom surface has been prepared, foundation materials that will support the actual liner are put in place. During construction of the foundation, the inspection procedures should provide for confirmation of the following items:

- Materials are in conformance with plans and specifications.
- Procedures for placing materials are appropriate.
- Compaction equipment and procedures conform to plans.
- Work is being conducted only during appropriate weather conditions.[3,4]

- Irregularities in materials or procedures are addressed appropriately as they are encountered.

In a cover system, bedding materials may be installed over lower impermeable materials (see subsection 9.3.3.3.4) to provide a foundation for the overlying synthetic membrane. In other cases, the impermeable materials in a cover system may be such that bedding materials are not necessary below the synthetic membrane layer. Regardless of which is the case, the five items listed above should be identified in inspection procedures relevant to any layer immediately below the synthetic membrane layer.

Depending on the design of the landfill cell, the liner system or the cover system may be penetrated by or placed over footings, pipes, or other appurtenances.[3,4] Further, depending on how the liner or cover will be secured at the perimeter of the landfill, it may be necessary to prepare the perimeter for liner or cover system attachment. This preparatory work is most important when the liner or cover layer is a synthetic membrane or material. The permit application reviewer should confirm that the inspection procedures that will be conducted just prior to the installation of such a cover or liner demonstrate knowledge of the importance of this preparatory work to the overall integrity of the liner or cover system. The inspection procedures should indicate that these areas will be inspected along with inspection of liner or cover foundation materials.

The final step in preparing foundation materials for covering by a synthetic liner material is often that of applying a sterilizing agent to prevent the growth of plants that could puncture the liner material.[3] If the application of a sterilizing agent is indicated in the liner or cover system design, the inspection procedures should include confirmation of the following items;

- The contents of sterilizing agent containers were inspected for conformity upon receipt.
- Appropriate storage conditions were maintained.
- Application was conducted under appropriate weather conditions.
- Appropriate application equipment and procedures were used.
- The application rate (dosage) was as specified in the plans.
- Appropriate time was allowed before initiation of liner layer installation.

9.3.3.3.4 Liner Materials--Inspection procedures during liner material placement will vary depending on whether the liner material is synthetic or a soil-based or admixed material.

Synthetic materials--Owners or operators of landfills who use synthetic liners or covers will have indicated the nominal thickness of those materials. In addition, they should be able to obtain the quality control parameters from the manufacturers of the materials. If this information has been submitted, it can be used by the permit application reviewer in judging the adequacy of the preinstallation inspection procedures. However, reliance on the manufacturer's quality control specifications alone is not an acceptable substitute for inspection. At a minimum, the owner or operator should indicate that the materials will be closely inspected at the site of installation by personnel specifically representing their interests. If rigorous inspection and test procedures will be employed at the site, in addition to visual inspection, the equipment and procedures to be used should be described and the type of damage or imperfection which they are intended to identify should be stated. If only a representative sample of the materials is to be inspected, the permit application should justify that the portion inspected is truly indicative of the condition of all the materials.

Synthetic sheets or membranes are shipped to the site as rolls or as accordian folds. They are typically on pallets and wrapped or otherwise covered. It will often be necessary to store these materials at or near the installation site. These materials should be protected from climatic extremes and vandalism during any storage period. Inspection procedures should provide for the following:

- Inspection upon receipt prior to any storage.
- Observation of handling during placement into storage.
- Periodic inspection while in storage.
- Observation of procedures and equipment for removal from storage and movement to installation site.
- Confirmation of appropriate weather conditions for placement.[3,4]
- Observation of equipment and procedures to place liner material at the site.
- Inspection of liner material after placement at the site and prior to installation.
- Approval for installation to proceed.

Inspection procedures that should be conducted after liner material installation are presented in subsection 9.3.3.4. The inspection items presented here are intended for implementation prior to and during placement of liner materials.

Synthetic liner material manufacturers conduct various tests and inspections at their manufacturing plants as part of their QA/QC procedures. The handling and transportation of these materials to the site of installation provides opportunities for damage. Thus, inspection of the materials upon

arrival at the site should be conducted. Units whose wrappings indicate potential damage or rough handling should be more closely inspected. Shipping papers should be compared to material markings and purchase orders to insure conformance with plan specifications. The inspection plans should specify liner acceptance criteria.

It is often necessary to store the synthetic liner materials onsite. During storage, all synthetic liner materials are susceptible to damage from sunlight and temperature excursions. A frequent manifestation of this damage is blocking.[3] Blocking occurs when the liner material sticks to itself during storage. When the material is subsequently unrolled or unfolded, blocking can result in delamination or tearing of the material. The inspection procedures should provide for an inspection of any proposed storage area prior to placement of liner materials. Specific criteria which the storage area should meet should be indicated in the plan. The condition of each unit of material when first placed in storage should be noted and the inspection procedures should provide for periodic reinspection of stored liner materials. The criteria which will be used to evaluate evidence of potential damage during storage should be stated as part of the inspection procedure. A means for insuring that potentially damaged materials are closely inspected during subsequent installation should be indicated.

Weather conditions can influence the potential for damage to synthetic liner materials during placement. Inspection procedures should provide for approval to commence placement based on weather conditions. High winds or extreme temperatures (hot or cold) should be criteria for postponing placement.[3]

Each panel of the overall liner is normally shipped to the landfill in units too large to be moved manually. All mechanical equipment that will be used to assist in the movement and placement of liner materials should be inspected and specifically approved for the purpose. The inspection of mechanical equipment should include consideration of the potential for damage to both the liner material and the underlying foundation materials.

After liner panels are partially unfolded or unrolled on the foundation material with the assistance of mechanical equipment, each panel is manually pulled out to its full size by a crew of workers. These workers will have cause to walk directly on the liner material. Therefore, the inspection procedures should indicate a means of insuring that proper footwear is worn by the crew.

The work crew also moves the fully extended panel into final position manually. This includes placement in anchor trenches and overlapping of adjacent panels. At this point, the panel is anchored down with sandbags and/or tires to temporarily secure it in the desired position for subsequent seaming. The inspection procedures should provide for a thorough inspection of the placed liner panel at this time. At a minimum the inspection should include:

- Observation of the entire exposed surface of the liner material for tears, punctures, thin spots, foreign materials, damage resulting from blocking, and air pockets trapped beneath the panel.

- Confirmation of sufficient liner overlap for proper anchoring at the perimeter of the landfill cell.

- Confirmation of adequate overlap of adjacent panels for subsequent seaming.

- Confirmation of the proper flatness of the liner panel with sufficient slack to accommodate temperature shrinkage. There should be no folds in the liner surface.

The procedure should provide for reinspection after correction of any problems identified.

Proper seaming of adjacent panels and sealing of the liner around penetrations or footings is of overriding importance in liner integrity. Thus, the inspection procedures should provide for close observation of seam-making procedures and subsequent testing of seams (seam testing is discussed in subsection 9.3.3.4). The inspector should be empowered to start or stop seaming operations.

During observation of field seaming operations, the inspection procedures should provide confirmation of the following:[3]

- Ambient conditions are appropriate (temperature, humidity, wind).

- Use of appropriate adhesives or other seaming equipment and materials.

- Adequate cleaning of liner material before seaming.

- The extent of seam overlap meets specifications, and

- The use of heat and hot equipment is carefully controlled to only those parts of the liner being seamed.

The inspection procedures should specify the conditions under which the inspector will not allow seaming to be conducted.

The installation crew will also be sealing synthetic liners and covers near penetrations and footings. They may also be working around the perimeters of the landfill if the liner or cover is being secured by other than the trench method.[3,4] The inspection procedures should indicate that this work will be observed and that confirmation of compliance with design specifications and above listed items regarding seaming will be obtained by the inspector.

Some synthetic liners are applied as a fluid and subsequently "cure" to a continuous sheet or membrane after application.[3] Since these fluids are delivered to the site in sealed containers it will not be possible for an inspector to ascertain the fluid conditions on receipt, other than to check conformance of label information and product specifications. However, inspection procedures stated in the permit application should provide for the following inspection items before and during application of these fluid synthetic liner materials;

- Container condition on receipt.
- Monitoring of storage conditions.
- Fluid condition when container is first opened.
- Appropriate application equipment and procedures employed.
- Suitable weather conditions (temperature, moisture) for application, and
- Allowance of adequate "cure" time before reapplication or initiation of next layer installation.

Soil-based or admixed materials--Inspection of soil-based or admixed materials moved to the site should preferably be conducted by an geotechnical engineer at the borrow area or at the site. If less than every load of materials will be inspected, the permit application should contain justification of the representativeness of inspection. When onsite materials are to be used with only minimal movement (digging, grading) or preparation, the inspection procedures should indicate visual observation by a representative of the owner or operator of the uniformity of these materials during these activities.

9.3.3.3.5 Leak Detection/Leachate Collection System Materials--The materials used to construct either a leak detection or a leachate collection system will typically consist of various pipe and fittings along with aggregate materials that will be placed around the pipes during installation. Whether a system is designated as a leak detection or a leachate collection system will depend on its location in the specific landfill cell. However, the inspection procedures for either system are the same. A discussion of procedures for inspecting aggregate materials follows this discussion ("Drainage/protective layer materials").

The inspection procedures should address three inspection periods. They are:

- Inspection of materials at receipt and placement in storage.
- Periodic inspection during storage.
- Inspection during installation.

Materials used to construct a leak detection/leachate collection system are much less susceptible to damage during handling and storage than synthetic liner materials. Therefore, an inspection procedure that provides only for inspection of these materials as they are being assembled into the overall system may be adequate. However, the inspection procedure must provide for a comparison of the materials being used to those specified in the plan specifications at some point prior to their permanent assembly into the overall system. The inspection procedures should indicate that the following items will be confirmed during a comparison between shipping papers, purchase orders, and original plan specifications:

- parts are constructed of the specified materials
- parts are of the correct size and shape
- parts meet the strength specifications

The inspection procedures should also provide for a means to confirm that the parts being assembled into the overall system are not damaged. Further, confirmation that the proper bonding materials and assembly procedures are being used must be included in the inspection procedures. As sections are completed they should be cleaned and flushed to remove debris and identify any blockage. Collection pipes should be checked for proper jointing, adequate slope, and positioning of terminal cleanouts. The air test (ASTM C828) can be used to test nonperforated sections of the pipe for integrity.

9.3.3.3.6 Drainage/Protective Layer Materials--Landfill cells will typically have a layer of aggregate/sand/soil placed over the completed leak detection/leachate collection system and underlying liner. This layer serves the dual purpose of enhancing liquid removal from the overlying waste and providing protection for the underlying liquid handling system and liner. Because of strict material size considerations for proper performance of this layer, it is likely that the site owner or operator will purchase the material offsite. The inspection procedure should indicate, therefore, that the material will be inspected by a geotechnical engineer either at the borrow area or upon its arrival at the site before installation. In addition, procedures should provide for observation of the equipment and procedures used to spread the layer of material. If geotextile materials are used as filters or protective layers, inspection procedures should follow the rationale presented for inspection of synthetic membrane liners.

The cover system at a landfill cell will also have a layer of material for drainage placed over the synthetic liner material. In cover system service, this layer enhances removal of precipitation from over the synthetic material and assists in delivering it to a run-off control system. Since proper performance of this layer in this service is also dependent on material size gradation, inspection procedures applicable to it should be at least as detailed as those for the liner system drainage layer.

9.3.3.3.7 Vegetative Support Layer Materials[5,6]--The vegetative support layer of a cover system consists of two parts--the soil and the vegetative species. The inspection procedures should address three broad concerns:

- The quality of the soil.
- The species to be planted.
- The time of seeding.

The inspection procedures should provide for observation of placement and final contouring of the vegetative layer. Confirmation of the following items should be indicated:[5]

- Before placement, test soil for pH, organic content, nitrogen, phosphorus, and potassium, and compare to plan specifications.
- During placement, confirm consistency of all material placed.
- Assure that appropriate weather conditions exist for placement.
- Assure that material thickness complies with plans and specifications.

After placement and during final contouring, the soil should again be tested for pH and nutrients. The addition of pH adjusting compounds and fertilizer should be conducted during the final contouring and surfacing if necessary. The inspector should oversee this process to insure that the appropriate materials are added, the correct dosages are applied, and subsequent testing is conducted.

The species to be planted and the time of planting are also concerns. The inspection procedures should assure that the inspector will confirm the following;[5]

- The seeds or seedlings to be planted are as specified by the plans.
- The weather conditions are appropriate for seeding/planting.
- The season of the year is appropriate for seeding/planting the specific species.
- Appropriate seeding/planting equipment and procedures are employed.
- Seeding/planting densities are correct for the specific species.
- The seeds/seedlings are properly protected during germination/rooting.

The inspection procedures should provide for frequent observation of the vegetative cover during the period of seed germination. The procedures should indicate how the progress of the vegetation will be evaluated and indicate what corrective actions will be employed the vegetation show signs of failure or is destroyed because of soil damage.

A worksheet for evaluating the inspection procedures for ensuring uniformity and integrity during installation is presented in Figure 9.3.4.

INSPECTION REQUIREMENTS

Has this part of the applicant's submittal been reviewed and evaluated? ____ Yes ____ No

In-situ Soils

Are in-situ soils inspected for:

- Proper grading and removal of irregularities and rocks? ____ Yes ____ No
- Water table height? ____ Yes ____ No
- Correct horizontal dimensions? ____ Yes ____ No
- Unanticipated water or other liquids? ____ Yes ____ No
- Previously unidentified strata? ____ Yes ____ No
- Organic material? ____ Yes ____ No
- Gas pockets? ____ Yes ____ No
- Soluble soils? ____ Yes ____ No

Foundation Materials

Are inspection procedures designed to confirm that:

- Materials conform to design specifications? ____ Yes ____ No
- Materials placement procedures are appropriate? ____ Yes ____ No
- Compacting equipment and procedures conform to plans? ____ Yes ____ No
- Work is suspended during adverse weather conditions? ____ Yes ____ No

Figure 9.3.4. Worksheet for determining the adequacy of inspection procedures before and during installation.

- Irregularities in materials and procedures are appropriately addressed? ____ Yes ____ No

Does the inspection plan address perimeter preparation prior to liner placement? ____ Yes ____ No

Does the inspection plan address the use and application of sterilizing agents? ____ Yes ____ No

Synthetic Liners and Covers

Do pre-installation inspection procedures address:

- Testing to insure conformance to manufacturers specifications? ____ Yes ____ No
- Visual inspection of synthetic liners upon receipt prior to storage? ____ Yes ____ No
- Observation of handling during placement into storage? ____ Yes ____ No
- Periodic inspection while in storage? ____ Yes ____ No
- Observation of procedures and equipment for removal from storage and transfer to installation site? ____ Yes ____ No
- Confirmation of appropriate weather conditions for placement? ____ Yes ____ No
- Observation of liner placement procedures and equipment? ____ Yes ____ No
- Approval for installation to proceed? ____ Yes ____ No

Do post-placement liner inspection procedures address:

- Visual observation of surface to identify tears, punctures, thin spots, damage due to blocking, and trapped air pockets? ____ Yes ____ No
- Confirmation of sufficient overlap at the perimeter and adequate panels to allow anchoring and seaming? ____ Yes ____ No
- Confirmation of proper flatness and slack requirements? ____ Yes ____ No

Does the inspection plan call for reinspection after corrective actions? ____ Yes ____ No

Figure 9.3.4 (continued).

Do liner seam inspection procedures confirm that:

- Ambient conditions are appropriate? ____ Yes ____ No
- Seaming equipment, adhesives, and materials are appropriate? ____ Yes ____ No
- Liner materials are adequately cleaned prior to seaming? ____ Yes ____ No
- Seam overlap dimension is as specified? ____ Yes ____ No
- Heat and/or equipment are carefully controlled? ____ Yes ____ No

Does the inspection plan identify conditions under which seaming will not be allowed? ____ Yes ____ No

If synthetic liner materials are applied as a fluid, do inspection procedures address:

- Container condition upon receipt? ____ Yes ____ No
- Monitoring of storage conditions? ____ Yes ____ No
- Fluid condition when container is first opened? ____ Yes ____ No
- Use of appropriate application procedures and equipment? ____ Yes ____ No
- Weather conditions for applications? ____ Yes ____ No
- Allowance of adequate cure time between applications? ____ Yes ____ No

Soil-based or Admixed Liners

- Are visual observations conducted to insure material uniformity? ____ Yes ____ No
- Are inspection procedures conducted by a geotechnical engineer or other qualified person? ____ Yes ____ No

Figure 9.3.4 (continued).

Leak Detection/Leachate Collection System Materials

Does the inspection plan address:

- Inspection at receipt and placement into storage? Yes No
- Periodic inspection during storage? Yes No
- Inspection during installation? Yes No

Are the inspection procedures adequate to confirm that:

- Parts are constructed of the specified materials? Yes No
- Parts are of the correct size and shape? Yes No
- Parts meet the strength specifications? Yes No
- Parts are not damaged? Yes No

Drainage/Protective Layer Material

Are inspection procedures designed to insure that aggregate sand/soil materials will meet the size specifications? Yes No

Are materials inspected by a geotechnical engineer? Yes No

Vegetative Support Layer Materials

Are vegetative layer placement and final contouring inspection procedures designed to evaluate:

- Soil pH, organic content, and nitrogen, phosphorous, and potassium levels prior to placement? Yes No
- Material consistency during placement? Yes No
- Material thickness? Yes No

Figure 9.3.4 (continued).

- Weather conditions?

	Yes	No
• Planting of seeds or seedlings?	____	____
• Seasonal considerations for planting?	____	____
• Seeding/planting densities?	____	____
• Seeds/seedling protection during germination/rooting?	____	____
Does the inspection plan include procedures for evaluating vegetative cover progress?	____	____
Does the plan specify actions to be taken if progress of the vegetative cover is inadequate or if the cover is damaged?	____	____

Figure 9.3.4 (continued).

9.3.3.4 Are procedures for inspection of synthetic liners and covers for uniformity and integrity after installation described?--

9.3.3.4.1 Introduction--Figure 9.3.5 is a chart of topics presented in this part. The provisions of §264.303(a)(1) require confirmation that synthetic liners and covers have tight seams and joints and do not have tears, blisters, or punctures after they have been installed. The use of the word "tight" in the regulation with regard to seams and joints is intended to mean complete, nonleaking closure whenever edges of the liner materials are joined together, around penetrations, footings or other appurtenances and at the edge of the landfill cell. The inspection procedures should also indicate the steps to be taken if the inspection reveals a problem.

An adequate inspection procedure, regardless of liner or cover construction materials, should be detailed regarding what will be checked for, how the checks will be conducted, and where the checks will be made. Specific parameters should be stated as grounds for failure of inspection.

9.3.3.4.2 Sheet and Membrane Materials--There are standard practices and ASTM methods employed by installers of membrane and sheet synthetic liners and covers to confirm the integrity of field-installed seams and joints. The specific seam test employed varies depending on the configuration of the finished seam.[3] The installer should keep a log of the test results for each seam. The specific method for synthetic material seam testing should be indicated. The inspection procedures should indicate review of the seam test log and provide for the observation of a sufficient number of tests to confirm that they are properly conducted.

9.3.3.4.3 Fluid Materials--After these materials have been allowed to cure for the time period recommended by the manufacturer, they should be thoroughly inspected. Whereas sheet or membrane materials undergo QA/QC checks at the point of manufacture, fluid materials are formed into a sheet onsite and, therefore, deserve more careful inspection. There are two reasons for detailed inspections of these materials;[7]

- The basic mix and a polymerization activator must be mixed onsite before application, and
- Application is by spray, squeegee, or trowel.

Errors in mixing proportions will affect the cure time and the physical characteristics of the cured material. Manual application of the material makes the final cured layer more susceptible to thin spots. It may be appropriate in some cases for the inspection procedures to include destructive physical and chemical tests on portions of these materials after installation to insure that the material meets original specifications after placement. The inspection procedures should provide for observation of repairs to portions of these materials that are tested.

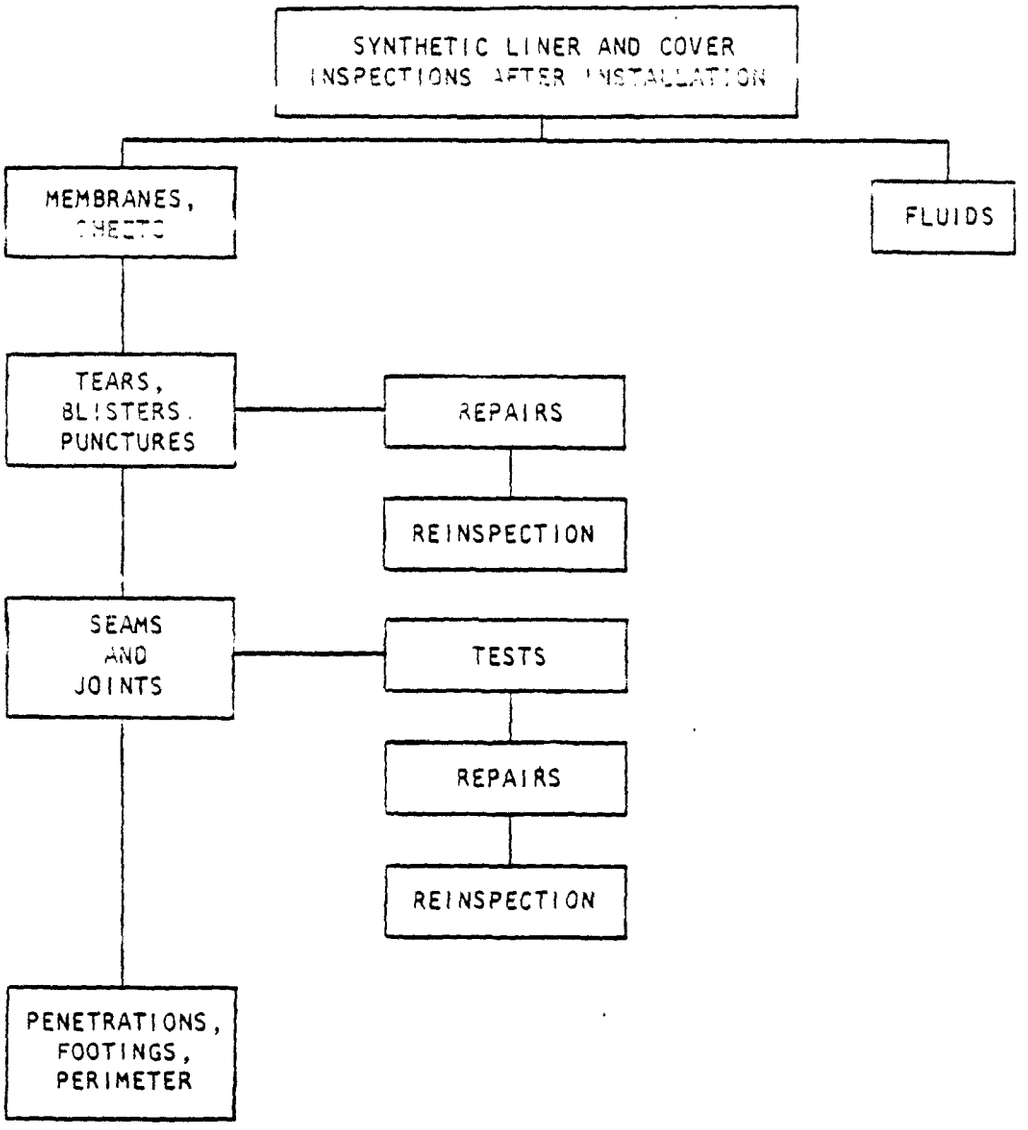


Figure 9.3.5. Inspection of synthetic liners and covers after installation.

9.3.3.5 Are procedures described for inspecting soil-based and admixed liners and covers after installation for imperfections that would increase permeability?

9.3.3.5.1 Introduction--Figure 9.3.6 is a chart of topics presented in this part. This subsection addresses inspections after installation of each layer in cover and liner systems that are constructed of soil-based or admixed materials.

9.3.3.5.2 In-Situ Soils--As previously described, in-situ soils do not generally require complex preparation procedures. A visual inspection should be conducted to identify any large irregularities (e.g., cracks, channels, root holes, large rocks, etc.) and to note any unanticipated standing water or other liquid on the finished surface. Tests should also be conducted to determine whether the finished surface is closer to the water table than originally anticipated, to check horizontal dimensions, and to identify any previously unidentified geologic strata which could jeopardize the function of the liner system. In some cases, the in-situ soil may serve as the foundation material. Foundation material inspection procedures are described below.

9.3.3.5.3 Foundation Material--Foundation soils must be inspected and tested to assure that their consistency and bearing capacity after installation and/or compaction meet design specifications. To this end, soil index properties and engineering properties that must be considered as part of the inspection plan include moisture content (i.e., Atterberg Limits), density, and bearing capacity. These properties are summarized here and explained in more detail in Section 9.2.1.3. Field laboratory methods for quantifying these properties are specified in proposed EPA Test Method 9100, which is incorporated as an appendix to the RCRA Technical Guidance Documents.[8]

Soils can be classified according to the Unified Soil Classification System which divides all soils into three major groups: coarse-grained (gravelly and sandy soils), fine-grained (inorganic silts and clays) and highly organic (organic silts and clays). In general, the coarse-grained soils are the most easily worked, and have the greatest resistance to compression. Fine-grained soils are more difficult to work, have greater compressibility, and have fair to poor shear strength. However, fine-grained soils are relatively impermeable and can serve as a secondary barrier to leachate flow.

Compaction is an essential step in preparing the soil foundation for impermeable liner installation. Soils are compacted to increase soil strength and bearing capacity, reduce the void ratio (reduce settlement and permeability) and reduce shrinkage. Compaction of sidewalls is particularly important for improved strength and stability. The degree to which a soil can be compacted is determined by a soil density-water content test generally referred to as the Proctor Test (either standard or modified). The test identifies the maximum density obtainable (for a specific energy input) as a function of soil moisture. Typical specifications for compacted fills specify the percentage of compaction based on density, but both moisture content and density may be specified. To illustrate the importance of moisture content, Figure 9.3.7 graphs density as a function of water content.[9]

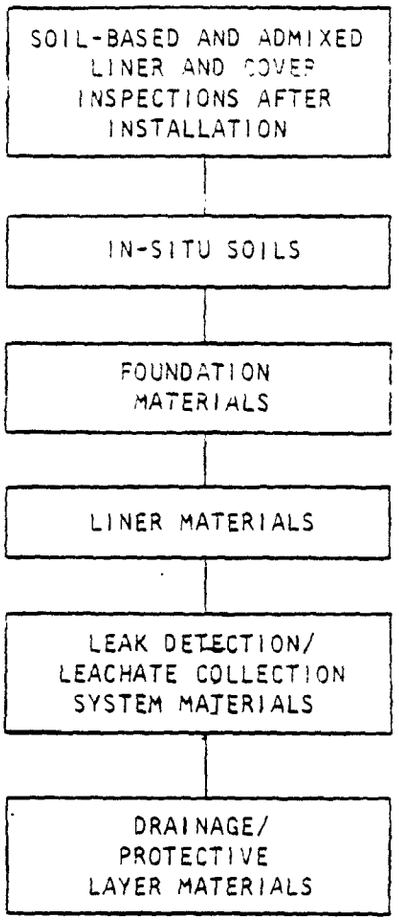


Figure 9.3.6. Inspection of soil-based and admixed liners and covers after installation.

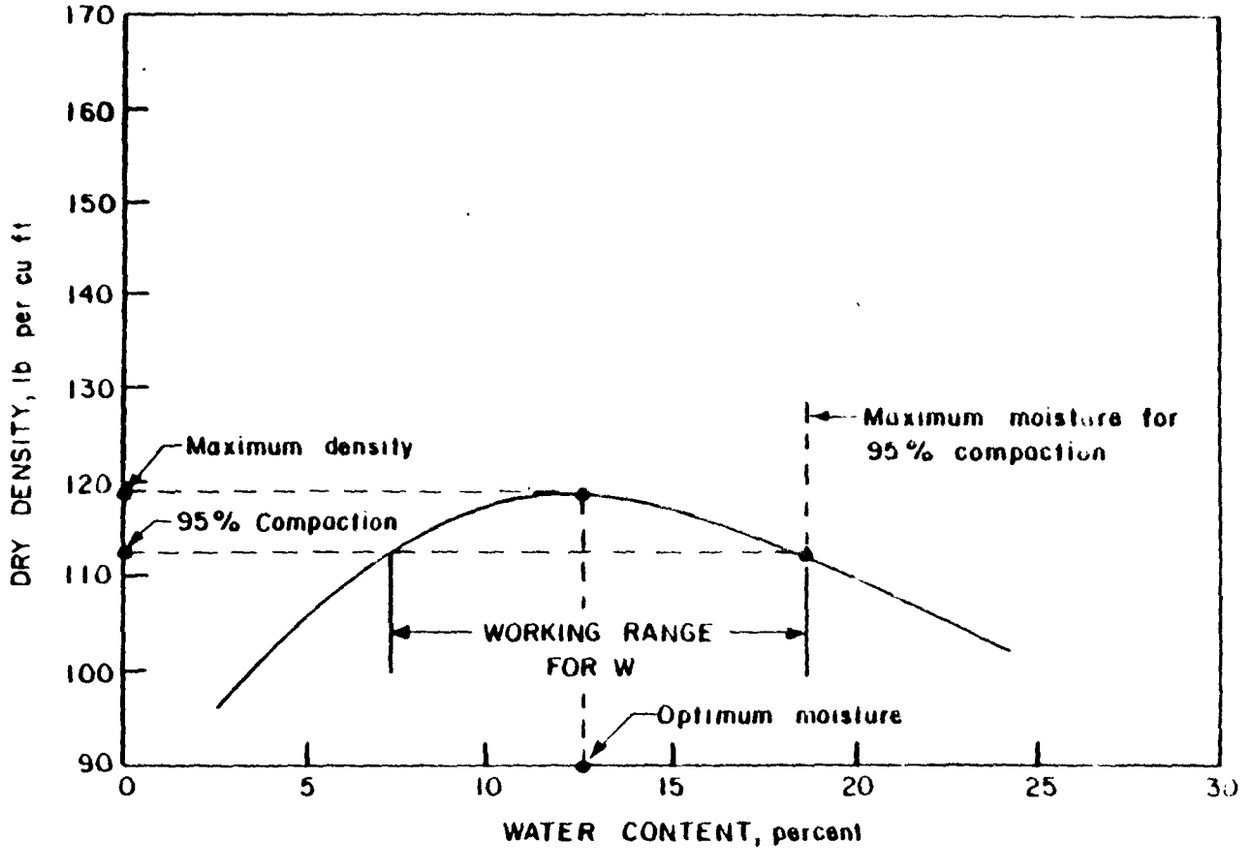


Figure 9.3.7. Moisture-density curve of a cohesive soil.

Source: Reference 9 (Sowers).

To evaluate compaction, the soil foundation can be tested for density and moisture content. The density must be greater than or equal to the value specified while the moisture content must fall within the working range, as illustrated by Figure 9.3.7. The application should specify a representative number of samples for analysis (e.g., one per 2000 ft^3 of soil). Clay soils should be compacted to a uniform high density. For a clayey soil the minimum field density should be 95 percent of the Proctor maximum density of the fraction smaller than 4.75 mm (No. 4 sieve). The moisture content should be ±1 percent of the design w-value (SW-870, p. 229).[3]

Atterberg Limits characterize the plasticity of a cohesive soil. Cohesive soil consistency is greatly affected by water content: a gradual increase in water content transforms a dry soil from a solid state, to a semi-solid state, to a plastic state, to a liquid state. The plastic limit is the soil moisture content just below which the soil is barely plastic and just above which the soil flows. At the liquid limit, soil behavior is a blend of plastic deformation and liquid flow. Figure 9.3.8 is a Plasticity Chart indicating the plasticity index of various cohesive soils as a function of the liquid limit.[10] In general, soils with liquid limits between 35 and 60 having a plasticity index above the A-line should be considered the most favorable in terms of toughness, dry strength, and permeability.

As a quality assurance check, the inspection program should include a determination of whether the soil foundation conforms to plasticity index specifications. A sufficient number of samples (e.g., one per 2,000 ft^3 of soil) must be taken to ensure a statistically significant representation of the foundation material.

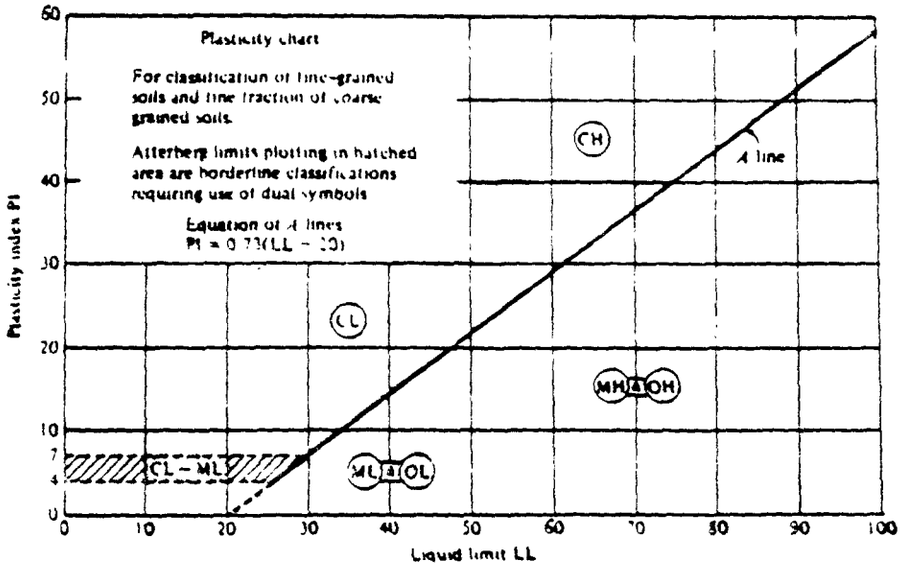
In addition to strength, a significant requirement for a soil liner is low permeability. To assess permeability, the inspection plan should include both laboratory testing and field trials. These tests should be conducted to verify that the K-value is within the required range, and should be used to correlate permeability with the density-moisture content function, thus verifying the relationship obtained during the pre-construction investigation upon which the design is based.

Laboratory and In-Situ Tests for Foundation Materials and Soil Liners

Foundation material laboratory and in-situ tests must be taken to ascertain whether the specified classifications and consistency have been met. Measurements of moisture content and compaction ensure that the foundation has the desired firmness. Laboratory permeability and in-situ infiltration tests should be conducted for foundations designed to serve as impermeable barriers. Available in-situ testing procedures include:

- Standard Penetration Tests (ASTM D1586)--This test provides a measure of the resistance of the soil to penetration of a split-spoon sampler thereby providing an indication of the relative density and consistency of the soil.

- Vane Shear Test (ASTM D2573)--This test is used to determine the in-situ shear strength of soft, saturated, cohesive soils.



KEY

CH Inorganic clays of high plasticity, fat clays

CL Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays

MH Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts

ML Inorganic silts, very fine sands, rock flour, silty or clayey fine sands

OH Organic clays of medium to high plasticity

OL Organic silts and organic silty clays of low plasticity

Figure 9.3.8. Plasticity chart.

Source: Reference 10 (Cernica).

- Pressuremeter Tests (No ASTM designation)--This test can be used to determine the cohesive strength of saturated clay soil.

- Plate Load Tests (ASTM D1194)--This is a method used to determine the bearing strength of soil in place.

- Cone Penetration Tests (ASTM D3441)--This test can be used to classify soil and estimate strength, compressibility, and bearing capacity.

- Infiltration Test (ASTM D-3385-75)--This test is used to determine the water transmission characteristics of the foundation material.

Applicable laboratory tests include the following:

- Compaction Tests (ASTM D698 and ASTM D1557)--These tests can be used to verify the moisture-density relationship identified in preconstruction testing.

- Consolidation Tests (ASTM D2435)--These tests provide soil data used in predicting the rate and amount of settlement of structures founded on clay.

- Unconfined Compression Tests (ASTM D2166)--These tests provide an approximate procedure for evaluating the shear strength of a cohesive (clay) soil.

- Direct Shear Tests (ASTM D3080)--These tests provide a measure of the shearing resistance of a soil across a predetermined failure plane.

- Triaxial Compression Tests (ASTM D2850)--These tests provide data for determining strength properties and stress-strain relations for soils.

- Saturated Hydraulic Conductivity Tests (ASTM D-2434-68)--These tests are used to determine the permeability of saturated soil.

To provide adequate quality control, the clay liner sampling and analysis program must provide a statistically valid representatation of the liner characteristics. Although actual sampling and analysis programs are highly site specific (primarily dependent upon the homogenity of the clay soil) the following example illustrates a quality control program for a hypothetical 3-foot soil liner covering 100 acres:

a. For determining the moisture content prior to compaction, and the density obtained following compaction, collect and test one soil sample for every 2,000 cubic yards of compacted soil liner.

b. For determining saturated hydraulic conductivity in the laboratory, collect and test one soil sample for every 16,000 cubic yards of compacted soil liner.

c. For monitoring field infiltration, conduct one measurement for every 40,000 cubic yards of compacted soil liner.

The inspection procedures should also include a visual inspection of the foundation by a qualified technical person. Visual observations should include subgrade appearance, earthwork activities, and workmanship (e.g., look for cracks, channels, root holes, etc.); lack of vegetation; drain orientation and placement; slope characteristics and preparation; and any other parameters that might influence the adequacy of the foundation.

9.3.3.5.4 Admixed Liners--There are a variety of admixed (formed-in-place) liners which have been successfully used for impounding and conveying water. Types of liners include asphalt-concrete, soil cement, and soil asphalt, all of which are hard-surface materials. Experience in using admixes in landfill applications is limited.

Hydraulic asphalt concrete (HAC) used as liners for hydraulic structures and waste disposal facilities, are controlled hot mixtures of asphalt cement and high quality mineral aggregate compacted into a uniform dense mass. They are similar to highway paving asphalt concrete but have a higher percentage of minor fillers and a higher percentage (usually 6.5 to 9.5) of asphalt cement. The asphalt used in HAC is usually a hard grade such as 40-50 or 60-70 penetration grade.

The application should include inspection procedures which insure that design specifications are met. To provide a relatively impermeable layer, two 2-inch layers of HAC (a total thichness of 4 inches) are recommended (SW-870).[3] The liner should be compacted to at least 97 percent of the density obtained by the Marshall Method or less than 4 percent void space. A void space of less than 2.5 percent has been shown to reduce permeability to 1×10^{-9} cm/s (SW-870).[3] The prepared subgrades should have side slopes of less than 3:1. The soil should be treated with a sterilizing agent to prevent puncture of the liner by weeds and roots. A visual inspection should be conducted to identify any surface irregularities such as cracks and lumps.

If wastes are expected to be acidic, the aggregate should be tested for carbonate content. Carbonates are readily attacked by acids and should be avoided in this situation. Asphalt liners should not be used at sites receiving petroleum derived wastes or petroleum compounds.

Soil cement is a compacted mixture of portland cement, water, and selected in-place soils. Permeability is dependent on soil type. A fine-grained soil produces a soil cement with a permeability coefficient of 10^{-6} cm/s. Coatings such as epoxy asphalt and epoxy coal tar have been used to reduce the permeability of soil cement.

The inspection program should insure that the soil cement liner meets design specifications. Soils that are not organic and contain less than 50 percent silt and clay are suitable for soil cement. The inspection should insure that the soil cement liner meets design criteria for cement content, moisture content, and the degree of compaction. The optimum cement content should be determined from wet-dry and freeze-thaw cycle laboratory tests,

ASTM D559 and ASTM D560, respectively. Soil cement liners may degrade under highly acidic environments. The soil cement liner should be visually inspected for inconsistencies such as cracks and lumps, etc.

Soil asphalt is a mixture of available onsite soil (usually with low plasticity) and liquid asphalt. The preferred soil type is a silty, gravelly soil with 10 to 25 percent silty fines. A high void content soil asphalt has a high permeability ($\sim 1.7 \times 10^{-3}$). Soil asphalts containing cutback asphalt are not recommended as lining materials. Soil asphalt made with asphalt emulsion is not sufficiently impermeable and requires a waterproof seal such as a hydrocarbon resistant or bituminous seal. The soil asphalt liner (with waterproof seal) should be inspected to insure that it conforms to design specifications. The inspection should include procedures which insure the required impermeability and a visual inspection of the liner to identify irregularities in the soil asphalt and the waterproof seal.

Figure 9.3.9 presents a worksheet which can be used to evaluate the adequacy of the applicant's plans for inspection after installation of liner systems.

9.3.3.6 Are procedures described for Inspections Weekly and After Storms?--

9.3.3.6.1 Introduction--Figure 9.3.10 is a chart of topics presented in this subsection. The provisions of §264.303(b) identify four physical systems that should be inspected on a weekly basis. They are:

(1) Run-on and run-off control systems,

(2) Leak detection systems,

(3) Wind dispersal control systems, and

(4) Leachate collection and removal systems.

The regulations require only new facilities to have leachate collection and removal systems. Similarly, only those new facilities seeking an exemption from the requirements of Part 264, Subpart F by using double liners will have leak detection systems. Some facilities, both new and existing, will have wind dispersal control systems, depending on the nature of the wastes disposed. All new and existing facilities will have run-on and run-off control systems.

The description of weekly inspection procedures should be specific regarding what, how, and where the stated systems will be checked. Criteria that will be used to evaluate the proper operation of these systems should be stated. The plans should indicate use of a form requiring written completion by the person conducting the inspection. An employee responsible for inspections should be identified by name or title.

9.3.3.6.2 Run-on and Run-off Control Systems--Inspections of run-on and run-off control systems will vary in complexity in relation to the complexity of the design. A run-on control system at a landfill is simply intended to

INSPECTION REQUIREMENTS

Has this part of the applicant's submittal been reviewed and evaluated? ____ Yes ____ No

Sheet and Membrane Materials

Does the application specify standard ASTM Methods for testing seams and joints? ____ Yes ____ No

What method(s) are specified? _____

_____

Do inspection procedures call for keeping and reviewing a seam test log? ____ Yes ____ No

Is a copy of the seam test log included in the inspection plan? ____ Yes ____ No

Fluid Materials

Does the application include detailed procedures for inspecting liners applied as fluids? ____ Yes ____ No

Are fluid materials checked for conformance with specifications before application? ____ Yes ____ No

Do inspection procedures provide for determination of liner thickness after installation and curing to allow for repair of thin spots? ____ Yes ____ No

Soil-Based and Admixed Liners

Do in-situ soil inspection procedures include:

- Visual inspections to identify large irregularities? ____ Yes ____ No
- Visual inspections to identify unanticipated standing water or other liquid? ____ Yes ____ No
- Tests to identify height of liner above water table? ____ Yes ____ No
- Checks of horizontal dimensions? ____ Yes ____ No

Figure 9.3.9. Worksheet for determining the adequacy of inspection procedures after installation.

Do foundation soil inspection procedures include:

- Tests to insure that the foundation materials meet specified soil classification criteria? Yes No
- Tests to insure that the specified moisture content and compaction are obtained? Yes No
- Tests to insure that the plasticity index specifications are met? Yes No
- Permeability determinations? Yes No

Are test procedures conducted to insure that admixed liners:

- Meet material specifications? Yes No
- Meet permeability specifications? Yes No
- Are placed to the specified thickness? Yes No
- Are free of irregularities? Yes No

Figure 9.3.9 (continued).

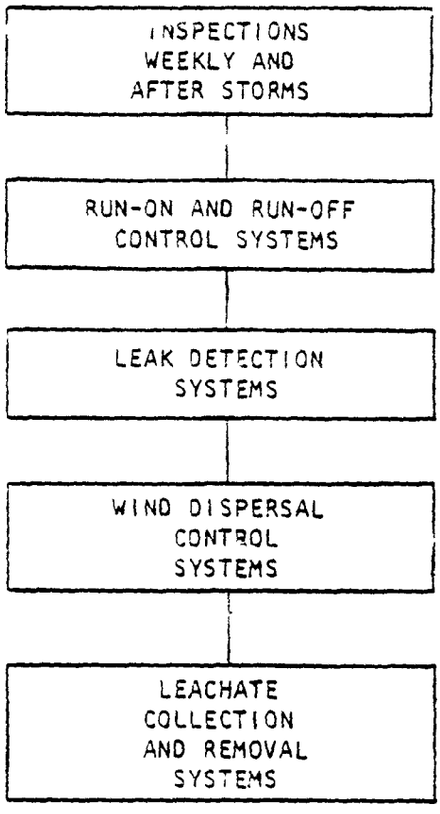


Figure 9.3.10. Inspections weekly and after storms.

divert the surface water flow around/away from the landfill. In all liklihood it will consist of trenches at most facilities, which may or may not be lined. The run-off control system is designed to collect and contain all liquid from the active portion of the landfill and deliver it to some type of holding or treatment facility. A run-off control system is likely to be of more sophisticated design than a run-on control system since it will be handling liquid that has been in contact with hazardous waste. Two broad concerns should be addressed by inspection procedures established for either of these systems, and include:

- The physical integrity of the system remains as originally constructed.
- The capacity of the system remains as originally constructed.

For either run-on or run-off control systems, inspections of physical integrity should address;

- The liquid collection trench, culvert, or piping for maintained slope, any breaches, and tight joints.
- If the conveyance system is lined, the liner material should be checked for adhesion to substrate, holes, wear points, and cracks.
- If mechanical equipment (pumps, valve, gates) is part of the system, all components should be checked for leaks, operability, or other damage.

For run-on control systems, inspections to confirm maintained design capacity should address;

- The presence of sedimentation, debris, or other materials that could inhibit system flow.
- The condition of terrain downgradient from the system exit that could cause liquids to back up into the system.

For run-off control systems, inspections to confirm maintained design capacity should address;

- The presence of sedimentation or encrustation in the system.
- The operability of mechanical equipment in the system.
- The status (full/empty) of run-off holding or treatment systems.

The holding/treatment systems associated with the run-off control system are identified as storage, treatment, or disposal facilities under Part 264, and must be inspected as required by §270.14(b)(5) and §264.15.

9.3.3.6.3 Leak Detection Systems--Inspections of leak detection systems are required to determine if liquid is present, thus indicating leakage from the facility. The inspection procedures should indicate how the check for liquids will be made and what criteria will be selected as positive indication of the presence of liquids. The inspection procedures should also indicate what actions will be implemented by the inspector when liquids are found in the leak detection system.

9.3.3.6.4 Wind Dispersal Control Systems--There are many design options for wind dispersal control at a landfill. In some cases, more than one system will be installed. Wind dispersal controls at landfills are necessary to prevent the dispersal of hazardous waste particles and soil that may have been in contact with hazardous waste.

The inspection procedures should indicate close visual observation of all wind dispersal control systems on a weekly basis, at a minimum. During periods of high winds or when wastes are more susceptible to wind dispersal, the inspection frequency should be increased. The inspection procedures should indicate that the inspector has the authority to require immediate repair or cleaning of wind dispersal control systems. Cleaning would be necessary where fences or burlap screens are installed to catch any wind blown materials.

9.3.3.6.5 Leachate Collection and Removal Systems--A leachate collection and removal system is installed under the landfill cell to provide for removal of leachate and maintain the depth of leachate on the liner below 1-foot. Leachate must be stored and/or treated after removal. Procedures for inspecting leachate collection systems should provide for the following;

- Confirmation that leachate depth above the liner is less than 1 foot at all points.
- Check of depth of leachate in collection sumps.
- Observation of mechanical equipment in operation (i.e., sump pumps and associated piping).
- Recording of leachate depths and flow rates in all parts of the system.

The intent of inspecting these systems weekly and after storms is to insure continued operation and to determine if the system is in the process of becoming clogged or has clogged. Detailed guidance on what constitutes adequate inspection of these systems is not possible unless the design of the system is known. However, as with other inspections, the procedures should state what, where, why, and how checks of the system will be made. Specific criteria that would trigger corrective actions should be stated.

The inspection procedure should indicate what specific actions will be taken to monitor for existing or potential clogging of the leachate collection and removal system. For instance, leachate depths and flow rates at several points in the system can be recorded, graphed, or handled in other ways in an effort to identify sudden, abnormal changes.

Properly designed leachate collection and removal systems are amenable to cleaning on a periodic basis through the use of high pressure water (50 psi).[11] Such inspection and cleaning should be conducted after first placement of waste and periodically thereafter.

A worksheet for evaluating the inspection procedures conducted weekly and after storms is presented in Figure 9.3.11.

9.3.4 Draft Permit Preparation

Condition D of Permit Module XV addresses monitoring and inspection requirements. The condition is implemented through reference to a permit attachment that includes inspection terms and scheduling, and remedial actions as appropriate. To be considered adequate for substitution in the permit condition attachment, the submitted application information should include details of procedures used and scheduling for inspecting various process operations during the following time periods:

- Before construction,
- During construction, and
- After construction of the liner and related facilities.

The attachment must also include weekly and after storm inspection procedures and schedules (during landfill operation) that address:

- Run-on and run-off control systems,
- Leak detection systems, where present,
- Wind dispersal control systems, where present, and
- Leachate collection and removal systems, where present.

Reference should be made to Permit Condition II.E. which requires the applicant to remedy any deterioration or malfunction discovered during an inspection and to keep a log of inspection records. For existing landfill portions that are exempt from liner requirements, the attachment need only address weekly and after storm inspections. Inspection requirements during the post-closure care period are discussed in subsection 9.4.

INSPECTION REQUIREMENTS

Has this part of the applicant's submittal been reviewed and evaluated?	Yes	No
Run-on and Run-off Control Systems		
Do weekly and after storm inspection procedures address:		
• Inspection of liquid collection trench, culvert or piping systems for proper slope, [illegible] joints.	Yes	No
• Inspection of lined conveyance systems for adhesion to substrate, holes, wear points, and cracks?	Yes	No
• Inspection of mechanical equipment for leaks, operability or other damage?	Yes	No
Do run-on control system inspection procedures include:		
• Inspection for the presence of sedimentation, debris, and other material that could inhibit flow?	Yes	No
• Inspection of the down gradient terrain to identify potential causes of liquid back up?	Yes	No
Do run-off control system inspection procedures include:		
• Inspection for the presence of sedimentation or encrustation?	Yes	No
• Inspections to determine the operability of mechanical equipment?	Yes	No
• Inspections to determine the status (full/empty) of holding or treatment systems?	Yes	No
Leak Detection System		
Are procedures for monitoring the leak detection system fully described?.	Yes	No
Does the inspection plan specify actions to be taken in the event of a leak?	Yes	No

Figure 9.3.11. Worksheet for determining the adequacy of weekly and after storm inspection procedures.

Wind Dispersal Control Systems

Does the inspection plan include procedures for weekly visual inspections of wind dispersal control systems?	Yes	No
Does the inspection frequency increase during periods of high winds?	Yes	No

Leachate Collection and Removal Systems

Does the inspection plan identify specific weekly and after storm inspection procedures to identify:

• Leachate depths greater than 1 foot over the liner?	Yes	No
• Depth of leachate in collection sumps?	Yes	No
• Mechanical equipment malfunctions?	Yes	No
• Leachate depths and flow rates in all parts of the system?	Yes	No
Does the inspection plan identify specific criteria that would trigger remedial action?	Yes	No
Do the inspection procedures identify specific actions to monitor for existing and potential physical or chemical clogging of the leachate collection and removal system?	Yes	No

Figure 9.3.11 (continued).

9.5.5 References

1. U.S. EPA. Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Volume I. Office of Solid Waste. Washington, D.C. 1983.

2. Capone, S. V., et al. Permit Applicants' Guidance Manual for the General Facility Standards of 40 CFR 264. Prepared by GCA/Technology Division for the U.S. Environmental Protection Agency. Office of Solid Waste. Washington, D.C. Draft. June 1983.

3. Lining of Waste Impoundment and Disposal Facilities, SW-870, U.S. EPA, SHWRD/MERL-CINN, September 1980.

4. Schultz, D. W., and M. P. Micklas, Jr. Placement Procedures for Various Impoundment Liners, Solid Wastes Management, July 1982, p. 24.

5. Evaluating Cover Systems for Solid and Hazardous Waste, SW-867 (Revised Edition), U.S. EPA, SHWRD/MERL-CINN, September 1982.

6. Design and Construction of Covers for Solid Waste Landfills, EPA-600/2-79-165, U.S. EPA, SHWRD/MERL-CINN, August 1979.

7. Brochure B-74P (05-2-79) 5M, Chevron Industrial Membrane, Commercial-Industrial Elastomeric, Chevron U.S.A. Inc./Asphalt Division, P.O. Box 7643, San Francisco, CA 94120.

8. U.S. EPA. RCRA Technical Guidance Documents. A Series of Manuals Published with the Land Disposal Standards of July 26, 1982.

9. Sowers, G. B., and G. F.Sowers. Introductory Soil Mechanics and Foundations. Third Edition. MacMillan Publishing Co., Inc., New York. 1970.

10. Cernica, T. N. Geotechnical Engineering. Holt, Rinehart, and Winston. New York. 1982.

11. Telephone conversation. Greg Woelfel, Northern Regional Engineer, Waste Management, Inc. (414-476-8858) and S. Capone, GCA/Technology Division. 18 March 1983.

9.4 LANDFILL CLOSURE AND POST-CLOSURE

9.4.1 The Federal Requirements

Section 270.21(e) specifies the information that must be submitted to demonstrate the applicant's closure plans. That information includes:

> "Detailed plans and an engineering report describing the final cover which will be applied to each landfill or landfill cell at closure in accordance with §264.310(a), and a description of how each landfill will be maintained and monitored after closure in accordance with §264.310(b). This information should be included in the closure and post-closure plans submitted under §270.14(b)(13)."

The standards of §264.310 must be supported upon implementation of the closure and post-closure plans, as follows:

> "(a) At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to:
>
> (1) Provide long-term minimization of migration of liquids through the closed landfill;
>
> (2) Function with minimum maintenance;
>
> (3) Promote drainage and minimize erosion or abrasion of the cover;
>
> (4) Accommodate settling and subsidence so that the cover's integrity is maintained; and
>
> (5) Have a permeability less than or equal to the permeability of any bottom liner system or natural soils present.
>
> (b) After final closure, the owner or operator must comply with all post-closure requirements contained in §264.117-264.120, including maintenance and monitoring throughout the post-closure care period (specified in the permit under §264.117). The owner or operator must:
>
> (1) Maintain the integrity and effectiveness of the final cover, including making repairs to the cap as necessary to correct the effects of settling, subsidence, erosion, or other events;
>
> (2) Maintain and monitor the leak detection system in accordance with §264.302, where such a system is present between double liner systems;
>
> (3) continue to operate the leachate collection and removal system until leachate is no longer detected;
>
> (4) Maintain and monitor the groundwater monitoring system and comply with all other applicable requirements of Subpart F of this Part;
>
> (5) Prevent run-on and run-off from eroding or otherwise damaging the final cover; and
>
> (6) Protect and maintain surveyed benchmarks used in complying with §264.309.

(c) During the post-closure care period, if liquid leaks into a leak detection system installed under §264.302, the owner or operator must notify the Regional Administrator of the leak in writing within seven days after detecting the leak. The Regional Administrator will modify the permit to require compliance with the requirements of Subpart F of this Part."

9.4.2 Summary of Necessary Application Information

The provisions of §270.21(e) and §264.310 require the submittal of two plans; a closure plan and a post-closure plan. The closure plan must include detailed plans and an engineering report describing the design and construction of the final cover (cap) that will be installed on each landfill or landfill cell. Specific information items which must be addressed in the closure plan are set forth in §264.310(a) and in §264.110 through §264.115 in Subpart G of Part 264.

The post-closure plan must include a description of how each landfill or cell will be maintained and monitored after it is closed. Specific information items which must be addressed in the post-closure plan are set forth in §264.310(b) and in §264.117 through §264.120 in Subpart G of Part 264.

The fundamental function of the final cover is to prevent the entry of liquids into the closed unit and, thus, leachate formation and migration of leachate from the site. The application should demonstrate that the design will:[1]

- Minimize migration of liquids through the closed cell or landfill.
- Minimize maintenance requirements.
- Promote drainage and minimize erosion or abrasion of the cover.
- Accommodate settling and subsidence.
- Provide a cover that has equal or less permeability than any bottom liner system or subsoil underlying the landfill.

The application should also demonstrate that the owner/operator will:

- Maintain the final cover (i.e., repairs due to settling, subsidence, erosion, etc.)
- Maintain the leak detection system (where such a system is installed between double liners).
- Operate the leachate collection and removal system until leachate is undetected.
- Maintain the ground water monitoring system.
- Prevent run-on and runoff.

- Maintain benchmarks used as the basis for determining top cover settling and subsidence, and compliance with §264.309.

9.4.3 Guidance on Evaluating Application Information

A flow chart is presented in Figure 9.4.1 to demonstrate the regulations which are applicable to closure of hazardous waste landfills.

Information on the intent of the closure and post-closure requirements is available from preambles to the Federal Register Notices which established the requirements. The major issues are discussed in the Notices listed below.

FEDERAL REGISTER NOTICE			SECTION AFFECTED
Date	Page	Vol.	
19 May 1980	33196	45	Subpart G
19 May 1980	33212	45	Subpart N
12 Jan 1981	2818	46	Subpart G
13 Feb 1981	12424	46	Subpart N
26 July 1982	32314	47	Subpart N

9.4.3.1 Available References--

Concurrent with the promulgation of the landfill permitting regulations, the EPA released the RCRA Technical Guidance Document, "Landfill Design, Liner Systems and Final Cover" (Draft, Issued July 1982).[2] The Guidance Document provides design specifications for a final cover design approved by the EPA as being consistent with the intent of §264.310. The basis for that design and supporting technical data are contained in "Evaluating Cover Systems for Solid and Hazardous Waste (SW-867).[3] SW-867 provides a detailed 39-step approach for evaluating the adequacy of closure and post-closure plans and engineering reports with respect to the requirements of §264.310(a). The procedure is specifically intended for use by staff members in the Regional EPA Offices and/or state offices.

Procedures detailed in SW-867 are based on data contained in "Design and Construction of Covers for Solid Waste Landfills," EPA-600/2-79-165 (August 1979).[4] This report provides extensive detail which is sufficient, in combination with site-specific data, to design a final cover for a landfill cell. Additional information can be obtained from conference and symposium proceedings. Although many of these papers specifically address caps used for remedial actions, they do provide insight into potential problems with function, design and maintenance of final covers. References 5 through 9 listed in subsection 4.5 are also useful sources of information on closure.

Additional data on closure practices are likely to become available through continued research in the area of landfilling hazardous waste.

9.4.3.2 Permit Application Review Procedures--

As discussed below in subsection 9.4.3.2.1, EPA Publication SW-867 provides a stepwise procedure for evaluating engineering plans for final cover construction and maintenance. The sequence of procedures is illustrated by Figures 9.4.2, 9.4.3, and 9.4.4. The first three procedures, which encompass

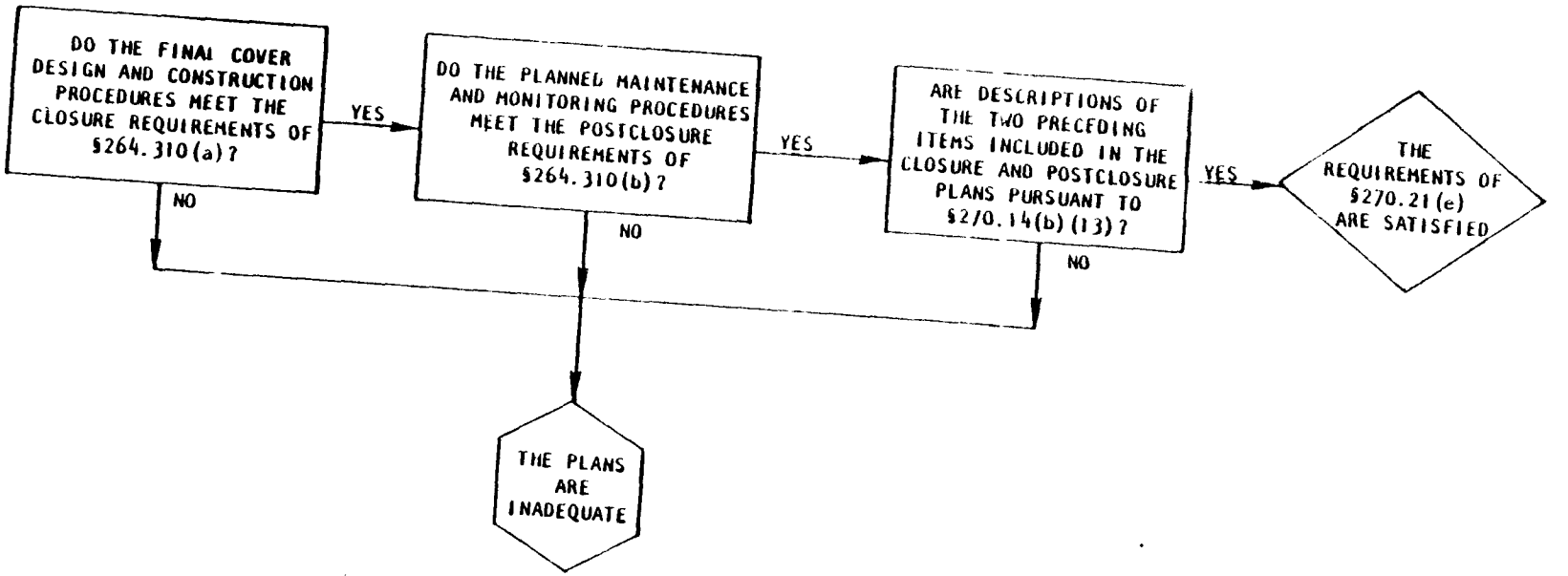


Figure 9.4.1. Regulations applicable to closure of hazardous waste landfills.

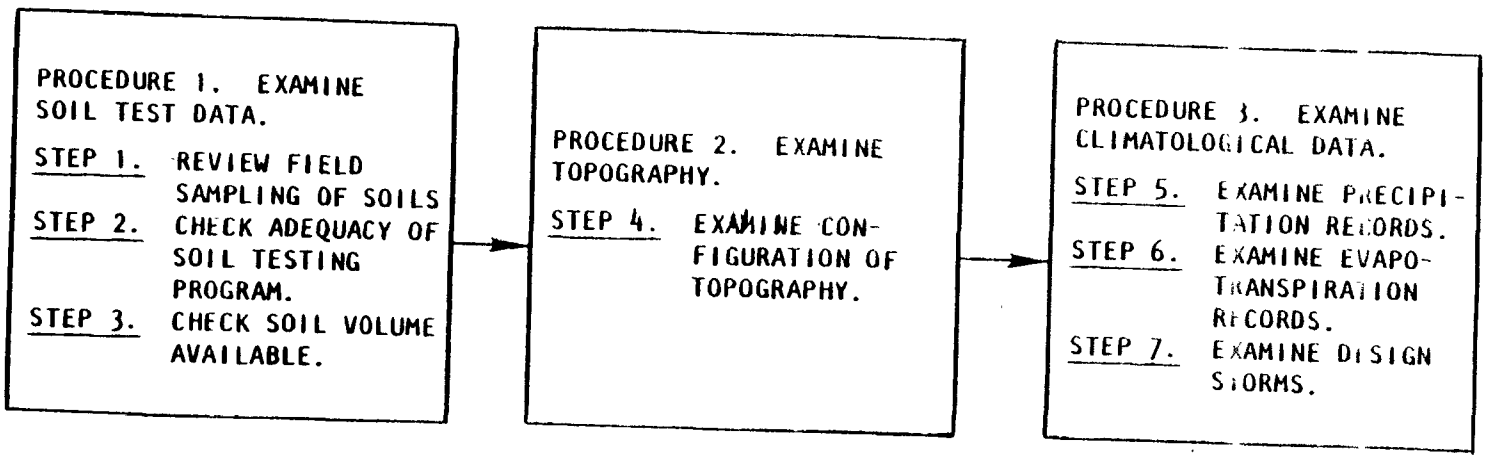


Figure 9.4.2. Examine background data.

Source: Reference 3 (SW-867).

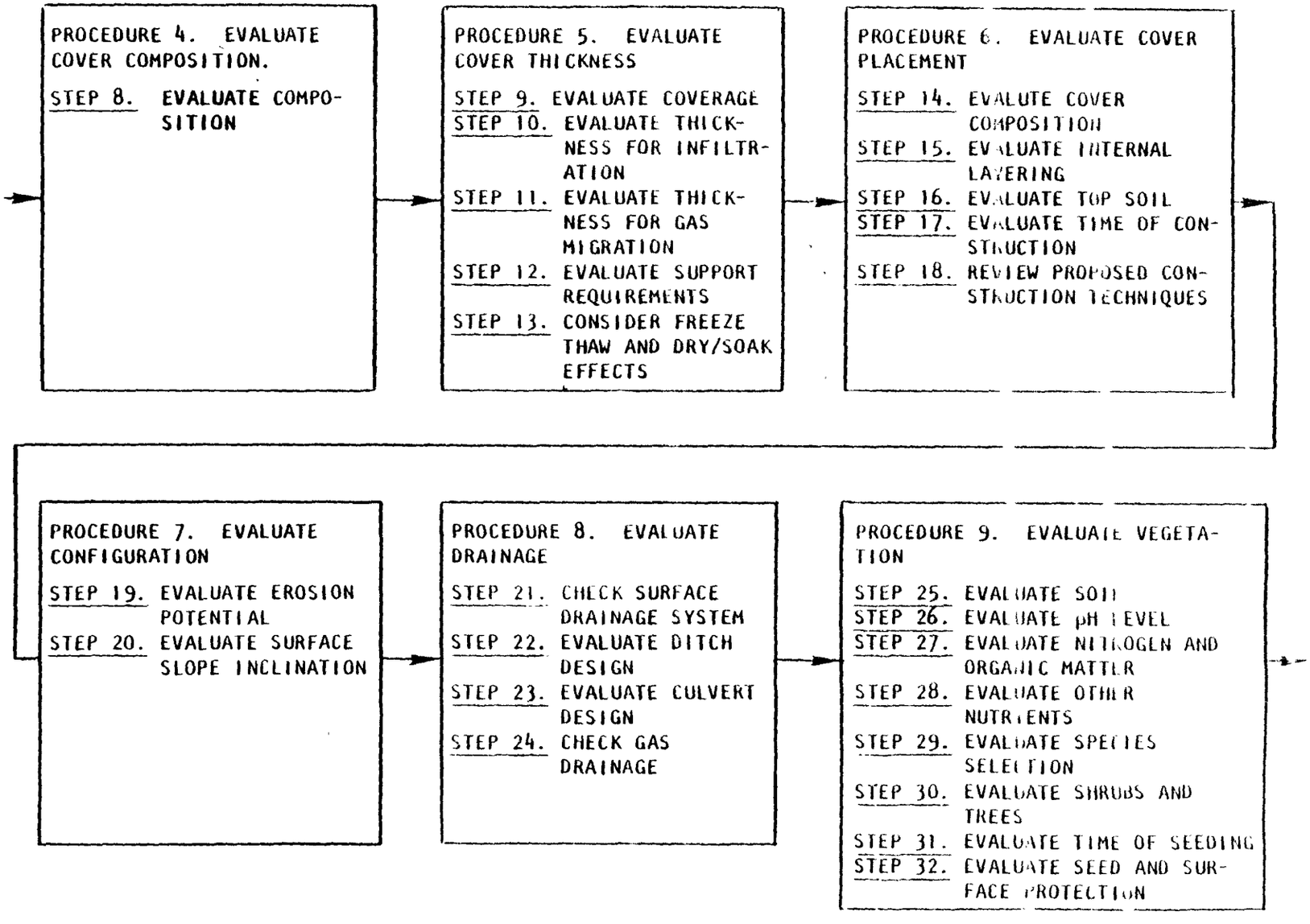


Figure 9.4.3. Characterize the cover system.

Source: Reference 3 (SW-867).

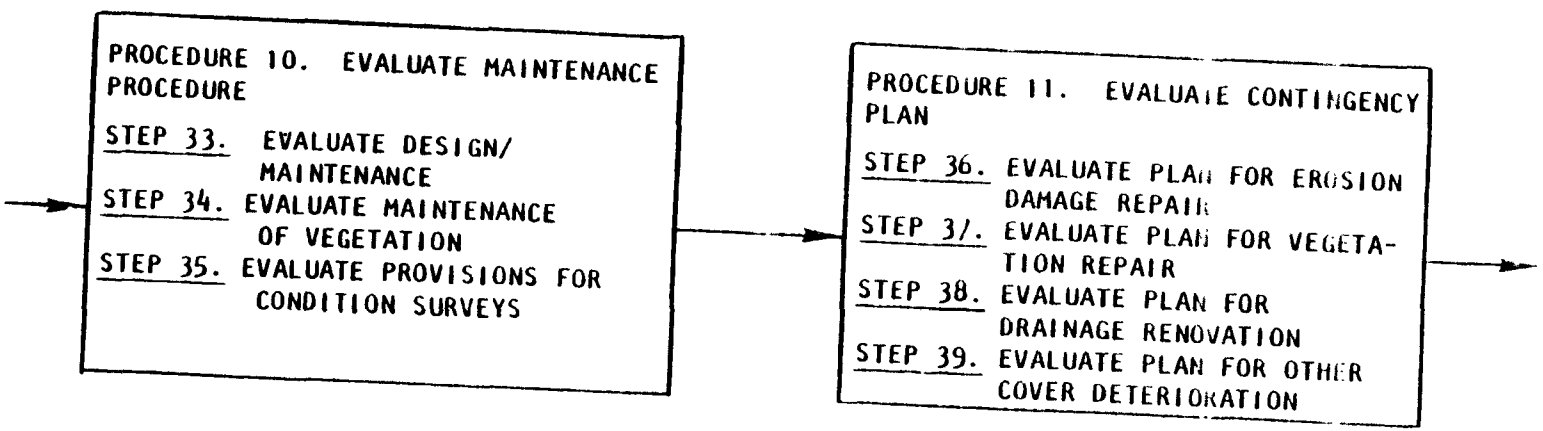


Figure 9.4.4. Evaluate post-closure plan.

Source: Reference 3 (SW-867).

seven steps (see Figure 9.4.2), constitute a review of materials and conditions at the site under consideration. The six procedures identified in Figure 9.4.3 encompass 25 steps and pertain to the characteristics of the cover system. Figure 9.4.4 identifies procedures used to evaluate the adequacy of post-closure plans in a total of seven steps. The following discussion describes evaluation procedures and their relationship to §264.310:

9.4.3.2.1 Examine Background Data (see Figure 9.4.2)--

- Examine soil test data (Steps 1-3)--Establish that the applicant has satisfactorily documented the physical characteristics, volume, and spacial distribution of the soil types to be used in the cover. These data must be reasonably accurate since they directly affect the adequacy of the cover system and the feasibility of the cover operation.

- Examine topography (Step 4)--The surface configuration is examined to assure that evaluations can be made in regard to slope stability, water erosion, and wind erosion. Topographical data are often presented in the form of cross sections showing the thickness of the closure cover and solid waste and the limits of natural soil previously extracted for use as cover.

- Examine climatological data (Steps 5-7)--Permit applications should contain data on average monthly precipitation, design storms, and evapotranspiration. Average precipitation data are generally provided for 20 years of rainfall records. Design storm data should be provided for storms of 1-hour or longer duration, with a recurrence interval of 10 to 20 years. Since evapotranspiration is an important factor in removing moisture from the cover, the application should include an estimation of average monthly evapotranspiration rates.

9.4.3.2.2 Characterize the Cover System (see Figure 9.4.3)

- Evaluate composition (Step 8)--Cover composition should be evaluated with regard to trafficability, gas migration, and water percolation. Since minimizing infiltration is of particular importance, it will generally be necessary to reject simple one-layer designs in favor of multilayer systems which include a clay soil layer or a synthetic membrane liner.

- Evaluate cover thickness (Steps 9-13)--In addition to federal and state cover requirements, the cover thickness may be governed by the quantity of borrow available, infiltration, gas migration, trafficability and support requirements, freeze/thaw and dry/soak effects, cracking, differential settlement, membrane protection, and vegetative requirements. These factors should be addressed in permit applications.

- Evaluate cover placement procedure (Steps 14-18)--Cover can be improved in several ways as it is constructed. Materials may be added for better grading, hauling and spreading equipment can be operated in a manner which increases compaction, and layering can be used. Internal layering can combine favorable characteristics of several materials. Synthetic membrane liners used in this configuration should be at least 20 mils thick and should be placed in a relaxed state between smooth layers of soil to prevent damage. Synthetic liners are often necessary to maintain permeability at or below that of the bottom liner system.

- Evaluate configuration (Steps 19-20)--Configuration should be evaluated in terms of erosion potential and infiltration control. Erosion has the effect of degrading the cover, thereby seriously reducing its effectiveness.

- Evaluate drainage (Steps 21-24)--The application should address surface runoff drainage for the cover and surrounding area. Ditches and culverts should be sized to handle the design storm runoff. The evaluator should apply design storm data to Manning's equation to check the specified dimensions.

- Evaluate vegetation (Steps 25-32)--Establishment and maintenance of vegetation requires an evaluation of soil type, nutrient and pH levels, climate, species selection, mulching, and seeding time. Species should be selected on the basis of environmental and biological strengths and limitations.

9.4.3.2.3 Evaluate Post-Closure Plan (See Figure 9.4.4)

- Evaluate maintenance procedure (Steps 33-35)--Regular maintenance intervals should be planned to repair settling and erosion damage and to maintain the vegetative cover. Provisions should also be made for site monitoring by a qualified technical person to periodically inspect the cover condition and take ground water samples.

- Evaluate contingency plan (Steps 36-39)--A contingency plan should be established to deal with future unforeseen problems such as excessive wind and water erosion, loss of vegetation, and drainage system failures. The evaluator should consider the likely effectiveness of post-closure plans to address such problems in a timely manner.

The procedural information provided above was obtained from EPA Publication SW-867. Information contained in this document can be supplemented with other references listed in Section 9.4.5.

9.4.3.3 Other Sources of Information--

An example of the kind of general evaluation data that can be obtained from symposia proceedings is presented in Table 9.4.1. The table is excerpted from a paper entitled "'Containment' Strategies to Manage Abandoned Hazardous

TABLE 9.4.1. COVER MATERIAL GENERAL PERFORMANCE CRITERIA EVALUATION
Source: Reference 10.

Cover material	Historical applications as a cover material	Trafficability	Impede water percolation	Radon gas control	Erosion control	Aid surface runoff	Desiccation	Freeze/thaw stability	Seismic stability	Crack resistance	Side-slope stability	Potential for side-slope seepage	Discourages rodent burrowing	Supports vegetation	Ease of construction	Proven 100-year life	Cost of placement	Biological deterioration	Root penetration
Spray asphalt emulsion	-	-	+	+	+	+	+	+	-	-	-	+	-		-		+	-	-
Hydraulic asphalt	-	+	+	+	+	+	+	+	-	+	+	+	+	-	-	-	-	-	-
Synthetic	-	-	+	-	+	+	+	+	-	-	-	+	-		-	-	-	-	-
Synthetic -- PVC	-	-	+	-	+	+	+	+	-	-	-	+	-		-	-	-	-	-
Synthetic -- neoprene	-	-	+	-	+	+	+	+	-	-	-	+	-	-	-	-	-	-	-
Synthetic -- CPE	-	-	+	-	+	+	+	+	-	-	-	+	-	-	-	-	-	-	-
Concrete	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	+
Low permeability native soils	+	-	+	+	-	+	-	-	-	-	+	+	-	+	+	+	+	+	-
Onsite soils	+	+	-	+	-	-	-	-	-	-	+	+	-	+	+	+	+	+	-
Soil admixtures (bentonite)	+	-	+	+	-	+	-	-	-	-	+	+	-	+	+	+	+	+	-
Bentonite	+	-	+	+	-	+	-	+	-	-	+	+	-	-	+	+	-	+	-
Well-graded gravel	+	+	-	-	+	-	+	+	+	+	+	-	+	-	+	+	+	+	-
Riprap	+	+	-	-	+	-	+	+	+	+	+	-	+	-	+	+	+	+	-
Silty-sand (soil)	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	-
Clayey-sand (soil)	+	-	+	+	-	+	-	+	-	-	+	+	-	+	+	+	+	+	-
Soil cement	-	-	+	+	+	+	+	+	-	+	+	+	+	-	-	-	-	+	-
Soil asphalt	-	-	+	+	+	+	+	+	-	+	+	+	+	-	-	-	-	-	-
Multilayered -- grass/topsoil/gravel/clay/soil	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-

Waste Sites in a Cost Effective Manner," presented at the Fifth Annual Madison Conference by WESTON Designers/Consultants of West Chester, Pennsylvania.[10] The table evaluates various cover materials by indicating positive performance ratings with a plus sign and negative performance ratings with a minus sign.

Additional information that a permit writer can use to evaluate post-closure plans is included in Reference 3 (EPA-600/2-79-165). Papers presented in Reference 5 by Lutton[11] and Rogoshewski[12] provide information on repairs to cover systems.

A worksheet for determining the adequacy of closure and post-closure procedures is presented in Figure 9.4.5.

9.4.4 Draft Permit Preparation

Condition M of Permit Module II addresses closure and post-closure permit requirements. Performance standards of the condition are implemented through reference to a permit attachment that includes plans and specifications for the proposed closure and post closure plan. To be suitable for substitution in the permit condition attachment, the submitted application information should include:

- Detailed plans and an engineering report describing design and construction of the final cover, and
- A post closure plan describing maintenance and monitoring procedures following closure.

9.4.5 References

1. U.S. Environmental Protection Agency. Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Volume I. Office of Solid Waste. Washington, D.C. 1983.

2. U.S. Environmental Protection Agency. RCRA Technical Guidance Document (Draft) Landfill Design, Liner Systems and Final Cover. July 1982.

3. U.S. Environmental Protection Agency. Evaluating Cover Systems for Solid and Hazardous Waste. Second Edition. SW-867. September 1982.

4. Design and Evaluation of Covers for Solid Waste Landfills. EPA-600/2-79-165. August 1979.

5. Municipal Solid Waste: Land Disposal, Proceedings of the Fifth Annual Research Symposium (Orlando, Florida - March 26-28, 1979), EPA-600/9-79-023a, U.S. EPA, MERL/CINN, August 1979.

6. Disposal of Hazardous Waste. Proceedings of the Sixth Annual Research Symposium, (Chicago, Illinois - March 17-20, 1980), EPA-600/9-80-010, U.S. EPA, MERL/CINN, March 1980.

Has this part of the applicant's submittal been reviewed and evaluated?	Yes	No
Have the physical characteristics, volume, and spacial distribution of soil types been documented?	Yes	No
Has the site topography been examined to assist in evaluating:		
• Slope stability?	Yes	No
• Water erosion?	Yes	No
• Wind erosion?	Yes	No
Are climatological data provided for?		
• Average monthly precipitation?	Yes	No
• Design storms?	Yes	No
• Evapotranspiration?	Yes	No
Has the cover system been evaluated with regard to:		
• Traffic?	Yes	No
• Gas migration?	Yes	No
• Water percolation?	Yes	No

Figure 9.4.5. Worksheet for evaluating closure and post-closure procedures.

Has the cover thickness been evaluated on the basis of:

- State and Federal requirements? ____ Yes ____ No
- Quantity of borrow available? ____ Yes ____ No
- Infiltration? ____ Yes ____ No
- Gas migration? ____ Yes ____ No
- Traffic support requirements? ____ Yes ____ No
- Freeze/thaw and dry/soak effects? ____ Yes ____ No
- Cracking? ____ Yes ____ No
- Differential settlement? ____ Yes ____ No
- Membrane protection? ____ Yes ____ No
- Vegetative requirements? ____ Yes ____ No

Do cover placement procedures include an evaluation of:

- Cover composition? ____ Yes ____ No
- Internal layering? ____ Yes ____ No
- Top soil? ____ Yes ____ No
- Time of construction? ____ Yes ____ No
- Proposed construction techniques? ____ Yes ____ No

Figure 9.4.5 (continued).

Has the cover configuration been analyzed in terms of:

- Erosion potential? ____ Yes ____ No
- Infiltration control? ____ Yes ____ No

Has surface drainage been evaluated for:

- Ditch design? ____ Yes ____ No
- Culvert design? ____ Yes ____ No
- Gas migration? ____ Yes ____ No

Has the vegatative cover been evaluated in terms of:

- Soil type? ____ Yes ____ No
- Nutrient and pH levels? ____ Yes ____ No
- Climate? ____ Yes ____ No
- Species selection? ____ Yes ____ No
- Seeding time? ____ Yes ____ No

Post-closure

Have regular maintenance intervals been establishd to:

- Identify and repair settling and erosion damage? ____ Yes ____ No
- Maintain the vegetative cover? ____ Yes ____ No
- Monitor ground water? ____ Yes ____ No

Figure 9.4.5 (continued).

Has a contigency plan been established to provide for:

- Erosion damage repair? _____ Yes _____ No
- Vegetation repair? _____ Yes _____ No
- Drainage renovation? _____ Yes _____ No
- Cover deterioration repair? _____ Yes _____ No

Figure 9.4.5 (continued).

7. Land Disposal: Hazardous Waste, Proceedings of the Seventh Annual Research Symposium (Philadelphia, Pennsylvania, March 16-18, 1981), EPA-600/9-81-002b, U.S. EPA, MERL/CINN, March 1981.

8. Land Disposal of Hazardous Waste, Proceedings of the Eighth Annual Research Symposium (Ft. Mitchell, Kentucky-March 8-10, 1982), EPA-600/9-82-002, U.S. EPA, MERL/CINN, March 1982.

9. Fifth Annual Madison Conference of Applied Research and Practice on Municipal and Industrial Waste, September 22-24, 1982, (Proceedings), Sponsored by the Department of Engineering and Applied Science, University of Wisconsin-Extension, Madison, WI.

10. Weston Designers/Consultants. "Containment" Strategies to Manage Abandoned Hazardous Waste Sites in a Cost Effective Manner. Paper presented at the Fifth Annual Madison Conference (see Reference 8).

11. Lutton, R. J., et al., "Case Study of Repairing Eroded Landfill Cover"

12. Rogoshewski, P. J. and R. S. Wetzel, "Handbook for Remedial Actions at Waste Disposal Sites."

9.5 HANDLING AND DISPOSAL OF IGNITABLE OR REACTIVE WASTES

9.5.1 The Federal Requirements

Paragraph (f) of §270.21 requires the following information in the permit application:

> "If ignitable or reactive wastes will be landfilled, an explanation of how the standards of §264.312 will be complied with."

The Part 264 standards to be supported are the special requirements of §264.312, which state:

> "(a) Except as provided in paragraph (b) of this section, and in §264.316, ignitable or reactive waste must not be placed in a landfill, unless the waste is treated, rendered, or mixed before or immediately after placement in a landfill so that:
>
> (1) The resulting waste, mixture, or dissolution of material no longer meets the definition of ignitable or reactive waste under §§261.21 or 261.23 of this Chapter; and
>
> (2) Section 264.17(b) is complied with.
>
> (b) Ignitable wastes in containers may be landfilled without meeting the requirements of paragraph (a) of this section, provided that the wastes are disposed of in such a way that they are protected from any material or conditions which may cause them to ignite. At a minimum, ignitable wastes must be disposed of in nonleaking containers which are carefully handled and placed so as to avoid heat, sparks, rupture, or any other condition that might cause ignition of the wastes; must be covered daily with soil or other noncombustible material to minimize the potential for ignition of the wastes; and must not be disposed of in cells that contain or will contain other wastes which may generate heat sufficient to cause ignition of the waste."

The referenced §264.17(b) requirements stipulate that:

> "(b) Where specifically required by other Sections of this Part, the owner or operator of a facility that treats, stores or disposes ignitable or reactive waste, or mixes incompatible waste or incompatible wastes and other materials, must take precautions to prevent reactions which:
>
> (1) Generate extreme heat or pressure, fire or explosions, or violent reactions;
>
> (2) Produce uncontrolled toxic mists, fumes, dusts, or gases in sufficient quantities to threaten human health or the environment;
>
> (3) Produce uncontrolled flammable fumes or gases in sufficient quantities to pose a risk of fire or explosions;
>
> (4) Damage the structural integrity of the device or facility;
>
> (5) Through other like means threaten human health or the environment."

9.5.2 Summary of Necessary Application Information

The Part B Permit Applicants' Manual[1] requires the applicant to submit information according to two optional requirements, as follows:

- Option 1 -
  - a description of the methods of treating ignitable or reactive wastes before or immediately after placement in the landfill,
  - results of field or laboratory testing illustrating that the wastes will be rendered nonreactive or nonignitable, and
  - a description of how §264.17(b) will be complied with.
- Option 2 (applicable only to ignitable wastes in containers)
  - a description of how ignitable wastes disposed of in containers will be protected from materials or conditions which could cause them to ignite, including handling procedures, daily cover characteristics, and characteristics of other wastes placed in the same cell.

The documentation provided should be based on scientific and engineering literature, pilot or bench scale tests, waste analyses, or the results of similar treatment based on experience or case histories.

9.5.3 Guidance on Evaluating Application Information

9.5.3.1 Regulatory Applicability and Intent--

Figure 9.5.1 is a summary of applicable regulations that the applicant must address if he plans to handle and dispose of ignitable or reactive wastes.

The requirements of §264.312 reflect the interim status standards (§265.312) for ignitable and reactive wastes. The interim status standards (§265.312) and the permitting standards (§264.312) for ignitable and reactive wastes have been discussed in the preambles of several Federal Register Notices. The following Notices contain applicable information.

Federal Register Notice			
Date	Page	Vol.	Section Affected
19 May 1980	33162	45	§265.17
19 May 1980	33182	45	§265.17
19 May 1980	33213	45	§265.312
12 Jan 1981	2809	46	§264.17 & §265.17
5 Feb 1981	11148	46	§264.312
20 Feb 1981	13492	46	§265.312
29 Jun 1981	33507	46	§265.312
17 Nov 1981	56592	46	§265.312
25 Feb 1982	8304	47	§265.312
26 Jul 1982	32331	47	§264.312
26 Jul 1982	32333	47	§265.312

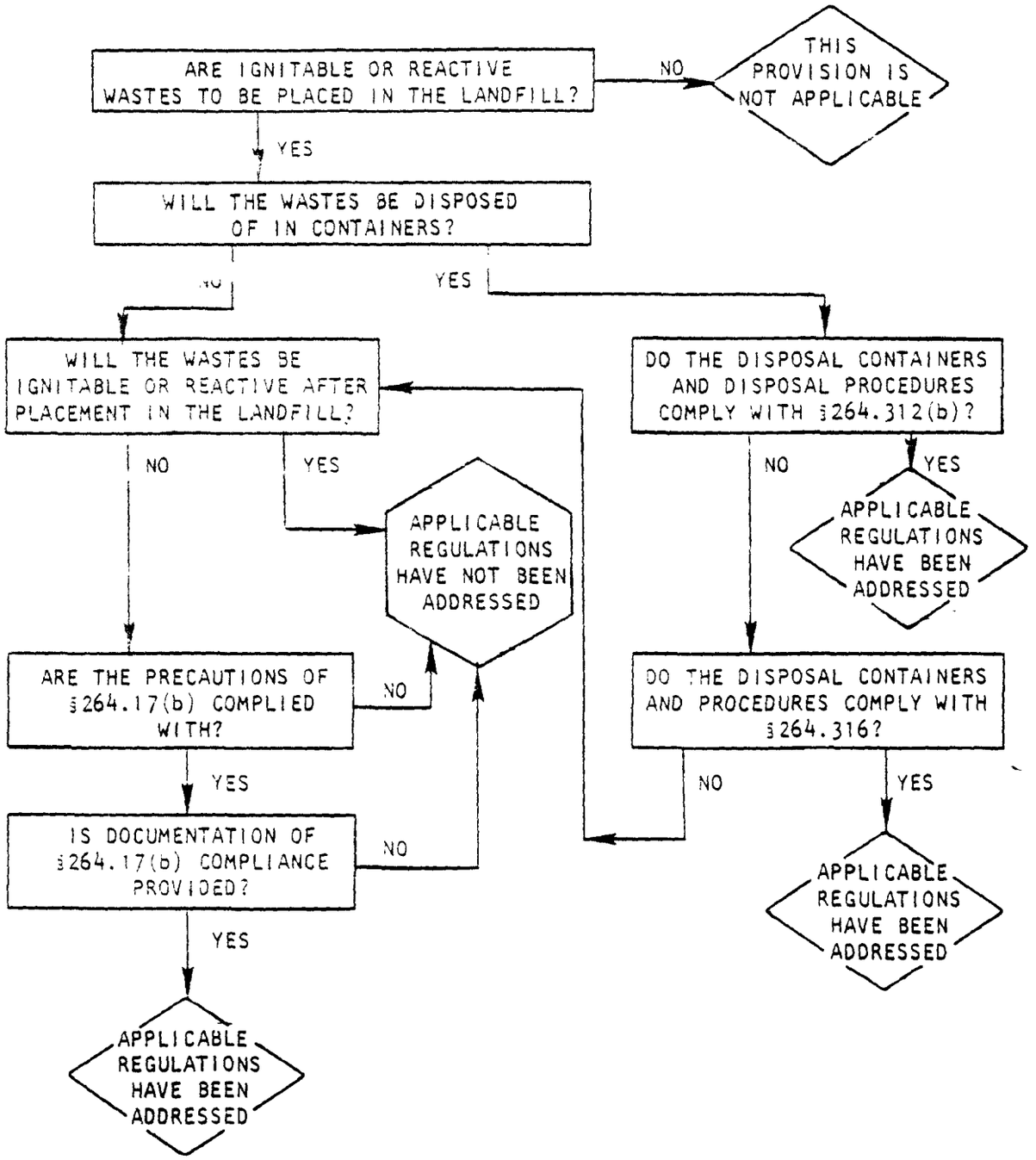


Figure 9.5.1. Applicability of regulations to handling and disposal of ignitable and reactive wastes.

The following Notices contain preamble discussions of §261.21 and §261.23. These sections of 40 CFR Part 261 identify criteria for ignitable and reactive wastes.

Federal Register Notice

Date	Page	Vol.	Section Affected
19 May 1980	33103	45	§261.21
19 May 1980	33109	45	§261.23
7 Jul 1981	35246	46	§261.21

9.5.3.1.1 Are ignitable or reactive wastes to be placed in the landfill?--If an applicant provides information that none of the wastes intended for disposal in the landfill are reactive or ignitable, this section is not applicable. Information that would be acceptable includes the results of tests or analyses conducted on the wastes by the landfill owner/operator or the waste generator. Documentation based on scientific or engineering literature may also be acceptable. If the applicant has demonstrated that all wastes are neither ignitable or reactive, the permit writer must indicate in the permit that ignitable or reactive wastes are not permitted for receipt or disposal at the landfill.

The characteristic of ignitability is exhibited by a solid waste if it has any of the four properties listed in §261.21(a). Specifically, §261.21(a)(1) addresses liquids, §261.21(a)(2) addresses nonliquids, §261.21(a)(3) addresses compressed gases, and §261.21(a)(4) addresses oxidizers. The provisions of §261.21(a)(1) identify three ASTM standard methods that can be used to determine ignitability. They are:

- ASTM Standard D-93-79
- ASTM Standard D-93-80
- ASTM Standard D-3278-78

These methods are also described in Section 2.1.1 of "Test Methods for Evaluating Solid Waste-Physical/Chemical Methods" (July 1982) Second Edition, SW-846[2] along with methods for ignitable compressed gases and oxidizers.

The characteristic of reactivity is exhibited by a solid waste if it has any of the eight properties listed in §261.23(a). Those properties are based largely on the definition employed by the National Fire Protection Association. The NFPA's headquarters are in Batterymarch Park, Quincy, MA and there is also a Washington, D.C. Office. Telephone numbers are:

General and Executive	(617) 328-9290
Publicaton Sales	(617) 770-3002
Washington, D.C. Office	(202) 484-8200

Detailed information on identification and testing of reactive wastes is provided in Section 2.1.3 of SW-846.

In addition to using the methods referenced in the regulations, the permit applicant may use other methods to determine ignitability or reactivity if he has petitioned and received approval from the Administrator, as allowed under §260.20 and §260.21. If the permit reviewer encounters methodologies whose acceptability cannot be determined, SW-846 suggests contacting the Manager, Waste Analysis Program (WH-565), Waste Characterization Branch, Office of Solid Waste, Washington, D.C. 20460 (202) 755-9187 for assistance.

9.5.3.1.2 Will ignitable or reactive wastes be treated before or immediately after disposal?--There are two requirements in §264.312(a) regarding disposal of ignitable or reactive wastes in landfills. First, the ignitable or reactive waste must be treated, rendered, or mixed before or immediately after placement in the landfill so that the resulting waste, mixture, or dissolution of material is no longer ignitable or reactive. Second, the provisions of §264.17(b) must be complied with.

To satisfy the requirement of §264.312(a), the landfill permit applicant must document in the permit application that the materials and procedures employed at the landfill, either before or immediately after waste disposal, will be such that the waste will no longer meet the definitions of ignitable or reactive, as specified in Part 261.

9.5.3.1.3 Are the precautions of §264.17(b) complied with?--If the owner/operator proposes to treat ignitable and/or reactive wastes, he must comply with §264.17(b) of Subpart B of Part 264. This stipulation requires the owner to "take precautions to prevent reactions which...threaten human health or the environment." There are four specific types of reactions listed in §264.17(b) which must be prevented, as listed in subsection 9.5.1.

9.5.3.1.4 Is documentation of compliance with §264.17(b) provided?--Documentation that the precautions of §264.17(b) will be effective is required by §264.17(c), as follows:

> "When required to comply with paragraphs (a) or (b) of this Section, the owner or operator must document that compliance. This documentation may be based on references to published scientific or engineering literature, data from trial tests (e.g., bench scale or pilot scale tests), waste analyses (as specified in §264.13), or the results of the treatment of similar wastes by similar treatment processes and under similar operating conditions."

The owner or operator of a landfill who is treating ignitable or reactive wastes must document that the treatment employed will not itself be hazardous. The permit application may be judged dificient if the required documentation is not submitted or if it is judged to be inadequate.

9.5.3.1.5 Will containers of ignitable wastes be disposed of, and if so, disposed of in compliance with §264.312(b)?--Section 264.312(b) allows landfilling of containerized ignitable waste if:

- the containers are not leaking,
- container handling and placement will avoid heat, sparks, rupture, and ignition of the waste,
- the containers are covered daily with noncombustible material, and
- the containers are not placed in landfill cells that do or will contain wastes that generate heat sufficient to cause ignition of the ignitable waste.

Note that §264.312(b) applies only to ignitable wastes in containers. A permit application which proposes to dispose of containerized reactive wastes under §264.312(b) should be judged inadequate. Reactive wastes may be disposed of in lab packs under certain circumstances consistent with the requirements of §264.316(e), as discussed below. Otherwise, such wastes must be rendered nonreactive and disposed of in accordance with §264.312(a).

9.5.3.1.6 Do containers and handling procedures comply with §264.316(e)?--Paragraphs (a) through (d) of §264.316 deal with the disposal of any hazardous waste at landfills when the waste is in small containers in overpacked drums (lab packs). The requirements of those paragraphs and the related §264.315 requirements are discussed in subsection 9.8. However, the requirements of paragraph (e) of §264.316 are applicable to reactive wastes in containers, as follows:

- for other than cyanide- and sulfide-bearing wastes,* the waste must be treated or rendered nonreactive before containerization in lab packs, or
- for cyanide- and sulfide-bearing wastes, the wastes can be containerized in lab packs without being treated or rendered nonreactive.

Thus, for all reactive wastes that are not cyanide- or sulfide-bearing, the waste must be treated or rendered nonreactive before it can be placed in a landfill, regardless of whether it is in a lab pack. However, cyanide- and sulfide-bearing reactive wastes in lab packs can be landfilled without being treated or rendered nonreactive, but only if the containerization complies with paragraphs (a) through (d) of §264.316 for lab packs, as discussed in subsection 9.8.

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*Cyanide- and sulfide-bearing wastes are defined in §261.23(a)(5) of Subpart C of Part 261.

The first requirement of §264.316(e) mandates that the reactive wastes (other than cyanide- and sulfide-bearing) be treated or rendered nonreactive before containerization in lab packs. This activity will typically be conducted by the generator and not by the owner or operator of a landfill. In these cases, the permit application should incorporate documented assurances from the generator to the landfill owner or operator that the noncyanide- and nonsulfide-bearing reactive wastes have been rendered nonreactive before lab pack containerization. The documentation should contain details of the materials and procedures that will be employed by the generator.

In some cases, even cyanide- and sulfide-bearing reactive wastes may be rendered nonreactive by the generator before containerization in lab packs. It is recommended that the permit reviewer request documentation which indicates the procedures employed to transform the cyanide- or sulfide-bearing wastes.

9.5.3.1.7 Summary

The listing below is a summary of the key points which the owner/operator must address to comply with the regulations governing the disposal of ignitable and reactive wastes in landfills.

- Demonstrate whether the wastes to be placed in a landfill are ignitable or reactive.
- Document treatment methods to render the waste nonignitable or nonreactive.
- Document that procedures for handling and disposal of ignitable and reactive wastes are adequate to prevent harm to humans and the environment.
- If the owner/operator does not intend to render ignitable wastes nonignitable, then he must stipulate that the waste will be containerized in nonleaking containers and disposed of in a manner that will avoid ignition or reaction of the wastes.
- If reactive wastes are to be disposed of in lab packs, the owner/operator must demonstrate that the waste will be rendered nonreactive before containerization in lab packs unless the wastes are cyanide- and sulfide-bearing reactive wastes.

9.5.3.2 Evaluation of the Technical Adequacy of the Applicant's Submittal--

Figure 9.5.2 presents the major topics that are discussed in this subsection. The permit reviewer should first determine which of the technical topics are applicable to the facility and operation of concern. For instance, if the applicant proposes to containerize ignitable wastes in conformance with the requirements of §264.312(b), then the discussion about treating, rendering, or mixing the waste so that it is no longer ignitable or reactive does not apply. If any applicable topics are not adequately addressed by the applicant, the application and the proposed disposal methods may be technically deficient.

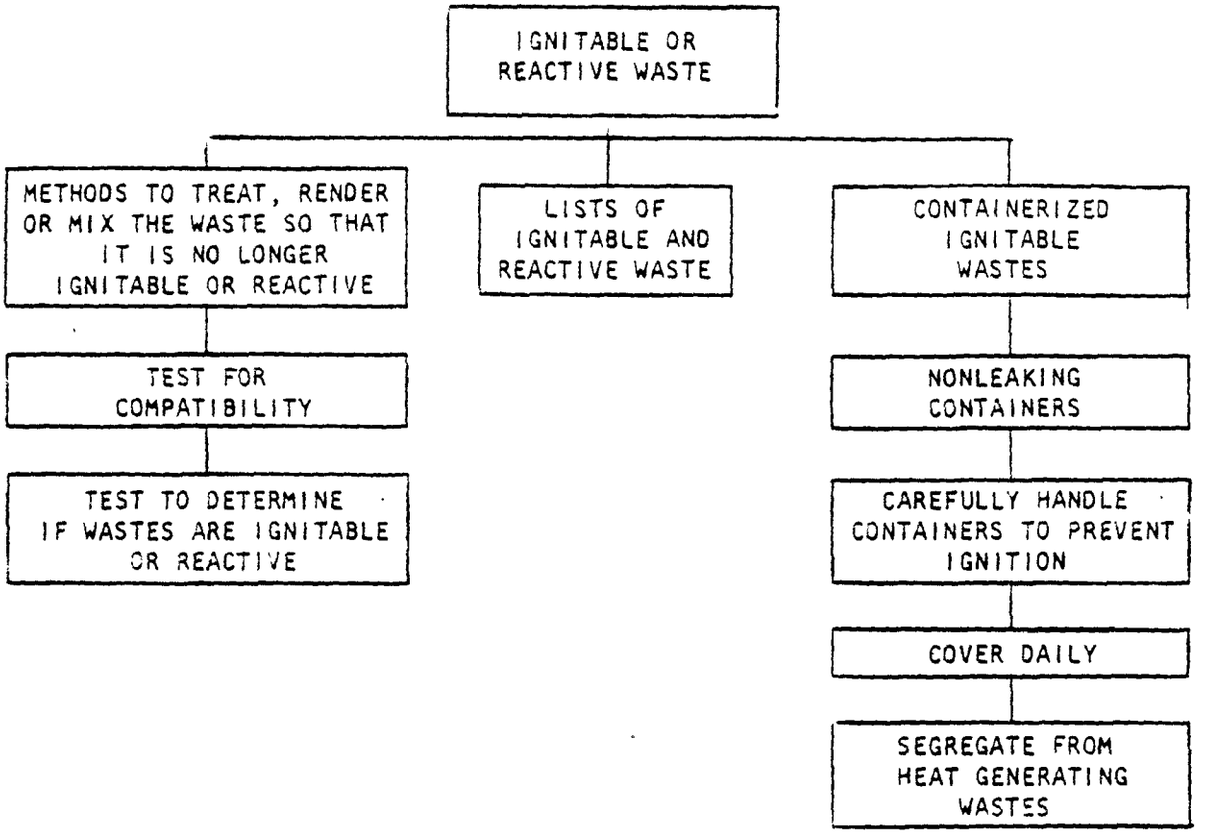

Figure 9.5.2. Flow diagram for evaluating the technical adequacy of the application for disposal of ignitable or reactive waste.

9.5.3.2.1 Lists of Ignitable and Reactive Wastes--In Part 261, Subpart D - Lists of Hazardous Wastes, ignitable wastes are identified by an "(I)" and reactive wastes are identified with an "(R)". Table 9.5.1 lists the hazardous wastes, by EPA Hazardous Waste Number, which are identified in Subpart D as being ignitable. Table 9.5.2 lists the hazardous wastes, by EPA Hazardous Waste Number, which are identified in Subpart D as being reactive. At a minimum, if the applicant indicates that any of these wastes will be disposed in a landfill, he must document how compliance with §264.312 will be achieved.

The permit reviewer should refer to EPA-600/2-80-076, A Method for Determining the Compatibility of Hazardous Wastes (Reference 3), which provides a list of 174 chemicals which are extremely reactive. If these "extremely reactive" compounds are mixed with water or most other compounds, heat may be generated, or toxic and/or flammable gases may be produced. In addition, explosions may occur, or highly unstable mixtures may result.

If the following materials are mixed with water, flammable gas will be generated:

- Metals, such as sodium and potassium
- Nitrides
- Sulfides, Inorganic
- Strong Reducing Agents

Reference 3 also provides a list of materials which are combustible and flammable and a list of materials which are explosive. A worksheet for determining the adequacy of the applicant's information on identification of ignitable and reactive waste is presented in Figure 9.5.3.

9.5.3.2.2 Methods to Treat, Render, or Mix Waste so that it is no longer Ignitable or Reactive--There are a number of methods available to treat, render, or mix wastes so that they are no longer ignitable or reactive. Several treatment processes which previously were only used in the organic or inorganic chemical industry are being considered for broader application in the treatment of hazardous waste. Over 50 processes have been demonstrated to be applicable to hazardous waste treatment, although the technical and economic feasibility of a number of these processes has not been demonstrated on a commercial scale. JRB has identified several of the most promising nonbiological treatment methods along with general information regarding feed stream requirements, output streams, and the current state of technology.[4-9] An overview of these technologies is presented in Table 9.5.3 (after Reference 4). The applicant may propose to employ one or a combination of these methods to treat ignitable or reactive wastes.

The applicant may propose to render ignitable or reactive compounds nonignitable or nonreactive by diluting the waste with other compatible material. However, dilution has the disadvantage that hazardous reactions may result if the mixed materials are incompatible. Dilution with liquids is undesirable because of added liquids in the landfill and greater attendant

TABLE 9.5.1. IGNITABLE WASTES

EPA hazardous waste No.	Hazardous waste
F003	Spent nonhalogenated solvents
F005	Spent nonhalogenated solvents
U001	Acetaldehyde
U112	Acetic acid, ethyl ester
U002	Acetone
U003	Acetonitrile
U008	Acrylic acid
U012	Aniline
U012	Benzenamine
U019	Benzene
U239	Benzene, dimethyl-
U056	Benzene, hexahydro-
U055	Benzene, (1-methylethyl),
U169	Benzene, nitro-
U085	2,2-bioxizane
U031	c-butanol
U159	2-butanone
U074	2-butene, 1,4-dichloro-
U031	n-butyl alcohol
U156	Carbonochloridic acid, methyl ester
U055	Cumnene
U056	Cyclohexane
U057	Cyclohexanone
U074	1,4-dichloro-2-butene
U085	1,2:3,4-diepoxybutane
U092	Dimethylamine
U110	Dipropylamine

(continued)

TABLE 9.5.1 (continued)

EPA hazardous waste No.	Hazardous waste
U001	Ethanol
U008	Ethanenitrile
U117	Ethane, 1,1-oxybis
U112	Ethyl acetate
U113	Ethyl acrylate
U115	Ethylene oxide
U117	Ethyl ether
U125	2-furancarboxaldehyde
U213	Furan, tetrahydro-
U125	Furtural
U124	Furfuran
U140	Isobutyl alcohol
U152	Methacrytonitrile
U092	Methanamide, N-methyl
U045	Methane, chloro-
U153	Methanethiol
U154	Methanol
U154	Methyl alcohol
U186	1-methyl butadiene
U045	Methyl chloride
U156	Methyl chlorocarbonate
U159	Methyl ethyl ketone
U161	Methyl isobutyl ketone
U162	Methyl methacrylate
U161	4-methyl-2-pentanone
U169	Nitrobenzene
U171	2-nitropropane

(continued)

TABLE 9.3.1 (continued)

EPA hazardous waste No.	Hazardous waste
U115	Oxirane
U186	1,3-pentadiene
U194	1-propanamine
U110	1-propanamine
U171	Propane, 2-nitro
U140	1-propanol, 2-methyl-
U002	2-propanone
U152	2-propenenitrile, 2-methyl
U008	2-propenoic acid
U113	2-propenoic acid, ethyl ester
U162	2-propenoic acid, 2-methyl-, methyl ester
U194	n-propylamine
U213	Tetrahydrofuran
U153	Thiomethanol
U239	Xylene

TABLE 9.5.2. REACTIVE WASTES

EPA hazardous waste No.	Hazardous waste
F007	Spent cyanide plating bath solutions ...
F008	Plating bath sludges ...
F009	Spent stripping and cleaning bath solutions ...
F010	Quenching bath sludge ...
F011	Spent cyanide solutions from salt bath ...
K011	Bottom stream from wastewater ... acrylonitrile
K013	Bottom stream from the acetonitrile column ...
K027	Centrifuge and distillation residues from toluene diisocyanate production
K044	Wastewater treatment sludges from the manufacturing and processing of explosives
K045	Spent carbon from the treatment of wastewater containing explosives
K047	Pink/red water from TNT operations
P009	Ammonium picrate
P065	Mercury fulminate
P112	Methane, tetranitro-
P081	Nitroglycerine
P009	Phenol, 2,4,6-trinitro-, ammonium salt
P112	Tetranitromethane
P112	Zinc phosphide

(continued)

TABLE 9.5.2 (continued)

EPA hazardous waste No.	Hazardous waste
U006	Acetyl chloride
U223	Benzene, 1,3-diisocyanatomethyl
U020	Benzenesulfonyl chloride
U023	Benzene, (trichloromethyl)
U024	Benzene, 1,3,5-trinitro-
U023	Benzotrichloride
U160	2-butanone peroxide
U033	Carbon oxyfluoride
U033	Carbonyl fluoride
U133	Examine
U096	Alpha, alpha-dimethylbenzylhydroperoxide
U006	Ethynol chloride
U133	Hydrazine
U086	Hydroperoxide, 1-methyl-1-phenyethyl-
U189	Phosphorous sulfide
U205	Selenium disulfide
U189	Sulfur phosphide
U205	Sulfur selenide
U223	Toluene diisocyanate
U234	Sym-trinitrobenzene

HANDLING AND DISPOSAL OF IGNITABLE OR REACTIVE WASTES

Has this part of the applicant's submittal been read and evaluated?	Yes	No
Did the applicant identify any wastes as being hazardous or reactive?	Yes	No
Are there any additional wastes listed in subsection 9.1 which are ignitable or reactive according to Tables 9.5.1 and 9.5.2?	Yes	No

Figure 9.5.3. Worksheet for evaluating the applicant's submittal on ignitable and reactive waste identification.

TABLE 9.5.3. OVERVIEW OF HAZARDOUS WASTE TREATMENT PROCESSES
Source: Reference 4-9

Process	Description	Feed requirements/preferences	Output streams	Technology status
Carbon Adsorption	Waste stream is contacted with carbon to selectively adsorb hazardous organic materials. When carbon reaches its capacity for adsorption it must be disposed of or regenerated.	• Used for liquid organic or nonmetal anion wastes • More amenable to treatment of compounds with low polarity, and low degree of ionization • Treats organic concentrations of up to about 1% • Oil and grease should be less than 10 ppm.	• 'Purified' stream containing unadsorbed compounds • Carbon which must be thermally regenerated (or disposed of).	• Widely used for treatment of segregated waste streams containing phenols, cyanide wastes, refinery wastes, TNT, toluene, p-chlorobenzene and others.
Distillation	Boiling of liquid solution and condensation of vapor for purposes of separating waste stream components.	• Organic containing slurries and sludges • High organic concentrations, avoid compounds which polymerize or are nonvolatile • Tarry, viscous streams may require pretreatment.	Recovered solvent, still bottoms, sludge.	• Technology well established • Widely used for solvent recovery and fractionation of petroleum compounds
Electrolysis	Process oxidizes or reduces waste components at the surface of conductive electrodes immersed in an electrolyte.	Aqueous solutions containing ~10% metals or nonmetal anions.	Recovered metals, solution with 2 10 ppm metals.	Technology is well established in industry, but application to hazardous waste treatment has been limited; use in electroplating and electrometallurgy.
Hydrolysis	Refers to degradation reactions of the following form. $XY + H_2O \rightarrow HY + XOH$. Generally carried out at elevated temerature and pressure in the presence of a catalyst.	• Treats organic liquid, slurry, sludge or solid wastes • No concentration limit • Hydrolyzable organics include esters, ethers, nitriles, organiphosphorus pesticides, halogenated compounds, amides, etc.	• Hydrolysis products which in some cases are more toxic • High temperature hydrolysis may yield vapor products.	• Process is widely used by organic chemical industry but requires further research for applications to hazardous wastes • Process has been used in pesticide degradation and in treatment of acid sludge from petroleum industry.

(continued)

TABLE 9.5.3 (continued)

Process	Description	Feed requirements/preferences	Output streams	Technology status
Ion Exchange	Interchange of ions between an aqueous solution and a solid material.	• Aqueous solutions of metals, nonmetal anions and water soluble, ionic organics • Concentrations should be less than 2500 ppm (because of regeneration requirements) although concentrations up to 4000 ppm may be acceptable • Sensitive to suspended matter, oxidants, and some organics, especially aromatics.	• Purified product stream • Small, concentrated stream with spent regenerant and high concentrations of pollutant.	Used in several areas of hazardous waste treatment; • Electroplating wastewaters • Metal finishing wastes • "Sour water" condensate from petroleum refining. • Recovery of chromium. • Removal of cyanides.
Liquid Ion Exchange	Involves transfer of waste component into an immiscible organic phase.	• Treats mainly aqueous streams containing free or complexed metal ions, and other inorganic species • Volume of extractants required places a practical upper limit of 10 g/l • Sensitive to oxidants, surfactants, and suspended solids.	Cleaned streams and stripping liquors which contain small amounts of extraction solvent.	Many possible applications in pilot scale stage, some commercial applications. • Metal pickling liquors • Copper recovery from Echants solutions • Removal of zinc and cyanide from electroplating rinsewater.
Liquid/Liquid Organic Extraction	Separation of a liquid from solution by contact with an immiscible liquid.	Aqueous streams low in suspended solids; solute concentration in excess of 10% may make process impractical; favors extraction of hydrophobic compounds.	Purified stream containing low levels of contaminants; solute stream which is usually recycled.	Currently has limited use in treatment of phenols and related compounds, solvent recovery and separation, deoiling of quench water, and acetic acid recovery.
Neutralization	Chemical reaction between an acid and base to obtain a neutral solution.	Usually aqueous streams with strong acid or bases; but also sludges and solids.	Stream of altered pH.	Widely practiced.
Chemical Oxidation	Conversion of a waste to a higher oxidation state for purposes of detoxification.	Low to moderate concentrations of oxidizable materials (few 1000 ppm); nonmetal anion or organic waste liquid slurry, or sludge.	Waste with oxidized compounds and oxidizing agents; waste stream is lower in COD than feed stream.	Current applications for hazardous wastes include. • Oxidation of cyanide in metal finishing wastes • Oxidation of phenol • Oxidation of organic residues of benzidine, aldehydes, mercaptans and unsaturated acids in wastewater.

(continued)

TABLE 9.5.3 (continued)

Process	Description	Feed requirements/preferences	Output streams	Technology status
Precipitation/ Sedimentation	Physiochemical process for removal of precipitable soluble substances and/or suspended particles from solution.	Aqueous or low viscosity non-aqueous solutions of metals, no upper concentration limit.	Metal sulfides, hydroxides or oxides, total dissolved solid concentrations governed by solubility product of precipitates.	Widely used.
Chemical Reduction	Lowering of oxidation state for detoxification.	Low to moderate concentrations of liquid, slurry or sludges (<1%) which can be reduced.	Reduced compounds and reducing agents.	Used or demonstrated in several waste treatment applications: • Reduction of Cr(VI) to Cr(III) • Removal of dissolved lead compounds • Removal of silver, mercury and other metals.
Steam Stripping	A form of fractional distillation used to remove volatile components from aqueous streams.	Dilute liquid or slurry wastes with volatile organics.	Treated stream with traces of organics, and a concentrated vapor or liquid of volatile organics.	Technology is well demonstrated, uses include: • Ammonia stripping from coke oven gas and sour water • Phenol stripping • Stripping of low-molecular-weight chlorinated hydrocarbons is under study.
Ultraviolet/ Ozone Destruction	Oxidation of organics activated with UV radiation by ozone.	Aqueous wastes with low concentrations (<1%) of oxidizable compounds.	Oxidized wastes, often completely mineralized to CO_2.	Known to be effective for PCBs, TCDD, nitrobenzene, hydrazines.
Wet Air Oxidation (Catalyzed)	Catalytic (bromide-nitrate-manganese catalyst) oxidation of organics at elevated temperature and pressure.	Liquid, slurry or sludge containing oxidizable compounds.	Oxidized compounds, some completely mineralized to CO_2; used catalyst.	Although wet air oxidation is fully developed commercially, the catalyzed process is not yet commercial. Demonstrated for PCBs, phenols, a number of halogenated compounds, malethion, nitrobenzene, acetonitrile, etc.

leachate generation. If other than a small quantity of waste requires dilution, an alternative treatment process should be selected to minimize the landfilling of liquids.

The reviewer should consider incineration as an alternative to the disposal of ignitable or reactive wastes. Incineration is particularly applicable to ignitable materials since wastes containing solvents and other organic materials are easily incinerated. Incineration reduces waste volume so that the remaining material will require less space when disposed of at a landfill. Incineration may reduce the potential for groundwater contamination from the ash compared to that associated with disposing of the parent waste.

There are a number of data sources which may assist the reviewer in evaluating an applicant's proposed method of waste treatment, including References 10 through 18 which are listed in subsection 9.5.5. Chapters 8 and 9 of Metry (Reference 10) list an additional 200 references on physical and chemical treatment of hazardous waste.

9.5.3.2.3 Test for Compatibility--Reference 3 (Hatayama et al., EPA-600/2-80-076, April 1980) addresses hazardous waste compatibility and incorporates a hazardous waste compatibility chart (see subsection 9.7 of this manual) which illustrates the compatibility of 41 binary combinations of hazardous chemical wastes. The reason for incompatibility is noted for each combination. Acurex is developing a test kit to assist in categorizing unknown wastes into one of these 41 reactivity groups.[19] Although most applicable to distinguishing and handling otherwise unknown wastes at Superfund sites, the technique may also be of value in managing wastes at RCRA facilities.

9.5.3.2.4 Testing of Ignitable and Reactive Waste--If treatment will be used to render wastes nonignitable or nonreactive and the wastes will then be handled without special consideration for ignitability or reactivity, the applicant must test or document by some other means that the waste is truly no longer ignitable or reactive. If testing is to be employed, the applicant must specify what testing procedures he will use. Available methods to test for ignitability are set forth in §261.21. Two test methods are acceptable for determining the flashpoint: Pensky-Martens Closed Cup Tester using the test method specified in ASTM standard D-93-79 or D-93-80, or a Steaflash Closed Cup Tester, using the test method specified in ASTM Standard D-3278-78. These procedures are documented in Test Methods for Evaluating Solid Waste (SW-846).[2]

To test if a treated waste has the characteristics of reactivity, the applicant should base his demonstration on tests for: water reactivity, flashpoint/flammability, oxidation/reduction potential, pH, and the presence of cyanide or sulfide. The testing procedures employed should conform with the ASTM standards and test methods incorporated in SW-846.[2]

A worksheet for determining the adequacy of he applicant's submittal on ignitable and reactive waste treatment is presented in Figure 9.5.4.

TREATMENT OF IGNITABLE OR REACTIVE WASTES

Are treatment procedures conducted prior to or immediately following placement in the landfill?	Yes	No
Are treatment processes consistent with those described in this subsection and cited references?	Yes	No
During treatment operations, are precautions taken to prevent:		
• Extreme heat or pressure, fire or explosions, or violent reactions?	Yes	No
• Uncontrolled toxic mists, fumes, dusts, or gases?	Yes	No
• Uncontrolled flammable fumes or gases?	Yes	No
• Damage to the structural integrity of the device or facility?	Yes	No
Has the applicant specified a test procedure for ensuring that treated wastes are nonreactive or nonignitable?	Yes	No

Figure 9.5.4. Worksheet for evaluating ignitable and reactive waste treatment procedures.

9.5.3.2.5 Containerized Ignitable Waste--Rather than treat, render, or mix an ignitable waste so that it is no longer ignitable, the applicant may propose to landfill ignitable waste in containers. However, improper handling of ignitable wastes in containers could result in fire or explosion. Containers should be handled with nonsparking tools and equipment. The applicant should specify the safety procedures that will be employed when handling ignitable wastes. When disposing of ignitable wastes in containers, the reviewer must evaluate the application for compliance with §264.314. This standard requires that containers placed in a landfill must be greater than 90 percent full. If such containers are less than 90 percent full and fillers will be used, the permit reviewer should assure that the fillers are nonreactive and request supporting documentation, if necesary. Further discussion of fillers is provided in subsection 9.7 of this manual.

When disposing of ignitable wastes in containers, the reviewer must also evaluate the application for compliance with §264.314(b)(1). This standard requires that "free liquids" be removed prior to placement of containerized waste in a landfill if the landfill is not equipped with a liner and leachate collection and recovery system. The reviewer should refer to Section 8 of this document which discusses methods to remove "free liquids" from containerized waste.

The applicant should specify the types of containers which will be employed to dispose of ignitable or reactive wastes. The containers should be in good condition (e.g., no apparent rusting or structural defects). The permit reviewer may elect to require that all containers meet the container requirements of the Department of Transportation Regulations (Subpart D - Specifications for Metal Barrels, Drums, Kegs, Cases, Trunks, and Boxes).

9.5.3.2.6 Nonleaking Containers--The applicant must demonstrate how he will check to determine that all containers are in good condition. Inspection procedures to be conducted prior to container burial should be documented in the application. If any containers are found to be leaking, the waste must be recontainerized or removed and treated to be rendered nonignitable or nonreactive.

Rather than open a damaged container and transfer the contents to a container in good condition, it may be advisable for the operator to place the damaged container inside an overpacked drum. If a void space exists between the over pack and damaged container, the space should be filled so that the over pack is at least 90 percent full. To fill the void space, the applicant should employ a compatible absorbent material. Subsection 9.7 of this document presents further discussion of applicable fillers and absorbents.

9.5.3.2.7 Carefully Handle Containers to Prevent Ignition--The applicant must specify container handling methods to avoid heat, sparks, rupture, or any other condition that might cause ignition of the waste. The applicant should specify the types of container handling equipment and tools that will be employed. All tools and equipment should be constructed of nonsparking materials. For proper placement of the containers in the landfill, it is recommended that a tractor barrel grappler be employed. Such equipment allows

the operator to accurately place the container in the landfill while causing a minimal amount of damage to the container (a certain extent of container denting is allowable providing that the structural integrity if not impaired). Tractor barrel grappler equipment has the added advantage of providing some distance between the operator and container.

If containers holding ignitable waste must be opened, nonsparking remote container opening equipment should be employed. The applicant should specify what measures will be taken if a container is in bad condition or begins to leak during container handling. The best procedure is to have ready access to compatible absorbent materials for control of spills. Empty containers should also be available.

9.5.3.2.8 Daily Cover of Ignitable Waste--Containerized ignitable waste placed in a landfill must be covered daily with soil or other noncombustible material (§264.312(b)) to minimize the potential for ignition of the waste. The applicant should clearly state the type of cover material to be employed and the thickness of the applied daily cover. The depth of daily cover required is dependent on the type of cover material employed. For example, for a given depth, fine grained clayey soil will seal off disposed waste more effectively than a coarse grained gravely soil. If a soil cover material is employed, six inches is generally a sufficient depth of cover. A manufacturer of a foam cover material claims that 2 inches of their foam product is equivalent to six inches of soil cover.[20] Use of such foams, however, must be carefully considered from the standpoint of compatibility with waste materials.

9.5.3.2.9 Segregate Containerized Ignitable Waste from Other Wastes which May Generate Heat--The applicant is required to demonstrate that containerized ignitable wastes will not be disposed of in cells that contain or will contain other wastes which may generate heat sufficient to cause ignition of the waste. In general, ignitable wastes will have to be segregated from wastes which may be subject to microbrial degradation or wastes which will react with water and cause an exothermic reaction. Either of these waste types may produce sufficient heat to cause ignition of certain wastes. Waste material which may generate heat due to microbrial degradation would generally have a high organic content. This may preclude the co-disposal of waste material high in organic content such as solvents, oil sludges, municipal waste and various wastes from the organic chemical manufacturing industry.

If an applicant proposes to place an ignitable waste in the same cell with another waste type, it must be determined whether this other waste type may react exothermically with water and generate sufficient heat to cause ignition. However, wastes which are reactive with water should not be disposed of in the landfill. Section 264.312 requires that any reactive waste be treated, rendered or mixed before or immediately after placement in a landfill so that the resulting waste, mixture or dissolution of material no longer meets the definition of ignitable of reactive waste under §261.21 or §261.23. Nonetheless, the reviewer should check to be certain that any wastes which are to be co-disposed with an ignitable waste are nonreactive. In Part 261, Subpart D - Lists of Hazardous Wastes, those wastes which are reactive are designated by an "(R)" hazard code. Also, any waste which has an

EPA hazardous waste number of D003 exhibits the characteristics of reactivity. The reviewer should cross-check those wastes which will be co-disposed with an ignitable waste with the wastes in the Subpart D list which are reactive (listed in Table 9.5.2 of this section). However, not all of the waste in the Subpart D list which are designated to be reactive, will react exothermically with water. A waste is reactive if it exhibits any of the eight properties listed in §261.23.

A worksheet for determining the adequacy of the applicants submittal on ignitable wastes disposed of in containers is presented in Figure 9.5.5.

9.5.4 Draft Permit Preparation

As noted in Module XV, Condition F, the permit must specify how the facility will handle ignitable and reactive wastes. The condition is implemented through reference to a permit attachment. To be suitable for substitution in the permit condition attachment, the submitted application should address the following two options, where applicable:

- Option 1--A description of proposed methods for treating ignitable or reactive waste before or immediately after placement in the landfill. Field and laboratory test results illustrating that the wastes will be rendered nonreactive and nonignitable and a description of precautions used to prevent dangerous reactions should be provided.

- Option 2--(Applicable only to containerized ignitable wastes)-- A description of how the containerized ignitable wastes will be managed and protected from materials or conditions that could cause them to ignite.

If the permit applicant does not adequately address disposal procedures for reactive or ignitable wastes, the permit writer should either write specific conditions to implement this provision or should indicate a condition that prohibits the disposal of reactive or ignitable wastes.

9.5.5 References

1. U.S. Environmental Protection Agency. Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Volume I. Office of Solid Waste. Washington, D.C. 1983.

2. U.S. Environmental Protection Agency. Test Methods for Evaluating Solid Waste. Second Edition. SW-846. July 1982.

3. Hatayama, et. al., A Method for Determining the Compatability of Hazardous Wastes. EPA-600/2-80-076, 1980.

4. JRB Associates, Inc., Techniques for Evaluating Environmental Processes Associated with the Land Disposal of Specific Hazardous Materials, Volume I: Fundamentals. EPA Contract No. 68-01-5052, March 31, 1982.

HANDLING AND DISPOSAL OF IGNITABLE OR REACTIVE WASTES

Are inspection procedures adequate to ensure that containers are in good condition prior to burial?	Yes	No
Are acceptable procedures presented for dealing with leaking containers?	Yes	No
Are container handling procedures and equipment designs adequate to avoid heat, sparks, ruptures, and ignition of the waste?	Yes	No
Did the applicant document the characteristics and depth of the daily cover material?	Yes	No
Are containerized ignitable wastes segregated from wastes which could generate heat?	Yes	No

Figure 9.5.5. Worksheet for evaluating disposal procedures for containerized ignitable wastes.

5. DeRenzo, D. J. Unit Operations for Treatment of Hazardous Industrial Wastes. Noyes Data Corp. 1978.

6. Schalit, L. and G. Staples. Fostering Industrial Innovative Technology to Attain Agency Goals: Technological Opportunities, Volume II, Prepared for Office of Research and Development, U.S. Environmental Protection Agency. Science Applications, Inc., (SAI-0/2-80-523-LJ). 1980.

7. Pytlewski, L. L., et al. The Reaction of PCBs with Sodium, Oxygen, and Polyethylene Glycol. In: Proceedings of the Sixth Annual Research Symposium on Treatment of Hazardous Wastes, March 17-20, 1980. Chicago, Illinois. U.S. EPA--Municipal Environmental Research Laboratory. EPA-600/9-80-011.

8. Edward, B. H., et al. Emerging Technologies for the Destruction of Hazardous Waste. Ultraviolet/Ozone Destruction. In: Proceedings of the Seventh Annual Research Symposium on Land Disposal of Hazardous Wastes. Philadelphia. U.S. EPA--Municipal Environmental Research Laboratory. (EPA-600/9-81-002b). 1981.

9. Miller, R. A., et al. Evaluation of Catalytic Wet Oxidation for Treatment of Hazardous Wastes. In: Proceedings of Seventh Annual Research Symposium on Land Disposal of Hazardous Wastes. Philadelphia. U.S. EPA--Municipal Environmental Research Laboratory. (EPA-600/9-81-002b). 1981.

10. Metry, Amir, A., The Handbook of Hazardous Waste Management. Technomic Publishing Company, Inc., Westport, CT., 1980.

11. TRW Systems, Inc. Recommended Methods of Reduction, Neutralization, Recovery, or Disposal of Hazardous Waste. Volume I-XVI. U.S. Environmental Protection Agency, Washington, D.C., 1973.

12. EPA-600/2-82-001c, Treatability Manual. Volumes I-IV. U.S. Environmental Protection Agency, Washington, D.C., Sept. 1981.

13. Battelle Memorial Institute. Program for the Management of Hazardous Waste. Volumes 1 and 2. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Washington, D.C., 1974.

14. Booz-Allen Applied Research, Inc. A Study of Hazardous Effects and Disposal Methods. U.S. Environmental Protection Agency. Cincinnati, OH, 1972.

15. Bretherick, L., Handbook of Reactive Chemical Hazards. CRL Press, Inc., Cleveland, OH, 1975.

16. Fire Protection Guide on Hazardous Materials. Sixth Edition. National Fire Protection Association, Boston, Massachusetts, 1975.

17. Nemerow, N.L., Liquid Waste of Industry: Theories, Practice, and Treatment. Addison-Wesley Publishing Co., Reading, MA. 1972.

18. Toxic and Hazardous Industrial Chemicals Safety Manual for Handling and Disposal, with Toxicity and Hazard Data. The International Technical Information Institute, Torahomon-Tachikawa Bldg. 6-5, 1 Chome, Nishi-Shimbashi, Minato-KW, Tokyo, Japan, 1975.

19. Wolbach, C. D., U. Spannagel, and R. Whitney. Field Scheme for Determination of Waste Reactivity Groups. Prepared by Acurex Corporation for the U.S. Environmental Protection Agency. Presented in the Proceedings of the Ninth Annual Research Symposium--Land Disposal, Incineration, and Treatment of Hazardous Waste. Fort Mitchell, Kentucky. May 1983.

20. Sanifoam, Inc.. Product Information, 1370 Logan Avenue, Suite D, Costa Mesa, California, 92626, (714) 557-5070.

9.6 SPECIAL REQUIREMENTS FOR INCOMPATIBLE WASTES

9.6.1 The Federal Requirement

The information requirements of §270.21(g) specify that:

> "If incompatible wastes, or incompatible wastes and materials will be landfilled, an explanation of how §264.313 will be complied with [must be submitted]."

Special requirements for incompatible wastes are specified in §264.313, stating that:

> "Incompatible wastes, or incompatible wastes and materials, (see Appendix V of this part for examples) must not be placed in the same landfill cell, unless §264.17(b) is complied with."

The referenced requirements of §264.17(b) are:

> "Where specifically required by other Sections of this Part, the owner or operator of a facility that treats, stores or disposes ignitable or reactive waste, or mixes incompatible waste or incompatible wastes and other materials, must take precautions to prevent reactions which:
> (1) Generate extreme heat or pressure, fire or explosions, or violent reactions;
> (2) Produce uncontrolled toxic mists, fumes, dusts, or gases in sufficient quantities to threaten human health or the environment;
> (3) Produce uncontrolled flammable fumes or gases in sufficient quantities to pose a risk of fire or explosions;
> (4) Damage the structural integrity of the device or facility;
> (5) Through other like means threaten human health or the environment."

9.6.2 Summary of Necessary Application Information

The Part B Permit Applicants' Manual[1] instructs the applicant to submit documentation including detailed plans, engineering reports, and operating plans showing that the standards of §264.313 or §264.17(b) will be complied with. The documentation may include published literature, trial tests, waste analyses, or results from past experience.

9.6.3 Guidance on Evaluating Application Information

9.6.3.1 Regulatory Applicability and Intent--

Figure 9.6.1 summarizes the regulations applicable to handling and disposal of incompatible wastes at landfills.

Compliance with the provisions of §264.313 requires the owner/operator to indicate in the permit application the specific steps that will be undertaken to identify incompatible wastes and insure segregation of those wastes when landfilled. The intent of §264.313 is discussed in the preambles of several Federal Register notices, as listed below:

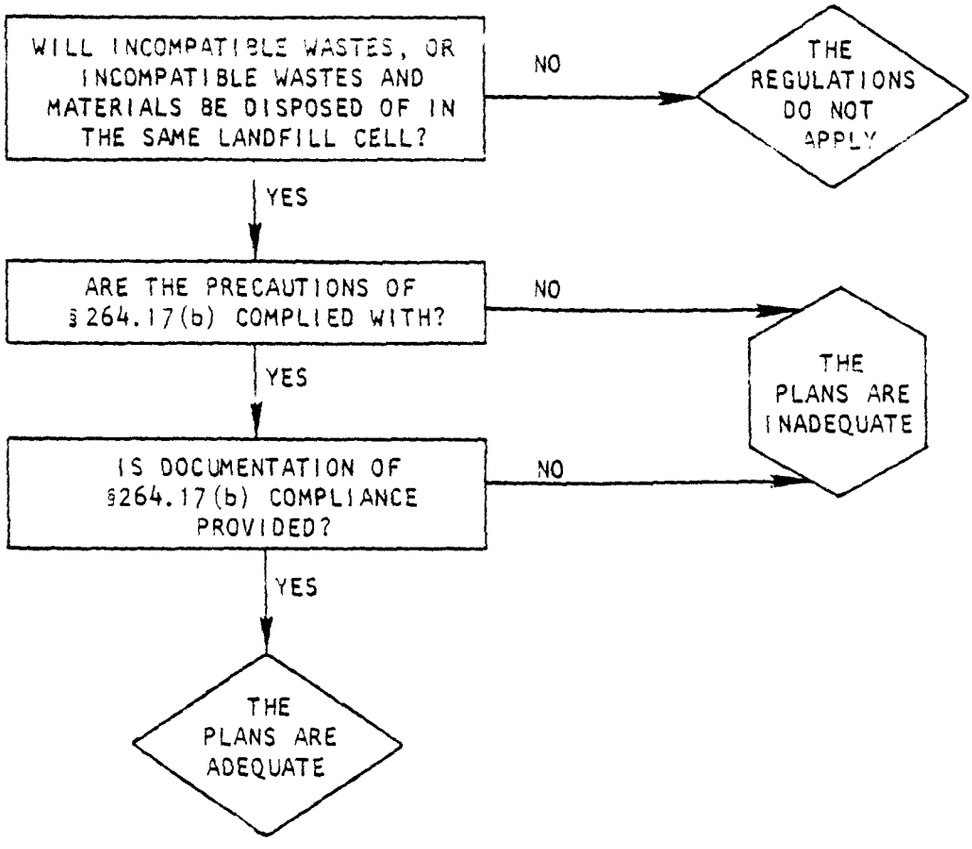

Figure 9.6.1. Regulations applicable to handling and disposal of incompatible wastes at landfills.

Federal Register Notice Date	Page	Vol.	Section Affected
19 May 1980	33162	45	§265.17
19 May 1980	33182	45	§265.17
19 May 1980	33213	45	§265.313 and Appendix V
12 Jan 1981	2809	46	§264.17 and Appendix V
5 Feb 1981	11148	46	§264.313
26 July 1982	32233	47	§264.313

Reference is made above to pertinent preamble discussions in Part 265 to address regulations for incompatible wastes applicable to interim status facilities.

There is no characteristic of incompatibility in 40 CFR Part 261. Rather, Appendix V of Part 264 presents examples of potentially incompatible wastes. A definition of incompatible wastes is provided in §260.10 of Subpart B of Part 260. Technical references are also available that identify incompatible waste combinations, as discussed in the following subsections.

9.6.3.1.1 Will incompatible wastes, or incompatible wastes and materials be disposed of in the same landfill cell?--It is the responsibility of the landfill owner or operator to identify whether or not wastes are compatible. For most commercial landfills, the number of different wastes received will undoubtedly result in cases of incompatibility. For onsite landfills operated by the waste generator or landfills receiving only a small number of different wastes, it may be possible for the applicant to document in the permit application that all wastes are compatible. If it is shown that all wastes are compatible with each other and with other materials in the landfill, the permit application is adequate.

Based on a literal interpretation of the regulations, only a waste that has already been identified as a hazardous waste can be further identified as an incompatible waste. The §260.10 definition states that an incompatible waste "means a hazardous waste which..." and Appendix V of Part 264 states "Many hazardous wastesd, when mixed with...". However, the intent of the regulations is to avoid combination of incompatible wastes whether they are initially hazardous or nonhazardous. Therefore, all wastes must be considered.

9.6.3.1.2 Are the precautions of §264.17(b) complied with?--There are circumstances under which incompatible wastes could be disposed of in the same landfill cell. As an example, the permit applicant could propose to place incompatible wastes far apart from each other in the same cell and place wastes or materials which are mutually compatible with those wastes between them. If the applicant can show, to the permit reviewer's satisfaction, that

this approach is a precaution that will "prevent reactions which...threaten human health or the environment," then it could be judged to adequately comply with the intent of §264.17(b).

9.6.3.1.3 Is documentation provided to demonstrate compliance with §264.17(b)?--Documentation is required by §264.17(c) to show that the precautions of §264.17(b) will be effective, as noted below:

> "When required to comply with paragraphs (a) or (b) of this Section, the owner or operator must document that compliance. This documentation may be based on references to published scientific or engineering literature, data from trial tests (e.g., bench scale or pilot scale tests), waste analyses (as specified in §264.13), or the results of the treatment of similar wastes by similar treatment processes and under similar operating conditions."

The owner or operator of the landfill must supply documentation that the procedures employed will allow incompatible wastes to be disposed of safely in the same landfill cell. The permit application is deficient if the required documentation is not submitted or if it is judged to be inadequate. If the application indicates that incompatible wastes will not be disposed of in the same landfill cell, then procedures to insure this must be stated. Also, if an application indicates that a waste will be treated so that it is no longer incompatible when disposed of, documentation is required to show that the process is effective and will result in compliance with §264.17(b).

9.6.3.2 Evaluation of the Technical Adequacy of the Applicant's Submittal--

9.6.3.2.1 Introduction--To augment the information on incompatible wastes presented in Appendix V of Part 264, the permit application reviewer should reference two additional technical reports to determine if the applicant has correctly investigated the compatibility of the wastes to be handled. These documents are identified below, and a brief description of the contents of each is provided.

A Method for Determining the Compatibility of Hazardous Wastes (EPA-600/2-80-076, April 1980)[2] was prepared for the EPA's Municipal Environmental Research Laboratory by researchers at the California Department of Health Services. The abstract of the report states;

> "This report describes a method for determining the compatibility of binary combinations of hazardous wastes. The method consists of two main parts, namely: (1) the step-by-step compatibility analysis procedures, and (2) the hazardous wastes compatibility chart. The key element in the use of the method is the compatibility chart. Wastes to be combined are first subjected through the compatibility procedures for identification and classification, and the chart is used to predict the compatibility of the wastes on mixing.

The chart consists of 41 reactivity groups of hazardous wastes designated by Reactivity Group Numbers (RGN). The RGN are displayed in binary combinations on the chart, and the compatibility of the combinations are designated by Reaction Codes (RC).

The method is applicable to four categories of wastes based on available compositional information: (1) compositions known specifically, (2) compositions known nonspecifically by chemical classes or reactivities, (3) compositions known nonspecifically by common or generic names of wastes, (4) compositions unknown requiring chemical analysis."

The report cites 79 references and incorporates 5 appendices which provide a significant amount of additional data on the compatibility of various chemicals wastes.

Reference 3, Techniques for Evaluating Environmental Processes Associated with Land Disposal of Specific Hazardous Materials, Volume II, Incompatible Wastes, March 31, 1982, was prepared for the EPA Office of Solid Waste by JRB Associates, Inc., McLean, Virginia. This document discusses processes that enhance pollutant migration potential through the liquid phase in soils. Three general processes were identified, including;

- direct solubility effects between waste constituents
- chemical reactions between waste constituents which generate reaction products which are more mobile than the original waste constituents
- processes whereby waste interactions with the environment decrease the soil's ability to attenuate pollutant migration.

Eighteen additional references are cited in the report.

9.6.3.2.2 Hazardous Waste Compatibility--Because many types of hazardous wastes are extremely reactive, the compatibility of hazardous wastes to be combined must be thoroughly evaluated. Combining wastes which are incompatible may result in:[3] (1) heat generation, (2) fire, (3) toxic gases, such as HCN or H_2S, (4) flammable gases, such as H_2 or C_2H_2, (5) innocuous gases, such as N_2 or CO_2, which can cause container pressurization, (6) explosion due to extremely vigorous reactions or reactions producing enough heat to denotate unstable reactants or reaction products, (7) violent polymerization resulting in generation of extreme heat and flammable gases, and (8) solubilization of toxic substances including metals. Therefore, the applicant must identify the methods he will employ for estimating the potential consequences of mixing different classes of wastes.

Insufficient or inaccurate information about a waste or wastes is the primary cause of inadvertently combining incompatible wastes. Regardless of efforts to adequately characterize wastes via the waste analysis plan, properties of some wastes may change with time and temperature, thereby producing more or different hazardous components.[3]

A second cause of accidents is indiscriminate handling of waste which might encompass the following:

- Containers which are supposedly empty may contain incompatible residual wastes.
- Haulers may "top off" their load on the way to the disposal site.
- Rough handling could cause container rupture or leakage that might result in commingling of otherwise segregated incompatible wastes.
- Indiscriminate disposal of containerized incompatible wastes in the same cell could result in mixing of incompatible wastes if containers corrode and leak.

9.6.3.2.3 Determination of the Compatibility of Hazardous Wastes--As mentioned earlier, A Method for Determining the Compatibility of Hazardous Wastes (EPA-600/2-80-076)[4] is a valuable resource document for determining the compatibility of binary waste combinations. The method provided in this report consists of two main parts: (1) stepwise compatibility analysis procedures, and (2) use of a hazardous waste compatibility chart. Wastes under consideration are first identified and classified and then the compatibility chart is used to assess the compatibility of the wastes upon mixing. The remainder of this section provides background information for employing EPA-600/2-80-076. The five general steps necessary to determine the compatibility of two waste types are summarized below. Discussion of implementation of these steps is as reported in Reference 4 by Hatayama, et al. (EPA-600/9-80-010, March 1980). Figure 9.6.2 summarizes the steps to be taken to determine hazardous waste compatibility.

Step 1: Waste Characterization

The first step in determining the compatibility of two different waste types is to accurately characterize the wastes. The applicant should provide as much information as possible about waste composition to illustrate compliance with §264.13 (Waste Analysis Plan) and as part of the list of hazardous wastes incorporated in the application (§270.21(a)).

Step 2:* List Name of Compounds or Classes of Compounds or Generic Name of Waste

"Starting with one waste, Waste A, list the names of or the classes of compounds found in the wastes, or list its generic name on the vertical axis of the Worksheet for Determination of Hazardous Waste Compatibility (Figure 9.6.3). The compositon of a waste is Known Specifically when the constituents are listed by chemical names such as ethylene glycol, sodium nitrate, etc. The composition is Known Nonspecifically by Classes when the constituents are identified only by chemical classes or reactivities such as alcohols, caustics, mercaptans, etc. The composition is Known Nonspecifically by Generic Name when the waste is classified as spent caustic, tanning sludge, copper plating waste, etc."

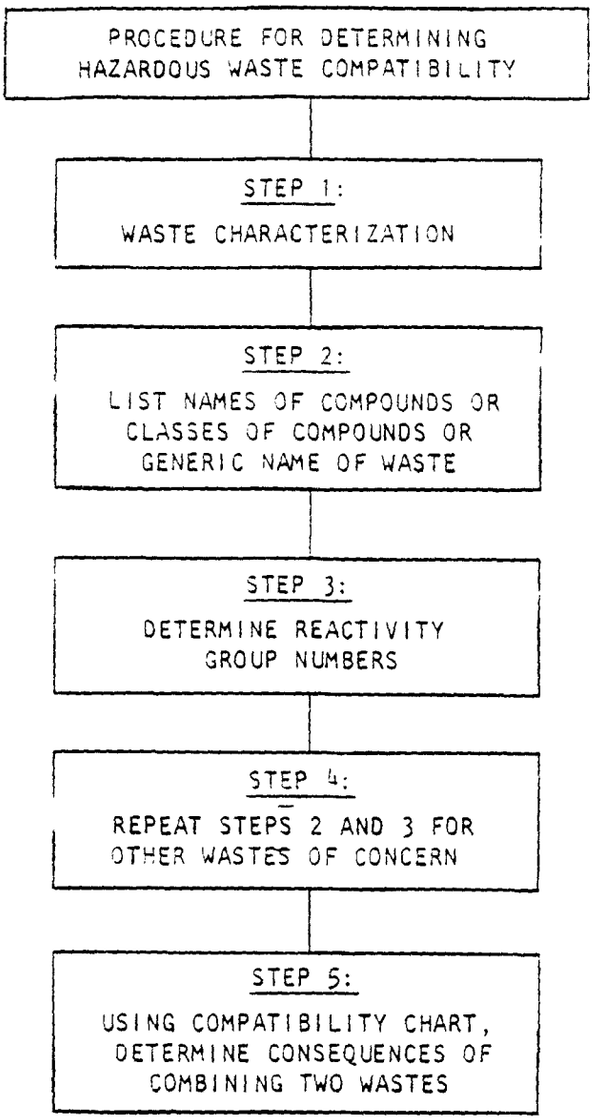

Figure 9.6.2. Flow diagram for assessing the compatibility of hazardous wastes using procedures specified in EPA-600/2-80-076.[2]

Waste A _____ Source _____

Waste B _____ Source _____

Name of Waste Evaluation _____ Date _____

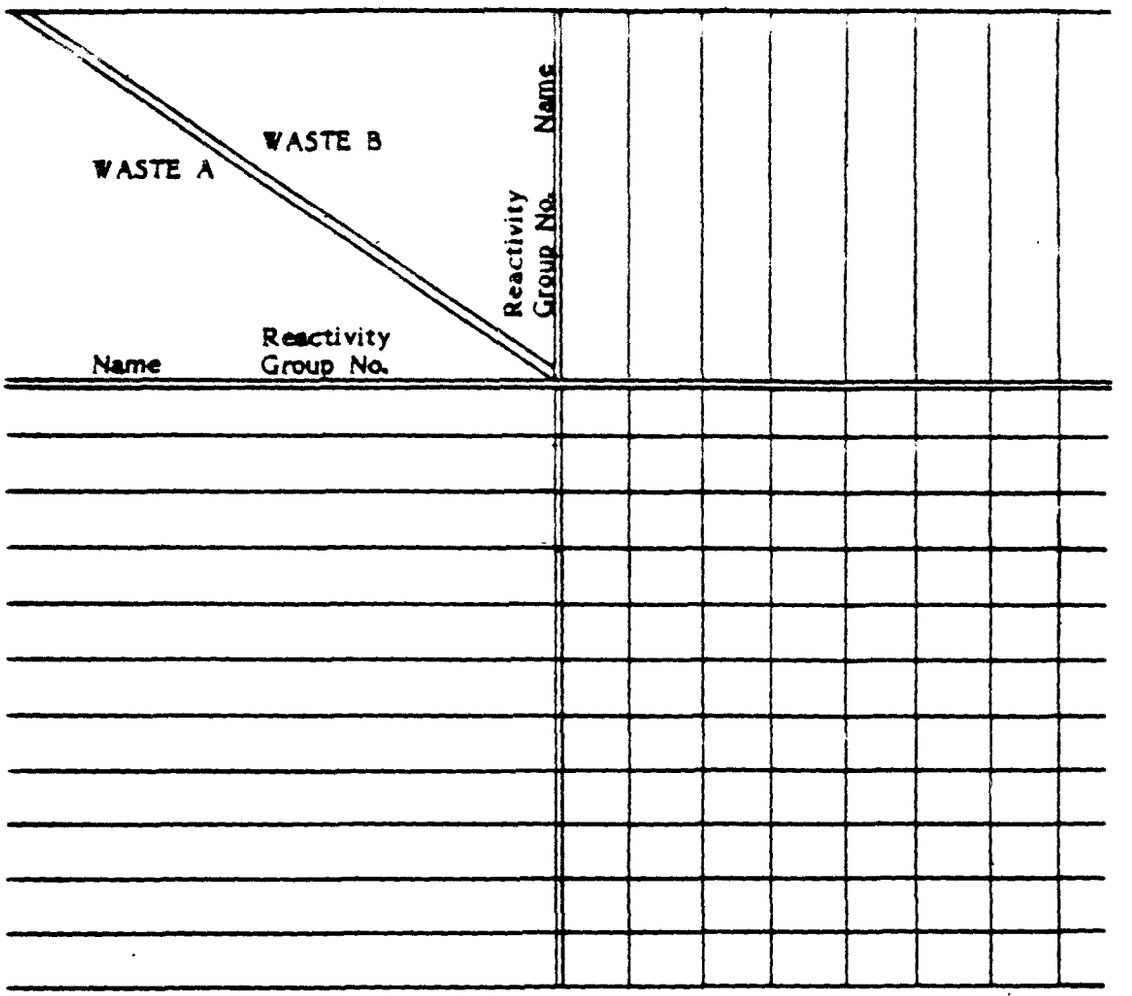

Figure 9.6.3. Worksheet for determination of hazardous waste compatibility.

Source: Reference 2.

Step 3:* Determine Reactivity Group Numbers

"When the composition of Waste A is Known Specifically by chemical names, consult the List of Chemical Names [in Appendix I of Reference 1] to obtain the Reactivity Group Number (RGN) for each chemical constituent. These RGNs are then noted on the Worksheet. If a compound is not on the list, a synonym can be found in various chemical references (Merck,[5] Hawley,[6]). When a suitable synonym cannot be found, the RGN of the component may alternatively be determined based on its chemical class or reactivity.

When the composition of the waste is Known Specifically by Classes, consult the List of Waste Constituents by Chemical Class and Reactivity [in Appendix II of Reference 1] to determine the corresponding RGN.

When the composition of the waste is Known Nonspecifically by Generic Name, go to the Industry Index and List of Generic Names of Wastes [in Appendix III of Reference 1] to obtain the corresponding RGN and note it on the worksheet."

Step 4:* Repeat Steps 2 and 3 for Other Waste(s) of Concern

"Repeat Steps 2 and 3 for the second waste, Waste B, and note the information on the horizontal axis of the Worksheet."

Step 5:* Using Compatibility Chart, Determine Consequences of Combining Two Wastes

"Consult the Hazardous Waste Compatibility Chart (Figure 9.6.4) and note the Reaction Codes (RC) between all binary combinations of RGN of Waste A and Waste B. If any RC corresponds to any binary combination of RGN between Wastes A and B, then Wastes A and B are incompatible and should not be mixed.

9.6.3.2.4 Limitations of the Method--Although this procedure should provide a useful aid in determining the compatibility of hazardous waste, the method must be used with caution because there are numerous factors which will influence waste component reactions. Among these are temperature, catalytic effects of dissolved or particulate metals, soil reactions, and reactions between the waste and surfaces it may be in contact with.[3] Consequently, the permit reviewer may elect to require the applicant to perform laboratory compatibility analysis prior to actual co-disposal of wastes. Acurex is currently developing a field test kit[7] for categorizing unknown wastes into the reactivity groups noted in Figure 9.6.4. The incorporated test procedures could be applicable in identifying the compatibility of poorly characterized wastes.

A worksheet for determining the adequacy of the applicant's submittal on incompatible wastes is presented in Figure 9.6.5.

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*Quoted from Hatayama, H. K., et al. EPA-600/9-80-010, March 1980. (Reference 4).

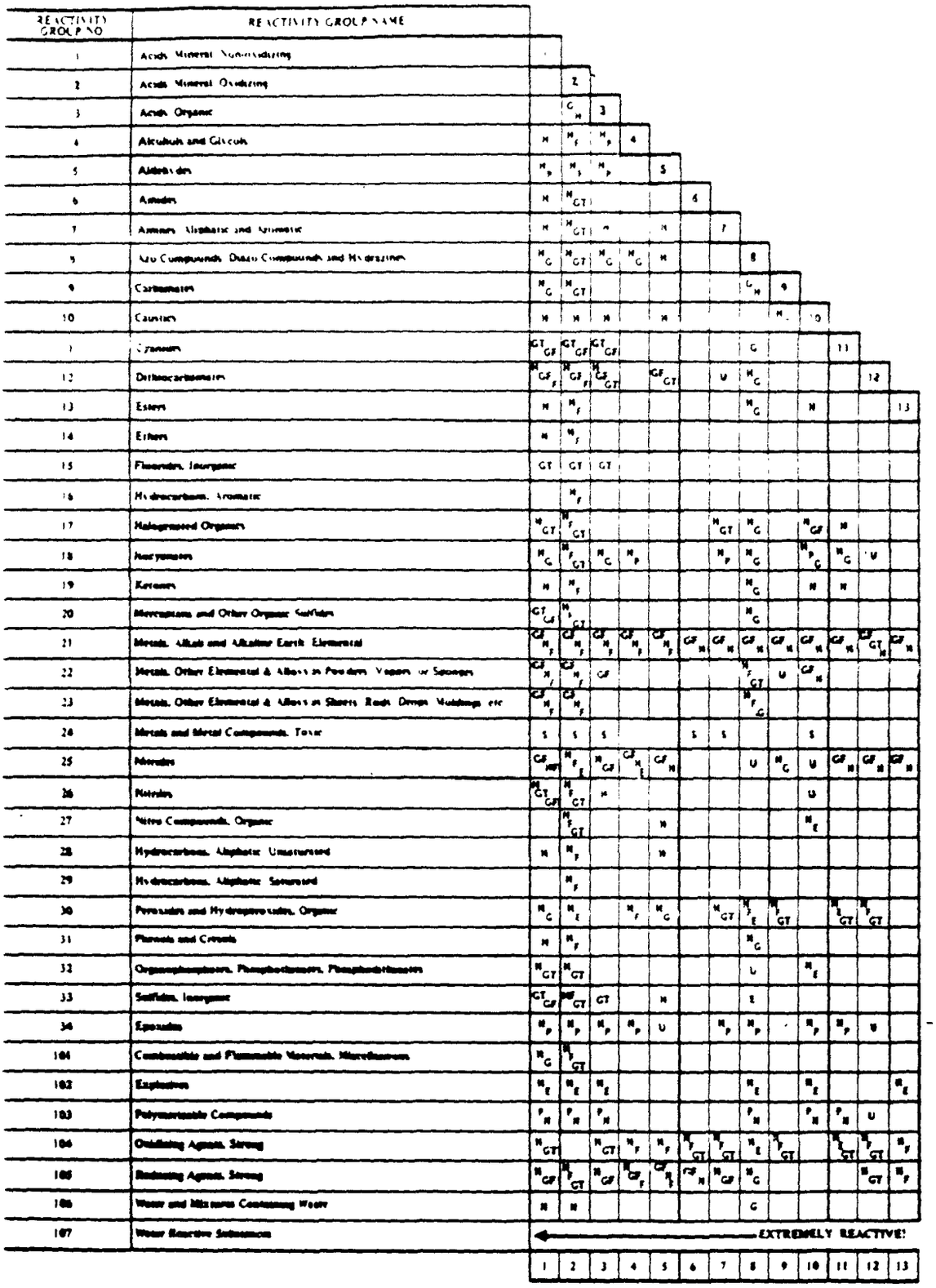

Figure 9.6.4. Hazardous waste compatibility chart.

Source: Reference 2.

REACTIVITY CODE	CONSEQUENCES
H	Heat generation
F	Fire
G	Innocuous and non-flammable gas generation
GT	Toxic gas generation
GF	Flammable gas generation
E	Explosion
P	Violent polymerization
S	Solubilization of toxic substances
U	May be hazardous but unknown

Example:

$H_{F_{GT}}$	Heat generation, fire, and toxic gas generation

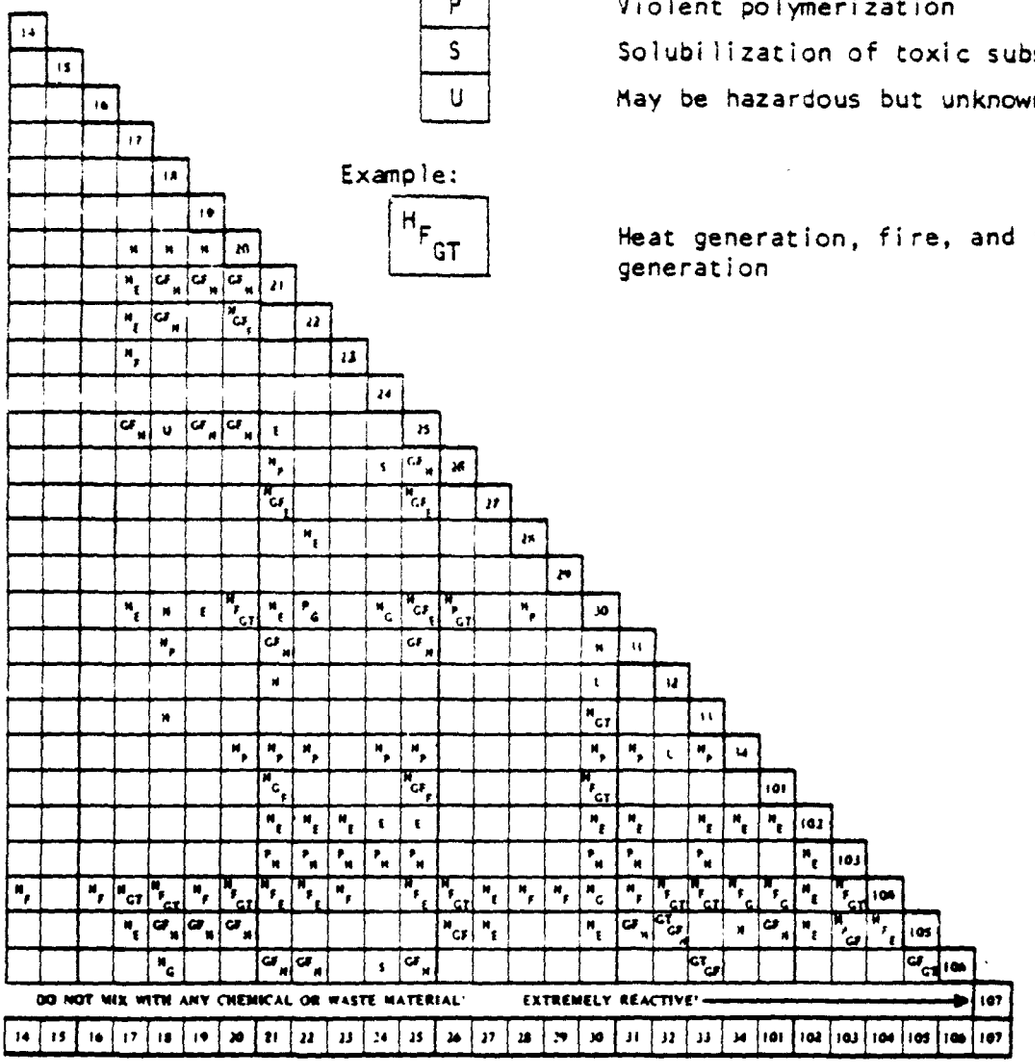

Figure 9.6.4 (continued)

SPECIAL REQUIREMENTS FOR INCOMPATIBLE WASTES

Has this part of the applicant's submittal been read and evaluated?	Yes	No
Have acceptable procedures been used to accurately characterize the wastes?	Yes	No
Were wastes properly categorized by reactivity group numbers?	Yes	No
Was waste compatibility identified using the Reference 2 compatibility chart or other acceptable means?	Yes	No
Does the information submitted on waste compatibility include all wastes identified in Section 9.1?	Yes	No
If incompatible wastes are disposed in the same cell, are adequate measures taken to segregate wastes?	Yes	No
Did the applicant address the compatibility of container residues and leakage from damaged containers?	Yes	No

Figure 9.6.5. Worksheet for evaluating disposal procedures for incompatible wastes.

9.6.4 Draft Permit Preparation

Condition G of Permit Module XV addresses disposal requirements for incompatible wastes. The condition is implemented through reference to a permit attachment that specifies handling procedures for incompatible wastes. To be suitable for substitution in the permit condition attachment, the submitted application information should include detailed plans, engineering reports, and operating plans to document compliance with the regulations. Documentation on handling of incompatible wastes during operation should be placed in the operating record (see Module II, Condition L.1). If the permit applicant does not specify methods for handling incompatible wastes, the permit writer should either specify conditions under which they may be accepted or should write in a condition prohibiting the acceptance of incomatible wastes.

9.6.5 References

1. U.S. EPA. Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Volume I. Office of Solid Waste. Wasnington, D.C. 1983.

2. Hatayama, H. K., et al., A Method for Determining the Compatibility of Hazardous Wastes. EPA-600/2-80-076, April 1980.

3. JRB Associates, Inc. Techniques for Evaluating Environmental Processes Associated with Land Disposal of Specific Hazardous Materials, Volume II, Incompatible Wastes. Prepared for the U.S. EPA Office of Solid Waste. March 31 1982.

4. Hatayama, H. K., et al., Hazardous Waste Compatibility. Presented in Disposal of Hazardous Waste, Proceedings of the Sixth Annual Research Symposium. EPA-600/9-80-010, March 1980.

5. Merck and Company, Inc. 1976. The Merck Index. 9th Edition, Rahway, NJ.

6. Hawley, G. G. 1971. The Condensed Chemical Dictionary. 8th Edition. Van Nostrand Reinhold Company, New York, Cincinnati, Toronto, London, Melbourne.

7. Wolbach, C. D., U. Spannagel, and R. Whitney. Field Scheme for Determination of Waste Reactivity Groups. Prepared by Acurex Corporation for the U.S. Environmental Protection Agency. Presented in the Proceedings of the Ninth Annual Research Symposium--Land Disposal, Incineration, and Treatment of Hazardous Wastes. Fort Mitchell, Kentucky. May 1983.

9.7 DISPOSAL OF LIQUID WASTE IN LANDFILLS

9.7.1 The Federal Requirement

Paragraph (h) of §270.21 requires the following:

"If bulk or noncontainerized liquid waste or wastes containing free liquids is to be landfilled, an explanation of how the requirements of §264.314 will be complied with [must be submitted]."

The referenced Part 264 standard states the following:

"§264.314 Special requirements for liquid waste.

(a) Bulk or noncontainerized liquid waste or waste containing free liquids must not be placed in a landfill unless:

(1) The landfill has a liner and leachate collection and removal system that meet the requirements of §264.301(a); or

(2) Before disposal, the liquid waste or waste containing free liquids is treated or stabilized, chemically or physically (e.g., by mixing with an absorbent solid), so that free liquids are no longer present.

(b) Containers holding free liquids must not be placed in a landfill unless:

(1) All free-standing liquid: (i) has been removed by decanting, or other methods; (ii) has been mixed with absorbent or solidified so that free-standing liquid is no longer observed; or (iii) has been otherwise eliminated; or

(2) the container is very small, such as an ampule; or

(3) The container is designed to hold free liquids for use other than storage, such as a battery or capacitor; or

(4) The container is a lab pack as defined in §264.316 and is disposed of in accordance with §264.316."

9.7.2 Summary of Necessary Application Information

The Part B Permit Applicants' Manual[1] instructs the applicant to explain how he plans to comply with the standards of §264.314 if the facility will accept liquid wastes or wastes containing free liquids. If the facility accepts bulk or noncontainerized liquid waste or waste containing free liquids, the applicant must present:

- documentation to demonstrate the adequacy of the landfill liner and leachate collection system, or
- proposed methods of chemically or physically treating or stabilizing liquid wastes to eliminate free liquids before disposal in the landfill.

Section 9.2 of this manual presents guidance on evaluating the adequacy of the proposed liner and leachate collection system.

If the owner/operator will accept containers holding free liquids and these containers are not ampules or similarly small containers; batteries, capacitors, or similar containers; or lab packs; then he must provide the following information:

- proposed methods for decanting or otherwise removing free standing liquids from the container before disposal, or
- proposed absorbents to be added to the container, or
- proposed methods of solidifying the free standing liquids in the container, or
- other proposed methods of eliminating free standing liquids.

If ampules, batteries, capacitors, or similar containers are the only types that will be accepted, the owner/operator should indicate expected quantities, types, and proposed disposition. If lab packs will be accepted, the applicant must provide documentation to demonstrate compliance with the standards of §264.316. Section 9 of this manual addresses review of application information intended to meet this requirement.

9.7.3 Guidance On Evaluating Application Information

9.7.3.1 Regulatory Applicability and Intent--

Figure 9.7.1 presents a flow chart for determining the applicability of regulations covering the applicant's plans for handling and disposing of liquid wastes.

9.7.3.1.1 Will Bulk or Noncontainerized Liquid Waste or Waste Containing Free Liquids be Placed in the Landfill?--To assure successful operation of the facility, it is the applicant's responsibility to identify the physical characteristics of all wastes to be disposed of in the landfill, as required by §264.13--General Requirements for Waste Analysis.

If the applicant states that no type of liquid wastes will be received or disposed of at the landfill, then the permit writer must indicate in the permit that bulk or noncontainerized liquid waste or wastes containing free liquids are specifically not permitted for disposal at the landfill. If this is the case, the reader may proceed directly to subsection 9.8.3.1.3. However, the permit reviewer is cautioned to note the difference between receiving and disposing of a waste. If bulk or noncontainerized wastes containing free liquids are received at the landfill and then containerized, the owner or operator is disposing of containers holding free liquids and must comply with §264.314(b) (see subsection 9.8.3.1.3 and 9.8.3.1.4, which follow). Similarly, if containers holding free liquids are received at the facility but are emptied into a landfill cell, then the owner/operator is disposing of bulk or noncontainerized free liquids and must comply with §264.314(a) (see subsection 9.8.3.1.2 which follows).

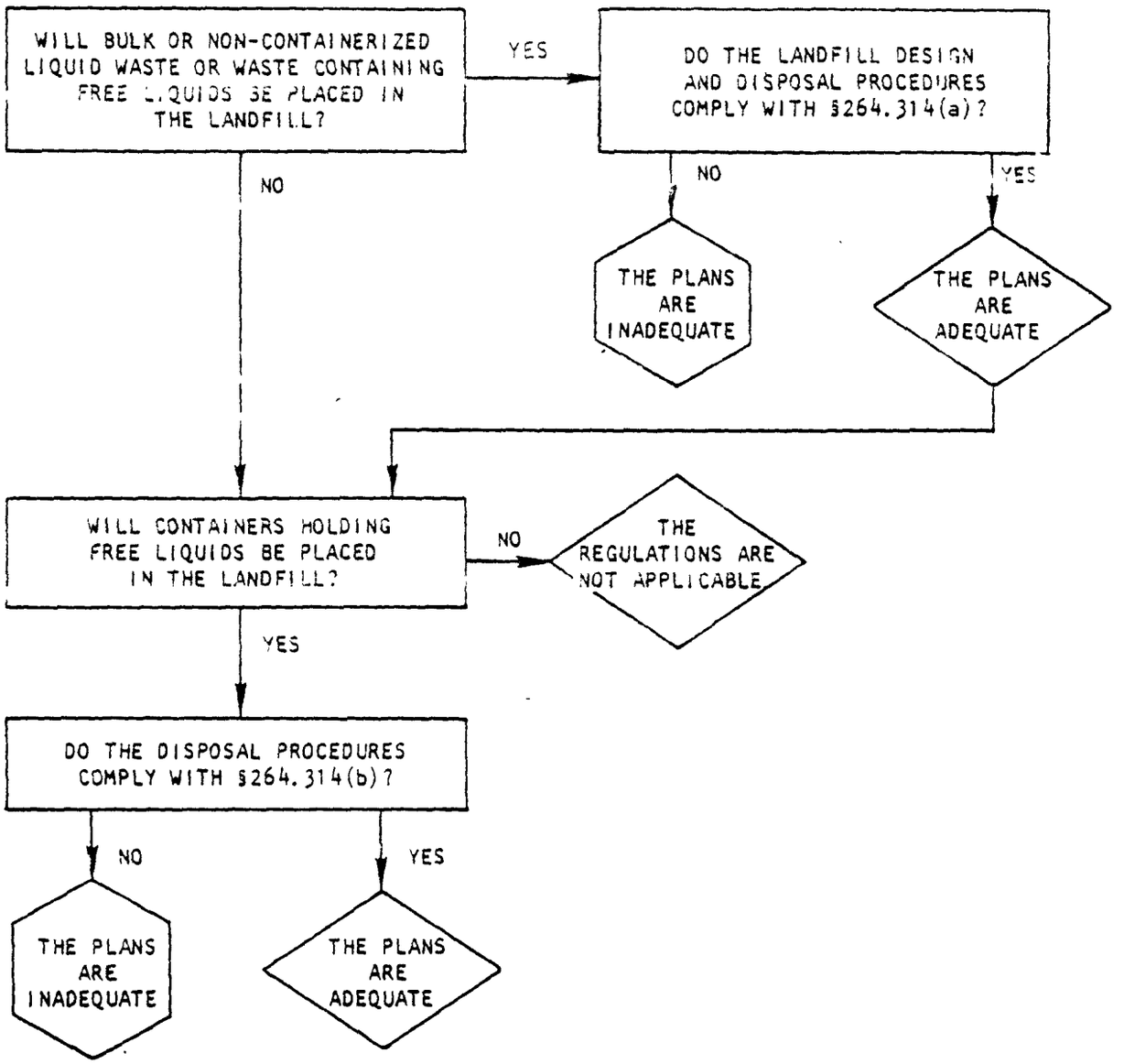

Figure 9.7.1. Regulations applicable to management of liquid wastes at landfills.

9.7.3.1.2 Do the Landfill Design and Disposal Procedures Comply with §264.314(a)?--The applicant for a landfill permit who has stated that bulk or noncontainerized liquid waste or waste containing free liquids will be received for disposal has two options for disposing of the waste at the landfill; (1) disposal in a landfill cell with a liner and a leachate collection and removal system, or (2) treatment of the waste prior to disposal so that free liquids are no longer present. A permit application which indicates receipt of such wastes and does not indicate disposal by one of these methods may be inadequate.

If these wastes are to be disposed of in a landfill with a liner and leachate collection/removal system, the liner and leachate collection system must meet the requirements of §264.301(a) (see subsection 9.2). The application should also address compatibility and ignitability/reactivity concerns. The application is technically inadequate if it proposes to dispose of these wastes (without prior elimination of free liquid) in a landfill cell that does not have a liner and leachate collection system or if the liner and leachate collection system do not meet the §264.301(a) requirements.

If liquid wastes are treated chemically or physically before disposal so that free liquids are no longer present, the treated waste can be disposed of in any landfill cell, as long as compatibility and ignitability/reactivity criteria are met. However, in these cases, the application must provide a detailed description of the treatment method to be used and documentation of effectiveness in eliminating free liquids. If a landfill cell does not contain a liner and leachate collection system, free liquids or wastes containing liquids cannot be disposed of in that cell based on the presumption that wastes previously discharged will chemically or physically eliminate the free liquids or liquids contained in the waste. However, it would be allowable to mix the two wastes (if compatible) to eliminate free liquids and then place the mixture in a landfill cell that does not have a liner and leachate collection system.

9.7.3.1.3 Will Containers Holding Free Liquids Be Placed in the Landfill?--Guidance on the meaning of free-standing liquid can be found in the preamble to an interim final amendment to 40 CFR Part 265, published on March 22, 1982 at 47 FR 12317, and in the preamble to regulations published on May 19, 1980 at 45 FR 33213. Section 260.10 defines free standing liquids as "... liquids which readily separate from the solid portion of a waste under ambient temperature and pressure."

If the applicant states that containerized free liquids will not be disposed of at the landfill, then the permit writer must indicate in the permit that containers holding free liquids are specifically not permitted for disposal at the landfill. If these wastes will be received at the landfill but emptied from the containers for disposal, the application must demonstrate compliance with §264.314(a).

9.7.3.1.4 Do the Disposal Procedures Comply with §264.314(b)?--The provisions of §264.314(b) allow the owner/operator some latitude in deciding how containers holding free liquids will be disposed of in the landfill. Specifically, free standing liquids can be removed from the container, they

can be mixed with absorbent or solidified in the container, or they can be eliminated by any other method or procedure acceptable to the permitting authority.

Very small containers, such as ampules, or containers that hold liquids for reasons other than storage, such as batteries or capacitors, can be directly disposed of without elimination of free liquids. However, the intent of the regulation is to allow disposal of small containers as they may randomly appear in the waste. The placement of large quantities of these types of small containers holding free liquids in the same part of the landfill would increase the potential for generation of significant quantities of leachate and landfill subsidence. Therefore, such a procedure is not in concert with the intent of the regulation.

The provisions of §264.314(b) allow placement of lab packs in landfills. However, a container holding free liquids must meet the specific criteria of §264.316 (see subsection 9.8) to be classified as a lab pack and, therefore, be acceptable for disposal in a landfill.

Further, §264.315 (see subsection 9.8) incorporates requirements for disposal of containers in landfills regardless of the physical characteristics of the contained wastes. The requirements of §264.315 are germane to containers which are processed according to options of §264.314(b)(1).

9.7.3.2 Assessment of the Technical Adequacy of the Applicant's Plans for Disposal of Liquid Wastes--

Figure 9.7.2 illustrates the technical topics that are discussed in this section. Each topic is presented individually so that specific sections applicable to the facility in question can be referenced.

The permit reviewer should consider the long-term potential for ground water contamination associated with adopting the applicant's proposed liquids management techniques since corrective action will be required if hazardous wastes leach out of the landfill and are detected in the ground water. Such corrective action is generally extremely costly and could negate the short-term cost savings associated with selecting an unsuccessful stabilization technique. Therefore, the permitting agency should encourage the applicant to implement treatment or stabilization methods which, in addition to eliminating free liquids, also limit the potential for future waste leaching. If waste leaching is highly likely in the long term regardless of sorbent addition, a technique such as encapsulation (with high initial costs) may be cost effective over the long term. In summary, although §264.314 requires the elimination of free liquids during placement, the applicant and the reviewer should consider the possibility of leachate migration in the long term in spite of adopting the selected method.

The applicant must provide reliable information about the composition and characteristics of the waste to be processed so that the effectiveness of any proposed treatment/stabilization method can be evaluated. The waste characteristics may dictate whether a stabilization process such as encapsulation is applicable or whether sorbent addition will suffice. The

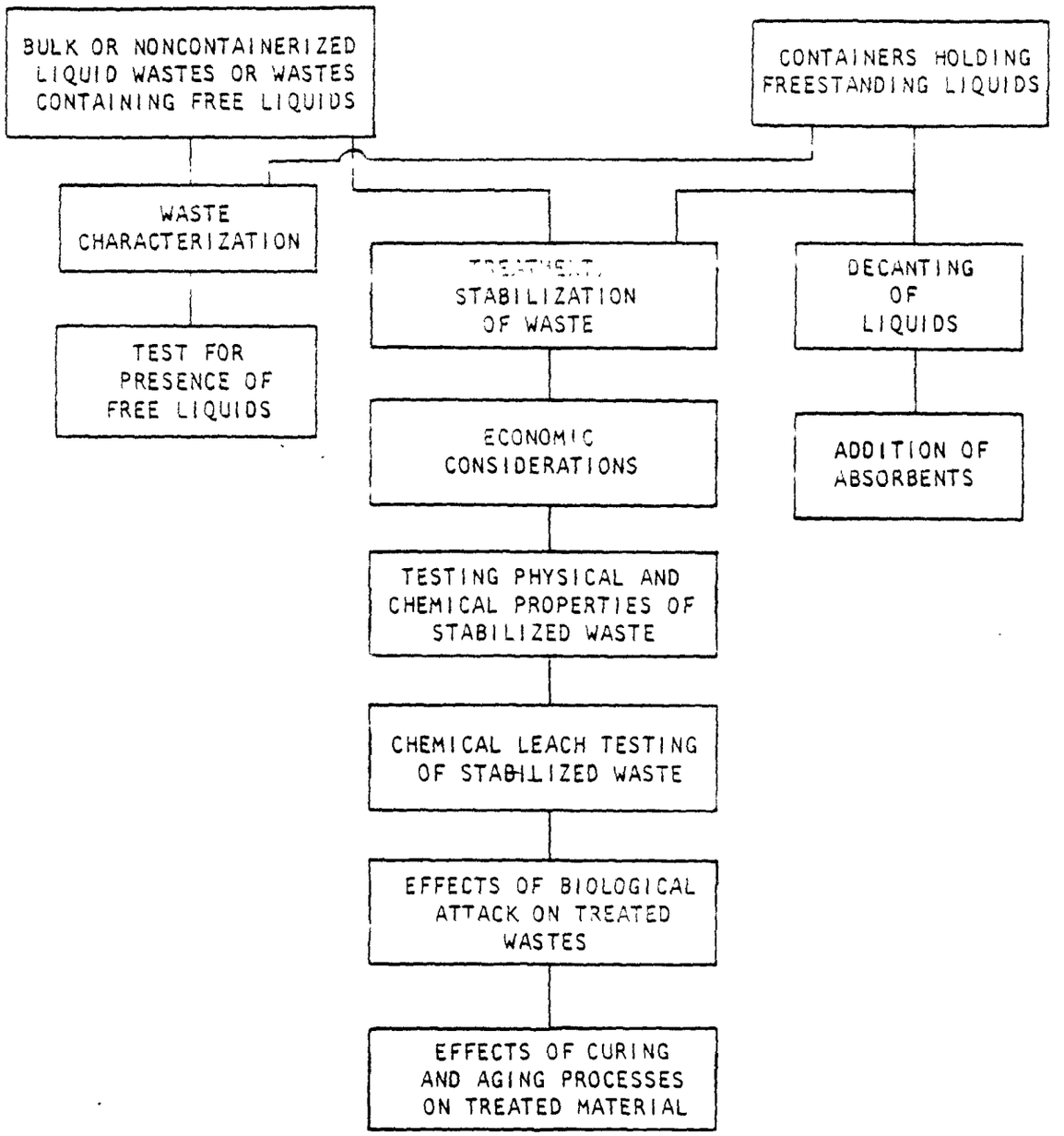

Figure 9.7.2. Assessment of technical adequacy of the applicant's plans for disposal of liquid wastes.

applicant needs to identify both the physical and chemical characteristics of the waste. The permit reviewer should consider the applicant's overall waste analysis plan submitted in response to the requirements of §270.14(b)(2) and (3).

9.7.3.2.1 Test for Presence of Free Liquids--EPA defines "free liquids" as "liquids which readily separate from the solid portion of a waste under ambient temperature and pressure."[2] The applicant is not required to test containers for free liquid content if he chooses to consider all containers of waste as holding free liquids and disposes of them in accordance with §264.314(b). However, the applicant may choose to demonstrate that free liquids are not present in a containerized or bulk waste. If so, he must describe the test protocol to be employed or he must provide other certification that the waste does not contain free liquids.

EPA currently recognizes two test protocols for determining the presence of free liquids.[3] One method, designated the paint filter method, is described in 47 FR 8311, February 25, 1982. The paint filter method is a gravity test which calls for a 100 ml representative sample of the waste to be placed in a 400 micron, conical paint filter for 5 minutes. The filter specified is a standard paint filter supported by a funnel on a ring stand with a beaker or cylinder below the funnel to capture any free liquid that passes through the filter. If any liquid passes through the filter, the waste is considered to hold free liquids and is subject to the requirements of §264.314(b). If the paint filter test is to be used to measure the percentage of free liquids in the waste in individual containers, a longer test period probably would be necessary to achieve an accurate measurement (e.g., 15 to 45 minutes).[4]

The second procedure for determination of liquids is designated the inclined plane method and is described in the preamble to the May 1980 regulation (45 FR 34214). The inclined plane method calls for the placement of 1 to 5 kilograms of waste on a level or slightly sloping plate of glass or other similar flat and smooth solid material for at least 5 minutes. If a liquid phase separation is observed, the waste contains "free liquids". It should be noted that the applicant may petition EPA under §260.20 and 260.21 for use of an equivalent test protocol.

If the applicant chooses to test for the presence of free liquids, he must describe how a representative sample of the waste will be obtained. In those cases where a demonstration is being made on a batch (e.g., truckload) of similar containerized waste, the sample or samples must be representative of all containers in the lot. The applicant's sampling program should conform to the guidance provided in Test Methods for Evaluating Solid Waste--Physical/Chemical Methods, SW-846.[5]

The applicant may not need to test for free liquids if he can demonstrate or certify in another manner that the waste does not contain free liquids. Such certification could be acceptable if the landfill owner/operator receives containerized wastes on a continuous basis from a specific generator and knows by contractual agreement or prior observation that these containerized wastes

do not vary and do not contain free liquids. The permit reviewer is referred to the Permit Applicant's Manual for the General Facility Standards[6] and the requirements for waste analysis plans.

9.7.3.2.2 Management of Bulk or Noncontainerized Liquid Wastes--If bulk or noncontainerized liquid waste or bulk wastes containing free liquids are to be placed in a landfill that is not equipped with a liner and leachate collection system, then the applicant must demonstrate how free liquids will be eliminated to comply with the requirements of §264.314(a). There are a variety of physical and chemical treatment methods which the applicant may employ to eliminate free liquids from noncontainerized waste. Section 9.7.3.2.3 of this document describes treatment/stabilization methods available to solidify the waste to make it acceptable for disposal. Some of the treatment/stabilization methods are relatively inexpensive, such as cement-based processes, while other methods, such as various encapsulation techniques, are relatively expensive. For a given waste type, it is likely that free liquids can be eliminated using a variety of methods, but all will have varying attendant costs.

9.7.3.2.3 Treatment/Stabilization Technology--"Treatment" is defined by the EPA in §260.10 as "any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste, or to render such waste nonhazardous, or less hazardous; safer to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume." Treatment processes include a wide array of techniques such as thermal, chemical, physical, and biological treatment or stabilization. Applicable liquid treatment techniques were reviewed in Section 9.5 in the discussion of ignitable and reactive wastes.

Stabilization techniques are those which act to limit waste solubility or to detoxify the waste contaminants. Solidification techniques accomplish the same results by the production of a monolithic block of waste with high structural integrity.[7]

The long-term effectiveness of the proposed treatment/stabilization method in limiting future leachate migration should be one of the foremost selection criteria. If geological or hydrological conditions could allow significant leachate migration and result in ground water contamination, a process should be employed which renders the constituents nonhazardous and/or immobile.

There is no single treatment/stabilization method which is ideal for all types of hazardous wastes. For example, although a waste material with a low concentration of organics may be satisfactorily treated by a cement-based treatment process, it would not be treated effectively by organic polymer treatment methods since the organics may retard the set of polymers. Table 9.7.1 indicates the compatibility of selected waste categories with different waste solidification/stabilization techniques (reprinted from EPA SW-872).[7]

TABLE 9.7.1. COMPATIBILITY OF SELECTED WASTE CATEGORIES WITH DIFFERENT WASTE SOLIDIFICATION/STABILIZATION TECHNIQUES
Source: Reference 7.

Waste component	Treatment type						
	Cement based	Lime based	Thermoplastic solidification	Organic polymer (UF)*	Surface encapsulation	Self-cementing techniques	Glassification and synthetic mineral formation
Organics							
1. Organic solvents and oils	Many impede setting, may escape as vapor	Many impede setting, may escape as vapor	Organics may vaporize on heating	May retard set of polymers	Must first be absorbed on solid matrix	Fire danger on heating	Wastes decompose at high temperatures
2. Solid organics (e.g., plastics, resins, tars)	Good--often increases durability	Good--often increases durability	Possible use as binding agent	May retard set of polymers	Compatible--many encapsulation materials are plastic	Fire danger on heating	Wastes decompose at high temperatures
Inorganics							
1. Acid wastes	Cement will neutralize acids	Compatible	Can be neutralized before incorporation	Compatible	Can be neutralized before incorporation	May be neutralized to form sulfate salts	Can be neutralized and incorporated
2. Oxidizers	Compatible	Compatible	May cause matrix breakdown, fire	May cause matrix breakdown	May cause deterioration of encapsulating materials	Compatible if sulfates are present	High temperatures may cause undesirable reactions
3. Sulfates	May retard setting and cause spalling unless special cement is used	Compatible	May dehydrate and rehydrate causing splitting	Compatible	Compatible	Compatible	Compatible in many cases
4. Halides	Easily leached from cement, may retard setting	May retard set, most are easily leached	May dehydrate	Compatible	Compatible	Compatible if sulfates are present	Compatible in many cases
5. Heavy metals	Compatible	Compatible	Compatible	Acid pH solubilizes metal hydroxides	Compatible	Compatible if sulfates are present	Compatible in many cases
6. Radioactive materials	Compatible	Compatible	Compatible	Compatible	Compatible	Compatible if sulfates are present	Compatible

*Urea-Formaldehyde resin.

Solidification/stabilization techniques are, in general, new technologies which have evolved out of the need for finding solutions for the disposal of difficult to handle hazardous waste. The adequacy of solidification/stabilization techniques in reducing long-term contaminant migration has not been thoroughly documented in all cases and it appears that more work is necessary to optimize treatment procedures for individual wastes. Nevertheless, preliminary evidence indicates that some solidification/stabilization techniques are effective at reducing the potential for ground water contamination. Some of the hazardous chemicals and wastes which can be stabilized and solidified effectively include:[8,9]

- electroplating wastes
- spent pickle liquors
- spent acids
- alkaline cleaners
- inorganic pigment wastes
- leather tanning and finishing wastes
- petroleum bottom tank sludges
- drine wastes
- air pollution control residues
- wastewater treatment sludges
- aqueous wastes containing soluble toxic organics

During review of a permit application which specifies that a solidification/stabilization technique will be employed, questions may arise concerning the long-term stability attendant with the process. In such cases, the permit reviewer should refer to EPA-600/2-82-099 which is a study of the physical and leaching properties of solidified/stabilized industrial waste.[10] Tests were conducted on four solidification/stabilization processes: (1) a lime-fly ash, pozzolanic cement that yields a solid microencapsulation system, (2) a cement/soluble-silicate treatment process that produces a soil-like product, (3) an organic polymer system that produces a hard, rubber-like solid, and (4) a macroencapsulation process that solidifies the waste and then bonds it in a polyethylene jacket. The lime-fly ash pozzolanic solidification produced a solid soil/cement-like product with good structural integrity but poor durability. Concentrations of hazardous elements (toxic heavy metals and insoluble salts) in leachates from this treated product were actually higher in about half the cases than they were in leachates from similar untreated material. The cement/soluble-silicate treatment process produced more consistent containment of hazardous elements with 60 to 70 percent of the constituents having lower levels in the leachate from the treated sludge than in leachate from the untreated control columns. The organic polymer system proved to be counterproductive in limiting release of hazardous elements from an electroplating waste and a paint production sludge. Both wastes lost most constituents at much higher rates than the control columns, possibly because of the acidification and resulting dissolution of the sludge that was required to produce the polymerization reaction used in this process. The macroencapsulation process that solidifies the waste and then bonds it in a polyethylene jacket gave excellent containment of all constituents but cadmium.[10]

Several applicable treatment/stablization methods are discussed in the following subsections. This information summarizes the data presented in the "Guide to the Disposal of Chemically Stabilized and Solidified Waste" (EPA SW-872, September 1982)[7] and other references, as noted.

9.7.3.2.4 Cement/Pozzolan Solidification/Stabilization Techniques--A cement-based process involves the reaction of water in the waste with anhydrous Portland cement powder. Similarly, a lime-pozzolan solidification involves the reaction of lime and a pozzolanic material in the presence of water in the waste material to form compounds possessing cementitious properties. Cement and pozzolanic-based techniques are employed singularly or in combination. When a pozzolan is mixed with cement, the lime that is liberated during the setting and hardening of cement combines with the pozzolan, resulting in the formation of a lime-pozzolan compound.

Some of the advantages of the cement/pozzolan-based process are that it is relatively inexpensive; it does not require specialized equipment or advanced technology; the product can be coated; and the process provides a stable product in many cases. However, there are disadvantages. For instance, certain wastes, such as wastes with high sulfate content, may not be adaptable to the technique. Additionally, it is likely that some leaching may occur, and the final product is voluminous and heavy.[7]

Recent testing has been conducted on the leachability of wastes stabilized by cement/pozzolan-based stabilization techniques. A lime-fly ash pozzolanic solidification process produced a solid soil cement-like product with good structural integrity but poor durability. Concentrations of hazardous elements in leachates from this treated product were actually higher in about half the cases than they were in leachates from similar untreated material. A cement/soluble-silicate treatment process, produced a semi-friable material with low strength and a soil-like consistency. This process produced more consistent containment of hazardous elements with 60 to 70 percent of the constituents (toxic heavy metals and inorganic salts) having lower levels in the leachate from the treated sludge than in leachate from the untreated control columns.[10]

Although FGD sludges are exempted as nonhazardous solid wastes by EPA, the pozzolanic process is reported to be effective at stabilizing sludges from wet flue gas desulfurization (FGD) systems. Test data show that FGD sludge treated by the pozzolanic process is more environmentally acceptable over untreated sludge because of reduced leaching potential and improved handling characteristics. Woodward and West provide pertinent information on commercially available pozzolanic treatment methods for stabilizing FGD sludge.[11]

Polymer impregnation and the application of surface coatings may help to increase the effectiveness of the cement/pozzolan-based process. The polymer impregnation process is accomplished by soaking the waste-concrete mixture in styrene monomer to fill the pores, followed by heating to induce polymerization. Surface coating materials include asphalt emulsion, and

vinyl. Problems have been encountered with surface coating because of poor adhesion of the coating onto the waste or lack of strength of the concrete material containing the waste.[7]

9.7.3.2.5 Thermoplastic Techniques--Thermoplastic solidification/stabilization techniques use an organic thermoplastic material which is mixed with the waste to form a plastic matrix. Thermoplastic materials include bitumen, paraffin, and polyethylene. The waste is generally dried, heated, and dispersed through a heated plastic matrix which is then cooled to solidify the mass. The resulting mass is a relatively stable product which is generally superior to cement-based systems at reducing the potential for leachate generation.[7]

Thermoplastic techniques are relatively expensive because of complicated processing equipment and high energy costs for drying (incorporating wet wastes greatly increases losses through leaching). The technique cannot be used on waste material containing organic chemicals which act as solvents for the matrix. Other wastes which cannot be treated by this method include: strongly oxidizing salts, such as nitrates, chlorates, or perchlorates; materials that decompose at high temperatures, especially citrates and certain types of plastic (e.g., polyethylene, polypropylene, acetal copolymer, and other crystalline resins);[12] and tetraborates or iron and aluminum salts (these compounds cause premature hardening and can clog and damage mixing equipment).[7]

9.7.3.2.6 Organic Polymer Process--One well-documented organic polymer process employs urea-formaldehyde to encase waste material. Other polymers which could be used for this process include vinyl ester-styrene and polyester resin. In the organic polymer process, wet or dry wastes are mixed with a polymer to which a catalyst is added. The resulting product is a polymerized material which does not chemically combine with the waste but forms a mass that entraps waste particles.[7]

No information could be found in the available literature regarding the long-term leaching characteristics of wastes treated by polymerization methods. Since no chemical reaction occurs between the waste and polymer in the solidification process, a breakdown of the waste material may result in a release of hazardous materials. Secondary containment in steel drums may be worth consideration when employing an organic polymer process.

9.7.3.2.7 Surface Encapsulation Techniques--Surface encapsulation techniques, often referred to as "jacketing", enclose waste material which has been pressed or bonded together in a coating of inert material. Polyethylene is frequently used to jacket waste material. The major advantage of surface encapsulation is that it virtually eliminates the potential for leaching if the cover material stays intact. However, the technique is expensive due to high costs for resin material, equipment, skilled labor, and energy utilized during drying, fusing of the binder, and forming of the jacket. The TRW Corporation has investigated many alternative binding and coating systems and developed what it considers to be the optimum system. This system has been tested, and published data on the processes are available in Reference 13. The TRW surface encapsulation system requires that the waste material be thoroughly dried. The dried wastes are stirred into an acetone solution of

modified 1,2-polybutadiene for 5 minutes which is then allowed to set for 2 hours. The coated material is placed in a mold, subjected to slight mechanical pressure, and heated to between 120°C and 200°C to produce fusion. The agglomerated material is a hard, tough, solid block. A polyethylene jacket 3.5 mm thick is fused over the solid block and adheres to the polybutadiene binder.[7]

9.7.3.2.8 Self Cementing Processes--Self cementing processes are employed to stabilize industrial wastes which contain large amounts of calcium sulfate and calcium sulfites such as flue-gas cleaning or desulfurization sludges. Usually a small portion (8 to 10 percent by weight) of the dewatered waste sulfate/sulfite sludge is calcined under carefully controlled conditions to produce a partially dehydrated cementitious calcium sulfate or sulfite. This calcined waste is then reintroduced into the bulk of the waste sludge along with other proprietary additives. The finished product is a hard, plaster-like material with good handling characteristics and/or permeability. This is a relatively inexpensive treatment method which generates a solid product with leaching characteristics similar to products of cement and lime-based cementing processes.[7]

9.7.3.2.9 Classification and Production of Synthetic Minerals or Ceramics--Classification may prove to be an effective treatment for dealing with extremely toxic wastes. The waste material is combined with silica and can be fused in glass or formed into a synthetic silicate mixture. This is expected to form an extremely stable product which will have a low potential for leaching. The high costs associated with the process may preclude it for all but the most hazardous wastes.[7] Classification is being studied for use in stabilization of radioactive wastes.

9.7.3.2.10 Economic Considerations--If more than one treatment/stabilization method will provide a stable waste, the owner/operator will attempt to select the cost-effective method. In most of the aforementioned stabilization systems, the cost of materials is the highest cost element. Other budget items include costs for: equipment, operators, and fees or royalties for use of patented processes. When considering the costs of materials, equipment, and energy required to treat a given amount of waste, the cement-based and pozzolanic systems are the least expensive of available solidification/stabilization processes. Table 9.7.2 presents economic considerations for waste stabilization/solidification techniques (reprinted from EPA SW-872).[7]

9.7.3.2.11 Testing Physical and Chemical Properties of Stabilized Waste--The applicant should supply a protocol for testing the physical and chemical properties of the stabilized or solidified waste. Information should be provided on the reaction of the treated waste to applied stresses, permeability of the stabilized waste, wet/dry durability, and freeze/thaw durability. Use of leaching tests conducted under static or continuous flow conditions could be appropriate. These testing procedures will help establish whether the treatment method will be effective at stabilizing the waste over the long term.

TABLE 9.7.2. PRESENT AND PROJECTED ECONOMIC CONSIDERATIONS FOR WASTE STABILIZATION/SOLIDIFICATION SYSTEMS
Source: Reference 7.

Type of treatment system	Major materials required	Unit cost[a] of material	Amount of material required to treat 100 lbs of raw waste	Cost of material[a] required to treat 100 lbs of raw waste	Equipment cost[a]	Energy use
Cement-based	Portland Cement	$0.30/lb	100 lb	$ 3.00	Low	Low
Pozzolanic	Lime Flyash	$0.03/lb	100 lb	$ 3.00	Low	Low
Thermoplastic (bitumen-based)	Bitumen Drums	$0.05/lb $27/drum	100 lb 0.8 drum	$18.00	Very high	High
Organic polymer (polyester system)	Polyester Catalyst Drums	$0.45/lb $1.11/lb	43 lb of polyester-catalyst mix	$27.70	Very high	High
Surface encapsulation (polyethylene)	Polyethylene	Varies	Varies	$ 4.50[b]	Very high	High
Self-cementing	Gypsum (from waste)	c	100 lb	c	Moderate	Moderate
Classification/mineral synthesis	Feldspar	$0.03/lb	Varies	--	High	Very high

[a]Costs are in terms of 1980 dollars.

[b]Based on the full cost of $91/ton.

[c]Negligible, but energy costs for calcining are appreciable.

References 14 and 15 present a discussion of testing procedures available to evaluate the physical and chemical properties of the treated waste. Testing procedures are also discussed in EPA SW-872.[7] The results of laboratory testing to determine the physical properties and chemical leaching characteristics of five industrial wastes that had been solidified or stabilized by one or more of four processes (lime-fly ash pozzolanic, cement/pozzolan, organic polymer, polyethylene encapsulation) are presented in EPA-600/2-82-099.[10]

9.7.3.2.12 Effects of Biological Attack on Treated Wastes[7]--The permit reviewer should consider the effects that biological attack can have on the long-term containment of solidified/stabilized waste. Biological attack can occur by direct utilization of some solidification material as a substrate for bacterial growth, or by the biological production of acid materials that can attack and corrode treated wastes.[7] Of four solidification materials studied by Columbo and Neilson (Portland type II cement, urea-formaldehyde (UF) resin, asphalt, and vinyl ester-styrene), UF resin has the greatest potential for biological degradation.[16] Organic acids released by the decaying of organic material, such as plant roots, can cause corrosion of some waste materials, particularly those solidified with a lime or cement-based process.[7]

9.7.3.2.13 Effects of Curing and Aging Process on Treated Material[7]--The applicant should address the issue of curing if a cementitious solidification system is employed. It has been demonstrated that for cementitious systems, less leaching was observed when cement-based samples had been cured more than 100 days.[7] The conditions of curing are also important. Solidified materials cured under humid conditions are less leachable than treated material allowed to dry during curing.[7]

The applicant should also consider the effects of aging on treated waste material. Urea formaldehyde solidification systems and treatment systems that involve bitumen-based or polymer systems extended with water may provide decreased containment of the waste with age.[7] Consequently, if the waste material is extremely toxic and long-term containment is imperative, an alternative treatment method that will provide long-term containment, such as glassification, should be selected.

9.7.3.2.14 Containers Holding Free Standing Liquids--If containers holding free standing liquids are to be placed in a landfill that is not equipped with a liner and leachate collection system, then the applicant must demonstrate how free standing liquids will be removed to comply with §264.314(b). One method of removing free standing liquids is simple decanting. This is a straightforward procedure but it is complicated by the fact that the applicant must now dispose of the decanted liquids. If the applicant proposes to decant free standing liquids he must demonstrate how the requirements of §264.315 will be met. These requirements specify that containers placed in a landfill must be at least 90 percent full unless the container is very small such as an ampule. One way to comply is to add a filler material so that the container is at least 90 percent full.

Sorbent materials can be divided into three general classifications: natural organic (e.g., straw, sawdust), natural inorganic (e.g., clays, calcium carbonate), and synthetic (e.g., polyurethane). Each generic type is different in terms of cost and effectiveness. The natural organic and inorganic sorbents are generally readily available and less expensive than the synthetic sorbents. Although more expensive, the synthetics are more versatile than natural sorbents and tend to exhibit higher sorption capacity for many organic hazardous wastes. Both natural and synthetic sorbents can be treated to improve their versatility and sorption capacity.[18]

Sorbents should be selected based upon: safety, sorption capacity, cost, availability, and ease of application. Safety must be considered in the context of avoiding sorbent-liquid combinations that may result in explosion, fire, or generation of toxic fumes. Herrick, et al. (EPA-600/2-82-030, July 1982), provides a matrix listing the compatibility of 90 hazardous waste types with 28 sorbents.[18] A summary of this matrix is presented in Table 9.7.3. Because many such sorbents are inert materials, most combinations of hazardous liquids and sorbent materials appear to be safe.

Little data exist concerning the sorption capacity of different sorbents with different hazardous liquids. Consequently, the applicant will need to rigorously demonstrate, based on laboratory results or engineering calculations, the amount of sorbent required to eliminate free liquids.

A worksheet for determining the adequacy of the applicant's submittal for management of liquid wastes (bulk and containerized) is presented in Figure 9.7.3.

9.7.4 Draft Permit Preparation

Condition H.1 of Permit Module XV addresses landfill disposal of bulk or noncontainerized liquid wastes or wastes containing free liquids. This condition is implemented through reference to a permit attachment that includes plans and specifications for liquid waste treatment/disposal options. If liquids are to be disposed of in a landfill cell, the permit attachment must illustrate that the cell has an adequate leachate collection and removal system as discussed in subsection 9.2.2.4. If, as an alternative to free liquid disposal, liquid wastes are to be removed or treated, the attachment must describe the accepted methods for treatment, stabilization, or elimination of liquid wastes prior to landfill disposal. If the applicant does not address liquid waste disposal, the permit writer should specify conditions under which liquid wastes can be disposed or should prohibit the acceptance and disposal of liquid waste.

9.7.5 References

1. U.S. EPA. Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Volume I. Office of Solid Waste. Washington, DC. 1983.

2. 40 CFR Part 260, Subpart B, §260.10, "Definitions."

The use of absorbents is a common method to eliminate free standing liquids from containers. The use of absorbents is often preferred over decanting to avoid subsequent handling of decanted liquids. Section 7.3.2.5 of this document discusses the use of absorbents and provides a matrix of available absorbents and their compatibility with various hazardous wastes.

As an alternative to removing free standing liquids by decanting or the addition of an absorbent, the applicant may propose to empty the waste into a large container or impoundment and employ a treatment/stabilization method. If such a procedure is employed, the applicant is now disposing of a bulk or noncontainerized waste and, therefore, all the free liquids (not just free standing liquids) must be removed prior to placement of the waste if the landfill is not equipped with a liner and leachate collection system.

9.7.3.2.15 Decanting of Liquids and other Methods of Liquid Removal--Decanting of free liquids, although not a "treatment method", may be an effective way of removing free liquids from a waste. This method is more adaptable to wastes containing solids which do not remain in suspension, but instead settle to the bottom of the container. Decanting may be followed by a treatment/stabilization method, or if the landfill incorporates a liner and leachate collection system, the decanted liquid may be disposed of in the landfill cell.

In additon to decanting, there are several other methods of physical separation. Some of the techniques employed to dewater municipal sludges may be applicable to hazardous industrial wastes. One such method is vacuum filtration. The process separates solids and liquids by porous media filtration. Media employed for this purpose include steel coils, metal mesh, and cloth.[17]

If proper weather conditions prevail, hazardous wastes can be dewatered in sludge drying beds. Dewatering occurs through evaporation.[17] If sludge drying beds are proposed, the issue of hazardous waste leaching must be considered. Additionally, this method may not be appropriate for wastes which could create an air pollution problem through evaporation and dispersion of volatile compounds.

Another way of separating solids from liquids is through the use of continuous centrifuges. This method has been employed successfully in the chemical and mining industry for many years. It has also been used effectively to dewater municipal wastes and wastes generated by paper-mills, foundries, and refineries.[17]

9.7.3.2.16 Addition of Absorbent Material--Although the EPA has stated that the addition of an absorbent material does not constitute "treatment" of free liquids (February 25, 1982, 47 FR 8304), the technique is widely used because of its low cost. However, addition of an absorbent may not stabilize the waste over the long term and, hence, the waste may be susceptible to leaching. Consequently, the use of an absorbent may not always be a viable approach.

TABLE 9.7.3. COMPATIBILITY OF HAZARDOUS LIQUIDS AND SELECTED SORBENT MATERIALS
Source: Reference 18

Sorbent materials	Acids and derivatives	Alcohols and phenols	Aldehydes and ketones	Epoxides	Esters	Halogen compounds	Hydrocarbons	Nitrogen compounds	Organo metallic compounds	Organo phosphorus compounds	Sulfur compounds	Acids	Inorganic halides	Other
Animal Materials[a]	D	D	D	D	D	D	D	D	D	D	D	C	D	D
Activated Carbon	A	A	A	A	A	A	A	A	A	A	A	A	A	B
Cellulose[b]	D	A	D	D	B	D	A	D	D	D	D	C	D	D
Cellulose Conwed[c]	A	A	B	D	B	B	A	B	A	A	B	C	D	D
Minerals, Calcium Carbonated	D	B	D	D	D	B	B	D	D	D	D	A	B	B
Minerals, Other[d]	A	A	B	A	A	B	A	A	A	A	A	A	D	D
Minerals, Treated Hazorb[e]	D	A	B	D	A	B	A	B	D	D	D	A	D	B
Perlite and Cellulose, Treated (Fiberperl,[f] Sorbent CB)	D	D	D	D	D	D	B	D	D	D	D	D	D	D
Polyolefins														
JM Oil Sorbent[h]	B	A	A	A	A	A	A	A	A	A	A	A	B	D
Oil Snare,[i] Quick-Wick	D	D	B	D	A	B	A	B	D	D	D	D	D	D
Other Polyolefins	D	B	D	D	A	B	A	B	D	D	D	D	D	D
Polyurethanes														
Graboil[k]	D	D	D	D	D	D	B	D	D	D	D	D	D	D
Petro-Trap[l]	D	B	B	D	D	D	B	D	D	D	D	D	D	D
SCC Absorbent[m]	D	B	D	D	A	B	A	B	D	D	D	D	D	D
Cross-linked Copolymer Imbiber Beads[n]	D	D	D	D	D	B	A	D	D	D	D	D	D	D
Multi-Purpose Gelling Agent	A	A	A	A	A	B	A	A	D	A	A	B	D	B

(continued)

TABLE 9.7.3 (continued)

[a]Wool, feathers, leather shavings.

[b]Bark, hulls, peat moss, sawdust, straw.

[c]Proprietary product of Conwed Corporation. Information is abstracted from company's advertising materials.

[d]Ash, clays, perlite, sand, vermiculite.

[e]Proprietary product of Diamond Shamrock Corporation.

[f]Proprietary product of Grefco, Inc.

[g]Proprietary product of Clean Water, Inc.

[h]Proprietary product of 3M Company. Information is abstracted from company's advertising materials.

[i]Proprietary product of Parker Systems, Inc.

[j]Proprietary product of Clark-Cutler-McDermott Company.

[k]Proprietary product of KBH Cybernetics, Ltd.

[l]Proprietary product of Best Textile Company.

[m]Proprietary product of Sorbent Sciences Corporation.

[n]Proprietary product of Dow Chemical Company.

KEY:

A = The sorbent material has been found to be compatible with more than 50 percent of the compounds tested in the chemical class.

B = The sorbent material has been found to be compatible with less than 50 percent of the compounds tested in the chemical class.

C = The sorbent material has been found to be incompatible with all compounds tested in the chemical class.

D = Little or no data were available concerning the compatibility of compounds tested in the chemical class with selected sorbents.

DISPOSAL OF LIQUID WASTES IN LANDFILLS

GENERAL INFORMATION

Has this part of the applicant's submittal been read and evaluated? ____ Yes ____ No

Are acceptable methods specified for analyzing the wastes for free liquids? ____ Yes ____ No

- BULK OR NON-CONTAINERIZED WASTE DISPOSAL

  Does the landfill meet leachate collection and removal system requirements specified in Section 9.2? ____ Yes ____ No

  If not,

  Are wastes treated to eliminate free liquids? ____ Yes ____ No

  Is a detailed description of the treatment method(s) provided? ____ Yes ____ No

  Did the applicant document the effectiveness of the treatment process(es)? ____ Yes ____ No

- CONTAINERIZED WASTE DISPOSAL

  Are containerized wastes treated to eliminate free liquids? ____ Yes ____ No

  Which of the following methods are used:

  - Solidification/stabilization? ____ Yes ____ No
  - Mixing with absorbent materials? ____ Yes ____ No
  - Decanting? ____ Yes ____ No
  - Other methods (specify)_____

Figure 9.7.3. Worksheet for evaluating disposal procedures for liquid wastes.

If decanting is used, did the applicant describe procedures for disposing the decanted liquid? ____ Yes ____ No

Are containers at least 90 percent full after eliminating the free liquids? ____ Yes ____ No

Are detailed procedures for the treatment processes provided? ____ Yes ____ No

Are any free liquids disposed in very small containers? ____ Yes ____ No

If so,

- Are such containers disposed in small quantities? ____ Yes ____ No

  and

- Are the containers widely dispersed throughout the disposal area? ____ Yes ____ No

Do lab packs containing free liquids meet the requirements specified in Section 9.8? ____ Yes ____ No

TREATMENT/STABILIZATION

Are treatment/stabilization techniques employed to minimize the potential for long-term waste leaching? ____ Yes ____ No

Did the applicant supply a protocol for testing the physical and chemical properties of stabilized and solidified waste? ____ Yes ____ No

Does the applicant address the effects of curing and aging on solidified materials and treated wastes? ____ Yes ____ No

Figure 9.7.3 (continued)

3. Telephone interview with Alison Kerester, Attorney, U.S. EPA, Division of Solid Wastes, March 22, 1982.

4. Found in Preamble Notice of February 25, 1982 at 47 FR 8311.

5. U.S. Environmental Protection Agency. Test Methods for Evaluating Solid Waste. Second Edition. SW-846. July 1982.

6. Capone, S. V., et al. Permit Applicants Manual for the General Facility Standards of 40 CFR 264. Prepared for the U.S. Environmental Protection Agency, Office of Solid Waste by GCA/Technology Division. June 1983.

7. U.S. EPA. Guide to the Disposal of Chemically Stabilized and Solidified Waste. SW-872. September 1982.

8. Pojasek, Robert B., Toxic and Hazardous Waste Disposal, Volume II. Ann Arbor Science, Ann Arbor, Michigan. 1979.

9. Stanczyk, T. F., B. C. Senefelder and J. H. Clarke. Solidification/ Stabilization Processes Appropriate to Hazardous Chemicals and Waste Piles. 1982 Hazardous Spills Conference, Milwaukee, Wisconsin. April 19-22, 1982.

10. Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station, Physical Properties and Leach Testing of Solidified/Stabilized Wastes. EPA 600/2-82-009. February 1983.

11. Woodward, John P. and B. W. West. The Stabilization of Sludges from Wet Flue Gas Desulfurization Systems. In Toxic and Hazardous Waste Disposal, Volume II, Robert B. Pojasek, Ann Arbor Science, Ann Arbor, Michigan. 1979.

12. Kirk-Othmer. Encyclopedia of Chemical Technology. Third edition. John Wiley & Sons, New York. 1982. Volume 18, p. 184.

13. Lubowitz, H. R., R. L. Denham and G. A. Zakrzewski. Development of a Polymetric Cementing and Encapsulating Process for Managing Hazardous Wastes. EPA 600/2-77-045, U.S. Environmental Protection Agency, Cincinnati, Ohio. 1977.

14. Thompson, D. W. and P. G. Malone. Physical Properties Testing of Raw and Stabilized Industrial Sludges. In Toxic and Hazardous Waste Disposal, Volume II, Robert B. Pojasek, Ann Arbor Science, Ann Arbor, Michigan. 1979.

15. Anderson, M. A., et al. Test Factors Affecting the Release of Materials from Industrial Wastes in Leaching Tests. In Toxic and Hazardous Waste Disposal, Volume II, Robert B. Pojasek, Ann Arbor Science, Ann Arbor, Michigan. 1979.

16. Columbo, P. and R. M. Neilson, Jr. Properties of Radioactive Wastes and Waste Containers. BNL-NUREG-50692, Brookhaven National Laboratory, Upton, New York. 1977.

17. Clark, J. W., W. Viessman, Jr., and M. J. Hammer. Water Supply and Pollution Control, 2nd Ed. International Textbook Co., Scranton, PA. 1971.

18. Herrick, E. C., D. Carstea and G. Goldgraben. Sorbent Materials for Cleanup of Hazardous Spills, EPA 600/2-82-030. July 1982.

9.8 SPECIAL REQUIREMENTS FOR CONTAINERS AND LAB PACKS

9.8.1 The Federal Requirement

The information requirements for containers and lab packs are specified in §270.21(i), as follows:

> "If containers of hazardous waste are to be landfilled, an explanation of how the requirements of §264.315 or §264.316, as applicable, will be complied with [must be submitted]."

The referenced standards of §264.315 specify special requirements for containers and state that:

> "Unless they are very small, such as an ampule, containers must be either:
> (a) At least 90 percent full when placed in the landfill, or
> (b) Crushed, shredded, or similarly reduced in volume to the maximum practical extent before burial in the landfill."

The referenced standards of §264.316 specify requirements for disposal of lab packs and state that:

> "Small containers of hazardous waste in overpacked drums (lab packs) may be placed in a landfill if the following requirements are met:
> (a) Hazardous waste must be packaged in non-leaking inside containers. The inside containers must be of a design and constructed of a material that will not react dangerously with, be decomposed by, or be ignited by the contained waste. Inside containers must be tightly and securely sealed. The inside containers must be of the size and type specified in the Department of Transportation (DOT) hazardous materials regulations (49 CFR Parts 173, 178, and 179), if those regulations specify a particular inside container for the waste.
> (b) The inside containers must be overpacked in an open head DOT-specification metal shipping container (49 CFR Parts 178 and 179) of no more than 416-liter (110 gallon) capacity and surrounded by, at a minimum, a sufficient quantity of absorbent material to completely absorb all of the liquid contents of the inside containers. The metal outer container must be full after packing with inside containers and absorbent material.
> (c) The absorbent material used must not be capable of reacting dangerously with, being decomposed by, or being ignited by the contents of the inside containers in accordance with §264.17(b).
> (d) Incompatible wastes, as defined in §260.10 of this chapter, must not be placed in the same outside container.
> (e) Reactive wastes, other than cyanide- or sulfide-bearing waste as defined in §261.23(a)(5) of this chapter, must be treated or rendered non-reactive prior to packaging in accordance with paragraphs (a) through (d) of this section. Cyanide- and sulfide-bearing reactive waste may be packed in accordance with paragraphs (a) through (d) of this section without first being treated or rendered non-reactive."

9.8.2 Summary of Necessary Application Information

The Part B Permit Applicants' Manual[1] requires the applicant to explain how he will eliminate voids in containers and assure that they are at least 90 percent full before disposal. If this specification can not be met, the applicant is directed to indicate the methods he will use to crush, shred, or similarly reduce the volume of such containers before burial in the landfill.

If lab packs are or will be accepted at the facility, the applicant is directed to:

- provide information in his application to illustrate conformance with the standards specified in §264.316.
- present inspection plans for determining that inside containers are nonleaking, constructed of nonreactive materials, are tightly and securely sealed, and meet Department of Transportation (DOT) requirements.
- indicate that open head DOT overpacked drums of no more than 110-gallon capacity will be used.
- specify any absorbents used inside the overpack and demonstrate that the container is full before disposal.
- document that the absorbent used is nonreactive.
- document methods for determining that incompatible or reactive wastes (other than cyanide- or sulfide-bearing wastes) are not placed in the same outside container.
- indicate the arrangements that have been made to treat or otherwise render reactive wastes nonreactive before placement in overpacked drums.

9.8.3 Guidance on Evaluating Application Information

9.8.3.1 Regulatory Applicability and Intent--

Figure 9.8.1 presents a flow chart for determining the applicability of container standards to the facility under review. Sections 264.315 and 264.316 require that all containers be substantially full and that any free liquids must be absorbed before the containers are placed in a landfill cell. The purpose of this rule is to minimize subsidence in the landfill resulting from decaying containers having void spaces.[2] The occurrence of subsidence after final closure would result in damage to the final cover (i.e., cap). The integrity of the final cover must be maintained to limit the percolation of run-on and precipitation through the landfill.

9.8.3.1.1 Will Containers of Hazardous Waste be Placed in the Landfill?--

There are two specific sections of Part 264, Subpart N which address the disposal of containers in landfills. The first, §264.315, applies to all containerized hazardous waste or containers which held hazardous wastes,

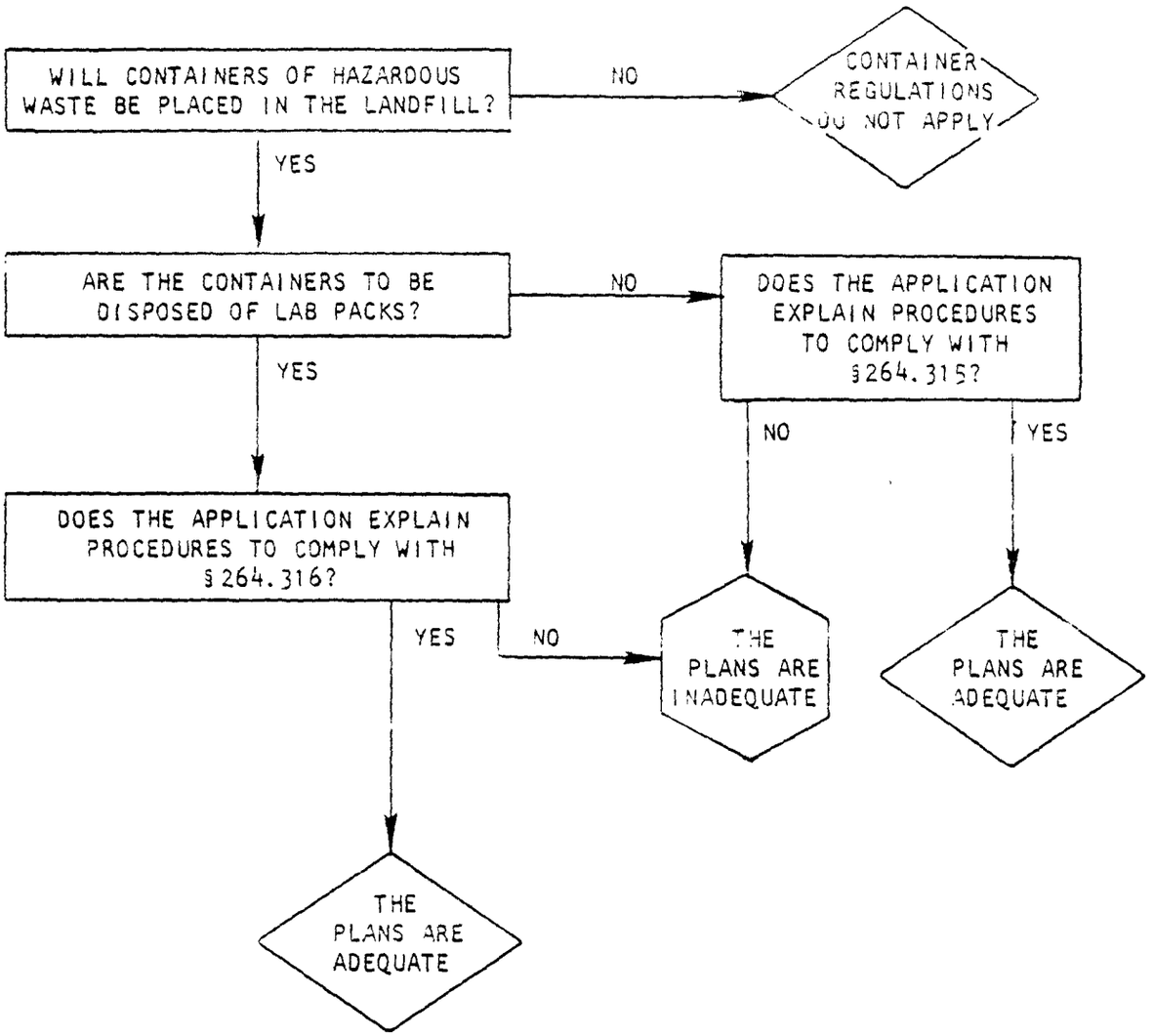

Figure 9.8.1. Applicability of regulations for containers.

regardless of the physical characteristics of the waste (see subsection 9.8.3.1.3). The second, §264.316, applies to the disposal of containers commonly referred to as "lab packs." These are containers which hold many smaller containers of hazardous waste (see subsection 9.8.3.1.4).

It is the responsibility of the owner or operator of a landfill to state in the permit application whether or not waste will be received in containers and specifically indicate how those containers will be handled from receipt through disposal of the waste in the landfill. If the applicant states that wastes in containers will not be disposed of at the landfill, then the permit writer must indicate in the permit that containers holding wastes are specifically not permitted for disposal in the landfill.

If liquid wastes in containers are disposed of by emptying the wastes from the container into the landfill, waste disposal must comply with §264.314(a) (see subsection 9.7) and disposal of the container must comply with §264.315 (see subsection 9.8.3.1.3).

9.8.3.1.2 Are the Containers to be Disposed of Lab Packs?--The terms "lab packs" and "overpacked drums" are analogous, but are not defined in §260.10. However, a description and discussion of regulatory intent are presented in the preamble to a Federal Register Notice amending Part 265, Subpart N, published November 17, 1981 at 46 FR 56592.

If a permit application indicates disposal of lab packs in the landfill, a demonstration that the packaging and disposal will comply with §264.316 is required (see subsection 9.8.3.4). If packaging or disposal does not meet those criteria or containers other than lab packs will be disposed of at the landfill, then container disposal must meet the criteria of §264.315 (see subsection 9.8.3.3).

9.8.3.1.3 Does the Application Explain Procedures to Comply with §264.315?--The primary purpose of the §264.315 criteria is to prevent subsidence of the landfill cover which could occur after closure from collapse of deteriorated containers. A complete discussion of regulatory intent and rationale can be found in the Federal Register published July 26, 1982, at 47 FR 32331.

The requirements of §264.315 apply to all containers regardless of the physical or chemical characteristics of the waste they are holding or have held. The requirements also apply regardless of container size and shape, with the stated exception of containers that "...are very small, such as an ampule,...". The landfill owner or operator must indicate in the permit application how compliance with the §264.315 requirements will be insured in addition to compliance with the requirements of §264.312(b) and §264.314(b) when these other requirements are applicable.

9.8.3.1.4 Does the Application Explain Procedures to Comply with §264.316?--A discussion of the regulatory intent of §264.316 is presented in the preamble to the Federal Register Notice amending Part 265, Subpart N, published November 17, 1981, at 46 FR 56592. The requirements of §264.316 apply to all containers which are lab packs regardless of the physical characteristics of the wastes they contain.

Owners or operators of off-site landfills will have to obtain the information necessary to substantiate compliance with §264.316 from waste generators. However, the landfill owners and operators will also have to describe how compliance with these requirements by waste generators will be assured before lab packs are placed in the landfill. The language of the preamble at 46 FR 56592 clearly states "the disposal option...may be utilized by any type of generator. It is designed to accommodate generators...". Thus, the owner or operator of an off-site landfill must indicate how compliance with §264.316 will be monitored so that noncomplying lab packs will not be disposed of in the landfill.

9.8.3.2 Evaluation of the Technical Adequacy of the Applicant's Submittal--Figure 9.8.2 presents the major topics that will be discussed in this subsection. The permit reviewer should first determine which of these technical topics are applicable to the applicant's facility and operation. For instance, if the applicant will not accept lab packs, only the discussion which addresses the individual drum handling is applicable. If any of the associated topics are not adequately addressed by the applicant, the application and proposed handling methods may be technically deficient.

9.8.3.2.1 Measures for Minimizing Environmental Releases During Container Handling--Subpart I of Part 264 regulates the use and management of containers. Although this regulation applies only to hazardous waste facilities that store hazardous waste (storage is defined as holding a waste more than 90 days), the requirements should also be followed by facilities which only handle containers if there is a potential for environmental release. During container handling there is often a potential for leakage or spillage of hazardous waste.

Losses as a result of container handling may be minimal in some cases, such as during testing for 90 percent capacity, but may be significant in other cases, such as during emptying of partially filled containers. Losses of hazardous wastes may also occur in the container handling area if the containers are damaged during handling or if they are shipped in damaged or poorly sealed containers.

In specifying the measures that will be employed to prevent releases, the applicant should consider measures that will limit releases to ground water, surface water, and the ambient air. In addition, provisions for protection against fire and explosions should be considered.

Available techniques to minimize environmental releases during container handling are described below:[3]

- Prevention of Ground and Surface Water Contamination

  - Provide drainage around the container handling area to minimize run-on. This can be accomplished by constructing a system of dikes and drains.

  - Use an impervious liner in the container handling area to prevent leaching of spilled material into ground water.

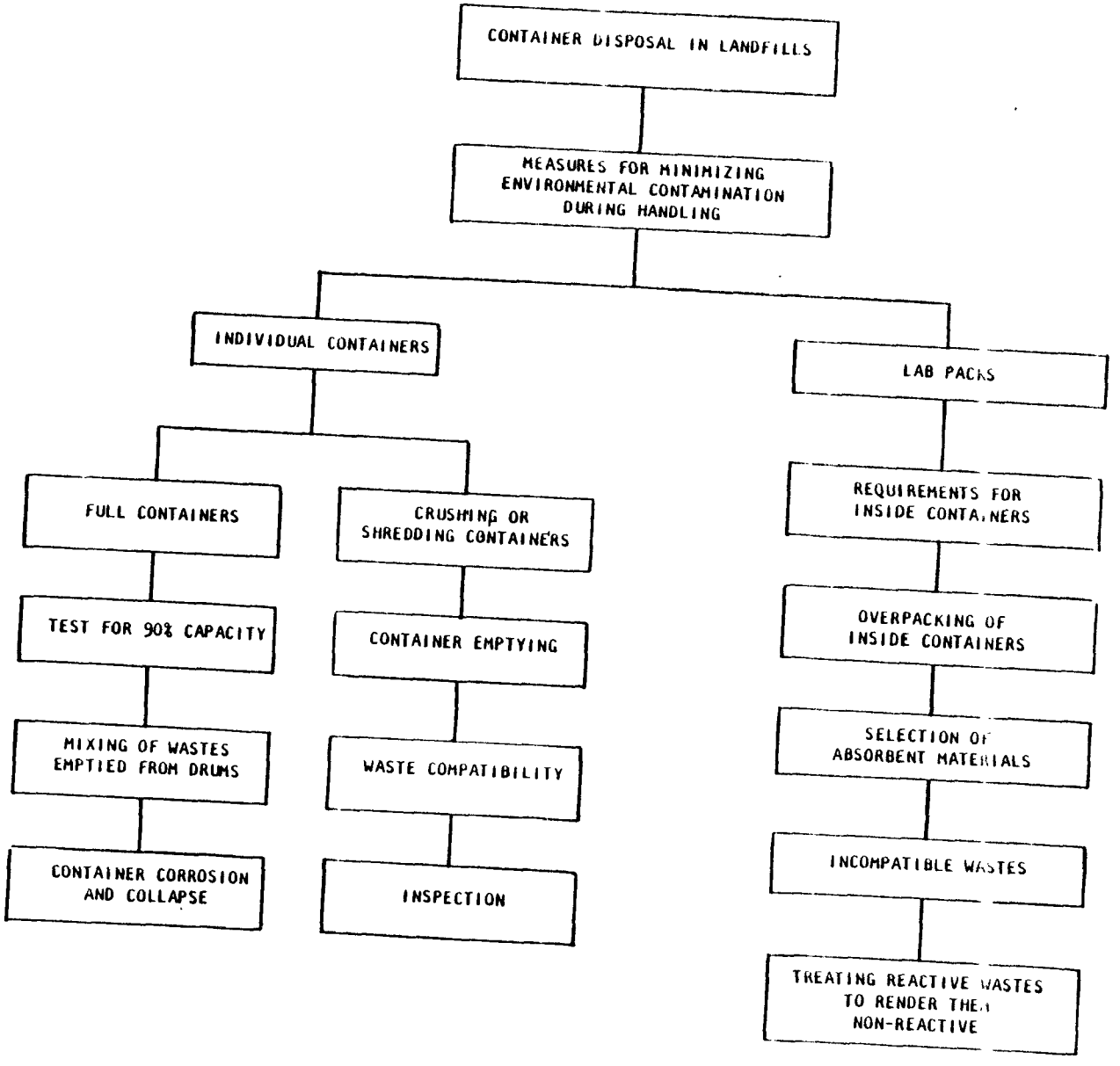

Figure 9.8.2. Technical aspects of container disposal in landfills.

- Utilize a sump pump to promptly remove spills and rainwater from the container handling area for proper handling.

- Use sorbents or vacuum equipment to clean up spills promptly.

- Prevention of Air Pollution

  - Avoid uncontrolled mixing of incompatible wastes by determining the compatibility of binary combinations of hazardous wastes.

  - Re-containerize containers which are leaking or prone to rupture or leaking.

  - Promptly reseal drums after opening.

  - Utilize vacuum units which are equipped with vapor scrubbers.

  - Minimize the release of vapors from handling and mixing tanks by covering such tanks.

- Fire Protection

  - Use nonsparking hand tools, drum opening tools and explosion proof pumps when handling flammable, explosive, or unknown wastes.

  - Avoid uncontrolled mixing of incompatible wastes.

  - Avoid storage of explosive or reactive wastes in the vicinity of active operations or areas used by plant personnel.

  - Cover stored drums which are known to be reactive with water.

9.8.3.2.2 Containers Must be 90 Percent Full--Section 264.315 requires that containers must be 90 percent full when placed in a landfill unless they are very small, such as an ampule. To comply with this rule, the applicant must have provisions for checking the depth from the top of the container to the waste level. In a typical 55-gallon drum, a 4-inch depth is equivalent to a void space of approximately 10 percent.[4] The void space can be checked by simply removing the bung hole in the lid, providing there is one, and measuring the depth to the waste material with a rod. If the container lid does not have a bung hole, the lid must be removed to check for the amount of void space.

Opening drums or other sealed containers may be hazardous to facility personnel unless proper safety procedures are followed. During container opening, gases can be released or the contents can be spilled. When handling flammable, explosive, or otherwise reactive wastes, nonsparking equipment must be employed and drums should be opened with a pneumatic impact wrench, operated from a remote site. Operator personnel should be dressed in protective clothing.

It is expected that the waste generator will generally fill containers to at least 90 percent capacity in consideration of cost and the problems of managing partially full containers. This practice may be particularly true at onsite facilites. For offsite facilities, it will be wise for the owner/operator to specify that he will accept containers, only if they are full.

9.8.3.2.3 Mixing of Wastes Emptied from Drums--The landfill operator should demonstrate how containers which are less then 90 percent full will be handled. Generally, such containers will either be emptied or they will be filled to greater than 90 percent capacity with compatible materials. If the waste is a liquid, the material can be decanted or pumped to a storage or treatment facility or emptied into a landfill cell containing compatible wastes and constructed with a bottom liner and leachate collection system.

If various waste types are combined, the applicant must address the issue of waste compatibility. Reactions of incompatible wastes could result in serious accidents to facility operators or could cause extensive damage to the environment or facility property and equipment. The permit reviewer should refer to subsection 9.6.3 for a discussion of waste compatibility. That section provides a listing of available references for evaluating the compatibility of hazardous wastes.

Instead of combining waste materials, the applicant may elect to add a filler material to obtain 90 percent full containers. This may be preferable to combining wastes which are potentially incompatible. However, the filler should be a nonreactive material. If an absorbent material is used as a filler, the added advantage of eliminating free liquids may be obtained. Filler materials are also available which will tend to stabilize the containerized waste. Section 9.7 of this document discusses solidification/stabilization methods for hazardous wastes.

9.8.3.2.4 Container Corrosion and Collapse--If the applicant proposes to place containers in a landfill which is not equipped with a liner and leachate collection system, it will be appropriate for the applicant to insure the integrity of the drum until the final cover (i.e., cap) is placed on the landfill. Until then, the landfill and drummed wastes will be subject to rainfall percolation. If the containers corrode and wastes escape or are exposed, hazardous materials could leach out of the landfill into the ground water. If so, corrective action could be required. Remedial measures are generally costly. The leachate problem could have been avoided, however, if the containers had remained intact. Some methods available to avoid the problems attendant with container collapse are listed below:[5]

- Solidification/stabilization of the contained waste to minimize waste leaching after container decay.

- External encapsulation of drums. Containers can be encapsulated by a number of materials. Polyethylene or fiberglass polyethylene overpacks are reported to compete on a cost basis with conventional steel drum overpacks presently used at landfill facilities.

- Drum burial techniques can be selected to reduce the degree of container collapse. In many cases, it may be best to bury containers upright to avoid loss of contents during handling and maintain ease in identification before burial. Alternatively, lateral container orientation places the minimum container dimension in the vertical direction and, therefore, minimizes the vertical extent of compression upon eventual collapse of the drum.

- Container longevity is dependent on container construction. The use of thick walled containers or containers with special coatings will provide longer life.

In contrast to the rationale presented above, it may be preferable to intentionally empty and crush containers or to allow containers to leak and collapse prior to placement of the final cover if the landfill is equipped with a liner and leachate collection system. Such action may increase the long-term stability of the final cover because settling and collapse after closure will be minimized.

The time required for container corrosion and collapse is questionable if the containers are not intentionally emptied and crushed. Further, it is uncertain whether the applicant has much control over promoting container failure by any other means. Nevertheless, the use of bare steel and thin-walled containers may promote container collapse.[5] If landfill cells are available that incorporate a liner and leachate collection system, the most appropriate drum handling technique may be that of emptying and crushing drums, thus, allowing the leachate collection system to handle any contained liquids or resulting leachate. Naturally, waste compatibility and waste/liner compatibility must be considered.

9.8.3.2.5 Crushing and/or Shredding of Containers--To minimize subsidence in the landfill as a result of decaying containers, the applicant has the option to crush, shred or similarly reduce the volume of the containers to the maximum extent possible. Mechanical means of reducing the volume of containers can be effective and can generally be accomplished with heavy equipment that the landfill operator would normally employ.

Containers are typically crushed using heavy earth moving equipment. If the applicant proposes to crush or shred drums without completely emptying them first, he must demonstrate that he has enough knowledge of the waste to insure that the contents are nonreactive and/or nonexplosive under such conditions.

Because the effectiveness of the crushing operation is dependent on the completeness of crushing, the applicant should specify how he will inspect the crushed containers before burial.

In addition to crushing by heavy equipment, there are a number of commercially available processes which can be employed to crush or shred containers. When employing commercial crushing or shredding equipment, it is generally necessary to first empty the containers. The applicant should

specify how the containers will be emptied and how the emptied waste will be handled. Good operating practice dictates that the emptied material be promptly stored, treated, or disposed.

9.8.3.2.6 Compatability of Waste Types--At some point in the process of handling containerized waste, the applicant may combine various waste types. This may occur when wastes are emptied into the same location, or when containers are crushed and residual wastes intermingle. When different waste types are combined, the applicant must assure that the wastes are compatible. Commingling of wastes which are incompatible could result in generation of toxic or ignitable fumes, fires, or explosions. Wastes may also be incompatible if the combination of two waste types would increase the mobility of a waste in the environment (e.g., one waste constituent dissolves another waste constituent). The applicant must report the different types of waste that will be combined and the procedures he has followed and will follow to assure that wastes are compatible.

The permit reviewer should have available a report by Hatayama, et al. (1980) entitled "A Method for Determining the Compatibility of Hazardous Wastes" which deals with waste reactions that can cause a safety hazard because of possible explosions, fire, or generation of toxic gases.[6] The permit reviewer should also consider a report by JRB Associates entitled "Techniques for Evaluating Environmental Processes Associated with the Land Disposal of Specific Hazardous Materials, Volume II, Incompatible Wastes."[7] This report explains the environmental hazard arising from combining wastes which will increase the mobility of a contaminant through increased solubility. Each report provides applicable waste compatibility matrices.

9.8.3.2.7 Small Containers--Small containers of hazardous waste in overpacked drums (lab packs) may be placed in a landfill if the specific conditions of §264.315 are met. The conditions of §264.316 are intended for generators of hazardous waste. The owner or operator of an offsite landfill must indicate how compliance with §264.316 will be attained to avoid placement of noncomplying lab packs in the landfill.

Methods which landfill operators can use to help assure that lab packs comply with §264.316 include:

- Visual inspection.
- Opening of a representative sample population of the outside containers to assure that the outer container is full and that a sufficient quantity of absorbent material has been used.
- Specifying in a contract between the landfill operator and the generator that:
  - The absorbent material will not react dangerously or be decomposed by the container contents,
  - The wastes in a single outside container are compatible,

- No reactive wastes are disposed of in overpacked drums other than cyanide- or sulfide-bearing wastes.

A worksheet for determining the adequacy of the applicant's submittal on containerized waste disposal is presented in Figure 9.8.3.

9.8.4 Draft Permit Preparation

Condition I of Permit Module XV addresses special requirements for landfill disposal of containers. The condition is implemented through reference to a permit attachment that describes methods used to fill or crush the waste containers. Permit application data can be substituted for the attachment provided the application explains how the voids will be eliminated in the containers to assure that they will be at least 90 percent full. Alternatively, the submitted application should indicate methods used to crush, shred, or otherwise reduce the container's volume prior to burial. If the submitted application does not adequately address methods used to reduce container volume, the permit writer should either write in appropriate disposal conditions or should write in a condition which prohibits disposal of containers. Small containers, such as ampules, are exempt from this requirement.

Requirements for landfill disposal of small containers of hazardous waste in overpacked drums are discussed in Condition J of Permit Module XV. Permit application information to be inserted as the attachment should include the following:

- An inspection plan demonstrating how the applicant will determine that the inside containers are nonleaking, constructed of nonreactive materials, tightly sealed, and meet applicable DOT requirements.
- A specification that overpacked drums will be open head metal shipping containers having a capacity of no greater than 110 gallons.
- Specifications for any absorbent materials used inside the lab pack.
- A description of methods used to avoid placement of incompatible wastes in the same lab pack.
- A description of methods to treat or render reactive wastes (other than cyanide- or sulfide-bearing wastes) nonreactive prior to packaging.

If methods used to dipose of lab packs are not adequately addressed in the submitted application, the permit writer should write a specific condition for lab pack disposal or should include a condition prohibiting disposal of lab packs.

SPECIAL REQUIREMENTS FOR CONTAINERS AND LAB PACKS

Has this part of the applicant's submittal been read and evaluated? ____ Yes ____ No

Container Disposal

Will hazardous waste be landfilled in containers? ____ Yes ____ No

Are measures taken to prevent releases of hazardous waste during handling? ____ Yes ____ No

Did the applicant consider measures to limit releases to ground water, surface water, and the ambient air? ____ Yes ____ No

Are provisions for protecting against fire and explosions considered? ____ Yes ____ No

Does the applicant include provisions for identifying drums which are less than 90 percent full? ____ Yes ____ No

Are safety procedures for opening drums adequate? ____ Yes ____ No

What material(s) will be used to fill containers which are less than 90 percent full?_____

_____

If wastes are used to fill container void space, are they compatible with container contents as determined in subsection 9.6.3? ____ Yes ____ No

For unlined landfills with no leachate control system, are adequate measures taken to ensure that containers remain intact until application of the final cover? ____ Yes ____ No

Figure 9.8.3. Worksheet for evaluating disposal procedures for containers and lab packs.

Did the applicant specify equipment and procedures for crushing or shredding containers? ____ Yes ____ No

Are containers emptied before crushing? ____ Yes ____ No

If not,

Did the applicant demonstrate that the wastes are nonreactive and nonexplosive under such conditions? ____ Yes ____ No

Does the applicant explain how the crushed containers will be inspected for volume reduction prior to burial? ____ Yes ____ No

Lab Pack Disposal

Are lab packs smaller than 110 gallons, as required by §264.316(b)? ____ Yes ____ No

Did the applicant include procedures to inspect lab packs for:

- Leaks? ____ Yes ____ No
- Sufficient quantities of absorbent material? ____ Yes ____ No
- Void space? ____ Yes ____ No

Has the absorbent material been tested to assure that it will not react with the container contents? ____ Yes ____ No

Will reactive wastes other than cyanide- and sulfide-bearing wastes be excluded from the lab packs, as required by §264.316(e)? ____ Yes ____ No

Figure 9.8.3 (continued)

9.8.5 References

1. U.S. Environmental Protection Agency. Permit Applicants' Guidance Manual for Hazardous Waste Land Storage, Treatment, and Disposal Facilities. Volume I. Office of Solid Waste. Washington, D.C. 1983.

2. U.S. Environmental Protection Agency, RCRA Guidance Document for Landfill Design--Liner Systems and Final Cover. Draft--July 1982.

3. Wetzel, R., K. Wagner, and A. N. Tafuri. Drum Handling Practices at Abandoned Sites. In Management of Uncontrolled Hazardous Waste Sites, Washington, DC. November 29 to December 1, 1982.

4. Found in Preamble Notice of July 26, 1982 at 47 FR 32331.

5. Farino, W. J. and C. W. Young. Suitable Methods for Drum Disposal at Hazardous Waste Landfills. Final White Paper prepared by GCA/Technology Division for U.S. Environmental Protection Agency, Hazardous Waste Management Division, February 1983.

6. Hatayama, et al. A Method for Determining the Compatibility of Hazardous Wastes, U.S. Environmental Protection Agency, 600/2-80-076, 1980.

7. JRB Associates, Inc. Techniques for Evaluating Environmental Processes Associated with the Land Disposal of Specific Hazardous Materials, Volume II, Incompatible Wastes, March 31, 1982.

9.9 TECHNICAL ADEQUACY CHECKLIST

Table 9.9.1 is a technical adequacy checklist provided to assist the permit writer in evaluating the applicant's entire submittal on landfills. The checklist highlights major technical topics in each section and may be used to compile and record data gaps and inconsistencies where additional information is required. The checklist should be updated as additional technical data are obtained from the applicant.

TABLE 9.9.1. TECHNICAL ADEQUACY CHECKLIST

Technical topic	Is this topic applicable to the facility?	Was the topic addressed?	Has the submittal been checked for completeness and accuracy?	Is the applicant's plan technically adequate?	Is further action required?	Comments
Listing of hazardous waste						
- Existing facility						
- New facility						
Liner system design						
- Ground water						
- Waste/liner compatibility						
- Synthetic liner permeability						
- Resistance to pressure gradients and stresses						
- Resistance to climatic conditions and sunlight						
- Foundation design and integrity						
Leachate collection and removal systems						
- Calculation of load bearing capacity						
- Acceptability of filter fabrics (geotextiles)						
- Selection and sizing of filter and drainage media						
- Selection of pipe perforation or slot size						
Liner and leachate collection and removal system exemption						

(continued)

TABLE 9.9.1 (continued)

Technical topic	Is the topic applicable to the facility?	Was the topic addressed?	Has the submittal been checked for completeness and accuracy?	Is the applicant's plan technically adequate?	Is further action required?	Comments
Run-on control						
- Determination of magnitude of 25-year storm event						
- Calculation of peak run-on rate for design storm event						
Run-off control						
- Determination of magnitude/ intensity of 24-hour, 25-year storm event						
- Calculation of run-off volume from design storm event						
Management of units associated with run-on and run-off control systems						
- Run-off control						
- Run-on control						
Management of wind dispersal						
Subpart F exemption						
Monitoring and inspection requirements						
- General information						
- Inspection procedures before and during inspection						
-- In-situ soils						
-- Foundation materials						

(continued)

TABLE 9.9.1 (continued)

Technical topic	Is the topic applicable to the facility?	Was the topic addressed?	Has the submittal been checked for completeness and accuracy?	Is the applicant's plan technically adequate?	Is further action required?	Comments
-- Synthetic liners and covers						
-- Soil-based or admixed liners						
-- Leak detection/leachate collection system materials						
-- Drainage/protective layer material						
-- Vegetative support layer materials						
- Post-installation inspection procedures						
-- Sheet and membrane materials						
-- Fluid materials						
-- In-situ soils						
-- Foundation materials						
-- Liner materials						
-- Leak detection/leachate collection system materials						
-- Drainage/protective layer materials						
- Weekly and after storm inspection procedures						
-- Run-on and run-off control systems						
-- Leak detection system,						

(continued)

TABLE 9.9.1 (continued)

Technical topic	Is the topic applicable to the facility?	Was the topic addressed?	Has the submittal been checked for completeness and accuracy?	Is the applicant's plan technically adequate?	Is further action required?	Comments
-- Wind dispersal control systems						
-- Leachate collection and removal systems						
Landfill closure and post-closure						
- Closure						
- Post-closure						
Handling and disposal of ignitable or reactive wastes						
- General information						
- Option 1--treatment to render wastes nonignitable or nonreactive						
- Option 2--ignitable wastes disposed in nonleaking containers						
Handling of incompatible wastes						
Disposal of liquid wastes						
- General information						
- Bulk or noncontainerized waste disposal						
Special requirements for containers and lab packs						

SECTION 10.0

COMPLETENESS CHECKLIST

This section contains a checklist of items which must be included in a RCRA permit application. The checklist separately covers the items required in Part A and B of a land storage, treatment, and disposal permit application. The checklist is 41 pages long and addresses all of the permit application requirements that are discussed in this manual. The checklist also addresses the general information requirements of §270.14(b) on pages 3 through 14 and 21.

It is recommended that this checklist be used during review of the completeness of any permit application. After conducting the review, this checklist will provide a table of contents and a summary of the permit application. As such, it will assist permit reviewers in preparation of deficiency letters. The cover sheet can be used to indicate personnel who conducted the review and will provide a mechanism for checking on questions and comments which arise at later stages in the review process.

Each required information item is briefly stated. Regulatory citations are provided which enable quick location of the full text of the regulation that contains each required item. If no citation is indicated next to a specific item, the last citation indicated above the item contains the requirement.

Spaces are provided for indication of whether the item is included, not included, inadequate, or not applicable. Space is also provided to record the location of items in the application.

The required items are listed in the sequence that they are presented in 40 CFR 270 except where presentation of information from a later section is specifically requested by the subject regulatory citation. A major exception is that the additional information requested in §270.14(c) is listed at the end of the checklist beginning on page 35.

RCRA PERMIT APPLICATION COMPLETENESS CHECKLISTS FOR PARTS A & B

Date Application Received _____

Applicant Name _____

Applicant Contact _____

Applicant Contact Telephone Number _____

EPA I.D. Number _____

Permit Review Team

Name	Parts Reviewed	Date Review Completed

Comments _____

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.10(d) and 270.13		**Part A Requirements**						
270.13(g)		- Statement that facility is new or existing						
270.13(g)		- Statement that application is first or revised						
270.13(m)		- Description of business conducted						
270.13(c)		- SIC Codes						
270.13(a)		- Description of activities requiring permit						
270.13(b)		- Facility: Name						
270.13(b)		- Mailing Address						
270.13(b)		- Location						
270.13(b)		- Latitude and Longitude						
270.13(h)(1)		- Scale drawing (existing facility only)						
		- Sufficient detail						
270.13(i)		- Topographic Map						
		- Sufficient detail						
270.13(i)		- Other map						
		- Sufficient detail						
270.13(h)(2)		- Photographs (existing facilities only)						
		- Sufficient detail						
270.13(e)		- Owner: Name						
		- Address						
		- Telephone						
270.13(d)		- Operator: Name						
		- Address						
		- Telephone						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.13(d)		- Identification of facility ownership status and status as Federal, State, private, public, or other entity						
270.13(f)		- Statement that facility is or is not on Indian lands						
270.13(k)		- Listing of all permits and construction approvals received/applied for						
270.13(j)		- List of 40 CFR 261 wastes and annual amounts to be handled						
270.13(i)		- Description of all processes to be used to handle wastes and design capacity of each process						
		Part A Certification and Signatories						
270.11(d)		- Certification paragraph						
270.11(a)		- Appropriate signatory						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14		Part B General Information Requirements						
270.14(b)(1)		- General description of the facility						
270.14(b)(2)	264.13(a)	- Chemical and physical analysis of hazardous wastes to be handled						
270.14(b)(3)		- Waste analysis plan						
	264.13(b)(1)-(5)	- Analysis parameters with rationale						
		- Test methods for analyzing parameters						
		- Procedure for collecting representative samples						
		- Frequency of analyses						
		- List and description of waste analyses to be generator supplied						
	264.13(b)(6) and 264.17(c)	- Waste analysis procedures for ignitable, reactive, incompatible wastes						
	264.13(c)	- Procedures to determine identity of each waste movement						
		- Procedures for collecting representative samples						
270.14(b)(4)		- Security description for active portion of facility						
	264.14(a)	- Security procedures waiver justification						
		- Unknowing/unauthorized contact with waste not harmful						
		- Unknowing/unauthorized disturbance of waste or equipment cannot cause violation of Part 264						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(b)(4)	264.14(b)	- Description of 24-hour surveillance system						
		- Description of artificial or natural barriers						
		- Description of controlled entry/egress procedures						
	264.14(c)	- Description of warning signs						
		- List of languages on signs						
		- Statement of 25-foot legibility						
		- Description of sign locations and numbers of signs						
270.14(b)(5)		- General Inspection Schedule and Procedures Description						
	264.15(b)(1)	- Written schedule						
	264.15(b)(2) and 265.15(d)	- Statement as to where, at facility, inspection schedule and inspection records will be kept						
	264.15(b)(1)	- Identification of equipment/processes to be inspected						
	264.15(b)(3)	- Identification of types of problems each equipment/process to be checked for						
	264.15(b)(4)	- Frequency of inspections by equipment/process						
	264.15(c)	- Schedule of remedial action						
270.14(b)(5) and 270.17(d)	264.15(a) and 264.226	- Specific Inspection Requirements for Surface Impoundments						
		- Description of procedures for						
		- Inspection of liners/covers during and immediately after installation						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(b)(5) and 270.17(d)	264.15(a) and 264.226	- Inspections weekly and after storms for						
		- Operation of overtopping controls						
		- Sudden drop in impoundment liquid level						
		- Presence of liquid in leak detection system						
		- Integrity of dikes/containment devices						
		- Statement from qualified engineer that structural integrity of dikes will be certified upon construction completion						
		- Qualified engineer's certification of dike integrity for						
		- Stress						
		- Piping/scouring						
270.14(b)(5) and 270.18(e)	264.15(a) and 264.254	- Specific Inspection Requirements for Waste Piles						
		- Description of procedures for						
		- Inspection of liners/covers during and immediately after installation						
		- Inspections weekly and after storms for						
		- Operation of run-on/run-off controls						
		- Liquids in leak detection system						
		- Proper functioning of wind dispersal controls						
		- Leachate in and proper operation of leachate collection/removal system						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(b)(5) and 270.20(c)(5)	264.15(a) and 264.273(g)	- Specific Inspection Requirements for Land Treatment Units						
		- Description of procedures for units inspections weekly and after storms for						
		- Operation of run-on/run-off controls						
		- Function of wind dispersal controls						
270.14(b)(5) and 270.21(d)	264.15(a) and 264.303	- Specific Inspection Requirements for Landfills						
		- Description of procedures for						
		- Inspection of liners/covers during and immediately after installation						
		- Inspections weekly and after storms for						
		- Operation of run-on/run-off controls						
		- Liquids in leak detection system						
		- Proper functioning of wind dispersal controls						
		- Leachate in and proper operation of leachate collection/removal system						
270.14(b)(6)	Part 264 Subpart C	- Preparedness and Prevention Documentation						
		- Waiver(s) request and justification						
	264.32(a)	- Description of internal communications/ alarm system(s)						
	264.34(a)	- Documentation of personnel access to internal communication/alarm system(s)						
	264.32(b)	- Description of external communications/ alarm system(s)						
	264.34(b)	- Documentation of personnel access to external communications/alarm system(s)						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(b)(6)	264.32(c)	- Description of fire control/ extinguishing, spill control, and decontamination equipment						
	264.32(d)	- Documentation of adequate water volume and pressure for above equipment						
	264.33	- Documentation of equipment testing/ maintenance schedule and procedures						
	264.35	- Documentation of adequate isle space						
	264.37 (also 264.52(c))	- Documentation and descriptions of arrangements or attempts at arrangements with;						
		- Police department(s)						
		- Fire department(s)						
		- Hospitals						
		- Local emergency response teams						
		- State emergency response teams						
		- Emergency response contractors						
		- Equipment suppliers						
	264.37(a)(2)	- Documentation of agreements designating primary emergency authority						
270.14(b)(7)	Part 264 Subpart D	- Contingency Plan Documentation						
	264.51 and 264.52(a)	- Criteria for implementation of contingency plan						
	264.52(d)	- Emergency Coordinators Identification						
		- Names						
		- Addresses						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(b)(7)		- Home/Work Phones						
	264.55	- Documentation of Qualifications						
		- Documentation of Authority						
		- Description of notification procedure						
	264.52(e)	- Emergency equipment list						
		- Documentation of equipment location						
		- Physical description of equipment						
		- Statement of equipment capabilities						
	264.52(f)	- Evacuation Plan						
		- Criteria for implementation						
		- Description of signal(s) to implement						
		- Description of primary and alternate routes						
	264.53	- Contingency Plan Copy Location						
		- Description of location of facility's copy of plan						
		- Number of duplicate copies distributed and their location						
	264.54	- Contingency Plan Amendment						
		- Identification of person responsible and authorized to change/amend plan						
		- Description of procedure to change/ amend facility copy of plan						
		- Description of procedure to insure update of all copies of plan						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(b)(7)	264.56	- Detailed Emergency Procedures						
		- Procedure for facility personnel notification						
		- Procedure for state/local agency notification						
		- procedure for identification of character, source, amount, and areal extent of released materials						
		- Procedure for assessment of environment/human health hazards						
		- Identification of On-Scene Coordinator for geographic area						
		- Description of specific responses and control procedures for						
		- Fire						
		- Explosion						
		- Spill						
		- Description of process shutdown and monitoring procedures						
		- Description of cleanup procedures and associated material treating, storing, disposal procedures						
		- Description of emergency equipment cleaning and refitting procedures						
		- Description of procedures to insure incompatible waste segregation during cleanup						
270.14(b)(7) and 270.17(f)	264.227	- Specific Contingency Plan Requirements for Surface Impoundments						
		- Procedure for stopping waste addition to impoundment						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
	264.227	- Procedure for containing leakage						
		- Procedure to prevent catastrophic failure						
		- Procedure for emptying impoundment						
		- Procedure for recertifying and reactivating impoundment						
		- Procedure for closing impoundment						
[Note: There are no §122.25 requirements which parallel Part 264, Subpart E. However, the applicant should be familiar with the following sections of the regulations since the requirements in them will be enforceable under any permit received. Part 264, Subpart E, §264.70 through §264.77 Part 270, Subpart C, §270.30(j) and §270.30(l) The applicant should be prepared to respond to inquiries by the permit application reviewers regarding these requirements]								
270.14(b)(8)		- Preventive Procedures, Structures, and Equipment Documentation, including descriptions of equipment/procedures to						
		- Prevent hazards during unloading operations						
		- Prevent run-off and flooding						
		- Prevent water supply contamination						
		- Mitigate equipment failure and power outages						
		- Prevent undue personnel exposure to wastes						
270.14(b)(9)	264.17	- Prevention of Accidental Ignition or Reaction Documentation						
		- Description of separation and protection of ignitable, reactive, incompatible wastes						
		- Description of ignitable, reactive, incompatible wastes handling procedures						
		- Description of number, location, and type of warning/prohibition signs						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Documentation that procedures are adequate to prevent accidental ignitions or reactions						
		- Description of number, location, and type of warning/prohibition signs						
		- Documentation that procedures are adequate to prevent accidental ignitions or reactions						
270.14(b)(9) and 270.17(h) and 270.17(i)	264.17(b)	- Specific Ignitable/Reactive Waste Requirements for Surface Impoundments						
	264.229	- Procedures that render waste nonreactive or nonignitable						
		- Procedures for preventing reactions						
		- Procedures for protecting wastes						
		- "Emergency use only" documentation						
	264.230	- Incompatible waste segregation or protection procedures						
270.14(b)(9) and 270.18(g) and 270.18(h)	264.17(b)	- Specific Ignitable/Reactive Waste Requirements for Waste Piles						
	264.256	- Procedures that render waste nonreactive or nonignitable						
		- Procedures for preventing reactions						
		- Procedures for protecting wastes						
	264.257	- Incompatible waste segregation or protection procedures						
270.14(b)(9) and 270.20(g) and 270.20(h)	264.17(b)	- Specific Ignitable/Reactive Waste Requirements for Land Treatment Facilities						
	264.281	- Documentation that application to soil renders waste nonreactive/nonignitable and prevents reactions						
		- Procedures for protecting wastes						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
	264.282	- Procedures which insure that incompatible wastes are not applied to same treatment zone						
270.14(b)(9) and 270.21(f) and 270.21(g)	264.17(b)	- Specific Ignitable/Reactive Waste Requirements for Landfills						
	264.312	- Procedures that render wastes nonreactive and nonignitable						
		- Procedures for preventing reactions						
		- Procedures for protecting wastes						
	264.313	- Procedures for insuring that incompatible wastes will not be disposed of in same landfill cell						
	264.316 (c)-(e)	- Procedures for identifying contents and insuring proper landfilling of incoming labpacks						
270.14(b)(10)		- Traffic Documentation						
		- Identification of;						
		- Waste movement routes						
		- Number of movements by type vehicle						
		- Quantity of waste moved per movement per vehicle						
		- Traffic control signals and personnel						
		- Route surface composition and load bearing capacity						
270.14(b)(11)		- Facility Location Documentation						
270.14(b)(11)(i) and (ii)		- Political jurisdiction identified (new facilities only)						
		- Comparison to Appendix VI of Part 264						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Demonstration that faults with displacement in Holocene time are more than 3000 feet from facility						
	264.18(a)	- Demonstration that no faults pass within 200 feet of sites where T/S/D to be conducted						
270.14(b)(11)(iii)-(iv)	264.18(b)	- Documentation of facility location relative to 100-year flood plain level or wave action flooding						
		- Documentation that facility can withstand the 100-year flood without washout of hazardous waste by:						
		- Analysis of hydrodynamic/hydrostatic forces resulting at site from 100-year flood, and						
		- Presentation of operating units and flood protection devices design and how they will prevent washout, or						
		- Plan for removal of waste before washout including,						
		- Timing of removal relative to flood levels						
		- Estimated time to remove all waste						
		- Location to which waste will be moved and proof of compliance with Parts 122 through 124 and 264 through 267 of this Chapter						
		- Detailed description of personnel, equipment, and procedures for waste removal sufficient to insure availability in time for use						
		- Analysis of potential for discharge during waste movement						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(b)(11)(v)		- A plan documenting how and on what time schedule the facility will comply with §264.18(b) if not in compliance (existing facilities only).						
270.14(b)(12)	264.16	- Personnel Training Program Documentation						
		- Outline of introductory and continuing personnel training programs						
		- Identification and qualifications of program instructor						
		- Brief description of how training program meets actual job tasks						
		- Description of procedures to insure all appropriate personnel receive appropriate training and receive annual training review						
		- Description of records to be kept, their location, and procedures to insure they are retained for proper length of time						
270.14(b)(13)	264.112	- Closure Plan Documentation						
		- Description of partial and final closure procedures						
		- Description of maximum unclosed portion during facility life						
		- Estimate of maximum waste inventory in storage/treatment during facility life						
	264.114	- Equipment decontamination procedure						
		- Estimated year of closure						
	264.113	- Description of closure schedule including						
		- Total time to close						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(b)(13)	264.113	- trackable intervening closure activities						
		- Location(s) and number of copies of closure plan						
		- Identification of person responsible for storage and updating of facility copy of closure plan						
		- Procedure for updating all other copies of closure plan						
270.14(b)(13) and 270.17(g)	264.112 and 264.228(a)	- Specific Closure Plan Requirements for Surface Impoundments						
		- Procedures for removal and/or decontamination of all wastes and materials/equipment associated with the impoundment, or						
		- Detailed plans and engineering reports describing						
		- Elimination of free liquids						
		- Stabilization of remaining wastes						
		- Design of final cover demonstrating						
		- Liquid migration minimization						
		- Function with minimum maintenance						
		- Drainage promotion						
		Erosion/abrasion minimization						
		- Settling/subsidence accomodation						
		- Permeability less than liner or subsoils						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(b)(13) and 270.18(a)	264.112	- Specific Closure Plan Requirements for Waste Piles						
	264.258(a)	- Procedure for removal and/or decontamination of all wastes and materials/equipment associated with the waste pile						
	264.258(b)	- Procedure for closing in conformance with landfill closing requirements						
270.14(b)(13) and 270.20(f)	264.112	- Specific Closure Plan Requirements for Land Treatment Facilities						
	264.280(a)	- Procedures to maximize degradation of waste in treatment zone						
		- Procedures to minimize waste runoff						
		- Run-off system maintenance procedures						
		- Wind dispersal control procedures						
		- Procedures for compliance with food-chain crop growth						
		- Procedures for unsaturated zone monitoring						
		- Description of vegetative cover						
		Procedures for establishing vegetative cover						
270.14(b)(13) and 270.21(e)	264.112 and 264.310(a)	- Specific Closure Plan Requirements for Landfills						
		- Detailed plans and an engineering report which describes the final cover components in detail						
		Documentation that the final cover will						
		- Provide long term minimization of migration of liquids through closed landfill						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Function with minimum maintenance						
		- Promote drainage and minimize erosion/abrasion						
		- Settle/subside without losing integrity						
		- Be less permeable than bottom liners or subsoils						
270.14(b)(13)	264.117 and 264.118	- Post-Closure Plan Documentation						
		- Description of ground water monitoring activities and frequencies						
		- Description of maintenance activities and frequencies for:						
		- Final containment structures						
		- Facility monitoring equipment						
		Location(s) and number of copies of post-closure plan						
		Identification and location (address and phone number) of person responsible for storage and updating of facility copy of post closure plan prior to closure						
		Identification and location (address and phone number) of person responsible for storage and updating facility copy of post closure plan during post-closure period						
		Procedure for updating all other copies of post-closure plan						
270.14(b)(13) and 270.17(g)	264.118 and 264.228(b)	- Specific Post-Closure Plan Requirements for Surface Impoundments						
		Procedures for maintenance and repair of final cover						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Procedures for maintenance and monitoring of leak detection system						
		- Procedures for maintenance and monitoring of ground water monitoring system						
		- Procedures for compliance with Subpart F						
		- Procedures for preventing run on/run-off final cover damage						
270.14(b) (13) and 270.18(i)	264.118 and 264.258(b)	Specific Post Closure Plan Requirements for Waste Piles						
		- Procedures for post-closure care that meet the requirements for landfills						
270.14(b) (13) and 270.20(f)	264.118 and 264.280(c)	Specific Post-Closure Plan Requirements for Land Treatment Facilities						
		- Procedures to enhance degradation of wastes in treatment zone						
		- Procedure for maintaining vegetative cover						
		- Procedure for maintaining run-on controls						
		- Procedure for maintaining run-off controls						
		- Procedures for wind dispersal control						
		- Procedures to insure compliance with food-chain crop prohibitions						
		- Procedures for unsaturated zone monitoring						
270.14(b) (13) and 270.21(e)	264.118 and 264.310(b)	Specific Post-Closure Plan Requirements for Landfills						
		- Procedures for maintenance and repair of final cover						
		- Monitoring and maintenance procedures for leak detection system						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Procedure for leachate collection/removal system operation						
		- Procedures to maintain and monitor ground water monitoring system						
		- Procedures for compliance with Subpart F						
		- Procedures for preventing final cap erosion due to run on and run-off						
		- Procedures for protection and maintenance of benchmarks						
	264.310(c)	- Procedures to be undertaken if liquid is found in leak detection system						
270.14(b)(14)	264.120	- Documentation of Notice on Deed (existing facilities only)						
		- Statement that land used to manage wastes						
		- Statement of restricted use per § 84.117(c)						
	264.119	Documentation of type, location, and quantity of wastes filed with local authority and EPA Regional Administrator						
270.14(b)(15)	264.142	- Closure Cost Estimate						
	264.143 and 264.146	Documentation of a financial assurance mechanism for closure that is						
	264.151(a)	Closure trust fund						
	264.151(b)	Surety bond guaranteeing payment						
	264.151(c)	Surety bond guaranteeing performance						
	264.151(d)	Closure letter of credit						
	264.151(e)	Closure insurance						
	264.151(f) and (h)	Financial test and corporate guarantee						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Multiple financial mechanism for one facility						
		- Single financial mechanism for multiple facilities						
270.14(b)(16)	264.144	Post-Closure Cost Estimate						
	264.145 and 264.146	Documentation of a financial assurance mechanism for post-closure that is;						
	264.151(a)	- Closure trust fund						
	264.151(b)	- Surety bond guaranteeing payment						
	264.151(c)	- Surety bond guaranteeing performance						
	264.151(d)	- Post-closure letter of credit						
	264.151(e)	- Post-closure insurance						
	264.151(f) and (h)	- Financial test and corporate guarantee						
		- Multiple financial mechanism for one facility						
		- Single financial mechanism for multiple facilities						
270.14(b)(17)	264.147	- Documentation of Insurance						
		- Request for variance from insurance						
	264.151(i) and (j)	- Insurance for sudden/accidental occurrences						
		- Insurance for nonsudden/accidental occurrences						
	264.151(g)	- Financial test for liability coverage						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(b)(18)	264.109	- Documentation of a State Required Financial Mechanism for Closure, Post-Closure, or Liability including						
		- EPA I.D. number						
		- Facility name						
		- Facility address						
		- Amounts of liability coverage or funds assured						
	264.150	- Documentation of State Assumed Responsibility for Closure Post-Closure or Liability including						
		- Letter from State describing State's responsibilities						
		Facility EPA I.D. number						
		Facility name						
		Facility address						
		Amounts of liability coverage or funds assured						
270.14(b)(19)		- Topographic map showing a distance of 1000 feet around facility at a scale of not more than 1 inch equals 200 feet that clearly shows						
		Contours						
		Proper contour intervals						
		Map scale and date						
		- 100-year flood plain area						
		Surface waters and intermittent streams						
		- Surrounding land uses						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(b) (19)		- Wind rose						
		- North orientation						
		- Legal boundaries of facility site						
		- Access control						
		- Injection and withdrawal wells onsite and offsite						
		- Buildings and recreation areas						
		- Runoff control systems						
		- Access and internal roads						
		- Storm, sanitary, and process sewerage systems						
		Loading and unloading areas						
		Fire control facilities						
		Barriers for drainage or flood control						
		Location of past or present operational units and equipment cleanup areas						
270.17		Specific Part B Information Requirements for Surface Impoundments						
270.17(a)		List of hazardous wastes placed or to be placed in impoundment						
270.17(b)	264.221	Detailed plans and an engineering report describing						
270.17(b)(1)	264.221(a)	- Liner system construction (new only)						
	264.221(a)(1)	- Material of construction						
		- Chemical properties						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.17(b)(1)		- Physical strength						
		- Thickness						
	264.221(a)(2)	- Foundation design/integrity						
	264.221(a)(3)	- Area covered						
	264.221(a)(1)	- Liner system integrity against (new only)						
		- Internal and external pressure gradients						
		- Contact with waste/leachate						
		- Climatic conditions						
		- Installation stresses						
		- Daily operational stresses						
	264.221(b)	- Liner system exemption including						
		- Nature and quantity of wastes						
		- Alternative design and operation						
		- Impoundment location description						
		- Hydrogeologic setting						
		- Attenuative capacity of materials between impoundment and groundwater and surface water						
		- Documentation of no migration to ground/surface waters at any future time						
270.17(b)(2)	264.221(c)	- Procedures/equipment to prevent overtopping from						
		- Normal operation						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.17(b)(2)	264.221(c)	- Abnormal operation						
		- Overfilling						
		- Wind/wave action						
		- Raintall						
		- Run-on						
		- Equipment malfunctions						
		- Human error						
270.17(b)(3)	264.221(d)	- Structural integrity of dikes						
270.17(c)	264.222(a)	Documentation for Part 264, Subpart F exemption including						
		- Impoundment and liner location above seasonal highwater table						
		- Two liners meeting §264.221(a) requirements						
		- Leak detection system between liners						
270.18		Specific Part B Information Requirements for Waste Piles						
270.18(a)		List of hazardous wastes placed or to be placed in each waste pile						
270.18(b)	264.250(c)	Documentation of general exemption from §264.251 and Part 264, Subpart F, including,						
		- Waste pile protection from precipitation						
		- Procedures for insuring liquids are not placed in pile						
		- Description of run-on controls						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Description of wind dispersal controls other than wetting						
		- Decomposition/reactions do not cause leachate generation						
270.18(c)	264.251(a)	- Detailed plans and an engineering report describing,						
270.18(c)(1)	264.251(a)(1)	- Liner system construction (new only)						
	264.221(a)	- Material of construction						
		- Chemical properties						
		- Physical strength						
		- Thickness						
		- Foundation design/integrity						
		- Area covered						
		- Liner system integrity against (new only)						
		- Internal and external pressure gradients						
		- Contact with waste/leachate						
		- Climatic conditions						
		- Installation stresses						
		- Daily operational stresses						
	264.251(a)(2)	- Leachate collection and removal system to maintain less than one foot of leachate on liner including,						
		- Materials of construction						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.18(c)(1)		- Chemical resistance to waste/ leachate						
		- Strength sufficient to prevent collapse						
		- Provisions to prevent clogging						
	264.251(b)	- Liner system/leachate system exemption including,						
		- Nature and quantity of wastes						
		- Alternative design and operation						
		- Pile location description						
		- Hydrogeologic setting						
		- Attenuative capacity of materials between pile, ground and surface waters						
		- Documentation of no migration to ground/surface waters at any future time						
270.18(c)(2)	264.251(c)	- System for control of run-on from peak discharge of a 25 year storm						
270.18(c)(3)	264.251(d)	- System for control of run-off water volume of a 24-hour, 25-year storm						
270.18(c)(4)	264.251(e)	Procedures to manage collection and holding facilities associated with run-on and run-off control systems						
270.18(c)(5)	264.251(f)	- Wind dispersal control procedures						
270.18(d)	264.252(a)	Documentation for Part 264, Subpart F exemption including,						
		Pile and liners above seasonal high water table						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.18(d)								
		- Two liners meeting requirements of §264.251(a)(1)						
		- Leak detection system between liners						
		- Leachate system meeting §264.251(a)(2) requirements						
	264.253(b)	Documentation for Part 264, Subpart F exemption including,						
		- Pile and liners above seasonal high water table						
		- Liner meets §264.251(a)(1) requirements						
		- Soil characteristics/depths						
		- Leachate system meets §264.251(a)(2) requirements						
		- Schedule/procedures for liner inspection by waste removal						
		- Sufficient liner strength/thickness to allow periodic removal/replacement of wastes						
270.18(f)		Description of treatment carried out in or on the pile including,						
		- Details of treatment process						
		- Equipment used						
		- Nature and quality of residuals						
270.20		- Specific Part B Information Requirements for Land Treatment Facilities						
270.20(a)		Description of treatment demonstration plans by						
	264.272(b)	- Field test						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.20(a)		- Laboratory analysis						
		- Available data						
		- Operating data (existing units only)						
		- Submittal for laboratory analyses or field test demonstration permit including,						
	264.272(c)	- Documentation of accurate simulation						
		- Wastes and hazardous constituents descriptions (Part 261, Appendix VIII)						
		- Climatologic information						
		- Topographical data						
		- Operating practices						
		- Type of test to be conducted						
		- Test materials and methods						
		- Expected completion time						
		- Statement on appropriateness of demonstration						
		- Statement on human health and environment protection considering,						
		- Characteristics of wastes to be tested						
		- Operating and monitoring during tests						
		- Duration of test						
		- Volume of waste used in test						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Potential for hazardous waste migration to ground/surface waters (field tests only)						
270.20(b)	264.27 (a)	- Description of land treatment program						
		- Wastes to be land treated						
		- Design measures to maximize treatment including,						
270.20(b)(2)(i)	264.27 (a)	- Rate and method of waste application						
		- Soil pH control measures						
		- Microbial/chemical reaction enhancements						
		Treatment zone moisture control measures						
270.20(b)(3)	264.278 (a)-(f)	Unsaturated zone monitoring procedures including,						
		- List of and rational for selecting compounds to be monitored						
		Monitoring equipment, procedures, frequency						
		- Procedures for selecting sampling locations						
		- Sample collection procedures						
		- Sample preservation/shipment procedures						
		- Sample chain of custody control						
		- Sample analysis procedures						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Background value determination procedure						
		- Statistical methods description						
270.20(b)(4)		- List of hazardous constituents expected to be in, or derived from, wastes to be land treated						
270.20(b)(5)	264.271(c)	- The proposed vertical and horizontal dimensions of the treatment zone with maximum depth of						
		- No more than 5 feet from the initial soil surface						
		- More than 3 feet above the seasonal high water table						
270.20(c)	264.27 (b)-(f)	Description of land treatment unit design						
		- Procedures/equipment to prevent run on from peak discharge of 25-year storm						
		- Procedures/equipment to collect and control the run-off water volume from a 24 hour, 25-year storm						
		- Procedures/equipment to minimize run-off from treatment zone during active life						
		- Run-on and run-off collection and control systems management plan						
		- Procedures/equipment for wind dispersal control						
270.20(d)	264.276(c)	Documentation of request for growth of food-chain crops on treatment zone not receiving cadmium in wastes						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.20(d)	264.276(a)	- Statement that demonstration of no risk to human health will be conducted by,						
		- Field tests						
		- Greenhouse studies						
		- Available data						
		- Operating data (existing only)						
		- Demonstration program description, including						
		- Soil pH						
		- Cation exchange capacity of soil						
		- Specific wastes to be applied						
		- Waste application rates						
		- Waste application methods						
		- Identification of demonstration crops						
		- Planting and growth procedures						
		- Characteristics of crop						
		- Sample selection criteria						
		- Sample collection procedure						
		- Sample size						
		- Analyses methods						
		- Statistical data evaluation procedures						
		- Identification of comparison crops						
		- Characteristics of crop						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.20(d)	264.276(a)	- Planting and growth procedures						
		- Conditions of growth						
		- Sample selection criteria						
		- Sample collection procedures						
		- Sample size						
		- Analyses methods						
		- Statistical data evaluation procedures						
		- Request for a permit to conduct demonstration program						
270.20(e)	264.276(b)	- Documentation of request for growth of food-chain crops on treatment zone if wastes contain cadmium						
		- Cadmium concentration in waste						
		- Soil pH						
		- Annual application of cadmium in kilograms per hectare						
		- Soil cation exchange capacity						
		- Identification of animal feeds to be grown						
		Plan to prevent animal feed ingestion by humans						
		- Documentation of notice on deed						
270.21		- Specific Part B Information Requirements for landfills						
270.21(a)		List of hazardous wastes to be placed in each landfill cell						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.21(b)	264.301(a)	- Detailed plans and an engineering report describing						
270.21(b)(1)	264.301(a)(1)	- Liner system construction (new only)						
		- Material of construction						
		- Chemical properties						
		- Physical strength						
		- Thickness						
		- Foundation design/integrity						
		- Area covered						
		- Liner system integrity against (new only)						
		- Internal and external pressure gradients						
		- Contact with waste/leachate						
		- Climatic conditions						
		- Installation stresses						
		- Daily operational stresses						
	264.301(a)(2)	Leachate collection and removal system to maintain less than one foot of leachate on liner including,						
		- Materials of construction						
		- Chemical resistance to waste/ leachate						
		- Sufficient strength to prevent collapse						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.21(b)(1)		- Provisions to prevent clogging						
	264.301(b)	- Liner system/leachate system exemption including,						
		- Nature and quantity of wastes						
		- Alternative design and operation						
		- Landfill location description						
		- Hydrogeologic setting						
		- Attenuative capacity of materials between landfill and ground and surface waters						
		- Documentation of no migration to ground/surface waters at any future time						
270.21(b)(2)	274.301(c)	- System for control of run-on from peak discharge of a 25-year storm						
270.21(b)(3)	274.301(d)	- System for control of run-off water volume from a 24-hour, 25-year storm						
270.21(b)(4)	274.301(e)	- Procedures to manage collection and holding facilities associated with run-on and run-off control systems						
270.21(b)(5)	274.301(f)	- Wind dispersal control procedures						
270.21(c)	264.302(a)	- Documentation for Part 264, Subpart F exemption including,						
		- Landfill and liners above seasonal high water table						
		- Two liners meeting requirements of §264.301(a)(1)						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Leak detection system between liners						
		- Leachate system meeting §264.301(a)(2) requirements						
270.21(b)	264.31	- Documentation of procedures/equipment for landfilling liquid wastes						
270.21(a)	264.31	- Documentation of procedures/equipment for landfilling containers						
270.14(c)	Part 264 Subpart F	Part B Protection of Ground Water Information Requirements for Surface Impoundments, Waste Piles, Land Treatment Units, and Landfills						
270.14(c)(1)		- Interim status period ground-water monitoring data summary						
270.14(c)(2)		- Identification of uppermost and hydraulically interconnected aquifers under facility including,						
		Water flow rate and direction						
		Bases for identification						
270.14(c)(3) and 270.14(b)(19)		- Topographic map						
		- Delineation of property boundary						
	264.95(b)	Delineation of waste management area						
	264.95(a)	- Delineation of proposed point of compliance						
		Ground water monitoring well locations						
		- Location of aquifers						
270.14(c)(4)		- Descriptions of existing contamination						
		- Delineation of plume extent						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Appendix VIII constituents concentrations						
		- Concentrations throughout plume						
		- Maximum concentrations in plume						
270.14(c)(5)	264.97	- Detailed plans and an engineering report of Ground Water Monitoring Program						
	264.97(a)	- Descripton of wells						
		- Number of wells						
		- Locations						
		- Depths						
		- Assurance of unaffected background water measurement						
		- Assurance of compliance point ground water measurement						
	264.97(c)	- Casing description						
	264.97(d)	- Description of sampling/analysis procedures						
		- Sample collection methods						
		- Sample preservation/shipment						
		- Analytical procedures						
		- Chain of custody control						
	264.97(e)	Documentation of proper/adequate analytical procedures						
	264.97(f)	Procedure for determination of ground water elevation with each sample						
270.14(c)(6)	264.91(a)(4) and 264.98	- Description of Detection Monitoring Program including,						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(c)(6)(i)	264.93 and 264.98(a)	- List of indicator parameters, waste constituents, reaction products to be monitored for, including						
		- Type, quantities, concentrations expected in wastes						
		- Mobility, stability, persistence in unsaturated zone						
		- Detectability in ground-water						
270.14(c)(6)(iii)	264.98(a)(4) and 264.98(c)(1)	- Background ground-water concentration values and coefficients of variation established by						
	264.98(c)(3)	- Use of an appropriate ground water monitoring system, and						
	264.97(g)(1)	- Quarterly sampling of upgradient wells for one year, or						
	264.97(g)(3)	- Quarterly sampling of other wells for one year, and						
	264.97(g)(4)	- Data from a minimum of one sample/well and minimum of four samples per quarter, or						
		- Presentation of procedures to calculate such values						
270.14(c)(6)(ii)	264.98(c)	- Description of an appropriate ground-water monitoring system to be installed at the compliance point						
270.14(c)(6)(iv)	264.98(d)	- Procedures for collecting semi-annual ground-water samples at the compliance point during						
		- Active life						
		- Closure period						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Post-closure period						
	264.98(e)	- Procedure for annual determination of uppermost aquifer flow rate and direction						
	264.98(f) & 264.97(d)&(e)	- Documentation of sample collection and analysis procedures						
	264.98(g)	- Procedure for determining a statistically significant increase for any monitored parameter or constituent by						
		- Comparing compliance point data to background value data using the procedures in §264.97(h)(1) or (2), and						
		- Providing an estimate of the time period after sampling completion necessary to obtain results						
270.14(c)(6)	264.98(h)	- Procedure to be implemented if a statistically significant increase in any constituent or parameter is identified at any compliance point monitoring well, including						
	264.98(h)(1)	- Written notification to Regional Administrator						
	264.98(h)(2)	- Sample collection and analysis methods for all Appendix VIII constituents at all monitoring wells						
	264.98(h)(3)	- Method for establishing Appendix VIII constituent background values						
	264.98(h)(4)	- Preparation of an application for permit modification to establish compliance monitoring						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(c)(7)	264.91(a)(1) and 264.99	- Description of Compliance Monitoring Program, including						
		- List of wastes previously handled at facility						
		- Characterization of contaminated ground-water						
		- Hazardous constituents identified						
		- Hazardous constituents concentrations						
	264.97(b)	- Description of compliance monitoring system at the compliance point						
		- List of hazardous constituents to be compliance monitored						
	264.96	- Proposed compliance period						
	264.99(d)	- Procedure for collecting quarterly samples at compliance point during compliance period						
	264.99(c)(3)	- Procedures for establishing background concentration values for constituents that are based on						
		- Use of an appropriate ground water monitoring system, and						
	264.97(g)	- Data that is available prior to permit issuance						
		- Data that accounts for measurement errors in sampling and analysis						
		- Data that accounts for seasonal ground-water quality fluctuations						
		- Data from a minimum of one sample per well and a minimum of four samples from monitoring system, each time system is sampled						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
270.14(c)(7)(iv)	264.92 and 264.99(c)(1),(2)	- Proposed concentration limits for constituents with justification based on						
		- §264.94(a)(1) and §264.97(g)						
		- §264.94(a)(2)						
		- §264.94(b) and §264.99(c)(1)						
	264.99(e)	- Procedure for annual determination of uppermost aquifer flow rate and direction						
	264.99(f)	- Procedures for annual testing of all compliance point wells for Appendix VIII constituents						
	264.99(g)	- Documentation of all sampling and analysis procedures						
	264.99(h)	- Procedures for determining a statistically significant increase for any monitored constituent by						
		- Comparing compliance point data to the concentration limit using the procedure in §264.97(h)(2)						
		- Providing an estimate of the time period after sampling completion necessary to obtain results						
	264.99(i)	- Procedures to be implemented if the ground-water protection standard is exceeded at any compliance point monitoring well, including						
	264.99(i)(1)	- Written notification to Regional Administrator						
	264.99(i)(2)	- Preparation of an application for permit modification to establish a corrective action program, including						

Part 270	Part 264	Subject Requirement	Provided	Not Provided	Inadequate	Not Applicable	Location in Application	Comments
		- Details of program to comply with ground-water protection standard						
270.14(c)(7)(v)	264.99(i)(2)(i)	- Details of ground-water monitoring to demonstrate effectiveness of program						
270.14(c)(8)	264.91(a)(2) and 264.100	Description of Corrective Action Program, including						
270.14(c)(8)(i)		- Characterization of contaminated ground-water						
	264.100(a)(1)	- Identified hazardous constituents						
		- Concentrations of hazardous constituents						
270.14(c)(8)(ii)	264.100(a)(2)	- Concentration limit for each hazardous constituent						
270.14(c)(8)(iii)	264.100(b)	- Detailed plan and an engineering report describing the corrective actions to be taken at the compliance point						
	264.100(c)	- Time period necessary to implement corrective action program						
270.14(c)(8)(iv)	264.100(d)	Description of ground-water monitoring program that will be sufficient to assess the adequacy of corrective action						
	264.91(a)(3) and 264.100(e)	- Description of the corrective action to be taken for constituents in ground-water between compliance point and downgradient facility boundary						
	264.100(g)	- Procedure and content for semi-annually submitting written reports to the Regional Administrator on program effectiveness						
		Part B Certification and Signatories						
270.11(d)		- Certification paragraph						
270.11(a)		- Appropriate signatory						