INVISTA purchased the assets of the Seaford site on April 30, 2004 from E.I. DuPont de Nemours & Company (DuPont) but did not purchase the underlying property which it leases from DuPont. The ash landfill permit was transferred from DuPont to INVISTA on June 23, 2005. Therefore, by way of clarification, any references to activities, documents, data, reports and other information contained in this application that convey that such information occurred or are dated prior to June 23, 2005 were prepared by or on behalf of DuPont.

CONCEPTUAL CLOSURE PLAN

INVISTA SEAFORD POWERHOUSE ASH LANDFILL

SEAFORD PLANT

Seaford, Delaware

September 2003
Revised: July 25, 2007

1.0 OVERVIEW OF THE CLOSURE PLAN

1.1 INTRODUCTION

The Closure Plan for the Seaford Ash Landfill is designed to provide a long-term, environmentally sound closure. Refer to drawings W1567129 and W1567131 in Appendix A for the closure system plans, details, and sections. The process of closing the Seaford Ash Landfill will consist of construction of the closure cap cover system after ash has been filled to the maximum design elevations.

The cap cover system for the Seaford Ash Landfill consists of a geomembrane liner, 12 inches of protective fill and 6 inches of topsoil capable of sustaining a vegetative cover. The final cover system is designed to perform the following functions:

- minimize infiltration
- promote establishment of vegetative cover
- mitigate soil erosion
- provide stormwater management

The final cover system will consist of three major components as detailed in the drawings. Detailed descriptions of each component are presented in subsequent sections.

1.2 CLOSURE SCHEDULE

The Seaford Plant currently intends to close and cap the landfill after it is filled to the maximum design elevations. At the current fill rate, the landfill will be full by the end of year 2027. Closure will commence at the beginning of the construction season in the early spring of year 2028, and should be completed by early autumn of year 2028. Table 1 presents the closure construction schedule.

The anticipated closure year is contingent upon the estimated fill rate being maintained, disposition of plant activities, and weather conditions. The target date listed in Table 1 assumes an ash production rate from the powerhouse of about 37,000 cubic yards per year (non-compacted volume). Prior to placement in the landfill, the ash is dewatered, excavated, and dried as necessary to meet compaction requirements. Using a compaction factor of 1.5, the average landfill fill rate is about 25,000 in-place cubic yards per year. With a total ash capacity of about 600,000 in-place cubic yards remaining in the landfill (after completion of the current filling operation), and assuming an average fill rate of 25,000 in-place cubic yards per year, the landfill has about 24 years of air-space remaining. At this rate, the landfill will be full by the end of the year 2027. This date is also dependent on the Seaford Plant's ash utilization effort, which could extend the life of the landfill.

1.3 ENGINEER CERTIFICATION

After closure has been completed, the Seaford Plant will submit to the DNREC a certification that the landfill has been closed in accordance with the provisions in the approved Closure Plan. A responsible corporate official and an independent, qualified professional engineer registered in the State of Delaware will sign the Certification of Closure.

A construction report including as-built drawings of the limits of construction, variations from the proposed Closure Plan (if any), and results of the Construction Quality Control/Quality Assurance (CQA/QC) testing program (CQA/QC Plan included in the Engineering Report), at a minimum, will accompany the final Closure Certification.

2.0 DESIGN OF CLOSURE COMPONENTS

2.1 GENERAL

The cover system designed for the Seaford Ash Landfill meets the requirements of *Delaware Regulation Governing Solid Waste, Section 6: Industrial Landfills, Sub-Section J. - Closure, Item 3 - Closure plan contents*. The closure system design is documented on drawings W1567129 and W1567131, and the specifications. A geomembrane is included in this conceptual closure plan. However, in accordance with performance specifications of the regulations and waste characteristics (i.e. minimize environmental impact), alternate cap designs will be evaluated during final design.

Perimeter dikes will be constructed during each ash placement period (typically every 3 years) to maintain containment during the filling process. When each filling phase is completed, the disturbed area will be covered with cover soil and topsoil and seeded.

After the Seaford Ash Landfill has been filled to the maximum design elevations, the surficial ash and soil will be graded and compacted to receive the closure cap system. The following sections describe the cover system design in more detail.

2.2 CLOSURE CAP COMPONENTS

The closure cap will comprise 12.3 acres and will cover the area shown on drawing W1567129. The cap design details and sections are shown on drawing W1567131. The cover design consists of three components. Each of these components has a function in the overall performance of the cover system.

The following are short descriptions of each component and its function in ascending order of occurrence:

- A 40-mil thick, textured, high-density polyethylene (HDPE) geomembrane liner will be placed directly over the graded and compacted ash material to function as the barrier layer in the cover system. The completed landfill will have 3:1 (or flatter) sideslopes up to the top bench at elevation 88 feet. The ash above the top bench will be graded on a 10 percent slope up to the crest at elevation 92 feet. The positive slope will promote runoff of stormwater and prevent ponding on the completed cover system.

- A12-inch layer of general fill will be placed over the geomembrane to function as a protective soil layer to protect the geomembrane from damage.

- A 6-inch layer of topsoil will be vegetated with a hardy, shallow-root, low-maintenance ground cover. The grassy vegetative cover will minimize soil erosion and the shallow-root system will minimize the potential for the roots to puncture the geomembrane liner.

2.3 CLOSURE CAP AND SIDESLOPE COVER SYSTEM PERFORMANCE

USEPA's computer model HELP (Hydrologic Evaluation of Landfill Performance)" has been used to perform a water balance to estimate the quantity of fluid infiltration through the final cover system into the ash.

HELP uses a water balance method to estimate the quantity of precipitation, which will theoretically penetrate the landfill final cover system and percolate through the ash. Site specific data can be input into the model to assess final cover performance. To determine the quantity of rain penetrating the final cover, the model estimates runoff, cap drainage, and evapotranspiration.

These calculations are based on assumptions made regarding the runoff coefficient, root zone depth, quality of plant cover, soil porosity, and field capacity. All rainwater remaining after runoff, cap drainage, and evapotranspiration is assumed to infiltrate the ash.

The HELP model is generally accepted as a useful tool in the evaluation of cap designs. To simplify the analysis of these designs, the model makes several assumptions. The model assumes steady state flow and homogeneous isotropic materials. Steady state flow may be achieved in an unknown number of years after the site has been closed and final cover installed. The HELP model assumes the ash is in a long-term, steady state condition (i.e., no storage).

The HELP model requires input on the weather, landfill design, and soil type. To assist the user in operating the HELP model, the program has several internal databases listing default values for data associated with weather conditions for 102 cities throughout the United States, five vegetation cover types, and 42 soil types. The user may select default values from these databases that best represent the expected site-specific conditions. Alternately, the user may manually input pertinent data using the prescribed format. Details of data input are presented in the HELP model documentation.

Based on the results of the modeling, the proposed cover design for the closure cap would result in about 97 percent effectiveness in eliminating infiltration through the cover system into the ash material. This percentage is based on the average total precipitation for one year and the "percolation from base of cover" values generated by the HELP model. Little if any seepage is expected to reach the landfill materials, due to the efficiency of the final cover and surface drainage systems.

Grading of the cap area will mitigate the potential for any ponding of water on the landfill due to minor differential settlement. Minor differential settlement of the cap area would not result in ponding, since the maximum settlement would occur near the peak at the center of the cap area.

2.4 SLOPE STABILITY ANALYSIS

Slope stability analysis was performed for an ultimate closure scenario. This analysis was based on the most critical cross-section of the proposed final closure configuration.

The analysis was conducted using conservative strength data for the ash and underlying foundation soils. The Bishop method for circular-shaped failure surfaces was used to analyze the slope stability, utilizing the computer program XSTABL, developed by Interactive Software Designs, Inc., of Moscow, Idaho. This program permits analysis of stability using different soil layers and variations of strength parameters with both soil type and depth. A large number of potential failure surfaces were analyzed in order to determine a minimum (critical) factor of safety for slope stability.

The most critical cross-section was analyzed. This cross-section is located on the east side of the closed landfill. It has a maximum final rim elevation of 88 feet and a maximum crest elevation of 92 feet. A minimum factor of safety of 1.5 at the end of filling operations was computed. This factor of safety is conservative because very conservative strength parameters for the ash material were used and the ash will increase in strength over time due to overburden load and consolidation. The slope stability computer analysis results of the ultimate closure scenario are presented in Appendix B.

2.5 POST-CLOSURE CAP CONSTRUCTION SETTLEMENT

The potential for settlement of the closure cap due to consolidation of the foundation soils and consolidation of the ash material was analyzed. The foundation soils will consolidate due to the static load of the landfill. However, because the foundation soils underlying the lateral expansion area are primarily granular, most settlement will occur concurrent with the application of load, and essentially all settlement of the foundation soils will occur prior to construction of the final closure cap.

The ash material in the landfill will consolidate due to the load of the overlying materials (ash and closure cap soils). Because of the nature of the waste material, most of the consolidation will occur during landfilling, and the differential post-closure settlement is expected to be minimal. This minimal differential settlement would not reduce the hydraulic effectiveness of the cap.

2.6 POST-CLOSURE STORMWATER MANAGEMENT

The closure cap is sloped down from its peak at the center to the rim at a 10 percent slope. Surface run-off will drain by sheet flow over the cap system and down the exterior sideslopes, sloped at 3H:1V, to various locations around the perimeter of the landfill facility. Reverse sloping benches have been provided at intervals of 17 feet vertically to reduce the energy of sheeting stormwater. Attempts have been made to reduce the possibility of concentrated run-off at erosive velocities.

2.7 EROSION CONTROL

Prevention of erosion of the closure cap cover system soil layers is critical to the cover system performance. Loss of soil cover decreases the effectiveness of the cover system. The potential for water erosion was evaluated using the Universal Soil Loss Equation (USLE). The erosion calculation equation is highly dependent upon the type and amount of vegetation established on the final cover. Analysis has been performed assuming good vegetative cover conditions, reflecting the anticipated condition after closure. Based on this permanent cover condition, the calculated erosion due to water is 0.21 tons per acre per year for the closure cap, less than the maximum allowable soil loss of 2.0 tons per acre per year (per EPA Guide to Technical Resource for the Design of Land Disposal Facilities). Soil loss calculations are presented in Appendix B.

3.0 COVER CONSTRUCTION

3.1 CONSTRUCTION PROCEDURES

The procedures presented in this section have been developed based on the project drawings, located in Appendix A. The specifications (Appendix B of the Engineering Report) include references to subgrade preparation, geomembrane material and placement, general fill material and placement, topsoil material and placement, and seeding operations.

3.2 SURVEY CONTROL

Delineation of the existing extent of the landfill will continue to be referenced to survey monuments adjacent to the Seaford Ash Landfill, located as shown on the Topographic Survey Plan prepared by T. A. Surveying, Inc. and dated August 8, 2003. The concrete monuments are labeled on this drawing with horizontal coordinates and associated elevations. Alignment of these monuments shall be verified to the Delaware State Plane Coordinate System and National Geodetic Vertical Datum 1929. The horizontal control will be first order; the vertical control will be third order. These monuments are situated such that construction operations will not damage them.

The Seaford Ash Landfill final dimensions will be surveyed with respect to these monuments. A surveyor registered in the State of Delaware will prepare a plan drawing showing the closed landfill and surrounding terrain.

3.3 AIR EMISSION CONTROL

Airborne migration of landfill materials will be predominantly migration of dust particles during closure cap subgrade and bedding preparation activities. As the installation proceeds, the potential for fugitive dust containing ash and soil material will lessen and then be virtually eliminated once the composite geomembrane cap has been partially completed over the entire site.

A fine mist of water from a water wagon will be sprayed over the ash and soil material to control dust emissions, as needed, during closure cap subgrade preparation. The water truck will be kept on site and full of water during construction activities, and will be utilized at the discretion of field construction inspectors and representatives from the Seaford Plant.

3.4 STORMWATER, EROSION AND SEDIMENT CONTROL

During construction of the cover system, only precipitation that directly falls on the landfill will affect construction activities. Grading during subgrade preparation will be performed to promote drainage to a collection area.

3.5 PERSONNEL SAFETY

The hazards associated with the landfill materials are primarily associated with fugitive dust. The Closure Plan includes provisions to minimize dust during subgrade preparation and cover soil placement.

The general contractor implementing the Closure Plan and all independent site groups associated with the Seaford Ash Landfill Closure will prepare a comprehensive Health and Safety Plan (HASP) that addresses task-specific personnel protective equipment, personnel decontamination, medical monitoring, compound hazard potential, air monitoring, emergency procedures, and regulatory compliance.

Prior to beginning of closure activities, the contractor will be fully informed as to the nature and characteristics of the landfill material. All pertinent data in the possession of the Seaford Plant regarding landfill materials at the start of closure will be made available to the selected contractor.

3.6 CONSTRUCTION INSPECTIONS

Inspection procedures for construction of the cover systems are contained in the CQA/QC Plan. The plan addresses construction procedures, field and laboratory testing, and remedial action for imperfect sections. The plan includes inspections of earthen and geosynthetic components of the cover system.

4.0 POST-CLOSURE PLAN

The Closure Plan described in the previous sections is designed to isolate the landfill from the environment and minimize stormwater infiltration. Upon completion of the closure cap system, the landfill will be inspected on a regular basis and maintained as necessary. The post-closure activities required for the Seaford Ash Landfill after closure will involve a continuation of the existing monitoring program, plus additional tasks associated with the landfill cap.

- Continue the current groundwater monitoring program, which includes field work, laboratory testing, and written reports.

- Make regular inspections of the landfill to identify any maintenance issues.

- Maintain, as necessary, all stormwater and erosion control measures implemented during closure.

- Cut the grass on the landfill, as necessary. Two cuttings per year are assumed for cost estimating purposes.

Additional information required by the Delaware Regulations Governing Solid Waste (DRGSW) to be included in the Post-Closure Plan is provided below:

- Post-Closure Contact: The Site Environmental Manager will be the person to contact about the facility during the post-closure period. The current contact information is provided below:

  Mr. Michael A. Terry
  Environmental Manager
  25876 DuPont Road
  Seaford, Delaware 19973

  Telephone: (302) 629-1221
  Facsimile: (302) 629-1839
  Email: Michael.A.Terry@invista.com

- Post-Closure land use: Future use of the landfill and solid waste storage area is anticipated to remain a grass covered landfill with a grass covered open area.

- Post-Closure Landfill Gas Control Plan: Due to the inert nature of the ash material, a landfill gas control and/or recovery plan is not necessary.

- Post-Closure Elevations: Drawing W1567129 is a topographical map depicting the proposed post-closure elevations and is included in Appendix A of the Engineering Report.

- Post Closure Construction Quality Assurance/Quality Control (CQA/QC) Plan: A CQA/QC Plan is provided in Appendix C of the Engineering Report.

Section 5 – Financial Assurance

Please note that the material presented in this section reflects the present financial assurance mechanism being utilized by INVISTA to demonstrate that funds necessary for closure, post-closure care, and corrective action are available. INVISTA has made a formal request to DNREC to change the present mechanism from a Trust Fund to an insurance policy as allowed by the regulations. DNREC is presently evaluating INVISTA's request.

5.0 FINANCIAL ASSURANCE

This section provides information required in *Delaware Regulation Governing Solid Waste, Section 6: Industrial Landfills, Sub-Section J. - Closure, Item 3 - Closure plan contents.*

Costs associated with performing Closure and Post-Closure activities are presented in this section. These costs include both capital and operating costs. The subsequent subsections present the estimates and the assumptions used in developing them.

5.1 CLOSURE COSTS

The total estimated cost to construct the closure system for the Seaford Ash Landfill (12.3 acres) is $1,260,280 in year 2003 dollars. Annually adjusting the closure cost estimate for inflation and assuming an inflation rate 1.021 for the year 2004, 1.026 for 2005, and 1.0327 for 2006 the estimated closure cost is $1,363,372.

These costs are based on the specific tasks listed in Table 2. A description of the specific tasks with associated assumptions is presented below.

- **Mobilization/Demobilization** – Mobilizing and demobilizing all equipment, personnel, trailers, etc. to complete the construction of the landfill closure system.

- **Strip and Stockpile Topsoil** – Strip the top 6 inches of topsoil covering the entire area to be capped. Stockpile the topsoil on-site for later use in the cap construction. The total volume of topsoil to strip over the 12.3 acres is 10,000 in-place cubic yards. This equates to a stockpile of 12,000 cubic yards assuming a 1.2 bulking factor.

- **Final Site Grading** – Grade the landfill surface, after stripping topsoil, to the lines and grades on the drawings. Minimal grading is assumed for the estimate (i.e. no major movement of soil required). This task also includes the smooth-drum rolling (or compacting) of the entire surface to prepare the subgrade for the geomembrane.

- **Geomembrane** – Install a 40-mil thick, textured, high-density polyethylene (HDPE) geomembrane over the approved subgrade. This task includes purchase, transportation, and installation of the geomembrane.

- **Cover Soil** – Place 12 inches of cover soil over the geomembrane. A total of about 20,000 in-place cubic yards of cover soil is required for the 12.3 acres. Assuming a bulking factor of 1.3, a total of about 26,000 cubic yards of cover soil will need to be purchased from an off-site borrow source. This task includes purchase, transportation, placement, and compaction of the cover soil.

- **Topsoil** – A total of about 10,000 in-place cubic yards of topsoil is required over the entire 12.3 acres of cap. For this estimate, assume all of this volume will be available from the topsoil stripped from the landfill and stockpiled. The cost to remove from the stockpile, place and compact the stockpiled topsoil on the landfill is about $5 per bulk cubic yard.

- **Hydroseeding** – Hydroseed over the topsoil on the entire 12.3 acres of landfill. The hydroseeding will include seed, fertilizer, and mulch.

- **Geotextile** – A geotextile will be placed over approved subgrade under the proposed access road. The access road is about 1,600 feet long by 20 feet wide. About 32,000 square feet of geotextile is required. The cost of the geotextile includes, purchase, transportation, and installation.

- **Crushed Stone** – Crushed stone will be purchased from an off-site borrow source, transported to the site, placed over the geotextile, and compacted. The access road is about 1,600 feet long by 20 feet wide. With a stone thickness of 12 inches, the in-place volume is about 1,200 cubic yards. This equates to a total of 1,900 tons of stone using a bulking/conversion factor of 1.6 tons per cubic yard. The cost for the stone includes, purchase, transportation, placement, and compaction.

- **Concrete Barricades** – A total of about 1,300 lineal feet of concrete barricades will be purchased, transported, and placed on the downslope side of the access road along the steeper areas of the road.

- **CQA and Certification Report** – Construction quality assurance and the final certification report will be performed by an independent, third-party inspection firm. Full-time inspection for a period of 4 months is assumed for the estimate. In addition, CQA services include project management, laboratory testing, and a written certification report.

5.2 POST-CLOSURE COSTS

Costs associated with post-closure maintenance and operation of the Seaford Ash Landfill were developed based on tasks associated with on-going inspection and maintenance activities plus additional tasks required after capping. A description of the specific tasks with associated assumptions is presented below.

Annual post-closure costs were estimated to be $58,000 in year 2003 dollars. This annual cost will rise based on the inflation factor and the total estimated post-closure costs for the 30-year period is estimated to be $1,888,824.

A summary of the estimated post-closure costs is presented in Table 3. A description of the specific post-closure tasks with associated assumptions is presented below.

- Continue the current groundwater monitoring program, which includes field work, laboratory testing, and written reports. The estimated cost for field work and report preparation is $26,000. The estimated cost for laboratory testing is $21,000. These costs are based on the costs for the current groundwater monitoring that is in effect.

- Make regular inspections of the landfill to identify any maintenance issues. Assume one hour per week at $100 per hour for estimating purposes.

- Maintain, as necessary, all stormwater and erosion control measures implemented during closure. An allowance of $1,000 per year is assumed for erosion control maintenance.

- Cut the grass on the landfill, as necessary. Two cuttings per year are assumed for cost estimating purposes at a cost of $5,000.

- All above unit costs are in year 2003 dollars.

- Present worth factor used for calculating the post-closure costs are based on a time period of 30 years.

5.3 INSURANCE POLICY

See Section 11 for the financial assurance documentation.

Table 1 - Closure Plan Schedule

Task	Year and Month																							
	2027												2028											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Active landfill operation	■	■	■	■	■	■	■	■	■	■	■	■												
Strip topsoil and grade surface																■	■							
Proof roll/compact subgrade																	■	■						
Geomembrane liner placement																		■	■					
Cover soil placement																			■	■				
Topsoil placement																				■	■			
Hydroseed																					■	■		
CQA and certification report																■	■	■	■	■	■	■	■	
Start of post-closure (30 years)																							■	■

1. INVISTA will notify DNREC of its intent to close the landfill 180 days prior to final receipt of waste. An updated closure plan and closure schedule will be submitted if changes to the existing plan and schedule are necessary.

2. INVISTA will notify DNREC 30 working days prior to commencing closure activities.

TABLE 2
INVISTA Seaford Site Ash Landfill
Estimated Closure Cost Summary

Task	Units	Unit Cost	Quantity	Cost	
				Year 2005	Year 2006
Mobilization/Demobilization	lump sum	$30,000	1	$31,426	$32,454
Strip & Stockpile Topsoil	cubic yards	$4	10,000	$41,902	$43,272
Final Site Grading	acres	$3,000	12.3	$38,654	$39,918
Geomembrane Barrier	square feet	$0.75	536,000	$421,113	$434,884
Cover/Protective Soil	cubic yards	$15	26,000	$408,543	$421,902
Topsoil (use on-site topsoil)	cubic yards	$5	12,000	$62,853	$64,908
Hydroseeding	acres	$2,600	12.3	$33,501	$34,596
Geotextile (under access road)	square feet	$0.20	32,000	$6,704	$ 6,924
Crushed Stone (access road)	tons	$20	1,900	$39,807	$41,108
Concrete Barricades (access road)	lineal feet	$100	1,300	$136,181	$140,634
CQA and Certification Report	lump sum	$95,000	1	$99,517	$102,771
Total				$1,320,201	$1,363,372

Notes:
(1) 1.021 est. 2004 inflation factor, 1.026 est. 2005 inflation factor &1.0327est. 2006 inflation factor
(2) All material costs are in-place costs

TABLE 3
INVISTA Seaford Site Ash Landfill
Estimated Post-Closure Cost Summary

Task	Annual Cost	Annual Cost X 30 Years	2005 Cost 2004 cost X Inflation Rate of 1.026	2006 Cost 2005 cost X Inflation Rate of 1.0327
	Year 2003	Year 2003	Year 2005	Year 2006
Groundwater Monitoring - Field Work and Reports	$26,000	$780,000	$817,086	$ 843,805
Groundwater Monitoring - Laboratory Costs	$21,000	$630,000	$659,954	$681,534
Regular Inspections (1 hour/week @ 52 weeks)	$5,200	$156,000	$163,417	$ 168,761
Annual Erosion Control Maintenance	$1,000	$30,000	$31,426	$ 32,454
Grass Cutting (2 cuttings per year)	$5,000	$150,000	$157,132	$ 162,270
Totals	$58,200	$1,746,000	$1,829,015	$1,888,824

Notes:

(1) Post-closure begins after completion of closure in year 2028

(2) 1.021 est. 2004 inflation factor, 1.026 est. 2005 inflation factor & 1.0327est. 2006 inflation factor

(3) 30-year post-closure period

APPENDIX B
Calculations

Closure System Efficiency
(HELP Model Results)

SLOPE = 10% (TOP "FLAT" PORTION)

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** HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
**
** HELP MODEL VERSION 3.07 (1 NOVEMBER 1997)
**
** DEVELOPED BY ENVIRONMENTAL LABORATORY
**
** USAE WATERWAYS EXPERIMENT STATION
**
** FOR USEPA RISK REDUCTION ENGINEERING LABORATORY
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PRECIPITATION DATA FILE:     C:\HELP307\DATA4.D4
TEMPERATURE DATA FILE:       C:\HELP307\DATA7.D7
SOLAR RADIATION DATA FILE:   C:\HELP307\DATA13.D13
EVAPOTRANSPIRATION DATA:     C:\HELP307\DATA11.D11
SOIL AND DESIGN DATA FILE:   C:\HELP307\DATA10.D10
OUTPUT DATA FILE:            C:\HELP307\SLOPE10.OUT
```

TIME: 11:12 DATE: 4/13/2006

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TITLE: SEAFORD ASH LANDFILL

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NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE

COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 6

THICKNESS	=	6.00 INCHES
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1900 VOL/VOL
WILTING POINT	=	0.0850 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4134 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.720000011000E-03 CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 5

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4570 VOL/VOL
FIELD CAPACITY	=	0.1310 VOL/VOL
WILTING POINT	=	0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4570 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.04 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	2 - EXCELLENT

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
GOOD STAND OF GRASS, A SURFACE SLOPE OF 10.%

AND A SLOPE LENGTH OF 150. FEET.

SCS RUNOFF CURVE NUMBER	=	64.50	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	18.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	7.965	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.202	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.206	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	7.965	INCHES
TOTAL INITIAL WATER	=	7.965	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
WILMINGTON DELAWARE

STATION LATITUDE	=	39.80	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	107	
END OF GROWING SEASON (JULIAN DATE)	=	298	
EVAPORATIVE ZONE DEPTH	=	18.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.20	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	71.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.11	2.99	3.87	3.39	3.23	3.51
3.90	4.03	3.59	2.89	3.33	3.54

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31.20	33.20	41.80	52.40	62.20	71.20
76.00	74.80	67.80	56.30	45.60	35.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE
AND STATION LATITUDE = 39.80 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.00	145200.031	100.00
RUNOFF	6.046	21948.004	15.12
EVAPOTRANSPIRATION	32.531	118085.914	81.33
PERC./LEAKAGE THROUGH LAYER 3	1.418978	5150.892	3.55
AVG. HEAD ON TOP OF LAYER 3	10.3907		
CHANGE IN WATER STORAGE	0.004	15.204	0.01
SOIL WATER AT START OF YEAR	8.358	30338.203	
SOIL WATER AT END OF YEAR	8.362	30353.408	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.011	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.54	161680.156	100.00
RUNOFF	13.126	47648.453	29.47
EVAPOTRANSPIRATION	30.137	109396.477	67.66
PERC./LEAKAGE THROUGH LAYER 3	1.434081	5205.714	3.22
AVG. HEAD ON TOP OF LAYER 3	10.3371		
CHANGE IN WATER STORAGE	-0.157	-570.476	-0.35
SOIL WATER AT START OF YEAR	8.362	30353.408	
SOIL WATER AT END OF YEAR	8.205	29782.932	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.006	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	47.53	172533.891	100.00

RUNOFF	11.556	41949.277	24.31
EVAPOTRANSPIRATION	36.492	132466.797	76.78
PERC./LEAKAGE THROUGH LAYER 3	1.411999	5125.557	2.97
AVG. HEAD ON TOP OF LAYER 3	10.3378		
CHANGE IN WATER STORAGE	-1.931	-7007.845	-4.06
SOIL WATER AT START OF YEAR	8.205	29782.932	
SOIL WATER AT END OF YEAR	6.261	22726.182	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.013	48.906	0.03
ANNUAL WATER BUDGET BALANCE	0.0000	0.114	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
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PRECIPITATION	34.33	124617.867	100.00
RUNOFF	3.537	12839.873	10.30
EVAPOTRANSPIRATION	30.325	110079.070	88.33
PERC./LEAKAGE THROUGH LAYER 3	0.908196	3296.753	2.65
AVG. HEAD ON TOP OF LAYER 3	6.6403		

CHANGE IN WATER STORAGE	-0.440	-1597.768	-1.28
SOIL WATER AT START OF YEAR	6.261	22726.182	
SOIL WATER AT END OF YEAR	5.834	21177.318	
SNOW WATER AT START OF YEAR	0.013	48.906	0.04
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.060	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	45.69	165854.734	100.00
RUNOFF	7.154	25969.131	15.66
EVAPOTRANSPIRATION	34.379	124795.930	75.24
PERC./LEAKAGE THROUGH LAYER 3	1.475497	5356.053	3.23
AVG. HEAD ON TOP OF LAYER 3	10.6780		
CHANGE IN WATER STORAGE	2.681	9733.601	5.87
SOIL WATER AT START OF YEAR	5.834	21177.318	
SOIL WATER AT END OF YEAR	8.515	30910.920	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00

ANNUAL WATER BUDGET BALANCE 0.0000 0.023 0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.24	2.51	4.08	2.94	3.87	5.39
	3.97	4.06	4.53	3.13	2.08	2.62
STD. DEVIATIONS	2.80	1.49	1.56	0.98	2.43	2.18
	2.03	2.06	1.93	0.83	0.44	2.54
RUNOFF						
TOTALS	1.891	0.760	2.276	0.000	0.808	0.690
	0.585	0.000	0.000	0.017	0.129	1.128
STD. DEVIATIONS	2.713	0.659	2.113	0.000	1.347	0.946
	1.308	0.000	0.000	0.027	0.289	1.867
EVAPOTRANSPIRATION						
TOTALS	0.812	1.043	2.267	3.232	3.221	5.595
	6.558	4.101	2.286	1.463	1.294	0.898
STD. DEVIATIONS	0.336	0.544	0.283	0.549	0.832	1.454
	0.679	2.004	0.941	0.142	0.149	0.165

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.1172	0.1042	0.1805	0.1642	0.1581	0.1351
	0.0730	0.0200	0.0140	0.0869	0.1223	0.1543
STD. DEVIATIONS	0.0642	0.0669	0.0363	0.0065	0.0198	0.0283
	0.0423	0.0329	0.0174	0.0676	0.0598	0.0577

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	9.9285	9.7187	15.3177	14.6165	13.6701	12.1312
	6.3228	1.7179	1.1722	7.4402	10.8849	13.2011
STD. DEVIATIONS	5.4610	6.3630	3.0963	0.5300	1.5715	2.3951
	3.7410	2.8812	1.4977	5.8378	5.2055	4.7045

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	42.42 (5.306)	153977.3	100.00
RUNOFF	8.284 (3.9678)	30070.95	19.529
EVAPOTRANSPIRATION	32.773 (2.7117)	118964.84	

77.261

PERCOLATION/LEAKAGE THROUGH 1.32975 (0.23694) 4826.994
3.13487
LAYER 3

AVERAGE HEAD ON TOP 9.677 (1.703)
OF LAYER 3

CHANGE IN WATER STORAGE 0.032 (1.6681) 114.54
0.074

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	5.26	19093.801
RUNOFF	2.924	10614.5273
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.006900	25.04743
AVERAGE HEAD ON TOP OF LAYER 3	18.000	
SNOW WATER	2.14	7777.3130
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.4557
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0670

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	2.6384	0.4397
2	5.4840	0.4570
3	0.0000	0.0000
SNOW WATER	0.000	

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SLOPE = 33% (3:1 SIDESLOPES)

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 **             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
**
 **               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)
**
 **                DEVELOPED BY ENVIRONMENTAL LABORATORY
**
 **                  USAE WATERWAYS EXPERIMENT STATION
**
 **            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY
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PRECIPITATION DATA FILE:      C:\HELP307\DATA4.D4
TEMPERATURE DATA FILE:        C:\HELP307\DATA7.D7
SOLAR RADIATION DATA FILE:    C:\HELP307\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP307\DATA11.D11
SOIL AND DESIGN DATA FILE:    C:\HELP307\DATA33.D10
OUTPUT DATA FILE:             C:\HELP307\SLOPE33.OUT
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TIME: 11:23   DATE: 4/13/2006

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TITLE: SEAFORD ASH LANDFILL

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NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE

COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 6

THICKNESS	=	6.00 INCHES
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1900 VOL/VOL
WILTING POINT	=	0.0850 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4134 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.720000011000E-03 CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 5

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4570 VOL/VOL
FIELD CAPACITY	=	0.1310 VOL/VOL
WILTING POINT	=	0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4570 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.04 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	2 - EXCELLENT

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
GOOD STAND OF GRASS, A SURFACE SLOPE OF 33.%

AND A SLOPE LENGTH OF 50. FEET.

SCS RUNOFF CURVE NUMBER	=	68.40	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	18.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	7.965	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.202	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.206	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	7.965	INCHES
TOTAL INITIAL WATER	=	7.965	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
WILMINGTON DELAWARE

STATION LATITUDE	=	39.80	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	107	
END OF GROWING SEASON (JULIAN DATE)	=	298	
EVAPORATIVE ZONE DEPTH	=	18.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.20	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	71.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.11	2.99	3.87	3.39	3.23	3.51
3.90	4.03	3.59	2.89	3.33	3.54

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31.20	33.20	41.80	52.40	62.20	71.20
76.00	74.80	67.80	56.30	45.60	35.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE
AND STATION LATITUDE = 39.80 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.00	145200.031	100.00
RUNOFF	6.048	21953.055	15.12
EVAPOTRANSPIRATION	32.531	118085.914	81.33
PERC./LEAKAGE THROUGH LAYER 3	1.417588	5145.844	3.54
AVG. HEAD ON TOP OF LAYER 3	10.3808		
CHANGE IN WATER STORAGE	0.004	15.204	0.01
SOIL WATER AT START OF YEAR	8.358	30338.203	
SOIL WATER AT END OF YEAR	8.362	30353.408	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.008	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.54	161680.156	100.00
RUNOFF	13.127	47649.340	29.47
EVAPOTRANSPIRATION	30.137	109396.477	67.66
PERC./LEAKAGE THROUGH LAYER 3	1.433838	5204.832	3.22
AVG. HEAD ON TOP OF LAYER 3	10.3356		
CHANGE IN WATER STORAGE	-0.157	-570.476	-0.35
SOIL WATER AT START OF YEAR	8.362	30353.408	
SOIL WATER AT END OF YEAR	8.205	29782.932	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.011	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	47.53	172533.891	100.00

RUNOFF	11.556	41947.605	24.31
EVAPOTRANSPIRATION	36.493	132469.562	76.78
PERC./LEAKAGE THROUGH LAYER 3	1.411698	5124.464	2.97
AVG. HEAD ON TOP OF LAYER 3	10.3359		
CHANGE IN WATER STORAGE	-1.931	-7007.845	-4.06
SOIL WATER AT START OF YEAR	8.205	29782.932	
SOIL WATER AT END OF YEAR	6.261	22726.182	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.013	48.906	0.03
ANNUAL WATER BUDGET BALANCE	0.0000	0.109	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	34.33	124617.867	100.00
RUNOFF	3.537	12839.899	10.30
EVAPOTRANSPIRATION	30.325	110079.070	88.33
PERC./LEAKAGE THROUGH LAYER 3	0.908189	3296.726	2.65
AVG. HEAD ON TOP OF LAYER 3	6.6403		

CHANGE IN WATER STORAGE -0.440 -1597.768
-1.28

SOIL WATER AT START OF YEAR 6.261 22726.182

SOIL WATER AT END OF YEAR 5.834 21177.318

SNOW WATER AT START OF YEAR 0.013 48.906
0.04

SNOW WATER AT END OF YEAR 0.000 0.000
0.00

ANNUAL WATER BUDGET BALANCE 0.0000 -0.059
0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	45.69	165854.734	100.00
RUNOFF	7.157	25979.096	15.66
EVAPOTRANSPIRATION	34.379	124795.930	75.24
PERC./LEAKAGE THROUGH LAYER 3	1.472752	5346.090	3.22
AVG. HEAD ON TOP OF LAYER 3	10.6603		
CHANGE IN WATER STORAGE	2.681	9733.601	5.87
SOIL WATER AT START OF YEAR	5.834	21177.318	
SOIL WATER AT END OF YEAR	8.515	30910.920	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00

ANNUAL WATER BUDGET BALANCE 0.0000 0.022
0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.24	2.51	4.08	2.94	3.87	5.39
	3.97	4.06	4.53	3.13	2.08	2.62
STD. DEVIATIONS	2.80	1.49	1.56	0.98	2.43	2.18
	2.03	2.06	1.93	0.83	0.44	2.54
RUNOFF						
TOTALS	1.891	0.762	2.274	0.000	0.810	0.689
	0.585	0.000	0.005	0.024	0.120	1.125
STD. DEVIATIONS	2.713	0.660	2.112	0.000	1.346	0.943
	1.308	0.000	0.007	0.034	0.269	1.862
EVAPOTRANSPIRATION						
TOTALS	0.812	1.043	2.267	3.232	3.221	5.595
	6.558	4.101	2.286	1.463	1.294	0.898
STD. DEVIATIONS	0.336	0.544	0.283	0.549	0.832	1.454
	0.679	2.004	0.941	0.142	0.149	0.165

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.1172	0.1042	0.1805	0.1642	0.1580	0.1351
	0.0730	0.0200	0.0140	0.0866	0.1218	0.1543
STD. DEVIATIONS	0.0642	0.0669	0.0363	0.0065	0.0198	0.0282
	0.0422	0.0329	0.0174	0.0675	0.0594	0.0577

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	9.9286	9.7186	15.3152	14.6165	13.6648	12.1287
	6.3215	1.7179	1.1717	7.4158	10.8502	13.1972
STD. DEVIATIONS	5.4610	6.3630	3.0953	0.5300	1.5674	2.3921
	3.7389	2.8812	1.4980	5.8305	5.1672	4.7005

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	42.42 (5.306)	153977.3	100.00
RUNOFF	8.285 (3.9673)	30073.80	19.531
EVAPOTRANSPIRATION	32.773 (2.7120)	118965.39	

77.262

PERCOLATION/LEAKAGE THROUGH 1.32881 (0.23634) 4823.591
3.13266
LAYER 3

AVERAGE HEAD ON TOP 9.671 (1.699)
OF LAYER 3

CHANGE IN WATER STORAGE 0.032 (1.6681) 114.54
0.074

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	5.26	19093.801
RUNOFF	2.924	10614.8359
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.006900	25.04743
AVERAGE HEAD ON TOP OF LAYER 3	18.000	
SNOW WATER	2.14	7777.3130
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.4557
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0670

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	2.6384	0.4397
2	5.4840	0.4570
3	0.0000	0.0000
SNOW WATER	0.000	

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Slope Stability
(Computer Results)

FS = 1.5

Ash Properties
γ = 90 pcf
c = 750 psf
ϕ = 0°

XSTABL File: SEAFORD2   8-29-2003   11:00

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*        Copyright (C) 1992 Ä 96        *
*   Interactive Software Designs, Inc.  *
*      Moscow, ID 83843, U.S.A.         *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.200                96 Ä 1300  *
*****************************************
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Problem Description : Seaford Ash Landfill - Closure

SEGMENT BOUNDARY COORDINATES

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7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	106.0	100.0	111.0	2
2	100.0	111.0	145.0	121.0	1
3	145.0	121.0	385.0	180.0	1
4	385.0	180.0	425.0	192.0	1
5	425.0	192.0	475.0	188.0	1
6	475.0	188.0	600.0	155.0	1
7	600.0	155.0	760.0	115.0	1

1 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	100.0	111.0	760.0	115.0	2

ISOTROPIC Soil Parameters

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2 Soil unit(s) specified

Soil   Unit Weight   Cohesion   Friction   Pore Pressure   Water

Unit No.	Moist (pcf)	Sat. (pcf)	Intercept (psf)	Angle (deg)	Parameter Ru	Constant (psf)	Surface No.
1	90.0	90.0	750.0	.00	.000	.0	0
2	120.0	120.0	.0	28.00	.000	.0	0

1 Water surface(s) have been specified

Unit weight of water = 62.40 (pcf)

Water Surface No. 1 specified by 2 coordinate points

****
PHREATIC SURFACE,
****

Point No.	x-water (ft)	y-water (ft)
1	.00	106.00
2	760.00	115.00

-- WARNING --
Water surface number 1 has been defined but is not used by any soil unit. The analysis will IGNORE water surface # 1. Please make sure that this assumption is consistent with your subsurface model.

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

900 trial surfaces will be generated and analyzed.

30 Surfaces initiate from each of 30 points equally spaced along the ground surface between x = .0 ft
and x = 300.0 ft

Each surface terminates between x = 300.0 ft
and x = 425.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = 70.0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

```
9.0 ft line segments define each trial failure surface.


   ---------------------
   ANGULAR RESTRICTIONS
   ---------------------

    The first segment of each failure surface will be inclined
    within the angular range defined by :

            Lower angular limit :=    -45.0 degrees
            Upper angular limit :=  (slope angle - 5.0) degrees


************************************************************************
   --  WARNING  --  WARNING  --  WARNING  --  WARNING  --  (# 48)
************************************************************************
Negative effective stresses were calculated at the base of a slice.
This warning is usually reported for cases where slices have low self
weight and a relatively high "c" shear strength parameter.  In such
cases, this effect can only be eliminated by reducing the "c" value.
************************************************************************

    ------------------------------------------------------------
    USER SELECTED option to maintain strength greater than zero
    ------------------------------------------------------------


    ************************************************************
    **      Factor of safety calculation for surface #   712    **
    **      failed to converge within FIFTY iterations          **
    **                                                          **
    **     The last calculated value of the FOS was  23.9761    **
    **     This will be ignored for final summary of results    **
    ************************************************************

Circular surface (FOS= 23.9761) is defined by: xcenter =    204.86
ycenter =    427.70   Init. Pt. =     237.93   Seg. Length =   9.00
-------------------------------------------------------------------


    ************************************************************
    **      Factor of safety calculation for surface #   719    **
    **      failed to converge within FIFTY iterations          **
    **                                                          **
    **     The last calculated value of the FOS was  21.6005    **
    **     This will be ignored for final summary of results    **
    ************************************************************

Circular surface (FOS= 21.6005) is defined by: xcenter =    174.09
ycenter =    602.98   Init. Pt. =     237.93   Seg. Length =   9.00
-------------------------------------------------------------------
```

```
*************************************************************
**     Factor of safety calculation for surface #   790    **
**     failed to converge within FIFTY iterations          **
**                                                         **
**    The last calculated value of the FOS was  37.0831    **
**    This will be ignored for final summary of results    **
*************************************************************
```

```
Circular surface (FOS= 37.0831) is defined by: xcenter =    245.24
ycenter =    348.69   Init. Pt. =    268.97   Seg. Length =   9.00
-------------------------------------------------------------------
```

```
*************************************************************
**     Factor of safety calculation for surface #   814    **
**     failed to converge within FIFTY iterations          **
**                                                         **
**    The last calculated value of the FOS was  31.4326    **
**    This will be ignored for final summary of results    **
*************************************************************
```

```
Circular surface (FOS= 31.4326) is defined by: xcenter =    279.60
ycenter =    215.27   Init. Pt. =    279.31   Seg. Length =   9.00
-------------------------------------------------------------------
```

```
*************************************************************
**     Factor of safety calculation for surface #   835    **
**     failed to converge within FIFTY iterations          **
**                                                         **
**    The last calculated value of the FOS was  50.0585    **
**    This will be ignored for final summary of results    **
*************************************************************
```

```
Circular surface (FOS= 50.0585) is defined by: xcenter =    276.09
ycenter =    219.12   Init. Pt. =    279.31   Seg. Length =   9.00
-------------------------------------------------------------------
```

```
*************************************************************
**     Factor of safety calculation for surface #   849    **
**     failed to converge within FIFTY iterations          **
**                                                         **
**    The last calculated value of the FOS was  51.1974    **
**    This will be ignored for final summary of results    **
*************************************************************
```

```
Circular surface (FOS= 51.1974) is defined by: xcenter =    293.67
ycenter =    166.29   Init. Pt. =    289.66   Seg. Length =   9.00
-------------------------------------------------------------------
```

```
************************************************************
**      Factor of safety calculation for surface #   864     **
**      failed to converge within FIFTY iterations            **
**                                                            **
**    The last calculated value of the FOS was  30.2901      **
**    This will be ignored for final summary of results      **
************************************************************
```

```
Circular surface (FOS= 30.2901) is defined by: xcenter =    281.40
ycenter =     277.86   Init. Pt. =     289.66   Seg. Length =   9.00
--------------------------------------------------------------------
```

```
************************************************************
**      Factor of safety calculation for surface #   886     **
**      failed to converge within FIFTY iterations            **
**                                                            **
**    The last calculated value of the FOS was  23.9901      **
**    This will be ignored for final summary of results      **
************************************************************
```

```
Circular surface (FOS= 23.9901) is defined by: xcenter =    306.51
ycenter =     169.89   Init. Pt. =     300.00   Seg. Length =   9.00
--------------------------------------------------------------------
```

```
************************************************************
**      Factor of safety calculation for surface #   887     **
**      failed to converge within FIFTY iterations            **
**                                                            **
**    The last calculated value of the FOS was  27.8106      **
**    This will be ignored for final summary of results      **
************************************************************
```

```
Circular surface (FOS= 27.8106) is defined by: xcenter =    305.82
ycenter =     172.32   Init. Pt. =     300.00   Seg. Length =   9.00
--------------------------------------------------------------------
```

```
************************************************************
**      Factor of safety calculation for surface #   891     **
**      failed to converge within FIFTY iterations            **
**                                                            **
**    The last calculated value of the FOS was  24.6400      **
**    This will be ignored for final summary of results      **
************************************************************
```

```
Circular surface (FOS= 24.6400) is defined by: xcenter =    305.15
ycenter =     191.43   Init. Pt. =     300.00   Seg. Length =   9.00
--------------------------------------------------------------------
```

Factors of safety have been calculated by the :

* * * * *   SIMPLIFIED BISHOP METHOD   * * * * *

The most critical circular failure surface
is specified by 29 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	206.90	136.22
2	214.68	131.69
3	222.71	127.63
4	230.96	124.04
5	239.41	120.93
6	248.02	118.32
7	256.77	116.21
8	265.63	114.61
9	274.56	113.53
10	283.54	112.97
11	292.54	112.93
12	301.53	113.40
13	310.47	114.40
14	319.35	115.92
15	328.11	117.95
16	336.75	120.48
17	345.23	123.51
18	353.51	127.03
19	361.58	131.01
20	369.40	135.46
21	376.95	140.36
22	384.21	145.68
23	391.14	151.42
24	397.74	157.55
25	403.96	164.05
26	409.80	170.90
27	415.23	178.08
28	420.23	185.56
29	423.82	191.64

**** Simplified BISHOP FOS = 1.457 ****

```
**************************************************************************
**                                                                      **
**  Out of the    900 surfaces generated and analyzed by XSTABL,        **
**       10 surfaces were found to have MISLEADING FOS values.          **
**                                                                      **
**************************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : Seaford Ash Landfill - Closure

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	1.457	288.76	268.14	155.26	206.90	423.82	2.912E+07
2.	1.511	276.39	289.45	175.04	196.55	420.93	3.321E+07
3.	1.527	275.65	299.58	183.80	196.55	424.50	3.519E+07
4.	1.570	304.00	227.84	115.44	227.59	412.40	1.942E+07
5.	1.575	253.47	341.05	226.20	175.86	423.07	4.597E+07
6.	1.577	324.52	216.36	103.48	248.28	425.04	1.735E+07
7.	1.578	243.09	360.18	246.65	165.52	422.89	5.187E+07
8.	1.594	323.13	220.91	105.63	248.28	424.59	1.740E+07
9.	1.620	311.01	244.23	124.17	237.93	423.35	2.036E+07
10.	1.642	280.26	244.04	130.41	206.90	395.51	2.146E+07

* * * END OF FILE * * *

Closure Cap Erosion

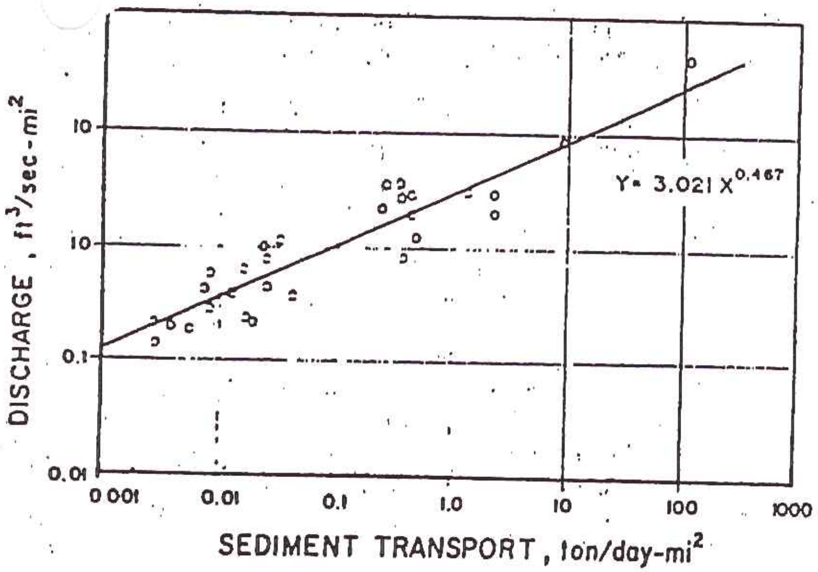

FIGURE 5.10. The relationship between suspended sediment transport and discharge for the Menomonee River in Wauwatosa, Wisconsin. (Compiled from the U.S. Geological Survey, Wisconsin Department of Natural Resources, and Southeastern Wisconsin Regional Planning Commission data. To convert from $ft^3/sec/mi^2$ to $m^3/s\text{-}km^2$, multiply by 0.011; to convert from U.S. ton-day mi^2 to SI tonnes/day-km^2, multiply by 0.35.)

3. The sediment delivery method, in which sediment yield to some downstream section or deposition point is based on an estimate of the total upstream (upland) erosion factored down to account for the loss (or gain) of sediment during overland and channel transport. This method requires expressing the ratio between the sediment yield and gross upstream erosion, usually based on an empirical or semi-empirical formula. Both determination of the delivery ratio (DR) and upland gross erosion estimates are still unreliable if calibration and verification survey data are not available.
4. Bedload function methods use mathematical equations developed for calculating the rate and quantity of sediment materials in the bed portion of alluvial (sediment carrying and depositing) streams. Application of these equations requires information on sediment particle size, channel gradient and cross sections, and flow-duration curves. The equation can be used when sediment transport is not limited by the upstream supply, but depends solely on the transport capacity of

the flow. These models are mostly applicable to noncohesive, larger grain size sediments.
5. Methods using empirical equations relating sediment yield (directly measured by methods 1 or 2) to watershed hydrologic and/or morphologic characteristics. Most of these empirical equation have severely limited applications, even in the region of origin (Foster, Meyer, and Onstad, 1977).
6. Simulation watershed sediment load models, which usually are attached to a watershed hydrologic model. The watershed models are capable of simulating individual storm events or seasonal water and sediment yields. The hydrologic portion is necessary for determining so-called hydrologically active areas, that is, areas from which most intensive surface runoff and erosion occur. Chapter 9 includes an expanded discussion of mathematical modeling.

Estimating Upland Erosion

Variables influencing upland (sheet) erosion are climate, soil properties, vegetation, topography, and human activities. Rainfall, snowfall, and temperature are the primary climatic factors. Soil particles are detached and transported by the impact of rainfall energy, resulting in eroded materials being carried by surface runoff. Freezing temperatures and snow cover affect permeability and reduce the energy of precipitation. Conversely, spring rains occurring when subsoils are still frozen may cause high sediment yields due to reduced soil permeability.

The major soil properties related to erosion are soil texture and composition. Soil texture determines the permeability and erodibility of soils. Permeability and infiltration determine whether or not the soil surface is hydrologically active (that is, yielding or not yielding surface runoff). Erosion occurs only when surface runoff is generated or when wind picks up loose particles.

The chemical composition of soils (minerals, clay, and organic matter) provide bonding of soil particles, and thus affects erosion rates. Loose soils (silt and fine sand) with low chemical and clay content have the highest erodibility.

Vegetation influences sediment yields by dissipating rainfall energy, binding the soil, and increasing porosity by its root system, reducing soil moisture by evapotranspiration, thereby increasing infiltration. Organic residues also provide better texture and reduce erodibility.

The topographic factors of greatest importance are slope and the path length traversed by sediment generating flow. Human activities are related mostly to agricultural land use and construction.

Since many of the just-mentioned factors are seasonal and vary throughout the year, it follows that sediment yield and its chemical composition from a watershed also vary with time. Walling and Kane (1983) demonstrated that certain mineralogical characteristics of liberated sediment, such as Si, Al, Fe, Ti, and K, remain relatively constant over a range of hydrological conditions, while others, particularly those associated with organic fractions, may exhibit considerable variations.

Universal Soil Loss Equation

The universal soil loss equation (USLE) is the most common and best known estimator of soil loss caused by upland erosion. The equation and its development utilized more than 40 years of experimental field observations gathered by the Agricultural Research Service of the USDA. The USLE, formulated by Wischmeier and Smith (1965), predicts primarily sheet and rill erosion. The equation is

$$A = (R)(K)(LS)(C)(P) \qquad (5.2)$$

where

A = calculated soil loss in tonnes/ha for a given storm or period
R = rainfall energy factor
K = soil erodibility factor
LS = slope-length factor
C = cropping management (vegetative cover) factor
P = erosion-control practice factor

The equation expresses soil loss/unit area due to erosion by rain. It does not include wind erosion and it does not give direct sediment yield estimates.

The ***rainfall energy factor*** (R_r) is equal to the sum of the rainfall erosion indices for all storms during the period of prediction. For a single storm it is defined as follows:

$$R_r = \Sigma[(2.29 + 1.15 \ln X_i)D_i]I' \qquad (5.3)$$

where

i = rainfall hyetograph time interval
D_i = rainfall during time interval i (cm)
I = maximum 30-min rainfall intensity of the storm (cm/hr)
X_i = rainfall intensity (cm/hr)

Average annual rainfall energy factors were determined for the eastern portions of the United States, and were later developed for the remainder

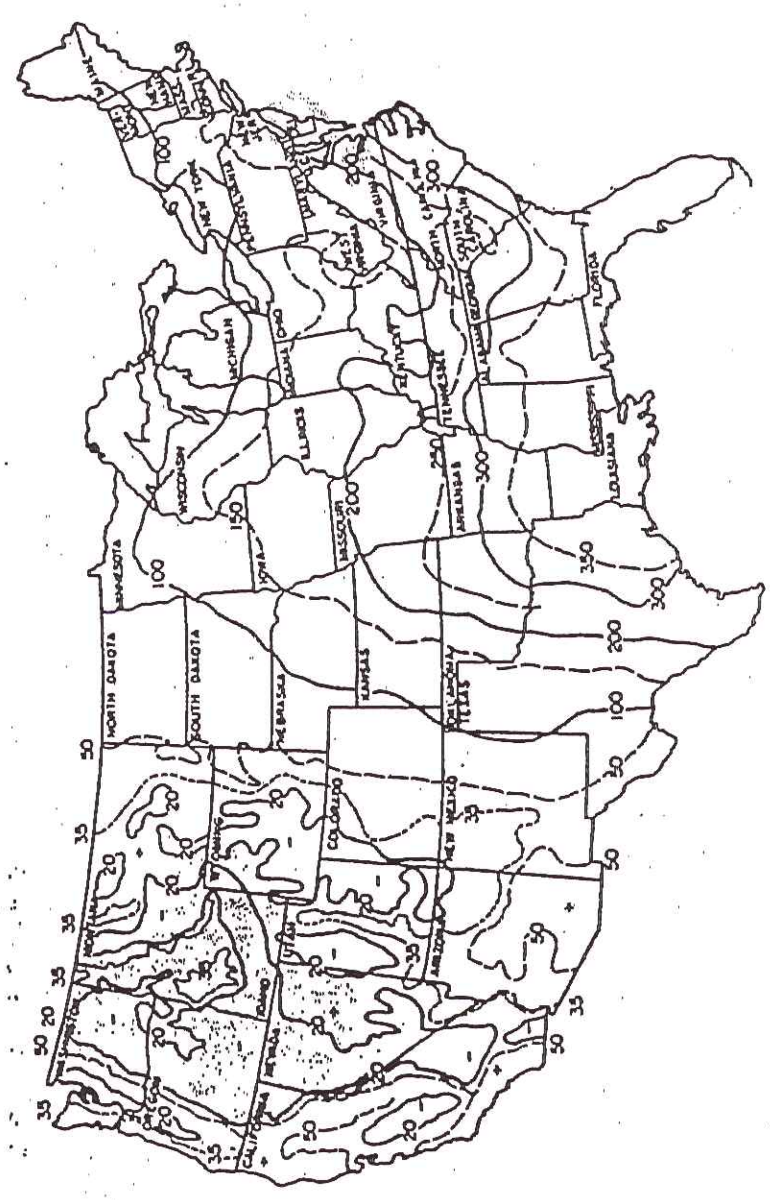

FIGURE 5.11 Values of the annual rainfall-energy factor (R) in tons/acre. To convert to tonnes/ha, multiply by 2.24. (From Stewart et al., 1975.)

1 tonne (metric) = 2,205 lb = 1.1025 tons 1 ton = 2,000 lb
1 ha = 10,000 m^2 = 2.47 acres 1 acre = 4,840 yd^2 = 43,560 ft^2 = 4047 m^2

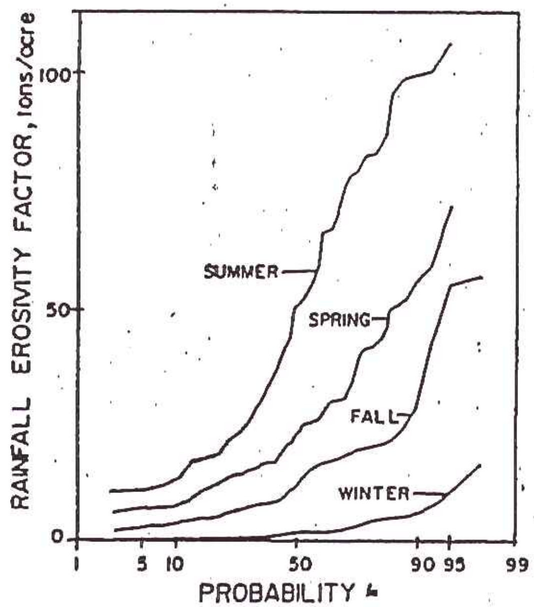

FIGURE 5.12. Seasonal cumulative frequency of the rainfall energy factor (R) for southeastern Wisconsin in tons/acre. To convert to tonnes/ha, multiply by 2.24.

of the country. The distribution of average R_r factors for the 48 conterminous states are shown in Figure 5.11. These curves can help as first estimates of the gross erosion potential, but as shown on Figure 5.12, significant yearly and seasonal differences in the magnitudes of the rainfall energy factor R_r may be typical. In the midwestern part of the United States, summer rains have the highest rainfall erosive energy; while the effect of winter precipitation on sediment yields is minimal.

The distribution of erosive rain differs significantly for different regions of the country. In the western plains and Great Lakes regions, from 40% to 50% of the erosive rainfall normally occurs during a 2-month period following spring planting when soils have the least protection. In most Corn Belt areas and the eastern parts of Kansas, Oklahoma, and Texas, the value is about 35%, while, for the lower Mississippi Valley and southeastern United States, the value is 20% to 23%. In the dry-land grain-growing region of the Pacific Northwest, about 80% to 90% of the annual erosion occurs in the winter months when the soil has little crop cover, since grain is seeded late in the fall (Steward et al., 1975).

Both erosion by rainfall energy (interrill erosion) and detachment of soil particles by overland runoff (rill erosion) contribute to soil loss (Foster, Lombardi, and Moldenhauer, 1982). Thus, the rainfall factor (R) should also include the effects of runoff. A modification of Equation (5.3) was proposed by Foster, Meyer, and Onstad (1977):

$$R = aR_r + bcQq^{1/3} \quad (5.4)$$

where

a and b = weighting parameters ($a + b = 1$)
c = an equality coefficient
Q = runoff volume (cm)
q = maximum runoff rate (cm/hr)

The weighting factor compares the relative amounts of erosion caused by rainfall and runoff under unit conditions. It was suggested that the detachment of particles by runoff and rain energy is about evenly divided ($a = b = 0.5$). The equality coefficient in metric (SI) units is about 15. Substituting values for a, b, and c into the USLE, the overall rainfall factor (R) becomes

$$R = 0.5R_r + 7.5Qq^{1/3} \quad (5.5)$$

However, the proportion between the rainfall and runoff erosivity may vary greatly between regions. Wischmeier (1976) pointed out that, for example, in the Palouse region of the Pacific Northwest, 90% of erosion is caused by runoff from thaw and snowmelt. A discussion of various functional forms of the rainfall erosivity factors—both rill and interrill effects—is included in Foster, Lombardi, and Moldenhauer (1982).

Williams and Berndt (1977) proposed a modified soil loss equation (MUSLE) that replaced the rainfall energy factor by a runoff energy parameter that is proportional to $(Q \times q)^{0.56}$. Equations (5.4), (5.5), and MUSLE of Williams and Bernt provide soil loss estimates in tonnes per storm (per area). Williams and Berndt pointed out that although q and Q are correlated, the runoff flow rate is more related to detachment, while the peak flow rate defines sediment transport. If flow is retarded by vegetation or other means, the peak flow rate is reduced, thus reducing sediment transport.

The soil erodibility factor (K) is a measure of potential erodibility of soil and has units of tonnes/unit of rainfall erosion index for a 22-m-long overland flow length on a 9% slope in clean-tilled continuous fallow

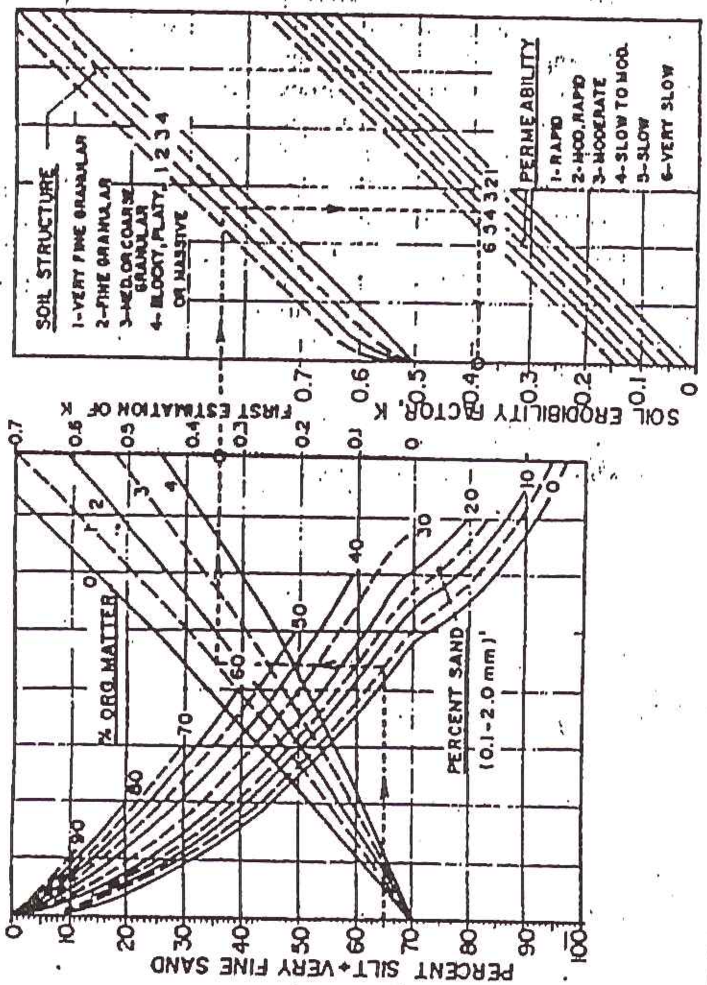

FIGURE 5.13. Soil erodibility nomograph for determining (*K*) factor for U.S. mainland soils. (Reprinted with permission from W. H. Wischmeier, C. B. Johnson, and B. V. Cross, *J. Soil Water Conserv.* 26:189–193. *Copyright © 1971 by the Journal of Soil and Water Conservation.*)

TABLE 5.3 Magnitude of Soil Erodibility Factor, K

	K for Organic Matter Content (%)		
Technical Class	0.5	2	4
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.16
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.35
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13–0.2	

Source: After Steward et al. (1975).

Note: The values shown are the estimated averages of broad ranges of specific soil values. When a texture is near the borderline of two texture classes, use the average of the two *K* values.

ground (Wischmeier and Smith, 1965; Wischmeier, 1976). It is a function of soil texture and composition. The soil erodibility nomograph shown on Figure 5.13 is used to find the appropriate values of the soil erodibility factor using five parameters: percent silt and fine sand, that is, 0.05 to 0.1 mm fractions; percent sand >0.1 mm; percent organic matter; textural class; and permeability. The general magnitudes of the soil erodibility factors are given in Table 5.3.

The slope-length factor (*LS*) is a function of overland runoff length and slope. It is a dimensionless parameter that adjusts the soil loss estimates for the effects of length and the steepness of the field slope. The general magnitudes of the LS factor are given in Figure 5.14. For slopes >4%, the LS factor can be estimated as follows:

$$LS = L^{1/2}(0.0138 + 0.00974S + 0.00138S^2) \quad (5.6)$$

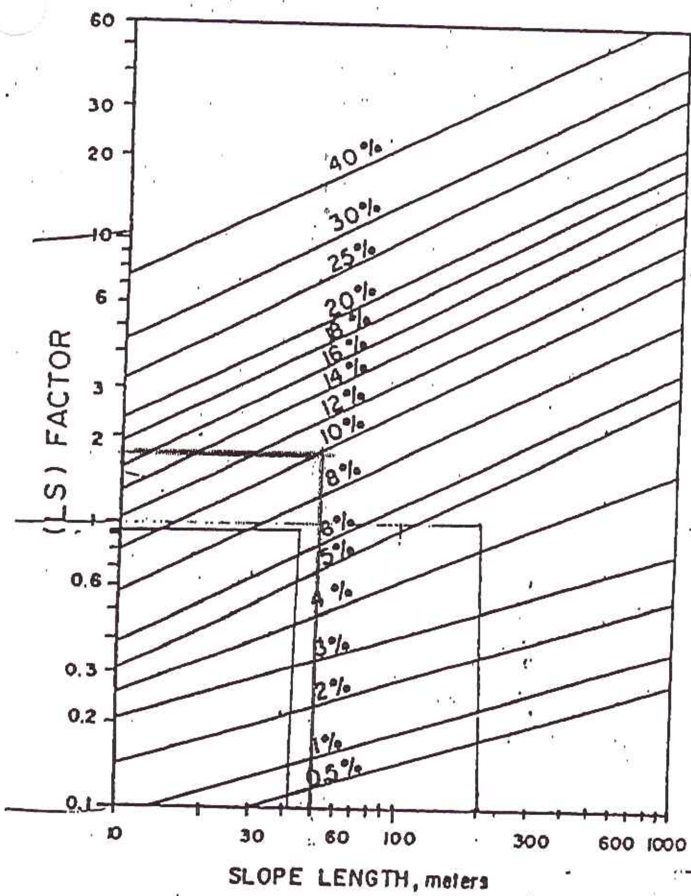

FIGURE 5.14. Slope-length factor (LS) for different slopes. (From Stewart et al., 1975.)

where

L = length in meters from the point of origin of the overland flow to the point where the slope decreases to the extent that deposition begins or to the point at which runoff enters a defined channel

S = the average slope (%) over the runoff length

Values of the LS factor estimated for length >100 meters or slopes >18% are extrapolated beyond the experimental data from which the magnitudes of the factor was determined.

If the average slope is used in calculating the LS factor, predicted

erosion differs from actual erosion when the slope is not unifo[illegible]ne equation for LS factors shows that when the actual slope is convex, the average slope will underestimate predicted erosion. Conversely, for a concave slope, the equation will overestimate actual erosion. To minimize these errors, large areas should be broken up into areas of fairly uniform slope. If sediment moves from an area with steep slope to an area of less steep slope, the smaller LS factor will control the amount eroded and the excess sediment is likely to be deposited.

The cropping management factor (C), also called the vegetation cover factor, estimates the effect of ground cover conditions, soil conditions, and general management practices on erosion rates. It is a dimensionless quantity with a value of one corresponding to continuous fallow ground, which has been defined as land that has been tilled up and down the slope and maintained free of vegetation and surface crusting. The effect of vegetation on erosion rates results from canopy protection, reduction of rainfall energy, and protection of soil by plant residues, roots, and mulches.

TABLE 5.4 Values of C for Cropland, Pasture, and Woodland

Land Cover or Land Use	C
Continuous fallow tilled up and down slope	1.0
Shortly after seeding prior to harvesting	0.3–0.8
For crops during main part of growing season	
Corn	0.1–0.3
Wheat	0.05–0.15
Cotton	0.4
Soybean	0.2–0.3
Meadow	0.01–0.02
For permanent pasture, idle land, unmanaged woodland	
Ground cover 85%–100%	
As grass	0.003
As weeds	0.01
Ground cover 80%	
As grass	0.01
As weeds	0.04
Ground cover 60%	
As grass	0.04
As weeds	0.09
For managed woodland	
Tree canopy of 75%–100%	0.001
40%–75%	0.002–0.004
20%–40%	0.003–0.01

Sources: Based on data from Stewart et al. (1975); Wischmeier and Smith (1965), and Wischmeier (1972).

TABLE 5.5 *C-Values and Slope-Length Limits (LS) for Construction Sites*

Mulch				
Type	Application (tonnes/ha)	Slope (%)	C	LS
No mulch or seeding		All	1.0	
Straw or hay tied down by anchoring and tracking equipment used on slope	2.25	<5	0.2	60
	2.25	6–10	0.2	30
	3.4	<5	0.12	90
	3.4	6–10	0.12	45
	4.5	<5	0.06	100
	4.5	6–10	0.06	60
	4.5	11–15	0.07	45
	4.5	16–20	0.11	30
	4.5	21–25	0.14	23
Crushed stone	300	<15	0.05	60
	300	16–20	0.05	45
	300	21–33	0.05	30
	540	<20	0.02	90
	540	21–35	0.02	60
Wood chips	15	<15	0.08	23
	15	16–20	0.08	15
	27	<15	0.05	45
	27	16–20	0.05	23
	56	<15	0.02	60
	56	16–20	0.02	45
	56	21–33	0.02	30
Asphalt emulsion 12 m^3/ha			0.03	
Temporary seeding with grain or fast-growing grass with		During first 6 weeks of growth		After the 6th week of growth
No mulch		0.70		0.10
Straw	2.25	0.20		0.07
Straw	3.4	0.12		0.05
Stone	300	0.05		0.05
Stone	540	0.02		0.02
Wood chips	15	0.08		0.05
Wood chips	27	0.05		0.02
Wood chips	56	0.02		0.02
Sod		0.01		0.01

Source: After Ports (1975).

Table 5.4 shows the general magnitudes of C for agricultural land, permanent pasture, and idle rural land. Grassed urban areas have C factors similar to those for permanent pasture. The C factor for construction sites can be reduced if the surface is protected by seeding or the application of hay, asphalt, wood chips, or other protective covers. The effects of these protective practices on C are given in Table 5.5.

The erosion control practice factor (P) accounts for the erosion-control effectiveness of such land treatment as contouring, compacting, established sedimentation basins, and other control structures. Terracing does not affect P because the soil loss reduction by terracing is reflected in the value of LS. Generally, C reflects protection of the soil surface against the impact of rain droplets and subsequent loss of soil particles. On the other hand, P involves treatments that retain liberated particles near the source and prevent further transport.

Values of P for various farm and urban practices are given in Tables 5.6 and 5.7, respectively. It should be pointed out that these coefficients are highly empirical and may be used only as a first approximation. More accurate models are available for several practices, included in the P factor, such as models for the removal efficiency of sedimentation ponds and buffer strips. These concepts are discussed in Chapters 9 and 10, respectively.

Reliability of the USLE. The universal soil loss equation was subjected to a lot of testing and criticizing; however, it withstood the test of time and today it is the only widespread and tested model. It has been used in many applications. The author of the equation (Wischmeier, 1976) reported the results of testing on the reliability of the equation. He pointed out that when the USLE is used for estimating the annual soil loss on many experimental testing plots, the average prediction error (coefficient of variation = deviation/mean estimate) was about 12%. Larger errors

TABLE 5.6 Values of P for Agricultural Lands

		Strip Cropping and Terracing	
Slope (percent) Crops	Contouring	Alternate Meadows	Closegrown
0–2.0	0.6	0.3	0.45
2.1–7.0	0.5	0.25	0.40
7.1–12.0	0.6	0.30	0.45
12.1–18.0	0.8	0.40	0.60
18.1–24.0	0.9	0.45	0.70
>24		–1.0–	

Source: After Wischmeier and Smith (1965).

TABLE 5.7 Values of P for Construction Sites

Erosion Control Practice	P
Surface Condition with No Cover	
Compact, smooth, scraped with bulldozer or scraper up and down hill	1.30
Same as above, except raked with bulldozer and root-raked up and down hill	1.20
Compact, smooth, scraped with bulldozer or scraper across the slope	1.20
Same as above, except raked with bulldozer and root raked across the slope	0.90
Loose as a disked plow layer	1.00
Rough irregular surface, equipment tracks in all directions	0.90
Loose with rough surface >0.3-m depth	0.80
Loose with smooth surface <0.3-m depth	0.90
Structures	
Small sediment basins	
0.09 ha basin/ha	0.50
0.13 ha basin/ha	0.30
Downstream sediment basin	
With chemical flocculants	0.10
Without chemical flocculants	0.20
Erosion-control structures	
Normal rate usage	0.50
High rate usage	0.40
Strip building	0.75

Source: After Ports (1973).

should be expected if the equation is used for predicting the soil loss of individual storms.

The accuracy of the model is increased if it is combined with a hydrological excess-rainfall model. Note that the rainfall erosivity factor, R, has a value greater than zero for every rainfall, hence, erosion and soil loss are anticipated by the soil loss equation for any precipitation. A hydrological excess-rainfall model in combination with the USLE would eliminate erosion by rainfalls with no excess rain.

The USLE was tested and specifically designed for the following applications (Wischmeier, 1976):

1. Predicting average annual soil movement from a given field slope under specified land-use and management conditions and from construction, rangeland, woodland, and recreational areas.
2. Guiding the selection of conservation practices for specific sites.
3. Estimating the reduction of soil loss attainable from various changes that a farmer might make in his cropping system or cultural practices.

4. Determining how much more intensively a given field could be safely cropped if contoured, terraced, or stripcropped.
5. Determining the maximum slope-length on which given cropping and management can be tolerated in a field.
6. Providing local soil loss data to agricultural technicians, conservation agencies, and others to use when discussing erosion-control plans with farmers and contractors.

The USLE will not provide direct estimates of the sediment yield and cannot be used for calculations of soil losses from spring snowmelt.

Example 5.1: Estimation of Annual Soil Loss

An erosive 100-ha farm field in southeast Wisconsin is situated on silt loam soil with a slope classification B (3% to 6% slope). The farmer is growing corn and plowing up and down the slope. Estimate the average annual soil loss per hectare without soil conservation and with contour plowing. The field has a square shape with a drainage ditch located on the side of the field. The overland slope is toward the drainage ditch.

Solution From Figure 5.10 the average annual rainfall erosivity for southeast Wisconsin is R_r = 125 U.S. tons/acre × 2.24 = 280 tonnes/ha. From Table 5.3 the average soil erodibility factor for silt loam soil is K = 0.42. The slope-length factor (LS) can be read from Figure 5.14 (overland flow length L = 1000 m, and average slope S = 45%) as LS = 1.

The plowing practice is to till up and down the slope of the continuous fallow field. Consequently the slope has a C factor of C = 1 after plowing and 0.1 to 0.3 for corn during the main growing season (Table 5.4), respectively. Average C for no soil conservation planting is assumed to be $C = (1 + 0.3)/2 = 0.65$. Since no erosion control is implemented, then P = 1. The average annual soil loss without soil conservation is then

$$A = (R)(K)(LS)(C)(P) = 280 \times 0.42 \times 1 \times 0.65 \times 1$$
$$= 76.4 \text{ tonnes/ha}$$

Implementing contour plowing will reduce the P factor to 0.5 (Table 5.7). Hence the soil loss will then be

$$A = 280 \times 0.42 \times 1 \times 0.65 \times 0.5 = 38.2 \text{ tonnes/ha}$$

Example 5.2: Soil Loss from a Construction Area for a Design Storm

A 50-ha land area is to be developed into a single family residential area. The soil map indicates that the soil is loam with the following composition:

Clay 20%
Silt 35%
Fine sand 20%
(Silt + fine sand) 55%
Coarse sand and gravel 25%

The organic content of the soil is 1.5%.

The lot has a square shape with a drainage ditch in the center. It has been proposed to replace the ditch with a storm sewer. The average slope of the lot toward the ditch is 2.4%.

Determine soil loss (potential erosion) for a storm for which the hyetograph is given in Figure 5.15. Soil loss should be determined from the pervious areas for the two periods, namely, during construction when all vegetation is stripped from the soil surface (100% pervious) and subsequent to construction when 25% of the area is impermeable (streets, roofs, driveways, etc.).

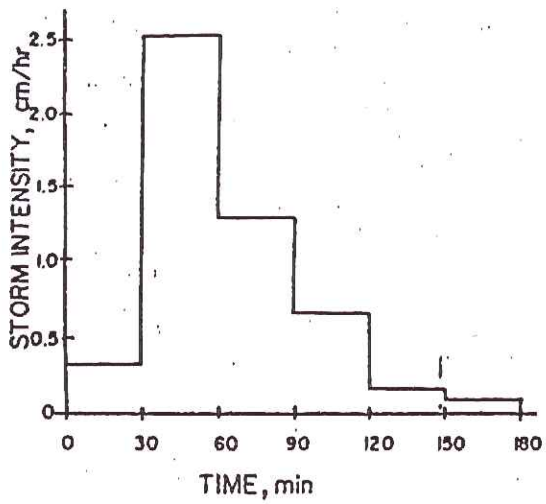

FIGURE 5.15. Storm hyetograph for Example 5.2.

Solution The rainfall energy factor R_r is determined from the hyetograph shown on Figure 5.15. From this information it can be determined that the maximum 30-min rainfall intensity is 2.5 cm/hr.

Utilizing Equation (5.4)

$$\begin{aligned} R_r = {} & [(2.29 + 1.15 \ln 0.3)0.15 \\ & + (2.29 + 1.15 \ln 2.5)1.25 \\ & + (2.29 + 1.15 \ln 1.25)0.6175 \\ & + (2.29 + 1.15 \ln 0.7)0.35 \\ & + (2.29 + 1.15 \ln 0.2)0.1 \\ & + (2.29 + 1.15 \ln 0.1)0.05]2.5 = 16.4 \end{aligned}$$

The soil erodibility factor is determined from Figure 5.13, assuming that the soil texture is fine grained and the permeability is moderate, giving a K value of 0.33.

To determine the LS factor for a 50-ha area with a ditch or storm sewer in the middle, the length of the overland flow $L = 0.5\sqrt{50 \times 100 \times 100} = 353.5$ m. With the use of Figure 5.14 or Equation (5.6), the LS factor for $L = 353$ and $S = 2.4\%$ becomes

$$LS = (353.5)^{1/2}[0.138 + (0.00974 \times 2.4) + (0.00138 \times 2.4^2)] = 0.47$$

Factors R_r, K, and LS are the same for both alternatives. The remaining factors, C and P must be evaluated for each alternative (P only if erosion-control practices are implemented during construction). For the period during construction (alternative 1), C is estimated assuming no vegetative protective cover and bulldozed soil. In this case, C is approximately the same as for bare fallow ground, that is, $C = 1$. In the absence of erosion-control practices, $P = 1$. Thus soil loss for this storm is

$$A = 16.4 \times 0.33 \times 0.47 \times 1 \times 1 = 2.54 \text{ tonnes/ha}$$

Thus, for 50 ha, total soil loss from the storm is

$$50 \times 2.54 = 127.3 \text{ tonnes.}$$

For the period after construction (alternative 2) and assuming that the pervious areas are covered by lawns, C is reduced to 0.01 and the soil loss/ha is

$$A = 16.4 \times 0.33 \times 0.47 \times 0.01 \times 1 = 0.025 \text{ tonnes/ha.}$$