CHAPTER 6

SUBPART F
CLOSURE AND POST-CLOSURE

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6.1 INTRODUCTION

The criteria for landfill closure focus on two central themes: (1) the need to establish low-maintenance cover systems and (2) the need to design a final cover that minimizes the infiltration of precipitation into the waste. Landfill closure technology, design, and maintenance procedures continue to evolve as new geosynthetic materials become available, as performance requirements become more specific, and as limited performance history becomes available for the relatively small number of landfills that have been closed using current procedures and materials. Critical technical issues that must be faced by the designer include the:

- Degree and rate of post-closure settlement and stresses imposed on soil liner components;
- Long-term durability and survivability of cover system;
- Long-term waste decomposition and management of landfill leachate and gases; and
- Environmental performance of the combined bottom liner and final cover system.

Full closure and post-closure care requirements apply to all MSWLF units that receive wastes on or after October 9, 1993. For MSWLF units that stop receiving wastes prior to October 9, 1993, only the final cover requirements of §258.60(a) apply.

*[NOTE: EPA finalized several revisions to 40 CFR Part 258 on October 1, 1993 (58 FR 51536) and issued a correction notice on October 14, 1993 (58 FR 53136). Questions regarding the final rule and requests for copies of the Federal Register notices should be made to the RCRA/Superfund Hotline at (800) 424-9346. These revisions delay the effective date for some categories of landfills. More detail on the content of the revisions is included in the introduction.

6.2 FINAL COVER DESIGN 40 CFR §258.60(a)

6.2.1 Statement of Regulation

(a) Owners or operators of all MSWLF units must install a final cover system that is designed to minimize infiltration and erosion. The final cover system must be designed and constructed to:

(1) Have permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1×10^{-5} cm/sec, whichever is less, and

(2) Minimize infiltration through the closed MSWLF unit by the use of an infiltration layer that contains a minimum of 18-inches of an earthen material, and

(3) Minimize erosion of the final cover by the use of an erosion layer that contains a minimum 6-inches of earthen material that is capable of sustaining native plant growth.

6.2.2 Applicability

These final cover requirements apply to all MSWLF units required to close in accordance with Part 258, including MSWLF units that received wastes after October 9, 1991 but stopped receiving wastes prior to October 9, 1993. Units closing during this two-year period are required to install a final cover.

The final cover system required to close a MSWLF unit, whether the unit is an existing unit, a new unit, or a lateral expansion of an existing unit, must be composed of an infiltration layer that is a minimum of 18 inches thick, overlain by an erosion layer that is a minimum of 6 inches thick.

The final cover should minimize, over the long term, liquid infiltration into the waste. The final cover must have a hydraulic conductivity less than or equal to any bottom liner system or natural subsoils present to prevent a "bathtub" effect. In no case can the final cover have a hydraulic conductivity greater than 1 x 10^{-5} cm/sec regardless of the permeability of underlying liners or natural subsoils. If a synthetic membrane is in the bottom liner, there must be a flexible membrane liner (FML) in the final cover to achieve a permeability that is less than or equal to the permeability of the bottom liner. Currently, it is not possible to construct an earthen liner with a permeability less than or equal to a synthetic membrane.

In approved States, an alternate cover system may be approved by the Director (see Section 6.3).

6.2.3 Technical Considerations

Design criteria for a final cover system should be selected to:

- Minimize infiltration of precipitation into the waste;
- Promote good surface drainage;
- Resist erosion;
- Control landfill gas migration and/or enhance recovery;
- Separate waste from vectors (e.g., animals and insects);
- Improve aesthetics;
- Minimize long-term maintenance;
- Protect human health and the environment; and
- Consider final use.

The first three points are directly related to the regulatory requirements. The other points typically are considered in designing cover systems for landfills.

Reduction of infiltration in a well-designed final cover system is achieved through good surface drainage and run-off with minimal erosion, transpiration of water by plants in the vegetative cover and root zone, and restriction of percolation through earthen material. The cover system should be designed to provide the desired level of long-term performance with minimal maintenance. Surface water run-off should be properly controlled to prevent excessive erosion and soil loss. Establishment of a healthy vegetative layer is key to protecting the cover from erosion. However, consideration also must be given to selecting plant species that are not deeply rooted because they could damage the underlying infiltration layer. In addition, the cover system should be geotechnically stable to prevent failure, such as sliding, that may occur between the erosion and infiltration layers, within these layers, or within the waste. Figure 6-1 illustrates the minimum requirements for the final cover system.

Infiltration Layer

The infiltration layer must be at least 18 inches thick and consist of earthen material that has a hydraulic conductivity (coefficient of permeability) less than or equal to the hydraulic conductivity of any bottom liner system or natural subsoils. MSWLF units with poor or non-existent bottom liners possessing hydraulic conductivities greater than 1×10^{-5} cm/sec must have an infiltration layer that meets the 1×10^{-5} cm/sec minimum requirement. Figure 6-2 presents an example of a final cover with a hydraulic conductivity less than or equal to the hydraulic conductivity of the bottom liner system.

For units that have a composite liner with a FML, or naturally occurring soils with very low permeability (e.g., 1×10^{-8} cm/sec), the Agency anticipates that the infiltration layer in the final cover will include a synthetic membrane as part of the final cover. A final cover system for a MSWLF unit with a FML combined with a soil liner and leachate collection system is presented in Figure 6-3a. Figure 6-3b shows a final cover system for a MSWLF unit that has both a double FML and double leachate collection system.

The earthen material used for the infiltration layer should be free of rocks, clods, debris, cobbles, rubbish, and roots that may increase the hydraulic conductivity by promoting preferential flow paths. To facilitate run-off while minimizing erosion, the surface of the compacted soil should have a minimum slope of 3 percent and a maximum slope of 5 percent after allowance for settlement. It is critical that side slopes, which are frequently greater than 5 percent, be evaluated for erosion potential.

Membrane and clay layers should be placed below the maximum depth of frost penetration to avoid freeze-thaw effects (U.S. EPA, 1989b). Freeze-thaw effects may include development of microfractures or realignment of interstitial fines, which can increase the hydraulic conductivity of clays by more than an order of magnitude (U.S. EPA, 1990). Infiltration layers may be subject to desiccation, depending on climate and soil water retention in the erosion layer. Fracturing and volumetric shrinking of the clay due to water loss may increase the hydraulic conductivity of the infiltration layer. Figure 6-4 shows the regional average depth of frost penetration; however, these values should not be used to find the maximum depth of frost penetration for a particular area of concern at a particular site. Information regarding the maximum depth of frost penetration for a particular area can be obtained from the Soil Conservation Service, local utilities, construction companies, and local universities.

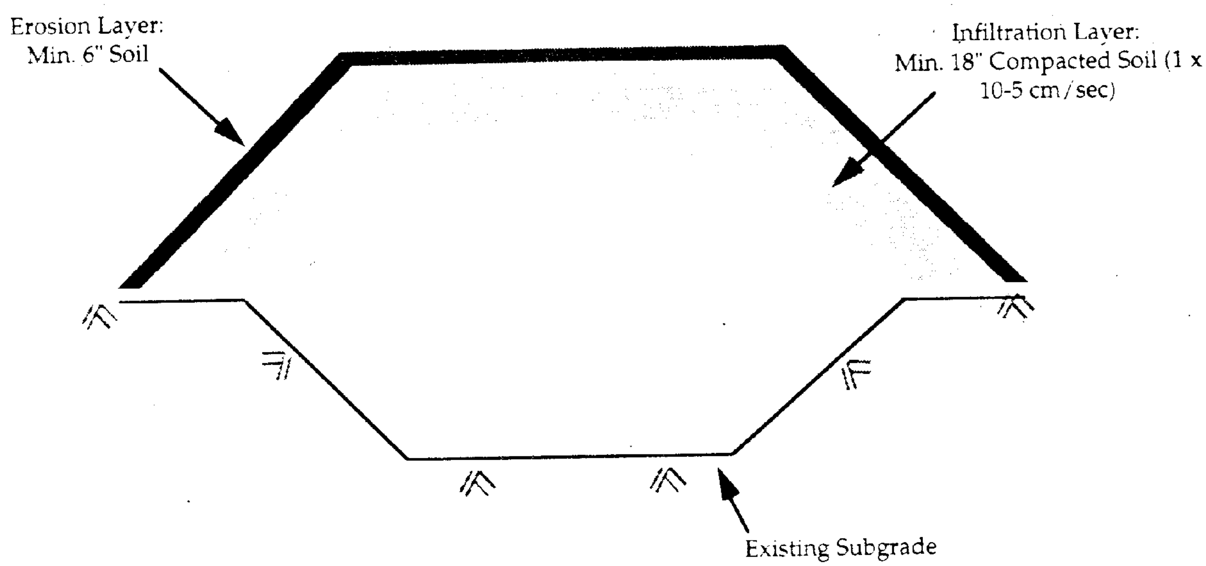

Figure 6-1
Example of Minimum Final Cover Requirements

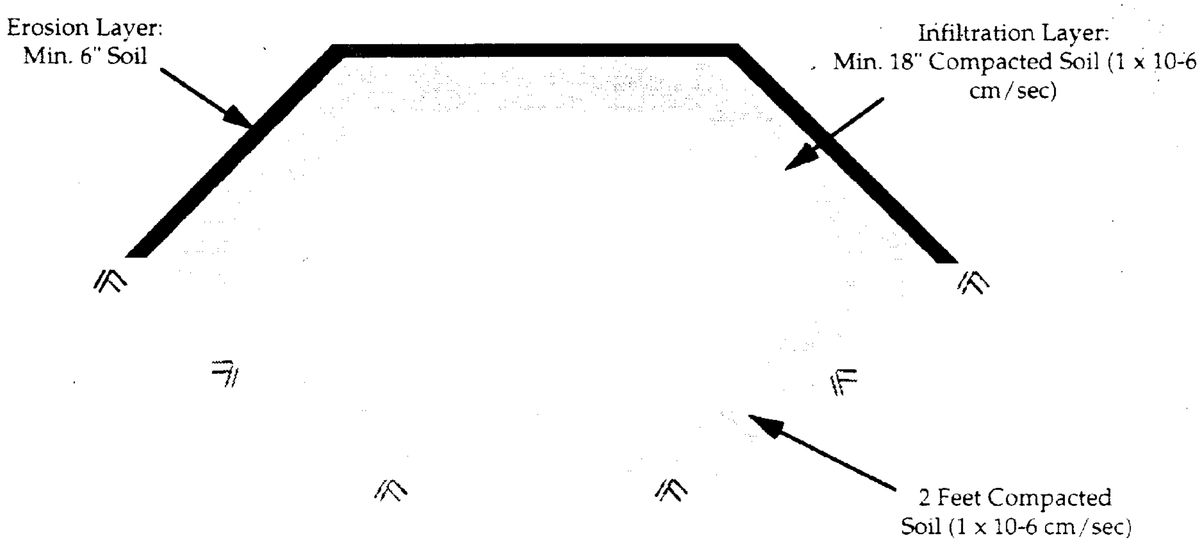

Figure 6-2
Example of Final Cover With Hydraulic Conductivity(K) ≤ K of Liner

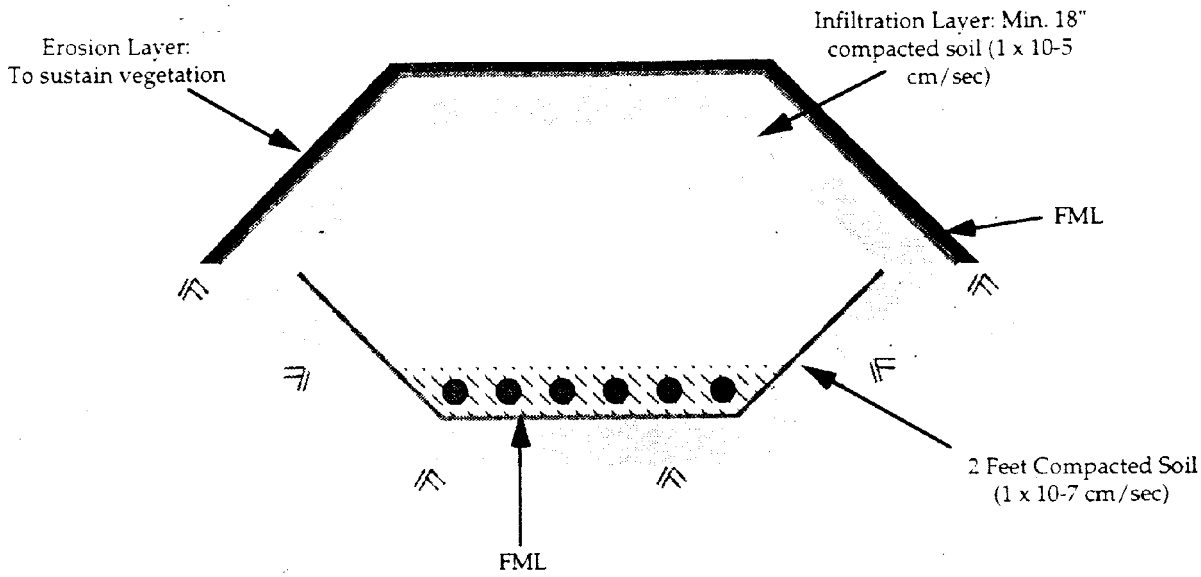

Figure 6-3a
Example of Final Cover Design for a MSWLF Unit With a FML and Leachate Collection System

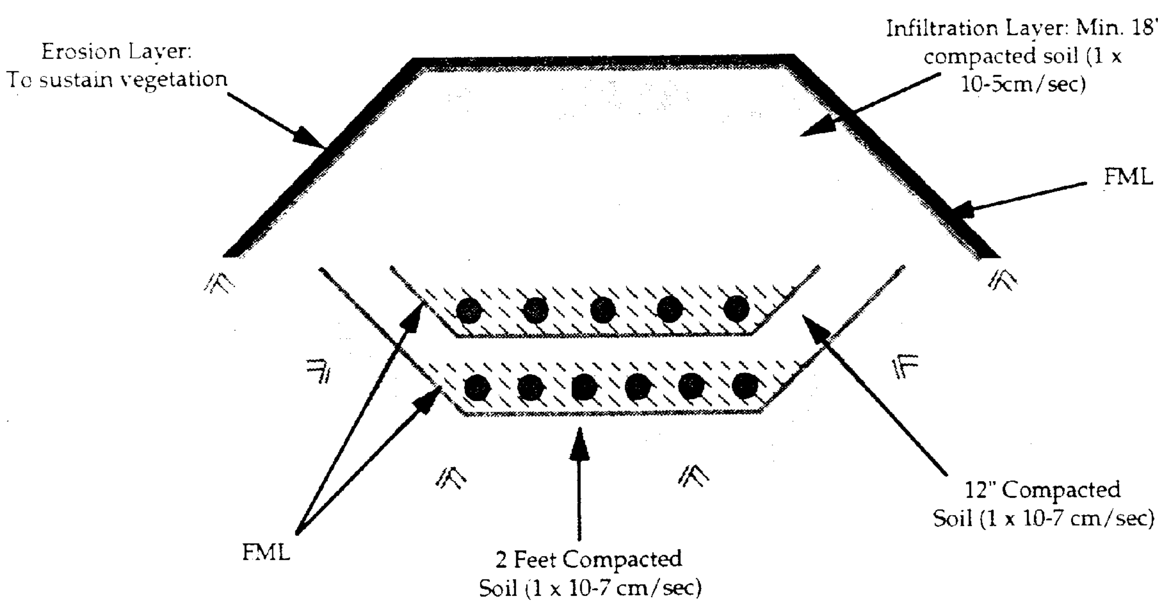

Figure 6-3b
Example of Final Cover Design for a MSWLF Unit With a Double FML and Leachate Collection System

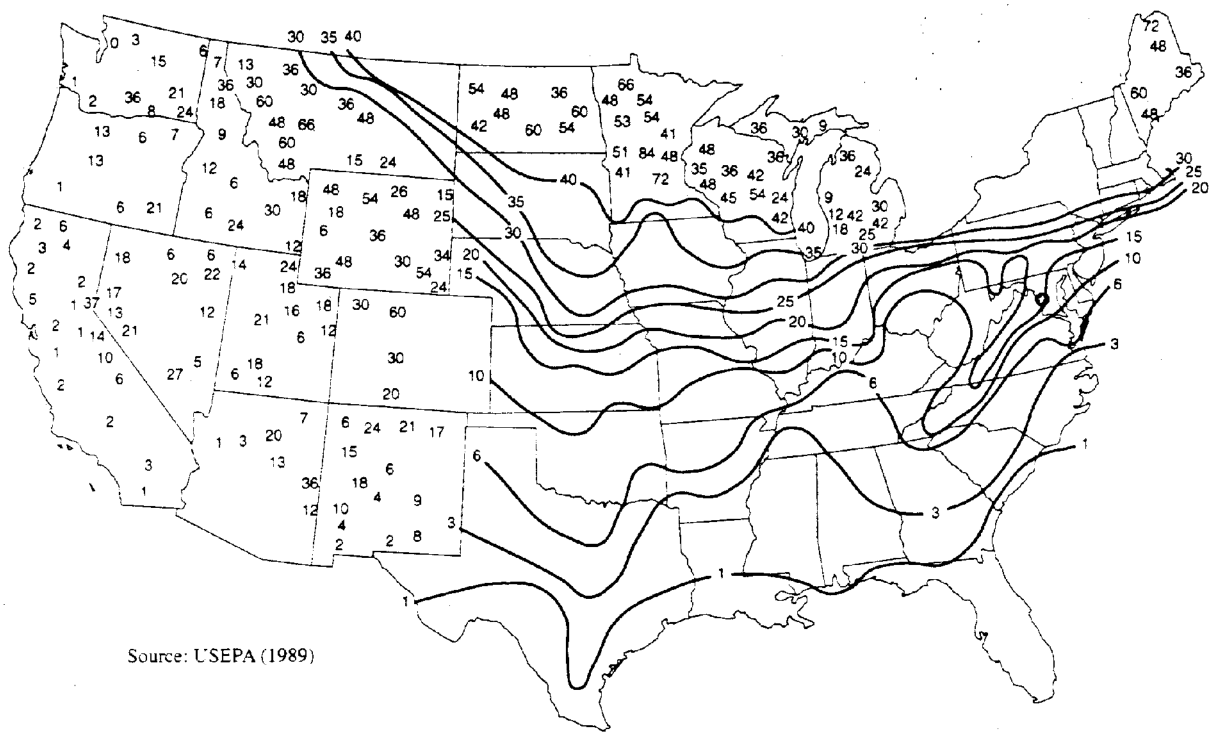

Figure 6-4
Regional Depth of Frost Penetration in Inches

The infiltration layer is designed and constructed in a manner similar to that used for soil liners (U.S. EPA, 1988), with the following differences:

- Because the cover is generally not subject to large overburden loads, the issue of compressive stresses is less critical unless post-closure land use will entail construction of objects that exert large amounts of stress.
- The soil cover is subject to loadings from settlement of underlying materials. The extent of settlement anticipated should be evaluated and a closure and post-closure maintenance plan should be designed to compensate for the effects of settlement.
- Direct shear tests performed on construction materials should be conducted at lower shear stresses than those used for liner system designs.

The design of a final cover is site-specific and the relative performance of cover design options may be compared and evaluated by the HELP (Hydrologic Evaluation of Landfill Performance) model. The HELP model was developed by the U.S. Army Corps of Engineers for the U.S. EPA and is widely used for evaluating expected hydraulic performance of landfill cover/liner systems (U.S. EPA, 1988).

The HELP program calculates daily, average, and peak estimates of water movement across, into, through, and out of landfills. The input parameters for the model include soil properties, precipitation and other climatological data, vegetation type, and landfill design information. Default climatologic and soil data are available but should be verified as reasonable for the site modeled. Outputs from the model include precipitation, run-off, percolation through the base of each cover layer subprofile, evapotranspiration, and lateral drainage from each profile. The model also calculates the maximum head on the barrier soil layer of each subprofile and the maximum and minimum soil moisture content of the evaporative zone. Data from the model are presented in a tabular report format and include the input parameters used and a summary of the simulation results. Results are presented in several tables of daily, monthly, and annual totals for each year specified. A summary of the outputs also is produced, including average monthly totals, average annual totals, and peak daily values for several simulation variables (U.S. EPA, 1988).

The HELP model may be used to estimate the hydraulic performance of the cover system designed for a MSWLF unit. Useful information provided by the HELP model includes surface run-off, duration and quantity of water storage within the erosion layer, and net infiltration through the cover system to evaluate whether leachate will accumulate within the landfill. For the model to be used properly, the HELP Model User's Guide and documentation should be consulted.

Geomembranes

If a geomembrane is used as an infiltration layer, the geomembrane should be at least 20 mils (0.5 mm) in thickness, although some geomembrane materials may need to be a greater thickness (e.g., a minimum thickness of 60 mils is recommended for HDPE because of the difficulties in making consistent field seams in thinner material).

Increased thickness and tensile strengths may be necessary to prevent failure under stresses caused by construction and waste settlement during the post-closure care period. The strength, resistance to sliding, hydraulic performance, and actual thickness of geomembranes should be carefully evaluated. The quality and performance of some textured sheets may be difficult to evaluate due to the variability of the textured surface.

Erosion Layer

The thickness of the erosion layer is influenced by depth of frost penetration and erosion potential. This layer is also used to support vegetation. The influence of frost penetration was discussed previously on page 6-3.

Erosion can adversely affect the performance of the final cover of a MSWLF unit by causing rills that require maintenance and repair. As previously stated, a healthy vegetative layer can protect the cover from erosion; conversely, severe erosion can affect the vegetative growth. Extreme erosion may lead to the exposure of the infiltration layer, initiate or contribute to sliding failures, or expose the waste. Anticipated erosion due to surface water run-off for given design criteria may be approximated using the USDA Universal Soil Loss Equation (U.S. EPA, 1989a). By evaluating erosion loss, the design may be optimized to reduce maintenance through selection of the best available soil materials or by initially adding excess soil to increase the time required before maintenance is needed. Parameters in the equation include the following:

$$X = RKLSCP$$

where
X = Soil loss (tons/acre/year)
R = Rainfall erosion index
K = Soil erodibility index
L = Slope length factor
S = Slope gradient factor
C = Crop management factor
P = Erosion control practice.

Values for the Universal Soil Loss Equation parameters may be obtained from the U. S. Soil Conservation Service (SCS) technical guidance document entitled "Predicting Rainfall Erosion Losses, Guidebook 537" (1978), available at local SCS offices located throughout the United States. State or local SCS offices can provide factors to be used in the soil loss equation that are appropriate to a given area of the country. Figure 6-5 can be used to find the soil loss ratio due to the slope of the site as used in the Universal Soil Loss Equation. Loss from wind erosion can be determined by the following equation (U.S. EPA, 1989a):

$$X' = I'K'C'L'V'$$

where
X' = Annual wind erosion
I' = Field roughness factor
K' = Soil erodibility index
C' = Climate factor
L' = Field length factor
V' = Vegetative cover factor.

A vegetative cover not only improves the appearance of the site, but it also controls erosion of the final cover; a vegetated cover may require only minimal maintenance. The vegetation component of the erosion layer should have the following

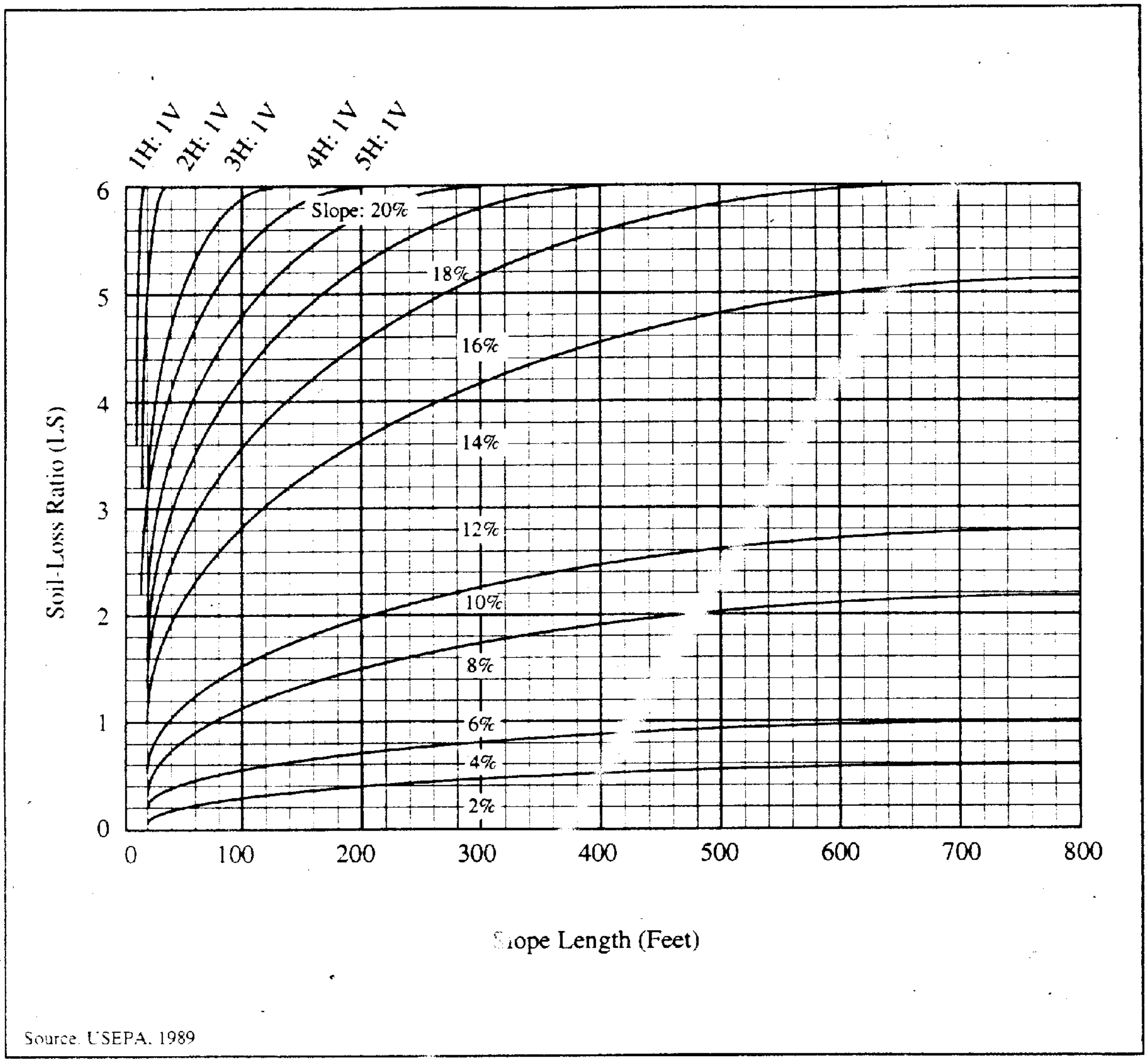

Figure 6-5
Soil Erosion Due to Slope

specifications and characteristics (U.S. EPA, 1989b):

- Locally adapted perennial plants that are resistant to drought and temperature extremes;
- Roots that will not disrupt the low-permeability layer;
- The ability to thrive in low-nutrient soil with minimum nutrient addition;
- Sufficient plant density to minimize cover soil erosion;
- The ability to survive and function with little or no maintenance (i.e., self-supportive); and
- Sufficient variety of plant species to continue to achieve these characteristics and specifications over time.

The use of deep-rooted shrubs and trees is generally inappropriate because the root systems may penetrate the infiltration layer and create preferential pathways of percolation. Plant species with fibrous or branching root systems are suited for use at landfills, and can include a large variety of grasses, herbs (i.e., legumes), and shallow-rooted plants. The suitable species in a region will vary, dependent on climate and site-specific factors such as soil type and slope gradient and aspect. The timing of seeding (spring or fall in most climates) is critical to successful germination and establishment of the vegetative cover (U.S. EPA, 1989b). Temporary winter covers may be grown from fast-growing seed stock such as winter rye.

Selection of the soil for the vegetative cover (erosion layer) should include consideration of soil type, nutrient and pH levels, climate, species of the vegetation selected, mulching, and seeding time. Loamy soils with a sufficient organic content generally are preferred. The balance of clay, silt, and sand in loamy soils provides an environment conducive to seed germination and root growth (USEPA, 1988).

The Director of an approved State can allow alternate designs to address vegetative problems (e.g., the use of pavement or other material) in areas that are not capable of sustaining plant growth.

6.3 ALTERNATIVE FINAL COVER DESIGN 40 CFR §258.60(b)

6.3.1 Statement of Regulation

(b) The Director of an approved State may approve an alternative final cover design that includes:

(1) An infiltration layer that achieves an equivalent reduction in infiltration as the infiltration layer specified in paragraphs (a)(1) and (a)(2) of this section, and

(2) An erosion layer that provides equivalent protection from wind and water erosion as the erosion layer specified in (a)(3) of this section.

6.3.2 Applicability

The Director of an approved State may approve alternative final cover systems that can achieve equivalent performance as the minimum design specified in §258.60(a). This provides an opportunity to incorporate different technologies or improvements into cover designs, and to address site-specific conditions.

6.3.3 Technical Considerations

An alternative material and/or an alternative thickness may be used for an infiltration layer as long as the infiltration layer requirements specified in §258.60(a)(1) and (a)(2) are met.

For example, an armored surface (e.g., one composed of cobble-rich soils or soils rich in weathered rock fragments) could be used as an alternative to the six-inch erosion layer. An armored surface, or hardened cap, is generally used in arid regions or on steep slopes where the establishment and maintenance of vegetation may be hindered by lack of soil or excessive run-off.

The materials used for an armored surface typically are (U.S. EPA, 1989b):

- Capable of protecting the underlying infiltration layer during extreme weather events of rainfall and/or wind;
- Capable of accommodating settlement of the underlying material without compromising the component;
- Designed with a surface slope that is approximately the same as the underlying soil (at least 2 percent slope); and
- Capable of controlling the rate of soil erosion.

The erosion layer may be made of asphalt or concrete. These materials promote run-off with negligible erosion. However, asphalt and concrete deteriorate due to thermal expansion and due to deformation caused by subsidence. Crushed rock may be spread over the landfill cover in areas where weather conditions such as wind, heavy rain, or temperature extremes commonly cause deterioration of vegetative covers (U.S. EPA, 1989b).

Other Considerations

Additional Cover System Components

To reduce the generation of post-closure leachate to the greatest extent possible, owners and operators can install a composite cover made of a geomembrane and a soil component with low hydraulic conductivity. The hydraulic properties of these components are discussed in Chapter 4 (Subpart D).

Other components that may be used in the final cover system include a drainage layer, a gas vent layer, and a biotic barrier layer. These components are discussed in the following sections and are shown in Figure 6-6.

Drainage Layer

A permeable drainage layer, constructed of soil or geosynthetic drainage material, may be constructed between the erosion layer and the underlying infiltration layer. The drainage layer in a final cover system removes percolating water that has infiltrated through the erosion layer after surface run-off and evapotranspiration losses. By removing water in contact with the low-permeability layer, the potential for

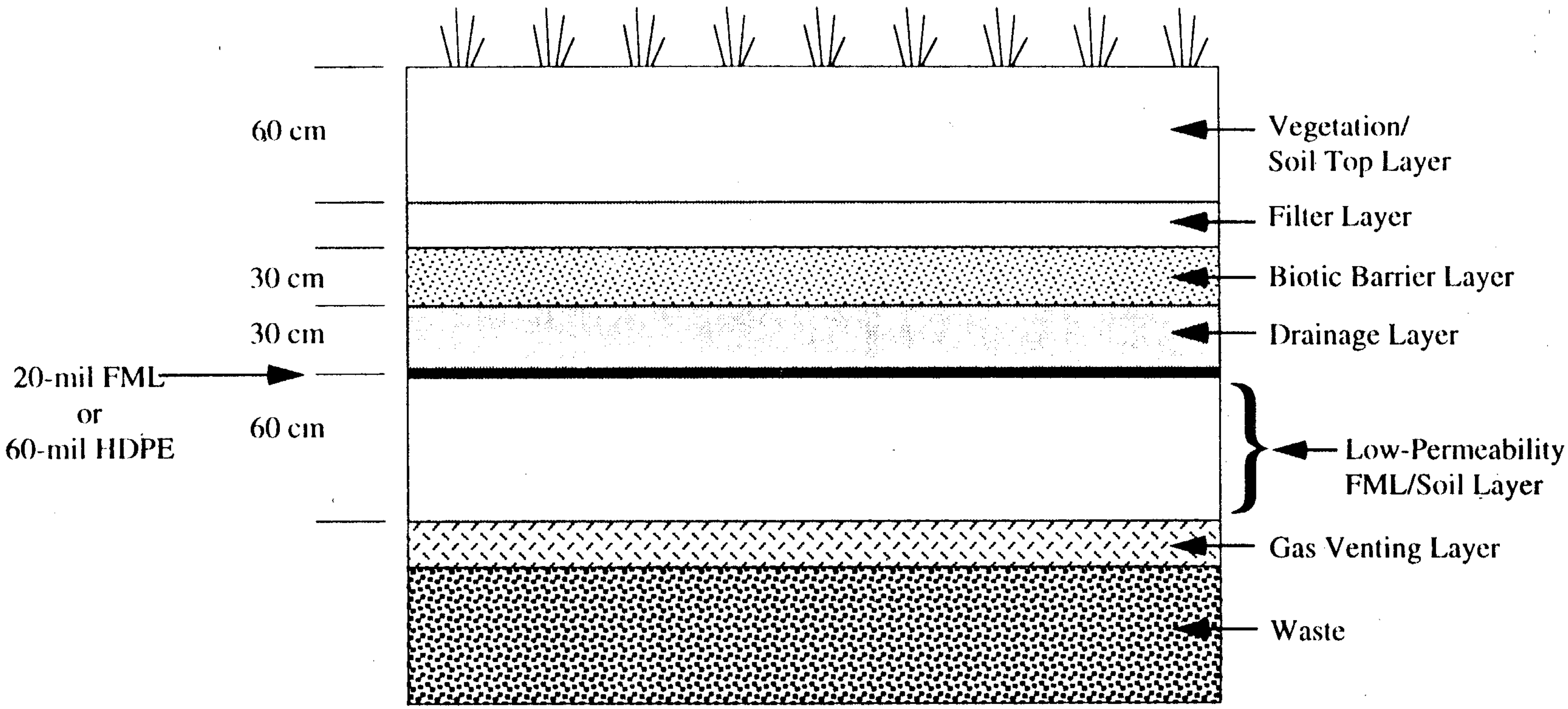

Figure 6-6
Example of an Alternative Final Cover Design

leachate generation is diminished. Caution should be taken when using a drainage layer because this layer may prematurely draw moisture from the erosion layer that is needed to sustain vegetation.

If a drainage layer is used, owners or operators should consider methods to minimize physical clogging of the drainage layer by root systems or soil particles. A filter layer, composed of either a low nutrient soil or geosynthetic material, may be placed between the drainage layer and the cover soil to help minimize clogging.

If granular drainage layer material is used, the filter layer should be at least 12 in. (30 cm) thick with a hydraulic conductivity in the range of 1×10^{-2} cm/sec to 1×10^{-3} cm/sec. The layer should be sloped at least 3 percent at the bottom of the layer. Greater thickness and/or slope may be necessary to provide sufficient drainage flow as determined by site-specific modeling (U.S. EPA, 1989b). Granular drainage material will vary from site to site depending on the type of material that is locally available and economical to use. Typically, the material should be no coarser than 3/8 inch (0.95 cm), classified according to the Universal Soil Classification System (USCS) as type SP, smooth and rounded, and free of debris that could damage an underlying geomembrane (U.S. EPA, 1989b).

Crushed stone generally is not appropriate because of the sharpness of the particles. If the available drainage material is of poor quality, it may be necessary to increase the thickness and/or slope of the drainage layer to maintain adequate drainage. The HELP model can be used as an analytical tool to evaluate the relative expected performance of alternative final cover designs.

If geosynthetic materials are used as a drainage layer, the fully saturated effective transmissivity should be the equivalent of 12 inches of soil (30 cm) with a hydraulic conductivity range of 1×10^{-2} cm/sec to 1×10^{-3} cm/sec. Transmissivity can be calculated as the hydraulic conductivity multiplied by the drainage layer thickness. A filter layer (preferably a non-woven needle punch fabric) should be placed above the geosynthetic material to minimize intrusion and clogging by roots or by soil material from the top layer.

<u>Gas Vent Layer</u>

Landfill gas collection systems serve to inhibit gas migration. The gas collection systems typically are installed directly beneath the infiltration layer. The function of a gas vent layer is to collect combustible gases (methane) and other potentially harmful gases (hydrogen sulfide) generated by micro-organisms during biological decay of organic wastes, and to divert these gases via a pipe system through the infiltration layer. A more detailed discussion concerning landfill gas, including the use of active and passive collection systems, is provided in Chapter 3 (Subpart C).

The gas vent layer is usually 12 in. (30 cm) thick and should be located between the infiltration layer and the waste layer. Materials used in construction of the gas vent layer should be medium to coarse-grained porous materials such as those used in the drainage layer. Geosynthetic materials may be substituted for granular materials in the vent layer if equivalent performance can be demonstrated. Venting to an exterior collection point can be provided by means such as horizontal pipes patterned laterally throughout the gas vent layer, which channel gases to vertical risers or lateral headers. If vertical risers are used, their number should be minimized (as they are frequently vandalized) and located at high points in the cross-section (U.S. EPA, 1989b). Condensates will form within the gas collection pipes; therefore, the design should address drainage of condensate to prevent blockage by its accumulation in low points.

The most obvious potential problem with gas collection systems is the possibility of gas vent pipe penetrations through the cover system. Settlement within the landfill may cause concentrated stresses at the penetrations, which could result in infiltration layer or pipe failure. If a geomembrane is used in the infiltration layer, pipe sleeves, adequate flexibility and slack material should be provided at these connections when appropriate. Alternatively, if an active gas control system is planned, penetrations may be carried out through the sides of the cover directly above the liner anchor trenches where effects of settlement are less pronounced. The gas collection system also may be connected to the leachate collection system, both to vent gases that may form inside the leachate collection pipes and to remove gas condensates that form within the gas collection pipes. This method generally is not preferred because if the leachate collection pipe is full, gas will not be able to move through the system. Landfill gas systems are also discussed in Chapter 3 (Subpart C).

Biotic Layer

Deep plant roots or burrowing animals (collectively called biointruders) may disrupt the drainage and the low hydraulic conductivity layers, thereby interfering with the drainage capability of the layers. A 30-cm (12-inch) biotic barrier of cobbles directly beneath the erosion layer may stop the penetration of some deep-rooted plants and the invasion of burrowing animals. Most research on biotic barriers has been done in, and is applicable to arid areas. Geosynthetic products that incorporate a time-released herbicide into the matrix or on the surface of the polymer also may be used to retard plant roots. The longevity of these products requires evaluation if the cover system is to serve for longer than 30 to 50 years (USEPA, 1991).

Settlement and Subsidence

Excessive settlement and subsidence, caused by decomposition and consolidation of the wastes, can impair the integrity of the final cover system. Specifically, settlement can contribute to:

- Ponding of surface water on the cap;
- Disruption of gas collection pipe systems;
- Fracturing of low permeability infiltration layers; and
- Failure of geomembranes.

The degree and rate of waste settlement are difficult to estimate. Good records regarding the type, quantity, and location of waste materials disposed will improve the estimate. Settlement due to consolidation may be minimized by compacting the waste during daily operation of the landfill unit or by landfilling baled waste. Organic wastes will continue to degrade and deteriorate after closure of the landfill unit.

Several models have been developed to analyze the process of differential settlement. Most models equate the layered cover to a beam or column undergoing deflection due to various loading conditions. While these models are useful to designers in understanding the qualitative relationship between the various land disposal unit characteristics and in identifying the constraining factors, accurate quantitative analytical methods have not been developed (U.S. EPA, 1988).

If the amount of total settlement can be estimated, either from an analytical approach or from empirical relationships from data collected during the operating life of the facility, the designer should attempt to estimate the potential strain imposed on the cover system components. Due to the uncertainties inherent in the settlement analysis, a biaxial strain calculation should be sufficient to estimate the stresses that may be imposed on the cover system. The amount of strain that a liner is capable of enduring may be as low as several percent; for geomembranes, it may be 5 to 12 percent (U.S. EPA, 1990). Geomembrane testing may be included as part of the design process to estimate safety factors against cover system failure.

The cover system may be designed with a greater thickness and/or slope to compensate for settlement after closure. However, even if settlement and subsidence are considered in the design of the final cover, ponding may still occur after closure and can be corrected during post-closure maintenance. The cost estimate for post-closure maintenance should include earthwork required to regrade the final cover due to total and differential settlements. Based on the estimates of total and differential settlements from the modeling methods described earlier, it may be appropriate to assume that a certain percentage of the total area needs regrading and then incorporate the costs into the overall post-closure maintenance cost estimate.

Sliding Instability

The slope angle, slope length, and overlying soil load limit the stability of component interfaces (geomembrane with soil, geotextile, and geotextile/soil). Soil water pore pressures developed along interfaces also can dramatically reduce stability. If the design slope is steeper than the effective friction angles between the material, sliding instability generally will occur. Sudden sliding has the potential to cause tears in geomembranes, which require considerable time and expense to repair. Unstable slopes may require remedial measures to improve stability as a means of offsetting potential long-term maintenance costs.

The friction angles between various media are best determined by laboratory direct shear tests that represent the design loading conditions. Methods to improve stability include using designs with flatter slopes, using textured material, constructing benches in the cover system, or reinforcing the cover soil above the membrane with geogrid or geotextile to minimize the driving force on the interface of concern. Methods for applying these design features can be found in (U.S. EPA 1989), (U.S.EPA 1991), and (Richardson and Koerner 1987).

6.4 CLOSURE PLAN
40 CFR §258.60(c)-(d)

6.4.1 Statement of Regulation

(c) The owner or operator must prepare a written closure plan that describes the steps necessary to close all MSWLF units at any point during their active life in accordance with the cover design requirements in §258.60(a) or (b), as applicable. The closure plan, at a minimum, must include the following information:

(1) A description of the final cover, designed in accordance with §258.60(a) and the methods and procedures to be used to install the cover;

(2) An estimate of the largest area of the MSWLF unit ever requiring a final cover as required under §258.60(a) at any time during the active life;

(3) An estimate of the maximum inventory of wastes ever on-site over the active life of the landfill facility; and

(4) A schedule for completing all activities necessary to satisfy the closure criteria in §258.60.

(d) The owner or operator must notify the State Director that a closure plan has been prepared and placed in the operating record no later than the effective date of this part, or by the initial receipt of waste, whichever is later.

6.4.2 Applicability

An owner or operator of any MSWLF unit that receives wastes on or after October 9, 1993, must prepare a closure plan and place the plan in the operating record. The plan must describe specific steps and activities that will be followed to close the unit at any time after it first receives waste through the time it reaches its waste disposal capacity.

The closure plan must include at least the following information:

- A description of the final cover and the methods and procedures to be used to install the cover;
- An estimate of the largest area that will have to be covered (typically this is the area that will exist when the final full capacity is attained); and
- A schedule for completing closure.

The area requiring cover should be estimated for the operating period from initial receipt of waste through closure.

The closure plan must be prepared and placed in the operating record before October 9, 1993 or by the initial receipt of waste, whichever is later. The owner or operator must notify the State Director when the plan has been completed and placed in the operating record.

6.4.3 Technical Considerations

The closure plan is a critical document that describes the steps that an owner or operator will take to ensure that all units will be closed in a manner that is protective of human health and the environment. Closure plans provide the basis for cost estimates that in turn establish the amount of financial responsibility that must be demonstrated.

The closure plan must describe all areas of the MSWLF unit that are subject to Part 258 regulations and that are not closed in accordance with §258.60. Portions of the landfill unit that have not received a final cover must be included in the estimate. The area to be covered at any point during the active life of the operating unit can be determined by examining design and planned operation procedures and by comparing the procedures with construction records, operation records, and field observations. Units are operated frequently in phases, with some phases conducted on top of previously deposited waste. If the owner or operator routinely closes landfill cells as they are filled, the plan should indicate the greatest number of cells open at one time.

The estimate must account for the maximum amount of waste on-site that may need to be disposed in the MSWLF unit over the life of the facility (this includes any waste on-site yet to be disposed). The maximum volume of waste ever on-site can be estimated from the maximum capacity of each unit and any operational procedures that may involve transfer of wastes to off-site facilities. Where insufficient design, construction, and operational records are found, areas and volumes may be estimated from topographic maps and/or aerial photographs.

Steps that may be included in the closure plan are as follows:

- Notifying State Director of intent to initiate closure §258.60(e);
- Determining the area to receive final cover;
- Developing the closure schedule;
- Preparing construction contract documents and securing a contractor;
- Hiring an independent registered professional engineer to observe closure activities and provide certification;
- Securing borrow material;
- Constructing the cover system;
- Obtaining signed certificate and placing it in operating record;
- Notifying State Director that certificate was placed in operating record; and
- Recording notation in deed to land or other similar instrument.

The closure plan should include a description of the final cover system and the methods and procedures that will be used to install the cover. The description of the methods, procedures, and processes may include design documents; construction specifications for the final cover system, including erosion control measures; quality control testing procedures for the construction materials; and quality assurance procedures for construction. A general discussion of the methods and procedures for cover installation is presented in Section 6.3.3.

6.5 CLOSURE CRITERIA 40 CFR §258.60(e)-(j)

6.5.1 Statement of Regulation

(e) Prior to beginning closure of each MSWLF unit as specified in

§258.60(f), an owner or operator must notify the State Director that a notice of the intent to close the unit has been placed in the operating record.

(f) The owner or operator must begin closure activities of each MSWLF unit no later than 30 days after the date on which the MSWLF unit receives the known final receipt of wastes or, if the MSWLF unit has remaining capacity and there is a reasonable likelihood that the MSWLF unit will receive additional wastes, no later than one year after the most recent receipt of wastes. Extensions beyond the one-year deadline for beginning closure may be granted by the Director of an approved State if the owner or operator demonstrates that the MSWLF unit has the capacity to receive additional wastes and the owner or operator has taken and will continue to take all steps necessary to prevent threats to human health and the environment from the unclosed MSWLF unit.

(g) The owner or operator of all MSWLF units must complete closure activities of each MSWLF unit in accordance with the closure plan within 180 days following the beginning of closure as specified in paragraph (f). Extensions of the closure period may be granted by the Director of an approved State if the owner or operator demonstrates that closure will, of necessity, take longer than 180 days and he has taken and will continue to take all steps to prevent threats to human health and the environment from the unclosed MSWLF unit.

(h) Following closure of each MSWLF unit, the owner or operator must notify the State Director that a certification, signed by an independent registered professional engineer or approved by Director of an approved State, verifying that closure has been completed in accordance with the closure plan, has been placed in the operating record.

(i)(1) Following closure of all MSWLF units, the owner or operator must record a notation on the deed to the landfill facility property, or some other instrument that is normally examined during title search, and notify the State Director that the notation has been recorded and a copy has been placed in the operating record.

(2) The notation on the deed must in perpetuity notify any potential purchaser of the property that:

(i) The land has been used as a landfill facility; and

(ii) Its use is restricted under §258.61(c)(3).

(j) The owner or operator may request permission from the Director of an approved State to remove the notation from the deed if all wastes are removed from the facility.

6.5.2 Applicability

These closure requirements are applicable to all MSWLF units that receive wastes on or after October 9, 1993. The owner or operator is required to:

- Notify the State Director of the intent to close;

- Begin closure within 30 days of the last receipt of waste (or 1 year if there is remaining capacity and it is likely that it will be used);

- Complete closure within 180 days following the beginning of closure (in approved States, the period of time to begin or complete closure may be extended by the Director);

- Obtain a certification, by an independent registered professional engineer, that closure was completed in accordance with the closure plan;

- Place the certificate in the operating record and notify the State Director; and

- Note on a deed (or some other instrument) that the land was used as a landfill and that its use is restricted. Should all wastes be removed from the unit in an approved State, the owner or operator may request permission from the Director to remove the note on the deed.

6.5.3 Technical Considerations

Closure activities must begin within 30 days of the last receipt of waste and must be completed within 180 days. Some MSWLF units, such as those in seasonal population areas, may have remaining capacity but will not receive the next load of waste for a lengthy period of time. These MSWLF units must receive waste within one year or they must close. Extensions to both the 1-year and the 180-day requirements may be available to owners or operators of MSWLF units in approved States. An extension may be granted if the owner or operator can demonstrate that there is remaining capacity or that additional time is needed to complete closure. These extensions could be granted to allow leachate recirculation or to allow for settlement. The owner or operator must take, and continue to take, all steps necessary to prevent threats to human health and the environment from the unclosed MSWLF unit. In general, this requirement should be established for a unit in compliance with the requirements of Part 258. The owner or operator may need to demonstrate how access to the unclosed unit will be controlled prior to closure or receipt of waste and how the various environmental control and monitoring systems (e.g., surface run-off, surface run-on, leachate collection, gas control system, and ground-water and gas monitoring) will be operated and maintained while the unit remains unclosed.

Following closure of each MSWLF unit, the owner or operator must have a certification, signed by an independent registered professional engineer, verifying closure. In approved States, the Director can approve the certification. The certificate should verify that closure was completed in accordance with the closure plan. This certification should be based on knowledge of the closure plan, observations made during closure, and documentation of closure activities provided by the owner or operator. The signed certification must be placed in the operating record and the State Director must be notified that the certification was completed and placed in the record.

After closure of all units at a MSWLF facility, the owner or operator must record a notation in the deed, or in records typically examined during a title search, that the property was used as a MSWLF unit and that its use is restricted under 40 CFR §258.61(c)(3). Section 258.61(c)(3) states:

"... Post-closure use of the property shall not disturb the integrity of the final cover, liner(s), or any other components of the containment systems or the function of the monitoring systems unless necessary to comply with the requirements of Part 258...and... The Director of an approved State may approve any other disturbance if the owner or operator demonstrates that disturbance of the final cover, liner, or other component of the containment system, including any removal of waste, will not increase the potential threat to human health or the environment."

These restrictions are described further in Section 6.7 (Post-Closure Plan) of this document.

The owner or operator may request permission from the Director of an approved State to remove the notation to a deed. The request should document that all wastes have been removed from the facility. Such documentation may include photographs, ground-water and soil testing in the area where wastes were deposited, and reports of waste removal activity.

6.6 POST-CLOSURE CARE REQUIREMENTS 40 CFR §258.61

6.6.1 Statement of Regulation

(a) Following closure of each MSWLF unit, the owner or operator must conduct post-closure care. Post-closure care must be conducted for 30 years, except as provided under paragraph (b) of this part, and consist of at least the following:

(1) Maintaining the integrity and effectiveness of any final cover, including making repairs to the cover as necessary to correct the effects of settlement, subsidence, erosion, or other events, and preventing run-on and run-off from eroding or otherwise damaging the final cover;

(2) Maintaining and operating the leachate collection system in accordance with the requirements in §258.40, if applicable. The Director of an approved State may allow the owner or operator to stop managing leachate if the owner or operator demonstrates that leachate no longer poses a threat to human health and the environment;

(3) Monitoring the ground water in accordance with the requirements of Subpart E and maintaining the ground-water monitoring system, if applicable; and

(4) Maintaining and operating the gas monitoring system in accordance with the requirements of §258.23.

(b) The length of the post-closure care period may be:

(1) Decreased by the Director of an approved State if the owner or operator demonstrates that the reduced period is sufficient to protect human health and the environment and this demonstration is approved by the Director of an approved State; or

(2) Increased by the Director of an approved State if the Director of an approved State determines that the lengthened period is necessary to protect human health and the environment.

6.6.2 Applicability

Post-closure care requirements apply to MSWLF units that stop receiving waste after October 9, 1993. They also apply to units that stop receiving waste between October 9, 1991, and October 9, 1993, and fail to complete closure within six months of the final receipt of waste.

Post-closure care requirements are focused on operating and maintaining the proper functions of four systems that prevent or monitor releases from the MSWLF unit:

- Cover system;
- Leachate collection system;
- Ground-water monitoring system; and
- Gas monitoring system.

Owners or operators must comply with these requirements for a period of 30 years following closure. In approved States, the post-closure care period may be shortened if the owner or operator demonstrates to the satisfaction of the Director that human health and the environment are protected. Conversely, the Director may determine that a period longer than 30 years is necessary. The requirement to operate and maintain the leachate collection system may be eliminated by the Director of an approved State if the owner or operator demonstrates that leachate does not pose a threat to human health and the environment.

6.6.3 Technical Considerations

When the final cover is installed, repairs and maintenance may be necessary to keep the cover in good working order. Maintenance may include inspection, testing, and cleaning of leachate collection and removal system pipes, repairs of final cover, and repairs of gas and ground-water monitoring networks.

Inspections should be made on a routine basis. A schedule should be developed to check that routine inspections are completed. Records of inspections detailing observations should be kept in a log book so that changes in any of the MSWLF units can be monitored; in addition, records should be kept detailing changes in post-closure care personnel to ensure that changing personnel will not affect post-closure care due to lack of knowledge of routine activities. The activities and frequency of inspections are subject to State review to ensure that units are monitored and maintained for as long as is necessary to protect human health and the environment.

Inspection of the final cover may be performed on the ground and through aerial photography. Inspections should be conducted at appropriate intervals and the condition of the facility should be recorded with notes, maps, and photographs. The inspector should take notice of eroded banks, patches of dead vegetation, animal burrows, subsidence, and cracks along the cover. The inspector also should note the condition of concrete structures (e.g., manholes), leachate collection and removal pipes, gas monitoring systems, and monitoring wells.

For larger facilities, annual aerial photography may be a useful way to document the extent of vegetative stress and settlement if either of these has been observed during routine inspections. It is important to coordinate the photography with the site "walkover" to verify interpretations made from aerial photographs. Aerial photography should not be used in place of a site walkover but in conjunction with the site walkover. An EPA document (U.S. EPA 1987) provides further information on using aerial photography for inspecting a landfill facility. (See the Reference section at the end of this chapter.)

Topographic surveys of the landfill unit(s) may be used to determine whether settlement has occurred. These should be repeated every few years until settlement behavior is established. If settlement plates are used, they should be permanent and protected from vandalism and accidental disturbance (U.S. EPA, 1987). Depressions caused by settlement may lead to ponding and should be filled with soil. Excessive settlement may warrant reconstructing or adding to portions of the infiltration layer. Damage caused by settlement such as tension cracks and tears in the synthetic membrane should be repaired.

Cover systems that have areas where the slope is greater than 5 percent may be susceptible to erosion. Large and small rills (crevices) may form along the cover where water has eroded the cover. This may lead to exposure of the synthetic geomembrane and, in severe cases, depending on the cover system installed, exposure of the waste. Erosion may lead to increased infiltration of surface water into the landfill. Areas showing signs of erosion should be repaired.

Certain types of vegetative cover (e.g., turf-type grasses) may require mowing at least two times a year. Mowing can aid in suppression of weed and brush growth, and can increase the vigor of certain grass species. Alternatively, certain cover types (e.g., native prairie grasses) require less frequent mowing (once every three years) and may be suitable for certain climates and facilities where a low-maintenance regime is preferable. For certain cover types, fertilization schedules may be necessary to sustain desirable vegetative growth. Fertilization schedules should be based on the cover type present. Annual or biennial fertilization may be necessary for certain grasses, while legumes and native vegetation may require little or no fertilizer once established. Insecticides may be used to eliminate insect populations that are detrimental to vegetation. Insecticides should be carefully selected and applied with consideration for potential effects on surface water quality.

Some leachate collection and removal systems have been designed to allow for inspections in an effort to ensure that they are working properly. Leachate collection and removal pipes may be flushed and pressure-cleaned on a regular schedule (e.g., annually) to reduce the accumulation of sediment and precipitation and to prevent biological fouling.

Similarly, gas collection systems should be inspected to ensure that they are working properly. Vents should be checked to ensure they are not clogged by foreign matter such as rocks. If not working properly, the gas collection systems should be flushed and pressure-cleaned.

At some landfill facilities, leachate concentrations eventually may become low enough so as not to pose a threat to human health or the environment. In an approved State, the Director may allow an owner or operator to cease managing leachate if the owner or operator can demonstrate that the leachate no longer poses a threat to human health and the environment. The demonstration should address direct exposures of leachate releases to ground water, surface water, or seeps. Indirect effects, such as accumulated leachate adversely affecting the chemical, physical, and structural containment systems that prevent leachate release, also should be addressed in the demonstration.

The threat posed by direct exposures to leachate released to ground water, to surface waters, or through seeps may be assessed using health-based criteria. These criteria and methods are available through the Integrated Risk Information System (IRIS) (a database maintained by U.S. EPA), the RCRA Facility Investigation Guidance (U.S. EPA, 1989c), the Risk Assessment Guidance for Superfund (U.S. EPA, 1989d), and certain U.S. EPA regulations, including MCLs established under the Safe Drinking Water Act and the ambient water quality criteria under the Clean Water Act. These criteria and assessment procedures are described in Chapter 5 (Subpart E) of this document. Concentrations at the points of exposure, rather than concentrations in the leachate in the collection system, may be used when assessing threats.

6.7 POST-CLOSURE PLAN 40 CFR §258.61(c)-(e)

6.7.1 Statement of Regulation

(c) The owner or operator of all MSWLF units must prepare a written post-closure plan that includes, at a minimum, the following information:

(1) A description of the monitoring and maintenance activities required in §258.61(a) for each MSWLF unit, and the frequency at which these activities will be performed;

(2) Name, address, and telephone number of the person or office to contact about the facility during the post-closure period; and

(3) A description of the planned uses of the property during the post-closure period. Post-closure use of the property shall not disturb the integrity of the final cover, liner(s), or any other components of the containment system, or the function of the monitoring systems unless necessary to comply with the requirements in Part 258. The Director of an approved State may approve any other disturbance if the owner or operator demonstrates that disturbance of the final cover, liner or other component of the containment system, including any removal of waste, will not increase the potential threat to human health or the environment.

(d) The owner or operator must notify the State Director that a post-closure plan has been prepared and placed in the operating record no later

than the effective date of this part, October 9, 1993, or by the initial receipt of waste, whichever is later.

(e) Following completion of the post-closure care period for each MSWLF unit, the owner or operator must notify the State Director that a certification, signed by an independent registered professional engineer or approved by the Director of an approved State, verifying that post-closure care has been completed in accordance with the post-closure plan, has been placed in the operating record.

6.7.2 Applicability

Owners and operators of existing units, new units, and lateral expansions of existing MSWLF units that stop receiving waste after October 9, 1993 are required to provide a post-closure plan. MSWLF units that received the final waste shipment between October 9, 1991 and October 9, 1993 but failed to complete installation of a final cover system within six months of the final receipt of waste also are required to provide a post-closure plan.

The post-closure plan describes the monitoring activities that will be conducted throughout the 30-year period. The plan also establishes:

- The schedule or frequency at which these activities are conducted;
- Name, address, and telephone number of a person to contact about the facility;
- A description of a planned use that does not disturb the final cover; and
- The procedure for verifying that post-closure care was provided in accordance with the plan.

In approved States only, the owner or operator may request the Director to approve a use that disturbs the final cover based on a demonstration that the use will not increase the potential threat to human health and the environment.

6.7.3 Technical Considerations

The State Director must be notified that a post-closure plan, describing the maintenance activities required for each MSWLF unit, has been placed in the operating record. The post-closure plan should provide a schedule for routine maintenance of the MSWLF unit systems. These systems include the final cover system, the leachate collection and removal system, and the landfill gas and ground-water monitoring systems.

The plan must include the name, address, and telephone number of the person or office to contact regarding the facility throughout the post-closure period. Additionally, the planned uses of the property during the post-closure period must be provided in the plan. These uses may not disturb the integrity of the final cover system, the liner system, and any other components of the containment or monitoring systems unless necessary to comply with the requirements of Part 258. Any other disturbances to any of the MSWLF components must be approved by the Director of an approved State. An example of an acceptable disturbance may include remedial action necessary to minimize the threat to human health and the environment.

Following completion of the post-closure care period, the State Director must be notified that an independent registered professional engineer has verified and certified that post-closure care has been completed in accordance with the post-closure plan and that this certification has been placed in the operating record. Alternatively, the Director of an approved State may approve the certification. Certification of post-closure care should be submitted for each MSWLF unit.

6.8 FURTHER INFORMATION

6.8.1 References

Giroud, J.P., Bonaparte, R., Beech, J.F., and Gross, B.A., "Design of Soil Layer -Geosynthetic Systems Overlying Voids". Journal of Geotextiles and Geomembranes, Vol. 9, No. 1, 1990, pp. 11-50.

Richardson, G.N. and R.M. Koerner, (1987). "Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments"; Hazardous Waste Engineering Research Laboratory; USEPA, Office of Research and Development; Cincinnati, Ohio; Contract No. 68-07-3338.

U.S. EPA, (1987). "Design, Construction and Maintenance of Cover Systems for Hazardous Waste: An Engineering Guidance Document"; PB87-19156; EPA/600/2-87/039; U.S. Department of Commerce, National Technical Information Service; U.S. Army Engineering Waterways Experiment Station; Vicksburg, Mississippi.

U.S. EPA, (1988). "Guide to Technical Resources for the Design of Land Disposal Facilities"; EPA/625/6-88/018; U.S. EPA; Risk Reduction Engineering Laboratory and Center for Environmental Research Information; Office of Research and Development; Cincinnati, Ohio 45268.

U.S. EPA, (1989a). "Seminar Publication - Requirements for Hazardous Waste Landfill Design, Construction and Closure"; EPA/625/4-89/022; U.S. EPA; Center for Environmental Research Information; Office of Research and Development; Cincinnati, Ohio 45268.

U.S. EPA, (1989b). "Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments"; EPA/530-SW-89-047; U.S. EPA; Office of Solid Waste and Emergency Response; Washington, D.C. 20460.

U.S. EPA, (1989c). "Interim Final: RCRA Facility Investigation (RFI) Guidance"; EPA 530/SW-89-031; U.S. EPA; Waste Management Division; Office of Solid Waste; U.S. Environmental Protection Agency; Volumes I-IV; May 1989.

U.S. EPA, (1989d). "Interim Final: Risk Assessment Guidance For Superfund; Human Health Evaluation Manual Part A"; OS-230; U.S. EPA; Office of Solid Waste and Emergency Response; July 1989.

U.S. EPA, (1991). "Seminar Publications - Design and Construction of RCRA/CERCLA Final Covers"; EPA/625/4-91/025; U.S. EPA, Office of Research and Development; Washington, D.C. 20460.

6.8.2 Organizations

U.S. Department of Agriculture
Soil Conservation Service (SCS)
P.O. Box 2890
Washington, D.C. 20013-2890
(Physical Location: 14th St. and Independence Ave. NW.)
(202) 447-5157

Note: This is the address of the SCS headquarters. To obtain the SCS technical guidance document concerning the Universal Soil Loss Equation (entitled "Predicting Rainfall Erosion Loss, Guidebook 537," 1978), contact SCS regional offices located throughout the United States.

6.8.3 Models

Schroeder, et al., (1988). "The Hydrologic Evaluation of Landfill Performance (HELP) Model"; U.S.EPA; U.S. Army Engineer Waterways Experiment Station; Vicksburg, MS 39181-0631; October 1988.

Schroeder, P.R., A.C. Gibson, J.M. Morgan, T.M. Walski, (1984). "The Hydrologic Evaluation of Landfill Performance (HELP) Model, Volume I - Users Guide for Version I (EPA/530-SW-84-009), and Volume II - Documentation for Version I (EPA/530-SW-84-010); U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, June 1984.

6.8.4 Databases

Integrated Risk Information System (IRIS), U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio.