PRELIMINARY DESIGN
CALCULATION PACKAGE
ON-SITE DISPOSAL FACILITY

REVISION B
VOLUME 2 OF 3
DECEMBER 1995

United States Department of Energy
Fernald Environmental Management Project
Fernald, Ohio

prepared by

GEOSYNTEC CONSULTANTS
1100 Lake Hearn Drive, NE, Suite 200
Atlanta, Georgia 30342

under

Fernald Environmental Restoration Management Corporation
Subcontract 95PS005028

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PRELIMINARY DESIGN CALCULATION PACKAGE ON-SITE DISPOSAL FACILITY

Volume II

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6. LEACHATE GENERATION RATE

6.1 Leachate Generation Rates

6.1 Leachate Generation Rates

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: LEACHATE GENERATION RATES

Computations By: (Cognizant Engineer)
Signature [signature] | Majdy Ahmed Othman | 4 Oct 1995 Date
Printed Name BIN LI | MAJDI A. OTHMAN
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Signature Majdy Ahmed Othman | 5 Oct 95 Date
Printed Name MAJDI A. OTHMAN
and Title PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature Rudolph Bonaparte | 5 Oct 95 Date
Printed Name Rudolph Bonaparte
and Title Principal

Record of Revision (Number and initial all revisions)

NO.	REASON	DATE	BY	CHECKED	APPROVAL	
0	30% Submittal	NA	NA	NA	NA	No Changes
B	Preliminary Design (EPA Submittal)	15 Dec 95	[illegible]			

Signature: _____
Number: _____
Registration Stamp (if applicable)

LEACHATE GENERATION RATES

EXECUTIVE SUMMARY

Purpose of Analysis

The purpose of this analysis is to estimate leachate generation rates for different stages of the life of the Fernald On-Site Disposal Facility (OSDF). These rates will be used to evaluate the performance of the leachate collection system (LCS), leakage detection system (LDS), and leachate transfer system (LTS).

Methods of Analysis

US Environmental Protection Agency (USEPA) Hydrologic Evaluation of Landfill Performance (HELP) Model Version 3.

Conclusions

Worst-case scenario leachate generation rates are:

For One Cell

- Peak daily = 1,751 gpad
- Peak monthly = 1,486 gpad
- Average Annual (AA) for initial stage of operation (i.e., 10 ft of waste) = 1,143 gpad
- AA for intermediate stage (30′ waste and intermediate cover) = 694 gpad
- AA for post-closure = 0.0019 gpad

For Entire OSDF

- Total leachate rate (1 cell in initial stage, 1 cell in intermediate stage, and 7 cells closed). = 11,941 gpd

LEACHATE GENERATION ANALYSES PROCEDURES

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INTRODUCTION

The purpose of this document is to summarize procedures which will be used to perform analyses to estimate the leachate generation rates for the FERNALD On-Site Disposal Facility (OSDF). This document also provides general description of the OSDF systems and operations which are relevant to these analyses.

GENERAL DESCRIPTION OF RELEVANT OSDF SYSTEMS AND OPERATIONS

General Layout of the OSDF

The OSDF will be 3600 ft long and 702 ft wide, based on the limits of waste. The final-closure cover system of the OSDF will extend beyond the limits of waste, and therefore, will have greater dimensions. The OSDF will be oriented such that the long side of the OSDF is in the north-south direction and will consist of 9 cells numbered 1 through 9 sequentially, from north to south (see Figure 1). Each cell will be 400 ft wide and 6.5 acres in size. The cell bottom will be graded to slope at a minimum of 2 percent from the north and south sides of the cell towards the center of the cell and to slope at a minimum of 1 percent from east to west as shown in Figure 1.

Double-Liner System

The OSDF double-liner system configuration is shown in Figure 2.

Final-Closure Cover System

Figure 3 shows the OSDF final-closure cover system configuration.

Leachate Collection System

The leachate collection system (LCS) is illustrated in Figures 2 and 4. Liquids which accumulate in the drainage layer of the LCS flow towards a 6-in. diameter perforated HDPE pipe located in the middle of the cell, referred to hereafter as the LCS pipe. This pipe is placed in a gravel trench and extends in the long direction of the cell. The pipe becomes solid at its down-slope end (i.e., the western end) just prior to intruding the double-liner system and the perimeter berm to outside the cell. A 6-in. diameter backup pipe will also be used which extends from a short distance inside the cell to outside the cell. The main and backup leachate pipes terminate into an individual sump (i.e., manhole) located outside the cell. A header pipe extends between all of the leachate sumps and flows towards a central sump located south of Cell 9. A forcemain will transfer flow from the central sump to the Advanced Waste Water Treatment (AWWT) facility located on the FERNALD site.

Excavation Grading Plan

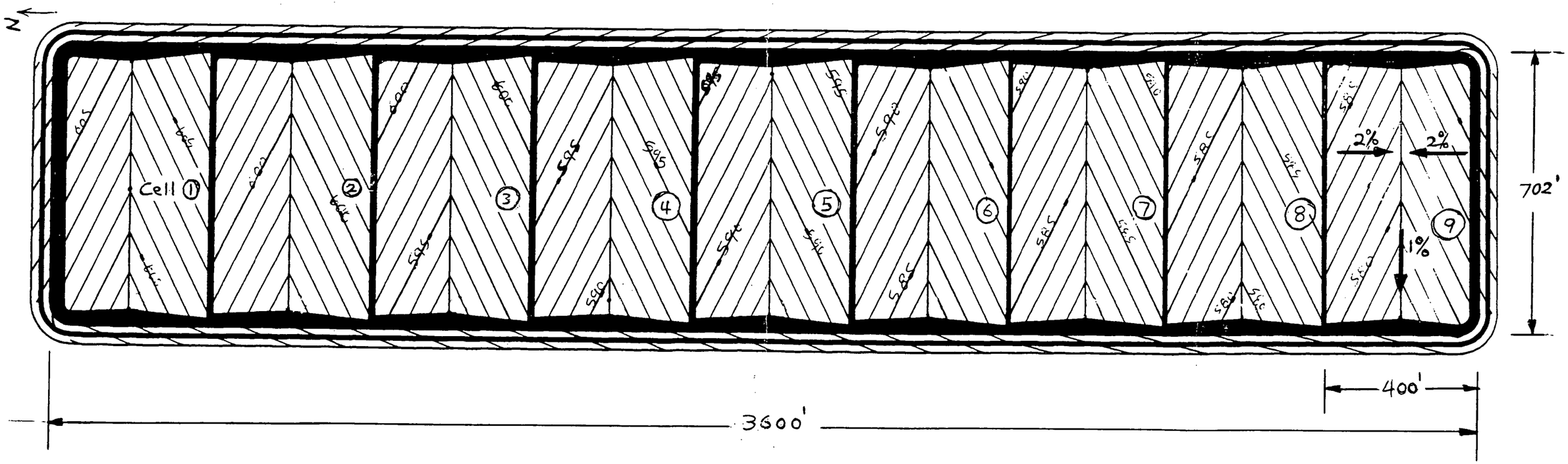

Figure 1. Configuration of the OSDF.

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Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 08.5

RB 30 Sept 95

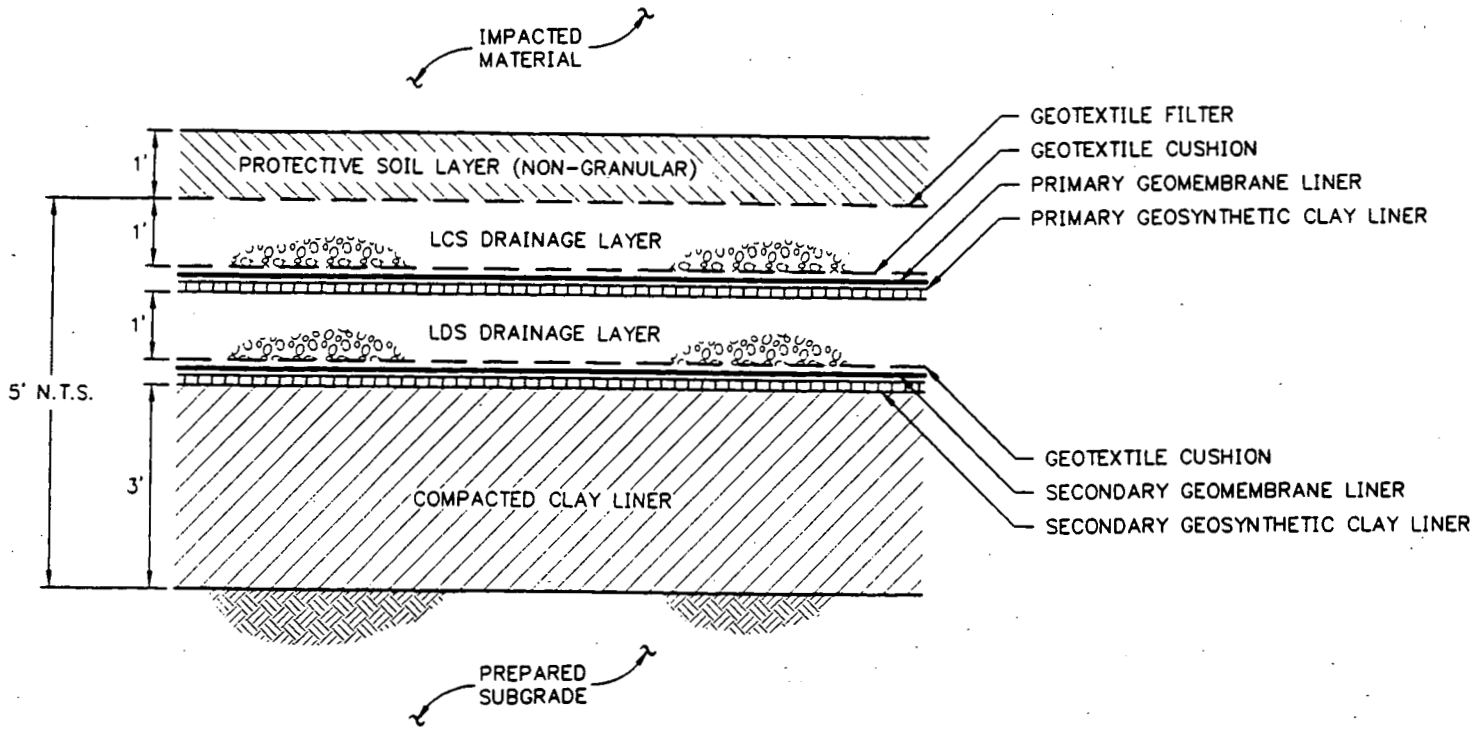

Figure 2 Double-Liner System

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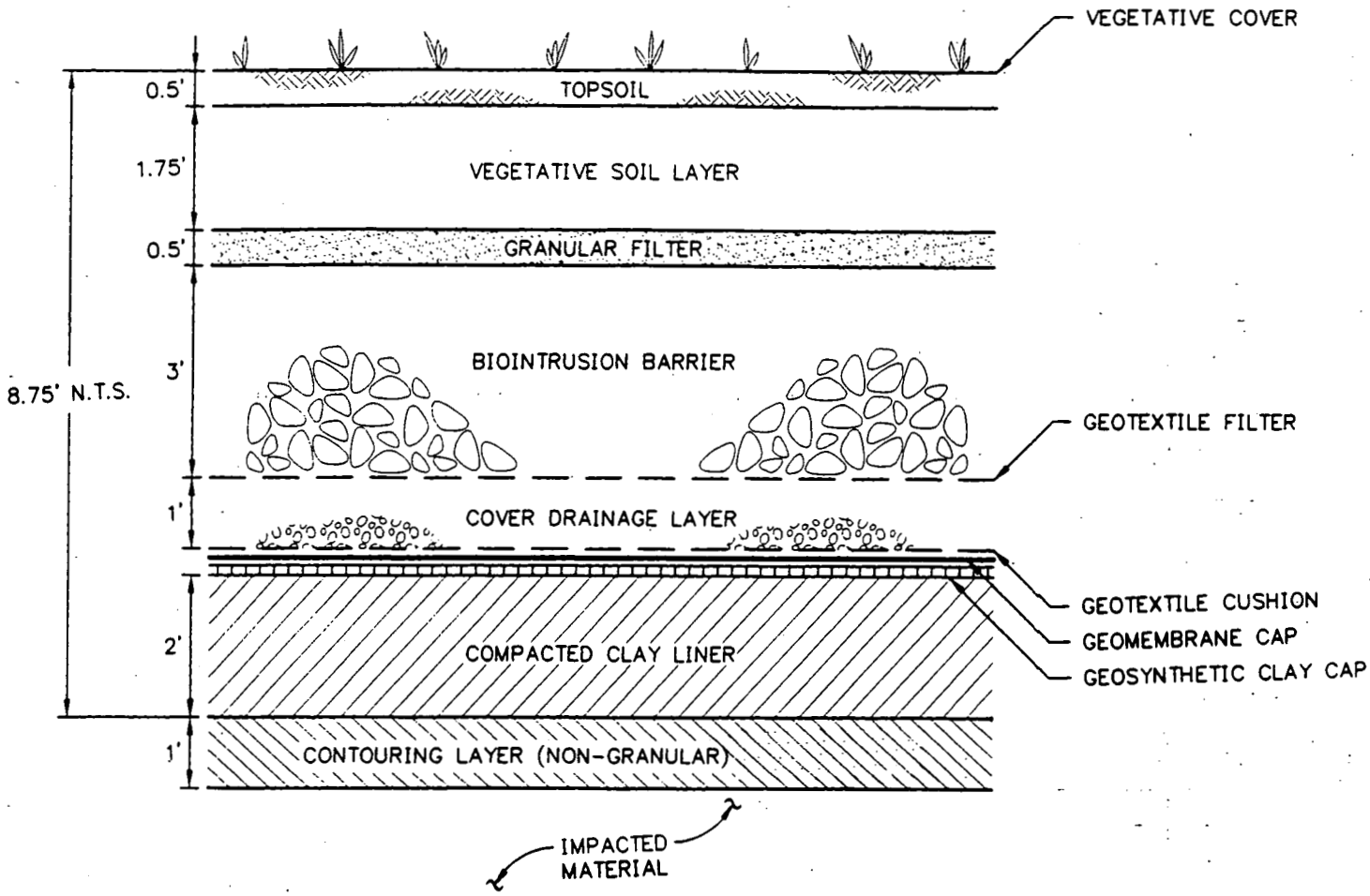

Figure 3. Final-Closure Cover System

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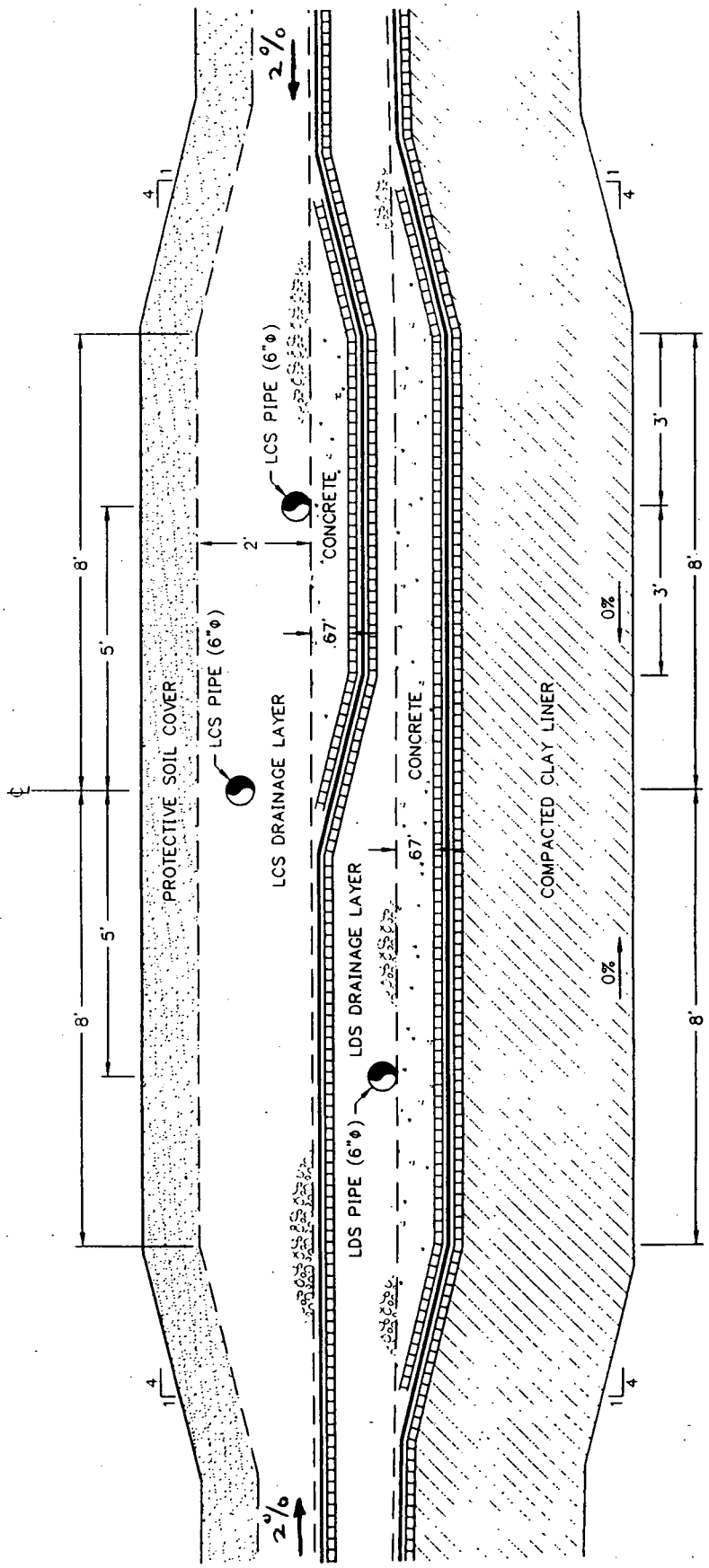

Figure 4. Leachate Collection System

Leakage Detection System

The leakage detection system (LDS) is similar to the LCS except that: (i) only one pipe is used to transfer collected liquids to an individual sump (i.e., manhole) located outside the cell; and (ii) the LDS sumps are not connected to each other or to the LCS sumps.

Waste Composition and Placement Procedures

Three waste materials make up most of the waste to be disposed of in the OSDF. These materials are: (i) contaminated soil (approximately 75 to 80 percent), (ii) rubble and debris (approximately 10 percent), and (iii) ash (approximately 10 to 15 percent). Other wastes which are relatively small in volume include sludge, municipal solid waste, and others. A waste handling and disposal plan is currently under development. However, a few observations can be made at this time. It is anticipated that contaminated soil will dominate most of the OSDF cells. Rubble will most likely be placed with contaminated soil in a layered configuration with the contaminated soil being the dominant material. However, it is likely that one or more cells may be dominated by ash. This is concluded based on the anticipated composition of the OSDF waste stream. Over 300,000 yd^3 of ash is expected to be disposed ~~off~~ of in the OSDF within a period of 1 to 2 years. During this time, not more than one or two cells will most likely be operational, and therefore, these cells may receive most of this ash.

Daily and Intermediate Cover

To control fugitive emissions, daily or weekly cover may be used which consists of ~~traps~~ tarps or geotextiles or a watering system may be utilized. Areas that will not receive waste for an extended period of time, due to winter weather for example, may be covered with a layer of soil 12 in. thick, referred to hereafter as intermediate cover.

Interim-Closure Cover System

Extended shutdowns (i.e., several months to years) of the OSDF may necessitate partial closure. All slopes will be graded to promote drainage and will be capped with an interim-closure cover system which consists of vegetative, drainage, and barrier layers.

LEACHATE GENERATION ANALYSIS

Leachate generation rates will be estimated for different stages of the OSDF life. These rates will be used to evaluate the performance of the LCS and the LDS. The leachate generation rates will also be used to analyze the leachate transmission system (LTS) sumps, pumps, and pipes. The remainder of this section describes the methods which will be used to estimate the leachate generation rates. The LCS, LDS, and LTS analyses are not described in this document.

The U.S. Environmental Protection Agency (USEPA) HELP Model Version 3.03 [Schroeder, et al., 1994a,b] will be used to estimate leachate generation rates for the OSDF. Using HELP, average and maximum daily, monthly, and annual leachate generation rates (as applicable) will be estimated for three cases representing different cell development periods which are:

- Case 1: Initial Period of Operation (10 ft of waste and daily cover);
- Case 2: Intermediate Period of Operation (30 ft of waste and intermediate cover); and
- Case 3: Post-Closure Period (full height of waste and final-closure cover system).

The estimated leachate generation rates and other information obtained from the HELP model results will be directly used to evaluate all hydraulic systems located inside the cell (e.g., LCS drainage layer, LCS pipe) and the hydraulic systems located outside the cell which service only one cell (e.g., LCS sump). The time unit to be used for a specific analysis dictates which leachate generation rate to use (i.e., average vs. maximum, daily vs. monthly).

To evaluate hydraulic systems which service more than one cell, total leachate generation rates will be calculated based on combinations of the three cell development cases described above to represent different stages of the life of the OSDF. For example, to size the LCS header pipe which services the entire OSDF, worst case scenario is used (i.e., maximum flow rate during the entire life of the OSDF). As an illustration, assume the leachate generation rate for Case 1 is L_1 gpad, for Case 2 is L_2 gpad, and for Case 3 is L_3 gpad. Also assume that during one of the OSDF life stages, 1 cell is in the initial period of operation, 2 cells are in the intermediate period of operation, 4 cells are capped with the final-closure cover system, and all other cells are not built yet. For this stage of the OSDF life, the total leachate generation rate is calculated as follows:

$$L_{total}\ (\text{gpad}) = (1 \times L_1 + 2 \times L_2 + 4 \times L_3) / 7$$

This computation will be performed for all possible scenarios and the most critical scenario will control the design of the LCS pipe.

REFERENCES

Schroeder, P.R., Lloyd, C.M., and Zappi, P.A. (1994a). "*The Hydrologic Evaluation of Landfill Performance (HELP) Model, User's Guide for Version 3.*" U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Report No. EPA/600/R-94/168a, Sep.

Schroeder, P.R., Dozier, T.S., Zappi, P.A., McEnroe, B.M., Sjostrom, J.W., and Peyton, R.L. (1994b). "*The Hydrologic Evaluation of Landfill Performance (HELP) Model Engineering Documentation for Version 3.*" U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Report No. EPA/600/R-94/168b, Sep, 116 p.

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Client: FERMCC Project: FERNALD OSDF Project/Proposal No.: FE3900 Task No.: 08.5

RB 30 Sept 95

HELP MODEL INPUT PARAMETERS

FERNALD OSDF

OBJECTIVE

To select values for the input parameters of HELP to model the Fernald OSDF. Values are selected for Case 1 – initial period of operation, Case 2 – intermediate period of operation, and Case 3 – post-closure period which are defined in procedures package.

WEATHER DATA REQUIREMENTS

The weather data required in the HELP model are classified into four groups: evapotranspiration, precipitation, temperature, and solar radiation data.

1. Evapotranspiration Data

The data needed are: location, evaporative zone depth, maximum leaf area index, dates starting and ending the growing season, normal average annual wind speed, and normal average quarterly relative humidity

- Location

The closest city given in the HELP model is Cincinnati, OHIO. The city of Cincinnati, OHIO is selected for the HELP model and the following data will be selected based on this city.

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- Evaporative Zone Depth

Based on the city of Cincinnati and a thick layer of loamy soil with a grassy form of vegetation, HELP gives the following values for evaporative zone depth:

Vegetative Cover Type		
Bare	Fair	Excellent
9"	21"	38"

Clayey soils would generally have larger evaporative zone depths and sandy soils would have smaller evaporative zone depths. So,

for case 1: mostly CL soils, bare, assume 12"

for case 2: Mostly CL soils, bare, assume 12"

for case 3: Mostly top soil, good, assume 30"

- Maximum Leaf Area Index (LAI)

Based on the guidance from HELP,

for case 1: Bare ground, LAI = 0.0

for case 2: Bare ground, LAI = 0.0

for case 3: Assume good grass, LAI = 3.5

- Dates starting and ending the growing season

Based on the guidance from HELP, for all three cases, growing season starting day is 104, ending day is 295.

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- Normal average annual wind speed

  Based on the guidance from HELP, for all three cases, average wind speed = 9.1 MPH

- Normal average quarterly relative humidity

  Based on the guidance from HELP, for all three cases,

  First quarter relative humidity = 70.0%
  Second quarter relative humidity = 67.0%
  Third quarter relative humidity = 73.0%
  Fourth quarter relative humidity = 72.0%

II. Precipitation Data

HELP has eight options for precipitation data. Option 1 is to use default precipitation option. Option 2 is to use synthetic precipitation option. Option 3 is to use create/edit precipitation option. The other five options are listed in manual.

Option 2 is chosen for this package. The data needed for this option are: location, number of years of data to be generated, and normal mean monthly precipitation.

- Location:

  The closest city given in HELP is Covington, Kentucky.

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So, the location of Covington, Kentucky will be used to generate the synthetic precipitation data for all the three cases.

- Number of years of data to be generated

  Use 100 years as HELP allow maximum of 100 years.

  for Case 1 modify the generated data with 25 year 24 hrs storm = 4.7"

  for Case 2 modify the generated data with 25 years 24 hrs storm = 4.7"

  for Case 3 modify the generated data with 2000 years 24 hrs storm = 13.0"

  (See Fig. 1)

- Normal mean monthly precipitation

  Use values based on HELP default

		HELP Default (in)
1	January	3.13
2	February	2.73
3	March	3.95
4	April	3.58
5	May	3.84
6	June	4.09
7	July	4.28
8	August	2.97
9	September	2.91
10	October	2.54
11	November	3.12
12	December	3.00

Source: Fig. 3 of 2000-Yr floodplain determination Parson's report _Aug 95

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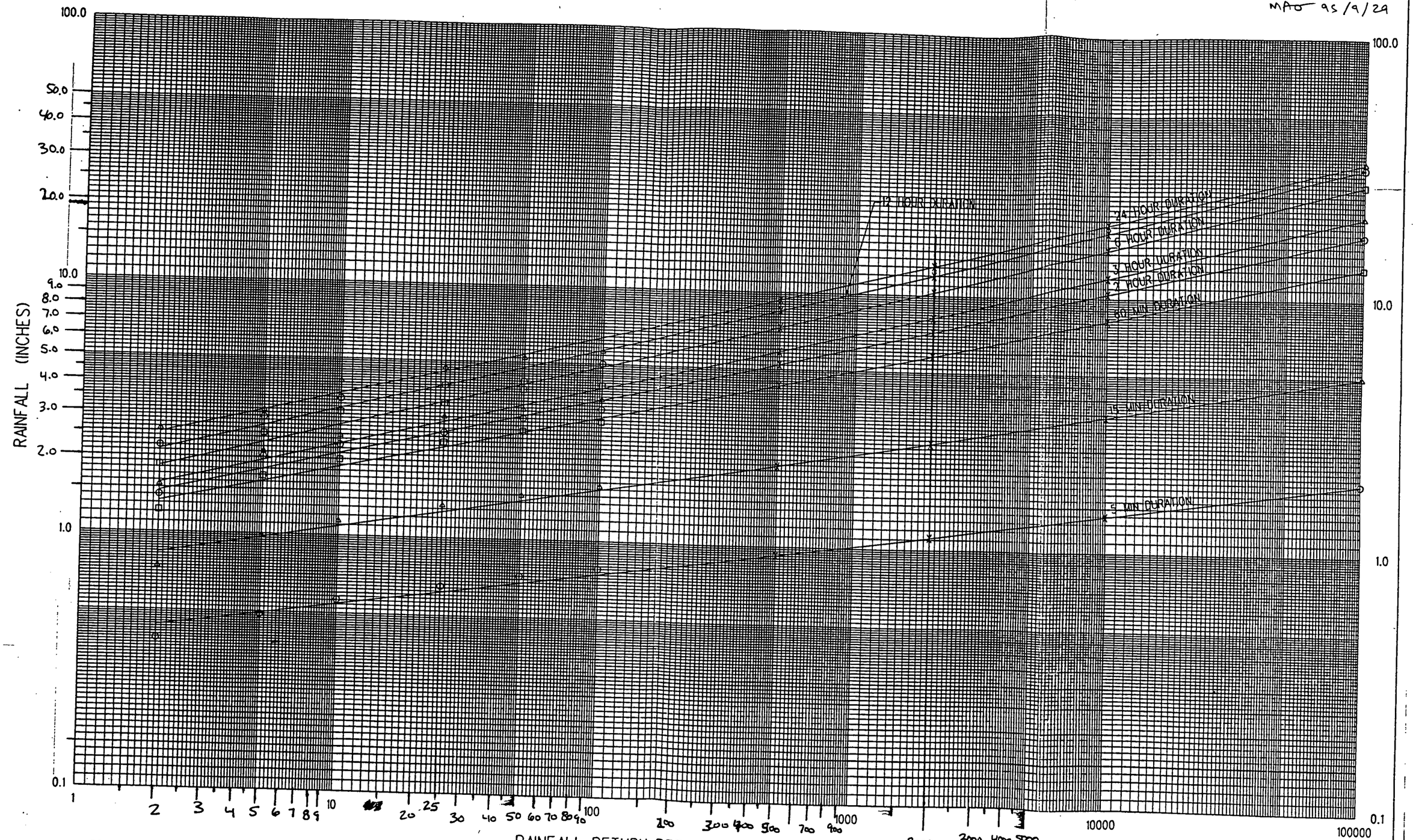

ESTABLISHED RAINFALL DATA POINTS: ⊙ △ ⊡ (SEE TABLE 1)

INTERPOLATED RAINFALL DATA POINTS: X (SEE TABLE 1)

FIGURE 1 000958

RAINFALL - DURATION CHART

Written by: RL Date: 95/9/29 Reviewed by: MAD Date: 95/9/29

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III Temperature Data

HELP has seven options for temperature data. Option 1 is to use synthetic temperature option. Option 2 is to use create / edit temperature option. The other five options are listed in HELP manual.

Option 1 is chosen for this package. The data needed for this option are: location, number of years of data to be generated, years of daily precipitation values, and normal mean monthly temperature.

- Location:

  The closest city given in HELP is Cincinnati, OHio so, the location of Cincinnati, OHio will be used to generate the synthetic temperature data for all the three cases.

- Number of years of data to be generated

  As HELP only allow a maximum of 100 years,

  Case 1 use 100 years

  Case 2 use 100 years

  Case 3 use 100 years

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- Normal mean monthly temperature RB 30 Sept 95

Use HELP default values for Cincinnati, OHIO:

		HELP Default (°F)
1	January	28.9
2	February	32.1
3	March	41.8
4	April	53.5
5	May	63.0
6	June	71.4
7	July	75.4
8	August	74.1
9	September	67.5
10	October	55.3
11	November	43.4
12	December	33.8

IV. Solar Radiation Data

HELP also has seven options. The option chosen for this package is option 1, which is the synthetic solar radiation option. The data needed for this option are: location, number of years of data to be generated, years of daily precipitation values, and latitude.

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- Location

The closest city given in HELP is Cincinnati, OHIO. So, the location of Cincinnati will be used to generate the synthetic temperature data for all the three cases.

- Number of years of data to be generated

As HELP only allow a maximum of 100 years,

Case 1 use 100 years

Case 2 use 100 years

Case 3 use 100 years

- Latitude

Use 39.29° for all the three cases. [USGS, 1981]
(city of Cincinnati is at 39.10°)

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SOIL AND DESIGN DATA REQUIREMENTS

Soil data will be chosen based on the information from GeoSyntec's design and Parsons' Geotechnical investigation results. The data needed are: Landfill general information and layer data.

I Landfill General information

- Project title

  Fernald On-site Disposal Facility

- Landfill area

  Area will be assumed equal to 1 acre (43,560 ft^2) for the purpose of forming a unit quantity.

  So Case1 = Case2 = Case3 = 1 acre.

- Percentage of landfill area where runoff is possible

  Case1 use 0% of landfill area

  Case2 use 0% of landfill area

  Case3 use 100% of landfill area

- Method of Initialization of Moisture storage

  Input manually if information is available on placement moisture content of the layer, otherwise, initial moisture content is initialized by HELP.

- Initial snow water storage

  Use values initialized by HELP

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II Layer Data

Layers to be used in all three cases are shown in attached Figure 1 (excluding daily and intermediate cover). The layer data is summarized in attached Table 1.

Data was selected based on information available from the OSDF project files, information available in the Literature, guidance provided by the HELP model, and GeoSyntec's experience. HELP provides default parameter values based on the soil classification according to the Unified Soil Classification System (USCS) or the United States Department of agriculture (USDA) textural classification system.

The layers (from top to bottom) and their properties are described on the following pages. Most of the values are based on HELP Manual (See Table 2 from HELP manual, which is attached)

1 Final Cover Top soil layer

1 Layer type: vertical percolation

2 Layer thickness: 6"

3 Soil texture:

Due to the lack of top soil from on-site sources, topsoil will most likely be imported from off site. It is anticipated that topsoil will be the typical topsoil that promotes plant growth and minimize erosion.

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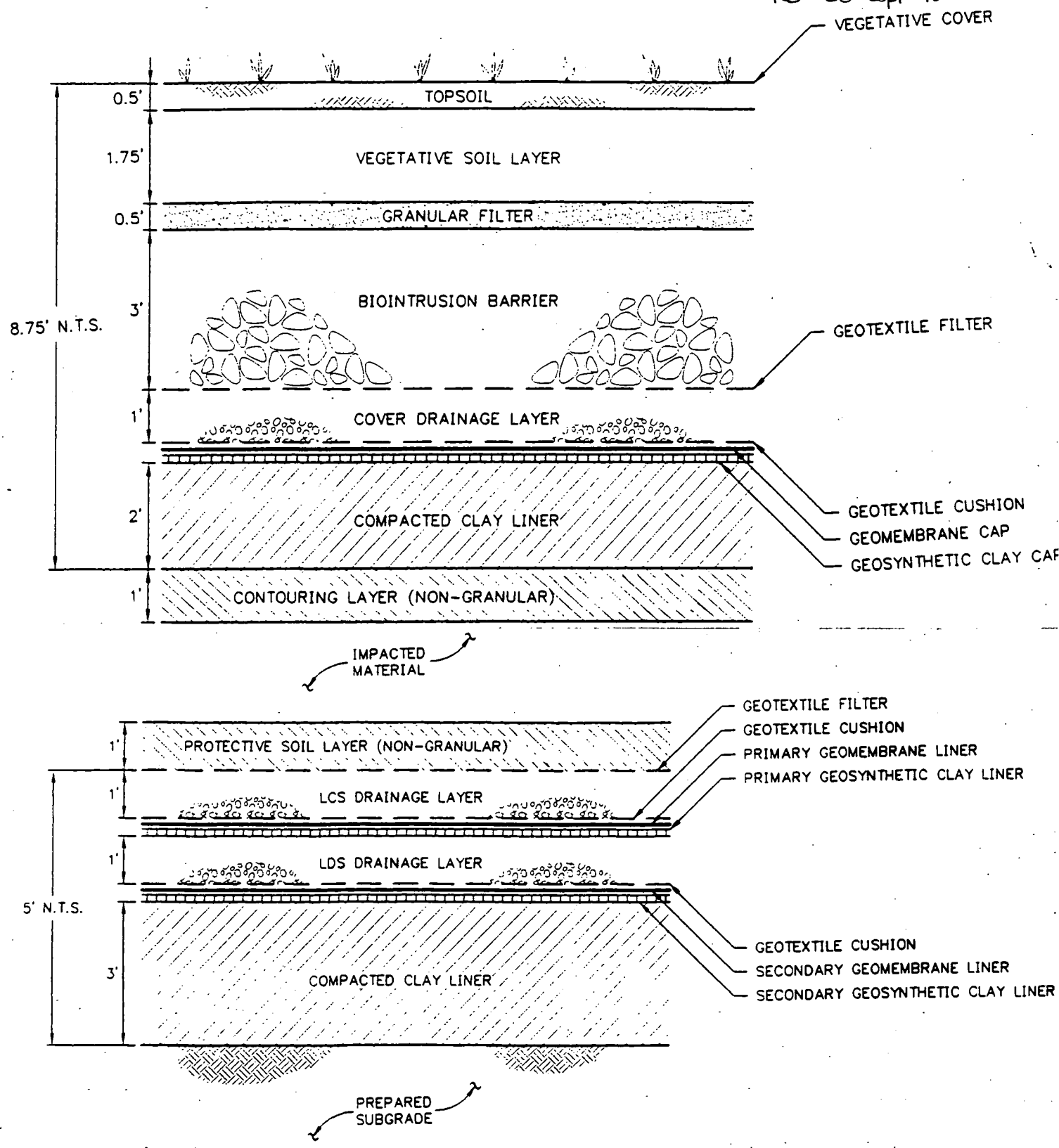

Figure 2: Typical Cross-Section of OSDF

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TABLE 1 - SUMMARY OF SOIL LAYER DATA FOR HELP MODEL OF FERNALD ON-SITE DISPOSAL FACILITY

Layer #	Layer Name	Layer Material	HELP Texture Number	Layer Type	Layer Thickness (in.)	Soil Texture: Porosity	Soil Texture: Field Capacity	Soil Texture: Wilting Point	Soil Texture: Saturated Hydraulic Conductivity (cm/sec)	Initial Volumetric Moisture Content	Rate of Subsurface Inflow To Layer	Lateral Drainage Layer Data: Maximum Drainage Length (ft)	Lateral Drainage Layer Data: Drainage Slope	Geomembrane Liner Data: Pinhole Density	Geomembrane Liner Data: Installation Defect Density (cm2/acre)	Geomembrane Liner Data: Placement Quality
1	Vegetative layer 1	Topsoil	10	1	6	0.398	0.244	0.136	1.2E-04		0					
2	Vegetative layer 2	Type 1	26	1	21	0.445	0.393	0.277	1.9E-06		0					
		Type 2	n/a	1	21	0.400	0.300	0.200	1.0E-04		0					
3	Filter Layer	Sand Filter	2	1	6	0.437	0.062	0.024	5.8E-03		0					
4	Biotic Barrier	Cobbles/Gravel	21(mod)	1	36	0.350	0.020	0.010	1.0E+02		0					
5	Drainage Layer	Crushed Stone	21(mod)	2	12	0.397	0.032	0.013	1.0E-01		0	430	13.40%			
6	Infiltration Barrier Layer 1	HDPE Liner	35	4	0.06				2.0E-13		0			0	1.0	Good
7	Infiltration Barrier Layer 2	GCL	17	3	0.25	0.750	0.747	0.400	3.0E-09							
		Compacted Clay	16	3	24	0.427	0.418	0.367	1.0E-07							
		COMBINED		3	24.25	0.430	0.421	0.367	7.5E-08		0					
8	Contouring Layer	Compacted Fill	26	1	12	0.445	0.393	0.277	1.9E-06		0					
9	Intermediate Cover	Compacted Fill	26	1	12	0.445	0.393	0.277	1.9E-06		0					
10	Waste	Type 1	26	1	varies	0.445	0.393	0.277	1.9E-06		0					
		Type 2	31	1	varies	0.578	0.076	0.025	4.1E-03		0					
11	Protective Soil	Compacted Fill	26	1	12	0.445	0.393	0.277	1.9E-06		0					
12	Leachate Collection System	Crushed Stone	21(mod)	2	12	0.397	0.032	0.013	1.0E-01		0	224	2.24%			
13	Primary Liner 1	HDPE Liner	35	4	0.06				2.0E-13		0			0	1.0	Good
14	Primary Liner 2	GCL	17	3	0.25	0.750	0.747	0.400	3.0E-09		0					
15	Leak Detection System	Crushed Stone	21(mod)	2	12	0.397	0.032	0.013	1.0E-01		0	224	2.24%			
16	Secondary Liner 1	HDPE Liner	35	4	0.06				2.0E-13		0			0	1.0	Good
17	Secondary Liner 2	GCL	17	3	0.25	0.750	0.747	0.400	3.0E-09							
		Compacted Clay	16	3	36	0.427	0.418	0.367	1.0E-07							
		COMBINED		3	36.25	0.429	0.420	0.367	8.2E-08		0					

Note: Layer Types Are: 1=Vertical Percolation, 2=Lateral Drainage, 3=Barrier Soil, 4=Geomembrane.

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Written by: B. L. Date: 95/9/29 (YY/MM/DD) Reviewed by: NAO Date: 95/9/29 (YY/MM/DD)

Client: Fermco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.5

RB 30 Sept 95

Table 2. HELP DEFAULT MATERIAL CHARACTERISTICS

Classification			Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	USDA	USCS	vol/vol	vol/vol	vol/vol	cm/sec
1	CoS	SP	0.417	0.045	0.018	1.0×10^{-2}
2	S	SW	0.437	0.062	0.024	5.8×10^{-3}
3	FS	SW	0.457	0.083	0.033	3.1×10^{-3}
4	LS	SM	0.437	0.105	0.047	1.7×10^{-3}
5	LFS	SM	0.457	0.131	0.058	1.0×10^{-3}
6	SL	SM	0.453	0.190	0.085	7.2×10^{-4}
7	FSL	SM	0.473	0.222	0.104	5.2×10^{-4}
8	L	ML	0.463	0.232	0.116	3.7×10^{-4}
9	SiL	ML	0.501	0.284	0.135	1.9×10^{-4}
10	SCL	SC	0.398	0.244	0.136	1.2×10^{-4}
11	CL	CL	0.464	0.310	0.187	6.4×10^{-5}
12	SiCL	CL	0.471	0.342	0.210	4.2×10^{-5}
13	SC	SC	0.430	0.321	0.221	3.3×10^{-5}
14	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}
15	C	CH	0.475	0.378	0.265	1.7×10^{-5}
16	Barrier Soil		0.427	0.418	0.367	1.0×10^{-7}
17	Bentonite Mat (0.6 cm)		0.750	0.747	0.400	3.0×10^{-9}
18	Municipal Waste (900 lb/yd³ or 312 kg/m³)		0.671	0.292	0.077	1.0×10^{-3}
19	Municipal Waste (channeling and dead zones)		0.168	0.073	0.019	1.0×10^{-3}
20	Drainage Net (0.5 cm)		0.850	0.010	0.005	$1.0\times10^{+1}$
21	Gravel		0.397	0.032	0.013	3.0×10^{-1}
22	L*	ML	0.419	0.307	0.180	1.9×10^{-5}
23	SiL*	ML	0.461	0.360	0.203	9.0×10^{-6}
24	SCL*	SC	0.365	0.305	0.202	2.7×10^{-6}
25	CL*	CL	0.437	0.373	0.266	3.6×10^{-6}
26	SiCL*	CL	0.445	0.393	0.277	1.9×10^{-6}
27	SC*	SC	0.400	0.366	0.288	7.8×10^{-7}
28	SiC*	CH	0.452	0.411	0.311	1.2×10^{-6}
29	C*	CH	0.451	0.419	0.332	6.8×10^{-7}
30	Coal-Burning Electric Plant Fly Ash*		0.541	0.187	0.047	5.0×10^{-5}
31	Coal-Burning Electric Plant Bottom Ash*		0.578	0.076	0.025	4.1×10^{-3}
32	Municipal Incinerator Fly Ash*		0.450	0.116	0.049	1.0×10^{-2}
33	Fine Copper Slag*		0.375	0.055	0.020	4.1×10^{-2}
34	Drainage Net (0.6 cm)		0.850	0.010	0.005	$3.3\times10^{+1}$

* Moderately Compacted (Continued)

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Table 2 (Cont.) HELP DEFAULT MATERIAL CHARACTERISTICS

Classification		Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	Geomembrane Material	vol/vol	vol/vol	vol/vol	cm/sec
35	High Density Polyethylene (HDPE)				2.0×10^{-13}
36	Low Density Polyethylene (LDPE)				4.0×10^{-13}
37	Polyvinyl Chloride (PVC)				2.0×10^{-11}
38	Butyl Rubber				1.0×10^{-12}
39	Chlorinated Polyethylene (CPE)				4.0×10^{-12}
40	Hypalon or Chlorosulfonated Polyethylene (CSPE)				3.0×10^{-12}
41	Ethylene-Propylene Diene Monomer (EPDM)				2.0×10^{-12}
42	Neoprene				3.0×10^{-12}

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The values for porosity, field capacity, wilting point, and saturated hydraulic conductivity for the topsoil were assumed based on default values of texture #10 provided by the HELP model for this type of material. The assumed properties of topsoil are:

porosity	=	0.398	Vol./Vol
Field Capacity	=	0.244	Vol/Vol
Wilting Point	=	0.136	Vol./Vol.
Sat. Hydraulic Conductivity	=	1.2E-4	cm/sec

4 Initial Volumetric Soil Water Content

Use HELP default initial soil moisture content.

5 Rate of subsurface inflow to layer

Assumed to be zero.

2 Final Cover Vegetative Soil Layer

1 Layer type: Vertical percolation

2 Layer thickness: 21"

3 Soil texture:

Vegetative support soil will probably come from the borrow area. The vegetative support soil will most likely be the brown till which is classified as CL based on USCS and as SiCL based

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on USDA. The vegetative support layer may also contain silt, sand, and slightly fine gravel.

Based on Section 3.5 of HELP Manual, for CL or SiCL with moderate compaction, soil texture type 26 can be used to define the properties of vegetative support layer.

The properties are:

	Texture #26	with sand fine gravel	
porosity	= 0.445	0.400	vol./vol
Field Capacity	= 0.393	0.300	vol./vol
Wilting Point	= 0.277	0.200	vol./vol
Sat. Hydraulic Conductivity	= 1.9E-6	1.0E-4	cm/sec

4. Initial Volumetric Soil Water Content

use HELP default initial soil moisture content

5. Rate of subsurface inflow into layer

Assume to be zero

3 Final Cover Granular Filter Layer

1. Layer type: Vertical percolation
2. Layer thickness: 6"
3. Soil texture:

Filter material may have to be imported from off site. As the function of this layer is to filter the fine-grained soils of the vegetative support layer from washing into the cobbles of the biointrusion

barrier layer, the filter sand should be well-graded and may be classified to be SW by USCS or S by USDA and hence texture 2 should be used to define the properties of granular filter layer. The properties are:

porosity	= 0.437	Vol/Vol.
Field Capacity	= 0.062	Vol./Vol.
Wilting Point	= 0.024	Vol./Vol.
Sat. Hydraulic Conductivity	= 5.8E-3	cm/sec

4 Initial Volumetric Soil Water Content

Use HELP default initial soil moisture content

5 Rate of subsurface Inflow into Layer

Assume to be zero.

4 Final Cover Biointrusion Barrier Layer – Cobbles

1 layer type: Vertical percolation

2 layer thickness: 36"

3 Soil texture

Cobbles will have to be imported from off site. The closest soil texture to cobbles given by HELP is gravel. The textural values given by HELP for gravel were modified to estimate the values for cobbles.

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The design requires that cobble need $d_{100} = 18"$ $d_{50} = 12"$ to $15"$ and $d_0 = 4"$, which should make this layer very permeable with high saturated hydraulic conductivity value. The properties of this layer are defined as:

porosity	= 0.350	Vol./Vol.
Field Capacity	= 0.020	Vol./vol.
Wilting Point	= 0.010	Vol./Vol.
Sat. Hydraulic Conductivity	= 1.0E+2	cm/sec

Note: The above values are assumed based on default values for gravel (Texture No. 21) and modified to account for the larger particle size of cobbles.

4 Initial Volumetric Soil Water Content

use HELP default initial soil moisture content.

5 Rate of Subsurface Inflow into Layer.

Assume to be zero.

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5 Final Cover Drainage Layer – Crushed Stone

1 Layer type: Lateral Drainage

2 Layer thickness: 12"

3 Soil texture

Crushed stone will have to be imported from off site. The values for porosity, field capacity, wilting point, and saturated hydraulic conductivity for the crushed stone will be based on default values for gravel (Texture No. 21) and their values are given by HELP as followings:

porosity	= 0.397	Vol./Vol.
Field Capacity	= 0.032	Vol./Vol.
Wilting Point	= 0.013	Vol./Vol.
Sat. Hydraulic Conductivity	= 1.0E-1	cm/sec

4: Initial Volumetric Soil Water content

Use HELP default initial soil moisture content

5: Rate of Subsurface Inflow Into Layer

Assume to be zero.

6: Lateral Drainage Layer Design Data

Maximum drainage length = 430 ft
Drain slope = 13.4 %
No leachate recirculation

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6 Final Cover Infiltration Barrier layer 1 – HDPE Geomembrane

1 Layer type: Geomembrane Liner

2 Layer thickness: 0.06" (60 mil)

3 Soil texture:

As the specific type of geomembrane to be used has not been determined, the best approach is to use HELP default values for Geomembrane Liner. The values are defined as follows:

Pinhole density in geomembrane liner: zero (Giroud and Bonaparte, 1989)

Geomembrane Liner installation defects: 1 cm^2/acre (same Ref.)

Geomembrane Liner placement Quality: good

Geomembrane Liner sat. Hydraulic Conductivity: 2.0×10^{-13} cm/sec

7. Final Cover Infiltration Barrier Layer 2 – Geosynthetic Clay Liner (GCL) and Compacted Clay Liner (CCL)

Component 1 – GCL

1 layer type: Barrier Soil Liner

2. Layer thickness: 0.25" (standard for most GCL's)

3 Soil Texture:

As the specific type of GCL to be used has not been determined, the best approach is to use HELP default values for Bentonite Mat. The values are defined as follows:

porosity = 0.750 Vol./Vol.

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Field Capacity = 0.747 Vol./Vol.

Wilting Point = 0.400 Vol./Vol.

Sat. Hydraulic Conductivity = 3.0E-9 cm/sec

4. Initial Volumetric Soil Water Content.

Use HELP default initial soil moisture content.

5. Rate of Subsurface Inflow Into Layer.

Assume to be zero.

Component 2 – CCL

1 Layer type: Barrier soil layer

2 Layer thickness: 24"

3 Soil texture:

CCL soil will most likely come from the borrow area. As with vegetative support soil, the CCL is most likely to be the brown till which is classified as CL based on USCS and SiCL based on USDA. However, the CCL will be well-compacted and need a specified maximum permeability of 1×10^{-7} cm/sec. Hence the HELP soil texture type 16 can be used to define the properties as follows:

porosity = 0.427 Vol./Vol.

Field Capacity = 0.418 Vol./Vol.

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Wilting point = 0.367 Vol./Vol.

Sat. Hydraulic Conductivity = 1.0E-07 cm/sec.

4 Initial Volumetric Soil Water content

Use HELP default initial soil moisture content

5 Rates of Subsurface Inflow Into Layer

Assume to be zero.

As HELP model does not allow two barrier soil liners to be placed adjacent to each other, the GCL and CCL layers will be combined into one layer with the new properties calculated as below. The calculating method is given on page 28-29 of HELP manual.

Combined Properties of GCL and CCL

1 Porosity (n)

From the definition of porosity $n_c = \frac{(V_v)_c}{(V_T)_c} = \frac{(V_v)_1 + (V_v)_2}{(V_T)_1 + (V_T)_2}$ ✓

V_v = Volume of voids

V_T = Total Volume

c = Combined

1 = Soil 1 (GCL)

2 = Soil 2 (CCL)

for a 1 inch x 1 inch area of liner

$(V_v)_1 = n_1 (V_T)_1 = 0.750 \times 0.25 \text{ in}^3 = 0.188 \text{ in}^3$ ✓

$(V_v)_2 = n_2 (V_T)_2 = 0.427 \times 24 \text{ in}^3 = 10.25 \text{ in}^3$ ✓

Therefore $n_c = \frac{0.188 + 10.25}{0.25 + 24} = \underline{\underline{0.430}}$ vol/vol ✓

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2. Field Capacity (FC)-

Since field capacity is a volumetric moisture content

$$FC_c = \frac{(V_w)_c}{(V_T)_c} = \frac{(V_w)_1 + (V_w)_2}{(V_T)_1 + (V_T)_2}$$

V_w = Volume of water C = Combined

V_T = Total Volume 1 = Soil 1 (GCL)

2 = Soil 2 (CCL)

for 1" x 1" area of liner

$(V_w)_1 = FC_1 (V_T)_1 = 0.74 \times 0.25 \text{ in}^3 = 0.187 \text{ in}^3$

$(V_w)_2 = FC_2 (V_T)_2 = 0.418 \times 24 \text{ in}^3 = 10.03 \text{ in}^3$

Therefore $FC_c = \frac{0.187 + 10.03}{0.25 + 24} = \underline{\underline{0.421}}$ Vol./Vol.

3. Wilting Point (WP)-

Since wilting point is a volumetric moisture content

$$WP_c = \frac{(V_w)_c}{(V_T)_c} = \frac{(V_w)_1 + (V_w)_2}{(V_T)_1 + (V_T)_2}$$

V_w = Volume of water C = Combined

V_T = Total Volume 1 = Soil 1 (GCL)

2 = Soil 2 (CCL)

for 1" x 1" area of liner

$(V_w)_1 = WP_1 (V_T)_1 = 0.400 \times 0.25 \text{ in}^3 = 0.1 \text{ in}^3$

$(V_w)_2 = WP_2 (V_T)_2 = 0.367 \times 24 = 8.81 \text{ in}^3$

Therefore $WP_c = \frac{0.100 + 8.81}{0.25 + 24} = \underline{\underline{0.367}}$ Vol./Vol.

4. Saturated Hydraulic Conductivity k_e

$$k_e = \frac{T_1 + T_2}{\frac{T_1}{k_1} + \frac{T_2}{k_2}} = \frac{0.25'' + 24''}{0.25''/3.0\times10^{-9} + 24''/1.0\times10^{-7}} = \underline{\underline{7.5\times10^{-8}}} \text{ cm/s}$$

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8 Final Cover Contouring Layer - Compacted Fill

1 Layer type: Vertical percolation

2 Layer thickness: 12"

3 Soil texture:

Compacted fill for the contouring layer will be similar to those material of the vegetative support layer. HELP default values for soil texture type 26 will be used to define the properties of this layer. The values are:

porosity	= 0.445	vol./vol.
Field Capacity	= 0.393	vol./vol.
wilting point	= 0.277	vol./vol.
Sat. Hydraulic Conductivity	= 1.9E-6	cm/sec

4 Initial Volumetric Soil Water Content

use HELP default initial soil moisture content

5 Rate of Subsurface Inflow into layer

Assume to be zero

9 Intermediate Cover - Compacted Fill

Same as Contouring layer.

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10 Waste - Contaminated Soils, bottom ash, Lime Sludge, and Rubble

1 Layer type: vertical percolation

2 Layer thickness: case 1 use 120" = 10' (assumed)

case 2 use 360" = 30' (assumed)

case 3 use 600" = 34' (see Fig 3)

3 soil texture

Based on waste handling and disposal plan which is currently under development, there will be mainly two type of in-cell-waste. Type 1 is the contaminated soil dominant waste. Type 2 is the ash dominant waste. According to HELP's default waste characteristics, type 1 & type 2 wastes' properties are:

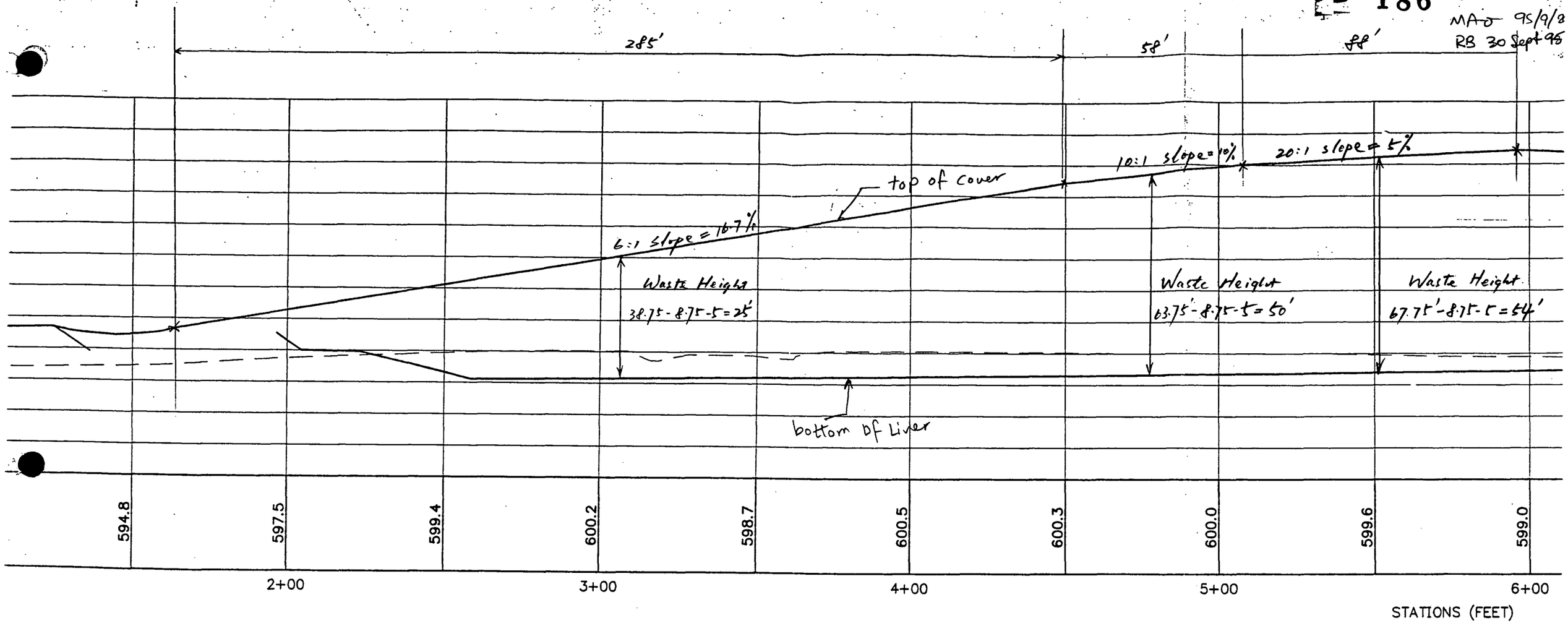
	Type 1	type 2	
porosity	0.445	0.578	Vol./vol.
Field Capacity	0.393	0.076	Vol./vol.
Wilting Point	0.277	0.025	Vol./Vol
Sat. Hydraulic Conductivity	1.7E-6	4.1E-03	cm/sec.

4 Initial Volumetric Soil Water Content

Use HELP default initial soil moisture content.

5 Rate of Subsurface Inflow into layer

Assume to be zero.



$$\text{Average Waste Height} = \frac{285 \times 25 + 58 \times 50 + 88 \times 54}{285' + 58' + 88'} = 34'$$

$$\text{Average slope} = \frac{285 \times 16.7\% + 58 \times 10\% + 88 \times 5\%}{285 + 58 + 88} = 13.4\%$$

Total Drainage length = 285' + 58' + 88' = 431' Say 430'

DET-NO SECTION
SHT-NO CELL FOUR INTER
HORIZONTAL SCALE: 1" = 30
VERTICAL SCALE: 1" = 30'
XREF: F95XA042

Figure 3: Typical Cell Cross-Section

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11. Protective soil layer (non-granular)

Same as contouring layer and intermediate cover layer.

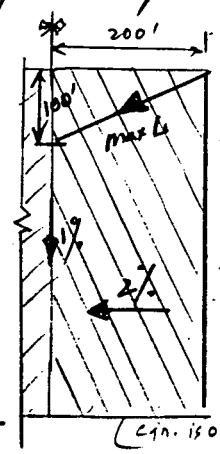
12. Leachate Collection System Drainage layer - Crushed Stone

This layer will be the same as cover drainage layer except that the lateral drainage layer design data has the following values.

Maximum drainage length = 224'

Drain slope = 2.24%

No leachate recirculation



max L $= \sqrt{200^2+100^2}$ ✓ $= 224$ ft ✓

max slope $\simeq \sqrt{(2\%)^2+(1\%)^2}$ ✓ $= 2.24\%$ ✓

(cfn. is ok because slopes are very flat) ✓

13. Primary Liner 1 - HDPE Geomembrane

This layer will be the same as final cover infiltration barrier layer 1. So all the input values will be the same as that layer

14. Primary Liner 2 - GeoSynthetic Clay liner (GCL)

This layer will be the same as the GCL layer of final cover infiltration barrier layer 2. So all the input values will be the same as that layer.

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15 Leak Detection System Drainage layer – Crushed stone

This layer will be the same as the leachate collection system drainage layer. so all the input values will be the same as that layer.

16 Secondary Liner 1 – HDPE Geomembrane

This layer will be the same as the primary liner 1. so all the input values will be the same as that layer.

17 Secondary Liner 2 – Geosynthetic clay liner (GCL) and compacted clay liner (CCL)

This layer will be the same as the final cover infiltration barrier layer 2. so the values for GCL, CCL, and combined are all the same as that layer.

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Runoff Curve number information

The information needed are surface slope, slope length, default texture and quality of vegetative cover. The input are:

Surface Slope:

Case 1 – 5% (assumed)

Case 2 – 15% (assumed)

Case 3 – 13.4% (Average) (see Fig 3)

Slope length:

Case 1 – 400' (width of cell)

Case 2 – 400' (width of cell)

Case 3 – 430' (Average) (see Fig 3)

Soil texture:

Case 1 – HELP texture # 26 } Same as site soil

Case 2 – HELP texture # 26 }

Case 3 – HELP texture # 10 } same as top soil

Vegetative Cover

Case 1 – Bare ground

Case 2 – Bare ground

Case 3 – Good stand of grass

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REFERENCES

1. USGS Topographic maps. 7.5 minute series, Shandon Quadrangle, OHIO, 1981

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LEACHATE GENERATION ANALYSES COMPUTATIONS RESULTS

Leachate generation rates were estimated for the three cases described in the procedures package which are:

(i) Case 1 : Initial period of operation (10 ft of waste);

(ii) Case 2 : Intermediate period of operation (30 ft of waste and 12 in. intermediate cover); and

(iii) Case 3 : Post-Closure period.

The layers used in the HELP model and their properties are summarized on the following page 2. Because the vegetative soil layer and the waste may have a wide range of material properties, the HELP analyses were performed for the anticipated lower and upper limits of these properties. Two runs were performed for each case labeled A and B.

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Table 1. Summary of Layer information Used In HELP Analyses for all cases

Layer Number for Case Analyzed								Layer Name	Layer Material	HELP Texture Number	Layer Type	(1) Layer Thickness (in.)	Soil Texture			
1A	1B	2A	2B	3A	3B	3C	3D						Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity (cm/sec)
				1	1	1	1	Vegetative layer 1	Topsoil	10	1	6	0.398	0.244	0.136	1.2E-04
				2	2			Vegetative layer 2	Type 1 (CL)	26	1	21	0.445	0.393	0.277	1.9E-06
						2	2		Type 2 (Loam)	n/a	1	21	0.400	0.300	0.200	1.0E-04
				3	3	3	3	Filter Layer	Sand Filter	2	1	6	0.437	0.062	0.024	5.8E-03
				4	4	4	4	Biotic Barrier	Cobbles/Gravel	21(mod)	1	36	0.350	0.020	0.010	1.0E+02
				5	5	5	5	Drainage Layer	Crushed Stone	21	2	12	0.397	0.032	0.013	1.0E-01
				6	6	6	6	Infiltration Barrier Layer 1	HDPE Liner	35	4	0.06				2.0E-13
								Infiltration Barrier Layer 2	GCL	17	3	0.25	0.750	0.747	0.400	3.0E-09
									Compacted Clay	16	3	24	0.427	0.418	0.367	1.0E-07
				7	7	7	7		COMBINED		3	24.25	0.430	0.421	0.367	7.5E-08
				8	8	8	8	Contouring Layer	Compacted Fill	26	1	12	0.445	0.393	0.277	1.9E-06
		1	1	9	9	9	9	Intermediate Cover	Compacted Fill	26	1	12	0.445	0.393	0.277	1.9E-06
1		2		10		10		Waste	Type 1 (soil)	26	1	varies	0.445	0.393	0.277	1.9E-06
	1		2		10		10		Type 2 (Ash)	31	1	varies	0.578	0.076	0.025	4.1E-03
2	2	3	3	11	11	11	11	Protective Soil	Compacted Fill	26	1	12	0.445	0.393	0.277	1.9E-06
3	3	4	4	12	12	12	12	Leachate Collection System	Crushed Stone	mod. 21	2	12	0.397	0.032	0.013	1.0E-01
4	4	5	5	13	13	13	13	Primary Liner 1	HDPE Liner	35	4	0.06				2.0E-13
5	5	6	6	14	14	14	14	Primary Liner 2	GCL	17	3	0.25	0.750	0.747	0.400	3.0E-09
6	6	7	7	15	15	15	15	Leak Detection System	Crushed Stone	mod. 21	2	12	0.397	0.032	0.013	1.0E-01
7	7	8	8	16	16	16	16	Secondary Liner 1	HDPE Liner	35	4	0.06				2.0E-13
								Secondary Liner 2	GCL	17	3	0.25	0.750	0.747	0.400	3.0E-09
									Compacted Clay	16	3	36	0.427	0.418	0.367	1.0E-07
8	8	9	9	17	17	17	17		COMBINED		3	36.25	0.429	0.420	0.367	8.2E-08

(1) Waste thickness = 120 in. (10 ft) for Cases 1A & 1B
= 360 in. (30 ft) for Cases 2A & 2B
= 408 in. (34 ft) for Cases 3A → 3D

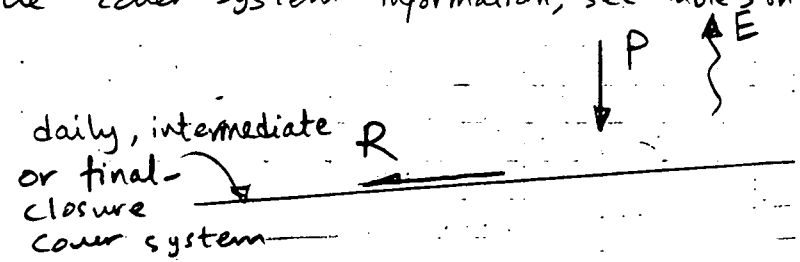
Written by: MAO B.L 95/10/4 Date: 95/10/4 (YY/MM/DD) Reviewed by: Date: / / (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.5

Table 2. Summary of HELP Model Results

Case Number	Average Annual Totals (in.)						Peak Daily Values (in.)				
	P	R	E	LD	$H_{avg.}$	I	P	R	LD	$H_{avg.}$	I
1A	40.26	0	33.77	6.48	0.373	2.4×10^{-5}	4.70	0	0.0645	1.977	3.6×10^{-7}
1B	40.26	0	24.82	15.39	1.120	7.3×10^{-5}	4.70	0	0.0646	1.984	3.6×10^{-7}
2A	40.26	0	33.69	6.52	0.344	2.2×10^{-5}	4.70	0	0.0639	1.951	3.6×10^{-7}
2B	40.26	0	30.61	9.35	0.543	3.4×10^{-5}	4.70	0	0.0646	1.984	3.6×10^{-7}
3A(1)	40.34	7.43	28.68	1.5×10^{-5}	0.000	2.5×10^{-6}	13.00	11.21	2.2×10^{-7}	0.000	5.5×10^{-9}
3B(1)	40.34	7.43	28.68	1.5×10^{-5}	0.000	2.5×10^{-6}	13.00	11.21	2.2×10^{-7}	0.000	5.5×10^{-9}
3C(1)	40.34	4.46	28.59	2.5×10^{-5}	0.000	2.5×10^{-6}	13.00	8.44	8.68×10^{-7}	0.000	5.5×10^{-9}
3D(1)	40.34	4.46	28.59	2.5×10^{-5}	0.000	2.5×10^{-6}	13.00	8.44	8.68×10^{-7}	0.000	5.5×10^{-9}

(1) For infiltration through the cover system information, see Table 3 on page 4.



LEGEND

P = Precipitation

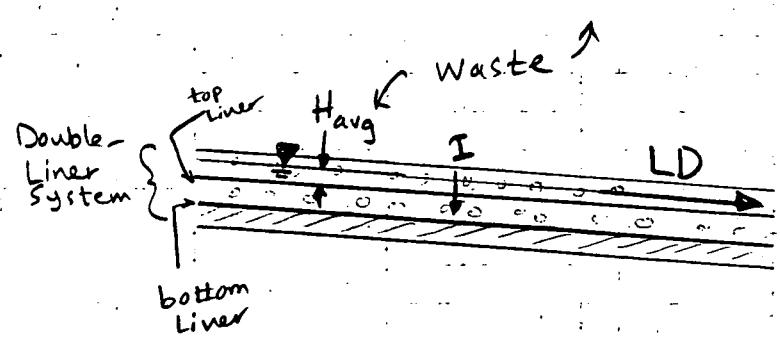
R = Runoff

E = Evapotranspiration

LD = Lateral Drainage in LCS drainage layer

H_{avg} = Average Head in LCS drainage layer

I = infiltration through top liner

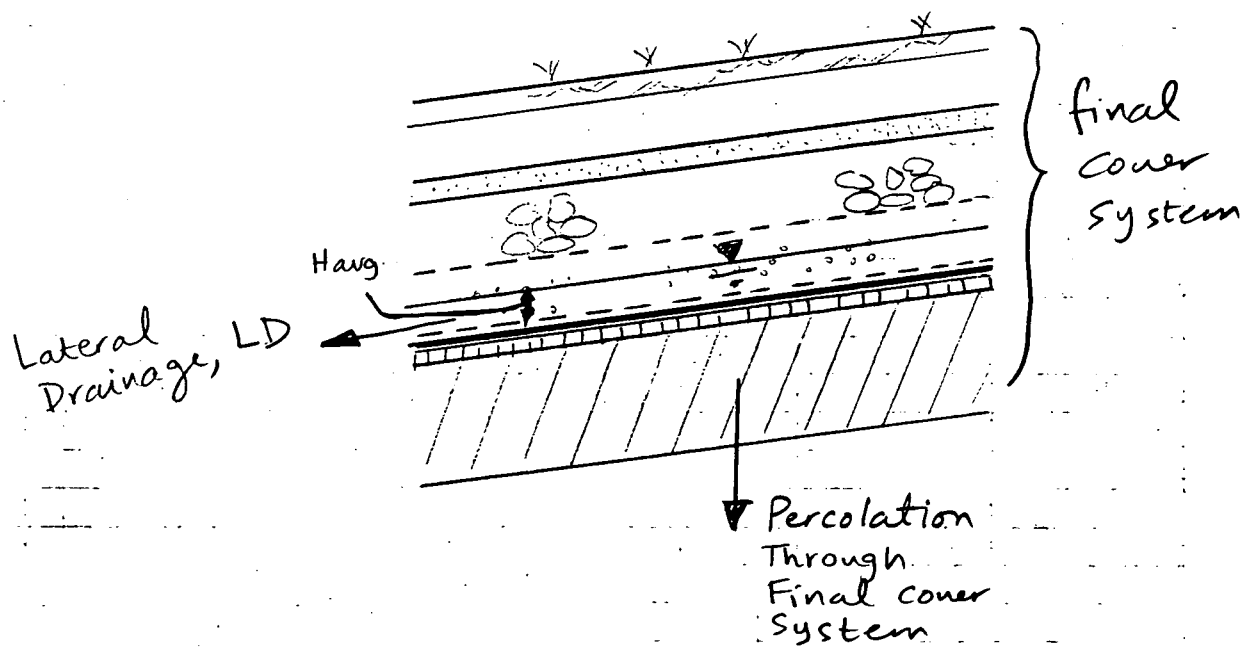


Written by: MAO BL 95/10/4 Date: 95/10/4 (YY/MM/DD) Reviewed by: Date: / / (YY/MM/DD)

Client: FEMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.5

Table 3. Summary of HELP Model Results Related to Final Cover System Flows

Parameter	Case 3A	Case 3B	Case 3C	Case 3D
• Lateral Drainage (annual) (in.)	4.24	4.24	7.29	7.29
• $H_{avg.}$ (annual) (in.)	0.067	0.067	0.115	0.115
• Percolation (annual) (in.)	1.76×10^{-5}	1.76×10^{-5}	2.75×10^{-5}	2.75×10^{-5}
• LD (peak daily (in.)	0.0883	0.0883	0.7809	0.7809
• $H_{avg.}$ (peak daily) (in.)	0.509	0.509	4.500	4.500
• Percolation (peak daily) (in.)	3.09×10^{-7}	3.09×10^{-7}	2.33×10^{-6}	2.33×10^{-6}
	✓	✓	✓	✓



Written by: MAO B.L. 95/10/4 Date: 95/10/4 (YY MM DD) Reviewed by: Date: / / (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.5

As described in the procedures package, the results of the HELP Model summarized on the previous pages will be used to design or evaluate the performance of the Leachate collection system (LCS), leakage detection system (LDS), and Leachate transmission system (LTS). Each component of these systems will be designed (or evaluated) to handle estimated flows associated with it.

From Table 2, Case 1B is the worst case scenario for leachate production. The estimated peak daily leachate production rate for Case 1B is 0.0646 in., which is equivalent to 1,751 gpad. The estimated average leachate production rate for case 1B for the peak month of the year is 1.7 in. in May (1,486 gpad). The average annual production rate was calculated to be 481 gpad for Case 1A, 1143 gpad for case 1B, 484 gpad for Case 2A, 694 gpad for case 2B, 0.0011 gpad for Cases 3B and 3C, and 0.0019 gpad for Cases 3C & 3D.

Written by: MAO B.L. 95/10/4 Date: 95/10/4 (YY/MM/DD) Reviewed by: Date: / / (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.5

To estimate leachate production rates for the entire OSDF at different stages of its life, different scenarios are assumed as follows:

Scenario Number (1)	No. of Cells @ Case 1	No. of Cells @ Case 2	No. of Cell @ Case 3	No. of Cells not developed	Total (2) Leachate Rate (gpd)
1	1	0	0	8	7,430
2	1	1	0	7	11,940
3	1	1	1	6	11,941
4	1	1	7	0	11,941 ← max.
5	0	1	8	0	4,511
6	0	0	9	0	0.11

Notes: (1) These scenarios assume cell development takes place sequentially and that no more than 2 cells will be operational at the same time.

(2) each cell is 6.5 acres; case 1 generation rate is assumed = 1143 gpad; case 2 = 694 gpad; & case 3 = 0.0019 gpad.

Estimates of design flows for the different components of the leachate transmission system (LTS) (i.e., Pipes and sumps) will be presented in the calculations package of the LTS.

Written by: BL Date: 95/10/4 (YY/MM/DD) Reviewed by: MAO Date: 95/10/5 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: Ø8.5

HELP MODEL OUTPUTS

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP3\CASE1A.D4
TEMPERATURE DATA FILE:       C:\HELP3\CASE1A.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\CASE1A.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\CASE1A.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\CASE1A.D10
OUTPUT DATA FILE:            C:\HELP3\CASE1A.OUT


TIME:  16:30     DATE:  10/ 3/1995


******************************************************************************

     TITLE:  Fernald OSDF - Case 1A

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.
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LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4091	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL

INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 5

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.25	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

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LAYER 6

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 7

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 8

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.25	INCHES

POROSITY	=	0.4290 VOL/VOL
FIELD CAPACITY	=	0.4200 VOL/VOL
WILTING POINT	=	0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4290 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.819999997000E-07 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #26 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 400. FEET.

SCS RUNOFF CURVE NUMBER	=	96.80	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	5.278	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	5.340	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	3.324	INCHES
INITIAL SNOW WATER	=	2.154	INCHES
INITIAL WATER IN LAYER MATERIALS	=	70.310	INCHES
TOTAL INITIAL WATER	=	72.464	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	104

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END OF GROWING SEASON (JULIAN DATE) = 295
AVERAGE ANNUAL WIND SPEED = 9.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 70.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 73.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 72.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR COVINGTON KENTUCKY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.13	2.73	3.95	3.58	3.84	4.09
4.28	2.97	2.91	2.54	3.12	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.29 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.45	2.84	3.77	3.69	3.83	4.10
	4.42	2.86	2.79	2.35	3.22	2.94
STD. DEVIATIONS	1.58	1.33	1.48	1.54	1.84	2.18
	1.94	1.59	1.78	1.10	1.36	1.21
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.943	1.288	2.795	4.401	5.135	4.346
	4.478	3.274	2.369	2.088	1.518	1.130
STD. DEVIATIONS	0.245	0.330	0.404	0.537	1.214	1.725
	1.560	1.530	1.127	0.737	0.334	0.173
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.2280	0.2317	0.4364	0.3731	0.4663	0.9767
	1.1313	0.8815	0.6204	0.4674	0.3595	0.3074
STD. DEVIATIONS	0.1904	0.2566	0.3594	0.2729	0.4883	0.5015
	0.4353	0.3695	0.2934	0.2077	0.1249	0.1160

PERCOLATION/LEAKAGE THROUGH LAYER 5

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TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 8

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 5

AVERAGES	0.1323	0.1577	0.2720	0.2343	0.3444	0.7940
	0.8726	0.6019	0.4040	0.2760	0.2118	0.1753
STD. DEVIATIONS	0.1298	0.2007	0.2812	0.2073	0.4292	0.5080
	0.4843	0.3934	0.2861	0.1568	0.0748	0.0673

DAILY AVERAGE HEAD ACROSS LAYER 8

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.26	(5.552)	146142.4	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	33.766	(4.1974)	122571.93	83.872
LATERAL DRAINAGE COLLECTED FROM LAYER 3	6.47968	(2.16426)	23521.223	16.09473
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00002	(0.00001)	0.087	0.00006
AVERAGE HEAD ACROSS TOP OF LAYER 5	0.373	(0.166)		
LATERAL DRAINAGE COLLECTED FROM LAYER 6	0.00002	(0.00001)	0.078	0.00005
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 8	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.014	(2.9337)	49.06	0.034

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	4.70	17061.000
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	0.06447	234.02110
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00132
AVERAGE HEAD ACROSS LAYER 5	1.977	
DRAINAGE COLLECTED FROM LAYER 6	0.00000	0.00129
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 8	0.000	
SNOW WATER	5.62	20394.9297

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4448
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.2664

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	47.3738	0.3948
2	4.9115	0.4093
3	0.4314	0.0360
4	0.0000	0.0000
5	0.1875	0.7500
6	0.3840	0.0320
7	0.0000	0.0000
8	15.5512	0.4290
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                 **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     C:\HELP3\CASE1B.D4
TEMPERATURE DATA FILE:       C:\HELP3\CASE1B.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\CASE1B.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\CASE1B.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\CASE1B.D10
OUTPUT DATA FILE:            C:\HELP3\case1b.OUT


TIME:  20:21     DATE:  10/ 3/1995


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     TITLE:  Fernald OSDF - Case 1B

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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 31

THICKNESS	=	120.00	INCHES
POROSITY	=	0.5780	VOL/VOL
FIELD CAPACITY	=	0.0760	VOL/VOL
WILTING POINT	=	0.0250	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1727	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.410000002000E-02	CM/SEC

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER

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MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 5

TYPE 3 - BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.25	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL

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WILTING POINT	=	0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08 CM/SEC

LAYER 6

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 7

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

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LAYER 8

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.25	INCHES
POROSITY	=	0.4290	VOL/VOL
FIELD CAPACITY	=	0.4200	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4290	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.819999997000E-07	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #31 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 400. FEET.

SCS RUNOFF CURVE NUMBER	=	96.80	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.644	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.936	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.300	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	41.947	INCHES
TOTAL INITIAL WATER	=	41.947	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

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EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	104
END OF GROWING SEASON (JULIAN DATE)	=	295
AVERAGE ANNUAL WIND SPEED	=	9.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR COVINGTON KENTUCKY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.13	2.73	3.95	3.58	3.84	4.09
4.28	2.97	2.91	2.54	3.12	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

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NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.29 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.45	2.84	3.77	3.69	3.83	4.10
	4.42	2.86	2.79	2.35	3.22	2.94
STD. DEVIATIONS	1.58	1.33	1.48	1.54	1.84	2.18
	1.94	1.59	1.78	1.10	1.36	1.21
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.975	1.170	2.345	2.868	3.059	2.901
	3.205	2.293	1.876	1.654	1.395	1.082

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STD. DEVIATIONS	0.225	0.297	0.448	0.771	0.957	1.013
	1.038	0.987	0.811	0.515	0.321	0.166

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	1.0080	1.1042	1.2893	1.4090	1.6995	1.5963
	1.4775	1.3294	1.2391	1.2225	1.0687	0.9486
STD. DEVIATIONS	0.5750	0.4793	0.4955	0.4737	0.4044	0.4244
	0.5198	0.5822	0.5519	0.5739	0.5307	0.4906

PERCOLATION/LEAKAGE THROUGH LAYER 5

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 8

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

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DAILY AVERAGE HEAD ACROSS LAYER 5

AVERAGES	0.8003	1.0136	1.0752	1.2896	1.5846	1.5171
	1.3094	1.1484	1.0862	1.0192	0.8803	0.7112
STD. DEVIATIONS	0.6061	0.5921	0.5871	0.5788	0.4973	0.5578
	0.6401	0.6874	0.6716	0.6677	0.6253	0.5442

DAILY AVERAGE HEAD ACROSS LAYER 8

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.26	(5.552)	146142.4	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	24.823	(2.5898)	90106.26	61.656
LATERAL DRAINAGE COLLECTED FROM LAYER 3	15.39211	(4.00820)	55873.355	38.23214
PERCOLATION/LEAKAGE THROUGH	0.00007	(0.00003)	0.266	0.00018

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LAYER 5

AVERAGE HEAD ACROSS TOP OF LAYER 5	1.120 (	0.404)		
LATERAL DRAINAGE COLLECTED FROM LAYER 6	0.00007 (	0.00003)	0.257	0.00018
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.00000 (	0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 8	0.000 (	0.000)		
CHANGE IN WATER STORAGE	0.045 (	3.0775)	162.50	0.111

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	4.70	17061.000
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	0.06463	234.60153
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00132
AVERAGE HEAD ACROSS LAYER 5	1.984	
DRAINAGE COLLECTED FROM LAYER 6	0.00000	0.00130

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PERCOLATION/LEAKAGE THROUGH LAYER 8	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 8	0.000	
SNOW WATER	5.62	20394.9297

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.5780
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0214

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	25.0127	0.2084
2	4.8724	0.4060
3	0.4162	0.0347
4	0.0000	0.0000
5	0.1875	0.7500
6	0.3840	0.0320
7	0.0000	0.0000
8	15.5512	0.4290
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     C:\HELP3\CASE2A.D4
TEMPERATURE DATA FILE:       C:\HELP3\CASE2A.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\CASE2A.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\CASE2A.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\CASE2A.D10
OUTPUT DATA FILE:            C:\HELP3\CASE2A.OUT


TIME:  10: 8     DATE:  10/ 4/1995


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     TITLE:  Fernald OSDF - Case 2A

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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 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4450	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 4.63 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	360.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4013	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 3

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TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4111	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0363	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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

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EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY	=	0.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.25 INCHES
POROSITY	=	0.7500 VOL/VOL
FIELD CAPACITY	=	0.7470 VOL/VOL
WILTING POINT	=	0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08 CM/SEC

LAYER 7

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.3970 VOL/VOL
FIELD CAPACITY	=	0.0320 VOL/VOL
WILTING POINT	=	0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0320 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000 CM/SEC
SLOPE	=	2.24 PERCENT
DRAINAGE LENGTH	=	224.0 FEET

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LAYER 8

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 9

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.25	INCHES
POROSITY	=	0.4290	VOL/VOL
FIELD CAPACITY	=	0.4200	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4290	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.819999997000E-07	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT

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SOIL DATA BASE USING SOIL TEXTURE #26 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 15.% AND A SLOPE LENGTH OF 400. FEET.

SCS RUNOFF CURVE NUMBER	=	96.90	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	13.323	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.350	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	8.310	INCHES
INITIAL SNOW WATER	=	0.669	INCHES
INITIAL WATER IN LAYER MATERIALS	=	171.294	INCHES
TOTAL INITIAL WATER	=	171.964	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	3.50	
START OF GROWING SEASON (JULIAN DATE)	=	104	
END OF GROWING SEASON (JULIAN DATE)	=	295	
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR COVINGTON KENTUCKY

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NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.13	2.73	3.95	3.58	3.84	4.09
4.28	2.97	2.91	2.54	3.12	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.29 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						

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TOTALS	3.45	2.84	3.77	3.69	3.83	4.10
	4.42	2.86	2.79	2.35	3.22	2.94
STD. DEVIATIONS	1.58	1.33	1.48	1.54	1.84	2.18
	1.94	1.59	1.78	1.10	1.36	1.21

RUNOFF

TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

EVAPOTRANSPIRATION

TOTALS	0.913	1.265	2.756	4.121	4.855	5.405
	4.937	2.880	2.573	1.976	1.091	0.920
STD. DEVIATIONS	0.215	0.323	0.416	0.726	1.115	1.101
	1.566	1.195	0.934	0.698	0.302	0.211

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.5514	0.3698	0.4868	0.4216	0.1632	0.1738
	0.4403	0.7949	0.8801	0.8540	0.7141	0.6671
STD. DEVIATIONS	0.1955	0.2485	0.2590	0.1737	0.1610	0.2702
	0.4118	0.4111	0.3043	0.2709	0.2202	0.2232

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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LATERAL DRAINAGE COLLECTED FROM LAYER 7

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 6

AVERAGES	0.3187	0.2435	0.2902	0.2508	0.0956	0.1140
	0.2867	0.5346	0.6067	0.5462	0.4480	0.3985
STD. DEVIATIONS	0.1384	0.1894	0.1807	0.1090	0.1104	0.2152
	0.3169	0.3590	0.3195	0.2692	0.1934	0.1763

DAILY AVERAGE HEAD ACROSS LAYER 9

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.26	(5.552)	146142.4	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	33.691	(3.7430)	122297.89	83.684
LATERAL DRAINAGE COLLECTED FROM LAYER 4	6.51718	(1.82434)	23657.371	16.18789
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00002	(0.00001)	0.079	0.00005
AVERAGE HEAD ACROSS TOP OF LAYER 6	0.344	(0.134)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	0.00002	(0.00001)	0.070	0.00005
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 9	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.052	(3.2567)	186.99	0.128

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BC 91/10/4

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	4.70	17061.000
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 4	0.06388	231.89029
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00130
AVERAGE HEAD ACROSS LAYER 6	1.951	
DRAINAGE COLLECTED FROM LAYER 7	0.00000	0.00127
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 9	0.000	
SNOW WATER	5.62	20394.9297

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4450

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.2708

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	4.9062	0.4088
2	146.5006	0.4069
3	5.0679	0.4223
4	0.5103	0.0425
5	0.0000	0.0000
6	0.1875	0.7500
7	0.3840	0.0320
8	0.0000	0.0000
9	15.5512	0.4290
SNOW WATER	0.000	

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B.C 95/10/4 Checker PJS 5 Oct 95 43/122

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                 **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
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PRECIPITATION DATA FILE:      C:\HELP3\CASE2B.D4
TEMPERATURE DATA FILE:        C:\HELP3\CASE2B.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\CASE2B.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\CASE2B.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\CASE2B.D10
OUTPUT DATA FILE:             C:\HELP3\CASE2B.OUT


TIME:  10:34     DATE:  10/ 4/1995


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     TITLE:  Fernald OSDF - Case 2B

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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 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3390	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 4.63 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 31

THICKNESS	=	360.00	INCHES
POROSITY	=	0.5780	VOL/VOL
FIELD CAPACITY	=	0.0760	VOL/VOL
WILTING POINT	=	0.0250	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0971	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.410000002000E-02	CM/SEC

LAYER 3

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TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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

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EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY	=	0.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.25 INCHES
POROSITY	=	0.7500 VOL/VOL
FIELD CAPACITY	=	0.7470 VOL/VOL
WILTING POINT	=	0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08 CM/SEC

LAYER 7

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.3970 VOL/VOL
FIELD CAPACITY	=	0.0320 VOL/VOL
WILTING POINT	=	0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0320 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000 CM/SEC
SLOPE	=	2.24 PERCENT
DRAINAGE LENGTH	=	224.0 FEET

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LAYER 8

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 9

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.25	INCHES
POROSITY	=	0.4290	VOL/VOL
FIELD CAPACITY	=	0.4200	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4290	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.819999997000E-07	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT

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SOIL DATA BASE USING SOIL TEXTURE #26 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 15.% AND A SLOPE LENGTH OF 400. FEET.

SCS RUNOFF CURVE NUMBER	=	96.90	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	7.848	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	15.744	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	3.774	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	60.251	INCHES
TOTAL INITIAL WATER	=	60.251	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	104
END OF GROWING SEASON (JULIAN DATE)	=	295
AVERAGE ANNUAL WIND SPEED	=	9.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR COVINGTON KENTUCKY

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NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.13	2.73	3.95	3.58	3.84	4.09
4.28	2.97	2.91	2.54	3.12	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.29 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						

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TOTALS	3.45	2.84	3.77	3.69	3.83	4.10
	4.42	2.86	2.79	2.35	3.22	2.94
STD. DEVIATIONS	1.58	1.33	1.48	1.54	1.84	2.18
	1.94	1.59	1.78	1.10	1.36	1.21

RUNOFF

TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

EVAPOTRANSPIRATION

TOTALS	0.922	1.247	2.603	3.349	4.131	4.705
	4.370	2.868	2.480	1.930	1.113	0.889
STD. DEVIATIONS	0.202	0.311	0.410	0.743	0.947	1.418
	1.543	1.229	1.022	0.686	0.225	0.158

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.6797	0.4838	0.6350	0.5258	0.4173	0.6683
	0.8362	1.1522	1.1249	1.0644	0.9160	0.8483
STD. DEVIATIONS	0.2902	0.2608	0.2793	0.2445	0.3332	0.4847
	0.5196	0.4249	0.3491	0.3369	0.3079	0.3001

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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LATERAL DRAINAGE COLLECTED FROM LAYER 7

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 6

AVERAGES	0.4110	0.3233	0.3837	0.3258	0.2723	0.4929
	0.6195	0.8881	0.8794	0.7589	0.6289	0.5356
STD. DEVIATIONS	0.2489	0.2365	0.2147	0.2123	0.2973	0.4754
	0.5184	0.4684	0.4045	0.3771	0.3391	0.3012

DAILY AVERAGE HEAD ACROSS LAYER 9

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.26	(5.552)	146142.4	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	30.608	(3.6011)	111105.99	76.026
LATERAL DRAINAGE COLLECTED FROM LAYER 4	9.35207	(3.01372)	33948.000	23.22940
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00003	(0.00002)	0.125	0.00009
AVERAGE HEAD ACROSS TOP OF LAYER 6	0.543	(0.257)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	0.00003	(0.00002)	0.116	0.00008
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 9	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.300	(3.5768)	1088.23	0.745

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	4.70	17061.000
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 4	0.06463	234.60153
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00132
AVERAGE HEAD ACROSS LAYER 6	1.984	
DRAINAGE COLLECTED FROM LAYER 7	0.00000	0.00130
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 9	0.000	
SNOW WATER	5.62	20394.9297

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3448
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1178

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	4.5457	0.3788
2	59.8707	0.1663
3	5.1306	0.4276
4	0.5529	0.0461
5	0.0000	0.0000
6	0.1875	0.7500
7	0.3840	0.0320
8	0.0000	0.0000
9	15.5512	0.4290
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                 **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:      C:\HELP3\CASE3A.D4
TEMPERATURE DATA FILE:        C:\HELP3\CASE3A.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\CASE3A.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\CASE3A.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\CASE3A.D10
OUTPUT DATA FILE:             C:\HELP3\CASE3A.OUT


TIME:  11:22     DATE:  10/ 4/1995


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     TITLE:  Fernald OSDF - Case 3A

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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 10

THICKNESS	=	6.00	INCHES
POROSITY	=	0.3980	VOL/VOL
FIELD CAPACITY	=	0.2440	VOL/VOL
WILTING POINT	=	0.1360	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.119999997000E-03	CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 4.63 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	21.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4207	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 2

THICKNESS	=	6.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.0620	VOL/VOL
WILTING POINT	=	0.0240	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1920	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.579999993000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.00	INCHES
POROSITY	=	0.3500	VOL/VOL
FIELD CAPACITY	=	0.0300	VOL/VOL
WILTING POINT	=	0.0100	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0300	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	100.000000000	CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0395	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	13.40	PERCENT

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DRAINAGE LENGTH = 430.0 FEET

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.25	INCHES
POROSITY	=	0.4300	VOL/VOL
FIELD CAPACITY	=	0.4210	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4300	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.750000027000E-07	CM/SEC

LAYER 8

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TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 9

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 10

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	408.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL

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EFFECTIVE SAT. HYD. COND. = 0.190000003000E-05 CM/SEC

LAYER 11

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 12

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 13

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TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 14

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.25	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

LAYER 15

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL

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INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 16

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 17

TYPE 3 - BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.25	INCHES
POROSITY	=	0.4290	VOL/VOL
FIELD CAPACITY	=	0.4200	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4290	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.819999997000E-07	CM/SEC

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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 13.% AND A SLOPE LENGTH OF 430. FEET.

SCS RUNOFF CURVE NUMBER	=	80.90	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	11.260	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.044	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	6.705	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	214.725	INCHES
TOTAL INITIAL WATER	=	214.725	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	3.50	
START OF GROWING SEASON (JULIAN DATE)	=	104	
END OF GROWING SEASON (JULIAN DATE)	=	295	
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00	%

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NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR COVINGTON KENTUCKY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.13	2.73	3.95	3.58	3.84	4.09
4.28	2.97	2.91	2.54	3.12	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.29 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

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	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.45	2.84	3.77	3.69	3.83	4.10
	4.51	2.86	2.79	2.35	3.22	2.94
STD. DEVIATIONS	1.58	1.33	1.48	1.54	1.84	2.18
	2.35	1.59	1.78	1.10	1.36	1.21
RUNOFF						
TOTALS	1.670	2.221	1.227	0.335	0.165	0.230
	0.327	0.097	0.186	0.051	0.353	0.571
STD. DEVIATIONS	1.437	1.567	1.280	0.678	0.499	0.587
	1.345	0.313	0.542	0.189	0.706	0.768
EVAPOTRANSPIRATION						
TOTALS	0.748	0.968	2.148	3.156	4.439	4.496
	4.185	2.661	2.464	1.894	0.838	0.682
STD. DEVIATIONS	0.164	0.236	0.395	0.641	1.024	1.484
	1.436	1.137	0.944	0.699	0.190	0.167
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.5559	0.1871	0.6842	1.1038	0.7188	0.4001
	0.0464	0.0224	0.0157	0.0400	0.0534	0.4127
STD. DEVIATIONS	0.5973	0.3306	0.5298	0.4305	0.3584	0.1806
	0.0382	0.0499	0.0426	0.1281	0.1835	0.5089
PERCOLATION/LEAKAGE THROUGH LAYER 7						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 12

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 14

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 15

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 17

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 7

AVERAGES	0.1024	0.0385	0.1272	0.2120	0.1336	0.0769
	0.0086	0.0042	0.0030	0.0074	0.0103	0.0767
STD. DEVIATIONS	0.1099	0.0680	0.0985	0.0827	0.0666	0.0347
	0.0071	0.0093	0.0082	0.0238	0.0352	0.0946

DAILY AVERAGE HEAD ACROSS LAYER 14

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ACROSS LAYER 17

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.34	(5.640)	146443.7	100.00

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RUNOFF	7.434	(3.3631)	26985.28	18.427
EVAPOTRANSPIRATION	28.680	(3.5378)	104107.97	71.091
LATERAL DRAINAGE COLLECTED FROM LAYER 5	4.24053	(1.50870)	15393.115	10.51129
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00002	(0.00001)	0.064	0.00004
AVERAGE HEAD ACROSS TOP OF LAYER 7	0.067	(0.024)		
LATERAL DRAINAGE COLLECTED FROM LAYER 12	0.00002	(0.00001)	0.055	0.00004
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 14	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 15	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 17	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 17	0.000	(0.000)		
CHANGE IN WATER STORAGE	-0.012	(1.3297)	-42.78	-0.029

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	13.00	47190.000
RUNOFF	11.205	40675.6289
DRAINAGE COLLECTED FROM LAYER 5	0.08827	320.41122
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000000	0.00112
AVERAGE HEAD ACROSS LAYER 7	0.509	
DRAINAGE COLLECTED FROM LAYER 12	0.00000	0.00081
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 14	0.000	
DRAINAGE COLLECTED FROM LAYER 15	0.00000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 17	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 17	0.000	
SNOW WATER	5.62	20394.9297

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3977

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.2171

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	2.3321	0.3887
2	7.7189	0.3676
3	0.6044	0.1007
4	1.0800	0.0300
5	0.3843	0.0320
6	0.0000	0.0000
7	10.4275	0.4300
8	4.7160	0.3930
9	4.7160	0.3930
10	160.3440	0.3930
11	4.7160	0.3930
12	0.3840	0.0320
13	0.0000	0.0000
14	0.1875	0.7500
15	0.3840	0.0320
16	0.0000	0.0000

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17	15.5512	0.4290
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                 **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:      C:\HELP3\CASE3B.D4
TEMPERATURE DATA FILE:        C:\HELP3\CASE3B.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\CASE3B.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\CASE3B.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\CASE3B.D10
OUTPUT DATA FILE:             C:\HELP3\CASE3B.OUT


TIME:  11:44     DATE:  10/ 4/1995


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     TITLE:  Fernald OSDF - Case 3B

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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 10

THICKNESS	=	6.00	INCHES
POROSITY	=	0.3980	VOL/VOL
FIELD CAPACITY	=	0.2440	VOL/VOL
WILTING POINT	=	0.1360	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.119999997000E-03	CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 4.63 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	21.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4207	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 3

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TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 2

THICKNESS	=	6.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.0620	VOL/VOL
WILTING POINT	=	0.0240	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1920	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.579999993000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.00	INCHES
POROSITY	=	0.3500	VOL/VOL
FIELD CAPACITY	=	0.0300	VOL/VOL
WILTING POINT	=	0.0100	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0300	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	100.000000000	CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0395	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	13.40	PERCENT

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DRAINAGE LENGTH = 430.0 FEET

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.25	INCHES
POROSITY	=	0.4300	VOL/VOL
FIELD CAPACITY	=	0.4210	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4300	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.750000027000E-07	CM/SEC

LAYER 8

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TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 9

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 10

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 31

THICKNESS	=	408.00	INCHES
POROSITY	=	0.5780	VOL/VOL
FIELD CAPACITY	=	0.0760	VOL/VOL
WILTING POINT	=	0.0250	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0760	VOL/VOL

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EFFECTIVE SAT. HYD. COND. = 0.410000002000E-02 CM/SEC

LAYER 11

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 12

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 13

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TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 14

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.25	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

LAYER 15

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL

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INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 16

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 17

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.25	INCHES
POROSITY	=	0.4290	VOL/VOL
FIELD CAPACITY	=	0.4200	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4290	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.819999997000E-07	CM/SEC

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BL 95/10/4

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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 13.% AND A SLOPE LENGTH OF 430. FEET.

SCS RUNOFF CURVE NUMBER	=	80.90	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	11.260	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.044	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	6.705	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	85.389	INCHES
TOTAL INITIAL WATER	=	85.389	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	104
END OF GROWING SEASON (JULIAN DATE)	=	295
AVERAGE ANNUAL WIND SPEED	=	9.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00 %

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NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR COVINGTON KENTUCKY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.13	2.73	3.95	3.58	3.84	4.09
4.28	2.97	2.91	2.54	3.12	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.29 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

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	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.45	2.84	3.77	3.69	3.83	4.10
	4.51	2.86	2.79	2.35	3.22	2.94
STD. DEVIATIONS	1.58	1.33	1.48	1.54	1.84	2.18
	2.35	1.59	1.78	1.10	1.36	1.21
RUNOFF						
TOTALS	1.670	2.221	1.227	0.335	0.165	0.230
	0.327	0.097	0.186	0.051	0.353	0.571
STD. DEVIATIONS	1.437	1.567	1.280	0.678	0.499	0.587
	1.345	0.313	0.542	0.189	0.706	0.768
EVAPOTRANSPIRATION						
TOTALS	0.748	0.968	2.148	3.156	4.439	4.496
	4.185	2.661	2.464	1.894	0.838	0.682
STD. DEVIATIONS	0.164	0.236	0.395	0.641	1.024	1.484
	1.436	1.137	0.944	0.699	0.190	0.167
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.5559	0.1871	0.6842	1.1038	0.7188	0.4001
	0.0464	0.0224	0.0157	0.0400	0.0534	0.4127
STD. DEVIATIONS	0.5973	0.3306	0.5298	0.4305	0.3584	0.1806
	0.0382	0.0499	0.0426	0.1281	0.1835	0.5089
PERCOLATION/LEAKAGE THROUGH LAYER 7						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 12

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 14

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 15

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 17

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 7

AVERAGES	0.1024	0.0385	0.1272	0.2120	0.1336	0.0769
	0.0086	0.0042	0.0030	0.0074	0.0103	0.0767
STD. DEVIATIONS	0.1099	0.0680	0.0985	0.0827	0.0666	0.0347
	0.0071	0.0093	0.0082	0.0238	0.0352	0.0946

DAILY AVERAGE HEAD ACROSS LAYER 14

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ACROSS LAYER 17

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.34	(5.640)	146443.7	100.00

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RUNOFF	7.434	(3.3631)	26985.28	18.427
EVAPOTRANSPIRATION	28.680	(3.5378)	104107.97	71.091
LATERAL DRAINAGE COLLECTED FROM LAYER 5	4.24053	(1.50870)	15393.115	10.51129
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00002	(0.00001)	0.064	0.00004
AVERAGE HEAD ACROSS TOP OF LAYER 7	0.067	(0.024)		
LATERAL DRAINAGE COLLECTED FROM LAYER 12	0.00002	(0.00001)	0.055	0.00004
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 14	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 15	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 17	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 17	0.000	(0.000)		
CHANGE IN WATER STORAGE	-0.012	(1.3297)	-42.78	-0.029

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	13.00	47190.000
RUNOFF	11.205	40675.6289
DRAINAGE COLLECTED FROM LAYER 5	0.08827	320.41122
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000000	0.00112
AVERAGE HEAD ACROSS LAYER 7	0.509	
DRAINAGE COLLECTED FROM LAYER 12	0.00000	0.00081
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 14	0.000	
DRAINAGE COLLECTED FROM LAYER 15	0.00000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 17	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 17	0.000	
SNOW WATER	5.62	20394.9297

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3977

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.2171

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	2.3321	0.3887
2	7.7189	0.3676
3	0.6044	0.1007
4	1.0800	0.0300
5	0.3843	0.0320
6	0.0000	0.0000
7	10.4275	0.4300
8	4.7160	0.3930
9	4.7160	0.3930
10	31.0080	0.0760
11	4.7160	0.3930
12	0.3840	0.0320
13	0.0000	0.0000
14	0.1875	0.7500
15	0.3840	0.0320
16	0.0000	0.0000

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17	15.5512	0.4290
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                 **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP3\CASE3C.D4
TEMPERATURE DATA FILE:       C:\HELP3\CASE3C.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\CASE3C.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\CASE3C.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\CASE3C.D10
OUTPUT DATA FILE:            C:\HELP3\CASE3C.OUT


TIME:  12:10     DATE:  10/ 4/1995


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     TITLE:  Fernald OSDF - Case 3C

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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 10

THICKNESS	=	6.00	INCHES
POROSITY	=	0.3980	VOL/VOL
FIELD CAPACITY	=	0.2440	VOL/VOL
WILTING POINT	=	0.1360	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1987	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.119999997000E-03	CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 4.63 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	21.00	INCHES
POROSITY	=	0.4000	VOL/VOL
FIELD CAPACITY	=	0.3000	VOL/VOL
WILTING POINT	=	0.2000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2823	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999975000E-04	CM/SEC

LAYER 3

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TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 2

THICKNESS	=	6.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.0620	VOL/VOL
WILTING POINT	=	0.0240	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1731	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.579999993000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.00	INCHES
POROSITY	=	0.3500	VOL/VOL
FIELD CAPACITY	=	0.0300	VOL/VOL
WILTING POINT	=	0.0100	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0300	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	100.000000000	CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0415	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	13.40	PERCENT

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DRAINAGE LENGTH = 430.0 FEET

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.25	INCHES
POROSITY	=	0.4300	VOL/VOL
FIELD CAPACITY	=	0.4210	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4300	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.750000027000E-07	CM/SEC

LAYER 8

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TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 9

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 10

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	408.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL

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EFFECTIVE SAT. HYD. COND. = 0.190000003000E-05 CM/SEC

LAYER 11

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 12

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 13

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TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 14

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.25	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

LAYER 15

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL

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INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 16

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 17

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.25	INCHES
POROSITY	=	0.4290	VOL/VOL
FIELD CAPACITY	=	0.4200	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4290	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.819999997000E-07	CM/SEC

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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 13.% AND A SLOPE LENGTH OF 430. FEET.

SCS RUNOFF CURVE NUMBER	=	80.90	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	7.702	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.099	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	5.088	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	211.163	INCHES
TOTAL INITIAL WATER	=	211.163	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	104
END OF GROWING SEASON (JULIAN DATE)	=	295
AVERAGE ANNUAL WIND SPEED	=	9.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00 %

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NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR COVINGTON KENTUCKY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.13	2.73	3.95	3.58	3.84	4.09
4.28	2.97	2.91	2.54	3.12	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.29 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

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	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.45	2.84	3.77	3.69	3.83	4.10
	4.51	2.86	2.79	2.35	3.22	2.94
STD. DEVIATIONS	1.58	1.33	1.48	1.54	1.84	2.18
	2.35	1.59	1.78	1.10	1.36	1.21
RUNOFF						
TOTALS	1.249	1.883	0.748	0.027	0.025	0.080
	0.154	0.027	0.036	0.011	0.035	0.184
STD. DEVIATIONS	1.291	1.451	1.054	0.061	0.072	0.164
	0.976	0.074	0.084	0.041	0.079	0.496
EVAPOTRANSPIRATION						
TOTALS	0.815	1.045	2.349	3.397	4.218	3.855
	4.169	2.721	2.412	1.870	0.945	0.788
STD. DEVIATIONS	0.182	0.268	0.384	0.683	1.208	1.456
	1.441	1.197	0.994	0.701	0.200	0.156
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.8885	0.3691	1.3487	1.2636	0.7841	0.2898
	0.2508	0.1180	0.1925	0.1491	0.4384	1.1982
STD. DEVIATIONS	1.0326	0.5623	1.1041	0.9748	0.6659	0.3883
	0.6968	0.2940	0.4751	0.3675	0.8462	1.0896
PERCOLATION/LEAKAGE THROUGH LAYER 7						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 12

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 14

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 15

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 17

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 7

AVERAGES	0.1638	0.0759	0.2507	0.2427	0.1457	0.0557
	0.0466	0.0219	0.0370	0.0277	0.0842	0.2227
STD. DEVIATIONS	0.1907	0.1157	0.2052	0.1872	0.1238	0.0746
	0.1295	0.0547	0.0913	0.0683	0.1625	0.2025

DAILY AVERAGE HEAD ACROSS LAYER 14

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ACROSS LAYER 17

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.34	(5.640)	146443.7	100.00

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RUNOFF	4.459	(2.7218)	16185.94	11.053
EVAPOTRANSPIRATION	28.586	(3.4126)	103766.20	70.857
LATERAL DRAINAGE COLLECTED FROM LAYER 5	7.29091	(3.30831)	26465.988	18.07247
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00003	(0.00001)	0.100	0.00007
AVERAGE HEAD ACROSS TOP OF LAYER 7	0.115	(0.052)		
LATERAL DRAINAGE COLLECTED FROM LAYER 12	0.00003	(0.00001)	0.091	0.00006
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 14	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 15	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 17	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 17	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.007	(1.0585)	25.43	0.017

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	13.00	47190.000
RUNOFF	8.439	30632.2266
DRAINAGE COLLECTED FROM LAYER 5	0.78091	2834.70923
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000002	0.00845
AVERAGE HEAD ACROSS LAYER 7	4.500	
DRAINAGE COLLECTED FROM LAYER 12	0.00000	0.00315
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 14	0.000	
DRAINAGE COLLECTED FROM LAYER 15	0.00000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 17	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 17	0.000	
SNOW WATER	5.62	20394.9297

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3277

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1578

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	2.2927	0.3821
2	6.1633	0.2935
3	0.5167	0.0861
4	1.0800	0.0300
5	0.3843	0.0320
6	0.0000	0.0000
7	10.4275	0.4300
8	4.7160	0.3930
9	4.7160	0.3930
10	160.3440	0.3930
11	4.7160	0.3930
12	0.3840	0.0320
13	0.0000	0.0000
14	0.1875	0.7500
15	0.3840	0.0320
16	0.0000	0.0000

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17	15.5512	0.4290
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
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PRECIPITATION DATA FILE:     C:\HELP3\CASE3D.D4
TEMPERATURE DATA FILE:       C:\HELP3\CASE3D.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\CASE3D.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\CASE3D.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\CASE3D.D10
OUTPUT DATA FILE:            C:\HELP3\CASE3D.OUT


TIME:  12:38     DATE:  10/ 4/1995


******************************************************************************

     TITLE:  Fernald OSDF - Case 3D

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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 10

THICKNESS	=	6.00	INCHES
POROSITY	=	0.3980	VOL/VOL
FIELD CAPACITY	=	0.2440	VOL/VOL
WILTING POINT	=	0.1360	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1987	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.119999997000E-03	CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 4.63 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	21.00	INCHES
POROSITY	=	0.4000	VOL/VOL
FIELD CAPACITY	=	0.3000	VOL/VOL
WILTING POINT	=	0.2000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2823	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999975000E-04	CM/SEC

LAYER 3

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TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 2

THICKNESS	=	6.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.0620	VOL/VOL
WILTING POINT	=	0.0240	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1731	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.579999993000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.00	INCHES
POROSITY	=	0.3500	VOL/VOL
FIELD CAPACITY	=	0.0300	VOL/VOL
WILTING POINT	=	0.0100	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0300	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	100.000000000	CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0415	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	13.40	PERCENT

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DRAINAGE LENGTH = 430.0 FEET

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.25	INCHES
POROSITY	=	0.4300	VOL/VOL
FIELD CAPACITY	=	0.4210	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4300	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.750000027000E-07	CM/SEC

LAYER 8

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TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 9

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 10

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 31

THICKNESS	=	408.00	INCHES
POROSITY	=	0.5780	VOL/VOL
FIELD CAPACITY	=	0.0760	VOL/VOL
WILTING POINT	=	0.0250	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0760	VOL/VOL

EFFECTIVE SAT. HYD. COND. = 0.410000002000E-02 CM/SEC

LAYER 11

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 26

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3930	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.190000003000E-05	CM/SEC

LAYER 12

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 13

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TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 14

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.25	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

LAYER 15

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL

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INITIAL SOIL WATER CONTENT	=	0.0320	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.24	PERCENT
DRAINAGE LENGTH	=	224.0	FEET

LAYER 16

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 17

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.25	INCHES
POROSITY	=	0.4290	VOL/VOL
FIELD CAPACITY	=	0.4200	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4290	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.819999997000E-07	CM/SEC

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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 13.% AND A SLOPE LENGTH OF 430. FEET.

SCS RUNOFF CURVE NUMBER	=	80.90	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	7.702	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.099	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	5.088	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	81.827	INCHES
TOTAL INITIAL WATER	=	81.827	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	104
END OF GROWING SEASON (JULIAN DATE)	=	295
AVERAGE ANNUAL WIND SPEED	=	9.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00 %

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NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR COVINGTON KENTUCKY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.13	2.73	3.95	3.58	3.84	4.09
4.28	2.97	2.91	2.54	3.12	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.29 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

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	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.45	2.84	3.77	3.69	3.83	4.10
	4.51	2.86	2.79	2.35	3.22	2.94
STD. DEVIATIONS	1.58	1.33	1.48	1.54	1.84	2.18
	2.35	1.59	1.78	1.10	1.36	1.21
RUNOFF						
TOTALS	1.249	1.883	0.748	0.027	0.025	0.080
	0.154	0.027	0.036	0.011	0.035	0.184
STD. DEVIATIONS	1.291	1.451	1.054	0.061	0.072	0.164
	0.976	0.074	0.084	0.041	0.079	0.496
EVAPOTRANSPIRATION						
TOTALS	0.815	1.045	2.349	3.397	4.218	3.855
	4.169	2.721	2.412	1.870	0.945	0.788
STD. DEVIATIONS	0.182	0.268	0.384	0.683	1.208	1.456
	1.441	1.197	0.994	0.701	0.200	0.156
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.8885	0.3691	1.3487	1.2636	0.7841	0.2898
	0.2508	0.1180	0.1925	0.1491	0.4384	1.1982
STD. DEVIATIONS	1.0326	0.5623	1.1041	0.9748	0.6659	0.3883
	0.6968	0.2940	0.4751	0.3675	0.8462	1.0896
PERCOLATION/LEAKAGE THROUGH LAYER 7						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 12

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 14

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 15

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 17

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 7

AVERAGES	0.1638	0.0759	0.2507	0.2427	0.1457	0.0557
	0.0466	0.0219	0.0370	0.0277	0.0842	0.2227
STD. DEVIATIONS	0.1907	0.1157	0.2052	0.1872	0.1238	0.0746
	0.1295	0.0547	0.0913	0.0683	0.1625	0.2025

DAILY AVERAGE HEAD ACROSS LAYER 14

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ACROSS LAYER 17

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.34	(5.640)	146443.7	100.00

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RUNOFF	4.459	(2.7218)	16185.94	11.053
EVAPOTRANSPIRATION	28.586	(3.4126)	103766.20	70.857
LATERAL DRAINAGE COLLECTED FROM LAYER 5	7.29091	(3.30831)	26465.988	18.07247
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00003	(0.00001)	0.100	0.00007
AVERAGE HEAD ACROSS TOP OF LAYER 7	0.115	(0.052)		
LATERAL DRAINAGE COLLECTED FROM LAYER 12	0.00003	(0.00001)	0.091	0.00006
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 14	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 15	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 17	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 17	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.007	(1.0585)	25.43	0.017

****

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	13.00	47190.000
RUNOFF	8.439	30632.2266
DRAINAGE COLLECTED FROM LAYER 5	0.78091	2834.70923
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000002	0.00845
AVERAGE HEAD ACROSS LAYER 7	4.500	
DRAINAGE COLLECTED FROM LAYER 12	0.00000	0.00315
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 14	0.000	
DRAINAGE COLLECTED FROM LAYER 15	0.00000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 17	0.000000	0.00002
AVERAGE HEAD ACROSS LAYER 17	0.000	
SNOW WATER	5.62	20394.9297

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3277

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1578

****

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	2.2927	0.3821
2	6.1633	0.2935
3	0.5167	0.0861
4	1.0800	0.0300
5	0.3843	0.0320
6	0.0000	0.0000
7	10.4275	0.4300
8	4.7160	0.3930
9	4.7160	0.3930
10	31.0080	0.0760
11	4.7160	0.3930
12	0.3840	0.0320
13	0.0000	0.0000
14	0.1875	0.7500
15	0.3840	0.0320
16	0.0000	0.0000

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17	15.5512	0.4290
SNOW WATER	0.000	

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APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATIONS PACKAGE

USEPA HELP MODEL

1. Schroeder, P.R., Lloyd, C.M., and Zappi, P.A., "*The Hydrologic Evaluation of Landfill Performance (HELP) Model, User's Guide for Version 3*," U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Report No. EPA/600/R-94/168a, Sep 1994.

2. Schroeder, P.R., Dozier, T.S., Zappi, P.A., McEnroe, B.M., Sjostrom, J.W., and Peyton, R.L, "*The Hydrologic Evaluation of Landfill Performance (HELP) Model Engineering Documentation for Version 3*," U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Report No. EPA/600/R-94/168b, Sep 1994, 116 p.

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Washington DC 20460

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The Hydrologic Evaluation of Landfill Performance (HELP) Model

User's Guide for Version 3

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THE HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE (HELP) MODEL

USER'S GUIDE FOR VERSION 3

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SECTION 1

INTRODUCTION

The Hydrologic Evaluation of Landfill Performance (HELP) computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through and out of landfills. The model accepts weather, soil and design data, and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled. The program was developed to conduct water balance analysis of landfills, cover systems and solid waste disposal and containment facilities. As such, the model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection and liner leakage that may be expected to result from the operation of a wide variety of landfill designs. The primary purpose of the model is to assist in the comparison of design alternatives as judged by their water balances. The model, applicable to open, partially closed, and fully closed sites, is a tool for both designers and permit writers.

1.1 BACKGROUND

The HELP program, Versions 1, 2 and 3, was developed by the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, for the U.S. Environmental Protection Agency (EPA), Risk Reduction Engineering Laboratory, Cincinnati, OH, in response to needs in the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, better known as Superfund) as identified by the EPA Office of Solid Waste, Washington, DC.

HELP Version 1 (Schroeder et al., 1984) represented a major advance beyond the Hydrologic Simulation on Solid Waste Disposal Sites (HSSWDS) program (Perrier and Gibson, 1980; Schroeder and Gibson, 1982), which was also developed at WES. The HSSWDS model simulated only the cover system, did not model lateral flow through drainage layers, and handled vertical drainage only in a rudimentary manner. The infiltration, percolation and evapotranspiration routines were almost identical to those used in the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model, which was developed by Knisel (1980) for the U.S. Department of Agriculture (USDA). The runoff and infiltration routines relied heavily on the Hydrology Section of the National Engineering Handbook (USDA, Soil Conservation Service, 1985). Version 1 of the HELP model incorporated a lateral subsurface drainage model and improved unsaturated drainage and liner leakage models into the HSSWDS

model. In addition, the HELP model provided simulation of the entire landfill including leachate collection and liner systems.

Version 2 (Schroeder et al., 1988) represented a great enhancement of the capabilities of the HELP model. The WGEN synthetic weather generator developed by the USDA Agricultural Research Service (ARS) (Richardson and Wright, 1984) was added to the model to yield daily values of precipitation, temperature and solar radiation. This replaced the use of normal mean monthly temperature and solar radiation values and improved the modeling of snow and evapotranspiration. Also, a vegetative growth model from the Simulator for Water Resources in Rural Basins (SWRRB) model developed by the ARS (Arnold et al., 1989) was merged into the HELP model to calculate daily leaf area indices. Modeling of unsaturated hydraulic conductivity and flow and lateral drainage computations were improved. Accuracy was increased with the use of double precision. Default soil data were improved, and the model permitted use of more layers and initialization of soil moisture content. Input and editing were simplified. Output was clarified, and standard deviations were reported.

In Version 3, the HELP model has been greatly enhanced beyond Version 2. The number of layers that can be modeled has been increased. The default soil/material texture list has been expanded to contain additional waste materials, geomembranes, geosynthetic drainage nets and compacted soils. The model also permits the use of a user-built library of soil textures. Computation of leachate recirculation between soil layers and groundwater drainage into the landfill have been added. Moreover, HELP Version 3 accounts for leakage through geomembranes due to manufacturing defects (pinholes) and installation defects (punctures, tears and seaming flaws) and by vapor diffusion through the liner. The estimation of runoff from the surface of the landfill has been improved to account for large landfill surface slopes and slope lengths. The snowmelt model has been replaced with an energy-based model; the Priestly-Taylor potential evapotranspiration model has been replaced with a Penman method, incorporating wind and humidity effects as well as long wave radiation losses (heat loss at night). A frozen soil model has been added to improve infiltration and runoff predictions in cold regions. The unsaturated vertical drainage model has also been improved to aid in storage computations. Input and editing have been further simplified with interactive, full-screen, menu-driven input techniques.

In addition, the HELP Version 3 model provides a variety of methods for specifying precipitation, temperature and solar radiation data. Now, data from the most commonly available government and commercial sources can be imported easily. Moreover, data used in HELP Version 2 can still be used with minimum user effort. Specifying weather data manually and editing previously entered weather data can be easily done by using built-in spreadsheet facilities.

The use of data files in Version 3 is much simpler and more convenient than HELP Version 2 because data are saved permanently in user defined file names at a user-specified location. Similarly, the user has more flexibility to define units for every type

of data needed to run the HELP model. Finally, Version 3 of the HELP model provides on-line help at every step of the data preparation process.

Although applicable to most landfill applications, the HELP model was developed specifically to perform hazardous and municipal waste disposal landfill evaluations as required by RCRA. Hazardous waste disposal landfills generally should have a liner to prevent migration of waste from the landfill, a final cover to minimize the production of leachate following closure, careful controls of runon and runoff, and limits on the buildup of leachate head over the liner to no more than 1 ft. The HELP model is useful for predicting the amounts of runoff, drainage, and leachate expected for reasonable designs as well as the buildup of leachate above the liner. However, the model should not be expected to produce credible results from input unrepresentative of landfills.

1.2 OVERVIEW

The principal purpose of this User's Guide is to provide the basic information needed to use the computer program. Thus, while some attention must be given to definitions, descriptions of variables and interpretation of results, only a minimal amount of such information is provided. Detailed documentation providing in-depth coverage of the theory and assumptions on which the model is based and the internal logic of the program is also available (Schroeder et al., 1994). Potential HELP users are strongly encouraged to study the documentation and this User's Guide before attempting to use the program to evaluate a landfill design. Additional documentation concerning the sensitivity of program inputs, application of the model and verification of model predictions are under development.

1.3 SYSTEM AND OPERATING DOCUMENTATION

1.3.1 Computer Equipment

The model entitled "The Hydrologic Evaluation of Landfill Performance" (HELP) was written to run on IBM-compatible personal computers (PC) under the DOS environment.

1.3.2 Required Hardware

The following IBM-compatible CPU (8088, 80286, 80386 or 80486) hardware is required:

1. Monitor, preferably color EGA or better

2. Floppy disk drive (5.25-inch double-sided, double- or high-density; or 3.5-inch double-sided, double- or high-density)

3. Hard disk drive or a second floppy disk drive

4. 400k bytes or more of available RAM memory

5. 8087, 80287, 80387 or 80486 math co-processor

6. Printer, if a hard copy is desired

1.3.3 Software Requirements

The user must use Microsoft or compatible Disk Operating Systems (MS-DOS) Version 2.10 or a higher version. The user interface executable module was compiled and linked with Microsoft Basic Professional Development System 7.1. Other executable components were compiled with the Ryan-McFarland FORTRAN Version 2.42. The Microsoft Basic Professional Development System and Ryan-McFarland FORTRAN compiler are not needed to run the HELP Model.

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THE HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE (HELP) MODEL

ENGINEERING DOCUMENTATION FOR VERSION 3

by

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SECTION 1

PROGRAM IDENTIFICATION

PROGRAM TITLE: Hydrologic Evaluation of Landfill Performance (HELP) Model

WRITERS: Paul R. Schroeder, Tamsen S. Dozier, John W. Sjostrom and Bruce M. McEnroe

ORGANIZATION: U.S. Army Corps of Engineers, Waterways Experiment Station (WES)

DATE: September 1994

UPDATE: None Version No.: 3.00

SOURCE LANGUAGE: The simulation code is written in ANSI FORTRAN 77 using Ryan-McFarland Fortran Version 2.44 with assembly language and Spindrift Library extensions for Ryan-McFarland Fortran to perform system calls, and screen operations. The user interface is written in BASIC using Microsoft Basic Professional Development System Version 7.1. Several of the user interface support routines are written in ANSI FORTRAN 77 using Ryan-McFarland Fortran Version 2.44, including the synthetic weather generator and the ASCII data import utilities.

HARDWARE: The model was written to run on IBM-compatible personal computers under the DOS environment. The program requires an IBM-compatible 8088, 80286, 80386 or 80486-based CPU (preferably 80386 or 80486) with an 8087, 80287, 80387 or 80486 math co-processor. The computer system must have a monitor (preferably color EGA or better), a 3.5- or 5.25-inch floppy disk drive (preferably 3.5-inch double-sided, high-density), a hard disk drive with 6 MB of available storage, and 400k bytes or more of available low level RAM. A printer is needed if a hard copy is desired.

AVAILABILITY: The source code and executable code for IBM-compatible personal computers are available from the National Technical Information Service (NTIS). Limited distribution immediately following the initial distribution will be available from the USEPA Risk Reduction Engineering Laboratory, the USEPA Center for Environmental Research Information and the USAE Waterways Experiment Station.

ABSTRACT: The Hydrologic Evaluation of Landfill Performance (HELP) computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through and out of landfills. The model accepts weather, soil and design data and uses solution techniques that account for surface storage, snowmelt, runoff, infiltration, vegetative growth, evapotranspiration, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Landfill systems including combinations of vegetation, cover soils, waste cells, lateral drain layers, barrier soils, and synthetic geomembrane liners may be modeled. The program was developed to conduct water balance analyses of landfills, cover systems, and solid waste disposal facilities. As such, the model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection, and liner leakage that may be expected to result from the operation of a wide variety of landfill designs. The primary purpose of the model is to assist in the comparison of design alternatives as judged by their water balances. The model, applicable to open, partially closed, and fully closed sites, is a tool for both designers and permit writers.

The HELP model uses many process descriptions that were previously developed, reported in the literature, and used in other hydrologic models. The optional synthetic weather generator is the WGEN model of the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) (Richardson and Wright, 1984). Runoff modeling is based on the USDA Soil Conservation Service (SCS) curve number method presented in Section 4 of the National Engineering Handbook (USDA, SCS, 1985). Potential evapotranspiration is modeled by a modified Penman method (Penman, 1963). Evaporation from soil is modeled in the manner developed by Ritchie (1972) and used in various ARS models including the Simulator for Water Resources in Rural Basins (SWRRB) (Arnold et al., 1989) and the Chemicals, Runoff, and Erosion from Agricultural Management System (CREAMS) (Knisel, 1980). Plant transpiration is computed by the Ritchie's (1972) method used in SWRRB and CREAMS. The vegetative growth model was extracted from the SWRRB model. Evaporation of interception, snow and surface water is based on an energy balance. Interception is modeled by the method proposed by Horton (1919). Snowmelt modeling is based on the SNOW-17 routine of the National Weather Service River Forecast System (NWSRFS) Snow Accumulation and Ablation Model (Anderson, 1973). The frozen soil submodel is based on a routine used in the CREAMS model (Knisel et al., 1985). Vertical drainage is modeled by Darcy's (1856) law using the Campbell (1974) equation for unsaturated hydraulic conductivity based on the Brooks-Corey (1964) relationship. Saturated lateral drainage is modeled by an analytical approximation to the steady-state solution of the Boussinesq equation employing the Dupuit-Forchheimer (Forchheimer, 1930) assumptions. Leakage through geomembranes is modeled by a series of equations based on the compilations by Giroud et al. (1989, 1992). The processes are linked together in a sequential order starting at the surface with a surface water balance; then evapotranspiration from the soil profile; and finally drainage and water routing, starting at the surface with infiltration and then proceeding downward through the landfill profile to the bottom. The solution procedure is applied repetitively for each day as it simulates the water routing throughout the simulation period.

SECTION 2

NARRATIVE DESCRIPTION

The HELP program, Versions 1, 2 and 3, was developed by the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, for the U.S. Environmental Protection Agency (EPA), Risk Reduction Engineering Laboratory, Cincinnati, OH, in response to needs in the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, better known as Superfund) as identified by the EPA Office of Solid Waste, Washington, DC. The primary purpose of the model is to assist in the comparison of landfill design alternatives as judged by their water balances.

The Hydrologic Evaluation of Landfill Performance (HELP) model was developed to help hazardous waste landfill designers and regulators evaluate the hydrologic performance of proposed landfill designs. The model accepts weather, soil and design data and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled. Results are expressed as daily, monthly, annual and long-term average water budgets.

The HELP model is a quasi-two-dimensional, deterministic, water-routing model for determining water balances. The model was adapted from the HSSWDS (Hydrologic Simulation Model for Estimating Percolation at Solid Waste Disposal Sites) model of the U.S. Environmental Protection Agency (Perrier and Gibson, 1980; Schroeder and Gibson, 1982), and various models of the U.S. Agricultural Research Service (ARS), including the CREAMS (Chemical Runoff and Erosion from Agricultural Management Systems) model (Knisel, 1980), the SWRRB (Simulator for Water Resources in Rural Basins) model (Arnold et al., 1989), the SNOW-17 routine of the National Weather Service River Forecast System (NWSRFS) Snow Accumulation and Ablation Model (Anderson, 1973), and the WGEN synthetic weather generator (Richardson and Wright, 1984).

HELP Version 1 (Schroeder et al., 1984a and 1984b) represented a major advance beyond the HSSWDS program (Perrier and Gibson, 1980; Schroeder and Gibson, 1982), which was also developed at WES. The HSSWDS model simulated only the cover system, did not model lateral flow through drainage layers, and handled vertical drainage only in a rudimentary manner. The infiltration, percolation and evapotranspiration routines were almost identical to those used in the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model, which was developed by Knisel (1980) for the U.S. Department of Agriculture (USDA). The runoff and infiltration

routines relied heavily on the Hydrology Section of the National Engineering Handbook (USDA, Soil Conservation Service, 1985). Version 1 of the HELP model incorporated a lateral subsurface drainage model and improved unsaturated drainage and liner leakage models into the HSSWDS model. In addition, the HELP model provided simulation of the entire landfill including leachate collection and liner systems.

Version 1 of the HELP program was tested extensively using both field and laboratory data. HELP Version 1 simulation results were compared to field data for 20 landfill cells from seven sites (Schroeder and Peyton, 1987a). The lateral drainage component of HELP Version 1 was tested against experimental results from two large--scale physical models of landfill liner/drain systems (Schroeder and Peyton, 1987b). The results of these tests provided motivation for some of the improvements incorporated into HELP Version 2.

Version 2 (Schroeder et al., 1988a and 1988b) presented a great enhancement of the capabilities of the HELP model. The WGEN synthetic weather generator developed by the USDA Agricultural Research Service (ARS) (Richardson and Wright, 1984) was added to the model to yield daily values of precipitation, temperature and solar radiation. This replaced the use of normal mean monthly temperature and solar radiation values and improved the modeling of snow and evapotranspiration. Also, a vegetative growth model from the Simulator for Water Resources in Rural Basins (SWRRB) model developed by the ARS (Arnold et al., 1989) was merged into the HELP model to calculate daily leaf area indices. Modeling of unsaturated hydraulic conductivity and flow and lateral drainage computations were improved. Default soil data were improved, and the model permitted use of more layers and initialization of soil moisture content.

In Version 3, the HELP model has been greatly enhanced beyond Version 2. The number of layers that can be modeled has been increased. The default soil/material texture list has been expanded to contain additional waste materials, geomembranes, geosynthetic drainage nets and compacted soils. The model also permits the use of a user-built library of soil textures. Computations of leachate recirculation and groundwater drainage into the landfill have been added. Moreover, HELP Version 3 accounts for leakage through geomembranes due to manufacturing defects (pinholes) and installation defects (punctures, tears and seaming flaws) and by vapor diffusion through the liner based on the equations compiled by Giroud et al. (1989, 1992). The estimation of runoff from the surface of the landfill has been improved to account for large landfill surface slopes and slope lengths. The snowmelt model has been replaced with an energy-based model; the Priestly-Taylor potential evapotranspiration model has been replaced with a Penman method, incorporating wind and humidity effects as well as long wave radiation losses (heat loss at night). A frozen soil model has been added to improve infiltration and runoff predictions in cold regions. The unsaturated vertical drainage model has also been improved to aid in storage computations. Input and editing have been further simplified with interactive, full-screen, menu-driven input techniques.

The HELP model requires daily climatologic data, soil characteristics, and design

specifications to perform the analysis. Daily rainfall data may be input by the user, generated stochastically, or taken from the model's historical data base. The model contains parameters for generating synthetic precipitation for 139 U.S. cities. The historical data base contains five years of daily precipitation data for 102 U.S. cities. Daily temperature and solar radiation data are generated stochastically or may be input by the user. Necessary soil data include porosity, field capacity, wilting point, saturated hydraulic conductivity, and Soil Conservation Service (SCS) runoff curve number for antecedent moisture condition II. The model contains default soil characteristics for 42 material types for use when measurements or site-specific estimates are not available. Design specifications include such things as the slope and maximum drainage distance for lateral drainage layers, layer thicknesses, leachate recirculation procedure, surface cover characteristics and information on any geomembranes.

Figure 1 is a definition sketch for a somewhat typical closed hazardous waste landfill profile. The top portion of the profile (layers 1 through 4) is the cap or cover. The bottom portion of the landfill is a double liner system (layers 6 through 11), in this case composed of a geomembrane liner and a composite liner. Immediately above the bottom composite liner is a leakage detection drainage layer to collect leakage from the primary liner, in this case, a geomembrane. Above the primary liner are a geosynthetic drainage net and a sand layer that serve as drainage layers for leachate collection. The drain layers composed of sand are typically at least 1-ft thick and have suitably spaced perforated or open joint drain pipe embedded below the surface of the liner. The leachate collection drainage layer serves to collect any leachate that may percolate through the waste layers. In this case where the liner is solely a geomembrane, a drainage net may be used to rapidly drain leachate from the liner, avoiding a significant buildup of head and limiting leakage. The liners are sloped to prevent ponding by encouraging leachate to flow toward the drains. The net effects are that very little leachate should leak through the primary liner and virtually no migration of leachate through the bottom composite liner to the natural formations below. Taken as a whole, the drainage layers, geomembrane liners, and barrier soil liners may be referred to as the leachate collection and removal system (drain/liner system) and more specifically a double liner system.

Figure 1 shows eleven layers--four in the cover or cap, one as the waste layers, three in the primary leachate collection and removal system (drain/liner system) and three in the secondary leachate collection and removal system (leakage detection). These eleven layers comprise three subprofiles or modeling units. A subprofile consists of all layers between (and including) the landfill surface and the bottom of the top liner system, between the bottom of one liner system and the bottom of the next lower liner system, or between the bottom of the lowest liner system and the bottom of the lowest soil layer modeled. In the sketch, the top subprofile contains the cover layers, the middle subprofile contains the waste, drain and liner system for leachate collection, and the bottom subprofile contains the drain and liner system for leakage detection. Six subprofiles in a single landfill profile may be simulated by the model.

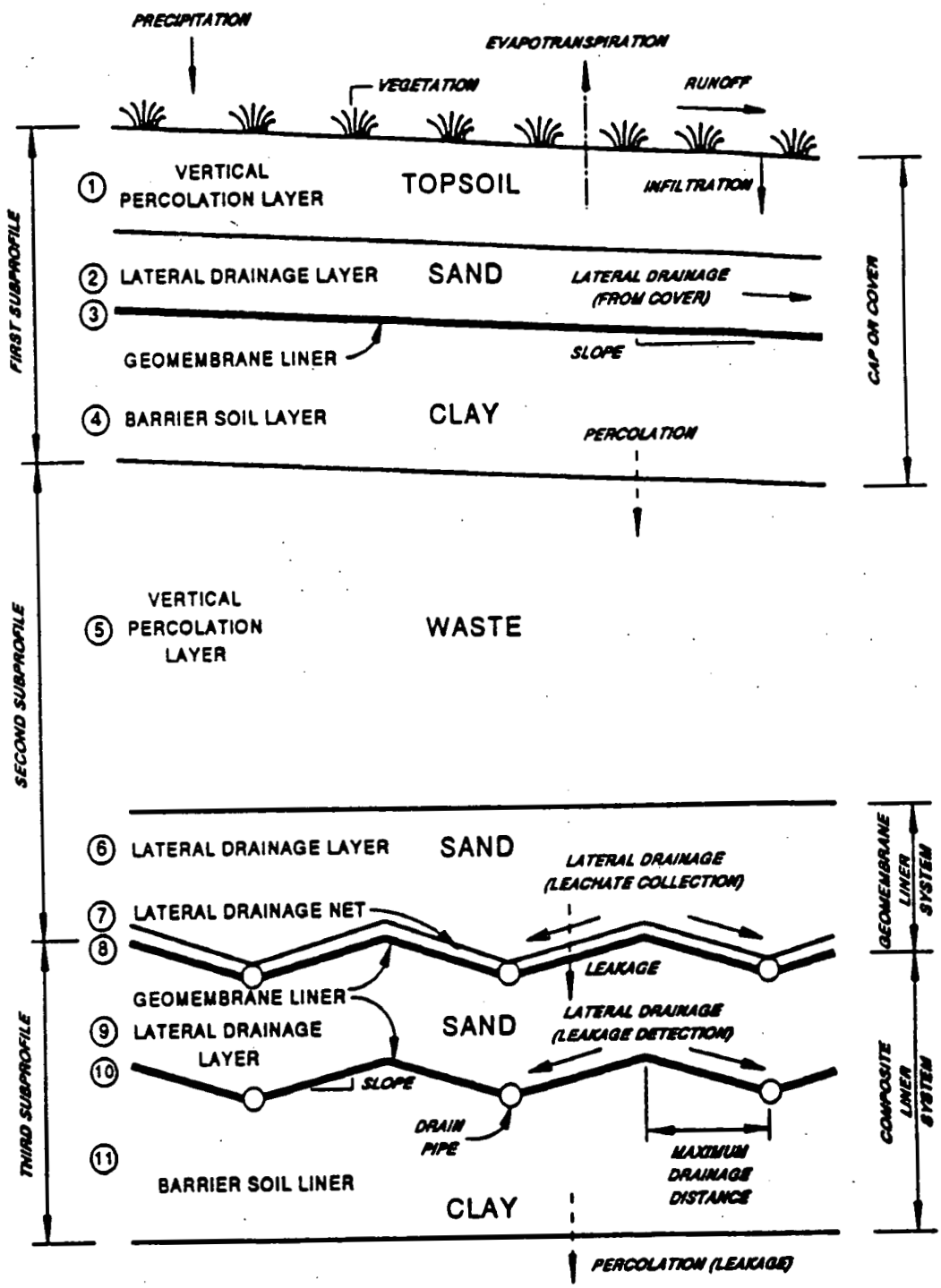


Figure 1. Schematic Profile View of a Typical Hazardous Waste Landfill

The layers in the landfill are typed by the hydraulic function that they perform. Four types are of layers are available: vertical percolation layers, lateral drainage layers, barrier soil liners and geomembrane liners. These layer types are illustrated in Figure 1. The topsoil and waste layers are generally vertical percolation layers. Sand layers above liners are typically lateral drainage layers; compacted clay layers are typically barrier soil liners. Geomembranes are typed as geomembrane liners. Composite liners are modeled as two layers. Geotextiles are not considered as layers unless they perform a unique hydraulic function.

Flow in a vertical percolation layer (e.g., layers 1 and 5 in Figure 1) is either downward due to gravity drainage or extracted by evapotranspiration. Unsaturated vertical drainage is assumed to occur by gravity drainage whenever the soil moisture is greater than the field capacity (greater than the wilting point for soils in the evaporative zone) or when the soil suction of the layer below the vertical percolation layer is greater than the soil suction in the vertical percolation layer. The rate of gravity drainage (percolation) in a vertical percolation layer is assumed to be a function of the soil moisture storage and largely independent of conditions in adjacent layers. The rate can be restricted when the layer below is saturated and drains slower than the vertical percolation layer. Layers, whose primary hydraulic function is to provide storage of moisture and detention of drainage, should normally be designated as vertical percolation layers. Waste layers and layers designed to support vegetation should be designated as vertical percolation layers, unless the layers provide lateral drainage to collection systems.

Lateral drainage layers (e.g., layers 2, 6, 7 and 9 in Figure 1) are layers that promote lateral drainage to collection systems at or below the surface of liner systems. Vertical drainage in a lateral drainage layer is modeled in the same manner as for a vertical percolation layer, but saturated lateral drainage is allowed. The saturated hydraulic conductivity of a lateral drainage layer generally should be greater than 1×10^{-3} cm/sec for significant lateral drainage to occur. A lateral drainage layer may be underlain by only a liner or another lateral drainage layer. The slope of the bottom of the layer may vary from 0 to 40 percent.

Barrier soil liners (e.g., layers 4 and 11 in Figure 1) are intended to restrict vertical flow. These layers should have hydraulic conductivities substantially lower than those of the other types of layers, typically below 1×10^{-6} cm/sec. The program allows only downward flow in barrier soil liners. Thus, any water moving into a liner will eventually percolate through it. The leakage (percolation) rate depends upon the depth of water-saturated soil (head) above the base of the layer, the thickness of the liner and the saturated hydraulic conductivity of the barrier soil. Leakage occurs whenever the moisture content of the layer above the liner is greater than the field capacity of the layer. The program assumes that barrier soil liner is permanently saturated and that its properties do not change with time.

Geomembrane liners (e.g., layers 3, 8 and 10 in Figure 1) are layers of nearly

impermeable material that restricts significant leakage to small areas around defects. Leakage (percolation) is computed to be the result from three sources: vapor diffusion, manufacturing flaws (pinholes) and installation defects (punctures, cracks, tears and bad seams). Leakage by vapor diffusion is computed to occur across the entire area of the liner as a function of the head on the surface of the liner, the thickness of the geomembrane and its vapor diffusivity. Leakage through pinholes and installation defects is computed in two steps. First, the area of soil or material contributing to leakage is computed as a function of head on the liner, size of hole and the saturated hydraulic conductivity of the soils or materials adjacent to the geomembrane liner. Second, the rate of leakage in the wetted area is computed as a function of the head, thickness of soil and membrane and the saturated hydraulic conductivity of the soils or materials adjacent to the geomembrane liner.

7. LEACHATE COLLECTION SYSTEM

7.1 Leachate Collection System
7.2 LCS Clogging Potential

7.1 Leachate Collection System

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: LEACHATE COLLECTION SYSTEM

Computations By: (Cognizant Engineer)
Signature: Robert A. Morgan III — Date: 95/10/6
Printed Name and Title: ROBERT A. MORGAN III, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: Paul J. Sabatini — Date: 6 Oct 95
Printed Name and Title: PAUL J. SABATINI, SR. STAFF ENGINEER

Computations Checked by:
Signature: Paul J. Sabatini — Date: 6 Oct 95
Printed Name and Title: PAUL J. SABATINI, SR. STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Robert A. Morgan III — Date: 95/10/6
Printed Name and Title: ROBERT A. MORGAN III, STAFF ENGINEER

Approved by: (PDP)
Signature: Majdy Ahmed Othman — Date: 95/10/6
Printed Name and Title: MAJDI A. OTHMAN, PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature: Rudolph Bonaparte — Date: 95/10/7
Printed Name and Title: Rudolph Bonaparte

Record of Revision (Number and initial all revisions)

NO.	REASON	DATE	BY	CHECKED	APPROVAL	
Ø	30% Submittal	NA	NA	NA	NA	No Changes
B	Preliminary Design EPA Submittal	15Dec95	[illegible]			

Signature: _____
Number: _____
Registration Stamp (if applicable)

Written By: RAM Date: 12DEC95 Reviewed by: PJS Date: 13 DEC 95

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 8.6

LEACHATE COLLECTION SYSTEM (LCS)

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this analysis is to evaluate the performance of the leachate collection system (LCS) components, which include the drainage layer, geotextile filter, soil filtration, and LCS collector pipe.

METHOD OF ANALYSIS

Drainage Layer: The maximum head, average head, and transmissivity of the drainage layer were calculated.

Geotextile Filter Design: The retention, permeability, and clogging criteria were calculated.

Soil Filtration Characteristics: The required particle size distribution was calculated for the protective soil layer.

LCS Collector Pipe Design: The pipe flow capacity, pipe filtration, and structural stability (wall crushing, wall buckling, and excessive ring deflection) were calculated for the LCS collector pipe design.

CONCLUSIONS

Drainage Layer:

- maximum anticipated leachate head, $h_{max} = 2.05$ in.
- average anticipated leachate head, $h_{avg} = 1.13$ in.
- calculated transmissivity, $\theta_d = 3.05\ cm^2/s$

Geotextile Filter Design:

- required equivalent opening size, $O_{95} \leq 210\ \mu m$
- required geotextile hydraulic conductivity, $k_{geotextile} > 10^{-5}$ cm/s
- required porosity, $n_g > 30\%$
- required percent open area, $A > 4\%$

Written By: RAM Date: 12DEC95 Reviewed by: PJS Date: 13 Dec 95

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.6

Soil Filtration Characteristics:

- required d_{85} of protective soil layer ≥ 0.4 mm
- required d_{15} of protective soil layer ≤ 0.1 mm

LCS Collector Pipe Design:

- pipe flow capacity, $Q_p = 198$ gpm
- required flow capacity, $Q_{pr} = 7.9$ gpm
- flow capacity factor of safety, $Q_p/Q_{pr} = 25$
- maximum allowable perforation diameter, $d_{h\,max} = 0.39$ in.
- factor of safety against pipe wall crushing, $FS_{wc} = 5.3$
- factor of safety against pipe wall buckling, $FS_{wb} = 4.4$
- factor of safety against excessive ring deflection, $FS_{rd} = 3.72$

Written By: RAM Date: 95/10/5 Reviewed by: MAO Date: 95/10/5

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 8.6

RB 95/10/5

LEACHATE COLLECTION SYSTEM (LCS)
CALCULATION PROCEDURES

INTRODUCTION

The purpose of this package is to present the calculation procedures for the leachate collection system. In particular, this package addresses the following analyses:

- drainage layer (average and maximum leachate head and transmissivity);
- geotextile filter design;
- soil filtration characteristics; and
- LCS collector pipe design (flow capacity, filtration characteristics and structural stability).

METHODS OF ANALYSIS

DRAINAGE LAYER

Leachate Head: The HELP model estimates leachate head in the LCS drainage layer. As a check, the closed-form analytical solution described by Giroud and Houlihan [1995] will be used to estimate leachate head. For the analytical solution, the leachate generation rate estimated using HELP and assumed characteristics of the leachate collection layer will be used to estimate the maximum and average hydraulic heads in the drainage layer.

Verification will be made that the maximum hydraulic head in the drainage layer is smaller than the maximum allowable head according to applicable regulations (i.e., 12 in.) and is smaller than the LCS drainage layer thickness. The average hydraulic head will be used to estimate the infiltration through the primary liner. The infiltration analysis is described elsewhere.

The following six-step approach based on Giroud and Houlihan [1995] will be used to calculate the maximum leachate head, h_{max}, and average leachate head, h_{avg};

- *Step 1.* Calculate the dimensionless parameter λ using the following equation:

$$\lambda = \frac{q_i}{k \tan^2 \beta} \qquad (1)$$

where: q_i = the impingement rate of flow into the drainage layer; k = hydraulic conductivity of the LCS drainage layer material; and β = angle between the horizontal and slope.

Written By: RAM Date: 95/10/5 Reviewed by: MAS Date: 95/10/5

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.6

RB 95/10/5

- *Step 2.* Use Equations 2 and 3 to calculate T_{max}.

$$T_{max} = j\left[\frac{\sqrt{1+4\lambda}-1}{2}\frac{\tan\beta}{\cos\beta}\right](L) \quad (2)$$

$$j = 1 - 0.12\exp\left[-\left[\log(8\lambda/5)^{5/8}\right]^2\right] \quad (3)$$

where: T_{max} = maximum leachate thickness; L = the length of the slope; j = corrective coefficient; λ = parameter defined by Equation (1); and β = angle between the horizontal and slope.

- *Step 3.* Calculate the maximum leachate head, h_{max}, from Equation 4.

$$h_{max} = T_{max}\cos\beta \quad (4)$$

- *Step 4.* Use Table 1 or Figure 1 to obtain T_{avg}/T_{max}.
- *Step 5.* From T_{max} obtained in Step 2 and T_{avg}/T_{max} obtained in Step 4, calculate T_{avg}.
- *Step 6.* Calculate the average leachate head, h_{avg}, from Equation 5.

$$h_{avg} = T_{avg}\cos\beta \quad (5)$$

Transmissivity: The minimum required transmissivity of the LCS drainage layer will be calculated as the product of the hydraulic conductivity of the drainage layer and the drainage layer thickness as shown in the following equation:

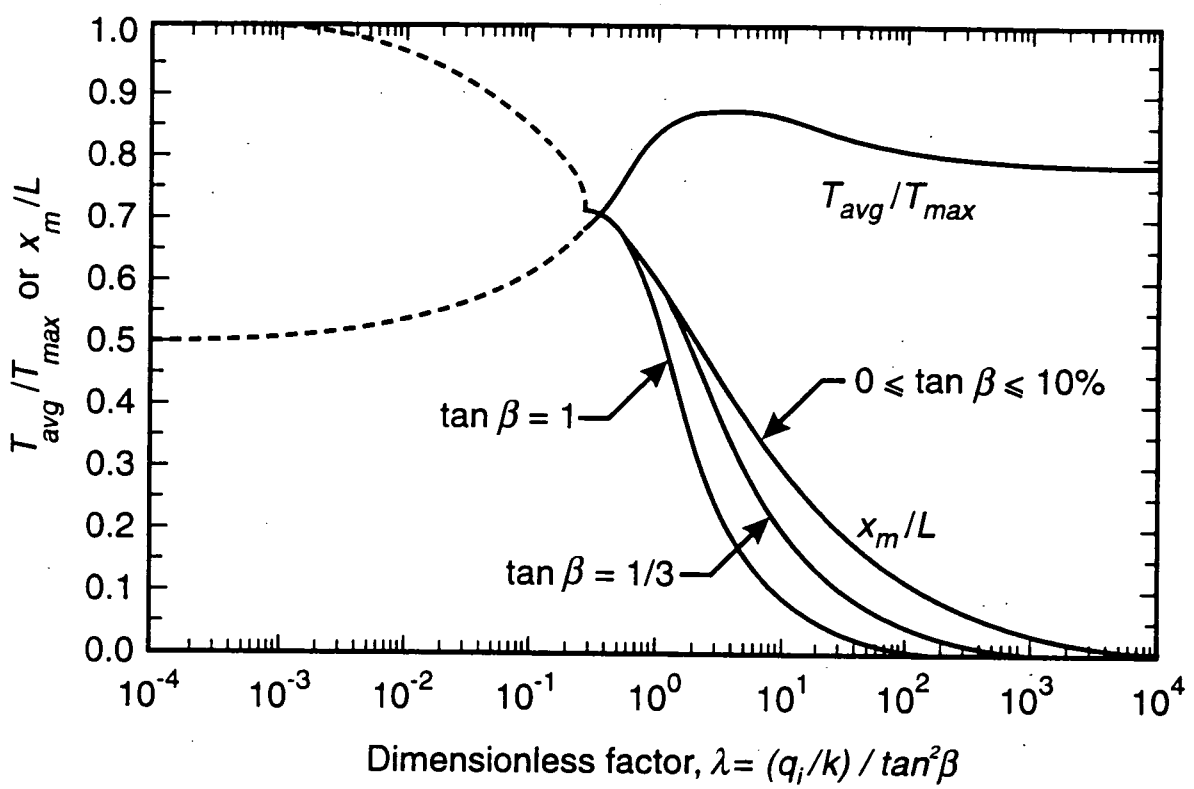
$$\theta_d = k_d D_d \quad (6)$$

where: θ_d = hydraulic transmissivity of the drainage layer; k_d = the hydraulic conductivity of the drainage material; and D_d = the thickness of the drainage layer.

GEOTEXTILE FILTER DESIGN

The LCS geotextile filter will separate the protective soil layer from the LCS drainage layer as shown in Figure 2. The LCS geotextile filter will be designed based on criteria proposed by Christopher and Holtz [1994], Giroud [1982], and USEPA [1987] which include a retention criterion, a permeability criterion, and a clogging criterion. These criteria are described in Table 2. Survivability requirements, such as grab, tear, puncture, and burst strength, to ensure adequate resistance to stresses applied on the geotextile during installation and during design life will be included in the material specifications for this project.

Figure 1: Values of T_{avg}/T_{max} and x_m/L.



X_m = ABSCISSA OF THE MAXIMUM OF THE LEACHATE PHREATIC SURFACE (m) (FROM CREST OF SLOPE)

Table 1: Values of T_{avg}/T_{max} and x_m/L.

$\lambda = \frac{q_i/k}{\tan^2\beta}$	$\frac{T_{avg}}{T_{max}}$	$\frac{x_m}{L}$	$\lambda = \frac{q_i/k}{\tan^2\beta}$	$\frac{T_{avg}}{T_{max}}$	$\frac{x_m}{L}$
0.00	0.500	1.000	0.50	0.73	0.68 - 0.68 - 0.67
0.002	0.50	0.99	0.53	0.74	0.68 - 0.68 - 0.66
0.005	0.51	0.98	0.57	0.75	0.67 - 0.67 - 0.65
0.01	0.52	0.97	0.62	0.76	0.66 - 0.66 - 0.64
0.02	0.53	0.94	0.67	0.77	0.66 - 0.66 - 0.63
0.03	0.54	0.92	0.73	0.78	0.65 - 0.65 - 0.61
0.04	0.55	0.90	0.80	0.79	0.64 - 0.63 - 0.59
0.05	0.56	0.89	0.87	0.80	0.63 - 0.62 - 0.57
0.07	0.57	0.86	0.95	0.81	0.62 - 0.61 - 0.55
0.08	0.58	0.85	1.05	0.82	0.60 - 0.60 - 0.53
0.09	0.59	0.84	1.16	0.83	0.59 - 0.58 - 0.51
0.10	0.60	0.83	1.32	0.84	0.57 - 0.56 - 0.47
0.12	0.61	0.82	1.58	0.85	0.57 - 0.53 - 0.43
0.14	0.62	0.80	2.0	0.86	0.51 - 0.49 - 0.37
0.15	0.63	0.79	3.2	0.87	0.44 - 0.41 - 0.26
0.16	0.64	0.78	5.5	0.86	0.36 - 0.31 - 0.16
0.17	0.65	0.77	8.5	0.85	0.30 - 0.23 - 0.11
0.18	0.66	0.76	13	0.84	0.25 - 0.17 - 0.07
0.20	0.67	0.75	19	0.83	0.21 - 0.13 - 0.05
0.23	0.68	0.73	30	0.82	0.17 - 0.09 - 0.03
0.25	0.69	0.71	55	0.81	0.13 - 0.05 - 0.02
0.35	0.70	0.70	135	0.80	0.08 - 0.02 - 0.01
0.40	0.71	0.70	1000	0.79	0.03 - 0.00 - 0.00
0.45	0.72	0.69	∞	0.785	0 - 0 - 0

Note: This table was established using Equations 46, 50 and 51 for values of $\lambda \geq 0.25$, and using charts, published by McEnroe and Schroeder (1988), for $\lambda < 0.25$. The ratio T_{avg}/T_{max} varies very little with the slope angle, β; when β varies between 0 and 45°, the change in T_{avg}/T_{max} is typically less than 0.03. Therefore, the tabulated values of T_{avg}/T_{max} (which are average values) are either unaffected or affected by $\pm$ 0.01. The two limit values for T_{avg}/T_{max}, i.e. 1/2 (for $\lambda = 0$) and $\pi/4$ (for $\lambda = \infty$), are accurate. For $\lambda < 0.5$, the values of x_m/L also vary very little with β; in this case, when β varies between 0 and 45°, the tabluated values of x_m/L are either unaffected or affected by $\pm$ 0.01. For $\lambda > 0.5$, the influence of β on x_m/L is significant. To illustrate the influence of β in this case, three values of x_m/L are tabulated in the last column: the value on the left is for $0 < \tan\beta < 10\%$, the middle value is for $\tan\beta = 1/3$ (i.e. a 1V:3H slope) and the value on the right is for $\tan\beta = 1$ (i.e. a 1V:1H slope) (see Figure 11). It should be noted that, in the charts by McEnroe and Schroeder (1988), the parameter λ is not used. Therefore, it does not appear in those charts that T_{avg}/T_{max} and, to a certain extent, x_m/L are independent of β.

Figure 2: Liner System on Landfill Base.

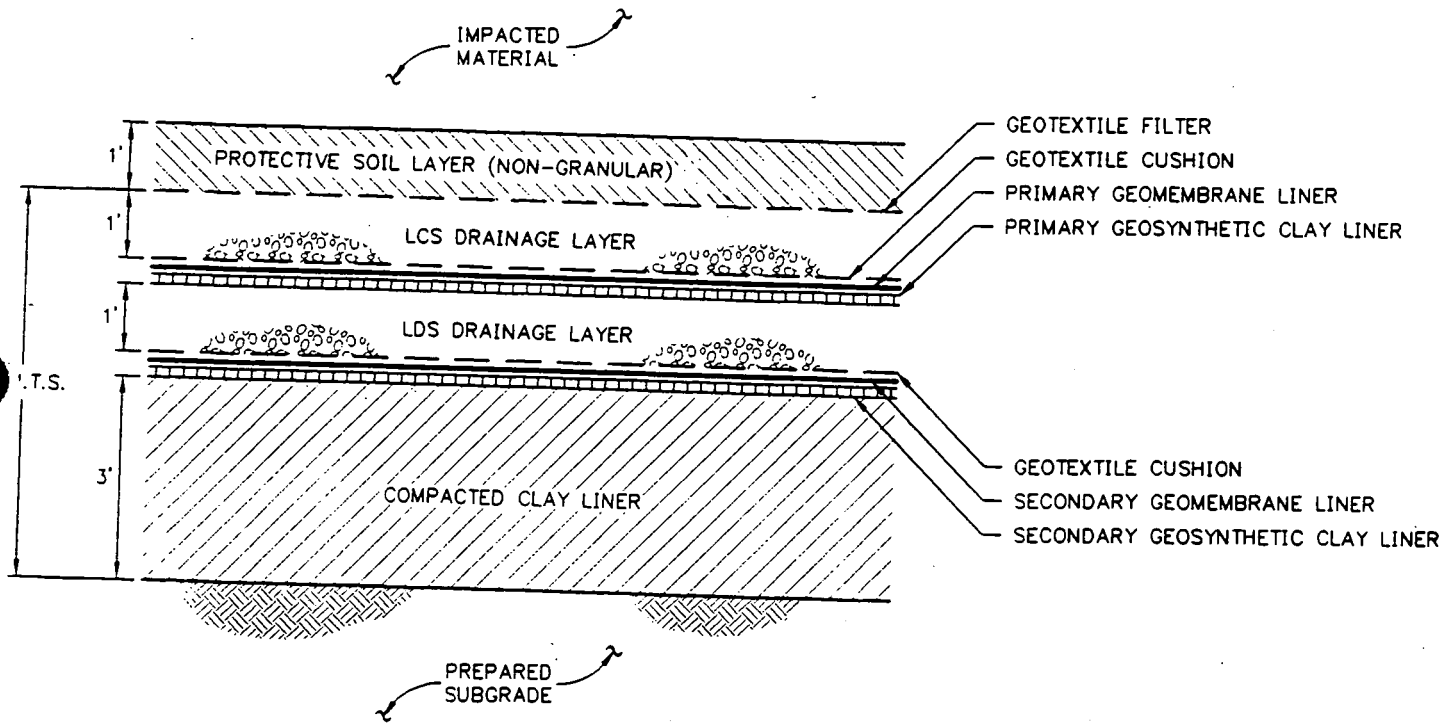


Table 2: Filter Criteria for Geotextile, Adapted From [Christopher and Holtz, 1984; Giroud, 1982; and USEPA, 1987]

1. RETENTION CRITERION

1.1 Soils with less than 50 percent particles < 0.075 mm (> US Sieve No. 200)

	Density index of the soil (Relative density)	Linear coefficient of uniformity of the soil	
		$1 < C'_u < 3$	$C'_u > 3$
loose soil	$I_D < 35\%$	$O_{95} < C'_u\, d_{50}$	$O_{95} < \frac{9}{C'_u} d_{50}$
medium dense soil	$35\% < I_D < 65\%$	$O_{95} < 1.5\, C'_u\, d_{50}$	$O_{95} < \frac{13.5}{C'_u} d_{50}$
dense soil	$I_D > 65\%$	$O_{95} < 2\, C'_u\, d_{50}$	$O_{95} < \frac{18}{C'_u} d_{50}$

1.2 Soils with more than 50 percent particles < 0.075 mm (US Sieve 200)

$O_{95} \leq 210\ \mu m$ ($\geq$ US Sieve 70)

2. PERMEABILITY CRITERION

2.1 Critical and/or Severe Applications

$k_{geotextile} > 10\ k_{soil}$

Table 2 (Continued): Filter Criteria for Geotextile, Adapted From [Christopher and Holtz, 1984; Giroud, 1982; and USEPA, 1987]

2.2 Noncritical and Nonsevere Applications

$k_{geotextile} > k_{soil}$

3. CLOGGING CRITERION

Nonwoven geotextiles: porosity, $n_g > 30\%$

Woven geotextiles: percent open area, $A > 4\%$

Notes: O_{95} is the apparent opening size (AOS) of the geotextile.

$$C_u' = \sqrt{d_{100}' / d_0'}$$

where d'_{100} and d'_0 are the top and bottom extremities, respectively, of a line drawn through the central portion of a soil particle-size distribution curve.

d_{50} and d_{85} are soil particle sizes for which 50% and 85%, respectively, of particles are finer by weight.

$I_D = (e - e_{min})/(e_{max} - e_{min})$, where: e = soil void ratio; e_{min} = soil minimum void ratio; and e_{max} = soil maximum void ratio.

$k_{geotextile}$ = geotextile hydraulic conductivity

k_{soil} = soil hydraulic conductivity

The porosity n_g (dimensionless) is calculated as follows: $n_g = 1 - \mu_g/(\rho_g\, t_g)$, where: μ_g = geotextile mass per unit area; ρ_g = polymer density; and t_g = geotextile thickness. Basic SI units are: μ_g (kg/m^2), ρ_g (kg/m^3), and t_g (m).

The geotextile filter must have openings which are small enough to retain fine-grained soil particles and prevent them from entering the LCS drainage layer, which could result in clogging or flow capacity reduction of the LCS drainage layer. The geotextile filter must also have openings which are large enough to allow leachate to pass through the soil/geotextile interface without significant flow impedance.

SOIL FILTRATION CHARACTERISTICS

It is assumed that in the very long term, the geotextile filter may not provide adequate filtration. Therefore, a check is made to ensure the soils are self filtering. The following filter criteria shall be followed to prevent particle migration or clogging of components:

- (d_{15} of LCS drainage layer material / d_{85} of protective soil layer material) ≤ 3 to 5.
- (d_{15} of LCS drainage layer material / d_{15} of protective soil layer material) ≥ 3 to 5.

LCS COLLECTOR PIPE DESIGN

The function of the LCS collector pipes is to convey the leachate collected by the LCS drainage layer to the LCS sumps. Collector pipes must have adequate flow capacity to convey the leachate and adequate structural resistance to withstand the applied loads. In addition, since collector pipes are perforated to permit flow of leachate into the pipes, the size of the perforations must be large enough to accept the flow of leachate into the pipe without the buildup of head, and small enough to prevent pipe bedding material from entering the pipe.

Pipe Flow Capacity: LCS pipe flow capacity should be greater than the maximum rate of flow into the pipe. The pipe flow capacity will be calculated using Manning's equation as follows:

$$Q_p = \frac{R_h^{0.66} i_p^{0.5} A_p}{n} \qquad (7)$$

where: Q_p = collector pipe flow capacity; R_h = hydraulic radius (defined as the ratio of the flow area to the perimeter of the wetted area; for a pipe with a circular cross section $R_h = B_i/4$; where B_i is pipe inner diameter); i_p = hydraulic gradient (slope of the collector pipe); A_p = cross-sectional area of the pipe; and n = Manning's roughness coefficient.

The rate of flow of leachate entering a collector pipe may be calculated by multiplying the rate of impingement on the LCS drainage layer by the plan area of the LCS drained by the pipe:

$$Q_{pr} = q_i A_d \tag{8}$$

where: Q_{pr} = flow capacity required for the collector pipes: q_i = design impingement rate on the LCS drainage layer; and A_d = plan area of the LCS drained by the pipe.

Pipe Filtration Characteristics The ability of the pipes to provide filtration may be characterized by the size of the perforations. Maximum allowable diameter of perforations in the collector pipe will be specified to ensure retention of LCS gravel particles. The maximum allowable diameter of perforations in the collector pipes to provide retention of gravel particles may be determined as follows [USEPA, 1983]:

$$d_{h\,\max} = \frac{d_{85}}{F} \tag{9}$$

where: $d_{h\,max}$ = maximum perforation diameter to provide particle retention; d_{85} = particle size of the pipe bedding material for which 85 percent by weight of the particles are finer; and F = factor varying from 1.2 to 2. For pipes with slots, replace d with w, where w is slot width in Equation 9.

Pipe Structural Stability Calculations will be performed to ensure the LCS pipe is able to withstand the loads applied on it with an adequate factor of safety. Failure mechanisms that will be checked are: (i) wall crushing; (ii) wall buckling; and (iii) excessive ring deflection. Stresses applied on the LCS pipe will be estimated for: (i) initial condition (Figure 3) (i.e., stresses due to traffic when a 6-in. thick layer of LCS drainage layer material and a 1-ft thick protective soil layer are placed on the pipe); and (ii) final condition (i.e., stresses due to overburden materials). Plastic pipe can be designed to resist failure by the above mechanisms using design methods presented in the technical literature [Uni-Bell, 1991; Phillips 66, 1988; and Chevron, 1992].

As indicated previously, the initial condition assumes that the collector pipe is buried under 6-in. of LCS drainage layer material and 1-ft of protective soil layer. The stresses due to traffic are assumed to be applied by a truck with a capacity of 35 tons and a wheel load of 20,000 lb when full. The total

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stress on the pipe is then the sum of the stresses applied by the soil layers and the stresses applied by the loaded truck, which can be calculated as described by ASCE [1979] as follows:

$$\sigma_{ic} = \gamma_p D_p + C_s \frac{PF_{ic}}{L_{ic} B_c} \tag{10}$$

where: σ_{ic} = stress on the collector pipe: γ_p = unit weight of the soil materials; D_p = thickness of the soil cover; B_c = outer pipe diameter; C_s = load coefficient (Table 3), which is a function of $B_c/(2D_p)$ and $L_{ic}/(2D_p)$; P = concentrated load; F_{ic} = impact factor accounting for dynamic loads; and L_{ic} = effective length of pipe, which is arbitrarily defined as follows by ASCE [1979]: L_{ic} = 3 ft if pipe is longer than 3 ft, and L_{ic} = actual pipe length if pipe is shorter than 3-ft.

During the post-closure condition, the stress applied to the pipe is due to the overburden materials above the pipe (i.e., protective soil cover material, compacted waste, and cover soils).

Wall Crushing: Wall crushing can occur when the stress in the pipe wall, due to external vertical pressure, exceeds the compressive strength of the pipe material. The factor of safety against pipe wall crushing may be calculated using the following equation:

$$FS_{wc} = \frac{2\sigma_y}{(SDR-1)\sigma_{max}} \tag{11}$$

where: FS_{wc} = factor of safety against pipe wall crushing; σ_y = compressive yield strength of the pipe; SDR = standard dimension ratio of the pipe; and σ_{max} = maximum stress applied to the pipe.

Wall Buckling: Wall buckling, a longitudinal wrinkling in the pipe wall, can occur when the external vertical pressure exceeds the critical buckling pressure of the pipe/bedding aggregate system. The factor of safety against pipe wall buckling may be calculated using the following equation:

$$FS_{wb} = \frac{1.2}{\sigma_{max}} \left[\frac{E'E}{(SDR)^3} \right]^{1/2} \tag{12}$$

where: FS_{wb} = factor of safety against pipe wall buckling; σ_{max} = maximum stress applied to the pipe; E' = modulus of soil reaction for pipe bedding; E = modulus of elasticity of the pipe material; and SDR = standard dimension ratio of the pipe.

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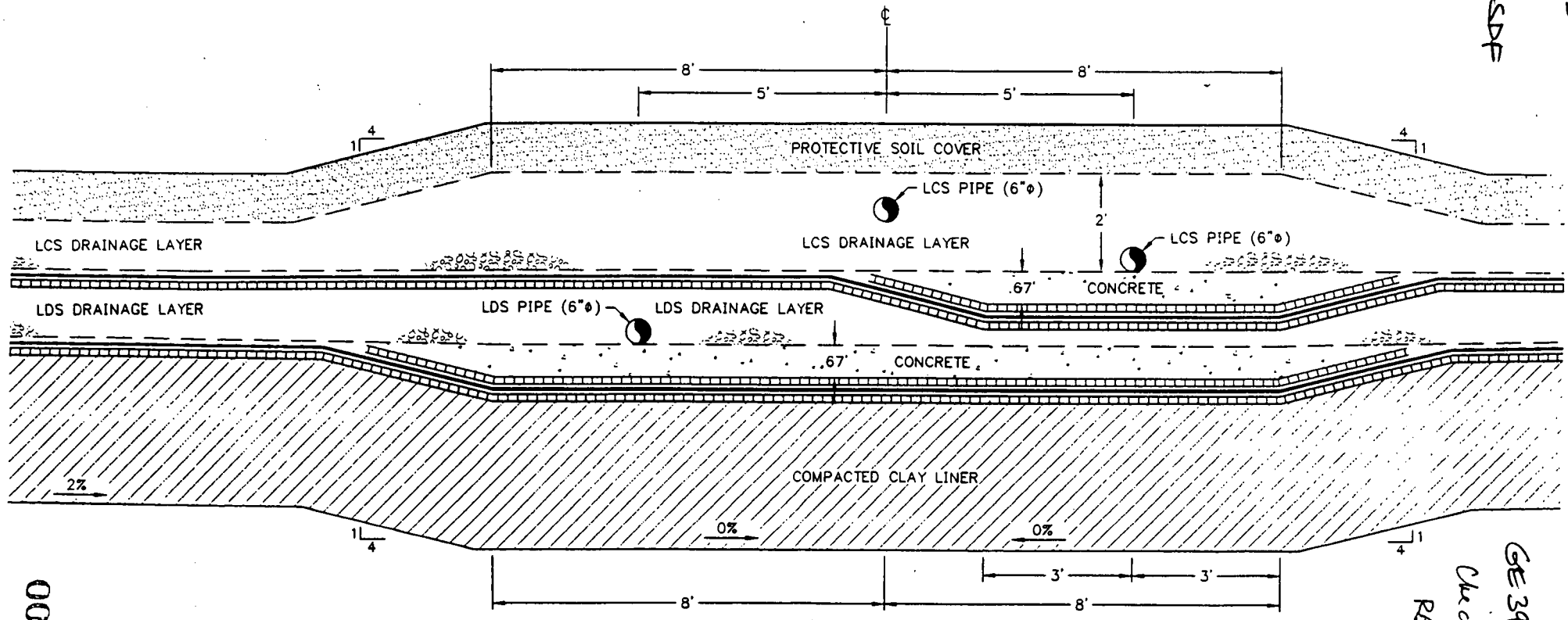

Figure 3: Leachate Collection and Leakage Detection Sump.

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Table 3: Load Coefficient C_s.

$\frac{B_c}{2D_p}$	$\frac{L_{1c}}{2D_p}$													
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	5.0
0.1	0.019	0.037	0.053	0.067	0.079	0.089	0.097	0.103	0.108	0.112	0.117	0.121	0.124	0.128
0.2	0.037	0.072	0.103	0.131	0.155	0.174	0.189	0.202	0.211	0.219	0.229	0.238	0.244	0.248
0.3	0.053	0.103	0.149	0.190	0.224	0.252	0.274	0.292	0.306	0.318	0.333	0.345	0.355	0.360
0.4	0.067	0.131	0.190	0.241	0.281	0.320	0.349	0.373	0.391	0.405	0.425	0.440	0.454	0.460
0.5	0.079	0.155	0.224	0.284	0.336	0.379	0.414	0.441	0.463	0.481	0.505	0.525	0.540	0.548
0.6	0.089	0.174	0.252	0.320	0.379	0.428	0.467	0.499	0.524	0.544	0.572	0.596	0.613	0.624
0.7	0.097	0.189	0.274	0.349	0.414	0.467	0.511	0.546	0.584	0.597	0.628	0.650	0.674	0.688
0.8	0.103	0.202	0.292	0.373	0.441	0.499	0.546	0.584	0.615	0.620	0.674	0.703	0.725	0.740
0.9	0.108	0.211	0.306	0.391	0.463	0.524	0.574	0.615	0.647	0.673	0.711	0.742	0.766	0.784
1.0	0.112	0.219	0.318	0.405	0.481	0.544	0.597	0.639	0.673	0.701	0.740	0.774	0.800	0.816
1.2	0.117	0.229	0.333	0.425	0.505	0.572	0.628	0.674	0.711	0.740	0.783	0.820	0.849	0.868
1.5	0.121	0.238	0.345	0.440	0.525	0.596	0.650	0.703	0.742	0.774	0.820	0.861	0.894	0.916
2.0	0.124	0.244	0.355	0.454	0.540	0.613	0.674	0.725	0.766	0.800	0.849	0.894	0.930	0.956

Note: This dimensionless coefficient has been obtained by elastic theory [ASCE, 1979].

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Excessive Ring Deflection: Ring deflection is the change in vertical diameter of the pipe as the pipe/bedding aggregate system deforms under the external vertical pressure. The actual ring deflection of the pipe must be less than the allowable ring deflection of the pipe. The factor of safety against excessive ring deflection may be calculated using the following equation:

$$FS_{RD} = \frac{\Delta_R E'}{100\sigma_{max}} \tag{13}$$

where: Δ_R = allowable ring deflection in percent; E' = modulus of soil reaction for pipe bedding; and σ_{max} = maximum stress applied to the pipe. The allowable ring deflection of the pipe will be obtained from the manufacturers and technical literature.

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LEACHATE COLLECTION SYSTEM (LCS)
DATA VERIFICATION

INTRODUCTION

As described in the calculation procedures package, the following analyses will be performed:

- drainage layer (average and maximum leachate head and transmissivity);
- geotextile filter design;
- soil filtration characteristics; and
- LCS collector pipe design (flow capacity, filtration characteristics and structural stability).

In order to perform the analyses described above, the following data is required:

DRAINAGE LAYER

Leachate Head:

q_i = the maximum impingement rate of flow into the drainage layer = 0.0646 in. /day (peak daily value from HELP leachate generation analyses results; Case 1B) = 1.9×10^{-6} cm/sec

k = hydraulic conductivity of the LCS drainage layer material = 0.1 cm/sec

β = angle between the horizontal and slope = 1.28° (2.24%)

L = the length of the slope = 224 ft (2688 in.)

Transmissivity:

k = hydraulic conductivity of the drainage material = 0.1 cm/sec

D = the thickness of the drainage layer = 12 in. (30.5 (cm)

GEOTEXTILE FILTER DESIGN

It is expected that more than 50% of particles of the protective soil will be < 0.075 mm (i.e., U.S. sieve 200).

k_{soil} = protective soil hydraulic conductivity = 1×10^{-6} cm/s (assumed)

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SOIL FILTRATION CHARACTERISTICS

It is anticipated that the brown clay onsite will be used as the protective soil layer and crushed stone will be used as the drainage layer. The following values were taken from the attached grain-size distribution chart:

- d_{15} of LCS drainage layer material = particle size of LCS drainage layer material for which 15 percent by weight of the particles are finer = 0.3 - 2.0 mm.
- d_{85} of LCS drainage layer material = particle size of LCS drainage layer material for which 85 percent by weight of the particles are finer = 20 - 30 mm.

LCS COLLECTOR PIPE DESIGN

The geometric characteristics of the 6-in. nominal diameter HDPE SDR-11 pipes are as follows:

- outer diameter, B_c = 6.625 in.;
- wall thickness, t = 0.602 in.;
- inner diamter, B_i = 5.421 in.;
- mean radius, r = 3.01 in.; and
- perforation diameter, d_h = 0.625 in.

The characteristics of the pipes to be used in structural stability calculations, as estimated from manufacturer's literature [Phillips 66, 1988], are as follows:

- modulus of elasticity of 2.74×10^6 psf after 50 years;
- compressive yield strength of the pipe 216,000 psf; and
- allowable ring deflection of SDR-11 pipe used for gravity flow is 7.0 percent.

Pipe Flow Capacity:

$R_h = B_i / 4$ = hydraulic radius = 1.36 in. (3.45 cm)

i_p = hydraulic gradient = 0.57° (1%)

$A_p = \pi B_i^2 / 4$ = cross-sectional area of the pipe = 23.1 in^2 (1.5×10^{-2} m^2)

n = Manning's roughness coefficient = 0.013 $s/m^{0.33}$ (for smooth pipe)

Required Capacity for Collector Pipes:

q_i = the impingement rate of flow into the drainage layer = 0.06447 in./day (peak daily value from HELP leachate generation analyses results; Case 1) = 1.9×10^{-6} cm/sec

A_d = plan area of the LCS drained by the pipe = 6.5 acres

.02 **GRANITE CURBING:** The granite from which the curbing is made l have a percentage of wear of not more than 65.

TYPES OF CURBING: The granite curbs covered by these specifications are two types as follows:

TYPE A: All granite for Type A curbs shall be of the thickness and height indicated on the Plans, and shall be cut in lengths of at least 5 feet and not more than 10 feet. Tops of all curbs shall be dressed to an even, smooth surface for full length, have straight even edges and shall slope ¼ of an inch from the back down to the front edge. All Type A curbing shall have the ends squared so as to permit joints, being made not more than ⅛ inch wide for the full depth. The back face shall be hand-dressed to a depth of at least 4 inches below that part of the back which is to be exposed. The front face of Type A Granite Curb shall be hand-dressed to a depth of one inch below the indicated elevation of the underside of the existing or proposed base course, pavement or gutter. The ends of the circular curb length shall be cut along radial lines so as to permit joints not more than ⅛ inch wide. Circular curb must conform accurately to the required radius. Dressed surfaces shall not have projections or depressions more than ⅛ inch from the plane surface of the curb.

TYPE B: Unless otherwise specified, all Type B granite curbing shall be 5 inches thick and 17 inches deep, and at least 5 feet in length. The curb front shall have a top margin draught and shall have a smooth face 10 inches deep. A quarry face, if free from holes, and with all bumps exceeding allowed tolerance pointed level, will be considered a smooth face. Tops of all curb shall present even, smooth faces for the full length. Joints shall be squared and when abutted with adjacent sections shall present no crack or joint exceeding ½ inch in width. The allowable tolerances in dimensions and faces or top surfaces of curbing are as follows:

Thickness	5¼" plus or minus ¼"
Depth	17" plus or minus 1"
Top Surface	¼" in 5 feet
Side Surface	½" in 5 feet

Circular or radial curb as required or as shown on Plans, in addition to the quality and face requirements for straight curbs, shall conform accurately to the required radius. The ends of the circular curb sections shall be cut radially and square with the top of the curb, so that when the sections are joined, the crack between sections will not be more than ⅛ inch wide.

TESTS: Methods of Tests shall be in accordance with the following:

Percent Wear AASHTO: T 96

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SECTION 806—AGGREGATE FOR DRAINAGE

806.01 COARSE AGGREGATE FOR UNDERDRAIN: This material shall be composed of aggregate meeting the requirements of Class "A" or "B" Coarse Aggregate with the gradation meeting the requirements for Size No. 89, Table 800.01.H.

A. TEST: Method of Test shall be in accordance with the following:

Sieve Analysis AASHTO: T 27

806.02 CRUSHED STONE DRAINAGE MATERIAL: This material shall be composed of aggregate meeting the requirements of Class "A" or "B" Coarse aggregate meeting the following gradation requirements:

SIZE	PERCENT BY WEIGHT
Passing 2" Sieve	100
Passing 1½" Sieve	95-100
Passing No. 10 Sieve	10-35
Passing No. 100 Sieve	0-10

A. TEST: Method of Test shall be in accordance with the following:

Sieve Analysis AASHTO: T 27

806.03 DRAINAGE BLANKET: This material shall be composed of aggregate meeting the requirements of class "A" or "B" Coarse Aggregate meeting the following gradation requirements:

SIZE	PERCENT BY WEIGHT
Passing No. 10 Sieve	75-100
Passing No. 40 Sieve	25-50
Passing No. 60 Sieve	0-25
Passing No. 200 Sieve	0-8
Percent Clay	0-5

A. TESTS: Method of Tests shall be in accordance with the following:

Sieve Analysis AASHTO: T 27 & T 11

SECTION 810—ROADWAY MATERIALS

810.01 ROADWAY MATERIALS: Materials for roadway construction shall not contain any logs, stumps, sod, weeds, or other perishable matter. They are divided into six major classes, and Classes I, II and III are further subdivided and are identified by description and physical property requirements as specified in Table 810-1. Classes IV, V and VI are identified by descriptive requirements.

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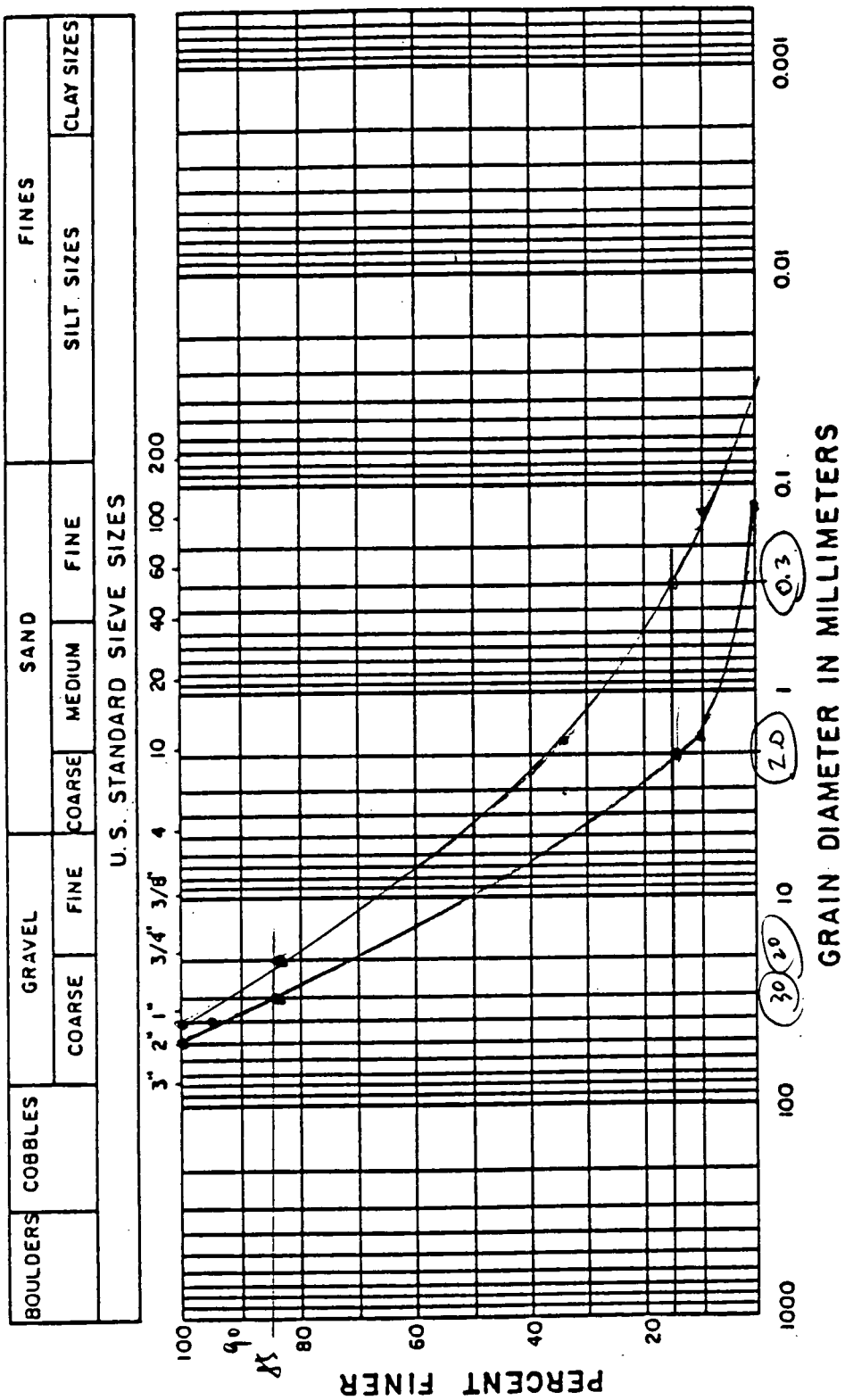
SOIL CLASSIFICATION TEST RESULTS

SAMPLE NO. _____ DEPTH _____

SOIL DESCRIPTION _____

Crushed Stone Dump Material



LIQUID LIMIT (LL) _____

PLASTIC LIMIT (PL) _____

PLASTICITY INDEX (PI) _____

COEFFICIENT OF UNIFORMITY (C_U) _____

COEFFICIENT OF CURVATURE (C_C) _____

UNIFIED SOIL CLASSIFICATION (USC) _____

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FIGURE NO.	
PROJECT NO.	
DOCUMENT NO.	
PAGE NO.	

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Required Capacity for Collector Pipes:

q_i = the impingement rate of flow into the drainage layer = 0.06447 in./day (peak daily value from HELP leachate generation analyses results; Case 1) = 1.9×10^{-6} cm/sec

A_d = plan area of the LCS drained by the pipe = 6.5 acres

Pipe Filtration:

d_{85} = particle size of the pipe bedding material for which 85 percent by weight of the particles are finer = 20 - 30 mm

F = factor varying from 1.2 to 2 = 2 (conservative estimate)

Structural Stability:

γ_p = unit weight of the soil materials = 125 pcf (18.8 kN/m^3)

D_p = thickness of the soil cover = Case 1 = 18 in.; Case 2 = assumed 65 ft

P = concentrated load = 20,000 lb (90 kN) (assumed based on truck with a capacity of 35 tons and a wheel load of 20,000 lb when full)

F_{ic} = impact factor accounting for dynamic loads = 1.5 [ASCE, 1979; see procedures package for reference]

B_c = outer pipe diameter = 0.552 ft (0.168 m)

L_{ic} = effective length of pipe = 3 ft (1 m)

Wall Crushing:

σ_y = compressive yield strength = 216,000 psf (10,346 kPa)

SDR = standard dimension ratio of the pipe = 11

Wall Buckling:

E' = modulus of soil reaction for pipe bedding = 432,000 psf (20,560 kPa) (Countryside)

E = modulus of elasticity of the pipe material = 2.74×10^6 psf (1.31×10^5 kPa) (50-yr design life)

SDR = standard dimension ratio of the pipe = 11

Excessive Ring Deflection:

Δ_R = allowable ring deflection in percent = 7 percent

E' = modulus of soil reaction for pipe bedding = 432,000 psf (20,560 kPa)

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LEACHATE COLLECTION SYSTEM (LCS)

CALCULATION RESULTS

DRAINAGE LAYER

- LEACHATE HEAD:

$$\lambda = \frac{q_i}{k \tan^2\beta} = \frac{1.9\times10^{-6}\ \frac{cm}{s}}{\left(0.1\ \frac{cm}{s}\right)\tan^2 1.28^\circ}$$

$$\underline{\underline{\lambda = 0.038}}$$

$$j = 1 - 0.12 \exp\left[-\left[\log\left(\frac{8\lambda}{5}\right)^{5/8}\right]^2\right]$$

$$\underline{\underline{j = 0.933}}$$

$$T_{max} = j\left[\frac{\sqrt{1+4\lambda}-1}{2}\ \frac{\tan\beta}{\cos\beta}\right] L$$

$$= 0.933\left[\frac{\sqrt{1+4(0.038)}-1}{2}\ \frac{\tan 1.28^\circ}{\cos 1.28^\circ}\right] 2688\text{ in}$$

$$\underline{\underline{T_{max} = 2.05\text{ in}}}$$

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$$h_{max} = T_{max} \cos\beta = (2.05 \text{ in.}) \cos 1.28^\circ$$

$$\underline{\underline{h_{max} = 2.05 \text{ in.}}}$$

- FOR a $\lambda = 0.038$, $T_{AVG}/T_{max} = 0.55$ (BASED ON TABLE 1 OF CALCULATIONS PROCEDURES PACKAGE REPRODUCED FROM GIROUD AND HOULIHAN.)

$$T_{AVG} = 0.55\, T_{max} = 0.55\,(2.05 \text{ in.})$$

$$\underline{\underline{T_{AVG} = 1.13 \text{ in.}}}$$

$$h_{AVG} = T_{AVG} \cos\beta = (1.13 \text{ in.}) \cos 1.28^\circ$$

$$\underline{\underline{h_{AVG} = 1.13 \text{ in.}}}$$

- IT IS NOTED THAT THE AVERAGE HEAD (T_{AVG}) IN THE DRAINAGE LAYER CALCULATED USING THE HELP MODEL FOR THE PEAK DAY WAS 1.977 in. WHICH IS NOT SIGNIFICANTLY DIFFERENT FROM THE VALUES CALCULATED ABOVE.

BASED ON THESE RESULTS, IT IS CONCLUDED THAT THE MAXIMUM HEAD IS LESS THAN THE ALLOWABLE HEAD OF 12 in. AND THAT THE MAXIMUM THICKNESS IS LESS THAN THE THICKNESS OF THE DRAINAGE LAYER (i.e., 12 in.).

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- TRANSMISSIVITY:

$$\Theta_d = k_d D_d = (0.1\ cm/s)(12\ in.)(2.54\ cm/in.)$$

$$\Theta_d = 3.05\ cm^2/s$$

GEOTEXTILE FILTER DESIGN

- RETENTION CRITERION:
  - IT IS EXPECTED MORE THAN 50% OF PARTICLES IN THE PROTECTIVE SOIL LAYER WILL BE SMALLER THAN 0.075 mm (#200 SIEVE). THEREFORE, THE REQUIRED APPARENT OPENING SIZE IS, ACCORDING TO TABLE 2 OF PROCEDURES PACKAGE, $O_{95} \leq 210\ \mu m$ (i.e., ≥ U.S. SIEVE 70)

- PERMEABILITY CRITERION:
  - ASSUME CRITICAL OR SEVERE APPLICATION TO BE CONSERVATIVE: $k_{geotextile} > 10\ k_{soil}$

$$k_{soil} \approx 10^{-6}\ cm/s \rightarrow k_{geotextile} > 10^{-5}\ cm/s$$

THIS REQUIREMENT IS EASILY ACHIEVABLE BY MOST GEOTEXTILES.

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- CLOGGING CRITERION
  - FOR NONWOVEN GEOTEXTILES: POROSITY, $n_g > 30\%$

    FOR WOVEN GEOTEXTILES: PERCENT OPEN AREA, $A > 4\%$

SOIL FILTRATION CHARACTERISTICS

PROTECTIVE SOIL LAYER	(1)
LCS DRAINAGE LAYER MATERIAL	(2)

- $d_{15(2)} = 0.3 - 2.0$ mm
- $\dfrac{d_{15(2)}}{d_{85(1)}} \leq 3 - 5 \longrightarrow \therefore \underline{\underline{d_{85(1)} \geq 0.4 \text{ mm}}}$ ✓
- $\dfrac{d_{15(2)}}{d_{15(1)}} \geq 3 - 5 \longrightarrow \therefore \underline{\underline{d_{15(1)} \leq 0.1 \text{ mm}}}$ ✓

$\therefore$ THE PROTECTIVE SOIL LAYER SHOULD HAVE A PARTICLE SIZE DISTRIBUTION THAT MEETS THE FOLLOWING CONDITIONS:

$d_{85} \geq 0.4$ mm; and

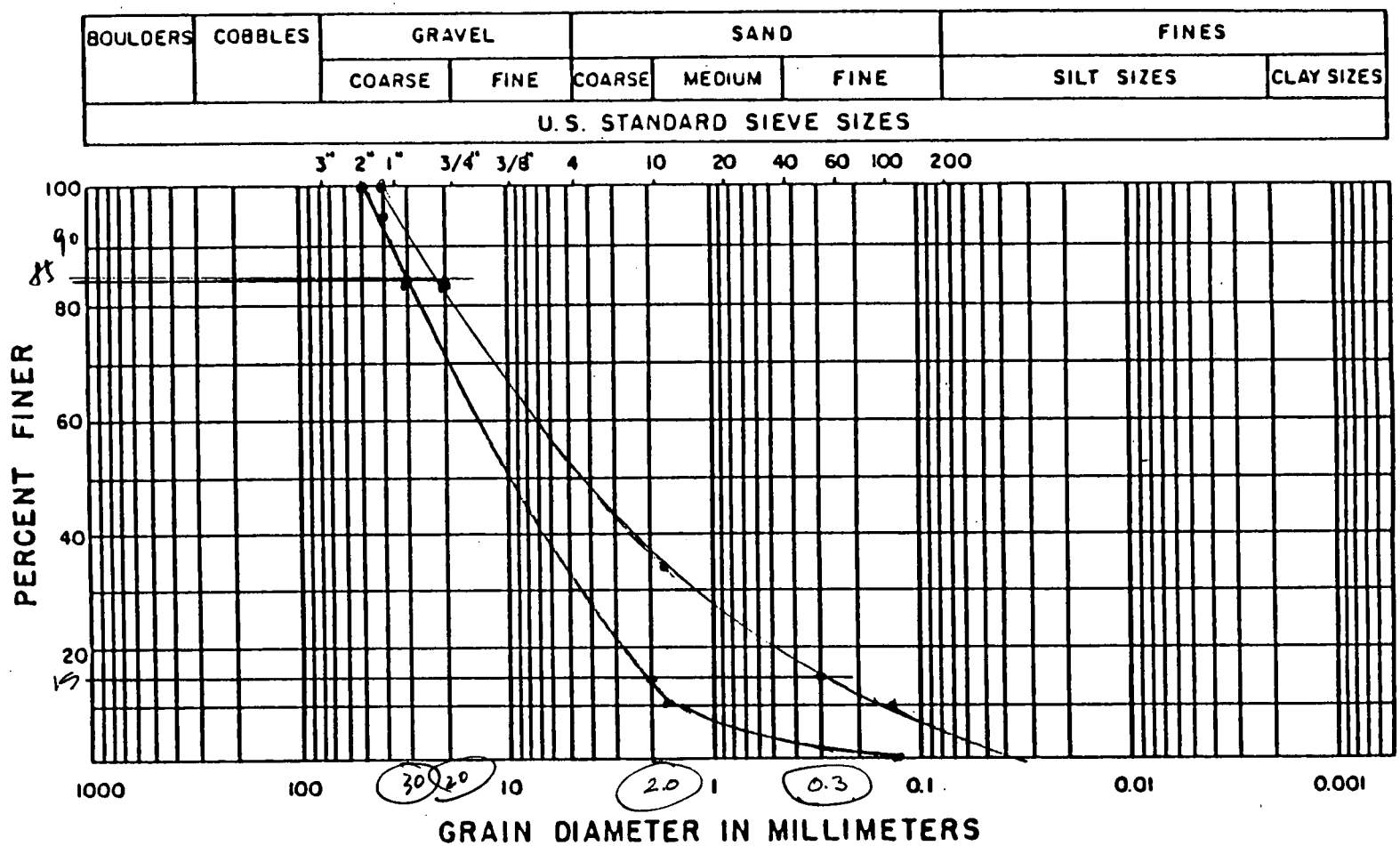
$d_{15} \leq 0.1$ mm

Crushed Stone Drainage Material

SOIL CLASSIFICATION TEST RESULTS

SAMPLE NO. _____ DEPTH _____

SOIL DESCRIPTION _____



COEFFICIENT OF UNIFORMITY (C_u) _____ LIQUID LIMIT (LL) _____

COEFFICIENT OF CURVATURE (C_c) _____ PLASTIC LIMIT (PL) _____

PLASTICITY INDEX (PI) _____

UNIFIED SOIL CLASSIFICATION (USC) _____

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Written by: RAM Date: 95/10/5 (YY/MM/DD) Reviewed by: Date: / / (YY/MM/DD)

Client: Ferrgco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 8.6

LCS COLLECTOR PIPE DESIGN

- PIPE FLOW CAPACITY:

$$Q_p = \frac{R_h^{0.66}\, i_p^{0.5}\, A_p}{n} = \frac{(0.0345\,m)^{0.66}(0.01)^{0.5}(1.5\times10^{-2}\,m^2)}{0.013\ s/m^{0.33}}$$

$$Q_p = 1.25\times10^{-2}\ m^3/s\ (198\ gpm)$$

- REQUIRED CAPACITY FOR COLLECTOR PIPES

$$Q_{pr} = q_i A_d = 1.9\times10^{-8}\ \frac{m}{s}\left(2.63\times10^4\ m^2\right)$$

$$Q_{pr} = 5.0\times10^{-4}\ m^3/s\ (7.9\ gpm)$$

- THE CALCULATED FLOW CAPACITY OF THE 6-in. NOMINAL DIAMETER COLLECTOR PIPES IS GREATER THAN THE CALCULATED RATES OF FLOW ENTERING THE PIPES. THEREFORE, FROM A FLOW CAPACITY STANDPOINT, THE 6-in NOMINAL DIAMETER PIPES CAN BE SPECIFIED FOR THE LCS COLLECTOR PIPES.

- RATIO OF PIPE FLOW CAPACITY TO REQUIRED CAPACITY:

$$\frac{Q_p}{Q_{pr}} = \frac{198\ gpm}{7.9\ gpm} = 25$$

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- PIPE FILTRATION: (USE d_{85} = 20mm (CONSERVATIVE))

$$d_{h\,max} = \frac{d_{85}}{F} = \frac{20mm}{2} = 10mm$$

$$d_{h\,max} = 0.39 \text{ in. } (10 \text{ mm})$$

- STRUCTURAL STABILITY:

- INITIAL CONDITION: (C_s = 0.20 ; from TABLE 3 of CALCULATION PROCEDURES)

(1) 6 in. LCS drainage layer
(2) 1 ft. protective soil layer

$$\sigma_{ic} = \gamma_p D_p + C_s \frac{PF_{ic}}{L_{ic} B_c}$$

$$= 120 \text{ pcf } (1.5 \text{ ft}) + 0.20 \frac{20{,}000 \text{ lb } (1.5)}{3 \text{ ft } (0.552 \text{ ft})}$$

$$\sigma_{ic} = 3{,}800 \text{ psf}$$

- POST-CLOSURE CONDITION: STRESS APPLIED TO PIPE IS DUE TO OVERBURDEN MATERIALS ABOVE THE PIPE.

$$\sigma = \gamma H = 125 \text{ pcf } (65 \text{ ft})$$

$$\sigma = 8{,}125 \text{ psf}$$

Written by: RAH Date: 99/10/5 (YY MM DD) Reviewed by: Date: / / (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.6

- WALL CRUSHING:

$$FS_{WC} = \frac{2\sigma_y}{(SDR-1)\,\sigma_{max}} = \frac{2(216{,}000\ psf)}{(11-1)(8{,}125\ psf)}$$

$$FS_{WC} = 5.3$$

- THIS FACTOR OF SAFETY IS GREATER THAN THE MINIMUM ACCEPTABLE FACTOR OF SAFETY AGAINST WALL CRUSHING OF 2 RECOMMENDED BY THE MANUFACTURER.

- WALL BUCKLING:

$$FS_{Wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'E}{(SDR)^3}\right]^{1/2}$$

$$= \frac{1.2}{8{,}125\ psf}\left[\frac{(432{,}000\ psf)(2.74\times10^6\ psf)}{(11)^3}\right]^{1/2}$$

$$FS_{Wb} = 4.40$$

- THIS FACTOR OF SAFETY IS GREATER THAN THE MINIMUM ACCEPTABLE FACTOR OF SAFETY AGAINST WALL BUCKLING OF 2 RECOMMENDED BY THE MANUFACTURER.

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- EXCESSIVE RING DEFLECTION:

$$FS_{rd} = \frac{\Delta_R E'}{100\,\sigma_{max}} = \frac{7\,(432{,}000\,psf)}{100\,(8{,}125\,psf)}$$

$$FS_{rd} = 3.72$$

- THIS FACTOR OF SAFETY IS GREATER THAN THE MINIMUM ACCEPTABLE FACTOR OF SAFETY OF 1 RECOMMENDED BY THE MANUFACTURER.

7.2 LCS Clogging Potential

8. LEAK DETECTION SYSTEM

8.1 Leak Detection System

8.1 Leak Detection System

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: LEAK DETECTION SYSTEM

Computations By: (Cognizant Engineer)
Signature Robert A. Morg-III — Date 12 OCT 1995
Printed Name ROBERT A. MORGAN III
and Title STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature [illegible] — Date 13 OCT. 1995
Printed Name BIN LI
and Title Assistant Project Engineer

Computations Checked by:
Signature [illegible] — Date 13 Oct. 1995
Printed Name BIN LI
and Title Assistant Project Engineer

Computations Backchecked by: (Cognizant Engineer)
Signature Robert A. Morg-III — Date 13 OCT 1995
Printed Name ROBERT A. MORGAN III
and Title STAFF ENGINEER

Approved by: (PDP)
Signature Majdy Ahmed Othman — Date 13 OCT 1995
Printed Name MAJDI A. OTHMAN
and Title PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature Rudolph Bonaparte — Date 14 Oct 95
Printed Name Rudolph Bonaparte
and Title Principal

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO	14 Oct 95	NA	NA	NA
Ø	30% Submitted	NA	NA	NA	NA No changes
B	Preliminary Design - EPA Submitted	15 Dec 95			

Written By: RAM Date: 15 DEC 95 Reviewed by: B.L. Date: 12/15/95

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 4.6

LEAK DETECTION SYSTEM (LDS)

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this package is to present the calculation procedures for analysis of the leak detection system (LDS). In particular, this package addresses migration through the primary liner, maximum thickness of liquid in LDS drainage layer, travel time in the LDS, LDS pipe design, and action leakage rate.

METHOD OF ANALYSIS

Migration through Primary Layer: The amount of flow into the LDS was estimated using the USEPA HELP model analysis performed in the Leachate Generation Rate Calculations package.

Maximum Thickness of Liquid in LDS Drainage Layer: The maximum and average thicknesses of liquid in the LDS and the transmissivity of the LDS drainage layer were calculated.

Time of Travel in the LDS: The maximum time of travel of liquids in the LDS drainage layer and the pipe (i.e., leak detection time) was calculated.

LDS Pipe Design: The pipe flow capacity, pipe filtration, and structural stability (wall crushing, wall buckling, and excessive ring deflection) were calculated.

Action Leakage Rate: The action leakage rate was calculated in accordance with procedures for RCRA Subtitle C facilities, as described in 40 CFR § 264.

CONCLUSIONS

Maximum Thickness of Liquid in LDS Drainage Layer:

- maximum thickness of liquid, $T_{max} = 5.47 \times 10^{-3}$ ft.
- average thickness of liquid, $T_{ave,w} = 9.57 \times 10^{-5}$ ft.
- calculated transmissivity, $\theta_d = 3.05$ cm^2/s

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Time of Travel in LDS:

- time of travel in LDS drainage layer, t_{DL} = 336.13 hr
- time of travel in the LDS pipe, t_p = 0.06 hr
- total time of travel in LDS, t = 336.19 hr (14 days)

LDS Pipe Design:

- pipe flow capacity, Q_p = 198 gpm
- required flow capacity, $Q_R = 4.41 \times 10^{-5}$ gpm
- flow capacity factor of safety, $Q_p/Q_{pr} = 4.49 \times 10^6$, OK
- maximum allowable perforation diameter, 0.39 in. $\leq d_{h\,max} \leq$ 0.66 in.
- factor of safety against pipe wall crushing, FS_{wc} = 4.09 , OK
- factor of safety against pipe wall buckling, FS_{wb} = 3.39 , OK
- factor of safety against excessive ring deflection, FS_{rd} = 2.86 , OK

Action Leakage Rate:

- action leakage rate, Q = 200 gpad

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Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.6

RB 13 Oct 95.

LEAK DETECTION SYSTEM (LDS)
CALCULATION PROCEDURES

INTRODUCTION

The purpose of this package is to present the calculation procedures for the leak detection system (LDS). In particular, this package addresses the following analyses:

- migration through primary layer;
- maximum thickness of liquid in LDS drainage layer;
- time of travel in LDS drainage layer;
- LDS pipe flow capacity;
- LDS pipe structural stability; and
- action leakage rate.

The LDS for the Fernald On-site Disposal Facility (OSDF) is shown in Figure 1.

METHODS OF ANALYSIS

MIGRATION THROUGH PRIMARY LAYER

The purpose of this section of the package is to describe the potential sources of flow into the leak detection layer. Gross, et al [1990] discussed the potential sources of flow from LDSs of double-lined landfills. As shown in Figure 2, these sources include: (i) leakage through defects in the primary liner; (ii) water from precipitation that impinges the LDS during construction ("construction water"); (iii) water expelled from the granular LDS due to compression of the layer ("compression water"); (iv) water squeezed out of a clay component of a composite top liner as a result of clay consolidation ("consolidation water"); and (v) ground water that infiltrates the bottom liner and enters the leak detection layer ("infiltration water").

For the OSDF liner system, all of these sources may contribute flow to the LDS. However, the magnitude and the time period is different for each source. Construction water and compression water may be of significant amounts but will seep out of the LDS within days or weeks of installation of the primary liner. The geosynthetic clay liner (GCL) in the primary liner composite is thin and will be placed dry. Therefore, little or no consolidation water is expected. Infiltration of ground water is expected. Infiltration of the ground water is expected to be minimal or non existent for most of the cells

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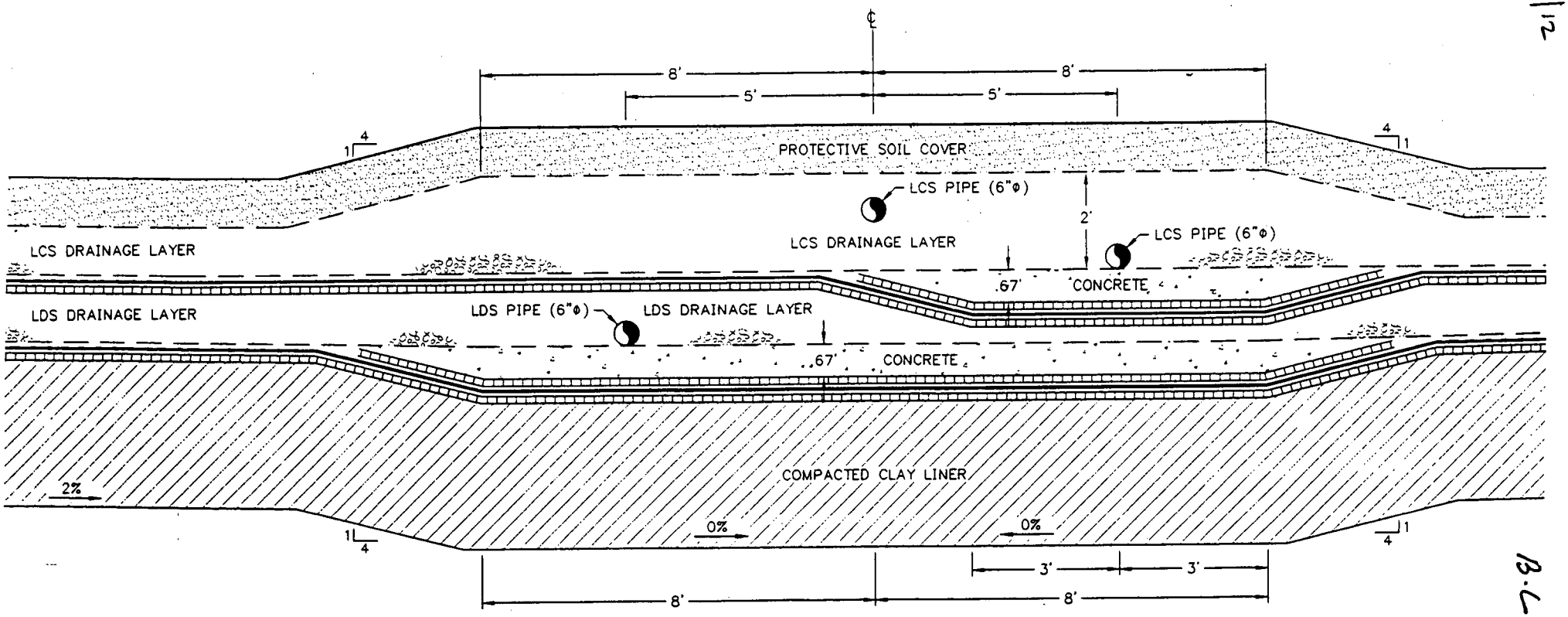

FIGURE 1: Leachate Collection and Leak Detection Sump.

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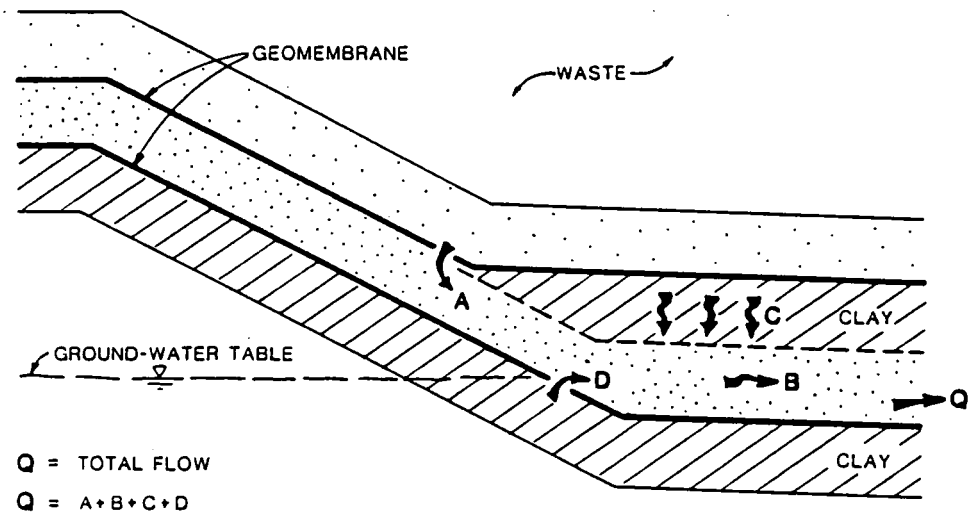
FIGURE 2: Sources of flow from leakage detection layers.



Q = TOTAL FLOW

Q = A+B+C+D

SOURCES:

A = TOP LINER LEAKAGE

B = CONSTRUCTION WATER AND COMPRESSION WATER

C = CONSOLIDATION WATER

D = INFILTRATION WATER

because: (i) the perched ground water is either below the liner system or is only a few feet above the liner system part of the time and therefore the upward hydraulic gradient is very small; and (ii) the secondary liner is composed of a geomembrane underlain by a GCL and a 3-ft thick layer of compacted clay, and therefore very little or no infiltration should be expected.

Based on the above, the primary source of flow in the LDS is assumed to be due to primary liner leakage. The amount of flow into the LDS is 2.45×10^{-5} gpm (average annual daily flow) or 4.41×10^{-5} gpm (peak daily flow) based on the HELP model analysis conducted in the Leachate Generation Rate Calculations package.

MAXIMUM THICKNESS OF LIQUID IN LDS DRAINAGE LAYER

The maximum and average thicknesses of liquid in the LDS can be calculated using the following approach based on Bonaparte and Giroud [1995]:

$$T_{\max} = \sqrt{\frac{Q}{k}} \tag{1}$$

$$T_{ave,w} = \frac{3}{4} T_{\max} \frac{1 + \left(\frac{2}{9}\right) M}{\sqrt{1 + \frac{2}{M}\left(1 + \frac{M}{2}\right)}} \tag{2}$$

$$M = \frac{T_{\max}}{L \sin \beta} \tag{3}$$

where: T_{max} = the maximum thickness of liquid in the LDS which occurs vertically under the primary liner geomembrane hole, Q = the leakage rate through the hole in the primary liner , k = the hydraulic conductivity of the LDS drainage material, $T_{ave,w}$ = the average flow thickness in the entire zone wetted as a result of this leakage, L = horizontal length of slope, and β = the slope angle. The above equations are based on the following assumptions [Bonaparte and Giroud, 1995]: (i) the primary liner leakage rate is constant and steady-state conditions prevail; (ii) the top liner is a geomembrane with free flow through the geomembrane hole (i.e., the leakage rate through the top liner is low enough that the liquid heads in the LDS are independent of liquid heads in the LCS); (iii) capillarity of the drainage medium is not

considered; and (iv) the flow velocity is small, therefore, the flow is laminar and Darcy's equation can be used.

The transmissivity of the LDS drainage layer will be calculated as the product of the hydraulic conductivity of the drainage layer and the drainage layer thickness as shown in the following equation:

$$\theta_d = k_d D_d \tag{4}$$

where: θ_d = hydraulic transmissivity of the drainage layer; k_d = the hydraulic conductivity of the drainage material; and D_d = the thickness of the drainage layer.

TIME OF TRAVEL IN THE LDS

The amount of time necessary to detect a leak in the primary liner is referred to as the time of travel. The time of travel in the LDS is composed of the time of travel in the LDS drainage layer in addition to the time of travel in the LDS pipe.

The time of travel in the LDS drainage layer is calculated based on Darcy's equation as follows:

$$t_{DL} = \frac{Ln}{ki} \tag{5}$$

where: k = the hydraulic conductivity of the LDS drainage material, i = the hydraulic gradient (slope of LDS drainage layer), n = the porosity of the LDS drainage material, L = length of flow in the LDS drainage layer, and t_{DL} = time of travel in the LDS drainage layer.

The time of travel in the LDS pipe is calculated based on Manning's equations as follows:

$$t_p = \frac{L_p\, n}{R_h^{0.66}\, i_p^{0.5}} \tag{6}$$

where: R_h = hydraulic radius (defined as the ratio of the flow area to the perimeter of the wetted area; for a pipe with a circular cross section $R_h = B_i/4$; where B_i is pipe inner diameter); i_p = hydraulic gradient (slope of the collector pipe); A_p = cross-sectional area of the pipe; n = Manning's roughness coefficient, L_p = length of pipe, and t_p = time of travel in the pipe.

The total time of travel, t, in the LDS is calculated as:

$$t = t_{DL} + t_p \tag{7}$$

LDS PIPE FLOW CAPACITY

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Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 8.6

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Pipe Flow Capacity: LDS pipe flow capacity should be greater than the maximum rate of flow into the pipe. The pipe flow capacity will be calculated using Manning's equation as follows:

$$Q_p = \frac{R_h^{0.66}\, i_p^{0.5}\, A_p}{n} \tag{8}$$

where: Q_p = collector pipe flow capacity; R_h = hydraulic radius (defined as the ratio of the flow area to the perimeter of the wetted area; for a pipe with a circular cross section $R_h = B_i/4$; where B_i is pipe inner diameter); i_p = hydraulic gradient (slope of the collector pipe); A_p = cross-sectional area of the pipe; and n = Manning's roughness coefficient.

The rate of flow of liquid entering the LDS collector pipe will be assumed equal to the rate of infiltration of liquids through the primary liner. This rate will be calculated using the USEPA HELP model as part of the Leachate Generation Rate Calculations package.

Pipe Filtration Characteristics The ability of the pipes to provide filtration may be characterized by the size of the perforations. Maximum allowable diameter of perforations in the collector pipe will be specified to ensure retention of LDS gravel particles. The maximum allowable diameter of perforations in the collector pipes to provide retention of gravel particles may be determined as follows [USEPA, 1983]:

$$d_{h\,\max} = \frac{d_{85}}{F} \tag{9}$$

where: $d_{h\,max}$ = maximum perforation diameter to provide particle retention; d_{85} = particle size of the pipe bedding material for which 85 percent by weight of the particles are finer; and F = factor varying from 1.2 to 2. For pipes with slots, replace d with w, where w is slot width in Equation 9.

LDS PIPE STRUCTURAL STABILITY

Calculations will be performed to ensure the LDS pipe is able to withstand the loads applied on it with an adequate factor of safety. Failure mechanisms that will be checked are: (i) wall crushing; (ii) wall buckling; and (iii) excessive ring deflection. Stresses applied on the LDS pipe will be estimated for: (i) initial condition (Figure 1) (i.e., stresses due to traffic when a 6-in. thick layer of LDS drainage layer

material is placed on the pipe); and (ii) final condition (i.e., stresses due to overburden materials). Plastic pipe can be designed to resist failure by the above mechanisms using design methods presented in the technical literature [Uni-Bell, 1991; Phillips 66, 1988; and Chevron, 1992].

As indicated previously, the initial condition assumes that the collector pipe is buried under 6-in. of LCS drainage layer material and 1-ft of protective soil layer. The stresses due to traffic are assumed to be applied by a truck with a capacity of 35 tons and a wheel load of 20,000 lb when full. The total stress on the pipe is then the sum of the stresses applied by the soil layers and the stresses applied by the loaded truck, which can be calculated as described by ASCE [1979] as follows:

$$\sigma_{ic} = \gamma_p D_p + C_s \frac{PF_{ic}}{L_{ic} B_c} \tag{10}$$

where: σ_{ic} = stress on the collector pipe: γ_p = unit weight of the soil materials; D_p = thickness of the soil cover; B_c = outer pipe diameter; C_s = load coefficient (Table 1), which is a function of $B_c/(2D_p)$ and $L_{ic}/(2D_p)$; P = concentrated load; F_{ic} = impact factor accounting for dynamic loads; and L_{ic} = effective length of pipe, which is arbitrarily defined as follows by ASCE [1979]: L_{ic} = 3 ft if pipe is longer than 3 ft, and L_{ic} = actual pipe length if pipe is shorter than 3-ft.

During the post-closure condition (i.e., final condition), the stress applied to the pipe is due to the overburden materials above the pipe (i.e., protective soil cover material, compacted waste, and cover soils).

Wall Crushing: Wall crushing can occur when the stress in the pipe wall, due to external vertical pressure, exceeds the compressive strength of the pipe material. The factor of safety against pipe wall crushing may be calculated using the following equation:

$$FS_{wc} = \frac{2\sigma_y}{(SDR-1)\sigma_{max}} \tag{10}$$

where: FS_{wc} = factor of safety against pipe wall crushing; σ_y = compressive yield strength of the pipe; SDR = standard dimension ratio of the pipe; and σ_{max} = maximum stress applied to the pipe.

Wall Buckling: Wall buckling, a longitudinal wrinkling in the pipe wall, can occur when the external vertical pressure exceeds the critical buckling pressure of the pipe/bedding aggregate system. The factor of safety against pipe wall buckling may be calculated using the following equation:

TABLE 1: Load Coefficient C_s.

$\frac{B_c}{2D_p}$	$\frac{L_{1c}}{2D_p}$													
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	5.0
0.1	0.019	0.037	0.053	0.067	0.079	0.089	0.097	0.103	0.108	0.112	0.117	0.121	0.124	0.128
0.2	0.037	0.072	0.103	0.131	0.155	0.174	0.189	0.202	0.211	0.219	0.229	0.238	0.244	0.248
0.3	0.053	0.103	0.149	0.190	0.224	0.252	0.274	0.292	0.306	0.318	0.333	0.345	0.355	0.360
0.4	0.067	0.131	0.190	0.241	0.281	0.320	0.349	0.373	0.391	0.405	0.425	0.440	0.454	0.460
0.5	0.079	0.155	0.224	0.284	0.336	0.379	0.414	0.441	0.463	0.481	0.505	0.525	0.540	0.548
0.6	0.089	0.174	0.252	0.320	0.379	0.428	0.467	0.499	0.524	0.544	0.572	0.596	0.613	0.624
0.7	0.097	0.189	0.274	0.349	0.414	0.467	0.511	0.546	0.584	0.597	0.628	0.650	0.674	0.688
0.8	0.103	0.202	0.292	0.373	0.441	0.499	0.546	0.584	0.615	0.620	0.674	0.703	0.725	0.740
0.9	0.108	0.211	0.306	0.391	0.463	0.524	0.574	0.615	0.647	0.673	0.711	0.742	0.766	0.784
1.0	0.112	0.219	0.318	0.405	0.481	0.544	0.597	0.639	0.673	0.701	0.740	0.774	0.800	0.816
1.2	0.117	0.229	0.333	0.425	0.505	0.572	0.628	0.674	0.711	0.740	0.783	0.820	0.849	0.868
1.5	0.121	0.238	0.345	0.440	0.525	0.596	0.650	0.703	0.742	0.774	0.820	0.861	0.894	0.916
2.0	0.124	0.244	0.355	0.454	0.540	0.613	0.674	0.725	0.766	0.800	0.849	0.894	0.930	0.956

Note: This dimensionless coefficient has been obtained by elastic theory [ASCE, 1979].

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$$FS_{wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'E}{(SDR)^3}\right]^{1/2} \tag{11}$$

where: FS_{wb} = factor of safety against pipe wall buckling; σ_{max} = maximum stress applied to the pipe; E' = modulus of soil reaction for pipe bedding; E = modulus of elasticity of the pipe material; and SDR = standard dimension ratio of the pipe.

Excessive Ring Deflection: Ring deflection is the change in vertical diameter of the pipe as the pipe/bedding aggregate system deforms under the external vertical pressure. The actual ring deflection of the pipe must be less than the allowable ring deflection of the pipe. The factor of safety against excessive ring deflection may be calculated using the following equation:

$$FS_{RD} = \frac{\Delta_R E'}{100\sigma_{max}} \tag{12}$$

where: Δ_R = allowable ring deflection in percent; E' = modulus of soil reaction for pipe bedding; and σ_{max} = maximum stress applied to the pipe. The allowable ring deflection of the pipe will be obtained from the manufacturers and technical literature.

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ACTION LEAKAGE RATE

An action leakage rate shall be defined for the LDS that establishes a threshold response actions in the event of excessive LDS flow. The action leakage rate is the maximum design flow rate that the leak detection system (LDS) can remove without the fluid head on the bottom liner exceeding one foot. Action leakage rates shall be established in accordance with procedures for RCRA Subtitle C facilities, as described in 40 CFR § 264.

The USEPA [1992] presents the following procedure for calculating the action leakage rate:

$$Q = k\,h \tan\alpha\, B_{avg} \tag{13}$$

$$B_{avg} = D/\sin\alpha \tag{14}$$

where: Q = flow rate in the LDS (drainage layer); h = head on the bottom liner; k = hydraulic conductivity of the drainage medium; α = slope of the LDS; D = leak detection system thickness; and B_{avg} = average width of the flow in the leak detection system, perpendicular to the flow.

with EPA Hazardous Waste Numbers D004 through D017; and

(2)(i)(A) The monofill has at least one liner for which there is no evidence that such liner is leaking;

(B) The monofill is located more than one-quarter mile from an underground source of drinking water (as that term is defined in § 144.3 of this chapter); and

(C) The monofill is in compliance with generally applicable groundwater monitoring requirements for facilities with permits under RCRA 3005(c); or

(ii) The owner or operator demonstrates that the monofill is located, designed and operated so as to assure that there will be no migration of any hazardous constituent into ground water or surface water at any future time.

(f) The owner or operator of any replacement landfill unit is exempt from paragraph (c) of this section if:

(1) The existing unit was constructed in compliance with the design standards of section 3004(o)(1)(A)(i) and (o)(5) of the Resource Conservation and Recovery Act; and

(2) There is no reason to believe that the liner is not functioning as designed.

(g) The owner or operator must design, construct, operate, and maintain a run-on control system capable of preventing flow onto the active portion of the landfill during peak discharge from at least a 25-year storm.

(h) The owner or operator must design, construct, operate, and maintain a run-off management system to collect and control at least the water volume resulting from a 24-hour, 25-year storm.

(i) Collection and holding facilities (e.g., tanks or basins) associated with run-on and run-off control systems must be emptied or otherwise managed expeditiously after storms to maintain design capacity of the system.

(j) If the landfill contains any particulate matter which may be subject to wind dispersal, the owner or operator must cover or otherwise manage the landfill to control wind dispersal.

(k) The Regional Administrator will specify in the permit all design and operating practices that are necessary to ensure that the requirements of this section are satisfied.

(l) Any permit under RCRA 3005(c) which is issued for a landfill located within the State of Alabama shall require the installation of two or more liners and a leachate collection system above and between such liners, notwithstanding any other provision of RCRA.

(Approved by the Office of Management and Budget under control number 2050-0007)

[47 FR 32365, July 26, 1982, as amended at 50 FR 4514, Jan. 31, 1985; 50 FR 28748, July 15, 1985; 55 FR 11875, Mar. 29, 1990; 57 FR 3489, Jan. 29, 1992]

EFFECTIVE DATE NOTE: At 57 FR 3489, Jan. 29, 1992 § 264.301 was amended by redesignating paragraphs (f) through (k) as (g) through (l), by revising paragraphs (c) and (d), and by adding new paragraph (f), effective July 29, 1992. For the convenience of the reader, the superseded text is set forth below.

§ 264.301 Monitoring and inspection.

* * * * *

(c) The owner or operator of each new landfill, each new landfill unit at an existing facility, each replacement of an existing landfill unit, and each lateral expansion of an existing landfill unit, must install two or more liners and a leachate collection system above and between the liners. The liners and leachate collection systems must protect human health and the environment. The requirements of this paragraph shall apply with respect to all waste received after issuance of the permit for units where the part B of the permit application is received by the Regional Administrator after November 8, 1984. The requirement for the installation of two or more liners in this paragraph may be satisfied by the installation of a top liner designed, operated, and constructed of materials to prevent the migration of any constituent into such liner during the period such facility remains in operation (including any post-closure monitoring period), and a lower liner designed, operated, and constructed to prevent the migration of any constituent through such liner during such period. For the purpose of the preceding sentence, a lower liner shall be deemed to satisfy such requirement if it is constructed of at least a 3-foot thick layer of recompacted clay or other natural material with a permeability of no more than 1×10^{-7} centimeter per second.

(d) Paragraph (c) of this section will not apply if the owner or operator demonstrates to the Regional Administrator, and the Regional Administrator finds for such landfill, that alternative design and operating practices, together with location characteristics, will prevent the migration of any hazardous constituent into the ground water or surface water at least as effectively as such liners and leachate collection systems.

* * * * *

§ 264.302 Action leakage rate.

(a) The Regional Administrator shall approve an action leakage rate for surface impoundment units subject to § 264.301(c) or (d). The action leakage rate is the maximum design flow rate that the leak detection system (LDS) can remove without the fluid head on the bottom liner exceeding 1 foot. The action leakage rate must include an adequate safety margin to allow for uncertainties in the design (e.g., slope, hydraulic conductivity, thickness of drainage material), construction, operation, and location of the LDS, waste and leachate characteristics, likelihood and amounts of other sources of liquids in the LDS, and proposed response actions (e.g., the action leakage rate must consider decreases in the flow capacity of the system over time resulting from siltation and clogging, rib layover and creep of synthetic components of the system, overburden pressures, etc.).

(b) To determine if the action leakage rate has been exceeded, the owner or operator must convert the weekly or monthly flow rate from the monitoring data obtained under § 264.303(c), to an average daily flow rate (gallons per acre per day) for each sump. Unless the Regional Administrator approves a different calculation, the average daily flow rate for each sump must be calculated weekly during the active life and closure period, and monthly during the post-closure care period when monthly monitoring is required under § 264.303(c).

[57 FR 3490, Jan. 29, 1992]

EFFECTIVE DATE NOTE: At 57 FR 3490, Jan. 29, 1992 § 264.302 was added effective July 29, 1992.

§ 264.303 Monitoring and inspection.

(a) During construction or installation, liners (except in the case of existing portions of landfills exempt from § 264.301(a)) and cover systems (e.g., membranes, sheets, or coatings) must be inspected for uniformity, damage, and imperfections (*e.g.*, holes, cracks, thin spots, or foreign materials). Immediately after construction or installation:

(1) Synthetic liners and covers must be inspected to ensure tight seams and joints and the absence of tears, punctures, or blisters; and

(2) Soil-based and admixed liners and covers must be inspected for imperfections including lenses, cracks, channels, root holes, or other structural non-uniformities that may cause an increase in the permeability of the liner or cover.

(b) While a landfill is in operation, it must be inspected weekly and after storms to detect evidence of any of the following:

(1) Deterioration, malfunctions, or improper operation of run-on and run-off control systems;

(2) Proper functioning of wind dispersal control systems, where present; and

(3) The presence of leachate in and proper functioning of leachate collection and removal systems, where present.

(c)(1) An owner or operator required to have a leak detection system under § 264.301(c) or (d) must record the amount of liquids removed from each leak detection system sump at least once each week during the active life and closure period.

(2) After the final cover is installed, the amount of liquids removed from each leak detection system sump must be recorded at least monthly. If the liquid level in the sump stays below the pump operating level for two consecutive months, the amount of liquids in the sumps must be recorded at least quarterly. If the liquid level in the sump stays below the pump operating level for two consecutive quarters, the amount of liquids in the sumps must be recorded at least semi-annually. If at any time during the post-closure care period the pump operating level

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MAO 95/10/12

Written By: RAM Date: 95/10/12 Reviewed by: B.L Date: 95/10/13

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.6

RB 13 Oct 95

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USEPA, "*Action Leakage Rates for Leak Detection Systems*", Supplemental Background Document for the Final Double Liners and Leak Detection Systems Rule for Hazardous Waste Landfills, Waste Piles, and Surface Impoundments, Office of Solid Waste, January 1992.

Written By: RAM Date: 95/10/12 Reviewed by: B.L Date: 95/10/13

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 8.6

RB 13 Oct 95

LEAK DETECTION SYSTEM (LDS)

DATA VERIFICATION

INTRODUCTION

As described in the calculation procedures package, the following analyses will be performed:

- migration through primary layer;
- maximum thickness of liquid in LDS drainage layer;
- time of travel in LDS drainage layer;
- LDS pipe flow capacity;
- LDS pipe structural stability; and
- action leakage rate.

In order to perform the analyses described above, the following data is required:

MIGRATION THROUGH PRIMARY LAYER

Maximum Thickness of Liquid in LDS Drainage Layer:

Q = leakage rate through the hole in the primary liner (= rate of infiltration through primary liner calculated using HELP)

= 2.45×10^{-5} gpm (average annual daily flow calculated using HELP)

= 4.41×10^{-5} gpm (peak daily flow calculated using HELP)

k = hydraulic conductivity of the LDS drainage layer material = 0.1 cm/sec

β = the slope angle = 1.28° (2.24%)

L = the horizontal of the slope = 224 ft (2688 in.)

Transmissivity:

k = hydraulic conductivity of the drainage material = 0.1 cm/sec

D = the thickness of the drainage layer = 12 in. (30.5 (cm)

TIME OF TRAVEL IN THE LDS (See Figure 1 and 2)

Time of Travel in the LDS:

L = length of flow in the LDS = 224 ft

n = porosity of the LDS drainage material = 0.397 (see Leachate Generation Data Verification Package)

k = the hydraulic gradient of the LDS drainage material = 0.1 cm/s

i = the slope of the LDS drainage layer = 1.28° (2.24%)

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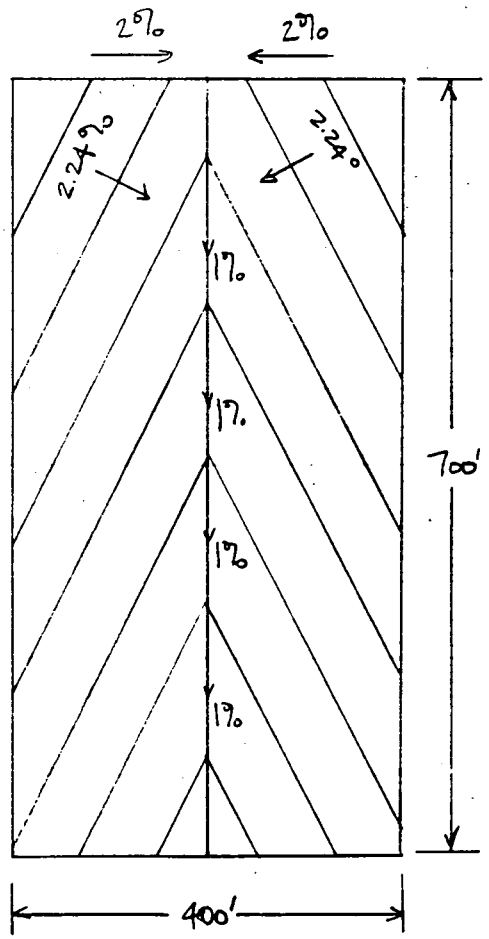
Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

RB 13 Oct 95

FIGURE 1: SCHEMATIC OF CELL LAYOUT

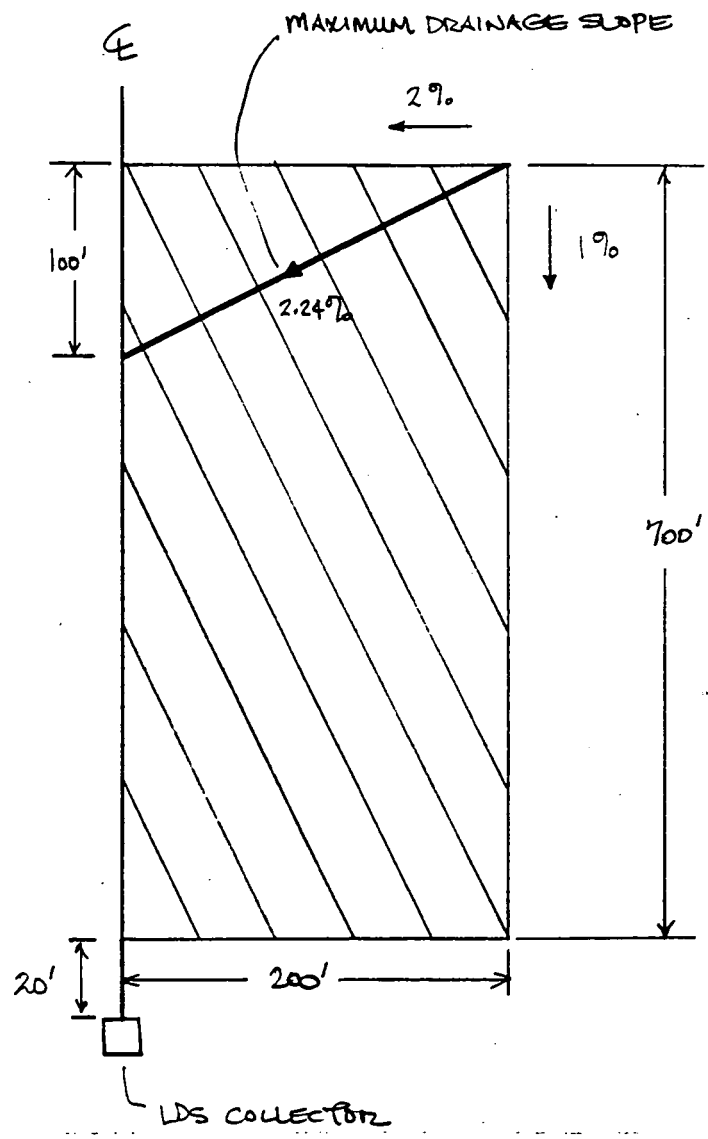


Written by: RAM Date: 95/10/12 (YY/MM/DD) Reviewed by: BL. Date: 95/10/13 (YY/MM/DD)

Client: FERMCO Project: FERNALD DSDF Project/Proposal No.: GE 3900 Task No.: 8.6

RB 13 Oct 95

FIGURE 2: CALCULATION OF MAXIMUM DRAINAGE SLOPE



N.T.S.

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Time of Travel in the LDS Pipe:

L_p = length of pipe = 620 ft (189 m)

$R_h = B_i / 4$ = hydraulic radius = 1.36 in. (3.45 cm)

i_p = hydraulic gradient = 0.57° (1%)

n = Manning's roughness coefficient = 0.013 $s/m^{0.33}$ (for smooth pipe)

LDS PIPE DESIGN

The geometric characteristics of the 6-in. nominal diameter HDPE SDR-11 pipes are as follows:

- outer diameter, B_c = 6.625 in.;
- wall thickness, t = 0.602 in.;
- inner diamter, B_i = 5.421 in.;
- mean radius, r = 3.01 in.; and
- perforation diameter, d_h = 0.625 in.

The characteristics of the pipes to be used in structural stability calculations, as estimated from a manufacturer's literature [Phillips 66, 1988], are as follows:

- modulus of elasticity of 2.74×10^6 psf after 50 years;
- compressive yield strength of the pipe 216,000 psf; and
- allowable ring deflection of SDR-11 pipe used for gravity flow is 7.0 percent.

Pipe Flow Capacity:

$R_h = B_i / 4$ = hydraulic radius = 1.36 in. (3.45 cm)

i_p = hydraulic gradient = 0.57° (1%)

$A_p = \pi B_i / 4$ = cross-sectional area of the pipe = 23.1 in^2 (1.5×10^{-2} m^2)

n = Manning's roughness coefficient = 0.013 $s/m^{0.33}$ (for smooth pipe)

Required Capacity for Collector Pipes:

Q_r = required capacity (= rate of infiltration through primary liner calculated using HELP)

= 2.45×10^{-5} gpm (average annual daily flow calculated using HELP)

= 4.41×10^{-5} gpm (peak daily flow calculated using HELP)

Pipe Filtration:

d_{85} = particle size of the pipe bedding material for which 85 percent by weight of the particles are finer = 20 - 30 mm (LCS Data Verification Package for reference)

F = factor varying from 1.2 to 2

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Structural Stability:

γ_p = unit weight of the soil materials = 125 pcf (18.8 kN/m^3)

D_p = thickness of the soil cover = Case 1 = 6 in.; Case 2 = assumed 70 ft

P = concentrated load = 20,000 lb (90 kN) (assumed based on truck with a capacity of 35 tons and a wheel load of 20,000 lb when full)

F_{ic} = impact factor accounting for dynamic loads = 1.5 [ASCE, 1979; see LDS Procedures Package for reference]

B_c = outer pipe diameter = 0.552 ft (0.168 m)

L_{ic} = effective length of pipe = 3 ft (1 m)

Wall Crushing:

σ_y = compressive yield strength = 216,000 psf (10,346 kPa)

SDR = standard dimension ratio of the pipe = 11

Wall Buckling:

E' = modulus of soil reaction for pipe bedding = 432,000 psf (20,560 kPa)

E = modulus of elasticity of the pipe material = 2.74×10^6 psf (1.31×10^5 kPa)

SDR = standard dimension ratio of the pipe = 11

Excessive Ring Deflection:

Δ_R = allowable ring deflection in percent = 7 percent

E' = modulus of soil reaction for pipe bedding = 432,000 psf (20,560 kPa)

ACTION LEAKAGE RATE

k = hydraulic conductivity of the drainage medium = 0.1 cm/s

h = head on the bottom liner = 12 in.

α = slope of the LDS = 1.28° (2.24%)

D = leak detection system thickness = 12 in.

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LEAK DETECTION SYSTEM (LDS)

CALCULATION RESULTS

Written by: RAM Date: 95/10/13 Reviewed by: BC Date: 95/10/13

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.6

MAXIMUM THICKNESS OF LIQUID IN LDS DRAINAGE LAYER

- $Q = 2.45 \times 10^{-5}$ gpm (average annual daily flow from HELP)

$$T_{max} = \sqrt{\frac{Q}{k}} = \sqrt{\frac{(2.45\times10^{-5}\ \text{gal/min})(\text{min}/60\text{s})(\text{ft}^3/7.48\ \text{gal})}{0.1\ \text{cm/s}\ (\text{ft}/30.48\ \text{cm})}}$$

$$T_{max} = 4.08 \times 10^{-3}\ \text{ft}\ (1.24\times10^{-3}\ \text{m})$$ ✓

$$M = \frac{T_{max}}{L \sin\beta} = \frac{4.08\times10^{-3}\ \text{ft}}{(224\ \text{ft})\sin 1.28^\circ}$$

$$M = 8.15\times10^{-4}$$ ✓

$$T_{AVE,W} = \frac{3}{4} T_{max} \frac{1 + \left(\frac{2}{9}\right)M}{\sqrt{1 + \frac{2}{M}\left(1 + \frac{M}{2}\right)}}$$

$$= \frac{3}{4}\left(4.08\times10^{-3}\ \text{ft}\right)\frac{1 + \left(\frac{2}{9}\right)8.15\times10^{-4}}{\sqrt{1 + \frac{2}{8.15\times10^{-4}}\left(1 + \frac{8.15\times10^{-4}}{2}\right)}}$$

$$T_{AVE,W} = 6.18\times10^{-5}\ \text{ft}\ (1.88\times10^{-5}\ \text{m})$$ ✓

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- $Q = 4.41 \times 10^{-5}$ gpm (peak daily flow from HELP)

$$T_{max} = \sqrt{\frac{Q}{k}} = \sqrt{\frac{(4.41\times10^{-5}\ \text{gal/min})(\text{min}/60\text{s})(\text{ft}^3/7.48\ \text{gal})}{(0.1\ \text{cm/s})(\text{ft}/30.48\ \text{cm})}}$$

$$T_{max} = 5.47\times10^{-3}\ \text{ft}\ (1.67\times10^{-3}\ \text{m})$$

$$M = \frac{T_{max}}{L\sin\beta} = \frac{5.47\times10^{-3}\ \text{ft}}{(224\ \text{ft})\sin 1.28^\circ}$$

$$M = 1.09\times10^{-3}$$

$$T_{AVE,N} = \frac{3}{4}T_{max}\frac{1+\left(\frac{2}{9}\right)M}{\sqrt{1+\frac{2}{M}\left(1+\frac{M}{2}\right)}}$$

$$= \frac{3}{4}(5.47\times10^{-3}\ \text{ft})\frac{1+\left(\frac{2}{9}\right)(1.09\times10^{-3})}{\sqrt{1+\frac{2}{1.09\times10^{-3}}\left(1+\frac{1.09\times10^{-3}}{2}\right)}}$$

$$T_{AVE,N} = 9.57\times10^{-5}\ \text{ft}\ (2.92\times10^{-5}\ \text{m})$$

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- TRANSMISSIVITY:

$$\Theta_d = k_d D_d = (0.1\ cm/s)(30.48\ cm)$$

$$\Theta_d = 3.05\ cm/s$$

TIME OF TRAVEL IN THE LDS (SEE FIGURE 1)

- MAXIMUM SLOPE = 2.24%
- MAXIMUM DRAINAGE LENGTH = $\sqrt{(100\ ft)^2 + (200\ ft)^2}$

$$= 224\ ft$$

- TIME OF TRAVEL IN LDS:

$$t_{DL} = \frac{L\,n}{k\,i} = \frac{(224\ ft)(0.397)}{(0.1\ cm/s)(ft/30.48\ cm)(0.0224)}$$

$$t_{DL} = 1.21 \times 10^6\ s\ (336.13\ hr)$$

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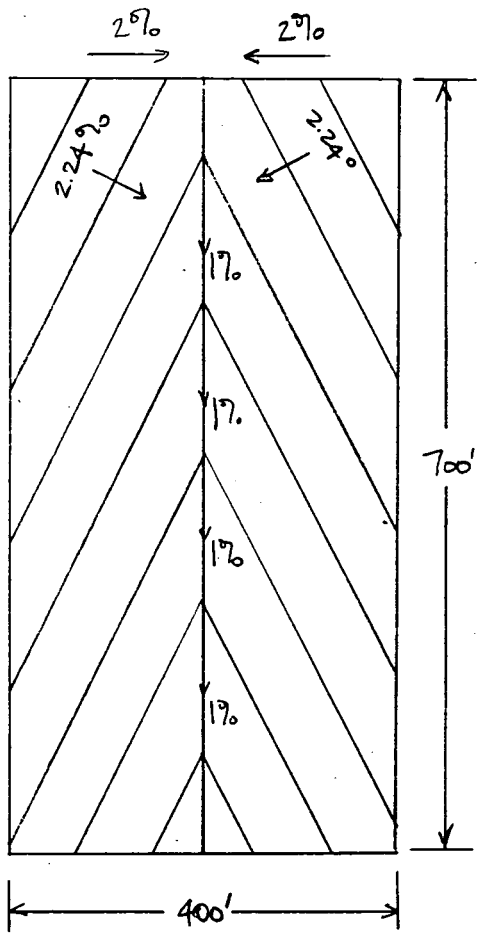
Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

FIGURE 1: SCHEMATIC OF CELL LAYOUT



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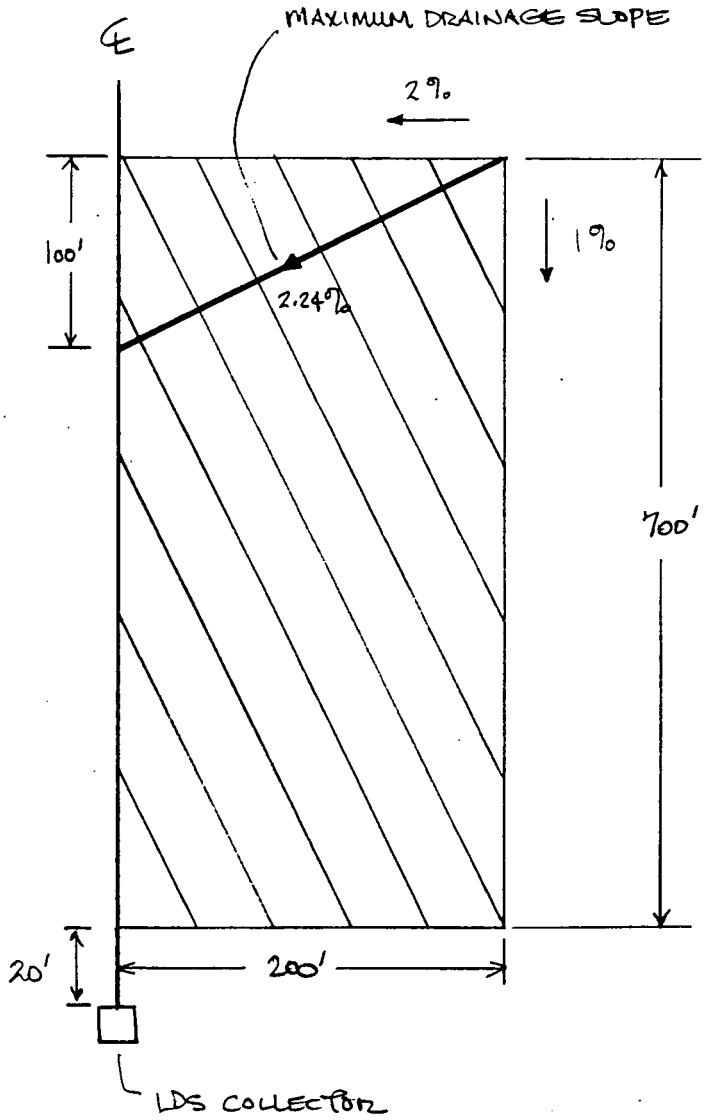
Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 8.6



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Written by: RAM Date: 95/10/13 (YY/MM/DD) Reviewed by: BL Date: 95/10/13 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 8.6

- TIME OF TRAVEL IN LDS PIPE:

$$t_p = \frac{L_p \; n}{R_h^{0.66} \; i_p^{0.5}} = \frac{(189\,m)(0.013\,s/m^{0.33})}{(0.0345\,m)^{0.66}(0.010)^{0.5}}$$

$$t_p = 226.70\,s \quad (0.06\,hr)$$

- TOTAL TIME OF TRAVEL IN LDS:

$$t = t_{DL} + t_p = 336.13\,hr + 0.06\,hr$$

$$t = 336.19\,hr \quad (14\text{ days})$$

LDS PIPE FLOW CAPACITY

- PIPE FLOW CAPACITY:

$$Q_p = \frac{R_h^{0.66} \; i_p^{0.5} \; A_p}{n} = \frac{(0.0345\,m)^{0.66}(0.01)^{.5}(1.5\times10^{-2}\,m^2)}{(0.013\,s/m^{0.33})}$$

$$Q_p = 0.0125\,m^3/s \quad (198\text{ gpm})$$

- REQUIRED CAPACITY (Q_R) = 4.41×10^{-5} gpm (peak daily → HELP)

- RATIO OF PIPE FLOW CAPACITY TO REQUIRED CAPACITY:

$$\frac{Q_p}{Q_R} = \frac{198\text{ gpm}}{4.41\times10^{-5}\text{ gpm}} = 4.49\times10^{6}$$

001194

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Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 8.6

- PIPE FILTRATION: (d_{85} = 20 mm; SEE LCS CALCULATION PACKAGE)

$F = 1.2$ to 2

$$d_{h\,max} = \frac{d_{85}}{F} = \frac{20\,mm}{1.2 \rightarrow 2}$$

$$\therefore \quad 10\,mm \le d_{h\,max} \le 16.67\,mm$$

$$(0.39\,in \le d_{h\,max} \le 0.66\,in) \checkmark$$

LDS PIPE STRUCTURAL STABILITY

- INITIAL CONDITION: ($C_s = 0.58$; from TABLE 8 of CALCULATION PROCEDURES)

$$\sigma_{ic} = \gamma_p D_p + C_s \frac{P F_{ic}}{L_{ic} B}$$

$$= (125\,pcf)(0.5\,ft) + 0.58 \frac{20{,}000\,lb\,(1.5)}{3\,ft\,(0.552\,ft)}$$

$$\sigma_{ic} = 10{,}569.75\,psf \checkmark$$

- POST-CLOSURE CONDITION:

$$\sigma = \gamma H = (125\,pcf)(70\,ft)$$

$$\sigma = 8{,}750\,psf \checkmark$$

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Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.6

• WALL CRUSHING:

$$FS_{WC} = \frac{2\sigma_y}{(SDR-1)\,\sigma_{max}} = \frac{2\,(216{,}000\,psf)}{(11-1)\,(10{,}569.75\,psf)}$$

$$FS_{WC} = 4.09 \checkmark$$

• THIS FACTOR OF SAFETY IS GREATER THAN THE MINIMUM ACCEPTABLE FACTOR OF SAFETY AGAINST WALL CRUSHING OF 2 RECOMMENDED BY THE MANUFACTURER.

• WALL BUCKLING:

$$FS_{Wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'\,E}{(SDR)^3}\right]^{1/2}$$

$$= \frac{1.2}{10{,}569.75\,psf}\left[\frac{(432{,}000\,psf)(2.74\times10^6\,psf)}{(11)^3}\right]^{1/2}$$

$$FS_{Wb} = 3.39 \checkmark$$

• THIS FACTOR OF SAFETY IS GREATER THAN THE MINIMUM ACCEPTABLE FACTOR OF SAFETY AGAINST WALL BUCKLING OF 2 RECOMMENDED BY THE MANUFACTURER.

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Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.6

• EXCESSIVE RING DEFLECTION:

$$FS_{rd} = \frac{\Delta_R E'}{100\,\sigma_{max}} = \frac{7\,(432{,}000\,psf)}{100\,(10{,}569.75\,psf)}$$

$$FS_{rd} = 2.86 \checkmark$$

• THIS FACTOR OF SAFETY IS GREATER THAN THE MINIMUM ACCEPTABLE FACTOR OF SAFETY AGAINST EXCESSIVE RING DEFLECTION OF 1 RECOMMENDED BY THE MANUFACTURER.

Written by: RAM Date: 95/10/13 Reviewed by: BL Date: 95/10/13

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.6

ACTION LEAKAGE RATE

$$B_{AVG} = D/\sin\alpha = 12''/\sin 1.28^\circ$$

$$B_{AVG} = 537.19 \text{ in. } (1{,}364.46 \text{ cm})$$

$$Q = k\, h \tan\alpha\, B_{AVG}$$

$$= (0.1 \text{ cm/s})(30.48 \text{ cm})(\tan 1.28^\circ)(1{,}364.46 \text{ cm})$$

$$Q = 92.93 \text{ cm}^3/\text{s} \quad (2{,}121 \text{ gal/day})$$

- RECOMMENDED FACTOR OF SAFETY IS 2 [USEPA, 1992]. HOWEVER, DUE TO LONG-TERM DESIGN LIFE OF FERNALD OSDF, A FACTOR OF SAFETY OF 10 WILL BE USED.

$$Q = (2{,}121 \text{ gal/day})/10$$

$$Q = 212 \text{ gal/day}$$

- ASSUMING 1 hole/acre: $Q = 212$ gpad ≈ 200 gpad

Written by: RAT Date: 95/10/13 (YY MM DD) Reviewed by: BL Date: 95/10/13 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.6

THIS CALCULATED ACTION LEAKAGE RATE OF 200 gpad IS CONSIDERED TO BE THE THRESHOLD VALUE FOR ACTION AS DESCRIBED IN THE REMEDIAL ACTION CONTINGENCY PLAN FOR THE OSDF.

9. LEACHATE TRANSMISSION SYSTEM

9.1 Leachate Transmission System

9.1 Leachate Transmission System

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: LEACHATE TRANSMISSION SYSTEM

Computations By: (Cognizant Engineer)
Signature: Majdy Ahmed Othman — Date: 20 Oct 1995
Printed Name and Title: MAJDI A. OTHMAN, PROJECT ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: Gary R. Schmertmann — Date: 21 Oct 95
Printed Name and Title: Gary R. Schmertmann, Sr. Project Engineer

Computations Checked by:
Signature: Gary R. Schmertmann — Date: 21 Oct 95
Printed Name and Title: Gary R. Schmertmann, Sr. Project Engineer

Computations Backchecked by: (Cognizant Engineer)
Signature: Majdy Ahmed Othman — Date: 20 Oct 1995
Printed Name and Title: MAJDI A. OTHMAN, PROJECT ENGINEER

Approved by: (PDP)
Signature: Majdy Ahmed Othman — Date: 20 Oct 1995
Printed Name and Title: MAJDI A. OTHMAN, PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature: Rudolph Bonaparte — Date: 22 Oct 1995
Printed Name and Title: Rudolph Bonaparte, Principal

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	30% submittal	22 Oct 95	NA	NA	NA
B	LTS gravity line changed from 8" to 6"ø	8 Dec 95	MAO	GRS	RB
	Temp. force main changed from 2" to 3"ø				

LEACHATE TRANSMISSION SYSTEM (LTS)

EXECUTIVE SUMMARY

Purpose of Analysis

The purpose of this calculations package is to perform design analyses for the LTS gravity line, temporary lift station pumps, and the permanent lift station.

Methods of Analysis

- The LTS gravity line flow capacity was checked to ensure its adequate to handle peak flow rates from the on-site disposal facility (OSDF).
- The structural stability of the LTS gravity line was checked to ensure adequate factors of safety against wall crushing, buckling, or excessive deflection.
- The temporary lift station pump requirements were estimated including flow capacity, hydraulic head, efficiency, and number of starting times per 1 hour.
- The capacity of the permanent LTS lift station was checked to ensure it can handle flows for reasonable periods of time during operations and in the post-closure stage.

Closure

* *Gravity Line Capacity*

- Peak flow rate into the LTS gravity line = 29.2 gpm.
- Gravity line flow capacity = 150 adequate gpm >> 29.2 gpm.

* *Gravity Line Stability*

- $FS_{wall\ crushing} = 31$
- $FS_{wall\ buckling} = 26$
- $FS_{ring\ deflection} = 22$

* *Temporary Lift Station Pump*

- $Q_{design} = 60$ gpm
- $H_p = 20$ ft

Maximum number of starts/hour = 1 to 2

* *Permanent Lift Station Capacity*

- Required = 1,752 gal, available = 4,890 gal

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LEACHATE TRANSMISSION SYSTEM DESIGN PROCEDURES

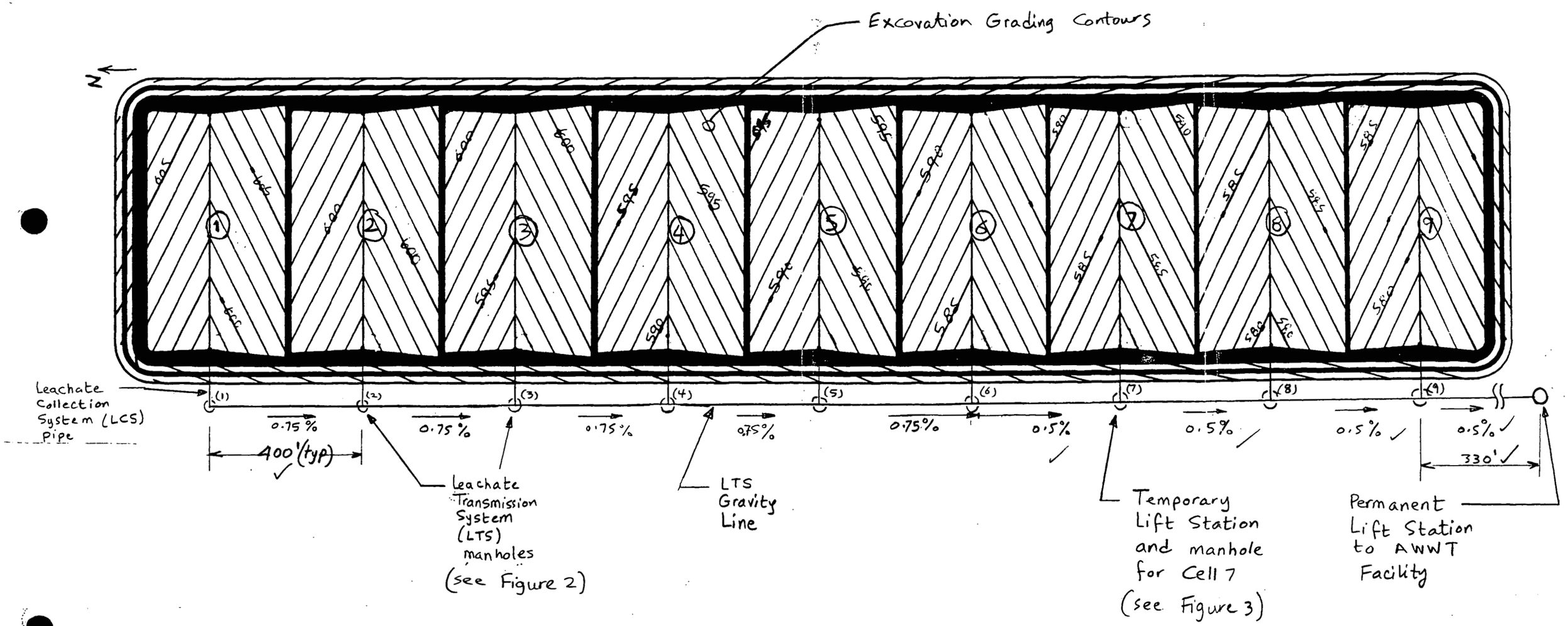
INTRODUCTION

The purpose of this package is to summarize procedures which will be used to design the leachate transmission system (LTS) of the FERNALD On-Site Disposal Facility (OSDF). In particular, this package describes methods to be used to design the LTS gravity line, pumps, and permanent lift station.

DESCRIPTION OF THE LTS

The LTS is illustrated in figures 1 and 2. Leachate generated in the OSDF cells flows in the leachate collection system (LCS) pipe which intrudes the double-liner system and the Perimeter berm to outside the cell. The LCS pipe enters the LTS manhole located outside the cell and terminates into a LTS gravity line. The LTS gravity line runs continnously along the western side of the OSDF and transmits leachate to a lift station.

Figure 1. LEACHATE TRANSMISSION SYSTEM (LTS)



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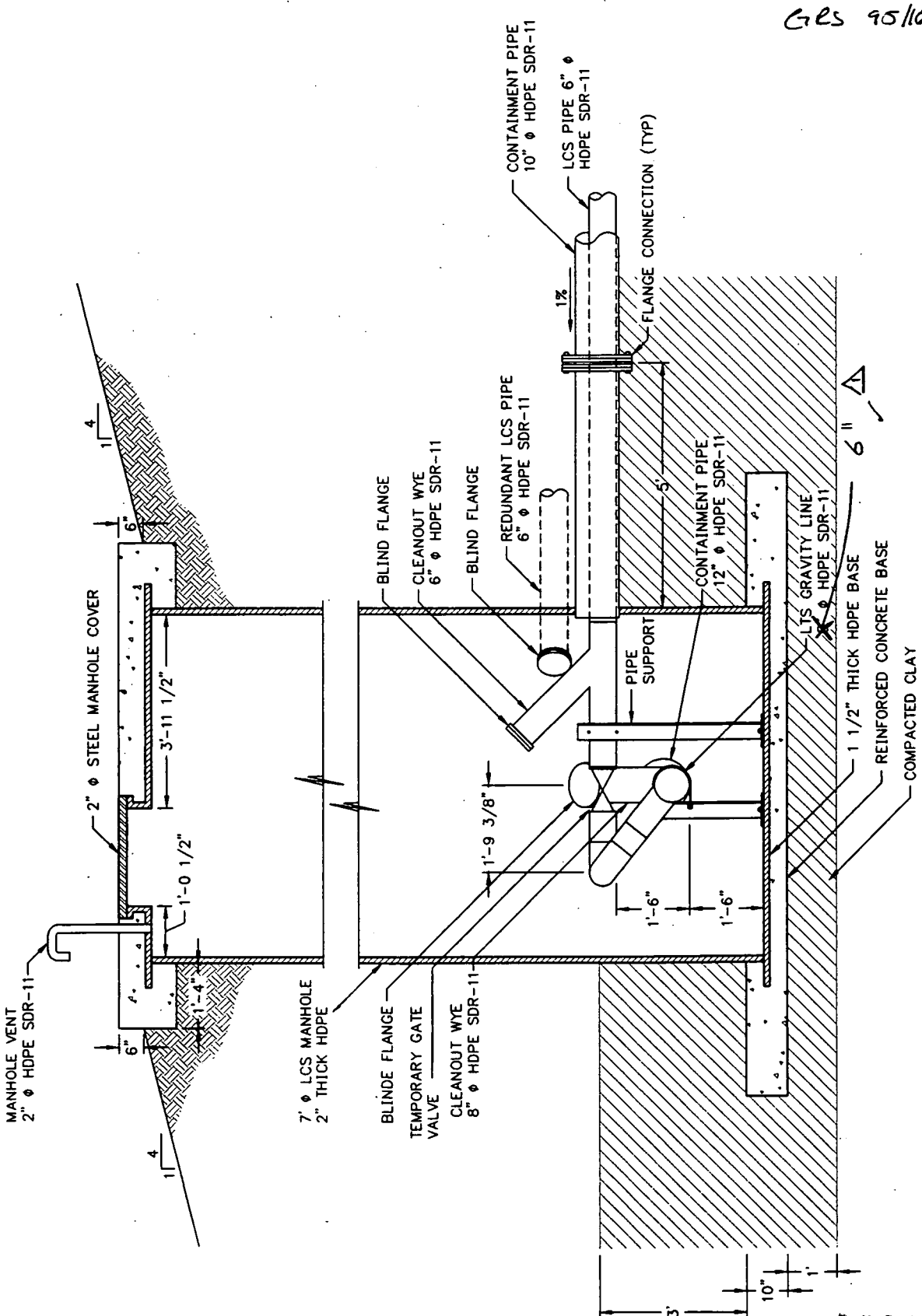

Figure 2. Leachate Transmission System (LTS) manhole

Note: Plumbing layout has been modified from that shown above. The current layout will be shown in future revisions of these calculations.

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For the OSDF, manhole 7 (i.e., manhole located outside cell 7) will be constructed at the beginning of the project and will be used as a temporary lift station. After cell 8 is constructed, manhole 7 will no longer be used as a lift station, but instead, ~~a permanent lift~~ liquid in the leachate transmission system will flow directly to a permanent lift station ~~station~~ located south east of the OSDF cell 9. RB 10/19/95 ~~will become operational~~. This phasing is intended to best address the existence of utility lines which run in the east-west direction south of cell 7.

Liquids which collect in the temporary lift station will be pumped out to the permanent lift station and then to the advanced waste water treatment (AWWT) facility (see Figure 3).

SCOPE

The scope of this procedures package is to to present design analysis methods which will be used to evaluate the following:

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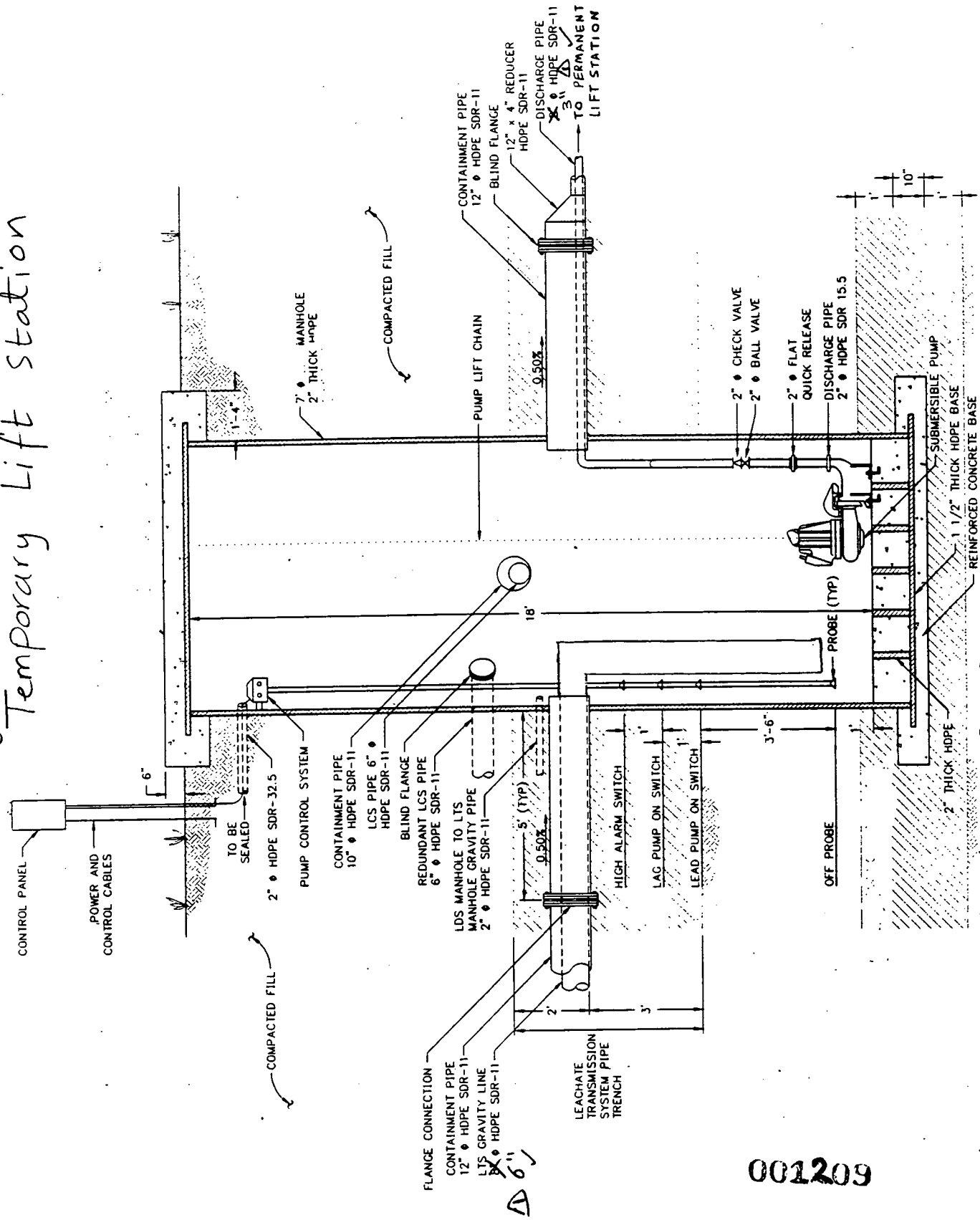
Figure 3. Temporary Lift station



Note: Plumbing layout has been modified from that shown above. The current layout will be shown in future revisions of this calculation.

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(i) LTS gravity line flow capacity;
(ii) LTS gravity line structural stability;
(iii) LTS temporary lift station pump capacity requirements; and
(iv) LTS permanent lift station size requirements.

consistent w DCP

LTS GRAVITY LINE FLOW CAPACITY

Two steps are involved in this analysis:

- Step 1: estimate leachate flow rate into the LTS gravity line; and
- Step 2: estimate gravity line flow capacity to check that it exceeds flow rate into the line.

Step 1: (estimate leachate flow rate into the LTS gravity line).

Two cases will be considered which are:

(i) Case 1: maximum flow anticipated during operations. This flow rate can be estimated from results of the USEPA HELP model analyses performed as part of the leachate generation rate calculation package;

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for the condition when 1 cell is in the initial stage of operations (i.e., 10 ft of waste), 1 cell is in the intermediate stage of operations (i.e., 30 ft of waste + intermediate cover), and 7 cells are capped. ✓ Because leachate generated in each cell varies in flow rate with time and this flow rate - time histogram is different for a cell in the initial stage of operation than for a cell in the intermediate stage of operation, the peak daily flows for these two cells will not occur on the same day. Therefore, it is conservative to design the gravity line to handle the sum of <u>peak daily flows</u> for each cell. ✓ It is noted that leachate generated in capped cells is negligible. ✓

(ii) Case 2: flow anticipated due to a 24-hr, 2-yr storm event in 1 cell prior to any waste placement in addition to flow from 1 cell in the intermediate stage of operations. ✓

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- flow from 1 cell in its intermediate stage of operations was estimated using the USEPA HELP model as part of the leachate generation rate calculations package. ✓

- flow due to a storm event can be estimated based on the following assumptions:
  - all of the precipitation which falls within the limits of the cell collects in the leachate collection system (i.e., no evaporation or runoff). ✓
  - The USEPA HELP model will be used to analyze flows in the LCS of one cell due to this storm event. ✓
    Peak daily flow will be used.

- It is conservatively assumed that the peak flows in the newly constructed cell and in the cell at the intermediate stage of operations will occur on the

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same day and therefore will be added. ✓

RB 10/19/95

This is a conservative design basis; flows from larger storm events can be regulated, if necessary, to control flow rate into LTS using the temporary gate valve that will be installed on each leachate collection system pipe.

Step 2: (estimate gravity line flow capacity)

The pipe capacity will be calculated using Manning's equation as follows:

$$Q_p = \frac{R_h^{0.66} \; i_p^{0.5} \; A_p}{n} \quad (1)$$ ✓

steady, uniform fully turbulent flow ✓

where: Q_p = gravity line flow capacity;

R_h = hydraulic radius defined as the ratio of the flow area to the perimeter of the wetted area; for a circular pipe with B_i inner diameter → $R_h = B_i/4$; ✓

Pipe flowing full under atmospheric pressure ✓

i_p = hydraulic gradient (slope of the gravity line); ✓

A_p = cross-sectional area of the pipe $= \frac{\pi B_i^2}{4}$ ✓, and

n = Manning's roughness coefficient.

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LTS GRAVITY LINE STRUCTURAL STABILITY

The structural stability of the gravity line involves calculating the factor of safety against three failure mechanisms: (i) wall crushing; (ii) wall buckling; and (iii) excessive ring deflection. Methods (and references) to calculate these factors of safety are described in details in the leachate collection system calculations package. These methods are summarized below.

- Wall Crushing:

$$FS_{wc} = \frac{2\,\sigma_y}{(SDR - 1)\,\sigma_{max}} \qquad (2)$$

where: FS_{wc} = factor of safety against wall crushing;

σ_y = compressive yield strength of the pipe;

SDR = Standard dimension ratio = pipe outer diameter / pipe thickness; and

σ_{max} = maximum stress applied on the pipe.

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- Wall Buckling:

$$FS_{wb} = \frac{1.2}{\sigma_{max}} \left[\frac{E' E}{(SDR)^3} \right]^{1/2} \quad (3)$$

where: FS_{wb} = factor of safety against pipe buckling;

σ_{max} = maximum stress applied on the pipe;

E' = modulus of soil reaction for pipe bedding;

E = modulus of elasticity of the pipe material; and

SDR = Standard dimension of the pipe.

- Excessive Ring Deflection

$$FS_{RD} = \frac{\Delta_R \; E'}{100 \; \sigma_{max}} \quad (4)$$

where: FS_{RD} = factor of safety against ring deflection;

E' = modulus of soil reaction for pipe bedding; and

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Δ_R = allowable ring deflection in percent; and

σ_{max} = maximum stress applied on the pipe.

For these analyses, σ_{max} will be assumed to be due to the weight of soil materials placed above the pipe in addition to stresses from a loaded truck, as follows:

$$\sigma_{max} = \gamma_p D_p + C_s \frac{P F_{ic}}{L_{ic} B_c} \qquad (5)$$

where: γ_p = unit weight of materials above the pipe;

D_p = depth of the pipe;

B_c = outer pipe diameter;

C_s = load coefficient (from Table 1) = function $\left(\frac{B_c}{2D_p}, \frac{L_{ic}}{2D_p}\right)$;

P = concentrated load from truck wheels;

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F_{ic} = impact factor accounting for dynamic loads; and ✓

L_{ic} = effective length of pipe (if pipe length ≥ 3 ft → L_{ic} = 3 ft ; if pipe length < 3 ft → L_{ic} = pipe length) ✓

Table 1: Load Coefficient C_s.

$\frac{B_c}{2D_p}$	$\frac{L_{ic}}{2D_p}$													
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	5.0
0.1	0.019	0.037	0.053	0.067	0.079	0.089	0.097	0.103	0.108	0.112	0.117	0.121	0.124	0.128
0.2	0.037	0.072	0.103	0.131	0.155	0.174	0.189	0.202	0.211	0.219	0.229	0.238	0.244	0.248
0.3	0.053	0.103	0.149	0.190	0.224	0.252	0.274	0.292	0.306	0.318	0.333	0.345	0.355	0.360
0.4	0.067	0.131	0.190	0.241	0.281	0.320	0.349	0.373	0.391	0.405	0.425	0.440	0.454	0.460
0.5	0.079	0.155	0.224	0.284	0.336	0.379	0.414	0.441	0.463	0.481	0.505	0.525	0.540	0.548
0.6	0.089	0.174	0.252	0.320	0.379	0.428	0.467	0.499	0.524	0.544	0.572	0.596	0.613	0.624
0.7	0.097	0.189	0.274	0.349	0.414	0.467	0.511	0.546	0.584	0.597	0.628	0.650	0.674	0.688
0.8	0.103	0.202	0.292	0.373	0.441	0.499	0.546	0.584	0.615	0.620	0.674	0.703	0.725	0.740
0.9	0.108	0.211	0.306	0.391	0.463	0.524	0.574	0.615	0.647	0.673	0.711	0.742	0.766	0.784
1.0	0.112	0.219	0.318	0.405	0.481	0.544	0.597	0.639	0.673	0.701	0.740	0.774	0.800	0.816
1.2	0.117	0.229	0.333	0.425	0.505	0.572	0.628	0.674	0.711	0.740	0.783	0.820	0.849	0.868
1.5	0.121	0.238	0.345	0.440	0.525	0.596	0.650	0.703	0.742	0.774	0.820	0.861	0.894	0.916
2.0	0.124	0.244	0.355	0.454	0.540	0.613	0.674	0.725	0.766	0.800	0.849	0.894	0.930	0.956

✓

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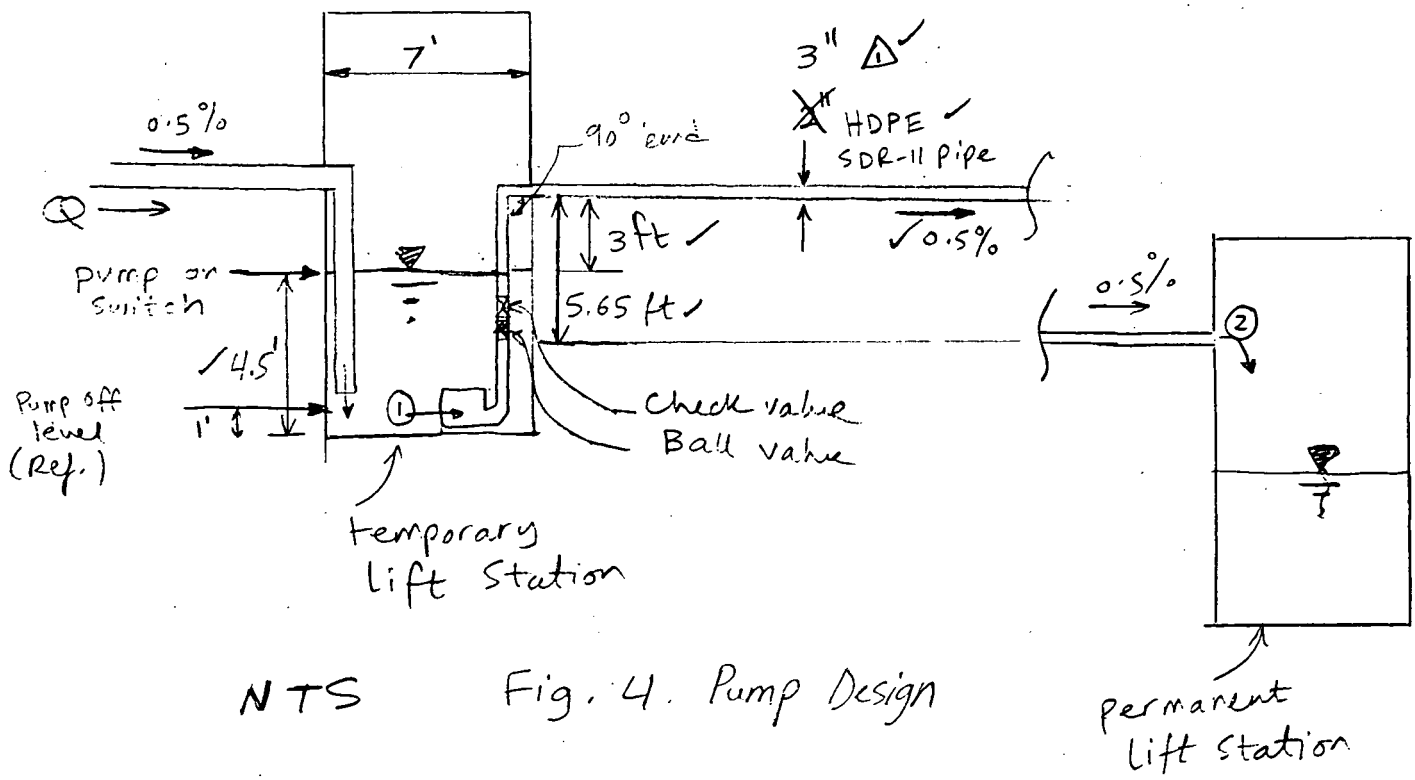
LTS TEMPORARY LIFT STATION PUMP CAPACITY REQUIREMENTS

The LTS temporary lift station is shown in Figure 3 on page 5. A simplified schematic is shown below as figure 4. Two pumps will be used to pump leachate from the temporary lift station to the permanent lift station.



NTS Fig. 4. Pump Design

Each of the two pumps should have capacity which exceeds the inflow rate into the lift station and should be able to provide

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hydraulic head which exceeds the friction loss in the 3" ~~X~~ pipe and the elevation head difference between the pump and the end of the pipe. The pump required flow capacity will be calculated to be the maximum flow rate anticipated during operations multiplied by a factor of safety of 3, or the maximum flow anticipated during a 2-yr 24-hr storm immediately after cell construction multiplied by a factor of safety of 2, whichever is larger.

consistent with calc. for gravity line flow capacity check

The hydraulic head needed from the pump is calculated using the conservation of energy equation as follows:

$$z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + H_P = z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \sum h_{L_{1-2}} \quad (6)$$

where: z_1 = elevation at point 1 measured from a reference point;

P_1 = pressure at point 1;

γ = unit weight of leachate;

V_1 = velocity at point 1;

g = gravity;

z_2, P_2, V_2 defined similarly to z_1, P_1, V_1

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H_p = hydraulic pressure provided by pump; ✓

$\sum h_{L_{1-2}}$ = summation of frictional loss between point 1 and 2. ✓

The velocity terms in Equation (6) are negligible and therefore can be deleted. ✓

$$\Longrightarrow \quad H_p = (Z_2 - Z_1) + \left(\frac{P_2 - P_1}{\gamma}\right) + \sum h_{L_{1-2}} \quad (7)$$

The friction head loss in this system is caused by: (i) inlet; (ii) ball value; (iii) check valve; (iv) 90° elbow; and (v) friction in the 3" Δ ✓ ~~2~~ pipe. ✓ To estimate these components, different procedures are used as follows:

- For inlet values and elbows, an equivalent length of straight pipe is available in the literature for the type of the value and its diameter. An example of these values is attached as Page 17. ✓

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Table 2 Equivalent Length of Straight Pipe for Various Fittings (feet)

(turbulent flow only, for any fluid)

fittings			pipe size (in.) 1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8	10	12	14	16	18	20	24
regular 90° ell	screwed	steel	2.3	3.1	3.6	4.4	5.2	6.6	7.4	8.5	9.3	11.0	13.0										
		c.i.										9.0	11.0										
	flanged	steel			0.92	1.2	1.6	2.1	2.4	3.1	3.6	4.4	5.9	7.3	8.9	12.0	14.0	17.0	18.0	21.0	23.0	25.0	30.0
		c.i.										3.6	4.8		7.2	9.8	12.0	15.0	17.0	19.0	22.0	24.0	28.0
long radius 90° ell	screwed	steel	1.5	2.0	2.2	2.3	2.7	3.2	3.4	3.6	3.6	4.0	4.6										
		c.i.										3.3	3.7										
	flanged	steel			1.1	1.3	1.6	2.0	2.3	2.7	2.9	3.4	4.2	5.0	5.7	7.0	8.0	9.0	9.4	10.0	11.0	12.0	14.0
		c.i.										2.8	3.4		4.7	5.7	6.8	7.8	8.6	9.6	11.0	11.0	13.0
regular 45° ell	screwed	steel	0.34	0.52	0.71	0.92	1.3	1.7	2.1	2.7	3.2	4.0	5.5										
		c.i.										3.3	4.5										
	flanged	steel			0.45	0.59	0.81	1.1	1.3	1.7	2.0	2.6	3.5	4.5	5.6	7.7	9.0	11.0	13.0	15.0	16.0	18.0	22.0
		c.i.										2.1	2.9		4.5	6.3	8.1	9.7	12.0	13.0	15.0	17.0	20.0
tee-line flow	screwed	steel	0.79	1.2	1.7	2.4	3.2	4.6	5.6	7.7	9.3	12.0	17.0										
		c.i.										9.9	14.0										
	flanged	steel			0.69	0.82	1.0	1.3	1.5	1.8	1.9	2.2	2.8	3.3	3.8	4.7	5.2	6.0	6.4	7.2	7.6	8.2	9.6
		c.i.										1.9	2.2		3.1	3.9	4.6	5.2	5.9	6.5	7.2	7.7	8.8
tee-branch flow	screwed	steel	2.4	3.5	4.2	5.3	6.6	8.7	9.9	12.0	13.0	17.0	21.0										
		c.i.										14.0	17.0										
	flanged	steel			2.0	2.6	3.3	4.4	5.2	6.6	7.5	9.4	12.0	15.0	18.0	24.0	30.0	34.0	37.0	43.0	47.0	52.0	62.0
		c.i.										7.7	10.0		15.0	20.0	25.0	30.0	35.0	39.0	44.0	49.0	57.0
180° return bend	screwed	steel	2.3	3.1	3.6	4.4	5.2	6.6	7.4	8.5	9.3	11.0	13.0										
		c.i.										9.0	11.0										
	reg. flanged	steel			0.92	1.2	1.6	2.1	2.4	3.1	3.6	4.4	5.9	7.3	8.9	12.0	14.0	17.0	18.0	21.0	23.0	25.0	30.0
		c.i.										3.6	4.8		7.2	9.8	12.0	15.0	17.0	19.0	22.0	24.0	28.0
	long rad. flanged	steel			1.1	1.3	1.6	2.0	2.3	2.7	2.9	3.4	4.2	5.0	5.7	7.0	8.0	9.0	9.4	10.0	11.0	12.0	14.0
		c.i.										2.8	3.4		4.7	5.7	6.8	7.8	8.6	9.6	11.0	11.0	13.0
globe valve	screwed	steel	21.0	22.0	22.0	24.0	29.0	37.0	42.0	54.0	62.0	79.0	110.0										
		c.i.										65.0	86.0										
	flanged	steel			38.0	40.0	45.0	54.0	59.0	70.0	77.0	94.0	120.0	150.0	190.0	260.0	310.0	390.0					
		c.i.										77.0	99.0		150.0	210.0	270.0	330.0					
gate valve	screwed	steel	0.32	0.45	0.56	0.67	0.84	1.1	1.2	1.5	1.7	1.9	2.5										
		c.i.										1.6	2.0										
	flanged	steel								2.6	2.7	2.8	2.9	3.1	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
		c.i.										2.3	2.4		2.6	2.7	2.8	2.9	2.9	3.0	3.0	3.0	3.0
angle valve	screwed	steel	12.8	15.0	15.0	15.0	17.0	18.0	18.0	18.0	18.0	18.0	18.0										
		c.i.										15.0	15.0										
	flanged	steel			15.0	15.0	17.0	18.0	18.0	21.0	22.0	28.0	38.0	50.0	63.0	90.0	120.0	140.0	160.0	190.0	210.0	240.0	300.0
		c.i.										23.0	31.0		52.0	74.0	98.0	120.0	150.0	170.0	200.0	230.0	280.0
swing check valve	screwed	steel	7.2	7.3	8.0	8.8	11.0	13.0	15.0	19.0	22.0	27.0	38.0										
		c.i.										22.0	31.0										
	flanged	steel			3.8	5.3	7.2	10.0	12.0	17.0	21.0	27.0	38.0	50.0	63.0	90.0	120.0	140.0					
		c.i.										22.0	31.0		52.0	74.0	98.0	120.0					
coupling or union	screwed	steel	0.14	0.18	0.21	0.24	0.29	0.36	0.39	0.45	0.47	0.53	0.65										
		c.i.										0.44	0.52										
inlets	bell mouth inlet	steel	0.04	0.07	0.10	0.13	0.18	0.26	0.31	0.43	0.52	0.67	0.95	1.3	1.6	2.3	2.9	3.5	4.0	4.7	5.3	6.1	7.6
		c.i.										0.55	0.77		1.3	1.9	2.4	3.0	3.6	4.3	5.0	5.7	7.0
	square mouth inlet	steel	0.44	0.68	0.96	1.3	1.8	2.6	3.1	4.3	5.2	6.7	9.5	13.0	16.0	23.0	29.0	35.0	40.0	47.0	53.0	61.0	76.0
		c.i.										5.5	7.7		13.0	19.0	24.0	30.0	36.0	43.0	50.0	57.0	70.0
	re-entrant pipe	steel	0.88	1.4	1.9	2.6	3.6	5.1	6.2	8.5	10.0	13.0	19.0	25.0	32.0	45.0	58.0	70.0	80.0	95.0	110.0	120.0	150.0
		c.i.										11.0	15.0		26.0	37.0	49.0	61.0	73.0	86.0	100.0	110.0	140.0

Used with permission of the Hydraulic Institute.

001221

Written by: MAO Date: 95/10/19 Reviewed by: R. Bonaparte Date: 95/10/19

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.6

GRS 95/10/21

- for friction loss in the pipe use the Darcy equation:

$$h_f = \frac{f\,L\,v^2}{2\,B_i\,g} \qquad (8)$$

where: h_f = friction head in pipe;

f = friction factor = function(Reynolds Number R_e, relative roughness of pipe $\frac{\varepsilon}{B_i}$)

See Figure 5;

$$R_e = \frac{B_i\,v}{\upsilon}$$

B_i = pipe inner diameter;

v = velocity of flow in pipe = $\frac{Q}{A}$ ave. velocity of

υ = Kinematic ~~velocity~~ viscosity of liquid

ε = specific roughness for pipe material.

Q = flow capacity of pump

A = area of pipe = $\frac{\pi B_i^2}{4}$

Written by: MAO Date: 95/10/19 (YY MM DD) Reviewed by: R. Bonaparte Date: 95/10/19 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.6

GRS 95/10/21

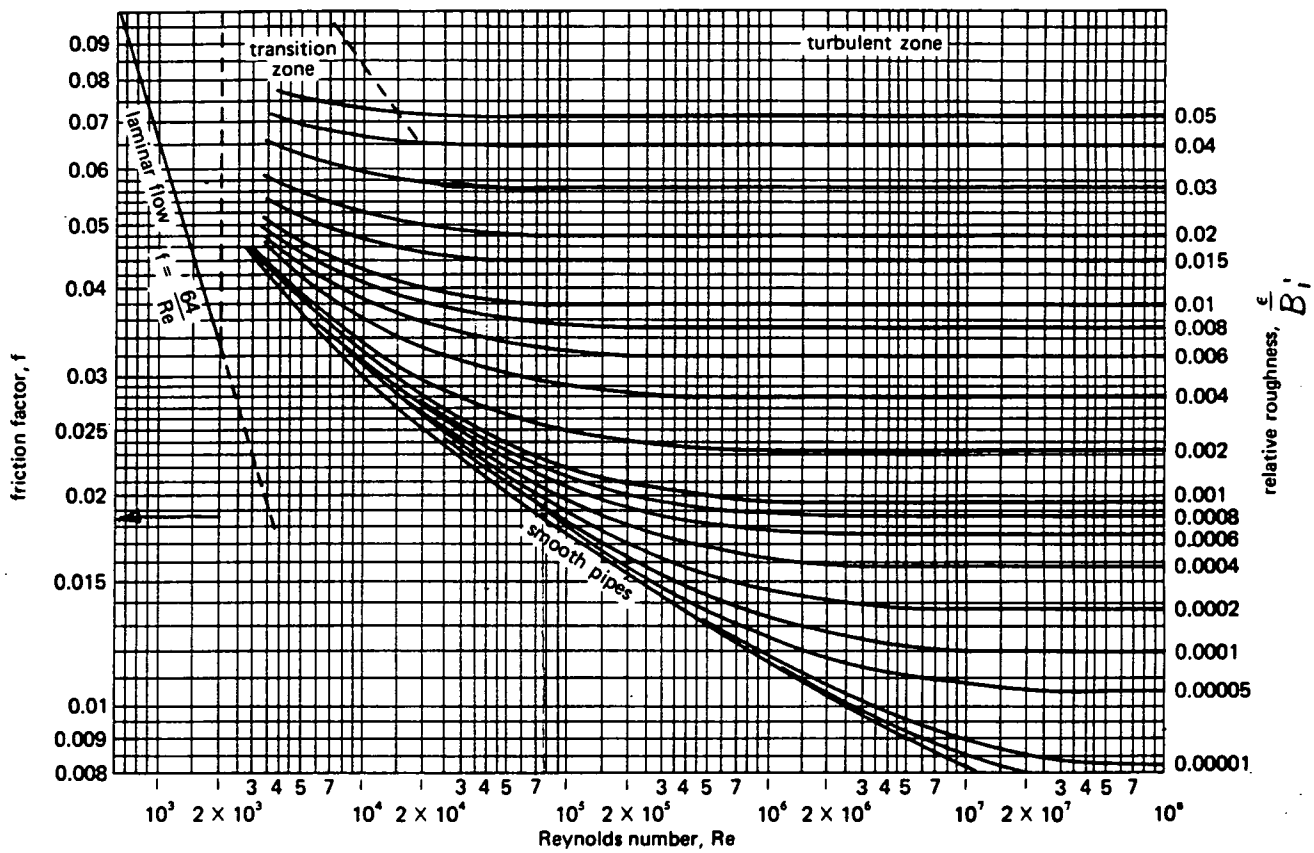

Figure 5. friction factor f as a function of Reynolds coefficient Re and relative roughness ($\frac{\varepsilon}{D}$). ✓

"Moody chart" ✓

Written by: MAO Date: 95/10/19 (YY MM DD) Reviewed by: R Bonapaik Date: 95/10/19 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.6

GRS 95/10/21

LTS PERMANENT LIFT STATION SIZING

The LTS permanent station should have capacity exceeding (i) the peak flow expected for the post-closure period over a one-week period and (ii) the peak flow expected during operations for a 1-hr period. These flow rates are available from the HELP model analyses performed as part of this package and the leachate generation rate package. The volume of liquid that can be stored in the permanent LTS lift station will be compared to these estimated peak flows. The permanent lift station dimensions are shown on Figure 6 attached on Page 21.

approx. storage volume = $\frac{\pi D^2}{4}(L)$

with D and L illustrated on p.21

Written by: MAO Date: 95/10/19 Reviewed by: R. Bonaparte Date: 95/10/19

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3509 Task No.: PB.6

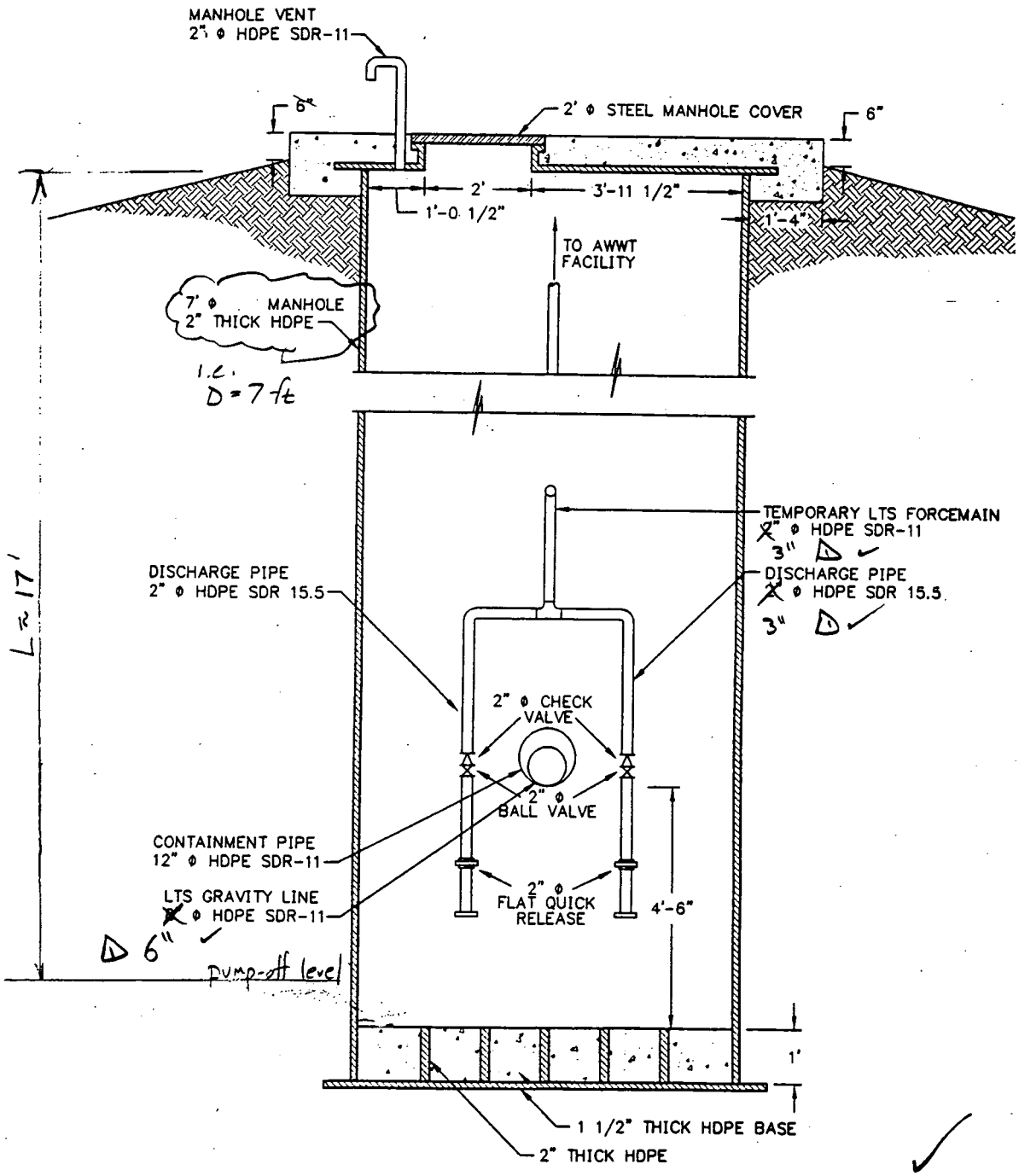

Figure 6. Permanent Lift Station.

Note: Plumbing layout has been modified from that shown above. The current layout will be shown in future revisions of this calculation.

Written by: MAO Date: 95/10/20 (YY MM DD) Reviewed by: GRS Date: 95/10/21 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: Φ8.6

LEACHATE TRANSMISSION SYSTEM RB 95/10/21
DATA VERIFICATION PACKAGE

LTS GRAVITY LINE FLOW CAPACITY

Step 1: (estimate flow rate into the LTS gravity line)

- Case 1 : (Operations flows)

From Leachate generation rate package, using the USEPA HELP model gave the following peak daily leachate generation rates:

- initial stage of operation case = 1,751 gpad ✓
- intermediate stage of operation case = 1,751 gpad ✓
- post-closure case = 0.0019 gpad.

- Case 2 : (cell construction flows)

- Run USEPA HELP for cell at condition just after placement of LCS drainage layer for the 2-yr, 24-hr storm. A detailed description of HELP data requirements and verification was included in the leachate generation rate package. Only changes in

Written by: MAO Date: 95/10/20 (YY MM DD) Reviewed by: GES Date: 95/10/21 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3906 Task No.: 98.6

95/10/21

the data from that package are listed below:

- precipitation data will be assumed zero for every day of the year except for 1 day where precipitation = 2-yr., 24-hr storm event precipitation = 2.5 inches ✓ (see Figure 3 of the 2000-yr flood plain determination Parson's report Aug 95).

- Evaporation will be essentially eliminated by assuming the evaporative zone depth = 1". ✓

- Runoff will be eliminated by assuming the fraction of runoff that can escape the cell = zero. ✓

- Only two layers will be modeled; the drainage layer and the geomembrane layer; the same material properties for these layers will be used as in the leachate generation package ✓. These properties are:

Written by: MAO Date: 95/10/20 (YY MM DD) Reviewed by: GRS Date: 95/10/21 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.6

RB 95/10/21

Drainage Layer:

thickness = 12" ✓

porosity = 0.397 vol/vol ✓

field capacity = 0.032 vol/vol ✓

wilting point = 0.013 vol/vol ✓

initial water content = 0.0304 vol/vol

Hydraulic Conductivity = 1×10^{-1} cm/s ✓

Slope = 2.24 % ✓

length = 224 ft ✓

Geomembrane:

thickness = 0.06" ✓

Hydraulic Cond. = 2×10^{-13} cm/s ✓

No holes or defects ✓

- For the intermediate stage of operation, peak flow rate = 1,751 gpad ✓

△ MAO 8 Dec 95
GRS 12 Dec 95

Written by: MAO Date: 95/10/20 Reviewed by: GRS Date: 95/10/21

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.6

RB 95/10/21

Step 2: (estimate pipe flow capacity)

The LTS gravity line will be an ~~8~~ 6 △✓-in. diameter pipe with SDR = 11

→ B_i = pipe inner diameter = ~~7.057~~ 5.421 △✓ in.
OD = ~~8.625~~ 6.625 △✓ " wall = ~~0.784~~ 0.602 △✓ " = ~~0.179~~ 0.138 △✓ m ✓

i_p = average slope of pipe =
(see figure 1 of procedures package)

$$\frac{0.75\% \times 2008\ ft + 0.5\% \times 1522\ ft}{2008\ ft + 1522\ ft}$$

= ~~0.64%~~ use minimum slope, 0.5%

n = manning's roughness coefficient
≃ 0.013 ✓ ~~s/m^0.33~~ dimensionless (for smooth pipe)
↳ conservative, a value of 0.009 is often used

LTS GRAVITY LINE STRUCTURAL STABILITY

* See data verification package for LCS ✓
Pipe diameter = 12 in. ✓
SDR = 11 ✓
σ_y = compressive yield strength of pipe
≃ 216,000 psf (HDPE) ✓
E' = modulus of soil reaction (assume
= 432,000 psf ✓

1 MAO 95/12/8 4a/7
GRS 12 Dec 95

DRISCOPIPE

Dimensions and Pressure Ratings
1000 Series Pipe

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Size	SDR	PSI @73.4	Weight lbs.	Dimensions - Inches Nominal O D	Approx. I D	Min. Wall
2"	11	160	.62	2.375	1.865	.216
	13.5	128	.52		2.023	.176
	15.5	110	.46		2.069	.153
	17	100	.42		2.095	.140
3"	7	267	2.00	3.500	2.500	.500
	9	200	1.62		2.722	.389
	11	160	1.35		2.864	.318
	13.5	128	1.12		2.982	.259
	15.5	110	.99		3.048	.226
	17	100	.91		3.088	.206
	19	89	.82		3.132	.184
	21	80	.74		3.166	.167
	26	64	.61		3.230	.135
	32.5	51	.49		3.284	.108
4"	7	267	3.31	4.500	3.214	.643
	9	200	2.67		3.500	.500
	11	160	2.23		3.682	.409
	13.5	128	1.85		3.834	.333
	15.5	110	1.63		3.920	.290
	17	100	1.50		3.970	.265
	19	89	1.35		4.026	.237
	21	80	1.23		4.072	.214
	26	64	1.00		4.154	.173
	32.5	51	.81		4.224	.138
5-3/8"	21	80	1.75	5.375	4.863	.256
	26	64	1.43		4.961	.207
	32.5	51	1.15		5.045	.165
5"	7	267	5.05	5.563	3.973	.795
	9	200	4.08		4.327	.618
	11	160	3.42		4.551	.506
	13.5	128	2.84		4.739	.412
	15.5	110	2.50		4.845	.359
	17	100	2.29		4.909	.327
	19	89	2.07		4.977	.293
	21	80	1.88		5.033	.265
	26	64	1.53		5.135	.214
	32.5	51	1.23		5.221	.171
6"	7	267	7.16	6.625	4.733	.946
	9	200	5.78		5.153	.736
	11	160	4.84		5.421	.602
	13.5	128	4.03		5.643	.491
	15.5	110	3.54		5.771	.427
	17	100	3.25		5.845	.390
	19	89	2.93		5.927	.349
	21	80	2.66		5.995	.315
	26	64	2.17		6.115	.255
	32.5	51	1.75		6.217	.204
7"	7	267	8.29	7.125	5.089	1.018
	9	200	6.69		5.541	.792
	11	160	5.61		5.829	.648
	13.5	128	4.66		6.069	.528
	15.5	110	4.10		6.205	.460
	17	100	3.76		6.287	.419
	19	89	3.39		6.375	.375
	21	80	3.08		6.445	.340
	26	64	2.51		6.577	.274
	32.5	51	2.02		6.685	.220
8"	7	267	12.14	8.625	6.161	1.232
	9	200	9.80		6.709	.958
	11	160	8.21		7.057	.784
	13.5	128	6.82		7.347	.639
	15.5	110	6.00		7.513	.556
	17	100	5.50		7.611	.507
	19	89	4.96		7.717	.454
	21	80	4.52		7.803	.411
	26	64	3.68		7.961	.332
	32.5	51	2.97		8.095	.265
10"	7	267	18.86	10.750	7.678	1.536
	9	200	15.23		8.362	1.194
	11	160	12.75		8.796	.977
	13.5	128	10.59		9.158	.796
	15.5	110	9.33		9.362	.694
	17	100	8.55		9.486	.632
	19	89	7.71		9.618	.566
	21	80	7.01		9.726	.512
	26	64	5.71		9.924	.413
	32.5	51	4.62		10.088	.331
12"	7	267	26.53	12.750	9.108	1.821
	9	200	21.44		9.916	1.417
	11	160	17.94		10.432	1.159
	13.5	128	14.89		10.862	.944
	15.5	110	13.12		11.104	.823
	17	100	12.03		11.250	.750
	19	89	10.84		11.408	.671
	21	80	9.86		11.536	.607
	26	64	8.04		11.770	.490
	32.5	51	6.48		11.966	.392
13"	7	267	29.24	13.386	9.562	1.912
	9	200	23.62		10.412	1.487
	11	160	19.78		10.952	1.217
	13.5	128	16.43		11.402	.992
	15.5	110	14.46		11.658	.864
	17	100	13.26		11.812	.787
	19	89	11.96		11.976	.705
	21	80	10.86		12.112	.637
	26	64	8.87		12.356	.515
	32.5	51	7.15		12.562	.412
14"	7	267	31.99	14.000	10.000	2.000
	9	200	25.84		10.888	1.556
	11	160	21.64		11.454	1.273
	13.5	128	17.97		11.926	1.037
	15.5	110	15.81		12.194	.903
	17	100	14.52		12.352	.824
	19	89	13.07		12.526	.737
	21	80	11.90		12.666	.667
	26	64	9.69		12.924	.538
	32.5	51	7.83		13.138	.431
16"	9	200	33.75	16.000	12.444	1.778
	11	160	28.27		13.090	1.455
	13.5	128	23.46		13.630	1.185
	15.5	110	20.65		13.936	1.032
	17	100	18.95		14.118	.941
	19	89	17.07		14.316	.842
	21	80	15.53		14.476	.762
	26	64	12.66		14.770	.615
	32.5	51	10.21		15.016	.492

FIFEPIPE
P.O. Box 761
Brandon, FL 33509
(813) 681-3785 or Bartow 533-9068
Fax # (813) 684-1284

001230

GEOSYNTEC CONSULTANTS

Written by: MAO Date: 95/10/20 (YY/MM/DD) Reviewed by: GRS Date: 95/10/21 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: Ø8.6

RB 95/10/21

E = modulus of elasticity of pipe material
= 2.74×10^5 psf ✓

Δ_R = allowable ring deflection = 7 % (for SDR = 11 gravity pipe) ✓

γ_p = unit wt. of material above the pipe (i.e., backfill) is assumed
= 125 pcf. ✓

Dp = depth to top of pipe ≈ 10 ft ✓ (see project design drawings) reasonable

B_c = outer pipe diameter = 12.75 in. ✓
= 1.0625 ft

L_{ic} = effective pipe length = 3 ft ✓

F_{ic} = impact factor for dynamic loads
= 1.5 ✓

For $\frac{L_{ic}}{2D_p} = \frac{3 \text{ ft}}{2 \times 10 \text{ ft}} = 0.15$ ✓ and $\frac{B_c}{2D_p}$

$= \frac{12.75/12 \text{ ft}}{2 \times 10 \text{ ft}} = 0.053$ ✓

→ load coefficient C_s = 0.015 ✓ (Table 1, procedures package) conservative extrapolation

001231

P = 20,000 lb assumed based on truck with capacity = 35 tons and wheel load = 20,000 lb when full. ✓

Δ MAJ 95/12/8
GRS 12 Dec 95

Written by: MAJ Date: 95/10/20 (YY MM DD) Reviewed by: GRS Date: 95/10/21 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3000 Task No.: 08.6

RB 95/10/21

LTS TEMPORARY LIFT STATION PUMP CAPACITY REQUIREMENTS

Using the pump off level as the reference point:

$z_1 = 0$ ✓

$\frac{P_1}{\gamma} =$ ~~3.5 ft~~ use pressure when liquid at pump off level $= 0$ ft

$z_2 = 0.85'$ ✓

$\frac{P_2}{\gamma} = 0$ ✓

From Table 2 of procedures package:

Equivalent lengths are:

- for regular 90° elbow = ~~8.5~~ 11.0 Δ ft ✓
- for check value (screwed) = ~~19~~ 27 Δ ft ✓
- no values available in Table 2 for Ball value → assume = ~~19~~ 27 Δ ft ✓
- for inlet assume square steel mouth → ~~4.3 ft~~ 6.7 Δ ✓

Pipe is ~~2"~~ 3" Δ SDR = 11 → B_i = ~~1.865~~ 2.864" = 0.239' Δ in = ~~0.155'~~ ~~1.943" = 0.162'~~

ν = kinematic velocity of leachate, assume equal to water @ 50°F average → $\nu = 1.41 \times 10^{-5}$ ft²/sec (Thermodynamics text books)

001232

Written by: MAG Date: 95/10/20 (YY MM DD) Reviewed by: R. Bonaparte Date: 95/10/21 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 98.6

L = 400' + 400' + 330' = 1130 ft ✓ equiv. lengths for valves + fittings to be added

e = specific roughness = 0.000005 ft ✓
for plastic pipes

LTS PERMANENT LIFT STATION SIZING

Diameter = 7 ft ✓
Depth = 17 ft ✓

Written by: MAO Date: 95/10/21 Reviewed by: GRS Date: 95/10/21

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: Ø8.6

LEACHATE TRANSMISSION SYSTEM CALCULATIONS

LTS GRAVITY FLOW CAPACITY

Step 1 : estimate flow rate into the LTS gravity line

Case 1 : maximum operations flow

= 1,751 gpad × 6.5 acres × 2 cells
+ 0.0019 gpad × 6.5 acres × 7 cells

= 22,763 gpd ✓ = 15.8 gpm ✓

Apply FOS = 3 (for pump calcs) → $Q_{①}$ = 15.8 × 3 = 47.4 gpm ✓

Case 2 : USEPA HELP output is attached

peak daily flow for a cell immediately after construction from a 2-hr, 24-hr storm event = 631 ft³/acre/day ✓

× 6.5 acres × ~~7.467~~ 7.481 ① ✓ gallons/ft³

= ~~32,626~~ 30,683 ① ✓ gpd ✓ = ~~21~~ 21.3 ① ✓ gpm ✓

+ flow for intermediate stage (7.9 gpm) ✓ i.e. ½ of flow calc. above for case 1

= ~~28.9~~ 29.2 ① ✓ gpm ✓

MA 95/10/21

GRS 95/10/21


```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                 **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\APPLICAT.ION\HELP\HELP3\MAJ.D4
TEMPERATURE DATA FILE:        C:\APPLICAT.ION\HELP\HELP3\MAJ.D7
SOLAR RADIATION DATA FILE:    C:\APPLICAT.ION\HELP\HELP3\MAJ.D13
EVAPOTRANSPIRATION DATA:      C:\APPLICAT.ION\HELP\HELP3\MAJ.D11
SOIL AND DESIGN DATA FILE:    C:\APPLICAT.ION\HELP\HELP3\MAJ.D10
OUTPUT DATA FILE:             C:\APPLICAT.ION\HELP\HELP3\MAJ.OUT


TIME:  17:26     DATE:  10/20/1995


******************************************************************************

     TITLE:  FERNALD OSDF, 24-hr 2-yr storm event, newly constructed cell

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                       TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =      12.00    INCHES
          POROSITY                   =       0.3970 VOL/VOL
          FIELD CAPACITY             =       0.0320 VOL/VOL
          WILTING POINT              =       0.0130 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0.0304 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.100000001000     CM/SEC
          SLOPE                      =       2.24    PERCENT
          DRAINAGE LENGTH            =     224.0     FEET
```

LAYER 2

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	0.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 224. FEET.

SCS RUNOFF CURVE NUMBER	=	70.50	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	1.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.013	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	0.397	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.013	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	0.365	INCHES
TOTAL INITIAL WATER	=	0.365	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	104	
END OF GROWING SEASON (JULIAN DATE)	=	295	
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00	%

MAJ 95/10/21
GRS 95/10/21

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR COVINGTON KENTUCKY

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NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.13	2.73	3.95	3.58	3.84	4.09
4.28	2.97	2.91	2.54	3.12	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.10 DEGREES

HEAD #1: AVERAGE HEAD ON TOP OF LAYER 2
DRAIN #1: LATERAL DRAINAGE FROM LAYER 1 (RECIRCULATION AND COLLECTION)
LEAK #1: PERCOLATION OR LEAKAGE THROUGH LAYER 2

****

DAILY OUTPUT FOR YEAR 1

DAY	AIR	SOIL	RAIN IN.	RUNOFF IN.	ET IN.	E. ZONE WATER IN./IN.	HEAD #1 IN.	DRAIN #1 IN.	LEAK #1 IN.
1	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
2	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
3	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
4	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
5	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
6			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
7	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
8	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
9	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
10	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
11	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00

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12	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
13	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
14	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
15	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
16	*	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
17	*	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
18	*	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
19		*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
20		*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
21			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
22			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
23			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
24			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
25			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
26			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
27			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
28			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
29			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
30			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
31			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
32	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
33	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
34			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
35	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
36	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
37	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
38			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
39			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
40			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
41			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
42			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
43			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
44			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
45			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
46			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
47			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
48			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
49			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
50			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
51			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
52			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
53	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
54	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
55			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
56	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
57	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
58			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
59			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
60			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
61	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
62	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
63			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
64			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
65	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
66	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
67			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
68	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
69			0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
70	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
71	*		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00

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72	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
73	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
74		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
75		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
76		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
77		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
78		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
79		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
80		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
81		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
82		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
83		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
84		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
85		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
86		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
87		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
88		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
89		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
90		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
91		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
92		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
93		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
94		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
95		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
96		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
97		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
98		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
99	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
100		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
101		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
102		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
103		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
104		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
105		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
106		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
107		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
108		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
109		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
110		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
111		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
112		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
113		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
114		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
115		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
116		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
117		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
118		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
119		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
120		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
121		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
122		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
123		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
124		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
125		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
126		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
127		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
128		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
129		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
130		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
131		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00

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132	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
133	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
134	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
135	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
136	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
137	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
138	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
139	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
140	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
141	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
142	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
143	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
144	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
145	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
146	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
147	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
148	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
149	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
150	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
151	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
152	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
153	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
154	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
155	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
156	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
157	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
158	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
159	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
160	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
161	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
162	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
163	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
164	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
165	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
166	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
167	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
168	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
169	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
170	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
171	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
172	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
173	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
174	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
175	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
176	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
177	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
178	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
179	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
180	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
181	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
182	2.50	0.000	0.003	0.2050	2.0108	.6068E-01	.2280E-06
183	0.00	0.000	0.000	0.0130	6.4924	.1738	.7361E-06
184	0.00	0.000	0.000	0.0130	6.0286	.1619	.6836E-06
185	0.00	0.000	0.000	0.0130	5.5965	.1510	.6346E-06
186	0.00	0.000	0.000	0.0130	5.1934	.1409	.5889E-06
187	0.00	0.000	0.000	0.0130	4.8170	.1316	.5462E-06
188	0.00	0.000	0.000	0.0130	4.4656	.1229	.5063E-06
189	0.00	0.000	0.000	0.0130	4.1369	.1151	.4691E-06
190	0.00	0.000	0.000	0.0130	3.8290	.1079	.4342E-06
191	0.00	0.000	0.000	0.0130	3.5404	.1012	.4014E-06

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192	0.00	0.000	0.000	0.0130	3.2697	.9471E-01	.3707E-06
193	0.00	0.000	0.000	0.0130	3.0166	.8868E-01	.3420E-06
194	0.00	0.000	0.000	0.0130	2.7794	.8314E-01	.3151E-06
195	0.00	0.000	0.000	0.0130	2.5570	.7795E-01	.2899E-06
196	0.00	0.000	0.000	0.0130	2.3485	.7310E-01	.2663E-06
197	0.00	0.000	0.000	0.0130	2.1529	.6856E-01	.2441E-06
198	0.00	0.000	0.000	0.0130	1.9695	.6430E-01	.2233E-06
199	0.00	0.000	0.000	0.0130	1.7975	.6033E-01	.2038E-06
200	0.00	0.000	0.000	0.0130	1.6361	.5662E-01	.1855E-06
201	0.00	0.000	0.000	0.0130	1.4843	.5327E-01	.1683E-06
202	0.00	0.000	0.000	0.0130	1.3419	.4992E-01	.1522E-06
203	0.00	0.000	0.000	0.0130	1.2086	.4663E-01	.1370E-06
204	0.00	0.000	0.000	0.0130	1.0839	.4360E-01	.1229E-06
205	0.00	0.000	0.000	0.0130	0.9676	.4080E-01	.1097E-06
206	0.00	0.000	0.000	0.0130	0.8588	.3794E-01	.9738E-07
207	0.00	0.000	0.000	0.0130	0.7572	.3561E-01	.8585E-07
208	0.00	0.000	0.000	0.0130	0.6621	.3323E-01	.7507E-07
209	0.00	0.000	0.000	0.0130	0.5735	.3083E-01	.6502E-07
210	0.00	0.000	0.000	0.0130	0.4916	.2786E-01	.5575E-07
211	0.00	0.000	0.000	0.0130	0.4197	.2378E-01	.4758E-07
212	0.00	0.000	0.000	0.0130	0.3582	.2030E-01	.4062E-07
213	0.00	0.000	0.000	0.0130	0.3057	.1732E-01	.3467E-07
214	0.00	0.000	0.000	0.0130	0.2610	.1479E-01	.2959E-07
215	0.00	0.000	0.000	0.0130	0.2228	.1262E-01	.2526E-07
216	0.00	0.000	0.000	0.0130	0.1901	.1077E-01	.2156E-07
217	0.00	0.000	0.000	0.0130	0.1623	.9196E-02	.1840E-07
218	0.00	0.000	0.000	0.0130	0.1385	.7850E-02	.1571E-07
219	0.00	0.000	0.000	0.0130	0.1182	.6700E-02	.1341E-07
220	0.00	0.000	0.000	0.0130	0.1009	.5719E-02	.1144E-07
221	0.00	0.000	0.000	0.0130	0.0861	.4881E-02	.9768E-08
222	0.00	0.000	0.000	0.0130	0.0735	.4167E-02	.8338E-08
223	0.00	0.000	0.000	0.0130	0.0628	.3556E-02	.7143E-08
224	0.00	0.000	0.000	0.0130	0.0536	.3036E-02	.6803E-08
225	0.00	0.000	0.000	0.0130	0.0457	.2591E-02	.6803E-08
226	0.00	0.000	0.000	0.0130	0.0390	.2212E-02	.6803E-08
227	0.00	0.000	0.000	0.0130	0.0333	.1888E-02	.6803E-08
228	0.00	0.000	0.000	0.0130	0.0284	.1611E-02	.6803E-08
229	0.00	0.000	0.000	0.0130	0.0243	.1375E-02	.6803E-08
230	0.00	0.000	0.000	0.0130	0.0207	.1174E-02	.6803E-08
231	0.00	0.000	0.000	0.0130	0.0177	.1002E-02	.6803E-08
232	0.00	0.000	0.000	0.0130	0.0151	.8553E-03	.6803E-08
233	0.00	0.000	0.000	0.0130	0.0129	.7301E-03	.6803E-08
234	0.00	0.000	0.000	0.0130	0.0110	.6232E-03	.6803E-08
235	0.00	0.000	0.000	0.0130	0.0094	.5319E-03	.6803E-08
236	0.00	0.000	0.000	0.0130	0.0080	.4540E-03	.6803E-08
237	0.00	0.000	0.000	0.0130	0.0068	.3875E-03	.6803E-08
238	0.00	0.000	0.000	0.0130	0.0058	.3308E-03	.6803E-08
239	0.00	0.000	0.000	0.0130	0.0050	.2823E-03	.6803E-08
240	0.00	0.000	0.000	0.0130	0.0043	.2410E-03	.6803E-08
241	0.00	0.000	0.000	0.0130	0.0036	.2057E-03	.6803E-08
242	0.00	0.000	0.000	0.0130	0.0031	.1756E-03	.6803E-08
243	0.00	0.000	0.000	0.0130	0.0026	.1499E-03	.6803E-08
244	0.00	0.000	0.000	0.0130	0.0023	.1279E-03	.6803E-08
245	0.00	0.000	0.000	0.0130	0.0019	.1092E-03	.6803E-08
246	0.00	0.000	0.000	0.0130	0.0016	.9320E-04	.6803E-08
247	0.00	0.000	0.000	0.0130	0.0014	.7955E-04	.6803E-08
248	0.00	0.000	0.000	0.0130	0.0012	.6790E-04	.6803E-08
249	0.00	0.000	0.000	0.0130	0.0010	.5796E-04	.6803E-08
250	0.00	0.000	0.000	0.0130	0.0009	.4947E-04	.6803E-08
251	0.00	0.000	0.000	0.0130	0.0007	.4222E-04	.6803E-08

252	0.00	0.000	0.000	0.0130	0.0006	.3604E-04	.6803E-08
253	0.00	0.000	0.000	0.0130	0.0005	.3076E-04	.6803E-08
254	0.00	0.000	0.000	0.0130	0.0005	.2626E-04	.6803E-08
255	0.00	0.000	0.000	0.0130	0.0004	.2241E-04	.6803E-08
256	0.00	0.000	0.000	0.0130	0.0003	.1913E-04	.6803E-08
257	0.00	0.000	0.000	0.0130	0.0003	.1633E-04	.6803E-08
258	0.00	0.000	0.000	0.0130	0.0002	.1393E-04	.6803E-08
259	0.00	0.000	0.000	0.0130	0.0002	.1189E-04	.6803E-08
260	0.00	0.000	0.000	0.0130	0.0002	.1015E-04	.6803E-08
261	0.00	0.000	0.000	0.0130	0.0002	.8662E-05	.6803E-08
262	0.00	0.000	0.000	0.0130	0.0001	.7393E-05	.6803E-08
263	0.00	0.000	0.000	0.0130	0.0001	.6309E-05	.6803E-08
264	0.00	0.000	0.000	0.0130	0.0001	.5384E-05	.6803E-08
265	0.00	0.000	0.000	0.0130	0.0001	.4595E-05	.6803E-08
266	0.00	0.000	0.000	0.0130	0.0001	.3921E-05	.6803E-08
267	0.00	0.000	0.000	0.0130	0.0001	.3346E-05	.6803E-08
268	0.00	0.000	0.000	0.0130	0.0001	.2855E-05	.6803E-08
269	0.00	0.000	0.000	0.0130	0.0000	.2436E-05	.6803E-08
270	0.00	0.000	0.000	0.0130	0.0000	.2078E-05	.6803E-08
271	0.00	0.000	0.000	0.0130	0.0000	.1773E-05	.6803E-08
272	0.00	0.000	0.000	0.0130	0.0000	.1512E-05	.6803E-08
273	0.00	0.000	0.000	0.0130	0.0000	.1290E-05	.6803E-08
274	0.00	0.000	0.000	0.0130	0.0000	.1100E-05	.6803E-08
275	0.00	0.000	0.000	0.0130	0.0000	.9379E-06	.6803E-08
276	0.00	0.000	0.000	0.0130	0.0000	.7995E-06	.6803E-08
277	0.00	0.000	0.000	0.0130	0.0000	.6815E-06	.6803E-08
278	0.00	0.000	0.000	0.0130	0.0000	.5807E-06	.6803E-08
279	0.00	0.000	0.000	0.0130	0.0000	.4946E-06	.6803E-08
280	0.00	0.000	0.000	0.0130	0.0000	.4212E-06	.6803E-08
281	0.00	0.000	0.000	0.0130	0.0000	.3585E-06	.6803E-08
282	0.00	0.000	0.000	0.0130	0.0000	.3050E-06	.6803E-08
283	0.00	0.000	0.000	0.0130	0.0000	.2594E-06	.6803E-08
284	0.00	0.000	0.000	0.0130	0.0000	.2204E-06	.6803E-08
285	0.00	0.000	0.000	0.0130	0.0000	.1871E-06	.6803E-08
286	0.00	0.000	0.000	0.0130	0.0000	.1587E-06	.6803E-08
287	0.00	0.000	0.000	0.0130	0.0000	.1345E-06	.6803E-08
288	0.00	0.000	0.000	0.0130	0.0000	.1138E-06	.6803E-08
289	0.00	0.000	0.000	0.0130	0.0000	.9614E-07	.6803E-08
290	0.00	0.000	0.000	0.0130	0.0000	.8106E-07	.6803E-08
291	0.00	0.000	0.000	0.0130	0.0000	.6820E-07	.6803E-08
292	0.00	0.000	0.000	0.0130	0.0000	.5721E-07	.6803E-08
293	0.00	0.000	0.000	0.0130	0.0000	.4784E-07	.6803E-08
294	0.00	0.000	0.000	0.0130	0.0000	.3984E-07	.6803E-08
295	0.00	0.000	0.000	0.0130	0.0000	.3301E-07	.6803E-08
296	0.00	0.000	0.000	0.0130	0.0000	.2718E-07	.6803E-08
297	0.00	0.000	0.000	0.0130	0.0000	.2220E-07	.6803E-08
298	0.00	0.000	0.000	0.0130	0.0000	.1795E-07	.6803E-08
299	0.00	0.000	0.000	0.0130	0.0000	.1433E-07	.6803E-08
300	0.00	0.000	0.000	0.0130	0.0000	.1123E-07	.6803E-08
301	0.00	0.000	0.000	0.0130	0.0000	.8593E-08	.6803E-08
302	0.00	0.000	0.000	0.0130	0.0000	.6338E-08	.6803E-08
303	0.00	0.000	0.000	0.0130	0.0000	.4414E-08	.6803E-08
304	0.00	0.000	0.000	0.0130	0.0000	.2771E-08	.6803E-08
305	0.00	0.000	0.000	0.0130	0.0000	.1369E-08	.6803E-08
306	0.00	0.000	0.000	0.0130	0.0000	.2251E-09	.3589E-08
307	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
308	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
309	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
310	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
311	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00

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GRS 95/10/21

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312		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
313		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
314		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
315		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
316		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
317		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
318		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
319		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
320		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
321		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
322		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
323		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
324		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
325		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
326		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
327	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
328		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
329		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
330		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
331		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
332		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
333		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
334		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
335		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
336		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
337		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
338	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
339		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
340		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
341		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
342		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
343		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
344	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
345	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
346	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
347	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
348	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
349	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
350		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
351		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
352	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
353	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
354	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
355	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
356	*	0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
357		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
358		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
359		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
360		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
361		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
362		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
363		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
364		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00
365		0.00	0.000	0.000	0.0130	0.0000	.0000E+00	.0000E+00

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MONTHLY TOTALS (IN INCHES) FOR YEAR 1

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	0.00	0.00	0.00	0.00	0.00	0.00
	2.50	0.00	0.00	0.00	0.00	0.00
RUNOFF	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION	0.000	0.000	0.000	0.000	0.000	0.000
	0.003	0.000	0.000	0.000	0.000	0.000
LATERAL DRAINAGE COLLECTED	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FROM LAYER 1	2.3782	0.1174	0.0009	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LAYER 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON	0.000	0.000	0.000	0.000	0.000	0.000
LAYER 2	2.511	0.067	0.001	0.000	0.000	0.000
STD. DEVIATION OF DAILY	0.000	0.000	0.000	0.000	0.000	0.000
HEAD ON LAYER 2	1.798	0.083	0.001	0.000	0.000	0.000

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	2.50	9075.000	100.00
RUNOFF	0.000	0.000	0.00 ✓
EVAPOTRANSPIRATION	0.003	12.479	0.14 ✓
DRAINAGE COLLECTED FROM LAYER 1	2.4966	9062.482	99.86
PERC./LEAKAGE THROUGH LAYER 2	0.000010	0.035	0.00
AVG. HEAD ON TOP OF LAYER 2	0.2149		
CHANGE IN WATER STORAGE	0.000	0.000	0.00
SOIL WATER AT START OF YEAR	0.717	2602.664	

SOIL WATER AT END OF YEAR	0.717	2602.664	
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	0.004	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 1

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.00	0.00	0.00	0.00	0.00	0.00
	2.50	0.00	0.00	0.00	0.00	0.00
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.003	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
LATERAL DRAINAGE COLLECTED FROM LAYER 1						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	2.3782	0.1174	0.0009	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 2

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	2.5111	0.0669	0.0005	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	2.50	(0.000)	9075.0	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	0.003	(0.0000)	12.48	0.138
LATERAL DRAINAGE COLLECTED FROM LAYER 1	2.49655	(0.00000)	9062.482	99.86206
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.00001	(0.00000)	0.035	0.00038
AVERAGE HEAD ACROSS TOP OF LAYER 2	0.215	(0.000)		
CHANGE IN WATER STORAGE	0.000	(0.0000)	0.00	0.000

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 1

186

	(INCHES)	(CU. FT.)
PRECIPITATION	2.50	9075.000
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 1	0.17385	631.05963
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.000001	0.00267
AVERAGE HEAD ACROSS LAYER 2	6.492	
SNOW WATER	0.00	0.0000

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2050
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0117

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MAQ 95/10/21
GRS 95/10/21

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FINAL WATER STORAGE AT END OF YEAR 1

186

LAYER	(INCHES)	(VOL/VOL)
1	0.3650	0.0304
2	0.0000	0.0000
SNOW WATER	0.000	

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Written by: MAO Date: 95/10/21 (YY MM DD) Reviewed by: GRS Date: 95/10/21 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 98.6

Apply FOS = 2 (for pump calcs) → $Q_{②}$ = ~~57.8~~ 58.4 Δ gpm

The largest flow rate is associated with case 2 = ~~57.8~~ 58.4 Δ gpm

Say 60 gpm (for pump calcs)

Written by: MAO Date: 95/10/21 (YY/MM/DD) Reviewed by: GRS Date: 95/10/21 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.6

Step 2 : estimate flow capacity of the gravity line

$$Q_p = \frac{R_h^{0.66} \, i_p^{0.5} \, A_p}{n}$$

$$A_p = \frac{\pi B_i^2}{4} = \frac{\pi \left(\cancel{0.179}\ 0.138\ \text{m}\right)^2}{4} = \cancel{0.0252}\ 0.0150\ \text{m}^2$$

$$R_h = \frac{B_i}{4} = \frac{\cancel{0.179}\ 0.138\ \text{m}}{4} = \cancel{0.0448}\ 0.0345\ \text{m}$$

$$i_p = \cancel{0.64\ \%}\ 0.5\%$$

$$n = 0.013\ \cancel{s/m^{0.33}}\ \text{dimensionless}$$

$$\rightarrow Q_p = \frac{\left(\cancel{0.0448}\ 0.0345\ \text{m}\right)^{0.66} \left(\cancel{0.0064}\ 0.005\right)^{0.5} \left(\cancel{0.0252}\ 0.0150\ \text{m}^2\right)}{0.013\ \cancel{s/m^{0.33}}}$$

$$= \cancel{0.02}\ \cancel{0.018}\ 0.0088\ \text{m}^3/\text{s} = \cancel{316}\ \cancel{285}\ 140\ \text{gpm}$$

Ratio of pipe flow capacity to peak flow rate into the pipe $= \dfrac{\cancel{285}\ \cancel{316}\ 140\ \text{gpm}}{\cancel{28.9}\ 29.2\ \text{gpm}} = \cancel{11}\ \cancel{9.9}\ 4.8$ o.k.

Written by: MAS Date: 95/10/21 (YY MM DD) Reviewed by: GRS Date: 95/10/21 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.6

LTS GRAVITY LINE STRUCTURAL CAPACITY

- Calculate σ_{max}:

$$\sigma_{max} = \gamma_p D_p + \frac{C_s \; P \; F_{ic}}{L_{ic} \; B_c}$$

$$= (125 \text{ pcf})(10 \text{ ft}) + \frac{(0.015)(20{,}000 \text{ lb})(1.5)}{3 \text{ ft} \; (1.0625 \text{ ft})}$$

$$= 1{,}250 \text{ psf} + 141 \text{ psf} = 1{,}391 \text{ psf}$$

- $$FS_{wc} = \frac{2 \; \sigma_y}{(SDR - 1) \; \sigma_{max}}$$

$$= \frac{2 \; (216{,}000 \text{ psf})}{(11-1)(1{,}391 \text{ psf})} = \underline{31} \quad \text{o.k.}$$

- $$FS_{wb} = \frac{1.2}{\sigma_{max}} \left[\frac{E' E}{(SDR)^3} \right]^{1/2}$$

$$= \frac{1.2}{1{,}391 \text{ psf}} \left[\frac{432{,}000 \text{ psf} \times 2.74 \times 10^6 \text{ psf}}{(11)^3} \right]^{1/2}$$

$$= \underline{26} \quad \text{o.k.}$$

Written by: MAO Date: 95/10/20 (YY MM DD) Reviewed by: GRS Date: 95/10/21 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 03.6

$$FS_{RD} = \frac{\Delta R \quad E'}{100 \quad \sigma_{max}}$$

$$= \frac{(7) \quad (432{,}000 \text{ psf})}{100 \times (1{,}391 \text{ psf})} = \underline{22} \text{ o.k.}$$

superseded by following pages

LTS TEMPORARY LIFT STATION PUMP

From equation (7) on page 16 of the procedures package

$$H_p = (z_2 - z_1) + \left(\frac{P_2 - P_1}{\gamma}\right) + \Sigma h_{L_{1-2}}$$

$$H_p = 0.85' + (\cancel{-3.5}\ 0') + \Sigma h_{L_{1-2}}$$

$$\Sigma h_{L_{1-2}} = \overset{4.3'}{h_{L_{inlet}}} + \overset{8.5'}{h_{L_{90^\circ \text{ elbow}}}} + \overset{19'}{h_{L_{check\ valve}}} + \overset{19'}{h_{L_{ball\ valve}}}$$

$$+ h_{L_{pipe\ friction}}$$

$h_{L_{pipe\ friction}}$ is obtained from equation (8)

Written by: GRS Date: 95 / 10 / 23 (YY MM DD) Reviewed by: GRS Date: ~~95 / 10 / 27~~ (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.6

CHECKED: RTD 23 OCT 1995

LTS Temporary Lift Station Pump

From eq. (7) on page 16 of procedures package

$$H_p = (z_2 - z_1) + \left(\frac{P_2 - P_1}{\gamma}\right) + \Sigma h_{L_{1-2}} \qquad (7)$$

$$H_p = (0.85' - 0) + \left(\frac{0-0}{0}\right) + \Sigma h_{L_{1-2}} = 0.85' + \Sigma h_{L_{1-2}}$$

where $\Sigma h_{L_{1-2}}$ is obtained from eq. (8) of procedures package

$$\Sigma h_{L_{1-2}} = \frac{f L v^2}{2 B_i g} \qquad (8)$$

where,

$$v = \frac{Q}{A} \qquad Q = 60 \text{ gpm} = 0.134 \text{ ft}^3/\text{sec}$$

$$A = \frac{\pi B_i^2}{4} = \frac{\pi (\cancel{0.162'}\ 0.239')^2}{4} = \cancel{0.021}\ 0.045 \text{ ft}^2$$

$$v = \frac{0.134 \text{ ft}^3/\text{sec}}{\cancel{0.021}\ 0.045 \text{ ft}^2} = \cancel{6.4}\ 3.0 \text{ ft/sec}$$

f is obtained from Fig 5 of procedures package based on Re and ε/B_i

$$Re = \frac{B_i v}{\nu} = \frac{\cancel{0.162'}\ 0.239' (\cancel{6.4 \text{ ft/sec}}\ 3.0)}{1.41 \times 10^{-5} \text{ ft}^2/\text{sec}} = \cancel{7.4}\ 5.1 \times 10^4$$

$$\varepsilon/B_i = \frac{0.000005 \text{ ft}}{\cancel{0.162}\ 0.239 \text{ ft}} = \cancel{3}\ 2.1 \times 10^{-5}$$

Using these values and Fig 5, $f \approx \cancel{0.0185}\ 0.021$

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Written by: GRS Date: 95/10/23 (YY MM DD) Reviewed by: Date: / / (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.6

CHECKER: RAM 23 OCT 1995

L = actual pipe length + equiv. lengths of fiting and valves

= 1130 ft + ~~8.5~~ ft (elbow) + ~~19~~ ft (check valve) + ~~19~~ ft (ball valve) + ~~4.5~~ (inlet)

= ~~1181~~ 1202 ft, 11.0, 27, 27, 6.7

So,

$$\Sigma h_{L1-2} = \frac{\cancel{0.0185}\ 0.021\ (\cancel{1181}\ 1202\ ft)(\cancel{6.4}\ 3.0\ ft/sec)^2}{2(\cancel{0.162}\ 0.239\ ft)(32.2\ ft/sec^2)} = \cancel{86}\ 14.76\ ft$$

Therefore,

$$H_p = 0.85\ ft + \cancel{86}\ 14.76\ ft = \cancel{87}\ 15.61\ ft \rightarrow \text{use } \cancel{100}\ 20\ ft$$

Conclude that each of the LTS temporary lift station pumps should be capable of pumping 60 gpm at a head of ~~100~~ 20 ft. This requirement may be in the relatively inefficient operating range of typical submersible centrifugal pumps. Recommend that the use of a larger diameter force main (eg. 3-inch) be considered during 60% design. A larger force main would result in less head loss and might allow for pump operation in a more efficient range. Consideration should include cost-benefit.

This commentary is no longer relevant because the calcs. have been revised for a 3" force main. GRS 12 Dec 95

Note: Minimum time from pump off to pump on can be estimated as the time for peak inflow to fill lift station from pump off level to pump on level (i.e. $\frac{3.5\ ft\ (\pi \frac{(7\ ft)^2}{4})}{\cancel{28.9}\ 29.2\ gpm}$) = 35 minutes. Therefore, no. of pump starts per hour will be well below max. desirable of 10.

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Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3905 Task No.: 03.6

LTS PERMANENT LIFT STATION SIZING

- peak flow for a one-week post-closure period = 0.0019 gpad × 9 cells × 6.5 acres/cell × 7 days/wk
  = 0.78 gallons/wk ✓

- peak flow during operations for a 1-hr period = ~~28.9~~ 29.2 △ ✓ gpm × 60 min.
  = ~~1734~~ 1752 △ ✓ gallons ✓ ← controls ✓

- capacity available = $\frac{\pi D^2}{4} \times L$
  $= \frac{\pi (7')^2}{4} (17')$

  = 654 ft^3 = 4890 gal ✓

∴ Available capacity > required capacity

o.k. ✓

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATIONS PACKAGE

USEPA HELP MODEL

1. Schroeder, P.R., Lloyd, C.M., and Zappi, P.A., "*The Hydrologic Evaluation of Landfill Performance (HELP) Model, User's Guide for Version 3*," U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Report No. EPA/600/R-94/168a, Sep 1994.

2. Schroeder, P.R., Dozier, T.S., Zappi, P.A., McEnroe, B.M., Sjostrom, J.W., and Peyton, R.L, "*The Hydrologic Evaluation of Landfill Performance (HELP) Model Engineering Documentation for Version 3*," U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Report No. EPA/600/R-94/168b, Sep 1994, 116 p.

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Office of Research and
Development
Washington DC 20460

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The Hydrologic Evaluation of Landfill Performance (HELP) Model

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THE HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE (HELP) MODEL

USER'S GUIDE FOR VERSION 3

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SECTION 1

INTRODUCTION

The Hydrologic Evaluation of Landfill Performance (HELP) computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through and out of landfills. The model accepts weather, soil and design data, and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled. The program was developed to conduct water balance analysis of landfills, cover systems and solid waste disposal and containment facilities. As such, the model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection and liner leakage that may be expected to result from the operation of a wide variety of landfill designs. The primary purpose of the model is to assist in the comparison of design alternatives as judged by their water balances. The model, applicable to open, partially closed, and fully closed sites, is a tool for both designers and permit writers.

1.1 BACKGROUND

The HELP program, Versions 1, 2 and 3, was developed by the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, for the U.S. Environmental Protection Agency (EPA), Risk Reduction Engineering Laboratory, Cincinnati, OH, in response to needs in the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, better known as Superfund) as identified by the EPA Office of Solid Waste, Washington, DC.

HELP Version 1 (Schroeder et al., 1984) represented a major advance beyond the Hydrologic Simulation on Solid Waste Disposal Sites (HSSWDS) program (Perrier and Gibson, 1980; Schroeder and Gibson, 1982), which was also developed at WES. The HSSWDS model simulated only the cover system, did not model lateral flow through drainage layers, and handled vertical drainage only in a rudimentary manner. The infiltration, percolation and evapotranspiration routines were almost identical to those used in the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model, which was developed by Knisel (1980) for the U.S. Department of Agriculture (USDA). The runoff and infiltration routines relied heavily on the Hydrology Section of the National Engineering Handbook (USDA, Soil Conservation Service, 1985). Version 1 of the HELP model incorporated a lateral subsurface drainage model and improved unsaturated drainage and liner leakage models into the HSSWDS

model. In addition, the HELP model provided simulation of the entire landfill including leachate collection and liner systems.

Version 2 (Schroeder et al., 1988) represented a great enhancement of the capabilities of the HELP model. The WGEN synthetic weather generator developed by the USDA Agricultural Research Service (ARS) (Richardson and Wright, 1984) was added to the model to yield daily values of precipitation, temperature and solar radiation. This replaced the use of normal mean monthly temperature and solar radiation values and improved the modeling of snow and evapotranspiration. Also, a vegetative growth model from the Simulator for Water Resources in Rural Basins (SWRRB) model developed by the ARS (Arnold et al., 1989) was merged into the HELP model to calculate daily leaf area indices. Modeling of unsaturated hydraulic conductivity and flow and lateral drainage computations were improved. Accuracy was increased with the use of double precision. Default soil data were improved, and the model permitted use of more layers and initialization of soil moisture content. Input and editing were simplified. Output was clarified, and standard deviations were reported.

In Version 3, the HELP model has been greatly enhanced beyond Version 2. The number of layers that can be modeled has been increased. The default soil/material texture list has been expanded to contain additional waste materials, geomembranes, geosynthetic drainage nets and compacted soils. The model also permits the use of a user-built library of soil textures. Computation of leachate recirculation between soil layers and groundwater drainage into the landfill have been added. Moreover, HELP Version 3 accounts for leakage through geomembranes due to manufacturing defects (pinholes) and installation defects (punctures, tears and seaming flaws) and by vapor diffusion through the liner. The estimation of runoff from the surface of the landfill has been improved to account for large landfill surface slopes and slope lengths. The snowmelt model has been replaced with an energy-based model; the Priestly-Taylor potential evapotranspiration model has been replaced with a Penman method, incorporating wind and humidity effects as well as long wave radiation losses (heat loss at night). A frozen soil model has been added to improve infiltration and runoff predictions in cold regions. The unsaturated vertical drainage model has also been improved to aid in storage computations. Input and editing have been further simplified with interactive, full-screen, menu-driven input techniques.

In addition, the HELP Version 3 model provides a variety of methods for specifying precipitation, temperature and solar radiation data. Now, data from the most commonly available government and commercial sources can be imported easily. Moreover, data used in HELP Version 2 can still be used with minimum user effort. Specifying weather data manually and editing previously entered weather data can be easily done by using built-in spreadsheet facilities.

The use of data files in Version 3 is much simpler and more convenient than HELP Version 2 because data are saved permanently in user defined file names at a user-specified location. Similarly, the user has more flexibility to define units for every type

of data needed to run the HELP model. Finally, Version 3 of the HELP model provides on-line help at every step of the data preparation process.

Although applicable to most landfill applications, the HELP model was developed specifically to perform hazardous and municipal waste disposal landfill evaluations as required by RCRA. Hazardous waste disposal landfills generally should have a liner to prevent migration of waste from the landfill, a final cover to minimize the production of leachate following closure, careful controls of runon and runoff, and limits on the buildup of leachate head over the liner to no more than 1 ft. The HELP model is useful for predicting the amounts of runoff, drainage, and leachate expected for reasonable designs as well as the buildup of leachate above the liner. However, the model should not be expected to produce credible results from input unrepresentative of landfills.

1.2 OVERVIEW

The principal purpose of this User's Guide is to provide the basic information needed to use the computer program. Thus, while some attention must be given to definitions, descriptions of variables and interpretation of results, only a minimal amount of such information is provided. Detailed documentation providing in-depth coverage of the theory and assumptions on which the model is based and the internal logic of the program is also available (Schroeder et al., 1994). Potential HELP users are strongly encouraged to study the documentation and this User's Guide before attempting to use the program to evaluate a landfill design. Additional documentation concerning the sensitivity of program inputs, application of the model and verification of model predictions are under development.

1.3 SYSTEM AND OPERATING DOCUMENTATION

1.3.1 Computer Equipment

The model entitled "The Hydrologic Evaluation of Landfill Performance" (HELP) was written to run on IBM-compatible personal computers (PC) under the DOS environment.

1.3.2 Required Hardware

The following IBM-compatible CPU (8088, 80286, 80386 or 80486) hardware is required:

1. Monitor, preferably color EGA or better

2. Floppy disk drive (5.25-inch double-sided, double- or high-density; or 3.5-inch double-sided, double- or high-density)

3. Hard disk drive or a second floppy disk drive

4. 400k bytes or more of available RAM memory

5. 8087, 80287, 80387 or 80486 math co-processor

6. Printer, if a hard copy is desired

1.3.3 Software Requirements

The user must use Microsoft or compatible Disk Operating Systems (MS-DOS) Version 2.10 or a higher version. The user interface executable module was compiled and linked with Microsoft Basic Professional Development System 7.1. Other executable components were compiled with the Ryan-McFarland FORTRAN Version 2.42. The Microsoft Basic Professional Development System and Ryan-McFarland FORTRAN compiler are not needed to run the HELP Model.

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THE HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE (HELP) MODEL

ENGINEERING DOCUMENTATION FOR VERSION 3

by

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SECTION 1

PROGRAM IDENTIFICATION

PROGRAM TITLE: Hydrologic Evaluation of Landfill Performance (HELP) Model

WRITERS: Paul R. Schroeder, Tamsen S. Dozier, John W. Sjostrom and Bruce M. McEnroe

ORGANIZATION: U.S. Army Corps of Engineers, Waterways Experiment Station (WES)

DATE: September 1994

UPDATE: None Version No.: 3.00

SOURCE LANGUAGE: The simulation code is written in ANSI FORTRAN 77 using Ryan-McFarland Fortran Version 2.44 with assembly language and Spindrift Library extensions for Ryan-McFarland Fortran to perform system calls, and screen operations. The user interface is written in BASIC using Microsoft Basic Professional Development System Version 7.1. Several of the user interface support routines are written in ANSI FORTRAN 77 using Ryan-McFarland Fortran Version 2.44, including the synthetic weather generator and the ASCII data import utilities.

HARDWARE: The model was written to run on IBM-compatible personal computers under the DOS environment. The program requires an IBM-compatible 8088, 80286, 80386 or 80486-based CPU (preferably 80386 or 80486) with an 8087, 80287, 80387 or 80486 math co-processor. The computer system must have a monitor (preferably color EGA or better), a 3.5- or 5.25-inch floppy disk drive (preferably 3.5-inch double-sided, high-density), a hard disk drive with 6 MB of available storage, and 400k bytes or more of available low level RAM. A printer is needed if a hard copy is desired.

AVAILABILITY: The source code and executable code for IBM-compatible personal computers are available from the National Technical Information Service (NTIS). Limited distribution immediately following the initial distribution will be available from the USEPA Risk Reduction Engineering Laboratory, the USEPA Center for Environmental Research Information and the USAE Waterways Experiment Station.

ABSTRACT: The Hydrologic Evaluation of Landfill Performance (HELP) computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through and out of landfills. The model accepts weather, soil and design data and uses solution techniques that account for surface storage, snowmelt, runoff, infiltration, vegetative growth, evapotranspiration, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Landfill systems including combinations of vegetation, cover soils, waste cells, lateral drain layers, barrier soils, and synthetic geomembrane liners may be modeled. The program was developed to conduct water balance analyses of landfills, cover systems, and solid waste disposal facilities. As such, the model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection, and liner leakage that may be expected to result from the operation of a wide variety of landfill designs. The primary purpose of the model is to assist in the comparison of design alternatives as judged by their water balances. The model, applicable to open, partially closed, and fully closed sites, is a tool for both designers and permit writers.

The HELP model uses many process descriptions that were previously developed, reported in the literature, and used in other hydrologic models. The optional synthetic weather generator is the WGEN model of the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) (Richardson and Wright, 1984). Runoff modeling is based on the USDA Soil Conservation Service (SCS) curve number method presented in Section 4 of the National Engineering Handbook (USDA, SCS, 1985). Potential evapotranspiration is modeled by a modified Penman method (Penman, 1963). Evaporation from soil is modeled in the manner developed by Ritchie (1972) and used in various ARS models including the Simulator for Water Resources in Rural Basins (SWRRB) (Arnold et al., 1989) and the Chemicals, Runoff, and Erosion from Agricultural Management System (CREAMS) (Knisel, 1980). Plant transpiration is computed by the Ritchie's (1972) method used in SWRRB and CREAMS. The vegetative growth model was extracted from the SWRRB model. Evaporation of interception, snow and surface water is based on an energy balance. Interception is modeled by the method proposed by Horton (1919). Snowmelt modeling is based on the SNOW-17 routine of the National Weather Service River Forecast System (NWSRFS) Snow Accumulation and Ablation Model (Anderson, 1973). The frozen soil submodel is based on a routine used in the CREAMS model (Knisel et al., 1985). Vertical drainage is modeled by Darcy's (1856) law using the Campbell (1974) equation for unsaturated hydraulic conductivity based on the Brooks-Corey (1964) relationship. Saturated lateral drainage is modeled by an analytical approximation to the steady-state solution of the Boussinesq equation employing the Dupuit-Forchheimer (Forchheimer, 1930) assumptions. Leakage through geomembranes is modeled by a series of equations based on the compilations by Giroud et al. (1989, 1992). The processes are linked together in a sequential order starting at the surface with a surface water balance; then evapotranspiration from the soil profile; and finally drainage and water routing, starting at the surface with infiltration and then proceeding downward through the landfill profile to the bottom. The solution procedure is applied repetitively for each day as it simulates the water routing throughout the simulation period.

SECTION 2

NARRATIVE DESCRIPTION

The HELP program, Versions 1, 2 and 3, was developed by the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, for the U.S. Environmental Protection Agency (EPA), Risk Reduction Engineering Laboratory, Cincinnati, OH, in response to needs in the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, better known as Superfund) as identified by the EPA Office of Solid Waste, Washington, DC. The primary purpose of the model is to assist in the comparison of landfill design alternatives as judged by their water balances.

The Hydrologic Evaluation of Landfill Performance (HELP) model was developed to help hazardous waste landfill designers and regulators evaluate the hydrologic performance of proposed landfill designs. The model accepts weather, soil and design data and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled. Results are expressed as daily, monthly, annual and long-term average water budgets.

The HELP model is a quasi-two-dimensional, deterministic, water-routing model for determining water balances. The model was adapted from the HSSWDS (Hydrologic Simulation Model for Estimating Percolation at Solid Waste Disposal Sites) model of the U.S. Environmental Protection Agency (Perrier and Gibson, 1980; Schroeder and Gibson, 1982), and various models of the U.S. Agricultural Research Service (ARS), including the CREAMS (Chemical Runoff and Erosion from Agricultural Management Systems) model (Knisel, 1980), the SWRRB (Simulator for Water Resources in Rural Basins) model (Arnold et al., 1989), the SNOW-17 routine of the National Weather Service River Forecast System (NWSRFS) Snow Accumulation and Ablation Model (Anderson, 1973), and the WGEN synthetic weather generator (Richardson and Wright, 1984).

HELP Version 1 (Schroeder et al., 1984a and 1984b) represented a major advance beyond the HSSWDS program (Perrier and Gibson, 1980; Schroeder and Gibson, 1982), which was also developed at WES. The HSSWDS model simulated only the cover system, did not model lateral flow through drainage layers, and handled vertical drainage only in a rudimentary manner. The infiltration, percolation and evapotranspiration routines were almost identical to those used in the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model, which was developed by Knisel (1980) for the U.S. Department of Agriculture (USDA). The runoff and infiltration

routines relied heavily on the Hydrology Section of the National Engineering Handbook (USDA, Soil Conservation Service, 1985). Version 1 of the HELP model incorporated a lateral subsurface drainage model and improved unsaturated drainage and liner leakage models into the HSSWDS model. In addition, the HELP model provided simulation of the entire landfill including leachate collection and liner systems.

Version 1 of the HELP program was tested extensively using both field and laboratory data. HELP Version 1 simulation results were compared to field data for 20 landfill cells from seven sites (Schroeder and Peyton, 1987a). The lateral drainage component of HELP Version 1 was tested against experimental results from two large--scale physical models of landfill liner/drain systems (Schroeder and Peyton, 1987b). The results of these tests provided motivation for some of the improvements incorporated into HELP Version 2.

Version 2 (Schroeder et al., 1988a and 1988b) presented a great enhancement of the capabilities of the HELP model. The WGEN synthetic weather generator developed by the USDA Agricultural Research Service (ARS) (Richardson and Wright, 1984) was added to the model to yield daily values of precipitation, temperature and solar radiation. This replaced the use of normal mean monthly temperature and solar radiation values and improved the modeling of snow and evapotranspiration. Also, a vegetative growth model from the Simulator for Water Resources in Rural Basins (SWRRB) model developed by the ARS (Arnold et al., 1989) was merged into the HELP model to calculate daily leaf area indices. Modeling of unsaturated hydraulic conductivity and flow and lateral drainage computations were improved. Default soil data were improved, and the model permitted use of more layers and initialization of soil moisture content.

In Version 3, the HELP model has been greatly enhanced beyond Version 2. The number of layers that can be modeled has been increased. The default soil/material texture list has been expanded to contain additional waste materials, geomembranes, geosynthetic drainage nets and compacted soils. The model also permits the use of a user-built library of soil textures. Computations of leachate recirculation and groundwater drainage into the landfill have been added. Moreover, HELP Version 3 accounts for leakage through geomembranes due to manufacturing defects (pinholes) and installation defects (punctures, tears and seaming flaws) and by vapor diffusion through the liner based on the equations compiled by Giroud et al. (1989, 1992). The estimation of runoff from the surface of the landfill has been improved to account for large landfill surface slopes and slope lengths. The snowmelt model has been replaced with an energy-based model; the Priestly-Taylor potential evapotranspiration model has been replaced with a Penman method, incorporating wind and humidity effects as well as long wave radiation losses (heat loss at night). A frozen soil model has been added to improve infiltration and runoff predictions in cold regions. The unsaturated vertical drainage model has also been improved to aid in storage computations. Input and editing have been further simplified with interactive, full-screen, menu-driven input techniques.

The HELP model requires daily climatologic data, soil characteristics, and design

specifications to perform the analysis. Daily rainfall data may be input by the user, generated stochastically, or taken from the model's historical data base. The model contains parameters for generating synthetic precipitation for 139 U.S. cities. The historical data base contains five years of daily precipitation data for 102 U.S. cities. Daily temperature and solar radiation data are generated stochastically or may be input by the user. Necessary soil data include porosity, field capacity, wilting point, saturated hydraulic conductivity, and Soil Conservation Service (SCS) runoff curve number for antecedent moisture condition II. The model contains default soil characteristics for 42 material types for use when measurements or site-specific estimates are not available. Design specifications include such things as the slope and maximum drainage distance for lateral drainage layers, layer thicknesses, leachate recirculation procedure, surface cover characteristics and information on any geomembranes.

Figure 1 is a definition sketch for a somewhat typical closed hazardous waste landfill profile. The top portion of the profile (layers 1 through 4) is the cap or cover. The bottom portion of the landfill is a double liner system (layers 6 through 11), in this case composed of a geomembrane liner and a composite liner. Immediately above the bottom composite liner is a leakage detection drainage layer to collect leakage from the primary liner, in this case, a geomembrane. Above the primary liner are a geosynthetic drainage net and a sand layer that serve as drainage layers for leachate collection. The drain layers composed of sand are typically at least 1-ft thick and have suitably spaced perforated or open joint drain pipe embedded below the surface of the liner. The leachate collection drainage layer serves to collect any leachate that may percolate through the waste layers. In this case where the liner is solely a geomembrane, a drainage net may be used to rapidly drain leachate from the liner, avoiding a significant buildup of head and limiting leakage. The liners are sloped to prevent ponding by encouraging leachate to flow toward the drains. The net effects are that very little leachate should leak through the primary liner and virtually no migration of leachate through the bottom composite liner to the natural formations below. Taken as a whole, the drainage layers, geomembrane liners, and barrier soil liners may be referred to as the leachate collection and removal system (drain/liner system) and more specifically a double liner system.

Figure 1 shows eleven layers--four in the cover or cap, one as the waste layers, three in the primary leachate collection and removal system (drain/liner system) and three in the secondary leachate collection and removal system (leakage detection). These eleven layers comprise three subprofiles or modeling units. A subprofile consists of all layers between (and including) the landfill surface and the bottom of the top liner system, between the bottom of one liner system and the bottom of the next lower liner system, or between the bottom of the lowest liner system and the bottom of the lowest soil layer modeled. In the sketch, the top subprofile contains the cover layers, the middle subprofile contains the waste, drain and liner system for leachate collection, and the bottom subprofile contains the drain and liner system for leakage detection. Six subprofiles in a single landfill profile may be simulated by the model.

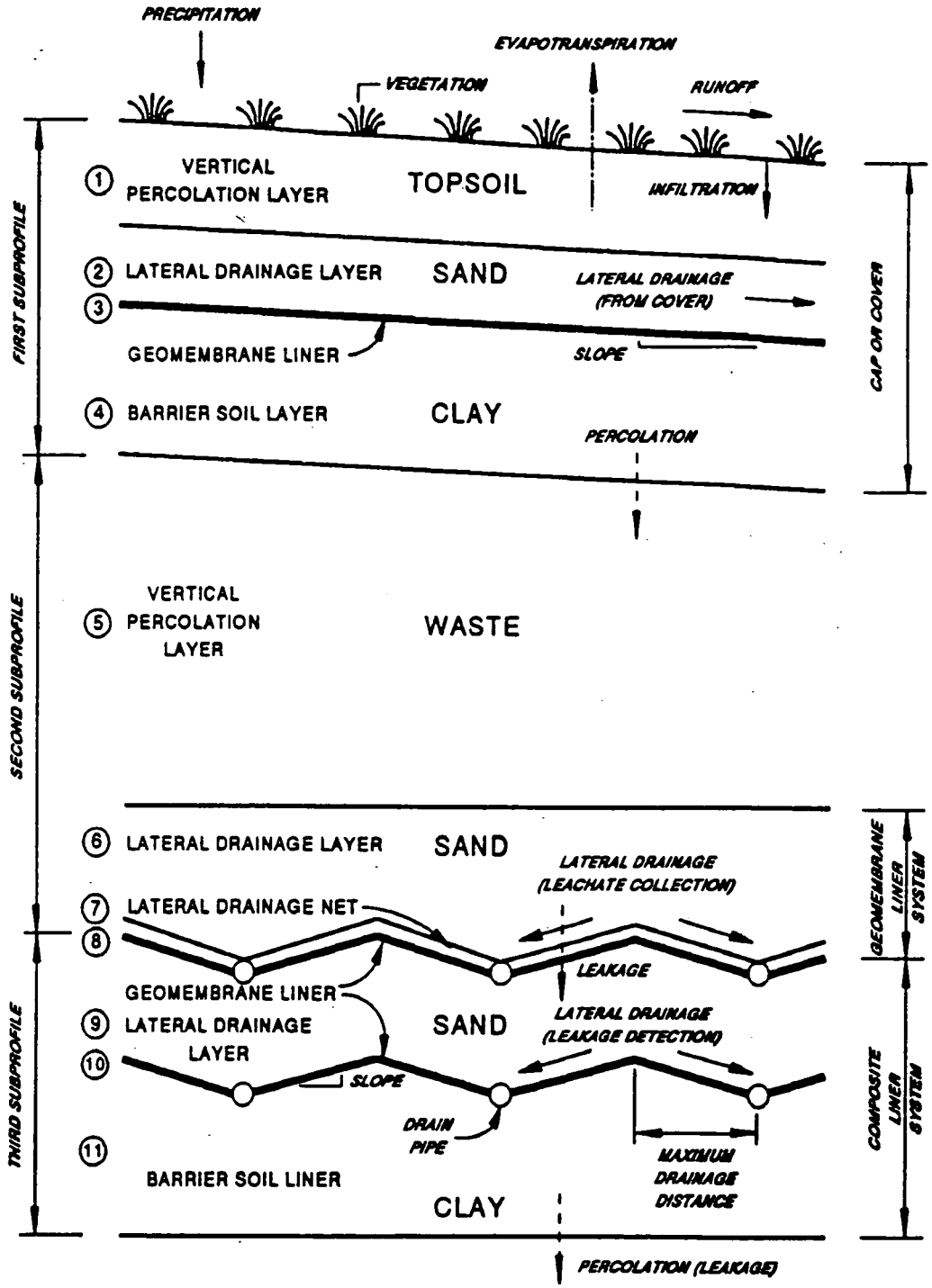

Figure 1. Schematic Profile View of a Typical Hazardous Waste Landfill

The layers in the landfill are typed by the hydraulic function that they perform. Four types are of layers are available: vertical percolation layers, lateral drainage layers, barrier soil liners and geomembrane liners. These layer types are illustrated in Figure 1. The topsoil and waste layers are generally vertical percolation layers. Sand layers above liners are typically lateral drainage layers; compacted clay layers are typically barrier soil liners. Geomembranes are typed as geomembrane liners. Composite liners are modeled as two layers. Geotextiles are not considered as layers unless they perform a unique hydraulic function.

Flow in a vertical percolation layer (e.g., layers 1 and 5 in Figure 1) is either downward due to gravity drainage or extracted by evapotranspiration. Unsaturated vertical drainage is assumed to occur by gravity drainage whenever the soil moisture is greater than the field capacity (greater than the wilting point for soils in the evaporative zone) or when the soil suction of the layer below the vertical percolation layer is greater than the soil suction in the vertical percolation layer. The rate of gravity drainage (percolation) in a vertical percolation layer is assumed to be a function of the soil moisture storage and largely independent of conditions in adjacent layers. The rate can be restricted when the layer below is saturated and drains slower than the vertical percolation layer. Layers, whose primary hydraulic function is to provide storage of moisture and detention of drainage, should normally be designated as vertical percolation layers. Waste layers and layers designed to support vegetation should be designated as vertical percolation layers, unless the layers provide lateral drainage to collection systems.

Lateral drainage layers (e.g., layers 2, 6, 7 and 9 in Figure 1) are layers that promote lateral drainage to collection systems at or below the surface of liner systems. Vertical drainage in a lateral drainage layer is modeled in the same manner as for a vertical percolation layer, but saturated lateral drainage is allowed. The saturated hydraulic conductivity of a lateral drainage layer generally should be greater than 1×10^{-3} cm/sec for significant lateral drainage to occur. A lateral drainage layer may be underlain by only a liner or another lateral drainage layer. The slope of the bottom of the layer may vary from 0 to 40 percent.

Barrier soil liners (e.g., layers 4 and 11 in Figure 1) are intended to restrict vertical flow. These layers should have hydraulic conductivities substantially lower than those of the other types of layers, typically below 1×10^{-6} cm/sec. The program allows only downward flow in barrier soil liners. Thus, any water moving into a liner will eventually percolate through it. The leakage (percolation) rate depends upon the depth of water-saturated soil (head) above the base of the layer, the thickness of the liner and the saturated hydraulic conductivity of the barrier soil. Leakage occurs whenever the moisture content of the layer above the liner is greater than the field capacity of the layer. The program assumes that barrier soil liner is permanently saturated and that its properties do not change with time.

Geomembrane liners (e.g., layers 3, 8 and 10 in Figure 1) are layers of nearly

impermeable material that restricts significant leakage to small areas around defects. Leakage (percolation) is computed to be the result from three sources: vapor diffusion, manufacturing flaws (pinholes) and installation defects (punctures, cracks, tears and bad seams). Leakage by vapor diffusion is computed to occur across the entire area of the liner as a function of the head on the surface of the liner, the thickness of the geomembrane and its vapor diffusivity. Leakage through pinholes and installation defects is computed in two steps. First, the area of soil or material contributing to leakage is computed as a function of head on the liner, size of hole and the saturated hydraulic conductivity of the soils or materials adjacent to the geomembrane liner. Second, the rate of leakage in the wetted area is computed as a function of the head, thickness of soil and membrane and the saturated hydraulic conductivity of the soils or materials adjacent to the geomembrane liner.

10. GEOSYNTHETIC MATERIALS

10.1 Liner System and Final Cover System Materials Evaluation

10.2 Liner System Frost Protection

10.1 Liner System and Final Cover System Materials Evaluation

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: LINER SYSTEM AND FINAL COVER SYSTEM MATERIALS EVALUATION

Computations By: (Cognizant Engineer)
Signature: Gary R. Schmertmann — Date: 16 Oct 95
Printed Name and Title: Gary R. Schmertmann, Senior Project Engr.

Assumptions and Procedures Checked by: (Checker)
Signature: Majdi Ahmed Othman — Date: 17 Oct 1995
Printed Name and Title: MAJDI A. OTHMAN, PROJECT ENGINEER

Computations Checked by:
Signature: Robert A. Morgan III — Date: 17 Oct 1995
Printed Name and Title: ROBERT A. MORGAN III, STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Gary R. Schmertmann — Date: 17 Oct 95
Printed Name and Title: Gary R. Schmertmann, Senior Project Engr.

Approved by: (PDP)
Signature: Gary R. Schmertmann — Date: 17 Oct 95
Printed Name and Title: Gary R. Schmertmann, Senior Project Engr.

Approved by: (DTL and TETL)
Signature: Rudolph Bonaparte — Date: 24 Oct 95
Printed Name and Title: Rudolph Bonaparte

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO	17 Oct 95	MA	NA	NA
0	30% submittal (revised Geomemb. Selection and GCL Selection section of Calculations)	23 Oct 95	GRS	JFB	RB
B	Added 'Executive Summary'	13 Dec 95	GRS	RAM	RB

Written by: GRS Date (Y/M/D): 95 / 12 / 13 Reviewed by: RAM Date: 13 DEC 95

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.7

RAM 13 DEC 1995

LINER SYSTEM AND FINAL COVER SYSTEM MATERIALS EVALUATION

EXECUTIVE SUMMARY

Purpose of Calculations:

- Select key characteristics of the following low-permeability geosynthetic components of the liner system: (i) primary geomembrane; (ii) primary geosynthetic clay liner (GCL); (iii) secondary geomembrane; (ii) secondary GCL; and (v) geotextile cushions.
- Select key characteristics of the following low-permeability geosynthetic components of the final cover system: (i) geomembrane cap; (ii) geosynthetic clay cap; and (iii) geotextile cushion.
- Evaluate puncture resistance of the geomembrane components of the liner and final cover systems.
- Evaluate significance of tensile stresses in the geosynthetic components of the liner and final cover systems.

Methodology

- Selection of key characteristics of low-permeability liner and final cover system components is made from the range of commercially-available geosynthetic products. The selection accounts for the intended function of the component as well as material durability, resistance to anticipated loads, and constructability.
- Puncture resistance of the geomembranes is evaluated by first estimating the maximum normal stress anticipated to act on each geomembrane. The anticipated stress is then compared to the allowable stress from Koerner et al. (1995) (Reference no. 2 in Procedures/Methods package).
- Tensile stresses in the geosynthetic components of the liner and final cover systems are evaluated by considering possible deformation modes that may induce tensile stresses and using information presented by Long et al. (1994) (Reference no. 3 in Procedures/Methods package) to assess the potential for tensile stresses to develop in veneer loading conditions.

001284

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Conclusions - The selected key characteristics are presented in the following tables:

Liner System Characteristic	Geomembrane	Primary GCL	Secondary GCL	Geotextile Cushion
polymer type	HDPE	NA	NA	PP or PET
thickness (mils)	80	NA	NA	NA
mass density (g/m^2) [oz/yd^2]	NA	NA	NA	340 [10]
surface texture	textured	NA	NA	NA
clay mineral	NA	sodium bentonite	sodium bentonite	NA
method of manufacture	NA	unreinforced - HDPE geomembrane backing	internally reinforced - geotextile backing	nonwoven needlepunch

Cover System Characteristic	Geomembrane	GCL	Geotextile Cushion
polymer type	HDPE	NA	PP or PET
thickness (mils)	40	NA	NA
mass density (g/m^2) [oz/yd^2]	NA	NA	270 [8]
surface texture	textured	NA	NA
clay mineral	NA	sodium bentonite	NA
method of manufacture	NA	unreinforced - HDPE geomembrane backing or internally reinforced - geotextile backing	nonwoven needlepunch

- Calculated factors of safety (FS) against geomembrane puncture are 3.3 for the liner system and 6.8 for the final cover system. These FS, which account for the effect of the geotextile cushions, exceed the min. required value of 3.0.

- Predicted tensile stresses in the liner and final cover system geosynthetics are negligible. Anchor trenches will be used as a construction expedient to resist minor transient tensile stresses that could be imposed during geosynthetics installation and liner system construction.

End of Executive Summary 001285

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Client.: FERMCO Project: OSDF Project No.: GE 3900 Task No.: 8.7

MAO 95/10/17

LINER SYSTEM AND FINAL COVER SYSTEM MATERIALS EVALUATION

PROCEDURES/METHODS

Purpose:

Present procedures and methods for selection of the low-permeability geosynthetic components of the liner system and final cover system (i.e., geomembranes and geosynthetic clay liners (GCLs)). Present procedures and methods for evaluation of the resistance of geosynthetic components of the liner system and cover system to imposed stresses.

Scope:

- Selection of key characteristics of the primary and secondary GCLs and geomembranes for the liner system.
- Selection of key characteristics of the geomembrane cap and geosynthetic clay cap for the final cover system.
- Evaluation of tensile resistance, anchorage, and puncture resistance of geomembranes in liner system and final cover system under anticipated loads during construction, operation, and post-closure.
- Selection of key characteristics of the geotextile cushions in the liner system and final cover system.

Statement of Design Problem:

Design of the liner system and cover system includes selection of the key characteristics of the geosynthetic components. Key characteristics considered in this calculation package are polymer type, method of manufacture, surface texture, and thickness or mass density. Selection of key characteristics is made from the

range of commercially-available geosynthetic products. The selection accounts for geosynthetic durability, constructability and resistance to anticipated loads.

The components of the liner system and final cover system are illustrated on the following page.

Selection of Geomembrane Characteristics:

Liner System

Key characteristics for the primary and secondary geomembranes in the liner system are polymer type, geomembrane thickness, and surface texture. The factors which will be considered in specifying these characteristics are hydraulic properties, mechanical properties, installation considerations, long-term behavior, and resistance to concentrated stresses and abrasion. The selection process will consider the anticipated liner system service conditions. The chemical compatibility of the selected geomembranes with OSDF leachate will be evaluated in a separate testing/analysis program described in project document No. F9530007.

Cover System

Key characteristics for the geomembrane cap in the final cover system are polymer type, geomembrane thickness, and surface texture. The factors which will be considered in specifying these characteristics are hydraulic properties, mechanical properties, installation considerations, long-term behavior, and resistance to concentrated stresses and abrasion. The selection process will consider the anticipated final cover system service conditions.

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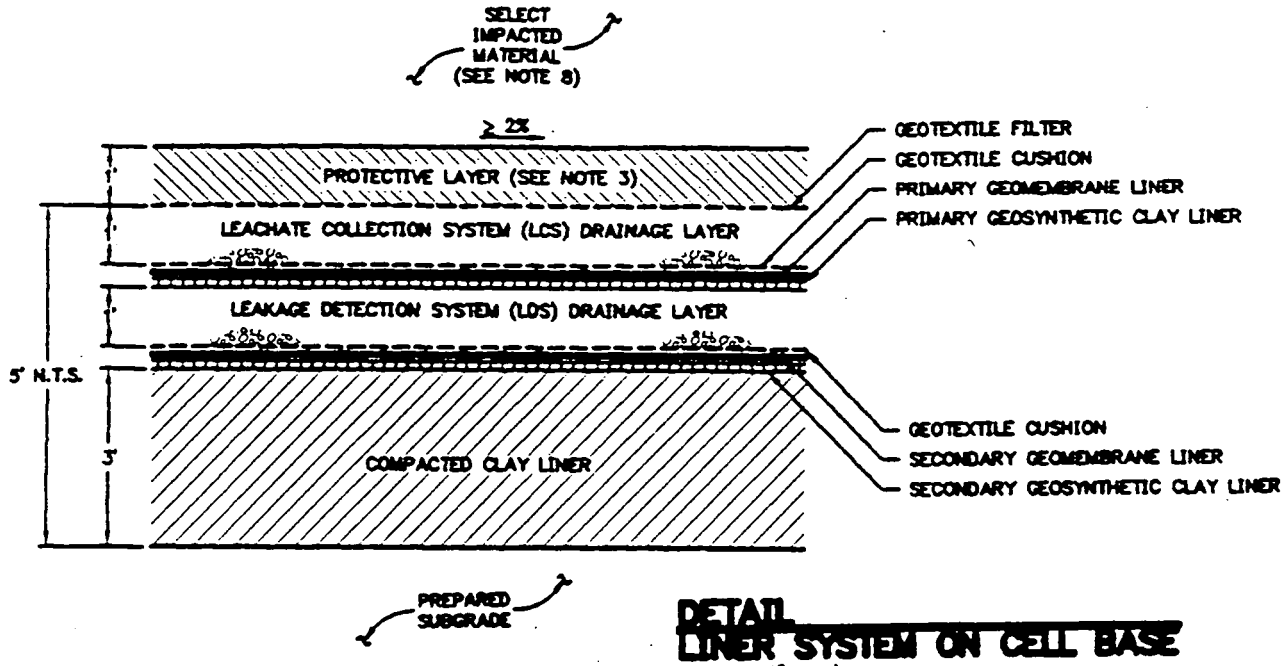
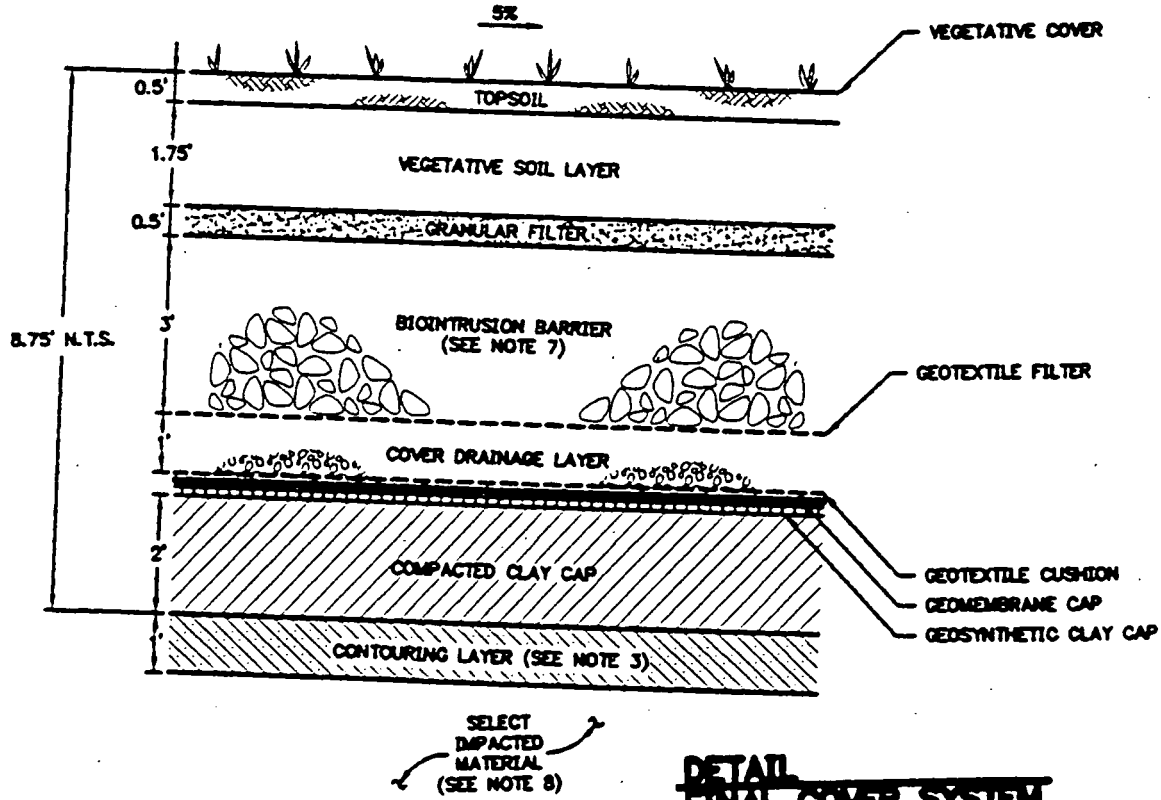
MAO 95/10/17



DETAIL
LINER SYSTEM ON CELL BASE



DETAIL
FINAL COVER SYSTEM

GE3900-8.7/F9530046 95.10.12

SOURCE: Project Drawing No. ~~F95-A027~~
"Liner and Cover System Details II"

Written by: GRS Date (Y/M/D): 95 / 10 / 15 Reviewed by: R. Bonaparte Date: 95/10/16

Client.: FERMCO Project: OSDF Project No.: GE 3900 Task No.: 8.7

MAO 95/10/17

Selection of GCL Characteristics:

Liner System

Key characteristics for the primary and secondary GCLs in the liner system are the clay mineral type and method of manufacture. The factors which will be considered in specifying these characteristics are hydraulic properties, plasticity of the clay component, and internal shear strength. An additional factor for the primary geomembrane is prevention of outward migration of the clay component. This additional factor is considered because the primary GCL will be placed in contact with the LDS drainage layer. The selection process will consider the anticipated liner system service conditions.

Cover System

Key characteristics for the GCL cap in the final cover system are the clay mineral type and method of manufacture. The factors which will be considered in specifying these characteristics are hydraulic properties, plasticity of the clay component, and internal shear strength. The selection process will consider the anticipated liner system service conditions.

Selection of Geotextile Cushion Characteristics:

Key characteristics for the two geotextile cushions in the liner system and the single geotextile cushion in the final cover system are the polymer type, mass density and method of manufacture. The factors which will be considered in specifying these characteristics are mechanical properties and demonstrated cushioning capability. The selection process will consider cushioning requirements during construction and post-closure conditions for both the liner system and final cover system. The ability of the selected geotextile cushion to provide puncture protection for the liner system geomembranes and the cover system geomembrane cap will be evaluated with detailed calculations described below.

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Evaluation of Puncture Protection for Geomembranes:

Introduction

Design of the liner system and final cover system includes evaluation of the potential for the gravel material in the liner system and cover system drainage layers to puncture the associated geomembranes. The evaluation considers the puncture potential under anticipated loads during construction, operation, and post-closure. In both the liner system and the cover system, geotextile cushions are used to prevent direct contact between the drainage gravel and geomembranes and therefore reduce the puncture potential.

Liner System

The evaluation will be performed for the secondary geomembrane. The results will be considered to be applicable to the primary geomembrane due to the fact that the loading conditions and materials of interest (i.e., geomembrane, geotextile, and drainage gravel) are essentially identical for both geomembranes,. The following step-by-step calculation procedure will be used.

1. Evaluate maximum vertical stress on geomembrane for operation and post-closure conditions. Conditions during facility operation will produce vertical stresses less than or equal to those for post-closure conditions. Therefore, operation conditions are implicitly considered in this step by evaluating post-closure conditions. Maximum vertical stress on the geomembrane for post-closure conditions will be evaluated using the following equation:

$$\sigma_{v,max} = T_{max}\,\gamma_{ave}$$

where, T_{max} = maximum thickness of material to be placed above geomembrane in final landfill configuration

γ_{ave} = average unit weight of material placed above geomembrane

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2. Evaluate maximum vertical stresses on geomembrane for construction conditions. Maximum stresses will be induced by construction equipment operating above the geomembrane. The maximum stresses will be calculated using the following equation:

$$\sigma_{v,max} = t\,\gamma + q\,A$$

where, t = thickness of material overlying geomembrane on which equipment is operating

γ = unit weight of overlying material

q = equipment ground pressure

A = pressure reduction factor; depends on size and configuration of pressure loading area and value of thickness, t

For this calculation, several sets of values for the parameters t and q will be obtained for tracked equipment from the restrictions on equipment operation above the geomembrane that are given in the project specifications. Values for t and q for wheeled equipment will be selected to represent a truck with a loaded weight of 35 tons and a tire pressure of 90 psi. This loaded weight is the same used in the "leachate collection system" calculation package to evaluate pipe crushing under equipment loads (document no. F9530017). This tire pressure is representative of off-road trucks. Loaded weight distribution between axles will be assumed to be 30:70 (front:rear).

The parameter γ will be taken as the same value used in the package entitled "Short-Term Liner System Stability on Side Slopes" (document no. F9530027).

The parameter A will be obtained using published elastic theory solutions from Reference 1 for vertical stress distributions below loaded areas, as shown on the following page. The pressure loading area for tracked equipment will be assumed to be an infinite strip with a width of 2 ft. The pressure loading area for wheeled equipment will be assumed to be a circular area with a radius determined by tire pressure and wheel loading.

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MAO 95/10/17

3.1 Loading on an Infinite Strip

3.1.1 UNIFORM VERTICAL LOADING (Fig.3.1)

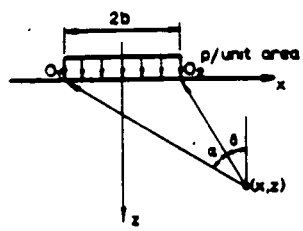

FIG.3.1

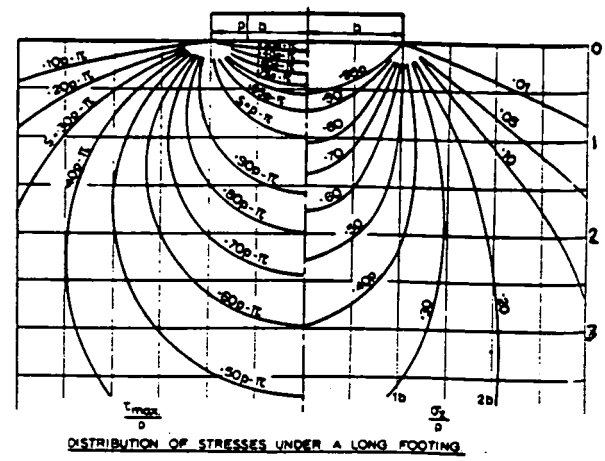

FIG.3.2 Stresses beneath a strip (Jurgenson,1934)

3.3 Loading on a Circular Area

3.3.1 UNIFORM VERTICAL LOADING (Fig.3.13)

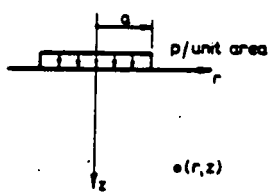

FIG.3.13

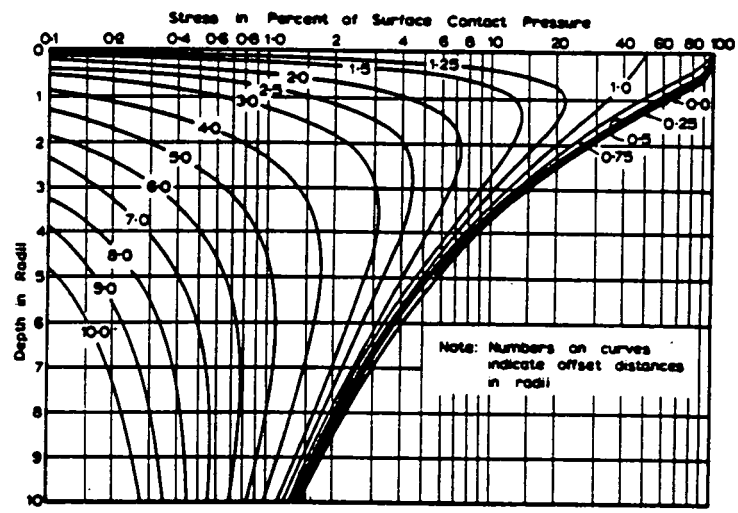

FIG.3.14 Vertical stress σ_z beneath uniform c load (Foster and Ahlvin, 1954).

SOURCE: Reference 1

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It is noted that this calculation for stresses induced by construction equipment does not account for potential vertical stress increases due to dynamic loading effects from equipment operation. Such potential stress increases are neglected because the project specification for granular drainage layer placement (project document no. F9530035) prohibits equipment maneuvers which are most likely to cause dynamic effects (i.e., hard braking and sharp turning).

3. Obtain vertical stress on geomembrane for evaluation of puncture protection.
The vertical stress, p_{actual}, will be taken as the largest value calculated from steps ~~2~~ 1. and ~~3~~ 2.

4. Evaluate allowable vertical stress on geomembrane.
The allowable vertical stress on the geomembrane, p_{allow}, will be evaluated using the procedure presented in Reference 2. This procedure is based on theoretical considerations along with puncture testing of HDPE geomembranes protected by needle-punched, nonwoven geotextiles.

The procedure uses the following equations:

$$p_{allow} = (p_{lab}) \div [\, MF_s \;\; MF_{pd} \;\; MF_a \;\; FS_{cr} \;\; FS_{cbd} \,]$$

where,
MF_s = modification factor for protrusion shape
MF_{pd} = modification factor for packing density
MF_a = modification factor for arching
FS_{cr} = factor of safety for creep
FS_{cbd} = factor of safety for chemical/biological degradation
p_{lab} = allowable vertical stress from controlled lab tests

Guidelines for selection of modification factors and factors of safety are provided in Reference 2.

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Reference 2 provides the following empirical formula for p_{lab} for 60-mil HDPE geomembranes:

$$p_{lab,60} = 450\ M / H^2 \quad \text{(kPa)}$$

where, M = mass per unit area of cushion geotextile (g/m^2)
H = effective protrusion height (mm), depends on maximum particle size of drainage gravel

For these calculations, a value of p_{lab} is needed for geomembranes with thicknesses other than 60-mil. Based on the statement in part I of Reference 2 that "the [theoretical] analysis shows that the puncture resistance of the geomembrane is linearly related to its thickness," the value for p_{lab} will be assumed to be proportional to the geomembrane thickness. For example, $p_{lab,40} = 0.67\ p_{lab,60}$ and $p_{lab,80} = 1.33\ p_{lab,60}$.

5. Compare the actual maximum vertical stress to allowable value.
The ratio of the allowable value to the actual value is taken as a global factor of safety against geomembrane puncture. Reference 2 recommends a minimum value of 3.0 for this ratio. This recommendation will be used for these calculations, as expressed by the following:

$$FS_{global} = p_{allow} / p_{actual} > 3.0$$

Cover System

The evaluation for the geomembrane cap will be performed using the same step-by-step calculation procedure given above for the liner system.

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Evaluation of Tensile Stresses in Geosynthetic Components:

Introduction and Background

Both short-term and long-term loadings can potentially induce local tensile stresses in the geosynthetic components of the liner system or final cover system of a disposal facility.

For liner systems in general, the development of geosynthetic tensile stresses is considered for lined side slope areas. Short-term loading may be evaluated for the condition after a drainage material layer is placed above the geosynthetic liner components but before protective soil or other material is placed within the cell. This is termed a "veneer" loading condition. Long-term loading may be evaluated for the condition where the settling of material in the cell produces "downdrag" loading on the geosynthetic components of the side slope liner. This type of downdrag is most likely to occur when highly compressible materials, such as municipal solid waste, are placed in the cell.

For cover systems in general, both short-term and long-term loadings involve the condition after a material layer(s) is placed above the geosynthetic cover system components. Both loading conditions are therefore of the veneer type.

With respect to veneer-type conditions, results presented in Reference 3 from strain compatibility analyses indicate that tension in geosynthetic components of typical liner and final cover systems will be negligible if the shearing resistance of each system interface exceeds the minimum necessary for the system to remain marginally stable in an infinite slope configuration (i.e., for the system to have an infinite-slope stability factor of safety exceeding 1.0). For purely frictional interfaces the necessary stability is achieved if the friction angle of the interface exceeds the slope angle. The results of the analyses in Reference 3 are applicable to the OSDF liner and final cover systems because the shear force vs. displacement relationships used for the interfaces exhibit initial stiffnesses of approximately 400 to 1,400 psf/in (1.6 to 5.2 kPa/mm) for a confining stress of approximately 350 psf (17 kPa), an initial stiffness range similar to that expected for the OSDF liner and cover system interfaces.

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For evaluating veneer-type conditions, the minimum shearing resistance of the liner system and final cover system interfaces will be compared to the minimum necessary for the system to be ~~remain~~ marginally stable on an infinite slope. If the shearing resistance exceeds the minimum necessary value then tensile stresses in the geosynthetics will be taken as negligible. If the tensile stresses in the geosynthetics are negligible, an anchor trench to resist these stresses is not needed, and thus, anchor trench pullout calculations are unnecessary. Even for this condition, however, an anchor trench should still be used as a construction expedient to resist minor transient stresses that could be imposed during geosynthetics installation and liner system construction.

Liner System

For short-term conditions, the minimum interface shearing resistance for the liner system is assessed in the calculation package "Short-Term Liner System Stability on Side Slopes" (document no. F9530027). The maximum slope angle of the liner system is also assessed in that package. A classical slope stability analysis for an infinite slope will be performed to assess whether the marginal stability criterion described above is satisfied.

For long-term conditions, downdrag-induced tensile stresses will be assumed to be negligible for the following reasons: (i) the maximum height of the lined side slopes is small (i.e. less than 15 ft); (ii) the side slopes are relatively flat (i.e., maximum inclination of 4H:1V); and (iii) the impacted material to be placed in the OSDF will not be highly compressible and is therefore not expected to undergo significant settlement. These conditions minimize the potential for downdrag stresses to develop in the geosynthetic components of the liner system.

Cover System

The minimum interface shearing resistance for the final cover system for short-term and long-term conditions and the maximum slope angle for the final cover system is assessed in the calculation package "Cover System Stability" (document

no. F9530022). A classical slope stability analysis for an infinite slope will be performed to assess whether the marginal stability criterion described above is satisfied.

References

1. Poulos, H.G. and Davis, E.H., *Elastic Solutions for Soil and Rock Mechanics*, John Wiley & Sons, New York, 1974, Sections 3.1 and 3.4.

2. Koerner, R.M., Wilson-Fahmy, R., and Narejo, D., "Puncture Protection of Geomembranes, Part I: Theory, Part II: Experimental , and Part III: Examples," Geosynthetic Research Institute, 1995.

3. Long, J.H., Gilbert, R.B. and Daly, J.J., "Geosynthetic Loads in Landfill Slopes: Displacement Compatibility," *Journal of Geotechnical Engineering*, ASCE, V. 120, No. 11, November 1994, pp. 2009-2025.

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Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.7

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LINER SYSTEM AND FINAL COVER SYSTEM MATERIALS EVALUATION – DATA VERIFICATION PACKAGE

PURPOSE: Evaluate data and parameters required to perform calculations and evaluations for the liner system and final cover system materials

SCOPE: Covers all data and parameter requirements presented in the "Procedures/Methods" package for this topic

REQUIRED DATA AND PARAMETERS:

This section is organized following the "Procedures/Methods" package

I Selection of Geomembrane Characteristics

No data required

II Selection of GCL Characteristics

No data required

III Selection of Geotextile Cushion Characteristics

No data required

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IV Evaluation of Puncture Protection for Geomembranes

This section uses the calculation step numbers (1 to 5) presented in the "Procedures/Methods" package

*** Liner System:**

(1) Evaluate Maximum Vert. Stress on Geomembrane for Operation and Post-Closure Conditions:

Need 2 parameters, γ_{ave} and T_{max}:

A. γ_{ave} represents the average unit weight of material to be placed above the geomembrane. This material includes liner system drainage gravel, liner system protective soil, impacted material, and final cover system materials. This value will be conservatively chosen as a near upper-bound estimate of the average unit weight. It is conservative to use a near upper-bound because the higher the unit weight, the greater the calculated stress on the geomembrane. An appropriate value is the same as that used for the "Foundation Settlement" calcs (doc. no. F9530021) because it was chosen on the same basis. The chosen value is:

$\gamma_{ave} = 125$ pcf ✓

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B. T_{max} represents the maximum thickness of material which will overlie the geomembrane in the final closure configuration. This thickness will be obtained by examing project drawings. The point of maximum elevation difference between the geomembrane and the top of the final cover system will be identified by observation of the subgrade grading plan and the final cover grading plan (see following two pages). The maximum difference found is approx. 68 ft ✓ (i.e. 660 − 592) at the location indicated on the drawings. T_{max} is obtained by subtracting 3 ft from this difference to account for the thickness of the compacted clay liner. Therefore,

$T_{max} = 65$ ft ✓

(2) Evaluate Max. Vert. Stress on Geomembrane for Construction Conditions:

Need 4 parameters t, q, γ, A

(i) γ represents unit weight of overlying material, primarily drainage gravel. A reasonable value for this parameter

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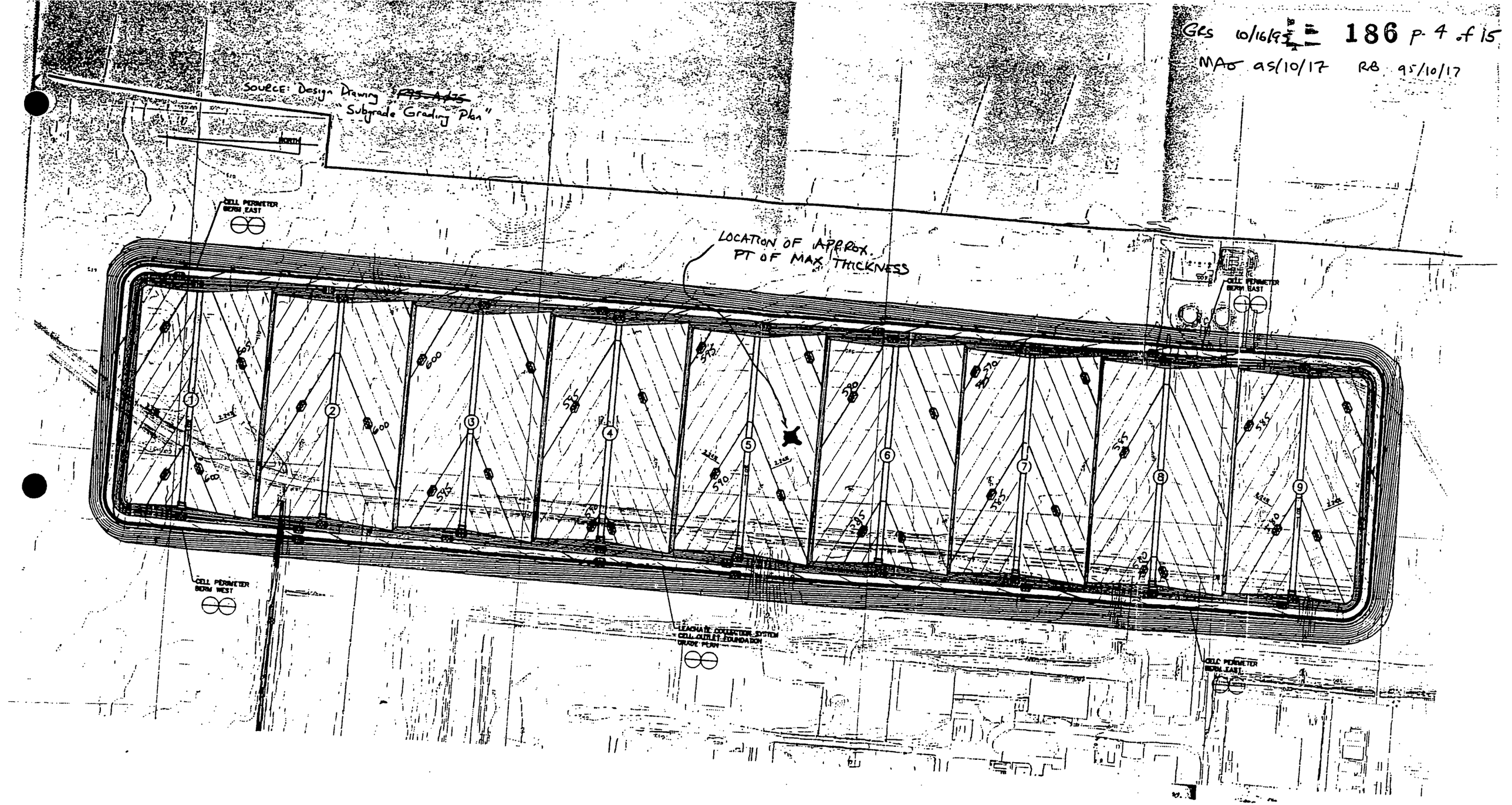

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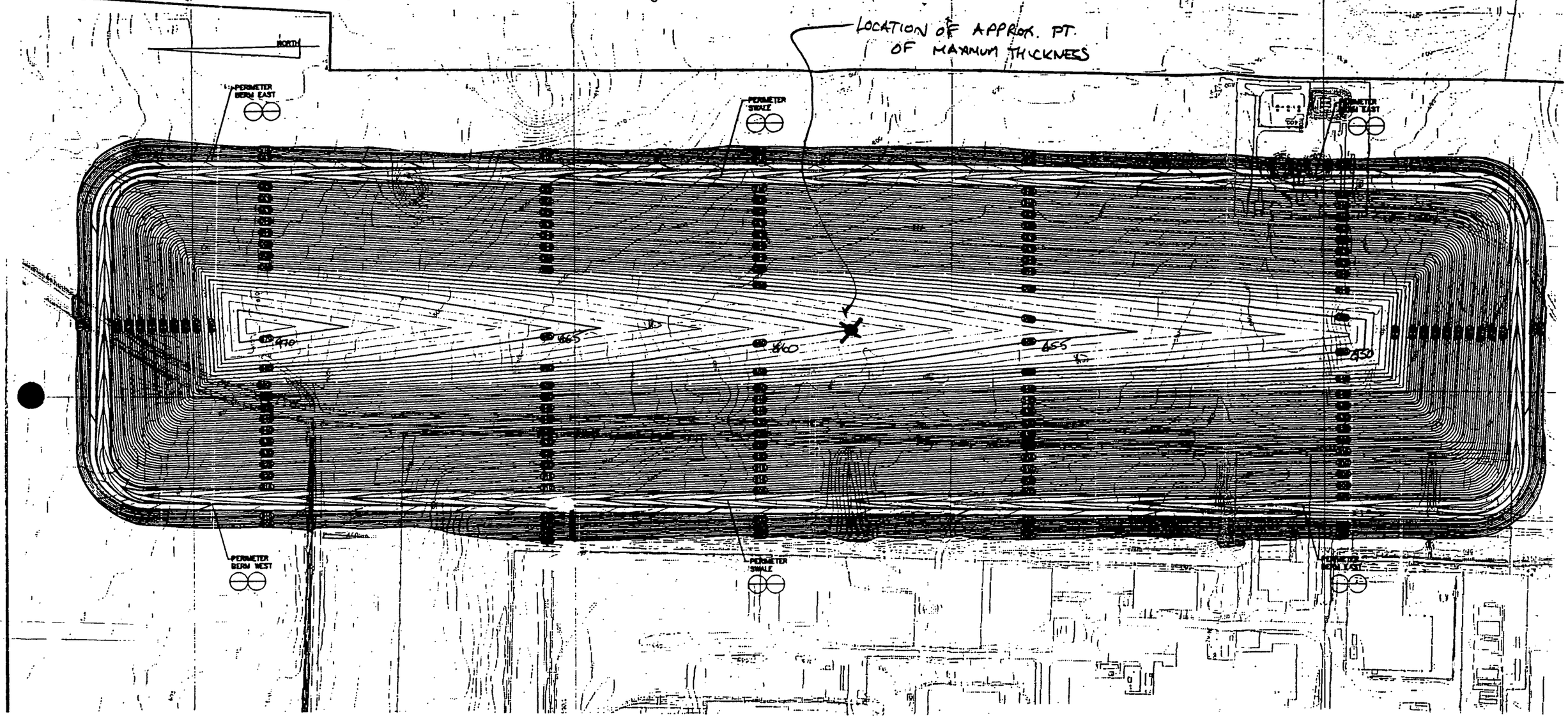
SOURCE: Design Drawing ~~No. F95-A081~~ "Final Cover System Grading Plan"



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is the same value used in the "Short-term liner system stability on Side Slopes" calculation package (doc. no. F95 30027). The chosen value is:

$\gamma = 125$ pcf ✓

(ii) t and q represent the thickness of material on which eqpt. is operating and the eqpt. ground pressure, respectively.

For tracked equipment the following values will be considered (taken from project specification "Granular Drainage Layer", doc. no. F95 30035):

t (in)	q (psi)
12	5
18	10
24	20

The pressure is applied on an infinite strip with a width of 2 ft.

For wheeled equipment, t is taken as 36", which is the maximum thickness over which eqpt. ground pressure is restricted by the granular drainage area specification

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q is taken as the eqpt. tire pressure, 90 psi

The area over which q is applied is assumed to be circular, with a radius sufficiently large to support the load from one rear tire of the truck. Therefore:

$$\pi\,(\text{radius of loading})^2 = \text{area of loading} = \frac{\text{Load on single rear wheel}}{\text{tire pressure}}$$

or

$$\text{radius of loading} = \sqrt{\frac{35\text{ ton}\,(2000\text{ lb/ton})\,(0.70)\,(\frac{1}{2})}{90\text{ psi}\;(\pi)}}$$

$$= 9.3\text{ in} \quad \text{use } \underline{10\text{ in.}}$$

(iii) 'A' represents a pressure reduction factor

For tracked equipment, use infinite strip loading solutions for vertical stress under center of strip. Using the solution plot given on page 9, values of 'A' are obtained as follows (note: parameter b in solution plot equals 1 ft):

t (in)	t/b	A
12	1.0	0.81
18	1.5	0.67
24	2.0	0.55

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For wheeled equipment use solution for vertical stress under center of loaded circular area. Using the solution plot given on p. 9, a value of 'A' is obtained as follows:

offset in radii = 0 (directly under loading)

depth in radii = $\frac{t}{\text{radius of loading}} = \frac{36 \text{ in}}{10 \text{ in}} = 3.6$ ✓

∴ from plot, A = 0.10 ✓

(3) Obtain vert. stress on geomembrane for evaluation of puncture protection:

No data needed

(4) Evaluate allowable vertical stress on geomembrane

Five modification factors and factors of safety are required. Reference 2 from the "procedures/methods" package provides selection guidance for these factors:

MF_s = m.f. for protrusion shape

Project specification for "Granular Drainage Layer" (project document no. F9530035), referred to as 'GDL spec' states that material can be angular

Therefore, MF_s = 1.0 from Ref. 2 ✓

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3.1 Loading on an Infinite Strip

3.1.1 UNIFORM VERTICAL LOADING (Fig.3.1)

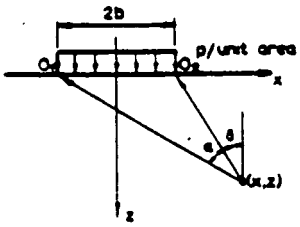

FIG.3.1

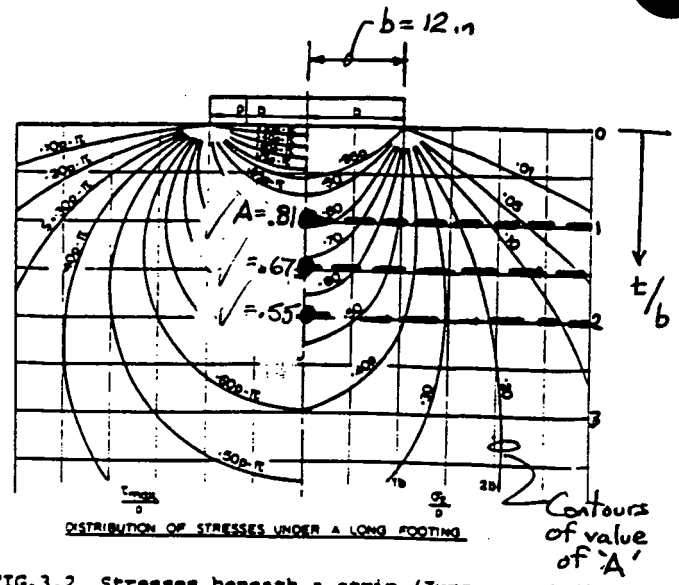

FIG.3.2 Stresses beneath a strip (Jurgenson,1934.

3.3 Loading on a Circular Area

3.3.1 UNIFORM VERTICAL LOADING (Fig.3.13)

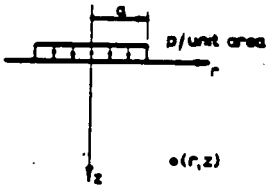

FIG.3.13

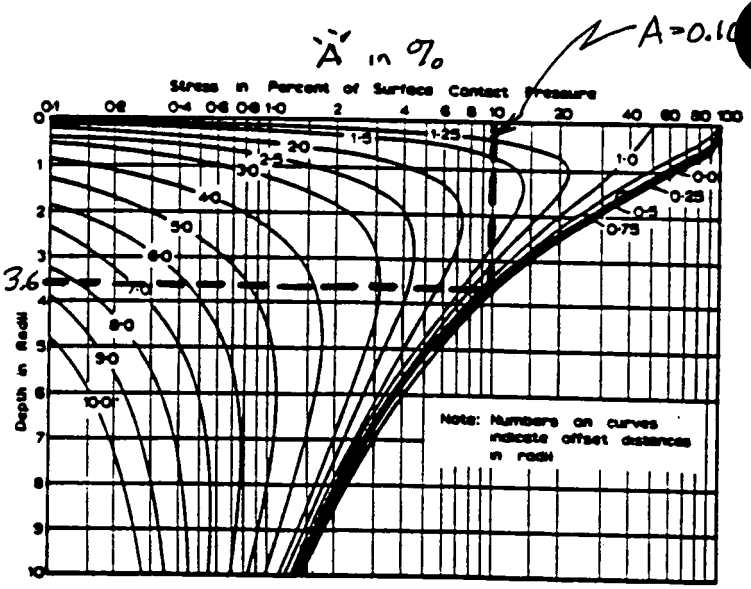

FIG.3.14 Vertical stress σ_z beneath uniform c load (Foster and Ahlvin, 1954).

SOURCE: Reference 1

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MF_{pd} = m.f. for packing density

Ref. 2 recommends a value of 0.5 for packed stones, with 'packed' meaning placed in a continuous layer rather than isolated stones

Therefore, use $MF_{pd} = \underline{0.5}$ ✓

MF_a = m.f. for arching

Degree of arching is unknown. Therefore assume no arching effect and use $\underline{MF_a = 1.0}$ from Ref. 2 ✓

FS_{cr} = f.s. for creep

Ref. 2 presents recommended values which vary with geotextile mass per unit area, M, and effective protrusion height, H. M will be determined within the "Calculations" package. H is taken as ½ the maximum gravel particle size, as recommended in Ref. 2. The maximum gravel particle size is 3/4 in. (19 mm) ✓ from the "GLD spec". Therefore, take $\underline{H = 9.5\ mm}$. ✓

The value of FS_{cr} will be selected from the following table (reproduced from Ref. 2, part II)

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Recommended Values for FS_{cr}

Note: For H=9.5 mm use values between H=6 and H=12mm.

M (g/m²)	H (mm) 38	25	12	6
0	N/R	N/R	N/R	>>1.5
270	N/R	N/R	>1.5*	1.5
550	N/R	1.5	1.3	1.2
1,100	1.3	1.2	1.1	1.0
> 1,100	~1.2	~1.1	~1.0	1.0

Source: Ref. 2, part II, Table 12

N/R = this combination of H and M is not recommended for design.

* Note: for calculation purposes this value will be assumed to equal 2.5

FS_{cbd} = f.s. for chemical/biological degradation

Ref. 2 states that the value "is felt to range between 1.0 and 2.0 with an average of 1.5." Based on this statement the value is taken as:

FS_{cbd} = 1.5 (short-term conditions) ✓

FS_{cbd} = 2.0 (long-term conditions) ✓

The calculation also requires a value for p_{lab}, the allowable vertical stress for controlled laboratory conditions. The value of p_{lab} will be obtained from

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the following equation, after the value of geomembrane thickness, G, is obtained in the "Calculations" package:

$$P_{lab} = \left(\frac{G}{60\ mil}\right)(450)\ M/H^2$$

units G: mil M = g/m²
P_{lab} = kPa H = mm (value established as 9.5 mm)

(5) Compare actual max. vert. stress to allowable value:
No data needed

* Final Cover System:

(1) Evaluate max. vert. stress on geomembrane for operation and post-closure conditions:
Need two parameters, γ and T_{max}

A. γ_{ave} represents the average unit weight of the drainage gravel and other cover system components to be placed above the geomembrane cap. This value taken as that used on p. 2 for the liner system. γ_{ave} = 125 pcf ✓

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B. T_{max} represents the maximum thickness of material which will overlie the geomembrane cap. This thickness is obtained from the final cover system design (see p. 3 of the "Procedures/Methods" package) as the combined thickness of the cover drainage layer [1.0 ft], biointrusion barrier [3.0 ft], granular filter [0.5 ft], vegatative soil layer [1.75 ft] and topsoil [0.5 ft]. The value is

$T_{max} = 6.75$ ft ✓

(2) Evaluate max. vert. stress on geomembrane for Construction Conditions:

Need 4 parameters t, q, γ, A

The same values obtained for the liner system ~~parameters~~ will be used for the final cover system. The limitations on equipment operations given in the project specification, the "GDL spec", apply to both liner and final cover system.

(3) Obtain vert. stress on geomembrane for evaluation of puncture protection:

No data needed

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(4) Evaluate allowable vertical stress on geomembrane:

Five modification factors and factors of safety are needed. The same values obtained for the liner system will be used for the final cover system. The gravel angularity and gradation specified for the cover drainage layer in the "GDL spec" is the same as for the LDS and LCS layers in the liner system.

The value of p_{lab} will be obtained using the equation given above for the liner system. This value can be computed after the thickness of the geomembrane cap is obtained in the "calculations" package.

(5) Compare actual max. vertical stress to allowable stress:
No data needed.

V Evaluation of Tensile Stresses in Geosynthetic Components

* Liner System:

The information in calculation package "Short-Term Liner System Stability on Side Slopes" (document no. F95300027) indicates that:

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- the weakest liner system interface has estimated shear strength parameters of $\delta = 20°$, $a = 0$
- the maximum side slope angle is 14° (i.e. 4H:1V)

* Final Cover System

The information in calculation package "Cover System Stability" (document no. F9530022) indicates that:

- the weakest final cover system interface has estimated shear strength parameters of $\delta = 13°$, $a = 0$; this case represents long-term, residual strength.
- The maximum cover system slope angle is 9.5° (i.e 6H:1V)

END OF DATA VERIFICATION SECTION

Written by: GRS Date (Y/M/D): 95 / 10 / 23 Reviewed by: Date:

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LINER SYSTEM AND FINAL COVER SYSTEM MATERIALS EVALUATION

CALCULATIONS

Purpose:

Present selection processes and calculations for selection and evaluation of the low-permeability geosynthetic components of the liner system and final cover system (i.e., geomembranes and GCLs) and for the geotextile cushion components of both systems.

Scope:

Presents selection processes and calculations as described in the "Procedures/Methods" package.

Selection of Geomembrane Characteristics:

Liner System

Polymer Type - Polymer types considered for the liner system geomembranes are high density polyethylene (HDPE), polyvinyl chloride (PVC), and chlorosulfonated polyethylene (CSPE). Geomembranes composed of these polymers are available from a number of manufacturers. The following bullets consider the key performance factors which relate to polymer type.

- The three identified polymers have acceptable hydraulic properties. All three have extremely low permeability and are impermeable for practical purposes.

- The most significant mechanical properties of geomembranes used in liner systems are tensile stiffness and yield strain. Although these properties vary somewhat with geomembrane thickness, HDPE is in general relatively stiff and has relatively small yield strain. PVC, in contrast, is relatively extensible and does not exhibit yield. The tensile properties of CSPE often fall between those of HDPE and PVC but are difficult to generalize because CSPE geomembranes

are often manufactured with embedded reinforcing fabrics, or scrims, which affect tensile response.

- Geomembranes composed of all three of the identified polymers have acceptable ability to maintain integrity when subjected to concentrated stresses. The best performance is obtained with more extensible geomembranes. Therefore, based on the relative extensibilities discussed above, PVC offers the most favorable performance.

- Key considerations with respect to geomembrane installation include ease of placement and seaming. PVC and CSPE are easier to place than HDPE because their greater flexibility makes them conform more easily to certain shapes and makes them less prone to develop large thermal expansion wrinkles. Acceptable placement and wrinkle control, can, however, be achieved with all three polymers if appropriate installation procedures are used. All three polymers are easily seamed, with HDPE usually achieving the highest seam strength.

- With respect to chemical resistance, it has been found that HDPE has the highest degree of compatibility with a wide variety of chemicals encountered in wastes (References 1 and 2). CSPE has good resistance to many chemicals, but is attacked by some which are relatively common, namely chlorinated solvents and hydrocarbons. PVC typically is the least chemically resistant of the three polymers.

- With respect to long-term durability, HDPE offers the best performance. HDPE is a highly inert and durable material that is not susceptible to chemical degradation (i.e., oxidation) under conditions expected to exist in the OSDF. In addition, HDPE is not susceptible to physical degradation (i.e., extraction or solvation) under conditions expected to exist in the OSDF. The durability of PVC geomembranes is significantly less favorable than that of HDPE. This is because PVC geomembranes are composed of approximately two-thirds PVC resin and one-third plasticizers. Over time, physical degradation (i.e., extraction) may cause plasticizer loss which results in reduced geomembrane

flexibility and dimensional stability. The durability of CSPE geomembranes is typically between that of HDPE and PVC.

Based on these performance factors, HDPE is selected for the geomembrane. This selection is based primarily on its superior chemical resistance and durability. The less favorable aspects of HDPE performance, related to response to concentrated stresses and installation, will be addressed through appropriate design, specification and construction quality assurance practices.

Geomembrane Thickness - A wide range of HDPE geomembrane thicknesses are available. The following bullets consider the key performance factors which relate to geomembrane thickness.

- The durability characteristics of a HDPE geomembrane generally improve with increasing material thickness.

- The abrasion resistance of HDPE geomembranes increases with geomembrane thickness. Experience indicates that geomembranes with thickness less than 40 to 60 mils may not have acceptable abrasion resistance within liner systems.

- The thicker the HDPE geomembrane, the higher its stiffness and the more prominent are the material's less favorable performance aspects (i.e., response to concentrated stresses and ease of installation issues). From this viewpoint, thicknesses less than 100 mils are desirable.

- The thinner the HDPE geomembrane, the more difficult it is to weld adjacent panels. For most effective welding, thicknesses of at least 40 mils are desirable, with 60 to 80 mils perhaps being best.

Based on these performance factors, a thickness of 80 mil is selected for the HDPE geomembrane. This selection balances the performance factors described above.

Surface Texture - Two surface textures are widely available for HDPE geomembranes, smooth and textured. The primary performance factor affected by surface texture is the shear strength of the interface between the geomembrane and

adjacent materials. The adjacent materials in the liner system are geotextile cushions and GCLs, both of which are known to form relatively weak interfaces with smooth HDPE geomembranes. Therefore, in order to provide higher interface shear strengths and thereby increase liner system stability, a textured surface is selected for the HDPE geomembrane.

Final Cover System

Polymer Type - Polymer types considered for the final cover system geomembrane are the same as considered for the liner system geomembranes. The performance factors listed above for the liner system are also relevant to the final cover system.

Based on these performance factors, HDPE is selected for the geomembrane. As described above for the liner system, this selection is based primarily on its superior chemical resistance and durability.

Geomembrane Thickness - As discussed above, a wide range of HDPE geomembrane thicknesses are available. The geomembrane thickness-related performance factors listed above for the liner system are also relevant to the final cover system. However, the cover system geomembrane will not be exposed to leachate. It is also desirable for the cover system geomembrane to be flexible enough to accommodate the differential settlements resulting from the settlement of the impacted material within the OSDF.

Based on these performance factors, a minimum thickness of 40 mil is selected for the HDPE geomembrane. This selection balances the performance factors.

Surface Texture - Two surface textures are widely available for HDPE geomembranes, smooth and textured. The primary performance factor affected by surface texture is the shear strength of the interface between the geomembrane and adjacent materials. The adjacent materials in the final cover system are the geotextile cushion and the GCL, both of which are known to form relatively weak interfaces with smooth HDPE geomembranes. Therefore, in order to provide higher interface shear strengths and thereby increase final cover system stability, a textured surface is selected for the HDPE geomembrane.

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Selection of GCL Characteristics:

Liner System

Clay Mineral Type - GCLs are commercially produced using sodium bentonite clay or calcium bentonite clay. The sodium bentonite is a more active clay mineral with greater plasticity and swell potential, properties which are needed for effective GCL hydraulic performance. In addition, the greater the clay plasticity and swell potential the more effective the GCL will be in sealing around any liner system defects. Therefore, sodium bentonite is selected as the GCL clay mineral.

Method of Manufacture - GCLs are commercially produced using one of the three manufacturing methods summarized below.

- Unreinforced with Geotextile Backing: A layer of dry, granular bentonite is placed between two geotextiles. A bentonite-based adhesive is used to adhere the geotextiles to the granular bentonite core.

- Unreinforced with HDPE Geomembrane Backing: A layer of bentonite is glued to one side of a HDPE geomembrane.

- Internally Reinforced with Geotextile Backing: a layer of dry, granular bentonite is placed between two geotextiles. The two geotextiles are joined by needlepunching or stitching. The needlepunched fibers or stitches serve to confine the bentonite and increase the in-plane shear strength of the GCL.

For the primary GCL, the key performance factors related to method of manufacture are shear strength and prevention of downward migration of bentonite into the underlying LDS drainage layer. Long-term prevention of bentonite migration can be best achieved by using an unreinforced geomembrane-backed product oriented with the geomembrane backing between the bentonite and the LDS drainage layer. The use of a unreinforced geomembrane-backed product in this orientation would also serve to minimize bentonite hydration by confining the bentonite between two geomembranes, i.e. the primary liner system geomembrane and the geomembrane backing of the GCL. Minimizing bentonite hydration will provide a relatively high

internal GCL shear strength for short-term and interim stability conditions. Therefore, an unreinforced HDPE-geomembrane-backed GCL is selected for the primary GCL. Furthermore, the selected geomembrane backing will have a textured surface to maximize interface shear strength.

For the secondary GCL, the key performance factor related to method of manufacture is shear strength. A relatively high internal GCL shear strength for short-term and interim stability conditions can be obtained by using an internally reinforced product with geotextile backing. Therefore, an internally reinforced product with a geotextile backing is selected for the secondary GCL. (Note: an unreinforced GCL with HDPE backing can also be used in this application.)

Final Cover System

Clay Mineral Type - The clay mineral type for the GCL cap is selected as sodium bentonite for the same reasons as given above for the liner system GCLs.

Method of Manufacture - The available manufacturing methods for GCLs were summarized above in the liner system section.

For the GCL cap, the key performance factor related to method of manufacture is shear strength. As discussed above for the liner system GCLs, a relatively high internal GCL shear strength can be obtained by using an internally reinforced product with geotextile backing. However, an acceptably high internal GCL shear strength can also be obtained using an unreinforced geomembrane-backed product oriented with the geomembrane backing between the bentonite and the compacted clay cap. The use of a unreinforced geomembrane-backed product in this orientation would serve to minimize bentonite hydration by confining the bentonite between two geomembranes, i.e. the geomembrane cap and the geomembrane backing of the GCL. Minimizing bentonite hydration will provide a relatively high internal GCL shear strength. Therefore, the GCL cap is selected as either an internally-reinforced geotextile-backed product or an unreinforced HDPE-geomembrane-backed product. Furthermore, if an unreinforced HDPE-geomembrane-backed product is used, the geomembrane backing will have a textured surface to maximize interface shear strengths.

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Selection of Geotextile Cushion Characteristics:

Polymer Type - Virtually all commercially available geotextiles are composed of either polypropylene (PP) or polyester (PET). Both polymers are suitable for cushioning applications (Reference 3). Therefore, the cushion geotextiles can be composed of either PP or PET.

Method of Manufacture - The three primary manufacturing methods used to produce geotextiles are summarized below.

- Woven: Orthogonal polymer fibers or filaments are woven together in a flat sheet-like structure. The product is relatively thin and incompressible.

- Nonwoven Needlepunched: A mat of randomly oriented polymer fibers is formed. Arrays of closely-spaced needles are punched through the mat to entangle the random fibers. The product is relatively thick and compressible.

- Nonwoven Heatbonded: A mat of randomly oriented polymer fibers is formed. The mat is heated and passed through rollers to melt the random fibers together at their points of contact. The product is relatively thin and incompressible.

For the geotextile cushions, the key performance factors related to method of manufacture are shear strength and cushioning ability. With respect to cushioning ability, Reference 3 indicates that method of manufacture is not a major factor. However, nonwoven needlepunched geotextiles have typically been used as cushions and available cushion design methods are based on these materials. Therefore, use of a nonwoven needlepunched product is desirable. In addition, use of a nonwoven needlepunched product is desirable because these products generally exhibit higher interface shear strengths with soils and textured geomembranes than other products. Considering these factors, a nonwoven needlepunched product is selected.

Mass Density - Nonwoven needlepunched geotextiles are available in a wide range of mass densities. Mass density is the key factor which determines cushioning capability (Reference 3).

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For the final cover system, minimal cushioning capability is needed for long-term conditions due to the relatively low magnitude of normal stresses that will act on the geomembrane cap. The need for cushioning for short-term construction will also be minimal due to the restrictions on construction equipment operation above the geomembrane cap that are given in the project specification "Granular Drainage Layer" (document no. F9530035). Based on the guidelines provided in Reference 2 of the "Procedures/Methods" package, the minimum geotextile mass density that should be considered for puncture protection against gravel is 270 g/m^2 (8 oz/yd^2). Therefore, a minimum mass density of 270 g/m^2 (8 oz/yd^2) is selected for the geotextile cushion in the final cover system.

For the liner system, it is anticipated that moderate cushioning capability is needed for long-term conditions due to the anticipated magnitude of normal stresses that will act on the primary and secondary geomembranes. The need for cushioning for short-term construction will be minimal due to the restrictions on construction equipment operation above the geomembrane cap that are given in the project specification "Granular Drainage Layer" (document no. F9530035). Based on these conditions, a minimum mass density of 340 g/m^2 (10 oz/yd^2) is selected for the geotextile cushions in the liner system. This mass density will provide more protection than the minimum mass density of 270 g/m^2 (8 oz/yd^2) given in Reference 2 of the "Procedures/Methods" package.

References

1. Haxo, H.E., White, R.M., Haxo, P.D. and Fong, M.A., "Liner Materials Exposed to Municipal Solid Waste Leachate", U.S. Environmental Protection Agency, December 1982, 169 p.

2. Schwope, A.D., Costas, P.F. and Lyman, W.J., "Resistance of Flexible Membrane Liners to Chemicals and Wastes", U.S. Environmental Protection Agency, September 1985, 217 p.

3. Hullings, D. and Koerner, R., "Puncture Resistance of Geomembranes Using a Truncated Cone Test," *Proc. of Geosynthetics '91*, Vol. 1, Atlanta, February 1991, pp. 273-285.

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Evaluation of Puncture Protection for Geomembranes

Liner System

① Evaluate max. vert. stress on geomembrane for operation and post-closure conditions:

$$\sigma_{v,max} = T_{max}\,\gamma_{ave} = 65\text{ ft}(125\text{ pcf}) = \underline{8{,}125\text{ psf}}$$ ✓

② Evaluate max. vert. stress on geomembrane for construction conditions: (calculated stresses are rounded to nearest 5 psf)

$$\sigma_{v,max} = t\gamma + qA$$

Tabular calc. for tracked eqpt.:

t (in)	γ (pcf)	q (psi)	A	① t·γ (psf)	② q·A (psf)	①+② $\sigma_{v,max}$ (psf)
12	125	5	0.81	125 ✓	585 ✓	710 ✓
18	125	10	0.67	190 ✓	965 ✓	1,155 ✓
24	125	20	0.55	250 ✓	1,585 ✓	1,835 ✓

Calc. for wheeled equipment:

$$\sigma_{v,max} = t\gamma + qA = 36\text{ in}\left(\tfrac{1}{12}\text{ ft/in}\right)(125\text{ pcf}) + 90\text{ psi}(0.10)\left(144\text{ in}^2/\text{ft}^2\right)$$

$$= 375 + 1{,}295\text{ psf} = 1{,}670\text{ psf}$$ ✓

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(3) obtain vertical stress on geomembrane for evaluation of puncture protection:

value from step (1) = 8,125 psf (long-term)

max. value from step (2) = 1,835 psf (construction)

P_{actual} is taken as largest value from steps (1) and (2)

$P_{actual} = 8{,}125$ psf ✓ (long-term)

(4) Evaluate allowable vert. stress on geomembrane

$P_{allow} = P_{lab} / [MF_s \; MF_{pd} \; MF_a \; FS_{cr} \; FS_{cbd}]$

$MF_s = 1.0$ $MF_{pd} = 0.5$ $MF_a = 1.0$

FS_{cr}: $H = 9.5$ mm

$M = 340$ g/m² (10 oz/yd²) from "Selection of Geotex. Cushion Characteristics"

$FS_{cr} = 1.75$ from table using values of H and M (interpolation)

$FS_{cbd} = 2.0$ (for long-term conditions)

P_{lab}: $H = 9.5$ mm $M = 340$ g/m²

$G = 80$ mil from "Selection of Geomembrane Characteristics"

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$$p_{lab} = \frac{80 \text{ mil}}{60 \text{ mil}} (450)\left(\frac{340}{9.5^2}\right) = 2{,}260 \text{ kPa} = 47{,}200 \text{ psf} \checkmark$$

Therefore

$$p_{allow} = \frac{47{,}200 \text{ psf}}{(1.0)(0.5)(1.0)(1.75)(2.0)} = 26{,}970 \text{ psf} \checkmark$$

(5) Compare actual maximum vert. stress to allowable value:

$$FS_{global} = \frac{p_{allow}}{p_{actual}} = \frac{26{,}970 \text{ psf}}{8{,}125 \text{ psf}}$$

$$= 3.3 \checkmark > 3.0$$

The calculated value exceeds the target value. Conclude that puncture protection is adequate.

Cover System

(1) Evaluate max. vert. stress on geomembrane for post-closure conditions:

$$\sigma_{v,max} = T_{max}\,\gamma_{ave} = 6.75 \text{ ft } (125 \text{ pcf}) = 845 \text{ psf} \checkmark$$

(2) Evaluate max. vert. stress on geomembrane for construction conditions:

Calculations are the same as those given above for the liner system. Therefore $\sigma_{v,max} = 1{,}835$ psf ✓

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(3) Obtain vertical stress on geomembrane for evaluation of puncture protection:

value from step (1) = 845 psf (long-term)

value from step (2) = 1,835 psf (construction)

P_{actual} is taken as largest value from steps (1) and (2)

P_{actual} = 1,835 psf ✓ (construction)

(4) Evaluate allowable vertical stress on geomembrane

$P_{allow} = P_{lab} / [MF_s \; MF_{pd} \; MF_a \; FS_{cr} \; FS_{cbd}]$

where $MF_s = 1.0$ $MF_{pd} = 0.5$ $MF_a = 1.0$

FS_{cr}: $H = 9.5$ mm

$M = 270$ g/m² (8 oz/yd²) from "Selection of Geotex. Cushion Characteristics"

$FS_{cr} = 2.0$ interpolated from table using values of H and M

$FS_{cbd} = 1.5$ (for short-term condition)

P_{lab}: $H = 9.5$ mm $M = 270$ g/m²

$G = 40$ mil from "Selection of Geomembrane Characteristics"

$$P_{lab} = \frac{40 \text{ mil}}{60 \text{ mil}} (450)\left(\frac{270}{9.5^2}\right) = 900 \text{ kPa} = 18{,}750 \text{ psf} ✓$$

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Therefore,

$$P_{allow} = \frac{18{,}750 \text{ psf}}{(1.0)(0.5)(1.0)(2.0)(1.5)} = 12{,}500 \text{ psf} \checkmark$$

(5) Compare actual maximum vert. stress to allowable value

$$FS_{global} = \frac{P_{allow}}{P_{actual}} = \frac{12{,}500 \text{ psf}}{1{,}835 \text{ psf}}$$

$$= 6.8 \checkmark > 3.0$$

The calculated value exceeds the target value.

Conclude that puncture protection is adequate.

Evaluation of Tensile Stresses in Geosynthetic components

Liner System

* Friction angle of weakest liner system interface is 20°.
* Maximum slope angle of lined side slope is 14°

Therefore, the system is stable for an infinite slope condition (i.e. friction angle exceeds slope angle) and geosynthetic tension is taken as negligible ✓

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Final Cover System

* Friction angle of weakest cover system interface is 13°
* Maximum slope angle of cover system is 9.5°

Therefore, the system is stable for an infinite slope condition (i.e. friction angle exceeds slope angle) and geosynthetic tension is taken as negligible.

10.2 Liner System Frost Protection

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: LINER SYSTEM FROST PROTECTION

Computations By: (Cognizant Engineer)
Signature Majdy Ahmed Othman — Date 16 Oct 1995
Printed Name and Title MAJDI A. OTHMAN, PROJECT ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature Paul J. Sabatini — Date 16 Oct 95
Printed Name and Title PAUL J. SABATINI, SR. STAFF ENGINEER

Computations Checked by:
Signature Paul J. Sabatini — Date 16 Oct 95
Printed Name and Title PAUL J. SABATINI, SR. STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature Majdy Ahmed Othman — Date 16 Oct 1995
Printed Name and Title MAJDI A. OTHMAN, PROJECT ENGINEER

Approved by: (PDP)
Signature Majdy Ahmed Othman — Date 16 Oct 1995
Printed Name and Title MAJDI A. OTHMAN, PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature Rudolph Bonaparte — Date 17 Oct 1995
Printed Name and Title Rudolph Bonaparte, Principal

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO	17 Oct 95	NA	NA	NA
Ø	30% Submittal	NA	NA	NA	NA - No Change.
B					

Written by: MAJDI A. OTHMAN Date: 15 Dec 1995 Reviewed by: RJS Date: 15 Dec 95

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.6

FROST PROTECTION OF COMPACTED CLAY LINER DURING WINTER

EXECUTIVE SUMMARY

Purpose of Analysis

The purpose of this analysis is to estimate the thickness of the protective soil layer needed to prevent freezing of the compacted clay liner.

Methods of Analysis

The modified Berggren method was used to model frost penetration into the liner system.

Conclusions

Required thickness of protective soil layer is:

- *Case A:* 1.1 ft if the LCS and LDS drainage layers are also placed on top of the clay liner.
- *Case B:* 1.70 ft if only the protective soil is placed on top of the clay liner.
- Based on the above, the minimum protective cover thickness for seasonal frost protection should be 1.5 ft for Case A and 2.5 ft for Case B.

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LINER SYSTEM BARRIER LAYER DEPTH OF FROST PENETRATION PROCEDURES

The modified Berggren method will be used to estimate the thickness of the protective soil layer needed to prevent freezing of the compacted clay barrier layer of the liner system (see Figure 1). This method is described in details in the final cover system calculations package. This method can be used for this analysis in a three-step procedure as follows:

Step 1: calculate the thermal ratio from the following equation:

$$\alpha = \frac{(T_i - T_f)\,t}{n\,FI_{air}}$$

where: T_i = average annual ground temperature (°F)

T_f = freezing temperature = 32°F

t = number of days in the freezing season

n = n-factor relating ground surface freezing index to

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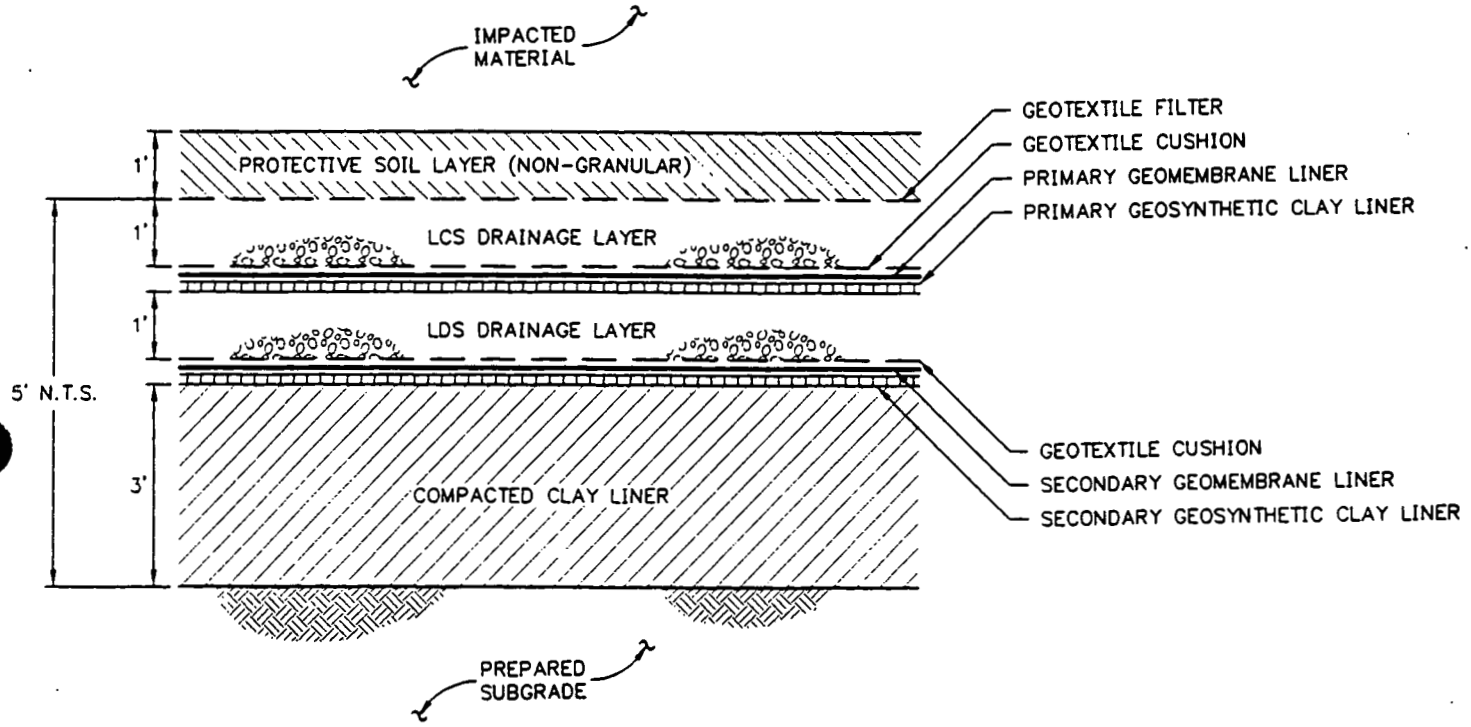

Figure 1. Liner system configuration

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air freezing index.

FI_{air} = air freezing index

Step 2: Calculate the freezing index for each layer from top to bottom.

$$FI_n = \frac{d_n L_n}{\lambda_n^2}\left[\frac{d_n}{K_{f_n}+K_{t_n}} + \sum_{i=1}^{n-1}\frac{d_i}{(K_{f_i}+K_{t_i})/2}\right]$$

λ_n = fusion parameter = $f(\mu_n$ and $\alpha)$; obtained from Figure 2 included on page 4.

$$\mu_n = \frac{\bar{C}_n}{\bar{L}_n}\,\frac{FI_{surface}}{t}$$

$$\bar{C}_n = \frac{1}{2}\,\frac{\sum_{i=1}^{n}(C_{f_i}+C_{t_i})\,d_i}{\sum_{i=1}^{n} d_i} \quad ; \quad \bar{L}_n = \frac{\sum_{i=1}^{n} L_i d_i}{\sum_{i=1}^{n} d_i}$$

where: C = specific heat capacity, K = thermal conductivity, L = latent heat of fusion, d = thickness of layer, $FI_{surface} = n\,FI_{air}$

Step 3 Compare freezing index at the surface to summation of freezing indices of the layers above the barrier layer, to estimate required thickness of protective layers.

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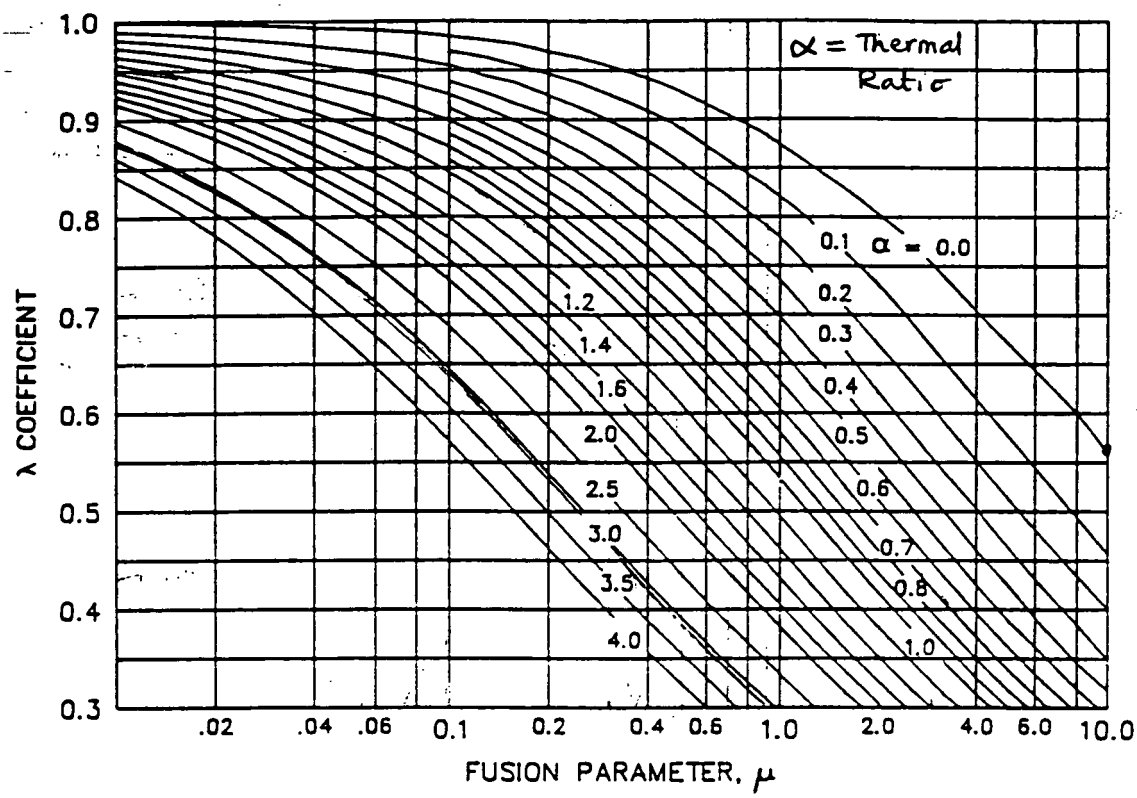

Figure 2. λ coefficient as a functon of thermal ratio, α, and fusion parameter, μ.

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Two scenarios will be analyzed which are:

- barrier layer is overlain by 1' LCS drainage layer, 1' LDS drainage layer, and 1' protective soil layer; check if the compacted clay liner will be protected from freezing.

- compacted clay liner is overlain by protective soil layer only; calculate required thickness of protective soil layer to prevent freezing of the compacted clay liner.

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LINER SYSTEM BARRIER LAYER DEPTH OF FROST PENETRATION DATA VERIFICATION

The data needed to perform the analysis using the Berggren method has been documented in the final cover system calculations package. This data is summarized below.

Weather Data

- T_i = 50 °F
- FI_{air} = 500 °F.days
- n = 0.70
- t = 60 days

Soil Data

Layer (1)	d (ft)	K_f (Btu / ft·hr·°F)	K_t (Btu / ft·hr·°F)	C_f (Btu / ft³·°F)	C_t (Btu / ft³·°F)	L (Btu / ft³)
① protective soil	variable	1.02	0.87	27.0	35.7	2,527
② LCS drainage	1 ft	0.58	0.87	22.0	23.3	369
③ LDS drainage	1 ft	0.58	0.87	22.0	23.3	369
④ compacted clay	3 ft	1.38	0.96	30.9	44.3	3,8[illegible]

(1) GCLs and geomembranes are not accounted for to simplify calculations, contributions from these layers are very small.

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The data presented in the table above was obtained from the final cover system package. To do that, the liner protective soil was assumed to have the same properties as the final cover vegetative soil; the LCS and LDS drainage layers, to be similar to the final cover drainage layer; and the liner and final cover compacted clay layers to be similar.

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LINER SYSTEM FROST PROTECTION CALCULATIONS

Case 1 : Compacted clay liner is overlain by 1-ft thick LDS drainage layer, 1-ft thick LCS drainage layer, and 1-ft thick protective soil layer (ignore effects of geomembranes and GCLs).

Step 1 (calculate the thermal ratio, α)

$$\alpha = \frac{(T_i - T_f)\,t}{n\,FI_{air}} = \frac{(50°F - 32°F)\,(60\text{ days})}{0.7 \times 500°F\cdot\text{days}} = 3.09$$

Step 2 (Calculate the freezing index FI for layers above the compacted clay liner).

$$\mu_{①} = \frac{C_{f①} + C_{t①}}{2}\;\frac{FI_{surface}}{L_{①}\,t}$$

$$= \frac{(27 + 35.7)\frac{Btu}{ft^3\,°F}}{2}\;\frac{350°F\cdot\text{days}}{2{,}527\frac{Btu}{ft^3} \times 60\text{ days}}$$

$$= 0.072$$

For $\alpha = 3.09$ and $\mu_{①} = 0.072 \longrightarrow \lambda_{①} = 0.68$

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$$FI_{①} = \frac{d_{①}^2 L_{①}}{\lambda_{①}^2 (k_{f①} + k_{t①})}$$

$$= \frac{(1)^2 ft^2 \; 2527 \frac{Btu}{ft^3}}{(0.68)^2 (1.02 + 0.87) \frac{Btu}{ft \cdot hr \cdot °F}} = 2,892 \; °F \cdot hr$$

$$= 120.5 \; °F \cdot days$$

$$\mu_{②} = \frac{\bar{c}_{②}}{\bar{L}_{②}} \frac{FI_{surface}}{t}$$

$$\bar{c}_{②} = \frac{1}{2} \frac{(c_{f1} + c_{t1}) d_1 + (c_{f2} + c_{t2}) d_2}{d_1 + d_2}$$

$$= \frac{1}{2} \frac{(27 + 35.7)(1) + (22 + 23.3)(1)}{2} = 27 \frac{Btu}{ft^3 \cdot °F}$$

$$\bar{L}_{②} = \frac{L_{①} d_{①} + L_{②} d_{②}}{d_{①} + d_{②}} = \frac{2527 (1) + 369 (1)}{(1) + (1)}$$

$$= 1,448 \frac{Btu}{ft^3}$$

$$\rightarrow \mu_{②} = \frac{27 \frac{Btu}{ft^3 \, °F}}{1,448 \frac{Btu}{ft^3}} \frac{350 \, °F \cdot days}{60 \, days} = 0.109$$

for $\mu_{②} = 0.109$ & $\alpha = 3.09 \longrightarrow \lambda_{②} = 0.62$

$$\rightarrow FI_{②} = \frac{d_2 L_2}{\lambda_2^2} \left[\frac{d_2}{k_{f2} + k_{t2}} + \frac{d_1}{(k_{f1} + k_{t1})/2} \right]$$

$$= \frac{(1 ft)(369 \frac{Btu}{ft^3})}{(0.62)^2} \left[\frac{1}{0.58 + 0.87} + \frac{1}{(1.02 + 0.87)/(2)} \right] \frac{ft}{\frac{Btu}{ft \cdot hr \cdot °F}}$$

$$= 1,678 \; °F \cdot hrs = 70 \; °F \cdot days$$

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$$\bar{C}_{③} = \frac{27.0 + 35.7 + 22.0 + 23.3 + 22.0 + 23.3}{6} = 25.6 \ \frac{Btu}{ft^3\,°F}$$

$$\bar{L}_{③} = \frac{1}{3}(2527 + 369 + 369) = 1{,}088 \ \frac{Btu}{ft^3}$$

$$\mu_{③} = \frac{25.6 \ \frac{Btu}{ft^3\,°F}}{1{,}088 \ \frac{Btu}{ft^3}} \ \frac{350\,°F.\,days}{60\ days} = 0.137$$

for $\mu_{③} = 0.137$ & $\alpha = 3.09 \rightarrow \lambda_{③} = 0.575$

$$FI_{③} = \frac{d_3 L_3}{\lambda_3^2}\left[\frac{d_3}{k_{f_3} + k_{t_3}} + \frac{d_1}{(k_{f_1} + k_{t_1})/2} + \frac{d_2}{(k_{f_2} + k_{t_2})/2}\right]$$

$$= \frac{(1\,ft)(369 \ \frac{Btu}{ft^3})}{(0.575)^2}\left[\frac{(1\,ft)}{(0.58 + 0.87)\frac{Btu}{ft\cdot hr\cdot °F}} + \frac{(1\,ft)}{\left(\frac{1.02 + 0.87}{2}\right)\frac{Btu}{ft\cdot hr\cdot °F}} + \frac{(1\,ft)}{\left(\frac{0.5 + 0.87}{2}\right)\frac{Btu}{ft\cdot hr\cdot °F}}\right]$$

$$= 3{,}580\ °F\cdot hrs = 149\ °F.\,days$$

$$FI_{①} + FI_{②} + FI_{③} = 120.5 + 70 + 149$$
$$= 339.5 < 350\ °F.\,day$$

Therefore, a protective soil layer slightly thicker than 1 ft is needed to protect the compacted clay liner from freezing. Assume $d_1 = 1.1$ ft, recalculate FI's.

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$$FI_{①} = \frac{(1.1)^2\ ft^2\ \ 2{,}527\ \frac{Btu}{ft^3}}{(0.68)^2\ (1.02+0.87)\ \frac{Btu}{ft\cdot hr\cdot {}^\circ F}} = 3499\ {}^\circ F.hrs$$

$$= 146\ {}^\circ F.days$$

$$\bar{C}_{②} = 27.2\ \frac{Btu}{ft^3\ {}^\circ F}, \quad \bar{L}_{②} = 1{,}499\ \frac{Btu}{ft^3}$$

$$\mu_{②} = \frac{27.2\ \frac{Btu}{ft^3\cdot {}^\circ F}}{1499\ \frac{Btu}{ft^3}}\ \frac{350\ {}^\circ F.days}{60\ days} = 0.106$$

$$\rightarrow \lambda_{②} = 0.62$$

$$FI_{②} = \frac{(1\ ft)(369\ \frac{Btu}{ft^3})}{(0.62)^2}\left[\frac{1}{0.58+0.87} + \frac{1.1}{\frac{1.02+0.87}{2}}\ \frac{ft}{\frac{Btu}{ft\cdot hr\cdot {}^\circ F}}\right]$$

$$= 1{,}779\ {}^\circ F.hrs = 74\ {}^\circ F.days$$

$$\bar{C}_{③} = 25.7\ \frac{Btu}{ft^3\cdot {}^\circ F}, \quad \bar{L}_{③} = 1{,}135\ \frac{Btu}{ft^3}$$

$$\mu_{③} = \frac{25.7\ \frac{Btu}{ft^3\ {}^\circ F}}{1{,}135\ \frac{Btu}{ft^3}}\ \frac{350\ {}^\circ F.day}{60\ days} = 0.132$$

$$\rightarrow \lambda_{③} = 0.575$$

$$FI_{③} = \frac{(1\ ft)(369\ \frac{Btu}{ft^3})}{(0.575)^2}\left[\frac{1}{0.58+0.87} + \frac{1.1}{\frac{1.02+0.87}{2}} + \frac{1}{\frac{0.58+0.87}{2}}\ \frac{ft}{\frac{Btu}{ft\cdot hr\cdot {}^\circ F}}\right]$$

$$= 3{,}608\ {}^\circ F.hr = 150\ {}^\circ F.days$$

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$$FI_{①} + FI_{②} + FI_{③} = 146 + 74 + 150$$
$$= 370\ ^\circ F.\ days > 350\ ^\circ F.\ days \checkmark$$

Therefore, a protective layer thickness of 1.1 ft is adequate to prevent freezing of compacted clay liner if 1-ft thick LDS and LCS layers are also placed on top of the compacted clay.

Case 2 : Compacted clay liner is overlain only by a protective soil layer.

As calculated earlier, $\alpha = 3.09$

$\mu_{①} = 0.072$, $\lambda_{①} = 0.68$

$$FI = \frac{d_{①}^2\ L_{①}}{\lambda_{①}^2 (k_{f①} + k_{t①})}$$

Solve for $d_{①}$ if $FI = 350\ ^\circ F.\ days$

$$\Rightarrow d_{①} = \sqrt{\frac{350\ ^\circ F.\ days\ (0.68)^2\ (1.02 + 0.87)\ \frac{Btu}{ft.hr.^\circ F}}{2527\ \frac{Btu}{ft^3}\left(\frac{1\ day}{24\ hr}\right)}}$$

$$= 1.7\ ft \checkmark$$

11. FINAL COVER SYSTEM

11.1 Final Cover System

11.1 Final Cover System

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: FINAL COVER SYSTEM

Computations By: (Cognizant Engineer)
Signature [signature] Majdy Ahmed Othman 12 Oct. 1995 Date
Printed Name BIN LI MAJDI A. OTHMAN
and Title Assistant Project Engineer PROJECT ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature [signature] 12 Oct 95 Date
Printed Name PAUL J. SABATINI
and Title SR. STAFF ENGINEER

Computations Checked by:
Signature [signature] 12 Oct 95 Date
Printed Name PAUL J. SABATINI
and Title SR. STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Majdy Ahmed Othman 13 Oct. 1995 Date
Printed Name BIN LI MAJDI A. OTHMAN
and Title Assistant Project Engineer PROJECT ENGINEER

Approved by: (PDP)
Signature Majdy Ahmed Othman 16 oct 1995 Date
Printed Name MAJDI A. OTHMAN
and Title PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature Rudolph Bonaparte 16 Oct 95 Date
Printed Name Rudolph Bonaparte
and Title Principal

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO	16 Oct 95	NA	NA	NA
Ø	30% Submittal	NA	NA	NA	NA No Change
B	Preliminary Design - EPA Submittal	15 Dec 95	[illegible]	—	—

Written By: BL Date: 95/12/13 Reviewed by: PJS Date: 13 Dec 95

Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE 3900 Task No.: 08.8

FINAL COVER SYSTEM

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this package is to evaluate the performance of the FERNALD On-Site Disposal Facility (OSDF) final-closure cover system. This evaluation includes infiltration , drainage layer, geotextile filter, soil filtration, biointrusion barrier layer, and frost penetration depth analyses.

METHODS OF ANALYSIS

Infiltration: Infiltration through the cover system was estimated using the USEPA HELP model.

Drainage Layer: The maximum and average thicknesses and heads, and the transmissivity of the drainage layer were calculated.

Geotextile Filter Design: The retention, permeability, and clogging requirements were calculated.

Soil Filtration Characteristics: The required particle size distribution was calculated for the vegetative soil layer material and the particle sizes of the other layer materials were checked for self-filtration.

Biointrusion Barrier Layer: The biointrusion layer was designed to minimize intrusion of plant roots and burrowing animals.

Frost Penetration Depth: The frost penetration depth into the cover system was calculated using the modified Berggren method.

CONCLUSIONS

Infiltration:

- average daily percolation = 2.05×10^{-3} gpad
- peak daily percolation = 6.33×10^{-2} gpad

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Drainage layer:

- maximum liquid thickness = 8.5 in.
- average liquid thickness = 4.4 in.
- maximum liquid head = 8.4 in.
- average liquid head = 4.4 in.
- calculated transmissivity = 3.05 cm^2/sec

Geotextile Filter Design:

- required equivalent opening size, $O_{95} \leq 210$ μm
- required geotextile hydraulic conductivity, $K > 5.8 \times 10^{-2}$ cm/s
- required porosity for non-woven geotextile, $n_g > 30\%$
- required percent open area for woven geotextile, $A > 4\%$

Soil Filtration Characteristics:

- required d_{85} of vegetative soil > 0.4 mm
- required d_{15} of vegetative soil < 0.03 mm
- granular filter, choke stone, and biointrusion barrier materials are self-filtering

Biointrusion Barrier Layer:

- recommended thickness = 3 ft.
- for a layer thickness of 3 ft, required maximum size (d_{100}) = 18 in.
- required minimum size (d_0) = 1 to 2 in.
- maximum allowable percentage of water absorbency = 1%

Frost Penetration Depth:

- estimated maximum frost penetration depth = 2.2 ft.

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FINAL-CLOSURE COVER SYSTEM PERFORMANCE CALCULATION PROCEDURES

INTRODUCTION

The purpose of this package is to present the calculation procedures for evaluation of the performance of the FERNALD On-Site Disposal Facility (OSDF) final-closure cover system. In particular, this package addresses the following issues:

- infiltration analysis (infiltration rate through composite cap);
- drainage layer analysis (hydraulic head and transmissivity);
- geotextile filter design;
- soil filtration characteristics;
- biointrusion barrier layer design;
- frost penetration depth analysis.

The final-closure cover system configuration is shown in Figure 1

METHODS OF ANALYSIS

INFILTRATION ANALYSIS

The final-closure cover system infiltration analysis will be performed using the HELP model as part of the leachate generation analysis to be performed elsewhere.

DRAINAGE LAYER ANALYSIS

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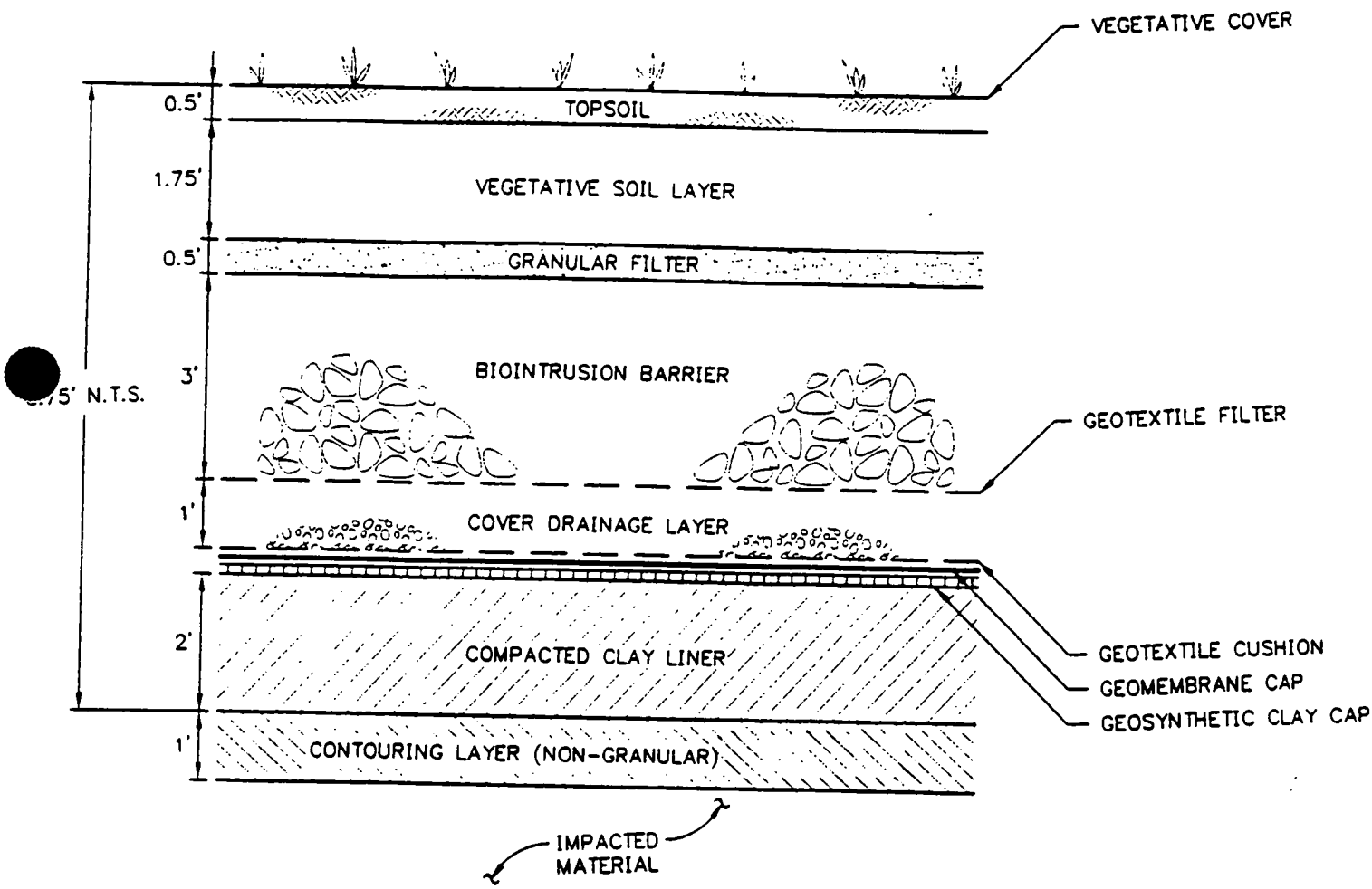
Figure 1: Final-Closure Cover System



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Hydraulic Head: As part of the leachate generation rate calculations to be performed elsewhere, the HELP model will be used to estimate hydraulic head in the final-closure cover system drainage layer. As a check, the closed-form analytical solution described by Giroud and Houlihan [1995] will be used to estimate hydraulic head. For the analytical solution, the impingement rate of flow into the cover drainage layer estimated using HELP and assumed characteristics of the cover drainage layer will be used to estimate the average and maximum hydraulic head and thickness in the drainage layer.

The following six-step approach based on Giroud and Houlihan [1995] will be used to calculate the maximum and average liquid thicknesses, T_{max} and T_{avg},, and the maximum and average hydraulic heads, h_{max} and h_{avg} :

- *Step1.* Calculate the dimensionless parameter λ using the following equation:

$$\lambda = \frac{q_i}{k \tan^2 \beta} \tag{1}$$

where: q_i = the impingement rate of flow into the drainage layer; k = hydraulic conductivity of the drainage layer material; and β = angle between the horizontal and slope.

- *Step 2.* Use Equations 2 and 3 to calculate T_{max}.

$$T_{max} = j\left[\frac{\sqrt{1+4\lambda}-1}{2}\frac{\tan\beta}{\cos\beta}\right](L) \tag{2}$$

$$j = 1 - 0.12\exp\left[-\left[\log(8\lambda/5)^{5/8}\right]^2\right] \tag{3}$$

where: T_{max} = maximum liquid thickness; L = length of the slope; j = corrective coefficient; λ = parameter defined by Equation (1); and β = angle between the horizontal and slope.

- *Step 3.* Calculate the maximum hydraulic head, h_{max}, from Equation 4.

$$h_{max} = T_{max}\cos\beta \tag{4}$$

- *Step 4.* Use Table 1 or Figure 2 to obtain T_{avg}/T_{max}.
- *Step 5.* From T_{max} obtained in Step 2 and T_{avg}/T_{max} obtained in Step 4, calculate T_{avg}.
- *Step 6.* Calculate the average hydraulic head, h_{avg}, from Equation 5.

$$h_{avg} = T_{avg}\cos\beta \tag{5}$$

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Table 1: Values of T_{avg}/T_{max} and x_m/L

$\lambda = \frac{q_i/k}{\tan^2\beta}$	$\frac{T_{avg}}{T_{max}}$	$\frac{x_m}{L}$	$\lambda = \frac{q_i/k}{\tan^2\beta}$	$\frac{T_{avg}}{T_{max}}$	$\frac{x_m}{L}$
0.00	0.500	1.000	0.50	0.73	0.68 - 0.68 - 0.67
0.002	0.50	0.99	0.53	0.74	0.68 - 0.68 - 0.66
0.005	0.51	0.98	0.57	0.75	0.67 - 0.67 - 0.65
0.01	0.52	0.97	0.62	0.76	0.66 - 0.66 - 0.64
0.02	0.53	0.94	0.67	0.77	0.66 - 0.66 - 0.63
0.03	0.54	0.92	0.73	0.78	0.65 - 0.65 - 0.61
0.04	0.55	0.90	0.80	0.79	0.64 - 0.63 - 0.59
0.05	0.56	0.89	0.87	0.80	0.63 - 0.62 - 0.57
0.07	0.57	0.86	0.95	0.81	0.62 - 0.61 - 0.55
0.08	0.58	0.85	1.05	0.82	0.60 - 0.60 - 0.53
0.09	0.59	0.84	1.16	0.83	0.59 - 0.58 - 0.51
0.10	0.60	0.83	1.32	0.84	0.57 - 0.56 - 0.47
0.12	0.61	0.82	1.58	0.85	0.57 - 0.53 - 0.43
0.14	0.62	0.80	2.0	0.86	0.51 - 0.49 - 0.37
0.15	0.63	0.79	3.2	0.87	0.44 - 0.41 - 0.26
0.16	0.64	0.78	5.5	0.86	0.36 - 0.31 - 0.16
0.17	0.65	0.77	8.5	0.85	0.30 - 0.23 - 0.11
0.18	0.66	0.76	13	0.84	0.25 - 0.17 - 0.07
0.20	0.67	0.75	19	0.83	0.21 - 0.13 - 0.05
0.23	0.68	0.73	30	0.82	0.17 - 0.09 - 0.03
0.25	0.69	0.71	55	0.81	0.13 - 0.05 - 0.02
0.35	0.70	0.70	135	0.80	0.08 - 0.02 - 0.01
0.40	0.71	0.70	1000	0.79	0.03 - 0.00 - 0.00
0.45	0.72	0.69	∞	0.785	0 - 0 - 0

Note: This table was established using Equations 46, 50 and 51 for values of $\lambda \geq 0.25$, and using charts, published by McEnroe and Schroeder (1988), for $\lambda < 0.25$. The ratio T_{avg}/T_{max} varies very little with the slope angle, β; when β varies between 0 and 45°, the change in T_{avg}/T_{max} is typically less than 0.03. Therefore, the tabulated values of T_{avg}/T_{max} (which are average values) are either unaffected or affected by $\pm$ 0.01. The two limit values for T_{avg}/T_{max}, i.e. 1/2 (for $\lambda = 0$) and $\pi/4$ (for $\lambda = \infty$), are accurate. For $\lambda < 0.5$, the values of x_m/L also vary very little with β; in this case, when β varies between 0 and 45°, the tabluated values of x_m/L are either unaffected or affected by $\pm$ 0.01. For $\lambda > 0.5$, the influence of β on x_m/L is significant. To illustrate the influence of β in this case, three values of x_m/L are tabulated in the last column: the value on the left is for $0 < \tan\beta < 10\%$, the middle value is for $\tan\beta = 1/3$ (i.e. a 1V:3H slope) and the value on the right is for $\tan\beta = 1$ (i.e. a 1V:1H slope) (see Figure 11). It should be noted that, in the charts by McEnroe and Schroeder (1988), the parameter λ is not used. Therefore, it does not appear in those charts that T_{avg}/T_{max} and, to a certain extent, x_m/L are independent of β.

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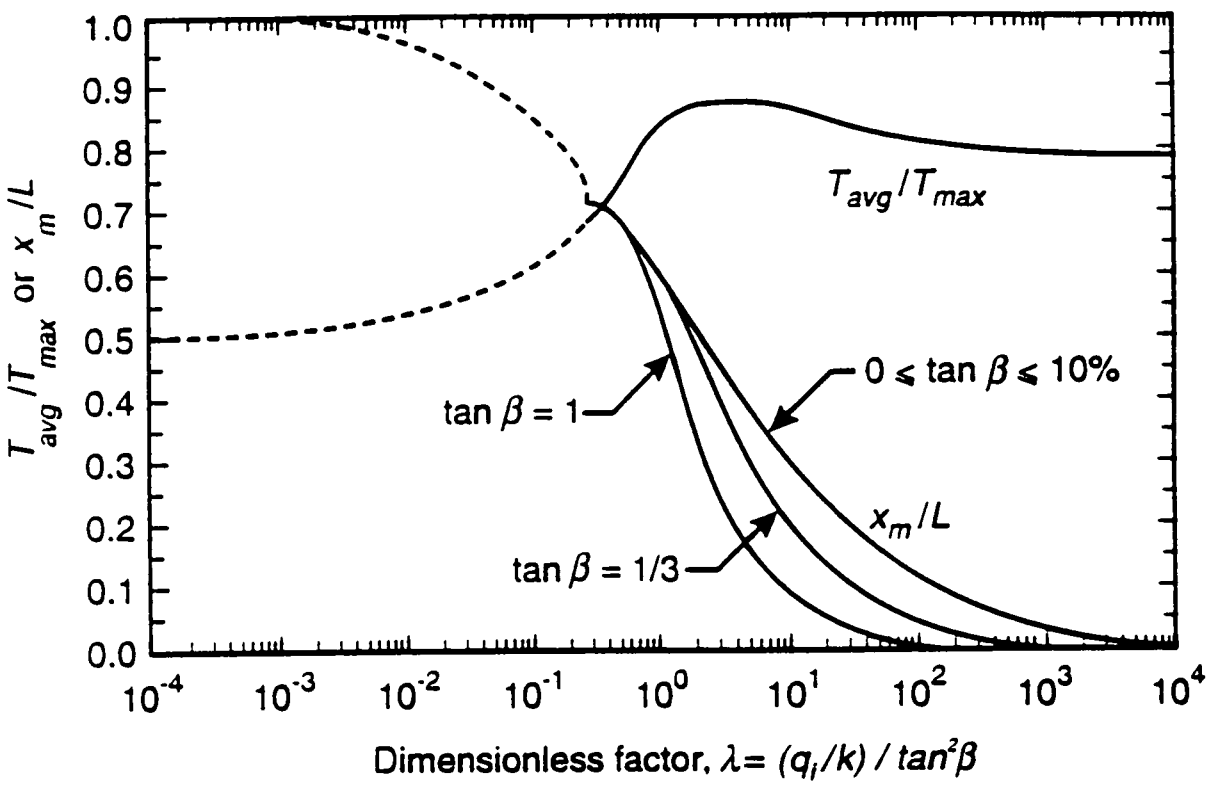
Figure 2: Values of T_{avg}/T_{max} and x_m/L



Transmissivity: The transmissivity of the drainage layer will be calculated as the product of the hydraulic conductivity of the drainage layer and the drainage layer thickness as shown in the following equation:

$$\theta_d = k_d D_d \tag{6}$$

where: θ_d = hydraulic transmissivity of the drainage layer; k_d = the hydraulic conductivity of the drainage material; and D_d = the thickness of the drainage layer.

GEOTEXTILE FILTER DESIGN

Geotextile filters are used to separate different material types from each other. In the final-cover system, a geotextile filter will be used between the biointrusion barrier layer and the cover drainage layer as shown in Figure 1. The geotextile filters will be designed based on criteria proposed by Christopher and Holtz [1994], Giroud [1982], and USEPA [1987] which include a retention criterion, a permeability criterion, and a clogging criterion. These criteria are described in Table 2. Survivability requirements, such as grab, tear, puncture, and burst strength, to ensure adequate resistance to stresses applied on the geotextile during installation and during design life will be included in the material specifications for this project.

In the cover system, the openings in the geotextile must be small enough to retain fine soil particles and prevent them from entering the cover drainage layer and must also be large enough to allow liquid to pass through the soil/geotextile interface without significant flow impedance.

SOIL FILTRATION CHARACTERISTICS

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Table 2: Filter Criteria for Geotextile, Adapted From [Christopher and Holtz, 1984; Giroud, 1982; and USEPA, 1987]

1. RETENTION CRITERION

1.1 Soils with less than 50 percent particles < 0.075 mm (> US Sieve No. 200)

	Density index of the soil (Relative density)	Linear coefficient of uniformity of the soil	
		$1 < C'_u < 3$	$C'_u > 3$
loose soil	$I_D < 35\%$	$O_{95} < C'_u\, d_{50}$	$O_{95} < \frac{9}{C'_u} d_{50}$
medium dense soil	$35\% < I_D < 65\%$	$O_{95} < 1.5\, C'_u\, d_{50}$	$O_{95} < \frac{13.5}{C'_u} d_{50}$
dense soil	$I_D > 65\%$	$O_{95} < 2\, C'_u\, d_{50}$	$O_{95} < \frac{18}{C'_u} d_{50}$

1.2 Soils with more than 50 percent particles < 0.075 mm (US Sieve 200)

$O_{95} \leq 210\ \mu m$ ($\geq$ US Sieve 70)

2. PERMEABILITY CRITERION

2.1 Critical and/or Severe Applications

$k_{geotextile} > 10\ k_{soil}$

Table 2 (Continued): Filter Criteria for Geotextile, Adapted From [Christopher and Holtz, 1984; Giroud, 1982; and USEPA, 1987]

2.2 Noncritical and Nonsevere Applications

$k_{geotextile} > k_{soil}$

3. CLOGGING CRITERION

Nonwoven geotextiles: porosity, $n_g > 30\%$

Woven geotextiles: percent open area, $A > 4\%$

Notes: O_{95} is the apparent opening size (AOS) of the geotextile.

$$C_u' = \sqrt{d_{100}' / d_0'}$$

where d'_{100} and d'_0 are the top and bottom extremities, respectively, of a line drawn through the central portion of a soil particle-size distribution curve.

d_{50} and d_{85} are soil particle sizes for which 50% and 85%, respectively, of particles are finer by weight.

$I_D = (e - e_{min})/(e_{max} - e_{min})$, where: e = soil void ratio; e_{min} = soil minimum void ratio; and e_{max} = soil maximum void ratio.

$k_{geotextile}$ = geotextile hydraulic conductivity

k_{soil} = soil hydraulic conductivity

The porosity n_g (dimensionless) is calculated as follows: $n_g = 1 - \mu_g/(\rho_g\, t_g)$, where: μ_g = geotextile mass per unit area; ρ_g = polymer density; and t_g = geotextile thickness. Basic SI units are: μ_g (kg/m^2), ρ_g (kg/m^3), and t_g (m).

The final-closure cover system contains a granular filter which separates the vegetative soil layer and the biointrusion barrier layer. Analyses will be performed to ensure that these soils are self filtering. The following filtration criteria will be used:

- (d_{15} of bottom material / d_{85} of top material) $\leq$ 3 to 5.
- (d_{15} of bottom material / d_{15} of top material) $\geq$ 3 to 5.

where d_{15} corresponds to the material particle size for which 15 percent by weight of the particles are finer and d_{85} corresponds to the material particle size for which 85 percent by weight of the particles are finer.

BIOINTRUSION BARRIER LAYER DESIGN

The purpose of the biointrusion barrier layer is to deter and inhibit downward advancement of roots and burrowing animals. However, all of the final-closure cover system components must be adequately designed to prevent biointrusion. These components will be designed to meet the requirements described below:

- The top soil layer should be vegetated with species of shallow roots (i.e., no deeply-rooted shrubs or trees).
- The top soil should be of favorable water and nutrient conditions to allow for healthy growth of plants and to discourage plant roots and animals from penetrating deeper into the underlying soil layers in search of water or nutrients. The top soil should also be thick enough and of appropriate hydraulic conductivity for optimal moisture retention (loamy soils make good top soils but gravels and cobbles don't).
- Appropriate materials for the granular filter layer and the choke layer should be selected to prevent migration of fines into the biointrusion layer.
- The biointrusion barrier layer should be of high conductivity (i.e., large voids) to prevent water or soil particles from filling the voids and therefore deter plant root penetration [Hakonson, 1986]. This can be achieved by specifying a minimum particle size of 1 to 2 inches.

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- The gradation of the biointrusion barrier layer material should be such that at least two voids exist along the depth of the biointrusion layer such that roots are obstructed from penetrating the biointrusion layer by at least two voids. This can be achieved by making the maximum particle size less than or equal to half of the layer thickness.
- High quality rock with low percentage of absorbency should be used for the biointrusion layer.
- The drainage layer and the barrier layer should be able to remove water from the cover system rapidly.
- The barrier layer should be protected from freeze-thaw cycling, so as to minimize degradation and ease of penetration.

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DEPTH OF FROST PENETRATION

The depth of frost penetration into the final-closure cover system will be calculated using the modified Berggren method [Aldrich and Paynter, 1953]. The temperature distribution in a soil with initial temperature (T_i) when its surface is subjected to a temperature (T_s) which is less than the freezing temperature (T_f) is shown below.

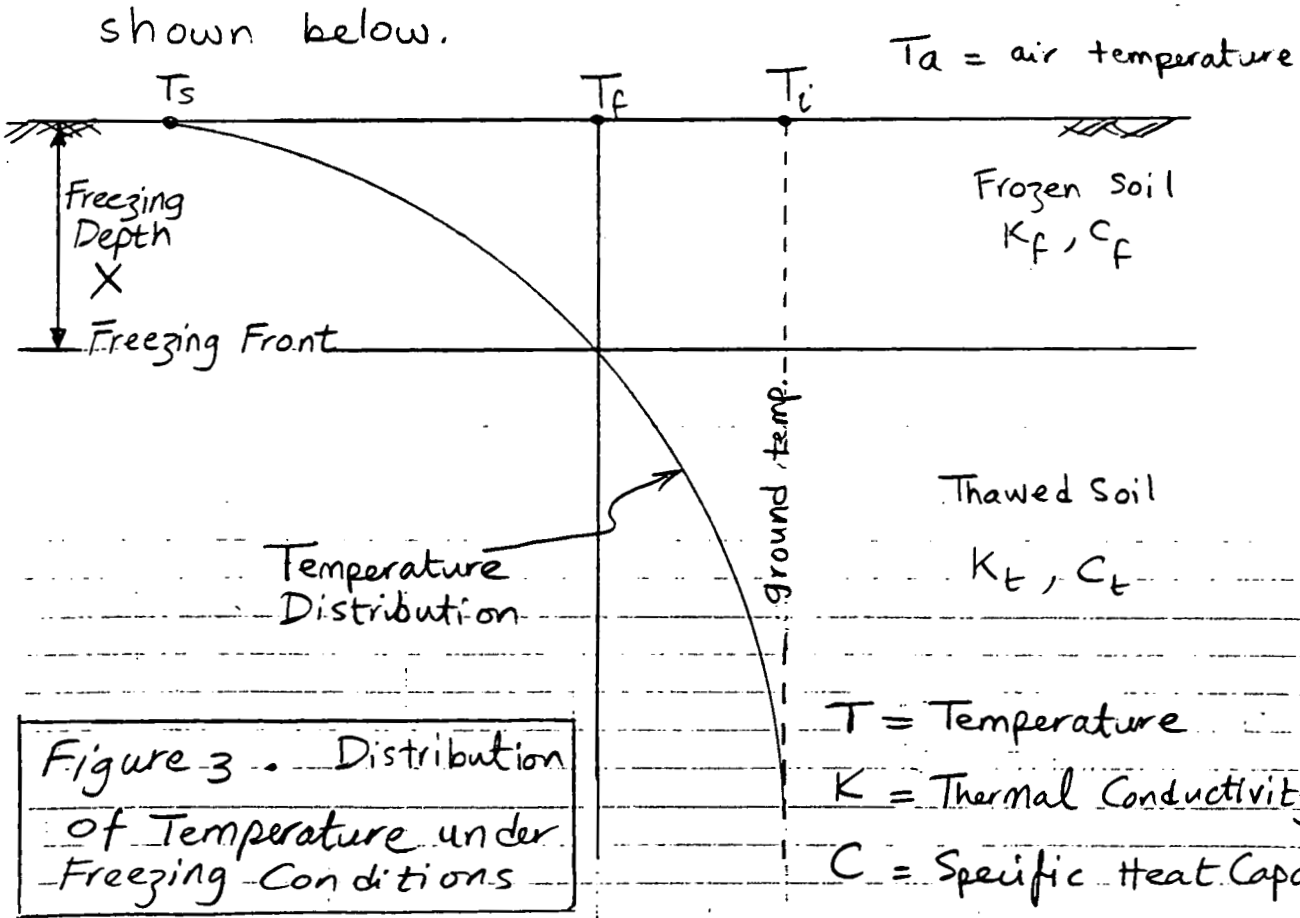

Figure 3. Distribution of Temperature under Freezing Conditions

subscript f represents frozen properties and subscript t represents thawed properties.

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Based on the modified Berggren method, the depth of frost penetration, X, can be calculated as:

$$X = \lambda \sqrt{\frac{(K_f + K_t)(T_f - T_s)\,t}{L}} \qquad (7)$$

where: K_f = thermal conductivity of frozen soil

K_t = thermal conductivity of thawed soil

T_f = freezing temperature

T_s = ground-surface temperature

t = time period soil surface is subject to temperature T_f

L = Latent heat of fusion of soil

λ is a parameter which is a function of the fusion parameter, μ, and the thermal ratio, α, as given in Figure 4.

$$\mu = \frac{C_f + C_t}{2} \cdot \frac{T_f - T_s}{L} \qquad (8)$$

$$\alpha = \frac{T_i - T_f}{T_f - T_s} \qquad (9)$$

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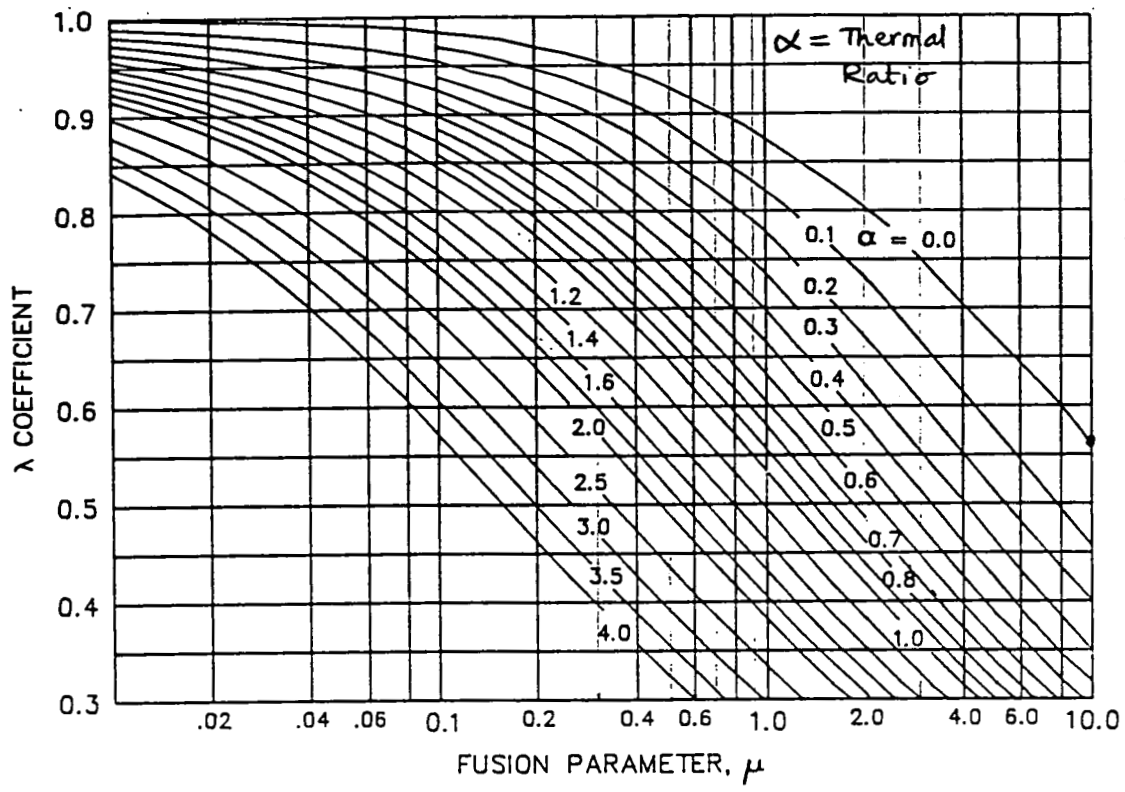

Figure 4. Lambda coefficient (after Aldrich and Paynter, 1953).

To apply the above equations to field cases where the surface temperature varies, the average surface temperature for the freezing period is used for T_s and T_i is taken as the mean annual air or ground temperature. The average surface temperature is estimated from the air temperature freezing index using

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a correction factor, n, to account for differences between the air temperature and the ground surface temperature. The air freezing index, FI, is defined as the sum of the deviations of mean daily air temperatures, Ta, from the freezing point calculated over the freezing season as follows:

$$FI_{air} = \sum_{i=1}^{t} (T_f - Ta_i) \qquad (10)$$

where t is the number of freezing season days. The soil surface freezing index is corrected using the n-factor which depends on the soil type and ground surface cover type as follows:

$$FI_{surface} = FI_{air} \times n \qquad (11)$$

Therefore, Equations 7, 8, 9 and can be rewritten as follows:

$$X = \lambda \sqrt{\frac{(K_f + K_t)\, FI_{surface}}{L}} \qquad (12)$$

$$\mu = \frac{C_f + C_t}{2} \frac{FI_{surface}}{L\, t} \qquad (13)$$

$$\alpha = \frac{(T_i - T_f)\, t}{FI_{surface}} \qquad (14)$$

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For a layered soil system, the modified Berggren method uses depth weighted thermal properties. The solution begins by determining the number of surface freezing degree days needed to freeze the first layer as follows:

$$FI_{①} = \frac{d_{①}^2 \, L_{①}}{\lambda_{①}^2 \left(K_{f①} + K_{t①}\right)} \qquad (15)$$

where $\lambda_{①}$ is a function of $\mu_{①}$ and α

$$\mu_{①} = \frac{C_{f①} + C_{t①}}{2} \; \frac{FI_{surface}}{L_{①} \; t}$$

- If $FI_{①} > FI_{surface} \Rightarrow X < d_{①}$; calculate X using Equation 12.
- If $FI_{①} < FI_{surface} \Rightarrow$ The freezing depth will exceed $d_{①}$; calculate the freezing index for layer 2 and so on.

For all layers except layer 1, the freezing index is calculated as follows:

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$$FI_n = \frac{d_n L_n}{\lambda_n^2}\left[\frac{d_n}{k_{f_n} + k_{t_n}} + \sum_{i=1}^{n-1} \frac{d_i}{(k_{f_i} + k_{t_i})/2}\right] \quad (16)$$

where λ_n = function (μ_n, α)

$$\mu_n = \frac{\bar{C}_n}{\bar{L}_n} \frac{FI_{surface}}{t} \quad (17)$$

$$\bar{C}_n = \frac{1}{2} \frac{\sum_{i=1}^{n} (C_{f_i} + C_{t_i}) d_i}{\sum_{i=1}^{n} d_i} \quad (18)$$

$$\bar{L}_n = \frac{\sum_{i=1}^{n} L_i d_i}{\sum_{i=1}^{n} d_i} \quad (19)$$

If $\sum_{i=1}^{n} FI_i > FI_{surface}$, the n th layer will partialy freeze → calculate thickness of layer n which will freeze (Y) by equating FI_n in Equation (16) to $\left(FI_{surface} - \sum_{i=1}^{n-1} FI_i\right)$ and d_n to Y.

An iterative solution is needed to solve this equation.

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FINAL-CLOSURE COVER SYSTEM PERFORMANCE DATA VERIFICATION

INTRODUCTION

As described in the calculation procedures package, the following analyses will be performed:

- infiltration analysis (infiltration rate through composite cap);
- drainage layer analysis (hydraulic head and transmissivity);
- geotextile filter design;
- soil filtration characteristics;
- biointrusion barrier layer design;
- frost penetration depth analysis.

In order to perform the analyses described above, the following data is required:

INFILTRATION ANALYSIS

The final-closure cover system infiltration analysis will be performed using the HELP model as part of the leachate generation analysis package.

DRAINAGE LAYER ANALYSIS

Hydraulic Head:

q_i = the maximum impingement rate of flow into the cover drainage layer = 0.7809 in. /day (peak daily value from the HELP model analyses results; Cases 3C and 3D) = 2.3×10^{-5} cm/sec

k = hydraulic conductivity of the cover drainage layer material = 0.1 cm/sec

β = average angle between the horizontal and slope = 7.63° (13.4%)

L = the length of the slope = 430 ft (5160 in.)

Transmissivity:

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k = hydraulic conductivity of the cover drainage material = 0.1 cm/sec

D = the thickness of the cover drainage layer = 12 in. (30.5 cm)

GEOTEXTILE FILTER DESIGN

The biointrusion barrier layer will consist of cobbles with minimum particle size of 4 inches. It is anticipated that the biointrusion layer may contain minimal amounts of fines (dust attached to the cobbles). These fines may migrate downwards and be retained on the geotextile. To be conservative, the geotextile retention criterion assuming the biointrusion protection layer material is a fine-grained soils will be used.

For the geotextile not to impede flow, it should have hydraulic conductivity greater than that of the granular filter layer which has an assumed hydraulic conductivity of 5.8×10^{-3} cm/sec.(see Leachate generation rate data verification package, Table 1).

SOIL FILTRATION CHARACTERISTICS

It is anticipated that a suitable soil from an on-site source will be used as the vegetative soil layer. An appropriate gradation of the vegetative soil layer will be selected based on the filtration criteria presented in the procedures package. ODOT aggregate base material will be used for the granular filter layer. ODOT #24 stone will be used for the choke layer on top of the biointrusion barrier; and the biointrusion barrier will have a d_{50} (the equivalent diameter of which 50 percent by dry weight of selected material is finer) of 12 inches and a maximum particle size of 18 inches, and a minimum particle size of 4 inches. The biointrusion layer material was selected based on criteria described in the procedures package.

The grain size distribution curves for the granular filter layer, the choke layer, and the biointrusion layer are shown in Figure 1. Based on these curves, d_{15} and d_{85} for these layers are summarized below:

- d_{15} of granular filter layer = 0.09 - 1.2 mm
- d_{85} of granular filter layer = 14 - 40 mm
- d_{15} of choke stone layer = 20 - 27 mm

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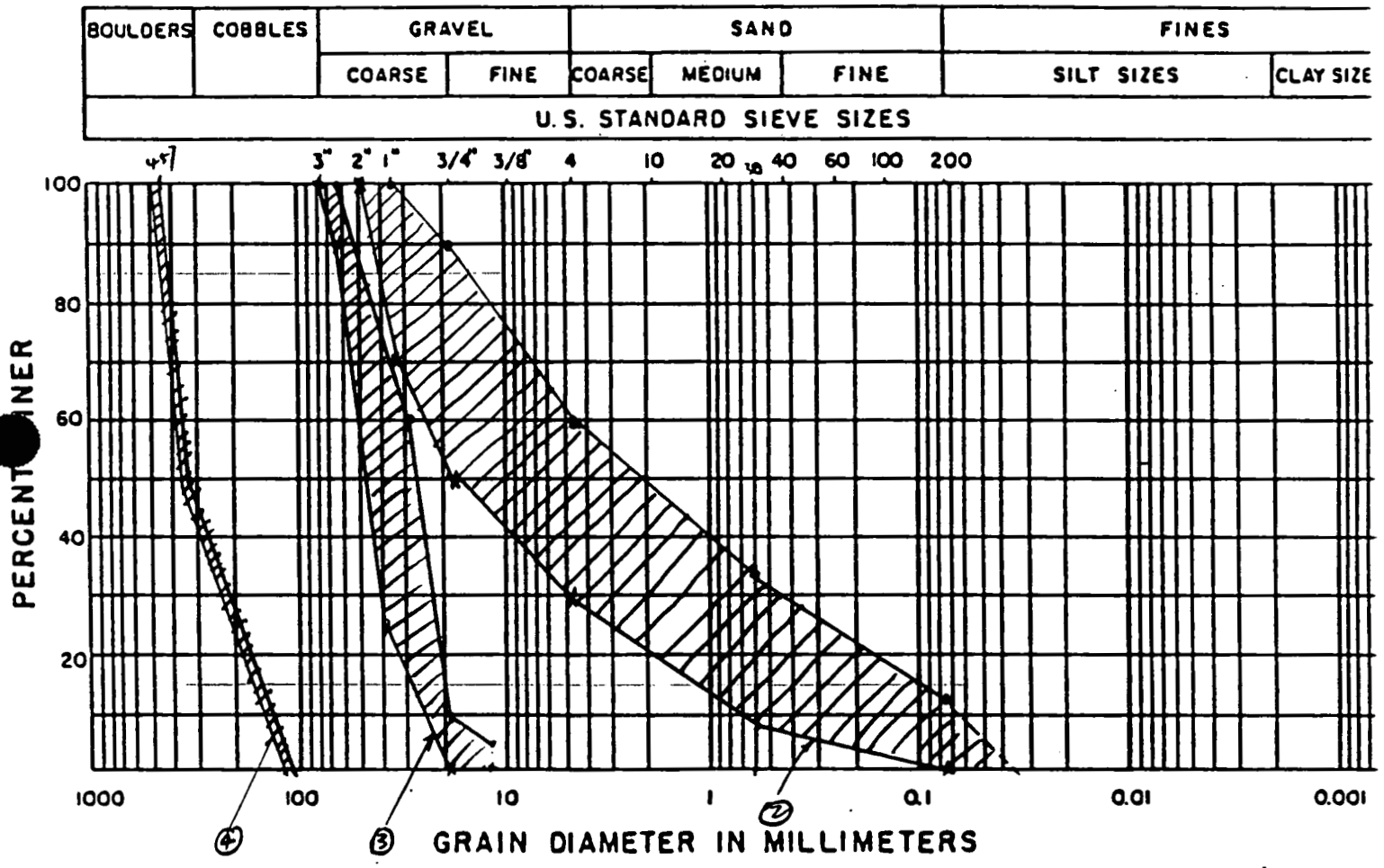
Figure 1: Grain Size Distribution Curves for Granular Filter Layer, Choke Layer, and Biointrusion Layer



②---- Granular Filter Layer

③---- Choke Stone Layer

④---- Biointrusion Layer

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- d_{85} of choke stone layer = 48 - 60 mm
- d_{15} of biointrusion barrier layer = 150 - 160 mm
- d_{85} of biointrusion barrier layer = 420 - 450 mm

BIOINTRUSION BARRIER LAYER DESIGN

The biointrusion barrier layer is selected to be 3 feet thick. The biointrusion barrier's material gradation must prevent the passage of finer-grained soils into the rock voids. High quality rock of low percentage of absorbency should be used for this layer.

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DEPTH OF FROST PENETRATION

Data Required to calculate the depth of frost penetration includes the following:

- Weather Data:
  - mean annual ground temperature, T_i
  - air freezing Index, FI_{air}
  - the n-factor relating air to ground surface temperatures, n
  - number of days in the freezing season, t
- Soil Thermal Properties (for each layer):
  - frozen and thawed thermal conductivities, K_f and K_t
  - frozen and thawed specific heat capacities, C_f and C_t
  - latent heat of fusion, L

This data is selected as described below.

- Weather Data:
  - mean annual ground temperature, T_i, for the OSDF site is conservatively assumed equal to 50°F.
  - air freezing index, FI_{air}, is obtained

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from Figure 2 which is a design freezing index contour map of the United States produced by the U.S. Army Corps of Engineers (USACOE). According to this figure, the FI_{air} for the OSDF site ≈500°F. days. For this analysis, assume FI_{air} = 500°F. days.

From the literature, n-factors are available for different surfaces (see Table 1 below).

Table 1. Values of n-factors for Different Surfaces (After Lunardini 1978)

Surface Type	Freezing-n_f
Spruce trees, brush, moss over peat—soil surface	0.29 (under snow)
As above with trees cleared—soil surface	0.25 (under snow)
Turf	0.5 (under snow)
Snow	1.0
Gravel	0.6 – 1.0
(probable range for northern conditions)	(0.9 – 0.95)
Asphalt pavement	0.29 – 1.0 or greater
(probable range for northern conditions)	(0.9 – 0.95)
Concrete pavement	0.25 – 0.95
(probable range for northern conditions)	(0.7 – 0.9)

Guidance provided in the UMTRA Technical Approach Document produced by US Department of Energy (USDOE) suggests the use

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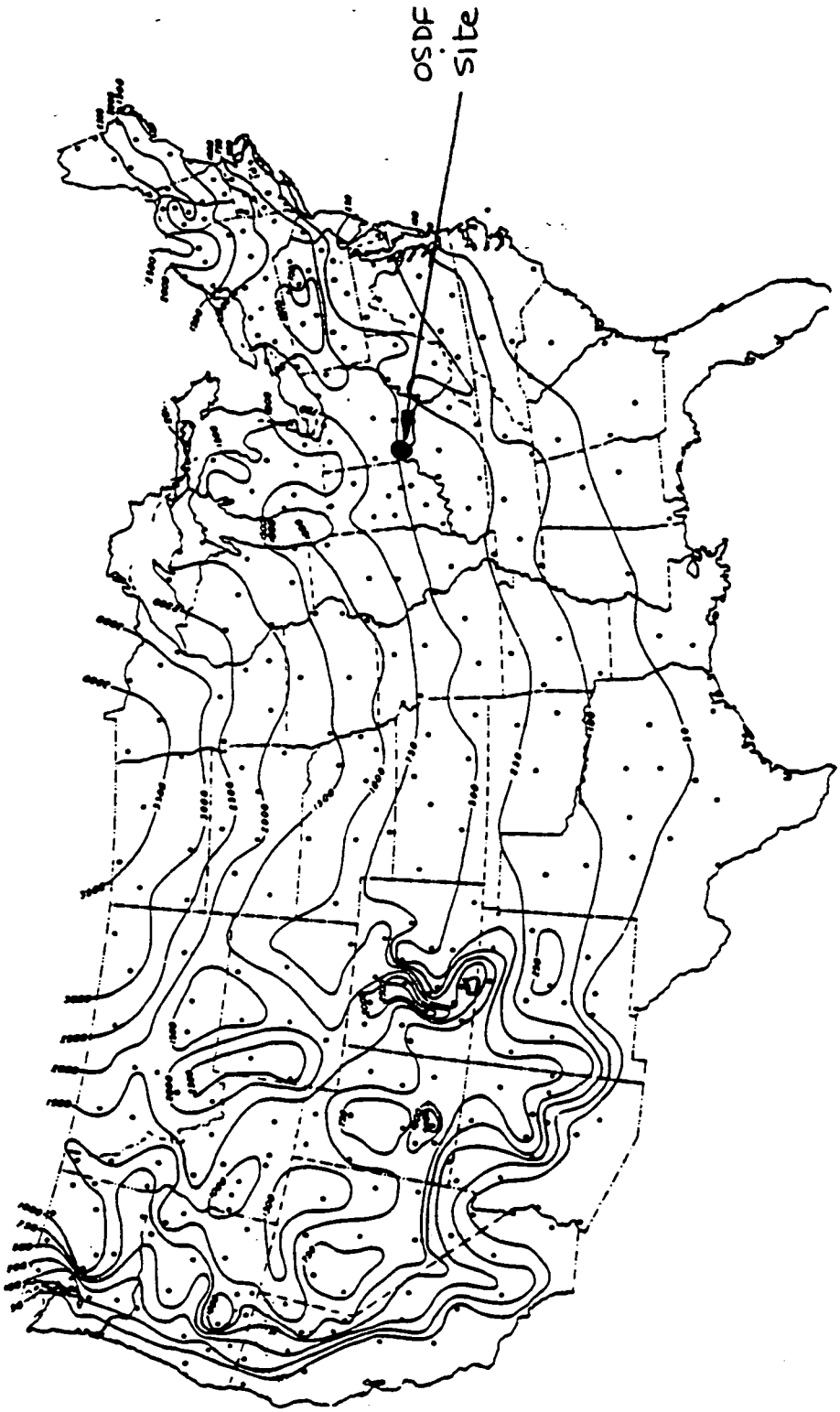

Figure 2. Design freezing index values for the conterminous United States.

Source: U.S. Army Corps of Engineers

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of an n-factor of 0.6 to 0.7 for UMTRA projects. For this analysis, an n-factor of 0.70 will be used to be conservative

- number of days in the freezing season, t, can be obtained from weather data published by the National Oceanic and Atmospheric Administration (NOAA). According to this data, for the Greater Cincinnati Airport, mean number of days with minimum temperature 32°F or less = 108 days. Mean number of days with the average temperature being 32°F or less should then be less than 108 days. For this analysis, the less number of days the design freezing index is associated with, the more conservative the estimate of depth of frost penetration is (i.e., larger depth is estimated).

For this analysis, assume t = 60 days.

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- Soil Thermal Properties

– frozen and thawed thermal conductivities (K_f and K_t) for all layers will be estimated based on the equations derived by Kersten [1949]. For coarse-grained soils (i.e., sands and gravels):

$$K_f = \frac{0.076\,(10)^{0.013\gamma_d} + \omega\,(0.032)\,(10)^{0.0146\gamma_d}}{12} \quad (1)$$

$$K_t = \frac{(0.7\log\omega + 0.4)\,(10)^{0.01\gamma_d}}{12} \quad (2)$$

For fine-grained soils (i.e., silts and clays):

$$K_f = \frac{0.01(10)^{0.022\gamma_d} + \omega\,(0.085)\,(10)^{0.008\gamma_d}}{12} \quad (3)$$

$$K_t = \frac{(0.9\log\omega - 0.2)\,(10)^{0.01\gamma_d}}{12} \quad (4)$$

where: ω = moisture content of soil by weight (%)

γ_d = dry unit weight (pcf)

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K_f and K_t are expressed in Btu/ft. hr. °F

The following table summarizes K_f and K_t values calculated from Equations (1) through (4) for all of the final cover system layers.

Layer	moisture content by volume (1) $\omega_{vol.}$ (%)	total Unit Weight (2) γ (pcf)	moisture content by weight (3) $\omega_{wt.}$ (%)	dry unit weight (4) γ_d (pcf)	K_f (5) Btu / ft. hr. °F	K_t (5) Btu / ft. hr. °F
(1) Topsoil	19.7	125	10.9	113	0.87	0.82
(2) Vegetative soil	28.2	125	16.4	107	1.02	0.87
(3) Granular filter	17.3	125	9.5	114	1.36	1.25
(4) Biointrusion barrier	3.0	125	1.5	123	0.50	0.74
(5) drainage Layer	4.2	125	2.1	122	0.58	0.87
(6) GCL/compacted clay	43.0	130	26	103	1.38	0.96

Notes: (1) volumitric moisture content values are as used in leachate generation calculations performed using USEPA HELP model.

(2) Assumed values based on expected material properties

(3) $\omega_{wt.} = \dfrac{\omega_{vol.}\,\gamma_w}{\gamma - \omega_{vol.}\,\gamma_w}$; where γ_w = unit wt. of water

$\omega_{wt} = \omega$ in Eqs 1→4.

(4) $\gamma_d = \dfrac{\gamma}{1+\omega_{wt.}}$

(5) for the granular filter, Biointrusion barrier, and drainage Layer, K_f and K_t were calculated using Eqs. 1 & 2, all others 3 and 4.

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- frozen and thawed specific heat capacities (C_f and C_t) for all layers will be estimated as follows:

$$C_f = \gamma_d \left(0.17 + \frac{0.5\,w}{100}\right) \quad (5)$$

$$C_t = \gamma_d \left(0.17 + \frac{w}{100}\right) \quad (6)$$

where: γ_d = dry unit weight (pcf)

w = moisture content by weight (%)

C_f and C_t are in $\frac{Btu}{ft^3 \cdot {}^\circ F}$

The following table summarizes C_f and C_t values for all of the final cover system layers

Layer	w (%)	γ_d (pcf)	C_f ($\frac{Btu}{ft^3 \cdot {}^\circ F}$)	C_t ($\frac{Btu}{ft^3 \cdot {}^\circ F}$)
(1) Topsoil	10.9	113	25.4 ✓	31.5 ✓
(2) Vegetative Soil	16.4	107	27.0	35.7
(3) Granular Filter	9.5	114	24.8	30.2
(4) Biointrusion barrier	1.5	123	21.8	22.8
(5) drainage layer	2.1	122	22.0 ✓	23.3 ✓
(6) GCL/compacted clay	26.0	103	30.9	44.3 ✓

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– Latent heat of fusion is calculated from the following equation:

$$L = \left(\gamma_d \frac{\omega}{100}\right) 144$$

where: L = Latent heat of fusion $\left(\frac{Btu}{ft^3}\right)$

γ_d = dry unit weight (pcf)

ω = moisture content by wt. (%)

The following table summarizes the calculated latent heat of fusion values for all of the final-closure cover system components.

Layer	ω (%)	γ_d (%)	L $\left(\frac{Btu}{ft^3}\right)$
① Top soil	10.9	113	1,774 ✓
② vegetative soil	16.4	107	2,527
③ granular filter	9.5	114	1,560
④ Biointrusion barrier	1.5	123	266 ✓
⑤ drainage layer	2.1	122	369
⑥ GCL / compacted clay	2.6	103	3,856 ✓

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SUMMARY OF DATA FOR DEPTH OF FROST PENETRATION CALCULATIONS

T_i = 50 °F

FI_{air} = 500 °F · day

n = 0.70

t = 60 days

Layer	K_f $\left(\frac{Btu}{ft \cdot hr \cdot °F}\right)$	K_t $\left(\frac{Btu}{ft \cdot hr \cdot °F}\right)$	C_f $\left(\frac{Btu}{ft^3 \cdot °F}\right)$	C_t $\left(\frac{Btu}{ft^3 \cdot °F}\right)$	L $\left(\frac{Btu}{ft^3}\right)$
① topsoil (6")	0.87	0.82	25.4	31.5	1,774
② vegetative soil (21")	1.02	0.87	27.0	35.7	2,527
③ granular filter (6")	1.36	1.25	34.8	30.2	1,560
④ biointrusion barrier (36")	0.50	0.74	21.8	22.8	266
⑤ drainage layer (12")	0.58	0.87	22.0	23.3	369
⑥ GCL / compacted clay (24.25")	1.38	0.96	30.9	44.3	3,856

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Final-Closure Cover System Performance Calculation Results

Infiltration Analysis

Based on HELP model analysis:

Cases 3C and 3D have the annual percolation and peak daily percolation maximum values.

- Average daily percolation:

2.75×10^{-5} (in/year)

$= 2.75 \times 10^{-5}$ (in) $\times \left(\frac{1}{12} \frac{ft}{in}\right) \div 365$ days

$\times 43560\ ft^2 \times 7.48\ gal/ft^3$

$= \underline{2.05 \times 10^{-3}}$ gpad. ✓

- Peak daily percolation:

2.33×10^{-6} (in/day)

$= 2.33 \times 10^{-6} \times \left(\frac{1}{12} \frac{ft}{in}\right)$

$\times 43560\ ft^2 \times 7.48\ gal/ft^3$

$= \underline{6.33 \times 10^{-2}}$ gpad ✓

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Drainage Layer Analysis

- Hydraulic Head

From HELP model analysis:

q_i = the maximum impingement rate of flow into the cover drainage layer = 0.7809 in/day = 2.3×10^{-5} cm/sec

$$\lambda = \frac{q_i}{k \tan^2\beta} \quad \text{where } k = 1.0E-1 = 0.1 \text{ cm/sec}$$

$$\beta = \tan^{-1}\frac{13.4}{100} = 7.63^\circ$$

$$\lambda = \frac{2.3 \times 10^{-5} \text{ cm/sec}}{0.1 \times \tan^2 7.63^\circ} = \underline{\underline{0.01282}} \checkmark$$

$$j = 1 - 0.12 \exp\left[-\left[\log(8\lambda/5)^{5/8}\right]^2\right] = \underline{\underline{0.961}} \checkmark$$

$$T_{max} = j\left\{\frac{\sqrt{1+4\lambda}-1}{2} \cdot \frac{\tan\beta}{\cos\beta}\right\}(L) \quad \text{where } L = 430 \text{ ft} = 5160 \text{ in}$$

$$= 0.961\left[\frac{\sqrt{1+4\times 0.01282}-1}{2} \cdot \frac{\tan 7.63^\circ}{\cos 7.63^\circ}\right](5160)$$

$$= \underline{\underline{8.49 \text{ in}}} \checkmark$$

$$h_{max} = T_{max} \cdot \cos\beta = 8.49 \times \cos 7.63^\circ$$

$$= \underline{\underline{8.42 \text{ in}}} \checkmark$$

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for a $\lambda = 0.01282$, $T_{avg}/T_{max} = 0.52$ (Based on Table 1 of calculations procedures package reproduced from Giroud and Houlihan)

$T_{avg} = 0.52\, T_{max} = 0.52\,(8.49)$

$T_{ave} = \underline{\underline{4.42 \text{ in}}}$ ✓

$h_{avg} = T_{ave} \cos\beta = 4.42 \times \cos 7.63^\circ$

$= \underline{\underline{4.38 \text{ in}}}$ ✓

- It is noted that the average head (T_{avg}) in the cover drainage layer calculated using the HELP model for the peak daily was 4.5 in which is nearly the same as the value calculated above.

- Based on these results, it is concluded that the maximum thickness is less than the thickness of the drainage layer (i.e. 12 inches)

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Client: Fermco Project: Fernald OSDF Project/Proposal No.: GE5900 Task No.: 08.8

- Transmissivity

$$\theta_d = K_d \cdot D_d = 0.1\ cm/sec \times 12\ inches\ (2.54\ cm/in)$$

$$= 3.05\ cm^2/sec$$ ✓

Geotextile filter Design

- Retention Criterion:

As it is assumed that more than 50% of particles in the dust attached to the cobbles will be smaller than 0.075 mm (US Sieve #200), the required apparent opening size is, according to table 2 of procedure package, $O_{95} \leq 210\ \mu m$ (i.e ≥ U.S Sieve 70)

- Permeability Criterion:

$$K_{geotextile} > 10\ K_{granular\ filter} = 10 \times 5.8 \times 10^{-3}\ cm/sec$$
$$= 5.8 \times 10^{-2}\ cm/sec$$

The selected geotextile should meet this requirement.

- Clogging Criterion:

For nonwoven geotextiles: porosity $n_g > 30\%$

Woven geotextiles: percent open area $A > 4\%$

Written by: BL Date: 95/10/11 (YY/MM/DD) Reviewed by: PJS Date: 95/10/12 (YY/MM/DD)

Client: Fermco Project: Fernald OSOF Project/Proposal No.: GE3900 Task No.: 08.8

Soil Filtration Characteristics

	d_{15}	d_{85}
Vegetative Soil ①	to be selected	to be selected
granular filter ②	0.09 - 1.2 mm	14 - 40 mm
choke layer ③	20 - 27 mm	48 - 60 mm
Biointrusion layer ④	150 - 160 mm	420 - 450 mm

• For layer ①

$$\frac{d_{15②}}{d_{85①}} \leq 3-5$$

$$\frac{0.09 \text{ to } 1.2}{d_{85①}} \leq 3-5 \quad \therefore d_{85①} > 0.4 \text{ mm} \checkmark$$

$$\frac{d_{15②}}{d_{15①}} \geq 3-5$$

$$\frac{0.09 \text{ to } 1.2}{d_{15①}} \geq 3-5 \quad \therefore d_{15①} < 0.03 \text{ mm} \checkmark$$

• checking ② and ③

$$\frac{d_{15③}}{d_{85②}} = \frac{20 \text{ to } 27}{14 \text{ to } 40} = 0.5 \text{ to } 1.929 \leq 3 \text{ to } 5 \checkmark$$

O.K

$$\frac{d_{15③}}{d_{15②}} = \frac{20 \text{ to } 27}{0.09 \text{ to } 1.2} = 16.7 \text{ to } 300 \geq 3 \text{ to } 5 \checkmark$$

O.K

Written by: BL. Date: 95/10/11 (YY MM DD) Reviewed by: RJS Date: 95/10/12 (YY MM DD)

Client: Fermco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 98.8

- Checking ③ and ④

$$\frac{d_{15}④}{d_{85}③} = \frac{150-160}{48-60} = 2.5 \text{ to } 3.33 \leq 3 \text{ to } 5 \checkmark \text{ O.K}$$

$$\frac{d_{15}②}{d_{15}③} = \frac{150-160}{20-27} = 5.56 \text{ to } 8 \geq 3 \text{ to } 5 \checkmark \text{ O.K}$$

Biointrusion barrier layer design

As the biointrusion barrier layer is selected to be 3 ft, the maximum particle size will be selected to be 18 inches which is half of the layer thickness. The minimum particle size will be selected to be 4 inches to meet the requirement of specifying a minimum particle size of 1 to 2 inches.

Based on the above selections and other requirements from calculation procedures package, the biointrusion barrier layer will use high quality rock of low percentage of absorbency with d_{max} = 18 inches, $d_{min} \geq$ 1 to 2 inches.

Written by: MAO Date: 95/10/12 (YY MM DD) Reviewed by: RJS Date: 95/10/12 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 8.8

DEPTH OF FROST PENETRATION

The depth of frost penetration into the final cover system is calculated herein based on the procedure and data summarized in the earlier parts of this package. The freezing index required to freeze each layer is calculated. The design freezing index at the ground surface is compared to the sum of calculated freezing indices of the layers from top to bottom to estimate the location of the freezing front and hence maximum depth of frost penetration. This analysis is performed in four steps as detailed below.

Step 1 (calculate the thermal ratio, α):

$$\alpha = \frac{(T_i - T_f)\, t}{FI_{surface}}$$

$$FI_{surface} = n \times FI_{air} = 0.7 \times 500\,^{\circ}F.\,days$$
$$= 350^{\circ}\,F.\,days$$

$T_i = 50\,^{\circ}F\,days$; $T_f = 32\,^{\circ}F\,days$

$t = 60\,days$

Written by: MAO Date: 95/10/12 (YY MM DD) Reviewed by: RJS Date: 95/10/12 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 08.8

$$\alpha = \frac{(50°F - 32°F) \times 60 \text{ days}}{350° F \cdot \text{days}} = 3.09 \checkmark$$

Step 2 (calculate the freezing index, FI, for the layers from top to bottom until ΣFI exceeds $FI_{surface}$).

$$FI_{①} = \frac{d_{①}^2 \, L_{①}}{\lambda_{①}^2 \left(K_{f①} + K_{t①}\right)}$$

$\lambda_{①}$ = function $(\mu_{①}, \alpha)$ as shown in figure 1.

$$\mu_{①} = \frac{C_{f①} + C_{t①}}{2} \; \frac{FI_{surface}}{L_{①} \; t}$$

For layer ①, $C_{f①} = 25.4 \dfrac{Btu}{ft^3 \cdot °F}$

$C_{t①} = 31.5 \dfrac{Btu}{ft^3 \cdot °F}$

$L_{①} = 1{,}774 \dfrac{Btu}{ft^3}$

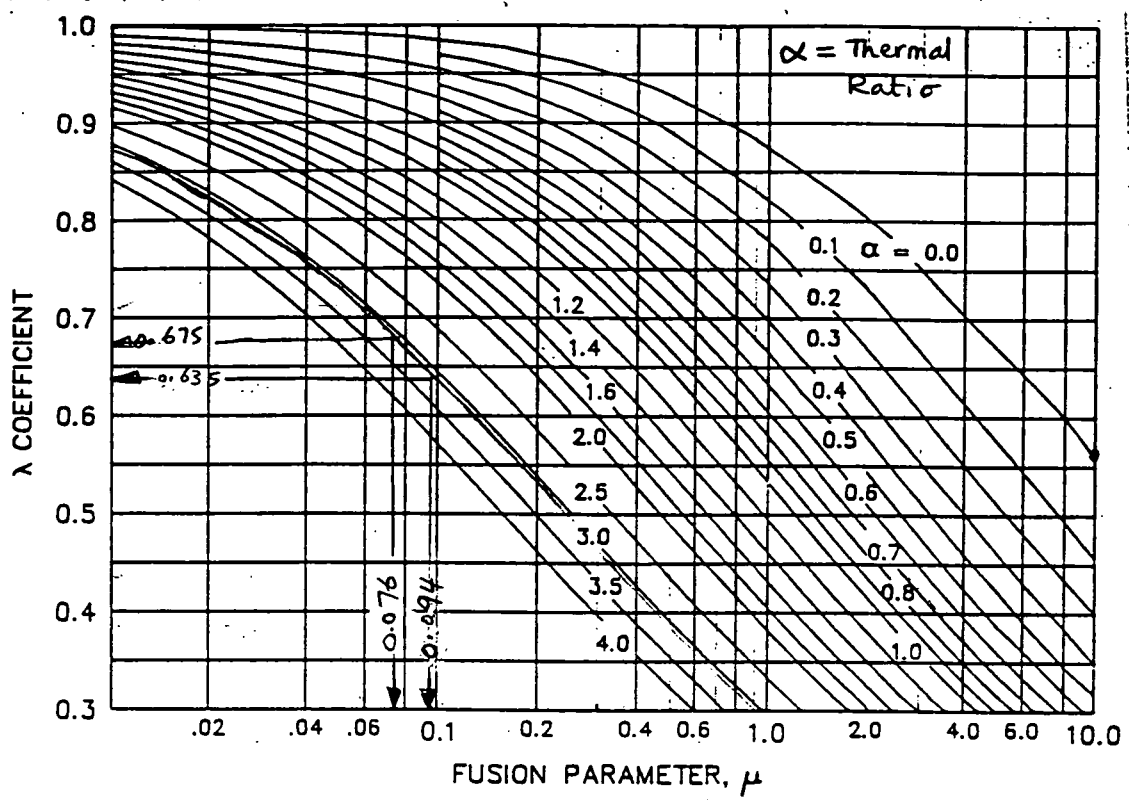
$$\rightarrow \mu_{①} = \frac{25.4 + 31.5}{2} \frac{Btu}{ft^3 \cdot °F} \; \frac{350 \, °F \cdot \text{days}}{\left(1{,}774 \frac{Btu}{ft^3}\right)(60 \text{ days})}$$

$= 0.094 \checkmark$

from Fig. 1 $\rightarrow \lambda_{①} = 0.635 \checkmark$

Written by: MAO Date: 95 / 10 / 12 (YY MM DD) Reviewed by: PJS Date: 95 / 10 / 12 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 08.8



$K_{f①} = 0.87 \frac{Btu}{ft \cdot hr \cdot °F}$, $K_{t①} = 0.82 \frac{Btu}{ft \cdot hr \cdot °F}$

$d_{①} = 0.5\ ft$

$$\rightarrow FI_{①} = \frac{(0.5\ ft)^2 \left(1{,}774 \frac{Btu}{ft^3}\right)}{(0.635)^2 (0.87 + 0.82) \frac{Btu}{ft \cdot hr \cdot °F}} = 651\ °F \cdot hrs = 27\ °F \cdot days$$

Because $FI_{①}$ (= 27 °F·day) < $FI_{surface}$ (= 350 °F·days)

→ layer ① will freeze and the freezing front will continue past layer ①

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Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: Ø B.8

Calculate $FI_{②}$

$$\bar{C}_{②} = \frac{1}{2} \sum_{i=1}^{2} (c_{f_i} + c_{t_i})\, d_i \Big/ \sum_{i=1}^{2} d_i$$

$$= \frac{1}{2} \frac{(25.4 + 31.5)\frac{Btu}{ft^3\,°F}(0.5\,ft) + (27.0 + 35.7)\frac{Btu}{ft^3\,°F}(1.75\,ft)}{0.5\,ft + 1.75\,ft}$$

$$= 30.7 \frac{Btu}{ft^3\,°F} \checkmark$$

$$\bar{L}_{②} = \sum_{i=1}^{2} L_i\, d_i \Big/ \sum_{i=1}^{n} d_i$$

$$= \frac{(1{,}774 \frac{Btu}{ft^3})(0.5\,ft) + (2{,}527 \frac{Btu}{ft^3})(1.75\,ft)}{0.5\,ft + 1.75\,ft}$$

$$= 2{,}360 \frac{Btu}{ft^3} \checkmark$$

$$\mu_{②} = \frac{\bar{C}_{②}}{\bar{L}_{②}} \frac{FI_{surface}}{t}$$

$$= \frac{(30.7\ Btu/ft^3\,°F)}{(2{,}360\ Btu/ft^3)} \frac{350\,°F\cdot days}{60\ days}$$

$$= 0.076 \checkmark$$

$$\lambda_{②} = f(\mu_{②}, \alpha) = 0.675 \checkmark$$

Written by: MAO Date: 95/10/12 (YY MM DD) Reviewed by: PJS Date: 95/10/12 (YY MM DD)

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$$FI_{②} = \frac{d_2 L_2}{\lambda_2^2}\left[\frac{d_2}{K_{f_2}+K_{t_2}} + \frac{d_1}{(K_{f_1}+K_{f_2})/2}\right]$$

$$= \frac{(1.75\ ft)(2527\ \frac{Btu}{ft^3})}{(0.675)^2}\left[\frac{1.75\ ft}{(1.02+0.87)\frac{Btu}{ft.hr.°F}} + \frac{0.5\ ft}{\frac{(0.87+0.82)}{2}\frac{Btu}{ft.hr.°F}}\right]$$

$$= 14{,}730\ °F.hrs = 614\ °F.days$$

$$\because FI_{①} + FI_{②} = 27 + 614 = 641\ °F.days$$

$$> FI_{surface} = 350\ °F.days$$

$\longrightarrow$ Only part of layer ② will freeze

<u>Step 3</u> (calculate thickness of Layer ② which will freeze Y)

This step is calculated by trial and error; a depth $d_{②}$ is assumed and $FI_{②}$ is calculated until $FI_{②} = (FI_{surface} - FI_{①}) = 323$ °F.days then $Y = d_{②}$

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Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

Assume $d_{②} = 1.2\ ft$

$$\rightarrow \overline{C}_{②} = \frac{1}{2}\frac{(25.4+31.5)\frac{Btu}{ft^3\,°F}(0.5\,ft)+(27.0+35.7)\frac{Btu}{ft^3\,°F}(1.2\,ft)}{(0.5+1.2)\,ft}$$

$$= 30.5\ \frac{Btu}{ft^3\,°F}$$

$$\overline{L}_{②} = \frac{\left(1{,}774\ \frac{Btu}{ft^3}\right)(0.5\,ft)+\left(2{,}527\ \frac{Btu}{ft^3}\right)(1.2\,ft)}{0.5\,ft+1.2\,ft}$$

$$= 2{,}306\ \frac{Btu}{ft^3}$$

$$\mu_{②} = \frac{30.5\ \frac{Btu}{ft^3\,°F}}{2306\ \frac{Btu}{ft^3}}\ \frac{350\,°F\cdot day}{60\ day} = 0.077$$

$$\rightarrow \lambda_{②} \simeq 0.67$$

$$FI_{②} = \frac{(1.2\,ft)\left(2{,}306\ \frac{Btu}{ft^3}\right)}{(0.67)^2}\left[\frac{1.2\,ft}{(1.02+0.87)\frac{Btu}{ft\cdot hr\cdot °F}}+\frac{0.5\,ft}{\frac{0.87+0.82}{2}\frac{Btu}{ft\cdot hr\cdot °F}}\right]$$

$$= 7{,}561\ °F\cdot hrs = 315\ °F\cdot days$$

$$\approx (FI_{surface} - FI_{①}) = 323\ °F\cdot days$$

$$\rightarrow Y \simeq 1.2\ ft$$

Step 4 (Calculate X): $X = 0.5\,ft + 1.2\,ft = 1.7\,ft$

Therefore, compacted clay is protected from freezing.

SECTION 12

12. STORMWATER MANAGEMENT

12.1 OSDF Perimeter Swale Sizing
12.2 OSDF Perimeter Berm Flood Protection
12.3 Borrow Area Stormwater Management

12.1 OSDF Perimeter Swale Sizing
12.2 OSDF Perimeter Berm Flood Protection

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: OSDF STORMWATER CALCULATIONS

Computations By: (Cognizant Engineer)
Signature: Eric S. Steinhauser — Date: 15 October 1995
Printed Name and Title: ERIC S. STEINHAUSER, PROJECT ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: [illegible] — Date: 16 Oct 95
Printed Name and Title: ROBERT S. COBLE II, STAFF ENGINEER

Computations Checked by:
Signature: [illegible] — Date: 16 Oct 95
Printed Name and Title: ROBERT S COBLE II, STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Eric S. Steinhauser — Date: 17 Oct 95
Printed Name and Title: ERIC S. STEINHAUSER, PROJECT ENGINEER

Approved by: (PDP)
Signature: [illegible] — Date: 17 Oct 93
Printed Name and Title: Kenneth W Cargill, Associate

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 17 Oct 93
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO	17 Oct 95	NA	NA	NA
0	Preliminary Design Submittal	20 Oct 95	[illegible]	[illegible]	[illegible]
B	Preliminary Design - EPA Submittal	15 Dec 95	[illegible]	—	—

Written by: ESS Date: 95/11/29 Reviewed by: JM Date: 95/11/29

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 8.1

STORMWATER MANAGEMENT: OSDF PERIMETER SWALE SIZING

EXECUTIVE SUMMARY

Purpose

The purpose of this document is to provide the engineering data and calculations used in the design of the OSDF perimeter drainage swale. The perimeter swale is designed to contain and control the OSDF runoff expected from a 2,000-year, 24-hour storm event.

Method of Analysis

The computer program TR-55 was used to determine the peak runoff expected from the storm event and standard open channel flow equations were used to size the perimeter swale. An iterative approach was required to obtain the optimum swale size.

Conclusions

The analyses showed that a parabolic swale with a variable geometry provided the optimum control of the 2,000-year and smaller storm events. The swales, located around the OSDF, will range in size from 40 feet wide by 2.5 feet deep to 56 feet wide by 3.5 feet deep. The channels will be either grass or riprap lined depending on the runoff flow velocities within the channels.

Written by: ESS Date: 95/10/13 (YY/MM/DD) Reviewed by: RLC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08/

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SURFACE-WATER MANAGEMENT

OSDF STORMWATER MANAGEMENT CALCULATIONS

SUMMARY OF CALCULATIONS

PURPOSE: THE PURPOSE OF THIS DOCUMENT IS TO SUMMARIZE THE CALCULATIONS USED TO DESIGN THE PERIMETER SWALE AND PERIMETER ACCESS AND FLOOD PROTECTION BERM FOR THE OSDF.

SCOPE: STORMWATER MANAGEMENT CALCULATIONS WILL BE PERFORMED USING PUBLISHED COMPUTER SOFTWARE AND FLOW EQUATIONS. THE CALCULATIONS PRESENTED HEREIN ARE ORGANIZED IN THE ORDER THEY WILL BE PERFORMED.

CALCULATIONS:

A. OSDF PERIMETER SWALE SIZING - PERFORMED IN MULTIPLE SECTIONS.

1. ASSUME THAT SWALE SECTION ANALYZED IS GRASS-LINED UNTIL CALCULATIONS INDICATE OTHERWISE.
2. OBTAIN MANNING'S COEFFICIENT (n) FROM USDA-SCS [1986] EXHIBIT 7-1. (pg 19 of 27 in Engr Data package)

   a. ASSUME AN n VALUE.

   b. CALCULATE FLOW VELOCITY (V) USING ASSUME n AND SWALE PARAMETERS
      - FLOW AREA (A)
      - WETTED PERIMETER (P_w)
      - SLOPE (s)

      $$V = \frac{1.49}{n}\left(\frac{A}{P_w}\right)^{2/3}(s)^{1/2}$$

   c. CALCULATE a V_r VALUE

      $$V_r = V \times \frac{A}{P_w}$$

   d. FROM EXHIBIT 7-1, OBTAIN n FOR V_r VALUE

   e. REPEAT STEPS (a) THROUGH (d) UNTIL ASSUMED n AND n FROM EXHIBIT 7-1 ARE EQUAL.
3. CHECK FLOW VELOCITIES, IF V > 5 FPS USE RIPRAP

Written by: BSS Date: 95/10/13 (YY MM DD) Reviewed by: AJC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

170:195

4. RUN TR-55 [USDA-SCS, 1986a] FOR SWALE PARAMETERS AND n VALUE FROM STEP (2). TR-55 CALCULATES PEAK FLOW.

5. CHECK THE CAPACITY OF THE SWALE SECTION ANALYZED. VERIFY THAT SWALE GEOMETRY CAN HANDLE PEAK FLOW (Q_p) (i.e., PEAK FLOW < MAXIMUM FLOW IN SWALE Q_{MAX})

$$Q_{MAX} = \frac{1.49}{n}\left(\frac{A}{P_w}\right)^{2/3}(S)^{1/2}(A) > Q_p$$

6. IF $Q_{MAX} > Q_p$, THEN SWALE GEOMETRY IS ACCEPTABLE. IF $Q_{MAX} < Q_p$, THEN INCREASE SWALE DIMENSIONS AND REPEAT STEPS (1) THROUGH (5) UNTILL $Q_{MAX} > Q_p$.

7. REPEAT STEPS (1) THROUGH (6) FOR EACH SWALE SECTION ANALYZED.

8. SIZE RIPRAP IN ACCORDANCE WITH USDA-SCS [1986] EXHIBIT 16-1.

B. OSDF PERIMETER ACCESS AND FLOOD CONTROL BERM.

1. REVIEW DATA FROM PARSONS [1995], TOP ELEVATION OF BERM THAT MUST BE IMPACTED BY A FLOOD MUST BE HIGH THAT FLOOD ELEVATION.

2. FOR PORTIONS OF OSDF THAT WILL RECEIVE RUNON STORMWATER, USE TR-55 TO CALCULATE PEAK FLOW AT A CHOKE POINT IN WATERSHED.

a. ASSUME A DEPTH OF STORMWATER FLOW DEPTH. OBTAIN n AND V AS DESCRIBED IN (A.2) ABOVE

b. RUN TR-55 FOR WATERSHED PARAMETERS, OBTAIN Q_p

c. CALCULATE FLOW AREA UNDER PEAK FLOW CONDITIONS AT CHOKE POINT.

$$A = \frac{Q_p}{V}$$

d. CHECK THAT 'A' REPRESENTS A FLOW DEPTH LESS THAN THAT ASSUMED.

e. REPEAT STEPS (a) THROUGH (d) UNTIL FLOW DEPTH IS LESS THAN THAT ASSUMED.

f. REPEAT STEPS (a) THROUGH (e) FOR EACH WATERSHED; COMBINE PEAK FLOWS FOR ADJACENT WATERSHEDS.

Written by: BSS Date: 95/10/13 (YY MM DD) Reviewed by: RAC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: Task No.:

JCL 170.495

REFERENCES:

PARSONS, "2000-YEAR FLOOD AND PROBABLE MAXIMUM FLOOD, SMELLNDLE FLOODPLAIN DETERMINATION", REVISION A, AUG 1995.

USDA-SCS, "TR-55 MICROCOMPUTER PROGRAM SYSTEM", VERSION 2.0, WASHINGTON, DC, JUN 1986a.

USDA-SCS, "ENGINEERING MANUAL FOR CONSERVATION PRACTICES", WASHINGTON, DC, NOV 1986b.

Written by: ESS Date: 95/10/13 (YY/MM/DD) Reviewed by: AAC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

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SURFACE-WATER MANAGEMENT

OSDF STORMWATER MANAGEMENT CALCULATIONS

VERIFICATION AND COLLECTION OF ENGINEERING DATA

PURPOSE: THE PURPOSE OF THIS DOCUMENT IS TO SUMMARIZE AND VERIFY THE ENGINEERING DATA USED TO DESIGN THE PERIMETER SWALE AND PERIMETER ACCESS AND FLOOD PROTECTION BERM FOR THE OSDF

SCOPE: THE DATA PRESENTED IN DOCUMENT IS ORGANIZED INTO THE FOLLOWING SECTIONS:

1. DATA FOR DRAINAGE AREAS AND SUBAREAS
2. RAINFALL DATA
3. SOIL AND VEGETATIVE COVER
4. MANNING'S COEFFICIENT
5. CHANNEL DATA
6. RIPRAP SIZING

/C Date: 95 / 10 / 16 (YY MM DD)

) Project: GE3900 Task No.: 08.1

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R DRAINAGE

PERIMETER

DRAINAGE
E ARE SHO
S THE DRAIN
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1 ALSO
DIMENSIONS
ONS. FIGURES 2 AND 3
AL OSDF

PROPOSED OS
WILL OCCUPY

ABOVE IN SHADE
OSDF FINAL COVER TOE.

PROPOSED SU
WERE OBTA
G-54, G-

BELOW. THESE
NUMBERS:

SWALE:

STATION	CHANNEL LENGTH
+50	
	1056
+06	
	1056
+62	
	1150
+12	
	827*
2+61**	

CUMMULATIVE COMBINED LENGTH & SLOPE	WEIGHTED SLOPE (FT/FT)
7.92	0.0075
15.84	0.0075
21.59	0.0066
29.86	0.0073

(45+40-40+12)
E STATION

SWALE:

STATION	CHANNEL LENGTH
+00	
	296
+96	
	234
5+30	
	1282
3+12	
	1012
3+24	
	1200
+24	

CUMMULATIVE COMBINED LENGTH & SLOPE	WEIGHTED SLOPE (FT/FT)
2.96	0.01
6.10	0.0115
15.72	0.0087
23.31	0.0083
29.31	0.0073

Written by: ESS Date: 95/10/13 (YY MM DD) Reviewed by: RLC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

170c+95

THE DRAINAGE AREAS ARE SUMMARIZED BELOW:

EAST SWALE:

SUBAREA	AREA CALCULATION	CUMMULATIVE AREA
A-1	½(750-298)(431) + (431)(1806-750) = 12.7 ACRES	12.7
A-2	(431)(2862-1806) = 10.4 ACRES	23.1
A-3	(431)(4012-200-2862) + ½(431)(200) = 10.4 ACRES	33.5
A-4	—	38.6

WEST SWALE:

SUBAREA	AREA CALCULATION	CUMMULATIVE AREA
B-1	½(431)(298+296) = 2.9 ACRES	2.9
B-2	½(530-296)(550) = 1.5 ACRES	4.4
B-3	½(750-530)(377) + (1812-750)(377) = 10.1 ACRES	14.5
B-4	(2874-1812)(377) = 9.2 ACRES	23.7
B-5	—	38.6

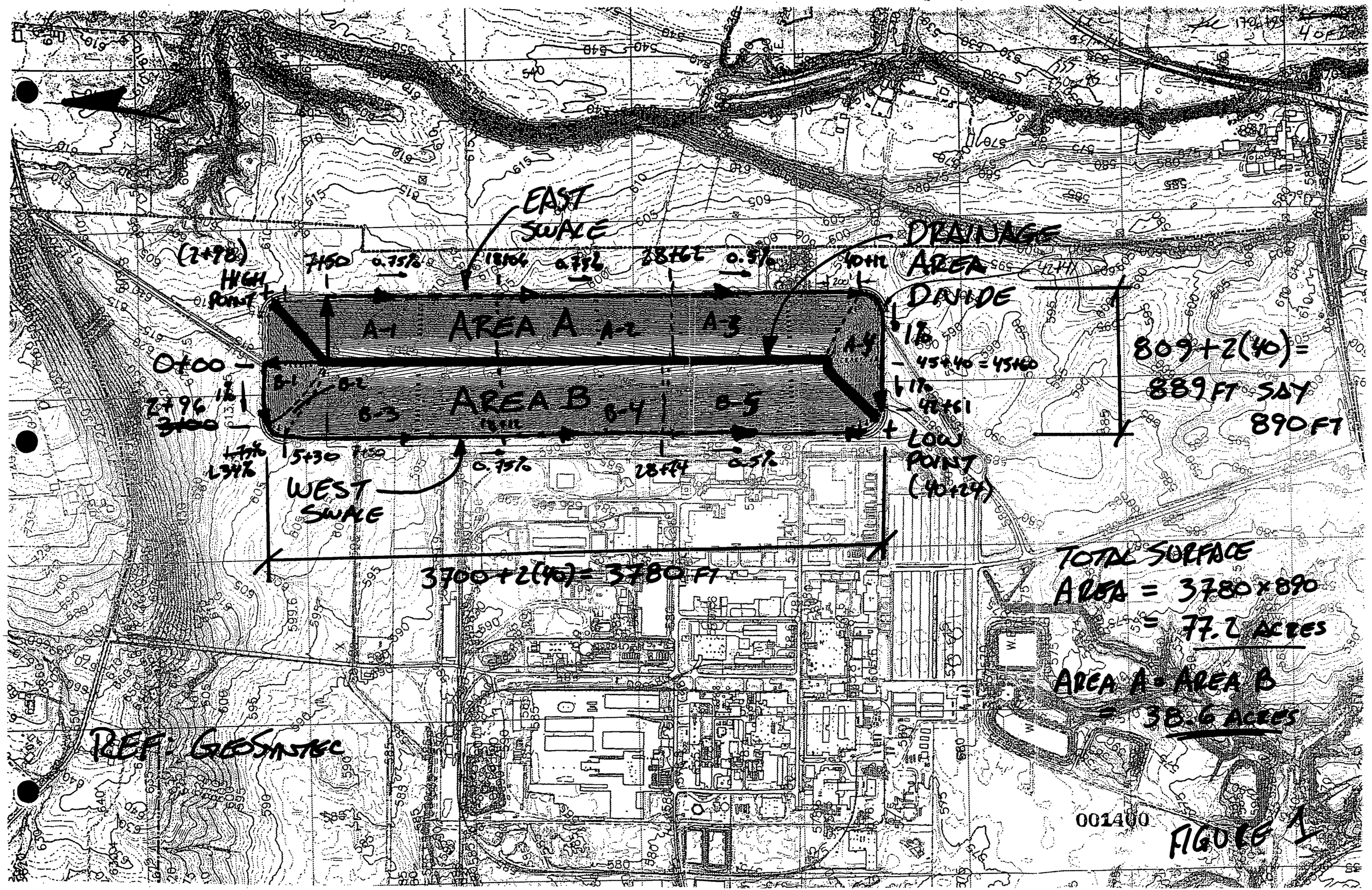
FLOW PARAMETERS PRIOR TO CHANNEL FLOW:

SHEET FLOW = 100 FT @ 0.05 FT/FT // ASSUME DENSE GRASS

SHALLOW CONCENTRATED FLOW (OVER UNPAVED SURFACE)

	FLOW LENGTH	SLOPE	COMBINED SLOPE & LENGTH
	42.96	0.10	4.296
	284.46	0.167	47.505
LENGTH =	327.42		51.801 ⇒ WEIGHTED SLOPE = 0.158 FT/FT

SAY 328 FT


EAST SWALE
DRAINAGE AREA DIVIDE
(7+98) HIGH POINT
7+50
0.75%
18+04
0.75%
28+62
0.5%
40+11
AREA A
A-1
A-2
A-3
A-4
0+00
1%
45+40 = 45+60
809+2(40)=
889 FT SAY
890 FT
AREA B
B-1
B-2
B-3
B-4
B-5
2+96
3+00
1%
41+61
LOW POINT (40+24)
5+30
7+50
0.75%
28+44
0.5%
WEST SWALE
3700+2(40)= 3780 FT
TOTAL SURFACE AREA = 3780 x 890
= 77.2 ACRES
AREA A + AREA B
= 38.6 ACRES
REF: GEOSYNTEC
001400
FIGURE 1

TOTAL P.01

GEOSYNTEC CONSULTANTS 155 13002 95

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Written by: RAM Date: 95/10/12 (YY/MM/DD) Reviewed by: A1c Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

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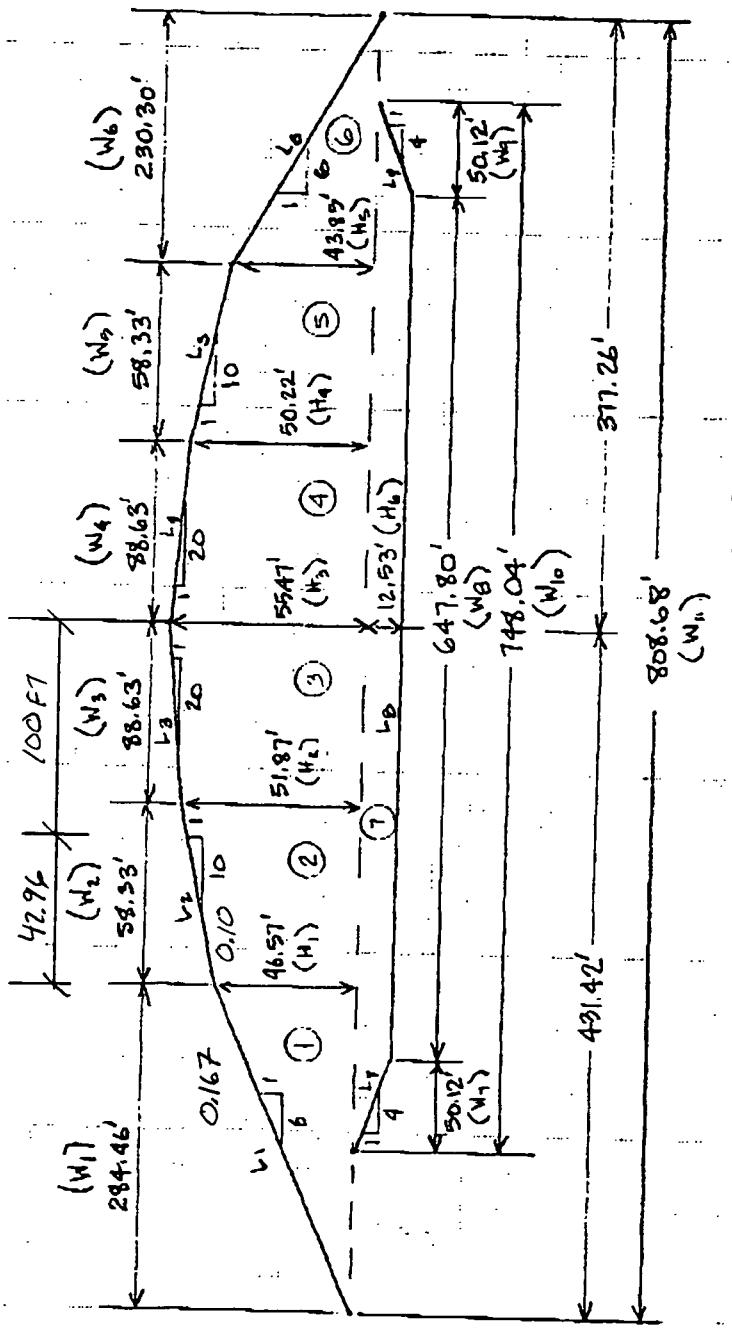
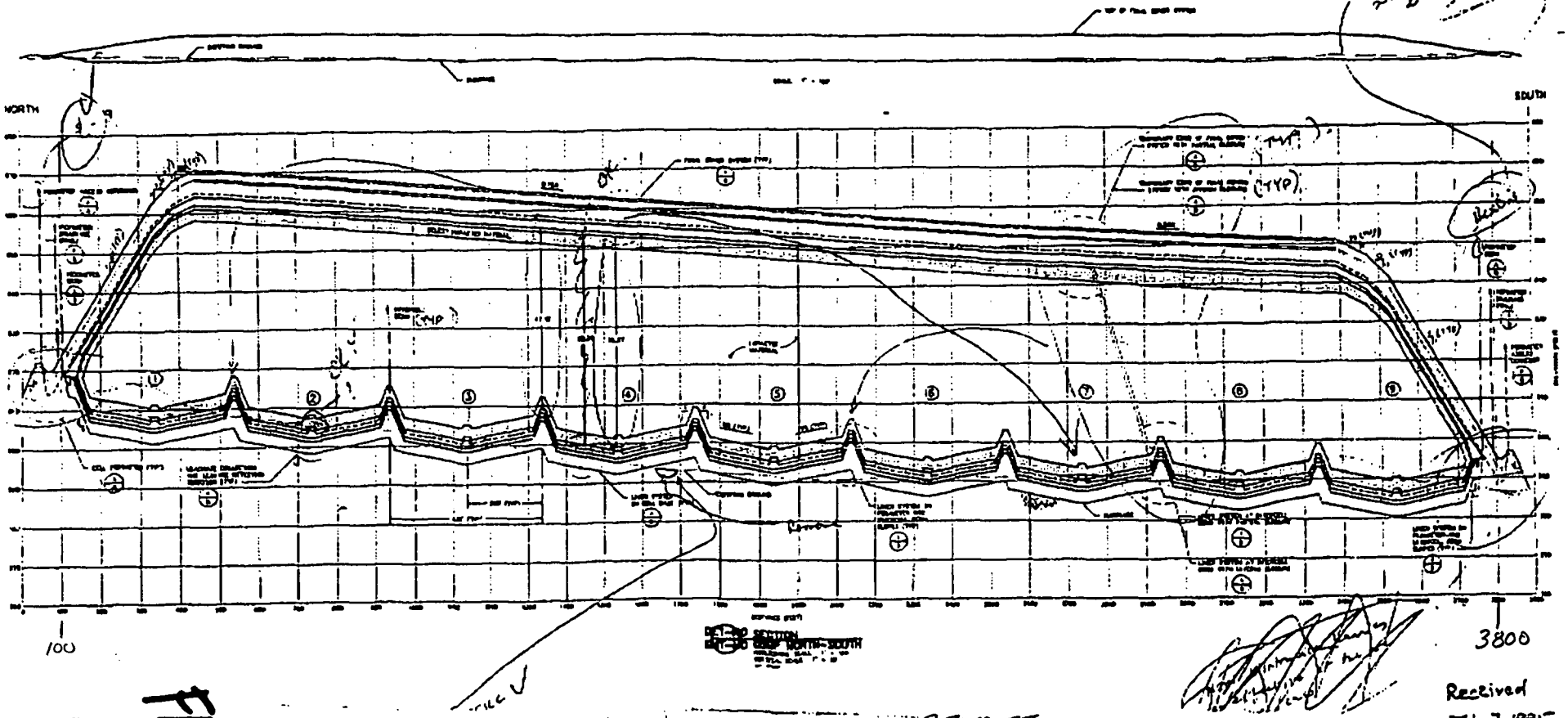


FIGURE 2 : E-W CROSS-SECTION

NTS

OCT-13-1995 14:41 GEOSYNTEC CONSULTANTS 404 705 2000 P.01/01



LENGTH = 3800 - 100 = 3700 FT

FIGURE 3

001402

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FC 17 Oct 95

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Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

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B. OSDF PERIMETER ACCESS AND FLOOD PROTECTION BERM

THE LIMIT OF THE PMP FLOOD PLAIN IS SHOWN ON FIGURE 4. A figure showing the ~~out~~limit of the 2000-yr flood plain is not available. THE DRAINAGE AREAS ASSOCIATED WITH RUNON TO THE PERIMETER BERM IS SHOWN ON FIGURE 5. FIGURE 5 ALSO SHOWS THE DRAINAGE FLOW PATH AND OTHER DIMENSIONS ASSOCIATED WITH DRAINAGE RUNON CALCULATIONS.

THE CHOKE POINTS IDENTIFIED ON FIGURE 5 REPRESENT CONSTRICTED FLOW AREAS THAT WILL BE MODELED AS CHANNELS

THE FLOW PARAMETERS, WHICH WERE SCALED OFF FIGURE 5, ARE SUMMARIZED BELOW.

DRAINAGE AREA	SHEET FLOW LENGTH	SHEET FLOW SLOPE	SHALLOW CONCENTRATED FLOW LENGTH	SHALLOW CONCENTRATED FLOW SLOPE	CHANNEL FLOW LENGTH	CHANNEL FLOW SLOPE
1	100	0.01	400	0.0125	500	0.010
2	100	0.10	1050	0.0171	1700	0.0035
3	100	0.12	1250	0.1024	350	0.0086
4	100	0.02	300	0.010	100	0.01

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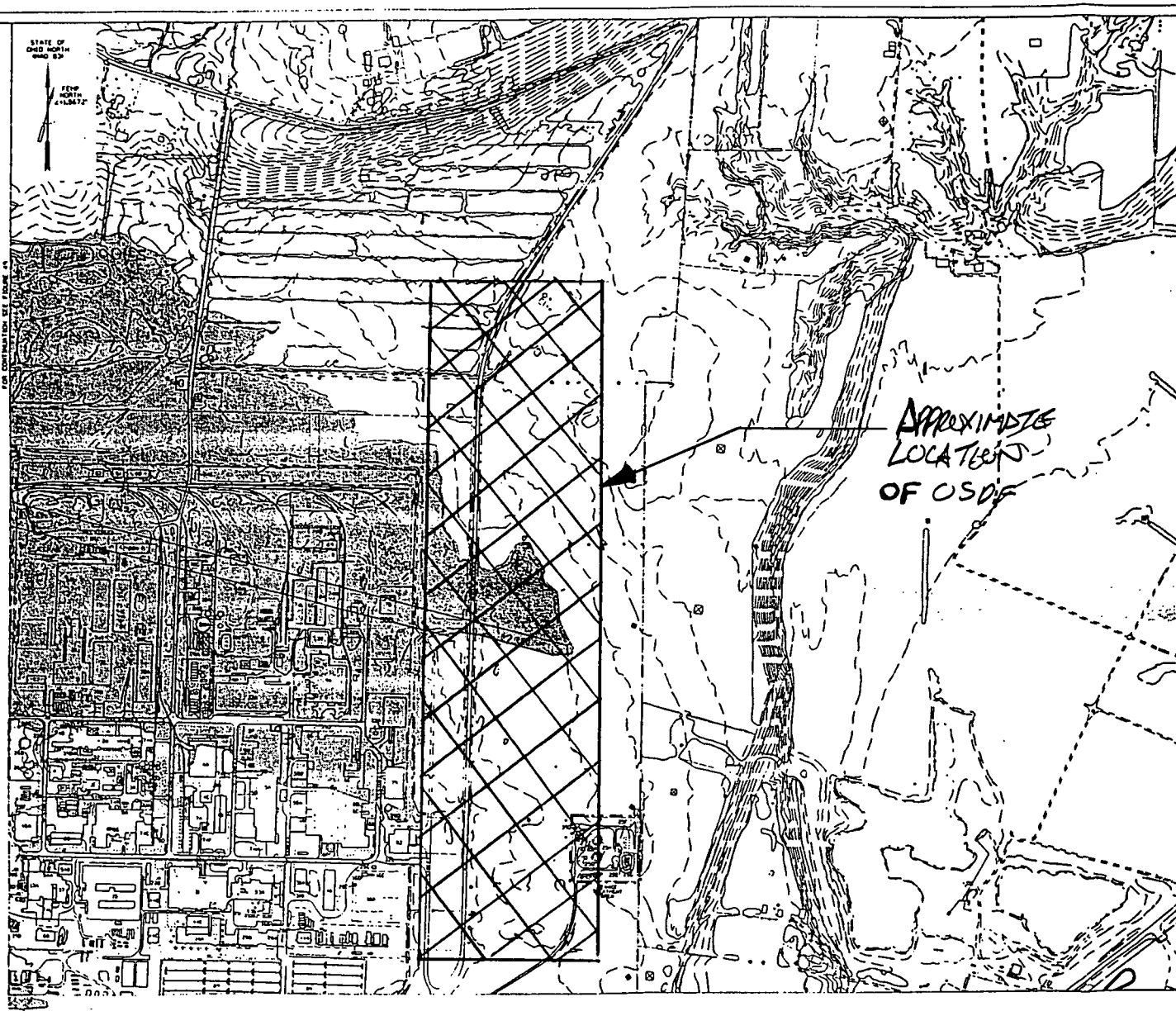

FIGURE 4

NOTES

1. EXISTING CONDITIONS SHOWN ON THIS DRAWING WERE PREPARED FROM FEMP SITE PROVIDED DATA FROM THE DOCUMENTS LISTED BELOW.

   EXISTING SITE DATA SOURCE (IN PLANT FILES)
   PARSONS TOPOGRAPHY, 1993
   WOOLPERT FIELD SURVEY DATED JULY 1993 FOR BRIDGE OPENINGS AT SECTIONS 2.3.1 AND 18

2. SECTIONS 2.1, 2.2, 2.3, AND 4.3 ARE INCORPORATED IN SECTIONS 2/3 AND 4/18 FOR BRIDGE DEFINITION.

LEGEND

- FLOOD LIMIT
- 304 — APPROXIMATE FLOOD ELEVATION (CONTOUR) LOCATION
- TREE LINE
- PADDYS RUN

REF: THIS DRAWING PREPARED BY
PARSONS
THE RALPH M. PARSONS CO. - CHAS. T. MAIN, INC. - ENGINEERING-SCIENCE, INC.
CINCINNATI, OHIO

PADDYS RUN
PMP
FLOOD PLAIN BOUNDARY
(PRODUCTION AREA)

FIGURE 5B

SCALE: AS SHOWN
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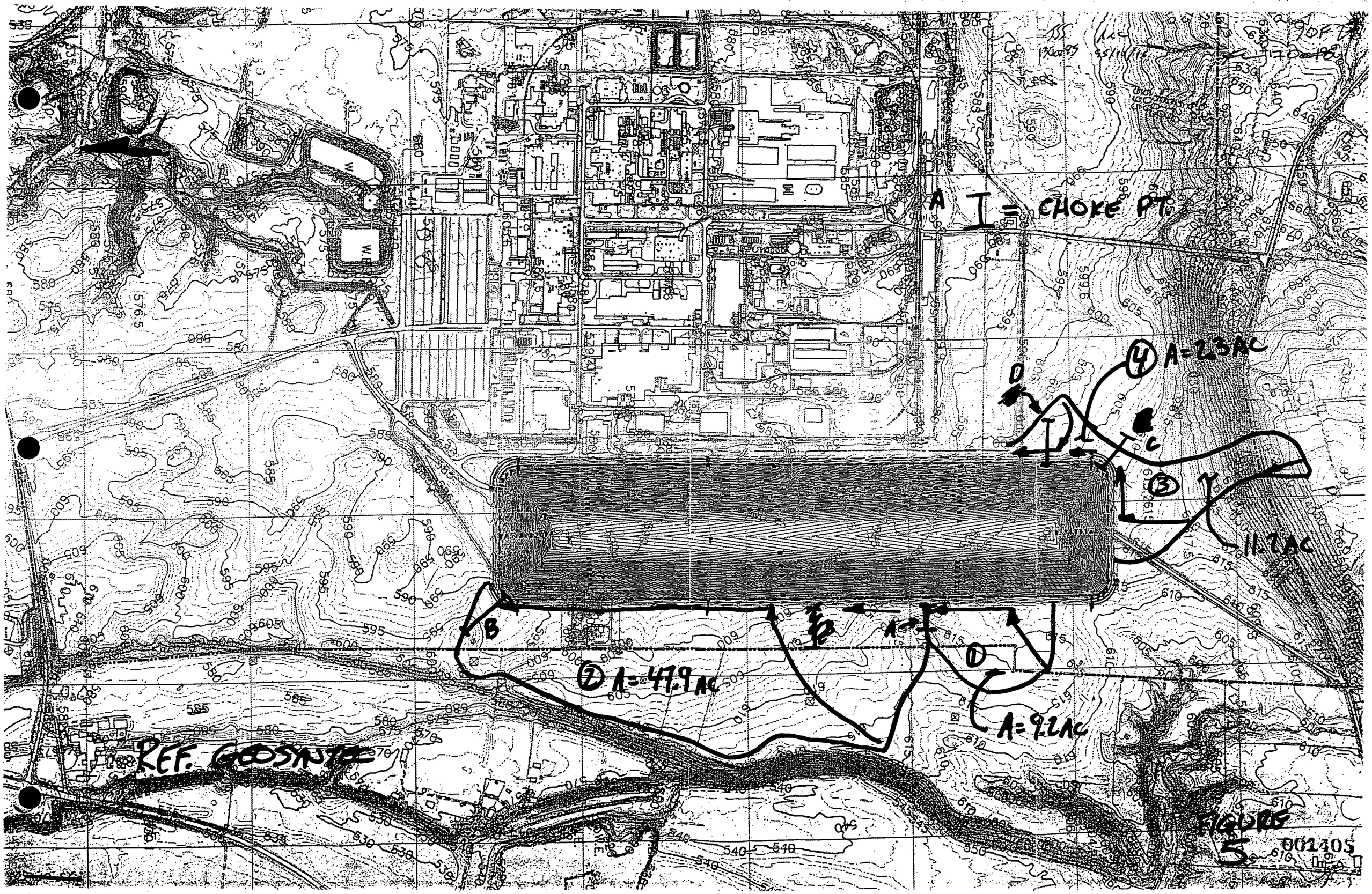

FIGURE 5

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2. RAINFALL DATA

CALCULATIONS FOR THE OSDF PERIMETER SWALE AND OSDF PERIMETER ACCESS AND FLOOD PROTECTION BERM ARE BASED ON THE 2,000-YR, 24-HOUR STORM. ROUTING CALCULATIONS REQUIRE THE RAINFALL DATA FROM A 2-YEAR, 24-HOUR STORM EVENT.

RAINFALL DATA USED FOR THE STORMWATER CALCULATIONS WAS OBTAINED FROM PARSONS [1995], TABLE A-1, AND IS INCLUDED IN THIS DOCUMENT. THE DATA COLLECTED BY PARSON APPEARS TO BE REASONABLE BASED ON AN INDEPENDENT REVIEW OF THE SAME DATA SOURCES.

THE RAINFALL DATA USED IN THE CALCULATIONS IS SUMMARIZED BELOW.

STORM EVENT	RAINFALL (IN.)	
2-YR	2.55	(For time of concentration, T_c, calculation required by TR-55)
2,000-YR	13.0	

RAINFALL IN OHIO IS CLASSIFIED AS A TYPE II DISTRIBUTION.

FLOOD ELEVATIONS WERE OBTAINED FROM PARSONS [1995] TABLE 3-1. THE MAXIMUM FLOOD ELEVATION IS APPROXIMATELY

596 FT MSL (PMP)

583.4 MSL (2000-yr)

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TABLE A-1 - RAINFALL DEPTH FOR A GIVEN DURATION (INCHES)

DURATION (YEARS)	TIME							
	HYDRO-35			TP-40				
	5 MIN	15 MIN	60 MIN	2 HOURS	3 HOURS	6 HOURS	12 HOURS	24 HOURS
2	0.387	0.739	1.223	1.408	1.54	1.848	2.2	2.552
5	0.49	0.979	1.69	2.016	2.112	2.496	2.88	3.072
10	0.564	1.139	1.99	2.277	2.475	3.069	3.465	4.059
25	0.65	1.34	2.38	2.6	3.0	3.4	4.0	4.7
50	0.72	1.49	2.67	3.0	3.25	3.9	4.2	5.2
* 100	0.78	1.64	2.95	3.3	3.6	4.1	5.0	5.6
* 500	0.93	2.1	4.3	5.2	5.9	7.3	8.5	9.4
2000	1.2	2.6	5.8	7.2	8.2	10.2	12.0	13.0
10,000	1.4	3.4	8.2	10.5	12.0	15.5	18.0	19.2
100,000	1.9	5.0	13.3	17.7	20.8	27.4	31.8	33.4
	DESIGN OF SMALL DAMS					HMR-51		

NOTE: Rainfall Points For 2, 5, and 10 year rainfall events were adjusted per TP-40. Values for the 500, 2000, and 10,000 Year Events were interpolated from Figure 3 (Appendix E)

* These values are used on PH Records for HEC-1.

REF: PARSONS, "2,000-YEAR FLOOD AND PROBABLE MAXIMUM FLOOD, SITEWIDE FLOOD PLAIN DETERMINATION", AUG. 1995.

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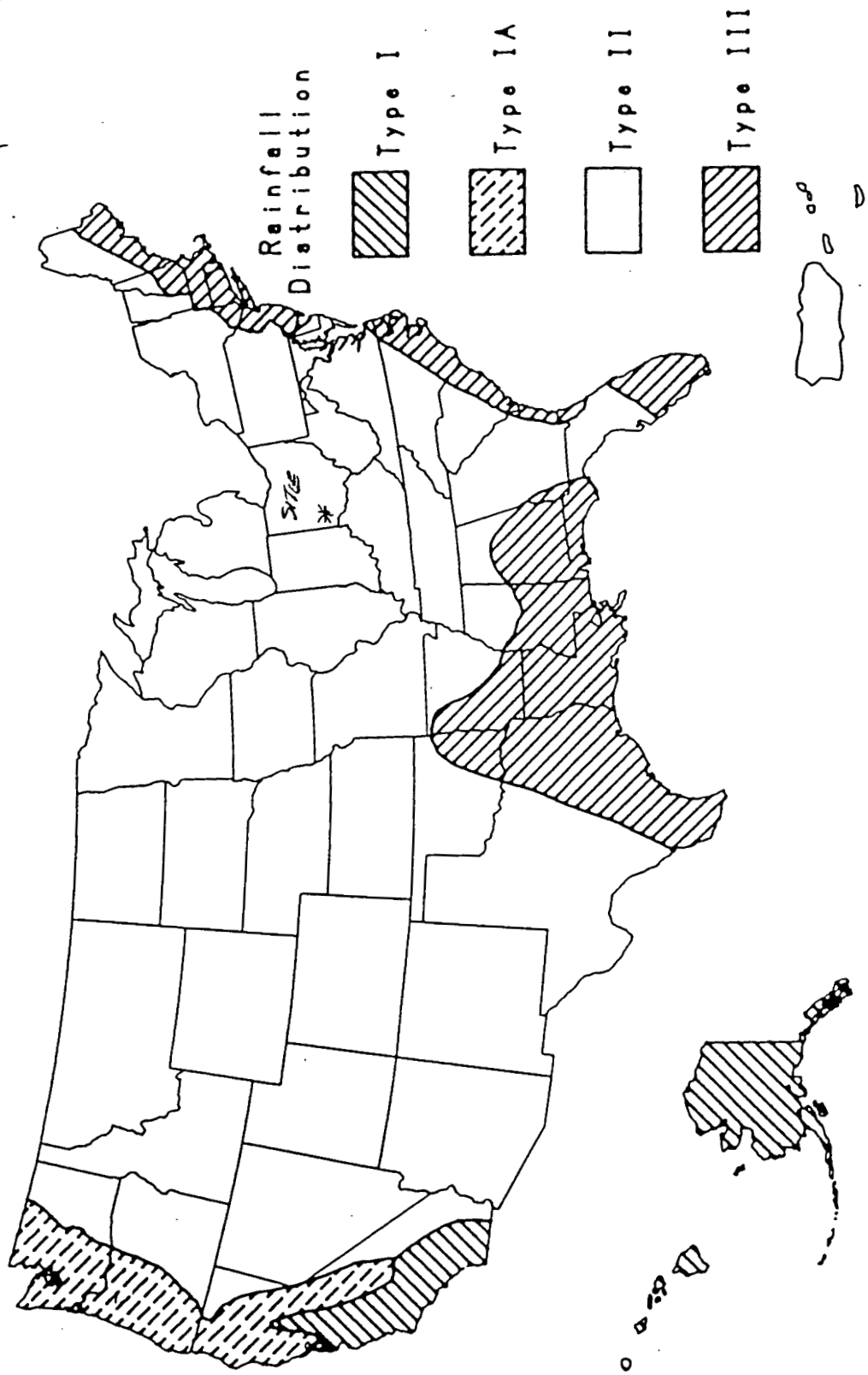

Figure B-2.—Approximate geographic boundaries for SCS rainfall distributions.

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TABLE 3-1 HEC-2 OUTPUT ELEVATION

CROSS-SECTION NUMBER	ELEVATION FOR		CROSS-SECTION NUMBER	ELEVATION FOR	
	2,000 YEAR	PMP		2,000 YEAR	PMP
1	536.0	542.0	26	553.6	569.2
2	536.4	542.6	28	554.3	570.2
2.1	536.3	542.4	29	553.8	569.3
2.2	536.5	543.1	30	553.5	569.1
3	536.7	543.6	31	554.4	570.2
4	536.8	543.6	32	557.2	571.6
5	536.8	543.7	32.1	557.2	572.9
5.1	536.9	543.8	33	556.5	572.0
6	536.9	543.9	34	557.3	571.8
7	537.1	544.1	35	559.6	574.3
8	538.0	545.0	35.1	560.1	574.3
9	538.7	545.8	36	558.6	573.3
9.1	538.7	545.9	37	562.2	576.3
9.2	538.8	546.0	37.1	562.7	575.8
10	538.8	546.0	38	565.4	576.8
11	538.8	545.8	38.1	567.6	577.7
12	541.6	549.2	39	571.4	586.8
13	543.5	552.6	40	571.6	587.9
15	546.3	556.1	42	571.5	587.9
16	546.5	556.5	43	575.6	588.0
17	545.1	554.9	44	581.3	595.5
17.1	546.1	555.3	45	581.6	595.5
18	546.6	556.2	46	581.4	595.5
19	546.9	556.5	46.1	581.5	595.4
20	546.7	556.4	47	581.4	595.5
21	546.7	556.4	48	580.9	595.4
21.1	546.5	556.0	49	582.9	595.7
22	546.8	556.5	50	583.4	595.9
23	547.8	557.1	51	583.2	595.5
24	548.9	559.5			
24.1	547.9	557.5			
25	547.6	558.9			
25.1	553.5	569.1			

Note: See Appendix D and E for HEC-2 Calculation supporting data. All water surface elevations at referenced to North American Vertical Datum 1929 (NAVD 29).

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3. SOIL AND VEGETATING COVER

BECAUSE OF THE AMOUNT OF RAINFALL ASSOCIATED WITH A 2,000-YR, 24-HR STORM EVENT, IT IS CONSERVATIVE TO ASSUME THAT THE SOIL WILL BECOME SATURATED QUICKLY. THIS CONDITION WOULD THEN BE MOST APPROPRIATELY MODELLED AS AN IMPERVIOUS SURFACE. THEREFORE THE MOST CONSERVATIVE RUNOFF CURVE NUMBER SHOULD BE USED.

FROM USDA-SCS [1986a] TABLE 2-2a, THE HIGHEST CURVE NUMBER (CN) IS 98.

USE A CN OF 98 FOR CALCULATIONS ASSOCIATED WITH THE OSDF PERIMETER SWALE AND THE OSDF PERIMETER ACCESS AND FLOOD PROTECTION BERM.

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

USDA-SCS [1986a]

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4. MANNING'S COEFFICIENTS

MANNING'S COEFFICIENTS ARE REQUIRED FOR FLOW CALCULATIONS.

FOR SHEET FLOW THE MANNING'S COEFFICIENT (n) IS OBTAINED FROM USDA-SCS [1986a) TABLE 3-1.

FOR CHANNEL FLOW, THE n FOR GRASS-LINED CHANNELS IS DEPENDENT ON THE RETARDANCE OF THE VEGETATION, THE FLOW VELOCITY, AND THE HYDRAULIC RADIUS. FROM USDA-SCS [1986b] EXHIBIT 7-2, A RETARDANCE CLASSIFICATION OF C WAS SELECTED. USING A RETARDANCE CLASSIFICATION, n MAY BE OBTAINED FROM USDA-SCS [1986b] EXHIBIT 7-1 AFTER THE FLOW VELOCITY AND HYDRAULIC RADIUS IS CALCULATED.

IF THE FLOW VELOCITY INDICATES THAT THE CHANNEL REQUIRES RIPRAP LINING, A n VALUE MAY BE OBTAINED FROM CHOW [1959].

A SUMMARY OF n VALUES TO BE USED FOR FLOW CALCULATIONS IS PRESENTED BELOW.

	n
SHEET FLOW:	
OVER FINAL OSDF SLOPES (DENSE GRASSES)	0.24
OVER UNDISTURBED LAND (SHORT GRASS PRAIRIE)	0.15
CHANNEL FLOW:	
GRASS-LINED	VARIES
RIPRAP-LINED	0.033

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,s^{0.4}} \qquad \text{[Eq. 3-3]}$$

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

where

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1),
L = flow length (ft),
P_2 = 2-year, 24-hour rainfall (in), and
s = slope of hydraulic grade line (land slope, ft/ft).

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

USDA-SCS

Retar-dance	Cover	Condition
A	Reed canarygrass	Excellent stand, tall (average 36 inches)
	Yellow bluestem Ischaemum	Excellent stand, tall (average 36 inches)
B	Smooth bromegrass	Good stand, mowed (average 12 to 15 inches)
	Bermudagrass	Good stand, tall (average 12 inches)
	Native grass mixture (little bluestem, blue grama, and other long and short midwest grasses)	Good stand, unmowed
	Tall fescue	Good stand, unmowed (average 18 inches)
	Lespedeza sericea	Good stand, not woody, tall (average 19 inches)
	Grass-legume mixture--Timothy, smooth bromegrass, or orchard grass	Good stand, uncut (average 20 inches)
	Reed canarygrass	Good stand, mowed (average 12 to 15 inches)
	Tall fescue, with bird's foot trefoil or lodino ..	Good stand, uncut (average 18 inches)
	Blue grama	Good stand, uncut (average 13 inches)
C	Bahia	Good stand, uncut (6 to 8 inches)
	Bermudagrass	Good stand, mowed (average 6 inches)
	Redtop	Good stand, headed (15 to 20 inches)
	Grass-legume mixture--summer (Orchard grass, redtop, Italian ryegrass, and common lespedeza) ...	Good stand, uncut (6 to 8 inches)
	Centipedegrass	Very dense cover (average 6 inches)
	Kentucky bluegrass	Good stand, headed (6 to 12 inches)
D	Bermudagrass	Good stand, cut to 2.5-inch height
	Red fescue	Good stand, headed (12 to 18 inches)
	Buffalograss	Good stand, uncut (3 to 6 inches)
	Grass-legume mixture--fall, spring (Orchard grass, redtop, Italian ryegrass, and common lespedeza).	Good stand, uncut (4 to 5 inches)
	Lespedeza sericea	After cutting to 2-inch height. Very good stand before cutting
E	Bermudagrass	Good stand, cut to 1.5-inch height.
	Bermudagrass	Burned stubble.

Exhibit 7-2. Classification of vegetation cover as to degree of retardance.

USDA-SCS, 1986

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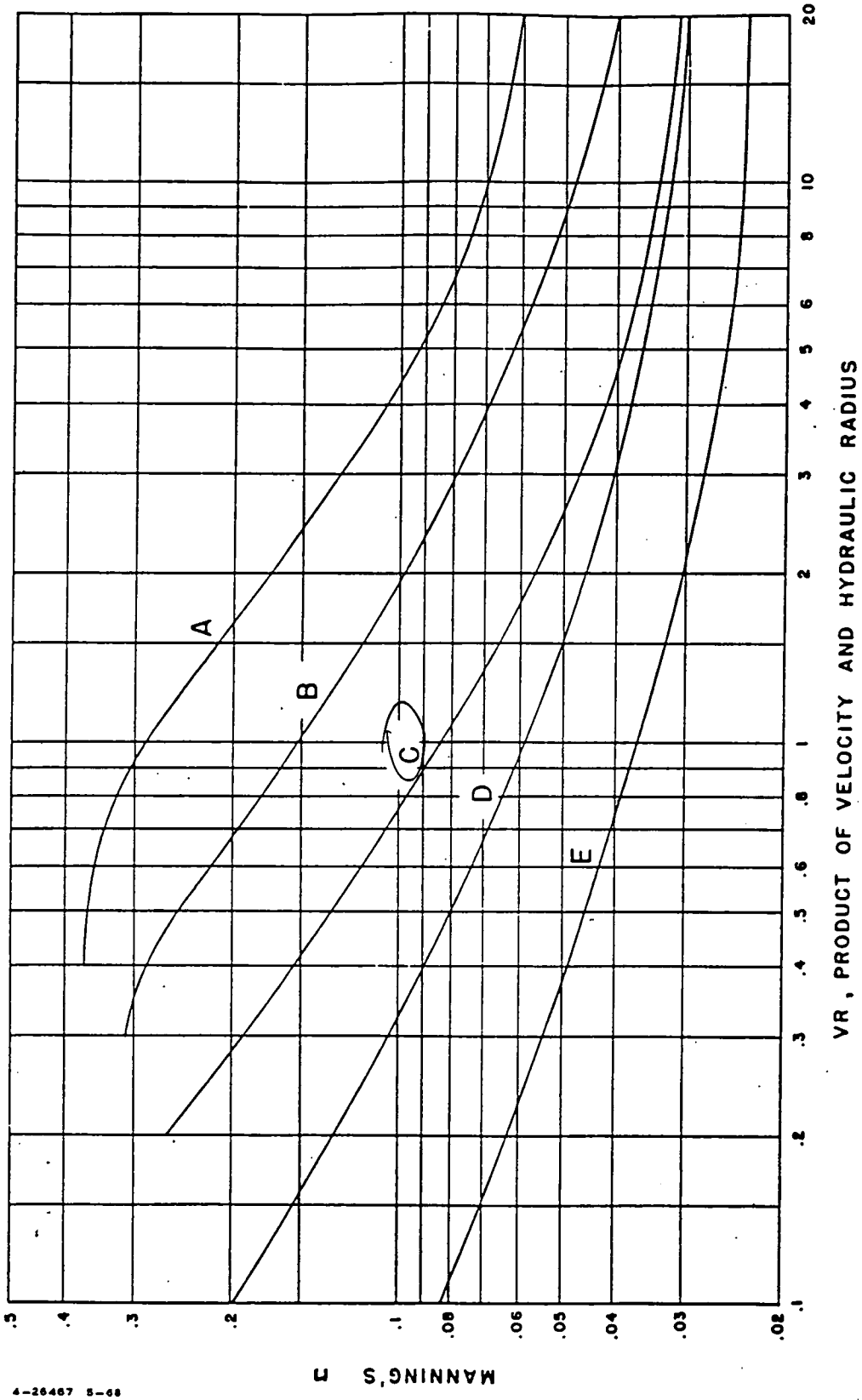

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Exhibit 7-1. Manning's "n" related to velocity, hydraulic radius, and vegetal retardance.

USDA-SCS, 1986

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VALUES OF THE ROUGHNESS COEFFICIENT n
(Boldface figures are values generally recommended in design)

Type of channel and description	Minimum	Normal	Maximum
A. CLOSED CONDUITS FLOWING PARTLY FULL			
A-1. Metal			
a. Brass, smooth	0.009	0.010	0.013
b. Steel			
1. Lockbar and welded	0.010	0.012	0.014
2. Riveted and spiral	0.013	0.016	0.017
c. Cast iron			
1. Coated	0.010	0.013	0.014
2. Uncoated	0.011	0.014	0.016
d. Wrought iron			
1. Black	0.012	0.014	0.015
2. Galvanized	0.013	0.016	0.017
e. Corrugated metal			
1. Subdrain	0.017	0.019	0.021
2. Storm drain	0.021	0.024	0.030
A-2. Nonmetal			
a. Lucite	0.008	0.009	0.010
b. Glass	0.009	0.010	0.013
c. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
d. Concrete			
1. Culvert, straight and free of debris	0.010	0.011	0.013
2. Culvert with bends, connections, and some debris	0.011	0.013	0.014
3. Finished	0.011	0.012	0.014
4. Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
5. Unfinished, steel form	0.012	0.013	0.014
6. Unfinished, smooth wood form	0.012	0.014	0.016
7. Unfinished, rough wood form	0.015	0.017	0.020
e. Wood			
1. Stave	0.010	0.012	0.014
2. Laminated, treated	0.015	0.017	0.020
f. Clay			
1. Common drainage tile	0.011	0.013	0.017
2. Vitrified sewer	0.011	0.014	0.017
3. Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
4. Vitrified subdrain with open joint	0.014	0.016	0.018
g. Brickwork			
1. Glazed	0.011	0.013	0.015
2. Lined with cement mortar	0.012	0.015	0.017
h. Sanitary sewers coated with sewage slimes, with bends and connections	0.012	0.013	0.016
i. Paved invert, sewer, smooth bottom	0.016	0.019	0.020
j. Rubble masonry, cemented	0.018	0.025	0.030

VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
B. LINED OR BUILT-UP CHANNELS			
B-1. Metal			
a. Smooth steel surface			
1. Unpainted	0.011	0.012	0.014
2. Painted	0.012	0.013	0.017
b. Corrugated	0.021	0.025	0.030
B-2. Nonmetal			
a. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
b. Wood			
1. Planed, untreated	0.010	0.012	0.014
2. Planed, creosoted	0.011	0.012	0.015
3. Unplaned	0.011	0.013	0.015
4. Plank with battens	0.012	0.015	0.018
5. Lined with roofing paper	0.010	0.014	0.017
c. Concrete			
1. Trowel finish	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	
8. On irregular excavated rock	0.022	0.027	
d. Concrete bottom float finished with sides of			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. Glazed	0.011	0.013	0.015
2. In cement mortar	0.012	0.015	0.018
g. Masonry			
1. Cemented rubble	0.017	0.025	0.030
2. Dry rubble	0.023	0.032	0.035
h. Dressed ashlar	0.013	0.015	0.017
i. Asphalt			
1. Smooth	0.013	0.013	
2. Rough	0.016	0.016	
j. Vegetal lining	0.030	.....	0.500

OPEN CHANNEL HYDRAULICS by Ven Te Chow, Copyright 1959 by McGraw-Hill

Written by: ESS Date: 95/10/13 Reviewed by: ALC Date: 95/10/16

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 081

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5. CHANNEL DATA

A. OSDF PERIMETER SWALE

A SCHEMATIC OF THE PROPOSED PERIMETER SWALE IS PRESENTED IN FIGURE 6.

FROM THIS FIGURE, THE CHANNEL FLOW PARAMETER ARE:

FREEBOARD: 6 IN.

MAXIMUM AREA FOR FLOW (A): 48 FT^2

WETTED PERIMETER (P_w): 36.2 FT

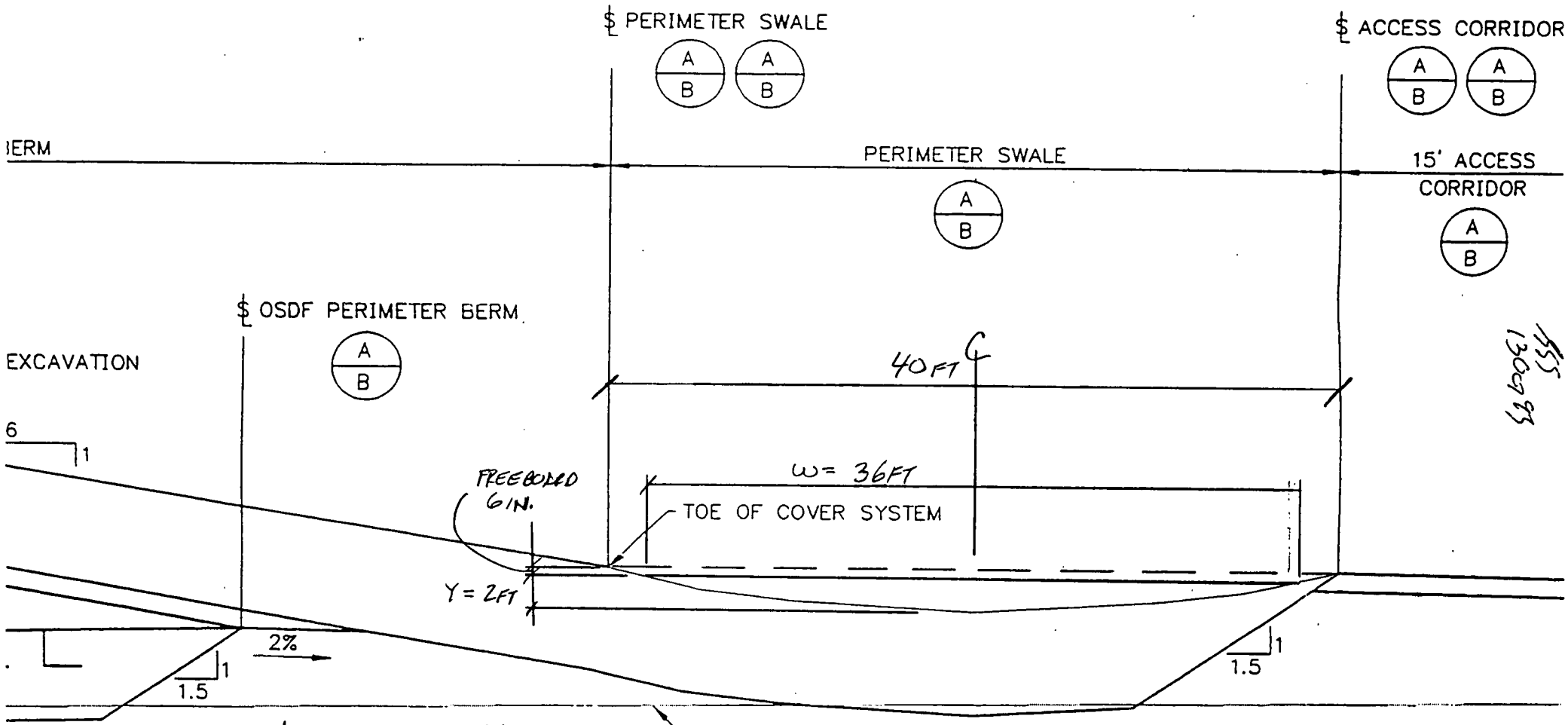
HYDRAULIC RADIUS (r): 1.33 FT

LIMITING VELOCITIES FOR THE CHANNEL As Described in the DCP ARE SUMMARIZED BELOW:

GRASS-LINED CHANNELS - $V < 5$ FT/S

RIPRAP-LINED CHANNELS - 5 FT/S $< V <$ 12 FT/S

NOTE SWALE GEOMETRY MAY CHANGE BASED ON RESULTS OF CALCULATIONS



AREA OF FLOW (A):

$A = \frac{2}{3} Y W$

$A = \frac{2}{3}(2)(36) = \underline{48\ FT^2}$

WETTED PERIMETER (P_W):

$$P_W = \left(4Y^2 + \frac{W^2}{4}\right)^{1/2} + \frac{W^2}{8Y} \ln\left(\frac{2Y + \left(4Y^2 + \frac{W^2}{4}\right)^{1/2}}{\frac{W}{2}}\right)$$

$$P_W = \left(4(2)^2 + \frac{(36)^2}{4}\right)^{1/2} + \frac{(36)^2}{8(2)} \ln\left(\frac{2(2) + \left(4(2)^2 + \frac{(36)^2}{4}\right)^{1/2}}{\frac{36}{2}}\right)$$

$P_W = 18.4 + 17.8 = \underline{36.2\ FT}$

HYDRAULIC RADIUS (r):

$r = \frac{A}{P_W} = \frac{48}{36.2} = \underline{1.33\ FT}$

DET-NO DETAIL

SHT-NO CELL TERMINATION

SCALE: 1" = 8'

XREF: F95XA035

FIGURE 6

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FC 17 Oct 95

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Written by: EGS Date: 95/10/13 (YY MM DD) Reviewed by: AJC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

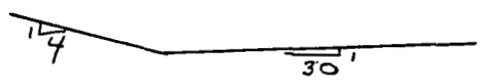
KC 17 Oct 95

B. OSDF PERIMETER ACCESS AND FLOOD PROTECTION BERM

SCHEMATICS OF THE VARIOUS CHANNEL GEOMETRIES FOR THE CHOKE POINTS IDENTIFIED ON FIGURE 5 ARE PRESENTED BELOW. ~~ALONG WITH~~ CALCULATED VALUES FOR FLOW AREA, WETTED PERIMETER, AND HYDRAULIC RADIUS FOR VARIOUS FLOW DEPTHS. AS WELL AS BERM HEIGHT AND SLOPE THROUGH THE CHOKE PT. ARE INDICATED ON TABLE 1

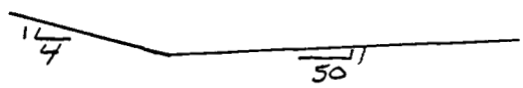
CHOKE PT. A:

CHOKE PT. B:



CHOKE PT. C:

CHOKE PT D:



TSS 30 Oct 95 RLC 95/10/16 24 OCT 22 fax 17 Oct 95

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TABLE 1

OSDF Perimeter Access and Flood Protection Berm

Channel Geometry and Calculation of Flow Area and Wetted Perimeter for various flow depths

Equations:

Flow Area (A): A = Y (W + Y/2 (1/S1 +1/S2))

Wetted Perimeter (Pw): Pw = W + Y ((1 + 1/S1^2)^0.5 + (1 + 1/S2^2)^0.5)

where: Y = maximum flow depth
W = width of channel bottom = 0
S1 = left slope (rise/run)
S2 = right slope (rise/run)

Hydraulic Radius (r): r = A/Pw

Choke Pt.	Flow Depth	S1	S2	A (sf)	Pw (ft)	r (ft)	Height of Berm	Channel Slope
A	1	0.25	0.05	12.00	24.15	0.50	8 ft	0.01
	2	0.25	0.05	48.00	48.30	0.99		
	3	0.25	0.05	108.00	72.44	1.49		
	4	0.25	0.05	192.00	96.59	1.99		
	5	0.25	0.05	300.00	120.74	2.48		
B	1	0.25	0.03	17.00	34.14	0.50	9 ft	0.0035
	2	0.25	0.03	68.00	68.28	1.00		
	3	0.25	0.03	153.00	102.42	1.49		
	4	0.25	0.03	272.00	136.56	1.99		
	5	0.25	0.03	425.00	170.70	2.49		
C	1	0.25	0.02	27.00	54.13	0.50	8 ft	0.0086
	2	0.25	0.02	108.00	108.27	1.00		
	3	0.25	0.02	243.00	162.40	1.50		
	4	0.25	0.02	432.00	216.53	2.00		
	5	0.25	0.02	675.00	270.67	2.49		
D	1	0.25	0.02	27.00	54.13	0.50	10 ft	0.01
	2	0.25	0.02	108.00	108.27	1.00		
	3	0.25	0.02	243.00	162.40	1.50		
	4	0.25	0.02	432.00	216.53	2.00		
	5	0.25	0.02	675.00	270.67	2.49		

Written by: ESS Date: 95/10/13 (YY MM DD) Reviewed by: Ac Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08-1

FC 17 Oct 95

6. RIPRAP SIZING

SHOULD RIPRAP BE REQUIRED IN THE OSDF PERIMETER SWALE, THE THE MAXIMUM RIPRAP STONE SIZE MAY BE OBTAINED FROM USDA-SCS [1986] EXHIBIT 16-1 BASED ON FLOW VELOCITY

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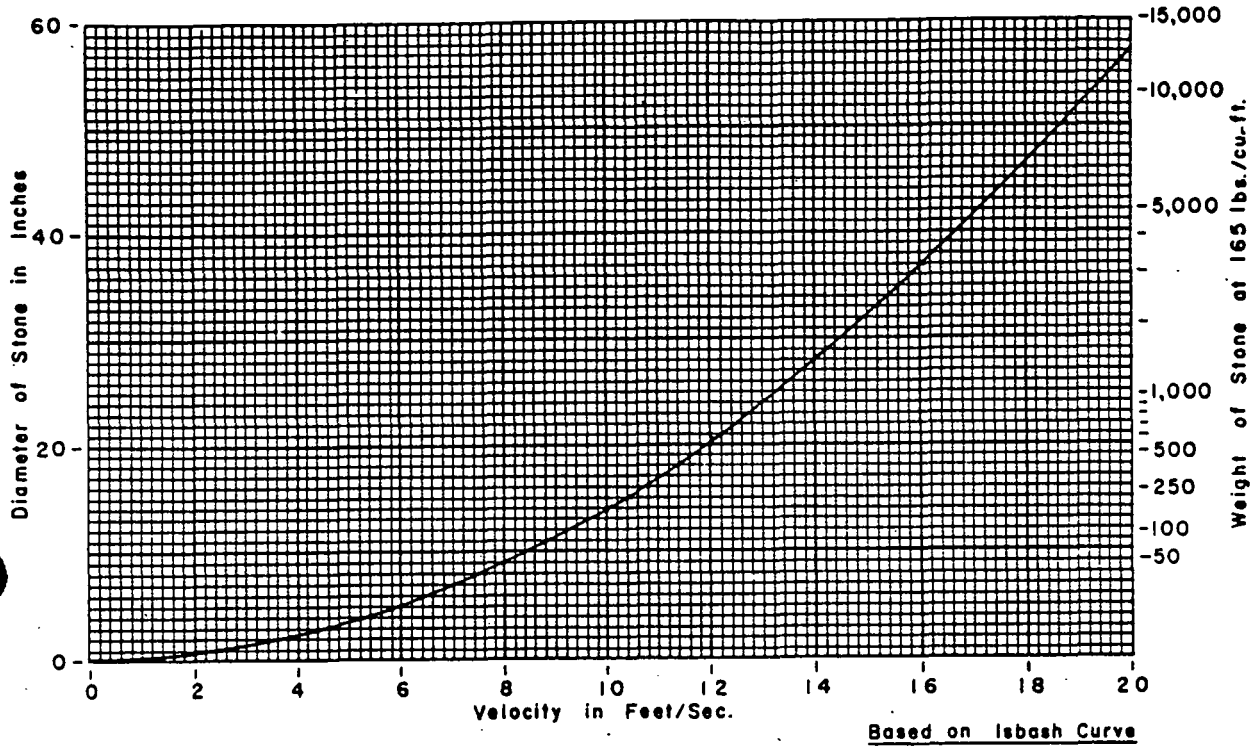


Exhibit 16-1 Maximum stone size for riprap

USDA- SCS [1986b]

001422

Written by: BS Date: 95/10/13 (YY MM DD) Reviewed by: MC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

FC 17 Oct 95

REFERENCES:

USDA-SCS, "URBAN HYDROLOGY FOR SMALL WATERSHEDS", TECHNICAL RELEASE 55 (TR-55), WASHINGTON, DC, JUN 1986a

USDA-SCS, "ENGINEERING FIELD MANUAL FOR CONSERVATION PRACTICES", WASHINGTON, DC, NOV 1986b.

PARSONS, "2,000-YEAR FLOOD AND PROBABLE MAXIMUM FLOOD, SITEWIDE FLOOD PLAIN DETERMINATION", REVISION A, AUG 1995

CHOW, "OPEN CHANNEL HYDRAULICS", 1959

GeoSyntec Consultants, "Design Criteria Package," in preparation

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: AAC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

SURFACE-WATER MANAGEMENT

OSDF STORMWATER MANAGEMENT CALCULATIONS

OSDF PERIMETER SWALE SIZING

PURPOSE: THIS CALCULATION PACKAGE INCLUDES THE CALCULATIONS TO SIZE THE OSDF PERIMETER SWALE.

SCOPE: THE OSDF PERIMETER SWALE IS DESIGNED TO CONTROL THE RUNOFF FROM THE OSDF EXPECTED FROM A 2,000-YR, 24-HR STORM EVENT. THE RUNOFF FROM THE OSDF WILL BE CONTROLLED AS SHOWN IN FIGURE 1.

THE ANALYSES PERFORMED USED TR-55 [USDA-SCS, 1986a] AN STANDARD OPEN CHANNEL FLOW EQUATIONS.

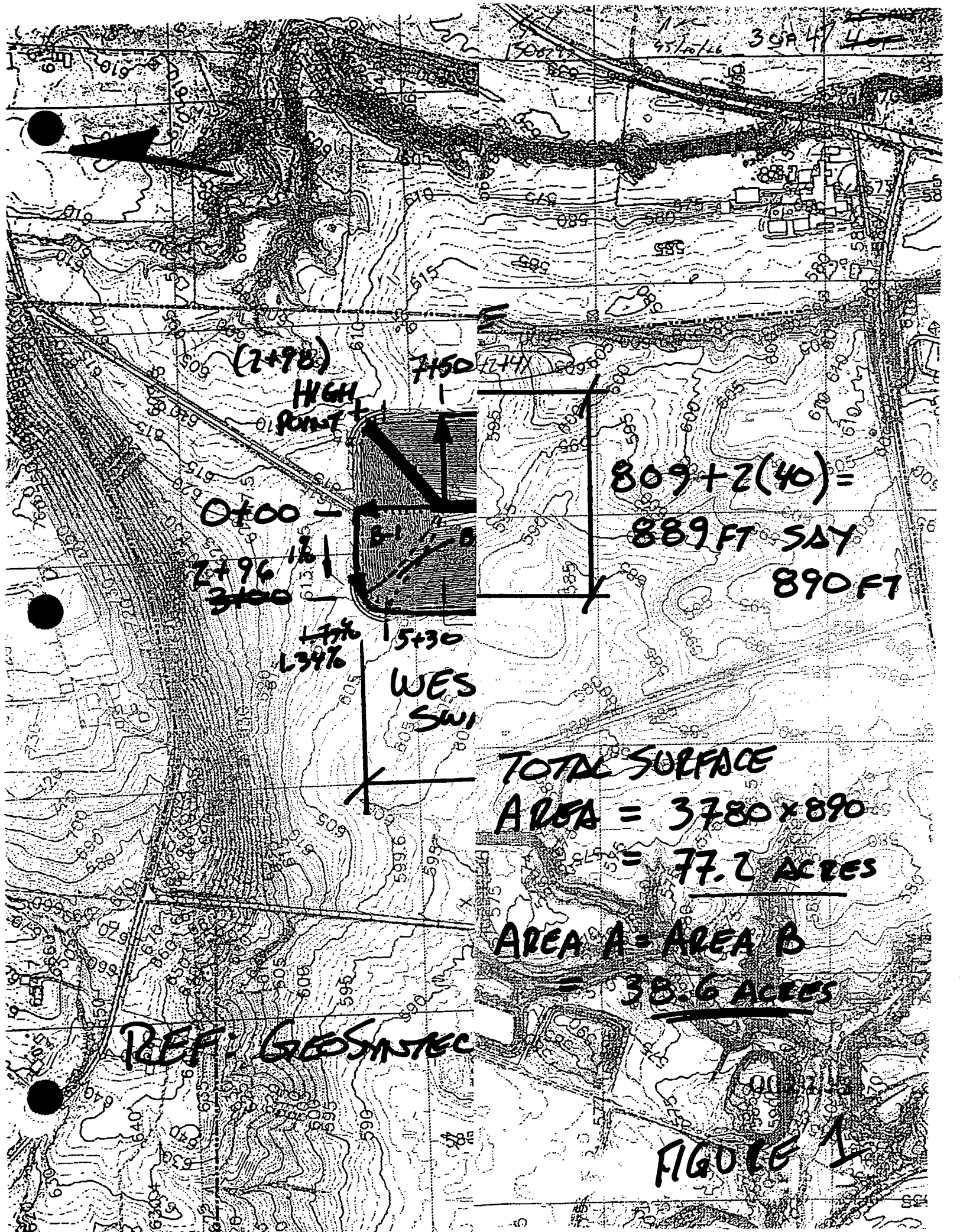
AN ITERATIVE APPROACH WAS USED TO OBTAIN THE SWALE SIZE.

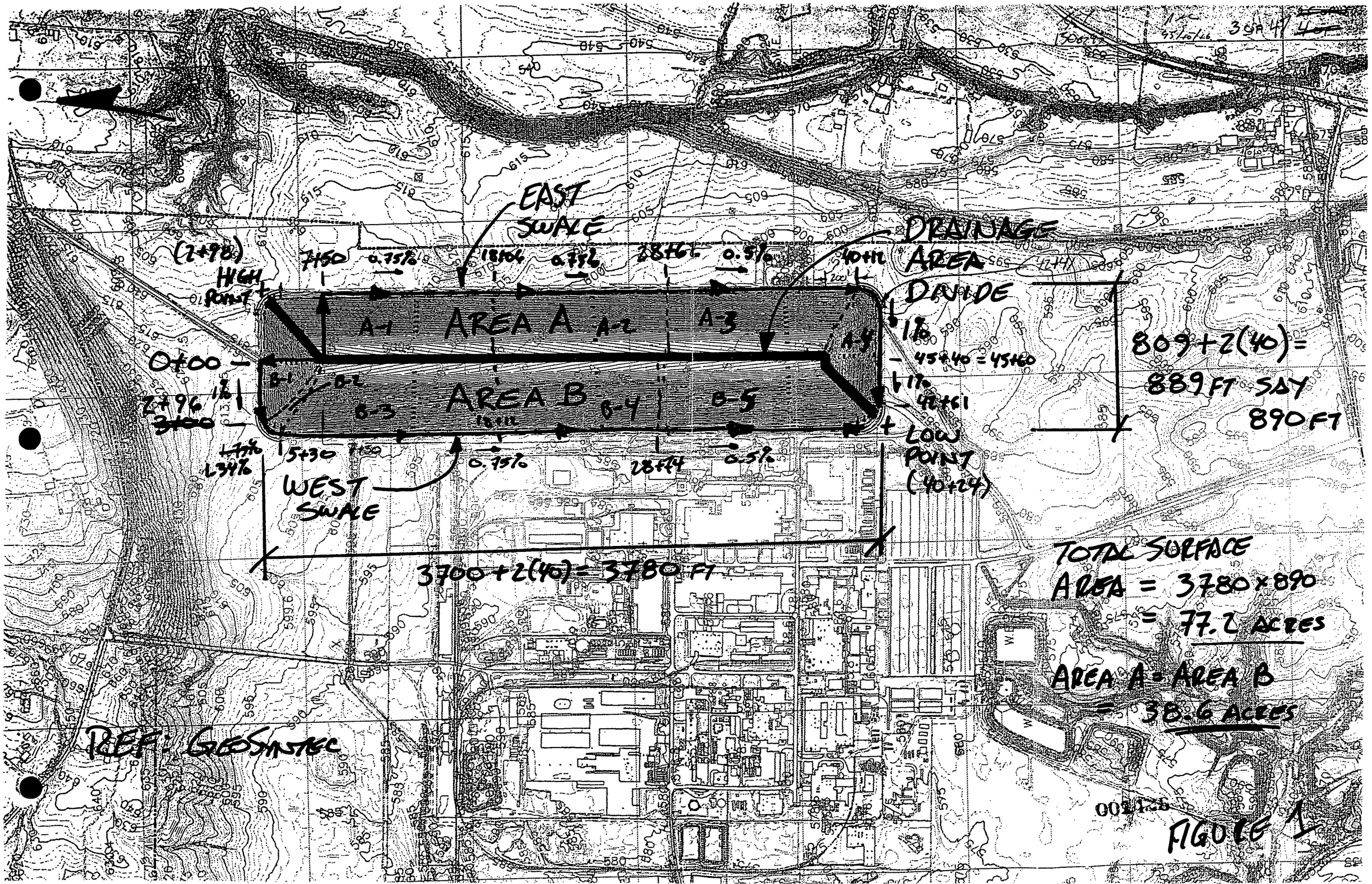
SUMMARY OF INPUT DATA:

EAST SWALE:

PARAMETERS	SUBAREA A-1	A-2	A-3	A-4	
AREA (ACRES/SQ.MILES)	12.7/0.0198	23.1/0.0361	33.5/0.0523	38.6/0.0603	✓
SHEET FLOW:					
LENGTH (FT)	100	100	100	100	
SLOPE (FT/FT)	0.05	0.05	0.05	0.05	
SURFACE	DENSE GRASS	DENSE GRASS	DENSE GRASS	DENSE GRASS	
SHALLOW CONCENTRATED FLOW:					
LENGTH (FT)	328	328	328	328	✓
SLOPE (FT/FT)	0.158	0.158	0.158	0.158	✓
SURFACE	UNPAVED	UNPAVED	UNPAVED	UNPAVED	
CHANNEL FLOW:					
LENGTH (FT)	1056	2112	3262	4089	✓
WEIGHTED SLOPE (FT/FT)	0.0075	0.0075	0.0066	0.0073	
MANNING'S COEFFICIENT	VARIES	VARIES	VARIES	VARIES	
FLOW AREA (FT^2)	48	48	48	48	✓
WETTED PERIMETER (FT)	36.2	36.2	36.2	36.2	✓
ACTUAL SLOPE (FT/FT)	0.0075	0.0075	0.005	0.01	

001424


(2+98)
HIGH POINT
7+50
0+00
2+96
3100
1.7%
L34%
5+30
WES
SW1
809+2(40)=
889 FT SAY
890 FT
TOTAL SURFACE
AREA = 3780 x 890
= 77.2 ACRES
AREA A - AREA B
= 38.6 ACRES
REF: GEOSYNTEC
FIGURE 1


EAST SWALE
DRAINAGE AREA DIVIDE
(2+98) HIGH POINT
7+50
0.75%
18+04
0.75%
28+66
0.5%
40+12
AREA A
A-1
A-2
A-3
A-4
AREA B
B-1
B-2
B-3
B-4
B-5
0+00
2+96
3+00
1%
45+40 = 45+60
1%
42+61
LOW POINT (40+24)
809+2(40)= 889 FT SAY 890 FT
5+30
L34%
0.75%
18+12
28+44
0.5%
WEST SWALE
3700+2(40)= 3780 FT
TOTAL SURFACE AREA = 3780×890 = 77.2 ACRES
AREA A = AREA B = 38.6 ACRES
REF: GEOSYNTEC
FIGURE 1

Written by: ESS Date: 95/10/15 (YY/MM/DD) Reviewed by: AJC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

ANALYSES:

EAST SWALE:

SUBAREA A-1

1. OBTAIN n FROM USDA-SCS [1986] EXHIBIT 7-1 FOR GRASS-LINED SWALE

a. CALCULATE VELOCITY FOR CHANNEL SECTION, ASSUME $n = 0.033$:

$$V = \frac{1.49}{0.033}\left(\frac{48}{36.2}\right)^{2/3}(0.0075)^{1/2} = 4.72 \text{ FPS}$$ ✓

b. CALCULATE V_r:

$$V_r = 4.72\left(\frac{48}{36.2}\right) = 6.25$$ ✓

FROM EXHIBIT 7-1, $n = 0.036$

c. RECALCULATE V:

$$V = 4.72\left(\frac{0.033}{0.036}\right) = 4.33 \text{ fps}$$ ✓

d. RECALCULATE V_r:

$$V_r = 4.33\left(\frac{48}{36.2}\right) = 5.74$$

FROM EXHIBIT 7-1, $n = 0.036$ ✓ ✓

2. RUN TR-55 USING INPUT DATA AND $n = 0.036$.

3. FROM TR-55, PEAK FLOW = 171 CFS (FILE: FERMCO\ESA1-1.55)

4. CHECK SWALE CAPACITY:

$$Q_{MAX} = \frac{1.49}{0.036}\left(\frac{48}{36.2}\right)^{2/3}(0.0075)^{1/2}(4e) = 208 \text{ CFS} > 171 \text{ CFS}$$ OK ✓

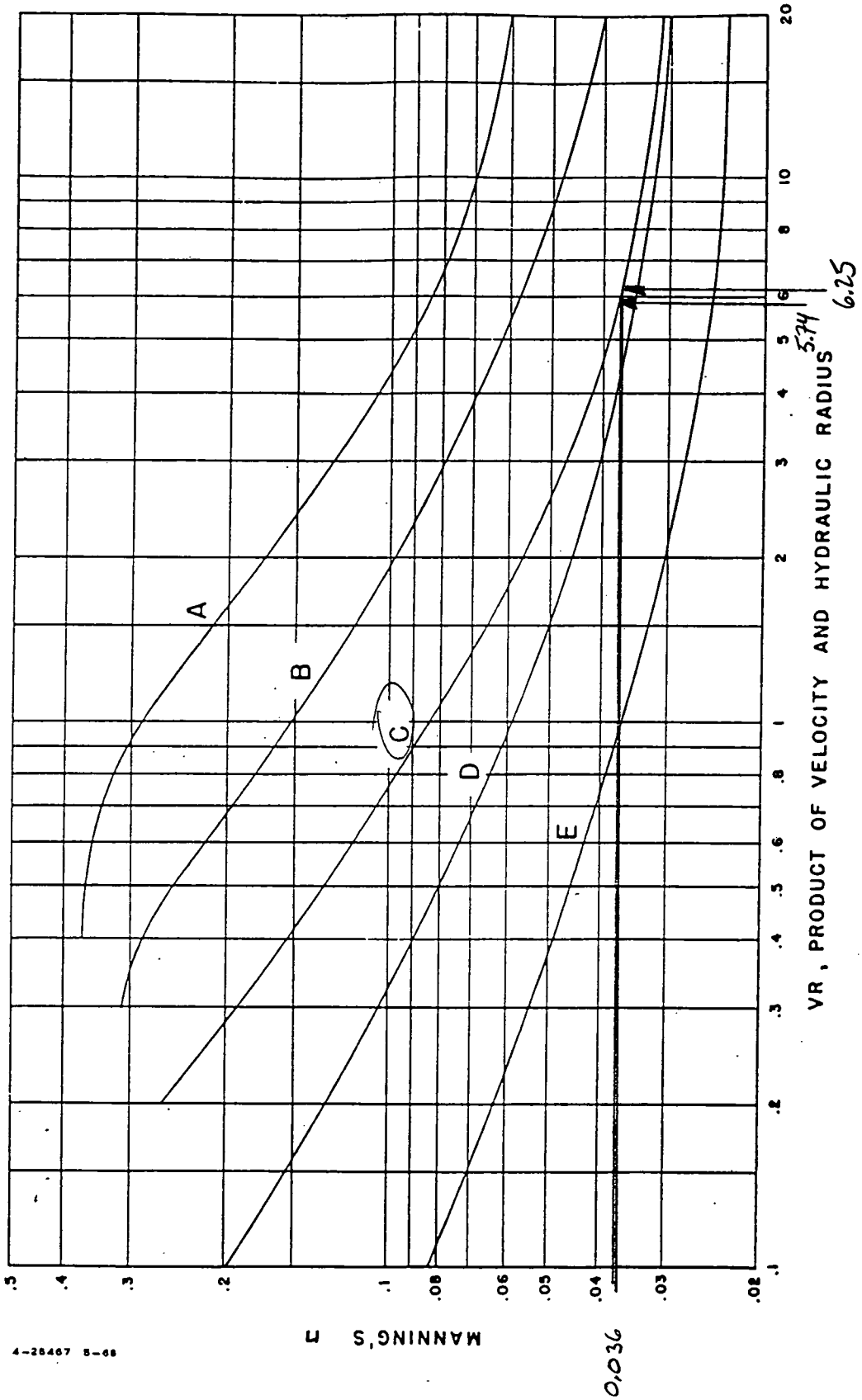


Exhibit 7-1. Manning's "n" related to velocity, hydraulic radius, and vegetal retardance.

USDA-SCS, 1936

EAST SWALE – A=1

4-28467 8-68

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: AMC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - EAST SWALE

Subarea #1 - A-1

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		1056	.0075			.03648	36.2		0.068
						Time of Concentration =			0.27*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\ESA1-1.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: AJC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - EAST SWALE

Total watershed area: 0.020 sq mi Rainfall type: II Frequency: 2000years

	Subareas
	A-1
Area(sq mi)	0.02
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.27*
(Used)	0.30
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) A-1
11.0	5	5
11.3	7	7
11.6	10	10
11.9	30	30
12.0	59	59
12.1	113	113
12.2	171P	171P ← PEAK FLOW
12.3	171	171
12.4	116	116
12.5	71	71
12.6	50	50
12.7	37	37
12.8	29	29
13.0	20	20
13.2	17	17
13.4	14	14
13.6	13	13
13.8	12	12
14.0	11	11
14.3	9	9
14.6	8	8
15.0	8	8
15.5	7	7
16.0	6	6
16.5	6	6
17.0	5	5
17.5	5	5
18.0	5	5
[illegible].0	4	4
[illegible]	3	3
[illegible].0	3	3
26.0	0	0

FILE: FERMCO\ESA1-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

2 of 2

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: AMC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 081

SUBAREA A-2

1. FROM SUBAREA A-1, USE $n = 0.036$ (GRASS-LINED SWALE)

2. RUN TR-55 USING INPUT DATA AND $n = 0.036$.

3. FROM TR-55, PEAK FLOW = 311 CFS (FILE: FERMCO\ESA2-1.55)

4. CHECK SWALE CAPACITY:

$$Q_{MAX} = 4.33 \times 48 = \underline{208 \text{ CFS}} < 311 \text{ CFS} \quad \text{NG}$$

5. TRY A LARGER SWALE ASSUMING $V = 4.33$ FPS

$$A = \frac{311}{4.33} = \underline{71.8} \text{ FT}^2$$

IF $Y = 2$ FT – $W = \frac{71.8}{2}\left(\frac{3}{2}\right) = 53.9$ FT (TOO WIDE)

IF $Y = \underline{2.5}$ FT – $W = \frac{71.8}{2.5}\left(\frac{3}{2}\right) = 43$ FT SAY $\underline{44 \text{ FT}}$

$$P_w = \left(4(2.5)^2 + \left(\frac{44}{4}\right)^2\right)^{1/2} + \frac{(44)^2}{8(2.5)} \ln\left(\frac{2(2.5) + \left(4(2.5)^2 + \frac{(44)^2}{4}\right)^{1/2}}{\frac{44}{2}}\right)$$

$$P_w = 22.6 + 21.8 = \underline{44.4 \text{ FT}}$$

$$A = \frac{2}{3}(2.5)(44) = \underline{73.3 \text{ FT}^2}$$

6. OBTAIN n FROM USDA-SCS [1986b] EXHIBIT 7-1

a. CALCULATE V, ASSUME $n = 0.033$

$$V = \frac{1.49}{0.033}\left(\frac{73.3}{44.4}\right)^{2/3}(0.0075)^{1/2} = 5.46 \text{ FPS} > 5 \text{ FPS}$$

$\Rightarrow$ RIPRAP

$$V_r = 5.46\left(\frac{73.3}{44.4}\right) = 9.01$$

FROM EXHIBIT 7-1, $n = 0.033$ $\therefore$ LINE SWALE W/RIPRAP $n = 0.033$

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: RAC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

7. RUN TR-55 USING INPUT DATA EXPECT FOR THE FOLLOWING CHANNEL FLOW PARAMETERS:

$n = 0.033$

$A = 73.3\ FT^2$

$P_w = 44.4\ FT$

8. FROM TR-55, PEAK FLOW = 311 CFS (FILE: FERMCO\ESA2-2.55) ✓

9. CHECK SWALE CAPACITY:

$$Q_{max} = \frac{1.49}{0.033}\left(\frac{73.3}{44.4}\right)^{2/3}(0.0075)^{1/2}(73.3) = 400\ CFS > 311\ CFS$$ OK ✓

$V_{MAX} = 5.46\ FPS$

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: AAC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - EAST SWALE

Subarea #1 - A-2

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		2112	.0075			.03648	36.2		0.136
						Time of Concentration =			0.33*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\ESA2-1.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: AJC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - EAST SWALE

Total watershed area: 0.036 sq mi Rainfall type: II Frequency: 2000years

	Subareas
	A-2
Area(sq mi)	0.04
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.33*
(Used)	0.30
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) A-2
11.0	9	9
11.3	13	13
11.6	19	19
11.9	54	54
12.0	108	108
12.1	206	206
12.2	311P	311P ← PEAK FLOW
12.3	311	311
12.4	211	211
12.5	130	130
12.6	90	90
12.7	67	67
12.8	53	53
13.0	37	37
13.2	30	30
13.4	26	26
13.6	23	23
13.8	21	21
14.0	19	19
14.3	17	17
14.6	15	15
15.0	14	14
15.5	13	13
16.0	11	11
16.5	10	10
17.0	9	9
17.5	9	9
18.0	8	8
18.5	7	7
19.0	6	6
19.5	6	6
26.0	0	0

FILE: FERMCO\ESD2-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: AAC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - EAST SWALE

Subarea #1 - A-2

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		2112	.0075		.0337	3.3	44.4		0.107
								Time of Concentration =	0.31*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

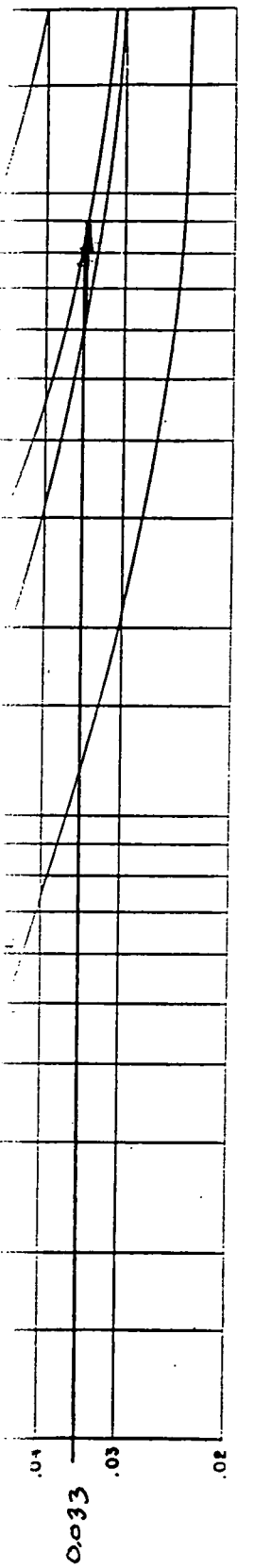
P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\ESA2-2.55

455
750293

18647



001436

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: ALC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3800 Task No.: 08.1

SUBAREA A-3

1. FROM SUBAREA A-2, USE $n = 0.033$ (RIPRAP)

2. RUN TR-55 USING INPUT DATA AND SWALE CROSS SECTION FROM A-2

3. FROM TR-55, PEAK FLOW = 395 CFS (FILE: FERMCO\ESA3-1.55)

4. CHECK SWALE CAPACITY:

$$Q_{MAX} = \frac{1.49}{0.033}\left(\frac{73.3}{44.4}\right)^{2/3}(0.005)^{1/2}(73.3) = 327\text{ cfs} < 395\text{ cfs}$$ NG ✓

5. TRY A LARGER SWALE CROSS SECTION ASSUMING V = 4 FPS ✓

$$A = \frac{395}{4} = 98.8\text{ FT}^2$$ ✓

IF $Y = 2.5$ — $W = \frac{98.8}{2.5}\left(\frac{3}{2}\right) = 59.2$ FT (TOO WIDE) ✓

IF $Y = 3$ — $W = \frac{98.8}{3}\left(\frac{3}{2}\right) = 49.4$ FT SAY 50 FT ✓

$$A = \frac{2}{3}(3)(50) = 100\text{ FT}^2$$

$$P_W = \left(4(3)^2 + \frac{(50)^2}{4}\right)^{1/2} + \frac{(50)^2}{8(3)}\ln\left(\frac{2(3) + \left(4(3)^2 + \frac{(50)^2}{4}\right)^{1/2}}{\frac{50}{2}}\right)$$

$$P_W = 25.7 + 24.8 = 50.5\text{ FT}$$ ✓

6. RUN TR-55 USING INPUT DATA EXCEPT FOR THE FOLLOWING CHANNEL FLOW PARAMETERS:

$n = 0.033$

$A = 100\text{ FT}^2$

$P_W = 50.5$ FT

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: AAC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

7. FROM TR-55, PEAK FLOW = 395 CFS (FILE: FERMCO\ESA3-2.55)

8. CHECK SWALE CAPACITY

$$Q_{MAX} = \frac{1.49}{0.033}\left(\frac{100}{50.5}\right)^{2/3}(0.005)^{1/2}(100) = 503 \text{ CFS} > 395 \text{ CFS}$$

OK

$V_{MAX} = 5.03$ FPS

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: AAC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - EAST SWALE

Subarea #1 - A-3

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		3262	.0066		.0337	3.3	44.4		0.177
								Time of Concentration =	0.38*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\ESA3-1.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: MC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - EAST SWALE

Total watershed area: 0.052 sq mi Rainfall type: II Frequency: 2000 years

	Subareas
	A-3
Area(sq mi)	0.05
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.38*
(Used)	0.40
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) A-3
11.0	12	12
11.3	17	17
11.6	24	24
11.9	51	51
12.0	94	94
12.1	181	181
12.2	312	312
12.3	395P	395P ← PEAK FLOW
12.4	383	383
12.5	288	288
12.6	199	199
12.7	144	144
12.8	109	109
13.0	69	69
13.2	51	51
13.4	42	42
13.6	37	37
13.8	33	33
14.0	29	29
14.3	25	25
14.6	23	23
15.0	21	21
15.5	19	19
16.0	17	17
16.5	15	15
17.0	14	14
17.5	13	13
18.0	12	12
18.5	11	11
19.0	9	9
20.0	8	8
26.0	0	0

FILE: FERMCO\ESA3-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

001440

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: AIC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - EAST SWALE

---------- Subarea #1 - A-3 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		3262	.0066			.033100	50.5		0.157
						Time of Concentration =			0.36*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\ESA3-2.55

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: MC Date: 95/10/16 (YY MM DD)

Client: FEMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

SUBAREA A-4

1. FROM SUBAREA A-3, USE $n = 0.033$ (RIPRAP)

2. RUN TR-55 USING INPUT DATA AND SWALE CROSS SECTION FROM A-3, AND $n = 0.033$

3. FROM TR-55, PEAK FLOW = 455 CFS (FILE: FEEMCO\ESA4-1.55)

4. CHECK SWALE CAPACITY:

$$Q_{MAX} = \frac{1.49}{0.033}\left(\frac{100}{50.5}\right)^{2/3}(0.01)^{1/2}(100) = 712 \text{ CFS} > 455 \text{ CFS}$$

OK

$V_{MAX} = 7.12$ FPS

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: AAC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - EAST SWALE

---------- Subarea #1 - A-4 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		4089	.0073		.033100		50.5		0.187

Time of Concentration = 0.39*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\ESD4-1.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-~~20~~ 15-95
County : BUTLER State: OH Checked: AJC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - EAST SWALE

Total watershed area: 0.060 sq mi Rainfall type: II Frequency: 2000 years

---------- Subareas ----------

	A-4
Area(sq mi)	0.06
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.39*
(Used)	0.40
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) A-4
11.0	14	14
11.3	19	19
11.6	28	28
11.9	59	59
12.0	108	108
12.1	208	208
12.2	360	360
12.3	455P	455P ← PEAK FLOW
12.4	442	442
12.5	332	332
12.6	229	229
12.7	166	166
12.8	125	125
13.0	80	80
13.2	59	59
13.4	48	48
13.6	42	42
13.8	38	38
14.0	34	34
14.3	29	29
14.6	26	26
15.0	24	24
15.5	22	22
16.0	19	19
16.5	17	17
17.0	16	16
17.5	15	15
18.0	14	14
19.0	12	12
[illegible]	11	11
[illegible].0	9	9
26.0	0	0

FILE: FERMCO\ESA4-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

Written by: ESS Date: 95/10/15 (YY/MM/DD) Reviewed by: MC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

WEST SWALE:

SUBAREA B-1

1. OBTAIN n FROM USDA-SCS [1986b] EXHIBIT 7-1 FOR GRASS-LINED SWALE

a. CALCULATE VELOCITY FOR CHANNEL SECTION, ASSUME $n = 0.036$:

$$V = \frac{1.49}{0.036}\left(\frac{48}{36.2}\right)^{2/3}(0.01)^{1/2} = 5.0 \text{ FPS} \rightarrow \text{MAY NEED RIPRAP}$$

b. CALCULATE V_r:

$$V_r = 5\left(\frac{48}{36.2}\right) = 6.6$$

FROM EXHIBIT 7-1, $n = 0.036$

HOWEVER, BECAUSE $V = 5.0$ FPS – USE $n = 0.033$ FOR RIPRAP

c. RECALCULATE V:

$$V = 5\left(\frac{0.036}{0.033}\right) = 5.45 \text{ FPS}$$

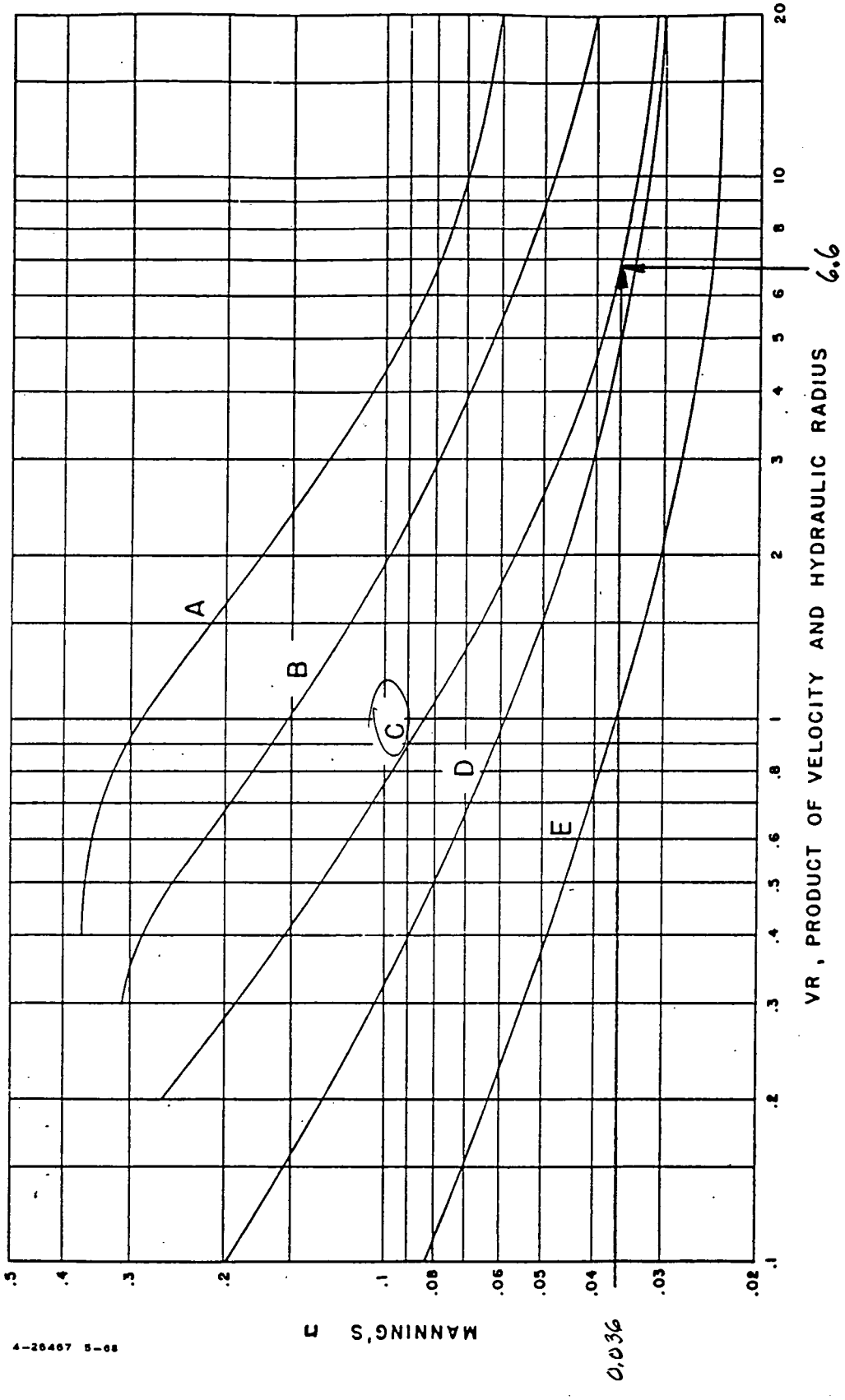
2. RUN TR-55 USING INPUT DATA AND $n = 0.033$

3. FROM TR-55, PEAK FLOW = 46 CFS (FILE: FERMCO\WSB1-1.55)

4. CHECK SWALE CAPACITY:

$$Q_{MAX} = \frac{1.49}{0.033}\left(\frac{48}{36.2}\right)^{2/3}(0.01)^{1/2}(48) = 262 \text{ CFS} > 46 \text{ CFS} \quad \underline{\text{OK}}$$

$V_{MAX} = 5.46$ FPS



4-26467 5-68

Exhibit 7-1. Manning's "n" related to velocity, hydraulic radius, and vegetal retardance.

USDA-SCS, 1973

WEST SWALE - B-1

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001446

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: A-C Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

---------- Subarea #1 - B-1 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		296	.01			.03348	36.2		0.015
						Time of Concentration =			0.21*

=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\WSB1-1.55

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TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: AJC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

Total watershed area: 0.004 sq mi Rainfall type: II Frequency: 2000 years

---------- Subareas ----------

	B-1
Area(sq mi)	0.00
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.21*
(Used)	0.20
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) B-1
11.0	1	1
11.3	2	2
11.6	3	3
11.9	12	12
12.0	23	23
12.1	42	42
12.2	46P	46P ← PEAK FLOW
12.3	28	28
12.4	14	14
12.5	10	10
12.6	7	7
12.7	6	6
12.8	5	5
13.0	4	4
13.2	4	4
13.4	3	3
13.6	3	3
13.8	3	3
14.0	2	2
14.3	2	2
14.6	2	2
15.0	2	2
15.5	2	2
16.0	1	1
16.5	1	1
17.0	1	1
17.5	1	1
18.0	1	1
18.5	1	1
19.0	1	1
19.5	1	1
26.0	0	0

FILE: FERMCO\WSB1-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: AIC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

SUBAREA B-2

1. FROM SUBAREA B-1, USE $n = 0.033$ (RIPRAP)

2. RUN TR-55 USING INPUT DATA AND $n = 0.033$.

3. FROM TR-55, PEAK FLOW = 70 CFS (FILE: FERMCO\WSB2-1.55)

4. CHECK SWALE CAPACITY:

$$Q_{MAX} = \frac{1.49}{0.033}\left(\frac{48}{362}\right)^{2/3}(0.0134)^{1/2}(48) = 303 \text{ CFS} > 70 \text{ CFS} \quad \underline{\underline{OK}}$$

$V_{MAX} = 6.31$ FPS

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: AAC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

Subarea #1 - B-2

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		530	.0115		.03348		36.2		0.025
						Time of Concentration =			0.22*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\WSB2-1.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-~~10~~15-95
County : BUTLER State: OH Checked: AJC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

Total watershed area: 0.007 sq mi Rainfall type: II Frequency: 2000years

---------- Subareas ----------

	B-2
Area(sq mi)	0.01
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.22*
(Used)	0.20
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) B-2
11.0	2	2
11.3	3	3
11.6	4	4
11.9	18	18
12.0	35	35
12.1	65	65
12.2	70P	70P ← PEAK FLOW
12.3	42	42
12.4	22	22
12.5	15	15
12.6	11	11
12.7	9	9
12.8	8	8
13.0	6	6
13.2	5	5
13.4	5	5
13.6	4	4
13.8	4	4
14.0	4	4
14.3	3	3
14.6	3	3
15.0	3	3
15.5	2	2
16.0	2	2
16.5	2	2
17.0	2	2
17.5	2	2
18.0	2	2
18.5	1	1
19.0	1	1
22.0	1	1
26.0	0	0

FILE: FERMCO\WSB2-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

Written by: ESS Date: 95/10/15 (YY/MM/DD) Reviewed by: AAC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08

SUBAREA B-3

1. FROM SUBAREA B-2, USE $n = 0.033$ (RIPRAP)

2. RUN TR-55 USING INPUT DATA AND $n = 0.033$.

3. FROM TR-55, PEAK FLOW = 195 CFS (FILE: FERMCO\WSB3-1.55)

4. CHECK SWALE CAPACITY:

$$Q_{MAX} = \frac{1.49}{0.033}\left(\frac{48}{36.2}\right)^{2/3}(0.0075)^{1/2}(48) = 226 \text{ CFS} > 195 \text{ CFS}$$ OK

$V_{MAX} = 4.7$ FPS

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: ABC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

Subarea #1 - B-3

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		1812	.0087		.03348		36.2		0.099
						Time of Concentration =			0.30*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\WSB3-1.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

Total watershed area: 0.023 sq mi Rainfall type: II Frequency: 2000 years

	Subareas
	B-3
Area(sq mi)	0.02
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.30*
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) B-3
11.0	6	6
11.3	8	8
11.6	12	12
11.9	34	34
12.0	68	68
12.1	129	129
12.2	195P	195P ← PEAK FLOW
12.3	195	195
12.4	132	132
12.5	82	82
12.6	57	57
12.7	42	42
12.8	33	33
13.0	23	23
13.2	19	19
13.4	16	16
13.6	15	15
13.8	13	13
14.0	12	12
14.3	11	11
14.6	10	10
15.0	9	9
15.5	8	8
16.0	7	7
16.5	6	6
17.0	6	6
17.5	5	5
18.0	5	5
19.0	5	5
20.0	4	4
21.0	3	3
26.0	0	0

FILE: FERMCO\WSB3-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: AAC Date: 95/10/26 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

SUBAREA B-4

1. FROM B-3, USE $n = 0.033$ (RIPRAP)

2. RUN TR-55 USING INPUT DATA AND $n = 0.033$.

3. FROM TR-55, PEAK FLOW = 279 CFS (FILE: FERMCO\WSB4-1.55)

4. CHECK SWALE CAPACITY:

$$Q_{MAX} = \frac{1.49}{0.033}\left(\frac{48}{36.2}\right)^{2/3}(0.0075)^{1/2}(48) = 226 \text{ CFS} < 279 \text{ CFS} \quad \text{NG}$$

5. TRY A LARGER SWALE CROSS SECTION (SEE EAST SWALE A-2)

$Y = 2.5$ FT $W = 44$ FT

$A = \frac{2}{3}(2.5)(44) = 73.3$ FT

$$P_w = \left(4(2.5)^2 + \frac{(44)^2}{4}\right)^{1/2} + \frac{(44)^2}{8(2.5)} \ln\left(\frac{2(2.5) + \left(4(2.5)^2 + \frac{(44)^2}{4}\right)^{1/2}}{\frac{44}{2}}\right)$$

$P_w = 22.6 + 21.8 = 44.4$ FT

6. RUN TR-55 USING INPUT DATA EXCEPT FOR THE FOLLOWING CHANNEL FLOW PARAMETERS:

$n = 0.033$

$A = 73.3$ FT^2

$P_w = 44.4$ FT

7. FROM TR-55, PEAK FLOW = 319 CFS (FILE: FERMCO\WB4-2.55)

8. CHECK SWALE CAPACITY

$$Q_{MAX} = \frac{1.49}{0.033}\left(\frac{73.3}{44.4}\right)^{2/3}(0.0075)^{1/2}(73.3) = 400 \text{ CFS} > 319 \text{ CFS}$$

OK

$V_{MAX} = 5.46$ FPS

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

---------- Subarea #1 - B-4 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		2824	.0083		.03348		36.2		0.158

Time of Concentration = 0.36*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\WSB4-1.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-~~20~~ 15-95
County : BUTLER State: OH Checked: Asc Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

Total watershed area: 0.037 sq mi Rainfall type: II Frequency: 2000 years

---------- Subareas ----------

	B-4
Area(sq mi)	0.04
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.36*
(Used)	0.40
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) B-4
11.0	8	8
11.3	12	12
11.6	17	17
11.9	36	36
12.0	67	67
12.1	128	128
12.2	221	221
12.3	279P	279P ← PEAK FLOW
12.4	271	271
12.5	203	203
12.6	141	141
12.7	102	102
12.8	77	77
13.0	49	49
13.2	36	36
13.4	30	30
13.6	26	26
13.8	23	23
14.0	21	21
14.3	18	18
14.6	16	16
15.0	15	15
15.5	13	13
16.0	12	12
16.5	10	10
17.0	10	10
17.5	9	9
18.0	8	8
18.0	8	8
[illegible]0	7	7
[illegible].0	6	6
26.0	0	0

FILE: FERMCO\WSB4-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

001457

2 OF 2

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-~~10~~ 15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

---------- Subarea #1 - B-4 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		2824	.0083		.0337	3.3	44.4		0.137
								Time of Concentration =	0.34*

=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\WSB4-2.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

Total watershed area: 0.037 sq mi Rainfall type: II Frequency: 2000years

---------- Subareas ----------

	B-4
Area(sq mi)	0.04
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.34*
(Used)	0.30
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) B-4
11.0	9	9
11.3	13	13
11.6	19	19
11.9	56	56
12.0	111	111
12.1	211	211
12.2	319P	319P ← PEAK FLOW
12.3	319	319
12.4	217	217
12.5	134	134
12.6	93	93
12.7	69	69
12.8	54	54
13.0	38	38
13.2	31	31
13.4	27	27
13.6	24	24
13.8	22	22
14.0	20	20
14.3	17	17
14.6	16	16
15.0	15	15
15.5	13	13
16.0	11	11
16.5	10	10
17.0	9	9
17.5	9	9
18.0	8	8
18.5	8	8
19.0	6	6
19.5	6	6
26.0	0	0

P - Peak Flow * - value(s) provided from TR-55 system routines

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: RAC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

SUBAREA B-5

1. FROM B-4, $n = 0.033$ (RIPRAP)

2. RUN TR-55 USING INPUT DATA, CROSS SECTION FROM B-4, AND $n = 0.033$.

3. FROM TR-55, PEAK FLOW = 455 CFS (FILE: WSB5-1.55)

4. CHECK SWALE CAPACITY:

$$Q_{MAX} = \frac{1.49}{0.033}\left(\frac{73.3}{44.4}\right)^{2/3}(0.005)^{1/2}(73.3) = 326 \text{ CFS} < 455 \text{ CFS}$$

NG

5. TRY A LARGER CROSS SECTION (SEE EAST SWALE A-3)

$y = 3$ FT $w = 50$ FT

$$A = \frac{2}{3}(3)(50) = \underline{100 \text{ FT}^2}$$

$$P_w = \left(4(3)^2 + \frac{(50)^2}{4}\right)^{1/2} + \frac{(50)^2}{8(3)} \ln\left(\frac{2(3) + \left(4(3)^2 + \frac{(50)^2}{4}\right)^{1/2}}{\frac{50}{2}}\right)$$

$$P_w = 25.7 + 24.8 = \underline{50.5 \text{ FT}}$$

6. RUN TR-55 USING INPUT DATA EXCEPT FOR THE FOLLOWING CHANNEL FLOW PARAMETERS

$n = 0.033$

$A = 100$ FT^2

$P_w = 50.5$ FT

7. FROM TR-55, PEAK FLOW = 455 CFS (FILE: WSB5-2.55)

8. CHECK SWALE CAPACITY:

$$Q_{MAX} = \frac{1.49}{0.033}\left(\frac{100}{50.5}\right)^{2/3}(0.005)^{1/2}(100) = 503 \text{ CFS} > 455 \text{ CFS}$$ OK

$V_{MAX} = 5.03$ FPS

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: Asc Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

---------- Subarea #1 - B-5 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		4024	.0073		.0337	3.3	44.4		0.207
								Time of Concentration =	0.41*
									=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE : FERMCO\WSB5-1.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

Total watershed area: 0.060 sq mi Rainfall type: II Frequency: 2000 years

---------- Subareas ----------

	B-5
Area(sq mi)	0.06
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.41*
(Used)	0.40
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) B-5
11.0	14	14
11.3	19	19
11.6	28	28
11.9	59	59
12.0	108	108
12.1	208	208
12.2	360	360
12.3	455P	455P ← PEAK FLOW
12.4	442	442
12.5	332	332
12.6	229	229
12.7	166	166
12.8	125	125
13.0	80	80
13.2	59	59
13.4	48	48
13.6	42	42
13.8	38	38
14.0	34	34
14.3	29	29
14.6	26	26
15.0	24	24
15.5	22	22
16.0	19	19
16.5	17	17
17.0	16	16
17.5	15	15
18.0	14	14
19.0	12	12
20.0	11	11
22.0	9	9
26.0	0	0

FILE: FERMCO\WSB5-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

---------- Subarea #1 - B-5 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.05	F					0.185
Shallow Concent'd		328	.158	U					0.014
Open Channel		4024	.0073		.033100		50.5		0.184

Time of Concentration = 0.38*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\WSB5-2.55

TABULAR HYDROGRAPH METHOD E 186 Version 2.00

Project : FERMCO - OSDF User: ESS 55 Date: 10-~~10~~ 15-95
County : BUTLER State: OH Checked: RSC Date: 10-16-95
Subtitle: PERIMETER SWALE SIZING FOR 2000 YEAR STORM - WEST SWALE

Total watershed area: 0.060 sq mi Rainfall type: II Frequency: 2000 years

---------- Subareas ----------

	B-5
Area(sq mi)	0.06
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.38*
(Used)	0.40
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) B-5
11.0	14	14
11.3	19	19
11.6	28	28
11.9	59	59
12.0	108	108
12.1	208	208
12.2	360	360
12.3	455P	455P ← PEAK FLOW
12.4	442	442
12.5	332	332
12.6	229	229
12.7	166	166
12.8	125	125
13.0	80	80
13.2	59	59
13.4	48	48
13.6	42	42
13.8	38	38
14.0	34	34
14.3	29	29
14.6	26	26
15.0	24	24
15.5	22	22
16.0	19	19
16.5	17	17
17.0	16	16
17.5	15	15
18.0	14	14
19.0	12	12
20.0	11	11
22.0	9	9
26.0	0	0

FILE: FERMCO\WSB5-2-55

P - Peak Flow * - value(s) provided from TR-55 system routines

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: AAC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08/

SUMMARY OF RESULTS:

EAST SWALE

SUBAREA	STATION	FLOW WIDTH (FT)	FLOW DEPTH (FT)	TOTAL* WIDTH (FT)	TOTAL* DEPTH (FT)	CHANNEL LINING
	2+98					
A-1		36	2	40	2.5	GRASS
	18+06					
A-2		44	2.5	50	3	RIPRAP
	28+62					
A-3		50	3	56	3.5	RIPRAP
	40+12					
A-4		50	3	56	3.5	RIPRAP
	42+61**					

* INCLUDES 0.5 FT OF FREEBOARD
** WEST SWALE STATION

WEST SWALE

SUBAREA	STATION	FLOW WIDTH (FT)	FLOW DEPTH (FT)	TOTAL* WIDTH (FT)	TOTAL* DEPTH (FT)	CHANNEL LINING
	2+98**					
B-1		36	2	40	2.5	RIPRAP
	2+96					
B-2		36	2	40	2.5	RIPRAP
	5+30					
B-3		36	2	40	2.5	RIPRAP
	18+12					
B-4		44	2.5	50	3	RIPRAP
	28+24					
B-5		50	3	56	3.5	RIPRAP
	40+24					

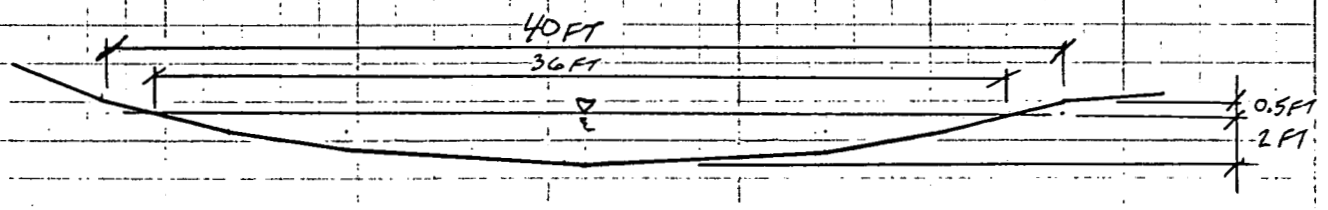
* INCLUDES 0.5 FT OF FREEBOARD
** EAST SWALE STATION

Written by: BSS Date: 95/10/15 (YY/MM/DD) Reviewed by: AJC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

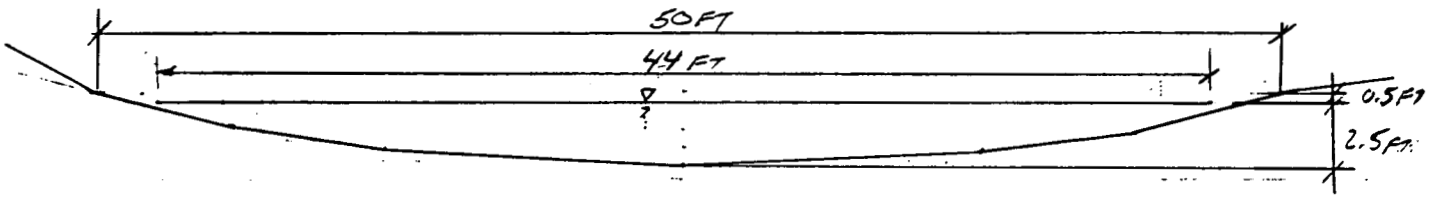
SWALE CROSS SECTIONS:

SWALE FOR SUBAREAS A-1, B-1, B-2, & B-3:

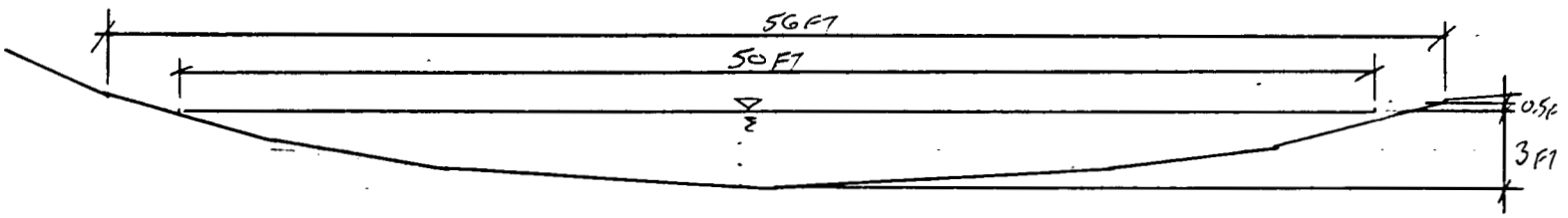


SWALE FOR SUBAREAS A-2 & B4:

50 ft



SWALE FOR SUBAREAS A-3, A-4, & B-5



RIPRAP SIZES:

V_{MAX} IN SWALE = 7.12 FPS @ A-4

FROM USDA-SCS [1986b] - MAXIMUM STONE SIZE = 7.5 IN.

SAY 8 IN

155
(50828)
A-1C
95-10-16
26 OF
40 OF 47
186

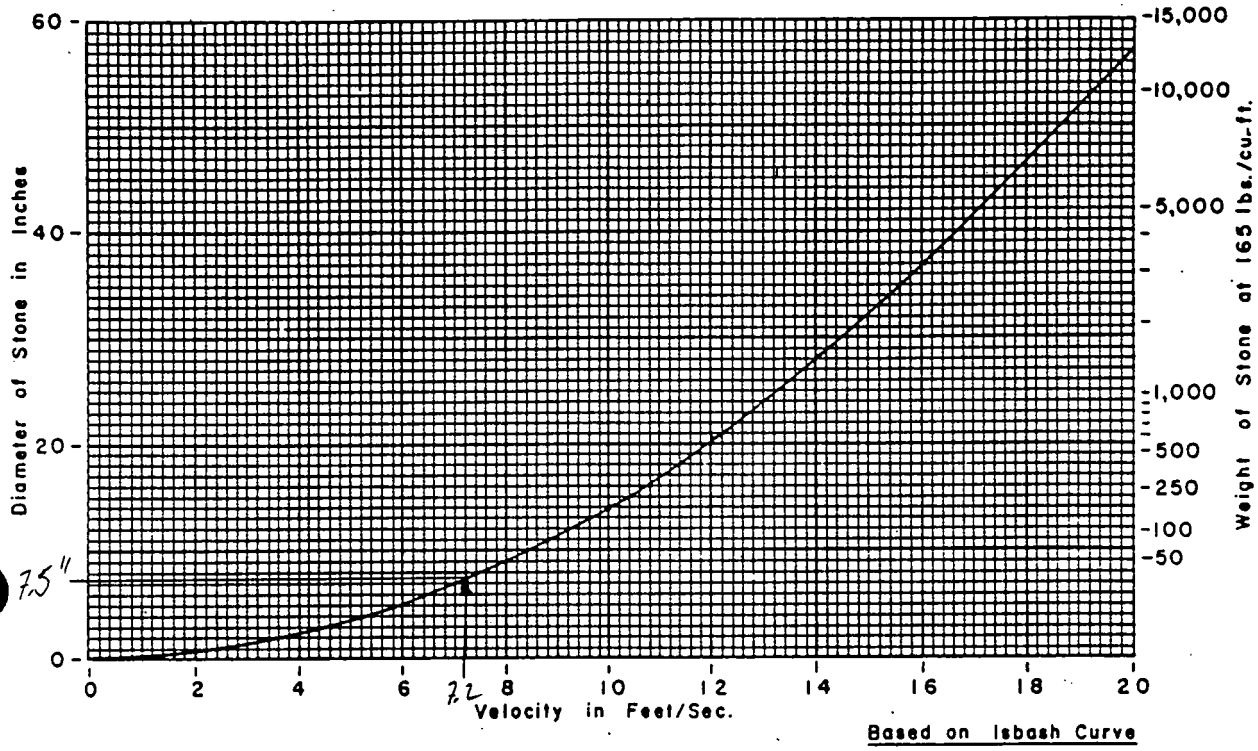


Exhibit 16-1 Maximum stone size for riprap

USDA- SCS [1986b]

Written by: ESS Date: 95/10/15 (YY/MM/DD) Reviewed by: AAc Date: 95/10/16 (YY/MM/DD)

Client: FEMCO Project: OSDF Project/Proposal No.: GE8200 Task No.: 08.1

REFERENCES:

USDA-SCS, "TR-55 MICROCOMPUTER PROGRAM SYSTEM", VERSION 2.0, WASHINGTON, D.C, JUN 1986a.

USDA-SCS, "ENGINEERING MANUAL FOR CONSERVATION PRACTICES", WASHINGTON, DC, NOV 1986b.

11.2 OSDF Perimeter Berm Flood Protection

Written by: ESS Date: 95/11/29 Reviewed by: JM Date: 95/11/29

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 8.1

STORMWATER MANAGEMENT: OSDF PERIMETER BERM FLOOD PROTECTION

EXECUTIVE SUMMARY

Purpose

The purpose of this document is to provide the engineering data and calculations used in the design of the OSDF perimeter access and flood protection berm. The perimeter access and flood protection berm is designed to protect the OSDF from:

- the flood waters resulting from the probable maximum precipitation event (PMP); and
- the stormwater run-on expected during a 2,000-year, 24-hour storm event.

Method of Analysis

To design for the flood waters resulting from the PMP, the elevation of the lowest part of the perimeter flood protection berm must be higher than the flood elevation expected from the PMP event. An August 1995 engineering report from Parsons Engineering showed that the maximum water surface elevation expected from the PMP is 596 ft msl and will encroach on the western side of the OSDF.

To design for the 2,000-year, 24-hour storm event, the computer program TR-55 was used to calculate the peak runoff expected from the areas surrounding the OSDF. After calculating the peak runoff rates, "choke" points were identified around the OSDF flood protection berm, which is an average of 10 ft high. Cross-sectional areas were calculated for a range of expected flow elevations at each "choke point". Standard open channel flow equations were then used with the peak runoff rates to calculate the maximum depth of flow at each "choke point". The height of the flood protection berm must exceed the maximum depth of flow at the "choke point".

Conclusions

The analyses showed that:

- the crest of the flood protection berm on the west side of the OSDF should be constructed to a minimum elevation of 596 ft;

Written by: BSS Date: 95/11/29 Reviewed by: JM Date: 95/11/29

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900C Task No.: E

STORMWATER MANAGEMENT: OSDF PERIMETER BERM FLOOD PROTECTION

- the height of the flood protection berm on the east side of the OSDF needs to be greater than 4 ft; and
- the height of the flood protection berm on the west side of the OSDF needs to be greater than 2 ft.

Written by: ESS Date: 95/10/15 (YY/MM/DD) Reviewed by: AJC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

SURFACE-WATER MANAGEMENT

OSDF STORMWATER MANAGEMENT CALCULATIONS

OSDF PERIMETER ACCESS AND FLOOD PROTECTION BERM

PURPOSE: THE PURPOSE OF THIS CALCULATION PACKAGE IS TO PROVIDE THE CALCULATIONS AND ANALYSES USED IN DESIGNING THE PERIMETER ACCESS AND FLOOD PROTECTION BERM FOR THE ON-SITE DISPOSAL FACILITY (OSDF)

SCOPE: THE OSDF PERIMETER ACCESS AND FLOOD PROTECTION BERM IS DESIGN TO PROTECT THE OSDF FROM:

1. FLOOD WATERS FROM THE PROBABLE MAXIMUM PRECIPITATION (PMP) EVENT; AND
2. STORM WATER RUNON FROM THE 25-YR, 24-HR STORM EVENT.

SUMMARY OF INPUT DATA:

PARAMETERS	SUBAREA* 1	2	3	4
AREA (ACRES/SQ.MILES)	9.2/0.0144	47.9/0.0748	11.2/0.0175	23/0.0036
SHEET FLOW:				
LENGTH (FT)	100	100	100	100
SLOPE (FT/FT)	0.01	0.10	0.12	0.02
SURFACE	DENSE GRASS	DENSE GRASS	DENSE GRASS	DENSE GRASS
SHALLOW CONCENTRATED FLOW:				
LENGTH (FT)	400	1050	1250	300
SLOPE (FT/FT)	0.0125	0.0171	0.1024	0.010
SURFACE	UNPAVED	UNPAVED	UNPAVED	UNPAVED
CHANNEL FLOW:				
LENGTH (FT)	500	1700	350	100
SLOPE (FT/FT)	0.010	0.0035	0.0086	0.01
MANNING'S COEFFICIENT	VARIES	VARIES	VARIES	VARIES
FLOW AREA (FT²)	SEE TABLE 1	SEE TABLE 1	SEE TABLE 1	SEE TABLE 1
WETTED PERIMETER (FT)	↓	↓	↓	↓

*SEE FIGURE 1

Written by: ESS Date: 95/10/15 (YY/MM/DD) Reviewed by: AJC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3800 Task No.: 08.1

RAINFALL: 2,000-YR, 24-HR = 13 IN., 2-YR, 24-HR = 2.55 IN.
RUNOFF CURVE NUMBER = 98
FLOOD ELEVATIONS: PMP = 596 FT MSL; 2,000-YR 24-HR = 583.4 FT MSL

FLOW EQUATIONS:

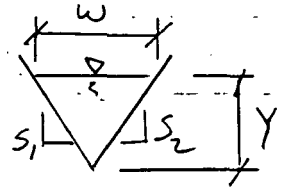
VELOCITY (V): $V = \frac{1.49}{n} r^{2/3} s^{1/2}$ (CHEZY'S EQUATION)

FLOW (Q): $Q = VA$

WHERE: n = MANNING'S COEFFICIENT

s = SLOPE (FT/FT) (RISE/RUN)

r = HYDRAULIC RADIUS (FT) = A/P_w



A = AREA OF FLOW (FT^2) = $\frac{Y^2}{2}\left(\frac{1}{S_1} + \frac{1}{S_2}\right)$ (VEE CHANNEL)

P_w = WETTED PERIMETER (FT) = $Y\left(\left(1+\frac{1}{S_1^2}\right)^{1/2} + \left(1+\frac{1}{S_2^2}\right)^{1/2}\right)$

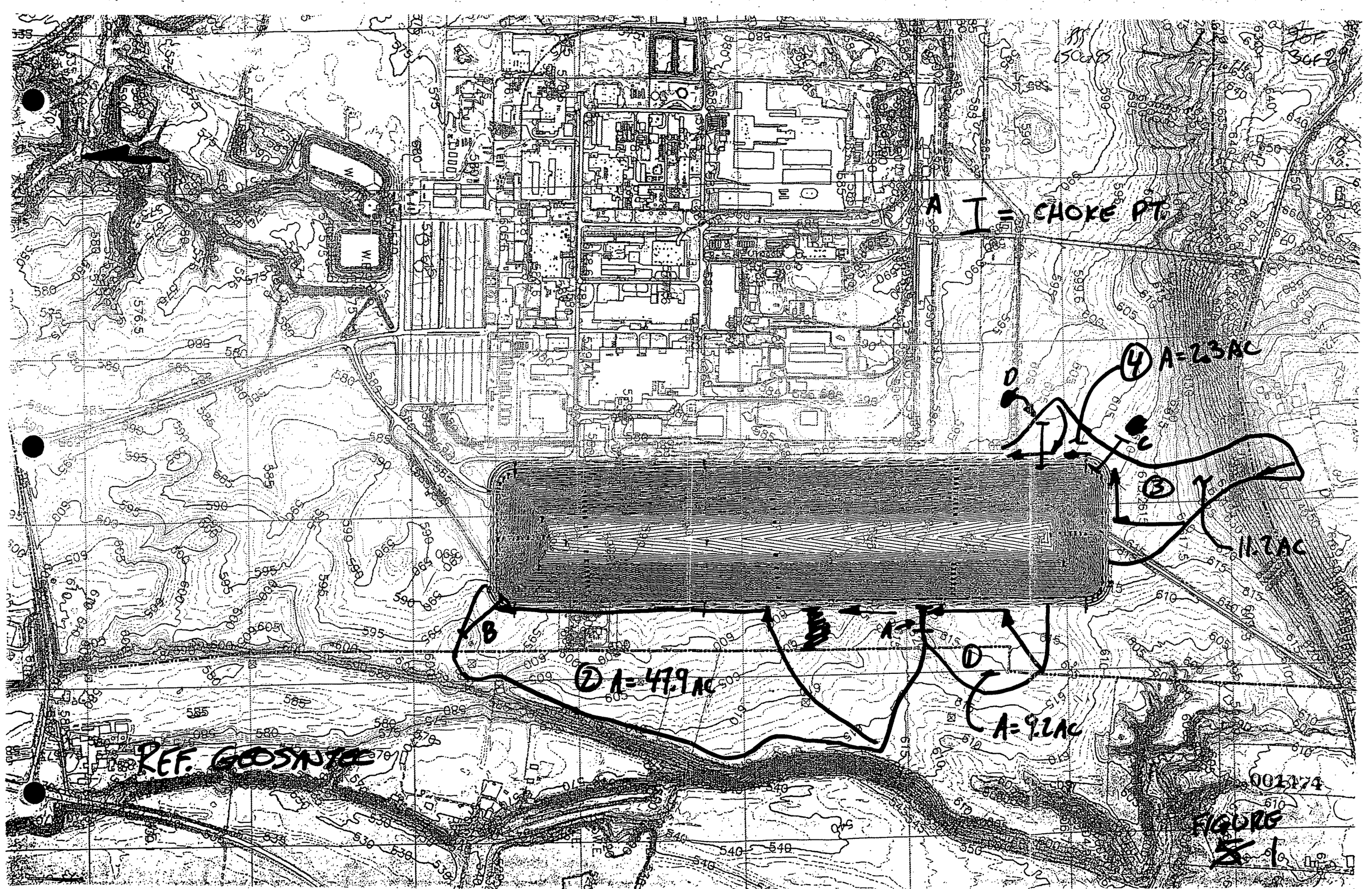
Y = MAXIMUM FLOOD DEPTH (FT)

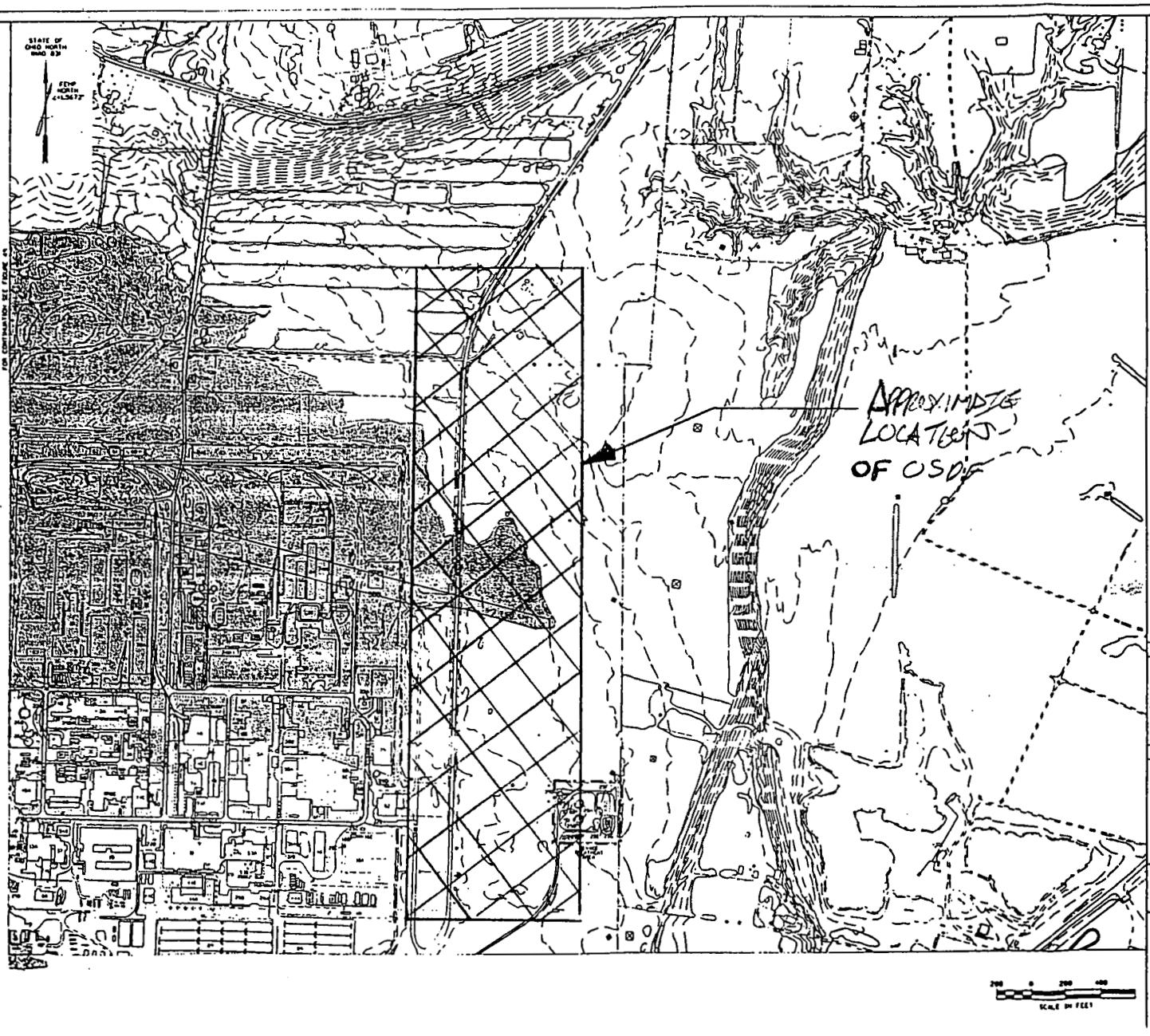
W = WIDTH AT WATER SURFACE (FT)

ANALYSIS:

FLOOD WATER ELEVATION

ACCORDING TO PARSONS [1995], THE MAXIMUM WATER SURFACE ELEVATION FOR THE PMP IS 596 FT MSL AND 583.4 FT MSL FOR THE 2,000-YR, 24-HR STORM EVENT. ALSO, THE PMP FLOOD WATER ARE EXPECTED TO ENCROACH ON THE WESTERN SIDE OF OSDF, SEE FIGURE 2. A MAP SHOWING THE FLOOD WATER ELEVATIONS FROM THE 2,000-YR, 24-HR STORM IS NOT AVAILABLE. HOWEVER, IT IS ASSUMED THAT THE BOUNDARY OF THE FLOOD WATERS OF THE 2,000-YR, 24-HR STORM WILL NOT EXCEED THE BOUNDARY OF THE PMP FLOOD WATERS.


A
I = CHOKE PT.
④ A=2.3AC
D
C
③
11.2AC
B
E
F
② A=47.9AC
①
A=9.2AC
REF. GOOSNECK
001474
FIGURE 5-1



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SSS 150ct95

ARC 95-10-16

FIGURE 2

NOTES

1. EXISTING CONDITIONS SHOWN ON THIS DRAWING WERE PREPARED FROM FEMA SITE PROVIDED DATA FROM THE DOCUMENTS LISTED BELOW.

   EXISTING SITE DATA SOURCE (IN PLANT FILES)
   PARSONS TOPOGRAPHY (1992)
   WOOLPERT FIELD SURVEY DATED JULY 1993 FOR BRIDGE OPENINGS AT SECTIONS 2,3,4 AND 10

2. SECTIONS 2.1, 2.2, 3.1 AND 3.2 ARE INCORPORATED IN SECTIONS 2/3 AND 4/10 FOR BRIDGE DEFINITION.

LEGEND

- FLOOD LIMIT
- 504 — APPROXIMATE FLOOD ELEVATION (CONTOUR) LOCATION
- TREE LINE
- PADDYS RUN

REF:

THIS DRAWING PREPARED BY
PARSONS
THE RALPH M. PARSONS CO. · CHAS. T. MAIN, INC. · ENGINEERING-SCIENCE, INC.
CINCINNATI, OHIO

PADDYS RUN
PMP
FLOOD PLAIN BOUNDARY
(PRODUCTION AREA)

FIGURE 5B

SCALE: AS SHOWN
CRU7/P0148

8 OF 29

skg03860.m(494.ws322) po148@ws322. Thu Aug 31 13:49:50 CDT 1995

001475

TABLE 1

OSDF Perimeter Access and Flood Protection Berm

Channel Geometry and Calculation of Flow Area and Wetted Perimeter for various flow depths

Equations:

Flow Area (A): A = Y (W + Y/2 (1/S1 +1/S2))

Wetted Perimeter (Pw): Pw = W + Y ((1 + 1/S1^2)^0.5 + (1 + 1/S2^2)^0.5)

where: Y = maximum flow depth
W = width of channel bottom = 0
S1 = left slope (rise/run)
S2 = right slope (rise/run)

Hydraulic Radius (r): r = A/Pw

Choke Pt.	Flow Depth	S1	S2	A (sf)	Pw (ft)	r (ft)	Height of Berm	Channel Slope
A	1	0.25	0.05	12.00	24.15	0.50	8 ft	0.01
	2	0.25	0.05	48.00	48.30	0.99		
	3	0.25	0.05	108.00	72.44	1.49		
	4	0.25	0.05	192.00	96.59	1.99		
	5	0.25	0.05	300.00	120.74	2.48		
B	1	0.25	0.03	17.00	34.14	0.50	9 ft	0.0035
	2	0.25	0.03	68.00	68.28	1.00		
	3	0.25	0.03	153.00	102.42	1.49		
	4	0.25	0.03	272.00	136.56	1.99		
	5	0.25	0.03	425.00	170.70	2.49		
C	1	0.25	0.02	27.00	54.13	0.50	8 ft	0.0086
	2	0.25	0.02	108.00	108.27	1.00		
	3	0.25	0.02	243.00	162.40	1.50		
	4	0.25	0.02	432.00	216.53	2.00		
	5	0.25	0.02	675.00	270.67	2.49		
D	1	0.25	0.02	27.00	54.13	0.50	10 ft	0.01
	2	0.25	0.02	108.00	108.27	1.00		
	3	0.25	0.02	243.00	162.40	1.50		
	4	0.25	0.02	432.00	216.53	2.00		
	5	0.25	0.02	675.00	270.67	2.49		

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: AAC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

RUNON EVALUATION:

EAST SIDE

A. CALCULATE HEIGHT OF STORMWATER AT CHECK PT. A

1. ASSUME DEPTH OF STORMWATER IS 4 FT.

a. OBTAIN n FROM USDA-SCS [1986b] EXHIBIT 7-1 FOR GRASS-LINED SWALE

i. CALCULATE VELOCITY FOR CHANNEL SECTION, ASSUME $n = 0.033$:

$$V = \frac{1.49}{0.033}\left(\frac{192}{96.59}\right)^{2/3}(0.010)^{1/2} = 7.14 \text{ FPS}$$

ii. CALCULATE V_r

$$V_r = 7.14\left(\frac{192}{96.59}\right) = 14.2$$

FROM EXHIBIT 7-1, $n = 0.032$

iii. RECALCULATE V:

$$V = 7.14\left(\frac{0.033}{0.032}\right) = 7.36 \text{ FPS}$$

iv. RECALCULATE V_r:

$$V_r = 7.36\left(\frac{192}{96.59}\right) = 14.6$$

FROM EXHIBIT 7-1, $n = \underline{0.032}$

b. RUN TR-55 USING INPUT DATA AND $n = 0.032$

c. FROM TR-55, PEAK FLOW = 109 CFS (FILE: FERMCO\EB1-1.55)

Written by: BSS Date: 95/10/15 (YY/MM/DD) Reviewed by: AAC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

d. CHECK HEIGHT OF STORMWATER RUNOFF

$$A = \frac{109}{7.36} = 14.8 \text{ FT}^2$$

FROM TABLE 1 DEPTH OF FLOW > 1FT < 2FT

2. ASSUME DEPTH OF STORMWATER IS 2FT

a. OBTAIN n FROM EXHIBIT 7-1

i. CALCULATE VELOCITY FOR CHANNEL SECTION, ASSUME n = 0.032

$$V = \frac{1.49}{0.032}\left(\frac{48}{48.3}\right)^{2/3}(0.01)^{1/2} = 4.62 \text{ FPS}$$

ii. CALCULATE V_r

$$V_r = 4.62\left(\frac{48}{48.3}\right) = 4.59$$

FROM EXHIBIT 7-1, n = 0.040

iii RECALCULATE V

$$V = 4.48\left(\frac{0.032}{0.04}\right) = 3.58 \text{ fps}$$

iv. RECALCULATE V_r

$$V_r = 3.58\left(\frac{48}{48.3}\right) = 3.56$$

FROM EXHIBIT 7-1, n = 0.042

v. RECALCULATE V

$$V = 3.58\left(\frac{0.040}{0.042}\right) = 3.41 \text{ FPS}$$

vi RECALCULATE V_r

$$V_r = 3.41\left(\frac{48}{48.3}\right) = 3.38 \quad n = \underline{0.044}$$

Written by: BSS Date: 95/10/15 (YY MM DD) Reviewed by: MC Date: 95/10/16 (YY MM DD)

Client: PERMCO Project: OSDF Project/Proposal No.: GE3800 Task No.: 08.1

b. RUN TR-55 USING INPUT DATA AND n = 0.044

c. FROM TR-55, PEAK FLOW = 109 CFS (FILE: PERMCO\ES1-2.55)

d. CHECK HEIGHT OF STORMWATER RUNOFF

$$A = \frac{109}{3.41} = 31.9\ FT^2$$ ✓

FROM TABLE 1, DEPTH OF FLOW < 2 FT OK

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-~~11~~ 15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

---------- Subarea #1 - 1 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.01	F					0.352
Shallow Concent'd		400	.0125	U					0.062
Open Channel		500	.010		.032192		96.6		0.019

Time of Concentration = 0.43*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\EB1-1.55

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TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

Total watershed area: 0.014 sq mi Rainfall type: II Frequency: 2000 years

---------- Subareas ----------

	1
Area(sq mi)	0.01
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.43*
(Used)	0.40
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) 1
11.0	3	3
11.3	5	5
11.6	7	7
11.9	14	14
12.0	26	26
12.1	50	50
12.2	86	86
12.3	109P	109P ← PEAK FLOW
12.4	105	105
12.5	79	79
12.6	55	55
12.7	40	40
12.8	30	30
13.0	19	19
13.2	14	14
13.4	12	12
13.6	10	10
13.8	9	9
14.0	8	8
14.3	7	7
14.6	6	6
15.0	6	6
15.5	5	5
16.0	5	5
16.5	4	4
17.0	4	4
17.5	4	4
18.0	3	3
19.0	3	3
[illegible]	3	3
[illegible]	2	2
26.0	0	0

001481

FILE: FERMCO\EBH1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

Subarea #1 - 1

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.01	F					0.352
Shallow Concent'd		400	.0125	U					0.062
Open Channel		500	.010		.04448		48.3		0.041

Time of Concentration = 0.45*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\EB1-2.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-~~11~~ 15-95
County : BUTLER State: OH Checked: RSC Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

Total watershed area: 0.014 sq mi Rainfall type: II Frequency: 200 years

---------- Subareas ----------

	1
Area(sq mi)	0.01
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.45*
(Used)	0.40
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) 1
11.0	3	3
11.3	5	5
11.6	7	7
11.9	14	14
12.0	26	26
12.1	50	50
12.2	86	86
12.3	109P	109P ← PEAK FLOW
12.4	105	105
12.5	79	79
12.6	55	55
12.7	40	40
12.8	30	30
13.0	19	19
13.2	14	14
13.4	12	12
13.6	10	10
13.8	9	9
14.0	8	8
14.3	7	7
14.6	6	6
15.0	6	6
15.5	5	5
16.0	5	5
16.5	4	4
17.0	4	4
17.5	4	4
18.0	3	3
18.5	3	3
19.0	3	3
19.5	2	2
26.0	0	0

FILE: FERMCO\EBI-2.55

001483

P - Peak Flow * - value(s) provided from TR-55 system routines

EAST SIDE - CHOKE PT. A

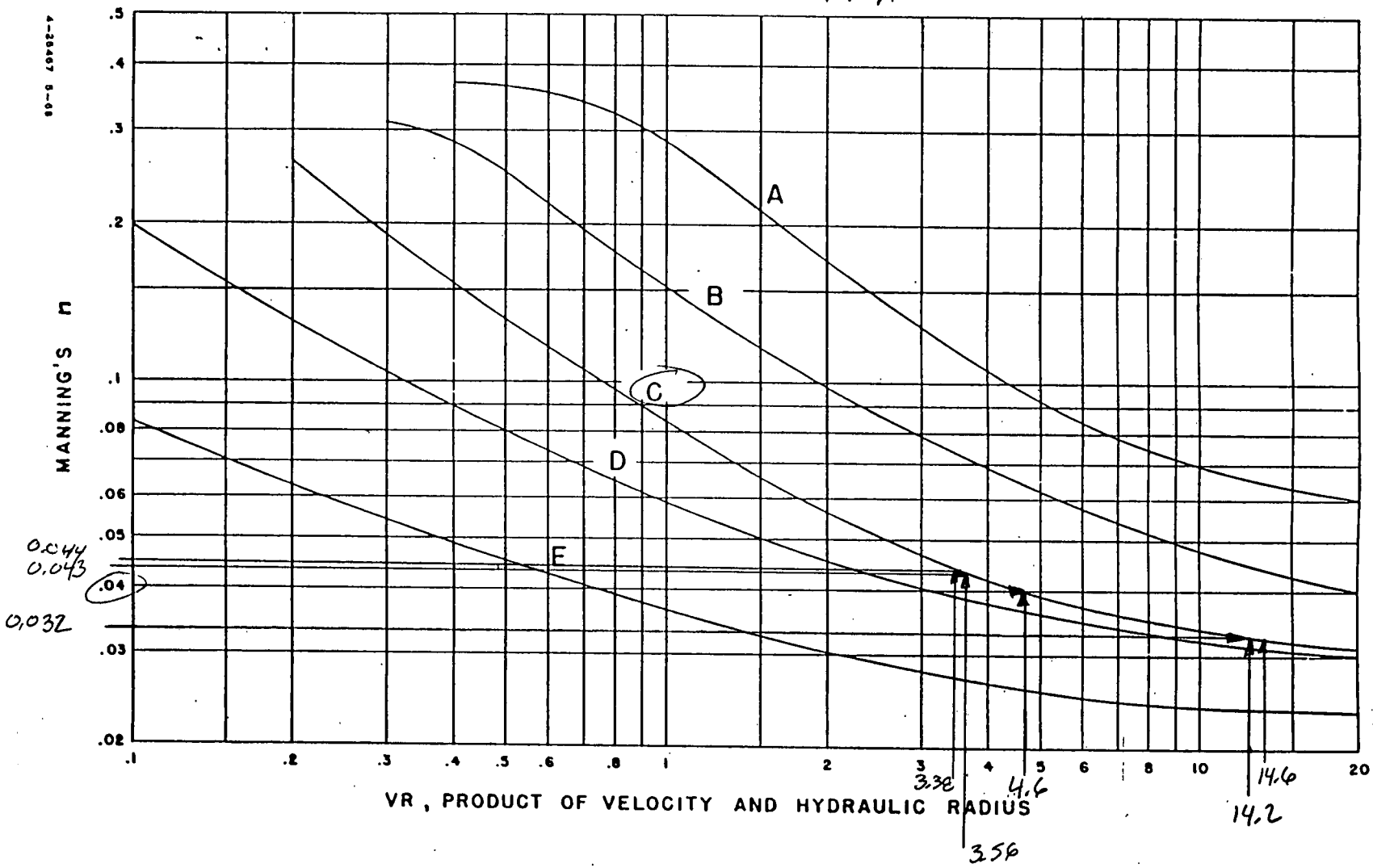


Exhibit 7-1. Manning's "n" related to velocity, hydraulic radius, and vegetal retardance.

USDA-SCS, 1986

TSS 1300 E7

NUC 95-10-16

18 OF 13 OF 29

FT 186

001484

Written by: ESS Date: 95/10/15 (YY/MM/DD) Reviewed by: AC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

B. CALCULATE HEIGHT OF STORMWATER AT CHECK PT. B.

1. ASSUME DEPTH OF STORMWATER IS 4 FT

a. OBTAIN n FROM EXHIBIT 7-1

i. CALCULATE V, ASSUME n = 0.042

$$V = \frac{1.49}{0.042}\left(\frac{272}{136.6}\right)^{2/3}(0.0035)^{1/2} = 3.32 \text{ FPS}$$

ii CALCULATE V_r

$$V_r = 3.32\left(\frac{272}{162.4}\right) = 6.61$$

FROM EXHIBIT 7-1, n = 0.036

iii RECALCULATE V

$$V = 3.32\left(\frac{0.042}{0.036}\right) = 3.87 \text{ FPS}$$

iv RECALCULATE V_r

$$V_r = 3.87\left(\frac{272}{136.6}\right) = 7.71 \text{ FPS}$$

FROM EXHIBIT 7-1, n = 0.035 OK

b. RUN TR-55 USING INPUT DATA AND n = 0.035

c. FROM TR-55, PEAK FLOW = 565 CFS (FILE: FERMCO\EB2-1.55)

d. CHECK HEIGHT OF STORMWATER RUNOFF OF COMBINED AREAS 1&2

$$A = \frac{565+109}{3.87} = 174 \text{ FT}$$

FROM TABLE 1, DEPTH OF FLOW < 4 FT OK

186

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: Asc Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

Subarea #1 - 2

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.1	F					0.140
Shallow Concent'd		1050	.0171	U					0.138
Open Channel		1700	.0035			.036272	137		0.122

Time of Concentration = 0.40*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\EB2-1.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: RSC Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

Total watershed area: 0.075 sq mi Rainfall type: II Frequency: 2000 years

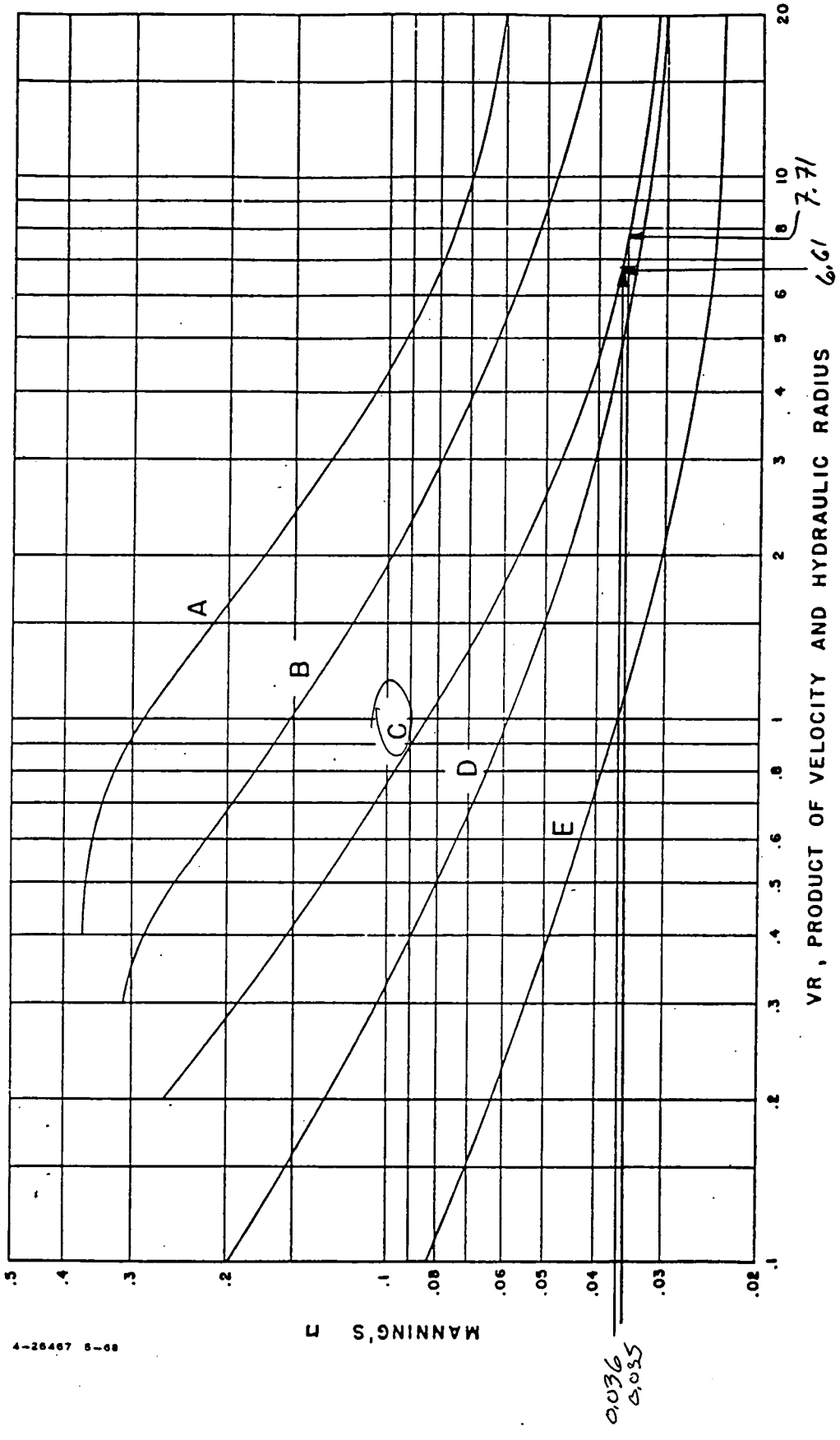
---------- Subareas ----------

	2
Area(sq mi)	0.07
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.40*
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) 2
11.0	17	17
11.3	24	24
11.6	34	34
11.9	73	73
12.0	135	135
12.1	259	259
12.2	447	447
12.3	565P	565P ← PEAK FLOW
12.4	548	548
12.5	411	411
12.6	284	284
12.7	206	206
12.8	156	156
13.0	99	99
13.2	73	73
13.4	60	60
13.6	52	52
13.8	47	47
14.0	42	42
14.3	36	36
14.6	32	32
15.0	30	30
15.5	27	27
16.0	24	24
16.5	21	21
17.0	20	20
17.5	19	19
18.0	17	17
19.0	15	15
20.0	13	13
[illegible]	11	11
[illegible]	0	0

FILE: FERMCO\EB2-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines



4-26467 5-68

Exhibit 7-1. Manning's "n" related to velocity, hydraulic radius, and vegetal retardance.

USDA-SCS, 1966

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: RAC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 081

NORTH SIDE

A. CALCULATE HEIGHT OF STORMWATER AT CHUTE PT. C

1. ASSUME DEPTH OF STORMWATER IS 4FT

a. OBTAIN n FROM EXHIBIT 7-1

i. CALCULATE V, ASSUME n = 0.035

$$V = \frac{1.49}{0.035}\left(\frac{432}{216.5}\right)^{2/3}(0.0086)^{1/2} = 6.27 \text{ FPS}$$

ii CALCULATE V_r

$$V_r = 6.27\left(\frac{432}{216.5}\right) = 12.5 \text{ FPS}$$

FROM EXHIBIT 7-1, n = 0.032

iii RECALCULATE V

$$V = 6.27\left(\frac{0.035}{0.032}\right) = 6.86 \text{ FPS}$$

iii RECALCULATE V_r

$$V_r = 6.86\left(\frac{432}{216.5}\right) = 13.7$$

FROM EXHIBIT 7-1, n = 0.032

b. RUN TR-55 USING INPUT DATA AND n = 0.032

c. FROM TR-55, PEAK FLOW = 179 CFS (FILE: NB3-1.55)

d. CHECK HEIGHT OF STORMWATER RUNOFF

$$A = \frac{179}{6.86} = 26 \text{ FT}^2$$

FROM TABLE 1 DEPTH OF FLOW < 1 FT

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: AAC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

b. RUN TR-55 USING INPUT DATA AND $n = 0.045$

c. FROM TR-55, PEAK FLOW = 179 CFS (FILE: FERMCO\NB3-2.55)

d. CHECK HEIGHT OF STORMWATER RUNOFF

$$A = \frac{179}{3.07} = 58\ FT^2$$

FROM TABLE 1, DEPTH OF FLOW < 2 FT OK

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

---------- Subarea #1 - 3 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.12	F					0.130
Shallow Concent'd		1250	.1024	U					0.067
Open Channel		350	.0086			.032432	216		0.014
						Time of Concentration =			0.21*

=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\NB3-1.55

TABULAR HYDROGRAPH METHOD 186 Version 2.00

Project : FERMCO - OSDF User: ~~EBB~~ BSS Date: 10-~~11~~ 15-95
County : BUTLER State: OH Checked: RSC Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

Total watershed area: 0.018 sq mi Rainfall type: II Frequency: 2000 years

---------- Subareas ----------

	3
Area(sq mi)	0.02
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.21*
(Used)	0.20
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) 3
11.0	5	5
11.3	7	7
11.6	10	10
11.9	47	47
12.0	90	90
12.1	165	165
12.2	179P	179P ← PEAK FLOW
12.3	107	107
12.4	56	56
12.5	37	37
12.6	29	29
12.7	23	23
12.8	19	19
13.0	16	16
13.2	14	14
13.4	12	12
13.6	11	11
13.8	10	10
14.0	9	9
14.3	8	8
14.6	7	7
15.0	7	7
15.5	6	6
16.0	5	5
16.5	5	5
17.0	4	4
17.5	4	4
18.0	4	4
19.0	4	4
20.0	3	3
21.0	3	3
26.0	0	0

FILE: FERMCO\NB3-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

001492

186

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-~~11~~ 15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

---------- Subarea #1 - 3 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.12	F					0.130
Shallow Concent'd		1250	.1024	U					0.067
Open Channel		350	.0086		.045108		108		0.032

Time of Concentration = 0.23*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\NB3-2.55

001493

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS 155 Date: 10-~~11~~ 15-95
County : BUTLER State: OH Checked: Asc Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

Total watershed area: 0.018 sq mi Rainfall type: II Frequency: 2000 years

---------- Subareas ----------

	3
Area(sq mi)	0.02
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.23*
(Used)	0.20
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) 3
11.0	5	5
11.3	7	7
11.6	10	10
11.9	47	47
12.0	90	90
12.1	165	165
12.2	179P	179P ← PEAK FLOW
12.3	107	107
12.4	56	56
12.5	37	37
12.6	29	29
12.7	23	23
12.8	19	19
13.0	16	16
13.2	14	14
13.4	12	12
13.6	11	11
13.8	10	10
14.0	9	9
14.3	8	8
14.6	7	7
15.0	7	7
15.5	6	6
16.0	5	5
16.5	5	5
17.0	4	4
17.5	4	4
18.0	4	4
19.0	4	4
20.0	3	3
21.0	3	3
26.0	0	0

FILE: FERMCO\NB3-255

P - Peak Flow * - value(s) provided from TR-55 system routines

NORTH SIDE - CHOKE PT C

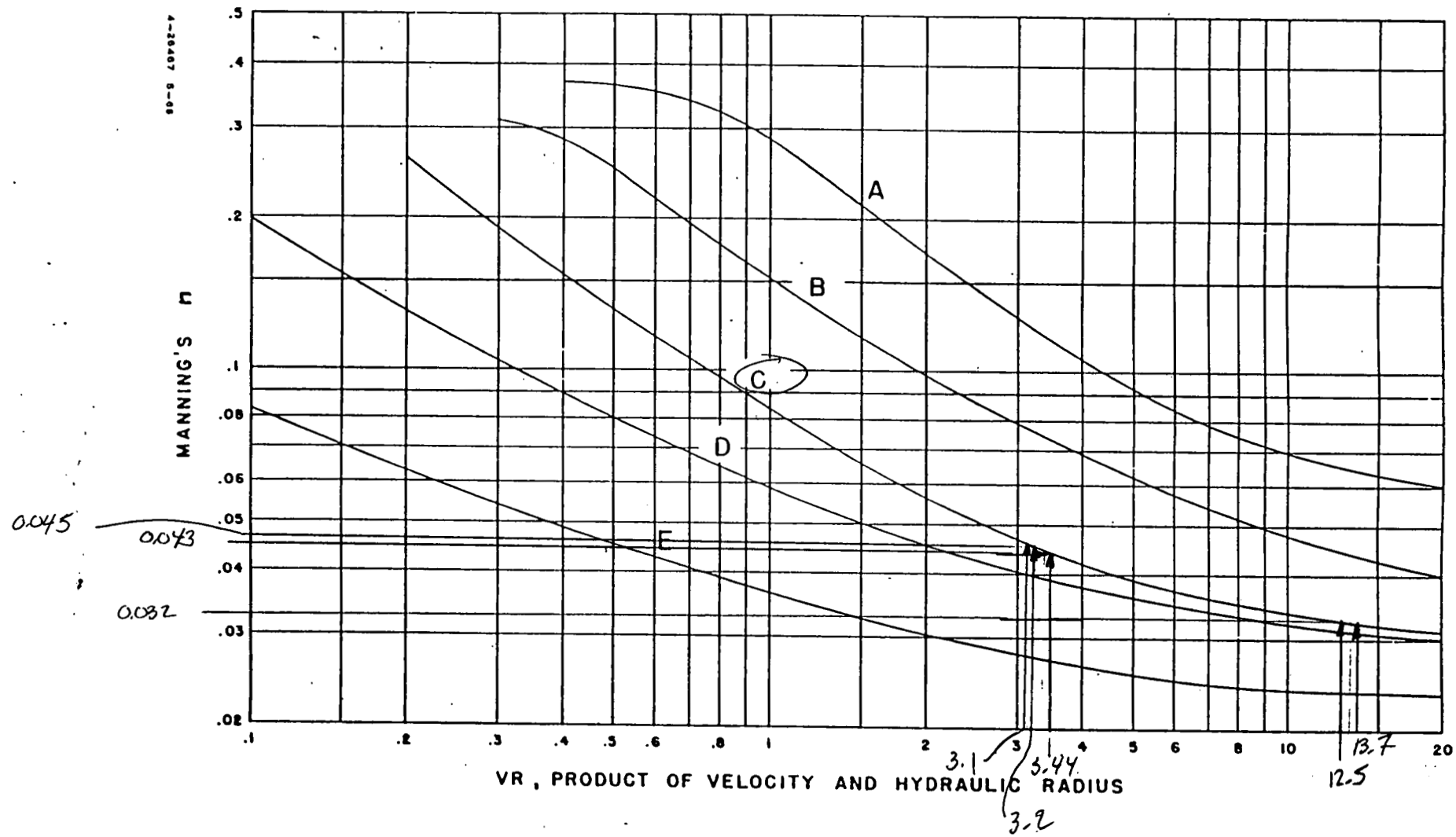


Exhibit 7-1. Manning's "n" related to velocity, hydraulic radius, and vegetal retardance.

USDA-SCS, 1986

001195

TT 186

Written by: ESS Date: 95/10/15 (YY/MM/DD) Reviewed by: RLC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSOF Project/Proposal No.: GE3900 Task No.: 08.1

B. CALCULATE HEIGHT OF STORM WATER AT CHOKE PT. D

1. ASSUME DEPTH OF STORMWATER IS 2 FT

a. OBTAIN n FROM EXHIBIT 7-1

i. CALCULATE V, ASSUME n = 0.045

$$V = \frac{1.49}{0.045}\left(\frac{108}{108.3}\right)^{2/3}(0.01)^{1/2} = 3.31 \text{ FPS}$$

ii. CALCULATE V_r

$$V_r = 3.31\left(\frac{108}{108.3}\right) = 3.30$$

FROM EXHIBIT 7-1, n = 0.043

iii. RECALCULATE V

$$V = 3.31\left(\frac{0.045}{0.043}\right) = 3.46 \text{ FPS}$$

iv. RECALCULATE V_r

$$V_r = 3.46\left(\frac{108}{108.3}\right) = 3.45 \text{ FPS}$$

FROM EXHIBIT 7-1, n = 0.043

b. RUN TR-55 USING INPUT DATA AND n = 0.043

c. FROM TR-55, PEAK FLOW = 31 CFS (FILE: FERMCO\NB4-1.55)

d. CHECK HEIGHT OF STORMWATER RUNOFF FROM COMBINED AREAS 3&4

$$A = \frac{(179+31)}{3.46} = 60.6 \text{ FT}^2$$

FROM TABLE 1, DEPTH OF FLOW < 2 FT OK

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-13-95
County : BUTLER State: OH Checked: Asc Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

---------- Subarea #1 - 4 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.02	F					0.266
Shallow Concent'd		300	.010	U					0.052
Open Channel		100	.01			.043108	108		0.008

Time of Concentration = 0.33*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\NB4-1.55

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TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS 85 Date: 10-~~11~~ 15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: PERIMETER ACCESS AND FLOOD PROTECTION BERM - 2000-YR STORM

Total watershed area: 0.004 sq mi Rainfall type: II Frequency: 2000 years

---------- Subareas ----------

	4
Area(sq mi)	0.00
Rainfall(in)	13.0
Curve number	98
Runoff(in)	12.76
Tc (hrs)	0.33*
(Used)	0.30
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) 4
11.0	1	1
11.3	1	1
11.6	2	2
11.9	5	5
12.0	11	11
12.1	21	21
12.2	31P	31P ← PEAK FLOW
12.3	31	31
12.4	21	21
12.5	13	13
12.6	9	9
12.7	7	7
12.8	5	5
13.0	4	4
13.2	3	3
13.4	3	3
13.6	2	2
13.8	2	2
14.0	2	2
14.3	2	2
14.6	2	2
15.0	1	1
15.5	1	1
16.0	1	1
16.5	1	1
17.0	1	1
17.5	1	1
18.0	1	1
19.0	1	1
20.0	1	1
21.0	1	1
26.0	0	0

FILE: FERMCO\NB41.55

P - Peak Flow * - value(s) provided from TR-55 system routines

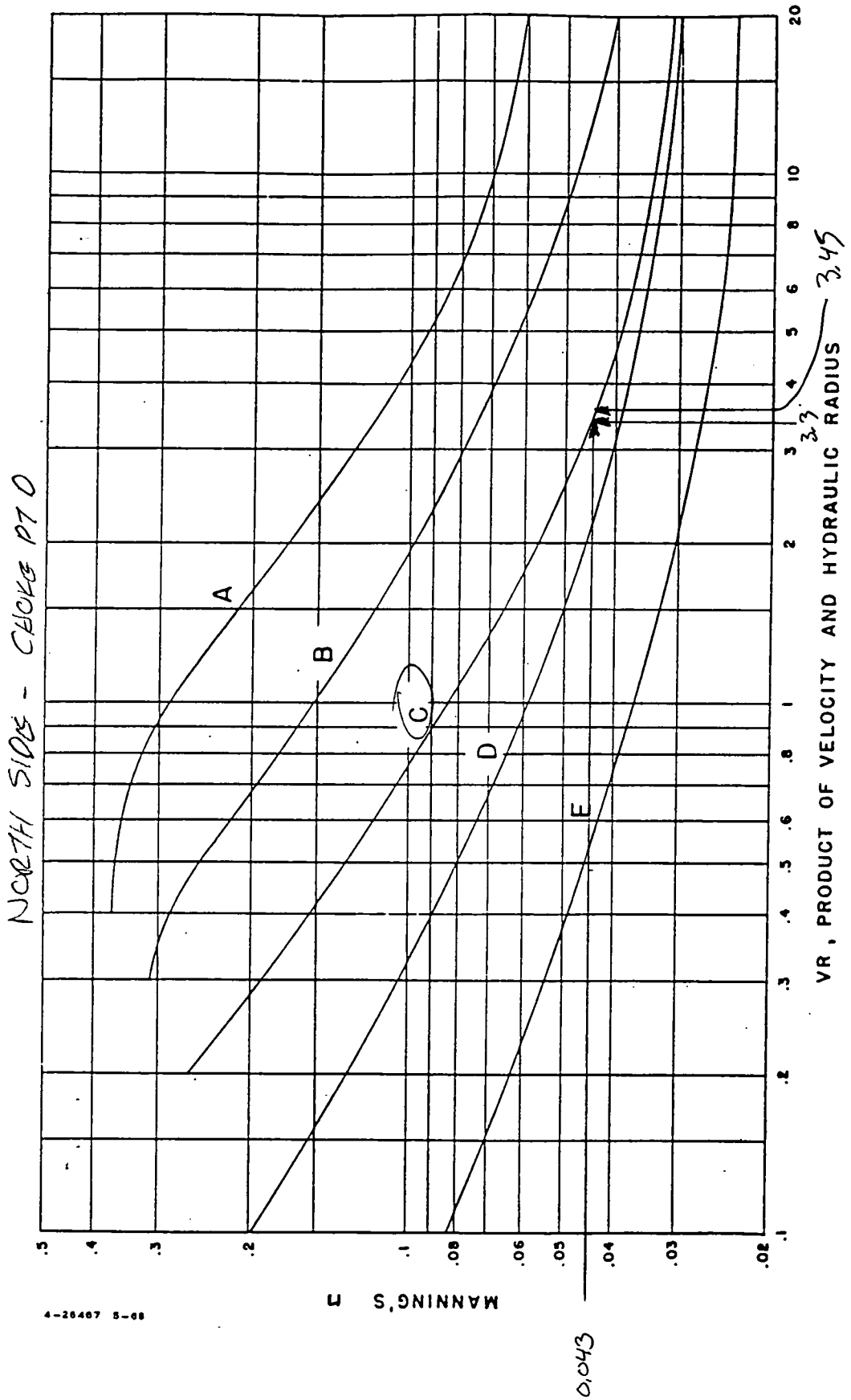

Exhibit 7-1. Manning's "n" related to velocity, hydraulic radius, and vegetal retardance.

Written by: ESS Date: 95/10/15 (YY MM DD) Reviewed by: AAC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08/

SUMMARY OF RESULTS:

1. HEIGHT OF BERM ON WEST SIDE OF OSDF SHOULD BE CONSTRUCTED TO AT LEAST ELEVATION 596 FT MSL.

2. HEIGHT OF STORMWATER RUNON TO EAST SIDE OF OSDF IS LESS THAN 4 FT.

3. HEIGHT OF STORMWATER RUNON TO NORTH OF OSDF IS LESS THAN 2 FT.

REFERENCES:

PARSONS, "2000-YEAR FLOOD AND PROBABLE MAXIMUM FLOOD, SITEWIDE FLOOD PLAIN DETERMINATION", REVISION A, AUG 1995.

USDA-SCS, "TR-55 MICROCOMPUTER PROGRAM SYSTEM", VERSION 2.0, WASHINGTON, DC, JUN 1986a.

USDA-SCS, "ENGINEERING MANUAL FOR CONSERVATION PRACTICES", WASHINGTON, DC, NOV 1986b.

Written by: ESS Date: 95/10/20 (YY MM DD) Reviewed by: AAC Date: 95/10/26 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.1

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATIONS PACKAGE

USDA-SCS TR-55

USDA-SCS, "URBAN HYDROLOGY FOR SMALL WATERSHEDS", TECHNICAL RELEASE 55 (TR-55), WASHINGTON, DC, JUN 1986.

USDA-SCS, "TR-55 MICROCOMPUTER PROGRAM SYSTEM", VERSION 2.0, README.1ST FILE, WASHINGTON, DC, JUN 1986.

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United States
Department of
Agriculture

Soil
Conservation
Service

Engineering
Division

Technical
Release 55

June 1986

Urban Hydrology for Small Watersheds

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Preface

Technical Release 55 (TR-55) presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs. These procedures are applicable in small watersheds, especially urbanizing watersheds, in the United States. First issued by the Soil Conservation Service (SCS) in January 1975, TR-55 incorporates current SCS procedures. This revision includes results of recent research and other changes based on experience with use of the original edition.

The major revisions and additions are—

1. A flow chart for selecting the appropriate procedure;
2. Three additional rain distributions;
3. Expansion of the chapter on runoff curve numbers;
4. A procedure for calculating travel times of sheet flow;
5. Deletion of a chapter on peak discharges;
6. Modifications to the Graphical Peak Discharge method and Tabular Hydrograph method;
7. A new storage routing procedure;
8. Features of the TR-55 computer program; and
9. Worksheets.

This revision was prepared by Roger Cronshey, Hydraulic Engineer, Hydrology Unit, SCS, Washington, DC; Dr. Richard H. McCuen, Professor of Civil Engineering, University of Maryland, College Park, MD; Norman Miller, Head, Hydrology Unit, SCS, Washington, DC; Dr.Walter Rawls, Hydrologist, Agricultural Research Service, Beltsville, MD; Sam Robbins (deceased), formerly Hydraulic Engineer, SCS, South National Technical Center (NTC), Fort Worth, TX; and Don Woodward, Hydraulic Engineer, SCS, Northeast NTC, Chester, PA. Valuable contributions were made by John Chenoweth, Stan Hamilton, William Merkel, Robert Rallison (ret.), Harvey Richardson, Wendell Styner, other SCS hydraulic engineers, and Teresa Seeman.

Revised June 1986

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Chapter 1: Introduction

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The conversion of rural land to urban land usually increases erosion and the discharge and volume of storm runoff in a watershed. It also causes other problems that affect soil and water. As part of programs established to alleviate these problems, engineers increasingly must assess the probable effects of urban development, as well as design and implement measures that will minimize its adverse effects.

Technical Release 55 (TR-55) presents simplified procedures for estimating runoff and peak discharges in small watersheds. In selecting the appropriate procedure, consider the scope and complexity of the problem, the available data, and the acceptable level of error. While this TR gives special emphasis to urban and urbanizing watersheds, the procedures apply to any small watershed in which certain limitations are met.

Effects of urban development

An urban or urbanizing watershed is one in which impervious surfaces cover or will soon cover a considerable area. Impervious surfaces include roads, sidewalks, parking lots, and buildings. Natural flow paths in the watershed may be replaced or supplemented by paved gutters, storm sewers, or other elements of artificial drainage.

Hydrologic studies to determine runoff and peak discharge should ideally be based on long-term stationary streamflow records for the area. Such records are seldom available for small drainage areas. Even where they are available, accurate statistical analysis of them is usually impossible because of the conversion of land to urban uses during the period of record. It therefore is necessary to estimate peak discharges with hydrologic models based on measurable watershed characteristics. Only through an understanding of these characteristics and experience in using these models can we make sound judgments on how to alter model parameters to reflect changing watershed conditions.

Urbanization changes a watershed's response to precipitation. The most common effects are reduced infiltration and decreased travel time, which significantly increase peak discharges and runoff. Runoff is determined primarily by the amount of precipitation and by infiltration characteristics related to soil type, soil moisture, antecedent rainfall, cover type, impervious surfaces, and surface retention. Travel time is determined primarily by slope, length of flow path, depth of flow, and roughness of flow surfaces. Peak discharges are based on the relationship of these parameters and on the total drainage area of the watershed, the location of the development, the effect of any flood control works or other natural or manmade storage, and the time distribution of rainfall during a given storm event.

The model described in TR-55 begins with a rainfall amount uniformly imposed on the watershed over a specified time distribution. Mass rainfall is converted to mass runoff by using a runoff curve number (CN). CN is based on soils, plant cover, amount of impervious areas, interception, and surface storage. Runoff is then transformed into a hydrograph by using unit hydrograph theory and routing procedures that depend on runoff travel time through segments of the watershed.

For a description of the hydrograph development method used by SCS, see chapter 16 of the SCS National Engineering Handbook, Section 4—Hydrology (NEH-4) (SCS 1985). The routing method (Modified Att-Kin) is explained in appendixes G and H of draft Technical Release 20 (TR-20) (SCS 1983).

Rainfall

TR-55 includes four regional rainfall time distributions. See appendix B for a discussion of how these distributions were developed.

All four distributions are for a 24-hour period. This period was chosen because of the general availability of daily rainfall data that were used to estimate 24-hour rainfall amounts. The 24-hour duration spans most of the applications of TR-55.

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One critical parameter in the model is time of concentration (T_c), which is the time it takes for runoff to travel to a point of interest from the hydraulically most distant point. Normally a rainfall duration equal to or greater than T_c is used. Therefore, the rainfall distributions were designed to contain the intensity of any duration of rainfall for the frequency of the event chosen. That is, if the 10-year frequency, 24-hour rainfall is used, the most intense hour will approximate the 10-year, 1-hour rainfall volume.

Runoff

To estimate runoff from storm rainfall, SCS uses the Runoff Curve Number (CN) method (see chapters 4 through 10 of NEH-4, SCS 1985). Determination of CN depends on the watershed's soil and cover conditions, which the model represents as hydrologic soil group, cover type, treatment, and hydrologic condition. Chapter 2 of this TR discusses the effect of urban development on CN and explains how to use CN to estimate runoff.

Time parameters

Chapter 3 describes a method for estimating the parameters used to distribute the runoff into a hydrograph. The method is based on velocities of flow through segments of the watershed. Two major parameters are time of concentration (T_c) and travel time of flow through the segments (T_t). These and the other parameters used are the same as those used in accepted hydraulic analyses of open channels.

Many methods are empirically derived from actual runoff hydrographs and watershed characteristics. The method in chapter 3 was chosen because it is basic; however, other methods may be used.

Peak discharge and hydrographs

Chapter 4 describes a method for approximating peak rates of discharge, and chapter 5 describes a method for obtaining or routing hydrographs. Both methods were derived from hydrographs prepared by procedures outlined in chapter 16 of NEH-4 (SCS 1985). The computations were made with a computerized SCS hydrologic model, TR-20 (SCS 1983).

The methods in chapters 4 and 5 should be used in accordance with specific guidelines. If basic data are improperly prepared or adjustments not properly used, errors will result.

Storage effects

Chapter 6 outlines procedures to account for the effect of detention-type storage. It provides a shortcut method to estimate temporary flood storage based on hydrologic data developed from the Graphical Peak Discharge or Tabular Hydrograph methods.

By increasing runoff and decreasing travel times, urbanization can be expected to increase downstream peak discharges. Chapter 6 discusses how flood detention can modify the hydrograph so that, ideally, downstream peak discharge is reduced approximately to the predevelopment condition. The shortcuts in chapter 6 are useful in sizing a basin even though the final design may require a more detailed analysis.

Selecting the appropriate procedures

Figure 1-1 is a flow chart that shows how to select the appropriate procedures to use in TR-55. In the figure, the diamond-shaped box labeled "Subareas required?" directs the user to the appropriate method based on whether the watershed needs to be divided into subareas. Watershed subdivision is required when significantly different conditions affecting runoff or timing are present in the watershed—for example, if the watershed has widely differing curve numbers or nonhomogeneous slope patterns.

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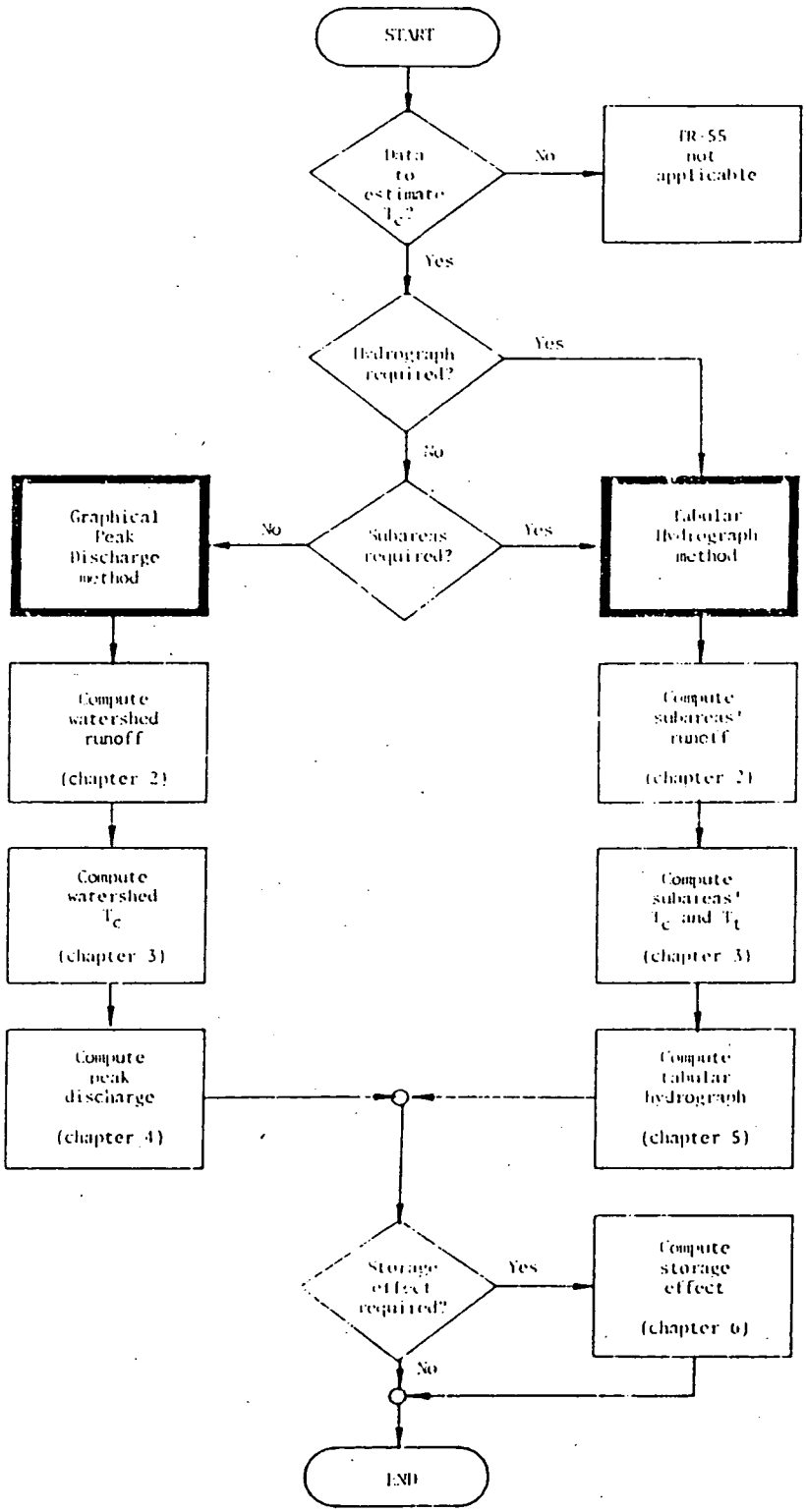

Figure 1-1.—Flow chart for selecting the appropriate procedures in TR-55.

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Limitations

To save time, the procedures in TR-55 are simplified by assumptions about some parameters. These simplifications, however, limit the use of the procedures and can provide results that are less accurate than more detailed methods. The user should examine the sensitivity of the analysis being conducted to a variation of the peak discharge or hydrograph. To ensure that the degree of error is tolerable, specific limitations are given in chapters 2 through 6. Additional general constraints to the use of TR-55 are as follows:

- The methods in this TR are based on open and unconfined flow over land or in channels. For large events during which flow is divided between sewer and overland flow, more information about hydraulics than is presented here is needed to determine T_c. After flow enters a closed system, the discharge can be assumed constant until another flow is encountered at a junction or another inlet.

- Both the Graphical Peak Discharge and Tabular Hydrograph methods are derived from TR-20 (SCS 1983) output. Their accuracy is comparable; they differ only in their products. The use of T_c permits them to be used for any size watershed within the scope of the curves or tables. The Graphical method (chapter 4) is used only for hydrologically homogeneous watersheds because the procedure is limited to a single watershed subarea. The Tabular method (chapter 5) can be used for a heterogeneous watershed that is divided into a number of homogeneous subwatersheds. Hydrographs for the subwatersheds can be routed and added.

- The approximate storage-routing curves (chapter 6) should not be used if the adjustment for ponding (chapter 4) is used. These storage-routing curves, like the peak discharge and hydrograph procedures, are generalizations derived from TR-20 routings.

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The TR-55 procedures have been incorporated in a computer program. The program, written in BASIC, requires less than 256K memory to operate and was developed for an MS-DOS operating system. Users of the program, however, still need to be familiar with the procedures in this TR. Features of the program include the following:

- The full screen (24 lines, 80 columns) is used to enter data. Flexibility of coding allows movement about the screen for quick data modifications.

- Function keys provide menu power to move to different modules (TR-55 chapters) within the program. Some keys are permanently defined while others vary by module.

- "Help" screens provide pertinent information to the user depending on location in the program. Two types of information are included: (1) define system operation and (2) describe input parameters.

- User files provide for optional entry of local data, such as rainfall-frequency, graphic peak discharge equation coefficients, and tabular hydrographs for other rainfall distributions.

Copies of the program can be obtained from—

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Telephone (703) 487-4650

TR-55 Microcomputer Program System Version Ver 2.0

Welcome to the TR-55 microcomputer program system. This README.1ST file is intended as an introduction to the system. The printed TR-55 document is the procedure reference for the methods. The program user should be familiar with both the computer hardware and the TR-55 document prior to using the program.

* * * COMPUTER REQUIREMENTS * * *

The program system will run under PC-DOS or MS-DOS provided that the special keys (function, arrow, HOME, END, INS, DEL, PgUp and PgDn) have the same extended ASCII codes as used on IBM compatible equipment. Only one floppy disk drive is required but two drives are recommended. About 280K RAM is needed to load the program.

* * * TR-55 SYSTEM FILES * * *

The system consists of two diskettes. Diskette #1 contains the executable program file, README and other required files. Diskette #2 contains the tabular hydrograph files, an executable system configuration file as well as samples of a county rainfall, a local soil name-hydrologic soil group and several input data files.

EXECUTABLE PROGRAM FILE -----

The TR-55 program is a compiled BASIC language executable file. It is a collection of the seven executable files used in the previous version of the system. A main menu, with the various TR55 chapters as choices, controls the program system. The remaining parts of the program can be categorized as follows:

Primary functions - Graphical Peak Discharge Method (Chapter 4)
Tabular Peak Discharge Method (Chapter 5)
Temporary Storage (Chapter 6)

Support functions - Runoff curve number (CN) (Chapter 2)
Time of concentration (Tc) and travel time through a subarea (Tt) (Chapter 3)

Utilities - Print (print current data and calculations)
Load (reload previously saved data)
Save (save current data)
Zero (initial data)

Some limitations that are included are:

Maximum of 10 subareas can be used for CN, Tc, Tt and tabular peak discharge computations.

Maximum of 7 rainfall frequencies can be used in the graphical peak discharge computations.

BASIC DATA FILES -----

The TR55.CFG file describes the drive designations available on the current system, the display monitor used and the tone of the "beep". Both color and monochrome are supported with the user free to select the color combinations desired. The use of the CONFIG.EXE program to create a TR55.CFG file is described in the section "CREATING A WORKING COPY OF TR-55 SYSTEM". Several sample xxx.CFG files are on the TR55 DISK#2.

The COVER.DAT file contains the numerous Table 2-2 land use descriptions along with appropriate hydrologic conditions and runoff curve numbers for the four soil groups. The file is loaded when the CN support function is used and for the PRINT utility.

Four tabular hydrograph files are available, one for each of the SCS TR-55 rainfall distributions (Type I,IA,II,III). The file for the selected rainfall distribution is used in the computation step in the tabular method. Only the file required need be available on the mounted diskettes. The files are appropriately titled TYPEI.TBL, TYPEIA.TBL, TYPEII.TBL, and TYPEIII.TBL.

OPTIONAL DATA FILES -----

Optional data files are user created files that the system reads if they are present, but will not prevent operation if they are not there. Five such files can be used, but only two (COUNTY.RF and SOILS.TYP) are expected to be widely used. The other three are briefly described to illustrate the flexibility they can add to the system. If any of the optional files are used the file naming convention given below must be adhered to for the TR-55 program to recognize them.

The COUNTY.RF file contains rainfall-frequency data for up to seven frequencies by county name. As many counties as desired may be included. The file can make life a lot easier for the system user, even if the user always applies TR-55 in only one county. The COUNTY.RF file can be created using a locally available ASCII editor and the following record formats.

Record 1 - Number of frequencies (maximum seven) included, followed by the frequencies. Separate each item with a comma or at least one space.

Record 2 - County name (all uppercase) with quotes (") around it, followed by the rainfall amounts (inches) corresponding to the Record 1 frequencies. Separate each item with a comma or at least one space.

Record 3+- Same as record 2. Continue with as many counties as needed for your state or area.

A sample COUNTY.RF file for the state of Maryland is included.

For those users that require county rainfall data from more than one state, separate rainfall files can be helpful (especially if the states have a county with the same name). To accommodate multiple state files, change the COUNTY.RF file name to COUNTY.xx where xx is the two letter state abbreviation. When a two letter state abbreviation and a

county name are entered as part of input, the appropriate COUNTY.xx file is searched for. If found it is used, if not the COUNTRY.RF file is used if it exists. (File search time is reduced when COUNTY.xx is used instead of COUNTY.RF.)

The SOILS.TYP can contain soil names and their applicable hydrologic soil groups (HSG). The file contents can be displayed in the Runoff Curve Number portion of the program by pressing the F10 key. No computation nor automatic data entry are done with this file. Its purpose is solely as a system user look up table.

The file can be created by using any locally available ASCII editor using the following limitations:

Maximum line length is 30 characters (suggest 25 characters for soil name and 5 for HSG)
Maximum of 100 lines in file

A sample SOILS.TYP file is included as an example. To view the sample file use the DOS command

```
TYPE A:SOILS.TYP |MORE
```

from the DOS prompt with TR55 Disk #1 in drive A.

The TYPE.RF, DISTRIB.RF, and VOLUME.RF files allow a rainfall distribution other than those in TR-55 to be used. The TYPE.RF file contains regression coefficients for peak discharge curves similar to those found in TR-55 Exhibit 4-. The DISTRIB.RF file contains tabular hydrographs similar to those found in Exhibit 5-. The VOLUME.RF file contains regression coefficients for a volume-discharge curve similar to those found in Figure 6-1.

The development of the background material required to generate these files is beyond the scope of TR-55. Because of the complexity of procedure no details are given here. For guidance on how to develop these files contact your NTC hydraulic engineer. A TYPE.RF and DISTRIB.RF file for the Delmarva (DElaware,MARyland, VirginiA) unit hydrograph and Type II rainfall is available from the NNTC (Chester, Pa). A similar file for the DELMARVA unit hydrograph and Type III rainfall is available from the SNTC (Ft. Worth, TX).

SAVED INPUT FILES -----

When using the TR-55 system, data is entered on input screens. Once entered, it may be desirable to keep the data for future reference. Both a SAVE and LOAD function are part of the TR-55 system for filing and retrieving data. The user devises a file name (up to eight characters) to which a ".55" is added by the system. The ".55" will identify the file as TR-55 user data. Several sample input files are on diskette #2.

* * * CREATING A WORKING COPY OF TR-55 SYSTEM * * *

Before running TR-55 for the first time a "working" copy of the program and data files should be made. The working copy will be the one used while the original diskettes are kept in a safe place. The

following files names, sizes and dates should be on the original two 5 1/4" program diskettes. The division of files between the two 5 1/4" diskettes follows:

Volume TR55#1 VER2

COVER	DAT	7040	4-15-86	README	EXE	38274	4-26-88
README	1ST	18139	1-16-90	TR55	EXE	264144	1-15-90

4 File(s) 33792 bytes free

Volume TR55#2 VER2

CGA	CFG	197	1-15-90	EX6-1	55	442	1-16-90
CONFIG	EXE	88096	1-15-90	EX6-2	55	453	1-16-90
COUNTY	RF	1633	4-15-86	EX6-3	55	466	1-16-90
EGA	CFG	197	1-15-90	EX6-4	55	467	1-16-90
EX2-1	55	488	1-16-90	SOILS	TYP	1066	1-15-90
EX2-2	55	527	1-16-90	TR55	CFG	320	1-15-90
EX2-3	55	562	1-16-90	TYPEI	TBL	46720	4-15-86
EX2-4	55	555	1-16-90	TYPEIA	TBL	46720	8-13-86
EX3-1	55	640	1-16-90	TYPEII	TBL	46848	4-15-86
EX4-1	55	952	1-16-90	TYPEIII	TBL	46720	4-15-86
EX5-1	55	2390	1-16-90	VGA	CFG	197	1-15-90
EX5-2	55	2450	1-16-90				

23 File(s) 60416 bytes free

FLOPPY DISK SYSTEM

Following instructions in your computer system operating manual, format two new diskettes. On one of the diskettes copy the file COMMAND.COM from the disk used to boot up your system. To this diskette add:

1. The "TR55.EXE" file (from TR55 DISK#1).

2. The "COVER.DAT" file (from TR55 DISK#1).

3. The appropriate "TYPExxx.TBL" file for your locale (from TR55 DISK#2). See the Figure B-2 rainfall distribution map in TR-55.

4. Run the configuration program by entering CONFIG (from TR55 DISK#2). One at a time select the: Color Scheme; Device Search Sequence; and Sound Generation options to set colors, available disk drives and tone of BEEP. Include only the disk drives available in your system in the Device Search Sequence. Be sure to save the selections you make (using the File Input/Output option) on the working copy diskette with the name TR55 before loading. (The software will add ".CFG" extension to the file name.)

   There is a sample TR55.CFG file included in the program diskettes with the capability for adding the user name, county, and state automatically to the input and output screen headings. To do this, fill in the appropriate data in the sample TR55.CFG file with a local editor, being careful to line it up correctly under the other

entries. Be sure that the Device Search Sequence entries conform to the machine drives available, and save the file.

One can use this sample TR55.CFG file instead of running the CONFIG.EXE program to set one up. All that is necessary is that the user check and correct, if needed, the entries in the Device Search Sequence.

The above files are all that are required to operate the TR-55 program system.

The second formatted diskette can be used to hold the following files from TR55 DISK#2. This diskette may only be needed while learning to use the program.

1. "COUNTY.RF" and "SOILS.TYP" files. You will probably replace these with localized ones of your own.

2. The sample data files which end in ".55".

3. The remaining "TYPExxx.TBL" files which may be needed with the sample files or for training purposes.

HARD DISK SYSTEM

Create a subdirectory (TR55) on your hard disk for the TR55 files using your DOS Make Directory (MD) command The syntax for the command from the hard disk prompt is:

```
MKDIR \TR55
```

Move to the TR55 subdirectory using the DOS change directory (CD) command as follows:

```
CD \TR55
```

Using the two TR-55 original diskettes copy all of the files referenced above for the floppy disk system onto the hard disk. Also create the TR55.CFG file by executing CONFIG.

(If the disk drive designation and TR55 subdirectory name are added to your systems PATH command, TR55 can be executed from anyplace regardless of what is currently the default drive and directory. See your DOS manual for more information on the PATH command.)

* * * HELPFUL OPERATING HINTS * * *

HELP screens are available to assist the user. They are accessed by pressing function key F1 for pertinent information about the current part of the system being viewed. Reviewing (and printing using the PrtSc key) the HELP screens as you go through the TR-55 system the first time is a good idea. Remember, the reference for the TR-55 program is the 1986 TR-55 revision.

When you are ready to load the new TR55 on your system, copy any

data files (those ending in ".55") you wish to save from the TR55 directory to a floppy diskette. You do not need to copy the examples (EX2-1.55, etc.) as they are included in your new diskettes. Then delete all the files left in the TR55 directory and load in the new TR55 program diskettes.

If you have data SAVEd with previous program versions, the files may be unusable with this version. Both LOAD and SAVE utilities have been rewritten to make the saved data files more compact.

* * * CHANGES FROM PREVIOUS VERSION * * *

1. The seven executable modules were combined into one, reducing size of overall program and eliminating load time between modules. This also eliminated the truncated print problem which occurred on certain buffered printers.

2. Use of TR55.CFG file allows recognition of color monitors and different disk drive configurations. User can control colors and drives.

3. Use of the SOILS.TYP file provides local soil names and their hydrologic soil group(s) as a look up reference.

4. Text strings no longer accept " as a valid character because of problems which occured when data was SAVEd and reLOADed. When a " is entered an apostrophe (') is used instead.

5. Computed CN's of less than 40 now result in a warning message and no transfer of the value to one of the primary functions. The older program version would not allow user to leave CN portion of program until CN was raised.

6. Rainfall types can be entered in both upper and lower cases.

7. Correct display of small (<0.10 sq mi) drainage areas on tabular input screen when area was converted from acres entered in the CN portion of program. (Computations were OK.)

8. Transfer of computed Tc values > 2 hours are not permitted to tabular method.

9. Method used to find closest tabular Tc or Tt table values is revised. When such values were exactly halfway between table values, inaccuracies in storing floating point numbers may have made the value appear to be closer to one table value then the other.

10. Correct printing of rounded Tc and Tt values as well as addition of an extra decimal place to Manning's n.

11. Display of drainage area and rainfall data in the temporary storage portion of program when data is loaded directly to that screen.

12. Eliminate many of the "beeps" and user verification required when function key or ESC are pressed.

13. Allow user to select the path in addition to drive on both

LOADing and SAVEing.

14. Add Range as an acceptable sheet flow surface type.

15. Where program control will go when ESC key is pressed is now displayed at the bottom of most screens with the active function keys.

* * * STARTING UP THE TR-55 SYSTEM * * *

Now the fun begins ---- Put the working copy of diskette #1 on the default disk drive or CD to the TR55 subdirectory on the hard disk and enter "TR55".

HAPPY COMPUTING from the original TR-55 Computer Program Team

Ted Burns	SCS	Morgantown, West Virginia
Roger Cronshey	SCS	Washington D.C.
James Hailey	SCS	Temple, Texas
Clint Liezert	SCS	Medina, Ohio
Ralph Roberts	ARS	Beltsville, Maryland

Program changes for the current version were made by:

Ralph Roberts and Roger Cronshey

12.3 Borrow Area Stormwater Management

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: BORROW AREA STORMWATER MANAGEMENT

Computations By: (Cognizant Engineer)
Signature: Daniel G. Pass — Date: 10 OCT. 95
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: Daniel B. Wisialowski — Date: 23 OCT 95
Printed Name and Title: DANIEL B. WISIALOWSKI, ASSISTANT PROJECT ENGINEER

Computations Checked by:
Signature: Patrick B. Rhodes — Date: 20 OCT 1995
Printed Name and Title: PATRICK B. RHODES, STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Daniel G. Pass — Date: 23 OCT 95
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Approved by: (PDP)
Signature: Kara Olen — Date: 10/23/95
Printed Name and Title: Kara Olen, Asst. Proj Engr.

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 24 Oct 95
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	30% submittal	24 Oct 95	NA	NA	NA
B	Preliminary Design - EPA Submitted	15 Dec 95	[illegible]		

GeoSyntec Consultants

Written by: Daniel Pass Date: 15 Dec 1995 Reviewed by: K-Olen Date: 95-12-15

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.12

BORROW AREA STORMWATER MANAGEMENT

EXECUTIVE SUMMARY

This calculation was prepared to develop the stormwater management system for the East Field borrow area (borrow area). The borrow area is approximately 80 acres and is located in the south east corner of the Fernald site. The South Entrance road divides the borrow area approximately in half.

The computer program TR-55 (USDA-SCS, 1995) was used to calculate peak runoff rates for both the existing and proposed final conditions for the borrow area for the design storm (i.e., the 25-year, 24-hour storm). The results indicated that the total peak flow to Paddy's Creek for the proposed final conditions will not exceed the total peak flow to Paddy's Creek for the existing conditions and a stormwater detention basin is therefore not required. Storm water management structures consisting of one dual 30-inch diameter culvert system, one 30-inch diameter culvert, two rip-rap aprons, and three trapezoidal grass-lined drainage swales were designed as permanent stormwater management features for the borrow area.

GEOSYNTEC CONSULTANTS

Written by: Daniel Pass Date: 10October 95 Reviewed by: Patrick Rhodes DBW 23 OCT 95 Date: 20 OCT 19 19 OCT 1995

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

Borrow Area Stormwater Management: Collection and Verification of Engineering Data.

Purpose: The purpose of this document is to summarize and verify the engineering data used to design the stormwater management system for the borrow area. This data will be used to design, for the borrow area, permanent (i.e., long-term) stormwater management structures.

Scope: Collection and verification of data related to precipitation type and amount, ground surface soil type, cover condition and slope are presented here. Sources of data and the determination of design values are also presented. Data was collected from site-specific information and published correlations.

Design: Engineering data is used to calculate the peak runoff at the borrow area for the 25 yr.-24 hr. storm event for the existing and proposed final grades. The calculated results are used to design storm drainage structures including culverts and swales.

Written by: Daniel Pass Date: 10 October 95 Reviewed by: Patrick Rhode DBW 23 OCT 95 Date: 20 OCT 1995

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

KW 10/23/95

1) Precipitation: TR-55 requires the 2 yr.-24 hr. rainfall, the design rainfall (i.e.. the 25 yr.-24 hr. rainfall) and the SCS 24-hour rainfall distribution type as part of the program input.

Rainfall depth: These values were obtained from ~~USDA-SCS (1986, pp. B-4, B-5), see Figures 1 and 2.~~ A REPORT BY PARSONS USING TR55 FOR THE 25-YR.-24HR STORM AND TR55 + TP-40 FOR THE 2-YR.-24HR. STORM. SEE TABLE 10

- 2 yr.-24 hr. storm event rainfall = ~~2.94 in~~. 2.55 IN ✓ REV 1, 23 OCT 95
- 25 yr.-24 hr. storm event rainfall = ~~4.74 in~~. 4.7 IN ✓

Rainfall distribution type: The type was obtained from USDA-SCS (1986, pp. B-1) in accordance with the geographic location of the site, see Figure 3.

- SCS 24-hour rainfall distribution type is II ✓

2) Surficial Soil - Hydrologic Soil Group: TR-55 requires the classification of the drainage area surface soils according to Hydrologic Soil Group, HSG (i.e. . either A, B, C or D). The HSG is used in determination of Runoff Curve Numbers.

Predevelopment Conditions: Table 1 lists the names of surface soils located within the Borrow watershed area and their associated HSG classifications [See Tables A1 through A6 (USDA, 1986),]. The distribution of these soils across the site is shown in Figure 4 (USDA, 1992). Surface soils classify as group B for approximately 80% of the total drainage area and as group C for the remaining 20%.

Table 1: Surface soils located in borrow area, with HSG classification

Map Symbol	Soil Name	Hydrologic Soil Group
FeA, FdA	Fincastle Silt Loam	C
MaB, MaC2	Markland Silty Clay Loam	C
McA	Martinsville Silt Loam	B
MoE2	Miamian-Hennepin Silt Loams	C
RdA	Raub Silt Loam	C
RwB2	Russell Silt Loam	B
XfA, XfB2	Xenia Silt Loam	B

✓

Restored Conditions: The present topsoil covering the borrow area will be removed at the start of the borrow area development and replaced after excavation of borrow

is complete. Thus the topsoil layer for the restored conditions will be a mix of the existing topsoil layer soils. A review of existing geotechnical studies indicates that clay percentages decrease with depth to the bottom of the targeted brown till borrow material. The decreasing clay percentages suggests that the surface soils in the restored conditions will trend towards a better draining HSG classification than those of the predevelopment conditions.

Design HSG Classification: For analysis a HSG classification of C will be used for predevelopment and restored conditions, for the following reasons:

1. For comparison of runoff for predevelopment and restored conditions, the use of the same HSG for both predevelopment and restored conditions is conservative as the more permeable near surface soils of the restored conditions will result in less runoff than the existing near surface soils.
2. For the design of storm drainage structures, the selection of a group C for the whole drainage area is conservative (results in higher calculated inflows).

3) Surface Features: TR-55 input requires surface features data including topography, ground cover type and flow characteristics for evaluation of runoff, time of concentration and travel times.

Topography: The ground surface topography of the borrow area is shown in Figure 5. Elevation contours are based on a 1992 site flyover, provided by FERMCO.

Ground Cover Type and Hydrologic Condition: Descriptions of vegetal cover within the borrow watershed area were obtained from aerial photographs of the site.

- Predevelopment conditions-
  The existing vegetal cover for drainage areas north of Willey Rd. is grassland (US Dept. of Energy, 1994) (See Figure 6). Grasses are long and in good condition. The existing vegetal cover for the watershed area south of Willey Rd. consists of straight row crops generally aligned perpendicular to the direction of surface water flow that area.
- Restored Conditions-
  On-site areas will be reseeded. Hydrologic conditions are expected to be good. No grazing or mowing (i.e., for hay) will be permitted.

Based on the above ground cover descriptions, the following classifications for Ground Cover type and Hydrologic Condition were selected within the TR-55 program (USDA, 1986a):

Written by: Daniel Pass Date: 16October 95 Reviewed by: PBL DBN 23 OCT 95 Date: 20 OCT 1995

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

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Table 2: Borrow area ground cover, type and hydrologic condition[1].

Condition	Location	Ground Cover Type	Hydrologic Condition
Predevelopment	North Willey Rd.	Pasture, Grassland or Range	Good
	South Willey Rd.	Row Crop, Straight with Crop residue Cover	Good
Restored	North Willey Rd.	Meadow	not applicable
	South Willey Rd.	Row Crop, Straight with Crop residue Cover	Good

[1]Obtained from USDA (1986a), See Table A7 and A8.

Manning's Roughness Coefficients:

- Manning's roughness coefficients for overland (sheet) flow and channel flow are shown in Tables 3 and 4.

Condition	Location	Surface description	Manning Coefficient[1]	Corresponding TR55 Surface Code[2]
Predevelopment	North of Willey Rd.	Range (natural)	0.13	E
	South of Willey Rd.	Cultivated soils Residue cover > 20%	0.17	D
Restored	North of Willey Rd.	Range (natural)	0.13	E
	South of Willey Rd.	Cultivated soils Residue cover > 20%	0.17	D

[1]Obtained from USDA (1986a), See Table A9.
[2]Obtained from USDA (1986b), TR-55 computer program

Table 3: Manning's roughness coefficients for overland (sheet) flow.

Written by: Daniel Pass Date: 10October 95 Reviewed by: RCR DRW 23OCT95 Date: 20OCT1995

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

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Table 4. Manning Coefficients used for open channel flow

Condition	Location	Channel type	Channel Description	Manning Coefficient, n
Predevelopment	North of Willey Rd.	Flood plain, pasture and no brush	High grass	0.035[1]
	South of Willey Rd.	Flood plain, cultivated area	Mature field crops	0.040[1]
Restored	North of Willey Rd.	Flood plain, pasture and no brush	High grass	0.035[1]
	South of Willey Rd.	Flood plain, cultivated area	Mature	0.040[1]
Drainage Structures, predevelopment and restored		Culvert	Reinforced Concrete	0.012[2]
		Swale	Grassed	0.033[1]

[1] ~~Chow, 1959 - See Table A10~~ DW, 23 OCT 95

[2] American Iron and Steel Institute, 1983

Written by: Daniel Pass Date: 10October 95 Reviewed by: PBR DBW 23OCT95 Date: 20 OCT 1995

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

KW 10/23/95

References:

1. American Iron and Steel Institute, "Handbook of Steel Drainage & Highway Construction Products", 3rd edition., Washington, DC, 1983.

2. Chow, Ven Te, "Open-Channel Hydraulics", New York, NY, 1959.

3. Parsons, "On-Site Disposal Cell - Pre-design Activities Engineering Report - Operable Unit 2, Engineering Report", Rev. 0, April 1994.

4. Topographic plan, provided by FERMCO, August 1995.

5. United States Department of Energy, "Remedial Investigation - Operable Unit 5", March 1995.

6. United States Department of Agriculture - Soil Conservation Service, "Soil Service of Hamilton County, Ohio", Washington, DC, August 1982.

7. United States Department of Agriculture - Soil Conservation Service, Engineering Division, "TR-55 Microcomputer Program System", Washington, DC, June 1986a, 162 p.

8. United States Department of Agriculture - Soil Conservation Service, Engineering Division, "Urban Hydrology for Small Watersheds" Technical release 55, Washington, DC, June 1986a, 162 p.

9. PARSONS, "2000-YEAR FLOOD AND PROBABLE MAXIMUM FLOOD - SITEWIDE FLOODPLAIN DETERMINATION - OPERABLE UNIT 2", REVISION A, AUGUST 1995

REV 1 23OCT95

10. UNITED STATES DEPARTMENT OF COMMERCE - NATIONAL WEATHER SERVICE, "RAINFALL FREQUENCY ATLAS OF THE UNITED STATES FOR DURATIONS FROM 1 TO 100 YEARS", WASHINGTON, DC, MAY 1961.

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REPLACED BY REVISION 1 23 OCT 95

KW 10/23/95

DBW 95/10/23

TABLE ~~1~~ 10

RAINFALL DEPTH FOR A GIVEN DURATION (INCHES)

DURATION (YEARS)	TIME							
	HYDRO-35			TP-40				
	5 MIN	15 MIN	60 MIN	2 HOURS	3 HOURS	6 HOURS	12 HOURS	24 HOURS
2	0.387	0.739	1.223	1.408	1.54	1.848	2.2	2.552
5	0.49	0.979	1.69	2.016	2.112	2.496	2.88	3.072
10	0.564	1.139	1.99	2.277	2.475	3.069	3.465	4.059
25	0.65	1.34	2.38	2.6	3.0	3.4	4.0	4.7
50	0.72	1.49	2.67	3.0	3.25	3.9	4.2	5.2
• 100	0.78	1.64	2.95	3.3	3.6	4.1	5.0	5.6
• 500	0.93	2.1	4.3	5.2	5.9	7.3	8.5	9.4
2000	1.2	2.6	5.8	7.2	8.2	10.2	12.0	13.0
10,000	1.4	3.4	8.2	10.5	12.0	15.5	18.0	19.2
100,000	1.9	5.0	13.3	17.7	20.8	27.4	31.8	33.4
	DESIGN OF SMALL DAMS					HMR-51		

24-HR STORM

2-YEAR

25-YEAR

NOTE: Rainfall Points For 2, 5, and 10 year rainfall events were adjusted per TP-40. Values for the 500, 2000, and 10,000 Year Events were interpolated from Figure 3.

• These values are used on PH Records for HEC-1.

From 100 year & 500 year Flood Plain Determination Sitewide

Parsons, Sept. 93 Rev. 0 A

GP

SYS #142 C:\HECPACK\P091\TABLE1.CAL

Daniel Pass 23 Oct. 95 FERMCO/OSDF GE3900, Task 8.11

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DBW 95/10/23

Exhibit A-1, continued: Hydrologic soil groups for United States soils

EYOTA	A	FARRAGUT	C	FETTIC	D	FLATRON	D	FORKWOOD	B
EYRE	D	FARRAR	B	FETZER	C	FLATTOP	D	FORMADER	C
EZBIN	B	FARRELL	B	FEZ	C	FLAXTON	B	FORMAN	B
FABIUS	B	FARRENBURG	B	FIANCER	D	FLEAK	D	FORMDALE	B
FACEVILLE	B	FARROT	C	FIANDER, DRAINED	C	FLEER	A/D	FORNEY	D
FACEY	B	FARSON	B	FIAT	C	FLEISCHMANN	D	FORNOR	B
FACTORY	C	FARSON, WET	C	FIDALGO	C	FLEMING	C	FORREST	C
FACTORY, MOIST	B	FARVA	C	FIDDLER	C	FLEMINGTON	D	FORSEER	C
FADDIN	D	FARVANT	D	FIDDLETOWN	B	FLETCHER	B	FORSEY	B
FADOLL	B	FASHING	D	FIDDYMENT	D	FLEWSIE	B	FORSGREN	C
FAGAN	C	FASKIN	B	FIELD	C	FLEX	D	FORSYTH	A
FAGASA	C	FATHOM	A	FIELDCREEK	B	FLO	A	FORT COLLINS	B
FAHEY	B	FATIMA	B	FIELDING	B	FLOER	D	FORT MEADE	A
FAIM	C	FATTIG	C	FIELDON	B/D	FLOKE	D	FORT MOTT	A
FAIM, MOIST	B	FAUNCE	A	FIFER	D	FLOM	B/D	FORT ROCK	C
FAIRBANKS	B	FAUNSDALE	D	FIFIELD	C	FLOMATON	A	FORTANK	C
FAIRBURN	D	FAUQUIER	C	FILION	D	FLOMOT	B	FORTESCUE	C/D
FAIRCHILD	C	FAUSSE	D	FILIRAN	D	FLOODWOOD	B	FORTUNA	D
FAIRDALE	B	FAVRET	C	FILLMORE	D	FLORAHOME	A	FORTWINGATE	C
FAIRFAX	B	FAWIN	B	FINCASTLE	C	FLORALA	C	FORTYFOUR	C
FAIRFIELD	B	FAX	C	FINCH	C	FLORENCE	C	FORVIC	C
FAIRHAVEN	B	FAXON	B/D	FINCHFORD	A	FLORESVILLE	C	FORWARD	B
FAIRLIE	D	FAYETTE	B	FINDOUT	D	FLORIDANA	B/D	FOSS	B
FAIRLO	B	FAYETTEVILLE	B	FINGAL	C	FLORIDANA,	D	FOSSILON	D
FAIRMOUNT	D	FAYWOOD	C	FINGEROCK	D	DEPRESSIONAL		FOSSUM	A/D
FAIRPLAY	B	FE	D	FINLAND	C	FLORIDANA, FLOODED	D	FOSTER	C
FAIRPOINT	C	FEARS	B	FINLEY	B	FLORIN	C	FOSTORIA	B
FAIRPORT	C	FEATHERLEGS	B	FINLEYPOINT	B	FLORISSANT	C	FOUNTAIN	D
FAIRWAY	C	FEATHERSTONE	D	FINNERTY	D	FLORITA	B	FOUR STAR	C
FAIRYDELL	C	FEDJI	A	FINO	B	FLOTAG	B	FOUR STAR, DRAINED	B
FAIRYLAWN	D	FEDORA	B/D	FINOL	C	FLOWELL	C	FOURCHE	B
FAJARDO	C	FEDSCREEK	B	FIONE	B	FLOWEREE	B	FOURLOG	D
FALAYA	D	FELAN	B	FIFADA	C	FLOYD	B	FOURME	B
FALBA	D	FELCHER	B	FIREBALL	B	FLUETSCH	B	FOURMILE	B
FALCON	D	FELDA	B/D	FIREBOX	B	FLUGLE	B	FOX	B
FALFA	C	FELDA,	D	FIRESTEEL	B	FLUKER	C	FOXCREEK	D
FALFURRIAS	A	DEPRESSIONAL		FIRESTONE	C	FLUVANNA	C	FOXCREEK, DRAINED	C
FALK	C	FELICITY	A	FIRMAGE	B	FLYBOW	D	FOXHOME	B
FALKIRK	B	FELIPE	D	FIRO	D	FLYGARE	B	FOXMOUNT	C
FALKNER	C	FELIZ	B	FIROKE	B	FLYNN	B	FOXOL	D
FALLBROOK	B	FELKER	B	FIRSTVIEW	C	FLYNNCOVE	B	FOXTON	C
FALLCREEK	C	FELLOWSHIP	D	FIRTH	C	FOAD	C	FOXWORTH	A
FALLERT	B	FELOR	B	FIRTH, DRAINED	B	FOARD	D	FRADDLE	B
FALLON	C	FELT	B	FISHERMAN	D	FOEHLIN	B	FRAILEY	B
FALLON, NONFLOODED	B	FELTA	C	FISHERS	B	FOIDEL	B	FRAILTON	D
FALLSAM	D	FELTHAM	B	FISHFIN	D	FOLA	B	FRAM	B
FALLSINGTON	B/D	FELTNER	D	FISHHOOK	C	FOLDAHL	B	FRANCIS	A
FALOMA	D	FELTON	B	FISHLAKE	D	FOLEY	D	FRANCISCAN	C
FALSEN	A	FELTONIA	B	FISHPOT	C	FOLLET	D	FRANCISQUITO	C
FALULA	D	FENCE	B	FISHROCK	D	FOMSENG	C	FRANCITAS	D
FANAL	C	FENDALL	C	FISHTRAP	D	FONDA	D	FRANDSEN	B
FANCHER	C	FENELON	C	FISK	B	FONDIS	C	FRANKFORT	C
FANDANGLE	C	FENN	D	FITCHVILLE	C	FONNER	B	FRANKIRK	C
FANDOW	D	FENSTER	B	FITZGERALD	B	FONS	B	FRANKLIN	B
FANG	B	FENWICK	C	FITZHUGH	B	FONTANA	B	FRANKSTOWN	B
FANNIN	B	FENWOOD	B	FIVEBLOCK	C	FONTREEN	B	FRANKTOWN	D
FANNO	C	FERA	C	FIVEMILE	B	FOPIANO	D	FRANKVILLE	B
FANSHAW	B	FERDELFORD	C	FIVEMILE, SALINE	C	FORADA	B/D	FRATERNIDAD	D
FANTZ	C	FERDINAND	C	FIVEOH	B	FORAKER	D	FRAVAL	C
FANU	B	FEREBEE	D	FIVEPINE	D	FORBAR	D	FRAVAL, GRAVELLY	B
FAPS	C	FERGUS	B	FIVES	B	FORBES	C	FRAZER	C
FARAWAY	D	FERN CLIFF	B	FIVESPRINGS	C	FORBESVILLE	C	FRAZERTON	B
FARB	D	FERNANDO	B	FLACO	C	FORBING	D	FRED	C
FARBER	B	FERNCREEK	D	FLAGG	B	FORD	D	FREDENSBORG	C
FARGO	D	FERNDALE	B	FLAGLER	B	FORDICE	B	FREDERICK	B
FARISITA	D	FERNEY	D	FLAGSTAFF	D	FORDNEY	A	FREDON	C
FARLAND	B	FERNHAVEN	B	FLAK	C	FORDNEY, WET	C	FREDONIA	C
FARLOW	B	FERNLEY	C	FLAMBEAU	B	FORDTRAN	C	FREDONYER	C
FARLOW, HIGH	C	FERNOW	B	FLAMING	A	FORDUM	D	FREE	B/D
RAINFALL		FERNPOINT	B	FLANAGAN	B	FORDVILLE	B	FREEBURG	C
FARMELL	B	FERNWOOD	B	FLANDREAU	B	FORELAND	D	FREECE	D
FARMINGTON	C	FERRELO	B	FLANE	C	FORELLE	B	FREEDOM	C
FARMSWORTH	D	FERRIS	D	FLANLY	B	FORESMAN	B	FREEDOM, SALINE	B
FARMTON	D	FERROBURRO	D	FLASHER	D	FORESTBURG	A	FREEHOLD	B
FARNHAM	B	FERRON	D	FLAT HORN	B	FORESTDALE	D	FREELAND	C
FARNHAMTON	C	FERTALINE	D	FLATHEAD	B	FORESTER	C	FREEMAN	C
FARNUF	B	FERTEG	C	FLATIRONS	C	FORESTON	C	FREEMANVILLE	B
FARNUF, WET	C	FESTINA	B	FLATNOSE	B	FORGAY	B	FREEON	B
FARNUM	B	FETT	D	FLATONIA	D	FORK	C	FREER	C

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Exhibit A-1, continued: Hydrologic soil groups for United States soils

MAGOTSU	D	MANAWA	C	MARGO	B	MARYSTOWN	C	MAY	B
MAGUAYO	C	MANBURN	D	MARIA	B	MASADA	C	MAY DAY	D
MAHALA	D	MANCELONA	A	MARIANA	C	MASARDIS	A	MAYACAMA	C
MAHALASVILLE	B/D	MANCHESTER	A	MARIAS	D	MASARYK	A	MAYBELL	A
MAHAN	C	MANDAN	B	MARIAVILLE	D	MASCAMP	D	MAYBERRY	C
MAHANA	B	MANDARIN	C	MARICAO	B	MASCARENAS	C	MAYBESO	D
MAHASKA	B	MANDERFIELD	B	MARICOPA	B	MASCHETAH	B	MAYBID	D
MAHOGAN	C	MANDEVILLE	B	MARIETTA	C	MASCOTTE	B/D	MAYDOL	B
MAHONING	D	MANDY	C	MARILLA	C	MASCOTTE,	D	MAYER	B/D
MAHOOSUC	A	MANET	B	MARIMEL	C	DEPRESSIONAL		MAYES	D
MAHTOMEDI	A	MANFRED	D	MARIMEL, DRAINED	B	MASET	B	MAYFIELD	B
MAHTOWA	C/D	MANGUM	D	MARINA	B	MASHAM	D	MAYFLOWER	C
MAHUKONA	B	MANHATTAN	A	MARINE	C	MASHEL	B	MAYGER	C
MAIA	B	MANHEIM	C	MARION	D	MASHULAVILLE	B/D	MAYHEW	D
MAIDEN	C	MANI	C	MARIPO	B	MASKELL	B	MAYHEAD	B
MAILE	A	MANIKAN	B	MARIPOSA	C	MASON	B	MAYMEN	D
MAINSTAY	D	MANILA	C	MARISCAL	D	MASONFORT	D	MAYNARD LAKE	A
MAITLAND	B	MANISTEE	A	MARISSA	C	MASONTOWN	D	MAYO	B
MAJADA	B	MANITA	C	MARKES	D	MASSACK	C	MAYODAN	B
MAJUBA	C	MANITOWISH	B	MARKESAN	B	MASSACK, DRAINED	B	MAYOWORTH	C
MAKAALAE	B	MANLEY	B	MARKET	D	MASSADONA	D	MAYQUEEN	B
MAKAH	B	MANLIUS	C	MARKEY	A/D	MASSANETTA	B	MAYSDORF	B
MAKALAPA	D	MANN	B/D	MARKHAM	C	MASSANUTTEN	B	MAYSPRINGS	B
MAKAPILI	B	MANNING	B	MARKLAKE	D	MASSBACH	B	MAYTAG	D
MAKAWAO	B	MANOGUE	D	MARKLAND	C	MASSENA	C	MAYTOWN	C
MAKAWELI	B	MANOR	B	MARKLEPASS	D	MASSIE	D	MAYVILLE	B
MAKENA	B	MANSELO	B	MARKTON	C	MASTERSON	B	MAYWOOD	B
MAKI	C	MANSFIELD	D	MARLA	D	MATA	C	MAZARN	C
MAKIKI	B	MANSIC	B	MARLAKE	D	MATAGORDA	D	MAZASKA	C/D
MAKLAK	A	MANSKER	B	MARLBORO	B	MATAMOROS	C	MAZDALE	B
MAKOTI	B	MANSONIA	B	MARLEAN	B	MATANUSKA	B	MAZOURKA	C
MAL	C	MANTACHIE	C	MARLETTE	B	MATANZAS	B	MAZUMA	B
MALA	B	MANTECA	C	MARLOW	C	MATAPEAKE	B	MC CORT	B
MALABAR	B/D	MANTEO	C/D	MARLTON	C	MATAWAN	C	MCAFEE	C
MALABAR,	D	MANTER	B	MARMARTH	B	MATCHER	A	MCALLEN	B
DEPRESSIONAL		MANTON	B	MARMARTH, COOL	C	MATFIELD	C	MCALLISTER	C
MALABAR,	D	MANU	C	MARNA	C/D	MATGO	D	MCALPIN	C
FREQUENTLY		MANVEL	B	MAROSA	B	MATHENY	B	MCBEE	C
FLOODED		MANVEL, SALINE	C	MAPOTZ	C	MATHERS	B	MCBETH	D
MALABON	C	MANZANAR	C	MARPA	C	MATHERTON	B	MCBETH, SALINE	C
MALACHY	B	MANZANITA	C	MARPLEEN	D	MATHESON	B	MCBETH, DRAINED	C
MALAGA	B	MANZANITA,	B	MARQUETTE	A	MATHIAS	B	MCBIGGAM	C
MALAGA, STONY	A	GRAVELLY		MARQUEZ	C	MATHIS	C	MCBRIDE	B
MALAMA	A	MANZANO	B	MARR	B	MATHISTON	C	MCCAFFERY	A
MALARGO	B	MANZANOLA	C	MARRIOTT	B	MATHON	B	MCCAIN	C
MALAYA	D	MAPLE MOUNTAIN	B	MARROWBONE	C	MATLACHA	C	MCCALEB	B
MALBIS	B	MAPLECREST	B	MARSDEN	B	MATNEFLAT	B	MCCALL	B
MALCOLM	B	MAPLEHILL	C	MARSEILLES	B	MATOY	C	MCCALLY	D
MALDEN	A	MAPLETON	C	MARSELL	B	MATTAMUSKEET	D	MCCAMMON	C
MALEZA	B	MAPLETON, STONY	C/D	MARSHALL	B	MATTAN	D	MCCANN	B
MALHEUR	C	MARACK	C	MARSHAN	B/D	MATTAPEX	C	MCCAREY	C
MALIBU	D	MARAGUEZ	B	MARSHBROOK	D	MATTAPONI	C	MCCARRAN	B
MALIN	C	MARANA	B	MARSHDALE	D	MATUNUCK	D	MCCARTHY	B
MALJAMAR	B	MARATHON	B	MARSHDALE, DRAINED	C	MAU	C	MCCASH	B
MALLORY	C	MARBLE	A	MARSHFIELD	B/D	MAUBILA	C	MCCLAVE	C
MALM	C	MARBLECREEK	B	MARSING	B	MAUDE	B	MCCLEARY	D
MALMESA	D	MARBLEMOUNT	B	MART	B	MAUDLIN	B	MCCLELLAN	B
MALO	B	MARBLEMOUNT,	C	MARTEL	D	MAUGHAN	C	MCCLOUD	C
MALOTERRE	D	CHANNERY		MARTELLA	C	MAUKEY	C	MCCLURE	C
MALOTT	B	MARCADO	D	MARTIN	C	MAUMEE	A/D	MCCOIN	D
MALOY	B	MARCELINAS	D	MARTIN PENA	D	MAUNABO	D	MCCOLL	D
MALPAIS	B	MARCELLON	C	MARTINECK	D	MAUPIN	C	MCCOLLUM	B
MALSTROM	B	MARCETTA	B	MARTINEZ	D	MAUREPAS	D	MCCONNEL	B
MALVERN	C	MARCIAL	D	MARTINI	B	MAURERTOWN	D	MCCONNEL, FLOODED	A
MAMALA	D	MARCLAY	D	MARTINSBURG	B	MAURICE	B	MCCOOK	B
MAMOU	C	MARCOLA	C	MARTINSDALE	B	MAURY	B	MCCORNICK	C
MANAHAA	C	MARCONI	C	MARTINSON	C	MAUVAIS	C	MCCORT	B
MANAHAWKIN	D	MARCOTT	C	MARTINSVILLE	B	MAVCO	C	MCCOY	C
MANANA	C	MARCOU	B	MARTINTON	C	MAVEPICK	C	MCCREE	B
MANARD	D	MARCUM	C	MARTIS	B	MAVIF	B/D	MCCRORY	D
MANARD, GRAVELLY	C	MARCUS	B/D	MARTISCO	B/D	MAWAE	A	MCCROSKET	B
SUBSTRATUM		MARCUSE	D	MARTY	B	MAWER	B	MCCULLOUGH	B
MANASSA	C	MARCY	D	MARUMSCO	C	MAX	B	MCCULLY	C
MANASSAS	B	MARDIN	C	MARVAN	D	MAXCREEK	B/D	MCCUMBER	B
MANASTASH	C	MARENGO	C/D	MARVELL	B	MAXEY	C	MCCUNE	D
MANATEE	B/D	MARESUA	B	MARVIN	C	MAXFIELD	B/D	MCCURDY	C
MANATEE,	D	MARGATE	B/D	MARVYN	B	MAXTON	B	MCCUTCHEN	D
DEPRESSIONAL		MARGERUM	B	MARY	C	MAXVILLE	B	MCDADE	C
MANATEE, FLOODED	D	MARGIE	C	MARYSLAND	B/D	MAXWELL	D	MCDANIEL	B

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Exhibit A-1, continued: Hydrologic soil groups for United States soils

MCDERMOTT	B	MECKLENBURG	C	MERDEN	D	MIKIM, WET	C	MINNEOSA	B
MCDOLE	B	MECOSTA	A	MEREDITH	B	SUBSTRATUM		MINNEQUA	C
MCDONALD	C	MEDA	B	MERETA	C	MIKKALO	C	MINNETONKA	D
MCDONALDSVILLE	C/D	MEDANO	D	MERGEL	B	MILACA	C	MINNETONKA, SILTY	C/D
MCDUFF	C	MEDARY	C	MERIDIAN	B	MILAN	B	SUBSTRATUM	
MCELMO	C	MEDBURN	B	MERINO	C	MILBURY	C	MINNEWAUKAN	A/D
MCELROY	B	MEDCO	D	MERKEL	B	MILBY	B	MINNIECE	D
MCEWEN	B	MEDFORD	B	MERLIN	D	MILCAN	C	MINNIEPEAK	A
MCFADDEN	B	MEDFRA	C	MERMENTAU	C	MILDRED	C	MINNIEPEAK,	B
MCFAIN	C	MEDICINE	B	MERMILL	B/D	MILES	B	OVERBLOWN,	
MCFARLAND	B	MEDLEY	B	MERNA	B	MILFORD	B/D	GRAVELLY	
MCFAUL	C	MEDLIN	D	MEROS	A	MILHAM	B	MINNIEPEAK,	B
MCGAFFEY	B	MEDOMAK	D	MERRICK	B	MILITARY	B	OVERBLOWN	
MCGARR	C	MEDORA	B	MERRILL	C	MILL HOLLOW	B	MINNIEVILLE	C
MCGARVEY	C	MEDWAY	B	MERRILLAN	C	MILLADORE	C	MINNIMAUD	C
MCGARY	C	MEEGERNOT	B	MERRIMAC	A	MILLARD	B	MINNITH	C
MCGEHEE	C	MEEGERO	B	MERRITT	C	MILLBORO	D	MINNYE	B
MCGILVERY	D	MEEHAN	B	MERRITT, CLAYEY	B	MILLBROOK	B	MINOA	C
MCGINNIS	C	MEEKS	B	SUBSTRATUM,		MILLBURNE	B	MINOCQUA	B/D
MCGINTY	B	MEETEETSE	D	DRAINED		MILLER	D	MINTER	D
MCGIRK	C	MEGALOS	D	MERRITT, DRAINED	B	MILLERLAKE	B	MINTO	C
MCGIRK, LOW	D	MEGGETT	D	MERSHON	C	MILLERLUX	D	MINU	D
PRECIPITATION		MEGONOT	C	MERTON	B	MILLERTON	D	MINVALE	B
MCGOWAN	B	MEGUIN	B	MERTZ	C	MILLERVILLE	A/D	MINVEND	D
MCGRATH	B	MEHLHORN	C	MERWIN	A/D	MILLETT	B	MINWELLS	C
MCGREW	B	MEIKLE	D	MESA	B	MILLGROVE	B/D	MION	D
MCGUFFEY	D	MEISS	D	MESABA	C	MILLHEIM	C	MIPPON	C
MCGUIRE	B	MEKINOCK	D	MESCAL	C	MILLHI	D	MIRABAL	C
MCHENRY	D	MELAKWA	C	MESCALERO	C	MILLHOPPER	A	MIRACLE	C
MCILWAINE	B	MELAND	C	MESEI	D	MILLICH	D	MIRAGE	C
MCINTOSH	B	MELBOURNE	B	MESPUN	A	MILLICOMA	C	MIRAMAR	B
MCINTYRE	B	MELBY	B	MESSER	C	MILLIGAN	C	MIRAND	D
MCIVEY	C	MELD	C	MET	B	MILLING	D	MIRANDA	D
MCKAMIE	D	MELDER	B	METAMORA	B	MILLINGTON	B/D	MIRES	A
MCKAY	C	MELGA	D	METCALF	D	MILLIS	C	MIRES, STONY	B
MCKEE	D	MELHOMES	D	METEA	B	MILLPAW	C	MIRKWOOD	D
MCKEETH	B	MELITA	A	METH	C	MILLPOT	B	MIRROR	C
MCKELVIE	A	MELLENTHIN	D	METIGOSHE	B	MILLRACE	B	MIRROR LAKE	A
MCKENNA	D	MELLOR	D	METOLIUS	B	MILLROCK	A	MISAD	B
MCKENNA, DRAINED	C	MELLOR, STRATIFIED	C	METRE	D	MILLSAP	D	MISENHEIMER	C
MCKENZIE	D	SUBSTRATUM		METZ	B	MILLSDALE	B/D	MISHAK	D
MCKINLEY	B	MELLOTT	B	MEXICO	D	MILLSHOLM	D	MISHAK, DRAINED	C
MCKINNEY	C	MELOCHE	D	MEXISPRING	D	MILLSITE	B	MISSION	D
MCKNIGHT	B	MELOLAND	C	MEYSTRE	B	MILLVILLE	B	MISSISQUOI	A
MCLAIN	C	MELROSE	C	MHOON	D	MILLWOOD	D	MISSLER	B
MCLAURIN	B	MELTON	D	MIAMI	B	MILNER	B	MISSOULA	D
MCLEOD	B	MELVILLE	B	MIAMIAN	C	MILOK	B	MITCH	B
MCLOUGHLIN	B	MELVIN	D	MICANOPY	C	MILPITAS	C	MITCH, RARELY	C
MCMEEN	C	MEMALOOSE	C	MICCO	B/D	MILREN	C	FLOODED	
MCMILLE	B	MEMPHIS	B	MICHELSON	B	MILTON	C	MITCHELL	B
MCMULLIN	D	MENAHGA	A	MICHIGAMME	C	MILVAR	C	MITIWANGA	C
MCMURDIE	C	MENARD	B	MICKEY	D	MIMBRES	B	MITKOF	D
MCMURRAY	D	MENASHA	D	MICROY	C	MIMOSA	C	MITKOF, MODERATELY	C
MCMURRAY, DRAINED	C	MENBO	C	MIDAS	C	MINA	B	WET	
MCNARY	D	MENDEBOURE	C	MIDCO	A	MINALOOSA	B	MITRE	C
MCNEAL	B	MENDELTNA	D	MIDDLE	C	MINAM	B	MITRING	C
MCNULL	C	MENDELTNA,	B	MIDDLEBURY	B	MINAT	B	MITTEN	B
MCNULTY	B	LACUSTRINE		MIDDLEMARCH	B	MINATARE	D	MIVIDA	B
MCPAUL	B	SUBSTRATUM		MIDDLETOWN	B	MINCHEY	B	MIZEL	D
MCPHIE	B	MENDENHALL	D	MIDDLEWOOD	D	MINCHUMINA	D	MOAB	B
MCQUARRIE	D	MENDI	B	MIDELIGHT	B	MINCO	B	MOAG	D
MCQUEEN	C	MENDOCINO	B	MIDESSA	B	MINDEGO	C	MOANO	D
MCRAE	B	MENDON	B	MIDFORK	B	MINDEN	B	MOAPA	C
MCRAVEN	C	MENDOTA	B	MIDLAND	D	MINE	B	MOAULA	A
MCTAGGART	B	MENEFEE	D	MIDMONT	C	MINEOLA	A	MOBATE	D
MCVEGAS	D	MENFRO	B	MIDNIGHT	D	MINER	D	MOBEETIE	B
MCVICKERS	C	MENLO	D	MIDO	A	MINERAL	C	MOBERG	B
MEAD	D	MENO	C	MIDRAW	D	MINERAL MOUNTAIN	C	MOBL	B
MEADIN	A	MENOKEN	C	MIDVALE	C	MINERSVILLE	B	MOBRIDGE	B
MEADLAND	C	MENOMINEE	A	MIDWAY	D	MINESINGER	C	MOCA	D
MEADOWBROOK	B/D	MENTO	C	MIERHILL	C	MINETA	C	MOCAREY	D
MEADOWCREEK	C	MENTOR	B	MIERUF	B	MINGO	C	MOCHO	B
MEADOWLAKE	C	MENZEL	B	MIESEN	C	MINGUS	D	MOCKLEP	B
MEADOWVILLE	B	MEQUON	C	MIFFLIN	B	MINIDOKA	C	MOCMONT	B
MEANS	C	MER ROUGE	B	MIGEFN	B	MINKLER	D	MOCTILEME	C
MEARES	D	MERCED	D	MIGUEL	D	MINLITH	D	MODA	D
MECAN	B	MERCEDES	D	MIKE	D	MINNEHA	C	MODALE	C
MECHANICSBURG	C	MERCER	C	MIKESELL	C	MINNEISKA	B	MODENA	B
MEKESVILLE	C	MERCEY	C	MIKIM	B	MINNEOPA	B	MODESTO	C

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Table A3

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Exhibit A-1, continued: Hydrologic soil groups for United States soils

POQUONOCK	C	PREMIER	B	PUNCHBOWL	D	QUINLIVEN	C	RAMROD	C
PORFIRIO	C	PRENTISS	C	PUNG	C	QUINN	B/D	RAMSDELL	D
PORRETT	D	PRESA	B	PUNGO	D	QUINNEY	C	RAMSDELL, DRAINED	C
PORRONE	B	PRESHER	B	PUNOHU	A	QUINTANA	B	RAMSEY	D
PORT	B	PRESTO	B	PUNSIT	C	QUINTO	D	RAMSHORN	B
PORT BYRON	B	PRESTON	A	PUNTA	B/D	QUINTON	C	RANA	D
PORTAGE	D	PREVITT	B	PUNTILLA	B	QUITERIA	B	RANCE	C
PORTAGEVILLE	D	PREY	C	PURCELLA	B	QUITMAN	C	RANCHOSECO	D
PORTALES	B	PRICE	B	PURCHES	C	QUIVERA	C	RANDADO	C
PORTALTO	B	PRIDA	C	PURDAM	C	QUONSET	A	RANDALL	D
PORTERFIELD	C	PRIDHAM	D	PURDY	D	QUOPANT	D	RANDCORE	D
PORTERS	B	PRIESTLAKE	B	PURETT	B	QUOSATANA	D	RANDMAN	D
PORTERVILLE	D	PRIETA	D	PURGATORY	C	RABBITEX	B	RANDOLPH	C
PORTHILL	D	PRIM	D	PURNER	D	RABER	C	RANDS	C
PORTIA	C	PRIMEAUX	C	PUROB	D	RABIDEUX	B	RANDSBURG	D
PORTINO	C	PRIMEN	D	PURSLEY	B	RABUN	B	RANGEE	D
PORTLAND	D	PRINGHAR	B	PURVES	D	RACE	B	RANGER	C
PORTMOUNT	B	PRINCETON	B	PUSHMATAHA	C	RACINE	B	RANPUFF	D
PORTNEUF	B	PRINEVILLE	C	PUSTOI	B	RACKER	A	RANSLO	D
PORTOLA	B	PRING	B	PUTNAM	D	RACOMBES	B	RANSOM	B
PORTSMOUTH	B/D	PRINGLE	D	PUTNEY	B	RACOON	C/D	RANSTEIN	B
PORUM	D	PRITCHARD	C	PUTT	C	RAD	B	RANTOUL	D
POSANT	D	PRITCHETT	C	PUTTSTER	C	RAD, LACUSTRINE	C	RAPATEE	D
POSEN	B	PROCHASKA	A/D	PUU OO	A	SUBSTRATUM		RAPELJE	B
POSEY	B	PROCTOR	B	PUU OPAE	B	RAD, FLOODED	C	RAPH	B
POSEYVILLE	C	PROGRESSO	C	PUU PA	A	RADDLE	B	RAPHO	B
POSITAS	D	PROMISE	D	PUU PA, NONSTONY	B	RADER	D	RAPIDAN	B
POSKIN	C	PRONO	D	PUUKALA	C	RADERSBURG	B	RAPLEE	C
POSO	B	PRONG	C	PUUONE	C	RADFORD	B	RAPPAHANNOCK	D
POSOS	C	PROPHETSTOWN	B/D	PUYALLUP	B	RADLEY	B	RAPSON	B
POST	D	PROSPECT	B	PYBURN	D	RADNOR	C	RARDEN	C
POTAMUS	B	PROSPER	B	PYLE	B	RAFAEL	D	RARICK	C
POTCHUB	C	PROSSER	C	PYLON	D	RAFTON	D	RARITAN	C
POTEET	C	PROTIVIN	C	PYOTE	A	RAFTRIVER	C	RASBAND	B
POTELL	B	PROUT	C	PYRAMID	D	RAGLAN	B	RASILLE	B
POTH	C	PROUTY	C	PYRMONT	D	RAGNAR	B	RASSER	B
POTLATCH	C	PROVIDENCE	C	PYRMONT, BEDROCK	C	RAGNEL	B	RASSET	B
POTOMAC	A	PROVIG	C	SUBSTRATUM		RAGO	C	RASTUS	C
POTOSI	A	PROVO	D	PYWELL	D	RAGPIE	D	RATAKE	D
POTRATZ	C	PROVO BAY	D	QUAFENO	C	RAGSDALE	B/D	RATHBUN	C
POTSDAM	C	PROW	D	QUAKER	C	RAGSDALE, OVERWASH	B	RATHDRUM	B
POTTER	C	PRUDY	B	QUAKERTOWN	C	RAGTOWN	C	RATLAKE	D
POTTINGER	B	PRUE	B	QUAM	B/D	RAHAL	C	RATLEFLAT	B
POTTS	B	PRUITTON	B	QUAMON	A	RAHM	C	RATLIFF	B
POTTSBURG	B/D	PRUNIE	D	QUANAH	B	RAHWORTH	B	RATON	D
POUDRE	D	PRYOR	C	QUANDER	B	RAIL	D	RATSOW	C
POUJADE	D	PSUGA	B	QUANTICO	B	RAILCITY	A	RATTLEP	D
POULSBO	D	PTARMIGAN	C	QUARLES	D	RAINBOW	C	RATTO	C
POUNCEY	D	PUAPUA	D	QUARTZBURG	C	RAINEY	C	RATTO, STONY	D
POVERTY	D	PUAULU	A	QUARTZVILLE	B	RAINIER	C	RAUB	C
POVEY	B	PUCHYAN	B	QUARZ	C	RAINO	D	RAUGHT	B
POWDER	B	PUDDLE	B	QUATAMA	C	RAINS	B/D	RAUVILLE	D
POWDERHORN	C	PUERCO	D	QUAY	B	RAINS, FLOODED	D	RAUZI	B
POWDERWASH	C	PUERTA	D	QUAZO	D	RAINSBORO	C	RAVALLI	D
POWEEN	C	PUERTECITO	D	QUEALMAN	C	RAINSVILLE	B	RAVALLI, BEDROCK	B
POWELL	C	PUETT	D	QUEALY	D	RAIRDENT	B	SUBSTRATUM	
POWER	B	PUFFER	D	QUEBRADA	C	RAISIO	C	RAVEN	A
POWERLINE	C	PUGET	D	QUEENY	D	RAKANE	C	RAVENDALE	D
POWLEY	D	PUGET, PROTECTED	C	QUEETS	B	RAKE	D	RAVENELL	D
POWNENT	C	PUGSLEY	C	QUEMADO	C	RAKIED	C	RAVENNA	C
POWWAHKEE	B	PUHI	B	QUENZER	D	RALEIGH	D	RAVENSWOOD	C
POWWATKA	C	PUHIMAU	D	QUERC	C	RALLOD	D	RAVIA	C
POY	D	PUICE	C	QUERENCIA	B	RALLS	B	RAVOLA	B
POYGAN	D	PULA	C	QUETICO	D	RALPH	B	RAWAM	C
POYNOR	B	PULANTAT	C	QUICKSELL	C	RALPHSTON	B	RAWE	C
POZO	C	PULASKI	B	QUICKSILVER	D	RALSEN	D	RAWLES	B
POZO BLANCO	B	PULCAN	C	QUICKVERT	C	RAMADERO	B	RAWLINS	B
PRAG	C	PULEHU	B	QUIDEN	B	RAMBLA	C	RAWSON	B
PRAIRIEVILLE	B	PULEXAS	B	QUIENSABE	C	RAMBOUILLET	B	RAWSONVILLE	C
PRAMISS	C	PULLMAN	D	QUIETUS	C	RAMELLI	D	RAYBURN	D
PRATHER	C	PULPIT	C	QUIGLEY	B	RAMIRES	C	RAYEX	D
PRATLEY	C	PULS	D	QUIHI	C	RAMMEL	C	RAYFORD	C
PRATT	A	PULSIPHER	D	QUILCENE	C	RAMO	C	RAYLAKE	D
PREACHER	B	PULTNEY	C	QUILLAYUTE	B	RAMONA	B	RAYMONDVILLE	D
PREAKNESS	B/D	PUMEL	D	QUILOTOSA	D	RAMONA, HARD	C	RAYNE	B
PREATORSON	B	PUMEL, NONGRAVELLY	C	QUILT	D	SUBSTRATUM		RAYNESFORD	B
PREBISH	C/D	PUMPER	B	QUIMA	B	RAMPART	B	RAYNHAM	C
PREBLE	D	PUNA	A	QUINCY	A	RAMPARTER	B	RAYNOLDSON	B
PRELO	B	PUNALUU	D	QUINLAN	C	RAMPS	B	RAYOHILL	C

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

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DGP Table A4

Daniel Pass 10 Oct. 95 FERMCO/OSDF GE3900, Task 8.11

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DBW 95/10/23

10/23/95

Exhibit A-1, continued: Hydrologic soil groups for United States soils

RODIE	B	ROSENDALE	C	RUBY	B	SABENYO	B	SAMINIEGO	C
RODMAN	A	ROSENWALL	D	RUBYHILL	C	SABINA	C	SAMISH	D
RODROF	D	ROSEVILLE	B	RUCH	B	SABINE	A	SAMMAMISH	D
ROEBUCK	D	ROSEWOOD	A/D	RUCKER	B	SABLE	B/D	SAMOIST	D
ROELLEN	D	ROSEWOOD, WET	D	RUCKLES	D	SAC	B	SAMOR	D
ROEMER	C	ROSEWORTH	D	RUCLICK	C	SACHEEN	A	SAMPSEL	D
ROETEX	D	ROSHE SPRINGS	D	RUDD	D	SACHETT	C	SAMPSON	B
ROFISS	B	ROSHE SPRINGS,	C	RUDDLEY	D	SACO	D	SAMSIL	D
ROGAN	B	DRAINED		RUDEEN	C	SACRAMENTO	D	SAMSULA	B/D
ROGERSON	D	ROSHOLT	B	RUDYARD	C	SACTUS	D	SAN ANDREAS	B
ROGERT	D	ROSINE	B	RUEDLOFF	B	SACUL	C	SAN ANTON	B
ROGRUBE	B	ROSITAS	A	RUELLA	B	SADDLE	C	SAN ANTONIO	C
ROGUE	B	ROSITAS, CLAYEY	C	RUFUS	D	SADDLEBACK	C/D	SAN ARCACIO	C
ROHAN	D	SUBSTRATUM		RUGAR	C	SADDLEGAP	B	SAN BENITO	B
ROHNERVILLE	B	ROSITAS, LOAMY,	C	RUGG	B	SADDLEROCK	D	SAN EMIGDIO	B
ROHONDA	C	WET		RUGLES	F	SADER	D	SAN GERMAN	D
ROHRERSVILLE	D	ROSITAS, WET	C	RUHE	D	SADIE	C	SAN ISABEL	A
ROIC	D	ROSLYN	B	RUIDOSO	C	SADLER	C	SAN JOAQUIN	D
ROJO	C	ROSMAN	B	RUINPOINT	B	SAFFELL	B	SAN JON	C
ROLETTE	C	ROSNEY	B	RUIZ	A	SAG	B	SAN JOSE	B
ROLFE	C	ROSS	B	RUKO	D	SAGANING	A/D	SAN JUAN	A
ROLIE	D	ROSSBURG	B	RULE	B	SAGASER	B	SAN LUIS	C
ROLISS	B/D	ROSSFIELD	B	RUMBLECREEK	B	SAGE	D	SAN MATEO	B
ROLLA	C	ROSSMOOR	B	RUMBO	C	SAGECREEK	B	SAN MIGUEL	D
ROLLINGSTONE	C	ROSSMOYNE	C	RUMFORD	B	SAGEDALE	C	SAN SABA	D
ROLOC	D	ROSWELL	A	RUMLEY	B	SAGEHILL	B	SAN SEBASTIAN	B
ROLOFF	C	ROSY	B	RUMNEY	C	SAGEMOOR	B	SAN SIMEON	D
ROMBERG	B	ROTAMER	B	RUMPAH	D	SAGERS	B	SAN TIMOTEO	C
ROMBO	C	ROTAN	C	RUMPLE	C	SAGERTON	C	SAN YSIDRO	D
ROME	B	ROTHICAN	B	RUMUNG	C	SAGLE	C	SANCHEZ	D
ROMEO	D	ROTHIEMAY	C	RUNE	C	SAGO	D	SANCLEMENTE	D
ROMERO	D	ROTHSAY	B	RUNEBERG	C/D	SAGOUSPE	C	SANDALL	C
ROMGAN	C	ROTINOM	F	RUNGE	B	SAGOUSPE, DRAINED	B	SANDBRANCH	B
ROMIA	B	ROTO	C	RUNN	D	SAGUACHE	B	SANDCREEK	D
ROMINE	B	ROTTULEE	C	RUPLE	C	SAHALIE	B	SANDERSON	B
ROMINELL	C	ROUBIDEAU	C	RUPLEY	A	SAHUARITA	B	SANDHILL	B
ROMNELL	B/D	ROUEN	C	RUSCO	C	SAID	B	SANDIA	B
ROMSTOCK	B	ROUGHCREEK	D	RUSCO, PONDED	D	SAIDO	B	SANDOSE	A
ROMULUS	D	ROUGHLOCK	B	RUSE	D	SAILBOAT	C	SANDOVAL	D
RONAN	D	ROUGHMOUNT	C	RUSH	B	SAILBOAT, DRAINED	B	SANDRIDGE	A
RONO	C	ROUND BUTTE	D	RUSHMORE	B/D	SAIPAN	B	SANDSPRING	B
RONDEAU	A/D	ROUNDABOUT	C	RUSHTOWN	A	SAL	D	SANDUN	B
RONDELL	B	ROUNDBARN	B	RUSHVILLE	C	SALADAR	D	SANDUSKY	D
RONDOWA	B	ROUNDHEAD	B/D	RUSO	B	SALADON	D	SANDVIEW	B
RONNEBY	C	ROUNDOR	C	RUSON	C	SALAL	C	SANDWASH	C
RONSEL	B	ROUNDTOP	C	RUSS	B	SALAMATOF	D	SANDWICK	B
RONSON	B	ROUNDUP	C	RUSSELL	B	SALANDER	B	SANELI	D
ROONEY	D	ROUNDY	C	RUSSIAN	B	SALAS	C	SANFORD	B
ROOSET	C	ROUSSEAU	A	RUSSLER	C	SALCHAKET	B	SANGER	D
ROOSEVELT	C	ROUTON	D	RUSTICO	F	SALCO	B	SANGO	C
ROOT	B/D	ROUTT	C	RUSTIGATE	C	SALEM	B	SANHEDRIN	B
ROOTEL	C	ROVAL	D	RUSTON	B	SALERATUS	C	SANIBEL	B/D
ROPER	B/D	ROWDEN	C	RUSTY	B	SALERNO	B/D	SANILAC	B
ROSALIE	B	ROWDY	B	RUTAB	B	SALGA	C	SANJE	B
ROSAMOND	B	ROWE	C	RUTERSVILLE	C	SALIDA	A	SANLOREN	B
ROSAMOND,	C	ROWEL	D	RUTHERFORD	C	SALINAS	B	SANPETE	B
SALINE-ALKALI,		ROWENA	C	RUTLAND	C	SALISBURY	C	SANPITCH	C
FLOODED		ROWLAND	C	RUTLEGE	B/D	SALIX	B	SANPOIL	D
ROSANE	D	ROWLEY	C	RYAN	D	SALKUM	B	SANSARC	D
ROSANKY	C	ROXAL	D	RYAN PARK	B	SALLISAW	B	SANTA	D
ROSARIO	C	ROXANA	B	RYARK	A	SALLYANN	C	SANTA CLARA	C
ROSCOE	D	ROXBURY	B	RYCO	D	SALMO	C/D	SANTA FE	D
ROSCOMMON	A/D	ROXER	B	RYDE	C	SALMON	B	SANTA ISABEL	D
ROSE CREEK	C	ROXTON	D	RYDER	C	SALONIE	D	SANTA LUCIA	C
ROSE CREEK,	B	ROY	B	RYDOLPH	C	SALT CHUCK	A	SANTA MARTA	C
DRAINED		ROYAL	B	RYEGATE	C	SALT LAKE	D	SANTA YNEZ	D
ROSE VALLEY	D	ROYCE	C	RYELL	B	SALTAIR	D	SANTANA	D
ROSEBERRY	D	ROYGORGE	D	RYELL, SALINE	D	SALTER	B	SANTANELA	D
ROSEBLOOM	D	ROYOSA	A	RYEPATCH	C	SALTERY	D	SANTAQUIN	A
ROSEBOROUGH	B	ROYST	C	RYER	C	SALTESE	D	SANTAROSA	B
ROSEBUD	B	ROYSTONE	B	RYKER	B	SALTINE	C	SANTEE	D
ROSEBURG	B	ROZA	C	RYMAN	C	SALTON	D	SANTIAGO	B
ROSEDHU	B/D	ROZELLVILLE	B	RYORP	C	SALUDA	C	SANTIAM	C
ROSEGLEN	B	ROZETTA	B	RYPOC	B	SALVISA	C	SANTO	B
ROSEHAVEN	B	ROZLEE	C	RYUS	B	SALZER	D	SANTO TOMAS	B
ROSEHILL	D	RUARK	B/D	SAAR	C	SALZER, PROTECTED	C	SANTONI	D
ROSELAND	B	RUBICON	A	SABANA	D	SAMBA	D	SANWELL	B
ROSELLA	D	RUBIO	C/D	SABANA SECA	C	SAMBRITO	B	SAPEHA	B
ROSELMS	D	RUBSON	B	SABE	B	SAMDAY	D	SAPELO	D

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
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Table A5

Daniel Pass 10 Oct. 95 FERMCO/OSDF GE3900, Task 8.11

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DBW 95/10/23

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Exhibit A-1, continued: Hydrologic soil groups for United States soils

WILSON	D	WISHARD	C	WOODS CROSS	D	WYNOOSE	D	YEGEN	B
WILSONGULCH	B	WISHBONE	B	WOODSEYE	D	WYOCENA	B	YEGUAS	C
WILSONVILLE	D	WISHEYLU	C	WOODSFIELD	C	WYOMING	A	YELJACK	B
WILSOR	B	WISHKAH	D	WOODSIDE	B	WYRENE	B	YELLOWBAY	B
WILST	C	WISHKAH, DRAINED	C	WOODSLAKE	D	WYSOCKING	C/D	YELLOWHOUND	B
WILTON	B	WISKAN	C	WOODSON	D	XANA	B	YELLOWROCK	A
WINADA	C	WISKIFLAT	B	WOODSTOCK	C/D	XANADU	B	YELLOWSTONE	D
WINBERRY	C	WISNER	B/D	WOODSTOWN	C	XAVIER	B	YELM	C
WINCHESTER	A	WISTER	C	WOODTELL	D	XENIA	B	YEMASSEE	C
WINCHUCK	C	WITBECK	B/D	WOODVILLE	D	XENO	B	YENCE	C
WIND RIVER	B	WITEFELS	B	WOODWARD	B	XERTA	C	YENLO	B
WINDCOAT	D	WITHAM	D	WOODWEST	D	XERXES	D	YENRAB	A
WINDER	B/D	WITHEE	C	WOOFUS	D	XICA	C	YEOMAN	B
WINDER,	D	WITHERBEE	A/D	WOOLPER	C	XINE	C	YEOPIM	B
DEPRESSIONAL		WITHERELL	D	WOOLSEY	B	XIPE	D	YERINGTON	A
WINDHAM	B	WITHERS	C	WOOLSTALF	B	XIPE, MODERATELY	C	YERMO	B
WINDICREEK	A	WITT	B	WOOLSTED	B	WET		YESUM	B
WINDMILL	B	WITTEN	D	WOONSOCKET	B	XMAN	D	YETTEM	B
WINDSOR	A	WITTENBERG	B	WOOSLEY	C	YACOLT	B	YETULL	A
WINDTHORST	C	WITZEL	D	WOOSTER	C	YAGO	C	YIGO	B
WINDWHISTLE	C	WIX	C	WORCESTER	C	YAHANA	C	YIPOR	B
WINDWHISTLE, WARM	B	WIXOM	B	WORDEN	C	YAHARA	C	YLIG	C
WINDY	B	WOCKLEY	C	WORF	D	YAHNE	C	YOBE	C
WINDYPOINT	B	WODA	D	WORFKA	D	YAHOLA	B	YOCHUM	C
WINEG	B	WODEN	B	WORFMAN	D	YAHOO	D	YOCKEY	C
WINEMA	C	WODSKOW	C	WORFSTONE	C	YAINAX	B	YODER	B
WINETTI	B	WODSKOW, DRAINED	B	WORK	C	YAKI	D	YODY	C
WINEVADA	C	WOHLY	B	WORK, GRAVELLY	B	YAKIMA	B	YOHURT	D
WINFALL	B	WOLCO	C	WORLAND	C	YAKUS	D	YOKAYO	D
WINFIELD	B	WOLCOTT	B/D	WORLEY	D	YAKUTAT	A	YOKOHL	D
WING	D	WOLDALE	D	WORMSER	C	YALELAKE	B	YOKUT	B
WINGATE	B	WOLDALE, DRAINED	C	WOROCK	B	YALESVILLE	C	YOLLABOLLY	D
WINGER	B/D	WOLF	B	WORSHAM	D	YALLANI	B	YOLO	B
WINGINAW	D	WOLF POINT	C	WORTH	C	YALMER	B	YOLOGO	D
WINGVILLE	D	WOLFCREEK	B	WORTHEN	B	YAMAC	B	YOMBA	B
WINIFRED	C	WOLFESON	C	WORTHING	D	YAMHILL	C	YOMONT	B
WINK	B	WOLFESON, WET	D	WORTMAN	D	YAMO	B	YONGES	D
WINKEL	D	WOLFEY	C	WORTMAN, SANDY	A	YAMSAY	D	YONNA	D
WINKLEMAN	C	WOLFPEN	A	WOVOKA	C	YANA	B	YORBA	D
WINKLEMAN, WET	D	WOLFTEVER	C	WRANGELL	D	YANCY	D	YORK	C
WINKLER	B	WOLLARD	C	WRANGO	A	YANKEE	D	YORKTOWN	D
WINLER	D	WOLLENT	D	WRAYHA	D	YANKTON	B	YORKTREE	C
WINLO	D	WOLOT	B	WREDAH	B	YANUSH	B	YORKVILLE	D
WINN	C	WOLVERINE	A	WRENCOE	D	YAP	B	YOST	D
WINNEBAGO	B	WOMACK	C	WRENMAN	C	YAPOAH	B	YOST, DRAINED	C
WINNECONNE	C	WOO	B	WRENTHAM	C	YAQUI	B	YOUD	D
WINNECOOK	C	WOO, OVERWASH	C	WRIGHT	C	YAQUINA	D	YOUGA	B
WINNEMUCCA	B	WOO, WET	C	WRIGHTMAN	C	YAQUINA, DRAINED	C	YOUGA, SANDY	D
WINNESHIEK	B	WOOD RIVER	D	WRIGHTSBORO	C	YARCO	D	SUBSTRATUM	
WINNETT	D	WOODBECK	B	WRIGHTSVILLE	D	YARDLEY	C	YOUJAY	D
WINNSBORO	D	WOODBINE	B	WRIGHTWOOD	B	YARTS	B	YOUMAN	C
WINOM	D	WOODBRIDGE	C	WUKOKI	B	YATAHONEY	C	YOUNGSTON	B
WINONA	D	WOODBURN	C	WUKSI	A	YATAHONEY, STONY	D	YOUNGSTON, WET	C
WINOOSKI	B	WOODBURY	D	WULFERT	D	YATES	D	YOURAME	B
WINOPEE	B	WOODCOCK	B	WUNJEY	B	YAUCO	C	YOUTLKUE	D
WINRIDGE	D	WOODFORD	D	WUPATKI	D	YAUHANNAH	B	YOVIMPA	D
WINSHIP	C	WOODGULCH	A	WURNO	C	YAUPON	D	YPSI	C
WINSPECT	B	WOODHALL	C	WURSTEN	B	YAWDIM	D	YRIBARREN	D
WINSTON	B	WOODHURST	C	WURTSBORO	C	YAWHEE	B	YSIDORA	C
WINT	D	WOODIN	C	WYALUSING	D	YAWKEY	B	YTURBIDE	A
WINTERFIELD	A/D	WOODINGTON	B/D	WYANDOTTE	D	YAXON	B	YTURRIA	A
WINTERHAVEN	B	WOODINVILLE	D	WYANT	C	YEAGER	A	YUBA	D
WINTERIDGE	B	WOODINVILLE,	C	WYARD	B	YFARY	C	YUKO	D
WINTERS	C	DRAINED		WYARNO	B	YEATES HOLLOW	B	YUKON	D
WINTERSBURG	C	WOODLAWN	B	WYATT	C	YEATES HOLLOW,	C	YULEE	D
WINTERSET	C	WOODLEAF	C	WYCOLO	C	LOAMY SUBSTRATUM,		YUNES	D
WINTHROP	A	WOODLY	B	WYE	B	STONY		YUNQUE	C
WINTLEY	B	WOODLYN	D	WYEAST	D	YEATES HOLLOW,	C	YURM	D
WINTON	C	WOODMANSIE	B	WYETH	B	LOAMY SUBSTRATUM		YUTRUE	D
WINTONER	B	WOODMERE	B	WYEVILLE	C	YEATES HOLLOW,	C	YUVAS	D
WINU	C	WOODMONT	C	WYICK	D	STONY		ZAAR	D
WINZ	D	WOODPASS	B	WYKEHAM	B	YEATES HOLLOW,	C	ZABA	B
WIOTA	B	WOODROCK	C	WYKOFF	B	NONSTONY		ZACA	D
WIPPLE	C	WOODROW	B	WYMAN	B	YEATES HOLLOW, DRY	C	ZACHARIAS	B
WIRT	B	WOODROW,	C	WYMORE	D	YEATES HOLLOW,	C	ZACHARY	C
WISCOW	D	SALINE-ALKALI		WYNDMERE	B	COBBLY		ZACK	D
WISE	C	WOODROW,	C	WYNN	B	YEATON	C	ZADOG	A/D
WISEMAN	A	OCCASIONALLY		WYNNVILLE	C	YECROSS	A	ZADVAR	D
ISFLAT	D	FLOODED		WYNONA	C	YEDLICK	B	ZAFRA	B

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

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DBW 95/10/23

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Table 2-2c.—Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
	NORTH SIDE WILLEY RD., PROPOSED - OUTSIDE BORROW AREA GRADING LIMIT				
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
	NORTH SIDE WILLEY RD, EXISTING				
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
	NORTH SIDE WILLEY Rd, PROPOSED - WITHIN BORROW AREA GRADING LIMITS				
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	[4]30	48	65	73
Woods—grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	[4]30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1]Average runoff condition, and $I_a = 0.2S$.

[2]*Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

[3]*Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

[4]Actual curve number is less than 30; use CN = 30 for runoff computations.

[5]CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

[6]*Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

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Table 2-2b.—Runoff curve numbers for cultivated agricultural lands[1]

Cover description			Curve numbers for hydrologic soil group—			
Cover type	Treatment[2]	Hydrologic condition[3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
		SOUTH SIDE WILLEY RD, EXISTING AND PROPOSED				
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

[1]Average runoff condition, and $I_a = 0.2S$.
[2]*Crop residue cover* applies only if residue is on at least 5% of the surface throughout the year.
[3]Hydrologic condition is based on combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.
Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

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Table A8

Daniel Pass 10 Oct. 95 FERMCO/OSDF GE3900, Task 8.11

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KW 10/23/95

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
SOUTH SIDE WILLEY RD, EXISTING AND PROPOSED	
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
NORTH SIDE WILLEY RD, EXISTING AND PROPOSED	
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

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TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
EXISTING AND PROPOSED D-2. Flood plains			
a. Pasture, no brush			
NORTH SIDE OF ACCESS Rd. 1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
SOUTH SIDE OF ACCESS Rd. 2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage >100 ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	.....	0.060
b. Irregular and rough section	0.035	.....	0.100

Table A10
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PAGES 17 AND 18 SUPERSEDED BY REV 1

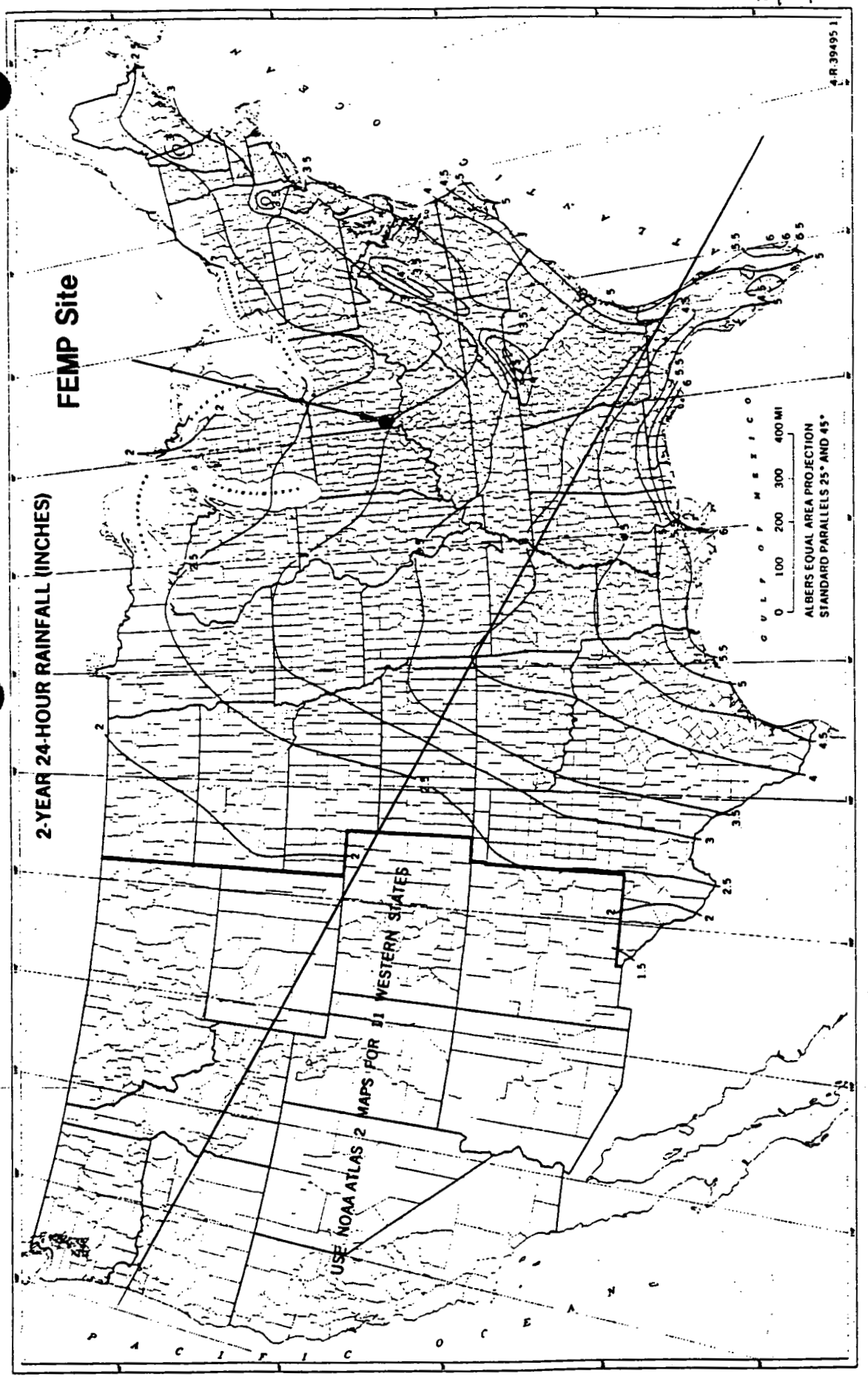

Figure B-3.—Two-year, 24-hour rainfall.

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Figure 1

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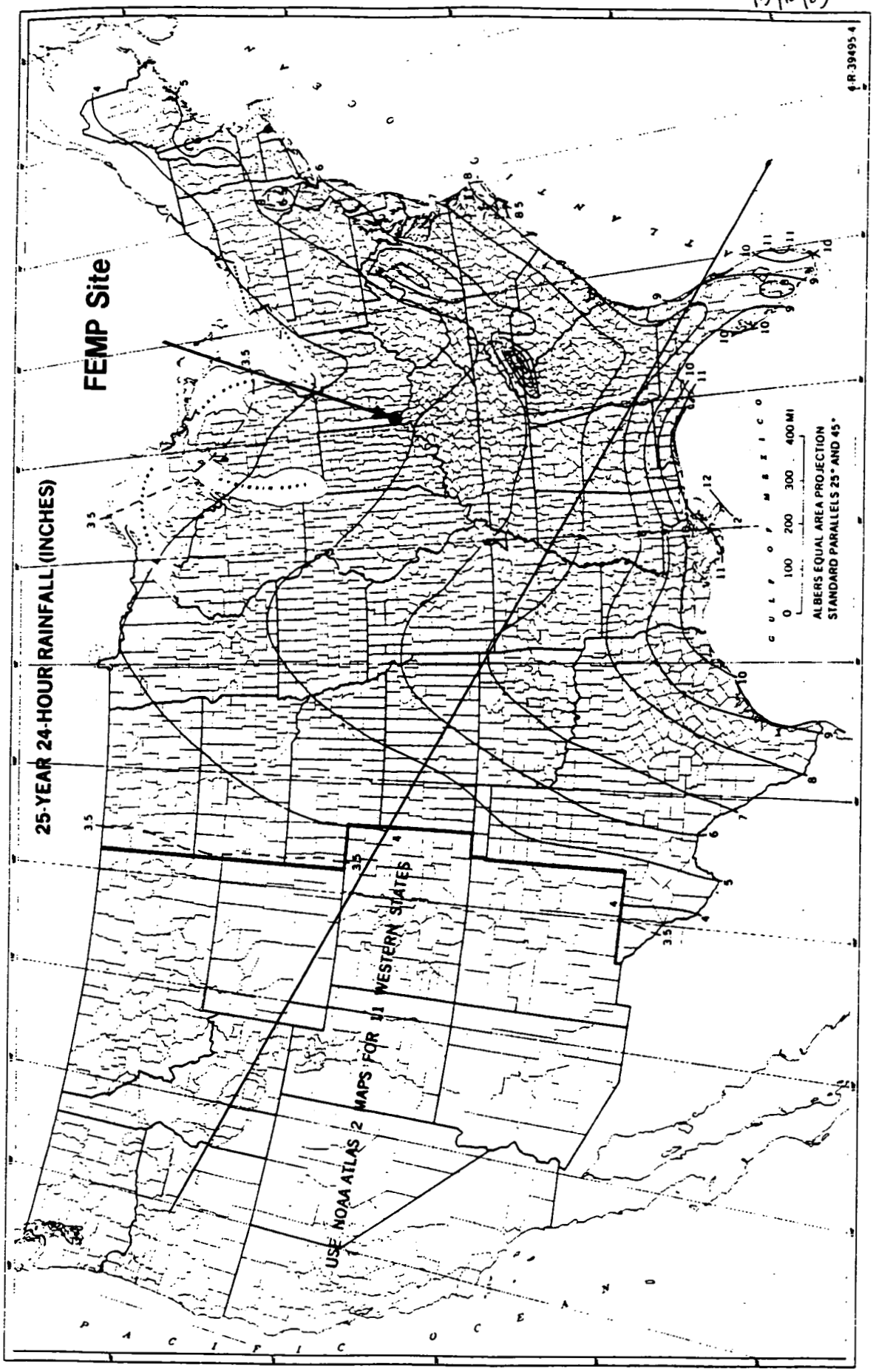

Figure B-6.—Twenty-five-year, 24-hour rainfall.

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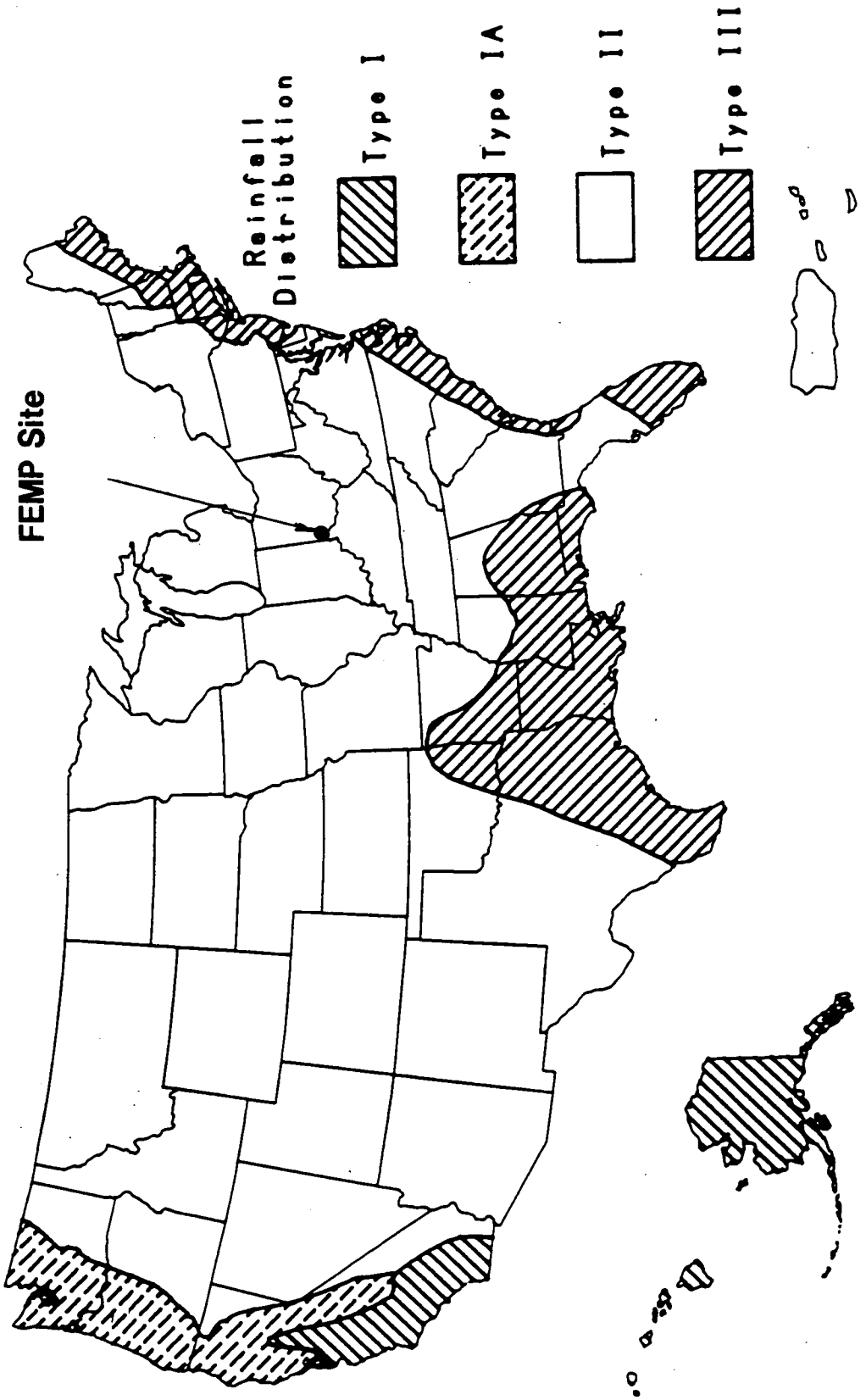

Figure B-2.—Approximate geographic boundaries for SCS rainfall distributions.

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(210-VI-TR-55, Second Ed., June 1986)

D&P Figure 3

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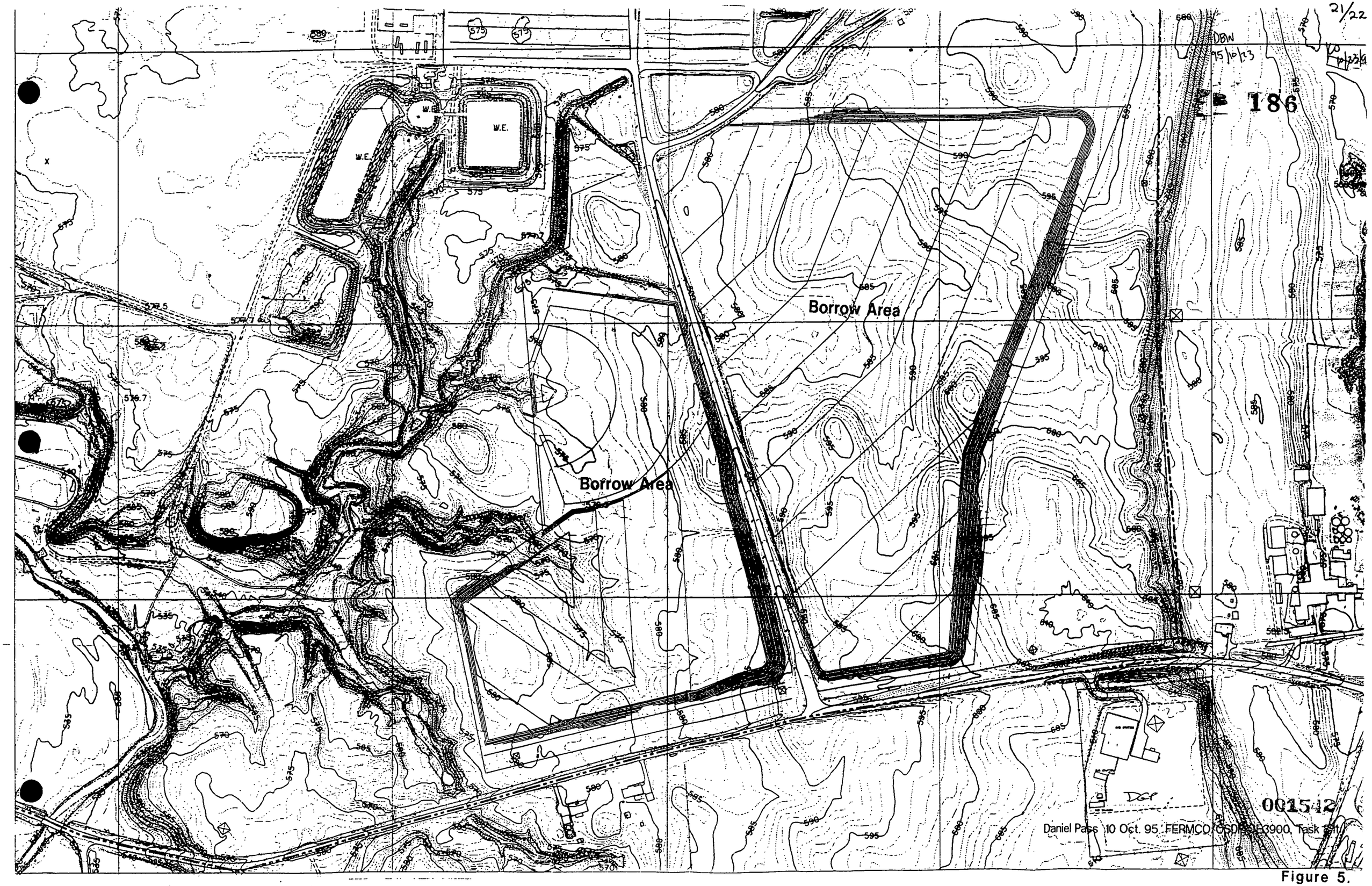
20/22
US RESERVATION
(ATOMIC ENERGY COMMISSION)
Area
Daniel Pass 10 Oct. 95 FERMCO/OSDF GE3900, Task 8.11
Figure 4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W.E.
W.E.
W.E.
Borrow Area
Borrow Area
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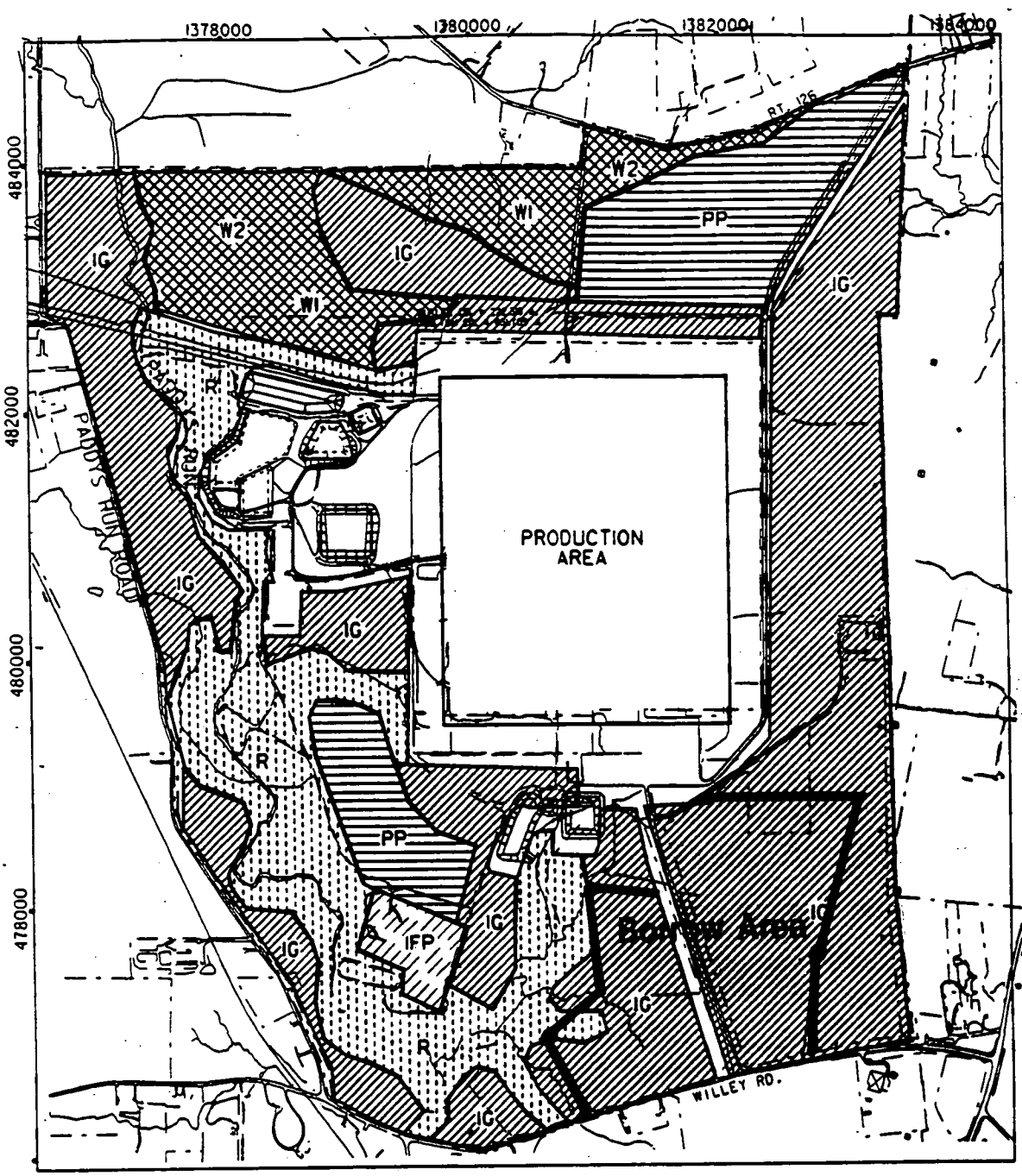
Daniel Pass 10 Oct. 95 FERMCO/CSDP UE3900, Task 3911

Figure 5.

186 DRW 95/10/23 22/22



LEGEND:

- INTRODUCED GRASSLAND (IG)
- PINE PLANTATION (PP)
- RIPARIAN (R) WOODLANDS
- EARLY SUCCESSION (W1) MID-SUCCESSION (W2)
- INACTIVE FLYASH PILE (IFP)
- FEMP BOUNDARY

NOTE

HABITAT BOUNDARIES ARE APPROXIMATE.

001543

SCALE

1350 675 0 1350 FEET

STATE PLANAR COORDINATE SYSTEM 1927

/RES2236/FIG4-1.DGN QUS RJ

DRAFT FINAL

FIGURE 3-64. HABITAT TYPES PRESENT ON THE FEMP

Figure 6

Daniel Pass 10 Oct. 95 FERMCO/OSDF GE3900, Task 8.11 DGP

Written by: Daniel Pass Date: 10 October 95 Reviewed by: PBR DBW 23OCT95 Date: 20OCT1995

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

Stormwater Management Calculations:

The purpose of these calculations is to:

1. Determine the peak borrow area runoff rates for the 25 y. - 24 hr. design storm, for both existing and post-development conditions. The results will be used to show that a no greater peak runoff rate occurs after development than existed prior to development.

2. Determine peak flow rates for drainage areas and sub-areas for use in design of borrow area stormwater management structures.

3. Design stormwater management structures.

Drainage area maps for both existing and post-development conditions are presented in Figures 1 and 2. Stormwater drainage structure locations are presented in Figure 3. Design data values are listed below.

Summary of Data:

• Design storm	25 yr. - 24 hr. event
• 25 yr. - 24 hr. rainfall	~~4.74 in.~~ Use Parson's data: 4.7 in Δ1
• 2 yr. - 24 hr. rainfall	~~2.74~~ in 2.55 in 23OCT95
• Soil Type, existing and post-development	C
• Cover Condition	
1. Existing Conditions	
North of Willey Rd.	Grassland, in good condition
South of Willey Rd.	Straight row crops, in good condition
2. Post-development Conditions	
North of Willey Rd. within borrow area grading limit	Grasses, in good condition
North of Willey Rd. outside borrow area grading limit	as existing condition
South of Willey Rd.	as existing condition

Determination of existing and post-development peak flow rates: The PC program TR-55 (USDA-SCS, 1986b) is used to estimate peak runoff rates. The procedure for obtaining design data used in the TR-55 program is described in detail in the Collection and Verification of Data package.

1. Curve Number: TR-55 uses input data related to soil type and cover conditions to obtain a SCS curve number for each drainage area. These values are presented below.

Table 1: Existing conditions for borrow area drainage areas.

Area Name	Sub-area Name	Area (acres)	Cover conditions	Weighted CN
I	none	10.3	grassland	74
II	none	41.8	grassland	74
III	A	19.7	grassland	74
III	B	3.9	grassland	74
III	C	3.9	grassland	74
III	D	22.5	straight row crops	82
IV	none	10.2	grassland	74

Table 2: Post-development conditions for borrow area drainage areas.

Area Name	Sub-area Name	Area (acres)	Cover conditions	Weighted CN
1	none	53.1	79 % meadow 21 % grassland	72
2	none	15.7	87 % meadow 13 % grassland	71
3	A	23.3	straight row crops	82
3	B	23.7	meadow	71
4	none	11.5	meadow	71

2. Time of Concentration: Drainage is generally from East to West and all flow ultimately discharges to Paddy's Creek. For each drainage area, for both existing and post-development conditions, the longest flow path was identified and broken down by flow type (i.e., sheet, shallow concentrated and open channel) into individual flow segments (See Figures 1 and 2). For each flow type TR-55 calculates a time of concentration using one of the following equations [USDA-SCS, 1986a]:

- Sheet flow: Sheet flow was assumed to change to shallow concentrated after 100 ft.

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,s^{0.4}} \qquad \text{[Equation 1]}$$

where:

T_t = travel time (hr);
n = Manning's roughness coefficient;
L = maximum flow length;
P_2 = rainfall from a 2-year, 24-hour storm event (in.); and
s = slope (grade) of land (ft/ft).

- Shallow Concentrated Flow:

  For slopes greater than 0.005 ft/ft, the average runoff velocity, V, is obtained using Figure 29 [USDA-SCS, 1986a] AI 23 OCT 95

  After obtaining V, calculate T_t using the following equation [USDA-SCS, 1986a]:

$$T_t = \frac{L}{3600\ V} \qquad \text{[Equation 2]}$$

  where:

  T_t = travel time (hr);
  L = maximum flow length (ft); and
  V = average runoff velocity (ft/s).

- Open Channel Flow: The drainage swales for the borrow area are assumed to have a V-shaped cross-section. Flow velocity is calculated using Manning's equation. Time of travel is then calculated using equation 1.

$$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n} \qquad \text{[Equation 3]}$$

  where:

  V = flow velocity (ft/s);
  r = hydraulic radius (ft), which is equal to a/p_w;
  a = cross sectional area of flow (ft^2);
  p_w = wetted perimeter (ft);
  s = slope of channel (ft/ft);
  n = Manning's coefficient of roughness; and

- A summary of the flow path data for both existing and post-development conditions, as well as TR-55 calculated travel times (t_t) and times of concentration (t_c), is presented in Tables 3 to 6 . PAGES 16 AND 17

AI 23 OCT 95

3. Peak Flow Rate: Peak flow rates for the 25 yr. 24 hr. storm event were calculated using the Tabular Hydrograph method in TR-55. Input data including rainfall, CN, Tc and Tt values are presented in previous sections of this calculation summary. The resulting peak flows to Paddy's Creek are:

- Peak flow rate for entire borrow area watershed, existing and post-development conditions.

Table 7 : Peak flow rates and peak runoff rate for existing conditions

Drainage Area Name	Flow Rate (Q), Cfs ~~(at 12.3 hr.)~~
I	~~23~~ 22
II	~~80~~ 78
III	~~94~~ 99 AI, 23 OCT 95
IV	~~17~~ 26
Peak Runoff Rate	~~214~~ Cfs 225

Table 8 : Peak flow rates and peak runoff rate for post-development conditions

Drainage Area Name	Flow Rate (Q), Cfs ~~(at 12.3 hr.)~~
1	~~23~~ 64
2	~~80~~ 23
3	93 ~~94~~ ~~97~~ AI, 23 OCT 95
4	~~17~~ 22
Peak Runoff Rate	~~169~~ Cfs 206

- The results indicate that the TOTAL post-development peak flow rates will not exceed the TOTAL pre-development flow rates.

- Peak flow rates for individual drainage areas for post-development conditions

Table 8: Peak flow rates for individual drainage areas

Drainage Area-Sub-area Names	Peak Flow Rate, (Q) Cfs	Time (from start of rainfall), hr.
1	~~65~~ 64	12.6
2	23	12.4
3	93 ~~93~~ ~~97~~ AI, 23 OCT 95	12.3
3-A	~~55~~ 54	12.4
3-B	~~45~~ 45	12.3
4	22	12.3

- TR-55 input values and output is provided in Attachment A.

AI, 23 OCT 95

~~2.~~ Borrow Area Stormwater Structures: The post development peak flow rates are used to design the following drainage structures (See Figure 3).

- Drainage swales along the east Side of the South Access Rd. (Swales 1B and 2A).
- Drainage swale along the north edge of the borrow area (Swale 1A).
- Culverts under the South access Rd. (Culverts 1 and 2).
- Riprap aprons at outlets of culverts 1 and 2 (Aprons 1 and 2).

Calculations for these drainage structures are presented below.

Culverts: Culverts are designed to convey flow from the east to the west side of the South Access Rd. Location of culverts and drainage areas are shown in Figure 1.

1. Design parameters for each are as follows:

Culvert 1

- Design Discharge[1], Q = ~~65~~ 64 Cfs AI, 23 OCT 95
- Culvert type: Circular reinforced concrete
- Culvert Length, L = 95 ft
- Culvert Slope, S = 1 %
- Culvert Manning's Coefficient = 0.012
- End Type-
  - Inlet end - Groove end with headwall
  - Outlet end - flared section

Culvert 2

- Design Discharge[1], Q = 23 Cfs
- Culvert type: Circular reinforced concrete
- Culvert Length, L = 130 ft
- Culvert Slope, S = 1 %
- Culvert Manning's Coefficient = 0.012
- End Type-
  - Inlet end - Groove end with headwall
  - Outlet end - flared section

[1] Q, for 25 yr. - 24 hr. storm event.

2. Select Culvert Size: Pipes were analyzed for inlet control conditions using Manning's equation and the nomograph shown in Figure 4 (ACPA, 1987). The results are presented below. Inlet control conditions were assumed as discharge is to a nearly flat area.

Table 9 : Culvert diameter and headwater depth

Culvert	Diameter, in.	Headwater, ft
1	two 30[1]	3.1
2	30	2.4

[1]Two culverts will be used, each will convey half the design inflow (i.e., 32.5 Cfs per culvert)

3. Determine Outlet Velocities: Outlet velocities were determined using Manning's equation. The results are presented below. Note that for design flows pipes are partially full.

Table 10: Culvert outlet velocities

Culvert	Outlet Velocity, fps
1	9.9
2	9.1

Velocities exceed permissible channel velocity (4 fps - for Silty clay loam/Sandy clay loam soil with vegetation in fair [SCS-Ohio, 1987]).

Riprap Aprons: Rip Rap Aprons will be provided to reduce velocities at the culvert outlets to non-erosive velocities for the downstream receiving area. It is assumed that the culverts discharge to a flat area and therefore tailwater depth will be minimum. The design procedure used is as outlined in Technical Standards and Specifications for Outlet Protection and for Riprap [SCS-Ohio, 1987].

1. Apron length and riprap size were determined using the chart shown in Figure 5 (SWC, 1992). The results are presented below.

Table 11 : Results of analysis for riprap apron

Culvert	Minimum Apron Length[1], ft	Riprap Size[1], ft
1	14	0.4
2	6	0.3

[1]An extrapolation was made to obtain these values for 30 in. diameter culverts.

2. Use the following specifications (Table 12) for riprap aprons. Apron dimensions are shown in Figure 6 along with a schematic of the apron and associated outlet structure.

Table 12: Summary of riprap apron specifications for culverts.

Apron	Item	Culvert 1	Culvert 2
Dimensions	Length, ft	14	6
	Width at outlet, ft	10	8
	Width at end of apron, ft	19	8.5
Riprap	Thickness, in.	6	6
	Size d_{50}, ft	0.5	0.5
	Maximum diameter, ft	0.75	0.75

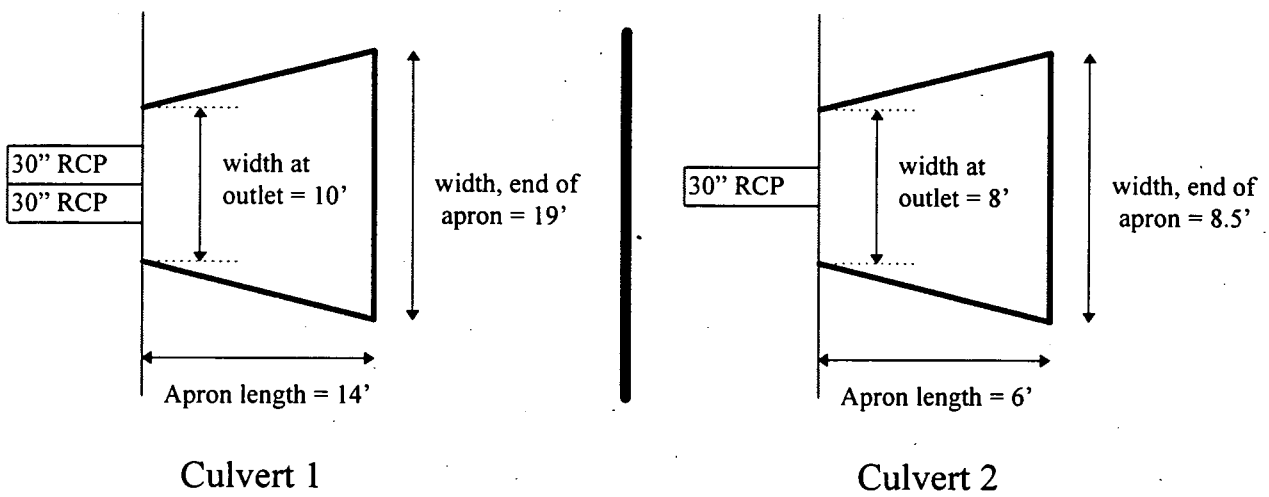


Figure 6 : Schematics for aprons and associated outlet structures

Permanent Drainage Swales: Permanent drainage swales, used to divert runoff from the borrow area to sediment ponds, will be provided at locations shown in Figure 1. The design procedure used is as outlined in Technical Standards and Specifications for Permanent and Temporary Diversions [SCS-OHIO, 1987].

1. Flow rates: Drainage areas contributing flow to these locations are shown in Figure ~~1~~ 3. Design flow rates are as follows:

   - Swales 1A and 1B: Design flows were calculated as a percentage of the total flow into culvert 1 (i.e., ~~65~~ 64 CFS Cfs), based on the percentage of the total area contributing to each swale. 23 OCT 95
   - Swale 2A: The design flow for swale 2A is the total flow rate into culvert 2.

2. Cross-section: Use a trapezoidal cross-section for drainage channel as shown in Figure 7. A Manning's roughness coefficient of 0.04 was obtained for a grass lined channel [AISI, 1983]

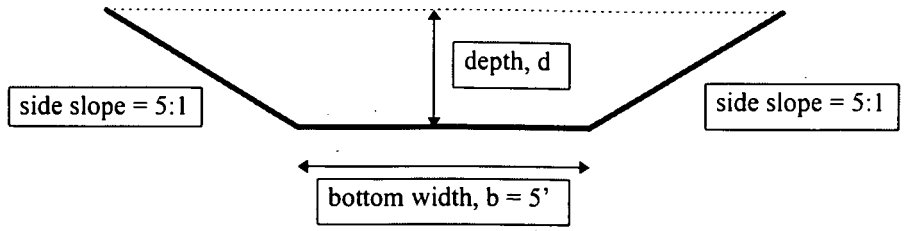


Figure 7: Cross section of drainage channel

3. Capacity: ~~Culverts~~ DRAINAGE CHANNELS were analyzed for capacity using a combination of Manning's and Chezy's equations as shown below [USDA-SCS, 1986c]. Results are shown in the following Table 3 13 AI 23 OCT 95

$$Q = a\frac{1.49\, r^{2/3}\, s^{1/2}}{n} \quad \checkmark \qquad \text{[Equation 4]}$$

where:

V = flow velocity (ft/s);
r = hydraulic radius (ft), which is equal to a/p_w;
a = cross sectional area of flow (ft^2);
p_w = wetted perimeter (ft);
s = slope of channel (ft/ft);
n = Manning's coefficient of roughness; and
Q = Design flow rate (ft^3/s).

Written by: Daniel Pass Date: 10 October 95 Reviewed by: PBR/PBR Date: 20 OCT 1995

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

DBW 23 OCT 95

Table 13: Results of capacity analysis for drainage channels.

Swale	Flow rate, Cfs	Channel depth, ft	Flow Velocity, fps	Additional depth requirements: Freeboard, ft	Additional depth requirements: Sedimentation, ft	Total depth Required, ft
1A	Δi, 23 OCT 95 ~~28.0~~ 27.6	1.08 → 1.1 ~~1.2~~ ~~1.3~~	2.52 → 2.5 ~~2.2~~	0.3	0.3	1.7 ~~1.8~~
1B	~~14.3~~ 13.8	0.78 → 0.8 ~~0.85~~	2.10 → 2.1 ~~1.8~~	0.3	0.3	1.4 ~~1.45~~
2A	23.0	0.98 → 1.0 ~~1.1~~	2.39 → 2.4 ~~2.1~~	0.3	0.3	1.6 ~~1.7~~

2. Design depths: Based on the above analysis drainage channels use the following depths.

Table 14: Drainage channel depths

Swale	Channel Depth, ft
1A	~~2.0~~ 1.75
1B	1.5
2A	1.75 Δi, 23 OCT 95

Channel slope conforms to the slope of drainage areas (i.e., 0.005).

REVIEW PROCEDURE

REFERENCES:

1. American Concrete pipe Association, "Concrete Pipe Design Manuel", Vienna Virginia, 1987.

2. American Iron and Steel Institute, "Handbook of Steel Drainage & Highway Construction Products", 3rd edition., Washington, DC, 1983.

3. Soil Conservation Service - Ohio, "Water Management and Sediment Control for Urbanizing Areas", Columbus, Ohio, 1987.

4. United States Department of Agriculture - Soil Conservation Service, Engineering Division, "TR-55 Microcomputer Program System", Washington, DC, June 1986a.

5. Virginia Department of Conservation and Recreation - Division of Soil and Water Conservation, "Virginia Erosion and Sediment Control Handbook", Richmond, Virginia, 1992.

6. UNITED STATES DEPARTMENT OF AGRICULTURE - SOIL CONSERVATION SERVICE, ENGINEERING DIVISION, "URBAN HYDROLOGY FOR SMALL WATERSHEDS", WASHINGTON, DC, JUNE 1986b.

REV 1, 23 OCT 95

7. PARSONS, "2000-YEAR FLOOD AND PROBABLE MAXIMUM FLOOD - SITEWIDE FLOODPLAIN DETERMINATION - OPERABLE UNIT 2", REVISION A, AUGUST 1995.

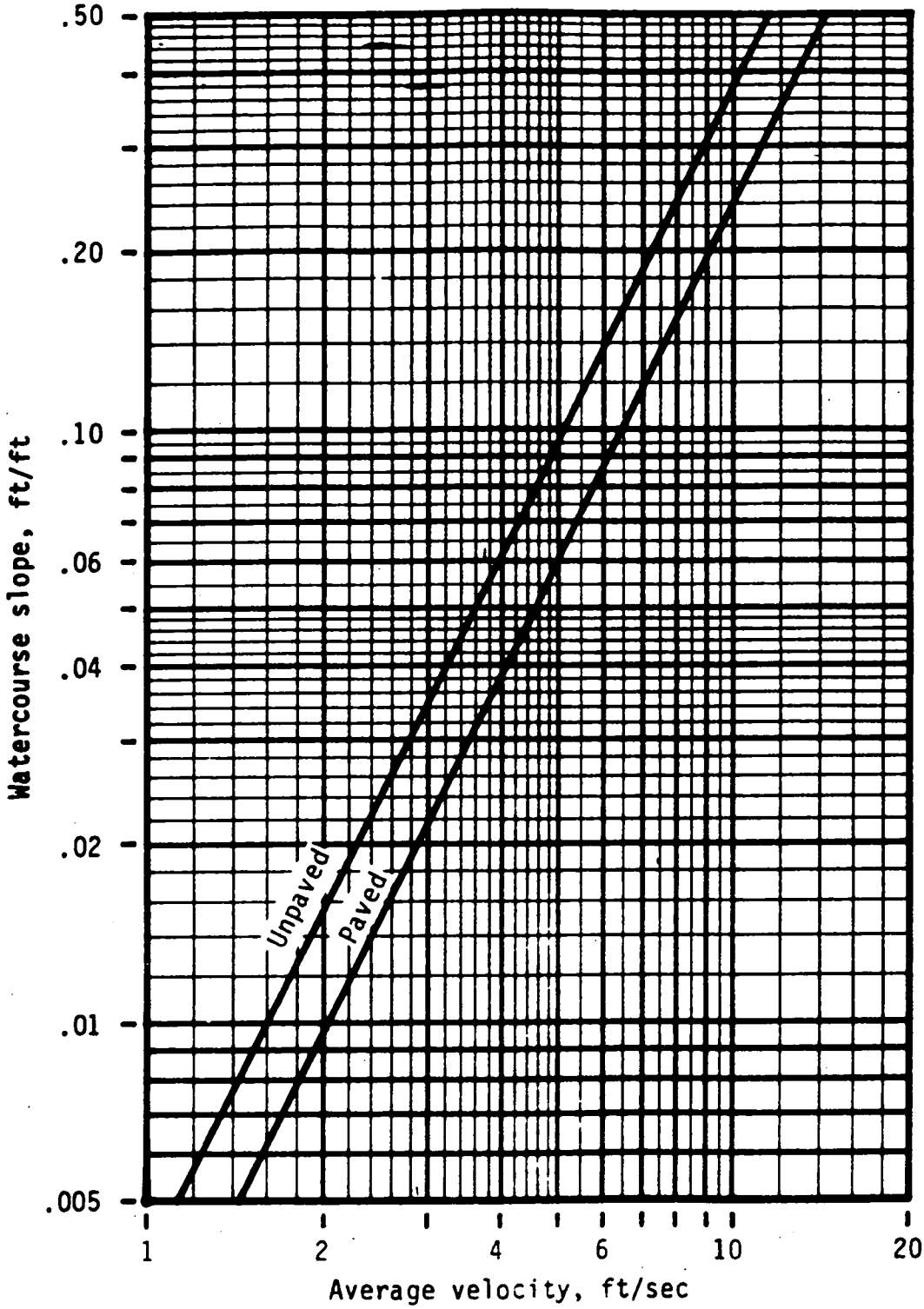


Figure 3-1.—Average velocities for estimating travel time for shallow concentrated flow.

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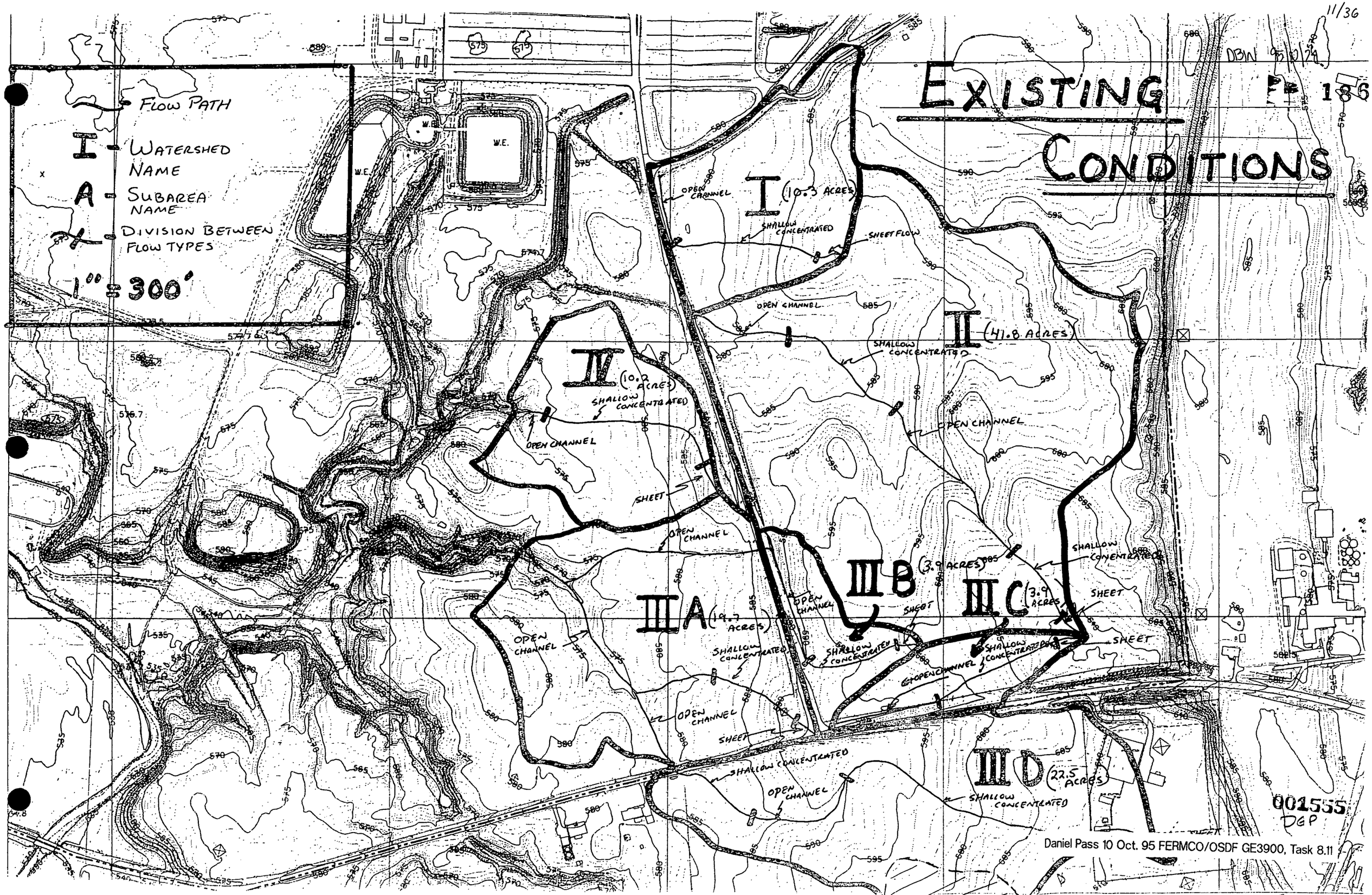
DBIN 95/10/24

EXISTING CONDITIONS



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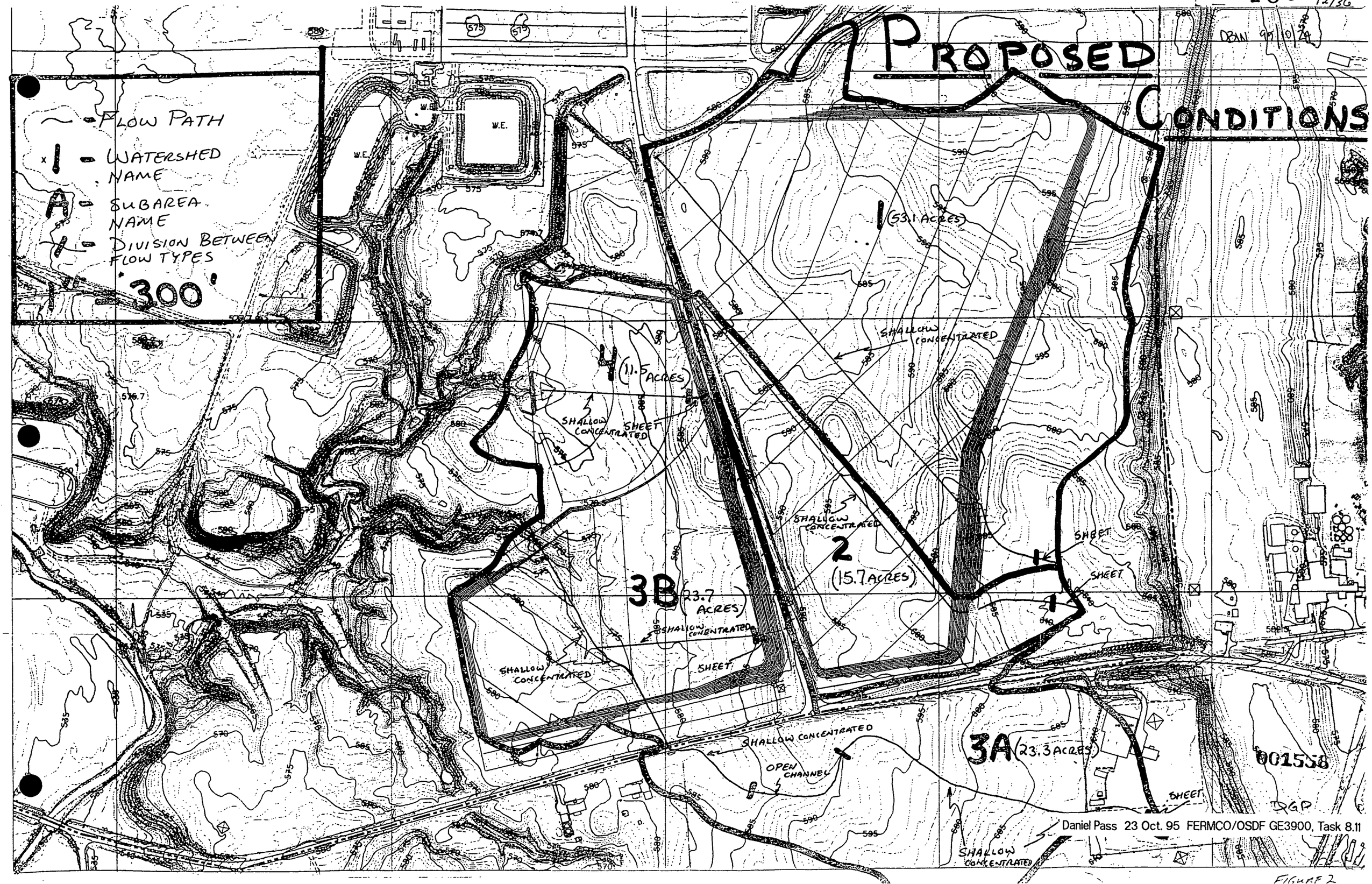
DEP


PROPOSED CONDITIONS
DBAN 95/10/24
~ - FLOW PATH
x | - WATERSHED NAME
A - SUBAREA NAME
- DIVISION BETWEEN FLOW TYPES
300'
W.E.
1 (53.1 ACRES)
2 (15.7 ACRES)
3A (23.3 ACRES)
3B (23.7 ACRES)
4 (11.5 ACRES)
SHALLOW CONCENTRATED
SHEET
OPEN CHANNEL
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DGP
Daniel Pass 23 Oct. 95 FERMCO/OSDF GE3900, Task 8.11

FIGURE 2

DBN 95/10/24

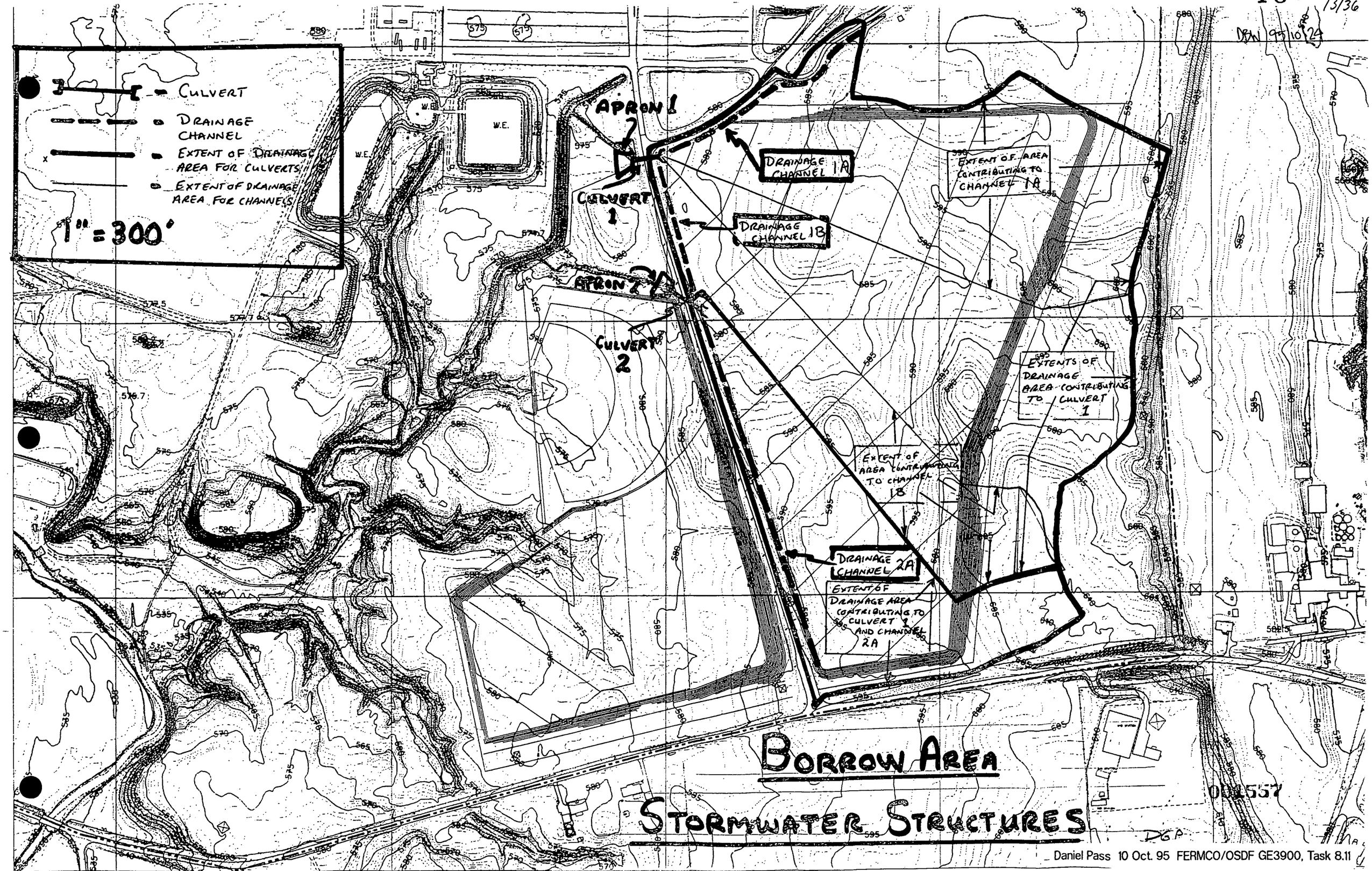

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FIGURE 3

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DBW 95/10/24

FIGURE 33

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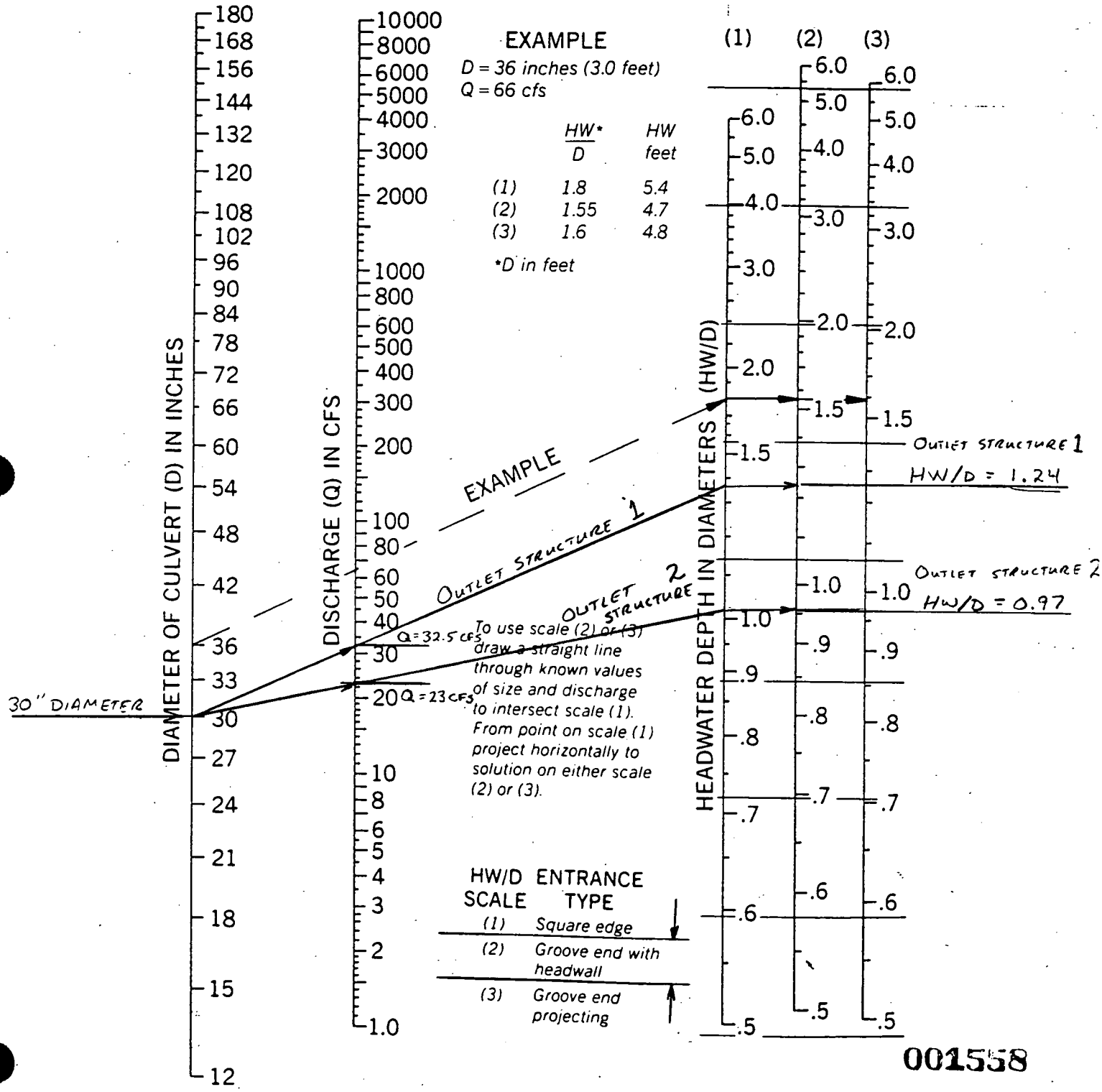
HEADWATER DEPTH FOR CIRCULAR CONCRETE PIPE CULVERTS WITH INLET CONTROL



001558

BUREAU OF PUBLIC ROADS JAN. 1963

HEADWATER SCALES 2&3
REVISED MAY 1964 DGP

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FIGURE 4

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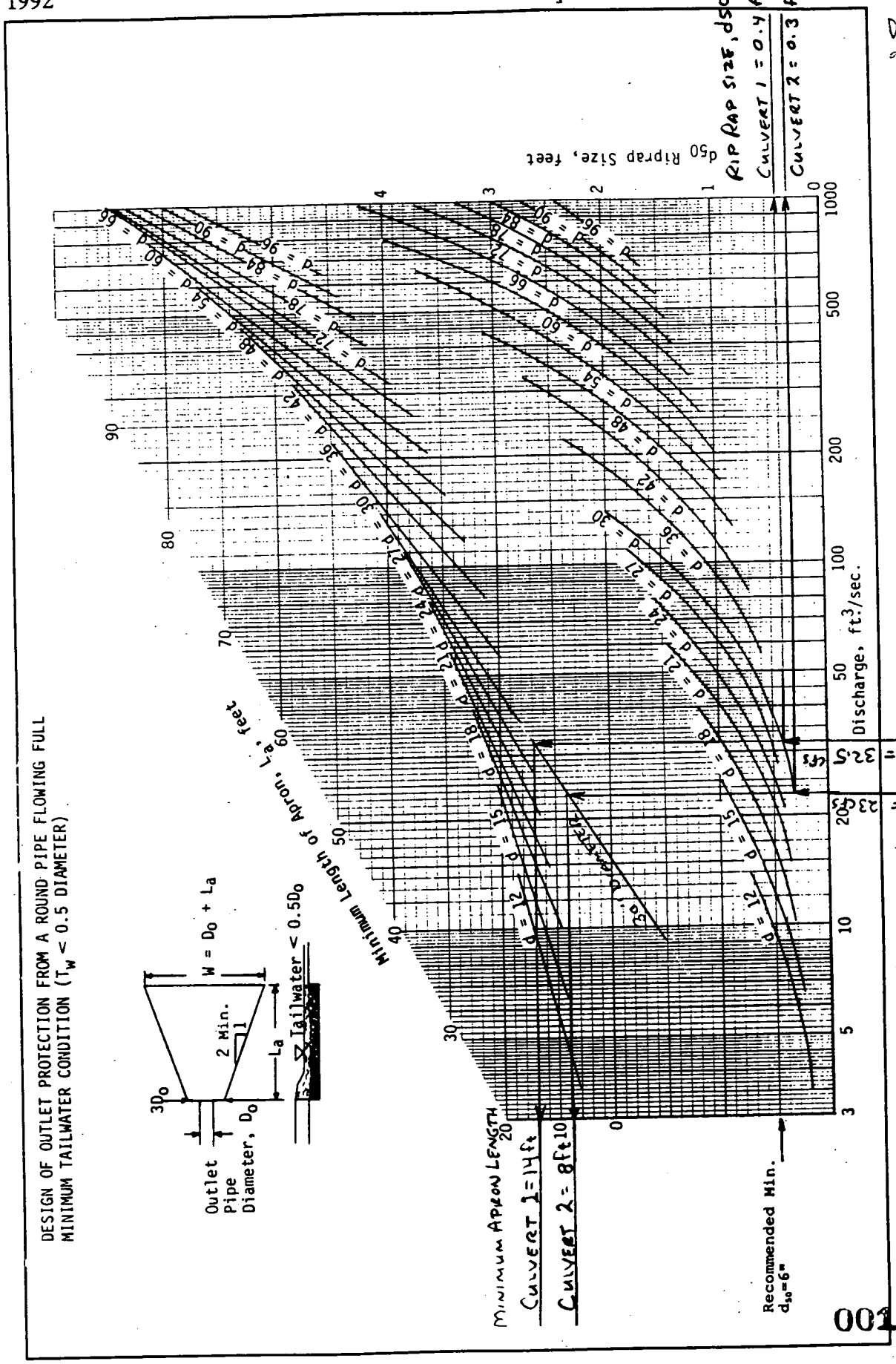
DBW 95/10/24



Source: USDA-SCS

Plate 3.18-3 DGP

Daniel Pass 10 Oct. 95 FERMCO/OSDF GE3900, Task 8.11

FIGURE 5

Table 3: Summary of flow path data and TR-55 calculated travel time, for existing conditions.

Drainage area		Travel Time, T_t											
	Sub-area	Sheet Flow			Shallow Concentrated Flow			Open Channel Flow					Total
Name	Name	Length, ft	Slope	T_t^1, hours	Length, ft	Slope	T_t^1, hours	Length, ft	Slope	Area, ft^2	WP, ft	T_t^1, hours	T_t^1, hours
I		100	0.0125	~~0.206~~ 0.221 ~~0.151~~	330	0.0242	0.037	125	0.014	24	40.1	0.01	0.29
					185	0.0108	0.031	125	0.014	67.5	90	0.008	
II		100	0.01	~~0.225~~ 0.241 ~~0.14~~	320	0.0141	0.046	680	0.0265	126	103	0.024	0.42
					505	0.0119	0.08	340	0.0103	18	60	0.049	
III	A	100	0.025	~~0.156~~ 0.167 ~~0.22~~	350	0.0329	0.033	970	0.0216	443	150	0.021	0.21
III	B	100	0.0357	~~0.135~~ 0.145 ~~0.21~~	320	0.025	0.035	450	0.0122	52.3	55.1	0.028	0.2
III	C	100	0.01	~~0.225~~ 0.241 ~~0.35~~	510	0.0261	0.054	350	0.01	5	20	0.058	0.34
III	D	100	0.0111	~~0.238~~ 0.256 ~~0.54~~	750	0.0087	0.138	420	0.0155	25	50.4	0.04	0.52
					870	0.0218	0.101						
IV		100	0.0233	~~0.16~~ 0.172	655	0.0233	0.074	120	0.0417	82.5	55.3	0.003	0.24

REVISION 1
2300795

Table 4: Summary of flow path data and TR-55 calculated time of concentration for post-development conditions.

Drainage area		Travel Time, T_t											
	Sub-Area	Sheet Flow			Shallow Concentrated Flow (SCF)			Open Channel Flow					Total
Name	Name	Length, ft	Slope	T_t^1, hours	Length, ft	Slope	T_t^1, hours	Length, ft	Slope	Area, ft^2	WP, ft	T_t^1, hours	T_t^1, hours
1		100	0.0071	~~0.258~~ 0.277	278	0.023	0.032						0.65
					1700	0.0065	0.363						
2		100	0.0068	~~0.262~~ 0.282	380	0.0286	0.039						0.60
					1480	0.0074	0.296						
3	A	100	0.0111	~~0.238~~ 0.256	750	0.0218	0.101	420	0.0155	0.0425	50.4	0.04	0.52
					870	0.0155	0.04						
3	B	100	0.16	~~0.074~~ 0.080	1050	0.0048	0.261						0.34
4		40	0.2	~~0.033~~ 0.035	580	0.0056	0.133						0.32
		60	0.01	~~0.0149~~ 0.0160									

0024560

DSP

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16/36

Table 5: Summary of flow path data and TR-55 calculated time of concentration, for existing conditions.

Drainage area		Time of Travel T_t					
	Sub-area	Open Channel Flow					Total
Name	Name	Length, ft	Slope	Area, ft^2	WP, ft	T_c1, hours	T_c1, hours
I							
II							
III	a						
III	b	580	0.0224	21	35.1	0.036	0.04
		370	0.0405	495	141	0.005	
III	c	610	0.0246	7	20.1	0.059	0.08
		990	0.0192	442	143	0.022	
III	d	990	0.0192	442	144	0.022	0.02
IV							

Table 6: Summary of flow path data and TR-55 calculated time of concentration for post-development conditions.

Drainage Area		Time of Concentration, T_c Shallow Concentrated Flow		
	Sub-Area			
Name	Name	Length, ft	Slope	T_c1, hours
1				
2				
3	A	900	0.0167	0.12
3	B			
4				

PAGES 18 THROUGH 36 REPLACED BY REVISION 1, 23 OCT 95 18/36

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

Project : Fermco/OSDF User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Predevelopement Conditions
Area : I

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COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	10.3(74)	-
Total Area (by Hydrologic Soil Group)				10.3	

SUBAREA: I TOTAL DRAINAGE AREA: 10.3 Acres WEIGHTED CURVE NUMBER: 74

001562

DGP

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : Fermco/OSDF User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Predevelopement Conditions
Area : II

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	41.8(74)	-
Total Area (by Hydrologic Soil Group)				41.8	

SUBAREA: II TOTAL DRAINAGE AREA: 41.8 Acres WEIGHTED CURVE NUMBER: 74

001563

DGP

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RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : Fermco/OSDF User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Predevelopement Conditions
Subarea : IIIA

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	19.7(74)	-
Total Area (by Hydrologic Soil Group)				19.7	

SUBAREA: IIIA TOTAL DRAINAGE AREA: 19.7 Acres WEIGHTED CURVE NUMBER: 74

001564

DGP

Daniel Pass 23 Oct. 95 FERMCO/OSDF GE3900, Task 8.11

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : Fermco/OSDF User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Predevelopement Conditions
Area : IIIB

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	3.86(74)	-
Total Area (by Hydrologic Soil Group)				3.86	

SUBAREA: IIIB TOTAL DRAINAGE AREA: 3.86 Acres WEIGHTED CURVE NUMBER: 74

001565

DGP

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : Fermco/OSDF User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Predevelopement Conditions
Subarea : IIIC

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	3.93(74)	-
Total Area (by Hydrologic Soil Group)				3.93	

SUBAREA: IIIC TOTAL DRAINAGE AREA: 3.93 Acres WEIGHTED CURVE NUMBER: 74

DGP

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : Fermco/OSDF User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Predevelopement Conditions
Area : IIID

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
			Acres (CN)			
CULTIVATED AGRICULTURAL LANDS						
Row crops	SR + Crop residue	good	-	-	22.5(82)	-
Total Area (by Hydrologic Soil Group)					22.5	

SUBAREA: IIID TOTAL DRAINAGE AREA: 22.5 Acres WEIGHTED CURVE NUMBER: 82

001567

DGP

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : Fermco/OSDF User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Predevelopement Conditions
Subarea : IV

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	10.2(74)	-
Total Area (by Hydrologic Soil Group)				10.2	

SUBAREA: IV TOTAL DRAINAGE AREA: 10.2 Acres WEIGHTED CURVE NUMBER: 74

001568

DGP

TIME OF CONCENTRATION AND TRAVEL TIME

Version 2.00

Project : Fermco/OSDF User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Predevelopement Conditions

Subarea #1 - I

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0125	e					0.221
Shallow Concent'd		330	.0242	u					0.037
Shallow Concent'd		185	.0108	u					0.031
Open Channel		125	.014		.035	24	40.1		0.010
Open Channel		125	.014		.035	67.5	90		0.008

Time of Concentration = 0.31*
=====

Subarea #2 - II

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0100	e					0.241
Shallow Concent'd		320	.0141	u					0.046
Shallow Concent'd		505	.0119	u					0.080
Open Channel		680	.0265		.035	126.	103		0.024
Open Channel		340	.0103		.035	18	60		0.049

Time of Concentration = 0.44*
=====

Subarea #3 - IIIA

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.025	e					0.167
Shallow Concent'd		350	.0329	u					0.033
Open Channel		970	.0216		.035	443	150		0.021

Time of Concentration = 0.22*
=====

* - Generated for use by TABULAR method

001569

DGP

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : Fermco/OSDF User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Predevelopement Conditions

Subarea #4 - IIIB

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0357	e					0.145
Shallow Concent'd		320	.025	u					0.035
Open Channel		450	.0122		.03	552.3	55.1		0.028
						Time of Concentration =			0.21*
									=====
Open Channel		580	.0224		.03	521	35.1		0.036
Open Channel		370	.0405		.035	495	141		0.005
							Travel Time =		0.04*
									=====

Subarea #5 - IIIC

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.010	e					0.241
Shallow Concent'd		510	.0261	u					0.054
Open Channel		350	.01		.0355		20		0.058
						Time of Concentration =			0.35*
									=====
Open Channel		610	.0246		.04 7		20.1		0.059
Open Channel		990	.0192		.035442		143		0.022
							Travel Time =		0.08*
									=====

Subarea #6 - IIID

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0111	d					0.256
Shallow Concent'd		750	.0087	u					0.138
Shallow Concent'd		870	.0218	u					0.101
Open Channel		420	.0155		.04 25		50.4		0.040
						Time of Concentration =			0.54*
									=====
Open Channel		990	.0192		.035442		144		0.022
							Travel Time =		0.02*
									=====

Subarea #7 - IV

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0233	e					0.172
Shallow Concent'd		655	.0233	u					0.074
Open Channel		120	.0417		.03582.5		55.3		0.003

001570 DGP

Time of Concentration = 0.25*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface	F Grass, Dense	--- Shallow Concentrated ---
B Fallow (No Res.)	G Grass, Burmuda	--- Surface Codes ---
C Cultivated < 20 % Res.	H Woods, Light	P Paved
D Cultivated > 20 % Res.	I Woods, Dense	U Unpaved
E Grass-Range, Short	J Range, Natural	

* - Generated for use by TABULAR method

DGP

TABULAR HYDROGRAPH METHOD

Version 2.00

Project : Fermco/OSDF User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Predevelopement Conditions

Total watershed area: 0.175 sq mi Rainfall type: II Frequency: 25 years

	Subareas						
	I	II	IIIA	IIIB	IIIC	IIID	IV
Area(sq mi)	0.02*	0.07*	0.03*	0.01*	0.01*	0.04*	0.02*
Rainfall(in)	4.7	4.7	4.7	4.7	4.7	4.7	4.7
Curve number	74*	74*	74*	74*	74*	82*	74*
Runoff(in)	2.13	2.13	2.13	2.13	2.13	2.81	2.13
Tc (hrs)	0.31*	0.44*	0.22*	0.21*	0.35*	0.54*	0.25*
(Used)	0.30	0.40	0.20	0.20	0.30	0.50	0.20
TimeToOutlet	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ia/P	0.15	0.15	0.15	0.15	0.15	0.09	0.15
(Used)	0.15	0.15	0.15	0.15	0.15	0.10	0.15

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) I	II	IIIA	IIIB	IIIC	IIID	IV
11.0	7	1	2	1	0	0	2	1
11.3	9	1	3	2	0	0	2	1
11.6	11	1	4	2	0	0	3	1
11.9	37	3	8	11	2	1	6	6
12.0	74	7	16	23	4	3	9	12
12.1	145	14	32	45	9	5	17	23
12.2	206	22P	59	51P	10P	8	30	26P
12.3	209P	22	78P	32	6	9P	46	16
[illegible]	180	16	77	17	3	6	52P	9
12.5	142	10	59	11	2	4	50	6
12.6	108	7	42	9	2	3	40	5
12.7	79	5	31	7	1	2	29	4
12.8	61	4	23	6	1	2	22	3
13.0	42	3	15	5	1	1	14	3
13.2	31	2	12	4	1	1	9	2
13.4	26	2	9	4	1	1	7	2
13.6	23	2	8	3	1	1	6	2
13.8	21	2	7	3	1	1	5	2
14.0	20	2	7	3	1	1	5	1
14.3	15	1	6	2	0	1	4	1
14.6	13	1	5	2	0	0	4	1
15.0	12	1	5	2	0	0	3	1
15.5	11	1	4	2	0	0	3	1
16.0	11	1	4	2	0	0	3	1
16.5	9	1	3	2	0	0	2	1
17.0	8	1	3	1	0	0	2	1
17.5	8	1	3	1	0	0	2	1
18.0	8	1	3	1	0	0	2	1
19.0	8	1	3	1	0	0	2	1
20.0	6	1	2	1	0	0	1	1
22.0	4	0	2	1	0	0	1	0
[illegible]	0	0	0	0	0	0	0	0

PEAK FLOW RATES EXISTING CONDITIONS

001572

P - Peak Flow * - value(s) provided from TR-55 system routines

DGP

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE 3900-08.2 User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Restored Conditions
Area : 1

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	13.5(74)	-
Meadow -cont. grass (non grazed)	----	-	-	39.6(71)	-
Total Area (by Hydrologic Soil Group)				53.1	

SUBAREA: 1 TOTAL DRAINAGE AREA: 53.1 Acres WEIGHTED CURVE NUMBER: 72

001573

DGP

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE 3900-08.2 User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Restored Conditions
Area : 2

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	2.01(74)	-
Meadow -cont. grass (non grazed)	----	-	-	13.7(71)	-
Total Area (by Hydrologic Soil Group)				15.7	
				====	

SUBAREA: 2 TOTAL DRAINAGE AREA: 15.71 Acres WEIGHTED CURVE NUMBER: 71

001574

DGP

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE 3900-08.2 User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Restored Conditions
Subarea : 3A

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
				Acres (CN)		
CULTIVATED AGRICULTURAL LANDS						
Row crops	SR + Crop residue	good	-	-	23.3(82)	-
Total Area (by Hydrologic Soil Group)					23.3	

SUBAREA: 3A TOTAL DRAINAGE AREA: 23.3 Acres WEIGHTED CURVE NUMBER: 82

001575 DGP

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE 3900-08.2 User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Restored Conditions
Subarea : 3B

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
	Acres (CN)			
OTHER AGRICULTURAL LANDS				
Meadow -cont. grass (non grazed) ----	-	-	23.7(71)	-
Total Area (by Hydrologic Soil Group)			23.7	

SUBAREA: 3B TOTAL DRAINAGE AREA: 23.7 Acres WEIGHTED CURVE NUMBER: 71

001576

DGP

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE 3900-08.2 User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Restored Conditions
Area : 4

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
		Acres (CN)		
OTHER AGRICULTURAL LANDS				
Meadow -cont. grass (non grazed) ----	-	-	11.5(71)	-
Total Area (by Hydrologic Soil Group)			11.5	

SUBAREA: 4 TOTAL DRAINAGE AREA: 11.5 Acres WEIGHTED CURVE NUMBER: 71

001577

DGP

TIME OF CONCENTRATION AND TRAVEL TIME

Version 2.00

Project : GE 3900-08.2 User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Restored Conditions

Subarea #1 - 1

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0071	e					0.277
Shallow Concent'd		278	0.023	u					0.032
Shallow Concent'd		1700	.0065	u					0.363

Time of Concentration = 0.67*
=====

Subarea #2 - 2

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0068	e					0.282
Shallow Concent'd		380	.0286	u					0.039
Shallow Concent'd		1480	.0074	u					0.296

Time of Concentration = 0.62*
=====

Subarea #3 - 3A

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0111	d					0.256
Shallow Concent'd		750	.0087	u					0.138
Shallow Concent'd		870	.0218	u					0.101
Open Channel		420	.0155			0.0425	50.4		0.040

Time of Concentration = 0.54*
=====

Shallow Concent'd		900	.0167	u					0.120

Travel Time = 0.12*
=====

Subarea #4 - 3B

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	0.16	e					0.080
Shallow Concent'd		1050	.0048	u					0.261

Time of Concentration = 0.34*
=====

* - Generated for use by TABULAR method

001578

DGP

TIME OF CONCENTRATION AND TRAVEL TIME

Version 2.00

Project : GE 3900-08.2 User: DGP Date: 10-02-95

County : Hamilton State: OH Checked: ____ Date: _____

Subtitle: East Field Borrow Area: Restored Conditions

---------- Subarea #5 - 4 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	40	.2	e					0.035
Sheet		60	.01	e					0.160
Shallow Concent'd		580	.0056	u					0.133

Time of Concentration = 0.33*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

001579

DGP

DANIEL PASS 23 OCT. 95 FERMCO/OSDF GE 3900 TASK 8.11

TABULAR HYDROGRAPH METHOD

Version 2.00

Project : GE 3900-08.2 User: DGP Date: 10-02-95
County : Hamilton State: OH Checked: ____ Date: _____
Subtitle: East Field Borrow Area: Restored Conditions

Total watershed area: 0.199 sq mi Rainfall type: II Frequency: 25 years

	Subareas 1	2	3A	3B	4
Area(sq mi)	0.08*	0.02*	0.04*	0.04*	0.02*
Rainfall(in)	4.7	4.7	4.7	4.7	4.7
Curve number	72*	71*	82*	71*	71*
Runoff(in)	1.97	1.89	2.81	1.89	1.89
Tc (hrs)	0.67*	0.62*	0.54*	0.34*	0.33*
(Used)	0.75	0.50	0.50	0.30	0.30
TimeToOutlet	0.00	0.00	0.00	0.00	0.00
Ia/P	0.17	0.17	0.09	0.17	0.17
(Used)	0.17	0.17	0.10	0.17	0.17

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) 1	2	3A	3B	4
11.0	5	1	1	2	1	0
11.3	7	2	1	2	1	1
11.6	10	3	1	3	2	1
11.9	21	4	2	6	6	3
12.0	36	5	3	10	12	6
12.1	70	8	6	17	26	13
12.2	122	14	12	32	43	21
12.3	160	26	19	48	45P	22P
[illegible]	167P	42	23P	54P	32	16
12.5	160	56	22	52	20	10
12.6	144	64P	18	41	14	7
12.7	124	64	14	30	11	5
12.8	105	58	11	23	9	4
13.0	71	41	7	14	6	3
13.2	52	29	5	10	5	3
13.4	39	21	4	8	4	2
13.6	31	16	3	6	4	2
13.8	27	13	3	5	4	2
14.0	24	11	3	5	3	2
14.3	19	9	2	4	3	1
14.6	18	8	2	4	3	1
15.0	16	7	2	3	3	1
15.5	14	6	2	3	2	1
16.0	12	5	1	3	2	1
16.5	11	5	1	2	2	1
17.0	10	4	1	2	2	1
17.5	10	4	1	2	2	1
18.0	10	4	1	2	2	1
19.0	8	3	1	2	1	1
20.0	7	3	1	1	1	1
22.0	6	2	1	1	1	1
[illegible]	0	0	0	0	0	0

PEAK FLOW RATES FOR POST-DEVELOPMENT CONDITIONS

P - Peak Flow * - value(s) provided from TR-55 system routines

001580

DGP

DANIEL PASS 23 OCT. 95 FERMCO/OSDF GE3900

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATIONS PACKAGE

USDA-SCS TR-55

1. United States Department of Agriculture, "*Urban Hydrology for Small Watersheds,*" Soil Conservation Service, Engineering Division, Washington, DC, Technical Release 55, June 1986.

PB 186

United States
Department of
Agriculture

Soil
Conservation
Service

Engineering
Division

Technical
Release 55

June 1986

Urban Hydrology for Small Watersheds

001582

Appendix C: Computer program

The TR-55 procedures have been incorporated in a computer program. The program, written in BASIC, requires less than 256K memory to operate and was developed for an MS-DOS operating system. Users of the program, however, still need to be familiar with the procedures in this TR. Features of the program include the following:

- The full screen (24 lines, 80 columns) is used to enter data. Flexibility of coding allows movement about the screen for quick data modifications.
- Function keys provide menu power to move to different modules (TR-55 chapters) within the program. Some keys are permanently defined while others vary by module.
- "Help" screens provide pertinent information to the user depending on location in the program. Two types of information are included: (1) define system operation and (2) describe input parameters.
- User files provide for optional entry of local data, such as rainfall-frequency, graphic peak discharge equation coefficients, and tabular hydrographs for other rainfall distributions.

Copies of the program can be obtained from—

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Telephone (703) 487-4650

Preface

Technical Release 55 (TR-55) presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs. These procedures are applicable in small watersheds, especially urbanizing watersheds, in the United States. First issued by the Soil Conservation Service (SCS) in January 1975, TR-55 incorporates current SCS procedures. This revision includes results of recent research and other changes based on experience with use of the original edition.

The major revisions and additions are—

1. A flow chart for selecting the appropriate procedure;
2. Three additional rain distributions;
3. Expansion of the chapter on runoff curve numbers;
4. A procedure for calculating travel times of sheet flow;
5. Deletion of a chapter on peak discharges;
6. Modifications to the Graphical Peak Discharge method and Tabular Hydrograph method;
7. A new storage routing procedure;
8. Features of the TR-55 computer program; and
9. Worksheets.

This revision was prepared by Roger Cronshey, Hydraulic Engineer, Hydrology Unit, SCS, Washington, DC; Dr. Richard H. McCuen, Professor of Civil Engineering, University of Maryland, College Park, MD; Norman Miller, Head, Hydrology Unit, SCS, Washington, DC; Dr.Walter Rawls, Hydrologist, Agricultural Research Service, Beltsville, MD; Sam Robbins (deceased), formerly Hydraulic Engineer, SCS, South National Technical Center (NTC), Fort Worth, TX; and Don Woodward, Hydraulic Engineer, SCS, Northeast NTC, Chester, PA. Valuable contributions were made by John Chenoweth, Stan Hamilton, William Merkel, Robert Rallison (ret.), Harvey Richardson, Wendell Styner, other SCS hydraulic engineers, and Teresa Seeman.

Revised June 1986

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Metric conversions

The English system of units is used in this TR. To convert to the International System of units (metric), use the following factors:

From English unit	To metric unit	Multiply by
Acre	Hectare	0.405
Square mile	Square kilometer	2.59
Cubic feet per second	Cubic meters per second	0.0283
Inch	Millimeter	25.4
Feet per second	Meters per second	0.3048
Acre-foot	Cubic meter	1233.489
Cubic foot	Cubic meter	0.0283

Perform rounding operations as appropriate to indicate the same level of precision as that of the original measurement. For example:

1. A stream discharge is recorded in cubic feet per second with three significant digits.
2. Convert stream discharge to cubic meters per second by multiplying by 0.0283.
3. Round to enough significant digits so that, when converting back to cubic feet per second, you obtain the original value (step 1) with three significant digits.

Definitions of symbols

Symbol	Unit	Definition
a	ft^2	Cross sectional flow area
A_m	mi^2	Drainage area
CN		Runoff curve number
CN_c		Composite runoff curve number
CN_p		Pervious runoff curve number
E_{max}		Maximum stage
F_p		Pond and swamp adjustment factor
H_w	ft	Head over weir crest
I_a	in	Initial abstraction
L	ft	Flow length
L_w	ft	Weir crest length
m		Number of flow segments
n		Manning's roughness coefficient
P	in	Rainfall
P_{imp}		Percent imperviousness
P_2	in	Two-year frequency, 24-hour rainfall
p_w	ft	Wetted perimeter
q	cfs	Hydrograph coordinate
q_i	cfs	Peak inflow discharge
q_o	cfs	Peak outflow discharge
q_p	cfs	Peak discharge
q_t	csm/in	Tabular hydrograph unit discharge
q_u	csm/in	Unit peak discharge
Q	in	Runoff
r	ft	Hydraulic radius
R		Ratio of unconnected impervious area to total impervious area
s	ft/ft	Slope of hydraulic grade line
S	in	Potential maximum retention after runoff begins
t	hr	Hydrograph time
T_c	hr	Time of concentration
T_p	hr	Time to peak
T_t	hr	Travel time
V	ft/s	Average velocity
V_r	acre-ft, ft^3, or watershed-inch	Runoff volume
V_s	acre-ft, ft^3, or watershed-inch	Storage volume

001587

Chapter 1: Introduction

The conversion of rural land to urban land usually increases erosion and the discharge and volume of storm runoff in a watershed. It also causes other problems that affect soil and water. As part of programs established to alleviate these problems, engineers increasingly must assess the probable effects of urban development, as well as design and implement measures that will minimize its adverse effects.

Technical Release 55 (TR-55) presents simplified procedures for estimating runoff and peak discharges in small watersheds. In selecting the appropriate procedure, consider the scope and complexity of the problem, the available data, and the acceptable level of error. While this TR gives special emphasis to urban and urbanizing watersheds, the procedures apply to any small watershed in which certain limitations are met.

Effects of urban development

An urban or urbanizing watershed is one in which impervious surfaces cover or will soon cover a considerable area. Impervious surfaces include roads, sidewalks, parking lots, and buildings. Natural flow paths in the watershed may be replaced or supplemented by paved gutters, storm sewers, or other elements of artificial drainage.

Hydrologic studies to determine runoff and peak discharge should ideally be based on long-term stationary streamflow records for the area. Such records are seldom available for small drainage areas. Even where they are available, accurate statistical analysis of them is usually impossible because of the conversion of land to urban uses during the period of record. It therefore is necessary to estimate peak discharges with hydrologic models based on measurable watershed characteristics. Only through an understanding of these characteristics and experience in using these models can we make sound judgments on how to alter model parameters to reflect changing watershed conditions.

Urbanization changes a watershed's response to precipitation. The most common effects are reduced infiltration and decreased travel time, which significantly increase peak discharges and runoff. Runoff is determined primarily by the amount of precipitation and by infiltration characteristics related to soil type, soil moisture, antecedent rainfall, cover type, impervious surfaces, and surface retention. Travel time is determined primarily by slope, length of flow path, depth of flow, and roughness of flow surfaces. Peak discharges are based on the relationship of these parameters and on the total drainage area of the watershed, the location of the development, the effect of any flood control works or other natural or manmade storage, and the time distribution of rainfall during a given storm event.

The model described in TR-55 begins with a rainfall amount uniformly imposed on the watershed over a specified time distribution. Mass rainfall is converted to mass runoff by using a runoff curve number (CN). CN is based on soils, plant cover, amount of impervious areas, interception, and surface storage. Runoff is then transformed into a hydrograph by using unit hydrograph theory and routing procedures that depend on runoff travel time through segments of the watershed.

For a description of the hydrograph development method used by SCS, see chapter 16 of the SCS National Engineering Handbook, Section 4—Hydrology (NEH-4) (SCS 1985). The routing method (Modified Att-Kin) is explained in appendixes G and H of draft Technical Release 20 (TR-20) (SCS 1983).

Rainfall

TR-55 includes four regional rainfall time distributions. See appendix B for a discussion of how these distributions were developed.

All four distributions are for a 24-hour period. This period was chosen because of the general availability of daily rainfall data that were used to estimate 24-hour rainfall amounts. The 24-hour duration spans most of the applications of TR-55.

One critical parameter in the model is time of concentration (T_c), which is the time it takes for runoff to travel to a point of interest from the hydraulically most distant point. Normally a rainfall duration equal to or greater than T_c is used. Therefore, the rainfall distributions were designed to contain the intensity of any duration of rainfall for the frequency of the event chosen. That is, if the 10-year frequency, 24-hour rainfall is used, the most intense hour will approximate the 10-year, 1-hour rainfall volume.

Runoff

To estimate runoff from storm rainfall, SCS uses the Runoff Curve Number (CN) method (see chapters 4 through 10 of NEH-4, SCS 1985). Determination of CN depends on the watershed's soil and cover conditions, which the model represents as hydrologic soil group, cover type, treatment, and hydrologic condition. Chapter 2 of this TR discusses the effect of urban development on CN and explains how to use CN to estimate runoff.

Time parameters

Chapter 3 describes a method for estimating the parameters used to distribute the runoff into a hydrograph. The method is based on velocities of flow through segments of the watershed. Two major parameters are time of concentration (T_c) and travel time of flow through the segments (T_t). These and the other parameters used are the same as those used in accepted hydraulic analyses of open channels.

Many methods are empirically derived from actual runoff hydrographs and watershed characteristics. The method in chapter 3 was chosen because it is basic; however, other methods may be used.

Peak discharge and hydrographs

Chapter 4 describes a method for approximating peak rates of discharge, and chapter 5 describes a method for obtaining or routing hydrographs. Both methods were derived from hydrographs prepared by procedures outlined in chapter 16 of NEH-4 (SCS 1985). The computations were made with a computerized SCS hydrologic model, TR-20 (SCS 1983).

The methods in chapters 4 and 5 should be used in accordance with specific guidelines. If basic data are improperly prepared or adjustments not properly used, errors will result.

Storage effects

Chapter 6 outlines procedures to account for the effect of detention-type storage. It provides a shortcut method to estimate temporary flood storage based on hydrologic data developed from the Graphical Peak Discharge or Tabular Hydrograph methods.

By increasing runoff and decreasing travel times, urbanization can be expected to increase downstream peak discharges. Chapter 6 discusses how flood detention can modify the hydrograph so that, ideally, downstream peak discharge is reduced approximately to the predevelopment condition. The shortcuts in chapter 6 are useful in sizing a basin even though the final design may require a more detailed analysis.

Selecting the appropriate procedures

Figure 1-1 is a flow chart that shows how to select the appropriate procedures to use in TR-55. In the figure, the diamond-shaped box labeled "Subareas required?" directs the user to the appropriate method based on whether the watershed needs to be divided into subareas. Watershed subdivision is required when significantly different conditions affecting runoff or timing are present in the watershed—for example, if the watershed has widely differing curve numbers or nonhomogeneous slope patterns.

001589

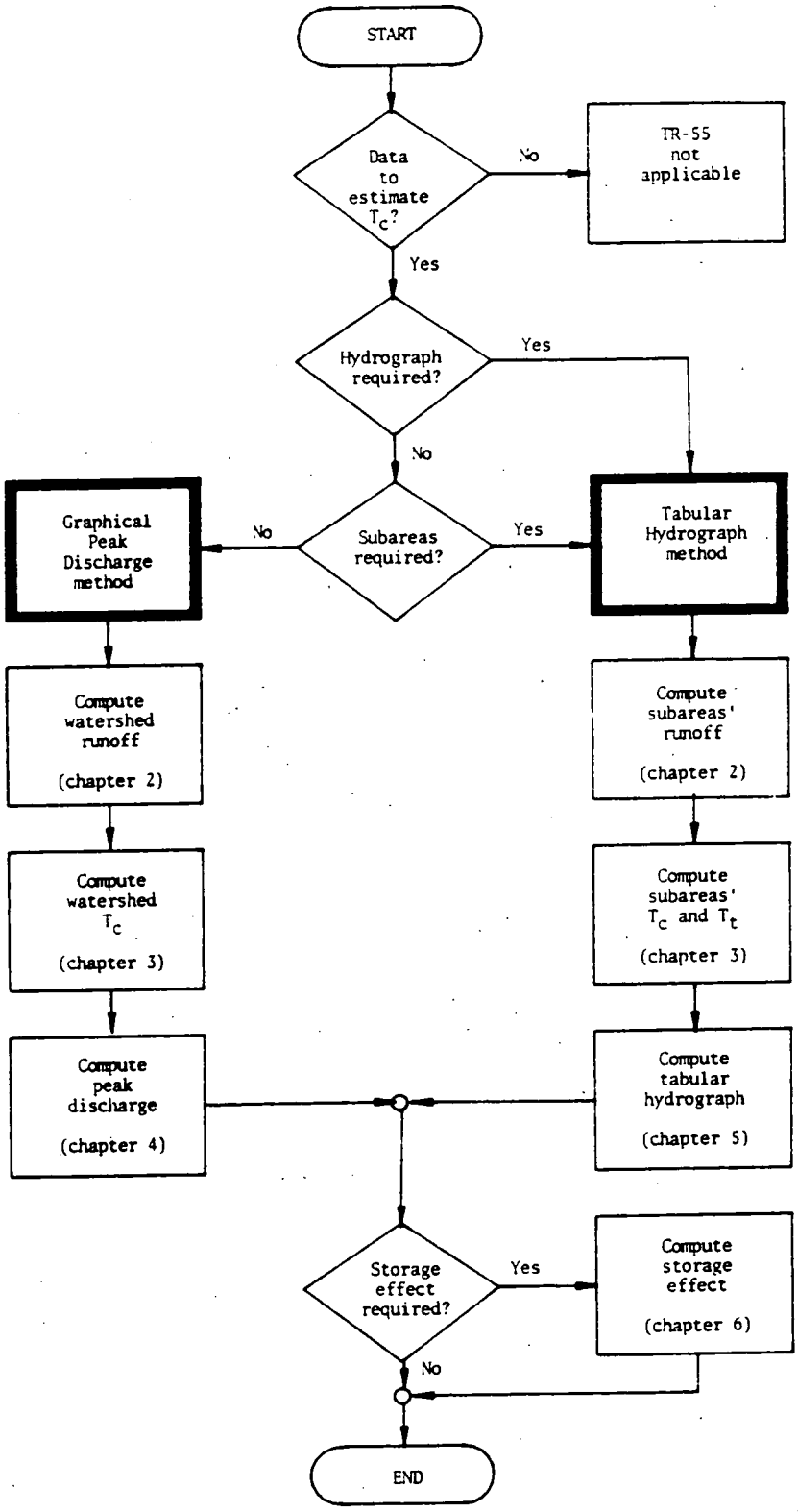

Figure 1-1.—Flow chart for selecting the appropriate procedures in TR-55.

001590

Limitations

To save time, the procedures in TR-55 are simplified by assumptions about some parameters. These simplifications, however, limit the use of the procedures and can provide results that are less accurate than more detailed methods. The user should examine the sensitivity of the analysis being conducted to a variation of the peak discharge or hydrograph. To ensure that the degree of error is tolerable, specific limitations are given in chapters 2 through 6. Additional general constraints to the use of TR-55 are as follows:

- The methods in this TR are based on open and unconfined flow over land or in channels. For large events during which flow is divided between sewer and overland flow, more information about hydraulics than is presented here is needed to determine T_c. After flow enters a closed system, the discharge can be assumed constant until another flow is encountered at a junction or another inlet.

- Both the Graphical Peak Discharge and Tabular Hydrograph methods are derived from TR-20 (SCS 1983) output. Their accuracy is comparable; they differ only in their products. The use of T_c permits them to be used for any size watershed within the scope of the curves or tables. The Graphical method (chapter 4) is used only for hydrologically homogeneous watersheds because the procedure is limited to a single watershed subarea. The Tabular method (chapter 5) can be used for a heterogeneous watershed that is divided into a number of homogeneous subwatersheds. Hydrographs for the subwatersheds can be routed and added.

- The approximate storage-routing curves (chapter 6) should not be used if the adjustment for ponding (chapter 4) is used. These storage-routing curves, like the peak discharge and hydrograph procedures, are generalizations derived from TR-20 routings.

PRELIMINARY DESIGN
CALCULATION PACKAGE
ON-SITE DISPOSAL FACILITY

REVISION B
VOLUME 3 OF 3
DECEMBER 1995

United States Department of Energy
Fernald Environmental Management Project
Fernald, Ohio

prepared by

GEOSYNTEC CONSULTANTS
1100 Lake Hearn Drive, NE, Suite 200
Atlanta, Georgia 30342

under

Fernald Environmental Restoration Management Corporation
Subcontract 95PS005028

NO. 29

186

PRELIMINARY DESIGN CALCULATION PACKAGE ON-SITE DISPOSAL FACILITY

Volume III

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December 1995
Revision B

United States Department of Energy

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Fernald, Ohio

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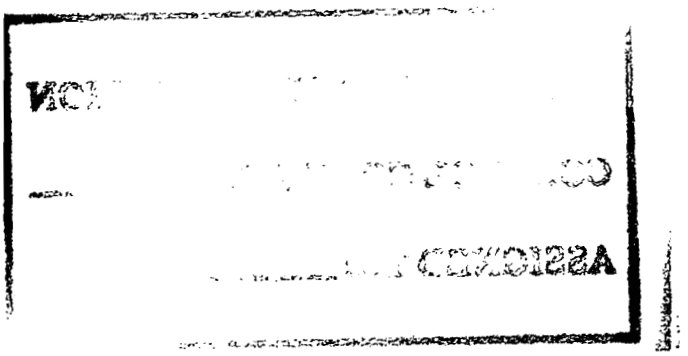
Under

Fernald Environmental Restoration Management Corporation
Subcontract 95PS005028

001593



SECTION 13

13. EROSION AND SEDIMENT CONTROL

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13.2 Borrow Area E&S Basin Sizing
13.3 Impacted Runoff Catch Basin Sizing
13.4 Revegetation Design
13.5 Erosion of OSDF Final Cover
13.6 Erosion Resistance: OSDF Perimeter Drainage Swale

13.1 OSDF E&S Basin Sizing

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: OSDF E&S BASIN SIZING

Computations By: (Cognizant Engineer)
Signature [signature] Date 15 Oct 95
Printed Name and Title ERIC S. STEINHAUSER, PROJECT ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 16 Oct 95
Printed Name and Title ROBERT S COBLE II, STAFF ENGINEER

Computations Checked by: Checked by:
Signature [signature] Date 16 Oct 95
Printed Name and Title ROBERT S COBLE II, STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 17 Oct 1995
Printed Name and Title ERIC S. STEINHAUSER, PROJECT ENGINEER

Approved by: (PDP)
Signature [signature] Date 17 Oct 95
Printed Name and Title Kenneth W Cargill

Approved by: (DTL and TETL)
Signature [signature] Date 17 Oct 95
Printed Name and Title Kenneth W Cargill

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO	17 Oct 95	NA	NA	NA
0	Preliminary (30%) Design Submittal	20 Oct 95	[illegible]	[illegible]	[illegible] 23
B	Preliminary Design - EPA Submittal	15 Dec 95	[illegible]	—	—

Written by: ESS Date: 95/11/29 Reviewed by: JM Date: 95/11/29

Client: FEMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 8.2

EROSION AND SEDIMENT CONTROL: OSDF E&S BASIN SIZING

EXECUTIVE SUMMARY

Purpose

The purpose of this document is to provide the engineering data and calculations used in the design of the OSDF erosion and sediment control (E&S) basin. The E&S basin was designed to control the runoff from a disturbed area equal to one-third of the total project area because it is expected that construction will be performed in three phases of approximately equal size. The same basin design will be used for each phase of construction. The basin was designed in accordance with Ohio Soil Conservation Service (Ohio-SCS) specifications.

Method of Analysis

The Ohio-SCS specifications were used to determine the size and shape of the sediment basin. The computer program TR-55 was used to determine the peak runoff expected from a 25-year, 24-hour storm event; and standard open channel flow equations were used to size the spillway.

Conclusions

The sediment basin should have interior dimensions of 55 feet by 110 feet and have a minimum sediment storage volume of 23,400 cubic feet. The spillway should be comprised of a 60-in. corrugated metal riser pipe attached to a 48-in. corrugated metal outlet pipe.

Written by: ESS Date: 95/10/13 (YY/MM/DD) Reviewed by: AAC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

file 170.+95

EROSION-SEDIMENT CONTROL

OSDF EES BASIN SIZING

VERIFICATION AND COLLECTION OF ENGINEERING DATA

PURPOSE: THE PURPOSE OF THIS DOCUMENT IS TO SUMMARIZE AND VERIFY THE ENGINEERING DATA USED TO DESIGN THE EES BASINS FOR THE OSDF

SCOPE: THE DATA PRESENTED IN THIS DOCUMENT IS ORGANIZED IN THE FOLLOWING SECTIONS:

1. DATA FOR DRAINAGE AREAS
2. RAINFALL DATA
3. SOIL AND VEGETATING COVER
4. MANNING'S COEFFICIENT
5. CHANNEL DATA
6. PIPE DATA

DATA:

1. DATA FOR DRAINAGE AREAS

BASED ON SITE DEVELOPMENT PHASE DRAWINGS, TWO EES BASINS WILL BE USED FOR EACH OF THE THREE DEVELOPMENT STAGES. AS SUCH, THE MAXIMUM DISTURBED AREA CONTRIBUTING TO THE EES BASIN IS EQUAL TO 1/6 OF THE TOTAL OSDF AREA.

FROM FIGURE 1, EACH BASIN WILL CONTROL RUNOFF FROM

$$\frac{77.2}{6} = 12.9 \text{ ACRES} \quad \text{SAY } 13 \text{ ACRES} = 0.0203 \text{ SQ. MILES}$$

Written by: ESS Date: 95/10/13 (YY MM DD) Reviewed by: AAC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSOF Project/Proposal No.: GE3900 Task No.: 08.2

fcc 17Oct95

FLOW PARAMETERS:

SHEET FLOW:

LENGTH = 100 FT
SLOPE = 0.01 FT/FT
SURFACE = SMOOTH SURFACE

SHALLOW CONCENTRATED FLOW:

LENGTH = 400 FT
SLOPE = 0.01 FT/FT
SURFACE = UNPAVED

CHANNEL FLOW:

LENGTH = 3780 FT (MAXIMUM)
SLOPE = 0.01 FT/FT

2. RAINFALL DATA

THE RAINFALL DATA USED IN THE CALCULATIONS IS SUMMARIZED BELOW [PARSON'S, 1995]:

STORM EVENT	RAINFALL (IN.)	
2-YR	2.55	(FOR T_c CALCULATION, REQUIRED BY TR-55)
25 ~~10~~ YR	~~4.06~~ 4.7	

RAINFALL IN OHIO IS CLASSIFIED AS A TYPE II DISTRIBUTION

3. SOIL AND VEGETATIVE COVER

FROM USDA-SCS [1986a] USE A CURVE NUMBER OF 94 FOR NEWLY GRADED AREAS.

Written by: ESS Date: / / YY MM DD Reviewed by: AAC Date: 95/10/16 YY MM DD

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: GE.2

170c195

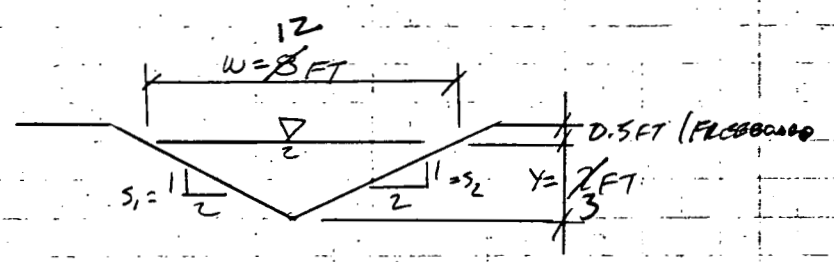
4. MANNING'S COEFFICIENTS

MANNING'S n ARE SUMMARIZED BELOW

	n	
CHANNEL FLOW	0.022	[CHOW, 1959]
CORRUGATED PIPE	0.024	[CHOW, 1959]

5. CHANNEL DATA

AN ASSUMED CHANNEL IS PRESENTED BELOW



AREA OF FLOW (A):

$$A = \frac{1}{2}(w)(Y)$$

$$A = \frac{1}{2}(8)(2) = 8\ FT^2 \quad (12)(3) = 18$$

WETTED PERIMETER (P_w)

$$P_w = Y\left(\left(1+\frac{1}{S_1^2}\right)^{1/2} + \left(1+\frac{1}{S_2^2}\right)^{1/2}\right)$$

$$P_w = 2\left(1+\frac{1}{(1/2)^2}\right)^{1/2} + \left(1+\frac{1}{(1/2)^2}\right)^{1/2}\Big) \quad (3)$$

$$P_w = 8.9\ FT \quad (13.4)$$

6. PIPE DATA:

USE NOMOGRAPH [HAMMER, 1986] AND HEAD DISCHARGE TABLE [USDA-SCS, 1986b] TO SIZE SPILLWAY.

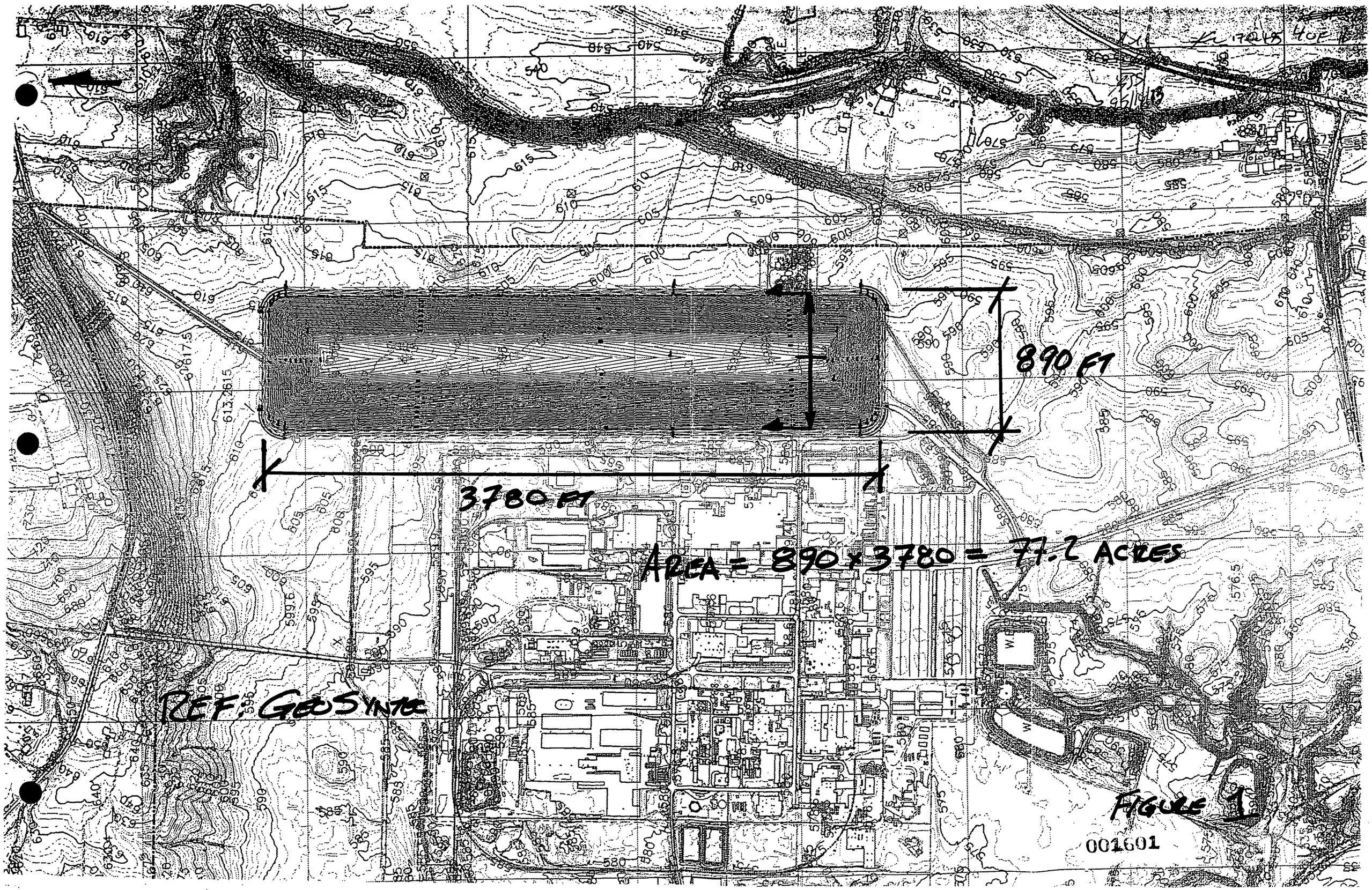

890 FT
3780 FT
AREA = 890 x 3780 = 77.2 ACRES
REF: GEOSYNTEC
FIGURE 1

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TABLE A-1 - RAINFALL DEPTH FOR A GIVEN DURATION (INCHES)

DURATION (YEARS)	TIME							
	HYDRO-35			TP-40				
	5 MIN	15 MIN	60 MIN	2 HOURS	3 HOURS	6 HOURS	12 HOURS	24 HOURS
2	0.387	0.739	1.223	1.408	1.54	1.848	2.2	2.552
5	0.49	0.979	1.69	2.016	2.112	2.496	2.88	3.072
10	0.564	1.139	1.99	2.277	2.475	3.069	3.465	4.059
25	0.65	1.34	2.38	2.6	3.0	3.4	4.0	4.7
50	0.72	1.49	2.67	3.0	3.25	3.9	4.2	5.2
* 100	0.78	1.64	2.95	3.3	3.6	4.1	5.0	5.6
* 500	0.93	2.1	4.3	5.2	5.9	7.3	8.5	9.4
2000	1.2	2.6	5.8	7.2	8.2	10.2	12.0	13.0
10,000	1.4	3.4	8.2	10.5	12.0	15.5	18.0	19.2
100,000	1.9	5.0	13.3	17.7	20.8	27.4	31.8	33.4
	DESIGN OF SMALL DAMS					HMR-51		

NOTE: Rainfall Points For 2, 5, and 10 year rainfall events were adjusted per TP-40. Values for the 500, 2000, and 10,000 Year Events were interpolated from Figure 3 (Appendix E)

* These values are used on PH Records for HEC-1.

PARSONS [1995]

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Figure B-2.—Approximate geographic boundaries for SCS rainfall distributions.

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Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

001604

MANNING'S NUMBER TABLES

VALUES OF THE ROUGHNESS COEFFICIENT n
(Boldface figures are values generally recommended in design)

Type of channel and description	Minimum	Normal	Maximum
A. CLOSED CONDUITS FLOWING PARTLY FULL			
A-1. Metal			
a. Brass, smooth	0.009	**0.010**	0.013
b. Steel			
1. Lockbar and welded	0.010	0.012	0.014
2. Riveted and spiral	0.013	0.016	0.017
c. Cast iron			
1. Coated	0.010	0.013	0.014
2. Uncoated	0.011	0.014	0.016
d. Wrought iron			
1. Black	0.012	0.014	0.015
2. Galvanized	0.013	0.016	0.017
e. Corrugated metal			
1. Subdrain	0.017	0.019	0.021
2. Storm drain	0.021	**0.024**	0.030
A-2. Nonmetal			
a. Lucite	0.008	0.009	0.010
b. Glass	0.009	0.010	0.013
c. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
d. Concrete			
1. Culvert, straight and free of debris	0.010	0.011	0.013
2. Culvert with bends, connections, and some debris	0.011	0.013	0.014
3. Finished	0.011	0.012	0.014
4. Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
5. Unfinished, steel form	0.012	0.013	0.014
6. Unfinished, smooth wood form	0.012	0.014	0.016
7. Unfinished, rough wood form	0.015	0.017	0.020
e. Wood			
1. Stave	0.010	0.012	0.014
2. Laminated, treated	0.015	0.017	0.020
f. Clay			
1. Common drainage tile	0.011	0.013	0.017
2. Vitrified sewer	0.011	0.014	0.017
3. Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
4. Vitrified subdrain with open joint	0.014	0.016	0.018
g. Brickwork			
1. Glazed	0.011	0.013	0.015
2. Lined with cement mortar	0.012	0.015	0.017
h. Sanitary sewers coated with sewage slimes, with bends and connections	0.012	0.013	0.016
i. Paved invert, sewer, smooth bottom	0.016	0.019	0.020
j. Rubble masonry, cemented	0.018	0.025	0.030

VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
B. LINED OR BUILT-UP CHANNELS			
B-1. Metal			
a. Smooth steel surface			
1. Unpainted	0.011	**0.012**	0.014
2. Painted	0.012	0.013	0.017
b. Corrugated	0.021	0.025	0.030
B-2. Nonmetal			
a. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
b. Wood			
1. Planed, untreated	0.010	0.012	0.014
2. Planed, creosoted	0.011	0.012	0.015
3. Unplaned	0.011	0.013	0.015
4. Plank with battens	0.012	0.015	0.018
5. Lined with roofing paper	0.010	0.014	0.017
c. Concrete			
1. Trowel finish	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	
8. On irregular excavated rock	0.022	0.027	
d. Concrete bottom float finished with sides of			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. Glazed	0.011	**0.013**	0.015
2. In cement mortar	0.012	**0.015**	0.018
g. Masonry			
1. Cemented rubble	0.017	0.025	0.030
2. Dry rubble	0.023	0.032	0.035
h. Dressed ashlar	0.013	0.015	0.017
i. Asphalt			
1. Smooth	0.013	0.013	
2. Rough	0.016	0.016	
j. Vegetal lining	0.030	.....	0.500

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VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
C. EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
D. NATURAL STREAMS			
D-1. Minor streams (top width at flood stage <100 ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D-2. Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage >100 ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	.....	0.060
b. Irregular and rough section	0.035	.....	0.100

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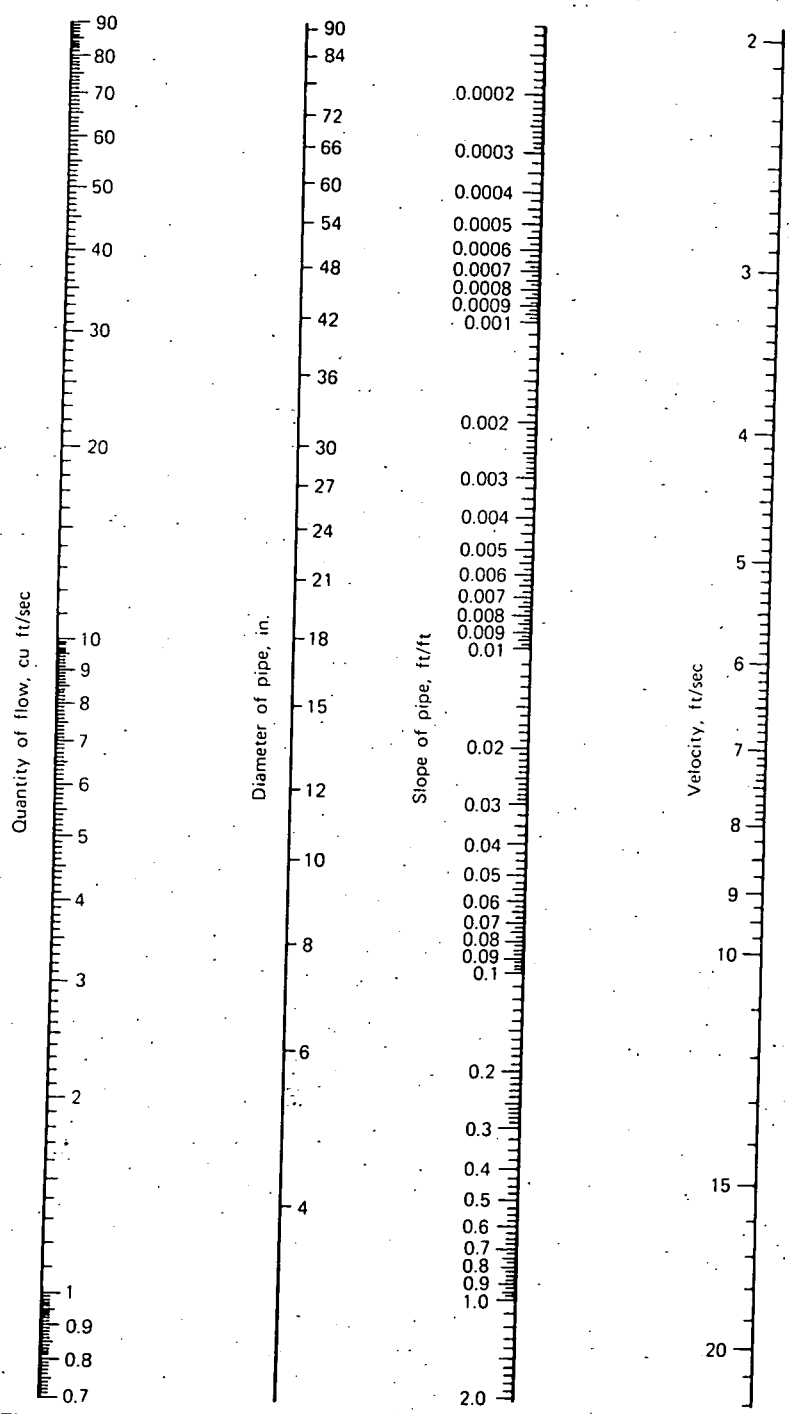

Figure 4-24 Nomograph for Manning formula, Eq. 4-25, for circular pipes flowing full based on $n = 0.013$.

[HAMMER, 1986]

$Q_{n=0.013} = Q_{n=0.015} \times \frac{0.015}{0.013}$

$V_{n=0.013} = V_{n=0.015} \times \frac{0.015}{0.013}$

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HEAD DISCHARGE TABLE FOR CORRUGATED METAL PIPE DROP INLETS (WEIR FLOW CONDITION)

Riser Diameter Inches	Head in Feet												
	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
15	2.7	3.8	4.9	6.3	ORIFICE								
18	3.2	4.5	5.9	7.6	9.3	10.9	FLOW						
21	3.8	5.3	7.0	8.8	10.7	12.8	15.0	CONDITIONS					
24	4.3	6.0	7.9	10.1	12.3	14.6	17.1	19.7	22.4	CONTROL			
30	5.4	7.5	9.8	12.6	15.4	18.2	21.4	24.6	28.0	31.7	35.5		
36	6.4	9.0	11.8	15.1	18.5	21.8	25.7	29.5	33.6	38.0	42.6	47.2	51.9
42	7.5	10.5	13.8	17.7	21.6	25.5	30.0	34.5	39.3	44.4	49.8	55.1	60.5
48	8.6	12.0	15.7	20.2	24.6	29.1	34.2	39.4	44.8	50.7	56.8	63.0	69.1
54	9.6	13.5	17.7	22.7	27.7	32.8	38.5	44.3	50.5	57.0	64.0	70.9	77.8
60	10.7	15.0	19.7	25.2	30.8	36.4	42.8	49.2	56.1	63.3	71.0	78.7	86.4

Riser Diameter Inches	Head in Feet								
	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5
42	66.5	72.5	ORIFICE FLOW						
48	76.0	82.8	89.7	96.9	104.1	CONDITIONS CONTROL			
54	85.5	93.2	100.9	109.0	117.1	125.6	134.5	143.3	
60	95.0	103.6	112.1	121.1	130.1	139.5	149.3	159.2	169.0

NOTES: (1) The discharge capacities shown in this table are based on the formula:

$$Q_2 = C_2 L H_2^{3/2}$$

Q_2 = discharge capacity of weir, in c.f.s.
C_2 = weir coefficient = 3.33
L = length of weir crest, in feet (for circular riser with headwall, L = 2.57 times diameter of riser).
H_2 = distance from crest of riser to water surface in reservoir, in feet.

(2) The diameter of the riser should be at least 1½ times the diameter of barrel.

(3) Use this table in conjunction with orifice flow and full pipe flow conditions to determine capacity of the drop inlet.

Figure 6-27 Chart for determining inlet proportions and required head over inlet

001608

Written by: ESS Date: 95/10/13 Reviewed by: AJC Date: 95/10/16

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

AC 170+95

REFERENCES:

PARSONS, "2000-YEAR FLOOD AND PROBABLE MAXIMUM FLOOD, SITEWIDE FLOOD PLAIN DETERMINATION", REVISION A, AUG 1995

USDA-SCS, "URBAN HYDROLOGY FOR SMALL WATERSHEDS", TECHNICAL RELEASE 55 (TR-55), WASHINGTON, DC, JUN 1986a

USDA-SCS, "ENGINEERING FIELD MANUAL FOR CONSERVATION PRACTICES", WASHINGTON, DC, NOV 1986b.

HAMMER, "WATER AND WASTEWATER TECHNOLOGY", 2ND ED, 1986, 550p.

CHOW, "OPEN CHANNEL HYDRAULICS", 1959.

Written by: ESS Date: 95/10/15 (YY/MM/DD) Reviewed by: A/c Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

EROSION-SEDIMENT CONTROL

OSDF E&S BASIN SIZING

PURPOSE: THIS CALCULATION PACKAGE INCLUDES THE CALCULATIONS TO SIZE THE E&S BASINS.

SCOPE: THE E&S BASINS ARE DESIGNED TO CONTROL RUNOFF FROM DISTURBED AREAS DURING CONSTRUCTION AND OPERATION OF THE OSDF.

THE ANALYSES PERFORMED USED TR-55 [USDA-SCS, 1986a] AND TEMPORARY SEDIMENT BASIN, TECHNICAL STANDARD AND SPECIFICATIONS [OHIO-SCS, 1987].

SUMMARY OF INPUT DATA:

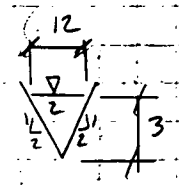
FOR EACH BASIN

AREA = 13 ACRES
= 0.0203 SQ. MILES

SHEET FLOW: LENGTH = 100 FT @ 0.01 FT/FT

SHALLOW CONCENTRATED FLOW = 400 FT @ 0.01 FT/FT

CHANNEL FLOW = 3780 FT @ 0.01 FT/FT



AREA = 18 FT²
WETTED PERIMETER (P_w) = 13.4 FT
$n = 0.027$

CURVE NUMBER = 94

$$Q = \frac{1.49}{n}\left(\frac{A}{P_w}\right)^{2/3} s^{1/2} A$$

Written by: BSS Date: 95/10/15 (YY/MM/DD) Reviewed by: AJC Date: 95/10/16 (YY/MM/DD)

Client: FEMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 082

CALCULATIONS:

1. SEDIMENT VOLUME (V_s):

$$V_s = 1800 \frac{cf}{AC}(13AC) = \underline{23{,}400\ cf}$$

2. SHAPE OF BASIN

BASIN LENGTH = 2 BASIN WIDTH [OHIO-SCS, 1987]

$L = 2W$

$A = W \times 2W = 2W^2$

ASSUME 4FT OF VOLUME STORAGE

$2W^2 \times 4 = 23{,}400\ cf$

$W = 54.1\ FT$ SAY $55\ FT \Rightarrow L = 110\ FT$

CHECK: $55FT \times 110FT \times 4FT = 24{,}200\ cf > 23{,}400\ cf$ OK

3. SIZE OF SPILLWAY

ACCORDING TO OHIO-SCS [1987], SPILLWAYS FOR BASINS WITH LESS THAN 20 ACRES OF CONTRIBUTING DRAINAGE AREA AND AND AN EMBANKMENT HEIGHT LESS THAN 5 FT (MEASURED FROM ORIGINAL GROUND SURFACE, MUST PASS THE FLOW FROM A 10-YR, 24-HR STORM. HOWEVER, THE SPILLWAY WILL BE DESIGNED TO PASS THE FLOW FROM A 25-YR, 24-HR STORM.

FROM TR-55: $Q_p = 55\ cfs$ (FILE: FEMCO\ES-1.55)

SELECT A CMP THAT CAN DISCHARGE Q_p UNDER FULL CONDITIONS

$$\therefore Q_{p\,n=0.024} = 55\,cfs = Q_{p\,n=0.013}\left(\frac{0.013}{0.024}\right) \Rightarrow Q_{p\,n=0.013} = 101.5\ cfs$$

FROM NOMOGRAPH, FOR $Q_p = 101.5\ cfs$ @ $0.01\ FT/FT \Rightarrow$ CMP = 48 IN. Ø

CHECK SWALE SIZES:

$$Q_{max\ swale} = \frac{1.49}{0.027}\left(\frac{18}{13.4}\right)^{2/3}(0.01)^{1/2}(18) = 121\ cfs > 55\ cfs \quad \text{OK}$$

001011

Written by: BSS Date: 95/10/15 (YY/MM/DD) Reviewed by: AMC Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 082

SPILLWAY RISER

$A_{RISER} = 1.3\, A_{PIPE}$ [OHIO-SCS, 1987]

$r^2_{RISER} \Rightarrow 1.3\, r^2_{PIPE}$

$r^2_{RISER} = 1.3\,(24)^2 = 748.8 \Rightarrow r = 27.4\,IN$

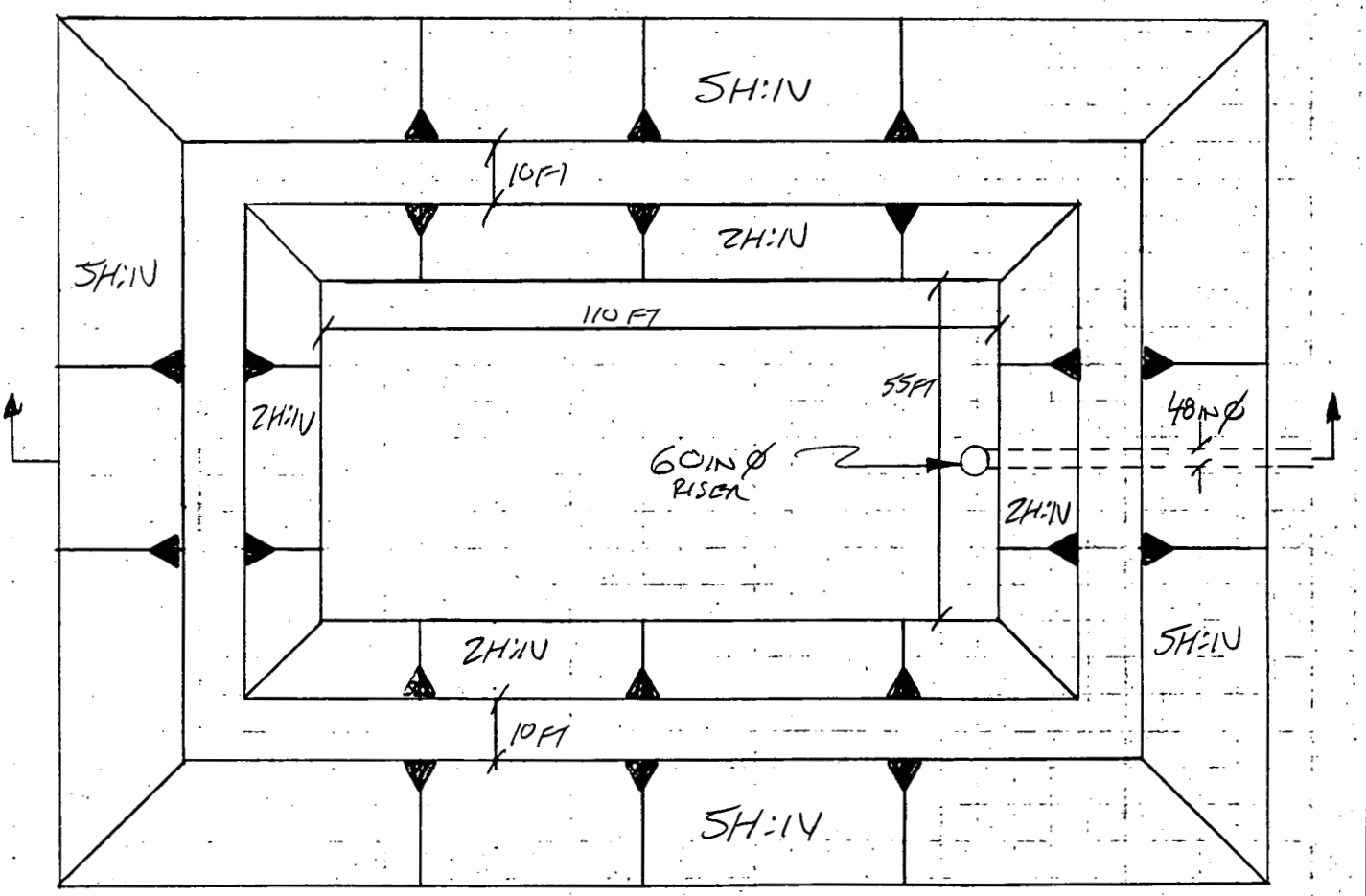
$\therefore$ RISER = 54.7 IN ϕ SAY 60 IN. ϕ

HEAD NEEDED ABOVE RISER:

FROM FIGURE 6-27 [USDA-SCS, 1986 b] FOR 60 IN. ϕ RISER AND $Q_p = 55$ CFS

HEAD = 1.21 FT

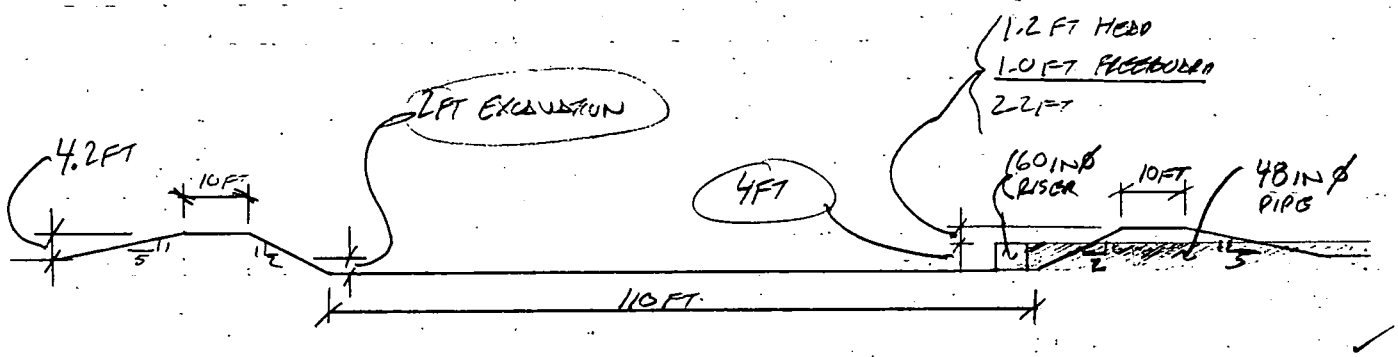
4. BASIN PLAN



Written by: BSS Date: 95/10/15 (YY MM DD) Reviewed by: AC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

BASIN SECTION



NOTE: AN EMERGENCY SPILLWAY MAY BE REQUIRED IF THE BERM IS CONSTRUCTED TO A HEIGHT GREATER THAN 5 FT ABOVE ORIGINAL GROUND SURFACE.

REFERENCES:

OHIO-SCS, "TECHNICAL STANDARD AND SPECIFICATION, TEMPORARY SEDIMENT BASIN", WATER MANAGEMENT AND SEDIMENT CONTROL FOR URBANIZING AREAS, COLUMBUS, OHIO, MAR 1987

USDA-SCS, "TR-55 MICROCOMPUTER PROGRAM SYSTEM", VERSION 2.0, WASHINGTON, DC, JUN 1986a

USDA-SCS, "ENGINEERING MANUAL FOR CONSERVATION PRACTICES", WASHINGTON, DC, NOV 1986b

HAMMER, "WATER AND WASTEWATER TECHNOLOGY", 2ND ED, 1986

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-15-95
County : BUTLER State: OH Checked: ASC Date: 10-16-95
Subtitle: E & S BASIN

Subarea #1 - A

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.01	A					0.030
Shallow Concent'd		400	.01	U					0.069
Open Channel		3780	.01		.02718		13.4		0.156

Time of Concentration = 0.26*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO\ES-1.55

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO - OSDF User: ESS 155 Date: 10-15-95
County : BUTLER State: OH Checked: Psc Date: 10-16-95
Subtitle: E & S BASIN

Total watershed area: 0.020 sq mi Rainfall type: II Frequency: 25 years

---------- Subareas ----------

	A
Area(sq mi)	0.02
Rainfall(in)	4.7
Curve number	94
Runoff(in)	4.01
Tc (hrs)	0.26*
(Used)	0.30
TimeToOutlet	0.00
Ia/P	0.03
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) A
11.0	2	2
11.3	2	2
11.6	3	3
11.9	10	10
12.0	19	19
12.1	36	36
12.2	55P	55P ← PEAK FLOW
12.3	55	55
12.4	37	37
12.5	23	23
12.6	16	16
12.7	12	12
12.8	9	9
13.0	7	7
13.2	5	5
13.4	5	5
13.6	4	4
13.8	4	4
14.0	3	3
14.3	3	3
14.6	3	3
15.0	3	3
15.5	2	2
16.0	2	2
16.5	2	2
17.0	2	2
17.5	2	2
18.0	1	1
19.0	1	1
20.0	1	1
22.0	1	1
26.0	0	0

FILE: FERMCO\ES-1.55

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P - Peak Flow * - value(s) provided from TR-55 system routines

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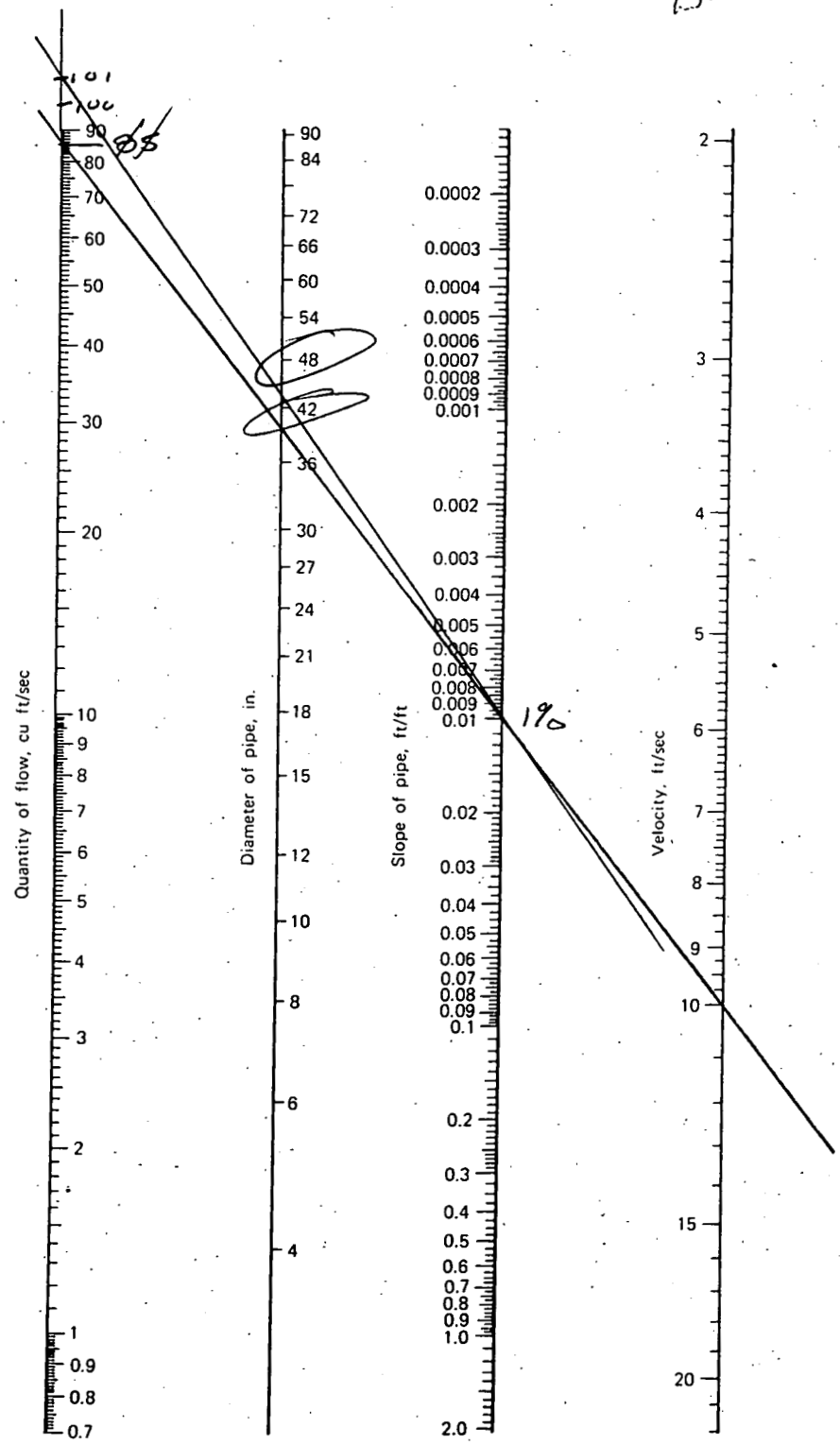

$$Q_{n\neq 0.013} = Q_{n=0.013}\left(\frac{0.013}{n}\right)$$

Figure 4-24 Nomograph for Manning formula, Eq. 4-25, for circular pipes flowing full based on $n = 0.013$.

[Hammer, 1986]

001016

HEAD DISCHARGE TABLE FOR CORRUGATED METAL PIPE
DROP INLETS
(WEIR FLOW CONDITION)

Riser Diameter Inches	Head in Feet												
	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
15	2.7	3.8	4.9	6.3	ORIFICE								
18	3.2	4.5	5.9	7.6	9.3	10.9	FLOW						
21	3.8	5.3	7.0	8.8	10.7	12.8	15.0	CONDITIONS					
24	4.3	6.0	7.9	10.1	12.3	14.6	17.1	19.7	22.4	CONTROL			
30	5.4	7.5	9.8	12.6	15.4	18.2	21.4	24.6	28.0	31.7	35.5		
36	6.4	9.0	11.8	15.1	18.5	21.8	25.7	29.5	33.6	38.0	42.6	47.2	51.9
42	7.5	10.5	13.8	17.7	21.6	25.5	30.0	34.5	39.3	44.4	49.8	55.1	60.5
48	8.6	12.0	15.7	20.2	24.6	29.1	34.2	39.4	44.8	50.7	56.8	63.0	69.1
54	9.6	13.5	17.7	22.7	27.7	32.8	38.5	44.3	50.5	57.0	64.0	70.9	77.8
60	10.7	15.0	19.7	25.2	30.8	36.4	42.8	49.2	56.1	63.3	71.0	78.7	86.4

Riser Diameter Inches	Head in Feet								
	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5
42	66.5	72.5	ORIFICE FLOW						
48	76.0	82.8	89.7	96.9	104.1	CONDITIONS CONTROL			
54	85.5	93.2	100.9	109.0	117.1	125.6	134.5	143.3	
60	95.0	103.6	112.1	121.1	130.1	139.5	149.3	159.2	169.0

NOTES: (1) The discharge capacities shown in this table are based on the formula:

$$Q_2 = C_2 L H_2^{3/2}$$

Q_2 = discharge capacity of weir, in c.f.s.
C_2 = weir coefficient = 3.33
L = length of weir crest, in feet (for circular riser with headwall, L = 2.57 times diameter of riser).
H_2 = distance from crest of riser to water surface in reservoir, in feet.

(2) The diameter of the riser should be at least 1½ times the diameter of barrel.

(3) Use this table in conjunction with orifice flow and full pipe flow conditions to determine capacity of the drop inlet.

001617

Figure 6-27 Chart for determining inlet proportions and required head over inlet

USDA-SCS [1986b]

Written by: ESS Date: 95/10/20 (YY MM DD) Reviewed by: AJC Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATION PACKAGE

USDA-SCS TR-55

USDA-SCS, "URBAN HYDROLOGY FOR SMALL WATERSHEDS", TECHNICAL RELEASE 55 (TR-55), WASHINGTON, DC, JUN 1986.

USDA-SCS, "TR-55 MICROCOMPUTER PROGRAM SYSTEM", VERSION 2.0, README.1ST FILE, WASHINGTON, DC, JUN 1986.

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United States Department of Agriculture

Soil Conservation Service

Engineering Division

Technical Release 55

June 1986

Urban Hydrology for Small Watersheds

001619

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20 Oct 95

Preface

Technical Release 55 (TR-55) presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs. These procedures are applicable in small watersheds, especially urbanizing watersheds, in the United States. First issued by the Soil Conservation Service (SCS) in January 1975, TR-55 incorporates current SCS procedures. This revision includes results of recent research and other changes based on experience with use of the original edition.

The major revisions and additions are—

1. A flow chart for selecting the appropriate procedure;
2. Three additional rain distributions;
3. Expansion of the chapter on runoff curve numbers;
4. A procedure for calculating travel times of sheet flow;
5. Deletion of a chapter on peak discharges;
6. Modifications to the Graphical Peak Discharge method and Tabular Hydrograph method;
7. A new storage routing procedure;
8. Features of the TR-55 computer program; and
9. Worksheets.

This revision was prepared by Roger Cronshey, Hydraulic Engineer, Hydrology Unit, SCS, Washington, DC; Dr. Richard H. McCuen, Professor of Civil Engineering, University of Maryland, College Park, MD; Norman Miller, Head, Hydrology Unit, SCS, Washington, DC; Dr. Walter Rawls, Hydrologist, Agricultural Research Service, Beltsville, MD; Sam Robbins (deceased), formerly Hydraulic Engineer, SCS, South National Technical Center (NTC), Fort Worth, TX; and Don Woodward, Hydraulic Engineer, SCS, Northeast NTC, Chester, PA. Valuable contributions were made by John Chenoweth, Stan Hamilton, William Merkel, Robert Rallison (ret.), Harvey Richardson, Wendell Styner, other SCS hydraulic engineers, and Teresa Seeman.

Revised June 1986

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Chapter 1: Introduction

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The conversion of rural land to urban land usually increases erosion and the discharge and volume of storm runoff in a watershed. It also causes other problems that affect soil and water. As part of programs established to alleviate these problems, engineers increasingly must assess the probable effects of urban development, as well as design and implement measures that will minimize its adverse effects.

Technical Release 55 (TR-55) presents simplified procedures for estimating runoff and peak discharges in small watersheds. In selecting the appropriate procedure, consider the scope and complexity of the problem, the available data, and the acceptable level of error. While this TR gives special emphasis to urban and urbanizing watersheds, the procedures apply to any small watershed in which certain limitations are met.

Effects of urban development

An urban or urbanizing watershed is one in which impervious surfaces cover or will soon cover a considerable area. Impervious surfaces include roads, sidewalks, parking lots, and buildings. Natural flow paths in the watershed may be replaced or supplemented by paved gutters, storm sewers, or other elements of artificial drainage.

Hydrologic studies to determine runoff and peak discharge should ideally be based on long-term stationary streamflow records for the area. Such records are seldom available for small drainage areas. Even where they are available, accurate statistical analysis of them is usually impossible because of the conversion of land to urban uses during the period of record. It therefore is necessary to estimate peak discharges with hydrologic models based on measurable watershed characteristics. Only through an understanding of these characteristics and experience in using these models can we make sound judgments on how to alter model parameters to reflect changing watershed conditions.

Urbanization changes a watershed's response to precipitation. The most common effects are reduced infiltration and decreased travel time, which significantly increase peak discharges and runoff. Runoff is determined primarily by the amount of precipitation and by infiltration characteristics related to soil type, soil moisture, antecedent rainfall, cover type, impervious surfaces, and surface retention. Travel time is determined primarily by slope, length of flow path, depth of flow, and roughness of flow surfaces. Peak discharges are based on the relationship of these parameters and on the total drainage area of the watershed, the location of the development, the effect of any flood control works or other natural or manmade storage, and the time distribution of rainfall during a given storm event.

The model described in TR-55 begins with a rainfall amount uniformly imposed on the watershed over a specified time distribution. Mass rainfall is converted to mass runoff by using a runoff curve number (CN). CN is based on soils, plant cover, amount of impervious areas, interception, and surface storage. Runoff is then transformed into a hydrograph by using unit hydrograph theory and routing procedures that depend on runoff travel time through segments of the watershed.

For a description of the hydrograph development method used by SCS, see chapter 16 of the SCS National Engineering Handbook, Section 4—Hydrology (NEH-4) (SCS 1985). The routing method (Modified Att-Kin) is explained in appendixes G and H of draft Technical Release 20 (TR-20) (SCS 1983).

Rainfall

TR-55 includes four regional rainfall time distributions. See appendix B for a discussion of how these distributions were developed.

All four distributions are for a 24-hour period. This period was chosen because of the general availability of daily rainfall data that were used to estimate 24-hour rainfall amounts. The 24-hour duration spans most of the applications of TR-55.

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One critical parameter in the model is time of concentration (T_c), which is the time it takes for runoff to travel to a point of interest from the hydraulically most distant point. Normally a rainfall duration equal to or greater than T_c is used. Therefore, the rainfall distributions were designed to contain the intensity of any duration of rainfall for the frequency of the event chosen. That is, if the 10-year frequency, 24-hour rainfall is used, the most intense hour will approximate the 10-year, 1-hour rainfall volume.

Runoff

To estimate runoff from storm rainfall, SCS uses the Runoff Curve Number (CN) method (see chapters 4 through 10 of NEH-4, SCS 1985). Determination of CN depends on the watershed's soil and cover conditions, which the model represents as hydrologic soil group, cover type, treatment, and hydrologic condition. Chapter 2 of this TR discusses the effect of urban development on CN and explains how to use CN to estimate runoff.

Time parameters

Chapter 3 describes a method for estimating the parameters used to distribute the runoff into a hydrograph. The method is based on velocities of flow through segments of the watershed. Two major parameters are time of concentration (T_c) and travel time of flow through the segments (T_t). These and the other parameters used are the same as those used in accepted hydraulic analyses of open channels.

Many methods are empirically derived from actual runoff hydrographs and watershed characteristics. The method in chapter 3 was chosen because it is basic; however, other methods may be used.

Peak discharge and hydrographs

Chapter 4 describes a method for approximating peak rates of discharge, and chapter 5 describes a method for obtaining or routing hydrographs. Both methods were derived from hydrographs prepared by procedures outlined in chapter 16 of NEH-4 (SCS 1985). The computations were made with a computerized SCS hydrologic model, TR-20 (SCS 1983).

The methods in chapters 4 and 5 should be used in accordance with specific guidelines. If basic data are improperly prepared or adjustments not properly used, errors will result.

Storage effects

Chapter 6 outlines procedures to account for the effect of detention-type storage. It provides a shortcut method to estimate temporary flood storage based on hydrologic data developed from the Graphical Peak Discharge or Tabular Hydrograph methods.

By increasing runoff and decreasing travel times, urbanization can be expected to increase downstream peak discharges. Chapter 6 discusses how flood detention can modify the hydrograph so that, ideally, downstream peak discharge is reduced approximately to the predevelopment condition. The shortcuts in chapter 6 are useful in sizing a basin even though the final design may require a more detailed analysis.

Selecting the appropriate procedures

Figure 1-1 is a flow chart that shows how to select the appropriate procedures to use in TR-55. In the figure, the diamond-shaped box labeled "Subareas required?" directs the user to the appropriate method based on whether the watershed needs to be divided into subareas. Watershed subdivision is required when significantly different conditions affecting runoff or timing are present in the watershed—for example, if the watershed has widely differing curve numbers or nonhomogeneous slope patterns.

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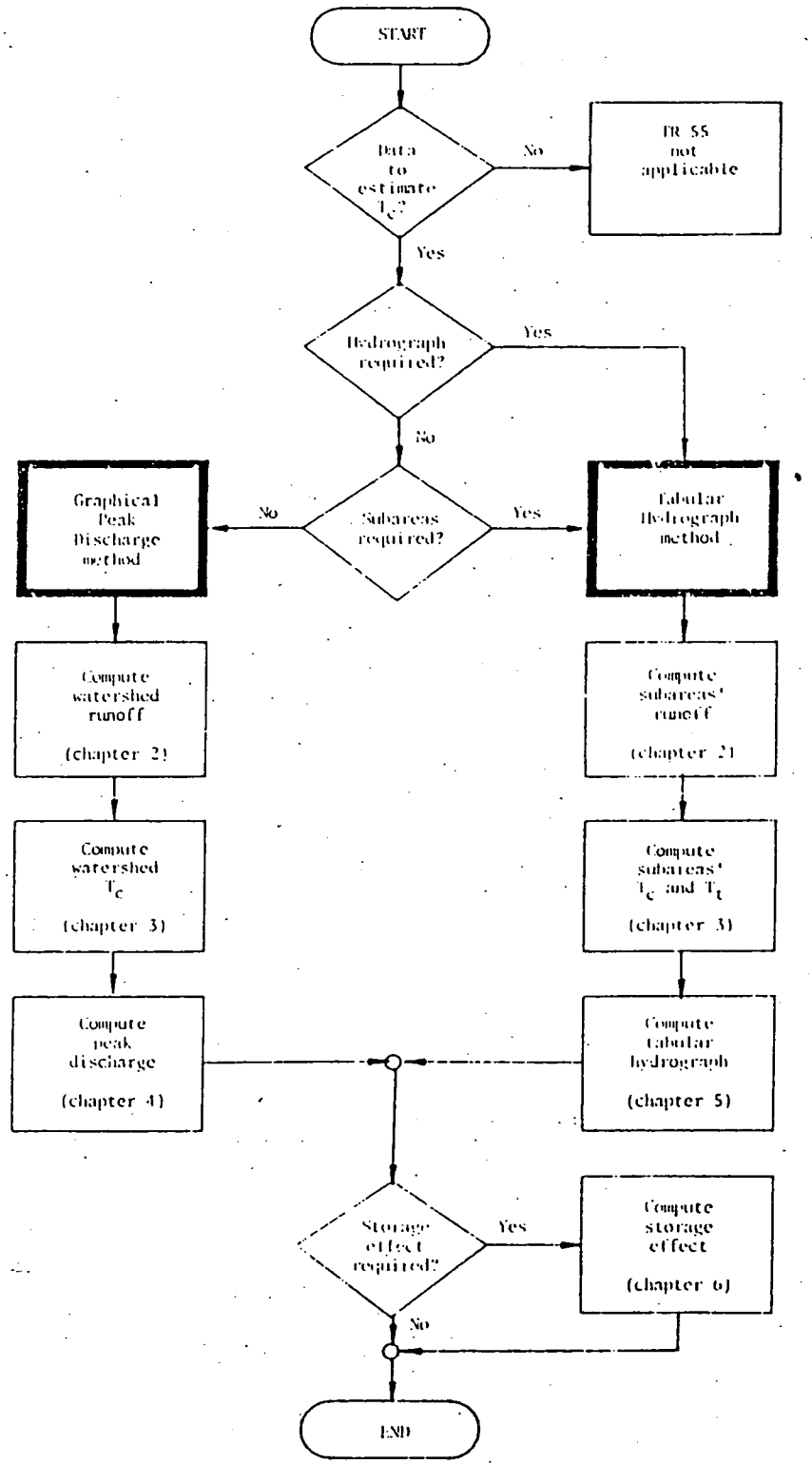

Figure 1-1.—Flow chart for selecting the appropriate procedures in TR-55.

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Limitations

To save time, the procedures in TR-55 are simplified by assumptions about some parameters. These simplifications, however, limit the use of the procedures and can provide results that are less accurate than more detailed methods. The user should examine the sensitivity of the analysis being conducted to a variation of the peak discharge or hydrograph. To ensure that the degree of error is tolerable, specific limitations are given in chapters 2 through 6. Additional general constraints to the use of TR-55 are as follows:

- The methods in this TR are based on open and unconfined flow over land or in channels. For large events during which flow is divided between sewer and overland flow, more information about hydraulics than is presented here is needed to determine T_c. After flow enters a closed system, the discharge can be assumed constant until another flow is encountered at a junction or another inlet.

- Both the Graphical Peak Discharge and Tabular Hydrograph methods are derived from TR-20 (SCS 1983) output. Their accuracy is comparable; they differ only in their products. The use of T_c permits them to be used for any size watershed within the scope of the curves or tables. The Graphical method (chapter 4) is used only for hydrologically homogeneous watersheds because the procedure is limited to a single watershed subarea. The Tabular method (chapter 5) can be used for a heterogeneous watershed that is divided into a number of homogeneous subwatersheds. Hydrographs for the subwatersheds can be routed and added.

- The approximate storage-routing curves (chapter 6) should not be used if the adjustment for ponding (chapter 4) is used. These storage-routing curves, like the peak discharge and hydrograph procedures, are generalizations derived from TR-20 routings.

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The TR-55 procedures have been incorporated in a computer program. The program, written in BASIC, requires less than 256K memory to operate and was developed for an MS-DOS operating system. Users of the program, however, still need to be familiar with the procedures in this TR. Features of the program include the following:

- The full screen (24 lines, 80 columns) is used to enter data. Flexibility of coding allows movement about the screen for quick data modifications.

- Function keys provide menu power to move to different modules (TR-55 chapters) within the program. Some keys are permanently defined while others vary by module.

- "Help" screens provide pertinent information to the user depending on location in the program. Two types of information are included: (1) define system operation and (2) describe input parameters.

- User files provide for optional entry of local data, such as rainfall-frequency, graphic peak discharge equation coefficients, and tabular hydrographs for other rainfall distributions.

Copies of the program can be obtained from—

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Telephone (703) 487-4650

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TR-55 Microcomputer Program System Version Ver 2.0

Welcome to the TR-55 microcomputer program system. This README.1ST file is intended as an introduction to the system. The printed TR-55 document is the procedure reference for the methods. The program user should be familiar with both the computer hardware and the TR-55 document prior to using the program.

* * * COMPUTER REQUIREMENTS * * *

The program system will run under PC-DOS or MS-DOS provided that the special keys (function, arrow, HOME, END, INS, DEL, PgUp and PgDn) have the same extended ASCII codes as used on IBM compatible equipment. Only one floppy disk drive is required but two drives are recommended. About 280K RAM is needed to load the program.

* * * TR-55 SYSTEM FILES * * *

The system consists of two diskettes. Diskette #1 contains the executable program file, README and other required files. Diskette #2 contains the tabular hydrograph files, an executable system configuration file as well as samples of a county rainfall, a local soil name-hydrologic soil group and several input data files.

EXECUTABLE PROGRAM FILE -----

The TR-55 program is a compiled BASIC language executable file. It is a collection of the seven executable files used in the previous version of the system. A main menu, with the various TR55 chapters as choices, controls the program system. The remaining parts of the program can be categorized as follows:

Primary functions - Graphical Peak Discharge Method (Chapter 4)
Tabular Peak Discharge Method (Chapter 5)
Temporary Storage (Chapter 6)

Support functions - Runoff curve number (CN) (Chapter 2)
Time of concentration (Tc) and travel time through a subarea (Tt) (Chapter 3)

Utilities - Print (print current data and calculations)
Load (reload previously saved data)
Save (save current data)
Zero (initial data)

Some limitations that are included are:

Maximum of 10 subareas can be used for CN, Tc, Tt and tabular peak discharge computations.

Maximum of 7 rainfall frequencies can be used in the graphical peak discharge computations.

BASIC DATA FILES -----

The TR55.CFG file describes the drive designations available on the current system, the display monitor used and the tone of the "beep". Both color and monochrome are supported with the user free to select the color combinations desired. The use of the CONFIG.EXE program to create a TR55.CFG file is described in the section "CREATING A WORKING COPY OF TR-55 SYSTEM". Several sample xxx.CFG files are on the TR55 DISK#2.

The COVER.DAT file contains the numerous Table 2-2 land use descriptions along with appropriate hydrologic conditions and runoff curve numbers for the four soil groups. The file is loaded when the CN support function is used and for the PRINT utility.

Four tabular hydrograph files are available, one for each of the SCS TR-55 rainfall distributions (Type I,IA,II,III). The file for the selected rainfall distribution is used in the computation step in the tabular method. Only the file required need be available on the mounted diskettes. The files are appropriately titled TYPEI.TBL, TYPEIA.TBL, TYPEII.TBL, and TYPEIII.TBL.

OPTIONAL DATA FILES -----

Optional data files are user created files that the system reads if they are present, but will not prevent operation if they are not there. Five such files can be used, but only two (COUNTY.RF and SOILS.TYP) are expected to be widely used. The other three are briefly described to illustrate the flexibility they can add to the system. If any of the optional files are used the file naming convention given below must be adhered to for the TR-55 program to recognize them.

The COUNTY.RF file contains rainfall-frequency data for up to seven frequencies by county name. As many counties as desired may be included. The file can make life a lot easier for the system user, even if the user always applies TR-55 in only one county. The COUNTY.RF file can be created using a locally available ASCII editor and the following record formats.

Record 1 - Number of frequencies (maximum seven) included, followed by the frequencies. Separate each item with a comma or at least one space.

Record 2 - County name (all uppercase) with quotes (") around it, followed by the rainfall amounts (inches) corresponding to the Record 1 frequencies. Separate each item with a comma or at least one space.

Record 3+- Same as record 2. Continue with as many counties as needed for your state or area.

A sample COUNTY.RF file for the state of Maryland is included.

For those users that require county rainfall data from more than one state, separate rainfall files can be helpful (especially if the states have a county with the same name). To accommodate multiple state files, change the COUNTY.RF file name to COUNTY.xx where xx is the two letter state abbreviation. When a two letter state abbreviation and a

county name are entered as part of input, the appropriate COUNTY.xx file is searched for. If found it is used, if not the COUNTRY.RF file is used if it exists. (File search time is reduced when COUNTY.xx is used instead of COUNTY.RF.)

The SOILS.TYP can contain soil names and their applicable hydrologic soil groups (HSG). The file contents can be displayed in the Runoff Curve Number portion of the program by pressing the F10 key. No computation nor automatic data entry are done with this file. Its purpose is solely as a system user look up table.

The file can be created by using any locally available ASCII editor using the following limitations:

Maximum line length is 30 characters (suggest 25 characters for soil name and 5 for HSG)
Maximum of 100 lines in file

A sample SOILS.TYP file is included as an example. To view the sample file use the DOS command

```
TYPE A:SOILS.TYP |MORE
```

from the DOS prompt with TR55 Disk #1 in drive A.

The TYPE.RF, DISTRIB.RF, and VOLUME.RF files allow a rainfall distribution other than those in TR-55 to be used. The TYPE.RF file contains regression coefficients for peak discharge curves similar to those found in TR-55 Exhibit 4-. The DISTRIB.RF file contains tabular hydrographs similar to those found in Exhibit 5-. The VOLUME.RF file contains regression coefficients for a volume-discharge curve similar to those found in Figure 6-1.

The development of the background material required to generate these files is beyond the scope of TR-55. Because of the complexity of procedure no details are given here. For guidance on how to develop these files contact your NTC hydraulic engineer. A TYPE.RF and DISTRIB.RF file for the Delmarva (DElaware,MARyland, VirginiA) unit hydrograph and Type II rainfall is available from the NNTC (Chester, Pa). A similar file for the DELMARVA unit hydrograph and Type III rainfall is available from the SNTC (Ft. Worth, TX).

SAVED INPUT FILES -----

When using the TR-55 system, data is entered on input screens. Once entered, it may be desirable to keep the data for future reference. Both a SAVE and LOAD function are part of the TR-55 system for filing and retrieving data. The user devises a file name (up to eight characters) to which a ".55" is added by the system. The ".55" will identify the file as TR-55 user data. Several sample input files are on diskette #2.

* * * CREATING A WORKING COPY OF TR-55 SYSTEM * * *

Before running TR-55 for the first time a "working" copy of the program and data files should be made. The working copy will be the one used while the original diskettes are kept in a safe place. The

155 20Oct95 ASC 20 Oct 95 A140F8

following files names, sizes and dates should be on the original two 5 1/4" program diskettes. The division of files between the two 5 1/4" diskettes follows:

Volume TR55#1 VER2

COVER	DAT	7040	4-15-86	README	EXE	38274	4-26-88
README	1ST	18139	1-16-90	TR55	EXE	264144	1-15-90

4 File(s) 33792 bytes free

Volume TR55#2 VER2

CGA	CFG	197	1-15-90	EX6-1	55	442	1-16-90
CONFIG	EXE	88096	1-15-90	EX6-2	55	453	1-16-90
COUNTY	RF	1633	4-15-86	EX6-3	55	466	1-16-90
EGA	CFG	197	1-15-90	EX6-4	55	467	1-16-90
EX2-1	55	488	1-16-90	SOILS	TYP	1066	1-15-90
EX2-2	55	527	1-16-90	TR55	CFG	320	1-15-90
EX2-3	55	562	1-16-90	TYPEI	TBL	46720	4-15-86
EX2-4	55	555	1-16-90	TYPEIA	TBL	46720	8-13-86
EX3-1	55	640	1-16-90	TYPEII	TBL	46848	4-15-86
EX4-1	55	952	1-16-90	TYPEIII	TBL	46720	4-15-86
EX5-1	55	2390	1-16-90	VGA	CFG	197	1-15-90
EX5-2	55	2450	1-16-90				

23 File(s) 60416 bytes free

FLOPPY DISK SYSTEM

Following instructions in your computer system operating manual, format two new diskettes. On one of the diskettes copy the file COMMAND.COM from the disk used to boot up your system. To this diskette add:

1. The "TR55.EXE" file (from TR55 DISK#1).

2. The "COVER.DAT" file (from TR55 DISK#1).

3. The appropriate "TYPExxx.TBL" file for your locale (from TR55 DISK#2). See the Figure B-2 rainfall distribution map in TR-55.

4. Run the configuration program by entering CONFIG (from TR55 DISK#2). One at a time select the: Color Scheme; Device Search Sequence; and Sound Generation options to set colors, available disk drives and tone of BEEP. Include only the disk drives available in your system in the Device Search Sequence. Be sure to save the selections you make (using the File Input/Output option) on the working copy diskette with the name TR55 before loading. (The software will add ".CFG" extension to the file name.)

   There is a sample TR55.CFG file included in the program diskettes with the capability for adding the user name, county, and state automatically to the input and output screen headings. To do this, fill in the appropriate data in the sample TR55.CFG file with a local editor, being careful to line it up correctly under the other

entries. Be sure that the Device Search Sequence entries conform to the machine drives available, and save the file.

One can use this sample TR55.CFG file instead of running the CONFIG.EXE program to set one up. All that is necessary is that the user check and correct, if needed, the entries in the Device Search Sequence.

The above files are all that are required to operate the TR-55 program system.

The second formatted diskette can be used to hold the following files from TR55 DISK#2. This diskette may only be needed while learning to use the program.

1. "COUNTY.RF" and "SOILS.TYP" files. You will probably replace these with localized ones of your own.

2. The sample data files which end in ".55".

3. The remaining "TYPExxx.TBL" files which may be needed with the sample files or for training purposes.

HARD DISK SYSTEM

Create a subdirectory (TR55) on your hard disk for the TR55 files using your DOS Make Directory (MD) command The syntax for the command from the hard disk prompt is:

```
MKDIR \TR55
```

Move to the TR55 subdirectory using the DOS change directory (CD) command as follows:

```
CD \TR55
```

Using the two TR-55 original diskettes copy all of the files referenced above for the floppy disk system onto the hard disk. Also create the TR55.CFG file by executing CONFIG.

(If the disk drive designation and TR55 subdirectory name are added to your systems PATH command, TR55 can be executed from anyplace regardless of what is currently the default drive and directory. See your DOS manual for more information on the PATH command.)

* * * HELPFUL OPERATING HINTS * * *

HELP screens are available to assist the user. They are accessed by pressing function key F1 for pertinent information about the current part of the system being viewed. Reviewing (and printing using the PrtSc key) the HELP screens as you go through the TR-55 system the first time is a good idea. Remember, the reference for the TR-55 program is the 1986 TR-55 revision.

When you are ready to load the new TR55 on your system, copy any

data files (those ending in ".55") you wish to save from the TR55 directory to a floppy diskette. You do not need to copy the examples (EX2-1.55, etc.) as they are included in your new diskettes. Then delete all the files left in the TR55 directory and load in the new TR55 program diskettes.

If you have data SAVEd with previous program versions, the files may be unusable with this version. Both LOAD and SAVE utilities have been rewritten to make the saved data files more compact.

* * * CHANGES FROM PREVIOUS VERSION * * *

1. The seven executable modules were combined into one, reducing size of overall program and eliminating load time between modules. This also eliminated the truncated print problem which occurred on certain buffered printers.

2. Use of TR55.CFG file allows recognition of color monitors and different disk drive configurations. User can control colors and drives.

3. Use of the SOILS.TYP file provides local soil names and their hydrologic soil group(s) as a look up reference.

4. Text strings no longer accept " as a valid character because of problems which occured when data was SAVEd and reLOADed. When a " is entered an apostrophe (') is used instead.

5. Computed CN's of less than 40 now result in a warning message and no transfer of the value to one of the primary functions. The older program version would not allow user to leave CN portion of program until CN was raised.

6. Rainfall types can be entered in both upper and lower cases.

7. Correct display of small (<0.10 sq mi) drainage areas on tabular input screen when area was converted from acres entered in the CN portion of program. (Computations were OK.)

8. Transfer of computed Tc values > 2 hours are not permitted to tabular method.

9. Method used to find closest tabular Tc or Tt table values is revised. When such values were exactly halfway between table values, inaccuracies in storing floating point numbers may have made the value appear to be closer to one table value then the other.

10. Correct printing of rounded Tc and Tt values as well as addition of an extra decimal place to Manning's n.

11. Display of drainage area and rainfall data in the temporary storage portion of program when data is loaded directly to that screen.

12. Eliminate many of the "beeps" and user verification required when function key or ESC are pressed.

13. Allow user to select the path in addition to drive on both

LOADing and SAVEing.

14. Add Range as an acceptable sheet flow surface type.

15. Where program control will go when ESC key is pressed is now displayed at the bottom of most screens with the active function keys.

* * * STARTING UP THE TR-55 SYSTEM * * *

Now the fun begins ---- Put the working copy of diskette #1 on the default disk drive or CD to the TR55 subdirectory on the hard disk and enter "TR55".

HAPPY COMPUTING from the original TR-55 Computer Program Team

Ted Burns	SCS	Morgantown, West Virginia
Roger Cronshey	SCS	Washington D.C.
James Hailey	SCS	Temple, Texas
Clint Liezert	SCS	Medina, Ohio
Ralph Roberts	ARS	Beltsville, Maryland

Program changes for the current version were made by:

Ralph Roberts and Roger Cronshey

13.2 Borrow Area E&S Basin Sizing

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: BORROW AREA E&S BASIN SIZING

Computations By: (Cognizant Engineer)
Signature: Kara L. Olen — Date: 10/22/95
Printed Name and Title: KARA L. OLEN, Asst. Proj Engr.

Assumptions and Procedures Checked by: (Checker)
Signature: Daniel B. Wisialowski — Date: 95/10/24
Printed Name and Title: DANIEL B. WISIALOWSKI, ASSISTANT PROJECT ENGINEER

Computations Checked by:
Signature: Daniel B. Wisialowski — Date: 95/10/24
Printed Name and Title: DANIEL B. WISIALOWSKI, ASSISTANT PROJECT ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Kara L. Olen — Date: 10/24/95
Printed Name and Title: Kara L. Olen, Asst. Proj Engr.

Approved by: (PDP)
Signature: Kara L. Olen — Date: 10/24/95
Printed Name and Title: Kara L. Olen, Asst. Proj. Engr.

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 24 Oct 95
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	30% Submittal	24 Oct 95	NA	NA	NA
B	Preliminary Design - EPA Submittal	15 Dec 95	[illegible]		

Written by: Kara Olen Date: 15 Dec 1995 Reviewed by: D. Wisniewski Date: 15 DEC 95

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.2

BORROW AREA E&S BASIN SIZING

EXECUTIVE SUMMARY

The computer program TR-55 (SCS, 1986) and design regulations of the Ohio Administrative Code (OAC 3745-27) were used to estimate the required storage volumes for four temporary erosion and sedimentation (E&S) basins for the borrow area. The locations of these temporary E&S basins are shown in Figure 2 of these calculations. OAC is used to calculated the required volume needed to contain sediment between scheduled basin cleanouts. TR-55 is used to calculate an additional volume required to temporarily detain the stormwater so that the peak flow rate out of each E&S basin for the design storm (25-yr 24-hr storm) does not exceed the peak runoff for the final restored conditions for the same location at the borrow area. The results indicate that the following temporary E&S basin volumes are required:

Temporary E&S Basin No.	Req'd Vol. (ac-ft)
1	6.98
2	2.90
3	7.21
4	2.36

Written by: Karla Allen Date: 95/10/22 Reviewed by: DBW Date: 95/10/24

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

K. Allen 10/24/95

Borrow Area E&S Basin Sizing

Summary of Calculations

The computer program TR-55 and design regulations presented in the Ohio Administrative Code, Chapter 3745-27 (6, b, i) are used to estimate the required storage volume for each of four temporary E&S basins at the borrow area. TR-55 is used to estimate the required basin volume based in peak inflow into the basin, peak outflow from the basin, and the design storm type and duration. Ohio Administrative Code, Chapter 3745-27(6, b, i) presents criteria for additional volume required to accomodate accumulated sediments. A summary of data used in the calculations, and results are presented below.

- Summary of Data

Data for TR-55:

- Design Storm = 25 yr - 24 hr. type II Storm ✓
- Rainfall for design Storm = 4.7 inches ✓

Written by: Kara Olen Date: 95/10/22 (YY MM DD) Reviewed by: DBW Date: 95/10/24 (YY MM DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

KOlen 10/24/95

- Rainfall for 2yr-24hr storm = 2.55 inches ✓
- Drainage Area Data (for existing Conditions①)

Drainage Area Name	Area (Ac)	Wt'd CN	tc (hr)	Corresponding E&S Basin No.
1	10.3	74	0.29	1
2	41.8	74	0.42	2
3	50.0	80	0.52	3
4	10.2	74	0.24	4 ✓

- Drainage Area Data (for Construction Conditions)

Drainage Area Name	Area (Ac)	Wt'd CN	tc (hr)	Corresponding E&S Basin No.
1	38.3	81	0.54	1
2	30.5	82	0.53	2
3a	23.3	82	0.54	3a
3b	23.7	85	0.34	3b ✓
4	11.5	91	0.33	4

Data for Additional Basin Volume for Sediments

- From Ohio Administrative - provide additional storage volume equal to the greater of the calculated runoff from a 10yr-24hr storm or 0.125 AC-FT for each acre of disturbed area

The total rainfall for the 10yr 24hr storm is 4.06 (See figure 1), From Parsons, 1995

① This data is taken directly from Calculation Package entitled Borrow area Stormwater management Calculations. These calculations are not repeated in this calculation package.

Written by: Karla Olen Date: 95 / 10 / 22 (YY MM DD) Reviewed by: DBW Date: 95 / 10 / 23 (YY MM DD)

Client: Fernes Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

K. Olen 10/24/95

- Summary of Results

Temp EDS Basin #	Ponding Volume (TR-55)			Additional Sediment Vol.	Tot. Vol.
	Q in (cfs)	Q out (cfs)	Vol (Ac-ft)	(Ac-ft)	(Ac-ft)
1	86	22	3.53	3.45	6.98
2	71	78	0	2.90	2.90
3	125	99	2.21	5.00	7.21
4	45	26	0.86	1.50	2.36

✓

Collection and Verification of Data

- Rainfall depth - The rainfall depth for the design storm (i.e. 25 yr-24 hr storm) and for the 2 yr 24 hr storm were obtained from Parsons (1995). See figure 1

  - 25 yr-24 hr storm event rainfall = 4.7 inches ✓
  - 25 yr-10 hr storm event rainfall = 4.06 ✓
  - 2 yr-24 hr storm event rainfall = 2.55 inches ✓

- Rainfall Distribution Type - The rainfall distribution type was obtained from USDA-SCS (1986) in accordance with the geographical location of the site (See figure 2).

  - Type II rainfall distribution ✓

Written by: Karla Olen Date: / / YY MM DD Reviewed by: DBW Date: 95 / 10 / 23 YY MM DD

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

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- Surficial Soil Hydrologic Soil Group

Surficial soil names and hydrologic soil groups were obtained from the Hamilton County Soil Survey (USDA, 1982) and are shown below and in Figure 3.

Map Symbol	Soil Name	Hydrologic Soil Group
FeA, FdA	Fincastle Silt Loam	C
MaB, MaC2	Markland Silty Clay Loam	C
McA	Martinsville Silt Loam	B
MoE2	Miamian-Hennepin Silt Loam	C
RdA	Raub Silt Loam	C
RuB2	Russell Silt Loam	B
XfA, XfB2	Xenia Silt Loam	B

Approximately 80% of the surface soils at the borrow area classify as type B & the remaining 20% as class C.

Available geotechnical data for the borrow area indicate that the clay content decreases with increasing depth, which indicates that the underlying soils are better drained than the surface soils.

Written by: Kara Olen Date: 95/10/22 (YY MM DD) Reviewed by: DBW Date: 95/10/24 (YY MM DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

K. Olen 10/24/95

For these calculations it will be assumed that all soils, for both existing and construction conditions classify as hydrologic soil group C. This will be conservative since proposed final conditions will generally contain better drained soils which would infiltrate more runoff than a soil group C. ✓

· Ground Cover Type & Hydrologic Condition

Descriptions of vegetal cover type & conditions were obtained from aerial photographs of the borrow area provided by Fernco. These vegetal cover type & conditions are presented in the table below:

- Existing Conditions

Borrow area: "Pasture, grassland or range" in good condition (CN=74) ✓

Offsite Area: (South of Willey Rd) "Straight Row Crops Plus Residue" in good condition (CN=82) ✓

- Construction Conditions

It will be assumed that during borrow activities, the contractor may expose up to 10 acres of bare soil at a time. For the purposes of these calculations, it will be assumed that 10 acres of bare soil is exposed, and only 5 of the previous 10 acres of exposed soil have established vegetation - for a conservative total of 15 acres of exposed bare soil. Therefore:

Borrow Area: "Fallow, Bare Soil" (CN=91) for first 15 Acres; "Pasture, grassland or range" in good condition (CN=74) ✓ ✓

Written by: Kara Allen Date: 95 / 10 / 22 Reviewed by: DBW Date: 95 / 10 / 24
YY MM DD YY MM DD

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

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OFFSITE Area: "Straight Row Crops Plus Residue"
(South of Willey Rd) in good condition (CN = 82) ✓

- Time of Concentration

TR-55 calculates the time of concentration, for the most hydraulically distant drainage path, using the following equations for sheet flow, shallow concentrated flow, and open channel flow:

- Sheet flow (assumed for first 100 ft):

$$T_t = \frac{0.007(nL)^{.8}}{(P_2)^{1/2}(S)^{.4}}$$ ✓

where: T_t = travel time (hr)
n = manning roughness coef.
L = length of sheet flow (ft)
P_2 = rainfall for 2yr - 24hr storm (in)
S = slope (ft/ft)

- Shallow Concentrated Flow (assumed after first 100 ft & continues until a well-defined channel is reached)

$$T_t = \frac{L}{3600V}$$ ✓

where: T_t = travel time (hr)
L = flow length (ft)
V = average runoff velocity (ft/s) (from figure 4)

Written by: Kara Olen Date: 95 / 10 / 22 (YY MM DD) Reviewed by: DBW Date: 95 / 10 / 24 (YY MM DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

K. Olen 10/24/95

- Open Channel flow (from Manning Eq.)

$$V = \frac{1.49}{n} r^{2/3} S^{1/2}$$ ✓

where: n = manning roughness coef.
r = hydraulic radius of ditch (full flow conditions assumed)
S = channel slope (ft/ft)

Once V is calculated, T_t is then calculated using the equation shown for shallow concentrated flow. ✓

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DBW 95/10/24 - 8/12
16 dm
10/24/95

RAINFALL DEPTH FOR A GIVEN DURATION (INCHES)

DURATION (YEARS)	TIME							
	HYDRO-35			TP-40				
	5 MIN	15 MIN	60 MIN	2 HOURS	3 HOURS	6 HOURS	12 HOURS	24 HOURS
2	0.387	0.739	1.223	1.408	1.54	1.848	2.2	2.552
5	0.49	0.979	1.69	2.016	2.112	2.496	2.88	3.072
10	0.564	1.139	1.99	2.277	2.475	3.069	3.465	4.059
25	0.65	1.34	2.38	2.6	3.0	3.4	4.0	4.7
50	0.72	1.49	2.67	3.0	3.25	3.9	4.2	5.2
• 100	0.78	1.64	2.95	3.3	3.6	4.1	5.0	5.6
• 500	0.93	2.1	4.3	5.2	5.9	7.3	8.5	9.4
2000	1.2	2.6	5.8	7.2	8.2	10.2	12.0	13.0
10,000	1.4	3.4	8.2	10.5	12.0	15.5	18.0	19.2
100,000	1.9	5.0	13.3	17.7	20.8	27.4	31.8	33.4
	DESIGN OF SMALL DAMS					HMR-51		

NOTE: Rainfall Points For 2, 5, and 10 year rainfall events were adjusted per TP-40. Values for the 500, 2000, and 10,000 Year Events were interpolated from Figure 3 (Appendix E)

• These values are used on PH Records for HEC-1.

(From Parsons, 1995)

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ATLANTA, GEORGIA

FIGURE NO.	FIGURE 1
PROJECT NO.	
DOCUMENT NO.	
FILE NO.	

DBW 95/10/24 9/12

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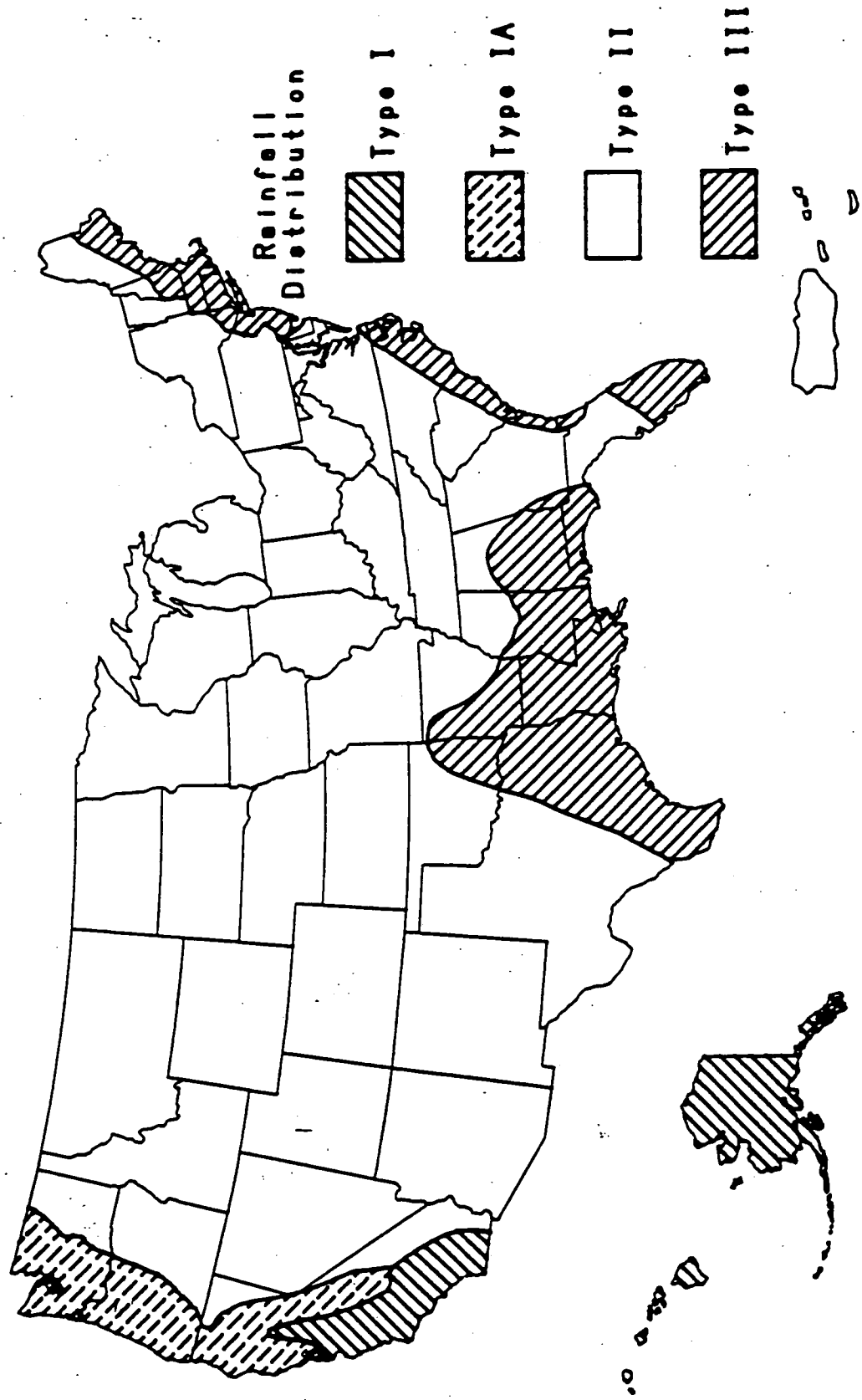


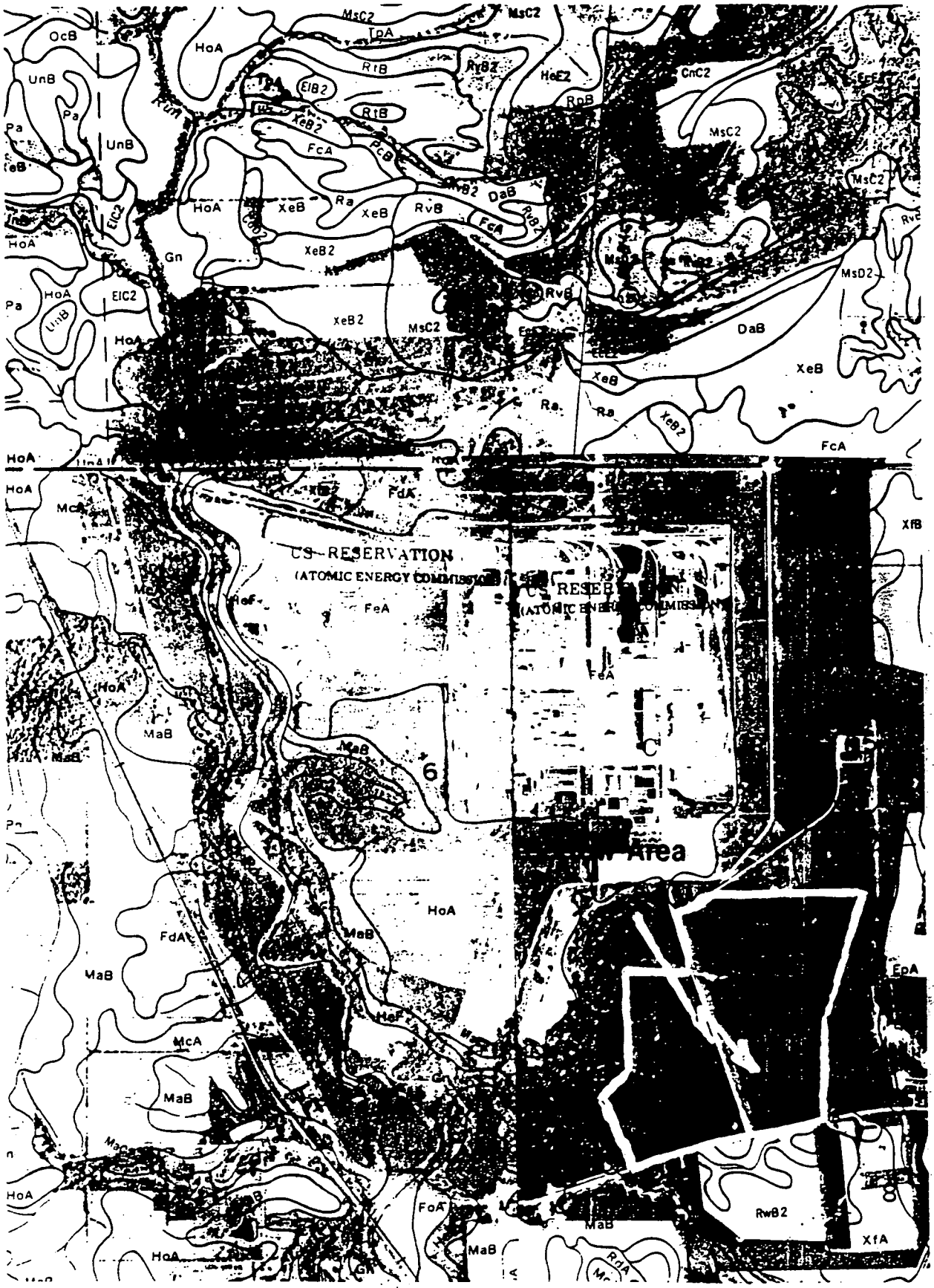
FROM TR-55, 1986

GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.	FIGURE 2
PROJECT NO.	
DOCUMENT NO.	
FILE NO.	

327693

DBW #95/10/24 10/12 10/24/95



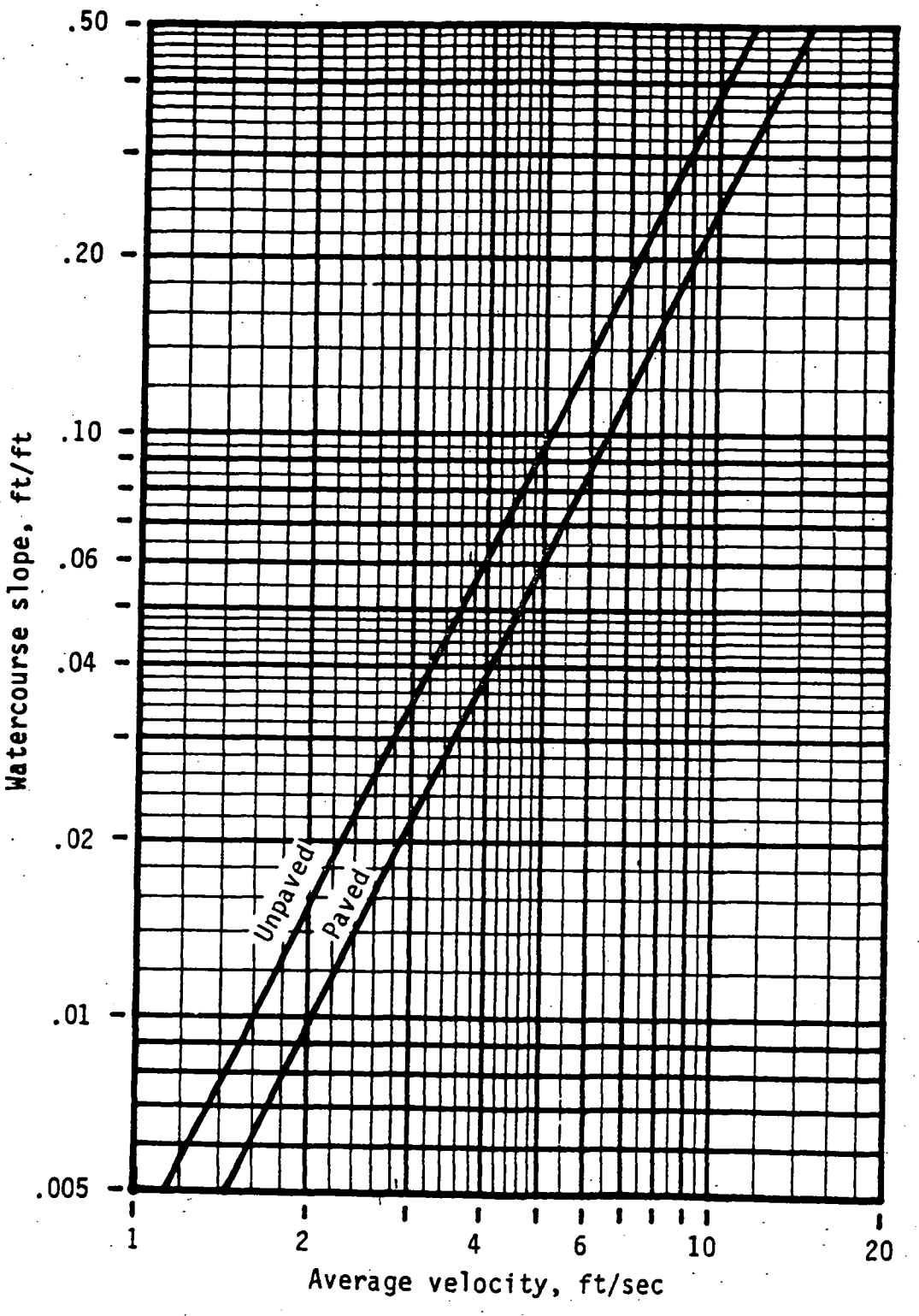
FROM "SOIL SURVEY OF HAMILTON COUNTY", 1982

GEOSYNTEC CONSULTANTS ATLANTA, GEORGIA	FIGURE NO. **FIGURE 3**
	PROJECT NO.
	DOCUMENT NO.
	FILE NO.

001647

DRAN 95/10/24 11/12

K. Olen 10/24/95



GEOSYNTEC CONSULTANTS
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FIGURE NO.	FIGURE 4
PROJECT NO.	
DOCUMENT NO.	
FILE NO.	

Written by: Kara Olen Date: 95 / 10 / 22 Reviewed by: DBW Date: 95 / 10 / 24
YY MM DD YY MM DD

Client: Fernew Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

K. Olen 10/24/95

References.

- United States Department of Agriculture - Soil Conservation Service, "Soil ~~Service~~ Survey of Hamilton County, Ohio", Washington, DC, August 1982.
- United States Department of Agriculture - Soil Conservation Service, Engineering Division, "TR-55 Microcomputer Program System", Washington, DC, June 1986a, 162 p.
- United States Department of Agriculture - Soil Conservation Service, Engineering Division, "Urban Hydrology for Small Watersheds" Technical release 55, Washington, DC, June 1986a, 162 p.
- Soil Conservation Service - Ohio, "Water Management and Sediment Control for Urbanizing Areas", Columbus, Ohio, 1987.
- Parsons, "2000 year flood and Probable Maximum Flood, Sitewide Flood Plain Determination", Revision A, Aug 1995
- Ohio Administrative Code, Solid Waste Disposal Regulations, Chapter 3745-27-08 (C)(6)

Written by: Kara Olen Date: 95/10/22 (YY MM DD) Reviewed by: NBW Date: 95/10/24 (YY MM DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

Borrow Area E&S Basin Sizing Calculations

① Calculate Peak Runoff to 4 locations where Temporary E&S basins will be located. FOR EXISTING CONDITIONS.

This calculation was performed in the Calculation Package titled "Borrow Area Stormwater Management Calculations", and are not repeated here. The drainage area Map for existing conditions is shown in Figure 1 & the peak flowrates as calculated in "Borrow Area Stormwater Management Calculations" are summarized below:

Subarea Name	Peak Q (cfs)
1	22
2	78
3	99
4	26

② Calculate Peak Runoff to 4 locations where Temporary E&S Basins will be located. FOR CONSTRUCTION CONDITIONS

This calculation was performed using TR55 assuming up to 15 Acres of exposed soil per area. The drainage area map and flow path components for the hydraulically most distance flow path for each area are shown

Written by: Kara Oler Date: 95/10/22 Reviewed by: DBW Date: 95/10/24

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

In Figure 2. TR-55 peak Q data is presented on pages 6-13 and the peak flows are summarized below:

Subarea Name	Peak Flow (cfs)
1	86
2	71
3	125
4	45

✓

③ Estimate Required Storage Volume

a) Routing Storage Volume needed based on peak inflow, peak outflow, & design storm

- Temporary E&S basins will be designed such that the peak outflow from the basin will not be greater than the existing peak flow to that location (i.e., peak flow prior to development). Peak inflow is the peak Q to each basin during construction conditions. These peak inflows and outflows are summarized below:

Basin	q_i (cfs)	q_o (cfs)
1	86	22
2	71	78
3	125	99
4	45	26

- Determine (q_o/q_i) and obtain (V_s/V_r) — storage volume over runoff volume from figure 3:

Written by: Kara Olen Date: 95/10/22 (YY/MM/DD) Reviewed by: DJW Date: 95/10/24 (YY/MM/DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

q_o/q_i	V_s/V_r	Basin #
0.26	0.408	1
1.10	—	2
0.79	0.180	3
0.58	0.244	4

✓

- Convert runoff in inches (as calculated in TR-55) to a volume with the following equation:

$$V_r = 53.33 Q A_m$$ ✓

where:

V_r = runoff volume (acre-ft)
Q = runoff (in)
A_m = drainage area (mi^2)
53.33 = conversion factor from in-mi^2 to acre-ft.

The resulting V_r values are:

Basin #	Q (in)	A (Ac)	Am (mi^2)	Vr (ac-ft)
1	2.72	38.3	0.0598	8.67
2	2.81	—	—	—
3	2.95	50.0	0.0781	12.28
4	3.69	11.5	0.0180	3.54

✓

- Compute required storage volume V_s:

$$V_s = V_r (V_s/V_r)$$

For Basin 1: $V_s = (8.67)(.408) = 3.53$ Ac-ft
For Basin 3: $V_s = (12.28)(.180) = 2.21$ Ac-ft
For Basin 4: $V_s = (3.54)(.244) = 0.86$ Ac-ft ✓

No storage is required for basin 2 because q_i is less than or approximately equal to q_o.

Written by: Kara Allen Date: 95/10/22 Reviewed by: DBW Date: 95/10/24

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

b) Storage Volumes required for sediment:

The Ohio Administrative Code (OAC Chapter 3745-27-08 (C)(6)) requires that minimum storage shall be provided for any sedimentation pond based on either the calculated runoff for the 10-yr 24hr storm event, or 0.125 AC-FT per yr (for each acre of disturbed area within the upstream drainage area) multiplied by the scheduled frequency of pond cleanout (in years), whichever is greater. It is assumed that the basins will be cleaned out every six months.

The storage values based on the above requirements are presented below. TR-55 output for the 10yr-24 hour storm is presented on pages 14-21. The 10yr-24hr storm volume was calculated by multiplying the runoff in inches (calculated by TR-55) by the drainage area.

1) Storage Volume from 10yr-24hr. storm:

Basin	Runoff (in.)	Runoff (ft)	Drainage Area (Ac)	Cleanout Freq. (yrs)	Storage (Ac-ft)
1	2.17	0.18	38.3	0.5	3.45
2	2.25	0.19	30.5	0.5	2.90
3	2.38	0.20	50.0	0.5	5.00
4	3.07	0.26	11.5	0.5	1.50 ✓

2) Storage Volume based on 0.125 ac-ft per acre disturbed area

Basin	Total Disturbed Area (Ac)	Multiplier (ac-ft)	Cleanout Freq. (yrs)	Storage (Ac-ft)
1	25.0	0.125	0.5	1.56
2	21.5	0.125	0.5	1.34
3	17.3	0.125	0.5	1.08
4	9.2	0.125	0.5	0.58 ✓

Written by: Kara Olen Date: 95/10/22 (YY/MM/DD) Reviewed by: DBW Date: 95/10/24 (YY/MM/DD)

Client: Kerneo Project: Kenneld Project/Proposal No.: GE3900 Task No.: 8.2

From the above it is apparent that the storage volume from the 10 yr.-24 hour storm is the governing volume. The total Temporary Sedimentation Basin Volumes are therefore equal to the storage volume from the 10-yr 24 hr storm (assuming 2 clearouts per year) plus the routing storage required for the 25-year 24 hour storm. The total volumes are presented below.

Basin #	25-yr.-24 hr. Vol. (Ac-ft)	10-yr.-24 hr. Storage (Ac-ft)	Total Volume (Ac-ft)
1	3.53	3.45	6.98
2	0	2.90	2.90
3	2.21	5.00	7.21
4	0.86	1.50	2.36

✓

c) Therefore - final total volumes required to the temporary E&S Basins are:

Basin #	Tot vol. (Ac-ft)
1	6.98
2	2.90
3	7.21
4	2.36

✓

Kolen 10/22/95
Fernco
Fernald - GE3900 8.2

6/25

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DBW Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (25-yr 24hr Storm)
Subarea : 1

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
				Acres (CN)		
CULTIVATED AGRICULTURAL LANDS						
Fallow	Bare soil	----	-	-	15(91)	-
OTHER AGRICULTURAL LANDS						
Pasture, grassland or range		good	-	-	23.3(74)	-
Total Area (by Hydrologic Soil Group)					38.3	

SUBAREA: 1 TOTAL DRAINAGE AREA: 38.3 Acres WEIGHTED CURVE NUMBER: 81

Kaler Fernas 10/23/95
Fernald-GE3900 8.2

7/25

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE3900-8.2 FERNALD
User: KLO
Date: 10-21-95
County : HAMILTON
State: OH
Checked: DBN
Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (25 yr 24hr storm)
Subarea : 2

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
			Acres (CN)			
CULTIVATED AGRICULTURAL LANDS						
Fallow	Bare soil	----	-	-	15(91)	-
OTHER AGRICULTURAL LANDS						
Pasture, grassland or range		good	-	-	15.5(74)	-
Total Area (by Hydrologic Soil Group)					30.5	

SUBAREA: 2 TOTAL DRAINAGE AREA: 30.5 Acres WEIGHTED CURVE NUMBER: 82

001656

Kidlen 10/22/95
Fernald GE3900-8.2

8/25

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DBW Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (25yr 24hr Storm)
Area : 3A

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
				Acres (CN)		
CULTIVATED AGRICULTURAL LANDS						
Row crops	SR + Crop residue	good	-	-	23.3(82)	-
Total Area (by Hydrologic Soil Group)					23.3	

SUBAREA: 3A TOTAL DRAINAGE AREA: 23.3 Acres WEIGHTED CURVE NUMBER: 82

001657

K. Olson 10/22/95
Fernald GE3900-8.2

9/25

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DBW Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (25-yr 24hr Storm)
Subarea : 3B

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
CULTIVATED AGRICULTURAL LANDS					
Fallow Bare soil	----	-	-	15(91)	-
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	8.7(74)	-
Total Area (by Hydrologic Soil Group)				23.7	

SUBAREA: 3B TOTAL DRAINAGE AREA: 23.7 Acres WEIGHTED CURVE NUMBER: 85

001658

KLOller 10/22/95
Fernald
Fernald- GE3900 8.2

10/25

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DBW Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (25yr-24hr Storm)
Area : 4

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
				Acres (CN)		
CULTIVATED AGRICULTURAL LANDS						
Fallow	Bare soil	----	-	-	11.5(91)	-
Total Area (by Hydrologic Soil Group)					11.5	

SUBAREA: 4 TOTAL DRAINAGE AREA: 11.5 Acres WEIGHTED CURVE NUMBER: 91

001679

Kloer 10/24/95
Fernald GE3900 8.2

11/25

TIME OF CONCENTRATION AND TRAVEL TIME — Version 2.00

Project : GE3900-8.2 FERNALD — User: KLO — Date: 10-21-95
County : HAMILTON — State: OH — Checked: DBW — Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (25-yr 24-hr Storm)

Subarea #1 - 1

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0150	E					0.205
Shallow Concent'd		420	.044	U					0.034
Shallow Concent'd		1350	.006	U					0.300
								Time of Concentration =	0.54*

Subarea #2 - 2

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0128	E					0.219
Shallow Concent'd		400	.0500	U					0.031
Shallow Concent'd		1250	.0060	U					0.278
								Time of Concentration =	0.53*

Subarea #3 - 3A

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0111	D					0.256
Shallow Concent'd		750	.0087	U					0.138
Shallow Concent'd		870	.0218	U					0.101
Open Channel		420	.0155		.04	25	50.4		0.040
								Time of Concentration =	0.54*
Shallow Concent'd		900	.0167	U					0.120
								Travel Time =	0.12*

Subarea #4 - 3B

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.16	E					0.080
Shallow Concent'd		1050	.0048	U					0.261
								Time of Concentration =	0.34*

* - Generated for use by TABULAR method

K. Oler 10/26/95
Fernald
Fernald - GE3900-8.2

12/25

TIME OF CONCENTRATION AND TRAVEL TIME — Version 2.00

Project : GE3900-8.2 FERNALD — User: KLO — Date: 10-21-95
County : HAMILTON — State: OH — Checked: DBW — Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (25yr - 24hr Storm)

-- Subarea #5 - 4 --

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	40	.2	E					0.035
Sheet		60	.01	E					0.160
Shallow Concent'd		580	.0056	U					0.133

Time of Concentration = 0.33*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

KLOller 10/22/95
Fernald-GE3900 8.2

13/25

TABULAR HYDROGRAPH METHOD Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DBW Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (25 yr 24 hr Storm)

Total watershed area: 0.199 sq mi Rainfall type: II Frequency: 25 years

	Subareas				
	1	2	3A	3B	4
Area(sq mi)	0.06*	0.05*	0.04*	0.04*	0.02*
Rainfall(in)	4.7	4.7	4.7	4.7	4.7
Curve number	81*	82*	82*	85*	91*
Runoff(in)	2.72	2.81	2.81	3.09	3.69
Tc (hrs)	0.54*	0.53*	0.54*	0.34*	0.33*
(Used)	0.50	0.50	0.50	0.30	0.30
TimeToOutlet	0.00	0.00	0.00	0.00	0.00
Ia/P	0.10	0.09	0.09	0.08	0.04
(Used)	0.10	0.10	0.10	0.10	0.10

Avg over area = 2.95"

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) 1	2	3A	3B	4
11.0	10	3	2	2	2	1
11.3	14	4	3	2	3	2
11.6	20	5	4	3	5	3
11.9	45	9	8	6	14	8
12.0	81	15	13	10	27	16
12.1	149	28	23	17	51	30
12.2	245	50	41	32	77P	45P
12.3	309P	76	63	48	77	45
12.4	294	86P	71P	54P	53	30
12.5	254	83	68	52	32	19
12.6	195	65	54	41	22	13
12.7	145	48	40	30	17	10
12.8	111	37	30	23	13	8
13.0	70	23	19	14	9	5
13.2	51	16	13	10	8	4
13.4	41	12	10	8	7	4
13.6	33	10	8	6	6	3
13.8	29	9	7	5	5	3
14.0	27	8	6	5	5	3
14.3	22	7	5	4	4	2
14.6	21	6	5	4	4	2
15.0	18	5	4	3	4	2
15.5	17	5	4	3	3	2
16.0	15	4	3	3	3	2
16.5	13	4	3	2	3	1
17.0	11	3	3	2	2	1
17.5	11	3	3	2	2	1
18.0	11	3	3	2	2	1
19.0	10	3	2	2	2	1
20.0	7	2	2	1	1	1
21.0	7	2	2	1	1	1
22.0	0	0	0	0	0	0

P - Peak Flow * - value(s) provided from TR-55 system routines

K. Allen 10/22/95
Fernald
Fernald-GE3900-8.2 RUNOFF CURVE NUMBER COMPUTATION Version 2.00

14/25

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DBW Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (10yr-24hr Storm)
Subarea : 1

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
				Acres (CN)		
CULTIVATED AGRICULTURAL LANDS						
Fallow	Bare soil	----	-	-	15(91)	-
OTHER AGRICULTURAL LANDS						
Pasture, grassland or range		good	-	-	23.3(74)	-
Total Area (by Hydrologic Soil Group)					38.3	

SUBAREA: 1 TOTAL DRAINAGE AREA: 38.3 Acres WEIGHTED CURVE NUMBER: 81

001663

K. Allen
Fernco
Fernald - GE3900 8.2 10/22/95

15/25

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DBN Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (10yr-24hr storm)
Subarea : 2

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
				Acres (CN)		
CULTIVATED AGRICULTURAL LANDS						
Fallow	Bare soil	----	-	-	15(91)	-
OTHER AGRICULTURAL LANDS						
Pasture, grassland or range		good	-	-	15.5(74)	-
Total Area (by Hydrologic Soil Group)					30.5	

SUBAREA: 2 TOTAL DRAINAGE AREA: 30.5 Acres WEIGHTED CURVE NUMBER: 82

KOler 10/24/95
Fernco
Fernald GE3900-8.2

16/25

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DBN Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (10yr- 24hr. Storm)
Subarea : 3A

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
				Acres (CN)		
CULTIVATED AGRICULTURAL LANDS						
Row crops	SR + Crop residue	good	-	-	23.3(82)	-
Total Area (by Hydrologic Soil Group)					23.3	

SUBAREA: 3A TOTAL DRAINAGE AREA: 23.3 Acres WEIGHTED CURVE NUMBER: 82

001665

Kolen 10/22/95
Fernald GE3900 8.2

17/25

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DBW Date: 95 10 24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (10 yr-24 hr Storm)
Subarea : 3B

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
			Acres (CN)			
CULTIVATED AGRICULTURAL LANDS						
Fallow	Bare soil	----	-	-	15(91)	-
OTHER AGRICULTURAL LANDS						
Pasture, grassland or range		good	-	-	8.7(74)	-
Total Area (by Hydrologic Soil Group)					23.7	

SUBAREA: 3B TOTAL DRAINAGE AREA: 23.7 Acres WEIGHTED CURVE NUMBER: 85

001666

KLOlen 10/22/95
Fernco
Fernald GE3900 8.2

18/25

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DBW Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (10yr-24hr storm)
Subarea : 4

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
				Acres (CN)		
CULTIVATED AGRICULTURAL LANDS						
Fallow	Bare soil	----	-	-	11.5(91)	-
Total Area (by Hydrologic Soil Group)					11.5	

SUBAREA: 4 TOTAL DRAINAGE AREA: 11.5 Acres WEIGHTED CURVE NUMBER: 91

KLOller 10/22/95
Fernald GE3900 8.2

19/25

TIME OF CONCENTRATION AND TRAVEL TIME

Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DPW Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (10yr-24hr storm)

Subarea #1 - 1

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0150	E					0.205
Shallow Concent'd		420	.044	U					0.034
Shallow Concent'd		1350	.006	U					0.300

Time of Concentration = 0.54*
=====

Subarea #2 - 2

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0128	E					0.219
Shallow Concent'd		400	.0500	U					0.031
Shallow Concent'd		1250	.0060	U					0.278

Time of Concentration = 0.53*
=====

Subarea #3 - 3A

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0111	D					0.256
Shallow Concent'd		750	.0087	U					0.138
Shallow Concent'd		870	.0218	U					0.101
Open Channel		420	.0155		.04	25	50.4		0.040

Time of Concentration = 0.54*
=====

Shallow Concent'd		900	.0167	U					0.120

Travel Time = 0.12*
=====

Subarea #4 - 3B

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.16	E					0.080
Shallow Concent'd		1050	.0048	U					0.261

Time of Concentration = 0.34*
=====

* Generated for use by TABULAR method

Kiolen 10/22/95
Fernow
Fernald GE3900 8.2

20/25

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DEW Date: 95|10|24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (10 yr - 24 hr storm)

---------- Subarea #5 - 4 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	40	.2	E					0.035
Sheet		60	.01	E					0.160
Shallow Concent'd		580	.0056	U					0.133

Time of Concentration = 0.33*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

KLOller 10/22/95
Fernas
Fernald GE3900.8.2

21/25

TABULAR HYDROGRAPH METHOD

Version 2.00

Project : GE3900-8.2 FERNALD User: KLO Date: 10-21-95
County : HAMILTON State: OH Checked: DBN Date: 95/10/24
Subtitle: BORROW AREA- CONSTRUCTION PHASE (10yr-24hr Storm)

Total watershed area: 0.199 sq mi Rainfall type: II Frequency: 10 years

	Subareas				
	1	2	3A	3B	4
Area(sq mi)	0.06*	0.05*	0.04*	0.04*	0.02*
Rainfall(in)	4.1	4.1	4.1	4.1	4.1
Curve number	81*	82*	82*	85*	91*
Runoff(in)	2.17	2.25	2.25	2.51	3.07
Tc (hrs)	0.54*	0.53*	0.54*	0.34*	0.33*
(Used)	0.50	0.50	0.50	0.30	0.30
TimeToOutlet	0.00	0.00	0.00	0.00	0.00
Ia/P	0.12	0.11	0.11	0.09	0.05
(Used)	0.12	0.11	0.11	0.10	0.10

$\frac{2.25+2.51}{2}$ = 2.38 inches for area 3

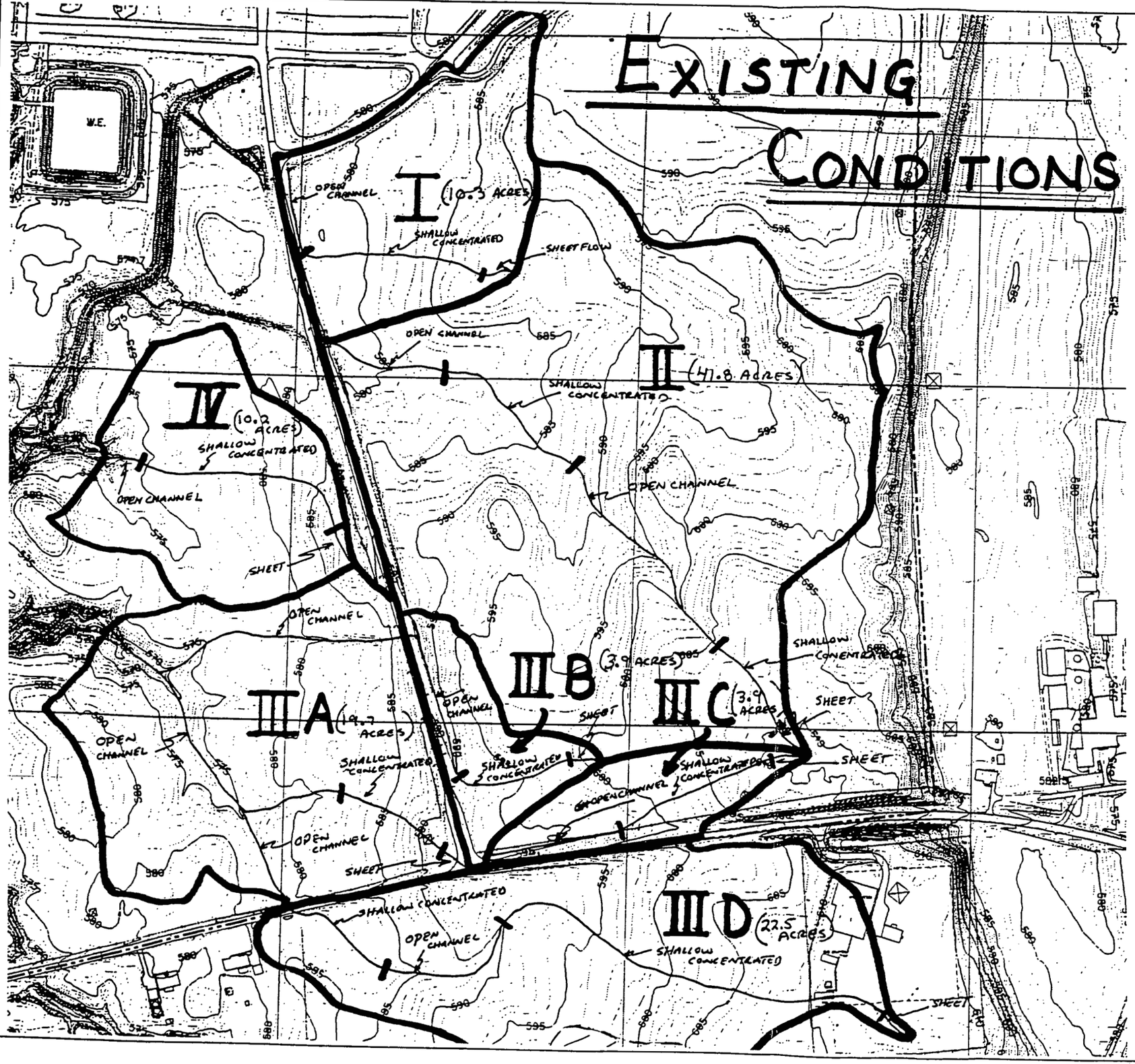
Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) 1	2	3A	3B	4
11.0	8	2	2	1	2	1
11.3	12	3	2	2	3	2
11.6	16	4	3	3	4	2
11.9	36	7	6	5	11	7
12.0	63	11	10	7	22	13
12.1	120	21	18	14	42	25
[illegible]	195	38	32	25	63P	37P
[illegible]	247P	59	50	38	63	37
12.4	235	68P	56P	43P	43	25
12.5	202	65	54	41	26	16
12.6	157	52	43	33	18	11
12.7	117	39	32	24	14	8
12.8	90	30	24	19	11	6
13.0	56	18	15	12	7	4
13.2	41	13	10	8	6	4
13.4	32	10	8	6	5	3
13.6	28	8	7	5	5	3
13.8	24	7	6	4	4	3
14.0	21	6	5	4	4	2
14.3	18	5	5	3	3	2
14.6	17	5	4	3	3	2
15.0	16	4	4	3	3	2
15.5	14	4	3	2	3	2
16.0	12	4	3	2	2	1
16.5	10	3	2	2	2	1
17.0	10	3	2	2	2	1
17.5	10	3	2	2	2	1
18.0	10	3	2	2	2	1
[illegible]	7	2	2	1	1	1
[illegible]	7	2	2	1	1	1
[illegible]	6	2	1	1	1	1
26.0	0	0	0	0	0	0

001670

P - Peak Flow * - value(s) provided from TR-55 system routines

EXISTING CONDITIONS

Kalen 10/22/95 DPW 95/10/24
Femco
Fernald GE3900 8.2



FLOW PATH

I - WATERSHED NAME

A - SUBAREA NAME

DIVISION BETWEEN FLOW TYPES

1" = 300'

N

FIGURE TAKEN FROM CALCULATION PACKAGE TITLED "BORROW AREA STORMWATER MANAGEMENT CALCULATIONS"

001671

Scale: 1" = 300'

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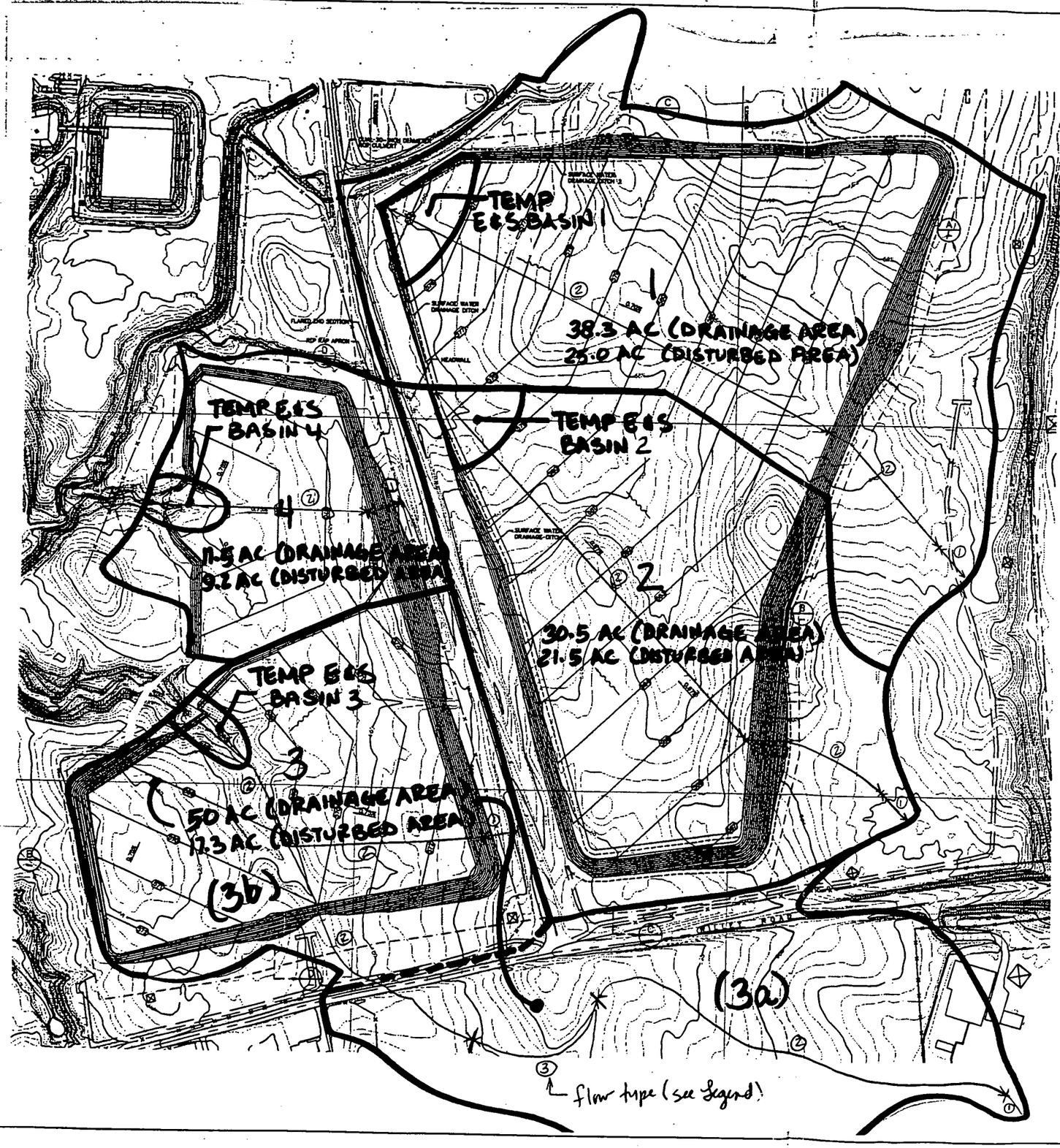
PROJECT NO.	FIGURE NO. FIGURE 1
DOCUMENT NO.	FILE NO.

327696



Legend for flow types: ① = Sheet flow
② = Shallow Concentrated flow
③ = Channel flow

Input Data for Tc calculation:

Sub Area	Sheet Flow			Shallow Conc. Flow			Channel Flow					
	Length (ft)	Slope (%)	Cover (a)	Length (ft)	Slope (%)	U/P (b)	Length (ft)	Slope (%)	n	A (sf)	P (ft)
1	100	1.5	c	420	4.4 (c)	U	—	—	—	—	—
				1350	0.6	U			—	—	—
2	100	1.2	e	400	5.0 (c)	U	—	—	—	—	—
				1250	0.6	U			—	—	—
3* 3a	100	1.1	d	750	0.9	U	430	1.0	0.04	25	50.4
				870	2.2	U					
				900	1.7	U					
3b	100	10.0	e	1050	0.5	U					
4*	40	20.0	e	580	0.6	U	—	—	—	—	—
	60	1.0	e								

* Data for sub areas 3 & 4 were taken from calculations package entitled "Barrow Area Storm Water Management Calculations" for proposed conditions.

Ⓐ Cover type d = cultivated land with > 20% residue
Cover type e = short range grass
Ⓑ U = unpaved surface
Ⓒ Weighted Average Slope was used.

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Koren 10/22/95
Fernco
Fernald GE3900
8.2

DBW 95/10/24

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GEOSYNTEC C
ATLANT

PROJECT NO.
DOCUMENT NO.

327696

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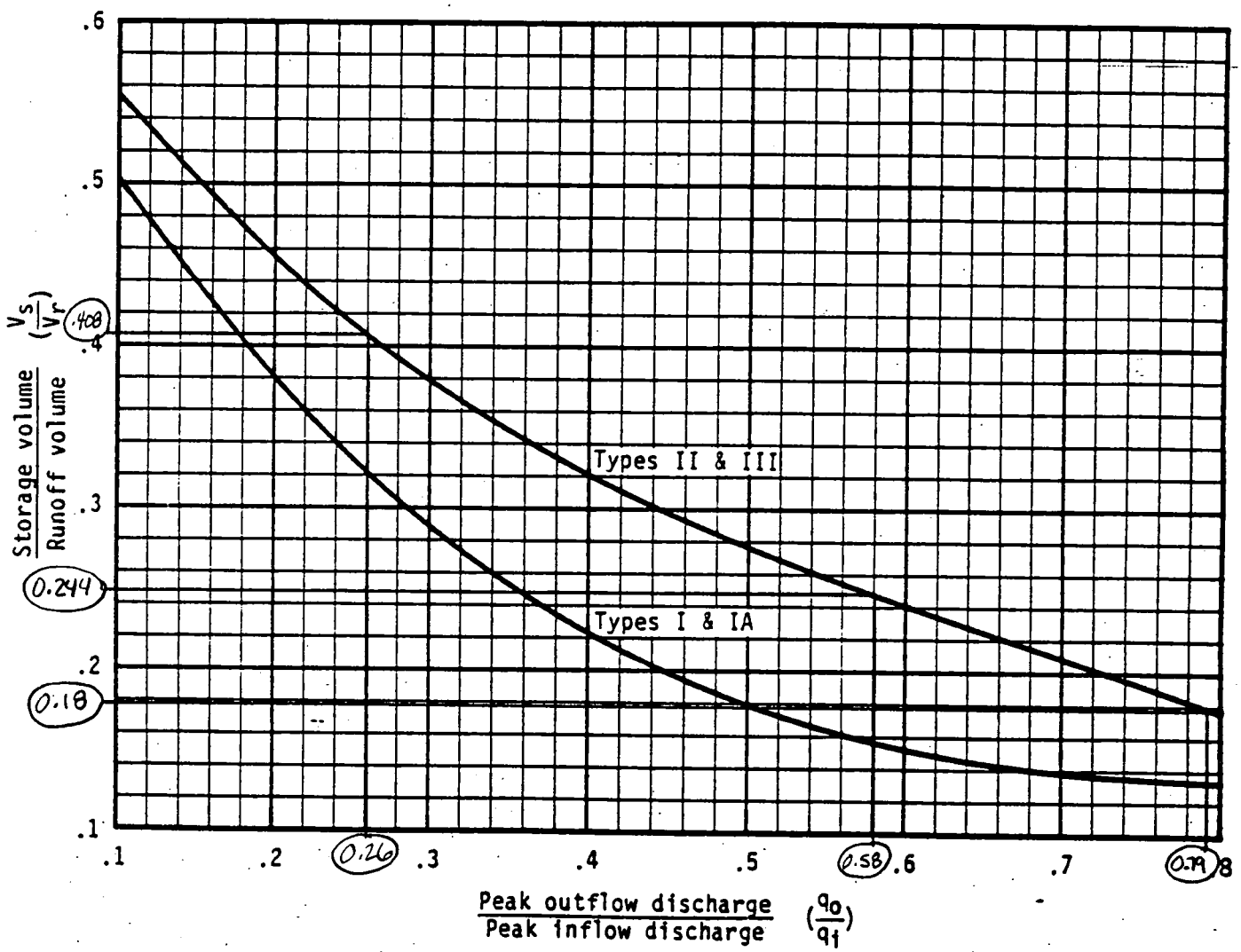
K. Olen 10/22/95
Fernald - GE3900 8.2

DBN 95/10/24 - 24/25



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ATLANTA, GEORGIA

FIGURE NO.	FIGURE 3
PROJECT NO.	
DOCUMENT NO.	
FILE NO.	

Written by: Kara Olen Date: 95 / 10 / 22 (YY MM DD) Reviewed by: DBN Date: 95 / 10 / 24 (YY MM DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

References.

- United States Department of Agriculture - Soil Conservation Service, "Soil ~~Service~~ Survey of Hamilton County, Ohio", Washington, DC, August 1982.
- United States Department of Agriculture - Soil Conservation Service, Engineering Division, "TR-55 Microcomputer Program System", Washington, DC, June 1986a, 162 p.
- United States Department of Agriculture - Soil Conservation Service, Engineering Division, "Urban Hydrology for Small Watersheds" Technical release 55, Washington, DC, June 1986a, 162 p.
- Soil Conservation Service - Ohio, "Water Management and Sediment Control for Urbanizing Areas", Columbus, Ohio, 1987.
- Parsons, "2000 year flood and Probable Maximum Flood, Sitewide Flood Plain Determination", Revision A, Aug 1995
- Ohio Administrative Code, Solid Waste Disposal Regulations, Chapter 3745-27-08(C)(6)

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATIONS PACKAGE

USDA-SCS TR-55

1. United States Department of Agriculture, "*Urban Hydrology for Small Watersheds,*" Soil Conservation Service, Engineering Division, Washington, DC, Technical Release 55, June 1986.

United States
Department of
Agriculture

Soil
Conservation
Service

Engineering
Division

Technical
Release 55

June 1986

Urban Hydrology for Small Watersheds

001676

Appendix C: Computer program

The TR-55 procedures have been incorporated in a computer program. The program, written in BASIC, requires less than 256K memory to operate and was developed for an MS-DOS operating system. Users of the program, however, still need to be familiar with the procedures in this TR. Features of the program include the following:

- The full screen (24 lines, 80 columns) is used to enter data. Flexibility of coding allows movement about the screen for quick data modifications.

- Function keys provide menu power to move to different modules (TR-55 chapters) within the program. Some keys are permanently defined while others vary by module.

- "Help" screens provide pertinent information to the user depending on location in the program. Two types of information are included: (1) define system operation and (2) describe input parameters.

- User files provide for optional entry of local data, such as rainfall-frequency, graphic peak discharge equation coefficients, and tabular hydrographs for other rainfall distributions.

Copies of the program can be obtained from—

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Telephone (703) 487-4650

001677

Preface

Technical Release 55 (TR-55) presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs. These procedures are applicable in small watersheds, especially urbanizing watersheds, in the United States. First issued by the Soil Conservation Service (SCS) in January 1975, TR-55 incorporates current SCS procedures. This revision includes results of recent research and other changes based on experience with use of the original edition.

The major revisions and additions are—

1. A flow chart for selecting the appropriate procedure;
2. Three additional rain distributions;
3. Expansion of the chapter on runoff curve numbers;
4. A procedure for calculating travel times of sheet flow;
5. Deletion of a chapter on peak discharges;
6. Modifications to the Graphical Peak Discharge method and Tabular Hydrograph method;
7. A new storage routing procedure;
8. Features of the TR-55 computer program; and
9. Worksheets.

This revision was prepared by Roger Cronshey, Hydraulic Engineer, Hydrology Unit, SCS, Washington, DC; Dr. Richard H. McCuen, Professor of Civil Engineering, University of Maryland, College Park, MD; Norman Miller, Head, Hydrology Unit, SCS, Washington, DC; Dr.Walter Rawls, Hydrologist, Agricultural Research Service, Beltsville, MD; Sam Robbins (deceased), formerly Hydraulic Engineer, SCS, South National Technical Center (NTC), Fort Worth, TX; and Don Woodward, Hydraulic Engineer, SCS, Northeast NTC, Chester, PA. Valuable contributions were made by John Chenoweth, Stan Hamilton, William Merkel, Robert Rallison (ret.), Harvey Richardson, Wendell Styner, other SCS hydraulic engineers, and Teresa Seeman.

Revised June 1986

001678

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Metric conversions

The English system of units is used in this TR. To convert to the International System of units (metric), use the following factors:

From English unit	To metric unit	Multiply by
Acre	Hectare	0.405
Square mile	Square kilometer	2.59
Cubic feet per second	Cubic meters per second	0.0283
Inch	Millimeter	25.4
Feet per second	Meters per second	0.3048
Acre-foot	Cubic meter	1233.489
Cubic foot	Cubic meter	0.0283

Perform rounding operations as appropriate to indicate the same level of precision as that of the original measurement. For example:

1. A stream discharge is recorded in cubic feet per second with three significant digits.
2. Convert stream discharge to cubic meters per second by multiplying by 0.0283.
3. Round to enough significant digits so that, when converting back to cubic feet per second, you obtain the original value (step 1) with three significant digits.

Definitions of symbols

Symbol	Unit	Definition
a	ft^2	Cross sectional flow area
A_m	mi^2	Drainage area
CN		Runoff curve number
CN_c		Composite runoff curve number
CN_p		Pervious runoff curve number
E_{max}		Maximum stage
F_p		Pond and swamp adjustment factor
H_w	ft	Head over weir crest
I_a	in	Initial abstraction
L	ft	Flow length
L_w	ft	Weir crest length
m		Number of flow segments
n		Manning's roughness coefficient
P	in	Rainfall
P_{imp}		Percent imperviousness
P_2	in	Two-year frequency, 24-hour rainfall
p_w	ft	Wetted perimeter
q	cfs	Hydrograph coordinate
q_i	cfs	Peak inflow discharge
q_o	cfs	Peak outflow discharge
q_p	cfs	Peak discharge
q_t	csm/in	Tabular hydrograph unit discharge
q_u	csm/in	Unit peak discharge
Q	in	Runoff
r	ft	Hydraulic radius
R		Ratio of unconnected impervious area to total impervious area
s	ft/ft	Slope of hydraulic grade line
S	in	Potential maximum retention after runoff begins
t	hr	Hydrograph time
T_c	hr	Time of concentration
T_p	hr	Time to peak
T_t	hr	Travel time
V	ft/s	Average velocity
V_r	acre-ft, ft^3, or watershed-inch	Runoff volume
V_s	acre-ft, ft^3, or watershed-inch	Storage volume

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Chapter 1: Introduction

The conversion of rural land to urban land usually increases erosion and the discharge and volume of storm runoff in a watershed. It also causes other problems that affect soil and water. As part of programs established to alleviate these problems, engineers increasingly must assess the probable effects of urban development, as well as design and implement measures that will minimize its adverse effects.

Technical Release 55 (TR-55) presents simplified procedures for estimating runoff and peak discharges in small watersheds. In selecting the appropriate procedure, consider the scope and complexity of the problem, the available data, and the acceptable level of error. While this TR gives special emphasis to urban and urbanizing watersheds, the procedures apply to any small watershed in which certain limitations are met.

Effects of urban development

An urban or urbanizing watershed is one in which impervious surfaces cover or will soon cover a considerable area. Impervious surfaces include roads, sidewalks, parking lots, and buildings. Natural flow paths in the watershed may be replaced or supplemented by paved gutters, storm sewers, or other elements of artificial drainage.

Hydrologic studies to determine runoff and peak discharge should ideally be based on long-term stationary streamflow records for the area. Such records are seldom available for small drainage areas. Even where they are available, accurate statistical analysis of them is usually impossible because of the conversion of land to urban uses during the period of record. It therefore is necessary to estimate peak discharges with hydrologic models based on measurable watershed characteristics. Only through an understanding of these characteristics and experience in using these models can we make sound judgments on how to alter model parameters to reflect changing watershed conditions.

Urbanization changes a watershed's response to precipitation. The most common effects are reduced infiltration and decreased travel time, which significantly increase peak discharges and runoff. Runoff is determined primarily by the amount of precipitation and by infiltration characteristics related to soil type, soil moisture, antecedent rainfall, cover type, impervious surfaces, and surface retention. Travel time is determined primarily by slope, length of flow path, depth of flow, and roughness of flow surfaces. Peak discharges are based on the relationship of these parameters and on the total drainage area of the watershed, the location of the development, the effect of any flood control works or other natural or manmade storage, and the time distribution of rainfall during a given storm event.

The model described in TR-55 begins with a rainfall amount uniformly imposed on the watershed over a specified time distribution. Mass rainfall is converted to mass runoff by using a runoff curve number (CN). CN is based on soils, plant cover, amount of impervious areas, interception, and surface storage. Runoff is then transformed into a hydrograph by using unit hydrograph theory and routing procedures that depend on runoff travel time through segments of the watershed.

For a description of the hydrograph development method used by SCS, see chapter 16 of the SCS National Engineering Handbook, Section 4—Hydrology (NEH-4) (SCS 1985). The routing method (Modified Att-Kin) is explained in appendixes G and H of draft Technical Release 20 (TR-20) (SCS 1983).

Rainfall

TR-55 includes four regional rainfall time distributions. See appendix B for a discussion of how these distributions were developed.

All four distributions are for a 24-hour period. This period was chosen because of the general availability of daily rainfall data that were used to estimate 24-hour rainfall amounts. The 24-hour duration spans most of the applications of TR-55.

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One critical parameter in the model is time of concentration (T_c), which is the time it takes for runoff to travel to a point of interest from the hydraulically most distant point. Normally a rainfall duration equal to or greater than T_c is used. Therefore, the rainfall distributions were designed to contain the intensity of any duration of rainfall for the frequency of the event chosen. That is, if the 10-year frequency, 24-hour rainfall is used, the most intense hour will approximate the 10-year, 1-hour rainfall volume.

Runoff

To estimate runoff from storm rainfall, SCS uses the Runoff Curve Number (CN) method (see chapters 4 through 10 of NEH-4, SCS 1985). Determination of CN depends on the watershed's soil and cover conditions, which the model represents as hydrologic soil group, cover type, treatment, and hydrologic condition. Chapter 2 of this TR discusses the effect of urban development on CN and explains how to use CN to estimate runoff.

Time parameters

Chapter 3 describes a method for estimating the parameters used to distribute the runoff into a hydrograph. The method is based on velocities of flow through segments of the watershed. Two major parameters are time of concentration (T_c) and travel time of flow through the segments (T_t). These and the other parameters used are the same as those used in accepted hydraulic analyses of open channels.

Many methods are empirically derived from actual runoff hydrographs and watershed characteristics. The method in chapter 3 was chosen because it is basic; however, other methods may be used.

Peak discharge and hydrographs

Chapter 4 describes a method for approximating peak rates of discharge, and chapter 5 describes a method for obtaining or routing hydrographs. Both methods were derived from hydrographs prepared by procedures outlined in chapter 16 of NEH-4 (SCS 1985). The computations were made with a computerized SCS hydrologic model, TR-20 (SCS 1983).

The methods in chapters 4 and 5 should be used in accordance with specific guidelines. If basic data are improperly prepared or adjustments not properly used, errors will result.

Storage effects

Chapter 6 outlines procedures to account for the effect of detention-type storage. It provides a shortcut method to estimate temporary flood storage based on hydrologic data developed from the Graphical Peak Discharge or Tabular Hydrograph methods.

By increasing runoff and decreasing travel times, urbanization can be expected to increase downstream peak discharges. Chapter 6 discusses how flood detention can modify the hydrograph so that, ideally, downstream peak discharge is reduced approximately to the predevelopment condition. The shortcuts in chapter 6 are useful in sizing a basin even though the final design may require a more detailed analysis.

Selecting the appropriate procedures

Figure 1-1 is a flow chart that shows how to select the appropriate procedures to use in TR-55. In the figure, the diamond-shaped box labeled "Subareas required?" directs the user to the appropriate method based on whether the watershed needs to be divided into subareas. Watershed subdivision is required when significantly different conditions affecting runoff or timing are present in the watershed—for example, if the watershed has widely differing curve numbers or nonhomogeneous slope patterns.

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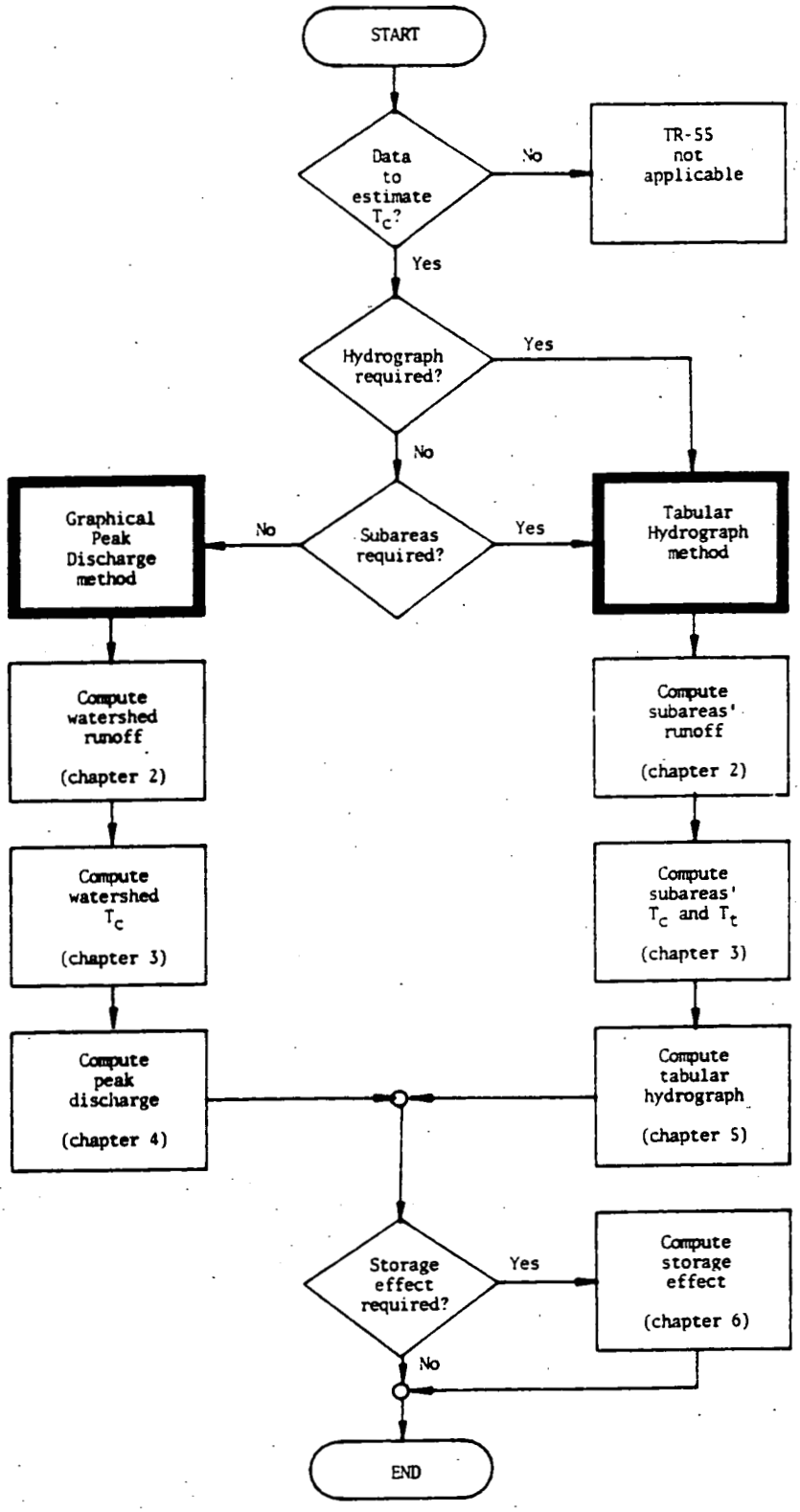

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Figure 1-1.—Flow chart for selecting the appropriate procedures in TR-55.

Limitations

To save time, the procedures in TR-55 are simplified by assumptions about some parameters. These simplifications, however, limit the use of the procedures and can provide results that are less accurate than more detailed methods. The user should examine the sensitivity of the analysis being conducted to a variation of the peak discharge or hydrograph. To ensure that the degree of error is tolerable, specific limitations are given in chapters 2 through 6. Additional general constraints to the use of TR-55 are as follows:

- The methods in this TR are based on open and unconfined flow over land or in channels. For large events during which flow is divided between sewer and overland flow, more information about hydraulics than is presented here is needed to determine T_c. After flow enters a closed system, the discharge can be assumed constant until another flow is encountered at a junction or another inlet.

- Both the Graphical Peak Discharge and Tabular Hydrograph methods are derived from TR-20 (SCS 1983) output. Their accuracy is comparable; they differ only in their products. The use of T_c permits them to be used for any size watershed within the scope of the curves or tables. The Graphical method (chapter 4) is used only for hydrologically homogeneous watersheds because the procedure is limited to a single watershed subarea. The Tabular method (chapter 5) can be used for a heterogeneous watershed that is divided into a number of homogeneous subwatersheds. Hydrographs for the subwatersheds can be routed and added.

- The approximate storage-routing curves (chapter 6) should not be used if the adjustment for ponding (chapter 4) is used. These storage-routing curves, like the peak discharge and hydrograph procedures, are generalizations derived from TR-20 routings.

001685

13.3 Impacted Runoff Catch Basin Sizing

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: IMPACTED RUNOFF CATCH BASIN SIZING

Computations By: (Cognizant Engineer)
Signature: Eric S. Steinhauser & Kara L. Olen — 15 Oct 1995 (Date)
Printed Name and Title: ERIC S. STEINHAUSER, PROJECT ENGINEER; Kara L. Olen, Asst. Proj. Engr.

Assumptions and Procedures Checked by: (Checker)
Signature: Daniel B. Wisialowski — 95/10/24 16 Oct 95 (Date)
Printed Name and Title: ROBERT S COBLE II, STAFF ENGINEER; DANIEL B. WISIALOWSKI, ASSISTANT PROJECT ENGINEER

Computations Checked by:
Signature: Daniel B. Wisialowski — 95/10/24 16 Oct 95 (Date)
~~ASSISTANT PROJECT ENGINEER~~
Printed Name and Title: ROBERT S COBLE II, STAFF ENGINEER; DANIEL B. WISIALOWSKI, ASSISTANT PROJECT ENGINEER

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Signature: Eric S. Steinhauser, Kara L. Olen — 17 Oct 1995 (Date)
Printed Name and Title: ~~ERC~~ Eric S. Steinhauser, PROJECT ENGINEER; Kara L Olen, Asst Proj Eng — 24 Oct 95

Approved by: (PDP)
Signature: Kara L. Olen — 10/24/95 (Date)
Printed Name and Title: Kara L. Olen, Asst Proj Eng.

Approved by: (DTL and TETL)
Signature: [illegible] — 24 Oct 95 (Date)
Printed Name and Title: Kenneth W Cargill

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO	24 Oct 95	NA	NA	NA
B	Preliminary Design - EPA Submittal	15 Dec 95	KL	—	—

Written by: Kara Olen Date: 15 Dec 1995 Reviewed by: [illegible] Date: 15 Dec 95

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.2

IMPACTED RUNOFF CATCH BASIN SIZING

EXECUTIVE SUMMARY

The computer program TR-55 (SCS, 1986) and design guidelines of the "Water Management and Sediment Control for Urbanizing Areas" (Ohio SCS, 1987) were used to estimate the required storage volume for the impacted runoff catch basins. The location of the worst-case (i.e., basin with the largest contributory area) impacted runoff catch basin is shown in Figure 1 of these calculations. The Ohio SCS guidelines are used to calculate the recommended basin volume needed to contain the accumulated sediments. TR-55 is used to calculate an additional volume required to temporarily detain the runoff so that the peak flow rate out of each impacted runoff catch basin for the design storm (25-yr 24-hr storm) can be discharged through a 6-inch diameter HDPE pipe and ultimately to the 8-inch diameter HDPE leachate transfer pipe. The resulting impacted catch basin geometry will be 80 ft long by 24 ft wide by 5 ft deep (or 9600 cf).

Written by: ESS Date: 95/10/13 (YY MM DD) Reviewed by: DBW Date: 95/10/24 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

K. Olin 10/24/95

EROSION-SEDIMENT CONTROL

IMPACTED RUNOFF CATCH BASIN SIZING

SUMMARY OF CALCULATIONS

PURPOSE: THE PURPOSE OF THIS DOCUMENT IS TO SUMMARIZE THE CALCULATIONS USED TO DESIGN THE IMPACTED RUNOFF CATCH BASINS FOR THE OSDF.

SCOPE: THE IMPACTED RUNOFF CATCH BASINS FOR THE OSDF WILL BE DESIGNED TO HANDLE THE RUNOFF FROM THE IMPACTED MATERIAL ACCESS ROAD FROM A 25-YR, 24-HR STORM AND WILL PROVIDE SEDIMENT STORAGE.

CALCULATIONS:

1. CALCULATE REQUIRED SEDIMENT VOLUME (1800 CF/ACRE) IN ACCORDANCE WITH OHIO-SCS [1987].
2. CALCULATE PEAK RUNOFF FROM A 25-YR, 24-HOUR STORM USING TR-55 [USDA-SCS, 1986].
3. CALCULATE SHAPE OF CATCH BASIN - SKETCH CATCH BASIN
4. CALCULATE DISCHARGE PIPE SIZE FOR PEAK RUNOFF

REFERENCES

OHIO-SCS, "TECHNICAL STANDARD AND SPECIFICATIONS", WATER MANAGEMENT AND SEDIMENT CONTROL FOR URBANIZING AREAS, COLUMBUS, OHIO, MAR 1987, 9p. (TEMPORARY SEDIMENT BASIN)

USDA-SCS, "TR-55 MICROCOMPUTER PROGRAM SYSTEM", VERSION 2.0, WASHINGTON, DC, JUN 1986.

Written by: ESS Date: 95/10/13 (YY MM DD) Reviewed by: DBW Date: 95/10/24 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

K.O. 10/24/95

EROSION - SEDIMENT CONTROL

IMPACTED RUNOFF CATCH BASIN SIZING

VERIFICATION AND COLLECTION OF ENGINEERING DATA

PURPOSE: THE PURPOSE OF THIS DOCUMENT IS TO SUMMARIZE AND VERIFY THE ENGINEERING DATA USED TO DESIGN THE IMPACTED RUNOFF CATCH BASINS FOR THE OSDF

SCOPE: THE DATA PRESENTED IN THIS DOCUMENT IS ORGANIZED IN THE FOLLOWING SECTIONS:

1. DATA FOR DRAINAGE AREAS
2. RAINFALL DATA
3. SOIL AND VEGETATIVE COVER
4. RESTRICTIONS
5. PIPE CAPACITY

DATA:

1. DATA FOR DRAINAGE AREAS.

BASED ON SITE DEVELOPMENT PHASE DRAWING (FIGURE 1), THE LONGEST IMPACTED MATERIAL ACCESS ROAD IS: 1.6 ACRES OR 0.0025 SQ MILES

FLOW PARAMETERS

SHEET FLOW:
LENGTH = 100 FT ✓
SLOPE = 0.0037 FT/FT

SHALLOW CONCENTRATED FLOW:
LENGTH = 1270 FT ✓
SLOPE = 0.0037

UNPAVED SMOOTH SURFACE ✓

NO CHANNEL FLOW. ✓

Written by: ESS Date: 95/10/13 Reviewed by: DBW Date: 95/10/24
YY MM DD YY MM DD

Client: FEMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 082

K.Oller 10/24/95

2. RAINFALL DATA

THE RAINFALL DATA USED IN THE CALCULATIONS IS SUMMARIZED BELOW [PARSONS, 1995]:

STORM EVENT	RAINFALL (IN.)
2-YR	2.55 ✓
25-YR	4.7 ✓

RAINFALL DATA IN OHIO IS CLASSIFIED AS A TYPE II DISTRIBUTION ✓

3. SOIL AND VEGETATIVE COVER

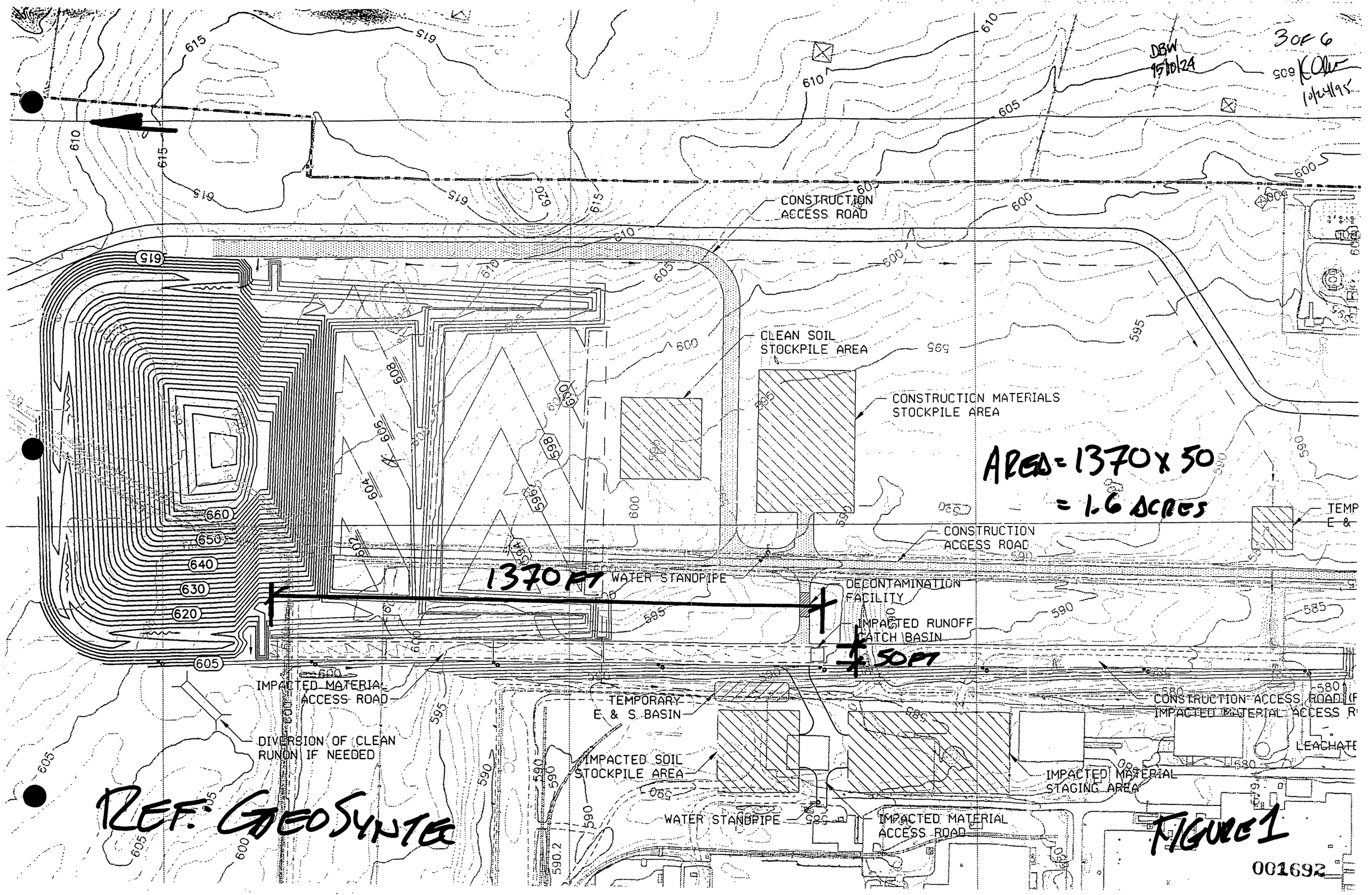
FROM USDA-SCS [1986a] USE A CURVE NUMBER OF 89 FOR A "DIRT" ROAD. ✓

4. PIPE CAPACITY:

The inlet control equation is used to to determine the head required to convey a desired outflow rate through the 6-inch diameter HDPE outlet pipes:

$$\frac{HW}{D} = c\left(\frac{Q}{AD^{1/2}}\right)^2 + Y - 0.5S \quad \text{(FHWA, 1985)}$$ ✓

where HW = headwater depth (ft); D = pipe diameter; Q = discharge rate (cfs); S = pipe slope (ft/ft); and c & Y = loss coefficients.


3 OF 6
DBW 95/10/24
1/24/95
CONSTRUCTION ACCESS ROAD
CLEAN SOIL STOCKPILE AREA
CONSTRUCTION MATERIALS STOCKPILE AREA
AREA = 1370 x 50
= 1.6 ACRES
CONSTRUCTION ACCESS ROAD
1370 FT
WATER STANDPIPE
DECONTAMINATION FACILITY
IMPACTED RUNOFF CATCH BASIN
50 FT
IMPACTED MATERIAL ACCESS ROAD
TEMPORARY E & S BASIN
DIVERSION OF CLEAN RUNON IF NEEDED
IMPACTED SOIL STOCKPILE AREA
WATER STANDPIPE
IMPACTED MATERIAL ACCESS ROAD
IMPACTED MATERIAL STAGING AREA
CONSTRUCTION ACCESS ROAD
IMPACTED MATERIAL ACCESS R
LEACHATE
TEMP
E &
REF: GEOSYNTEC
FIGURE 1
001692

DBW 95/10/24

4 of 6

K. Allen 10/24/95

TABLE A-1 - RAINFALL DEPTH FOR A GIVEN DURATION (INCHES)

DURATION (YEARS)	TIME							
	HYDRO-35			TP-40				
	5 MIN	15 MIN	60 MIN	2 HOURS	3 HOURS	6 HOURS	12 HOURS	24 HOURS
2	0.387	0.739	1.223	1.408	1.54	1.848	2.2	2.552
5	0.49	0.979	1.69	2.016	2.112	2.496	2.88	3.072
10	0.564	1.139	1.99	2.277	2.475	3.069	3.465	4.059
25	0.65	1.34	2.38	2.6	3.0	3.4	4.0	4.7
50	0.72	1.49	2.67	3.0	3.25	3.9	4.2	5.2
* 100	0.78	1.64	2.95	3.3	3.6	4.1	5.0	5.6
* 500	0.93	2.1	4.3	5.2	5.9	7.3	8.5	9.4
2000	1.2	2.6	5.8	7.2	8.2	10.2	12.0	13.0
10,000	1.4	3.4	8.2	10.5	12.0	15.5	18.0	19.2
100,000	1.9	5.0	13.3	17.7	20.8	27.4	31.8	33.4
	DESIGN OF SMALL DAMS					HMR-51		

NOTE: Rainfall Points For 2, 5, and 10 year rainfall events were adjusted per TP-40. Values for the 500, 2000, and 10,000 Year Events were interpolated from Figure 3 (Appendix E)

* These values are used on PH Records for HEC-1.

DBN 95/10/24

5 of 6

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Figure B-2.—Approximate geographic boundaries for SCS rainfall distributions.

001694

Written by: ESS Date: 95/10/13 (YY MM DD) Reviewed by: DBW Date: 95/10/24 (YY MM DD)

Client: FERMCO Project: OSOF Project/Proposal No.: GE3900 Task No.: 08.2

K. Olen 10/24/95

REFERENCES:

PARSONS, "200-YEAR FLOOD AND PROBABLE MAXIMUM FLOOD, SITEWIDE FLOOD PLAIN DETERMINATION", REVISION A, AUG 1995

USDA-SCS, "URBAN HYDROLOGY FOR SMALL WATERSHEDS", TECHNICAL RELEASE 55 (TR-55), WASHINGTON, DC, JUN 1986a

USDA-SCS, "ENGINEERING FIELD MANUAL FOR CONSERVATION PRACTICES", WASHINGTON, DC, NOV 1986b.

HAMMER, "WATER AND WASTEWATER TECHNOLOGY", 2ND ED, 1986, 550p.

CHOW, "OPEN CHANNEL HYDRAULICS", 1959.

US Dept of Transportation; Federal Highway Administration, "Hydraulic Design of Highway Culverts", Hydraulic Design Series #5, Report # FHWA-IP-85-15, September, 1985

Written by: BSS Date: 95/10/15 (YY MM DD) Reviewed by: _____ Date: __/__/__ (YY MM DD)

Client: FERMCO Project: OSOF Project/Proposal No.: GE3800 Task No.: OEL2

EROSION-SEDIMENT CONTROL

IMPACTED RUNOFF CATCH BASIN SIZING

PURPOSE: THIS CALCULATION PACKAGES INCLUDES THE CALCULATIONS TO SIZE THE IMPACTED RUNOFF CATCH BASINS.

SCOPE: THE IMPACTED RUNOFF CATCH BASINS ARE DESIGNED TO CONTROL THE RUNOFF FROM THE IMPACTED MATERIAL ACCESS ROAD.

THE ANALYSES PERFORMED USED TR-55 [USDA SCS, 1986] AND TEMPORARY SEDIMENT BASIN, TECHNICAL STANDARD AND SPECIFICATIONS [OHIO SCS, 1987]

SUMMARY OF INPUT DATA:

AREA = 1.6 ACRES ✓
= 0.0025 SQ. MILES ✓

SHEET FLOW: LENGTH = 100 FT @ 0.0037 FT/FT ✓

SHALLOW CONCENTRATED FLOW = 1270 FT @ 0.0037 FT/FT ✓

RAINFALL: 2-YR, 24-HR = 2.55 IN, 25-YR, 24-HR = 4.7 IN ✓

CURVE NUMBER = 89 ✓

CALCULATIONS:

1. SEDIMENT VOLUME (V_S)

$$V_S = 1800 \frac{CF}{AC} \left(1.6\ AC\right) = \underline{\underline{2,880\ CF}}$$ ✓

2. USE TR-55 TO CALCULATE PEAK FLOW (Q_p)
FROM TR-55, Q_p = 5 CFS (FILE = FERMCO\IRCB-1.55) ✓

Written by: Karen Olsen Date: 95/10/15 (YY/MM/DD) Reviewed by: DBW Date: 95/10/24 (YY/MM/DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 812

3. Size Catch Basin

- Discharge Pipe – A 6" diameter smooth-wall HDPE pipe will discharge the impacted runoff from the catch basin to the 8-inch diameter HDPE leachate transmission line.

- Assume a headwater depth of 3.5 feet for the 6" dia. HDPE pipe and calculate the discharge rate Q through the pipe:

$$\frac{HW}{D} = c\left[\frac{Q}{AD^{1/2}}\right]^2 + Y - 0.5S$$ [Inlet Control Eq.; FHWA, 1985] ✓

where:

A = X-sect. area of pipe (ft^2)
HW = Headwater Depth (ft)
D = Pipe diameter (ft)
Q = discharge rate (cfs)
S = Pipe slope (ft/ft) → assume .01
C, Y = Loss coefficients (See table 1):

For a projecting submerged pipe:

C = 0.0317 ✓
Y = 0.69 ✓

therefore:

$$\frac{3.5}{.5} = (.0317)\left[\frac{Q}{(.2)(.5)^{1/2}}\right]^2 + .69 - (0.5)(0.01)$$ ✓

Q = 1.93 cfs ✓

- Therefore, the peak flowrate out of the basin is 1.93 cfs if 3.5 ft of head is in the pipe. From TR-55, the peak flow rate into the basin is 5 cfs. Calculate the

Written by: Kara Oler Date: 95 / 10 / 15 (YY MM DD) Reviewed by: DBN Date: 95 / 10 / 24 (YY MM DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.2

required storage volume in the basin to route these flows (use the chart shown in Figure 1):

$q_i = 5$ cfs
$q_o = 1.93$ cfs

Q(runoff) = 3.49 inches (from TR-55 output) ✓

- $q_o/q_i = 1.93/5 = 0.39$ ✓

from Figure 1: $V_s/V_r = 0.325$ ✓

- Convert Q(runoff) from inches to volume:

$V_r = 53.33\,Q\,A_m$ (TR-55, 1986a) ✓

where

V_r = runoff volume (ac-ft)
Q = runoff (inches)
A_m = drainage area (sq. mi)
53.33 = conversion factor from in-mi² to ac-ft.

$\therefore V_r = (53.33)(3.49)(1.6\text{ ac} \times 43560/5280^2)$ ✓

$V_r = 0.47$ ac-ft ✓

- Compute Required Storage - V_s

$V_s = V_r(V_s/V_r) = (0.47)(.325) = \boxed{0.152 \text{ ac-ft}}$ ✓

• Calculate catch basin geometry:

- Req'd head in pipe to convey 1.93 cfs = 3.5 ft. ✓
- Req'd Ponding storage = 0.152 ac-ft = 6621 cf. ✓
- Catch Basin Plan area therefore equals:

$\frac{6621 \text{ cf}}{3.5 \text{ ft}} = 1892$ sf ✓

Written by: Kara Olen Date: 95 / 10 / 15 (YY MM DD) Reviewed by: DBW Date: 95 / 10 / 24 (YY MM DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 812

- let basin width equal 24 ft & basin length = 82 ft

$80 \times 24 = 1920$ sf > 1892 sf ✓ OK. ✓

- Calculate additional storage for sediment:
  - From Ohio SCS (1987), allow 1800 cf of storage per acre of disturbed area:

$$1800 \frac{cf}{ac} \times 1.6 \text{ ac} = 2880 \text{ cf.}$$ ✓

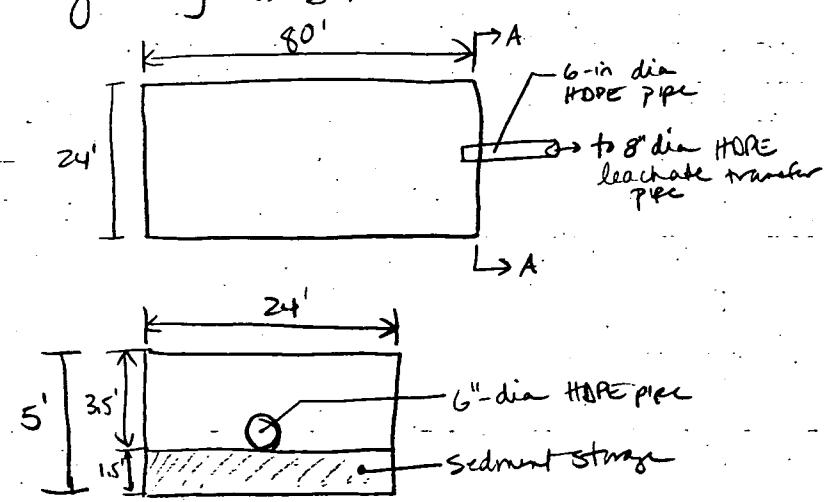
  - Calculate corresponding depth of sediment given plan dimensions of catch basin:

$$\frac{2880 \text{ cf}}{(24 \times 80)} = 1.5 \text{ ft.}$$ ✓

  - Therefore total catch basin depth is

$$3.5 \text{ ft} + 1.5 \text{ ft} = 5.0 \text{ ft.}$$ ✓

Catch basin geometry is shown below:



✓

Due to the relatively large size of the impacted materials catch basin, further evaluations will be conducted in an effort to reduce the size of the catch basin (e.g. pumping impacted water from the catch basin to the leachate transmission system).

K. Olen 10/15/95
Fermco
Fernald GE3901
8.2

TIME OF CONCENTRATION AND TRAVEL TIME

Version 2.00

Project : FERMCO - OSDF
County : BUTLER State: OH
Subtitle: IMPACTED RUNOFF CATCH BASIN

User: ESS Date: 10-~~10~~15-95
Checked: DBM Date: 95/10/24

---------- Subarea #1 - A ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	100	.0037	A					0.044
Shallow Concent'd		1270	.0037	U					0.359

Time of Concentration = 0.40*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

FILE: FERMCO|IRCB-1.55

K. Oler 10/15/95
Fermco
Fernald GE3900-8.2

TABULAR HYDROGRAPH METHOD

Version 2.00

Project : FERMCO - OSDF User: ESS Date: 10-~~10~~ 15-95
County : BUTLER State: OH Checked: DBN Date: 95/10/24
Subtitle: IMPACTED RUNOFF CATCH BASIN

Total watershed area: 0.002 sq mi Rainfall type: II Frequency: 25 years

---------- Subareas ----------

	A
Area(sq mi)	0.00
Rainfall(in)	4.7
Curve number	89
Runoff(in)	3.49
Tc (hrs)	0.40*
TimeToOutlet	0.00
Ia/P	0.05
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) A
11.0	0	0
11.3	0	0
11.6	0	0
11.9	1	1
12.0	1	1
12.1	2	2
12.2	4	4
12.3	5P	5P ← PEAK FLOW
12.4	5	5
12.5	4	4
12.6	3	3
12.7	2	2
12.8	1	1
13.0	1	1
13.2	1	1
13.4	1	1
13.6	0	0
13.8	0	0
14.0	0	0
14.3	0	0
14.6	0	0
15.0	0	0
15.5	0	0
16.0	0	0
16.5	0	0
17.0	0	0
17.5	0	0
18.0	0	0
19.0	0	0
[illegible]0	0	0
[illegible].0	0	0
[illegible].0	0	0

001701

FILE: FERMCO\IRCB-1.55

P - Peak Flow * - value(s) provided from TR-55 system routines

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Kiolen 10/15/95
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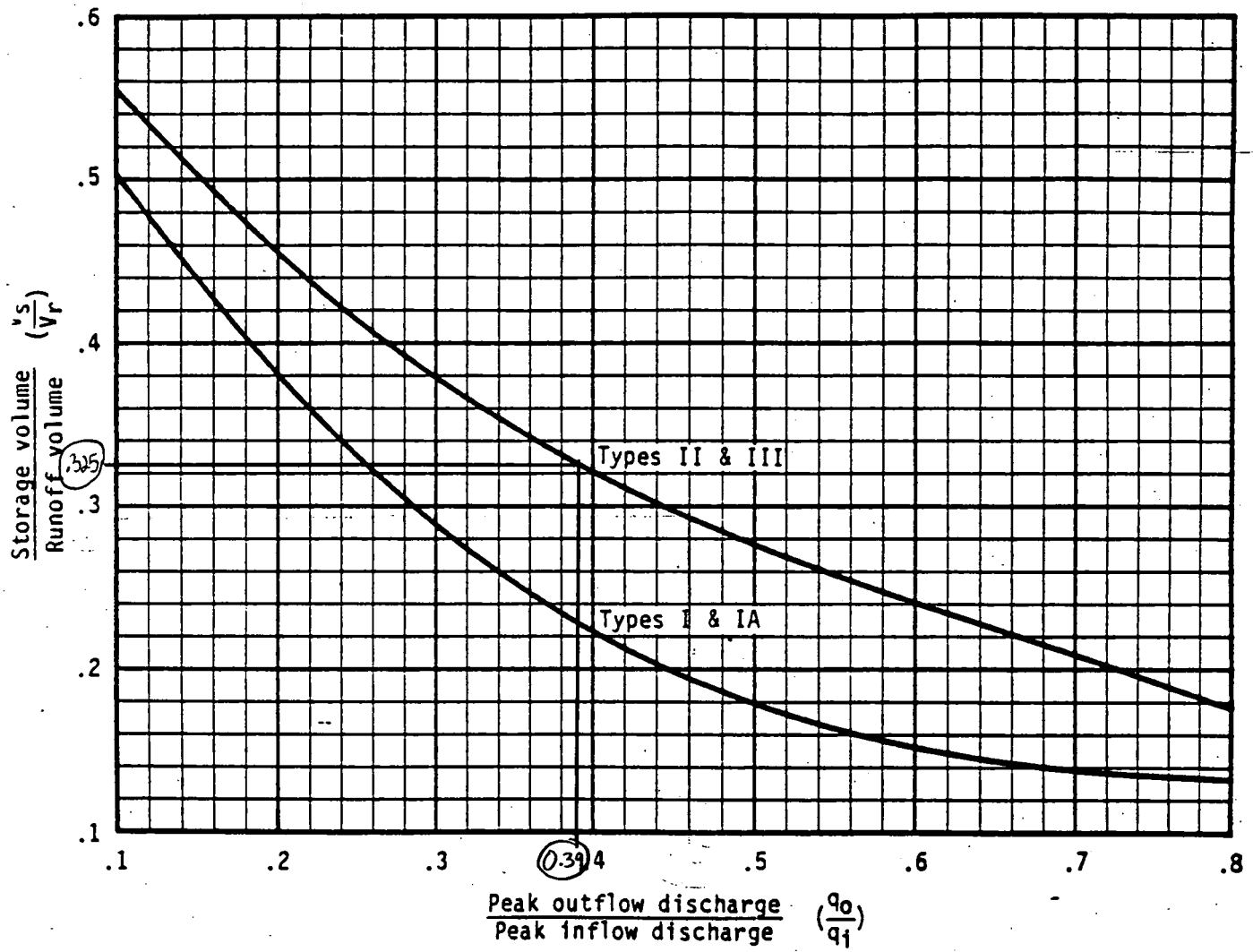
Fernald GE3900 812

DBN
95/10/23

7/9



001702

GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.	FIGURE 1
PROJECT NO.	
DOCUMENT NO.	
FILE NO.	

Kidder Fenner Fernald GE3900 8.2 10/15/95

DBW 95/10/24

8/9

Note: n for HDPE pipe is assumed to be equal to n for concrete (conservative assumption)

Constants for inlet control design equations.

CHART NO.	SHAPE AND MATERIAL	NOMOGRAPH SCALE	INLET EDGE DESCRIPTION	UNSUBMERGED EQUATION FORM	UNSUBMERGED K	UNSUBMERGED M	SUBMERGED c	SUBMERGED Y	References
1	Circular	1	Square edge w/headwall	1	0.0098	2.0	0.0398	0.67	(56) (57)
	Concrete	2	Groove end w/headwall		.0078	2.0	.0292	.74	(56) (57)
		3	Groove end projecting		.0045	2.0	.0317	.69	(56) (57)
2	Circular	1	Headwall	1	.0078	2.0	.0379	.69	(56) (57)
	CMP	2	Mitered to slope		.0210	1.33	.0463	.75	(57)
		3	Projecting		.0340	1.50	.0553	.54	(57)
3	Circular	A	Beveled ring, 45° bevels	1	.0018	2.50	.0300	.74	(57)
		B	Beveled ring, 33.7° bevels*		.0018	2.50	.0243	.83	(57)
8	Rectangular	1	30° to 75° wingwall flares		.026	1.0	.0385	.81	(56)
	Box	2	90° and 15° wingwall flares	1	.061	0.75	.0400	.80	(56)
		3	0° wingwall flares		.061	0.75	.0423	.82	(8)
9	Rectangular	1	45° wingwall flare d=.0430	2	.510	.667	.0309	.80	(8)
	Box	2	18° to 33.7° wingwall flare d=.0830		.486	.667	.0249	.83	(8)
10	Rectangular	1	90° headwall w/3/4" chamfers	2	.515	.667	.0375	.79	(8)
	Box	2	90° headwall w/45° bevels		.495	.667	.0314	.82	(8)
		3	90° headwall w/33.7° bevels		.486	.667	.0252	.865	(8)
11	Rectangular	1	3/4" chamfers; 45° skewed headwall	2	.522	.667	.0402	.73	(8)
	Box	2	3/4" chamfers; 30° skewed headwall		.533	.667	.0425	.705	(8)
		3	3/4" chamfers; 15° skewed headwall		.545	.667	.04505	.68	(8)
		4	45° bevels; 10°-45° skewed headwall		.498	.667	.0327	.75	(8)
12	Rectangular	1	45° non-offset wingwall flares	2	.497	.667	.0339	.803	(8)
	Box	2	18.4° non-offset wingwall flares		.493	.667	.0361	.806	(8)
	3/4" chamfers	3	18.4° non-offset wingwall flares 30° skewed barrel		.495	.667	.0386	.71	(8)
13	Rectangular	1	45° wingwall flares - offset	2	.497	.667	.0302	.835	(8)
	Box	2	33.7° wingwall flares - offset		.495	.667	.0252	.881	(8)
	Top Bevels	3	18.4° wingwall flares - offset		.493	.667	.0227	.887	(8)
16-19	C M Boxes	1	90° headwall	1	.0083	2.0	.0379	.69	(57)
		2	Thick wall projecting		.0145	1.75	.0419	.64	(57)
		3	Thin wall projecting		.0340	1.5	.0496	.57	(57)

[FROM FHWA, 1985]

001703

GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.	TABLE 1
PROJECT NO.	
DOCUMENT NO.	
FILE NO.	

Written by: ESS Date: 95/10/13 (YY/MM/DD) Reviewed by: DBW Date: 95/10/24 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

REFERENCES:

OHIO-SCS "TECHNICAL STANDARD AND SPECIFICATION, TEMPORARY SEDIMENT BASIN", WATER MANAGEMENT AND SEDIMENT CONTROL FOR URBANIZING AREAS, COLUMBUS, OHIO, MAR 1987, 9p.

USDA-SCS "TR-55 MICROCOMPUTER PROGRAM SYSTEM", VERSION 2.0, WASHINGTON, DC, JUN 1986

HAMMER, "WATER AND WASTEWATER TECHNOLOGY", 2ND ED, 1986, 550p

US Dept of Transportation, Federal Highway Administration, "Hydraulic Design of Highway Culverts", Hydraulic Design Series No. 5, Report No. FHWA-IP-85-15, September, 1985

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATIONS PACKAGE

USDA-SCS TR-55

1. United States Department of Agriculture, "*Urban Hydrology for Small Watersheds,*" Soil Conservation Service, Engineering Division, Washington, DC, Technical Release 55, June 1986.

United States
Department of
Agriculture

Soil
Conservation
Service

Engineering
Division

Technical
Release 55

June 1986

Urban Hydrology for Small Watersheds

001706

Appendix C: Computer program

The TR-55 procedures have been incorporated in a computer program. The program, written in BASIC, requires less than 256K memory to operate and was developed for an MS-DOS operating system. Users of the program, however, still need to be familiar with the procedures in this TR. Features of the program include the following:

- The full screen (24 lines, 80 columns) is used to enter data. Flexibility of coding allows movement about the screen for quick data modifications.

- Function keys provide menu power to move to different modules (TR-55 chapters) within the program. Some keys are permanently defined while others vary by module.

- "Help" screens provide pertinent information to the user depending on location in the program. Two types of information are included: (1) define system operation and (2) describe input parameters.

- User files provide for optional entry of local data, such as rainfall-frequency, graphic peak discharge equation coefficients, and tabular hydrographs for other rainfall distributions.

Copies of the program can be obtained from—

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Telephone (703) 487-4650

001707

Preface

Technical Release 55 (TR-55) presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs. These procedures are applicable in small watersheds, especially urbanizing watersheds, in the United States. First issued by the Soil Conservation Service (SCS) in January 1975, TR-55 incorporates current SCS procedures. This revision includes results of recent research and other changes based on experience with use of the original edition.

The major revisions and additions are—

1. A flow chart for selecting the appropriate procedure;
2. Three additional rain distributions;
3. Expansion of the chapter on runoff curve numbers;
4. A procedure for calculating travel times of sheet flow;
5. Deletion of a chapter on peak discharges;
6. Modifications to the Graphical Peak Discharge method and Tabular Hydrograph method;
7. A new storage routing procedure;
8. Features of the TR-55 computer program; and
9. Worksheets.

This revision was prepared by Roger Cronshey, Hydraulic Engineer, Hydrology Unit, SCS, Washington, DC; Dr. Richard H. McCuen, Professor of Civil Engineering, University of Maryland, College Park, MD; Norman Miller, Head, Hydrology Unit, SCS, Washington, DC; Dr.Walter Rawls, Hydrologist, Agricultural Research Service, Beltsville, MD; Sam Robbins (deceased), formerly Hydraulic Engineer, SCS, South National Technical Center (NTC), Fort Worth, TX; and Don Woodward, Hydraulic Engineer, SCS, Northeast NTC, Chester, PA. Valuable contributions were made by John Chenoweth, Stan Hamilton, William Merkel, Robert Rallison (ret.), Harvey Richardson, Wendell Styner, other SCS hydraulic engineers, and Teresa Seeman.

Revised June 1986

001708

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Metric conversions

The English system of units is used in this TR. To convert to the International System of units (metric), use the following factors:

From English unit	To metric unit	Multiply by
Acre	Hectare	0.405
Square mile	Square kilometer	2.59
Cubic feet per second	Cubic meters per second	0.0283
Inch	Millimeter	25.4
Feet per second	Meters per second	0.3048
Acre-foot	Cubic meter	1233.489
Cubic foot	Cubic meter	0.0283

Perform rounding operations as appropriate to indicate the same level of precision as that of the original measurement. For example:

1. A stream discharge is recorded in cubic feet per second with three significant digits.
2. Convert stream discharge to cubic meters per second by multiplying by 0.0283.
3. Round to enough significant digits so that, when converting back to cubic feet per second, you obtain the original value (step 1) with three significant digits.

Definitions of symbols

Symbol	Unit	Definition
a	ft^2	Cross sectional flow area
A_m	mi^2	Drainage area
CN		Runoff curve number
CN_c		Composite runoff curve number
CN_p		Pervious runoff curve number
E_{max}		Maximum stage
F_p		Pond and swamp adjustment factor
H_w	ft	Head over weir crest
I_a	in	Initial abstraction
L	ft	Flow length
L_w	ft	Weir crest length
m		Number of flow segments
n		Manning's roughness coefficient
P	in	Rainfall
P_{imp}		Percent imperviousness
P_2	in	Two-year frequency, 24-hour rainfall
p_w	ft	Wetted perimeter
q	cfs	Hydrograph coordinate
q_i	cfs	Peak inflow discharge
q_o	cfs	Peak outflow discharge
q_p	cfs	Peak discharge
q_t	csm/in	Tabular hydrograph unit discharge
q_u	csm/in	Unit peak discharge
Q	in	Runoff
r	ft	Hydraulic radius
R		Ratio of unconnected impervious area to total impervious area
s	ft/ft	Slope of hydraulic grade line
S	in	Potential maximum retention after runoff begins
t	hr	Hydrograph time
T_c	hr	Time of concentration
T_p	hr	Time to peak
T_t	hr	Travel time
V	ft/s	Average velocity
V_r	acre-ft, ft^3, or watershed-inch	Runoff volume
V_s	acre-ft, ft^3, or watershed-inch	Storage volume

Chapter 1: Introduction

The conversion of rural land to urban land usually increases erosion and the discharge and volume of storm runoff in a watershed. It also causes other problems that affect soil and water. As part of programs established to alleviate these problems, engineers increasingly must assess the probable effects of urban development, as well as design and implement measures that will minimize its adverse effects.

Technical Release 55 (TR-55) presents simplified procedures for estimating runoff and peak discharges in small watersheds. In selecting the appropriate procedure, consider the scope and complexity of the problem, the available data, and the acceptable level of error. While this TR gives special emphasis to urban and urbanizing watersheds, the procedures apply to any small watershed in which certain limitations are met.

Effects of urban development

An urban or urbanizing watershed is one in which impervious surfaces cover or will soon cover a considerable area. Impervious surfaces include roads, sidewalks, parking lots, and buildings. Natural flow paths in the watershed may be replaced or supplemented by paved gutters, storm sewers, or other elements of artificial drainage.

Hydrologic studies to determine runoff and peak discharge should ideally be based on long-term stationary streamflow records for the area. Such records are seldom available for small drainage areas. Even where they are available, accurate statistical analysis of them is usually impossible because of the conversion of land to urban uses during the period of record. It therefore is necessary to estimate peak discharges with hydrologic models based on measurable watershed characteristics. Only through an understanding of these characteristics and experience in using these models can we make sound judgments on how to alter model parameters to reflect changing watershed conditions.

Urbanization changes a watershed's response to precipitation. The most common effects are reduced infiltration and decreased travel time, which significantly increase peak discharges and runoff. Runoff is determined primarily by the amount of precipitation and by infiltration characteristics related to soil type, soil moisture, antecedent rainfall, cover type, impervious surfaces, and surface retention. Travel time is determined primarily by slope, length of flow path, depth of flow, and roughness of flow surfaces. Peak discharges are based on the relationship of these parameters and on the total drainage area of the watershed, the location of the development, the effect of any flood control works or other natural or manmade storage, and the time distribution of rainfall during a given storm event.

The model described in TR-55 begins with a rainfall amount uniformly imposed on the watershed over a specified time distribution. Mass rainfall is converted to mass runoff by using a runoff curve number (CN). CN is based on soils, plant cover, amount of impervious areas, interception, and surface storage. Runoff is then transformed into a hydrograph by using unit hydrograph theory and routing procedures that depend on runoff travel time through segments of the watershed.

For a description of the hydrograph development method used by SCS, see chapter 16 of the SCS National Engineering Handbook, Section 4—Hydrology (NEH-4) (SCS 1985). The routing method (Modified Att-Kin) is explained in appendixes G and H of draft Technical Release 20 (TR-20) (SCS 1983).

Rainfall

TR-55 includes four regional rainfall time distributions. See appendix B for a discussion of how these distributions were developed.

All four distributions are for a 24-hour period. This period was chosen because of the general availability of daily rainfall data that were used to estimate 24-hour rainfall amounts. The 24-hour duration spans most of the applications of TR-55.

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One critical parameter in the model is time of concentration (T_c), which is the time it takes for runoff to travel to a point of interest from the hydraulically most distant point. Normally a rainfall duration equal to or greater than T_c is used. Therefore, the rainfall distributions were designed to contain the intensity of any duration of rainfall for the frequency of the event chosen. That is, if the 10-year frequency, 24-hour rainfall is used, the most intense hour will approximate the 10-year, 1-hour rainfall volume.

Runoff

To estimate runoff from storm rainfall, SCS uses the Runoff Curve Number (CN) method (see chapters 4 through 10 of NEH-4, SCS 1985). Determination of CN depends on the watershed's soil and cover conditions, which the model represents as hydrologic soil group, cover type, treatment, and hydrologic condition. Chapter 2 of this TR discusses the effect of urban development on CN and explains how to use CN to estimate runoff.

Time parameters

Chapter 3 describes a method for estimating the parameters used to distribute the runoff into a hydrograph. The method is based on velocities of flow through segments of the watershed. Two major parameters are time of concentration (T_c) and travel time of flow through the segments (T_t). These and the other parameters used are the same as those used in accepted hydraulic analyses of open channels.

Many methods are empirically derived from actual runoff hydrographs and watershed characteristics. The method in chapter 3 was chosen because it is basic; however, other methods may be used.

Peak discharge and hydrographs

Chapter 4 describes a method for approximating peak rates of discharge, and chapter 5 describes a method for obtaining or routing hydrographs. Both methods were derived from hydrographs prepared by procedures outlined in chapter 16 of NEH-4 (SCS 1985). The computations were made with a computerized SCS hydrologic model, TR-20 (SCS 1983).

The methods in chapters 4 and 5 should be used in accordance with specific guidelines. If basic data are improperly prepared or adjustments not properly used, errors will result.

Storage effects

Chapter 6 outlines procedures to account for the effect of detention-type storage. It provides a shortcut method to estimate temporary flood storage based on hydrologic data developed from the Graphical Peak Discharge or Tabular Hydrograph methods.

By increasing runoff and decreasing travel times, urbanization can be expected to increase downstream peak discharges. Chapter 6 discusses how flood detention can modify the hydrograph so that, ideally, downstream peak discharge is reduced approximately to the predevelopment condition. The shortcuts in chapter 6 are useful in sizing a basin even though the final design may require a more detailed analysis.

Selecting the appropriate procedures

Figure 1-1 is a flow chart that shows how to select the appropriate procedures to use in TR-55. In the figure, the diamond-shaped box labeled "Subareas required?" directs the user to the appropriate method based on whether the watershed needs to be divided into subareas. Watershed subdivision is required when significantly different conditions affecting runoff or timing are present in the watershed—for example, if the watershed has widely differing curve numbers or nonhomogeneous slope patterns.

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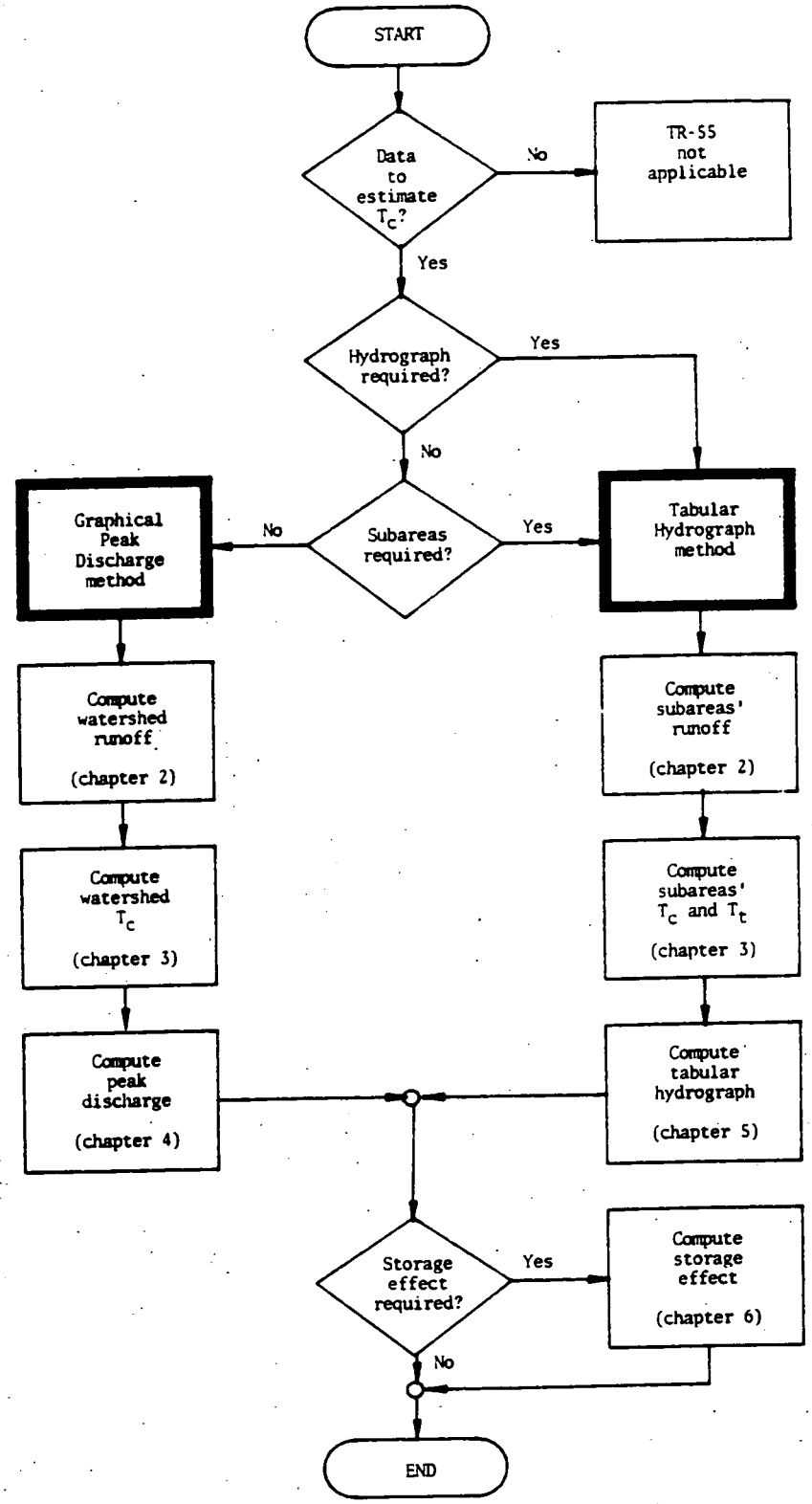

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Figure 1-1.—Flow chart for selecting the appropriate procedures in TR-55.

Limitations

To save time, the procedures in TR-55 are simplified by assumptions about some parameters. These simplifications, however, limit the use of the procedures and can provide results that are less accurate than more detailed methods. The user should examine the sensitivity of the analysis being conducted to a variation of the peak discharge or hydrograph. To ensure that the degree of error is tolerable, specific limitations are given in chapters 2 through 6. Additional general constraints to the use of TR-55 are as follows:

- The methods in this TR are based on open and unconfined flow over land or in channels. For large events during which flow is divided between sewer and overland flow, more information about hydraulics than is presented here is needed to determine T_c. After flow enters a closed system, the discharge can be assumed constant until another flow is encountered at a junction or another inlet.

- Both the Graphical Peak Discharge and Tabular Hydrograph methods are derived from TR-20 (SCS 1983) output. Their accuracy is comparable; they differ only in their products. The use of T_c permits them to be used for any size watershed within the scope of the curves or tables. The Graphical method (chapter 4) is used only for hydrologically homogeneous watersheds because the procedure is limited to a single watershed subarea. The Tabular method (chapter 5) can be used for a heterogeneous watershed that is divided into a number of homogeneous subwatersheds. Hydrographs for the subwatersheds can be routed and added.

- The approximate storage-routing curves (chapter 6) should not be used if the adjustment for ponding (chapter 4) is used. These storage-routing curves, like the peak discharge and hydrograph procedures, are generalizations derived from TR-20 routings.

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13.4 Revegetation Design

13.5 Erosion of OSDF Final Cover

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: EROSION OF OSDF FINAL COVER

Computations By: (Cognizant Engineer)
Signature [signature] Date 10/17/95
Printed Name DAVID W. WARREN
and Title STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 23 Oct 95
Printed Name Kenneth W Cargill
and Title Associate

Computations Checked by:
Signature [signature] Date 10/17/95
Printed Name PATRICK RHODES
and Title STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 10/17/95
Printed Name DAVID W. WARREN
and Title STAFF ENGINEER

Approved by: (PDP)
Signature [signature] Date 10/17/95
Printed Name Kara Olen
and Title Asst Proj. Engr.

Approved by: (DTL and TETL)
Signature [signature] Date 23 Oct 95
Printed Name Kenneth W Cargill
and Title Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO				
0	30% Submittal	23OCT95	DWW	PBR	[signature]
B	Changed title of p.1 to "Executive Summary"	13 DEC 95	DWW	PBR	[signature]

Written by: DAVE WARREN Date: 13-Dec-95 Reviewed by: PBR Date: 13-DEC-1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

EROSION RESISTANCE: OSDF FINAL COVER SYSTEM

EXECUTIVE SUMMARY

Provided in this package are the analyses of the resistance of the final cover topsoil to erosion. The analyses are parametric studies to outline different combinations of topsoil texture and grass cover that meet the following criteria:

- Soil loss from the final cover due to sheet and rill erosion no greater than 5 tons/acre/year
- No formation of gullies from water erosion in the final cover topsoil during the 2000-year, 24-hour storm. Gullies could quickly erode away the final cover topsoil and vegetative support layers, exposing the biotic barrier.

Topsoil textures analyzed were as follows:

Soil Classification	
USDA	USCS
Silt Loam	ML
Clay Loam	CL
Loam	ML
Sandy Loam	SM
Loamy Sand	SM
Sand	SW
-	GM
-	GC

No specific grass cover types were analyzed. The grass covers were defined by "vegetal retardance classes".

RESULTS:

All the topsoils analyzed will meet the erosion criteria, provided they have an adequate grass cover. However, the grass cover quality required with gravelly topsoils is slightly less than that required with other topsoils. Still, the grass cover is the critical component for minimizing erosion. To meet the erosion criteria, the grass cover must cover at least 95 percent of the ground (or 80 percent with gravelly topsoils), and classify in at least vegetal retardance class "C" (or "E" for clayey gravel (GC)topsoil).

Written by: DAVE WARREN Date: 20-Oct-95 Reviewed by: PBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

23 Oct 95

EROSION RESISTANCE - OSDF FINAL COVER SYSTEM

COLLECTION AND VERIFICATION OF ENGINEERING DATA

Purpose: The purpose of this document is to identify a range of topsoil and grass cover conditions for the OSDF final cover system to minimize sheet, rill, and gully erosion in accordance with the following criteria:

- demonstrate that topsoil loss to sheet and rill erosion will occur at a rate no greater than 5 tons/acre/year
- demonstrate that sheet erosion will not result in excessive soil loss over the design life of the OSDF (i.e., at least 200 years with continued effectiveness for up to 1000 years up to the extent practicable and reasonably achievable)
- demonstrate that the 2000-year, 24-hour storm will not cause gullies to form in the final cover topsoil

Scope: The erosion resistance calculations are conducted as a parametric study in which the variable components are topsoil type and grass type and density. A window of various combinations of topsoil and grass conditions required to meet the above criteria are identified.

Two methods are implemented to evaluate erosion resistance:

1. The Modified Universal Soil Loss Equation (MUSLE); Caltrans (1992) to calculate the rate of soil loss due to sheet and rill erosion; and
2. The Tractive Force Method; Temple (1980) developed for vegetative channels and modified for evaluating slopes in USDOE (1989); to calculate the potential for gullies to form in the topsoil from the 2000-year, 24-hour storm.

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Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

Collection and verification of the following data needed for these methods are discussed:

1. Modified Universal Soil Loss Equation
   - average annual rainfall energy
   - pertinent geometry (slope lengths and inclinations) for OSDF final cover
   - topsoil textural classification according to USDA Classification System
   - grass cover type and density

2. Tractive Force Method
   - properties for the topsoil
     - classification according to USCS
     - topsoil plasticity index (PI)
     - void ratio
   - pertinent geometry (slope lengths and inclinations) for OSDF final cover
   - rainfall and infiltration for the 2000-year, 24-hour storm
   - grass cover type and density

Written by: DAVE WARREN Date: 20-Oct-95 Reviewed by: PBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

COLLECTION AND VERIFICATION OF DATA FOR THE MODIFIED UNIVERSAL SOIL LOSS EQUATION (MUSLE):

1. Average annual rainfall energy.

The average annual rainfall energy (factor "R" in the MUSLE) is given in the Ohio SCS guidelines for "'Water Management and Sediment Control for Urbanizing Areas" (1987) as 175 for the OSDF area. See Figure 1.

2. Pertinent geometry (slope lengths and inclinations) for study area.

The pertinent geometry of the OSDF and East Field borrow area is shown on the design drawings for the Fernald OSDF, currently being prepared by GeoSyntec Consultants. Relevant drawings are shown in Figures 2 and 3. A verbal summary of the pertinent OSDF geometry is given below.

In summary, the OSDF, once complete, will have a rectangular footprint of approximately 3780 ft by 880 ft,. The OSDF final cover side slopes have three segments:

- a top segment of 20 Horizontal to 1 Vertical (20H:1V) that is 90 ft long on the east and west sides;
- a middle segment of 10H:1V that is 60 ft long on the east and west sides; and
- bottom segment of 6H:1V that is 290 ft long on the east side and 310 ft long on the west side.

The OSDF will be surrounded by a perimeter drainage swale. The bottom of the OSDF final cover slopes is the centerline of the perimeter swale.

The slope geometry of the OSDF final cover is used to determine the LS factor in the MUSLE, which is calculated using an equation in Caltrans (1992).

Written by: DAVE WARREN Date: 23OCT95 Reviewed by: PBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

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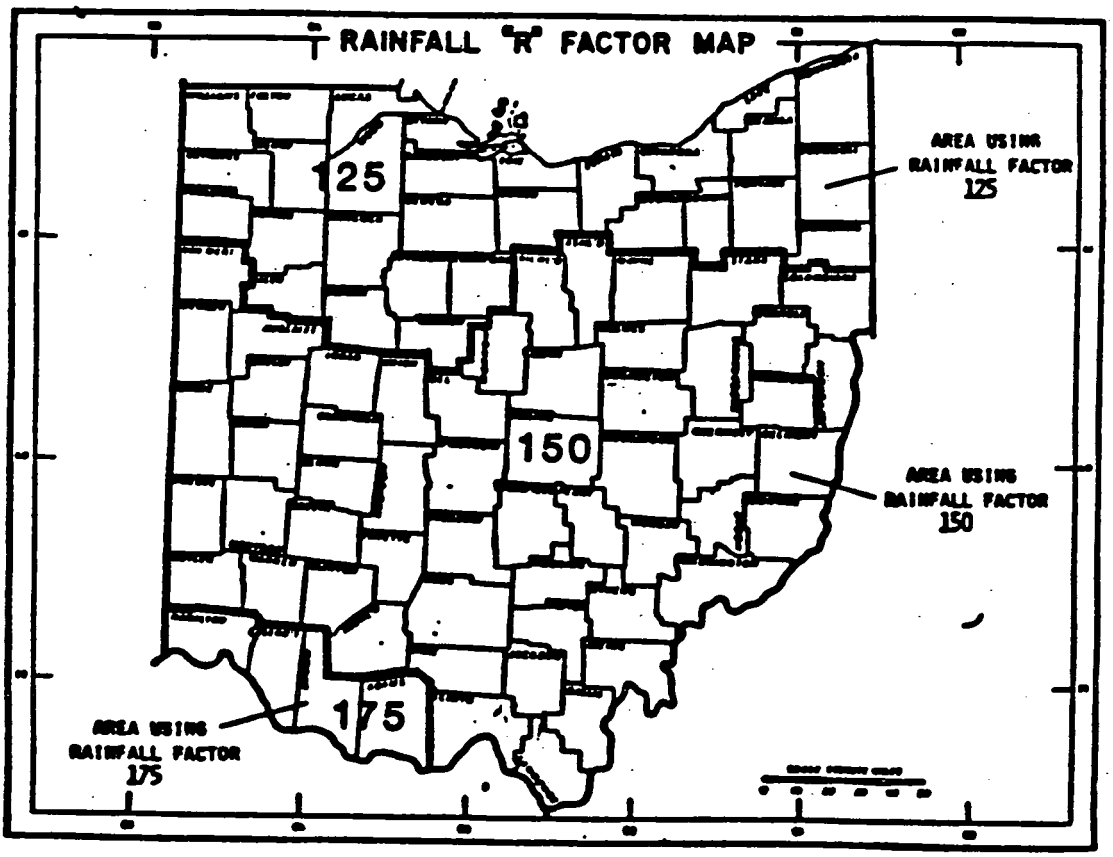

Figure 1 - Rainfall Energy Factor Map For Ohio. From Ohio SCS (1987)

3. Topsoil textural classification according to U.S. Department of Agriculture (USDA) System.

The topsoil USDA classification is used to determine a soil erodability factor in the MUSLE. The soil erodability factors given by the Ohio SCS (1987) for different USDA soil textures are shown in Table 1. All soils shown in Table 1 will be analyzed to determine acceptable topsoil / grass cover combinations.

***Table 1** - Soil Erodability Factor Values For Different Topsoil Textures From Ohio SCS (1987)*

Topsoil Texture	Soil Erodability Factor Value
Silt Loam	0.37
Clay Loam	0.32
Loam	0.32
Sandy Loam	0.24
Loamy Sand	0.17
Sand	0.15

On-site materials may be used as topsoil in the OSDF final cover. Extensive geotechnical data from Parsons (1995b,c) exists for the soils under the OSDF area and north portion of the East Field borrow area. The soils in these areas are glacial till, with the majority classifying as USCS Lean Clay (CL). Isolated portions of this soil that do not classify as CL generally classify as USCS Fat Clay (CH), Silt (ML), Silty Sand (SM), and Clayey Sand (SC). Some index information for these soils is shown in Table 4.

4. Grass cover type and density.

The grass cover type and density is used to estimate the vegetative measures, VM, factor in the MUSLE. Various values of the VM factor for different grass heights and percentages of ground covered by grass are shown in Figure 4, and summarized in Table 2.

***Table 2** - VM Factor Values For Grass Cover Densities (0% of grass taller than 0.5m)*

Percentage of ground covered with grass	VM factor (MUSLE)*
0%	0.45
20%	0.20
40%	0.10
60%	0.047
80%	0.029
95%	0.011

*From Caltrans (1992)

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Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

FC 23 OCT 95

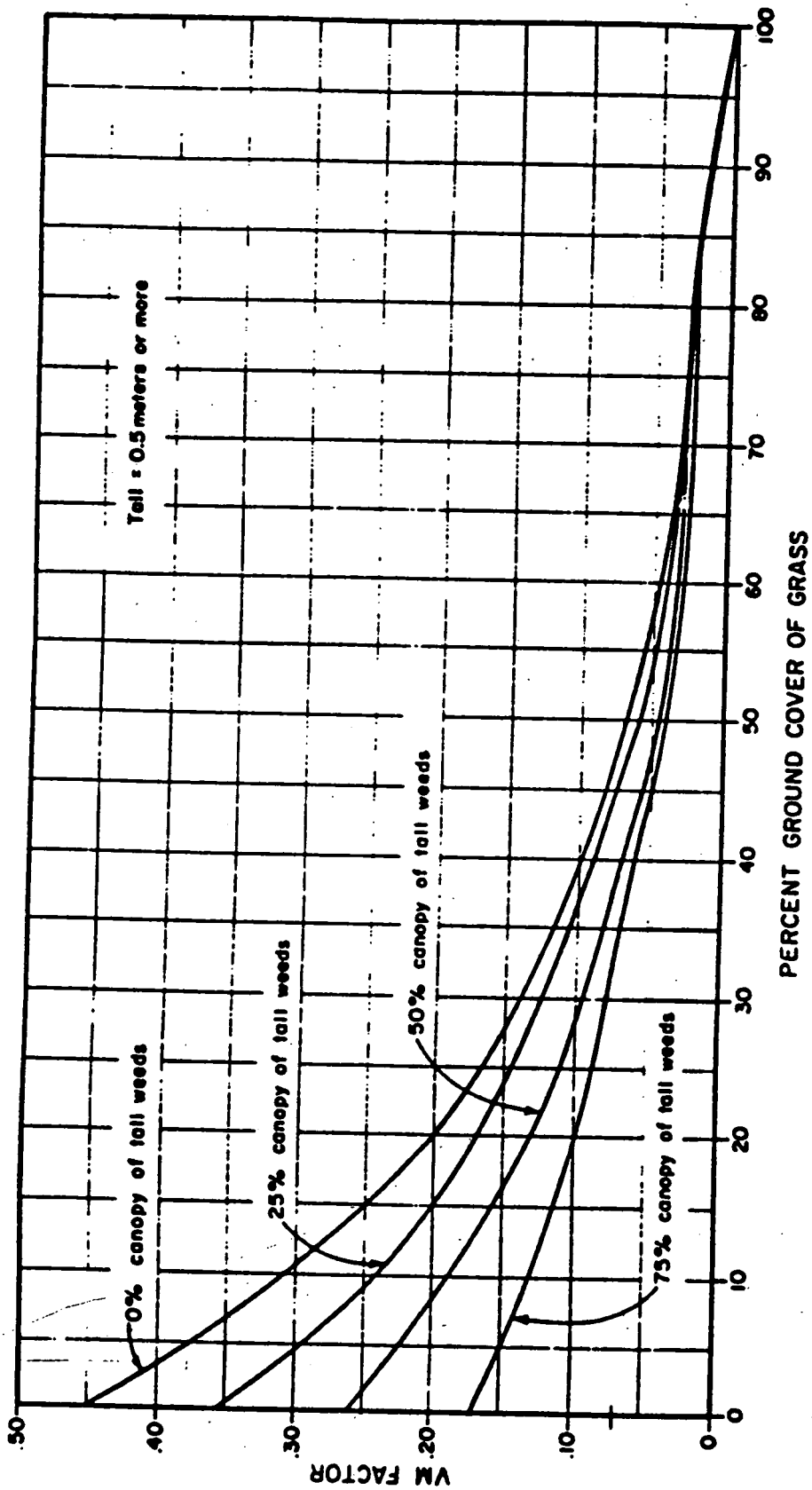

Figure 4 - VM Factor Values for Different Grass Cover Heights and Densities. From Caltrans (1992)

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Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

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COLLECTION AND VERIFICATION OF DATA FOR THE TRACTIVE FORCE METHOD:

1. Properties for the topsoil.

USCS Classification

The topsoil textural classifications were previously discussed in the collection and verification of data for the MUSLE. Schroeder et al. (1994) gives corresponding USCS classifications to the USDA soil textures listed in Table 1; these are shown in Table 3.

As mentioned in the collection and verification of data for the MUSLE, extensive geotechnical data from Parsons (1995b,c) exists for the soil under the OSDF area and north portion of the East Field borrow area. The soil in these areas is glacial till, with the majority classifying as USCS Lean Clay (CL). Isolated portions of this soil that do not classify as CL generally classify as USCS Fat Clay (CH), Silt (ML), Silty Sand (SM), and Clayey Sand (SC).

Topsoil plasticity index (PI)

The topsoil PI will be used to in conjunction with the USCS soil classification to determine the allowable tractive force on the soil. PI data for soils in the OSDF and north borrow area is shown in Table 4.

Topsoil void ratio

The topsoil void ratio will also be used in conjunction with the USCS soil classification to determine the allowable tractive force on the soil. The void ratio will be estimated from Schroeder et al. (1994), who give values of porosity for different soils based on degree of compaction and USDA textural classification (porosity can be converted to void ratio through a simple relation - see the calculations for further explanation). Porosity values are shown in Table 3.

2. Pertinent geometry (slope lengths and inclinations) for study area.

See the collection and verification of data for the MUSLE.

3. Rainfall and infiltration for the 2000-year, 24-hour storm

The rainfall depth for the 2000-year, 24-hour storm is 13 inches, as shown in Table 5. This value is used in the TR-55 method (USDA, 1986a) to determine the peak flow off the final cover. Furthermore, in TR-55 analysis, the runoff curve number (CN) is assumed to be 98 - the highest value allowed by TR-55. This corresponds to an infiltration rate of approximately zero (recommended by USDOE, 1989) See the calculations for further explanation.

Written by: DAVE WARREN Date: 20-Oct-95 Reviewed by: RBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

For 230AS

Table 3 - Porosities and USCS Classifications for Different Topsoil USDA Textures. From Schroeder et al. (1994)

LOOSE SOILS

Classification			Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	USDA	USCS	vol/vol	vol/vol	vol/vol	cm/sec
1	CoS	SP	0.417	0.045	0.018	1.0×10^{-2}
2	S	SW	0.437	0.062	0.024	5.8×10^{-3}
3	FS	SW	0.457	0.083	0.033	3.1×10^{-3}
4	LS	SM	0.437	0.105	0.047	1.7×10^{-3}
5	LFS	SM	0.457	0.131	0.058	1.0×10^{-3}
6	SL	SM	0.453	0.190	0.085	7.2×10^{-4}
7	FSL	SM	0.473	0.222	0.104	5.2×10^{-4}
8	L	ML	0.463	0.232	0.116	3.7×10^{-4}
9	SiL	ML	0.501	0.284	0.135	1.9×10^{-4}
10	SCL	SC	0.398	0.244	0.136	1.2×10^{-4}
11	CL	CL	0.464	0.310	0.187	6.4×10^{-5}
12	SiCL	CL	0.471	0.342	0.210	4.2×10^{-5}
13	SC	SC	0.430	0.321	0.221	3.3×10^{-5}
14	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}
15	C	CH	0.475	0.378	0.265	1.7×10^{-5}
16	Barrier Soil		0.427	0.418	0.367	1.0×10^{-7}
17	Bentonite Mat (0.6 cm)		0.750	0.747	0.400	3.0×10^{-9}
18	Municipal Waste (900 lb/yd³ or 312 kg/m³)		0.671	0.292	0.077	1.0×10^{-3}
19	Municipal Waste (channeling and dead zones)		0.168	0.073	0.019	1.0×10^{-3}
20	Drainage Net (0.5 cm)		0.850	0.010	0.005	$1.0\times10^{+1}$
21	Gravel		0.397	0.032	0.013	3.0×10^{-1}
22	L*	ML	0.419	0.307	0.180	1.9×10^{-5}
23	SiL*	ML	0.461	0.360	0.203	9.0×10^{-6}
24	SCL*	SC	0.365	0.305	0.202	2.7×10^{-6}
25	CL*	CL	0.437	0.373	0.266	3.6×10^{-6}
26	SiCL*	CL	0.445	0.393	0.277	1.9×10^{-6}
27	SC*	SC	0.400	0.366	0.288	7.8×10^{-7}
28	SiC*	CH	0.452	0.411	0.311	1.2×10^{-6}
29	C*	CH	0.451	0.419	0.332	6.8×10^{-7}
30	Coal-Burning Electric Plant Fly Ash*		0.541	0.187	0.047	5.0×10^{-5}
31	Coal-Burning Electric Plant Bottom Ash*		0.578	0.076	0.025	4.1×10^{-3}
32	Municipal Incinerator Fly Ash*		0.450	0.116	0.049	1.0×10^{-2}
33	Fine Copper Slag*		0.375	0.055	0.020	4.1×10^{-2}
34	Drainage Net (0.6 cm)		0.850	0.010	0.005	$3.3\times10^{+1}$

* Moderately Compacted

Written by: DAVE WARREN Date: 20-Oct-95 Reviewed by: PBC Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2 PC 23 OCT 95

Table 4 - Index Properties of Soils in the OSDF Area and North Borrow Area. From Parsons (1995c).

General Stratum	USCS Group Symbol	Moisture Content (percent dry wgt)		Liquid Limit	Plasticity Index	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Specific Gravity		Number of Tests
		(range)	(avg)	(range)	(range)	(range)	(range)	(range)	(range)	(range)	(avg)	
Brown Till (0 - 5 ft)	CL	12-30	21	21-50	7-32	0-12	2-49	35-62	18-48	2.63-2.79	2.71	31
Brown Till (5 - 10 ft)	CL	3-21	14	22-49	7-28	0-23	1-33	30-69	20-46	2.69-2.79	2.74	37
Brown Till (10 - 15 ft)	CL	11-15	13	24-42	9-23	0-10	13-41	34-48	22-43	2.69-2.78	2.74	9
Gray Till	CL	9-21	14	19-33	7-17	0-17	15-39	32-53	14-38	2.67-2.79	2.72	69
Gray Till	CL-ML	11-17	13	17-19	4-6	0-8	7-42	36-49	18-22	2.69-2.77	2.73	3
Brown Till	CH	19-25	23	50-57	23-38	0-12	3-14	38-66	31-48	2.67-2.73	2.70	8
Brown Till	GC	-	-	28	13	26	25	27	22	-	2.73	1
Brown or Gray Till	ML	11-24	15	16-23	0-4	0-7	3-38	43-84	8-18	2.70-2.73	2.72	6
Brown or Gray Till	SM	9-24	16	-	-	0-14	43-71	13-42	4-20	2.70-2.75	2.72	7
Brown or Gray Till	SC	9-11	10	19-25	8-12	24-26	29-55	13-27	8-18	2.69-2.74	2.72	4
Brown or Gray Till	SC-SM	11-20	16	18-24	5-8	0-18	38-56	26-35	12-18	2.70-2.75	2.72	2
Great Miami Aquifer	SM	2-15	8	-	-	0-32	53-84	10-36	1-5	2.72-2.77	2.75	15
Great Miami Aquifer	SW-SM	3-5	4	-	-	21-37	54-69	7-10	1-2	2.76-2.79	2.78	3
Great Miami Aquifer	SP-SM	2-4	3	-	-	0 - 3	88-91	8-10	0	2.69-2.77	2.73	2

Data Sources: Phase II Investigation (PO-132) Data, Phase III Investigation (PO-140) Data

Notes:

1. Percent clay defined as those particles finer than (0.005 mm) (Reference ASTM D 422)

Written by: DAVE WARREN Date: 20-Oct-95 Reviewed by: PBR Date: 23 OCT 1995

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Table 5 - Rainfall Depths in Inches for Different Storm Return Periods and Durations of Interest. From Parsons (1995a).

DURATION (YEARS)	TIME							
	HYDRO-35			TP-40				
	5 MIN	15 MIN	60 MIN	2 HOURS	3 HOURS	6 HOURS	12 HOURS	24 HOURS
2	0.387	0.739	1.223	1.408	1.54	1.848	2.2	2.552
5	0.49	0.979	1.69	2.016	2.112	2.496	2.88	3.072
10	0.564	1.139	1.99	2.277	2.475	3.069	3.465	4.059
25	0.65	1.34	2.38	2.6	3.0	3.4	4.0	4.7
50	0.72	1.49	2.67	3.0	3.25	3.9	4.2	5.2
* 100	0.78	1.64	2.95	3.3	3.6	4.1	5.0	5.6
* 500	0.93	2.1	4.3	5.2	5.9	7.3	8.5	9.4
2000	1.2	2.6	5.8	7.2	8.2	10.2	12.0	13.0
10,000	1.4	3.4	8.2	10.5	12.0	15.5	18.0	19.2
100,000	1.9	5.0	13.3	17.7	20.8	27.4	31.8	33.4
	DESIGN OF SMALL DAMS					HMR-51		

NOTE: Rainfall Points For 2, 5, and 10 year rainfall events were adjusted per TP-40. Values for the 500, 2000, and 10,000 Year Events were interpolated

4. Grass cover type and density

The grass cover type and density is used to estimate two coefficients, C_l and C_f, which are used in determining the actual tractive force applied and the soil surface - water interface for given flow conditions.. These coefficients are used in a curve fitting equation to the "vegetal retardance" curves, shown in Figure 5. The curves in Figure 5 are separated into vegetal retardance classes (A-E). Values of C_l and C_f for average uniform stands of grasses corresponding to each vegetal retardance class are shown in Table 6.

The grass cover type and density is used to estimate two coefficients, C_l and C_F, which are used in determining the actual tractive force applied at the soil surface - water interface for given flow conditions

Four predominant soil groups in the OSDF area and borrow areas area identified in USDA (1982). They are Fincastle (FdA), Martinsville (McA), Raub (RdA), and Xenia (XfA). Table 7 lists recommended grasses for these soil groups. Kentucky bluegrass and tall fescue are listed as recommended grasses for all these soil groups.

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23 OCT 95

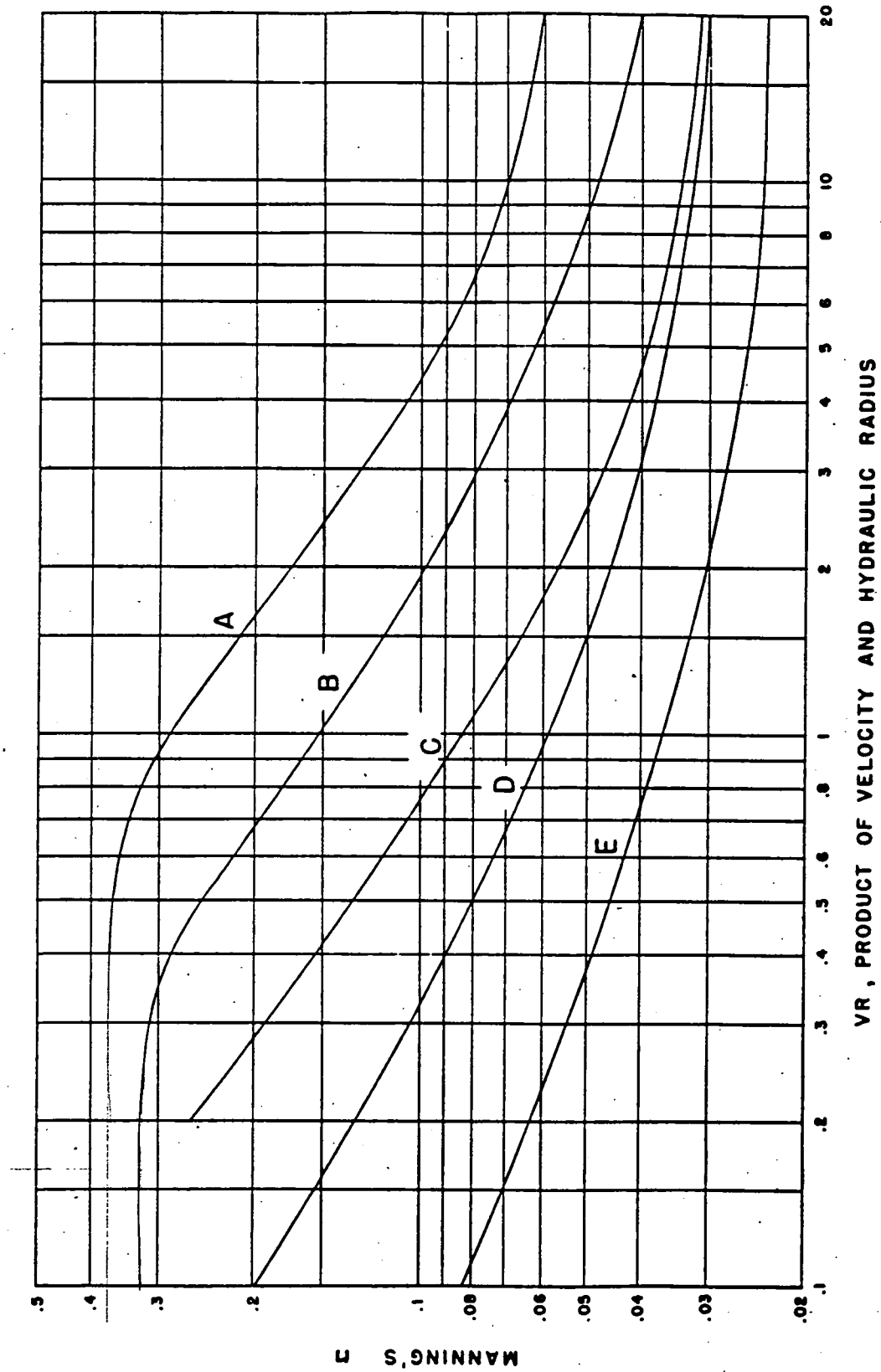

Figure 5 - "Vegetal Retardance Curves" for Average Uniform Stands of Grass Cover. From USDA (1986b).
See Table 6 for more information on vegetal retardance classes "A" - "E".

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Table 6 - Values of C_I and C_f for Good Uniform Stands of Grass. From USDOE (1989). FC 23049S

Cover	C_f	C_I[a]	Reference stem density (stems/square foot)[b]
Burmuda grass, 12-inch height	0.9	10.00	500
Weeping lovegrass			500
Buffalo grass			400
Kentucky bluegrass	0.87	7.64	350
Blue gramma			350
Grass-legume mixture	0.75	5.60	200
Weeping lovegrass	0.75	5.60	350
Burmuda grass, 6-inch height	0.75	5.60	350
Yellow bluestem	0.75	5.60	350
Alfalfa[c]	0.5	4.44	350
Lespedeza sericea, 2-inch height[c]	0.5	4.44	300
Common lespedeza	0.5	4.44	150
Sudan grass	0.5	2.88	50
Bermuda grass, burned stubble	0.5	2.88	50

[a]If vegetation is not uniformly distributed over the areas present, C_I and C_f will be set equal to zero. In other words, the cover will be designed as if it were bare soil only.

[b]Multiply the stem densities given by 1/3, 2/3, 1, 4/3, and 5/3, for poor, fair, good, very good, and excellent covers, respectively. The equivalent adjustment to C_f remains a matter of engineering judgment until more data are obtained or a more analytical model is developed. A reasonable, but arbitrary, approach is to reduce the cover factor by 20 percent for fair stands and 50 percent for poor stands. Values of C_f for untested covers may be estimated by recognizing that the cover factor is dominated by density and uniformity of cover near the soils surface. Thus, the sod-forming grasses near the top of the table exhibit higher C_f values than the bunch grasses and annuals near the bottom.

[c]For the legumes tested, the effective stem count for resistance (given) is approximately five times the actual stem count very close to the bed. Similar adjustment may be needed for other unusually large-stemmed, branching, and/or woody vegetation.

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Table 7 - Recommended Grasses for Planting in Soil Series in Hamilton County, Ohio. From USDA (1982).

Soil name and map symbol	Vines and ground cover	Shrubs	Trees	Grasses and legumes
EeB, EeC, EeD*: Eden	Cotoneaster, English ivy, myrtle, winter creeper, juniper.	Amur privet, redosier dogwood, Japanese yew, Tatarian honeysuckle.	Eastern redcedar, Norway maple, thornless honeylocust, radiant crabapple, yellow-poplar, Scotch pine.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
Urban land.				
EpA, EpB2, EpC2 Eldean	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily.	Leatherleaf viburnum, juniper, serviceberry.	Black walnut, eastern white pine, red pine, thornless honeylocust, white oak, yellow-poplar.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
ErA, ErB*: Eldean	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily.	Leatherleaf viburnum, juniper, serviceberry.	Black walnut, eastern white pine, red pine, thornless honeylocust, yellow-poplar, white oak.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
Urban land.				
FdA Fincastle	Bugleweed, goutweed, lily turf, plantain lily, yellow root, sweet woodruff.	Arrowwood, bottlebrush buckeye, red chokecherry, Amur privet, redosier dogwood.	Sweetgum, yellow-poplar, white ash, red maple, swamp white oak, London plane tree.	Kentucky bluegrass, redtop, tall fescue.
FeA*: Fincastle	Bugleweed, goutweed, lily turf, plantain lily, yellow root, sweet woodruff.	Arrowwood, bottlebrush buckeye, red chokecherry, Amur privet, redosier dogwood.	Sweetgum, yellow-poplar, white ash, red maple, swamp white oak, London plane tree.	Kentucky bluegrass, redtop, tall fescue.
Urban land.				
FoA, FoB2 Fox	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily.	Leatherleaf viburnum, juniper, serviceberry.	Eastern white pine, red pine, thornless honeylocust, white oak, yellow-poplar, white ash.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
FpA*: Fox	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily.	Leatherleaf viburnum, juniper, serviceberry.	Eastern white pine, red pine, thornless honeylocust, white oak, yellow-poplar, white ash.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
Urban land.				
Gn Genesee	Lilyofthevalley, pachysandra, myrtle, plantain lily.	Bayberry, redosier dogwood, nannyberry viburnum, Amur privet.	Eastern cottonwood, locust, Norway maple.	Red fescue, Kentucky bluegrass, tall fescue.
Go*: Genesee	Lilyofthevalley, pachysandra, myrtle, plantain lily.	Bayberry, redosier dogwood, nannyberry viburnum, Amur privet.	Eastern cottonwood, locust.	Red fescue, Kentucky bluegrass, tall fescue.
Urban land.				

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Table 7 - Continued

Soil name and map symbol	Vines and ground cover	Shrubs	Trees	Grasses and legumes
HeF Hennepin	Plantain lily, juniper, Hall honeysuckle, creeping speedwell.	Juniper	Thornless honeylocust	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
HoA Henshaw	Goutweed, bugleweed, European wild ginger, sweet woodruff, yellow root.	Arrowwood, red chokecherry, redosier dogwood, Amur privet.	Sweetgum, yellow-poplar, eastern cottonwood, red maple, silver maple, white ash.	Kentucky bluegrass, redtop, tall fescue.
Hu Huntington	Forsythia, lilyofthevalley, myrtle, pachysandra, plantain lily.	Bayberry, dogwood, nannyberry viburnum, Amur privet.	Norway maple, thornless honeylocust, black walnut, yellow-poplar.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
Ju Jules	Plantain lily, juniper, Hall honeysuckle.	Juniper, nannyberry viburnum.	Honeylocust, American sycamore, eastern cottonwood, Washington hawthorn.	Red fescue, Kentucky bluegrass, tall fescue.
Lg Lanier	Hall honeysuckle, juniper, plantain lily.	Juniper, nannyberry viburnum.	Honeylocust, American sycamore, eastern cottonwood, Washington hawthorn.	Red fescue, Kentucky bluegrass, tall fescue.
MaB, MaC2, MaD2, MaE2 Markland	European wild ginger, sweet woodruff, lilyofthevalley, myrtle, creeping thyme.	Red chokecherry, Amur privet, redosier dogwood, mockorange.	Eastern white pine, red pine, white oak, yellow-poplar.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
McA, McB Martinsville	Creeping thyme, Hall honeysuckle, juniper, moss pink, plantain lily.	Forsythia, leatherleaf viburnum, serviceberry, Japanese yew.	Eastern white pine, thornless honeylocust, red pine, white oak, yellow-poplar, black walnut.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
MnC2 Miamian	Forsythia, lilyofthevalley, myrtle, pachysandra, plantain lily.	Amur privet, redosier dogwood, Japanese yew, nannyberry viburnum.	Radiant crabapple, Norway maple, thornless honeylocust, yellow-poplar, eastern white pine.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
MoD2, MoE2*: Miamian	Forsythia, lilyofthevalley, myrtle, pachysandra, plantain lily.	Amur privet, redosier dogwood, Japanese yew, nannyberry viburnum.	Radiant crabapple, Norway maple, thornless honeylocust, yellow-poplar, eastern white pine.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
Hennepin	Plantain lily, juniper, Hall honeysuckle, creeping speedwell.	Juniper	Thornless honeysuckle	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
MuC*: Miamian	Forsythia, lilyofthevalley, myrtle, pachysandra, plantain lily.	Amur privet, redosier dogwood, Japanese yew, nannyberry viburnum.	Radiant crabapple, Norway maple, thornless honeylocust, yellow-poplar, eastern white pine.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.

See footnote at end of table.

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Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

Table 7 - Continued

Soil name and map symbol	Vines and ground cover	Shrubs	Trees	Grasses and legumes
MuC*: Urban land.				
PbB2, PbC2, PbD, PbE-- Parke	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily, English ivy.	Forsythia, leather-leaf viburnum, serviceberry, Japanese yew.	Eastern white pine, thornless honey-locust, red pine, white oak, yellow-poplar, black walnut.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
PcB, PcC*: Parke	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily, English ivy.	Forsythia, leather-leaf viburnum, serviceberry, Japanese yew.	Eastern white pine, thornless honey-locust, red pine, white oak, yellow-poplar, black walnut.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
Urban land.				
PfC, PfD, PfE Pate	Plantain lily, lily turf, yellow root, sweet woodruff, juniper.	Amur privet, redosier dogwood, Japanese yew.	Eastern white pine, Norway maple, radiant crabapple, thornless honey-locust, yellow-poplar.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
PhD*: Pate	Plantain lily, lily turf, yellow root, sweet woodruff, juniper.	Amur privet, redosier dogwood, Japanese yew.	Eastern white pine, Norway maple, radiant crabapple, thornless honey-locust, yellow-poplar.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
Urban land.				
Pn Patton	Bugleweed, fern, plantain lily, yellow root, gout-weed, sweet woodruff.	Red chokecherry, Amur privet, inkberry, mockorange.	Red maple, silver maple, sweetgum, swamp white oak, white ash.	Redtop, reed canarygrass, tall fescue, Kentucky bluegrass.
PrA, PrB, PrC2 Princeton	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily.	Forsythia, juniper, nannyberry viburnum, serviceberry.	Eastern white pine, red pine, white oak, yellow-poplar, black walnut.	Kentucky bluegrass, red fescue, crownvetch, tall fescue.
RdA Raub	Goutweed, bugleweed, plantain lily.	Arrowwood, red chokecherry, redosier dogwood.	Sweetgum, red maple, silver maple, poplar.	Redtop, tall fescue, Kentucky bluegrass.
Rn Ross	Juniper, plantain lily.	Juniper, nannyberry viburnum.	Honeylocust, black locust, Washington hawthorn, American sycamore.	Red fescue, Kentucky bluegrass, tall fescue.
RpA, RpB2, RpC2 Rossmoyne	Phlox, honeysuckle, lilyofthevalley, pachysandra, plantain lily, winter creeper.	Red chokecherry, Amur privet, mockorange, inkberry, redosier dogwood.	Eastern white pine, red maple, sweetgum, silver maple, yellow-poplar.	Redtop, Kentucky bluegrass, tall fescue, crownvetch.

See footnote at end of table.

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Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

Table 7 - Continued

Soil name and map symbol	Vines and ground cover	Shrubs	Trees	Grasses and legumes
UmB, UmC*: Urban land.				
Martinsville	Creeping thyme, Hall honeysuckle, juniper, moss pink, plantain lily.	Bayberry, redosier dogwood, nannyberry viburnum, Amur privet.	Norway maple, thornless honey-locust, black walnut, yellow-poplar.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
Uo*: Urban land.				
Patton	Bugleweed, European wild ginger, gout-weed, yellow root.	Red chokecherry, redosier dogwood, spice bush, common winterberry.	Red maple, swamp white oak, eastern cottonwood.	Redtop, reed canarygrass.
UrB*: Urban land.				
Rossmoyne	Phlox, honeysuckle, lilyofthevalley, pachysandra, winter creeper.	Red chokecherry, Amur privet, mockorange, inkberry, redosier dogwood.	Eastern white pine, red maple, sweetgum, silver maple.	Tall fescue, redtop, Kentucky bluegrass, crownvetch.
Ux*: Urban land.				
Stonelick	Plantain lily, juniper, moss pink, creeping speedwell.	Leatherleaf viburnum, juniper, service-berry.	Eastern white pine, red pine, white oak, black walnut.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
Wa Wakeland	Goutweed, bugleweed, European wild ginger, sweet woodruff.	Red chokecherry, redosier dogwood, spice bush, common winterberry.	Red maple, river birch, swamp white oak.	Redtop, red fescue, tall fescue.
WbA Warsaw Variant	Plantain lily, juniper, moss pink, creeping thyme.	Leatherleaf viburnum, juniper, service-berry.	Eastern white pine, red pine, white oak, black walnut.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
WeA Wea	Forsythia, lilyofthe-valley, pachysandra.	Leatherleaf viburnum, juniper, service-berry.	Eastern white pine, red pine, white oak, black walnut.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
WhA Whitaker	Goutweed, bugleweed, European wild ginger, sweet woodruff, lily turf, yellow root.	Arrowwood, red choke-cherry, redosier dogwood, Amur privet, spice bush.	Sweetgum, poplar, red maple, swamp white oak, London plane tree.	Kentucky bluegrass, redtop, tall fescue.
XfA, XfB2 Xenia	Forsythia, lilyofthe-valley, myrtle, pachysandra, winter creeper.	Forsythia, juniper, nannyberry viburnum, serviceberry.	Eastern white pine, red pine, white oak, yellow-poplar.	Tall fescue, Kentucky bluegrass, crownvetch.

* See description of the map unit for composition and behavior characteristics of the map unit.

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Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

EROSION RESISTANCE - OSDF FINAL COVER SYSTEM

CALCULATIONS

Purpose: The purpose of these calculations is to determine combination of topsoil and vegetative cover that will provide required erosion resistance in the On-Site Disposal Facility Final Cover.

Scope: Parametric study of various topsoil types and vegetation types to calculate various volumes of sediment eroded from the topsoil in the OSDF final cover in sheet and rill erosion. The Modified Universal Soil Loss Equation (MUSLE) (Caltrans, 1992) is the method used. The MUSLE is different from the Universal Soil Loss Equation (USLE); in that it is used to calculate soil loss from non-agricultural lands.

Parametric study of various topsoil types and vegetation types to calculate the potential for gullies to form in the OSDF final cover from the 2000-year, 24-hour design storm using the "Tractive Force Method". This method was developed by Temple (1980) for swales, and modified for slopes in USDOE (1989).

Design: The following requirements govern the selection of topsoil and vegetative cover:

1. Rate of soil loss due to sheet and rill erosion no greater than 5 tons/acre/year [Ohio Administrative Code, 3745-27-08 (C)(15)(f)]
2. No potential for gullies to form during the 2000-year, 24-hour storm (USDOE, 1989).

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Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

PRELIMINARY DISCUSSION-

Sheet erosion, rill erosion, and gully erosion are discussed in Maidment (1992) and USDOE (1989). Sheet erosion will occur as a result of raindrops impacting soil. Concentrated sheet flow (shallow concentrated flow) over the soil can cause rills, or very small gullies, to form (rill erosion). Sheet and rill erosion will occur to some degree in all topsoil - vegetative cover combinations, regardless of the erosive resistance. If shallow concentrated flow is strong enough to exceed the allowable tractive force of the topsoil and vegetation, gullies will form (gully erosion). Gully erosion can quickly wear away the topsoil and vegetative support layers in the OSDF final cover, exposing the biotic barrier. As shown below, if the soil lost to sheet and rill erosion is kept at or below 5 tons/acre/year, the biotic barrier will not be exposed by sheet and rill erosion within 980 years.

The calculations will proceed in the following sequence:

1. Estimate the rate of topsoil lost to sheet and rill erosion from the final cover for different topsoil and vegetative cover combinations using the MUSLE.

2. Evaluate the potential for gully erosion on the final cover using the tractive force method (on acceptable topsoil-vegetation combinations determined in Step 1).

Note - Time to Expose Biotic Barrier:
Topsoil and vegetative support layer in the final cover are 6 in and 21 in thick, respectively, totaling 27 in (2.25 ft). Assuming the unit weight of the soil in these layers is 100 lbs/ft^3:

Topsoil and vegetative support layer - weight per unit area = 100 lb/ft^3 x 2.25 ft = 225 lb/ft^2

Soil loss rate = (5 tons/acre/year) x (2000 lb/ton) / (43,560 ft^2/acre) = 0.23 lb/ft^2/year

(225 lb/ft^2) / (0.23 lb/ft^2/year) = **980 years**

Written by: DAVE WARREN Date: 21-Oct-95 Reviewed by: PBR Date: 23OCT1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

SECTION 1 - ESTIMATE EROSION RATE OF THE OSDF FINAL COVER FROM SHEET AND RILL EROSION, FOR DIFFERENT COMBINATIONS OF TOPSOIL AND GRASS COVER

Method: The Modified Universal Soil Loss Equation (MUSLE) is (Caltrans, 1992):

$$A = R \times K \times LS \times VM$$

Where, R = rainfall energy factor; K = soil erodability factor; LS = length and slope factor; VM = vegetative measures factor

STEP 1:

Find rainfall energy factor, R.

R = 175 (see collection and verification of data)

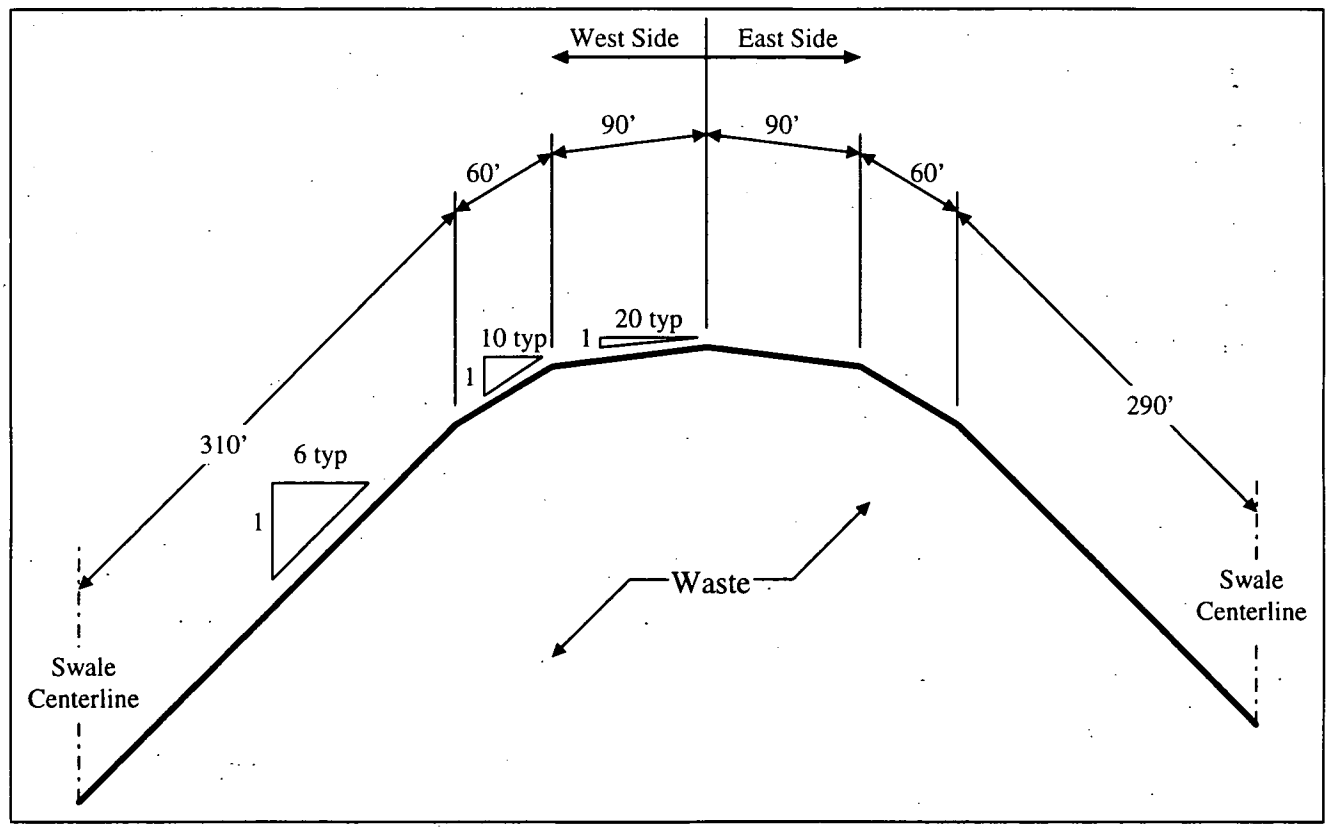


Figure 5 - OSDF West-East Cross-Section For Determining 'LS' Factor In MUSLE and USLE

D.W.W. 23 OCT 95 PBR 23 OCT 95 fc 23 OCT 95 6/50

SOURCE: Design Drawing No. F95-A081 "Final Cover System Grading Plan"

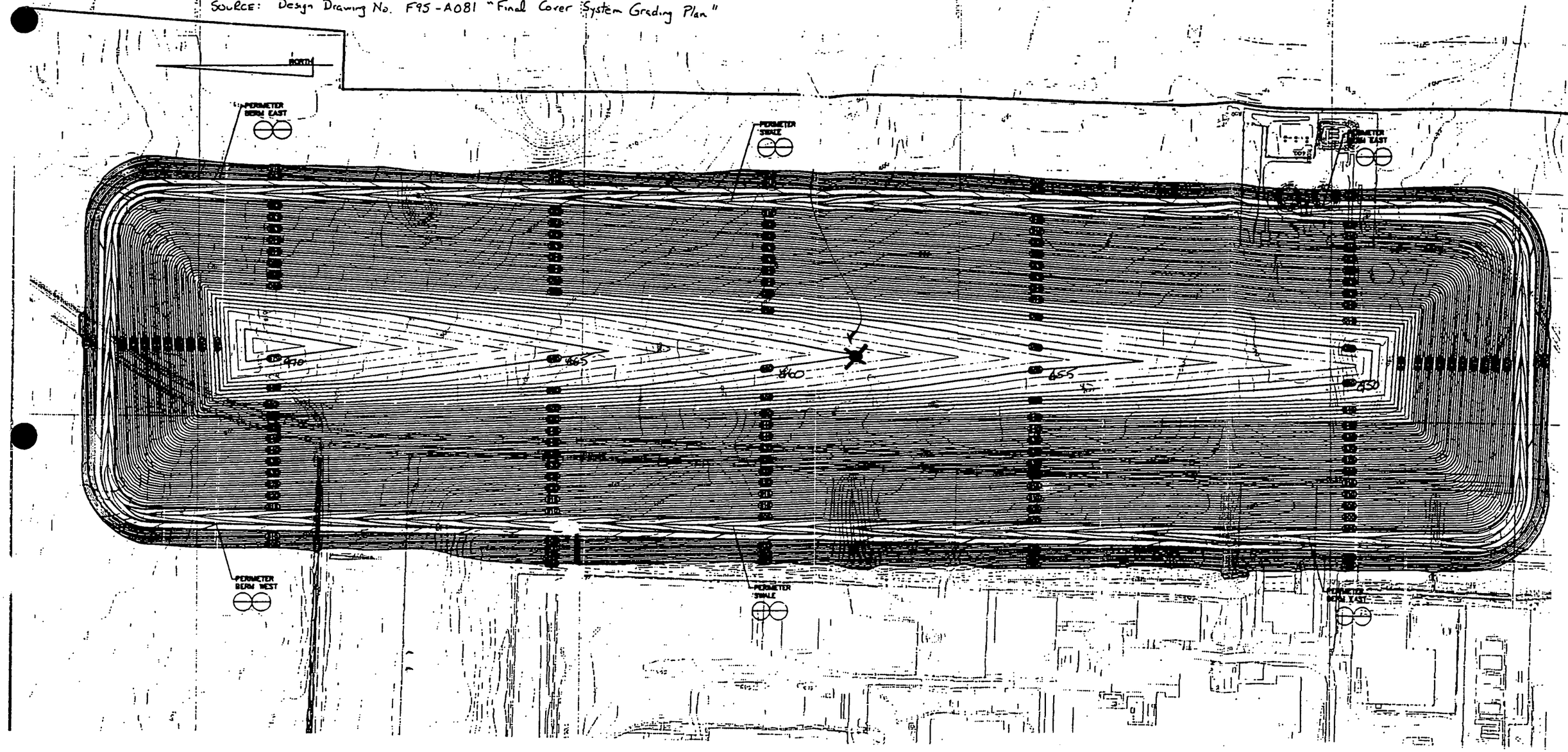
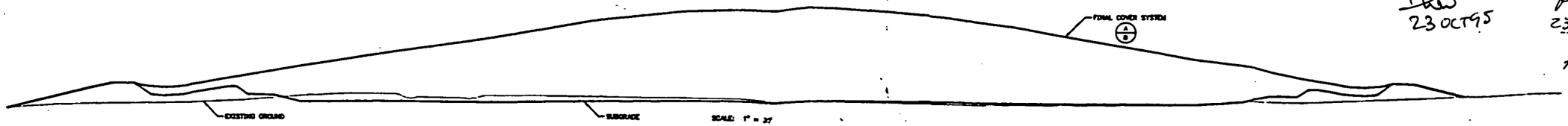
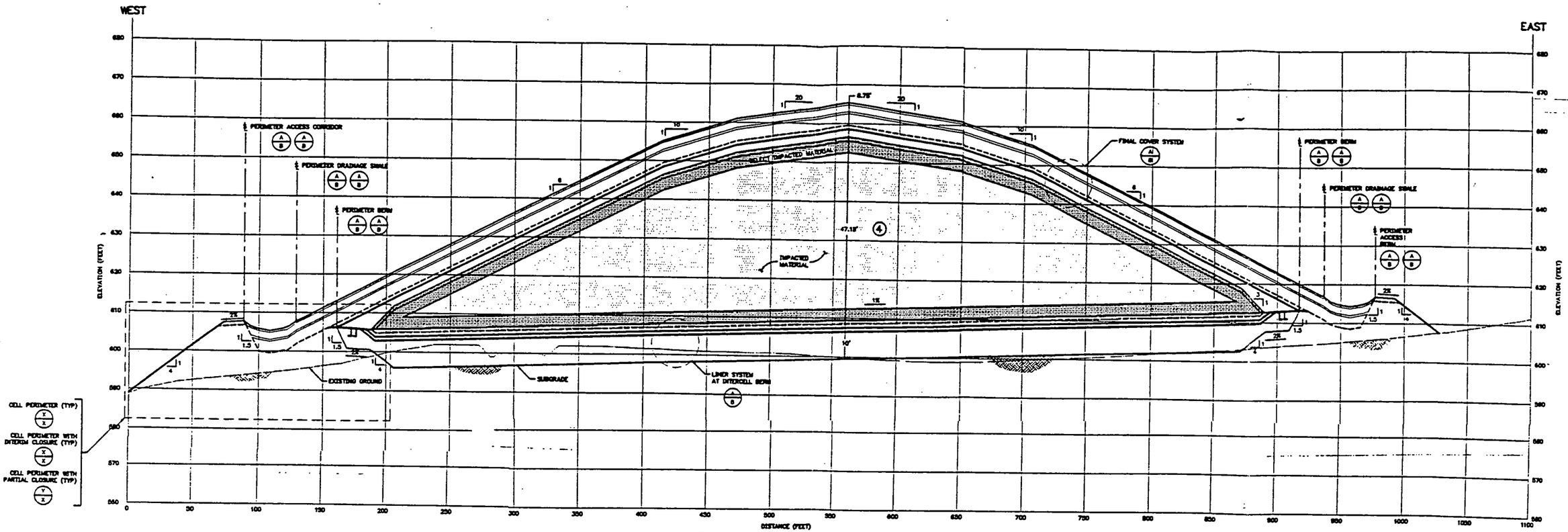


Figure 2 - Plan of OSDF Final Cover. From GeoSyntec (1995a)





DET-NO SECTION
SHT-NO OSDF WEST-EAST AT INTERCELL BERM
HORIZONTAL SCALE: 1" = 30'
VERTICAL SCALE: 1" = 10'

001741

NOTES:

1. SEE SHEET NO. C- AND C- FOR SECTION LOCATIONS.
2. ELEVATIONS ARE IN FEET ABOVE SEA LEVEL DATUM (NOTE: "SEA LEVEL DATUM" REFERS TO THE NATIONAL GEODETIC VERTICAL DATUM (NGVD) OF 1929).

PRELIMINARY DESIGN PACKAGE
(30% SUBMITTAL)

REV. NO.	DATE	DESCRIPTION	DES BY	DR BY	CHK BY	ENG BY	APP BY

OWNER/FACILITY
UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

CLIENT/PROJECT
FERNALD ENVIRONMENTAL RESTORATION MANAGEMENT CORPORATION
CERCLA/RCRA UNIT 2 ON-SITE DISPOSAL FACILITY

TITLE
OSDF CROSS-SECTION WEST-EAST AT INTERCELL BASE

GeoSyntec Consultants

PROJECT NO. GC3000-11
DOC NO. FSS-A022
SHEET NO. C-32

Figure 3 - West-East Cross Section of OSDF. From GeoSyntec (1995a)

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KL 23 OCT 95

STEP 2:

Find combined field length and slope factor, LS.

Use the equation for LS from Caltrans (1992):

$$LS = \left(\frac{650 + 450S + 65S^2}{10000 + S^2}\right)\left(\frac{L}{72.6}\right)^m$$

Where:
L = Slope length
S = Slope grade (%)
m = 0.3 for slope grades of 0 to 0.5%; 0.5 for slope grades of 0.51 to 10%; 0.6 for slope grades > 10%

Pertinent final cover geometry is shown in Figure 5. Compare LS for flow paths down east and west side slopes. Use the larger LS.

A. Find LS for individual slopes.

East Side Slope: **West Side Slope:**

Section	Length (ft)	Slope	m	LS	Section	Length (ft)	Slope	m	LS
Top	90	5.00%	0.5	0.503	Top	90	5.00%	0.5	0.503
Middle	60	10.00%	0.5	1.049	Middle	60	10.00%	0.5	1.049
Bottom	290	17.00%	0.6	6.043	Bottom	310	17.00%	0.6	**6.289**
TOTAL	450	13.40%*	0.6	**5.386**	**TOTAL**	460	13.74%*	0.6	**5.676**

*weighted average

B. Find total LS.

LS = the maximum LS calculated above = **6.289**

STEP 3:

Find required combinations of soil texture and percentage of grass cover that result in no greater than 5 tons/acre/year or less of soil being eroded away.

Soil Texture: Determines the "Soil erodability factor": K

Grass Cover Consistency: Vegetative measures factor, VM;

Sources of values for the coefficients K and VM are discussed in the collection and verification of data.

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Values of Soil Lost to Erosion in Tons/Acre/Year For Different Soil/Vegetation Combinations As Calculated by the Modified Universal Soil Loss Equation (R = 175, LS = 6.29)

Vegetation:		Grass					
Percent Ground Cover:		0%	20%	40%	60%	80%	95%
VM:		**0.45**	**0.2**	**0.1**	**0.047**	**0.029**	**0.011**
Topsoil	**K**						
Silt Loam	**0.37**	183.3	81.5	40.7	19.1	11.8	4.5
Clay Loam	**0.32**	158.5	70.4	35.2	16.6	10.2	3.9
Loam	**0.32**	158.5	70.4	35.2	16.6	10.2	3.9
Sandy Loam	**0.24**	118.9	52.8	26.4	12.4	7.7	2.9
Loamy Sand	**0.17**	84.2	37.4	18.7	8.8	5.4	2.1
Sand	**0.15**	74.3	33.0	16.5	7.8	4.8	1.8

The highlighted values in the above table show acceptable topsoil texture and grass cover combinations (i.e., yielding a soil loss rate to sheet and rill erosion equal to or less than 5 tons/acre/year). As calculated by the MUSLE, a grass ground cover of at least 95 percent is required to limit erosion to 5 tons/acre/year, for a topsoil with at least the erosion resistance of silt loam.

One point about topsoil: Caldwell and Reith (1993, p.94-95) recommend "clump grass in vegetated gravelly soil" as the "final cover erosion barrier with the most significant advantages". No K factor values were given for gravelly soil in the MUSLE reference used, but Caldwell and Reith, and the trend in the erosion rate solutions indicate that the erosion resistance of gravelly soil will be greater than sand. Therefore, a gravelly topsoil will provide adequate erosion resistance with a grass ground cover of 80%.

Local soils identified in the soil survey of Hamilton County, Ohio generally have silt loam topsoil, with subsoils ranging from sandy loam to clay loam (USDA, 1982). Kentucky bluegrass [identified as having very good erosion resistance in USDOE (1989)] and tall fescue are recommended grasses for all local soils and for most all soil series in Hamilton County (USDA, 1982). See the collection and verification of data for more information.

Based on the MUSLE results and discussion, using any of the soils shown the previous table and establishing a vigorous grass cover that covers at least 95 percent of the ground are required to limit erosion to 5 tons/acre/year.

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SECTION 2 - EVALUATE THE POTENTIAL FOR GULLIES TO FORM IN THE TOPSOIL OF THE OSDF FINAL COVER FROM THE 2000-YEAR, 24-HOUR STORM

Method: Use the "Tractive Force Method", modified to apply to slopes (USDOE, 1989).

STEP 1:

Find allowable tractive force for bare topsoil, τ_a.

A. Estimate pertinent soil index properties of topsoil.

1. Background

The results of Section 1 show that most any texture of topsoil, provided it can support a dense grass cover, will yield acceptable soil loss rates to sheet and rill erosion. On-site topsoils may be used for the OSDF final cover. Generally, the topsoils on the site are silt loam (ML) (USDA, 1982). Generally, the subsoils on the site are mostly CL, with small quantities of CH, ML and SM (Parsons, 1995b,c). Furthermore, Caldwell and Reith (1992) indirectly state that adding gravel to topsoils can increase the soils' erosion resistance.

Evaluate resistance to gully formation for a set of soils that encompasses the range of classifications outlined in the above paragraph.

2. USCS Classifications

Figure 6 shows the basic allowable tractive stress for different USCS soil classifications (including those common to the site). As interpreted from Figure 6:

USCS Soil Classification	Resistance to Gully Formation
ML,OL,SM	Low
GM,CL,SC	Moderate
CH	High
GC	Very High

USCS soil types corresponding to all USDA soil textures analyzed in Section 1 are shown below:

Soil Classification	
USDA	USCS
Silt Loam	ML
Clay Loam	CL
Loam	ML
Sandy Loam	SM
Loamy Sand	SM
Sand	SW

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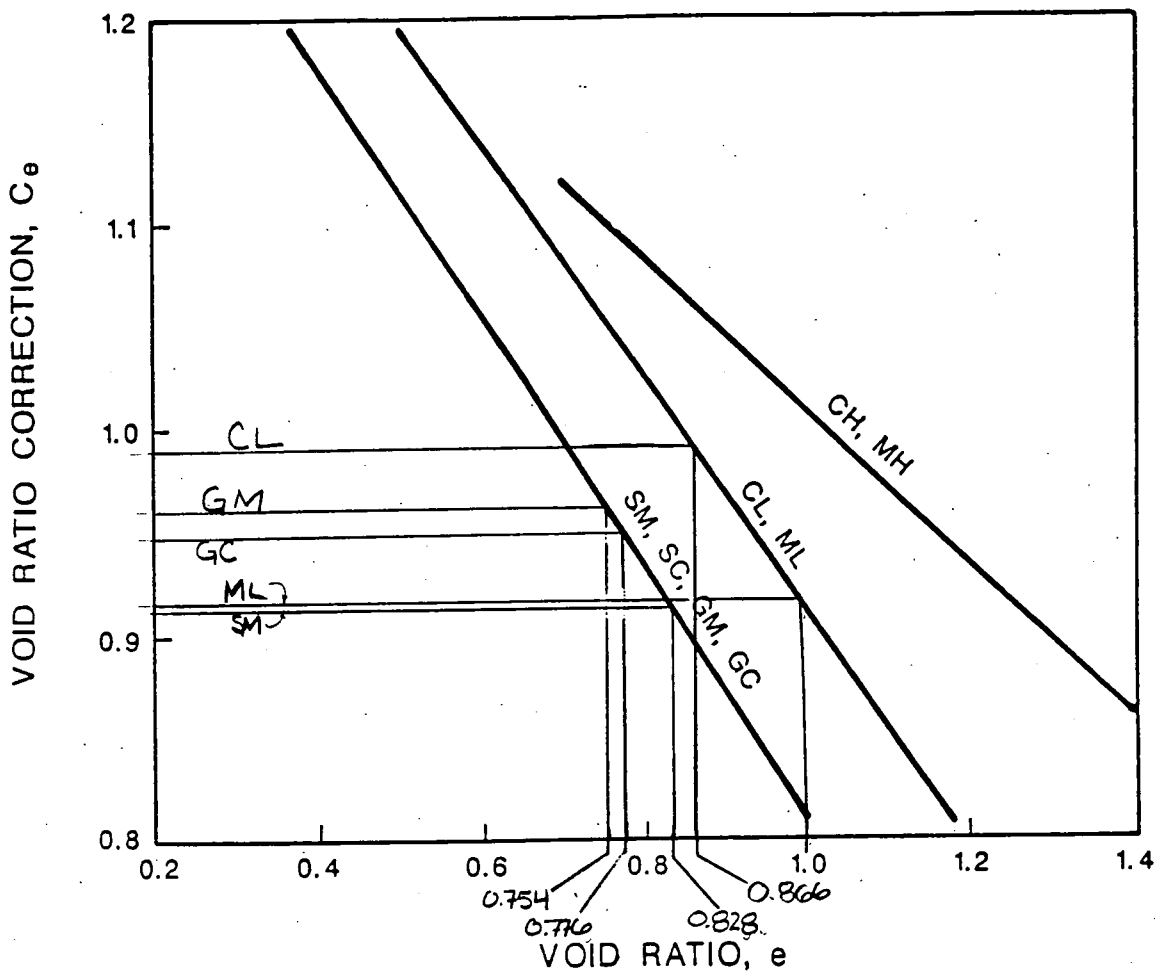

Figure 6 - Graph for Determining, τ_{ab} (from USDOE,1989)

Based on the information in the previous tables, analyze the tractive force for ML, SM, GM, CL, and GC. This will encompass the range of different erosion resistances achievable.

3. Plasticity Index (PI)

PI's from the site geotechnical data and from the USCS definitions are shown below. See the collection and verification of data for more detailed information.

Soil Type	Plasticity Index (PI)		
	Range from Site Data	USCS Minimum	**PI to use**
ML	0 - 4 (6*)	0	**0**
SM	0 (7*)	0	**0**
GM	NA	0	**0**
CL	7 - 32 (146*)	7	**10**
GC	13 (1*)	7	**10**

*Number of samples

The PI to use is a conservative (low) estimate of what the PI will be. From Figure 6, it can be seen that a lower PI will yield less allowable stress.

4. Void Ratio (e)

Schroeder et al.(1994) gives typical porosities for several loose soils (i.e., topsoils), based on USDA textures. These are shown in the table below, and in the collection and verification of data.

Soil Type		Porosity, n	Void Ratio, e
USDA	USCS		
Silt Loam	ML	0.501	1.00
Clay Loam	CL	0.464	0.866
Loam	ML	0.463	0.862
Sandy Loam	SM	0.453	0.828
Loamy Sand	SM	0.437	0.776
Sand	SW	0.437	0.776
Loamy Sand*	GM	0.437*	0.776
Sandy Clay*	GC	0.430*	0.754

USCS Soil Type	**Void Ratio To Use**
ML	**1.00**
SM	**0.828**
GM	**0.776**
CL	**0.866**
GC	**0.754**

*Chosen based on judgment as to what USDA soils would most closely correspond to GM and GC

Note that $e = \frac{n}{1-n}$

B. Estimate allowable tractive force for bare topsoil (τ_a):

The tractive force method in USDOE (1989) uses two equations; one for coarse-grained soils and one for fine-grained soils. All soils evaluated should be relatively fine-grained because they have to support a good grass cover. Note that as interpreted from the equations in USDOE (1989), GM and GC can be considered either coarse-grained or fine-grained soils. The equation in USDOE (1989) for fine-grained soils is:

$$\tau_a = \tau_{ab} C_e^2 \text{ (USDOE, 1989)}$$

RESULTS:

Soil	PI	τ_{ab} (Figure 6)	e	C_e (Figure 7)	τ_a
ML	0	0.02 psf*	1.00	0.91	**0.016 psf**
SM	0	0.02 psf*	0.828	0.915	**0.017 psf**
GM	0	0.03 psf*	0.776	0.96	**0.027 psf**
CL	10	0.03 psf	0.866	0.99	**0.029 psf**
GC	10	0.075 psf	0.754	0.95	**0.068 psf**

*τ_{ab} assumed to be same as that for soil with PI=10 because Temple (1980) gives τ_a=0.02 psf for "easily erodable soils", which corresponds to τ_{ab} for ML and SM at PI=10 on Figure 6.

STEP 2:

Find unit discharge, q.

The guidelines for the tractive force method recommend using the Rational Formula, modified to account for flow concentrations and infiltration, to obtain the unit discharge, q. Peak rainfall intensity for the 2000-year, 24-hour storm was not readily available, therefore, the TR-55 computer program (USDA, 1986a) was used to obtain q. According to Maidment (1992), TR-55 has largely replaced the rational method in the U.S. for runoff calculations.

Input and results from TR-55 are discussed below. See collection and verification of data for more information.

A. Runoff Curve No. (CN)

CN = 98

USDOE (1989) recommends using c=1.0 in the rational method (Q=ciA) when determining PMP storm runoff. In other words, all the soil is saturated by the time of interest, and any precipitation that hits the surface will run off. 98 is the highest CN the TR-55 program will allow to be used. CN=98 is approximately CN=100, which corresponds to 100 percent runoff

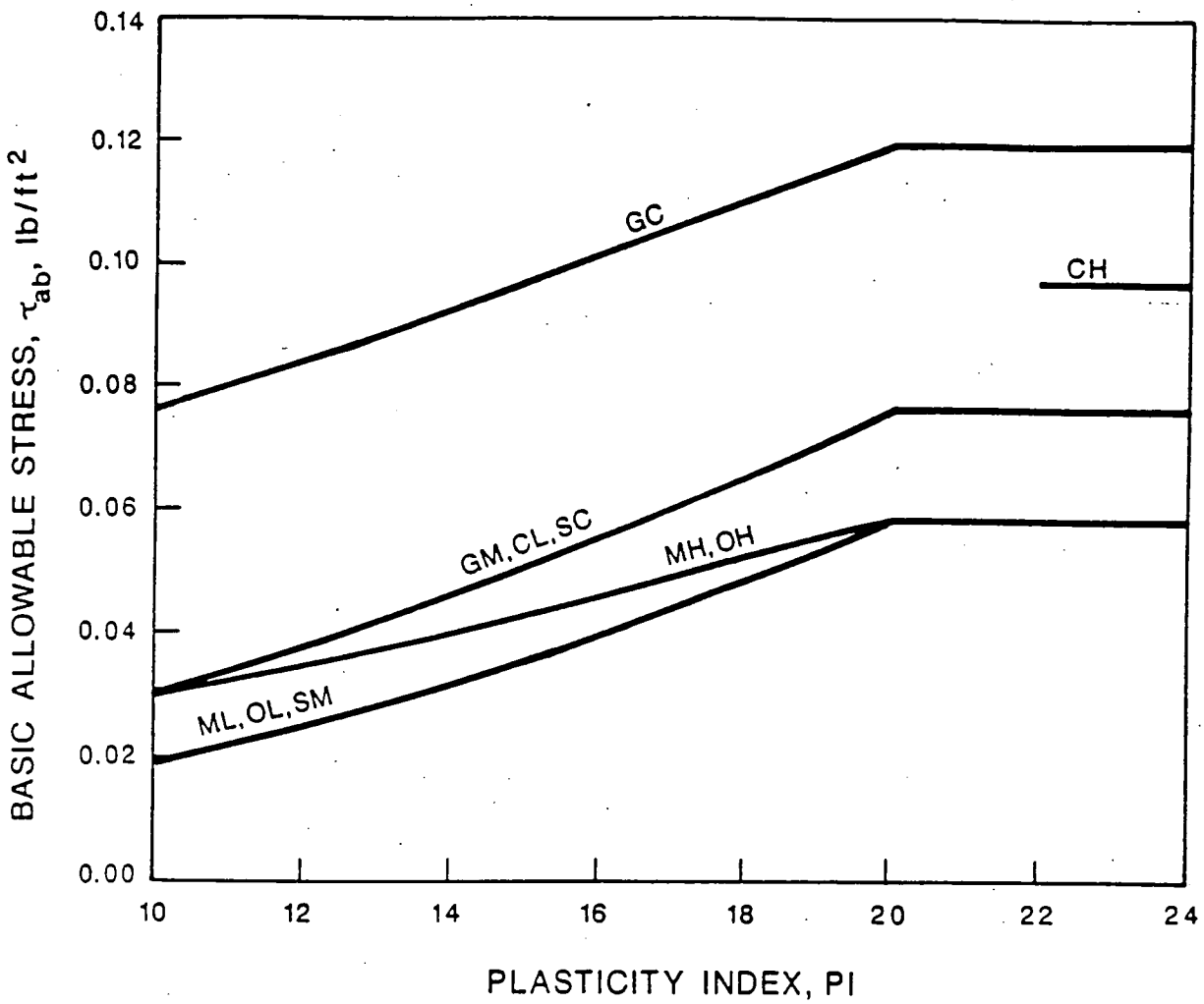

Figure 7 - Graph for Determining C_e (from USDOE,1989)

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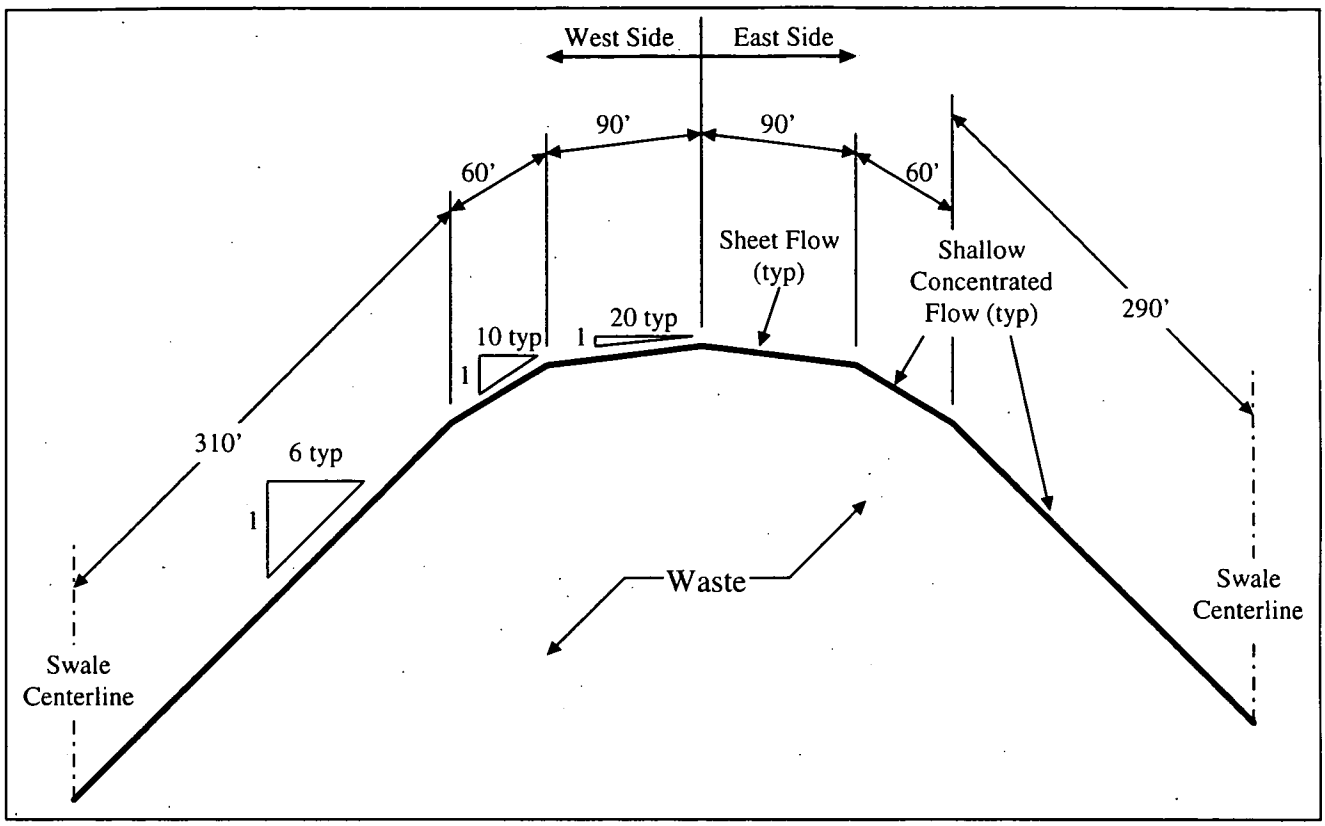

Figure 8 - OSDF West-East Cross-Section For Determining Peak Flow Off Final Cover

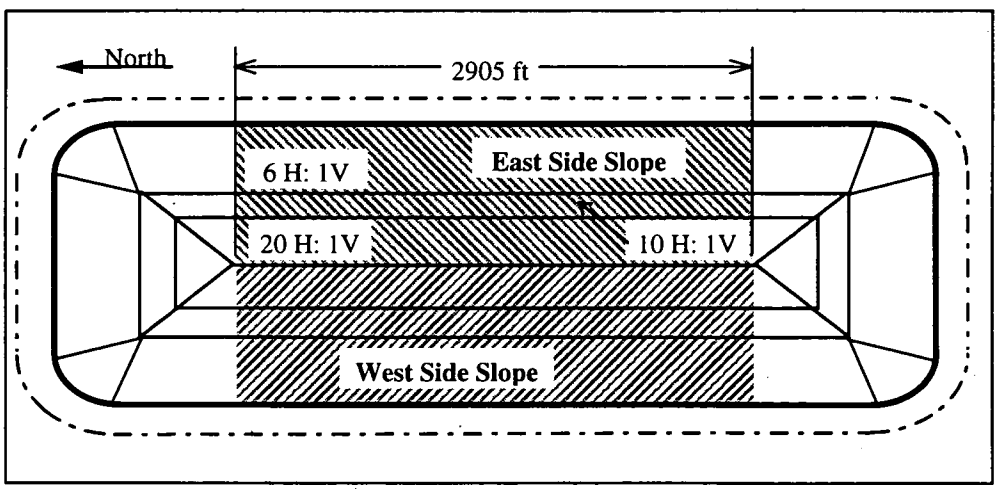

Figure 9 - OSDF Plan View Showing East and West Side Slope Widths

B. Flow Path Parameters.

See Figure 8 for lengths and slopes of segments. Assume sheet flow on 20H:1V slope, and shallow concentrated flow on other slopes. Assume the bottom edge of the 6H:1V slope is the centerline of the perimeter drainage swale. Assume fair grass cover on all slopes - this is conservative (less grass = more runoff).

The east and west side slopes are both 2905 feet wide, measured north-south (Figure 9). The 2-year, 24-hour rainfall is 2.55 inches (Parsons, 1995a).

Determine the time for a water drop to flow from the top to the bottom of the final cover slope; this is the longest drainage path on the final cover. Evaluate paths on both the east and west sides.

Flow Path Segment	Input Parameters	Values for East Slope	Values for West Slope
Segment 1	Length	90 ft	90 ft
	Slope	0.05	0.05
	Flow	Sheet	Sheet
	Ground Cover	Grass-Range, Short	Grass-Range, Short
	2-yr, 24-hr rain	2.55 in	2.55 in
Segment 2	Length	60 ft	60 ft
	Slope	0.10	0.10
	Flow	Shallow Conc.	Shallow Conc.
	Ground Cover	Unpaved	Unpaved
Segment 3	Length	290 ft	310 ft
	Slope	0.17	0.17
	Flow	Shallow Conc.	Shallow Conc.
	Ground Cover	Unpaved	Unpaved
All	Area	27 ac	31 ac

Note: Due to the compound grade of the final cover, the path a drop of water follows will be slightly longer and steeper than that for the cross section perpendicular to the slope, shown in Figure 3 and outlined in the above table. However, the length and grade difference between the true flow path and the path perpendicular to the slope is negligible.

With this geometry, use the program TR-55 (SCS, 1986a) to determine the peak flow off the east and west side slopes of the final cover. Use both the tabular hydrograph and graphical peak discharge methods. **Use the 2000-year, 24-hour storm: 13 inch rainfall (Parsons, 1995c), Type II distribution (SCS, 1986a).** The TR-55 results are summarized in the following table, and the computer program output is shown at the end of these calculations.

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Slope	Peak Flow, Q		**Peak Flow (per unit width), q**	
	Tabular	Graphical	**Tabular**	**Graphical**
East	544 cfs	502 cfs	**0.19 cfs/ft**	**0.175 cfs/ft**
West	624 cfs	576 cfs	**0.22 cfs/ft**	**0.20 cfs/ft**

As can be seen, the peak flow per unit width (q) is higher for the west slope than the east slope, and higher for the tabular method than the graphical method. Therefore, if the allowable tractive force is not exceeded on the west slope, it will not be exceeded on the east slope.

NOTE: Back-calculating an equivalent rainfall intensity from the peak flow above:

$q = 0.22$ cfs/ft $= ciA = 1.0 \times i \times 460$ ft $\quad i = 20.7$ in/hr

STEP 3:

Find vegetal coefficients C_I and C_f.

Values for C_I and C_f are given in USDOE (1989)for "good uniform" stands of grass, and are recommended to be reduced by 20 percent for "fair uniform" stands of grass. The coefficient values are grouped by "vegetal retardance class", and correspond to the curves in Figure 5. These are shown below. See collection and verification of data for more information.

Grass Cover	Vegetal Retardance Class	Good Stand		Fair Stand	
		C_I	C_f	C_I	C_f
Bermuda grass, 12-in high	A	10.00	0.9	8.00	0.72
Buffalo grass Kentucky bluegrass Blue gramma	B	7.64	0.87	6.11	0.70
Grass-legume mixture Weeping lovegrass Bermuda grass, 6-in high Yellow Bluestem	C	5.60	0.75	4.48	0.60
Alfalfa Lespedeza sericea, 2-in high Common lespedeza	D	4.44	0.50	3.55	0.40
Sudan grass Bermuda grass, burned stubble	E	2.88	0.50	2.30	0.40

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STEP 4:

Determine Manning's "n" for soil roughness (n_s).

Assume all soil types are fined-grained (d_{75} > 1.27mm). Therefore, n_s = 0.0156 (USDOE, 1989)

STEP 5:

Determine the Manning's computed flow resistance coefficient (n_r).

Use the equation from USDOE (1989): $n_r = e^{0.01329C_I(\ln RV)^2 - 0.09543C_I(\ln RV) + 0.2971C_I - 4.16}$

Where: RV = hydraulic radius x velocity ~ q = 0.22 cfs/ft

C_I = vegetal coefficient (Step 3)

This equation was fitted to the curves in Figure 5, but can predict a much higher n_r for low flows than would be interpreted from Figure 5. Because of this, and that a higher n_r will result in lower tractive force acting on the soil, use the smaller of:

n_r calculated with the above equation

n_r interpreted from Figure 5.

Results are as follows (RV = 0.22 cfs/ft):

Grass Cover			n_r (or n_v')		
Retardance Class	Quality	C_I	Calc'd	Max. from Figure 5	**To Use**
A	Good	10.00	1.752	0.35[1]	**0.350**
	Fair	8.00	0.681	0.33[2]	**0.330**
B	Good	7.64	0.575	0.31[1]	**0.310**
	Fair	6.11	0.279	0.28[2]	**0.250**
C	Good	5.60	0.219	0.25[1]	**0.198**
	Fair	4.48	0.129	0.19[2]	**0.119**
D	Good	4.44	0.127	0.13[1]	**0.117**
	Fair	3.55	0.083	0.10[2]	**0.078**
E	Good	2.88	0.061	0.06[1]	**0.058**
	Fair	2.30	0.046	0.05[1]	**0.044**

[1]Interpreted from Figure 4

[2]Calculated by: n_r(fair, class i) = [n_r(good, class i) + n_r(good, class i-1)] / 2

STEP 6:

Compute Manning's coefficient of resistance on a vegetated slope (n_v').

$n_v' = (n_r^2 - 0.0156^2 + n_s^2)^{1/2}$ and n_s = 0.0156, so $\mathbf{n_v' = n_r}$ (USDOE, 1989)

Values of n_v' are shown in Step 5.

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STEP 7:

Compute the flow depth down the vegetated slope.
Use Manning's Equation and continuity:

$$q = VD = \left(\frac{1.486}{n_v'} D^{2/3} S^{1/2}\right) D \qquad D = \left(\frac{q}{\frac{1.486}{n_v'} S^{1/2}}\right)^{3/5}$$

Where: V = velocity
D = flow depth
S = Slope

The worst case will be on the bottom (6H:1V) slope, since it is the steepest and receives the flow from the slopes above. Therefore, S = 1/6 = 0.17 The results are shown in the table in Step 9.

STEP 8:

Determine the coefficient of vegetal resistance, K_v.

$$K_v = (1 - C_f)\left(\frac{n_s}{n_v'}\right)^2 \quad \text{(USDOE, 1989)}$$

The results are shown in the table in Step 9.

STEP 9:

Determine the "effective actual" tractive shear stress, τ_e.

$\tau_e = K_v\, \tau_o = K_v\, (\gamma DS)$ (USDOE, 1989) (γ = unit weight of water = 62.4 pcf)

Results:

Step No.:		*3*	*5, 6*	*7*	*3*	*8*	*9*	*9*
Grass Cover			n_r or	Flow				
Group	Quality	C_I	n_v'	Depth, D (ft)	C_f	K_v	τ_o (psf)	τ_e **(psf)**
I	Good	10.00	0.350	0.29	0.90	1.99E-04	3.06	6.07E-04
	Fair	8.00	0.330	0.28	0.72	6.26E-04	2.95	1.85E-03
II	Good	7.64	0.310	0.27	0.87	3.29E-04	2.84	9.35E-04
	Fair	6.11	0.250	0.24	0.70	1.17E-03	2.50	2.91E-03
III	Good	5.60	0.198	0.20	0.75	1.54E-03	2.17	3.36E-03
	Fair	4.48	0.119	0.15	0.60	6.84E-03	1.60	1.10E-02
IV	Good	4.44	0.117	0.15	0.50	8.86E-03	1.59	1.40E-02
	Fair	3.55	0.078	0.12	0.40	2.39E-02	1.24	2.97E-02
V	Good	2.88	0.058	0.10	0.50	3.65E-02	1.04	3.79E-02
	Fair	2.30	0.044	0.08	0.40	7.42E-02	0.88	6.57E-02

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STEP 10:

Compare τ_e to τ_a.

If, $\tau_e > \tau_a$, OK, gullies will not form during the 2000-year, 24-hour storm
If, $\tau_e < \tau_a$, No Good, gullies will form during the 2000-year, 24-hour storm
Results are shown in table below:

Grass Cover		Topsoil Type:	ML	SM	GM	CL	GC
Retardance Class	Quality	τ_a (psf):	0.016	0.017	0.027	0.029	0.068
		τ_e (psf)					
A	Good	8.20E-05	**OK**	**OK**	**OK**	**OK**	**OK**
	Fair	8.18E-04	**OK**	**OK**	**OK**	**OK**	**OK**
B	Good	4.78E-04	**OK**	**OK**	**OK**	**OK**	**OK**
	Fair	2.91E-03	**OK**	**OK**	**OK**	**OK**	**OK**
C	Good	3.36E-03	**OK**	**OK**	**OK**	**OK**	**OK**
	Fair	1.10E-02	**OK**	**OK**	**OK**	**OK**	**OK**
D	Good	1.40E-02	**OK**	**OK**	**OK**	**OK**	**OK**
	Fair	2.97E-02	**No Good**	**No Good**	**No Good**	**No Good**	**OK**
E	Good	3.79E-02	**No Good**	**No Good**	**No Good**	**No Good**	**OK**
	Fair	6.57E-02	**No Good**	**No Good**	**No Good**	**No Good**	**OK**

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COMBINE RESULTS OF MUSLE AND RESULTS OF TRACTIVE FORCE METHOD:

Results of MUSLE (<=5.0 is OK):

Vegetation:		Grass					
Percent Ground Cover:		0%	20%	40%	60%	80%	95%
VM:		**0.45**	**0.2**	**0.1**	**0.047**	**0.029**	**0.011**
Soil	**K**						
Silt Loam	**0.37**	183.3	81.5	40.7	19.1	11.8	4.5
Clay Loam	**0.32**	158.5	70.4	35.2	16.6	10.2	3.9
Loam	**0.32**	158.5	70.4	35.2	16.6	10.2	3.9
Sandy Loam	**0.24**	118.9	52.8	26.4	12.4	7.7	2.9
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Sand	**0.15**	74.3	33.0	16.5	7.8	4.8	1.8

Results of Tractive Force Method:

Grass Cover		**Topsoil Type:**	ML	SM	GM	CL	GC
Retardance Class	Quality	τ_a (psf):	0.016	0.017	0.027	0.029	0.068
		τ_e (psf)					
A	Good	8.20E-05	**OK**	**OK**	**OK**	**OK**	**OK**
	Fair	8.18E-04	**OK**	**OK**	**OK**	**OK**	**OK**
B	Good	4.78E-04	**OK**	**OK**	**OK**	**OK**	**OK**
	Fair	2.91E-03	**OK**	**OK**	**OK**	**OK**	**OK**
C	Good	3.36E-03	**OK**	**OK**	**OK**	**OK**	**OK**
	Fair	1.10E-02	**OK**	**OK**	**OK**	**OK**	**OK**
D	Good	1.40E-02	**OK**	**OK**	**OK**	**OK**	**OK**
	Fair	2.97E-02	**No Good**	**No Good**	**No Good**	**No Good**	**OK**
E	Good	3.79E-02	**No Good**	**No Good**	**No Good**	**No Good**	**OK**
	Fair	6.57E-02	**No Good**	**No Good**	**No Good**	**No Good**	**OK**

From the MUSLE, a dense, uniform grass cover (covering at least 80 or 95 percent of the ground depending on the topsoil type) is needed to adequately resist sheet and rill erosion. From the Tractive Force Method, a good or fair uniform stand of grass (of at least vegetal retardance class C or E, depending on the topsoil type) is needed to adequately resist gully formation.

Results of these calculations show that a strong, dense grass cover is necessary to resist erosion. The topsoil may be silt loam, clay loam, loam, sandy loam, loamy sand, sand, or gravelly soil, provided it can support the grass cover; however, a gravelly clay (GC) topsoil will allow a less vigorous grass cover to be adequate.

Written by: DAVE WARREN Date: 20-Oct-95 Reviewed by: PBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

REFERENCES:

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RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

DWW

PBR 23OCT1995

Project : Fernald OSDF GE3900-08.2 User: DWW Date: 10-14-95
County : State: Checked: ____ Date: _____
Subtitle: Flow off West Side of Final Cover - Tabular Method
Subarea : Area1

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
	Acres (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Impervious Areas				
Paved parking lots, roofs, driveways	-	-	-	31(98)
Total Area (by Hydrologic Soil Group)				31
				====

SUBAREA: Area1 TOTAL DRAINAGE AREA: 31 Acres WEIGHTED CURVE NUMBER: 98

40/50

TIME OF CONCENTRATION AND TRAVEL TIME

Version 2.00

PBR 23OCT1995

Project : Fernald OSDF GE 3900-08.2 User: DWW Date: 10-14-95

County : State: Checked: ____ Date: _____

Subtitle: Flow off West Side of Final Cover - Tabular Method

Subarea #1 - Area1

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	90	.05	E					0.117
Shallow Concent'd		60	.1	U					0.003
Shallow Concent'd		310	0.17	U					0.013

Time of Concentration = 0.13*

=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

TABULAR HYDROGRAPH METHOD

Version 2.00

PBL 23Oct1995

Project : Fernald OSDF GE390-C8.2 User: DWW Date: 10-14-95
County : State: Checked: ____ Date: _____
Subtitle: Flow off West Side of Final Cover - Tabular Method

Total watershed area: 0.048 sq mi Rainfall type: II Frequency: 100 years

---------- Subareas ----------

	Area1
Area(sq mi)	0.05*
Rainfall(in)	13.0
Curve number	98*
Runoff(in)	12.76
Tc (hrs)	0.13*
(Used)	0.10
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) Area1
11.0	15	15
11.3	21	21
11.6	33	33
11.9	206	206
12.0	400	400
12.1	624P	624P
12.2	388	388
12.3	134	134
12.4	91	91
12.5	76	76
12.6	64	64
12.7	53	53
12.8	47	47
13.0	41	41
13.2	35	35
13.4	32	32
13.6	28	28
13.8	26	26
14.0	23	23
14.3	21	21
14.6	20	20
15.0	18	18
15.5	16	16
16.0	14	14
16.5	13	13
17.0	12	12
17.5	12	12
18.0	11	11
19.0	9	9
20.0	8	8
22.0	7	7
26.0	0	0

P - Peak Flow * - value(s) provided from TR-55 system routines

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

PBC 23OCT1995

Project : Fernald OSDF GE3400-082 User: DWW Date: 10-16-95
County : State: Checked: ____ Date: _____
Subtitle: Flow off West Side of Final Cover - Graphical Method
Subarea : area1

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
		Acres (CN)		
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Impervious Areas				
Paved parking lots, roofs, driveways	-	-	-	31(98)
Total Area (by Hydrologic Soil Group)				31

SUBAREA: area1 TOTAL DRAINAGE AREA: 31 Acres WEIGHTED CURVE NUMBER: 98*

* - Generated for use by GRAPHIC method

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

DWW BBL 23OCT1995

Project : Fernald OSDF GE 3900-08.2 User: DWW Date: 10-16-95
County : State: Checked: ____ Date: _____
Subtitle: Flow off West Side of Final Cover - Graphical Method

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	90	0.05	E					0.117
Shallow Concent'd		60	0.1	U					0.003
Shallow Concent'd		310	0.17	U					0.013
								Time of Concentration =	0.13*
									=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by GRAPHIC method

GRAPHICAL PEAK DISCHARGE METHOD

Version 2.00

PBR 23OCT1995

Project : Fernald OSDF GE3900-C8.2 User: DWW Date: 10-16-95
County : State: Checked: ____ Date: _____
Subtitle: Flow off West Side of Final Cover - Graphical Method

Data: Drainage Area : 31 * Acres
Runoff Curve Number : 98 *
Time of Concentration: 0.13 * Hours
Rainfall Type : II
Pond and Swamp Area : NONE

Storm Number	1
Frequency (yrs)	100
24-Hr Rainfall (in)	13
Ia/P Ratio	0.00
Used	0.10
Runoff (in)	12.76
Unit Peak Discharge (cfs/acre/in)	1.456
Pond and Swamp Factor 0.0% Ponds Used	1.00
Peak Discharge (cfs)	576

* - Value(s) provided from TR-55 system routines

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

DWW

PBR 23OCT195

Project : Fernald OSDF GE3900-08.2 User: DWW Date: 10-14-95
County : State: Checked: ____ Date: _____
Subtitle: Flow off East Side of Final Cover - Tabular Method
Subarea : Area1

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
	Acres (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Impervious Areas				
Paved parking lots, roofs, driveways	-	-	-	27.0(98)
Total Area (by Hydrologic Soil Group)				27
				====

SUBAREA: Area1 TOTAL DRAINAGE AREA: 27 Acres WEIGHTED CURVE NUMBER: 98

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

DWW 23OCT1995

Project : Fernald OSDF GE3500-08.2 User: DWW Date: 10-14-95
County : State: Checked: ____ Date: _____
Subtitle: Flow off East Side of Final Cover - Tabular Method

---------- Subarea #1 - Area1 ----------

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	90	.05	E					0.117
Shallow Concent'd		60	.1	U					0.003
Shallow Concent'd		255	0.17	U					0.011

Time of Concentration = 0.13*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by TABULAR method

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TABULAR HYDROGRAPH METHOD

Version 2.00

BBR 23OCT1995

Project : Fernald OSDF GE3500-C8-2 User: DWW Date: 10-14-95
County : State: Checked: ____ Date: _____
Subtitle: Flow off East Side of Final Cover - Tabular Method

Total watershed area: 0.042 sq mi Rainfall type: II Frequency: 100 years

---------- Subareas ----------

	Area1
Area(sq mi)	0.04*
Rainfall(in)	13.0
Curve number	98*
Runoff(in)	12.76
Tc (hrs)	0.13*
(Used)	0.10
TimeToOutlet	0.00
Ia/P	0.00
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) Area1
11.0	13	13
11.3	18	18
11.6	29	29
11.9	180	180
12.0	348	348
12.1	544P	544P
[illegible]	338	338
[illegible]	117	117
12.4	79	79
12.5	66	66
12.6	56	56
12.7	46	46
12.8	41	41
13.0	36	36
13.2	31	31
13.4	27	27
13.6	25	25
13.8	23	23
14.0	20	20
14.3	18	18
14.6	17	17
15.0	16	16
15.5	14	14
16.0	12	12
16.5	11	11
17.0	11	11
17.5	10	10
18.0	10	10
[illegible]	8	8
[illegible]	7	7
[illegible]	6	6
26.0	0	0

001765

P - Peak Flow * - value(s) provided from TR-55 system routines

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RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

PBR 23OCT1995

Project : Fernald OSDF GE3900-08.2 User: DWW Date: 10-16-95
County : State: Checked: _____ Date: _____
Subtitle: Flow off East Side of Final Cover - Graphical Method
Subarea : East

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
	Acres (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Impervious Areas				
Paved parking lots, roofs, driveways	-	-	-	27(98)
Total Area (by Hydrologic Soil Group)				27
				====

SUBAREA: East TOTAL DRAINAGE AREA: 27 Acres WEIGHTED CURVE NUMBER: 98*

* - Generated for use by GRAPHIC method

TIME OF CONCENTRATION AND TRAVEL TIME

Version 2.00

Project : Fernald OSDF GE3900-08.2 User: DWW Date: 10-16-95
County : State: Checked: ____ Date: _____
Subtitle: Flow off East Side of Final Cover - Graphical Method

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	2.55	90	0.05	E					0.117
Shallow Concent'd		60	0.1	U					0.003
Shallow Concent'd		290	0.17	U					0.012
								Time of Concentration =	0.13*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by GRAPHIC method

50/50

GRAPHICAL PEAK DISCHARGE METHOD

Version 2.00

DWW PBL 23OCT1995

Project : Fernald OSDF GE3400-08.2 User: DWW Date: 10-16-95
County : State: Checked: ____ Date: _____
Subtitle: Flow off East Side of Final Cover - Graphical Method

Data: Drainage Area : 27 * Acres
Runoff Curve Number : 98 *
Time of Concentration: 0.13 * Hours
Rainfall Type : II
Pond and Swamp Area : NONE

Storm Number	1
Frequency (yrs)	100
24-Hr Rainfall (in)	13
Ia/P Ratio	0.00
Used	0.10
Runoff (in)	12.76
Unit Peak Discharge (cfs/acre/in)	1.456
Pond and Swamp Factor 0.0% Ponds Used	1.00
Peak Discharge (cfs)	502

* - Value(s) provided from TR-55 system routines

13.6 Erosion Resistance: OSDF Perimeter Drainage Swale

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: EROSION RESISTANCE: OSDF PERIMETER DRAINAGE SWALE

Computations By: (Cognizant Engineer)
Signature _____ Date 23 OCT 95
Printed Name and Title DAVID W. WARREN, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature _____ Date 23 Oct 95
Printed Name and Title Kenneth W Cargill, Associate

Computations Checked by:
Signature _____ Date 23 OCT 1995
Printed Name and Title PATRICK B. RHODES, STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature _____ Date 23 OCT 95
Printed Name and Title DAVID W. WARREN, STAFF ENGINEER

Approved by: (PDP)
Signature _____ Date 10/23/95
Printed Name and Title Kara Olen, Asst Proj. Eng.

Approved by: (DTL and TETL)
Signature _____ Date 24 Oct 95
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	30% Submittal	24 Oct 95	NA	NA	NA
B	Changed Title of Page 1 to "Executive Summary"	13 DEC 95	DWW	PBR	[illegible]
—		—	—	—	—

Written by: DAVE WARREN Date: 13-Dec-95 Reviewed by: PBR Date: 13-DEC-1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

EROSION RESISTANCE: OSDF PERIMETER DRAINAGE SWALE

EXECUTIVE SUMMARY

Provided in this package are the analyses of the resistance of the topsoil in the perimeter drainage swale to erosion. The analyses are parametric studies to outline different combinations of topsoil texture and grass cover that meet the following criteria:

- Soil loss from the perimeter drainage swale due to sheet and rill erosion no greater than 5 tons/acre/year

- No formation of gullies from water erosion in the perimeter drainage swale during the 2000-year, 24-hour storm. Gullies could quickly erode away the topsoil and vegetative support layers in the swale, exposing the underlying biotic barrier.

Topsoil textures analyzed were as follows:

Soil Classification	
USDA	USCS
Silt Loam	ML
Clay Loam	CL
Loam	ML
Sandy Loam	SM
Loamy Sand	SM
Sand	SW
-	GM
-	GC

No specific grass cover types were analyzed. The grass covers were defined by percentage of ground covered, and by a "vegetal retardance class".

RESULTS:

All the topsoils analyzed will meet the erosion criteria, provided they have an adequate grass cover. The grass cover is the critical component for minimizing erosion. To meet the erosion criteria, the grass cover must be uniform and generally of sufficient strength to classify in vegetal retardance class "B". One subarea of the swale (A-4) required grass cover of sufficient strength to classify in vegetal retardance class "A" with all topsoils except clayey gravel (GC).

Written by: DAVE WARREN Date: 21-Oct-95 Reviewed by: PBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

PC 23 Oct 95

EROSION RESISTANCE - OSDF PERIMETER DRAINAGE SWALE:

COLLECTION AND VERIFICATION OF ENGINEERING DATA

Purpose: The purpose of this document is to identify a range of topsoil and grass cover conditions for the OSDF perimeter drainage swale to minimize sheet, rill, and gully erosion in accordance with the following criteria:

- rate of topsoil loss to sheet and rill erosion no greater than 5 tons/acre/year
- no excessive soil loss to sheet erosion over the design life of the OSDF (i.e., at least 200 years with continued effectiveness for up to 1000 years up to the extent practicable and reasonably achievable)
- the 2000-year, 24-hour storm will not cause gullies to form in the perimeter swale topsoil

Scope: The erosion resistance calculations are conducted as a parametric study in which the variable components are topsoil type and grass type and density. A window of various combinations of topsoil and grass conditions required to meet the above criteria are identified.

Two methods are implemented to evaluate erosion resistance:

1. The Modified Universal Soil Loss Equation (MUSLE); Caltrans (1992) to calculate the rate of soil loss due to sheet and rill erosion; and
2. The Tractive Force Method; Temple (1980) to calculate the potential for gullies to form in the topsoil from the 2000-year, 24-hour storm.

Written by: DAVE WARREN Date: 21-Oct-95 Reviewed by: PBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

KW 23Oct95

Collection and verification of the following data needed for these methods are discussed:

1. Modified Universal Soil Loss Equation
   - average annual rainfall energy
   - pertinent geometry (profiles and cross-sections) for OSDF perimeter drainage swale
   - topsoil textural classification according to USDA Classification System
   - grass cover type and density

2. Tractive Force Method
   - properties for the topsoil
     - classification according to USCS
     - topsoil plasticity index (PI)
     - void ratio
   - pertinent geometry (profiles and cross-sections) for OSDF perimeter drainage swale
   - rainfall and infiltration for the 2000-year, 24-hour storm
   - grass cover type and density

Written by: DAVE WARREN Date: 21-Oct-95 Reviewed by: PBR Date: 23 Oct 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

PC 23 Oct 95

COLLECTION AND VERIFICATION OF DATA FOR THE MODIFIED UNIVERSAL SOIL LOSS EQUATION (MUSLE):

1. Average annual rainfall energy.

The average annual rainfall energy (factor "R" in the MUSLE) is given in the Ohio SCS guidelines for "'Water Management and Sediment Control for Urbanizing Areas" (1987) as 175 for the OSDF area. See Figure 1.

2. Pertinent geometry (profiles and cross-sections) for study area.

The pertinent geometry of the OSDF perimeter drainage swale is shown on the design drawings for the Fernald OSDF, currently being prepared by GeoSyntec Consultants (1995a). For design, the perimeter drainage swale was divided into nine "subareas" (GeoSyntec, 1995b).. A ~~verbal~~ summary of the pertinent OSDF geometry is given below. The swale geometry is shown and summarized in Figure 2 and Table 1.

The slope lengths and inclinations of the OSDF perimeter drainage swale are used to determine the LS factor in the MUSLE. The equation for LS is shown in the calculations.

Table 1 - Pertinent Perimeter Swale Geometry and Flow Summary. From GeoSyntec (1995b)

Subarea	Length (ft)	Slope	Max Width (ft)	Max Depth (ft)	Max Flow (cfs)
East Swale					
A-1	1508	0.75%	40	2.5	171
A-2	1056	0.75%	50	3.0	311
A-3	1150	0.50%	56	3.5	395
A-4	555	1.28%	56	3.5	455
West Swale					
B-1	594	1.00%	40	2.5	46
B-2	234	0.88%	40	2.5	70
B-3	1282	0.75%	40	2.5	195
B-4	1012	0.75%	50	3.0	319
B-5	1200	0.50%	56	3.5	455

Written by: DAVE WARREN Date: 23 OCT 95 Reviewed by: ABL Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

OKFL 23 OCT 95

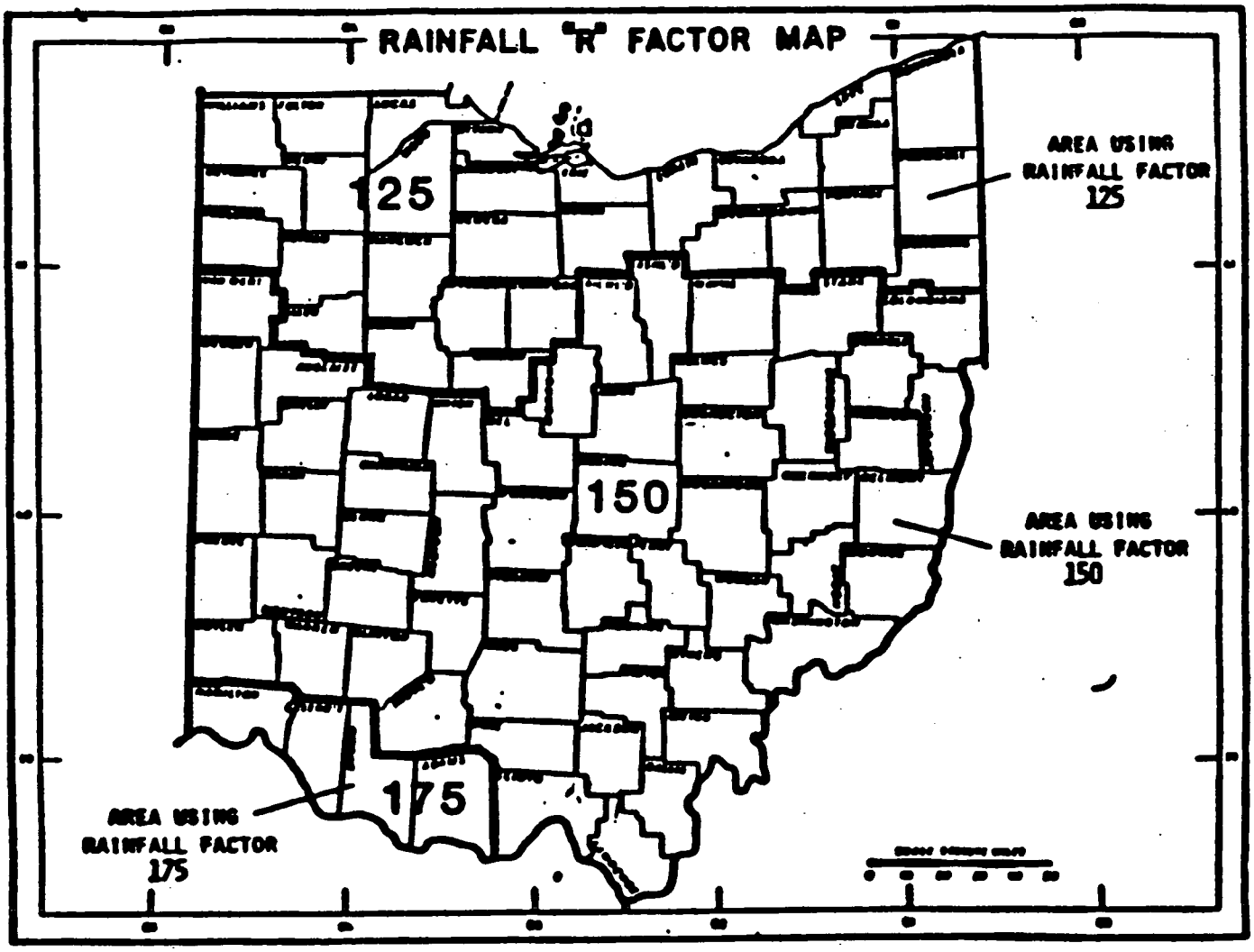
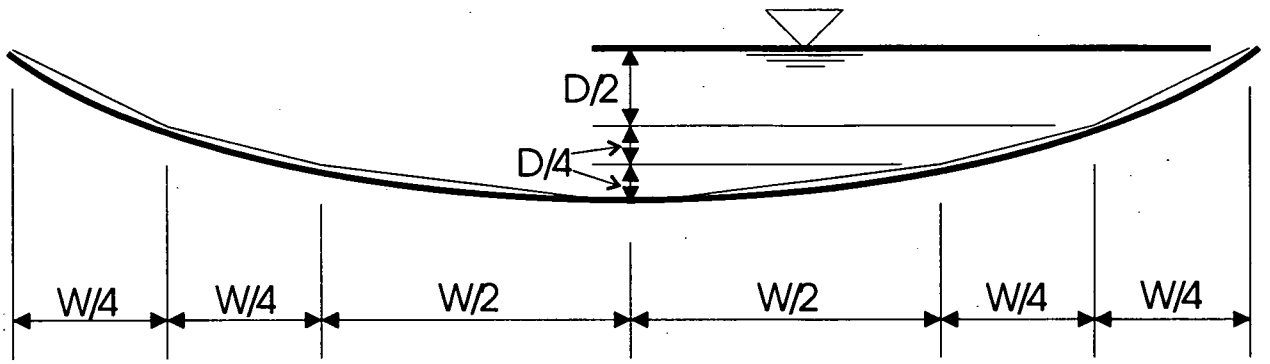


Figure 1 - Rainfall Energy Factor Map For Ohio. From Ohio SCS (1987)

Written by: DAVE WARREN Date: 23OCT95 Reviewed by: [illegible] Date: 23OCT1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

[illegible] 23 OCT 95



PERIMETER SWALE SUBAREA	W (ft)	D (ft)
A-1	40	2.5
A-2	50	3
A-3	56	3.5
A-4	56	3.5
B-1	40	2.5
B-2	40	2.5
B-3	40	2.5
B-4	50	3
B-5	56	3.5

Figure 2 - Typical Cross-Section of OSDF Perimeter Drainage Swale. Modified From GeoSyntec (1995b)

3. Topsoil textural classification according to U.S. Department of Agriculture (USDA) System.

The topsoil USDA classification is used to determine a soil erodability factor in the MUSLE. The soil erodability factors given by the Ohio SCS (1987) for different USDA soil textures are shown in Table 2. All soils shown in Table 2 will be analyzed to determine acceptable topsoil / grass cover combinations.

***Table 2** - Soil Erodability Factor Values For Different Topsoil Textures From Ohio SCS (1987)*

Topsoil Texture	Soil Erodability Factor Value
Silt Loam	0.37
Clay Loam	0.32
Loam	0.32
Sandy Loam	0.24
Loamy Sand	0.17
Sand	0.15

On-site materials may be used as topsoil in the OSDF perimeter drainage swale. Extensive geotechnical data from Parsons (1995b,c) exists for the soils under the OSDF area and north portion of the borrow area. The soils in these areas are glacial till, with the majority classifying as USCS Lean Clay (CL). Isolated portions of this soil that do not classify as CL generally classify as USCS Fat Clay (CH), Silt (ML), Silty Sand (SM), and Clayey Sand (SC). Some index information for these soils is shown in Table 5.

4. Grass cover type and density.

The grass cover type and density is used to estimate the vegetative measures, VM, factor in the MUSLE. Various values of the VM factor for different grass heights and percentages of ground covered by grass are shown in Figure 3, and summarized in Table 3.

***Table 3** - VM Factor Values For Grass Cover Densities (0% of grass taller than 0.5m)*

Percentage of ground covered with grass	VM factor (MUSLE)*
0%	0.45
20%	0.20
40%	0.10
60%	0.047
80%	0.029
95%	0.011

*From Caltrans (1992)

Written by: DAVE WARREN Date: 23OCT95 Reviewed by: RBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

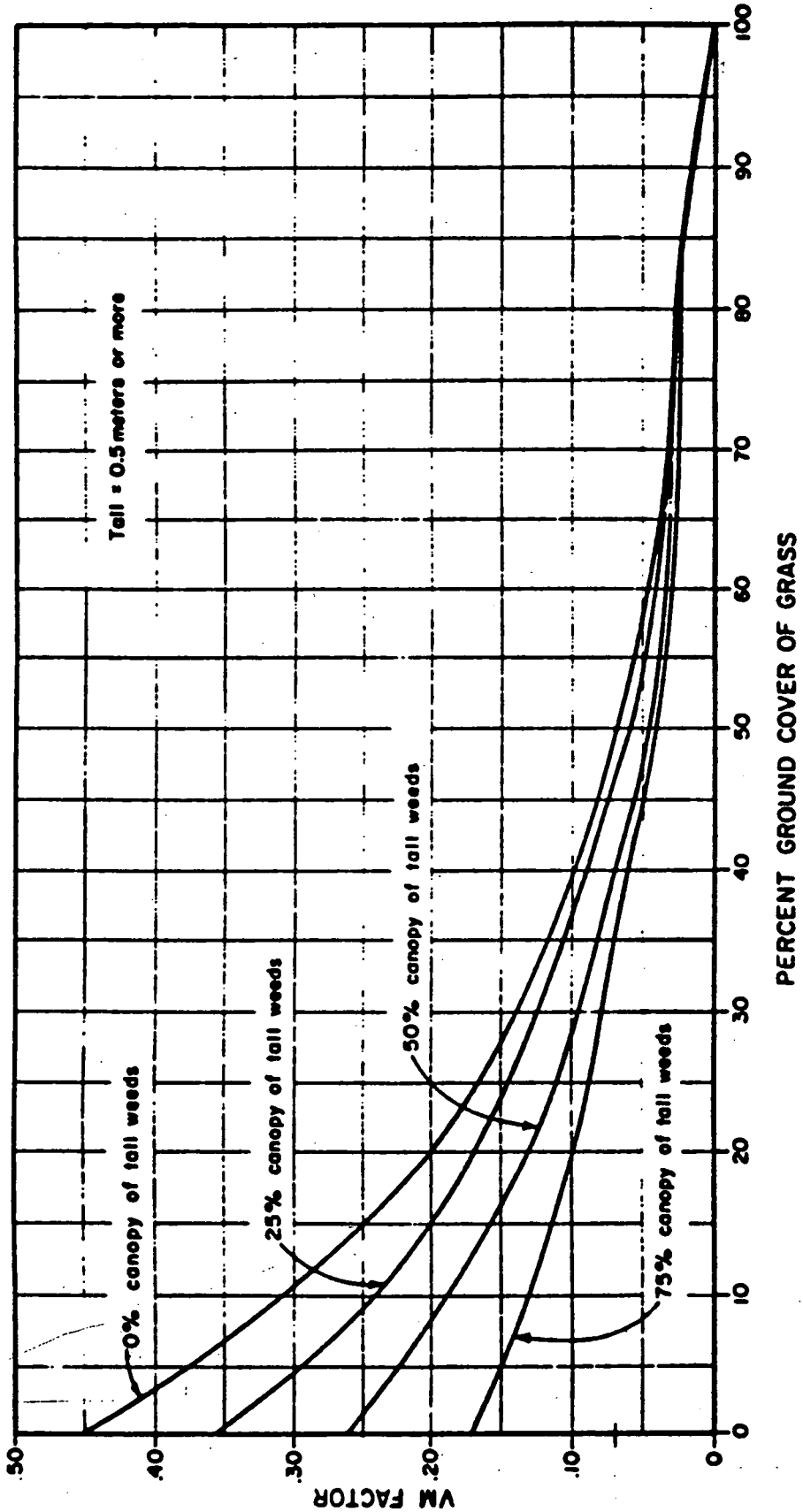


Figure 3 - VM Factor Values for Different Percentages of Grass Cover. From Caltrans (1992)

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COLLECTION AND VERIFICATION OF DATA FOR THE TRACTIVE FORCE METHOD:

1. Properties for the topsoil.

USCS Classification

The topsoil textural classifications were previously discussed in the collection and verification of data for the MUSLE. Schroeder et al. (1994) gives corresponding USCS classifications to the USDA soil textures listed in Table 3; these are shown in Table 4.

As mentioned in the collection and verification of data for the MUSLE, extensive geotechnical data from Parsons (1995b,c) exists for the soil under the OSDF area and north portion of the borrow area. The soil in these areas is glacial till, with the majority classifying as USCS Lean Clay (CL). Isolated portions of this soil that do not classify as CL generally classify as USCS Fat Clay (CH), Silt (ML), Silty Sand (SM), and Clayey Sand (SC).

Topsoil plasticity index (PI)

The topsoil PI will be used to in conjunction with the USCS soil classification to determine the allowable tractive force on the soil. PI data for soils in the OSDF and borrow area is shown in Table 5.

Topsoil void ratio

The topsoil void ratio will also be used in conjunction with the USCS soil classification to determine the allowable tractive force on the soil. The void ratio will be estimated from Schroeder et al. (1994), who give values of porosity for different soils based on degree of compaction and USDA textural classification (porosity can be converted to void ratio through a simple relation - see the calculations for further explanation). Porosity values are shown in Table 4.

2. Pertinent geometry (swale profiles and cross-sections) for study area.

See the collection and verification of data for the MUSLE.

3. Peak flow rates for the 2000-year, 24-hour storm

Peak flow rates in different subareas of the perimeter drainage swale for the 2000-year, 24-hour storm are shown in Table 1, and were determined in the swale design calculations (GeoSyntec, 1995b). For information, the rainfall depth from the 2000-year, 24-hour storm is 13 inches (Parsons, 1995a).

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Table 4 - Porosities and USCS Classifications for Different Topsoil USDA Textures. From Schroeder et al., 1994)

LOOSE SOILS

Classification			Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	USDA	USCS	vol/vol	vol/vol	vol/vol	cm/sec
1	CoS	SP	0.417	0.045	0.018	$1.0x10^{-2}$
2	S	SW	0.437	0.062	0.024	$5.8x10^{-3}$
3	FS	SW	0.457	0.083	0.033	$3.1x10^{-3}$
4	LS	SM	0.437	0.105	0.047	$1.7x10^{-3}$
5	LFS	SM	0.457	0.131	0.058	$1.0x10^{-3}$
6	SL	SM	0.453	0.190	0.085	$7.2x10^{-4}$
7	FSL	SM	0.473	0.222	0.104	$5.2x10^{-4}$
8	L	ML	0.463	0.232	0.116	$3.7x10^{-4}$
9	SiL	ML	0.501	0.284	0.135	$1.9x10^{-4}$
10	SCL	SC	0.398	0.244	0.136	$1.2x10^{-4}$
11	CL	CL	0.464	0.310	0.187	$6.4x10^{-5}$
12	SiCL	CL	0.471	0.342	0.210	$4.2x10^{-5}$
13	SC	SC	0.430	0.321	0.221	$3.3x10^{-5}$
14	SiC	CH	0.479	0.371	0.251	$2.5x10^{-5}$
15	C	CH	0.475	0.378	0.265	$1.7x10^{-5}$
16	Barrier Soil		0.427	0.418	0.367	$1.0x10^{-7}$
17	Bentonite Mat (0.6 cm)		0.750	0.747	0.400	$3.0x10^{-9}$
18	Municipal Waste (900 lb/yd³ or 312 kg/m³)		0.671	0.292	0.077	$1.0x10^{-3}$
19	Municipal Waste (channeling and dead zones)		0.168	0.073	0.019	$1.0x10^{-3}$
20	Drainage Net (0.5 cm)		0.850	0.010	0.005	$1.0x10^{-1}$
21	Gravel		0.397	0.032	0.013	$3.0x10^{-1}$
22	L*	ML	0.419	0.307	0.180	$1.9x10^{-5}$
23	SiL*	ML	0.461	0.360	0.203	$9.0x10^{-6}$
24	SCL*	SC	0.365	0.305	0.202	$2.7x10^{-6}$
25	CL*	CL	0.437	0.373	0.266	$3.6x10^{-6}$
26	SiCL*	CL	0.445	0.393	0.277	$1.9x10^{-6}$
27	SC*	SC	0.400	0.366	0.288	$7.8x10^{-7}$
28	SiC*	CH	0.452	0.411	0.311	$1.2x10^{-6}$
29	C*	CH	0.451	0.419	0.332	$6.8x10^{-7}$
30	Coal-Burning Electric Plant Fly Ash*		0.541	0.187	0.047	$5.0x10^{-5}$
31	Coal-Burning Electric Plant Bottom Ash*		0.578	0.076	0.025	$4.1x10^{-3}$
32	Municipal Incinerator Fly Ash*		0.450	0.116	0.049	$1.0x10^{-2}$
33	Fine Copper Slag*		0.375	0.055	0.020	$4.1x10^{-2}$
34	Drainage Net (0.6 cm)		0.850	0.010	0.005	$3.3x10^{-1}$

* Moderately Compacted

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Table 5 - Index Properties of Soils in the OSDF Area and Borrow Area. From Parsons (1995c).

General Stratum	USCS Group Symbol	Moisture Content (percent dry wgt)		Liquid Limit	Plasticity Index	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Specific Gravity		Number of Tests
		(range)	(avg)	(range)	(range)	(range)	(range)	(range)	(range)	(range)	(avg)	
Brown Till (0 - 5 ft)	CL	12-30	21	21-50	7-32	0-12	2-49	35-62	18-48	2.63-2.79	2.71	31
Brown Till (5 - 10 ft)	CL	3-21	14	22-49	7-28	0-23	1-33	30-69	20-46	2.69-2.79	2.74	37
Brown Till (10 - 15 ft)	CL	11-15	13	24-42	9-23	0-10	13-41	34-48	22-43	2.69-2.78	2.74	9
Gray Till	CL	9-21	14	19-33	7-17	0-17	15-39	32-53	14-38	2.67-2.79	2.72	69
Gray Till	CL-ML	11-17	13	17-19	4-6	0-8	7-42	36-49	18-22	2.69-2.77	2.73	3
Brown Till	CH	19-25	23	50-57	23-38	0-12	3-14	38-66	31-48	2.67-2.73	2.70	8
Brown Till	GC	-	-	28	13	26	25	27	22	-	2.73	1
Brown or Gray Till	ML	11-24	15	16-23	0-4	0-7	3-38	43-84	8-18	2.70-2.73	2.72	6
Brown or Gray Till	SM	9-24	16	-	-	0-14	43-71	13-42	4-20	2.70-2.75	2.72	7
Brown or Gray Till	SC	9-11	10	19-25	8-12	24-26	29-55	13-27	8-18	2.69-2.74	2.72	4
Brown or Gray Till	SC-SM	11-20	16	18-24	5-8	0-18	38-56	26-35	12-18	2.70-2.75	2.72	2
Great Miami Aquifer	SM	2-15	8	-	-	0-32	53-84	10-36	1-5	2.72-2.77	2.75	15
Great Miami Aquifer	SW-SM	3-5	4	-	-	21-37	54-69	7-10	1-2	2.76-2.79	2.78	3
Great Miami Aquifer	SP-SM	2-4	3	-	-	0 - 3	88-91	8-10	0	2.69-2.77	2.73	2

Data Sources: Phase II Investigation (PO-132) Data, Phase III Investigation (PO-140) Data

Notes:

1. Percent clay defined as those particles finer than (0.005 mm) (Reference ASTM D 422)

4. Grass cover type and density

The grass cover type and density is used to estimate two coefficients, C_I and C_F, which are used in determining the actual tractive force applied at the soil surface - water interface for given flow conditions. These coefficients are used in a curve fitting equation to the "vegetal retardance" curves shown in Figure 4. The curves in Figure 4 are separated into vegetal retardance classes (A-E). Values of C_I and C_F for average uniform stands of grasses corresponding to each vegetal retardance class are shown in Tables 6 and 7, respectively.

Four predominant soil groups in the OSDF area and borrow areas area identified in USDA (1982). They are Fincastle (FdA), Martinsville (McA), Raub (RdA), and Xenia (XfA). Table 8 lists recommended grasses for these soil groups. Kentucky bluegrass and tall fescue are listed as recommended grasses for all these soil groups.

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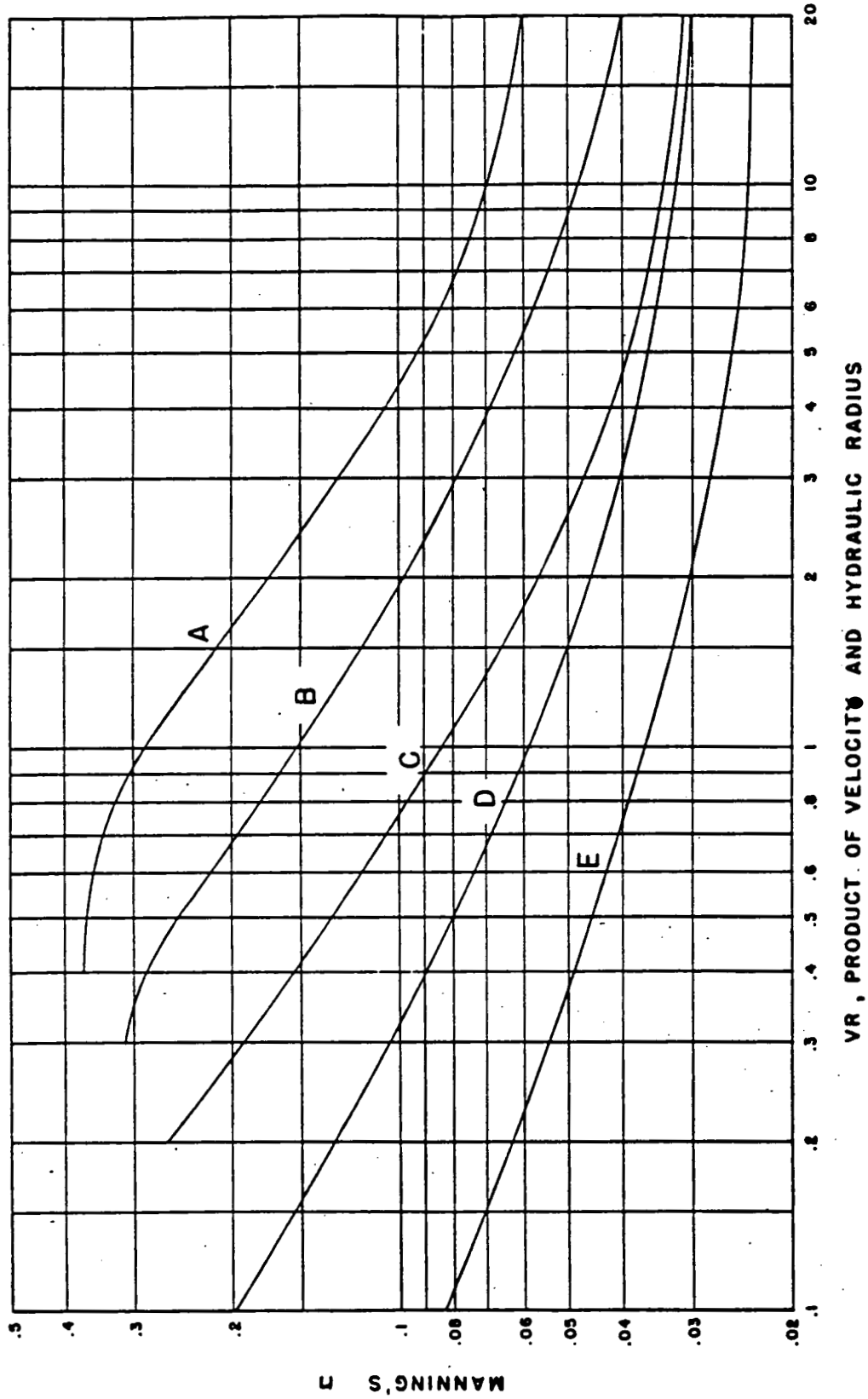

Figure 4 - "Vegetal Retardance Curves" for Average Uniform Stands of Grass Cover. From USDA (1986b).
See Tables 6 and 7 for more information on vegetal retardance classes "A" - "E".

Table 6 - Values of C_I for Average Uniform Stands of Grass. From Temple (1980).

Retardance curve index, C_I	Retardance class	Cover	Condition
10.0	A	Weeping lovegrass	Excellent stand, tall, (average 30 in.)
		Yellow bluestem Ischaemum	Excellent stand, tall, (average 36 in.)
7.643	B	Kudzu	Very dense growth, uncut
		Bermudagrass	Good stand, tall, (average 12 in.)
		Native grass mixture (little bluestem, blue grama, and other long and short midwest grasses)	Good stand, unmowed
		Weeping lovegrass	Good stand, tall, (average 24 in.)
		Lespedeza sericea	Good stand, not woody, tall (average 19 in.)
		Alfalfa	Good stand, uncut, (average 11 in.)
		Weeping lovegrass	Good stand, mowed, (average 13 in.)
		Kudzu	Dense growth, uncut
		Blue grama	Good stand, uncut, (average 13 in.)
5.601	C	Crabgrass	Fair stand, uncut (10 to 48 in.)
		Bermudagrass	Good stand, mowed (average 6 in.)
		Common lespedeza	Good stand, uncut (average 11 in.)
		Grass-legume mixture—summer (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6 to 8 in.)
		Centipedegrass	Very dense cover (average 6 in.)
		Kentucky bluegrass	Good stand, headed (6 to 12 in.)
4.436	D	Bermudagrass	Good stand, cut to 2.5-in. height
		Common lespedeza	Excellent stand, uncut (average 4.5 in.)
		Buffalograss	Good stand, uncut (3 to 6 in.)
		Grass-legume mixture—fall, spring (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (4 to 5 in.)
		Lespedeza sericea	After cutting to 2-in. height. Very good stand before cutting.
2.876	E	Bermudagrass	Good stand, cut to 1.5 in. height
		Bermudagrass	Burned stubble.

*Reproduced from USDA, SCS (1954) with a column added for curve index values.

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Table 7 - Values of C_F for Average Uniform Stands of Grass. From Temple (1980).

Cover		Cover factor, C_F	Slope range‡, percent	Permissible velocity: Erosion resistant soils ($\tau_a \simeq 0.034$ lb/ft^2) ft/s	Permissible velocity: Easily eroded soils ($\tau_a \simeq 0.020$ lb/ft^2) ft/s
Bermudagrass	.....	0.9	0-5	8	6
			5-10	7	5
			over 10	6	4
Buffalograss, Kentucky bluegrass, Smooth brome, Blue grama	.....	0.87	0-5	7	5
			5-10	6	4
			over 10	5	3
Grass mixture	.....	0.75	0-5‡	5	4
			5-10	4	3
Lespedeza sericea, Weeping lovegrass, Yellow bluestem, Kudzu, Alfalfa, Crabgrass	.....	0.5	0-5§	3.5	2.5
Common lespedeza‖, Sudangrass‖	.....	0.5	0-5#	3.5	2.5

• Reproduced from USDA, SCS (1954) with C_F and τ_a values added. Footnotes are as they appear on the original.

† Use velocities exceeding 5 ft/s only where good covers and proper maintenance can be obtained.

‡ Do not use on slopes steeper than 10 percent except for side slopes in a combination channel.

§ Do not use on slopes steeper than 5 percent except for side slopes in a combination channel.

‖ Annuals—used on mild slopes or as temporary protection until permanent covers are established.

Use on slopes steeper than 5 percent is not recommended.

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Table 8 - Recommended Grasses for Planting in Soil Series in Hamilton County, Ohio. From USDA (1982)

Soil name and map symbol	Vines and ground cover	Shrubs	Trees	Grasses and legumes
EeB, EeC, EeD*: Eden	Cotoneaster, English ivy, myrtle, winter creeper, juniper.	Amur privet, redosier dogwood, Japanese yew, Tatarian honeysuckle.	Eastern redcedar, Norway maple, thornless honeylocust, radiant crabapple, yellow-poplar, Scotch pine.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
Urban land.				
EpA, EpB2, EpC2 Eldean	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily.	Leatherleaf viburnum, juniper, serviceberry.	Black walnut, eastern white pine, red pine, thornless honeylocust, white oak, yellow-poplar.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
ErA, ErB*: Eldean	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily.	Leatherleaf viburnum, juniper, serviceberry.	Black walnut, eastern white pine, red pine, thornless honeylocust, yellow-poplar, white oak.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
Urban land.				
FdA Fincastle	Bugleweed, goutweed, lily turf, plantain lily, yellow root, sweet woodruff.	Arrowwood, bottlebrush buckeye, red chokecherry, Amur privet, redosier dogwood.	Sweetgum, yellow-poplar, white ash, red maple, swamp white oak, London plane tree.	Kentucky bluegrass, redtop, tall fescue.
FeA*: Fincastle	Bugleweed, goutweed, lily turf, plantain lily, yellow root, sweet woodruff.	Arrowwood, bottlebrush buckeye, red chokecherry, Amur privet, redosier dogwood.	Sweetgum, yellow-poplar, white ash, red maple, swamp white oak, London plane tree.	Kentucky bluegrass, redtop, tall fescue.
Urban land.				
FoA, FoB2 Fox	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily.	Leatherleaf viburnum, juniper, serviceberry.	Eastern white pine, red pine, thornless honeylocust, white oak, yellow-poplar, white ash.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
FpA*: Fox	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily.	Leatherleaf viburnum, juniper, serviceberry.	Eastern white pine, red pine, thornless honeylocust, white oak, yellow-poplar, white ash.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
Urban land.				
Gn Genesee	Lilyofthevalley, pachysandra, myrtle, plantain lily.	Bayberry, redosier dogwood, nannyberry viburnum, Amur privet.	Eastern cottonwood, locust, Norway maple.	Red fescue, Kentucky bluegrass, tall fescue.
Go*: Genesee	Lilyofthevalley, pachysandra, myrtle, plantain lily.	Bayberry, redosier dogwood, nannyberry viburnum, Amur privet.	Eastern cottonwood, locust.	Red fescue, Kentucky bluegrass, tall fescue.
Urban land.				

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Table 8 - Continued

Soil name and map symbol	Vines and ground cover	Shrubs	Trees	Grasses and legumes
HeF---------- Hennepin	Plantain lily, juniper, Hall honeysuckle, creeping speedwell.	Juniper----------	Thornless honeylocust	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
HoA---------- Henshaw	Goutweed, bugleweed, European wild ginger, sweet woodruff, yellow root.	Arrowwood, red chokecherry, redosier dogwood, Amur privet.	Sweetgum, yellow-poplar, eastern cottonwood, red maple, silver maple, white ash.	Kentucky bluegrass, redtop, tall fescue.
Hu---------- Huntington	Forsythia, lilyofthevalley, myrtle, pachysandra, plantain lily.	Bayberry, dogwood, nannyberry viburnum, Amur privet.	Norway maple, thornless honeylocust, black walnut, yellow-poplar.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
Ju---------- Jules	Plantain lily, juniper, Hall honeysuckle.	Juniper, nannyberry viburnum.	Honeylocust, American sycamore, eastern cottonwood, Washington hawthorn.	Red fescue, Kentucky bluegrass, tall fescue.
Lg---------- Lanier	Hall honeysuckle, juniper, plantain lily.	Juniper, nannyberry viburnum.	Honeylocust, American sycamore, eastern cottonwood, Washington hawthorn.	Red fescue, Kentucky bluegrass, tall fescue.
MaB, MaC2, MaD2, MaE2- Markland	European wild ginger, sweet woodruff, lilyofthevalley, myrtle, creeping thyme.	Red chokecherry, Amur privet, redosier dogwood, mockorange.	Eastern white pine, red pine, white oak, yellow-poplar.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
McA, McB---------- Martinsville	Creeping thyme, Hall honeysuckle, juniper, moss pink, plantain lily.	Forsythia, leatherleaf viburnum, serviceberry, Japanese yew.	Eastern white pine, thornless honeylocust, red pine, white oak, yellow-poplar, black walnut.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
MnC2---------- Miamian	Forsythia, lilyofthevalley, myrtle, pachysandra, plantain lily.	Amur privet, redosier dogwood, Japanese yew, nannyberry viburnum.	Radiant crabapple, Norway maple, thornless honeylocust, yellow-poplar, eastern white pine.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
MoD2, MoE2*: Miamian----------	Forsythia, lilyofthevalley, myrtle, pachysandra, plantain lily.	Amur privet, redosier dogwood, Japanese yew, nannyberry viburnum.	Radiant crabapple, Norway maple, thornless honeylocust, yellow-poplar, eastern white pine.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
Hennepin----------	Plantain lily, juniper, Hall honeysuckle, creeping speedwell.	Juniper----------	Thornless honeysuckle	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
MuC*: Miamian----------	Forsythia, lilyofthevalley, myrtle, pachysandra, plantain lily.	Amur privet, redosier dogwood, Japanese yew, nannyberry viburnum.	Radiant crabapple, Norway maple, thornless honeylocust, yellow-poplar, eastern white pine.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.

See footnote at end of table.

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Table 8 - Continued

Soil name and map symbol	Vines and ground cover	Shrubs	Trees	Grasses and legumes
MuC*: Urban land.				
PbB2, PbC2, PbD, PbE-- Parke----------	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily, English ivy.	Forsythia, leather-leaf viburnum, serviceberry, Japanese yew.	Eastern white pine, thornless honey-locust, red pine, white oak, yellow-poplar, black walnut.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
PcB, PcC*: Parke----------	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily, English ivy.	Forsythia, leather-leaf viburnum, serviceberry, Japanese yew.	Eastern white pine, thornless honey-locust, red pine, white oak, yellow-poplar, black walnut.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
Urban land.				
PfC, PfD, PfE--------- Pate	Plantain lily, lily turf, yellow root, sweet woodruff, juniper.	Amur privet, redosier dogwood, Japanese yew.	Eastern white pine, Norway maple, radiant crabapple, thornless honey-locust, yellow-poplar.	Red fescue, Kentucky bluegrass, crownvetch, tall fescue.
PhD*: Pate----------	Plantain lily, lily turf, yellow root, sweet woodruff, juniper.	Amur privet, redosier dogwood, Japanese yew.	Eastern white pine, Norway maple, radiant crabapple, thornless honey-locust, yellow-poplar.	Red fescue, Kentucky [illegible], crownvetch, fescue.
Urban land.				
Pn---------- Patton	Bugleweed, fern, plantain lily, yellow root, gout-weed, sweet woodruff.	Red chokecherry, Amur privet, inkberry, mockorange.	Red maple, silver maple, sweetgum, swamp white oak, white ash.	Redtop, reed canarygrass, tall fescue, Kentucky bluegrass.
PrA, PrB, PrC2-------- Princeton	Creeping speedwell, Hall honeysuckle, juniper, moss pink, plantain lily.	Forsythia, juniper, nannyberry viburnum, serviceberry.	Eastern white pine, red pine, white oak, yellow-poplar, black walnut.	Kentucky bluegrass, red fescue, crownvetch, tall fescue.
RdA---------- Raub	Goutweed, bugleweed, plantain lily.	Arrowwood, red chokecherry, redosier dogwood.	Sweetgum, red maple, silver maple, poplar.	Redtop, tall fescue, Kentucky bluegrass.
Rn---------- Ross	Juniper, plantain lily.	Juniper, nannyberry viburnum.	Honeylocust, black locust, Washington hawthorn, American sycamore.	Red fescue, Kentucky bluegrass, tall fescue.
RpA, RpB2, RpC2------- Rossmoyne	Phlox, honeysuckle, lilyofthevalley, pachysandra, plantain lily, winter creeper.	Red chokecherry, Amur privet, mockorange, inkberry, redosier dogwood.	Eastern white pine, red maple, sweetgum, silver maple, yellow-poplar.	Redtop, Kentucky bluegrass, tall fescue, crownvetch.

See footnote at end of table.

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Table 8 - Continued

Soil name and map symbol	Vines and ground cover	Shrubs	Trees	Grasses and legumes
UmB, UmC*: Urban land.				
Martinsville	Creeping thyme, Hall honeysuckle, juniper, moss pink, plantain lily.	Bayberry, redosier dogwood, nannyberry viburnum, Amur privet.	Norway maple, thornless honey-locust, black walnut, yellow-poplar.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
Uo*: Urban land.				
Patton	Bugleweed, European wild ginger, gout-weed, yellow root.	Red chokecherry, redosier dogwood, spice bush, common winterberry.	Red maple, swamp white oak, eastern cottonwood.	Redtop, reed canarygrass.
UrB*: Urban land.				
Rossmoyne	Phlox, honeysuckle, lilyofthevalley, pachysandra, winter creeper.	Red chokecherry, Amur privet, mockorange, inkberry, redosier dogwood.	Eastern white pine, red maple, sweetgum, silver maple.	Tall fescue, redtop, Kentucky bluegrass, crownvetch.
Ux*: Urban land.				
Stonelick	Plantain lily, juniper, moss pink, creeping speedwell.	Leatherleaf viburnum, juniper, service-berry.	Eastern white pine, red pine, white oak, black walnut.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
Wa Wakeland	Goutweed, bugleweed, European wild ginger, sweet woodruff.	Red chokecherry, redosier dogwood, spice bush, common winterberry.	Red maple, river birch, swamp white oak.	Redtop, red fescue, tall fescue.
WbA Warsaw Variant	Plantain lily, juniper, moss pink, creeping thyme.	Leatherleaf viburnum, juniper, service-berry.	Eastern white pine, red pine, white oak, black walnut.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
WeA Wea	Forsythia, lilyofthe-valley, pachysandra.	Leatherleaf viburnum, juniper, service-berry.	Eastern white pine, red pine, white oak, black walnut.	Tall fescue, red fescue, Kentucky bluegrass, crownvetch.
WhA Whitaker	Goutweed, bugleweed, European wild ginger, sweet woodruff, lily turf, yellow root.	Arrowwood, red choke-cherry, redosier dogwood, Amur privet, spice bush.	Sweetgum, poplar, red maple, swamp white oak, London plane tree.	Kentucky bluegrass, redtop, tall fescue.
XfA, XfB2 Xenia	Forsythia, lilyofthe-valley, myrtle, pachysandra, winter creeper.	Forsythia, juniper, nannyberry viburnum, serviceberry.	Eastern white pine, red pine, white oak, yellow-poplar.	Tall fescue, Kentucky bluegrass, crownvetch.

* See description of the map unit for composition and behavior characteristics of the map unit.

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EROSION RESISTANCE - OSDF PERIMETER DRAINAGE SWALE

CALCULATIONS

Purpose: The purpose of these calculations is to determine combinations of topsoil and vegetative cover that will provide required erosion resistance in the On-Site Disposal Facility Perimeter Drainage Swale.

Scope: Parametric study of various topsoil types and vegetation types to calculate various volumes of sediment eroded from the topsoil lining the OSDF perimeter drainage swale in sheet and rill erosion. The Modified Universal Soil Loss Equation (MUSLE) (Caltrans, 1992) is the method used. The MUSLE is different from the Universal Soil Loss Equation (USLE); in that it is used to calculate soil loss from non-agricultural lands.

Parametric study of various topsoil types and vegetation types to calculate the potential for gullies to form in the OSDF perimeter drainage swale from the 2000-year, 24-hour design storm using the "Tractive Force Method". This method was developed by Temple (1980) for swales, and modified for slopes in USDOE (1989).

Design: The following requirements govern the selection of topsoil and vegetative cover:

1. Rate of soil loss due to sheet and rill erosion no greater than 5 tons/acre/year [Ohio Administrative Code, 3745-27-08 (C)(15)(f)]
2. No formation of gullies from erosion during the 2000-year, 24-hour storm (USDOE, 1989).

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PRELIMINARY DISCUSSION-

Sheet erosion, rill erosion, and gully erosion are discussed in Maidment (1992) and USDOE (1989). Sheet erosion will occur as a result of raindrops impacting soil. Concentrated sheet flow (shallow concentrated flow) over the soil can cause rills, or very small gullies, to form (rill erosion). Sheet and rill erosion will occur to some degree in all topsoil - vegetative cover combinations, regardless of the erosive resistance. If shallow concentrated flow is strong enough to exceed the allowable tractive force of the topsoil and vegetation, gullies will form (gully erosion). Gully erosion can quickly wear away the topsoil and vegetative support layers in the OSDF final cover and perimeter drainage swale, exposing the biotic barrier. As shown below, if the soil loss to sheet and rill erosion is kept below 5 tons/acre/year, the biotic barrier will not be exposed by sheet and rill erosion within, 980 years.

The calculations will proceed in the following sequence:

1. Estimate the rate of topsoil loss to sheet and rill erosion from the perimeter drainage swale for different topsoil and vegetative cover combinations using the MUSLE.

2. Evaluate the potential for gully erosion on different sections of the perimeter drainage swale for different topsoil and vegetative cover combinations using the tractive force method.

3. Outline topsoil - vegetative cover combinations that are found satisfactory in both steps 1 and 2.

Note - Time to Expose Biotic Barrier:
The topsoil and vegetative support layer in the perimeter drainage swale are 6 in and 21 in thick, respectively, totaling 27 in (2.25 ft). Assuming the unit weight of the soil in these layers is 100 lbs/ft^3:

Topsoil and vegetative support layer - weight per unit area = 100 lb/ft^3 x 2.25 ft = 225 lb/ft^2

Soil loss rate = (5 tons/acre/year) x (2000 lb/ton) / (43,560 ft^2/acre) = 0.23 lb/ft^2/year

(225 lb/ft^2) / (0.23 lb/ft^2/year) = **980 years**

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SECTION 1 - ESTIMATE RATE OF TOPSOIL LOSS FROM THE OSDF PERIMETER DRAINAGE SWALE DUE TO SHEET AND RILL EROSION, FOR DIFFERENT COMBINATIONS OF TOPSOIL AND GRASS COVER

Method: The Modified Universal Soil Loss Equation (MUSLE) is (Caltrans, 1992):

$$A = R \times K \times LS \times VM$$

STEP 1:

Find rainfall erosivity factor, R.

R = 175 (see collection and verification of data)

STEP 2:

Find combined field length and slope factor, LS.

Use the equation for LS from Caltrans (1992):

$$LS = \left(\frac{650 + 450S + 65S^2}{10000 + S^2}\right)\left(\frac{L}{72.6}\right)^m$$

Where:

L = Slope length

S = Slope grade (%)

m = 0.3 for slope grades of 0 to 0.5%; 0.5 for slope grades of 0.51 to 10%; 0.6 for slope grades > 10%

Pertinent perimeter swale geometry is shown in Figure 2 and Table 1. Compare LS for flow paths along east and west swale and LS for sides of swale (sides of maximum swale cross-section). Use the larger LS.

A. LS for paths along swale (see Table 1 for swale geometry).

East Swale:					West Swale:				
Subarea	Length (ft)	Slope	m	**LS**	Subarea	Length (ft)	Slope	m	**LS**
A-1	1508	0.75%	0.5	0.467	B-1	594	1.00%	0.5	0.333
A-2	1056	0.75%	0.5	0.391	B-2	234	0.88%	0.5	0.197
A-3	1150	0.50%	0.5	0.355	B-3	1282	0.75%	0.5	0.430
A-4	555	1.28%	0.5	0.368	B-4	1012	0.75%	0.5	0.382
					B-5	1200	0.50%	0.5	0.362
TOTAL	4269	0.752%*	0.5	**0.786**	**TOTAL**	4322	0.722%*	~~0.3~~ 0.5	~~0.344~~ 0.778

*weighted average

B. LS for swale sides at maximum cross - section(see Figure 2 for swale geometry).

Section	Length (ft)	Slope	m	LS
Bottom	14.03	6.25%	0.5	0.223
Middle	7.05	12.5%	0.6	0.399
Top	7.22	25%	0.6	**1.237**
TOTAL	4269	0.752%*	0.5	**0.929**

*weighted average

C. Find LS

LS = maximum LS calculated above (for individual and combined slopes) = **1.237**

STEP 3:

Find required combinations of soil texture and percentage of grass cover that result in no greater than 5 tons/acre/year or less of soil being eroded away.

Soil Texture: Determines the "Soil erodability factor": K

Grass Cover Consistency: Vegetative measures factor, VM;

Sources of values for the coefficients K and VM are discussed in the collection and verification of data.

Values of Soil Lost to Erosion in Tons/Acre/Year For Different Soil/Vegetation Combinations As Calculated by the Modified Universal Soil Loss Equation (R = 175, LS = 1.237)

Vegetation:		Grass					
Percent Ground Cover:		0%	20%	40%	60%	80%	95%
VM:		**0.45**	**0.2**	**0.1**	**0.047**	**0.029**	**0.011**
Topsoil	**K**						
Silt Loam	**0.37**	36.0	16.0	8.0	3.8	2.3	0.9
Clay Loam	**0.32**	31.2	13.9	6.9	3.3	2.0	0.8
Loam	**0.32**	31.2	13.9	6.9	3.3	2.0	0.8
Sandy Loam	**0.24**	23.4	10.4	5.2	2.4	1.5	0.6
Loamy Sand	**0.17**	16.6	7.4	3.7	1.7	1.1	0.4
Sand	**0.15**	14.6	6.5	3.2	1.5	0.9	0.4

The highlighted values in the previous table show acceptable topsoil texture and grass cover combinations (i.e., yielding a soil loss rate to sheet and rill erosion no greater than 5 tons/acre/year). As calculated by the MUSLE, a grass ground cover of at least 60 percent will result in no more than 5 tons/acre/year of soil loss, for a topsoil with at least the erosion resistance of silt loam.

Local soils identified in the soil survey of Hamilton County, Ohio generally have silt loam topsoil, with subsoils ranging from sandy loam to clay loam (USDA, 1982). Kentucky bluegrass [identified as having very good erosion resistance in USDOE (1989)] and tall fescue are recommended grasses for all local soils and for most all soil series in Hamilton County (USDA, 1982). See the collection and verification of data for more information.

One point about topsoil: Caldwell and Reith (1993, p.94-95) recommend "clump grass in vegetated gravelly soil" as the vegetated cover "erosion barrier with the most significant advantages. No K factor values were given for gravelly soil in the MUSLE reference used, but Caldwell and Reith, and the trend in the erosion rate solutions indicate that the erosion resistance of gravelly soil will be greater than sand. Gravelly soil may not be needed to achieve acceptable soil loss rates to sheet and rill erosion, but may be necessary to help prevent the formation of gullies from the 2000-year, 24-hour storm, analyzed in the next section.

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SECTION 2 - EVALUATE THE POTENTIAL FOR GULLIES TO FORM IN THE TOPSOIL OF THE OSDF PERIMETER DRAINAGE SWALE FROM THE 2000-YEAR, 24-HOUR STORM

Method: Use the "Tractive Force Method", (Temple, 1980).

STEP 1:

Find allowable tractive force for bare topsoil, τ_a.

A. Estimate pertinent soil index properties of topsoil.

1. Background

The results of Section 1 show that most any texture of topsoil, provided it can support a dense grass cover, will yield acceptable soil loss rates to sheet and rill erosion. On-site topsoils may be used for the OSDF final cover. Generally, the topsoils on the site are silt loam (ML) (USDA, 1982). Generally, the subsoils on the site are mostly CL, with small quantities of CH, ML and SM (Parsons, 1995b,c). Furthermore, Caldwell and Reith (1992) indirectly state that adding gravel to topsoils can increase the soils' erosion resistance.

Evaluate resistance to gully formation for a set of soils that encompases the range of classifications outlined in the above paragraph.

2. USCS Classifications

Figure 5 shows the basic allowable tractive stress for different USCS soil classifications (including those common to the site). As interpreted from Figure 5:

USCS Soil Classification	Resistance to Gully Formation
ML,OL,SM	Low
GM,CL,SC	Moderate
CH	High
GC	Very High

USCS soil types corresponding to all USDA soil textures analyzed in Section 1 are shown below:

Soil Classification	
USDA	USCS
Silt Loam	ML
Clay Loam	CL
Loam	ML
Sandy Loam	SM
Loamy Sand	SM
Sand	SW

Based on the information in the previous tables, analyze the tractive force for ML, SM, GM, CL, and GC. This will encompass the range of different erosion resistances achievable.

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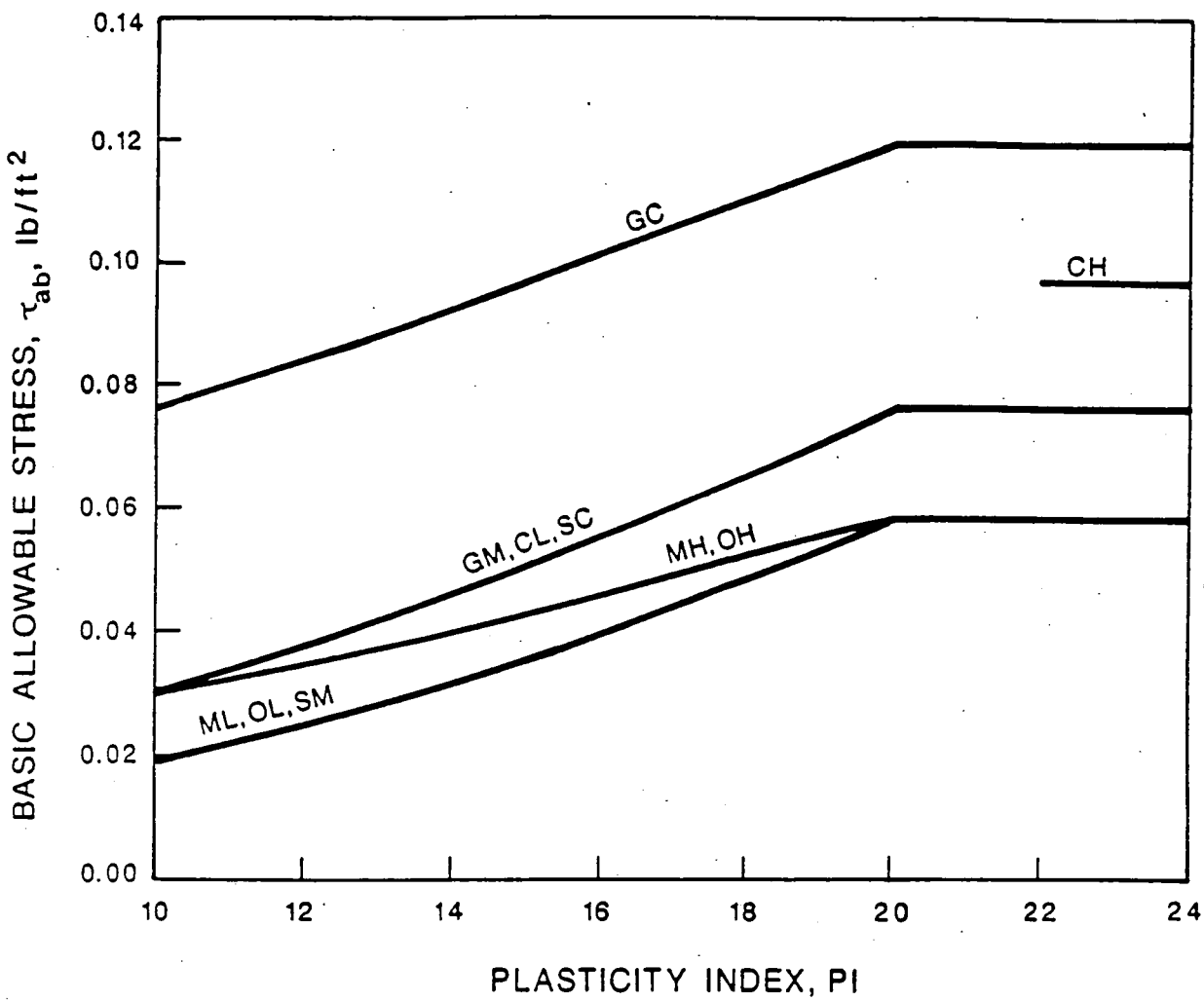

Figure 5 - Graph for Determining, τ_{ab} (from USDOE,1989)

3. Plasticity Index (PI)

PI's from the site geotechnical data and from the USCS definitions are shown below. See the collection and verification of data for more detailed information.

Soil Type	Plasticity Index (PI)		
	Range from Site Data	USCS Minimum	**PI to use**
ML	0 - 4 (6*)	0	**0**
SM	0 (7*)	0	**0**
GM	NA	0	**0**
CL	7 - 32 (146*)	7	**10**
GC	13 (1*)	7	**10**

*Number of samples

The PI to use is a conservative (low) estimate of what the PI will be. From Figure 5, it can be seen that a lower PI will yield less allowable stress.

4. Void Ratio (e)

Typical porosities for several loose soils (i.e., topsoils), based on USDA textures. These are shown in Table 5, and below:

Soil Type		Porosity,	Void
USDA	USCS	n	Ratio, e
Silt Loam	ML	0.501	1.00
Clay Loam	CL	0.464	0.866
Loam	ML	0.463	0.862
Sandy Loam	SM	0.453	0.828
Loamy Sand	SM	0.437	0.776
Sand	SW	0.437	0.776
Loamy Sand*	GM	0.437*	0.776
Sandy Clay*	GC	0.430*	0.754

USCS Soil Type	**Void Ratio To Use**
ML	**1.00**
SM	**0.828**
GM	**0.776**
CL	**0.866**
GC	**0.754**

*Chosen based on judgment as to what USDA soils would most closely correspond to GM and GC

Note that $e = \frac{n}{1-n}$

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B. Estimate allowable tractive force for bare topsoil (τ_a):

The tractive force method in USDOE (1989) uses two equations; one for coarse-grained soils and one for fine-grained soils. All soils evaluated should be relatively fine-grained because they have to support a good grass cover. Note that as interpreted from the equations in USDOE (1989), GM and GC can be considered either coarse-grained or fine-grained soils. The equation in USDOE (1989) for fine-grained soils is:

$$\tau_a = \tau_{ab} C_e^2 \quad \text{(USDOE, 1989)}$$

RESULTS:

Soil	PI	τ_{ab} (Figure 5)	e	C_e (Figure 6)	τ_a
ML	0	0.02 psf*	1.00	0.91	**0.016 psf**
SM	0	0.02 psf*	0.828	0.915	**0.017 psf**
GM	0	0.03 psf*	0.776	0.96	**0.027 psf**
CL	10	0.03 psf	0.866	0.99	**0.029 psf**
GC	10	0.075 psf	0.754	0.95	**0.068 psf**

*τ_{ab} assumed to be same as that for soil with PI=10 because Temple (1980) gives τ_a=0.02 psf for "easily erodable soils", which corresponds to τ_{ab} for ML and SM at PI=10 on Figure 4.

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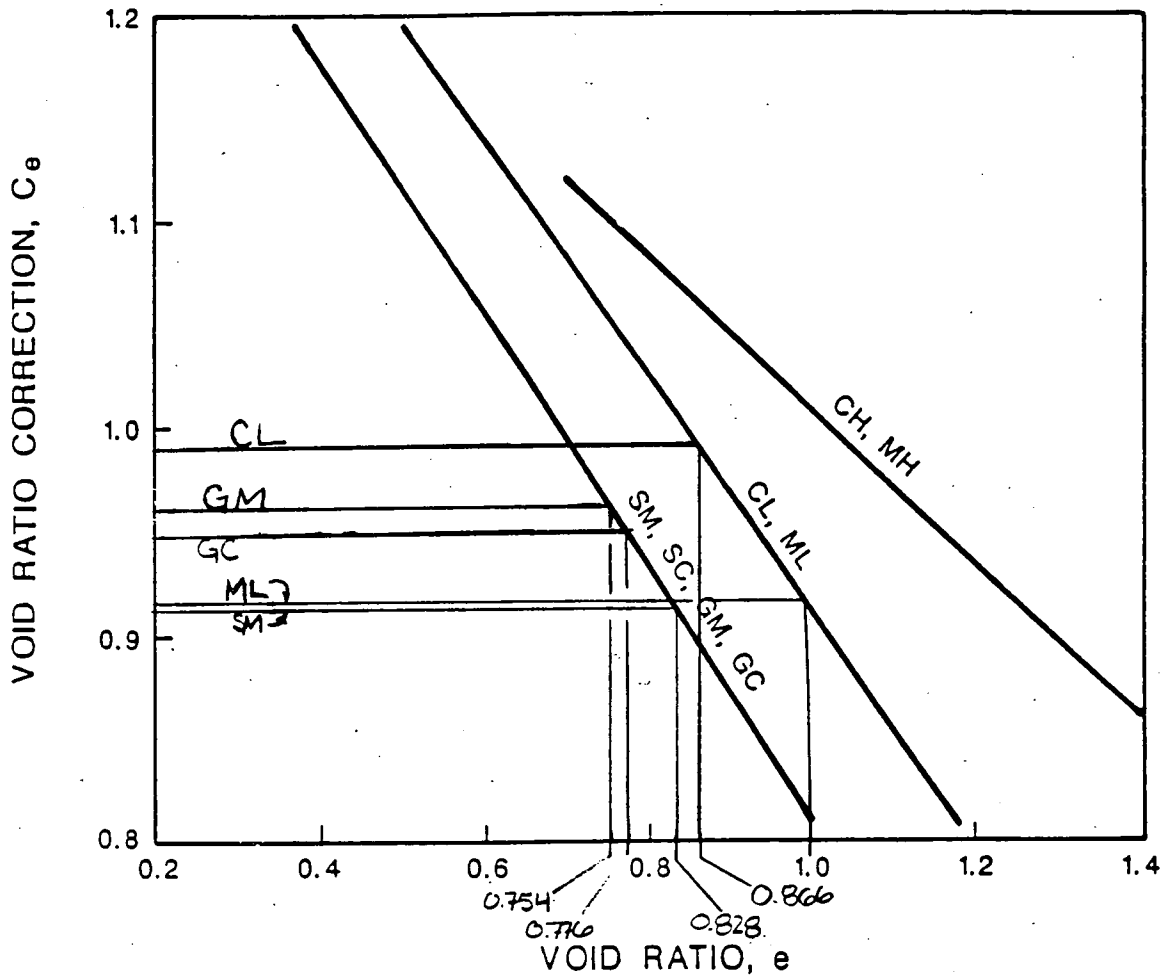

Figure 6 - Graph for Determining C_e (from USDOE,1989)

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STEP 2:

Calculate the "effective tractive force", τ_e, in each swale subarea, using the method of Temple (1980), as outlined below.

A. Given: Swale geometry
- -swale subarea length
- -swale maximum width
- -swale maximum depth
- -swale slope, S_o

Maximum flow in swale subarea

Vegetal parameters C_I and C_F that correspond to retardance classes "A - E" (see Tables 7 and 8)

Soil resistance coefficient, $n_s = 0.0156$ for fine-grained soils (Temple, 1980)

Unit weight of water = 62.4 pcf

B. Guess at a value for Manning's roughness coefficient, n

C. Calculate $AR_h^{2/3}$ from Manning's formula:

$$AR_h^{2/3} = \frac{Qn}{(1.486)(S_o)^{1/2}}$$

D. Guess at the maximum flow depth in the swale, D

E. Calculate the corresponding maximum flow width, W; flow area, A; wetted perimeter, WP; hydraulic radius, R_h; and the value $AR_h^{2/3}$

F. If $AR_h^{2/3}$ in "E" matches $AR_h^{2/3}$ in "C", go to "G"; otherwise go to "D"

G. Calculate the product of the velocity and hydraulic radius, VR_h

H. Calculate the "computed flow resistance coefficient", n_r, using the formula in Temple (1980)

$$n_r = e^{0.01329C_I(\ln VR_h)^2 - 0.09543C_I(\ln VR_h) + 0.2971C_I - 4.16}$$

I. If n_r in "H" matches n in "B", go to "J"; otherwise go to "B"

J. Calculate the slope of the energy grade line, S

K. Calculate the "effective tractive force", τ_e, using the formula in Temple (1980):

$$\tau_e = \gamma DS\left(1 - C_F\left(\frac{n_s}{n}\right)^2\right)$$

The procedure outlined above was performed on each subarea of the perimeter drainage swale, for each vegetation retardance class shown in Tables 6 and 7. The calculations for τ_e are shown Tables 9 - 17. The calculations are further explained in the check of the spreadsheet used to produce Tables 9-17, which is shown starting on the page after Table 18.

Notes:

In several swale subareas, for vegetal retardance class A (defined in Tables 6 and 7), the calculated flow depth was higher than the maximum depth of the swale. The reason for this is that the calculated roughness coefficient, n, for a swale with this vegetation is much higher than what is normal in grass-lined swales and what n was assumed to be in the swale sizing calculations (GeoSyntec, 1995b). In these calculations, it will be assumed that all swale subareas are deep enough to contain the flow (i.e, the swale sides will extend up following the same parabola equation as defines the current cross section). Doing this leads to the largest (most conservative) estimation of τ_e. An example of this is shown in Table 18, where a τ_e value calculatedby (1) using a deeper than actual swale was checked against τ_e calculated by (2) assuming the flow depth equal to the swale design depth (which yields a larger velocity), and τ_e calculated by (3) using a swale large enough to handle the flow (defined by a different parabola equation). As can be seen, the τ_e value calculated using method 1 is the largest (most conservative) of the three. Finally, if it is determined to design the swale with vegetation of retardance class A, those subareas that are currently too small to contain the design flow will be enlarged.

In all but one subarea, the energy grade slope was less than that of the swale bottom. To be conservative, the larger of the energy grade slope and the cell bottom slope was used in the equation for τ_e.

RESULTS:

The results of the effective tractive force calculations are shown below. The required vegetation retardance class is the least vigorous vegetation class for which any of the topsoils analyzed will be OK (i.e., allowable tractive force, τ_a, not exceeded by effective actual tractive force, τ_e).

Subarea	Required Vegetation Retardance Class*		Subarea	Required Vegetation Retardance Class*
A-1	B		B-1	C
A-2	B		B-2	C
A-3	B		B-3	B
A-4	A**		B-4	B
			B-5	B

*For uniform stands of grass, see Tables 7 and 8 for definition

**Vegetal retardance class B is OK with a GC soil

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CALCULATION OF PERIMETER SWALE EROSION POTENTIAL BY TRACTIVE FORCE METHOD

SWALE SUBAREA A-1 (EAST SWALE)

Table 9 - Calculation of Effective Actual Tractive Force, τ_e, For Perimeter Drainage Swale, Subarea A-1

	Swale Geometry					
1	Subarea Length (ft)	1508	1508	1508	1508	1508
2	Swale Width (ft)	40	40	40	40	40
3	Swale Depth (ft)	2.5	2.5	2.5	2.5	2.5
4	Swale Slope	0.75%	0.75%	0.75%	0.75%	0.75%
5	Maximum Flow, Q (cfs)	171	171	171	171	171
	Vegetation Parameters (Table 1 and 2 from Temple)					
	Retardance Class	A	B	C	D	E
6	C_I	10	7.643	5.601	4.436	2.876
7	C_F	0.9	0.87	0.75	0.5	0.5
8	*Guess at n*	*0.1076*	*0.0647*	*0.0430*	*0.0343*	*0.0258*
9	$AR^{2/3}$	142.975	85.971	57.137	45.576	34.282
	Flow Parameters					
10	*Guess at flow depth, D (ft)*	*3.05**	*2.41*	*2*	*1.8*	*1.58*
11	Flow width, W, (ft)	44.181	39.273	35.777	33.941	31.799
12	Area, A (ft^2)	89.836	63.099	47.703	40.729	33.495
13	Wetted Perimeter (ft)	44.737	39.664	36.073	34.194	32.007
14	Hydraulic Radius, R_h (ft)	2.008	1.591	1.322	1.191	1.046
15	$AR^{2/3}$	142.990	85.989	57.471	45.766	34.525
	Line 9 ~ Line 15 ?	OK	OK	OK	OK	OK
16	R_hV (ft^2/s)	3.82	4.31	4.74	5.00	5.34
17	n_r	0.1076	0.0647	0.0430	0.0344	0.0258
	Line 8 ~ Line 17 ?	OK	OK	OK	OK	OK
18	n_s	0.0156	0.0156	0.0156	0.0156	0.0156
19	γ (pcf)	62.4	62.4	62.4	62.4	62.4
20	Energy grade slope	< 0.75%	< 0.75%	< 0.75%	< 0.75%	< 0.75%

21		τ_e (psf)	3.00E-03	8.53E-03	3.09E-02	8.68E-02	1.35E-01
	Topsoil	τ_a (psf)					
$\tau_a > \tau_e$?	ML	1.60E-02	OK	OK	No Good	No Good	No Good
	SM	1.70E-02	OK	OK	No Good	No Good	No Good
	GM	2.70E-02	OK	OK	No Good	No Good	No Good
	CL	2.90E-02	OK	OK	No Good	No Good	No Good
	GC	6.80E-02	OK	OK	OK	No Good	No Good

*Flow depth is larger than swale depth - This is OK, it results in a conservative estimate of τ_e

See page before Table 9 for further explanation.

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CALCULATION OF PERIMETER SWALE EROSION POTENTIAL BY TRACTIVE FORCE METHOD

SWALE SUBAREA A-2 (EAST SWALE)

Table 10 - Calculation of Effective Actual Tractive Force, τ_e, For Perimeter Drainage Swale, Subarea A-2

	Swale Geometry					
1	Subarea Length (ft)	1056	1056	1056	1056	1056
2	Swale Width (ft)	50	50	50	50	50
3	Swale Depth (ft)	3	3	3	3	3
4	Swale Slope	0.75%	0.75%	0.75%	0.75%	0.75%
5	Maximum Flow, Q (cfs)	311	311	311	311	311
	Vegetation Parameters (Table 1 and 2 from Temple)					
	Retardance Class	A	B	C	D	E
6	C_I	10	7.643	5.601	4.436	2.876
7	C_F	0.9	0.87	0.75	0.5	0.5
8	*Guess at n*	*0.0860*	*0.0554*	*0.0387*	*0.0317*	*0.0245*
9	$AR^{2/3}$	207.831	133.882	93.524	76.607	59.208
	Flow Parameters					
10	*Guess at flow depth, D (ft)*	*3.41**	*2.78*	*2.36*	*2.15*	*1.91*
11	Flow width, W, (ft)	53.307	48.132	44.347	42.328	39.896
12	Area, A (ft^2)	121.185	89.204	69.773	60.670	50.801
13	Wetted Perimeter (ft)	53.883	48.557	44.680	42.618	40.138
14	Hydraulic Radius, R_h (ft)	2.249	1.837	1.562	1.424	1.266
15	$AR^{2/3}$	208.024	133.806	93.915	76.778	59.439
	Line 9 ~ Line 15 ?	OK	OK	OK	OK	OK
16	R_hV (ft^2/s)	5.77	6.40	6.96	7.30	7.75
17	n_r	0.0860	0.0554	0.0387	0.0317	0.0245
	Line 8 ~ Line 17 ?	OK	OK	OK	OK	OK
18	n_s	0.0156	0.0156	0.0156	0.0156	0.0156
19	γ (pcf)	62.4	62.4	62.4	62.4	62.4
20	Energy grade slope	0.712%	0.708%	0.706%	0.704%	0.702%

21		τ_e (psf)	5.25E-03	1.34E-02	4.49E-02	1.22E-01	1.81E-01
	Topsoil	τ_a (psf)					
$\tau_a > \tau_e$?	ML	1.60E-02	OK	OK	No Good	No Good	No Good
	SM	1.70E-02	OK	OK	No Good	No Good	No Good
	GM	2.70E-02	OK	OK	No Good	No Good	No Good
	CL	2.90E-02	OK	OK	No Good	No Good	No Good
	GC	6.80E-02	OK	OK	OK	No Good	No Good

*Flow depth is larger than swale depth - This is OK, it results in a conservative estimate of τ_e

See page before Table 9 for further explanation.

Written by: DAVE WARREN Date: 23OCT95 Reviewed by: PBL Date: 23OCT1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

Table 11 - Calculation of Effective Actual Tractive Force, τ_e, For Perimeter Drainage Swale, Subarea A-3

CALCULATION OF PERIMETER SWALE EROSION POTENTIAL BY TRACTIVE FORCE METHOD

SWALE SUBAREA A-3 (EAST SWALE)

	Swale Geometry					
1	Subarea Length (ft)	1150	1150	1150	1150	1150
2	Swale Width (ft)	56	56	56	56	56
3	Swale Depth (ft)	3.5	3.5	3.5	3.5	3.5
4	Swale Slope	0.50%	0.50%	0.50%	0.50%	0.50%
5	Maximum Flow, Q (cfs)	395	395	395	395	395
	Vegetation Parameters (Table 1 and 2 from Temple)					
	Retardance Class	A	B	C	D	E
6	C_I	10	7.643	5.601	4.436	2.876
7	C_F	0.9	0.87	0.75	0.5	0.5
8	*Guess at n*	*0.0812*	*0.0532*	*0.0376*	*0.0311*	*0.0242*
9	$AR^{2/3}$	305.246	199.988	141.345	116.911	90.972
	Flow Parameters					
10	*Guess at flow depth, D (ft)*	*4.01**	*3.29*	*2.81*	*2.57*	*2.28*
11	Flow width, W, (ft)	59.941	54.294	50.177	47.987	45.198
12	Area, A (ft^2)	160.243	119.085	93.999	82.217	68.701
13	Wetted Perimeter (ft)	60.649	54.821	50.594	48.351	45.503
14	Hydraulic Radius, R_h (ft)	2.642	2.172	1.858	1.700	1.510
15	$AR^{2/3}$	306.254	199.739	142.060	117.129	90.417
	Line 9 ~ Line 15 ?	OK	OK	OK	OK	OK
16	R_hV (ft^2/s)	6.51	7.21	7.81	8.17	8.68
17	n_r	0.0812	0.0532	0.0376	0.0311	0.0242
	Line 8 ~ Line 17 ?	OK	OK	OK	OK	OK
18	n_s	0.0156	0.0156	0.0156	0.0156	0.0156
19	γ (pcf)	62.4	62.4	62.4	62.4	62.4
20	Energy grade slope	0.449%	0.457%	0.464%	0.468%	0.474%

21		τ_e (psf)	4.61E-03	1.15E-02	3.77E-02	1.01E-01	1.47E-01
	Topsoil	τ_a (psf)					
$\tau_a > \tau_e$?	ML	1.60E-02	OK	OK	No Good	No Good	No Good
	SM	1.70E-02	OK	OK	No Good	No Good	No Good
	GM	2.70E-02	OK	OK	No Good	No Good	No Good
	CL	2.90E-02	OK	OK	No Good	No Good	No Good
	GC	6.80E-02	OK	OK	OK	No Good	No Good

*Flow depth is larger than swale depth - This is OK, it results in a conservative estimate of τ_e

See page before Table 9 for further explanation.

Written by: DAVE WARREN Date: 23 OCT 95 Reviewed by: PBL Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

CALCULATION OF PERIMETER SWALE EROSION POTENTIAL BY TRACTIVE FORCE METHOD

SWALE SUBAREA A-4 (EAST SWALE)

	Swale Geometry					
1	Subarea Length (ft)	555	555	555	555	555
2	Swale Width (ft)	56	56	56	56	56
3	Swale Depth (ft)	3.5	3.5	3.5	3.5	3.5
4	Swale Slope	1.28%	1.28%	1.28%	1.28%	1.28%
5	Maximum Flow, Q (cfs)	455	455	455	455	455
	Vegetation Parameters (Table 1 and 2 from Temple)					
	Retardance Class	A	B	C	D	E
6	C_I	10	7.643	5.601	4.436	2.876
7	C_F	0.9	0.87	0.75	0.5	0.5
8	*Guess at n*	*0.0732*	*0.0495*	*0.0358*	*0.0300*	*0.0237*
9	$AR^{2/3}$	198.106	133.965	96.888	81.191	64.141
	Flow Parameters					
10	*Guess at flow depth, D (ft)*	*3.28*	*2.74*	*2.35*	*2.17*	*1.95*
11	Flow width, W, (ft)	54.211	49.548	45.887	44.094	41.800
12	Area, A (ft^2)	118.542	90.508	71.889	63.790	54.339
13	Wetted Perimeter (ft)	54.736	49.950	46.206	44.378	42.041
14	Hydraulic Radius, R_h (ft)	2.166	1.812	1.556	1.437	1.293
15	$AR^{2/3}$	198.430	134.522	96.526	81.248	64.478
	Line 9 ~ Line 15 ?	OK	OK	OK	OK	OK
16	R_hV (ft^2/s)	8.31	9.11	9.85	10.25	10.82
17	n_r	0.0732	0.0495	0.0358	0.0300	0.0237
	Line 8 ~ Line 17 ?	OK	OK	OK	OK	OK
18	n_s	0.0156	0.0156	0.0156	0.0156	0.0156
19	γ (pcf)	62.4	62.4	62.4	62.4	62.4
20	Energy grade slope	1.387%	1.339%	1.300%	1.274%	1.236%

21		τ_e (psf)	1.29E-02	2.95E-02	9.04E-02	2.35E-01	3.37E-01
	Topsoil	τ_a (psf)					
$\tau_a > \tau_e$?	ML	1.60E-02	OK	No Good	No Good	No Good	No Good
	SM	1.70E-02	OK	No Good	No Good	No Good	No Good
	GM	2.70E-02	OK	No Good	No Good	No Good	No Good
	CL	2.90E-02	OK	No Good	No Good	No Good	No Good
	GC	6.80E-02	OK	OK	No Good	No Good	No Good

Table 12 - Calculation of Effective Actual Tractive Force, τ_e, For Perimeter Drainage Swale, Subarea A-4?

Written by: DAVE WARREN Date: 23 OCT 95 Reviewed by: DBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

CALCULATION OF PERIMETER SWALE EROSION POTENTIAL BY TRACTIVE FORCE METHOD

SWALE SUBAREA B-1 (WEST SWALE)

Table 13 - Calculation of Effective Actual Tractive Force, τ_e, For Perimeter Drainage Swale, Subarea B-1

	Swale Geometry					
1	Subarea Length (ft)	594	594	594	594	594
2	Swale Width (ft)	40	40	40	40	40
3	Swale Depth (ft)	2.5	2.5	2.5	2.5	2.5
4	Swale Slope	1.00%	1.00%	1.00%	1.00%	1.00%
5	Maximum Flow, Q (cfs)	46	46	46	46	46
	Vegetation Parameters (Table 1 and 2 from Temple)					
	Retardance Class	A	B	C	D	E
6	C_I	10	7.643	5.601	4.436	2.876
7	C_F	0.9	0.87	0.75	0.5	0.5
8	*Guess at n*	*0.2615*	*0.1188*	*0.0646*	*0.0468*	*0.0311*
9	$AR^{2/3}$	80.949	36.775	19.997	14.487	9.627
	Flow Parameters					
10	*Guess at flow depth, D (ft)*	*2.34*	*1.63*	*1.23*	*1.06*	*0.88*
11	Flow width, W, (ft)	38.699	32.299	28.057	26.046	23.732
12	Area, A (ft^2)	60.370	35.098	23.007	18.406	13.923
13	Wetted Perimeter (ft)	39.073	32.517	28.200	26.161	23.819
14	Hydraulic Radius, R_h (ft)	1.545	1.079	0.816	0.704	0.585
15	$AR^{2/3}$	80.684	36.931	20.087	14.560	9.733
	Line 9 ~ Line 15 ?	OK	OK	OK	OK	NO
16	R_hV (ft^2/s)	1.18	1.41	1.63	1.76	1.93
17	n_r	0.2615	0.1188	0.0646	0.0468	0.0311
	Line 8 ~ Line 17 ?	OK	OK	OK	OK	OK
18	n_s	0.0156	0.0156	0.0156	0.0156	0.0156
19	γ (pcf)	62.4	62.4	62.4	62.4	62.4
20	Energy grade slope	< 1.00%	< 1.00%	< 1.00%	< 1.00%	< 1.00%

21		τ_e (psf)	5.20E-04	2.28E-03	1.12E-02	3.68E-02	6.90E-02
	Topsoil	τ_a (psf)					
$\tau_a > \tau_e$?	ML	1.60E-02	OK	OK	OK	No Good	No Good
	SM	1.70E-02	OK	OK	OK	No Good	No Good
	GM	2.70E-02	OK	OK	OK	No Good	No Good
	CL	2.90E-02	OK	OK	OK	No Good	No Good
	GC	6.80E-02	OK	OK	OK	OK	No Good

Written by: DAVE WARREN Date: 23 OCT 95 Reviewed by: PBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

CALCULATION OF PERIMETER SWALE EROSION POTENTIAL BY TRACTIVE FORCE METHOD

SWALE SUBAREA B-2 (WEST SWALE)

Table 14 - Calculation of Effective Actual Tractive Force, τ_e, For Perimeter Drainage Swale, Subarea B-2

	Swale Geometry					
1	Subarea Length (ft)	234	234	234	234	234
2	Swale Width (ft)	40	40	40	40	40
3	Swale Depth (ft)	2.5	2.5	2.5	2.5	2.5
4	Swale Slope	0.88%	0.88%	0.88%	0.88%	0.88%
5	Maximum Flow, Q (cfs)	70	70	70	70	70
	Vegetation Parameters (Table 1 and 2 from Temple)					
	Retardance Class	A	B	C	D	E
6	C_I	10	7.643	5.601	4.436	2.876
7	C_F	0.9	0.87	0.75	0.5	0.5
8	*Guess at n*	*0.1883*	*0.0951*	*0.0556*	*0.0418*	*0.0291*
9	$AR^{2/3}$	94.556	47.755	27.920	20.990	14.613
	Flow Parameters					
10	*Guess at flow depth, D (ft)*	*2.52**	*1.84*	*1.43*	*1.25*	*1.07*
11	Flow width, W, (ft)	40.160	34.316	30.252	28.284	26.169
12	Area, A (ft^2)	67.468	42.095	28.840	23.570	18.667
13	Wetted Perimeter (ft)	40.577	34.577	30.432	28.431	26.285
14	Hydraulic Radius, R_h (ft)	1.663	1.217	0.948	0.829	0.710
15	$AR^{2/3}$	94.691	47.993	27.826	20.801	14.859
	Line 9 ~ Line 15 ?	OK	OK	OK	OK	NO
16	R_hV (ft^2/s)	1.73	2.02	2.30	2.46	2.66
17	n_r	0.1883	0.0951	0.0556	0.0418	0.0291
	Line 8 ~ Line 17 ?	OK	OK	OK	OK	OK
18	n_s	0.0156	0.0156	0.0156	0.0156	0.0156
19	γ (pcf)	62.4	62.4	62.4	62.4	62.4
20	Energy grade slope	0.800%	0.783%	0.782%	0.782%	0.778%

21		τ_e (psf)	9.50E-04	3.54E-03	1.55E-02	4.79E-02	8.45E-02
	Topsoil	τ_a (psf)					
$\tau_a > \tau_e$?	ML	1.60E-02	OK	OK	OK	No Good	No Good
	SM	1.70E-02	OK	OK	OK	No Good	No Good
	GM	2.70E-02	OK	OK	OK	No Good	No Good
	CL	2.90E-02	OK	OK	OK	No Good	No Good
	GC	6.80E-02	OK	OK	OK	OK	No Good

*Flow depth is larger than swale depth - This is OK, it results in a conservative estimate of τ_e
See page before Table 9 for further explanation.

Written by: DAVE WARREN Date: 23OCT95 Reviewed by: DBR Date: 23OCT1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

CALCULATION OF PERIMETER SWALE EROSION POTENTIAL BY TRACTIVE FORCE METHOD

SWALE SUBAREA B-4 (WEST SWALE)

Table 16 - Calculation of Effective Actual Tractive Force, τ_e, For Perimeter Drainage Swale, Subarea B-4

	Swale Geometry					
1	Subarea Length (ft)	1012	1012	1012	1012	1012
2	Swale Width (ft)	50	50	50	50	50
3	Swale Depth (ft)	3	3	3	3	3
4	Swale Slope	0.75%	0.75%	0.75%	0.75%	0.75%
5	Maximum Flow, Q (cfs)	319	319	319	319	319
	Vegetation Parameters (Table 1 and 2 from Temple)					
	Retardance Class	A	B	C	D	E
6	C_I	10	7.643	5.601	4.436	2.876
7	C_F	0.9	0.87	0.75	0.5	0.5
8	*Guess at n*	*0.0851*	*0.0550*	*0.0385*	*0.0316*	*0.0245*
9	$AR^{2/3}$	210.946	136.334	95.434	78.330	60.731
	Flow Parameters					
10	*Guess at flow depth, D (ft)*	*3.43**	*2.81*	*2.38*	*2.17*	*1.93*
11	Flow width, W, (ft)	53.463	48.391	44.535	42.525	40.104
12	Area, A (ft^2)	122.253	90.652	70.662	61.519	51.601
13	Wetted Perimeter (ft)	54.045	48.822	44.872	42.818	40.350
14	Hydraulic Radius, R_h (ft)	2.262	1.857	1.575	1.437	1.279
15	$AR^{2/3}$	210.668	136.946	95.644	78.330	60.794
	Line 9 ~ Line 15 ?	OK	OK	OK	OK	OK
16	R_hV (ft^2/s)	5.90	6.53	7.11	7.45	7.91
17	n_r	0.0851	0.0550	0.0385	0.0316	0.0245
	Line 8 ~ Line 17 ?	OK	OK	OK	OK	OK
18	n_s	0.0156	0.0156	0.0156	0.0156	0.0156
19	γ (pcf)	62.4	62.4	62.4	62.4	62.4
20	Energy grade slope	0.717%	0.714%	0.713%	0.711%	0.710%

21		τ_e (psf)	5.40E-03	1.38E-02	4.58E-02	1.24E-01	1.83E-01
	Topsoil	τ_a (psf)					
$\tau_a > \tau_e$?	ML	1.60E-02	OK	OK	No Good	No Good	No Good
	SM	1.70E-02	OK	OK	No Good	No Good	No Good
	GM	2.70E-02	OK	OK	No Good	No Good	No Good
	CL	2.90E-02	OK	OK	No Good	No Good	No Good
	GC	6.80E-02	OK	OK	OK	No Good	No Good

*Flow depth is larger than swale depth - This is OK, it results in a conservative estimate of τ_e
See page before Table 9 for further explanation.

Written by: DAVE WARREN Date: 23 OCT 95 Reviewed by: PBA Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

CALCULATION OF PERIMETER SWALE EROSION POTENTIAL BY TRACTIVE FORCE METHOD

SWALE SUBAREA B-3 (WEST SWALE)

Table 15 - Calculation of Effective Actual Tractive Force, τ_e, For Perimeter Drainage Swale, Subarea B-3

	Swale Geometry					
1	Subarea Length (ft)	1282	1282	1282	1282	1282
2	Swale Width (ft)	40	40	40	40	40
3	Swale Depth (ft)	2.5	2.5	2.5	2.5	2.5
4	Swale Slope	0.75%	0.75%	0.75%	0.75%	0.75%
5	Maximum Flow, Q (cfs)	195	195	195	195	195
	Vegetation Parameters (Table 1 and 2 from Temple)					
	Retardance Class	A	B	C	D	E
6	C_I	10	7.643	5.601	4.436	2.876
7	C_F	0.9	0.87	0.75	0.5	0.5
8	*Guess at n*	*0.1004*	*0.0617*	*0.0416*	*0.0335*	*0.0254*
9	$AR^{2/3}$	152.131	93.491	63.035	50.761	38.487
	Flow Parameters					
10	*Guess at flow depth, D (ft)*	*3.13**	*2.51*	*2.09*	*1.89*	*1.66*
11	Flow width, W, (ft)	44.757	40.080	36.573	34.779	32.594
12	Area, A (ft^2)	93.393	67.067	50.959	43.822	36.071
13	Wetted Perimeter (ft)	45.334	40.495	36.889	35.051	32.819
14	Hydraulic Radius, R_h (ft)	2.060	1.656	1.381	1.250	1.099
15	$AR^{2/3}$	151.208	93.881	63.207	50.857	38.417
	Line 9 ~ Line 15 ?	OK	OK	OK	OK	OK
16	R_hV (ft^2/s)	4.30	4.82	5.29	5.56	5.94
17	n_r	0.1004	0.0617	0.0416	0.0335	0.0254
	Line 8 ~ Line 17 ?	OK	OK	OK	OK	OK
18	n_s	0.0156	0.0156	0.0156	0.0156	0.0156
19	γ (pcf)	62.4	62.4	62.4	62.4	62.4
20	Energy grade slope	0.698%	0.691%	0.688%	0.687%	0.686%
21	**τ_e (psf)**	**3.54E-03**	**9.75E-03**	**3.44E-02**	**9.57E-02**	**1.47E-01**
	Topsoil / τ_a (psf)					
$\tau_a > \tau_e$?	**ML** 1.60E-02	**OK**	**OK**	**No Good**	**No Good**	**No Good**
	SM 1.70E-02	**OK**	**OK**	**No Good**	**No Good**	**No Good**
	GM 2.70E-02	**OK**	**OK**	**No Good**	**No Good**	**No Good**
	CL 2.90E-02	**OK**	**OK**	**No Good**	**No Good**	**No Good**
	GC 6.80E-02	**OK**	**OK**	**OK**	**No Good**	**No Good**

*Flow depth is larger than swale depth - This is OK, it results in a conservative estimate of τ_e
See page before Table 9 for further explanation.

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Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

CALCULATION OF PERIMETER SWALE EROSION POTENTIAL BY TRACTIVE FORCE METHOD

SWALE SUBAREA B-5 (WEST SWALE)

Table 17 - Calculation of Effective Actual Tractive Force, τ_e, For Perimeter Drainage Swale, Subarea B-5

	Swale Geometry					
1	Subarea Length (ft)	1200	1200	1200	1200	1200
2	Swale Width (ft)	56	56	56	56	56
3	Swale Depth (ft)	3.5	3.5	3.5	3.5	3.5
4	Swale Slope	0.50%	0.50%	0.50%	0.50%	0.50%
5	Maximum Flow, Q (cfs)	455	455	455	455	455
	Vegetation Parameters (Table 1 and 2 from Temple)					
	Retardance Class	A	B	C	D	E
6	C_I	10	7.643	5.601	4.436	2.876
7	C_F	0.9	0.87	0.75	0.5	0.5
8	*Guess at n*	*0.0770*	*0.0513*	*0.0367*	*0.0305*	*0.0240*
9	$AR^{2/3}$	333.425	222.139	158.918	132.071	103.925
	Flow Parameters					
10	*Guess at flow depth, D (ft)*	*4.17**	*3.46*	*2.96*	*2.72*	*2.43*
11	Flow width, W, (ft)	61.125	55.679	51.499	49.367	46.661
12	Area, A (ft^2)	169.929	128.433	101.625	89.519	75.591
13	Wetted Perimeter (ft)	61.876	56.247	51.949	49.764	46.997
14	Hydraulic Radius, R_h (ft)	2.746	2.283	1.956	1.799	1.608
15	$AR^{2/3}$	333.245	222.704	158.957	132.409	103.771
	Line 9 ~ Line 15 ?	OK	OK	OK	OK	OK
16	R_hV (ft^2/s)	7.35	8.09	8.76	9.14	9.68
17	n_r	0.0770	0.0513	0.0367	0.0305	0.0240
	Line 8 ~ Line 17 ?	OK	OK	OK	OK	OK
18	n_s	0.0156	0.0156	0.0156	0.0156	0.0156
19	γ (pcf)	62.4	62.4	62.4	62.4	62.4
20	Energy grade slope	0.438%	0.446%	0.452%	0.456%	0.461%

21		τ_e (psf)	5.34E-03	1.30E-02	4.17E-02	1.11E-01	1.61E-01
	Topsoil	τ_a (psf)					
$\tau_a > \tau_e$?	ML	1.60E-02	OK	OK	No Good	No Good	No Good
	SM	1.70E-02	OK	OK	No Good	No Good	No Good
	GM	2.70E-02	OK	OK	No Good	No Good	No Good
	CL	2.90E-02	OK	OK	No Good	No Good	No Good
	GC	6.80E-02	OK	OK	OK	No Good	No Good

*Flow depth is larger than swale depth - This is OK, it results in a conservative estimate of τ_e
See page _ for further explanation.

Written by: DAVE WARREN Date: 23 OCT 95 Reviewed by: PBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

CALCULATION OF PERIMETER SWALE EROSION POTENTIAL BY TRACTIVE FORCE METHOD

COMPARISON OF τ_e CALCULATED BY:

I - Assuming Swale Sides Extend Up (At Same Parabola Equation As Was Used To Define Design Cross-Section) Until They Equal Flow Depth

II - Assuming Flow Depth Equals Swale Depth Design Depth (Larger Velocity)

III - Swale Large Enough To Accomodate Flow (Different Parabola Equation)

Table 18 - Comparison of τ_e Values Calculated When Calculated Flow Depth Exceeds Swale Depth

SWALE SUBAREA B-5 (WEST SWALE)

		I	II	III
	Swale Geometry			
1	Subarea Length (ft)	1200	1200	1200
2	Swale Width (ft)	56	56	72
3	Swale Depth (ft)	3.5	3.5	4.5
4	Swale Slope	0.50%	0.50%	0.50%
5	Maximum Flow, Q (cfs)	455	455	455
	Vegetation Parameters (Table 1 and 2 from Temple)			
	Retardance Class	A	A	A
6	C_I	10	10	10
7	C_F	0.9	0.9	0.9
8	*Guess at n*	*0.0770*	*0.0770*	*0.0806*
9	$AR^{2/3}$	333.425	333.425	349.014
	Flow Parameters			
10	*Guess at flow depth, D (ft)*	*4.17**	*3.50*	*4.03*
11	Flow width, W, (ft)	61.125	56.000	68.136
12	Area, A (ft^2)	169.929	130.667	183.060
13	Wetted Perimeter (ft)	61.876	56.578	68.767
14	Hydraulic Radius, R_h (ft)	2.746	2.309	2.662
15	$AR^{2/3}$	333.245	228.302	351.616
	Line 9 ~ Line 15 ?	OK	NO	OK
16	R_hV (ft^2/s)	7.35	8.04	6.62
17	n_r	0.0770	0.0742	0.0806
	Line 8 ~ Line 17 ?	OK	NO	OK
18	n_s	0.0156	0.0156	0.0156
19	γ (pcf)	62.4	62.4	62.4
20	Energy grade slope	0.436%	0.454%	0.404%
21	τ_e (psf)	**5.34E-03**	**4.83E-03**	**4.70E-03**
		I	**II**	**III**

*Flow depth is larger than swale depth - This is OK, it results in a conservative estimate of τ_e as can be seen in the table above

Written by: DW Date: 95/10/18 Reviewed by: PBR Date: 95/10/23

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

CHECK OF TRACTIVE FORCE METHOD SPREADSHEET

CHECK PERIMETER SWALE SUBAREA A-4.

SWALE GEOMETRY:

MAX WIDTH: 56 FT
MAX DEPTH: 3.5 FT
SLOPE: ~1.25%
} FROM GEOSYNTEC (1995a).

SWALE HAS PARABOLIC CROSS-SECTION:

EQN - $y = a x^2 \longrightarrow 3.5 = a\left(\frac{56}{2}\right)^2 \quad a = 0.0045$

$y = 0.0045 x^2$

MAXIMUM FLOW IN SWALE: 455 cfs (GEOSYNTEC, 1995b)

VEGETAL PARAMETERS:
CHECK FOR RETARDANCE CLASS B - $C_I = 7.643$, $C_F = 0.87$
(FROM TABLES)

DETERMINE FLOW DEPTH AND VELOCITY IN SWALE BY ITERATION:

I. A. GUESS A VALUE FOR MANNING'S "n"

$$Q = \frac{1.486}{n} A R_h^{2/3} S^{1/2}$$

$$455 \text{ cfs} = \frac{1.486}{n} A R^{2/3} (0.0125)^{1/2} \qquad A R_h^{2/3} = 2706\, n$$

B. CALCULATE $AR_h^{2/3}$.

$$n = 0.0495 \longrightarrow A R_h^{2/3} = 133.95$$

Written by: DWW Date: 95 / 10 / 18 (YY MM DD) Reviewed by: PBR Date: 95 / 10 / 23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 98.2

I. A. GUESS A VALUE FOR FLOW DEPTH, D

TRY $D = 2.74$ ft

B. CALCULATE FLOW WIDTH AT WATER SURFACE, W

$y = 0.0045\,x^2 \rightarrow D = 0.0045\,(W/2)^2$

$2.74 = 0.0045\,(W/2)^2 \rightarrow W = 49.4$ ft

C. CALCULATE FLOW AREA, A.

$A = \frac{2}{3} D W$ (GEOSYNTEC, 1995b)

$A = \frac{2}{3}(2.74)(49.4) = 90.2\ ft^2$

D. CALCULATE WETTED PERIMETER, WP

$$WP = \sqrt{4D^2 + \frac{W^2}{4}} + \frac{W^2}{8D}\left[\ln\left(\frac{2D + \sqrt{4D^2 + \frac{W^2}{4}}}{\frac{W}{2}}\right)\right]$$

$$= \sqrt{4(2.74)^2 + \frac{49.4^2}{4}} + \frac{49.4^2}{8(2.74)}\left[\ln\left(\frac{2(2.74) + \sqrt{4(2.74)^2 + \frac{49.4^2}{4}}}{\frac{49.4}{2}}\right)\right]$$

$WP = 49.8$ ft

E. CALCULATE HYDRAULIC RADIUS, R_h

$$R_h = \frac{A}{WP} = \frac{90.2}{49.8} = 1.81$$

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Client: TERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 08.2

II. F. CALCULATE $AR_h^{2/3}$
CON'T

$$AR_h^{2/3} = (90.2)(1.81)^{2/3} = 134.0$$

G. DOES $AR_h^{2/3}$ IN STEP II-F MATCH $AR_h^{2/3}$ IN STEP I-B?

II-F → $AR_h^{2/3} = 134.0$

I-B → $AR_h^{2/3} = 134.0 \sim 134.0$ OK

IF II-F ≠ I-B CHOOSE ANOTHER FLOW DEPTH. ITERATE UNTIL II-F ~ I-B.

H. CALCULATE R_hV

$$R_hV = (1.811)\ Q/A = (1.81)\left(\frac{455}{90.2}\right) = 9.13\ ft^2/sec$$

I. CALCULATE n_r

USE EQUATION IN TEMPLE (1980):

$$n_r = e^{\left[0.01329\, C_I (\ln(R_hV))^2 - 0.09543\, C_I \ln(R_hV) + 0.2971\, C_I - 4.16\right]}$$

$C_I = 7.643$
$R_hV = 9.13\ ft^2/s$

$$\longrightarrow n_r = e^{-3.00} = 0.0495$$

J. DOES n_r (STEP II-J) EQUAL n (STEP I-A)?

$n_r = 0.0495$

$n = 0.0495 \sim n_r$ OK

IF II-J ≠ I-A CHOOSE ANOTHER n. ITERATE UNTIL II-J = I-A

Written by: DWW Date: 95 / 10 / 18 (YY MM DD) Reviewed by: BBR Date: 95 / 10 / 23 (YY MM DD)

Client: FERMIO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 08.7

CALCULATE EFFECTIVE TRACTIVE FORCE, τ_e

FROM TEMPLE (1980):

$$\tau_e = \gamma D S \left(1.0 - C_F\right)\left(\frac{n_s}{n}\right)^2$$

WHERE:
γ = UNIT WEIGHT OF WATER
D = AVERAGE FLOW DEPTH
S = SLOPE OF ENERGY GRADE LINE
C_F = VEGETAL COEFFICIENT
n_s = MANNING'S ROUGHNESS COEFF. FOR SOIL
n = MANNING'S ROUGHNESS COEFF.

γ = 62.4 pcf

D: ASSUME D = MAX. FLOW DEPTH (CONSERVATIVE)
D = 2.74 ft

S:
$$S = \frac{\left(Z_1 + D_1 + \frac{V_1^2}{2g}\right) - \left(Z_2 + D_2 + \frac{V_2^2}{2g}\right)}{L}$$

$$= \frac{Z_1 - Z_2}{L} + \frac{\left(D_1 + \frac{V_1^2}{2g}\right) - \left(D_2 + \frac{V_2^2}{2g}\right)}{L}$$

$\frac{Z_1 - Z_2}{L} = 1.28\%$

D_1 = SUBAREA A-3 FLOW DEPTH = 3.29 ft

$V_1 = \frac{\text{SUBAREA A-3 FLOW}}{\text{SUBAREA A-3 AREA}} = \frac{395 \text{ cfs}}{119 \text{ ft}^2} = 3.32 \text{ ft/s}$

D_2 = A-4 FLOW DEPTH = 2.74 ft

$V_2 = \frac{\text{A-4 FLOW}}{\text{A-4 AREA}} = \frac{455}{90.5} = 5.03 \text{ ft/s}$

L = SUBAREA A-4 LENGTH = 555 ft

CON'T →

Written by: DJW Date: 95/10/18 Reviewed by: PBR Date: 95/10/23

Client: FERMILO Project: OSDF Project/Proposal No.: GE3900 Task No.: OS.2

S CON'T:

$$S = 1.28\% + \frac{\left(3.29 + \frac{4.32^2}{2(32.2)}\right) - \left(2.74 - \frac{5.03^2}{2(32.2)}\right)}{555}$$

$= 1.28\% + 0.06\%$

$S = 1.34\% = 0.0134$

NOTE: IN MOST PERIMETER DRAINAGE SWALE SUBAREAS, THE ENERGY GRADE SLOPE WAS LESS THAN THE SWALE BOTTOM SLOPE. IN THESE CASES, THE SWALE BOTTOM SLOPE WAS USED FOR S, TO BE CONSERVATIVE.

C_F: $C_F = 0.87$ (SEE TABLE)

n_s: ASSUME SWALE BOTTOM HAS FINE-GRAINED SOIL

$\rightarrow n_s = 0.0156$ (TEMPLE, 1980)

n: ASSUME SWALE BOTTOM HAS FINE-GRAINED SOIL

$\rightarrow n = n_r = 0.0495$ (TEMPLE, 1980)

$$\tau_e = (62.4)(2.74)(0.0134)(1.0 - 0.87)\left(\frac{0.0156}{0.0495}\right)^2$$

$\tau_e = \underline{\underline{0.0296 \text{ psf}}}$

Written by: DAVE WARREN Date: 21-Oct-95 Reviewed by: PBR Date: 23 OCT 1995

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

COMBINE RESULTS OF MUSLE AND RESULTS OF TRACTIVE FORCE METHOD:

Results of MUSLE (<=5.0 is OK):

Vegetation:		Grass					
Percent Ground Cover:		0%	20%	40%	60%	80%	95%
VM:		**0.45**	**0.2**	**0.1**	**0.047**	**0.029**	**0.011**
Soil	**K**						
Silt Loam	**0.37**	36.0	16.0	8.0	3.8	2.3	0.9
Clay Loam	**0.32**	31.2	13.9	6.9	3.3	2.0	0.8
Loam	**0.32**	31.2	13.9	6.9	3.3	2.0	0.8
Sandy Loam	**0.24**	23.4	10.4	5.2	2.4	1.5	0.6
Loamy Sand	**0.17**	16.6	7.4	3.7	1.7	1.1	0.4
Sand	**0.15**	14.6	6.5	3.2	1.5	0.9	0.4

Results of Tractive Force Method:

Subarea	Required Vegetal Retardance Class*		Subarea	Required Vegetal Retardance Class*
A-1	**B**		**B-1**	**C**
A-2	**B**		**B-2**	**C**
A-3	**B**		**B-3**	**B**
A-4	**A**		**B-4**	**B**
			B-5	**B**

*For uniform stands of grass, see Tables 7 and 8 for definition

From the MUSLE, a grass cover of 40% of the ground area, with any topsoil type analyzed, is needed to adequately resist sheet and rill erosion. From the Tractive Force Method, a uniform stand of grass, of at least vegetal retardance B (with any topsoil analyzed) is needed to resist gully formation in all but one subarea of the perimeter drainage swale (A-4). In subarea A-4, a uniform stand of grass, of vegetal retardance class A (with any topsoil analyzed) or B (with GC topsoil), is needed to resist gully formation.

Results of these calculations show that a strong, dense grass cover can adequately resist erosion in all subareas of the perimeter drainage swale analyzed, and erosion is most likely to occur in subarea A-4. The topsoil may be silt loam, clay loam, loam, sandy loam, loamy sand, sand, or gravelly soil, provided it can support the grass cover.

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SECTION 14

14. WATER DEMAND

14.1 Decontamination Water Demand Estimation

14.2 Construction Water Demand Estimation

002849

14.1 Decontamination Water Demand Estimation

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: DECONTAMINATION WATER DEMAND ESTIMATION

Computations By: (Cognizant Engineer)
Signature [signature] Date Oct. 23. 1995
Printed Name and Title BIN LI Asst. Proj. Engr.

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 10/23/95
Printed Name and Title Kara Olen Asst. Proj. Engr.

Computations Checked by:
Signature [signature] Date 10/23/95
Printed Name and Title Kara L. Olen Asst. Proj. Engr.

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date Oct. 23. 1995
Printed Name and Title BIN LI Asst. Proj. Engr.

Approved by: (PDP)
Signature [signature] Date 10/23/95
Printed Name and Title Kara L. Olen Asst. Proj. Engr.

Approved by: (DTL and TETL)
Signature [signature] Date 24 Oct 95
Printed Name and Title Kenneth W Cargill Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	30% Submittal	24Oct95	NA	NA	NA
B	Preliminary Design - EPA Submittal	15Dec95	[signature]	—	—

Written By: BL Date: 95/12/13 Reviewed by: K. Olen Date: 95-12-13

Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.3

DECONTAMINATION WATER DEMAND ESTIMATION

EXECUTIVE SUMMARY

PURPOSE OF ESTIMATION

The purpose of this package is to estimate the water demand for the site decontamination facilities. This estimation includes water demand at the truck decontamination pad and the showers in construction trailer.

METHODS OF ESTIMATION

The Truck Decontamination Pad: The water demand quantity for the decontamination pad was calculated.

The Showers in Construction Trailer: The water demand quantity for the showers in construction trailer was calculated.

CONCLUSIONS

The Truck Decontamination Pad :

- water demand = 52,000 gallons/day

The Showers in Construction Trailer:

- water demand = 2,200 gallons/day

Total Decontamination:

- water demand = 54,200 gallons/day

Written by: BL Date: 95/10/20 (YY/MM/DD) Reviewed by: [illegible] Date: 95/10/23 (YY/MM/DD)

Client: Fernico Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.3

Decontamination Water Demand Estimation Calculation Procedures

Introduction

The purpose of this package is to present the calculation procedures for estimation of the water demand for the FERNALD On-Site Disposal Facility (OSDF) site decontamination facilities. In particular, this package addresses the following issues:

- Water demand for truck decontamination pad;
- Water demand for showers in construction trailer.

The truck decontamination pad plan is shown in Figure 1. The plan of showers in construction trailer is shown in Figure 2.

Method of Estimation

Truck Decontamination Pad

As shown in Figure 1, the number of spray nozzles will be given at each spray line. The water demand quantity Q_1 required for the pad is: (see Table 1 for 0.94)

$$Q_1 = (4 \times n) \times (q_1 \times 0.94) \times T_1 \quad (\text{gal/day})$$

where: n_1 = number of spray nozzles of each line

Written by: BL Date: 95 / 10 / 20 Reviewed by: K. Olen Date: 95 / 10 / 23
YY MM DD YY MM DD

Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.3

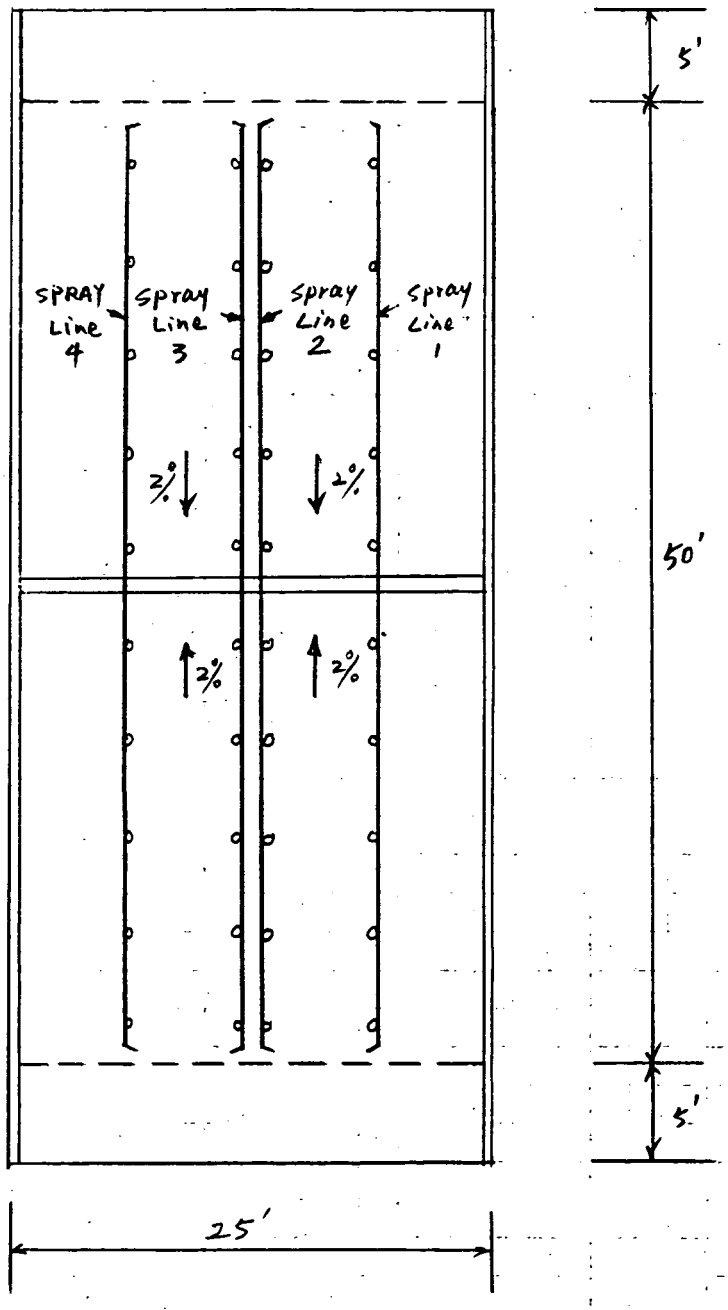

Figure 1: Plan of Decontamination Pad (N.T.S.)

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Client: Fermco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.3

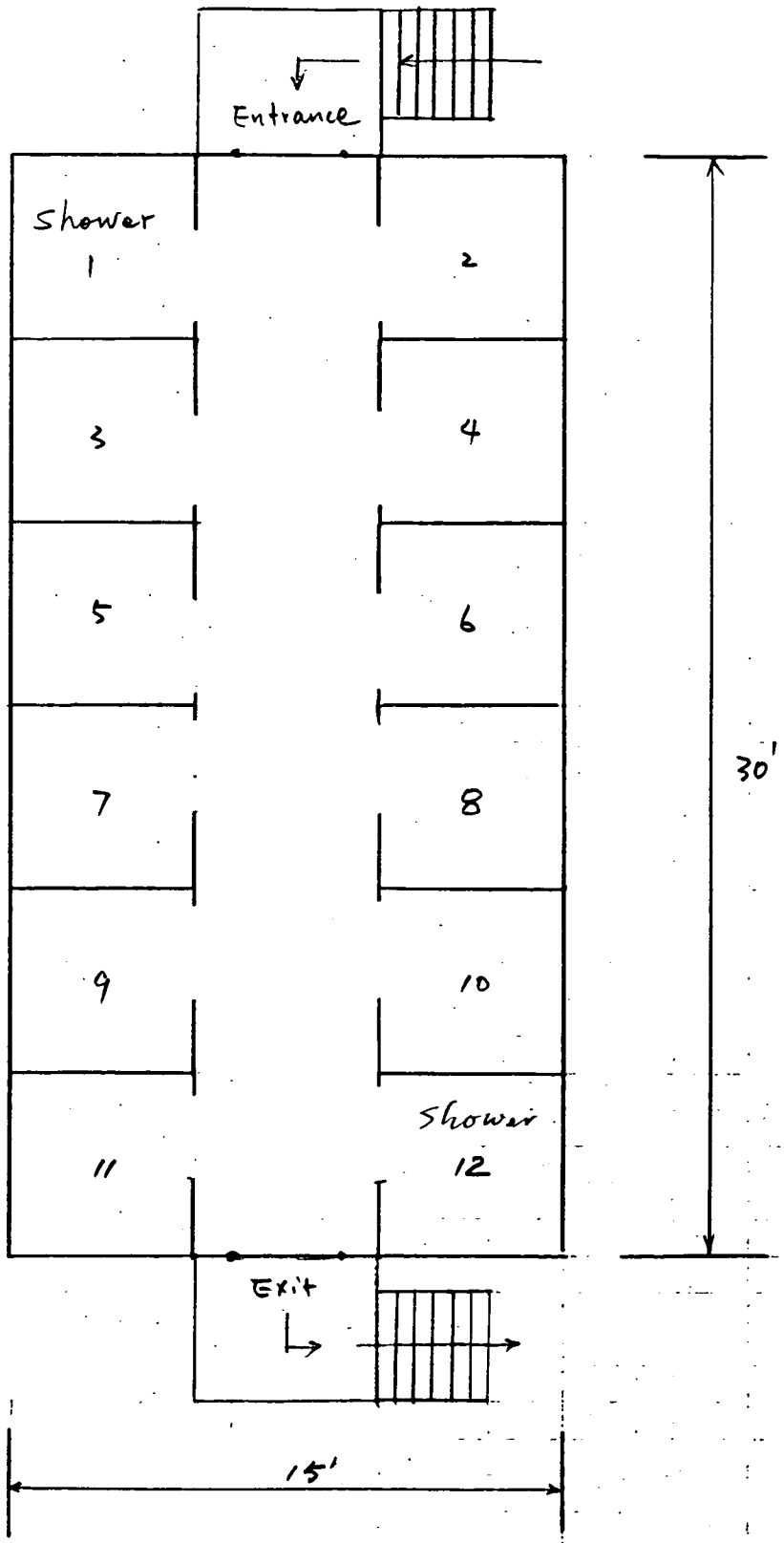

Figure 2: 12 showers in a 30'x15' construction trailer

Written by: BL Date: 95/10/20 Reviewed by: K. Oliver Date: 95/10/23

Client: Fernco Project: Fernald FSDF Project/Proposal No.: GE3900 Task No.: 08.3

q_1 = theoretical discharge of nozzle, in gallons per minute (Table 1)

T_1 = total spray time in minutes per day.

Showers in Construction Trailer

As shown in Figure 2, there are 12 showers in a 30'x10' construction trailer. The water demand quantity Q_2 required for the 12 showers is:

$$Q_2 = 12 \times q_2 \times T_2 \times n_2 \text{ (gal / day)}$$

where q_2 = discharge of shower nozzle, in gallon per min

T_2 = total shower time in minutes per day for each nozzle.

n_2 = number of showers provided by one shower head

Total Decontamination Water Demand

Total water demand for site decontamination facilities is:

$$Q = Q_1 + Q_2$$

Written By: RL Date: 95/10/20 Reviewed by: C. Oller Date: 95-10-23

Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.3

TABLE 1 Theoretical Discharge of Nozzles, in Gallons per Minute

Head		Velocity of discharge, feet per second	DIAMETER OF NOZZLE IN INCHES																									
Lbs.	Feet		1/8	1/4	3/16	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/2	4	4 1/2	5	5 1/2	6
10	23.1	38.58	0.37	1.48	3.20	5.90	13.2	23.6	36.8	53.2	73.2	94.4	119	148	178	212	299	378	475	590	715	850	1160	1512	1912	2360	2860	3400
15	34.7	47.25	0.45	1.81	4.02	7.23	16.2	28.7	45.0	65.1	89.4	116	146	181	218	260	354	463	586	723	880	1040	1430	1852	2344	2890	3520	4160
20	46.2	54.55	0.52	2.09	4.64	8.35	18.7	33.4	52.0	75.3	103	134	169	209	252	300	409	534	676	835	1018	1200	1640	2136	2700	3340	4072	4800
25	57.8	60.99	0.58	2.33	5.23	9.33	20.9	37.2	58.2	84.1	114	149	189	233	282	336	457	597	756	933	1138	1350	1828	2380	3024	3720	4552	5400
30	69.3	66.82	0.64	2.56	5.71	10.2	22.8	40.9	63.7	92.2	125	164	207	256	309	368	501	654	828	1022	1240	1480	2000	2616	3312	4080	4960	5920
35	80.9	72.16	0.69	2.76	6.16	11.0	24.7	44.2	68.8	99.6	135	177	223	276	334	397	541	707	895	1104	1340	1600	2160	2828	3580	4416	5360	6360
40	92.4	77.14	0.74	2.95	6.60	11.8	26.4	47.2	73.6	106	144	189	239	295	357	425	578	755	956	1180	1430	1700	2320	3020	3824	4720	5720	6800
45	104.0	81.83	0.78	3.13	6.99	12.5	28.0	50.2	78.1	113	153	200	253	313	378	450	613	801	1014	1252	1520	1800	2450	3200	4056	5000	6060	7200
50	115.5	86.26	0.82	3.30	7.37	13.2	29.5	52.9	82.3	119	161	211	267	330	399	475	646	845	1069	1320	1600	1900	2580	3380	4276	5280	6400	7600
55	127.1	90.46	0.86	3.46	7.73	13.8	30.9	55.4	86.3	125	169	221	280	346	418	498	678	886	1122	1385	1680	2000	2720	3544	4488	5540	6720	8000
60	138.6	94.49	0.90	3.62	8.08	14.5	32.3	57.8	90.1	130	177	231	293	362	437	520	708	925	1171	1446	1755	2080	2840	3700	4684	5784	7020	8320
65	150.2	98.35	0.94	3.77	8.40	15.1	33.6	60.2	93.8	136	184	241	305	377	455	542	737	963	1219	1506	1820	2165	2960	3850	4876	6024	7320	8660
70	161.7	102.06	0.97	3.91	8.73	15.6	34.9	62.5	97.4	141	191	250	316	391	472	562	765	999	1265	1561	1886	2250	3080	4000	5060	6244	7580	9000
75	173.3	105.65	1.01	4.04	9.03	16.2	36.1	64.6	101	146	198	259	327	404	488	582	792	1034	1309	1616	1960	2320	3170	4136	5236	6464	7840	9320
80	184.8	109.11	1.04	4.18	9.33	16.7	37.3	66.6	104	150	204	267	338	418	504	601	818	1068	1352	1669	2020	2404	3280	4272	5400	6676	8120	9616
85	196.4	112.46	1.07	4.31	9.62	17.3	38.5	68.8	107	155	210	275	348	431	520	620	843	1101	1394	1720	2080	2480	3380	4400	5576	6880	8320	9920
90	207.9	115.72	1.10	4.43	9.89	17.7	39.6	70.8	110	160	217	283	358	443	535	637	867	1133	1434	1770	2150	2540	3470	4522	5736	7080	8600	10160
95	219.5	118.89	1.13	4.55	10.2	18.2	40.7	72.8	113	164	223	291	368	455	550	655	891	1164	1474	1820	2200	2620	3560	4656	5896	7280	8800	10480
100	231.1	121.98	1.16	4.67	10.4	18.7	41.7	74.6	116	168	228	299	378	467	564	672	914	1194	1512	1866	2260	2700	3650	4776	6048	7464	9040	10800
105	242.6	125.00	1.19	4.78	10.7	19.1	42.8	76.5	119	172	234	306	387	478	578	688	937	1224	1549	1912	2320	2760	3750	4896	6200	7648	9260	11040
110	254.2	127.94	1.22	4.90	10.9	19.6	43.8	78.3	122	177	239	313	396	490	591	705	959	1253	1586	1957	2370	2820	3840	5012	6344	7828	9480	11280
115	265.7	130.82	1.25	5.01	11.2	20.0	44.8	80.1	125	181	245	320	405	501	605	720	980	1281	1621	2002	2420	2880	3920	5124	6484	8008	9720	11520
120	277.3	133.63	1.27	5.12	11.4	20.4	45.7	81.8	127	184	250	327	414	512	618	736	1001	1308	1656	2044	2470	2940	4000	5232	6624	8176	9920	11800
125	288.8	136.38	1.30	5.22	11.7	20.9	46.7	83.5	130	188	255	334	422	522	630	751	1022	1335	1691	2086	2520	3000	4100	5340	6764	8344	10160	12000
130	300.4	139.08	1.33	5.32	11.9	21.3	47.6	85.1	133	192	260	341	431	533	642	766	1042	1362	1724	2128	2570	3070	4180	5448	6896	8512	10320	12200

The actual quantity discharged by a nozzle will be less than above table. A well tapered smooth nozzle may be assumed to give above 94 per cent of the values in the tables.

SOURCE: *Pump Handbook* by I. J. Karassik et al. Copyright 1976, McGraw-Hill, Inc.

001827

Written by: B.L. Date: 95/10/20 (YY/MM/DD) Reviewed by: K. Oler Date: 95/10/23 (YY/MM/DD)

Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.3

K. Oler 10/24/95

Decontamination Water Demand Estimation Data Verification

Introduction

As described in the calculation procedures package, the following calculations will be performed:

- Water demand for truck decontamination pad.
- Water demand for showers in construction trailer.

In order to perform the above calculations, the following data is required.

Truck Decontamination Pad

n_1 = number of spray nozzles of each line = 10

q_1 = theoretical discharge of d = 3/16" nozzle = 5.71 gpm @ 30 psi

T_1 = Total spray time / day = 30 minutes/each time × 8 times = 240 min

Showers in construction trailer

q_2 = discharge of shower nozzle = 4 gpm (Assumed)

T_2 = shower time per nozzle = 15 minutes (Assumed)

n_2 = number of showers per shower head = 3 (Assumed)

Written by: BL Date: 95/10/20 (YY/MM/DD) Reviewed by: K. Olen Date: 95/10/23 (YY/MM/DD)

Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.3

Decontamination Water Demand Estimation Calculation Results

Truck decontamination Pad

The quantity of water required for the truck decontamination pad per day

$$Q_1 = (4 \times n) \times (q_1 \times 0.94) \times T_1$$
$$= 4 \times 10 \times 5.71 \times 0.94 \times 240$$
$$= 51527.04 \text{ gallons}$$

Say 52000 gallons/day

Showers in Construction Trailer

The quantity of water required for the showers in construction trailer:

$$Q_2 = 12 \times q_2 \times T_2 \times n_2$$
$$= 12 \times 4 \times 15 \times 3$$
$$= 2160 \text{ gallons}$$

Say 2200 gallons/day

Total Estimated Water Demand

$$Q = Q_1 + Q_2 = 52000 + 2200 = 54200 \text{ gallons/day}$$

13.2 Construction Water Demand

14.2 Construction Water Demand Estimation

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: CONSTRUCTION WATER DEMAND ESTIMATION

Computations By: (Cognizant Engineer)
Signature: [signature] Date: Oct 23. 1995
Printed Name and Title: BIN LI, Asst. Proj. Engr.

Assumptions and Procedures Checked by: (Checker)
Signature: [signature] Date: 10/23/95
Printed Name and Title: Kara L. Olen, Asst Proj Eng.

Computations Checked by:
Checked by:
Signature: [signature] Date: 10/23/95
Printed Name and Title: Kara L. Olen, Asst. Proj Eng.

Computations Backchecked by: (Cognizant Engineer)
Signature: [signature] Date: Oct 23. 1995
Printed Name and Title: BIN LI, Asst. Proj. Engr.

Approved by: (PDP)
Signature: [signature] Date: 10/23/95
Printed Name and Title: Kara L. Olen, Asst. Proj. Eng.

Approved by: (DTL and TETL)
Signature: [signature] Date: 24 Oct 95
Printed Name and Title: Kenneth W Cargill

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	30% Submittal	24 Oct 95	NA	NA	NA
B	Preliminary Design - EPA Submittal	15 Dec 95	[signature]	—	—

Written By: B.L Date: 94/12/13 Reviewed by: K. Ulen Date: 94-12-13

Client: Fernico Project: Fernald OSDF Project/Proposal No.: GE 5900 Task No.: 08.4

CONSTRUCTION WATER DEMAND ESTIMATION

EXECUTIVE SUMMARY

PURPOSE OF ESTIMATION

The purpose of this package is to estimate the water demand for irrigation of final cover vegetation, dust control spraying, compacted clay construction, and structural fill construction.

METHODS OF ESTIMATION

Irrigation: The water demand quantity for irrigation was calculated.

Dust Control: The water demand quantity for dust control was calculated.

Compacted Fill: The water demand quantity for compacted clay was calculated.

Structural Fill: The water demand quantity for structural fill was calculated.

CONCLUSIONS

Irrigation:

- water demand = 68,000 gallons/day (8 hours)

Dust Control:

- water demand = 85,000 gallons/day (8 hours)

Compacted Clay:

- water demand = 16,200 gallons/day (8 hours)

Structural Fill:

- water demand = 81,000 gallons/day (8 hours)

Total Construction:

- water demand = 250,200 gallons/day (8 hours)

Written by: BL Date: 95/10/20 (YY/MM/DD) Reviewed by: [illegible] Date: 95/10/23 (YY/MM/DD)

Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.4

Construction Water Demand Estimation Calculation Procedures

KW 10/24/95

Introduction

The purpose of this package is to present the calculation procedures for estimation of the water demand for site construction of the Fernald On-site Disposal Facility (OSDF) in Cincinnati, OHIO. In particular, this package addresses the following issues:

- Irrigation of final cover vegetation;
- Dust control;
- Compacted Clay Construction; and
- Structural fill construction.

Method of Estimation

Irrigation of Final Cover Vegetation

The water quantity required for Irrigation of final Cover vegetation is:

$$Q_1 = A_1 \times h_1$$

where A_1 is the area of final cover vegetation (Acres)
h_1 is the thickness of water uniformly sprayed to final cover vegetation each day.

Written by: BL Date: 95/10/20 (YY/MM/DD) Reviewed by: [illegible] Date: 95/10/23 (YY/MM/DD)

Client: Fermco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 0f.4

Dust Control

The water quantity required for dust control is:

$$Q_2 = A_2 \times h_2 \times n$$

where A_2 is the area that need dust control.
h_2 is the thickness of water uniformly applied to the area. n is number of spray/day.

Compacted clay construction

The water quantity required for compacted clay construction is:

$$Q_3 = \frac{\rho_s V_c}{(1+e)\gamma_w}(W_c - W_i)$$

Where ρ_s is soil unit weight
V_c is total volume of clay placed per day.
W_i is soil initial moisture content
W_c is moisture content @ compaction
γ_w is water unit weight
e is void ratio of soil

Structural Fill Construction

The water quantity required for structural fill construction is:

$$Q_4 = \frac{\rho_s V_s}{(1+e)\gamma_w}(W_c - W_i)$$

where ρ_s e. γ_w W_i W_c are the same as above
V_s is total volume of structural fill placed per day

Total Construction Water Demand

$$Q = Q_1 + Q_2 + Q_3 + Q_4$$

001835

Written by: BL Date: 95/10/20 (YY/MM/DD) Reviewed by: K. Olen Date: 95/10/23 (YY/MM/DD)

Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.4

K.O. 10/24/95

Construction Water Demand Estimation
Data Verification

Introduction

As described in the calculation procedures package, the following calculations will be performed:

- Water demand for irrigation of final cover vegetation;
- Water demand for dust control;
- Water demand for compacted clay construction; and
- structural fill construction water demand.

In order to perform the above calculations, the following data is required.

Irrigation of Final Cover Vegetation

A_1 = area of final cover vegetation = 10 acres (see note 1 on next page)

h_1 = thickness of water uniformly sprayed = $\frac{1}{4}$" per day

Dust Control

A_2 = area that needs dust control = 10 acres (see note 2 on next page)

h_2 = thickness of water uniformly sprayed = $\frac{1}{16}$"/per spray

n = number of spray per day = 5

Compacted Clay Construction

ρ_s = soil unit weight = 125 pcf

V_c = total volume placed per day = 1000 yd^3

001836

Written by: BL Date: 95/10/20 (YY/MM/DD) Reviewed by: K. Olsen Date: 95/10/23 (YY/MM/DD)

Client: Fermco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.4

K. Olsen 10/24/95

W_i = Soil initial moisture content = 13%

W_c = moisture content @ compaction = 19%

γ_w = water Unit weight = 62.4 pcf

e = soil void ratio = 0.5

Structural fill construction

ρ_s = soil Unit weight = 125 pcf

V_c : total volume placed per day = 5000 yd^3

W_i = soil initial moisture content = 13%

W_c = moisture content @ compaction = 19%

γ_w = water Unit weight = 62.4 pcf

e = soil Void ratio = 0.5

Note:

1. The 10 acres is based on the cover area of one cell.

2. The 10 acres is also based on the size of one cell.

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Client: Fermco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.4

Construction Water Demand Estimation
Calculation Results

Irrigation of Final Cover Vegetation

$$Q_1 = 10 \text{ acres} \times 43560 \text{ ft}^2/\text{acre} \times \frac{1}{4}'' \frac{1}{12 \text{ in/ft}} \times 7.48 \text{ gal/ft}^3$$

$= 67881$ gallons. Say **68000** gallons/day

Dust Control

$$Q_2 = 10 \text{ acres} \times 43560 \text{ ft}^2/\text{acre} \times \frac{1}{16}'' \frac{1}{12 \text{ in/ft}} \times 5 \times 7.48 \text{ gal/ft}^3$$

$= 84851$ gallons Say **85000** gallons/day

Compacted Clay Construction

$$Q_3 = \frac{\rho_s V_c}{(1+e)\gamma_w}(w_c - w_i) = \frac{125 \times 1000 \times 27 \text{ ft}^3/\text{yd}^3}{(1+0.5) \times 62.4} \times (0.19 - 0.13) \times 7.48 \text{ gal/ft}^3$$

$= 16182$ gallons Say **16,200** gallons/day

Structural fill Construction

$$Q_4 = \frac{\rho_s V_c}{(1+e)\gamma_w}(w_c - w_i) = \frac{125 \times 5000 \times 27 \text{ ft}^3/\text{yd}^3}{(1+0.5) \times 62.4} \times (0.19 - 0.13) \times 7.48 \text{ gal/ft}^3$$

$= 80913$ gallons Say **81000** gallons/day

Total Construction Water Demand

$$Q = Q_1 + Q_2 + Q_3 + Q_4$$

$= 68000 + 85000 + 16200 + 81000$

$= 250200$ gallons / day

001818

if working 8 hours/day

Water demand = 250,200/8 hrs = 521 gals/min. = 8.7 gal/s

SECTION 15

15. VOLUME CALCULATIONS

15.1 OSDF Required Volume
15.2 OSDF Capacity Verification
15.3 Earthwork Required Volumes
15.4 Borrow Area Capacity Verification

15.1 OSDF Required Volume

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: OSDF REQUIRED VOLUME

Computations By: (Cognizant Engineer)
Signature: Rudy Bonaparte — Date: 17 Oct 95
Printed Name and Title: Rudy Bonaparte, Principal

Assumptions and Procedures Checked by: (Checker)
Signature: [signature] — Date: 17 Oct 95
Printed Name and Title: Kenneth W Cargill, Associate

Computations Checked by:
Signature: [signature] — Date: 17 Oct 95
Printed Name and Title: Kenneth W Cargill, Associate

Computations Backchecked by: (Cognizant Engineer)
Signature: Rudolph Bonaparte — Date: 17 Oct 95
Printed Name and Title: Rudolph Bonaparte, Principal

Approved by: (PDP)
Signature: [signature] — Date: 17 Oct 95
Printed Name and Title: Kenneth W Cargill, Associate

Approved by: (DTL and TETL)
Signature: Rudolph Bonaparte — Date: 17 Oct 95
Printed Name and Title: Rudolph Bonaparte, Principal

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO	17 Oct 95	NA	NA	NA
Ø	30% Submittal	NA	NA	NA	NA No change
B	Preliminary Design - EPA Submitted	15 Dec 95	[illegible]	—	—

Written by: R. BONAPARTE Date: 15 Dec 1995 Reviewed by: [illegible] Date: 15 Dec 95

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.11

OSDF REQUIRED VOLUME

EXECUTIVE SUMMARY

Purpose

Calculate the required volume of the OSDF considering the design requirement of 2,500,000 yd^3 of "bank/unbulked" materials to be disposed and taking into account: (i) impacted material bulking; (ii) post-placement material settlement; and (iii) placement of seasonal (winter) closure cover soils.

Contents

- Calculation Procedure
- Data Verification Package
- Calculation Results

Findings

The required OSDF volume is 2,750,000 yd^3 assuming compaction of impacted soils to 90% relative compaction based on standard Proctor compaction procedures. The required volume is 2,880,000 yd^3 if 85% relative compaction is assumed.

Recommendations

- Design of OSDF for a volume of 2,880,000 yd^3
- Consider providing a contingency volume equal to about 10% of the required volume to account for:
  - additional volume resulting from confirmatory sampling
  - minor overexcavation
  - unanticipated seasonal (winter) or partial closure activities

Written by: R. Bonaparte Date: 95/10/17 (YY/MM/DD) Reviewed by: [illegible] Date: 95/10/17 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.12

[illegible] 17 Oct 95

CALCULATION

OSDF REQUIRED VOLUME

PROCEDURE

1. This document describes the procedure for estimating the required gross volume of the Fernald On-Site Disposal Facility (OSDF). The OSDF will accept certain wastes from remediation of five operable units at the Fernald Environmental Management Project (FEMP).

2. The required gross volume is the volume of OSDF airspace required to contain all of the impacted materials destined for the OSDF. The required volume must consider bulking, shrinkage, and settlement of impacted material from its "bank/unbulked" condition in-situ at the operable units to its compacted and compressed condition in the OSDF. The required volume must exist in the OSDF above the top of the leachate collection system and below the bottom of the compacted clay cap.

Written by: R Bonaparte Date: 95/10/17 (YY/MM/DD) Reviewed by: [illegible] Date: 95/10/17 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.12

[illegible] 17 Oct 95

3. The required gross volume of airspace depends on the following parameters, with the symbol for each parameter in parenthesis

- total bank/unbulked volume of impacted material (V_T)
- composition of impacted material reported as a volumetric fraction of the total volume:
  - soil (F_1)
  - concrete/asphalt (F_2)
  - solid waste (F_3)
  - flyash (F_4)
  - sludge (F_5)
  - building materials (F_6)
- bank/unbulked volume of each material identified above (V_i)
  - $V_1 = F_1 V_T$
  - $V_2 = F_2 V_T$
  - $V_3 = F_3 V_T$
  - $V_4 = F_4 V_T$
  - $V_5 = F_5 V_T$
  - $V_6 = F_6 V_T$

which, in general terms, may be expressed by

$$V_i = F_i V_T$$

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Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.12

[illegible] 170c+95

- shrink/swell/settlement factor for each material (S_i) calculated using the following equation

$$S_i = \frac{(\gamma_{dbui})}{(\gamma_{dci})} \times (1 - \varepsilon_{zi}) = S_{\gamma i} \cdot S_{\varepsilon i}$$

where γ_{dbui} = the average dry density of material i in the bank/unbulked condition

γ_{dci} = the average dry density of material i in the OSDF compacted condition

ε_{zi} = the average vertical compression of material i between the time it is placed and the time overlying material is placed to the final grade of the facility (assumed on average to be 4 months)

S_γ, S_ε = shrink/swell and settlement factors, respectively

- estimated volume of seasonal (winter) closure material (V_c), where V_c may be calculated by

$$V_c = \sum_{i=1}^{N} A_i d_i$$

001845

where: N = number of seasonal closures, A_i = area of seasonal closure i, and d_i = thickness of unrecoverable seasonal closure soil for

Written by: R. Bonaparte Date: 95 / 10 / 17 (YY MM DD) Reviewed by: [illegible] Date: 95 / 10 / 17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.12

[illegible] 17 Oct 95

seasonal closure i.

4. Using the parameters defined above, the required gross volume of airspace is obtained using the equation

$$V_R = \left(\sum_{i=1}^{6} V_i S_{fi} S_{\varepsilon i} \right) + V_c$$

$$= \left(\sum_{i=1}^{6} V_T F_i \left(\frac{\gamma_{dbui}}{\gamma_{dci}} \right) \left(1 - \varepsilon_{zi} \right) \right) + \left(\sum_{i=1}^{N} A_i d_i \right)$$

where V_r = total required volume

Written by: R Bonaparte Date: 95/10/17 (YY/MM/DD) Reviewed by: [illegible] Date: 95/10/17 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.12

[illegible] 17 Oct 95

CALCULATION

OSDF REQUIRED VOLUME

DATA VERIFICATION

Data inputs must be established for each of the parameters identified in the calculation procedure

1. Total volume (V_T) bank/unbulked
   - Based on the FERMCO Statement-of-Work (SOW)

$$V_T = 2,500,000 \text{ yd}^3$$

2. Composition fraction (F_i)
   - Utilize information in Appendix C of the SOW. This information comes from Table 7-3 of the Feasibility Study (draft) for Operable Unit 5.
   - The impacted-material composition (F_1 through F_6) is indicated for each material on Table 7-3.

$F_1 = 0.7708$

$F_2 = 0.0704$

$F_3 = 0.0074$

$F_4 = 0.0779$

$F_5 = 0.0198$

$F_6 = 0.0536$

Total = 1.0002

001847

R. Bonaparte 95/10/17 6/15
FERMCΦ OSDF

TABLE 7-3

MATERIAL ASSUMED TO MEET WASTE ACCEPTANCE CRITERIA FOR ON-PROPERTY DISPOSAL
(Assumed for CRARE Analysis)

Source	Material	Quantity (cubic yards)
OU2	F_3 Solid waste landfill material	18,000
	F_1 South Field material	120,000
	F_5 Lime sludge ponds material	18,000
	F_4 Active fly ash pile material	80,000
	F_4 Inactive fly ash pile material	109,000
	Subtotal	345,000
OU3	F_6 Windows, wood, insulation	58,571
	F_2 Asphalt and concrete	167,797
	F_6 Structural steel	2274
	F_6 Equipment, conduit/wire, piping	64,485
	F_6 Painted light gauge metals	224
	F_6 Brick	766
	F_6 Transite, floor tile, fire brick	3843
	Subtotal	297,960
OU4	F_2 Concrete	3000
	Subtotal	3000
OU5	F_1 Soil	1,750,000
	F_5 Sludge - groundwater/wastewater treatment facilities	30,000
	Subtotal	1,780,000
	TOTAL	2,425,960

7.1.3 Off-Property Disposal

This section provides information on the material assumed, as part of the adopted criteria remedy, to be disposed of off-property. Table 7-4 lists these wastes. Assumed quantities given are in-place cubic yards and no allowances have been made for volumes following excavation, treatment, and/or containerization.

001848

Written by: R. Bonaparte Date: 95/10/17 (YY/MM/DD) Reviewed by: [illegible] Date: 95/10/17 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.12

[illegible] 17 Oct 95

3. Estimate shrink/swell factors ($S_{\gamma i}$)

3.1 Soil Materials

The shrink/swell factors for soil materials are dependent on the depth from which material is excavated and the density to which it is compacted in the OSDF. The depth of excavation of OU5 soil (which is about 93.6% of the total soil removal based on Table 7-3) destined for on-site disposal is given below.

Depth Interval (ft)	% of Total Volume
0 to 0.5	17
0.5 to 1.5	17
1.5 to 2.5	7
2.5 to 5.5	18
5.5 to 10.5	21
10.5 to 15.5	14
15.5 to 20.5	6
	100%

001819

Note: These factors estimated using the drawing "Alternatives 3A and 3D-On-Property Undeveloped Park @ 1×10^{-6} BASE + LEVEL 1 + Level 2 + ALARA" which shows OU5 excavation contours.

Written by: R. Bonaparte Date: 95/10/17 (YY MM DD) Reviewed by: [signature] Date: 95/10/17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3400 Task No.: 8.12

[signature] 17 Oct 95

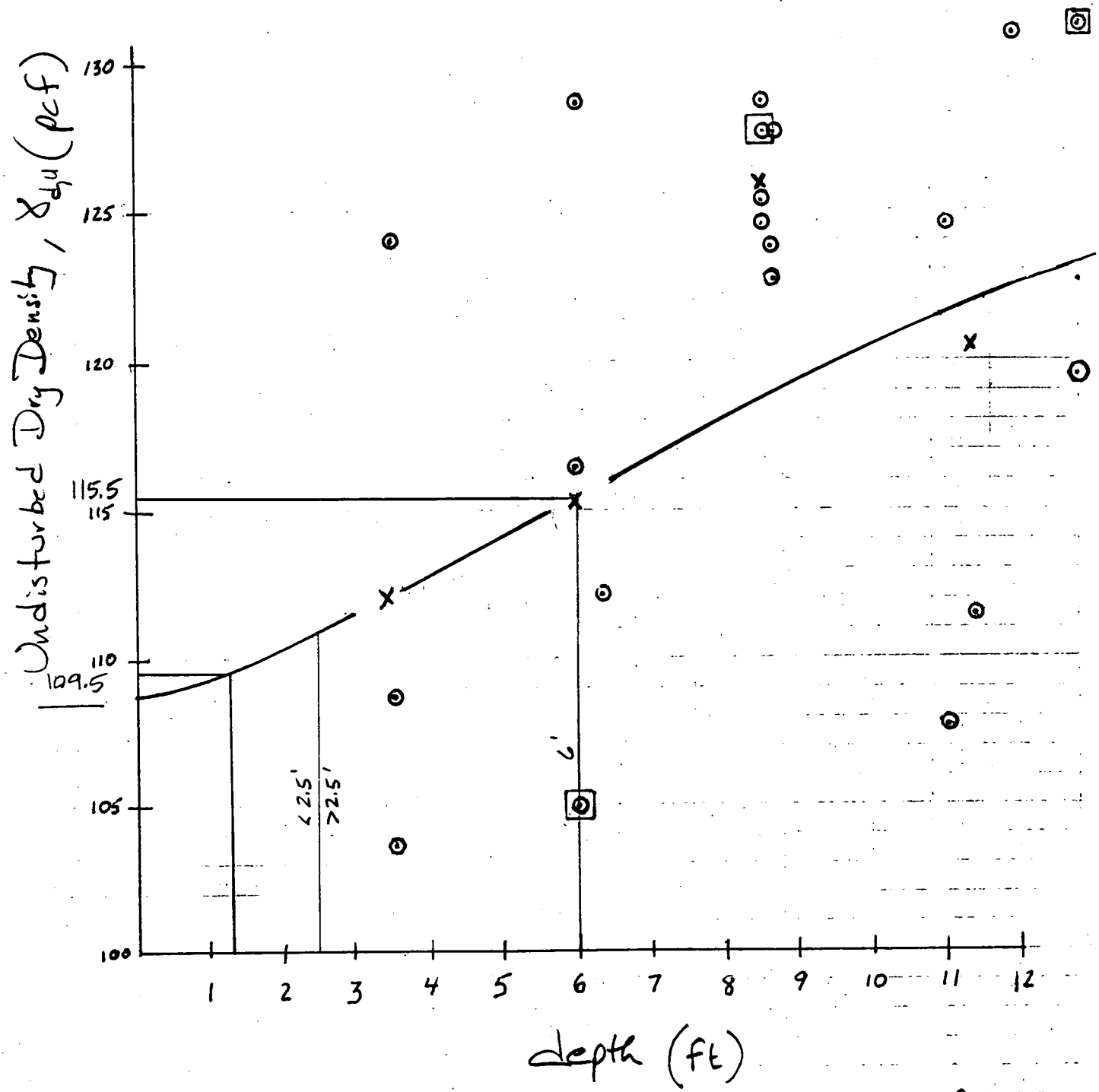
To estimate the shrink/swell factor, the ratio of the undisturbed dry density (γ_{du}) must be compared to the OSDF compacted dry density (γ_{dc}). This is accomplished using Figures 1 and 2 which were obtained from the Sept 1995 Parsons report "Geotechnical Investigation Report, On-Site Disposal Facility" for the OU5 soils. Figure 1 presents undisturbed dry density and Figure 2 presents maximum compaction dry density based on standard Proctor compaction. To obtain the OSDF compacted dry density, the maximum dry density in Figure 2 must be multiplied by the relative compaction. Two values of relative compaction will be considered 85% and 90%. Using these values, the following shrink/swell factors are obtained for 90% and 85% relative compaction:

Depth	(γ_{du})	90% (γ_{dc})	90% $S_{\gamma 1}$	85% γ_{dc}	85% $S_{\gamma 1}$
0 to 0.5	109	94.5	1.15	89.2	1.22
0.5 to 1.5	109.5	95.0	1.15	89.7	1.22
1.5 to 2.5	110.3	96.5	1.14	91.1	1.21
2.5 to 5.5	112.8	101.2	1.11	95.6	1.18
5.5 to 10.5	118.0	108.5	1.09	102.5	1.15
10.5 to 15.5	123.5	110.7	1.12	104.5	1.18
15.5 to 20.5	125±	110.7	1.13	104.5	1.20

Written by: VANDER LINDE Date: 95/10/7 (YY MM DD) Reviewed by: K. Olson Date: 95/10/7 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.12

RB 95/10/17
KO 17 Oct 95



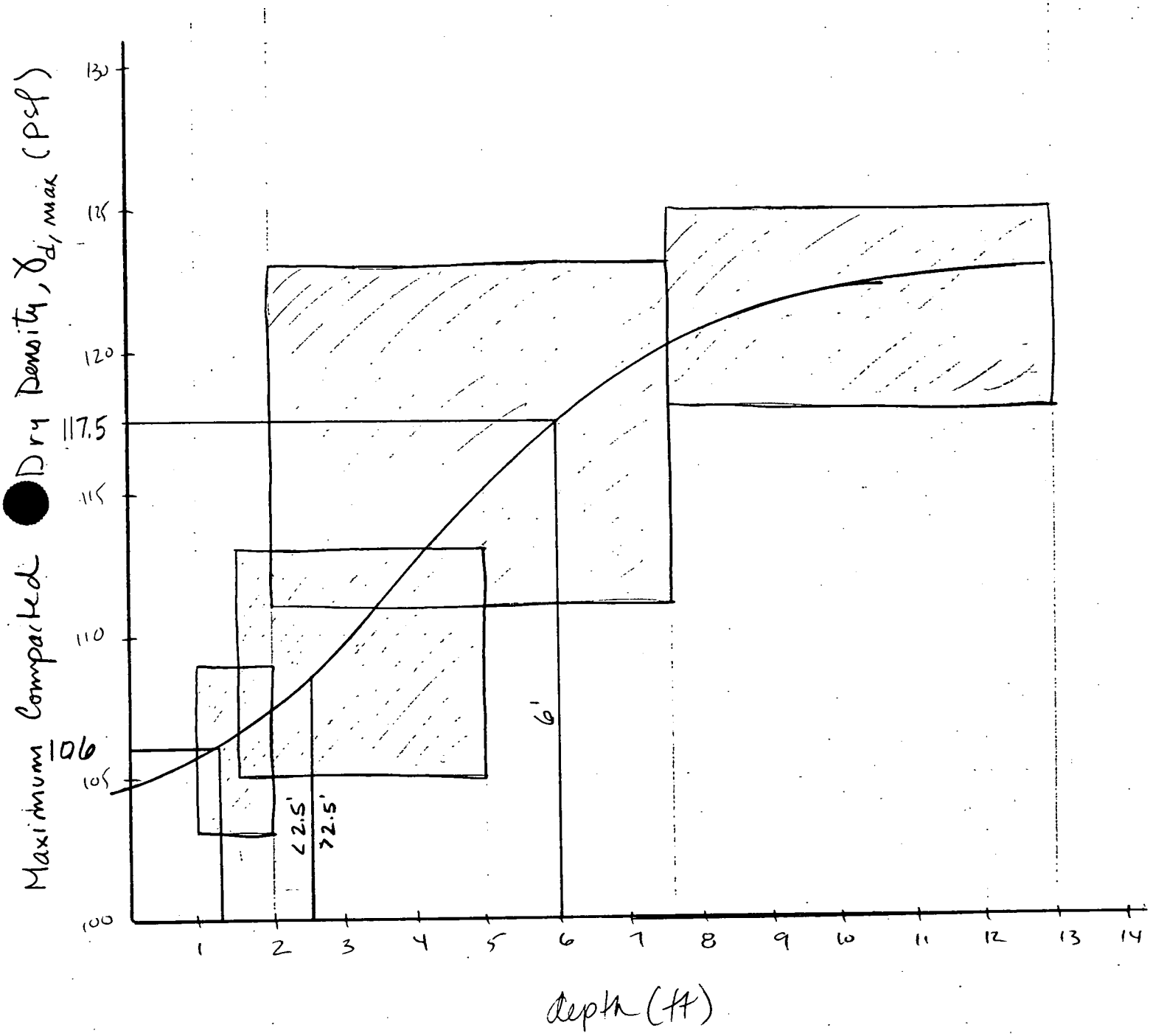
Ref.: Geotechnical Investigation Report, OSDF, Sept 1995, Table G-2

FIGURE 1

Written by: VANDERLINDE Date: 95/10/7 (YY MM DD) Reviewed by: K.Oh Date: 95/10/7 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.12

RB 95/10/17
KC 17Oct95



Ref.: Geotechnical Investigation Report, OSDF, Sept 1995, pg 4-13 to 4-16 and Appendix I

FIGURE 2

001852

Written by: R. Bonaparte Date: 95/10/17 (YY/MM/DD) Reviewed by: [signature] Date: 95/10/17 (YY/MM/DD)

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[signature] 17 Oct 95

The weighted average value of $S_{\gamma 1}$ for the OU5 soils at a relative compaction of 90% is 1.12. The weighted average value of $S_{\gamma 1}$ for the OU5 soils for 85% compaction is 1.059 times larger than the value for 90% compaction; for 85% compaction, $S_{\gamma 1}$ for the OU5 soils is 1.19.

Information for making a detailed estimate of $S_{\gamma 1}$ for the soil in the South field area is unavailable at this time. Therefore, the values derived for OU5 soils will be used for OU2 soils.

3.2 Concrete

Bank/unbulked concrete will bulk considerably when it is broken up and placed in the OSDF. A value of $S_{\gamma 2} = 1.3$ is assumed.

3.3 Solid Waste Landfill Material

The volume of solid waste is small, a value of $S_{\gamma 3} = 1.0$ is assumed for simplicity

3.4 Flyash

The flyash was placed in a loose state, but has probably densified slightly over time due to gravity loads and environmental factors. A value of $S_{\gamma 4} = 1.0$ is assumed.

001853

Written by: R. Bonaparte Date: 95 / 10 / 17 (YY MM DD) Reviewed by: [illegible] Date: 95 / 10 / 17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.12

[illegible] 17 Oct 95

3.5 Sludge

Some of the sludge is desiccated, while some is wet. Sludge will likely be mixed with soil during disposal. The volume of sludge is small. For simplicity, $S_{\gamma 5} = 1.0$ is assumed.

3.6 Building Materials

It is assumed that due to packaging at demolition and/or placement in the OSDF, building materials, on average, do not shrink or swell. Thus, $S_{\gamma 5} = 1.0$.

4. Estimate of Settlement Factors

4.1 Soil

Soil in the OSDF will settle under the weight of overlying layers. Calculations currently being performed for the "Impacted Material Settlement" calculation package indicate average impacted soil material settlements of 3% during filling of each OSDF cell. Thus, $S_{\varepsilon 1} = 0.97$

001854

4.2 Concrete

Concrete rubble has very little compressibility. $S_{\varepsilon 2} = 1.0$ is assumed for simplicity.

Written by: R. Bonaparte Date: 95/10/17 Reviewed by: [illegible] Date: 95/10/17

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.12

[illegible] 17 Oct 95

4.3 Solid Waste Landfill Material

Solid waste is compressible. However, since the bulking factor was taken as 1.0 in Section 3.3 (ie., it was assumed that no bulking occurred), the settlement factor is taken as 1.0.

4.4 Flyash

The flyash will likely settle in a manner similar to soil. A value of $S_{\varepsilon 4} = 0.97$ is assumed.

4.5 Sludge

The volume of sludge is small. Consistent with the assumption $S_{\gamma 5} = 1.0$, a value of $S_{\varepsilon 5}$ is also assumed.

4.6 Building Materials

The building materials are assumed to be incompressible. Thus, $S_{\varepsilon 6} = 1.0$

5. Seasonal (Winter) Closure Area (A_i)

The value of A_i is assumed to correspond to cover 2.5 acres (108,900 ft^2)

001855

6. Seasonal (Winter) Closure soil thickness (d_i)

The assumed average soil thickness is 1 ft

Written by: R. Bonaparte Date: 95/10/17 (YY/MM/DD) Reviewed by: FC Date: 95/10/17 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.12

FC 17 Oct 95

7. Number of Seasonal Closures

The active life of the OSDF may range from 7 to 25 years. For planning purposes, a 10 year life is assumed, with 9 seasonal closures. Therefore, N=9.

Written by: R. Bonaparte Date: 95/10/17 (YY MM DD) Reviewed by: [illegible] Date: 95/10/17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.12

CALCULATION

OSDF REQUIRED VOLUME

From the calculation procedure, for a relative compaction of 90%,

$$V_r(90\%) = V_T \sum_{i=1}^{6} F_i S_{\gamma i} S_{\varepsilon i} + \sum_{i=1}^{9} A_i d_i$$ ✓

$$= 2.5 \times 10^6 \, yd^3 (0.7708 \times 1.12 \times 0.97$$
$$+ 0.0704 \times 1.30 \times 1.0$$
$$+ 0.0074 \times 1.0 \times 1.0$$
$$+ 0.0779 \times 1.0 \times 0.97$$
$$+ 0.0198 \times 1.0 \times 1.0$$
$$+ 0.0536 \times 1.0 \times 1.0)$$
$$+ 9 \times 108{,}900 \, ft^2 \times 1 \, ft \div 27$$

$$= 2.5 \times 10^6 \, yd^3 (1.085) +$$ ✓

$$= 2{,}713{,}200 \, yd^3 + 36{,}000 \, yd^3$$ ✓

$$= 2{,}749{,}500 \, yd^3 \simeq 2{,}750{,}000 \, yd^3$$ ✓

Repeating the same calculation for 85% compaction using $S_{\gamma 1} = 1.19$ results in:

$$V_r(85\%) = 2{,}880{,}000 \, yd^3$$ ✓

001857

15.2 OSDF Capacity Verification

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: OSDF CAPACITY VERIFICATION

Computations By: (Cognizant Engineer)
Signature Robert A. Morgan III — Date 13 OCT 1995
Printed Name and Title ROBERT A. MORGAN III, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature Daniel B. Wisialowski — Date 16 OCT 95
Printed Name and Title DANIEL B. WISIALOWSKI, ASSISTANT PROJECT ENGINEER

Computations Checked by:
Signature [illegible] — Date 16 Oct, 1995
Printed Name and Title BEN CZ, Asst. Proj. Engineer.

Computations Backchecked by: (Cognizant Engineer)
Signature Robert A. Morgan III — Date 16 OCT 1995
Printed Name and Title ROBERT A. MORGAN III, STAFF ENGINEER

Approved by: (PDP)
Signature Dennis L. Vander Linde — Date 17 OCTOBER 1995
Printed Name and Title DENNIS L. VANDER LINDE, ASSISTANT PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature [illegible] — Date 17 Oct 95
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO	17 Oct 95	NA	NA	NA
Ø	30% Submittal	NA	NA	NA	NA
B	Preliminary Design - EPA Submittal	15 Dec 95	[illegible]		

Written By: RAM Date: 12 DEC 95 Reviewed by: DBW Date: 13 DEC 95

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

OSDF CAPACITY VERIFICATION

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this package is to present the OSDF capacity verification summary. Results are given for the volume of a 9 cell OSDF (ninth cell is a contingency cell) and an 8 cell OSDF.

METHOD OF ANALYSIS

The OSDF capacity (for a nine cell OSDF) was calculated using two methods: (1) hand calculated using the average end area method for the midsection (see Figure 1) and approximating the ends as a pyramid; and (2) using the Earthworks volume calculation package developed by SOFTDESK for AUTOCAD®. The OSDF capacity was also calculated by hand for an eight cell OSDF by subtracting one cell from the midsection (see Figure 1).

CONCLUSIONS

	9-CELL OSDF	8-CELL OSDF
HAND	3,118,801.48 cyd	2,753,689.11 cyd
AUTOCAD®	3,275,394.24 cyd	2,898,035.08 cyd
% DIFFERENCE	4.80%	4.98%

Written by: RATI Date: 95/10/12 (YY/MM/DD) Reviewed by: DBW Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

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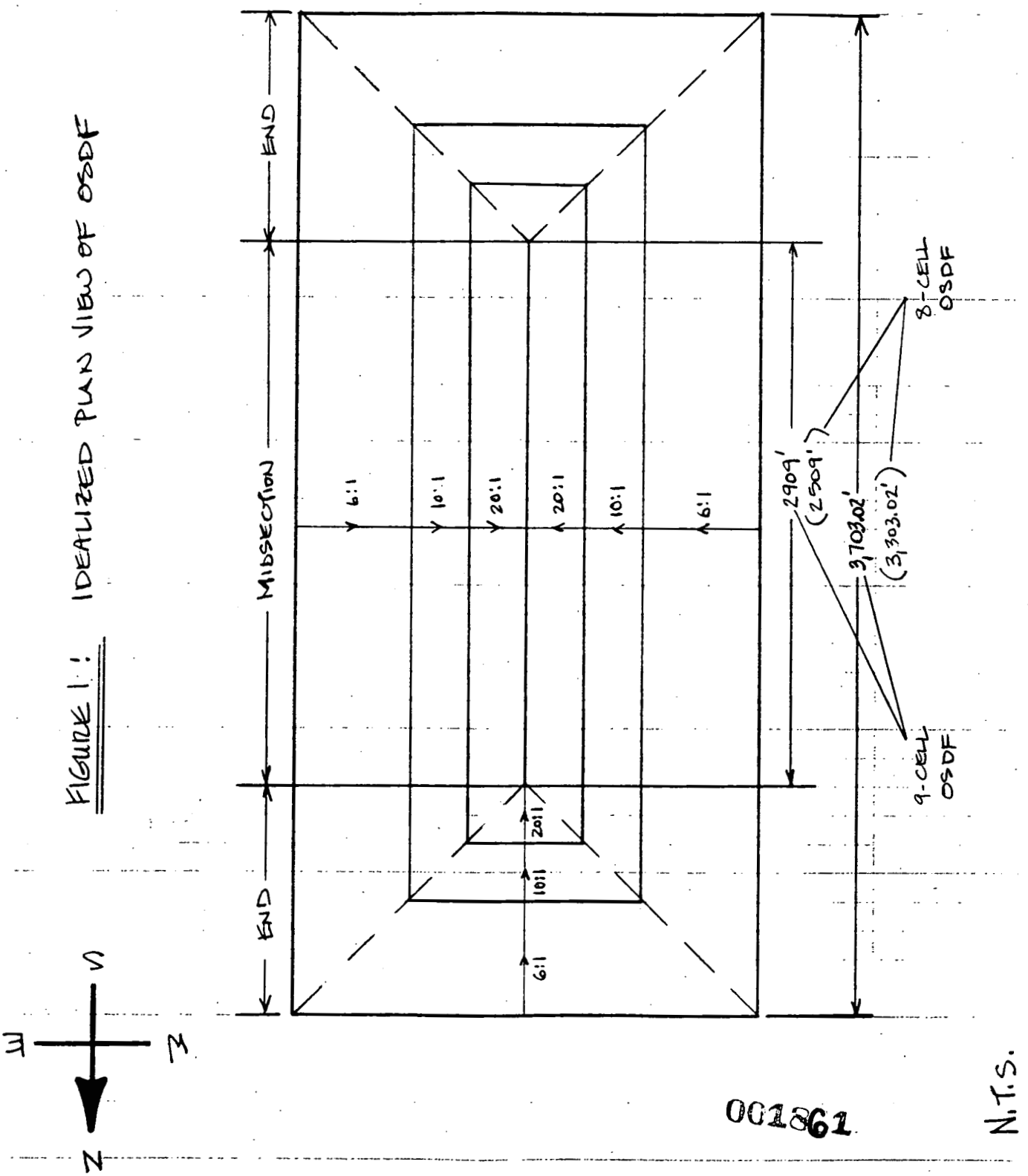
FIGURE 1: IDEALIZED PLAN VIEW OF OSDF



N.T.S.

001861

Written by: RAM Date: 95/10/11 (YY/MM/DD) Reviewed by: DBW Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

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OSDF CAPACITY VERIFICATION

CALCULATION PROCEDURES

Written by: RAM Date: 95/10/11 (YY/MM/DD) Reviewed by: DBW Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

KC 17 Oct 95

INTRODUCTION:

THE PURPOSE OF THIS PACKAGE IS TO PRESENT THE CALCULATION PROCEDURES FOR VOLUME VERIFICATION OF THE OSDF CAPACITY CALCULATED USING AUTOCAD®.

METHOD OF ANALYSIS:

STEP 1: DETERMINE THE GROSS AREA OF THE E-W CROSS-SECTION. THE CROSS-SECTION SHOWN IN FIGURE 1 & 2 REPRESENTS AN AVERAGE CROSS-SECTION BETWEEN THE INTERCELL BERM AND THE DRAINAGE CORRIDOR OF A CELL IN THE OSDF.

RAM 95/10/12 DBW 95/10/16 3 of 16

FERMCO FERNALD OSDF GE 3900 11.1 Rev 17 Oct 95

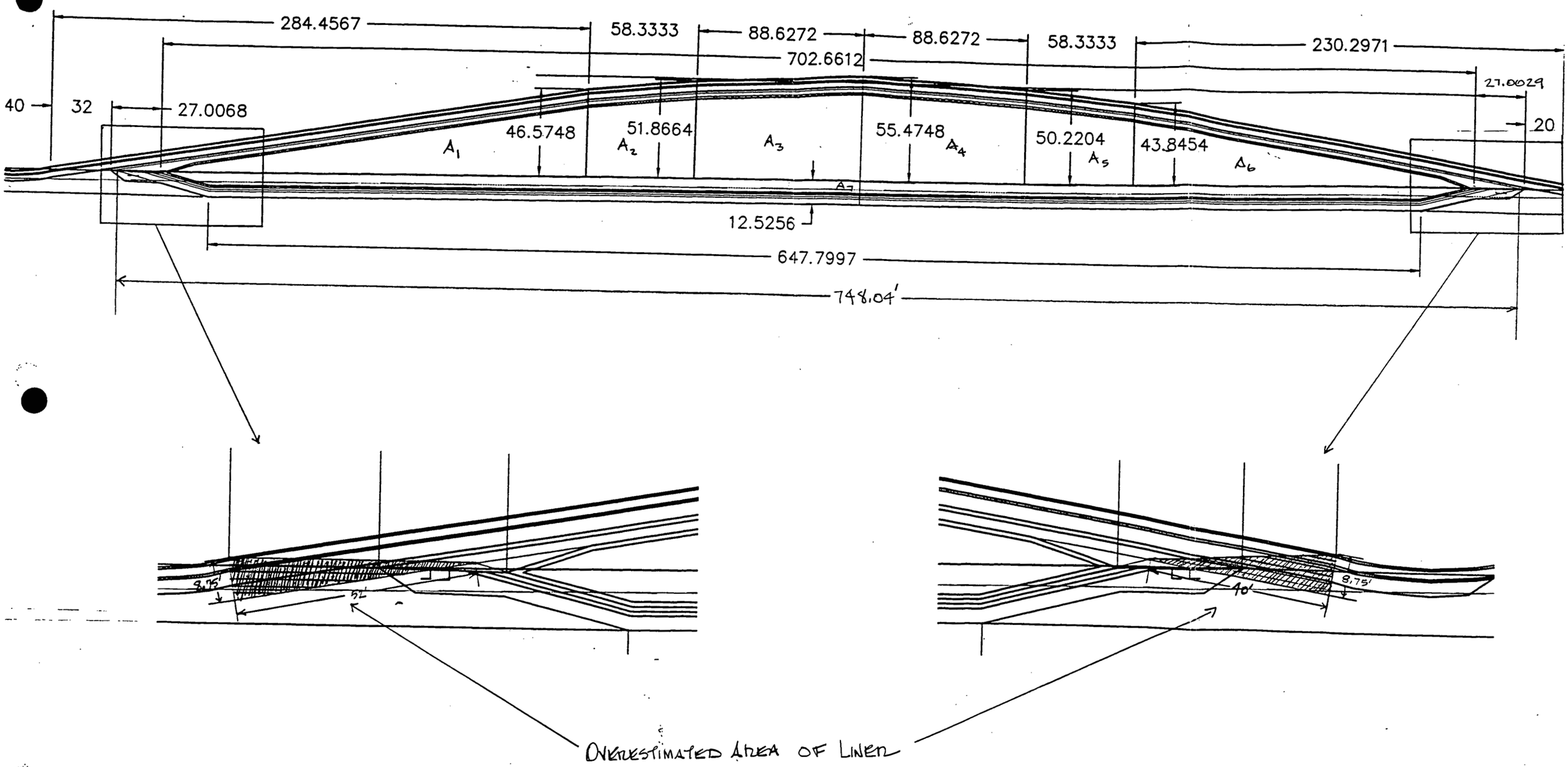


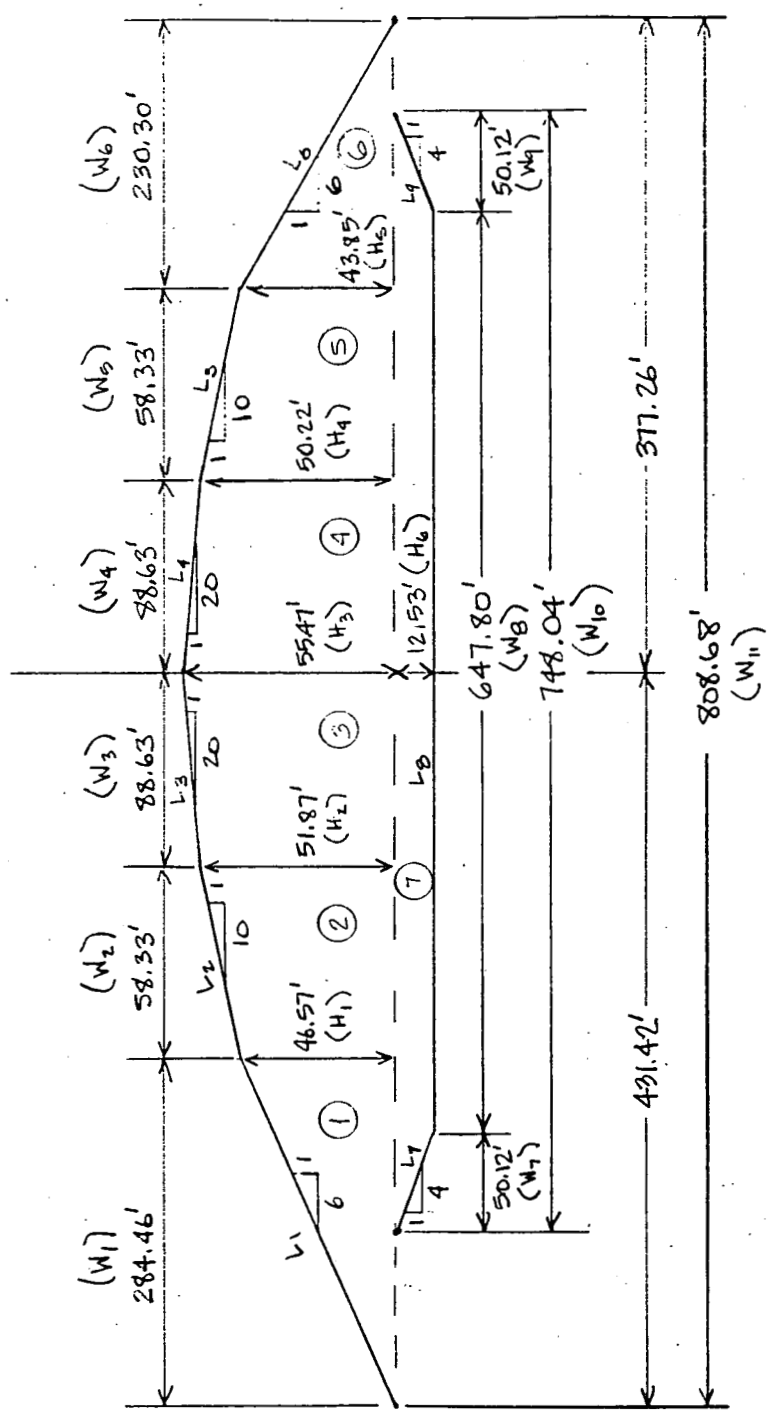
FIGURE 1:

Written by: RAH Date: 95 / 10 / 12 (YY MM DD) Reviewed by: DBW Date: 95 / 10 / 16 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

17 Oct 95

FIGURE 2 : E-W CROSS-SECTION



NTS

Written by: RAM Date: 95/10/12 (YY MM DD) Reviewed by: DBW Date: 95/10/16 (YY MM DD)

Client: Fernco Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

for 17 Oct 95

- EQUATIONS FOR VARIOUS DIMENSIONS (SEE FIGURE 2)

- $L_1 = \sqrt{H_1^2 + W_1^2}$ ✓
- $L_2 = \sqrt{(H_2 - H_1)^2 + W_2^2}$ ✓
- $L_3 = \sqrt{(H_3 - H_2)^2 + W_3^2}$ ✓
- $L_4 = \sqrt{(H_3 - H_4)^2 + W_4^2}$ ✓
- $L_5 = \sqrt{(H_4 - H_5)^2 + W_5^2}$ ✓
- $L_6 = \sqrt{H_5^2 + W_6^2}$ ✓
- $L_7 = \sqrt{H_6^2 + W_7^2}$ ✓
- $L_8 = W_8$ ✓
- $L_9 = \sqrt{H_6^2 + W_9^2}$ ✓

Written by: RAM Date: 95 / 10 / 12 Reviewed by: DBW Date: 95 / 10 / 16
YY MM DD YY MM DD

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

KC 17 Oct 95

- EQUATIONS FOR AREA OF E-W CROSS-SECTION

- $A_1 = \frac{1}{2}(W_1)(H_1)$ ✓
- $A_2 = \left(\frac{H_1 + H_2}{2}\right)(W_2)$ ✓
- $A_3 = \left(\frac{H_2 + H_3}{2}\right)(W_3)$ ✓
- $A_4 = \left(\frac{H_3 + H_4}{2}\right)(W_4)$ ✓
- $A_5 = \left(\frac{H_4 + H_5}{2}\right)(W_5)$ ✓
- $A_6 = \frac{1}{2}(W_6)(H_5)$ ✓
- $A_7 = (W_8)(H_6) + 2\left[\frac{1}{2}(H_6)(W_7)\right]$ ✓

- GROSS AREA OF E-W CROSS-SECTION

$$A_G = A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7$$ ✓

Written by: RAM Date: 95/10/12 Reviewed by: DBW Date: 95/10/16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

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STEP 2: CALCULATE THE CROSS-SECTIONAL AREA OF COVER AND LINER. (SEE FIGURE 3 AND 4)

- $A_c = 8.75' (L_1 + L_2 + L_3 + L_4 + L_5 + L_6)$ ✓

- $A_L = 5.0' (L_7 + L_8 + L_9)$ ✓

- OVER ESTIMATED AREA OF COVER (SEE FIGURE 1) $= A_o$

$A_o = \frac{1}{2}(40')(8.75') + \frac{1}{2}(52')(8.75') = 402.50\ SL^2$ ✓

- GROSS AREA OF LINER + COVER $= A_c + A_L - A_o$ ✓

STEP 3: CALCULATE THE NET AREA (i.e., AREA OF IMPACTED MATERIAL) OF THE E-W CROSS-SECTION.

- $A_N = A_G - (A_c + A_L - A_o)$ ✓

Written by: RAM Date: 95/10/12 Reviewed by: DBN Date: 95/10/16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 1.1

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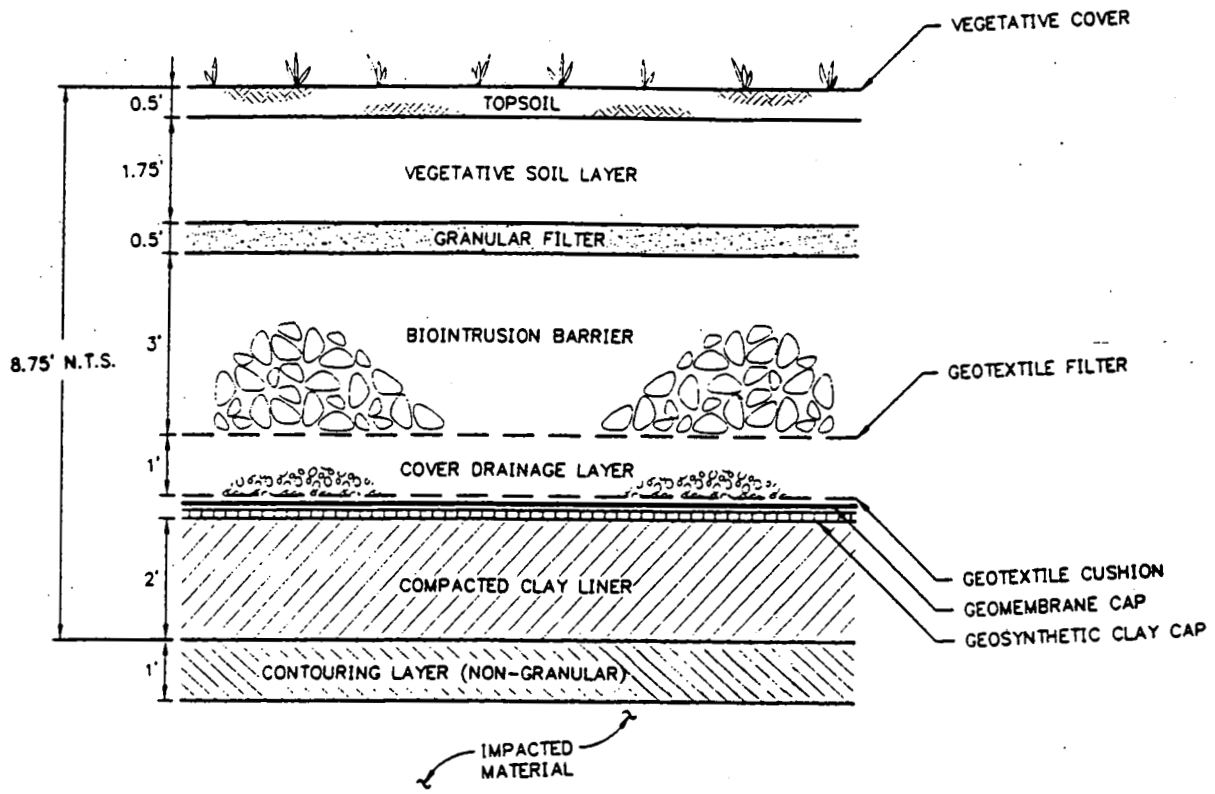
FIGURE 3 : FINAL COVER SYSTEM



Written by: RATM Date: 95/10/12 Reviewed by: DBN Date: 95/10/16

Client: FERMICO Project: REGINALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

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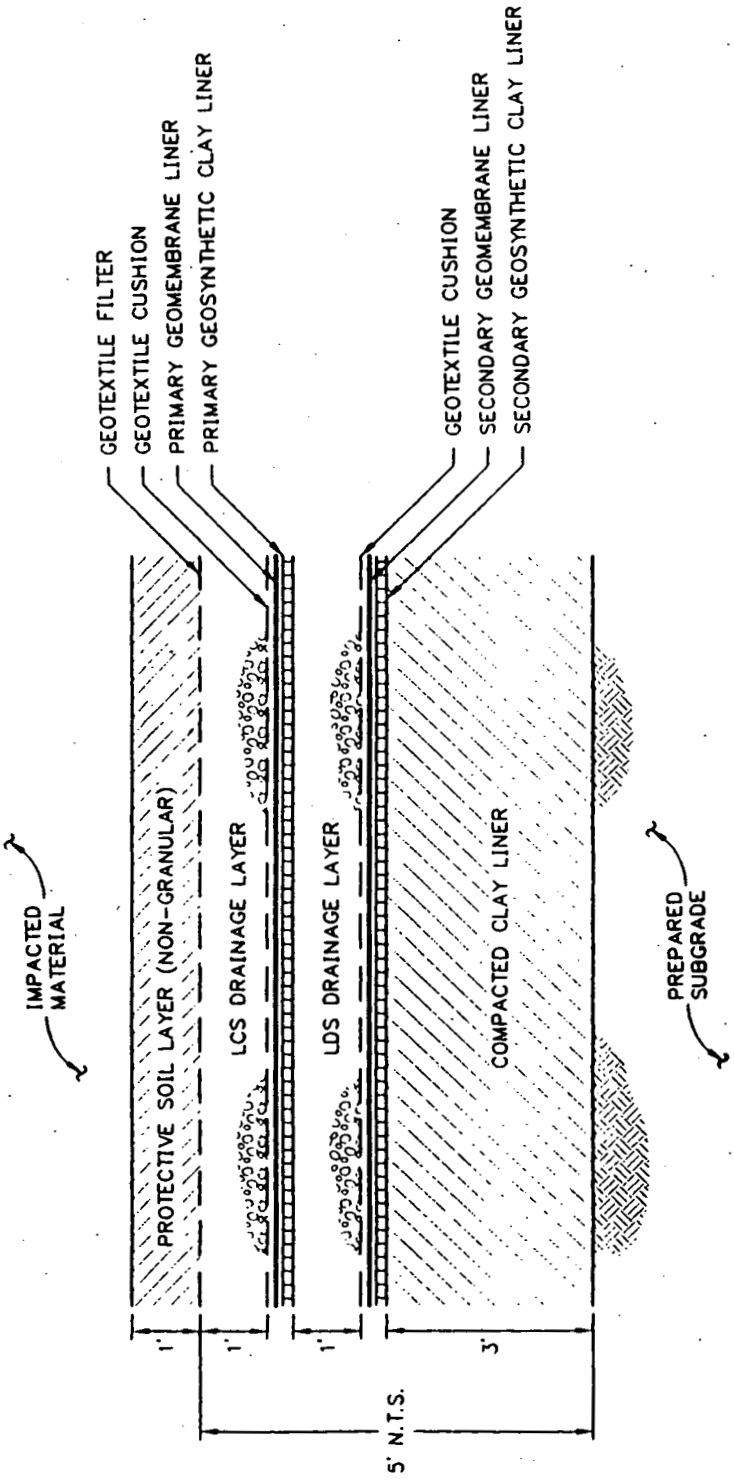
FIGURE 4: LINER SYSTEM ON OSDF BASE



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Written by: RAM Date: 95 / 10 / 12 Reviewed by: DBW Date: 95 / 10 / 16

Client: FERMACO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

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STEP 4: CALCULATE THE VOLUME OF ENDS BASED ON FIGURE 5, 6, & 7. THE ENDS COMBINED TOGETHER CREATE A VOLUME SIMILAR TO A PYRAMID. THE PYRAMID IS DIVIDED INTO 4 PARTS (20:1, 10:1, 6:1 SLOPES, AND THE LINER) FOR PURPOSES OF CALCULATING THE GROSS VOLUME OF THE ENDS.

- $$\forall_1 = \frac{1}{3}\left(H_3 - \frac{H_2+H_4}{2}\right)\left(W_3+W_4\right)^2 \checkmark$$

- $$\forall_2 = \frac{1}{3}\left(\frac{H_2+H_4}{2} - \frac{H_1+H_5}{2}\right)\left(\left(W_3+W_4\right)^2 + \left(W_2+W_3+W_4+W_5\right)^2 + \sqrt{\left(W_3+W_4\right)^2\left(W_2+W_3+W_4+W_5\right)^2}\right) \checkmark$$

- $$\forall_3 = \frac{1}{3}\left(\frac{H_1+H_5}{2}\right)\left(\left(W_2+W_3+W_4+W_5\right)^2 + \overbrace{\left(W_1+W_2+W_3+W_4+W_5+W_6\right)}^{=W_{11}}{}^2 + \sqrt{\left(W_2+W_3+W_4+W_5\right)^2 + \underbrace{\left(W_1+W_2+W_3+W_4+W_5+W_6\right)}_{=W_{11}}{}^2}\right) \checkmark$$

- $$\forall_4 = \frac{1}{3}\left(H_6\right)\left(\left(W_8\right)^2 + \left(W_{10}\right)^2 + \sqrt{\left(W_8^2\right)\left(W_{10}^2\right)}\right) \checkmark$$

- $$\forall_{ENDS} = \forall_1 + \forall_2 + \forall_3 + \forall_4 \quad \text{(GROSS VOLUME)} \checkmark$$

Written by: RAM Date: 95/10/12 (YY MM DD) Reviewed by: DBW Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

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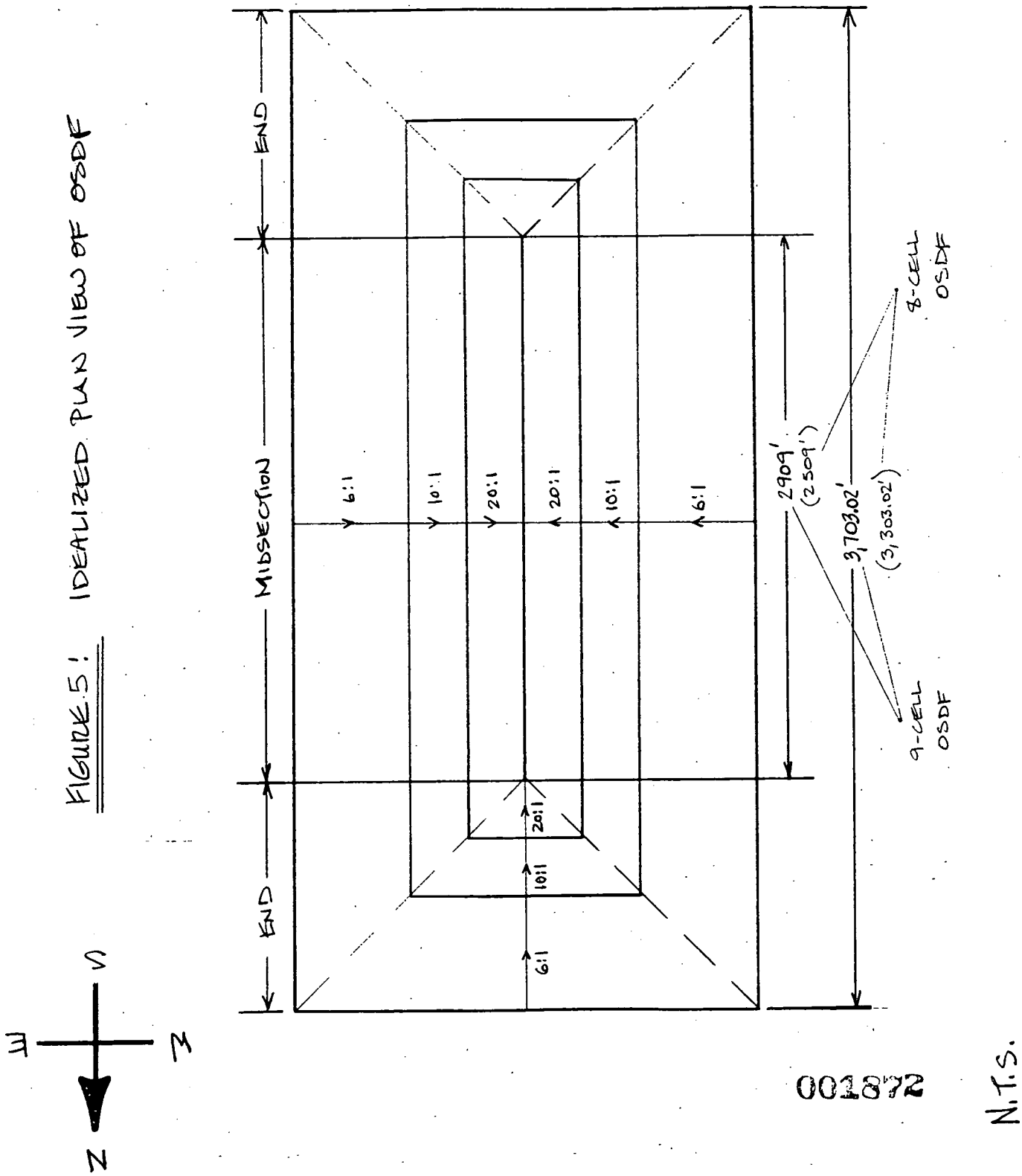
FIGURE 5: IDEALIZED PLAN VIEW OF OSDF



001872

N.T.S.

Written by: RAM Date: 95/10/12 (YY/MM/DD) Reviewed by: DGN Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

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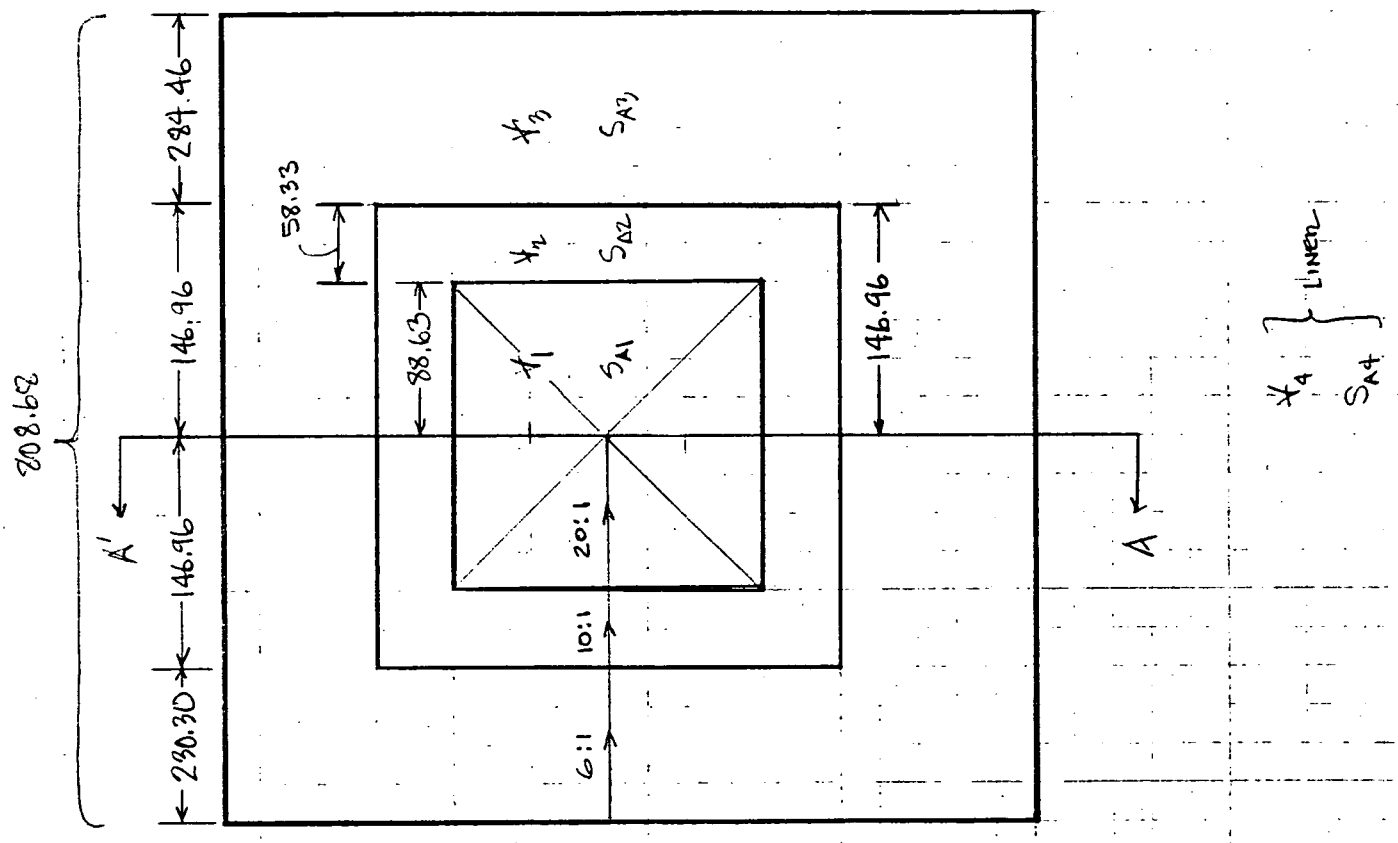

* FOR TRUNCATED PYRAMID:

$$V = \frac{a}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right)$$

REFERENCE:

O'ROURKE, C.E., GENERAL ENGINEERING HANDBOOK, McGRAW-HILL, NY, 1940, p.28 (Section 1)

FIGURE 6

001873

N.T.S.

Written by: RAH Date: 95/10/12 Reviewed by: DBW Date: 95/10/16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

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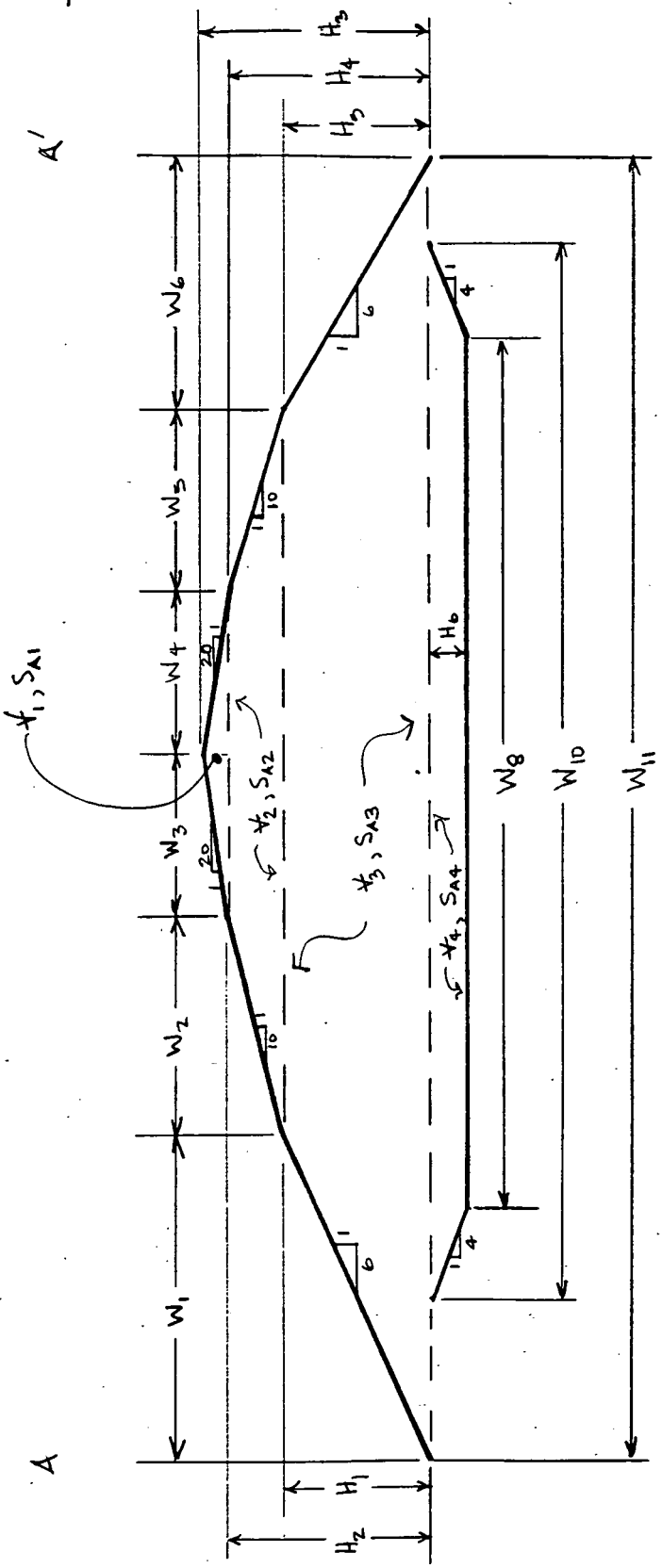

FIGURE 7: IDEALIZED CROSS-SECTION A-A' (FIGURE 6)

Written by: RAM Date: 95/10/12 (YY/MM/DD) Reviewed by: DBW Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

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STEP 5: IN ORDER TO DETERMINE THE VOLUME OF THE COVER AND LINER SYSTEM AT THE ENDS, IT IS NECESSARY TO CALCULATE THE SURFACE AREA OF THE ENDS.

- $S_{A1} = 2\left(\frac{1}{2}\left(2(W_3)\right)(L_3)\right) + 2\left(\frac{1}{2}\left(2(W_4)\right)(L_4)\right)$ ✓

- $S_{A2} = 4\left(\frac{L_2+L_5}{2}\right)\left(\frac{(W_3+W_4)+(W_2+W_3+W_4+W_5)}{2}\right)$ ✓

- $S_{A3} = 2\left(\frac{W_{11}+(W_2+W_3+W_4+W_5)}{2}\right)(L_1) + 2\left(\frac{W_{11}+(W_2+W_3+W_4+W_5)}{2}\right)(L_6)$ ✓

- $S_{A4} = W_8^2 + 4(L_7)\left(\frac{W_8+W_9}{2}\right)$ ✓

- V_c (COVER) $= 8.75'\,(S_{A1}+S_{A2}+S_{A3})$ ✓

- V_L (LINER) $= 5.0'\,(S_{A4})$ ✓

Written by: RAM Date: 95 / 10 / 11 (YY MM DD) Reviewed by: DBW Date: 95 / 10 / 16 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

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STEP 6: CALCULATE THE NET VOLUME OF THE ENDS.

- NET VOLUME (ENDS) = GROSS VOLUME − (VOL COVER + VOL LINER) ✓

STEP 7: CALCULATE VOLUME OF INTERCELL BERMS (SEE FIGURE 8)

- $A_1 = \frac{1}{2}(b_1)(h_1)$ ✓
- $A_2 = (h_1)(b_2)$ ✓
- $A_3 = (b_3)\left(\frac{h_2 + h_3}{2}\right)$ ✓
- $A_4 = (b_4)(h_4)$ ✓
- $A_5 = \frac{1}{2}(b_5)(h_4)$ ✓

- AVG. LENGTH OF INTERCELL BERMS $= \frac{W_8 + W_{10}}{2} = L_{AVG}$ (FIGURE 2) ✓

- TOTAL VOLUME OF INTERCELL BERMS (V_{IB})

THERE ARE 8 INTERCELL BERMS FOR 9-CELL OSDF

$$V_{IB} = \underset{(7)}{8}(A_1 + A_2 + A_3 + A_4 + A_5)(L_{AVG}) \checkmark$$

THERE ARE 7 INTERCELL BERMS FOR 8-CELL OSDF ✓

STEP 8: CALCULATE NET VOLUME (TOTAL)

- NET VOLUME = NET VOLUME (ENDS) + (A_N)(LENGTH OF MIDSECTION) − V_{IB} ✓

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FERMCO FERNALD OSDF

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GE 3900 11.1

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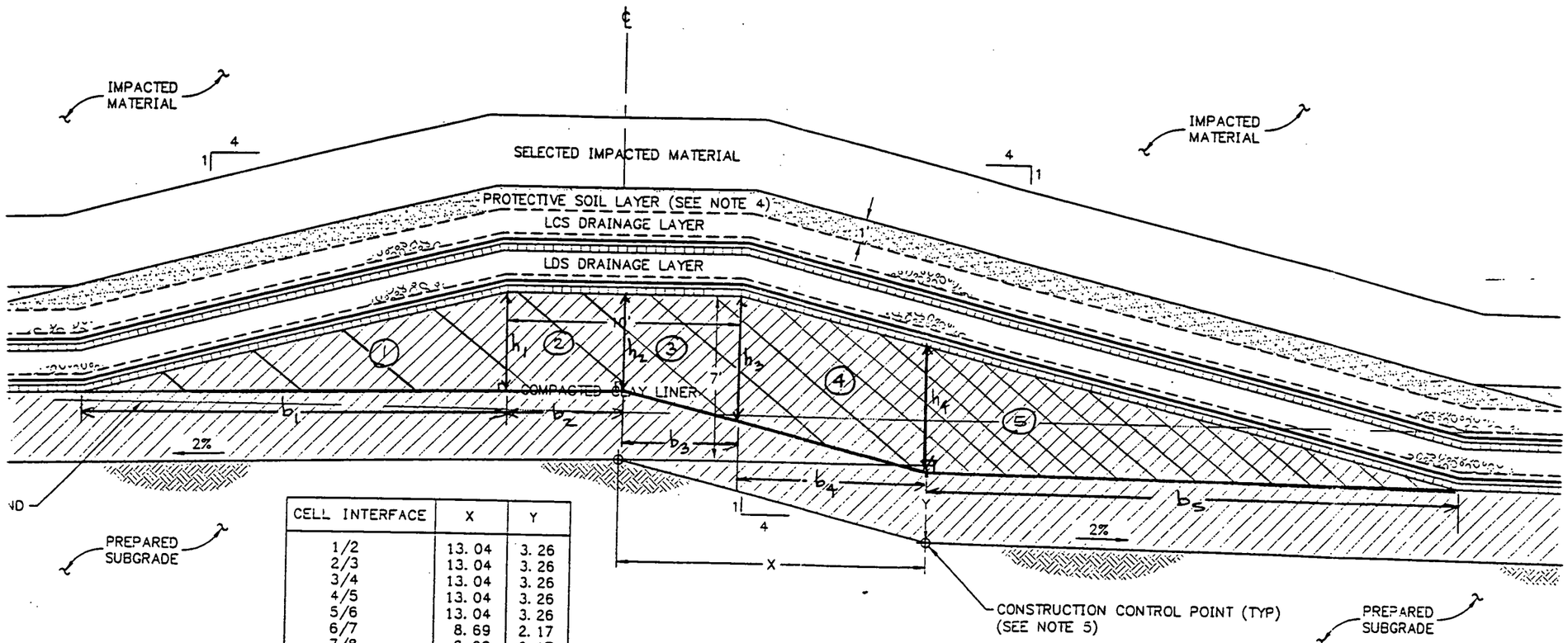

CELL INTERFACE	X	Y
1/2	13.04	3.26
2/3	13.04	3.26
3/4	13.04	3.26
4/5	13.04	3.26
5/6	13.04	3.26
6/7	8.69	2.17
7/8	8.69	2.17
8/9	8.69	2.17

DET-NO DETAIL

SHT-NO LINER SYSTEM AT INTERCELL BERM

~~SCALE 1" = 1'~~ NTS

XREF: F95XA025

FIGURE 8

001877

Written by: RAM Date: 95/10/12 (YY/MM/DD) Reviewed by: DBW Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

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OSDF CAPACITY VERIFICATION

DATA VERIFICATION PACKAGE

001878

Written by: RAM Date: 95/10/12 (YY/MM/DD) Reviewed by: DBW Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

fc 17 Oct 95

DIMENSIONS:

- DIMENSIONS OF AVERAGE E-W CROSS-SECTION (AUTOCAD®) ARE SHOWN IN FIGURE 1.

- N-S DIMENSIONS OF 9-CELL OSDF (9th CELL IS CONTINGENCY CELL):

  TOTAL LENGTH = 3,703.02 ft

  LENGTH OF MIDSECTION = 2,909 ft

- N-S DIMENSIONS OF 8-CELL OSDF (NO CONTINGENCY CELL):

  TOTAL LENGTH = 3,303.02 ft

  LENGTH OF MIDSECTION = 2,509 ft

RAM 95/10/12 DBW 95/10/16

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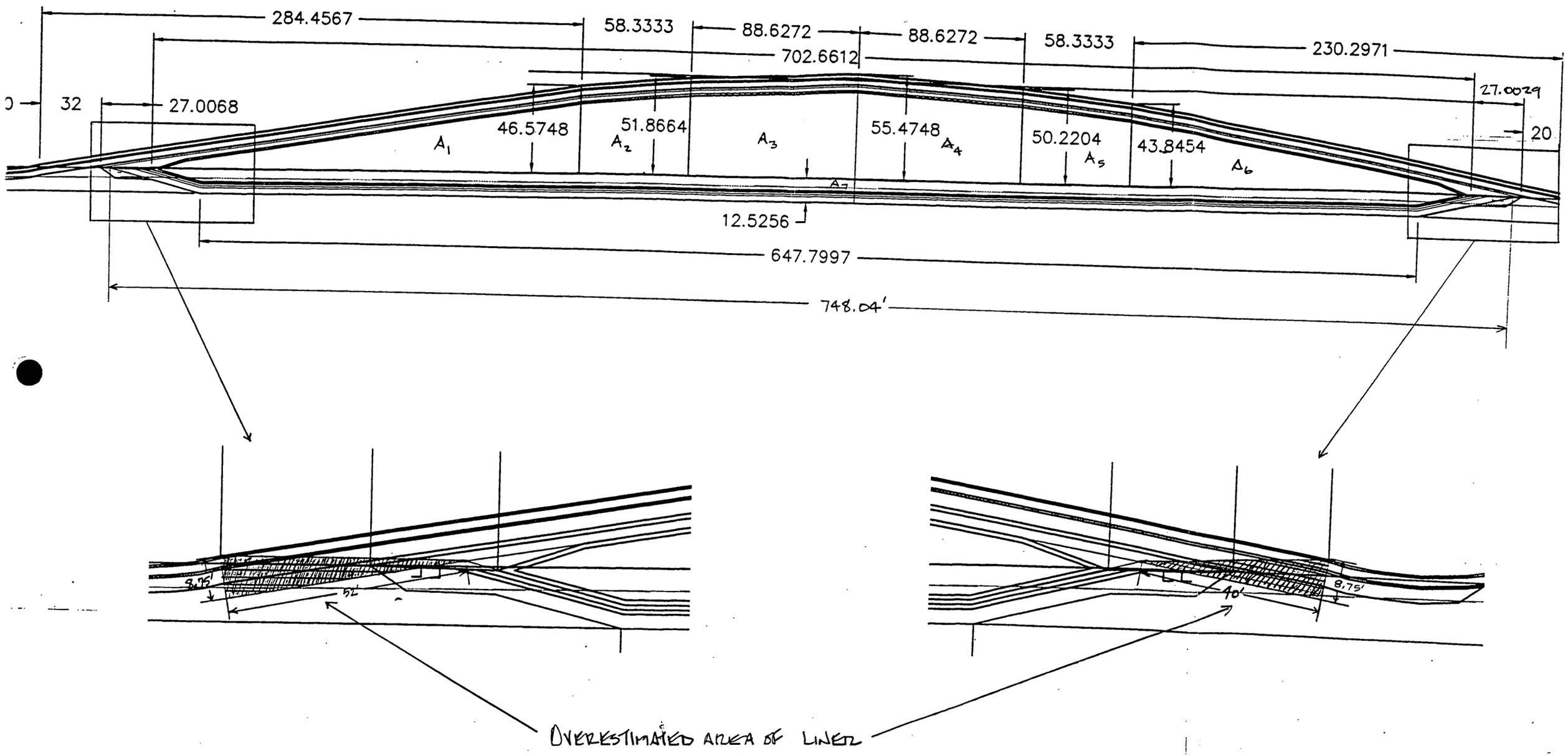


FIGURE 1:

Written by: RAM Date: 95/10/12 (YY MM DD) Reviewed by: BL Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

OSDF CAPACITY VERIFICATION CALCULATIONS

Written by: RAM Date: 95/10/12 (YY/MM/DD) Reviewed by: BL Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

CALCULATE VARIOUS DIMENSIONS SHOWN IN FIGURE 1:

- $L_1 = \sqrt{H_1^2 + W_1^2} = \sqrt{(46.57')^2 + (284.46')^2} = 288.25$ ft ✓
- $L_2 = \sqrt{(H_2 - H_1)^2 + W_2^2} = \sqrt{(51.87' - 46.57')^2 + (58.33')^2} = 58.57$ ft ✓
- $L_3 = \sqrt{(H_3 - H_2)^2 + W_3^2} = \sqrt{(55.47' - 51.87')^2 + (88.63')^2} = 88.70$ ft ✓
- $L_4 = \sqrt{(H_3 - H_4)^2 + W_4^2} = \sqrt{(55.47' - 50.22')^2 + (88.63')^2} = 88.79$ ft ✓
- $L_5 = \sqrt{(H_4 - H_5)^2 + W_5^2} = \sqrt{(50.22' - 43.85')^2 + (58.33')^2} = 58.68$ ft ✓
- $L_6 = \sqrt{H_5^2 + W_6^2} = \sqrt{(43.85')^2 + (230.30')^2} = 234.44$ ft ✓
- $L_7 = L_9 = \sqrt{H_6^2 + W_7^2} = \sqrt{(12.53')^2 + (50.12')^2} = 51.66$ ft ✓
- $L_8 = W_8 = 647.80'$

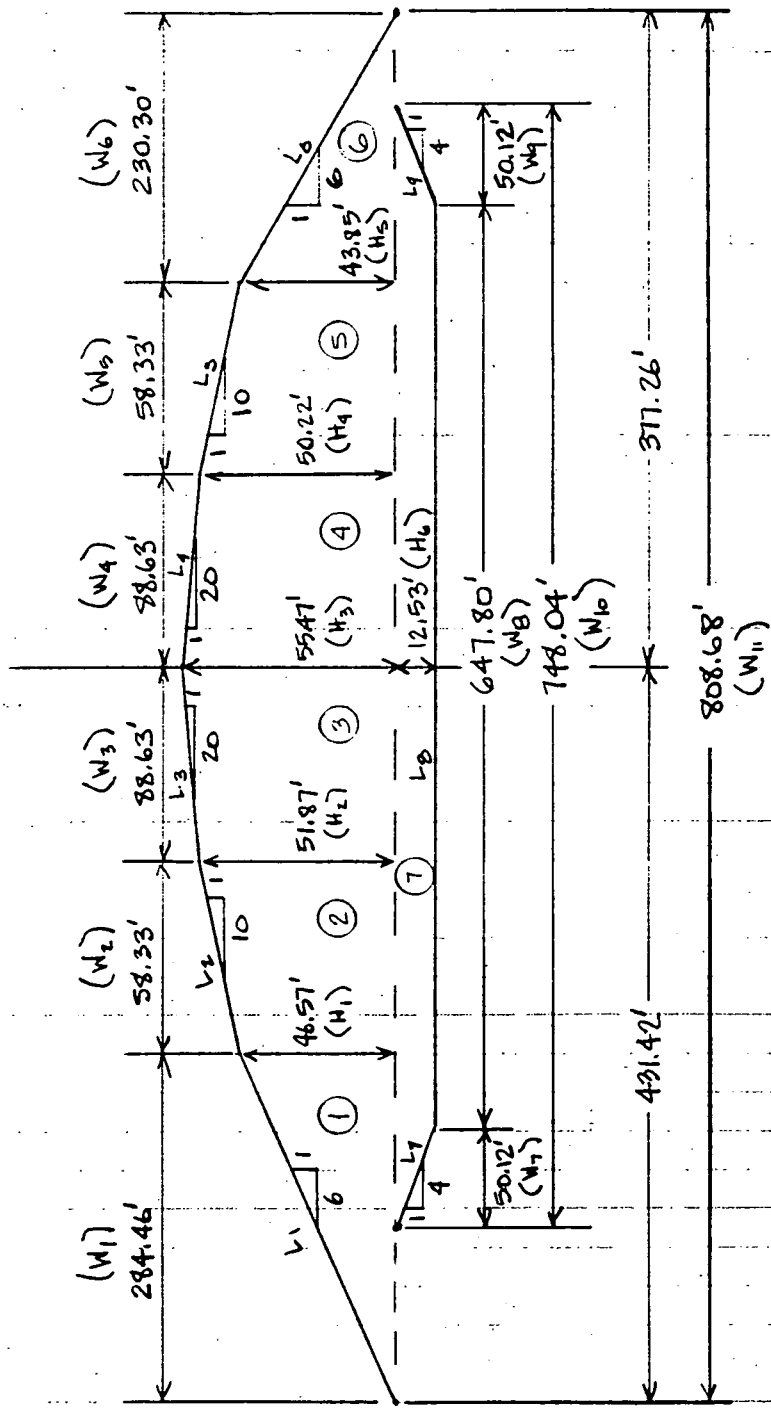
CALCULATE AREA OF E-W CROSS-SECTION

- $A_1 = \frac{1}{2}(W_1)(H_1) = \frac{1}{2}(284.46')(46.57') = 6{,}623.65$ ft^2 ✓
- $A_2 = \left(\frac{H_1 + H_2}{2}\right)(W_2) = \left(\frac{46.57' + 51.87'}{2}\right)(58.33') = 2{,}871.00$ ft^2 ✓
- $A_3 = \left(\frac{H_2 + H_3}{2}\right)(W_3) = \left(\frac{51.87' + 55.47'}{2}\right)(88.63') = 4{,}756.77$ ft^2 ✓

Written by: RAM Date: 95/10/12 (YY MM DD) Reviewed by: BL Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

FIGURE : E-W CROSS-SECTION



NTS

Written by: RAM Date: 95/10/12 (YY/MM/DD) Reviewed by: B.L Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

- $A_4 = \left(\frac{H_3+H_4}{2}\right)(W_4) = \left(\frac{55.47'+50.22'}{2}\right)(88.63') = 4{,}683.65\ ft^2$ ✓
- $A_5 = \left(\frac{H_4+H_5}{2}\right)(W_5) = \left(\frac{50.22'+43.85'}{2}\right)(58.33') = 2{,}743.55\ ft^2$ ✓
- $A_6 = \frac{1}{2}(H_5)(W_6) = \frac{1}{2}(43.85')(230.30') = 5{,}049.33\ ft^2$ ✓
- $A_7 = (W_8)(H_6) + 2\left[\frac{1}{2}(H_6)(W_7)\right]$

  $= (647.80')(12.53') + 2\left[\frac{1}{2}(12.53')(50.12')\right] = 8{,}744.94\ ft^2$ ✓

- $A_G = A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7$

$A_G = 35{,}472.89\ ft^2$ ✓

CALCULATE CROSS-SECTIONAL AREA OF COVER & LINER

- $A_C = 8.75'(L_1 + L_2 + L_3 + L_4 + L_5 + L_6)$

  $= 8.75'(288.25' + 58.57' + 88.70' + 88.79' + 58.68' + 234.44')$

  $A_C = 7{,}152.51\ ft^2$ ✓

- $A_L = 5.0'(L_7 + L_8 + L_9) = 5.0'(51.66' + 647.80' + 51.66')$

  $A_L = 3{,}755.60\ ft^2$ ✓

- $A_O = 402.5\ ft^2$ (AREA OF OVER ESTIMATION, SEE CALCULATION PROCEDURES PACKAGE)

Written by: RAM Date: 95/10/12 (YY MM DD) Reviewed by: B.L Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

CALCULATE NET AREA:

- $A_N = A_G - (A_C + A_L - A_O) = 35{,}472.89\ ft^2 - (7{,}152.51\ ft^2 + 3{,}755.60\ ft^2 - 402.5\ ft^2)$

$$A_N = 24{,}967.28\ ft^2 \checkmark$$

CALCULATE VOLUME OF ENDS:

- $$V_1 = \frac{1}{3}\left(H_3 - \frac{H_2 + H_4}{2}\right)(W_3 + W_4)^2$$

$$= \frac{1}{3}\left(55.47' - \frac{51.87' + 50.22'}{2}\right)(88.63' + 88.63')^2$$

$$V_1 = 46{,}346.13\ ft^3\ (1{,}716.52\ cyd) \checkmark$$

- $$V_2 = \frac{1}{3}\left(\frac{H_2 + H_4}{2} - \frac{H_1 + H_5}{2}\right)\left((W_3 + W_4)^2 + (W_2 + W_3 + W_4 + W_5)^2 + \sqrt{(W_3 + W_4)^2 (W_2 + W_3 + W_4 + W_5)^2}\right)$$

$$= \frac{1}{3}\left(\frac{51.87' + 50.22'}{2} - \frac{46.57' + 43.85'}{2}\right)\left((2 \cdot 88.63')^2 + (2 \cdot 88.63' + 2 \cdot 58.33')^2 + \sqrt{(2 \cdot 88.63')^2 (2 \cdot 88.63' + 2 \cdot 58.33')^2}\right)$$

$$V_2 = 330{,}475.60\ ft^3\ (12{,}239.84\ cyd) \checkmark$$

Written by: RAM Date: 95/10/12 Reviewed by: B.L Date: 95/10/16

Client: FERMACO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

- $$\forall_3 = \frac{1}{3}\left(\frac{H_1+H_5}{2}\right)\left((W_2+W_3+W_4+W_5)^2 + (W_{11})^2 + \sqrt{(W_2+W_3+W_4+W_5)^2(W_{11})^2}\right)$$

$$= \frac{1}{3}\left(\frac{46.97'+43.85'}{2}\right)\left((2\cdot 58.33'+2\cdot 88.63')^2 + (808.68')^2 + \sqrt{(2\cdot 58.33'+2\cdot 88.63')^2(808.68)^2}\right)$$

$$\forall_3 = 14{,}739{,}055.78\ ft^3\ (545{,}890.95\ cyd)$$ ✓

- $$\forall_4 = \frac{1}{3}(H_6)\left(W_8^2 + W_{10}^2 + \sqrt{(W_8^2)(W_{10}^2)}\right)$$

$$= \frac{1}{3}(12.53')\left((647.80')^2 + (748.04')^2 + \sqrt{((647.80')^2(748.04')^2)}\right)$$

$$\forall_4 = 6{,}113{,}758.70\ ft^3\ (226{,}435.51\ cyd)$$ ✓

- $$\forall_{ENDS} = \forall_1 + \forall_2 + \forall_3 + \forall_4 \quad \text{(GROSS VOLUME)}$$

$$= 46{,}346.13\ ft^3 + 330{,}475.60\ ft^3 + 14{,}739{,}055.78\ ft^3 + 6{,}113{,}758.70\ ft^3$$

$$\forall_{ENDS} = 21{,}229{,}636.21\ ft^3\ (786{,}282.82\ cyd)$$ ✓

Written by: RAM Date: 95/10/12 Reviewed by: BL Date: 95/10/16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

CALCULATE SURFACE AREA OF ENDS

- $S_{A1} = 2\left(\frac{1}{2}\left(2(W_3)\right)(L_3)\right) + 2\left(\frac{1}{2}\left(2(W_4)\right)(L_4)\right)$

$= \left(2(88.63')(88.70')\right) + \left(2(88.63')(88.79')\right)$

$S_{A1} = 31{,}461.88\ ft^2$ ✓

- $S_{A2} = 4\left(\frac{L_2+L_5}{2}\right)\left(\frac{(W_3+W_4)+(W_2+W_3+W_4+W_5)}{2}\right)$

$= 4\left(\frac{58.68'+58.57'}{2}\right)\left(\frac{(2\cdot 88.63')+(2\cdot 88.63'+2\cdot 58.33')}{2}\right)$

$S_{A2} = 55{,}245.86\ ft^2$ ✓

- $S_{A3} = 2\left(\frac{W_{11}+(W_2+W_3+W_4+W_5)}{2}\right)(L_1)$

$+ 2\left(\frac{W_{11}+(W_2+W_3+W_4+W_5)}{2}\right)(L_6)$

$= 2\left(\frac{808.68'+(2\cdot 88.63'+2\cdot 58.33')}{2}\right)(288.25')$

$+ 2\left(\frac{808.68'+(2\cdot 88.63'+2\cdot 58.33')}{2}\right)(234.44')$

$S_{A3} = 576{,}317.99\ ft^2$ ✓

Written by: RAM Date: 95/10/12 Reviewed by: R.L Date: 95/10/16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

- $S_{A4} = W_8^2 + 4(L_7)\left(\frac{W_9 + W_{10}}{2}\right)$

$= (647.80')^2 + 4(51.66')\left(\frac{647.8' + 748.04'}{2}\right)$ ✓

$S_{A4} = 563{,}863.03\ ft^2$ ✓

CALCULATE VOLUME OF COVER & LINER FOR ENDS

- $\forall_c = 8.75'(S_{A1} + S_{A2} + S_{A3})$

$= 8.75'(31{,}461.88\ ft^2 + 55{,}245.86\ ft^2 + 576{,}317.99\ ft^2)$

$\forall_c = 5{,}801{,}475.14\ ft^3\ (214{,}869.45\ cyd)$

- $\forall_L = 5.0'(S_{A4})$

$= 5.0'(563{,}863.03\ ft^2)$

$\forall_L = 2{,}819{,}315.14\ ft^3\ (104{,}419.08\ cyd)$ ✓

CALCULATE NET VOLUME OF ENDS

- $\forall_{ENDS}(NET) = \forall_{ENDS}(GROSS) - (\forall_c + \forall_L)$

$= 786{,}282.82\ cyd - (214{,}869.45\ cyd + 104{,}419.08\ cyd)$

$\forall_{ENDS}(NET) = 466{,}994.29\ cyd$ ✓

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Written by: RAM Date: 95/10/13 (YY MM DD) Reviewed by: B.L Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

CALCULATE VOLUME OF INTERCELL BERMS

- $A_1 = \frac{1}{2}(b_1)(h_1) = \frac{1}{2}(18')(4.1') = 36.9\ ft^2$ ✓
- $A_2 = (h_1)(b_2) = (4.1')(5.2') = 21.32\ ft^2$ ✓
- $A_3 = (b_3)\left(\frac{h_2+h_3}{2}\right) = (4.8')\left(\frac{4.1'+5.3'}{2}\right) = 22.56\ ft^2$ ✓
- $A_4 = (b_4)(h_4) = (8.1')(5.3') = 42.93\ ft^2$ ✓
- $A_5 = \frac{1}{2}(b_5)(h_4) = \frac{1}{2}(23')(5.3') = 60.95\ ft^2$ ✓

$A_T = A_1 + A_2 + A_3 + A_4 + A_5 = 184.66\ ft^2$ ✓

- $L_{AVG} = \frac{W_8 + W_{10}}{2} = \frac{647.80' + 748.04'}{2} = 697.92'$ ✓

\# of intercell berms 9-CELL OSDF

- $V_{IB-9} = 8(A_T)(L_{AVG}) = 8(184.66\ ft^2)(697.92')$

$V_{IB-9} = 1{,}031{,}023.26\ ft^3\ (38{,}186.05\ cyd)$ ✓

8-CELL OSDF

$V_{IB-8} = 7(A_T)(L_{AVG}) = 7(184.66\ ft^2)(697.92')$

$V_{IB-8} = 902{,}145.35\ ft^3\ (33{,}412.79\ cyd)$ ✓

Written by: RAM Date: 95/10/13 Reviewed by: BL Date: 95/10/16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3960 Task No.: 11.1

CALCULATE NET VOLUME (TOTAL) (9-CELL OSDF)

- $\forall_N(\text{TOTAL}) = \forall_{\text{ENDS}}(\text{NET}) + (A_N)(\text{LENGTH OF MIDSECTIONS}) - \forall_{IB-9}$

$= 466{,}994.29\ \text{cyd} + (24{,}967.28\ ft^2)(2909\ ft)(1\ yd^3/27\ ft^3) - 38{,}186.05\ \text{cyd}$

$\forall_N(\text{TOTAL}) = 3{,}118{,}801.48\ \text{cyd}$ ✓

CALCULATE NET VOLUME (TOTAL) (8-CELL OSDF)

- $\forall_N(\text{TOTAL}) = \forall_{\text{ENDS}}(\text{NET}) + A_N(\text{LENGTH OF MIDSECTION}) - \forall_{IB-8}$

$= 466{,}994.29\ \text{cyd} + (24{,}967.28\ ft^2)(2509\ ft)\left(\frac{1\ yd^3}{27\ ft^3}\right) - 33{,}412.79\ \text{cyd}$

$\forall_N(\text{TOTAL}) = 2{,}753{,}689.11\ \text{cyd}$ ✓

Written by: RAD Date: 95/10/13 (YY MM DD) Reviewed by: B.L Date: 95/10/16 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

OSDF CAPACITY VERIFICATION

(AUTOCAD® PROCEDURES AND QUANTITIES)

INTRODUCTION:

THE PURPOSE OF THIS SECTION IS TO PRESENT AN OVERVIEW OF THE AUTOCAD® PROCEDURES USED TO CALCULATE THE OSDF CAPACITY AND TO PRESENT THE CAPACITY QUANTITIES CALCULATED USING AUTOCAD®.

METHOD OF ANALYSIS:

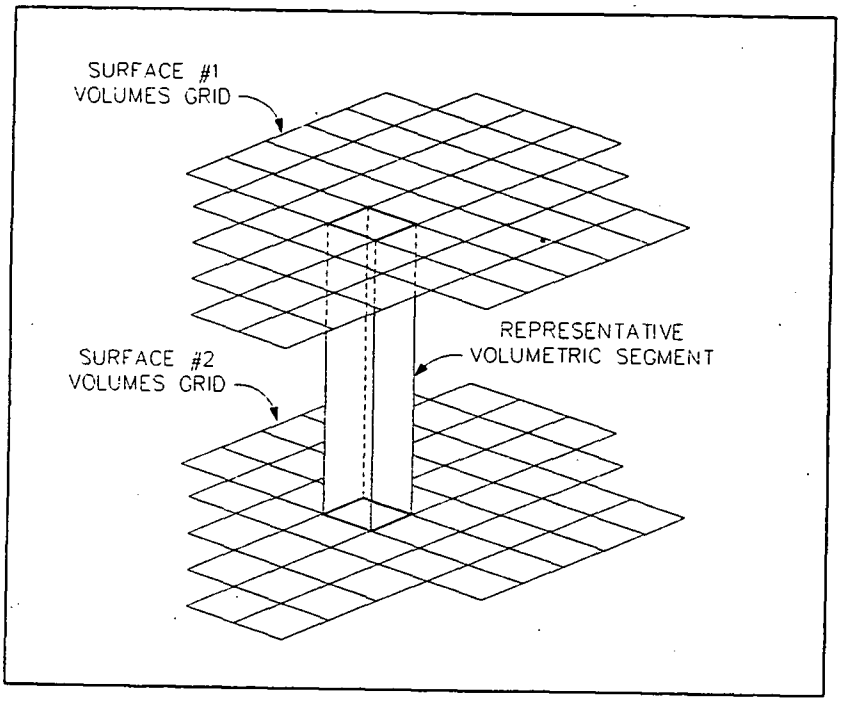
USING THE EARTHWORKS VOLUME CALCULATION PACKAGE DEVELOPED BY SOFTDESK FOR AUTOCAD® [SOFTDESK, 1994], THE USER CHOOSES TWO SURFACES BETWEEN WHICH AUTOCAD® CALCULATES THE VOLUME. AUTOCAD® GENERATES A TIN (TRIANGULAR IRREGULAR NETWORK) SURFACE FOR EACH OF THE SURFACES CHOSEN BY THE USER. THE TOP OF THE LEACHATE COLLECTION SYSTEM (LCS) PLAN AND THE TOP OF THE CONTOURING LAYER WERE THE TWO SURFACES CHOSEN IN ORDER TO DETERMINE THE OSDF CAPACITY USING THE GRID METHOD. THE GRID METHOD INTERPOLATES VOLUMES USING GRIDS (CHOSEN TO BE 10' x 10' GRIDS) OVERLAID ON THE

(CONTINUED)

Written by: RAM Date: 95/10/13 Reviewed by: B.L Date: 95/10/16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

THE TWO TIN SURFACES. THE VOLUMES ARE CALCULATED USING THE PRISMOIDAL VOLUME OF ALL GRIDS AND SUMMARIZING. THE FOLLOWING ILLUSTRATION IS A REPRESENTATION OF THE GRID METHOD.



Calculating Volumes Using Grid Based Earthworks Method

REFERENCE:

SOFTDESK, INC., SOFTDESK® CIVIL/SURVEY: EARTHWORKS REFERENCE MANUAL, HENNIKER, NH, NOVEMBER 1994.

Written by: RAM Date: 95/10/13 Reviewed by: B.L Date: 95/10/16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 11.1

- 9-CELL OSDF:

OSDF CAPACITY – CALCULATED USING AUTOCAD®

- SEE P. 15 AND 16 :

$$V_{NET}(\text{AUTOCAD® USER \#1}) = 3{,}278{,}426.60 \text{ cyd}$$

$$V_{NET}(\text{AUTOCAD® USER \#2}) = 3{,}272{,}361.87 \text{ cyd}$$

$$V_{NET}(\text{AVG}) = 3{,}275{,}394.24 \text{ cyd} \checkmark$$

COMPARISON: AUTOCAD® CAPACITY vs. HAND-CALC. CAPACITY

$$V_{NET}(\text{AUTOCAD®}) = 3{,}275{,}394.24 \text{ cyd} \checkmark$$

$$V_{NET}(\text{HAND}) = 3{,}118{,}801.48 \text{ cyd} \checkmark$$

$$\%\ \text{DIFFERENCE} = \frac{V_{NET}(\text{AUTOCAD®}) - V_{NET}(\text{HAND})}{V_{NET}(\text{AUTOCAD®})} * (100)$$

$$= \frac{3{,}275{,}394.24 \text{ cyd} - 3{,}118{,}801.48 \text{ cyd}}{3{,}275{,}394.24 \text{ cyd}} * (100)$$

$$\%\ \text{DIFFERENCE} = 4.80\% \checkmark$$

Written by: RAM Date: 95/10/16 (YY/MM/DD) Reviewed by: B.L. Date: 95/10/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 11.1

- 8-CELL OSDF:

OSDF CAPACITY - CALCULATED USING AUTOCAD®.

- SEE P.15 AND 16:

V_{NET} (AUTOCAD® USER #1) = 2,900,618.05 cyd ✓

V_{NET} (AUTOCAD® USER #2) = 2,895,452.11 cyd ✓

V_{NET} (AVG) = 2,898,035.08 cyd ✓

COMPARISON: AUTOCAD® CAPACITY vs. HAND-CALC. CAPACITY

V_{NET} (AUTOCAD®) = 2,898,035.08 cyd ✓

V_{NET} (HAND) = 2,753,689.11 cyd ✓

$$\% \text{ DIFFERENCE} = \frac{V_{NET}(\text{AUTOCAD®}) - V_{NET}(\text{HAND})}{V_{NET}(\text{AUTOCAD®})}(100)$$

$$= \frac{(2{,}898{,}035.08 \text{ cyd} - 2{,}753{,}689.11 \text{ cyd})}{2{,}898{,}035.08 \text{ cyd}}(100)$$

% DIFFERENCE = 4.98 % ✓

RAM 95/10/13

FERMCO FERNALD OSDF

GE3900 11.1

Subsite Volume Table: Unadjusted

Stratum	Surf1	Surf2	Cut yards	Fill yards	Net yards
Subsite: S1 cover	lcs	cov-8	0.00	312498.91	312498.91 (F)
Subsite: S2 cover	lcs	cov-8	0.00	382964.23	382964.23 (F)
Subsite: S3 cover	lcs	cov-8	0.00	380800.21	380800.21 (F)
Subsite: S4 cover	lcs	cov-8	0.00	380378.59	380378.59 (F)
Subsite: S5 cover	lcs	cov-8	0.00	380758.11	380758.11 (F)
Subsite: S6 cover	lcs	cov-8	0.00	381458.23	381458.23 (F)
Subsite: S7 cover	lcs	cov-8	0.00	377893.28	377893.28 (F)
Subsite: S8 cover	lcs	cov-8	0.00	377808.55	377808.55 (F)
Subsite: S9 cover	lcs	cov-8	0.00	303866.49	303866.49 (F)

3,278,426.60 cyd
(9-CELL OSDF)

- 400' LENGTH OF MIDSECTION
- V (8-CELL OSDF) = 3,278,426.60 − 377,808.55
  = 2,900,618.05 cyd
  (8-CELL OSDF)

B.L 95/10/16

RAM 95/10/13

FERMCO FERNALD OSDF GE3900 11.1

Subsite Volume Table: Unadjusted

Stratum	Surf1	Surf2	Cut yards	Fill yards	Net yards
Subsite: J1					
vol-1	johna	cov-8	0.00	311268.05	311268.05 (F)
Subsite: J2					
vol-1	johna	cov-8	0.00	381997.36	381997.36 (F)
Subsite: J3					
vol-1	johna	cov-8	0.00	380830.08	380830.08 (F)
Subsite: J4					
vol-1	johna	cov-8	0.00	380876.36	380876.36 (F)
Subsite: J5					
vol-1	johna	cov-8	0.00	380411.40	380411.40 (F)
Subsite: J6					
vol-1	johna	cov-8	0.00	380050.57	380050.57 (F)
Subsite: J7					
vol-1	johna	cov-8	0.00	377301.16	377301.16 (F)
Subsite: J8					
vol-1	johna	cov-8	0.00	376909.76	376909.76 (F)
Subsite: J9					
vol-1	johna	cov-8	0.00	302717.13	302717.13 (F)

3,272,361.87 cyd
(9-CELL OSDF)

- 400' LENGTH OF MIDSECTION
- ∀(8-CELL OSDF) = 3,272,361.87 − 376,909.76
  = 2,895,452.11 cyd
  (8-CELL OSDF)

Written By: RAT Date: 22 OCT 95 Reviewed by: Date:

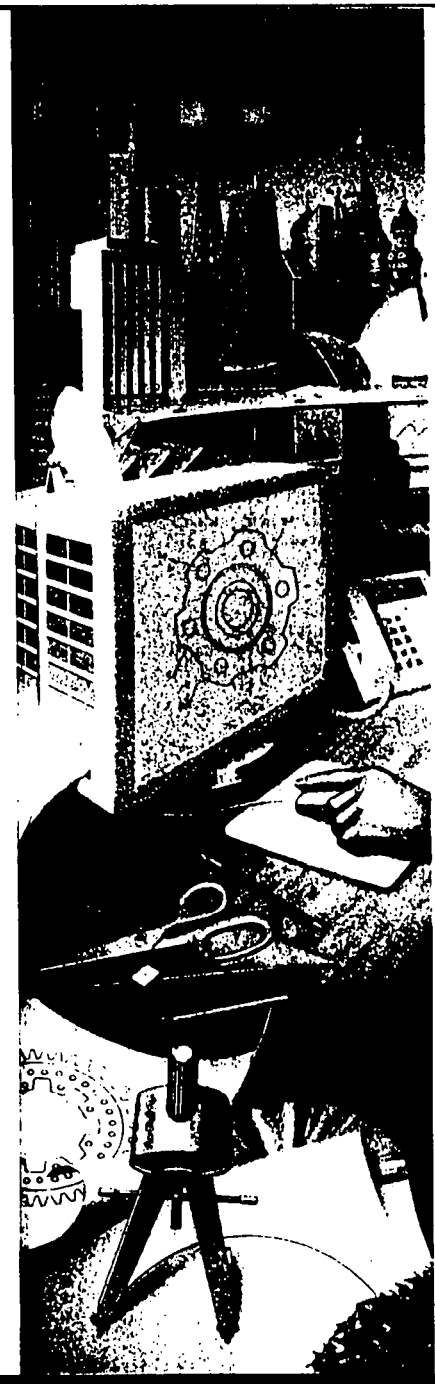
Client: Ferrosco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 11.1

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATIONS PACKAGE

1. Autodesk®, Inc., AutoCAD® Release 13 User's Guide, September 1994.

2. SOFTDESK®, Inc., SOFTDESK® Civil/Survey: Earthworks Reference Manual, Henner, NH, November 1994.



Autodesk.

AutoCAD® Release 13

USER'S GUIDE

A2-934

00105-010000-5020 September 15, 1994

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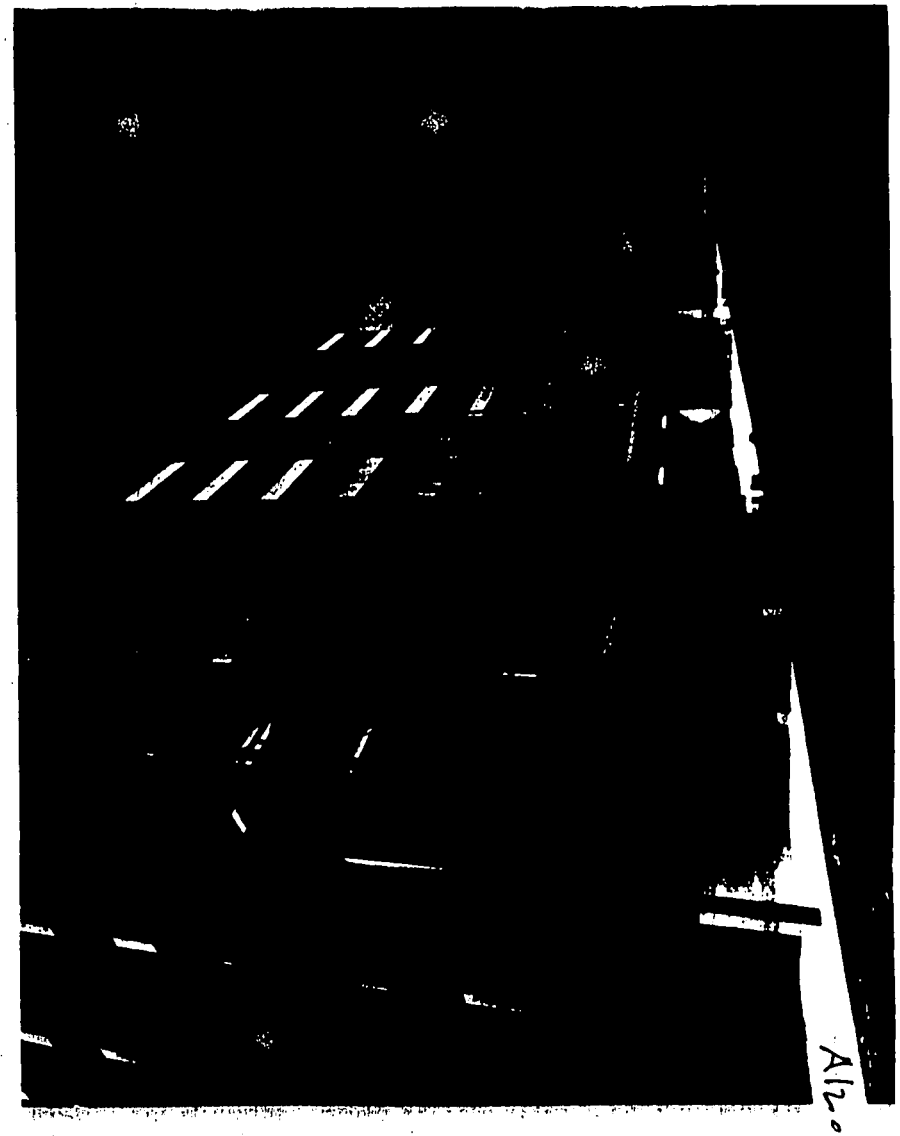

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INTRODUCTION

AutoCAD is a full-featured program for computer-aided design (CAD). With the AutoCAD drafting system, you can prepare realistic, accurate two-dimensional drawings and three-dimensional models. The *AutoCAD User's Guide* describes AutoCAD's powerful features and their procedures with a step-by-step graphical approach. This introduction describes how to

- Use AutoCAD documentation
- Find information about AutoCAD
- Learn AutoCAD with the *AutoCAD User's Guide*
- Interpret the conventions in AutoCAD documentation

The *AutoCAD User's Guide* is complemented by several documents in the AutoCAD documentation set. To learn more about the complete set of AutoCAD Release 13 documentation, see the *AutoCAD Documentation Guide*.

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Using AutoCAD Documentation

As a novice or experienced user, the best way to learn the details of AutoCAD's features is to use the *AutoCAD User's Guide* in conjunction with the *AutoCAD Command Reference*. After familiarizing yourself with a CAD concept and AutoCAD feature in the *User's Guide*, you can learn more details about a specific command using the *Command Reference*. The *Command Reference* is also available on line from the Help menu. It's a complete electronic version of the *Command Reference* and includes a glossary with more than 300 terms. With Help you can look up a command by name or by its placement on a menu or toolbar. Also, you can access Help with context-sensitive methods:

- For a command, enter **help** while the command is active or press F1 (Windows only)
- For a dialog box, select the dialog box Help button
- For a menu, select the menu name to open the menu, and then press F1 (Windows only).

If you're a novice user, you may want to take the *AutoCAD Quick Tour*, which introduces you to CAD concepts and AutoCAD features. Before starting with the *User's Guide*, you can get hands-on experience with the AutoCAD tutorial, *Learning AutoCAD*. If you're upgrading from an earlier release, you may want to look at *AutoCAD What's New in Release 13*, which is available on line from the Help menu.

Note For the latest changes to AutoCAD information and procedures, refer to the *readme.doc* file.

Using This Guide

The *User's Guide* describes the fundamental concepts and procedures first. Chapters 1 through 3 explain the basics. Beginners should understand these chapters before going further. Chapter 4 describes how to control the drawing display and chapter 5 explains editing methods. Chapters 6 through 10 explain two-dimensional drawing, followed by chapters 11 and 12, which describe the details of creating three-dimensional models. Chapters 13, 14, and 15 explain the specifics of using external databases, importing and exporting different file formats, and file management, respectively.

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Appendixes A, B, and C explain customizing toolbars, how to work with Windows applications, and standard libraries of fonts, PostScript patterns, and so on provided with AutoCAD. Appendix D explains compatibility issues you may encounter if you're upgrading from an older version of AutoCAD. The glossary (the printed version of the Help glossary) and index complete the *User's Guide*.

The *User's Guide* explains most AutoCAD features by introducing the drafting concept and feature, followed by procedural steps.

To calculate the area of an object

1 Start the AREA command using one of these methods:

Windows	From the Inquiry flyout on the Object Properties toolbar, choose Area.
DOS and UNIX	From the Assist menu, choose Inquiry. Then choose Area.

2 Enter **o** for Object.

3 Select an object.

command used for the same procedure

Command line equivalent AREA

other ways to do the same task

Alternate You also can use the DDMODIFY command to display an object's area and other information. If you use Windows, from the Object Properties toolbar, choose Properties. If you use DOS or UNIX, from the Modify menu, choose Properties.

information about similar features

Related Use the MASSPROP command to display additional information on solids and regions.

In most cases, the menu and the toolbar access (for Windows) are described in detail. However, as an experienced user, you may prefer to use the command line. The command line equivalent appears after the numbered steps. For detailed information about the command's options, see the *AutoCAD Command Reference*.

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Typographical Conventions

To orient you to AutoCAD features as they appear on the screen, specific terms are set in typefaces that distinguish them from the body text. Throughout AutoCAD documentation, the following conventions are used.

Formatting Conventions

Text element	*Example*
Keys you press on the keyboard The [↵] key is the same as [Enter] and [Return]	[Delete], [Esc]
Keys you press simultaneously on the keyboard	[Ctrl]+[C]
Menu items, prompts, and other text displayed on screen are in sans serif	From the File menu, choose Open. Command: **area** <First point>/Object/Add/Subtract:
Text you enter is in bold sans serif	At the Command prompt, enter **shape**
File names, names of directories, and instructions after prompt sequences are in italic	Select objects: *Use an object selection method* *disc.dwg* *c:\acad\support*
AutoCAD-named objects, such as layers, linetypes, and styles, and AutoCAD commands and system variables are in uppercase	SAVE, COPY, DWGNAME, BLIPMODE DISC-FRONT, DASHDOT, STANDARD
AutoLISP and C variables, sample code, and text in ASCII files are in monospaced font	`***POP1` The variable `pi` is preset to a value of pi
AutoLISP, ADS, and DIESEL function names are in bold monospaced font	**`command ads_command( )`**
Formal arguments specified in function definitions are in italic monospaced font	The *`string`* and *`mode`* arguments

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GETTING STARTED

This chapter lays the groundwork for learning and using AutoCAD. It provides basic, crucial information about the graphical and command interfaces. It explains how to set up the drawing environment and work effectively in that environment. Among other topics, this chapter covers

- Starting AutoCAD
- Getting help
- Using AutoCAD commands
- Specifying points in a coordinate system
- Setting up a new drawing
- Refreshing the screen display
- Moving around a drawing
- Working with named objects

For more details on AutoCAD features new to this release, see the on-line *AutoCAD What's New in Release 13*. To practice using commands together in exercises, see the on-line or printed tutorial, *Learning AutoCAD*.

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Softdesk® Civil/Survey

Earthworks Reference Manual

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Chapter 1

Introduction

The Softdesk *Earthworks* module is a complete package for Civil Engineers and Surveyors. Softdesk *Earthworks* calculates cut and fill quantities for sites, roadways, and other applications. It can calculate total site volumes or localized subsite volumes as well as producing a proposed site surface using grading commands. The *Earthworks* module operates within the AutoCAD drawing editor.

How this Guide is Organized

As a reference text, this guide provides detailed explanations of the unique Softdesk *Earthworks* commands. Information on installation, system basics, Setup commands, and customization can be found in the respective chapters of the *Softdesk COGO Reference Manual*. Information on project management can be found in the respective chapter of the *Softdesk DTM Reference Manual*.

This reference manual is divided into the following sections.

- Chapter 1, *Introduction*, provides a summary of the topics covered in this guide. It also describes the conventions used in this guide.
- Chapter 2, *Earthworks Settings*, describes the settings used to manage the *Earthworks* project.
- Chapter 3, *Grading*, describes commands that produce the finished surface of a site.
- Chapter 4, *Volumes*, describes commands that define the total site for volume calculations and compute the volume between two surfaces.
- Chapter 5, *Earthwork Tools*, describes commands that manipulate *DTM* and *Earthworks* entities by their layers, and commands that set, import, and list information about Earthworks points.
- Appendix A, *Glossary*, defines common *DTM* and *Earthwork* terms.

- Appendix B, *Revision History*, describes the changes made from the previous release of *Earthworks*.
- Appendix C, *File Listing*, contains a description of the files created by *Earthworks*.

For Unix and DOS installation and set up procedures for this module, see the *Softdesk Core Reference Manual.*

Requirements and Recommendations

This version of Earthworks operates on any true 386 or 486 compatible computer. The minimum hardware requirements for the software are as follows:

- 8MB of Ram, with 1MB of this memory containing 640K of conventional memory for AutoCAD Release 12 and 16MB of Ram with 1MB of this containing 640K of conventional memory for AutoCAD Release 13
- A floppy drive with a 3-1/2" high density drive. 5 1/4" high density drives are supported by special request only.
- The MAXV switch set to the amount of memory used by Softdesk and AutoCAD programs and data if using expanded memory.
- A 387 math coprocessor (486 computers have a built-in 387 coprocessor) is recommended, but not required.

The minimum software requirements for the software are as follows:

- DOS 5.0 or higher
- AutoCAD Release 12 or 13
- Softdesk *Core* Version 7.0
- Softdesk *COGO* Version 7.0
- Softdesk *DTM* Version 7.0

Conventions Used in this Guide

This section describes the format of the notations used in the Softdesk reference manuals. It is important to realize the distinctions between these conventions; to both expedite and ensure your comprehension of the material.

We have adopted some conventions that make descriptions more consistent and easier to understand.

Typographical Conventions

Throughout the manual we use different formatting to express different information. This section describes the typographical conventions used in this manual.

Formatting	Description
italic	Italicized text is used for filenames, file extensions, directory paths, manuals and module names. It is also used to represent variable data (data that may change from one instance to another).
`prompt text`	Text in this monospaced typeface represents text displayed on the computer screen, including prompts and the contents of ASCII text files.
bold	Bold text represents an action that you must make.
<Enter>	Text in angle brackets represents a key or keys on the computer keyboard.
{variable}	Italic text in curly brackets represents a variable value. The value displayed on your monitor may vary from one instance to another.
ZOOM	AutoCAD command names and system variable names are shown in all capital letters.
[Command]	Softdesk command names are shown with brackets.

In addition, the following formatting conventions are used to highlight important information:

Note: This denotes important information that you should keep in mind.

! This denotes a situation that may cause an error or a loss of data.

Menu Formats

Each menu reference in the manual contains the following information.

A menu location, or directory, is given to assist in locating the menu. This is given on the introductory menu page and is shown in the following form:

[Grading] → [Settings]

- Commands on the menu are described in the order in which they appear on the menu in the sections immediately following the menu path.

Command Reference Formats

Each command contains a description of the command, including tips on how to most effectively use a command. The command description often describes techniques to make a command easier to use, and may include prerequisites.

The complete prompt sequence is given with brief explanations where required. Any dialogue boxes accompanying the command are displayed and explained as well.

Installation

For information about installing the software, refer to the *Softdesk Core Reference Manual.*

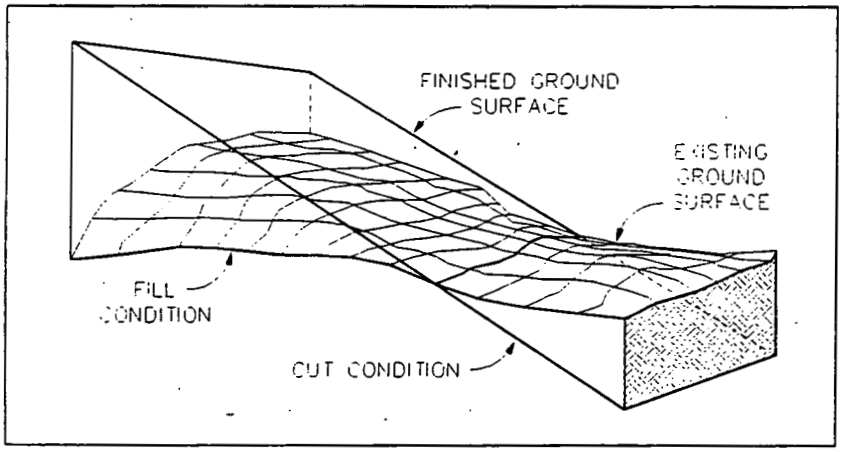
Changes From Previous Releases

The following sections contain information for previous users of the *Earthworks* module. For more information, see the Revision History appendix.

Defining Strata

One feature of *Earthworks* is the ability to define surface combinations and the associated volumetric differences as strata. Most commonly, a pairing of existing and finished ground surfaces and the resulting cut and/or fill, taken as a whole, may be referred to as a stratum.

The following illustration shows an example of a surface and a stratum.



Surface and Stratum

Multiple strata may also be defined with various types of combinations. For instance, an existing ground surface may be established, then one or more finished ground surfaces to compare with

that existing ground surface may be created. Surface pairings may then be defined as individual strata using the single existing ground surface and each of the multiple finished ground surfaces.

When calculating volumes, you will be prompted for the stratum to be used for those computations. Note that a TIN must have been created for each surface in the indicated stratum prior to executing any volumes calculations.

Average End Area Command Location

The [Average End Area] command of previous versions of *Earthworks* is now a type of calculation used to generate volumes. The explanation of the radio button that controls the type of section calculation can be found in the Volumes chapter.

15.3 Earthwork Required Volumes

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: EARTHWORK REQUIRED VOLUMES

Computations By: (Cognizant Engineer)
Signature: Kara Olen / Daniel Pass — Date: 10/17/95
Printed Name and Title: Kara Olen, Asst. Proj. Engr. / DANIEL PASS, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: Paul J. Sabatini — Date: 17 Oct 95
Printed Name and Title: PAUL J. SABATINI, JR. STAFF ENGINEER

Computations Checked by:
Signature: Paul J. Sabatini — Date: 17 Oct 95
Printed Name and Title: PAUL J. SABATINI, JR. STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Kara Olen / Daniel Pass — Date: 10/17/95
Printed Name and Title: Kara Olen, Asst. Project Eng. / DANIEL PASS, STAFF ENGINEER

Approved by: (PDP)
Signature: Kara Olen — Date: 10/17/95
Printed Name and Title: Kara L. Olen, Asst. Project Engineer

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 23 Oct 95
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO		NA	NA	NA
0	Preliminary (40%) Design Submittal	23 Oct 95			23
B	Preliminary Design - EPA Submittal	15 Dec 95			

Written by: Kara Olen Date: 15 Dec 1995 Reviewed by: PJS Date: 15 Dec 95

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.11

OSDF EARTHWORK/BORROW REQUIREMENTS

EXECUTIVE SUMMARY

Earthwork quantities for the OSDF are calculated in this section. All quantities are presented in terms of compacted volumes. The earthwork quantities were calculated for the following earthwork components of the OSDF:

- compacted clay liner,
- leachate detection system (LDS) drainage layer,
- leahcate collection system (LCS) drainage layer,
- granular protective layer,
- compacted clay cap,
- cover drainage layer,
- biointrusion layer,
- choke layer,
- granular filter,
- vegetative soil layer,
- topsoil,
- seasonal cover,
- structural fill, and
- road aggregate.

Materials for compacted clay liner, compacted clay cap, vegetative soil layer, seasonal cover, and structural fill are anticipated to be obtained on-site from either beneath the OSDF footprint or the East Field borrow area. These calculations also

Written by: Kara Olen Date: 15 Dec 1995 Reviewed by: PJS Date: 15 Dec 95

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.11

include any estimate of clay till quantities required from these areas to construct the above-mentioned components. The required quantities in cubic yards are summarized below.

	8 CELLS	9CELLS
• compacted clay liner	308,935	347,473
• leachate detection system (LDS) drainage layer	85,582	96,278
• leahcate collection system (LCS) drainage layer	85,582	96,278
• granulare protective layer	18,798	21,146
• compacted clay cap	199,348	223,052
• cover drainage layer	114,732	128,021
• biointrusion layer	344,195	384,062
• choke layer	37,859	42,244
• granular filter	57,363	64,007
• vegetative soil layer	200,781	224,037
• topsoil	57,363	64,007
• seasonal cover	29,785	34,040
• structural fill	286,029	313,407
• road aggregate	4,604	5,049

Of the above quantities, the compacted volume of on-site till required to construct the compacted clay liner, compacted clay cap, vegetative soil layer, seasonal cover, and structural fill is 1,024,878 CY for 8 cells and 1,142,009 CY for 9 cells.

Written by: Kara Olen Date: 95 / 10 / 17 Reviewed by: PJS Date: 95 / 10 / 17
YY MM DD

Client: Fernew Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

KO 10/17
PJS 23 Oct 95

OSDF Earthwork / Borrow Requirements

Summary

Earthwork quantities for the OSDF are calculated here. All quantities calculated are in terms of final compacted quantities. The earthwork components of the OSDF consist of:

- Compacted Clay Liner;
- Leachate Detection System (LDS) Drainage Layer;
- Leachate Collection System (LCS) Drainage Layer;
- Granular Protective Layer;
- Compacted Clay Cap;
- Cover Drainage layer;
- Biointrusion Layer;
- Choke Layer;
- Granular Filter;
- Vegetative Soil Layer;
- Topsoil;
- Seasonal Cover;
- Structural Fill (for Perimeter Access Corridor); and
- Road Aggregate

It is anticipated that several of the above components will be obtained from on-site borrow. These components are: (i) Compacted Clay Liner, (ii) Compacted Clay Cap, (iii) Vegetative Soil Layer, (iv) Seasonal Cover, and (v) Structural Fill. A portion of the on-site borrow material will be obtained from below the footprint of the OSDF, once all contaminated soils have been removed. The remainder of the borrow material will be obtained from the East Field borrow area. Also as part of these calculations, the quantity of borrow needed from the East field borrow area will be estimated. A ten to fifteen percent contingency volume will be added in the event that sufficient quantities of impacted soils (which will be used to construct the contouring layer above the waste & protective layer at the base of the lining system) are not available.

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Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

KW 10/17

KE 23 Oct 95

Procedures

Earthwork Quantity Calculations were conducted for each individual portions of the OSDF as summarized below.

Calculation #	Description
1	Intercell Berm (including Liner System)
2	Inner Cell Liner System
3	End Cell Liner System
4	Inner Cell Cover System
5	Cell 1 (End Cell) Cover System
6	Cell 9 (End Cell) Cover System
7	Seasonal Cover per cell
8	Structural Fill (for Perimeter
9	access Corridor) Per cell
	Road Aggregate per cell

The individual portions were combined as required to obtain total quantity estimates on a per cell basis, which is summarized in Calculation 10.

Calculation 11 estimates the total required volume of on-site borrow required to construct certain components of the OSDF as listed in the Summary Section of these calculations.

Calculation 12 estimates the total required volume of borrow needed from the East field borrow area.

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Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

KO 10/17
KL 23 Oct 95

Collection & Verification of Data

All data regarding OSDF geometry and earthwork component thicknesses were obtained from the design drawings entitled:

"United States Department of Energy
Fernald Environmental Management Project
On-Site Disposal Facility
Subcontract Number 95PS005028
Hamilton County and Butler County, Ohio
Preliminary Design Package"

The drawings are currently being prepared by GeoSyntec.

Volumes were calculated by hand using either of the methods below:

- direct measurement of all needed dimension; multiply to obtain volumes.
- obtaining cross-sectional areas of certain components using a digital planimeter; multiplying the area by the component length to obtain volumes.

As part of the calculation to determine the volume of on-site borrow required, it was necessary to estimate the change in volume the borrow material would undergo from its original in-situ volume to its final compacted volume. For this calculation, geotechnical data regarding in-situ density & recompacted density of the on-site materials was obtained from "Geotechnical Investigation Report - On-Site Disposal Facility, Revision A, September, 1995" (Parsons, 1995).

Also as part of the calculation to determine the volume of on-site borrow required, it was necessary to estimate the volume of contaminated materials that will be removed from the OSDF footprint. For this calculation a map entitled "On-Property Soil Excavation Footprint, Alternatives 3A and 3C, Case 7", obtained from Fernco.

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Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8, 11

Calculations

① Intercell berm earthwork quantity estimates

- Summary of dimensions to be used in calculations

Liner System Component thicknesses	figure 1
Length of Intercell berm (figure 5)	705 ft ✓
Width of Intercell berm (figure 2)	59 ft ✓
Approx. length along top of intercell berm (from toe to toe – see fig 2)	61 ft ✓
Cross-sectional Area of Compacted Clay at intercell berm (figure 2)	345 sf ✓
Additional Compacted Clay Area for liner system (figure 3)	98 sf ✓

- Earthwork Quantities Per Intercell Berm

Compacted Clay Liner

$$\frac{(345\ SF)(705\ FT) + (98\ SF)(59\ FT)(2\ sides)}{27\ cf/cy}$$ 9437 cy ✓

LDS drainage layer

$$\frac{(61\ FT)(705\ FT)(1\ FT)}{27\ cf/cy}$$ 1593 cy ✓

LCS drainage layer

$$\frac{(61\ FT)(705\ FT)(1\ FT)}{27\ cf/cy}$$ 1593 cy ✓

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Client: Fernow Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

Protective Layer (granular)

$$\frac{(61\,FT)(705\,FT)(1\,FT)}{27\,cf/cy}$$ 1593 cy ✓

② Inner Cell Liner System Earthwork Quantity Estimates

- Summary of dimensions to be used in calculations

Liner System Component Thicknesses	figure 1
Length of Inner Cell (from figure 5 and measured along the top of compacted clay for calculation of Clay liner liner Volumes only)	705 ft ✓
Length of Inner Cell (from figure 5 and measured from crest of liner system side slope to crest of liner system side slope for calculation of all other liner system components)	723 ft ✓
Cell Width (from figure 4 and measured from toe of intercell berm to toe of intercell berm at the top of the compacted clay)	340 ft ✓
Length of Cell Side Slope (from figure 3 for calculation of granular protective layer quantity)	30 ft ✓
Additional Compacted Clay Area for liner system (see figure 3)	98 SF ✓

Written by: Kevin Dan Pass Date: 95/10/17 Reviewed by: PJS Date: 95/10/17

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

• Earthwork Quantities Per inner base cell

Compacted Clay Liner

$$\frac{(705\ ft)(340\ ft)(3\ ft) + (98\ SF)(340\ ft)(2\ sides)}{27\ cf/cy} = 29{,}101\ cy$$

LDS Drainage Layer

$$\frac{(723\ ft)(340\ ft)(1\ ft)}{27\ cf/cy} = 9{,}104\ cy$$

LCS Drainage Layer

$$\frac{(723\ ft)(340\ ft)(1\ ft)}{27\ cf/cy} = 9{,}104\ cy$$

Protective Layer (Granular)

$$\frac{(30\ ft)(340\ ft)(1\ ft)(2\ sides)}{27\ cf/cy} = 756\ cy$$

③ End Cell Liner System Earthwork Quantity Estimates

Earthwork quantities in the end cells are equal to earthwork quantities for an inner cell liner system plus additional quantities from the north liner system side slope (for Cell 1) & South liner system side slope (for Cell 8). These additional quantities are approximately equal for Cell 1 & Cell 9. (See sketch next pg.) These additional quantities are calculated below and added to the base quantities for an inner cell lining system.

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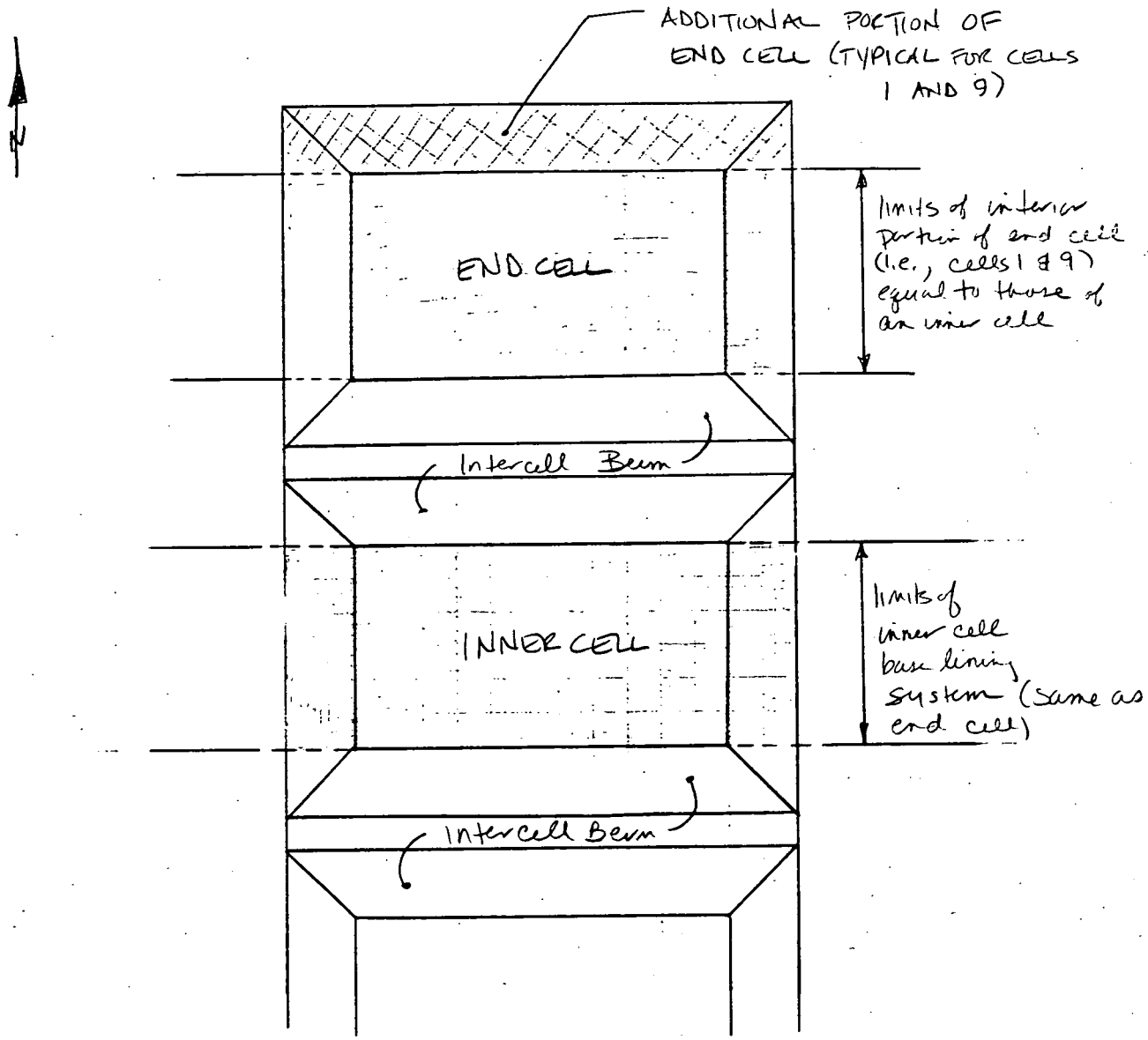

Sketch - Plan of OSDF Base liner System

(NTS)

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- Earthwork Quantities for north (Cell 1) and South (Cell 8) side slope liner system Per End Cell

Compacted Clay Liner

$$\frac{(723\,ft)(30\,FT)(3\,ft)+(98\,sf)(723\,ft)}{27\,cf/cy} = 5034\,cy$$

LDS Drainage Layer

$$\frac{(723\,ft)(30\,ft)(1\,ft)}{27\,cf/cy} = 803\,cy$$

LCS Drainage Layer

$$\frac{(723\,ft)(30\,ft)(1\,ft)}{27\,cf/cy} = 803\,cy$$

Protective Layer (Granular)

$$\frac{(723\,ft)(30\,ft)(1\,ft)}{27\,cf/cy} = 803\,cy$$

- Earthwork Quantities Per End Cell Base

Compacted Clay Liner

29,101 cy + 5034 cy = 34,135 cy

LDS Drainage Layer

9,104 cy + 803 cy = 9907 cy

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LCS Drainage Layer

9104 cy + 803 cy = 9907 cy

Protective Layer (Granular)

756 cy + 803 cy = 1559 cy

④ Inner Cell Cover System Earthwork Quantity Estimates

- Summary of Dimensions to be used in Calculations

Liner System Component Thicknesses	figure 1
Length of Final Cover System (for calculation of Compacted Clay Volume - see figure 5)	673 ft
Length of Cover System (for calculation of all other cover system components - see fig 5)	897 ft
Additional Compacted Clay Area For Final Cover System (figure 3)	127 sf
Width of final cover (from ℄ intercell berm to ℄ intercell berm - see figure 4)	400 ft

- Earthwork Quantities Per Inner Cell Final Cover

Compacted Clay Cap

$$\frac{(673\,ft)(400\,ft)(2\,ft) + (127\,sf)(400\,ft)(2\,sides)}{27\,cf/cy} = 23{,}704\,cy$$

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Cover Drainage Layer

$\frac{(897\,ft)(400\,ft)(1\,ft)}{27\,cf/cy} =$ 13,289 cy

Biointrusion Barrier

$\frac{(897\,ft)(400\,ft)(3\,ft)}{27\,cf/cy} =$ 39,867 cy

Choke Layer

$\frac{(897\,ft)(400\,ft)(0.33\,ft)}{27\,cf/cy} =$ 4385 cy

Granular Filter

$\frac{(897\,ft)(400\,ft)(0.5\,ft)}{27\,cf/cy} =$ 6644 cy

Vegetative Soil Layer

$\frac{(897\,ft)(400\,ft)(1.75\,ft)}{27\,cf/cy} =$ 23,256 cy

Topsoil Layer

$\frac{(897\,ft)(400\,ft)(0.5\,ft)}{27\,cf/cy} =$ 6,644 cy

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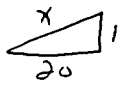
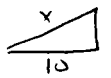
⑤ North End Cell (Cell 1) Final Cover System Earthwork Quantity Estimate

- Calculate surface area of cell 1 Final Cover to use in quantity calculations

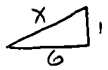
a) Determine Multiplier to convert plan areas to surface areas*:



for 20:1 slopes X = 20.025 ∴ Multiplier = 20.025/20 = 1.0012



for 10:1 slopes X = 10.0499 ∴ Multiplier = 10.0499/10 = 1.0050



for 6:1 slopes X = 6.0828 ∴ Multiplier = 6.0828/6 = 1.0138

b) Surface area of North Side of Cell 1 Final Cover (see Figure 6)

$$A = (1/2)\left(\frac{[80.3 + 72.3]}{2}\right)(1.0012) + (1/2)(292.8 + 177.3)\left(\frac{[56.2 + 51.0]}{2}\right)(1.0050) + (1/2)(819.9 + 292.8)\left(\frac{[239.8 + 263.0]}{2}\right)(1.0138)$$

(177.3)

$$= 6772 + 12{,}662 + 141{,}797 = 161{,}231 \text{ SF}$$

c) Surface area of East Side of Cell 1 Final Cover (see Figure 6)

$$A = (1/2)(172.5 + 92.2)(89.6)(1.0012) + (1/2)(228.7 + 172.5)(58.4)(1.0050) + (1/2)(468.5 + 228.7)(242.0)(1.0138)$$

$$= 11{,}873 + 11{,}774 + 85{,}525 = 109{,}172 \text{ SF}$$

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*This method is appropriate if plan lengths shown in Figure 6 are "true". For the purposes of this calculation it is assumed the OSDF sits on a flat surface, so that the only lengths that need to be corrected are those representing cover slope lengths.

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d) Surface area of West Side of Cell 1 Final Cover (See fig 6)

$$A = (1/2)(164.5 + 92.2)(87.7)(1.0012) + (1/2)(215.5 + 164.5)(57.1)(1.0050) + (1/2)(478.5 + 215.5)(285.5)(1.0138)$$

$$= 11,270 + 10,903 + 100,436 = 122,609 \text{ SF}$$

e) Total Surface Area of Cell 1 Final Cover (to toe of 6:1 slope)

$$A = 161,231 + 109,172 + 122,609 = 393,012 \text{ SF}$$

- Summary of dimensions to be used in calculations

Surface of Cell 1 Final Cover (from previous calculations)	393,012 SF
Perimeter of Cell (measured along toe of 6:1 slope - see figure 6)	1767 FT
See sketch (next pg) for more clarity — Avg Area to REDUCE compacted clay cap Volume by (from figure 5) $\left(\frac{78.2 \text{ FT} + 66.0 \text{ FT}}{2}\right)(1767 \text{ ft})$	127,401 SF
Area used to INCREASE all other cap components by (from figure 5) $(40 \text{ FT})(1767 \text{ ft})$	70,680 SF
Additional Compacted Clay area for Final Cover System (figure 3)	127 SF

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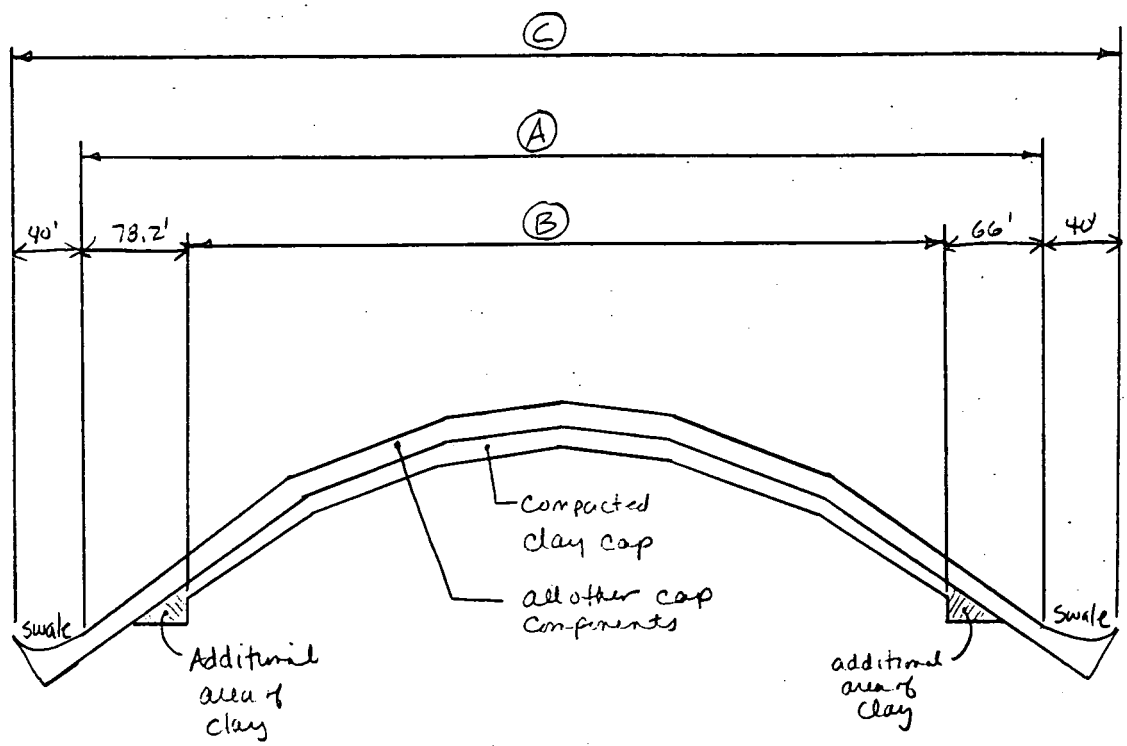

Sketch -
Simplified OSDF Final Cover X-section
(Looking North)
NTS.

- The calculated Cell 1 Cap surface area extends to the limits shown in (A) above.
- For calculation of the compacted clay cap volume this surface area was effectively reduced to the limits shown in (B) above by multiplying the avg distance between the limits of (A) & (B) (i.e., [78.2 ft + 66 ft]/2) by the perimeter of Cell 1 (i.e., 1767 ft). The 'additional areas of clay' shown above (also shown in figure 3) are added into the compacted clay cap calculation separately.
- For calculation of all other cap component volumes, the surface area was effectively increased to the limits shown in (C) above by multiplying 40 ft by the perimeter of Cell 1.

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- Earthwork Quantities for Final Cover at North End Cell

  - Compacted Clay liner:

$$\frac{[(393{,}012\ SF)(2\ FT) - (127{,}401\ SF)(2\ FT) + (127\ SF)(1767\ FT)]}{27\ cf/cy} = 27{,}987\ cy$$

  - Cover Drainage Layer

$$\frac{(393{,}012\ SF)(1\ FT) + (70{,}680\ SF)(1\ FT)}{27\ cf/cy} = 17{,}174\ cy$$

  - Biointrusion Barrier

$$\frac{(393{,}012\ SF)(3\ FT) + (70{,}680\ SF)(3\ FT)}{27\ cf/cy} = 51{,}521\ cy$$

  - Choke layer

$$\frac{(393{,}012\ SF)(.33\ FT) + (70{,}680\ SF)(.33\ FT)}{27\ cf/cy} = 5{,}667\ cy$$

  - Granular Filter

$$\frac{(393{,}012\ SF)(0.5\ FT) + (70{,}680)(0.5\ ft)}{27\ cf/cy} = 8587\ cy$$

  - Vegetative Soil Layer.

$$\frac{(393{,}012\ SF)(1.75\ FT) + (70{,}680)(1.75)}{27\ cf/cy} = 30{,}055\ cy$$

  - Topsoil Layer.

$$\frac{(393{,}012\ SF)(0.5\ FT) + (70{,}680)(0.5)}{27\ cf/cy} = 8587\ cy$$

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Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

⑥ South End Cell (Cell 9) Final Cover System Earthwork Quantity Estimates

a) Plan area multipliers are the same as those for the North End Cell: *

1.0012 for 20:1 slopes

1.0050 for 10:1 slopes

1.0138 for 6:1 slopes

b) Area of Cover at South End of South End Cell (see figure 7)

$$A = (1/2)(177.2)([104.5+91.6]/2)(1.0012) + (1/2)(293.3+177.2)([65.4+56.8]/2)(1.005)$$
$$+ (1/2)(809.8+293.3)([258.7+270.6]/2)(1.0138)$$
$$= 8707 + 14,446 + 147,982 = 171,135 \text{ SF}$$

c) Area of Cover at East Side of South End Cell (figure 7)

$$A = (1/2)(180.3+75.6)(87.4)(1.0012) + (1/2)(180.3+245.7)(57.3)(1.005)$$
$$+ (1/2)(245.7+504.4)(230.7)(1.0138)$$
$$= 11,196 + 12,266 + 87,718 = 111,180 \text{ SF}$$

d) Area of Cover @ West Side of South End Cell (figure 7)

$$A = (1/2)(75.6+167.2)(89.8)(1.0012) + (1/2)(167.2+224.0)(58.8)(1.005)$$
$$+ (1/2)(224+494.6)(285.8)(1.0138)$$
$$= 10,915 + 11,559 + 104,105 = 126,579 \text{ SF}$$

001949

*This method is appropriate if plan lengths shown in figure 7 are "true". For the purposes of this calculation, it is assumed that the OSDF sits on a flat surface, so that the only lengths that need to be corrected are those representing cover slope lengths. (actual slopes are small)

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e) Total Surface Area of Cell 8 Final Cover (to toe of 6:1 Slope)

$= 171,135 + 111,180 + 126,579 = 408,894$ ✓

- Summary of dimensions to be used in calculations:

Area of Cell 8 (South end Cell) Final Cover (from previous calculation) — 408,894 SF

Perimeter of Cell (Measured along toe of 6:1 Slope - see figure 7). — 1809 FT

See sketch (next pg) for more clarity

Avg area used to Reduce compacted Clay Cap volume by (from figure 5)

$\left[\frac{(78.2+66)}{2}\right](1809) =$ — 130,429 SF

Area used to increase all other cap components by (from figure 5)

$(40)(1809) =$ — 72,360 SF

Additional Compacted Clay Area for Cover System (from Figure 3) — 127 SF

- Earthwork Quantities for Final Cover at Cell 9 (South End Cell)

- Compacted Clay Liner

$$\frac{(408,894\ SF)(2\ FT) - (130,429\ SF)(2\ FT) + (127\ SF)(1809\ FT)}{27\ cf/cy} = 29,137\ cy$$

Written by: Kara Olen / Dan Pass Date: 95/10/17 Reviewed by: PJS Date: 95/10/17

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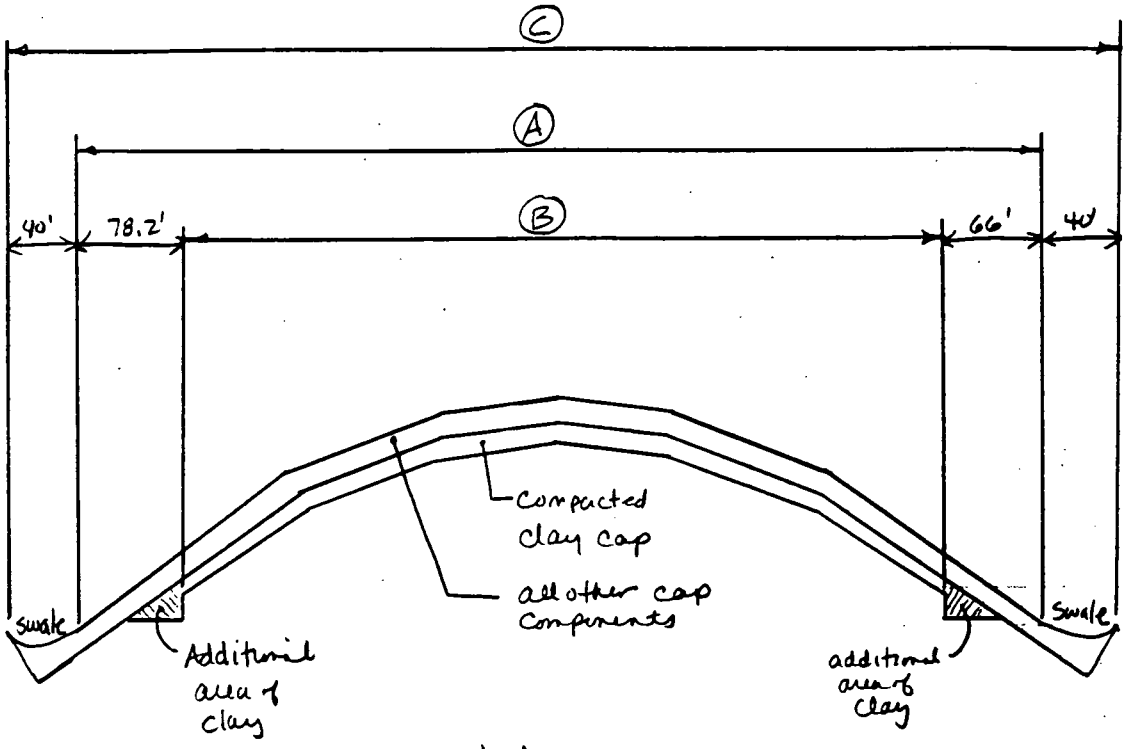

Sketch -
Simplified OSDF Final
Cover X-section
(Looking North)
NTS.

- The calculated Cell 8 Cap surface area extends to the limits shown in (A) above.
- For calculation of the compacted clay cap volume this surface area was effectively reduced to the limits shown in (B) above by multiplying the avg distance between the limits of (A) & (B) (i.e., [78.2 ft + 66 ft]/2) by the perimeter of Cell 8 (i.e., 1767 ft). The 'additional areas of clay' shown above (also shown in figure 3) are added into the compacted clay cap calculation separately.
- For calculation of all other cap component volumes, the surface area was effectively increased to the limits shown in (C) above by multiplying 40 ft by the perimeter of Cell 9.

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- Cover Drainage Layer

$$\frac{(408{,}894\ SF)(1FT) + (72360)(1FT)}{27\ cf/cy} = 17{,}824\ cy$$

- Biointrusion Barrier

$$\frac{(408{,}894\ SF)(3FT) + (72360)(3FT)}{27\ cf/cy} = 53{,}472\ cy$$

- Choke Layer

$$\frac{(408{,}894\ SF)(0.33FT) + (72360)(0.33FT)}{27\ cf/cy} = 5{,}882\ cy$$

- Granular Filter

$$\frac{(408{,}894\ SF)(0.5FT) + (72360)(0.5)}{27\ cf/cy} = 8912\ cy$$

- Vegetative Soil Layer

$$\frac{(408{,}894\ SF)(1.75FT) + (72360)(1.75)}{27\ cf/cy} = 31{,}192\ cy$$

- Topsoil

$$\frac{(408{,}894\ SF)(0.5FT) + (72360)(0.5)}{27\ cf/cy} = 8912\ cy$$

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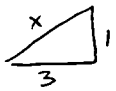
① Seasonal Cover Earthwork Quantity Estimates

- Plan Area Multiplier



$x = 3.16$ ∴ multiplier $= 3.16/3 = 1.0541$

- Plan area of exposed 3:1 per cell (approx. - from figure 8)

$A = 109{,}000$ SF

- Quantity of Seasonal Cover per cell:

$$V = \frac{(109{,}000\ SF)(1\ ft)(1.0541)}{27\ cf/cy} = 4255\ cy$$

② Structural Fill (for Perimeter Access Corridor) Quantity Estimates

- Summary of Dimensions to be Used in Calculations

Length of North End of Cell 1 (measured along ℄ - see figure 8)

(464 ft)(2 halves) = 928 ft

Width of Cell 1 (from figure 6) 413 ft

Width of Cells 2 through 7 (from figure 6) 400 ft

Width of Cell 8 (from figure 6) 389 ft

Length of South End of Cell 8 (from figure 6)

(474)(2 halves) = 948 ft

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Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

Cross sectional area of structural fill for Perimeter Access Road — figures 10-20

- Earthwork Quantities for Structural Fill for Perimeter access Corridor

Cell 1

$$\frac{(928\ ft)(843\ sf) + (413\ ft)(893\ sf + 1116\ sf)}{27\ cf/cy} = 59{,}705\ cy$$

Cell 2

$$\frac{(400\ ft)(769\ sf + 694\ sf)}{27\ cf/cy} = 21{,}674\ cy$$

Cell 3

$$\frac{(400\ ft)(781\ sf + 1240\ sf)}{27\ cf/cy} = 29{,}941\ cy$$

Cell 4

$$\frac{(400\ ft)(942\ sf + 1314\ sf)}{27\ cf/cy} = 33{,}422\ cy$$

Cell 5

$$\frac{(400\ ft)(1166\ sf + 1265\ sf)}{27\ cf/cy} = 36{,}015\ cy$$

Cell 6

$$\frac{(400\ ft)(1153\ sf + 1091\ sf)}{27\ cf/cy} = 33{,}244\ cy$$

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Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

Cell 7

$$\frac{(400\,ft)(806\,sf + 967\,sf)}{27\,cf/cy} = 26{,}267\ cy$$

Cell 8

$$\frac{(400\,ft)(583\,sf + 1265\,sf)}{27\,cf/cy} = 27{,}378\ cy$$

Cell 9

$$\frac{(389\,ft)(632 + 1004) + (948)(632)}{27\,cf/cy} = 45{,}761\ cy$$

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Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

⑨ Road Aggregate (for perimeter access corridor) Quantity Estimates

- Summary of Dimensions to be used in Calcs - Length of Perimeter access corridor per cell (from calculation step ⑧):

Cell 1

(928 ft + 413 ft + 413 ft) = 1754 ft

Cell 2 through Cell 7

(400 ft) (2 sides) = 800 ft

Cell 8

(948 ft + 389 ft + 389 ft) = 1726 ft

Width of Perimeter Access Road = 15 ft

Thickness of Road Aggregate = 1 ft

- Earthwork Quantities for Road Aggregate

Cell 1

(1754 ft)(15 ft)(1 ft)/27 cf per cy = 975 cy

Cells 2-7

(800 ft)(15 ft)(1 ft)/27 cf per cy = 445 cy/cell

Cell 8

(1726 ft)(15 ft)(1 ft)/27 cf per cy = 959 cy

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(10) Totals.

Quantities of each earthwork component are summarized in the table on the following page. A summary of OSDF earthwork components that each cell is comprised of is shown below.

Cell 1:
- End Cell Base liner System
- Cell 1 Final Cover System
- Intercell Berm
- Seasonal Cover
- Perimeter Access Corridor
- Roadway Aggregate

Cells 2 through 7:
- Inner Cell Base liner System
- Inner Cell Final Cover System
- Intercell Berm
- Seasonal Cover
- Perimeter Access Corridor
- Roadway Aggregate

Cell 8:
- End Cell Base liner System
- Cell 9 Final Cover System
- Perimeter Access Corridor
- Roadway Aggregate

Written by: [illegible] Date: 95 / 10 / 17 (YY MM DD) Reviewed by: PJS Date: 95 / 10 / 17 (YY MM DD)

Client: Fernes Project: Ferndale Project/Proposal No.: GE3900 Task No.: 8.11

Summary of Req'd Earthwork Quantities

43672 PJS

30066 PJS

Cell	Compacted Clay Liner (cy)	LDS Drainage Layer (cy)	LCS Drainage Layer (cy)	Granular Protective Layer (cy)	Compacted Clay Cap (cy)	Cover Drainage Layer (cy)	Biointrusion Layer (cy)	Choke Layer (cy)	Granular Filter (cy)	Vegetative Soil Layer (cy)	Topsoil (cy)	Seasonal Cover (cy)	Structural Fill (Perimeter Access Corridor (cy)	Road Aggregate (cy)
1	43,662	11,499	11,499	3,151	27,987	17,174	51,521	5,667	8,587	~~30,058~~	8,587	4,255	59,705	975
2	38,538	10,696	10,696	2,348	23,704	13,289	39,867	4,385	6,644	23,256	6,644	4,255	21,674	445
3	38,538	10,696	10,696	2,348	23,704	13,289	39,867	4,385	6,644	23,256	6,644	4,255	29,941	445
4	38,538	10,696	10,696	2,348	23,704	13,289	39,867	4,385	6,644	23,256	6,644	4,255	33,422	445
5	38,538	10,696	10,696	2,348	23,704	13,289	39,867	4,385	6,644	23,256	6,644	4,255	36,015	445
6	38,538	10,696	10,696	2,348	23,704	13,289	39,867	4,385	6,644	23,256	6,644	4,255	33,244	445
7	38,538	10,696	10,696	2,348	23,704	13,289	39,867	4,385	6,644	23,256	6,644	4,255	26,267	445
8	34,135	9,907	9,907	1,559	29,137	17,824	53,472	5,882	~~89,120~~	31,192	8,912	0	45,761	959
Total	~~300,025~~	85,582	85,582	18,798	199,348	114,732	344,195	37,859	~~137,574~~	200,781	57,363	29,785	286,029	4,604

~~308,947~~ 308,935 PJS

57,363 PJS

8912 PJS

The above totals represent construction of 8 cells. If nine cells are constructed, the revised totals will be:

347,473	96,278	96,278	21,146	223,052	128,021	384,062	42,244	64,007	224,037	64,007	34,040	313,407	5049

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Written by: Kevin Oler Date: 95/10/17 (YY/MM/DD) Reviewed by: RJS Date: 95/10/17 (YY/MM/DD)

Client: Fernew Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

(11) Quantities to be obtained from On-Site:

The following Components & Corresponding Quantity Estimates from the previous table will be obtained from on-site borrow:

COMPONENT	Quantity (8 cells) (cy)	Quantity (9 cells) (cy)
Compacted Clay Liner	308,935	347,473
Compacted Clay Cap	199,348	223,052
Vegetative Soil Layer	200,781	224,037
Seasonal Cover	29,785	34,040
Structural Fill	286,029	313,407
Total	1,024,878 cy	1,142,009 cy

Written by: Kara Olen / Dan Ross Date: OCT 16 1995 (YY MM DD) Reviewed by: PJS Date: 95 / 10 / 17 (YY MM DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

(12) VOLUME OF BORROW TO BE OBTAINED AT OSDF FOOTPRINT:

MATERIAL TO BE OBTAINED AT OSDF FOOTPRINT INCLUDES CONTAMINATED SOILS UNSUITABLE FOR USE IN CONSTRUCTION OF THE FACILITY. THE VOLUME OF THESE CONTAMINATED SOILS MUST BE SUBTRACTED FROM THE TOTAL VOLUME OF SOILS TO BE EXCAVATED TO OBTAIN THE VOLUME OF SOIL AT THE OSDF FOOTPRINT AVAILABLE TO AUGMENT BORROW TO BE OBTAINED FROM THE BORROW AREA.

a) TOTAL VOLUME TO BE EXCAVATED IS 426,002 CY. (FROM SUBGRADE GRADING PLAN)

b) VOLUME OF CONTAMINATED SOIL: OBTAINED USING PLANIMETERED AREAS SHOWN IN FIGURE 21.

- EXCAVATE 0 TO 9" OF MATERIAL FROM ENTIRE FOOTPRINT.

$$\frac{2{,}388{,}850\ SF \times (9/12)}{27\ CF/CY} = 66{,}357\ CY$$

- EXCAVATE 9" TO 2.5' OF CONTAMINATED MATERIAL AS SHOWN IN FIG 21. ASSUME 2.5' EXCAVATION FOR WORST CASE.

$$\frac{17360\ SF \times 2.5\ Ft}{27\ CF/CY} = 1{,}607\ CY$$

- EXCAVATE GREATER THAN 2½ FT OF CONTAMINATED MATERIAL AS SHOWN IN FIGURE 21 ASSUME 15 Ft EXCAVATION

$$\frac{10750\ SF \times 15\ Ft}{27\ CF/CY} = 5{,}972\ CY$$

- TOTAL VOLUME OF CONTAMINATED SOILS

$$66{,}357\ cy + 1{,}607\ cy + 5972\ cy = 73936\ cy$$

c) BORROW QUANTITY AVAILABLE FROM OSDF FOOTPRINT

$$426{,}002 - 73{,}936 = 352{,}066\ cy$$

Written by: Kara Olsen/Dan Pass Date: 95/10/17 (YY MM DD) Reviewed by: RJS Date: 95/10/17 (YY MM DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

d) Consider Bulking & Shrinkage Effects on borrow material.

From step (11) the total volume of on-site borrow needed is 1,024,878 for 8 cells. The percent of the total volume that each OSDF component will utilize, along with the anticipated compactive effort to be used during construction is shown below.

Component	Volume (Cy)	% total Volume	Anticipated Compaction Requirement (% γ_{dmax} based on ASTM D698)
Compacted Clay liner	308,935	30.1 ✓	98%
Compacted Clay Cap	199,348	19.5 ✓	95%
Veg. Soil Layer	200,781	19.6 ✓	90%
Seasonal Cover	29,785	2.9 ✓	95%
Struct Fill	286,029	27.9 ✓	95%
	Σ 1,024,878	100	

The weighted average percent of γ_{dmax} that the borrow materials will be compacted to is therefore:

$$\frac{(30.1)(98)+(19.5)(95)+(19.6)(90)+(2.9)(95)+(27.9)(95)}{100}$$

$$= 94.9\% \checkmark$$

Written by: Karen Olson / Dan Pass Date: 95 / 10 / 17 (YY / MM / DD) Reviewed by: PJS Date: 95 / 10 / 17 (YY / MM / DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

The following table shows the results of in situ density tests and Std. proctor density tests on soil samples from the OSDF footprint (Parsons, 1995). (See figure 22 & 23) The density corresponding to the 94.9% of the maximum dry density, which is the weighted average dry density that borrow soils will likely be compacted to, are also shown:

Sample Depth	Avg Depth	Remolded $\gamma_{d\,max}$ (range)	Remolded 94.9% $\gamma_{d\,max}$ (range)	Remolded 94.9% $\gamma_{d\,max}$ (Avg)	In-Situ γ_d
1.5-5.0	3	105-113	99.7 - 107.2	103.5	112
2.0-7.5	5	111-123	105.3 - 116.7	111.0	114
7.5-13.0	10	118-125	112.0 - 118.6	115.3	121

The corresponding ratio of Remolded 94.9% $\gamma_{d\,max}$ versus In situ γ_d is therefore:

Depth	γ_d(in situ) / γ_d(remold: 94.9% $\gamma_{d\,max}$)
3	1.08
5	1.03
10	1.05
	Avg 1.05

Therefore, on average, the borrow soils will swell approximately 5% when compacted to final OSDF densities.

Therefore, material excavated from the OSDF footprint will occupy a volume after compaction of

(352,067 cy)(1.05) = 369,670 cy.

001962

Written by: Kara Olin / Don Pass Date: 95 / 10 / 17 (YY MM DD) Reviewed by: RJS Date: 95 / 10 / 17 (YY MM DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

e) The total volume required from the east field borrow area is therefore equal to the total volume of on-site borrow required minus the compacted volume available from the OSDF footprint. This volume is then reduced by 5% to account for bulking.

Vol req'd @ East Field borrow area:

$= (1{,}024{,}878 \text{ cy} - 369{,}670)(0.95)$

$= 622{,}448$ cy (for construction of 8 cells)

$= (1{,}142{,}009 \text{ cy} - 369{,}670)(0.95)$

$= 733{,}722$ cy (for construction of 9 cells)

Add a 10% contingency factor. ∴ Total Volume of Borrow req'd from the East Field Borrow Area is:

$(622{,}448)(1.1) = 684{,}693$ cy for 8 cells

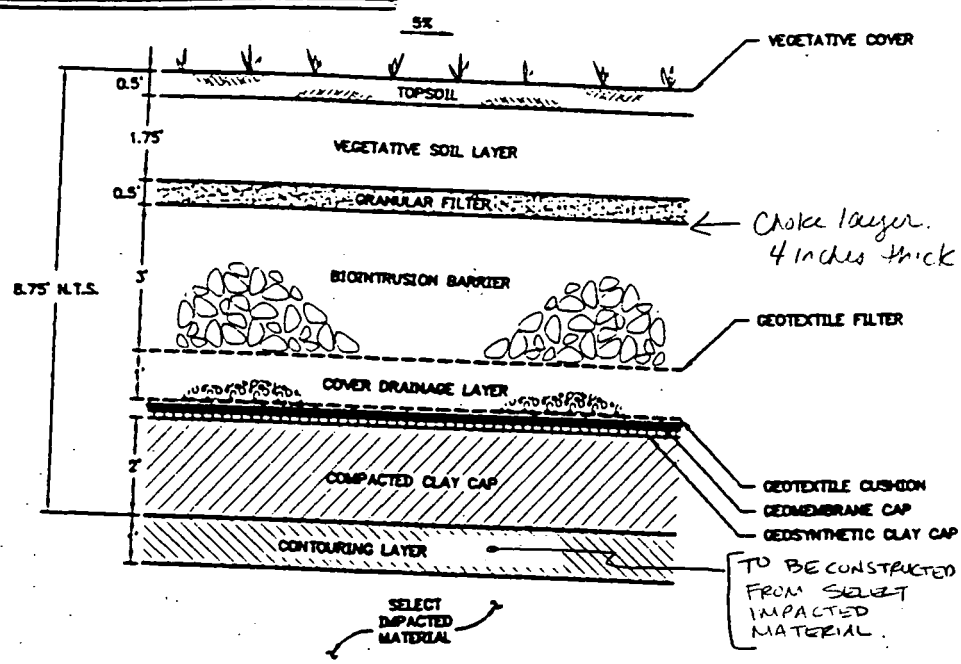
$(733{,}722)(1.1) = 807{,}094$ cy for 9 cells.

Written by: Laura Olen / Dan Pass Date: OCT 13 1995 (YY / MM / DD) Reviewed by: PJS Date: 95 / 10 / 17 (YY / MM / DD)

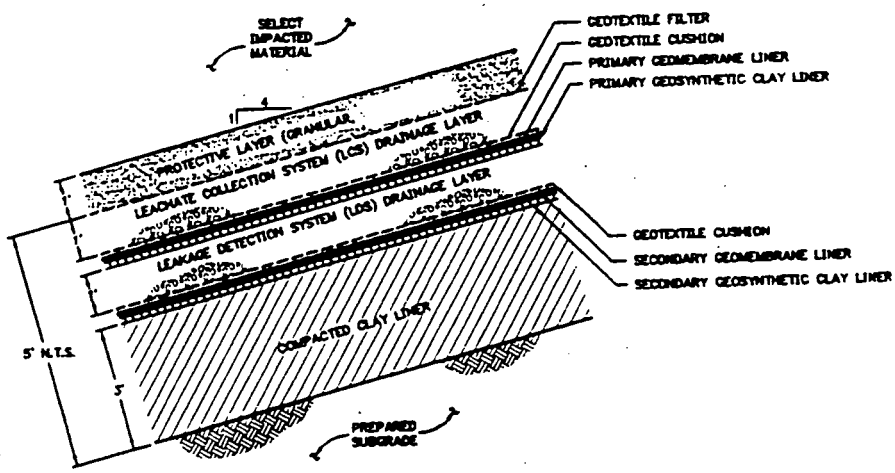
Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

COMPONENTS FOR COVER AND LINER SYSTEMS:

① COVER SYSTEM



② LINER SYSTEM ON LINER SIDE SLOPES AND ON INTERCELL BERMS



③ LINER SYSTEM ON CELL BASE

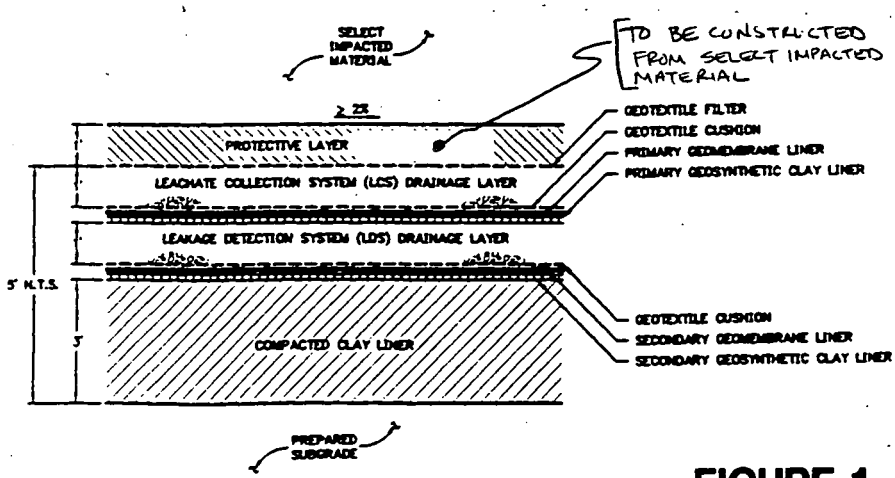


Figure taken from Drawing Entitled "Liner & Cover System Details I"

001964

FIGURE 1

Written by: Kevin Olson/Dan Pass Date: OCT 13 1995 (YY / MM / DD) Reviewed by: PJS Date: 95 / 10 / 17 (YY / MM / DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

CROSS SECTION FOR VOLUME CALCULATIONS AT INTERCELL BERM:

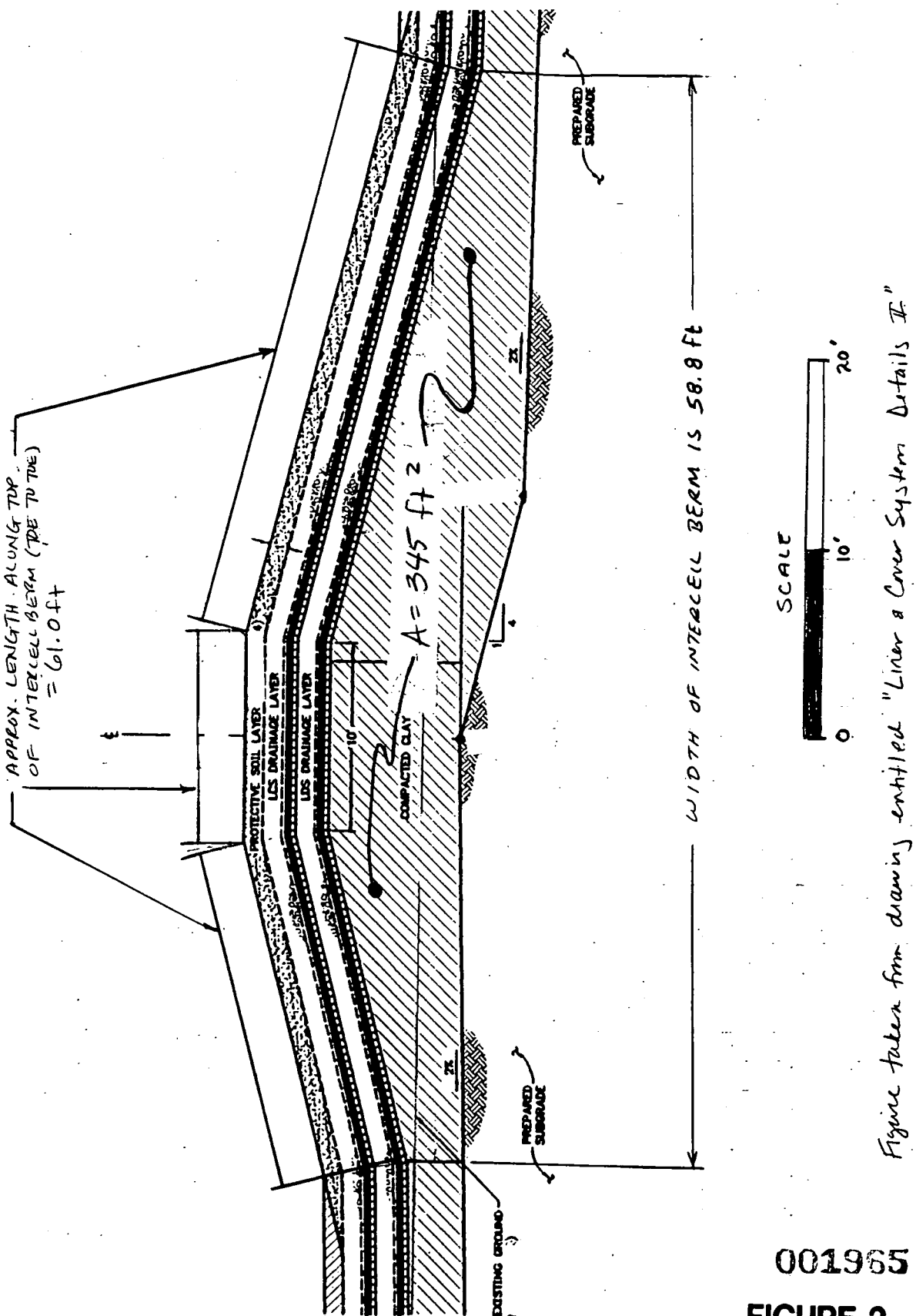


Figure taken from drawing entitled "Liner & Cover System Details II"

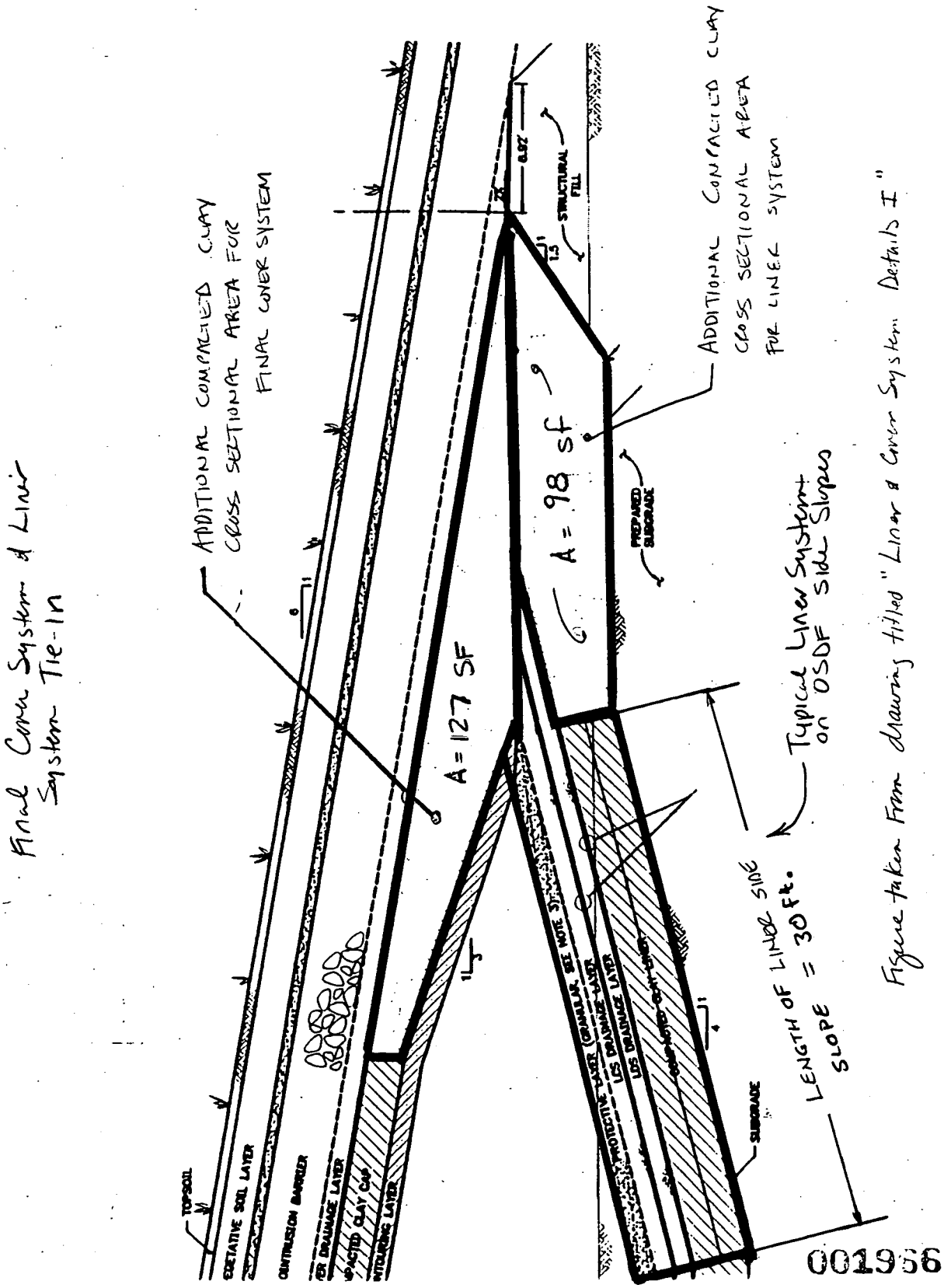
001965

FIGURE 2

OCT 13 1995

Written by: Kara Olen / Dan Pass Date: / / (YY MM DD) Reviewed by: PJS Date: 95 / 10 / 17 (YY MM DD)

Client: Fernew Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11



001956

FIGURE 3

Reviewed: RJS 95-10-17

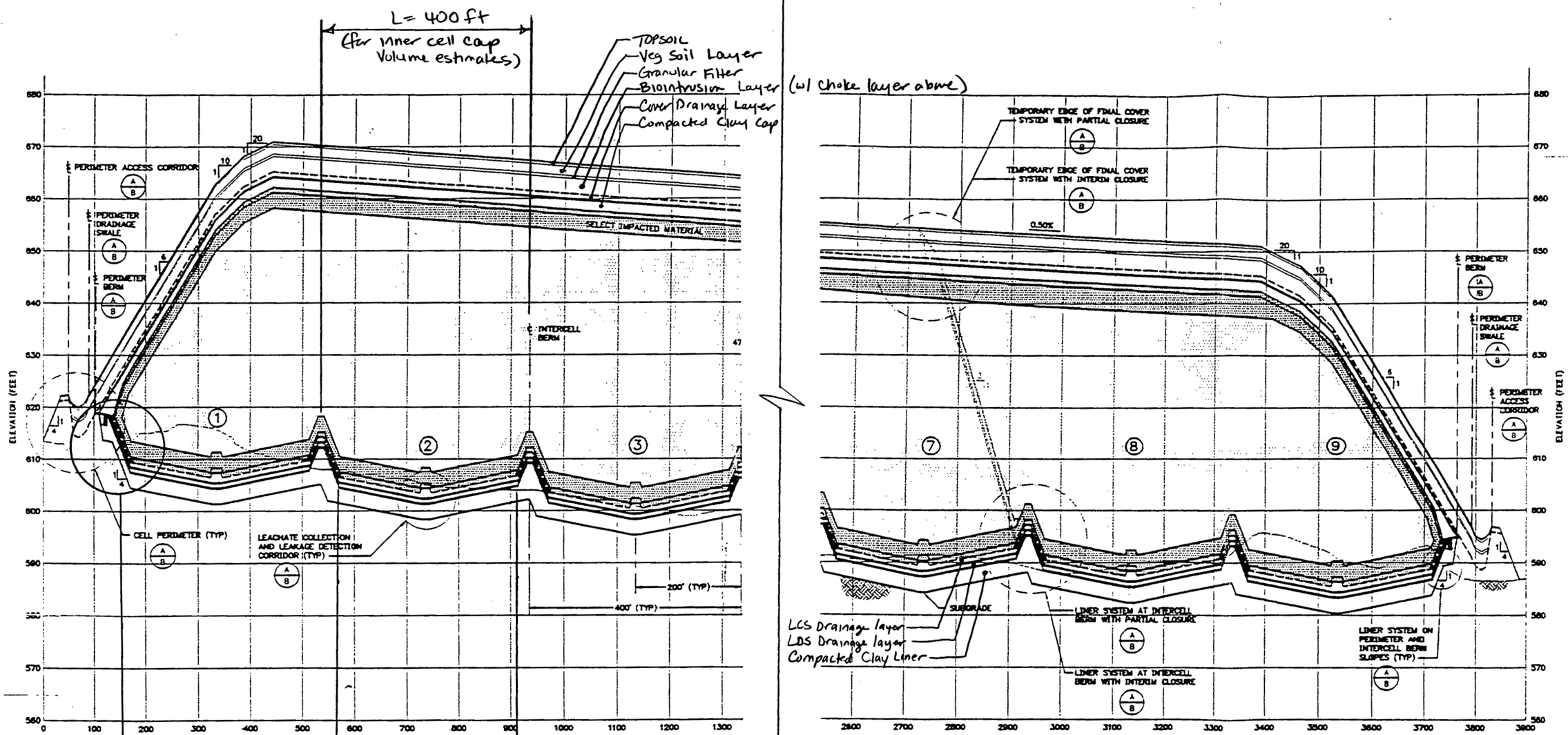


Figure taken from drawing titled "OSDF Cross Section - North-South"

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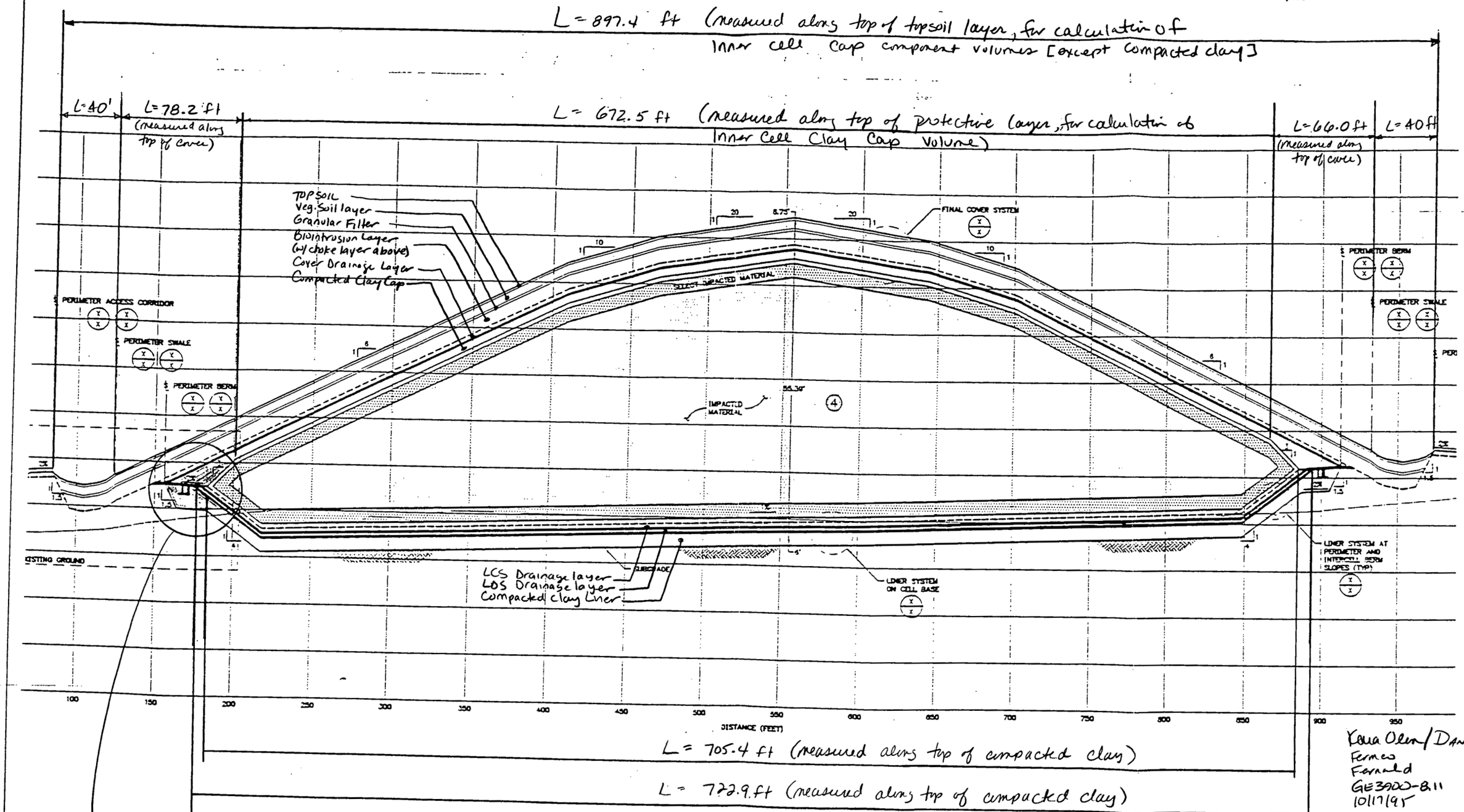
FIGURE 4

001967

327696

Reviewed : RJS 95-10-17



Kevin Olen / Dan Pass
Fermco
Fernald
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10/17/95

SEE FIGURE 3 FOR ADDITIONAL COMPACTED CLAY AT LINER SYSTEM & COVER SYSTEM.

Figure Taken from drawing titled "OSDF Cross Section West-East at Cell Base"

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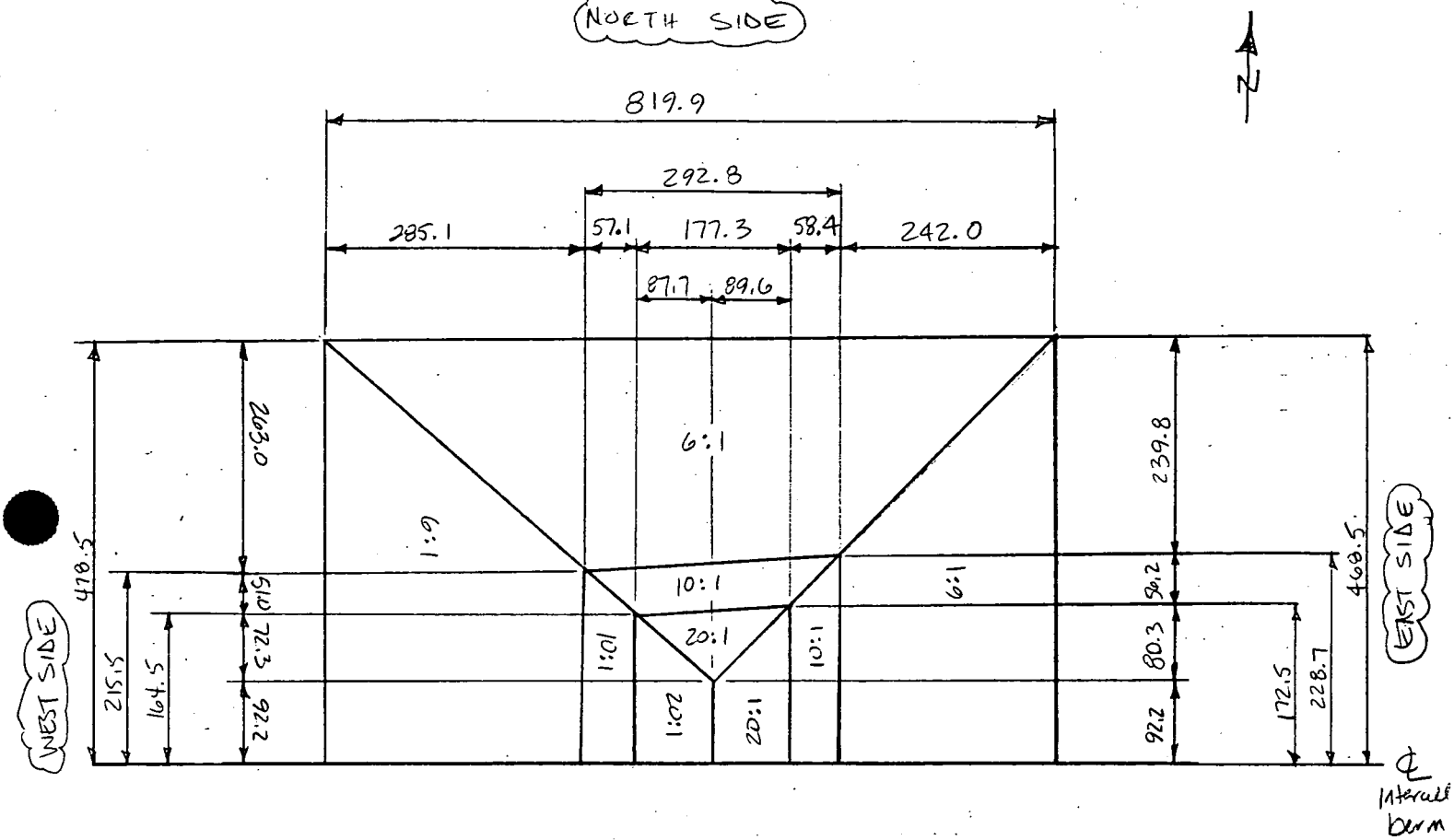
FIGURE 5

327696

Written by: Kara Olen / Dan Pass Date: 95/10/17 (YY/MM/DD) Reviewed by: PJS Date: 95/10/17 (YY/MM/DD)

Client: Fernow Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

FINAL COVER @ NORTH END CELL
(TO TOE OF 6:1 SLOPE)
(For calculation of Cell 1 Cap Surface area)



Length of Perimeter = 478.5 + 819.9 + 468.5 = 1766.9 ft

Note - Dimensions in this figure obtained from CADD measurements made on drawing titled "Final Cover System Grading Plan"

Scale 1" = 200'

001969

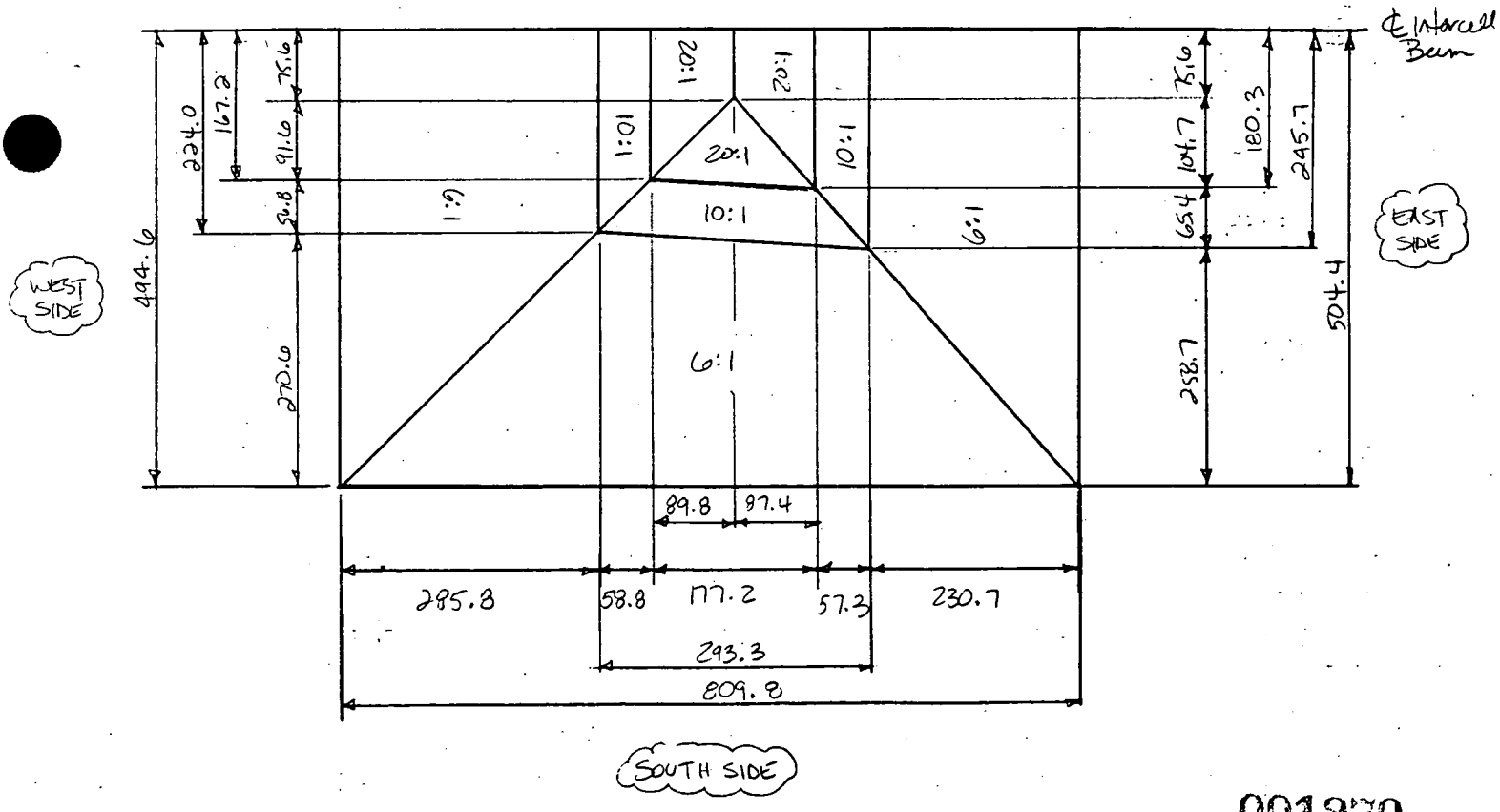
FIGURE 6

Written by: Kara Olin / Dan Pass Date: 95 / 10 / 17 (YY MM DD) Reviewed by: PJS Date: 95 / 10 / 17 (YY MM DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

FINAL COVER @
SOUTH END
(TO TOE OF 6:1 slope)
(For calculation of Cell 8 Cap Surface Area)

Note: Dimensions on this figure obtained from CADD measurements made on drawing titled "Final Cover System Grading Plan"



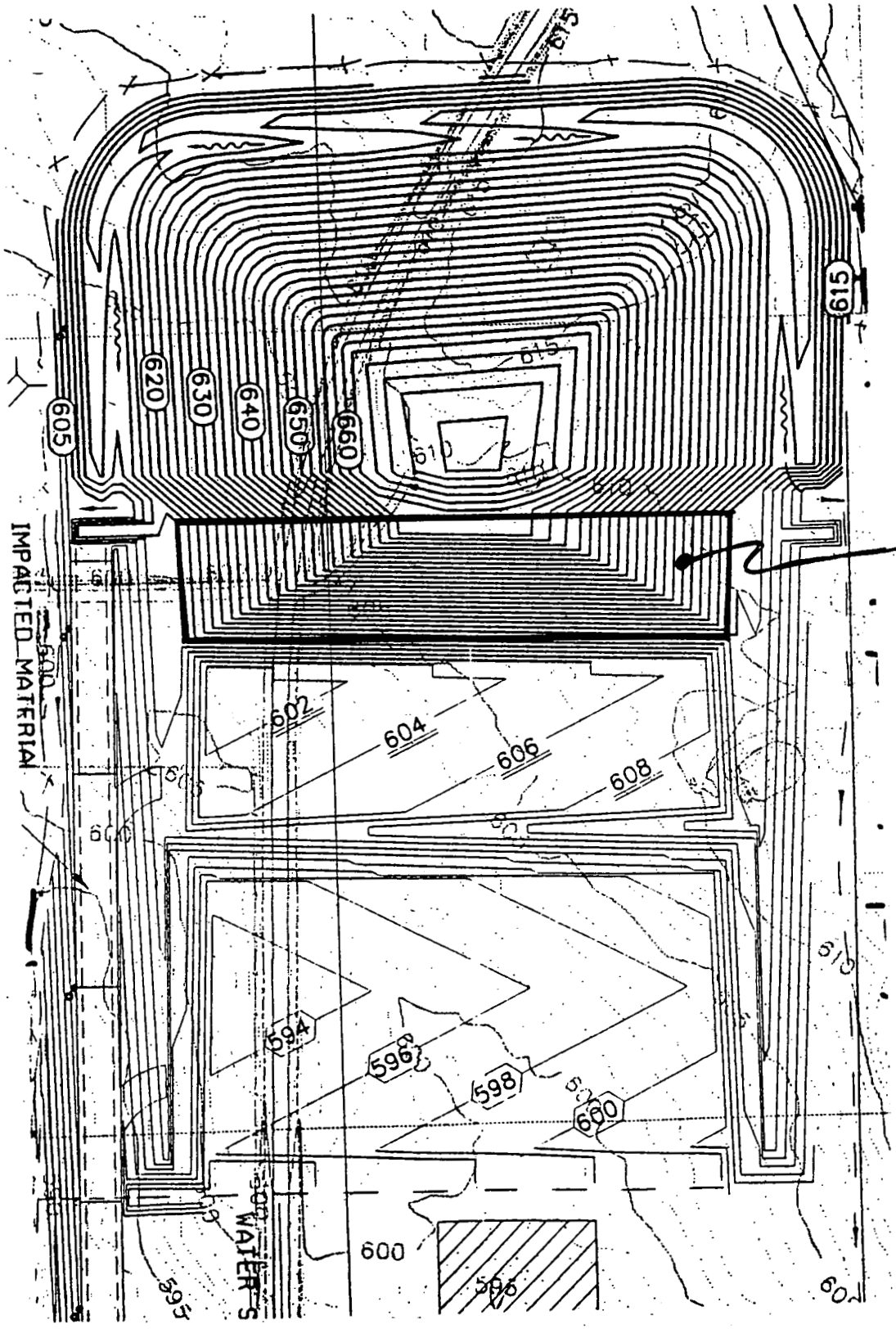
001970

Perimeter = 809.8 + 494.6 + 504.4 = 1808.8 FT

Scale 1" = 200 ft

FIGURE 7

Reviewed: PJS 95-10-17



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Formed
GE3900-8.11
10/11/95

Figure taken from dwg. titled "Site Development Plan – Early Stages"

Scale: 1" = 200'

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001971

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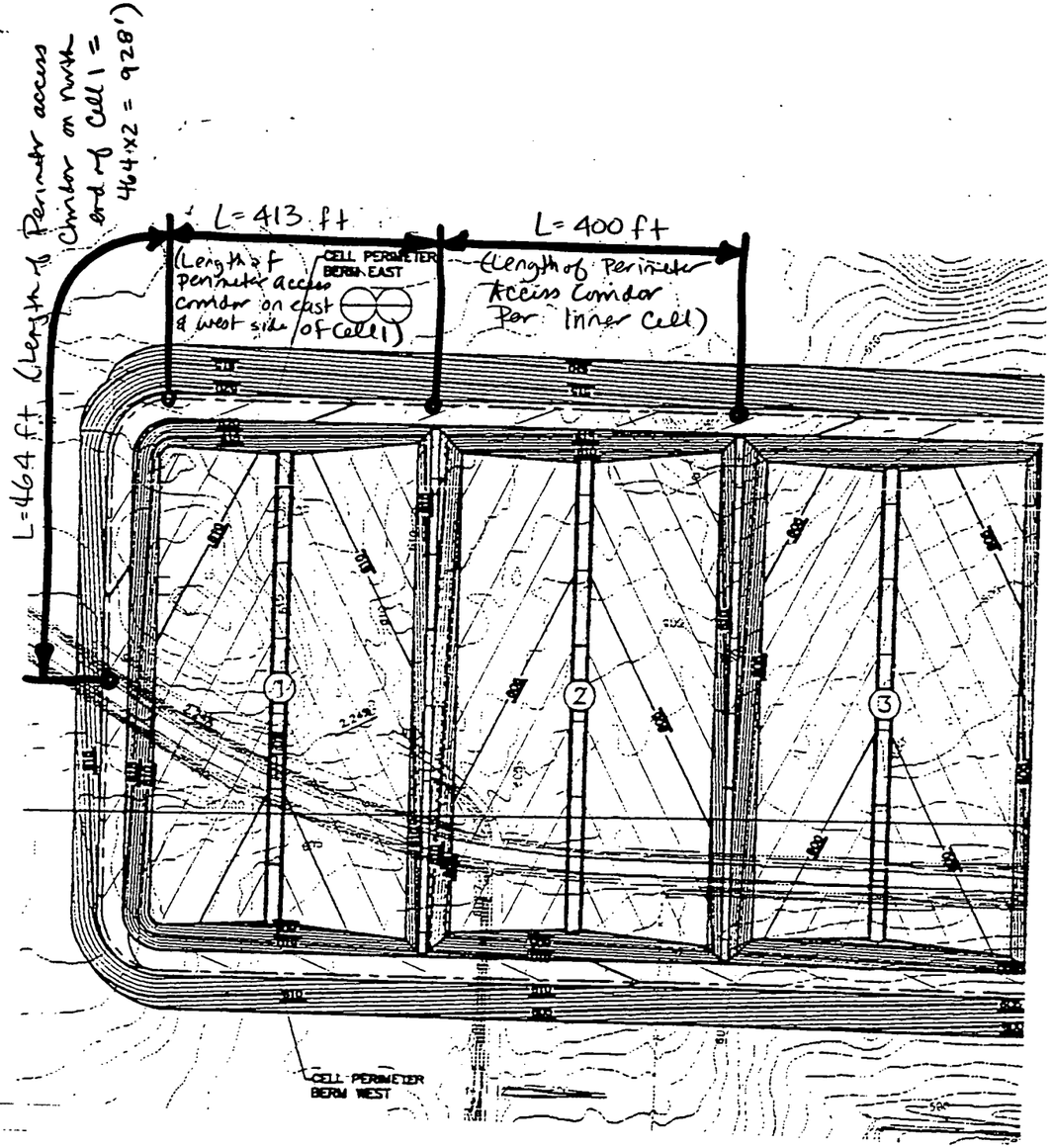
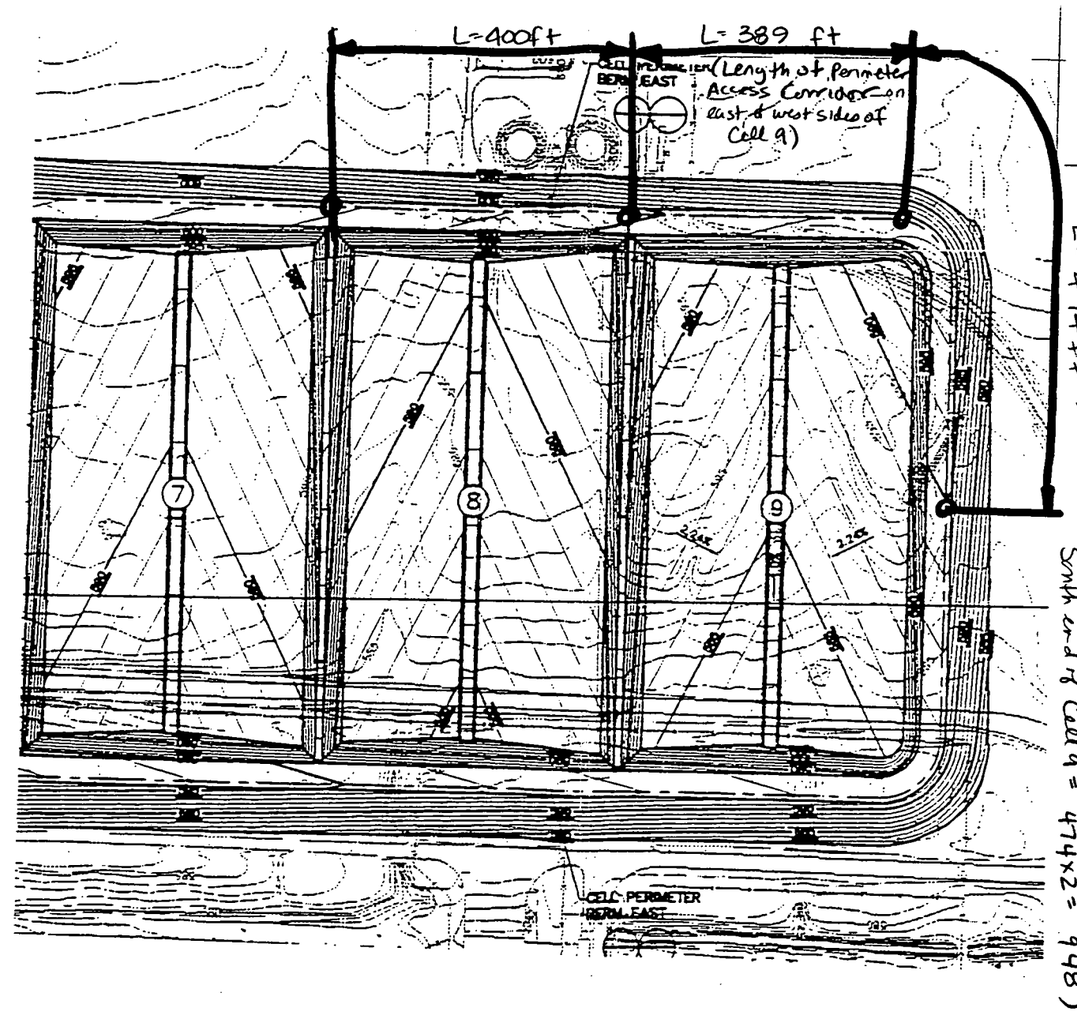
FIGURE 8

Reviewed FSS 95-10-17





NOTE: ALL LENGTHS ARE MEASURED ALONG PERIMETER ACCESS CORRIDOR STATION LINE.
Figure obtained from drawing titled "Leachate Collection System Grading Plan"

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Fernald
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10/17/95

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FIGURE 9

327696

Written by: Kara Olen / Dan Pass Date: 95 / 10 / 17 (YY MM DD) Reviewed by: RJB Date: 95 / 10 / 17 (YY MM DD)

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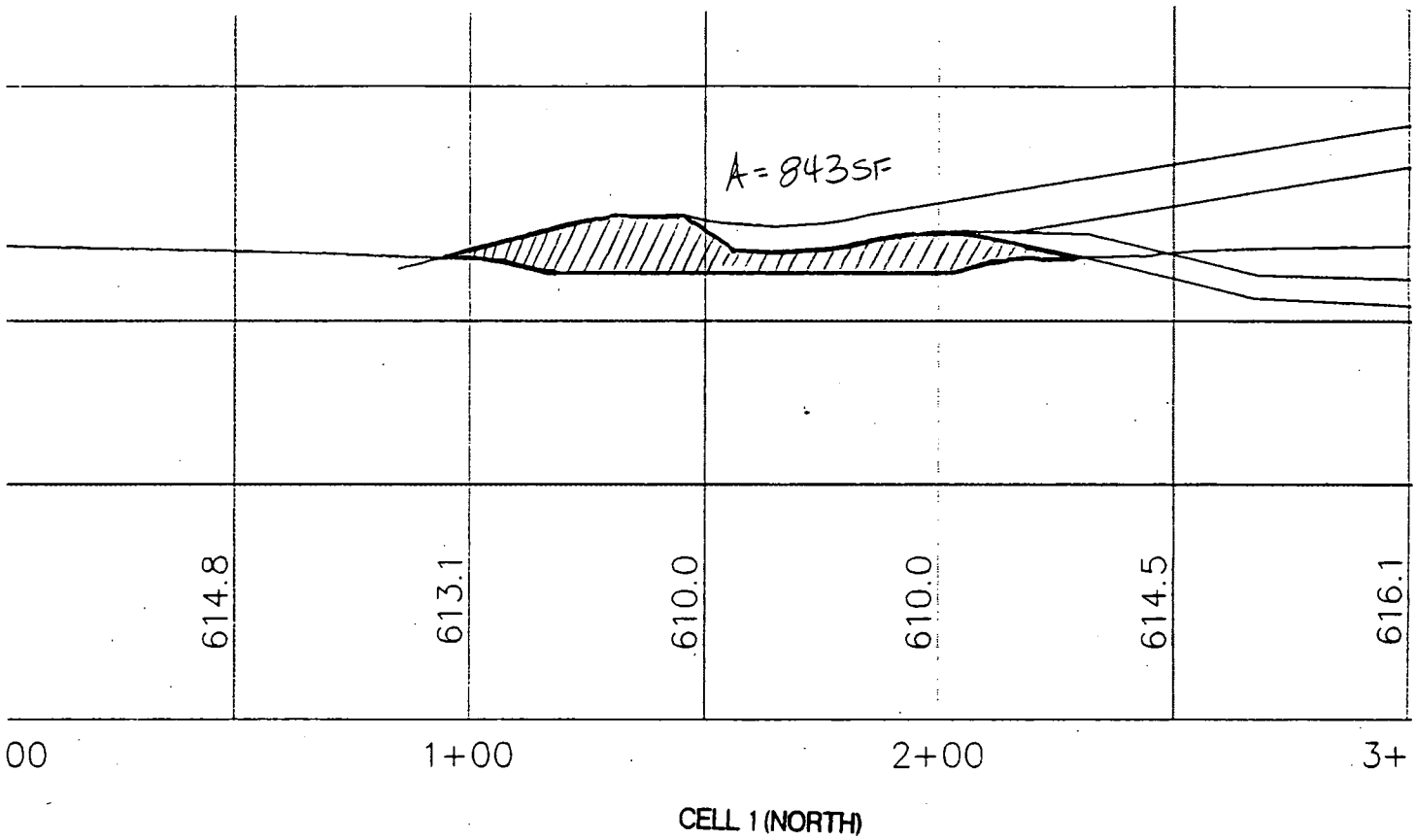
X-sectional area of
Struct. Fill @
Perimeter access Corridor



Note- Areas shown on figures 10 through 17 were obtained with a planimeter. Cross sections were prepared by CADD.

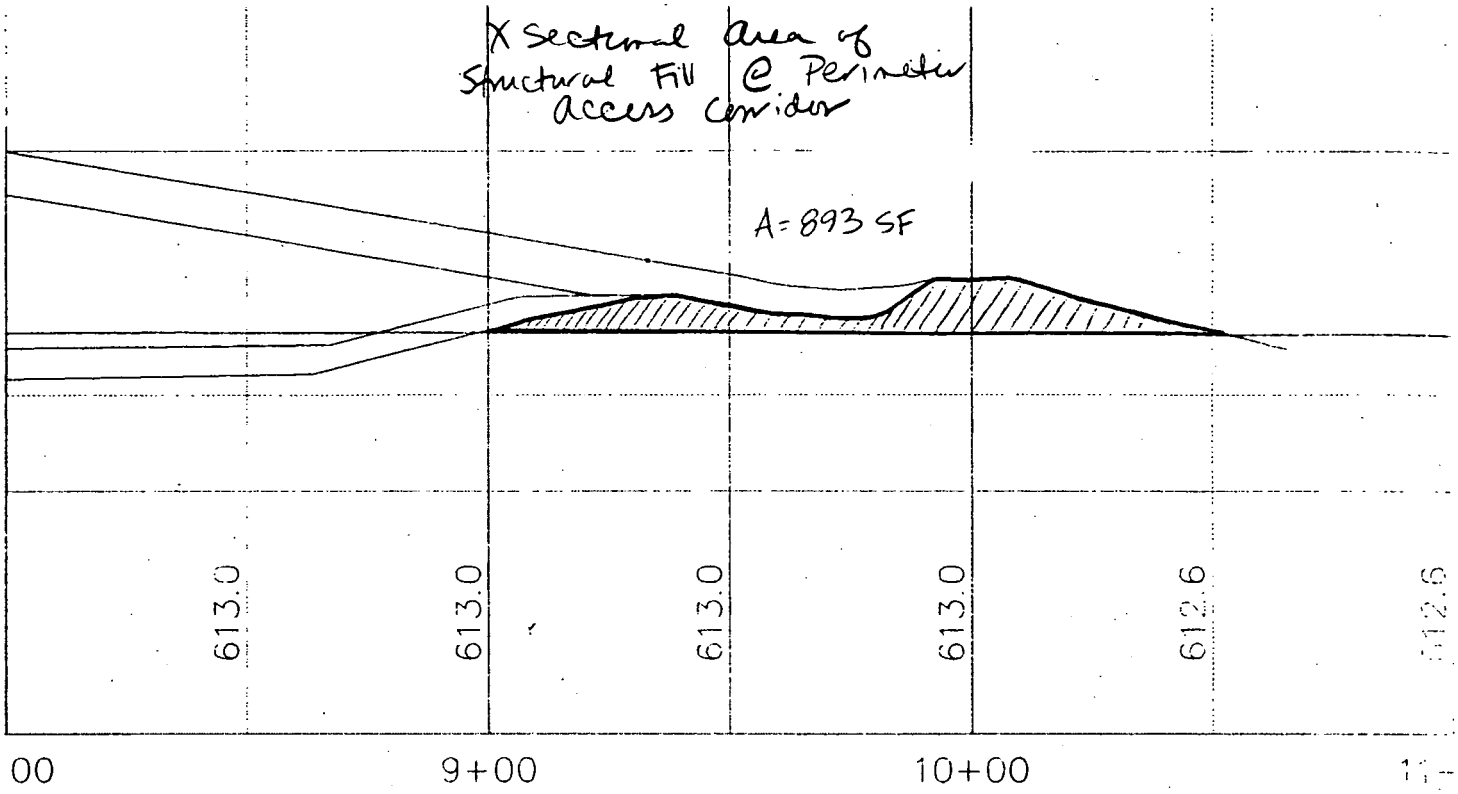
Scale: 1" = 40'

001973

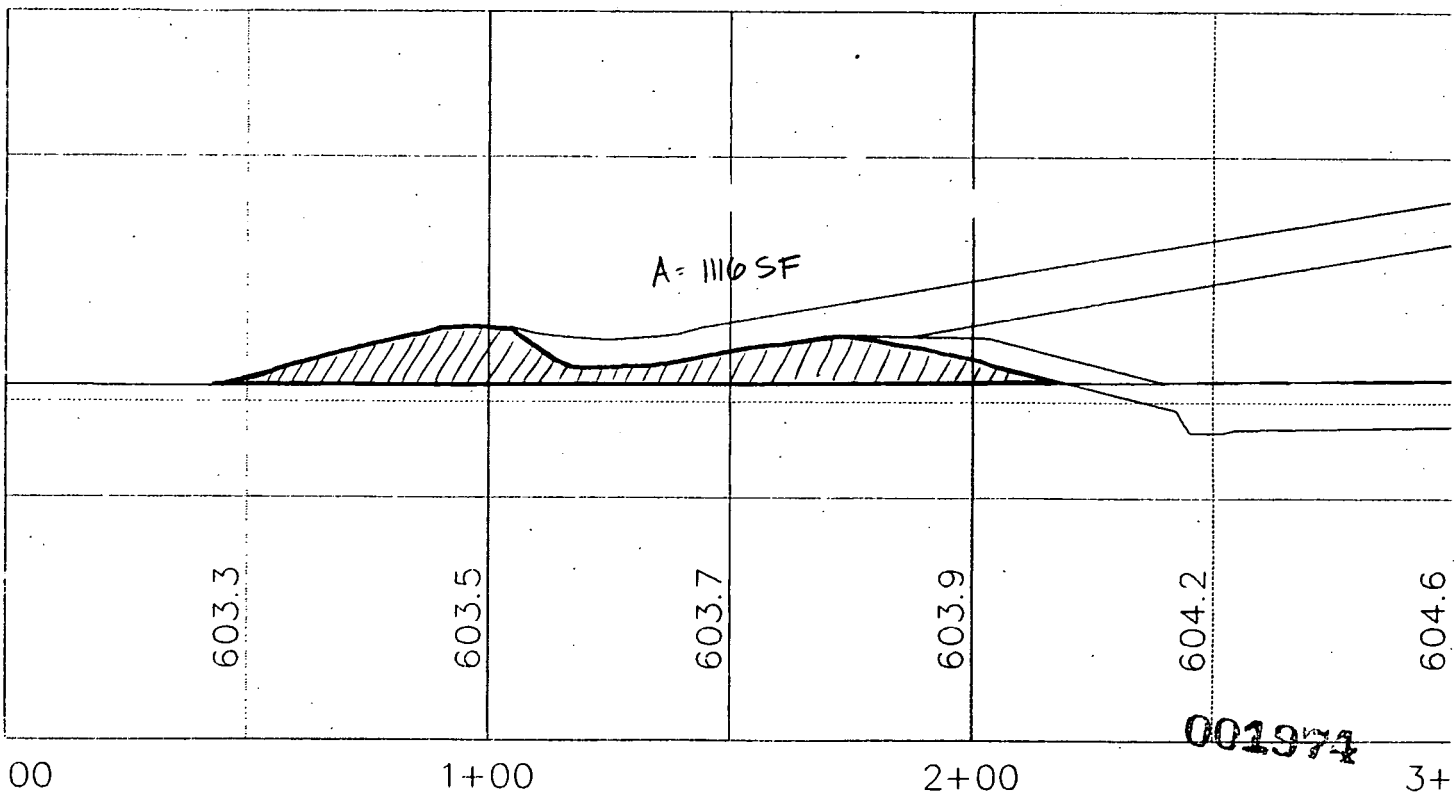
FIGURE 10

Written by: Kara Olsen / Dan Pass Date: 95/10/17 (YY MM DD) Reviewed by: RJS Date: 95/10/17 (YY MM DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11



CELL 1 (EAST)



001974

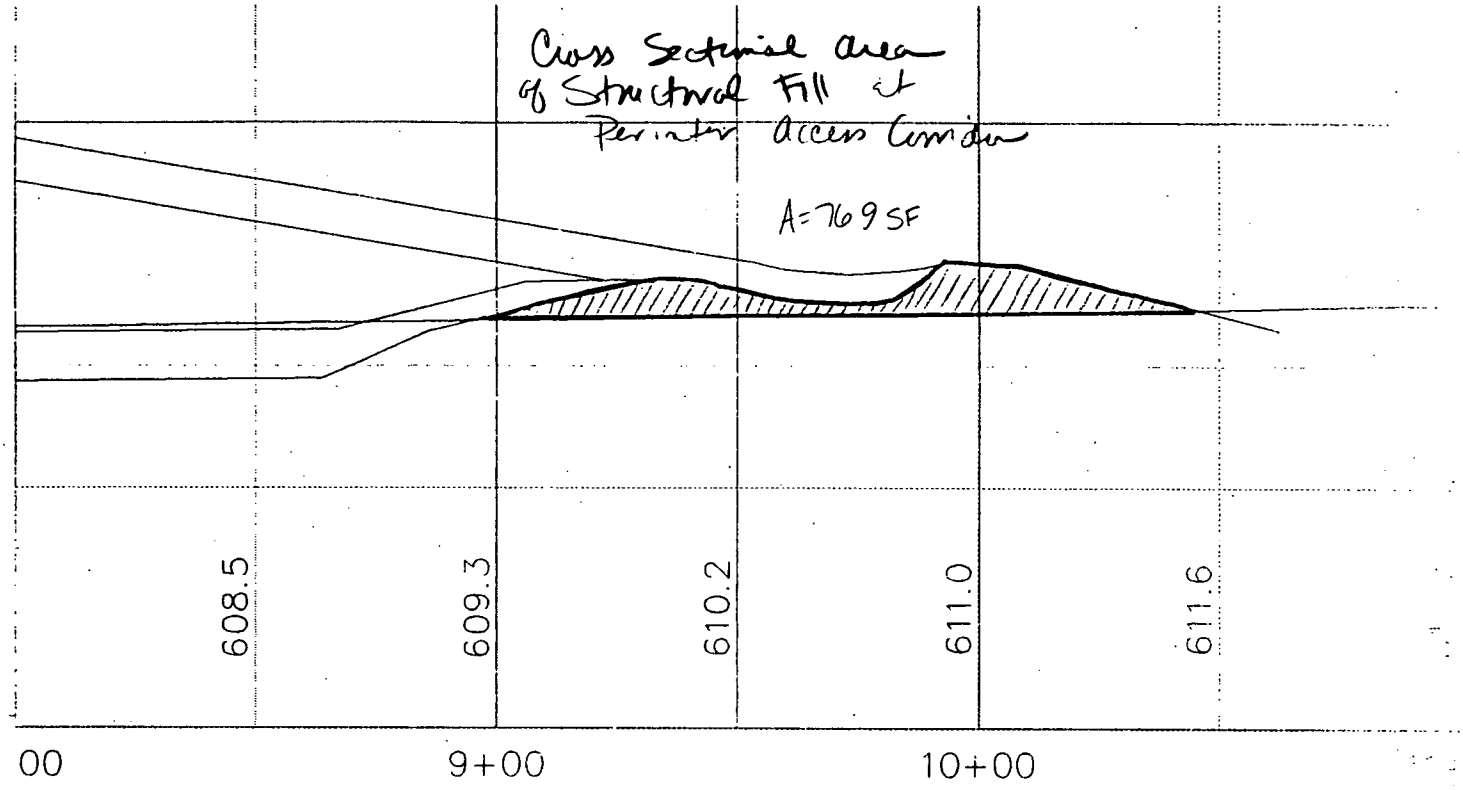
CELL 1 (WEST)

FIGURE 11

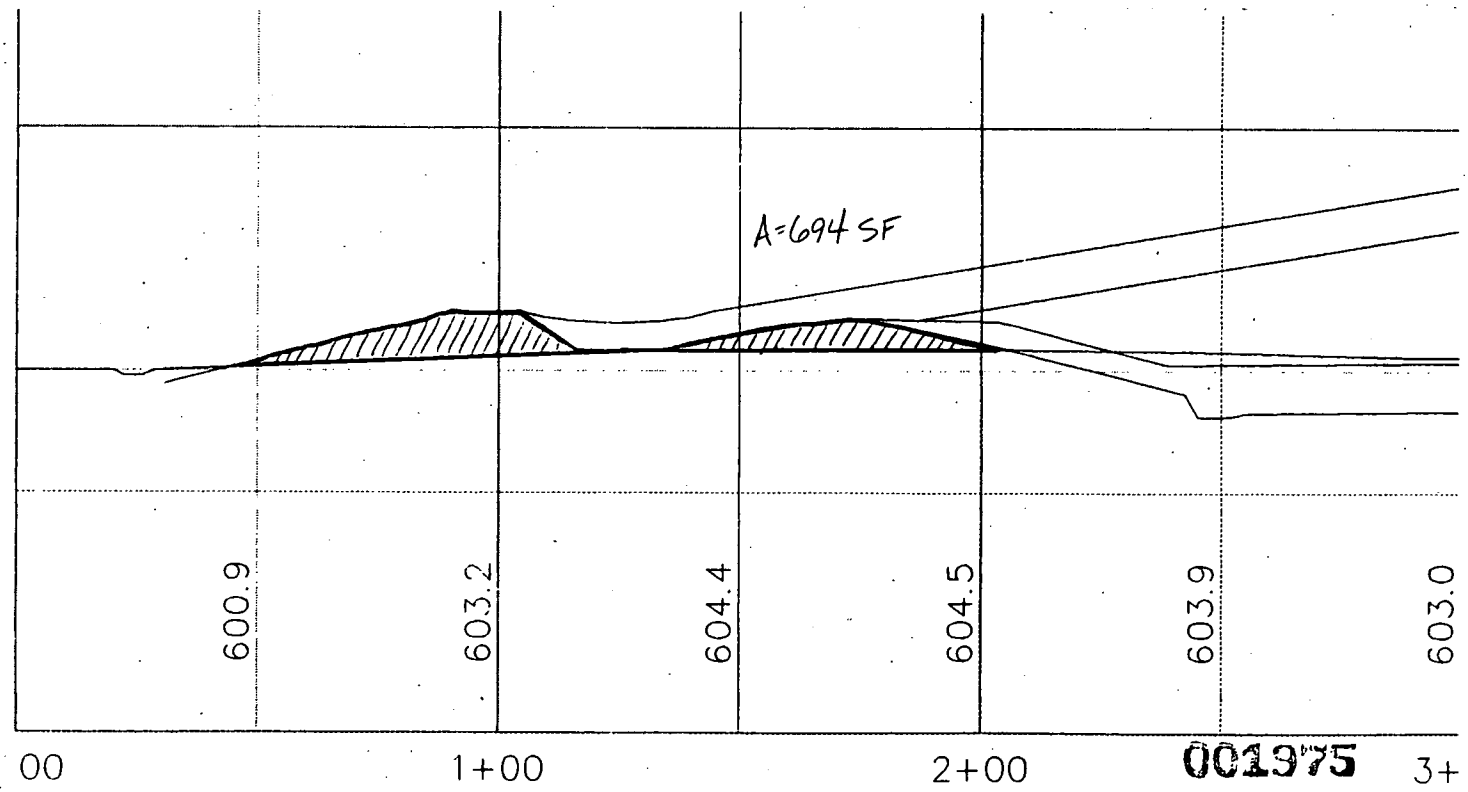
Scale 1" = 40'

Written by: Kara Olsen / Dan Pass Date: 95 / 10 / 17 (YY MM DD) Reviewed by: PJS Date: 95 / 10 / 17 (YY MM DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11



CELL 2 (EAST)



CELL 2 (WEST)

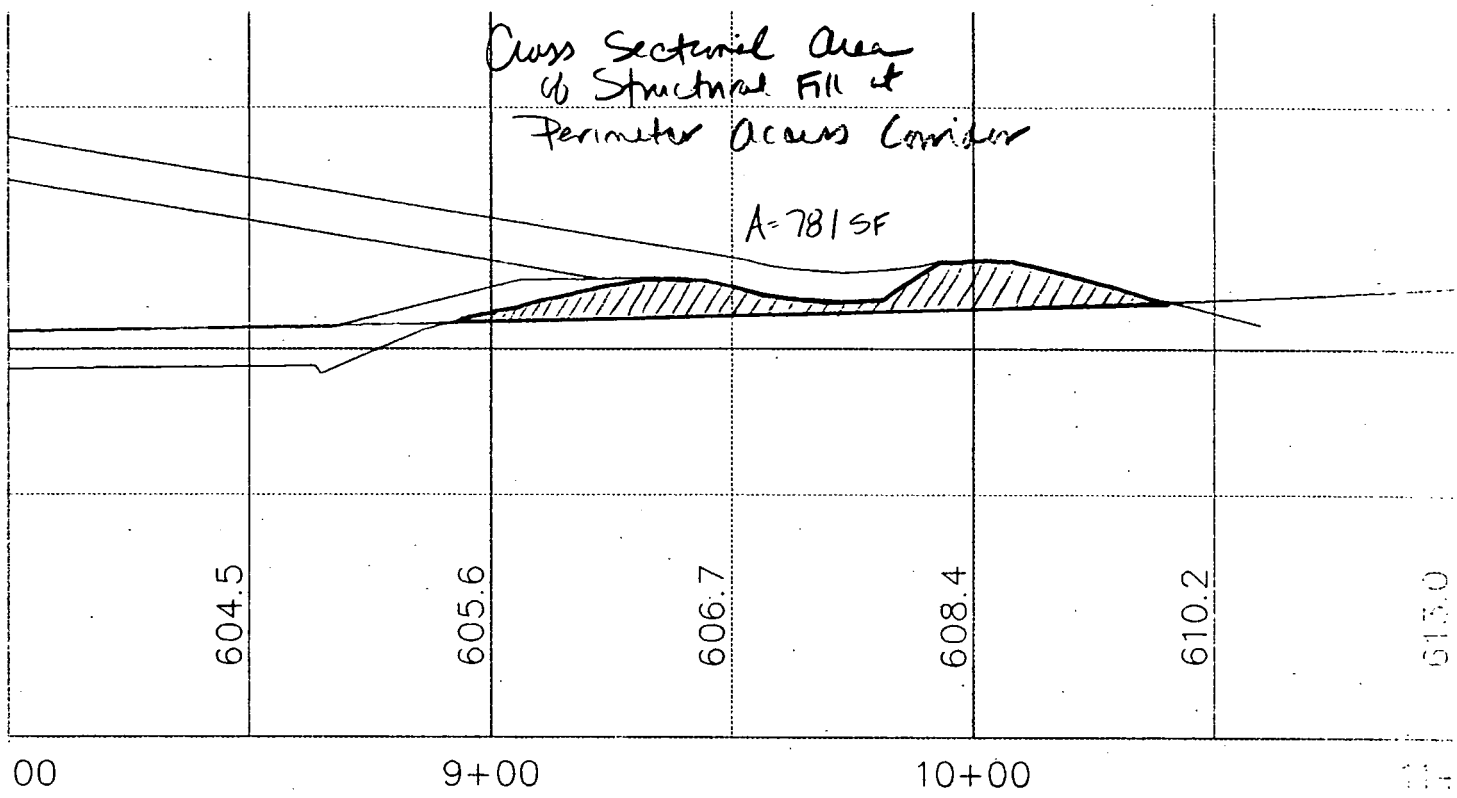
001975

FIGURE 12

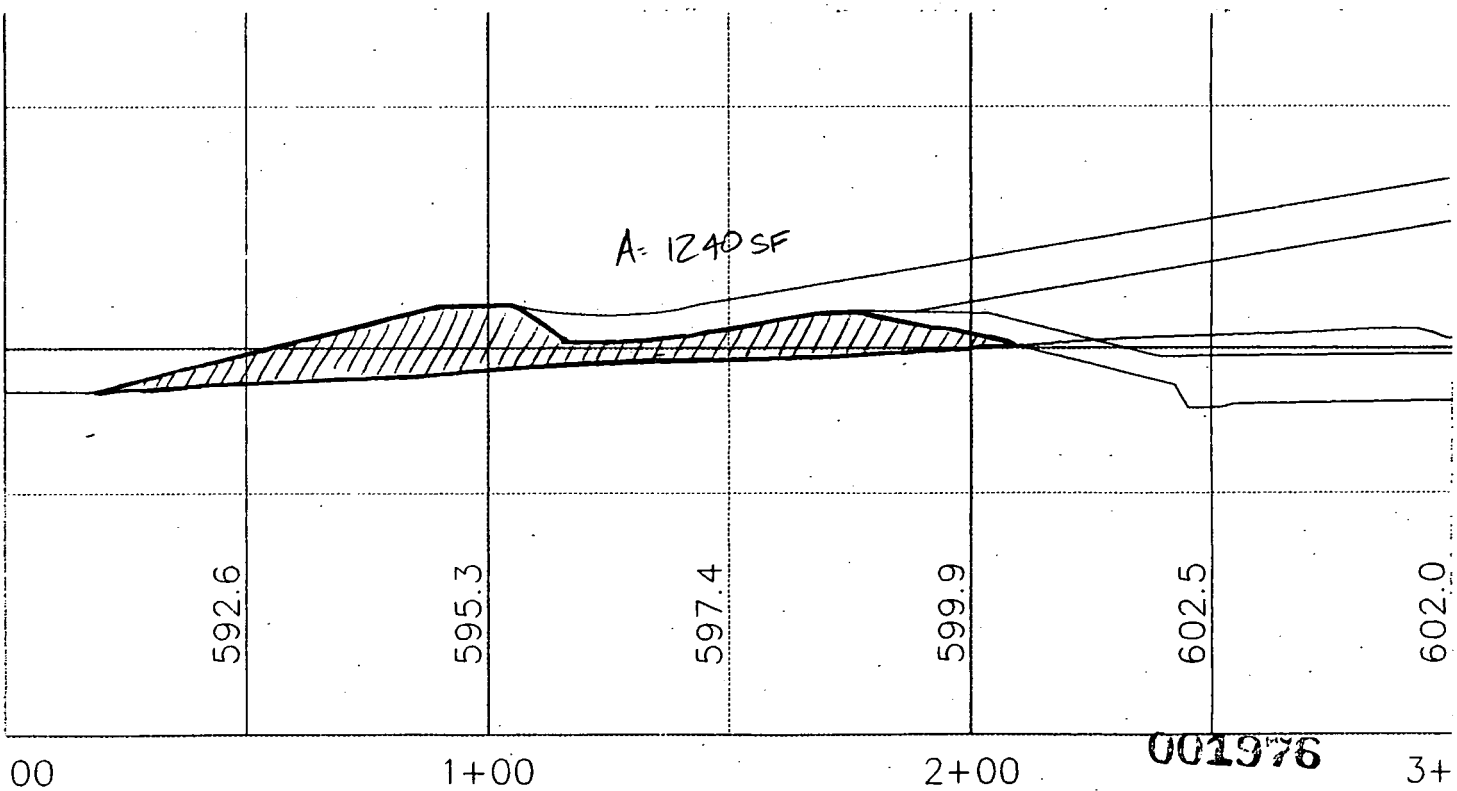
Scale: 1" = 40'

Written by: Kara Olen / Dan Pass Date: 95/10/17 (YY MM DD) Reviewed by: FJB Date: 95/10/17 (YY MM DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11



CELL 3 (EAST)



001976

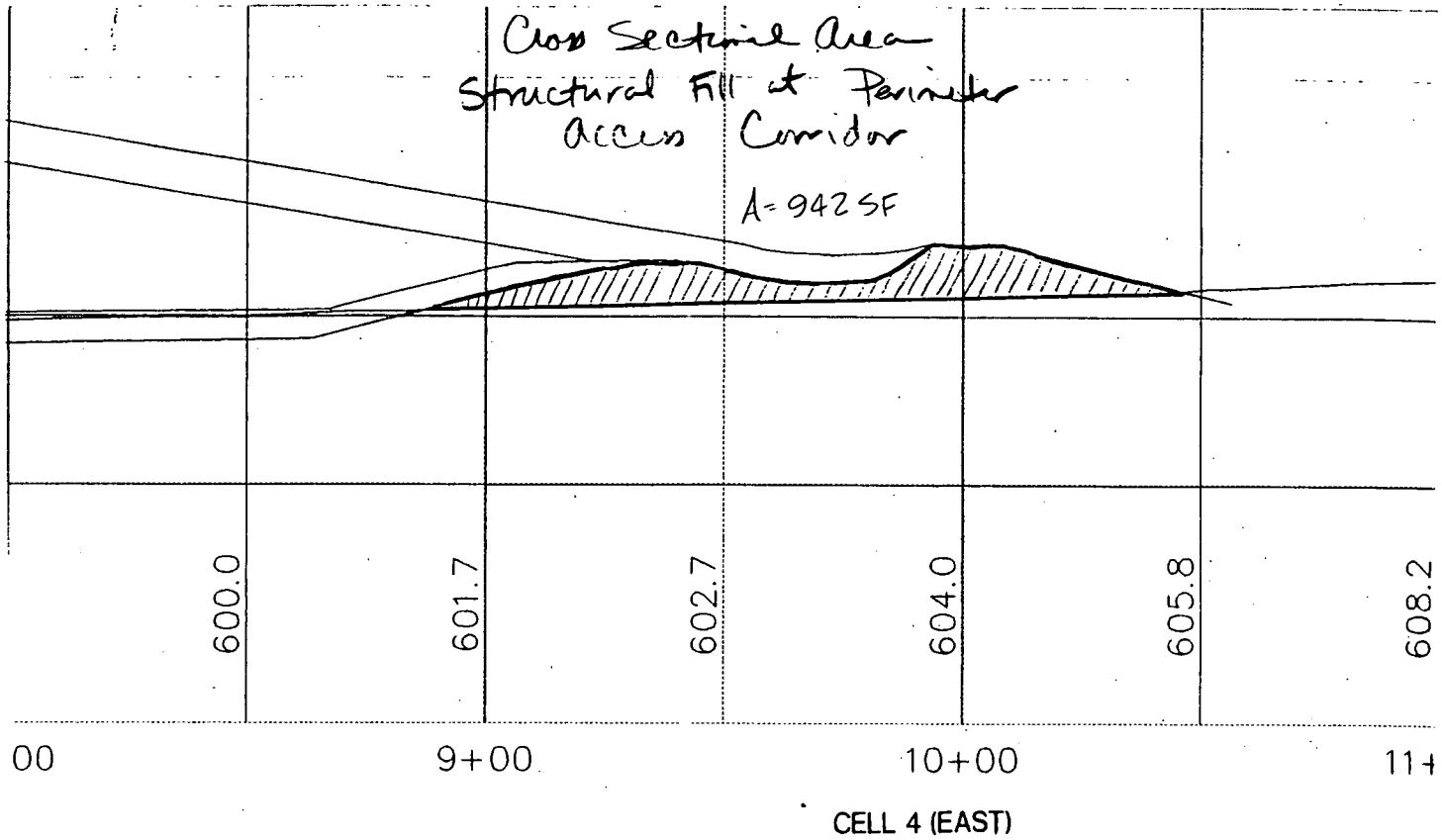
CELL 3 (WEST)

FIGURE 13

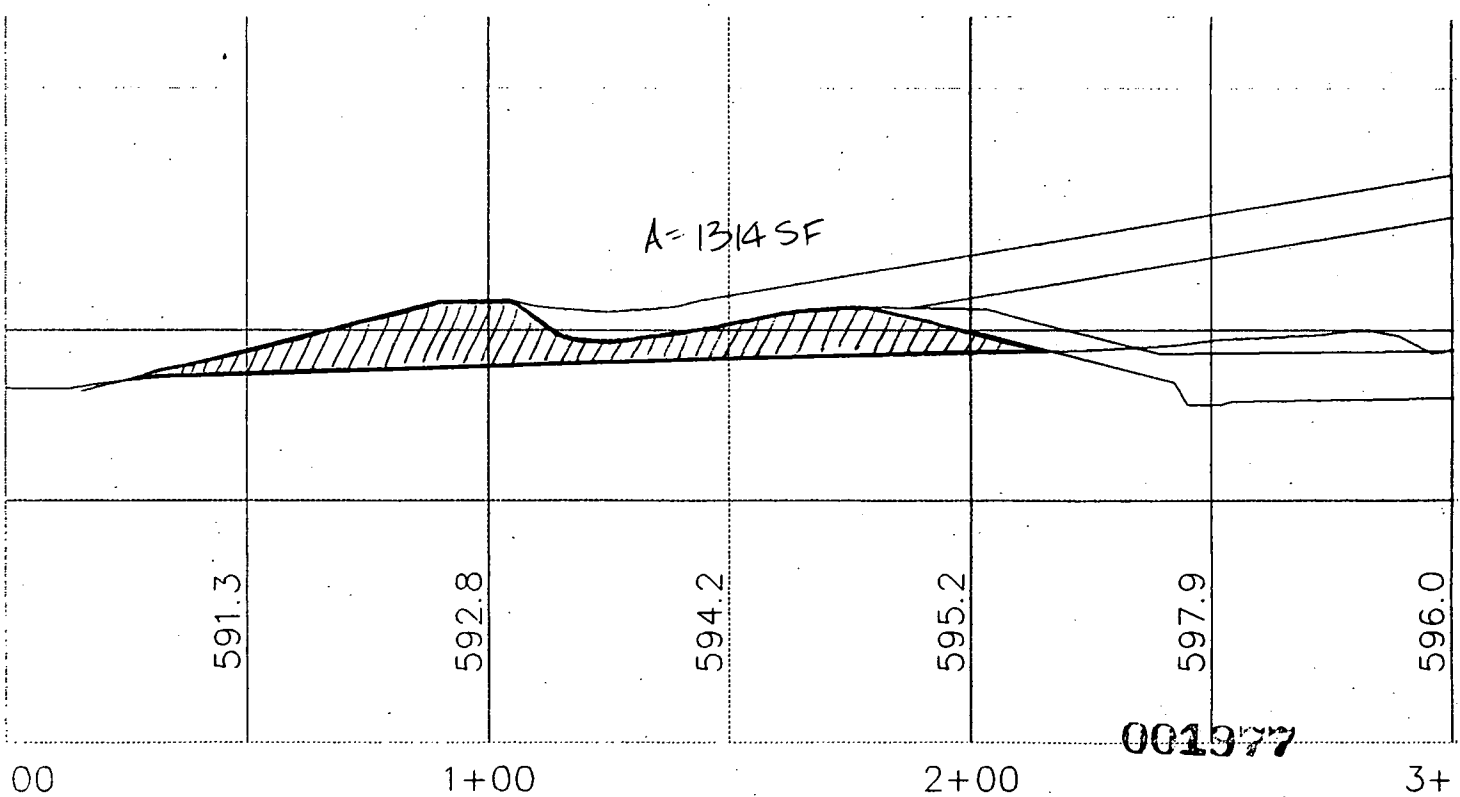
Scale: 1" = 40 ft

Written by: Kara Allen / Dan Pass Date: 95 / 10 / 17 (YY MM DD) Reviewed by: PCS Date: 95 / 10 / 17 (YY MM DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11



CELL 4 (EAST)



001977

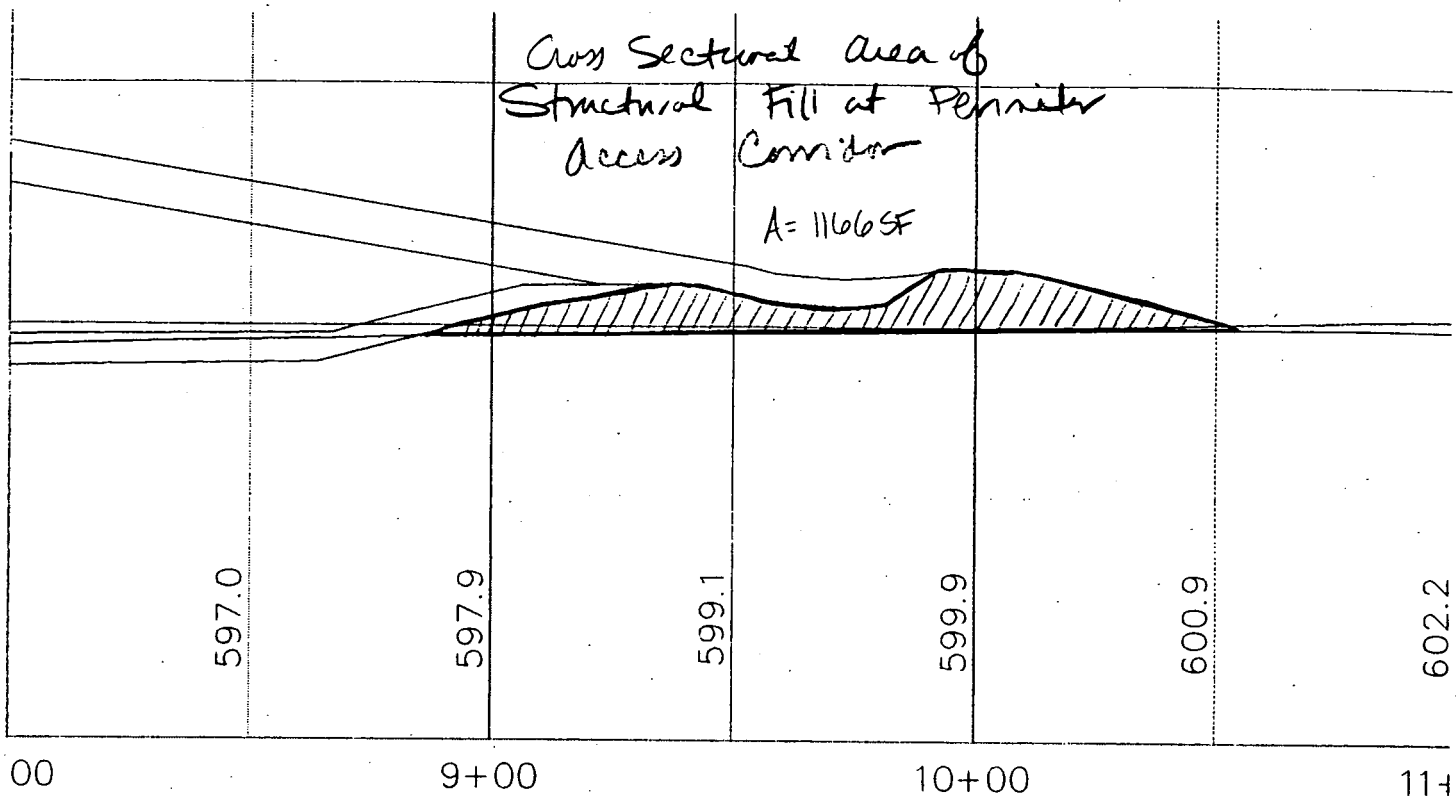
CELL 4 (WEST)

FIGURE 14

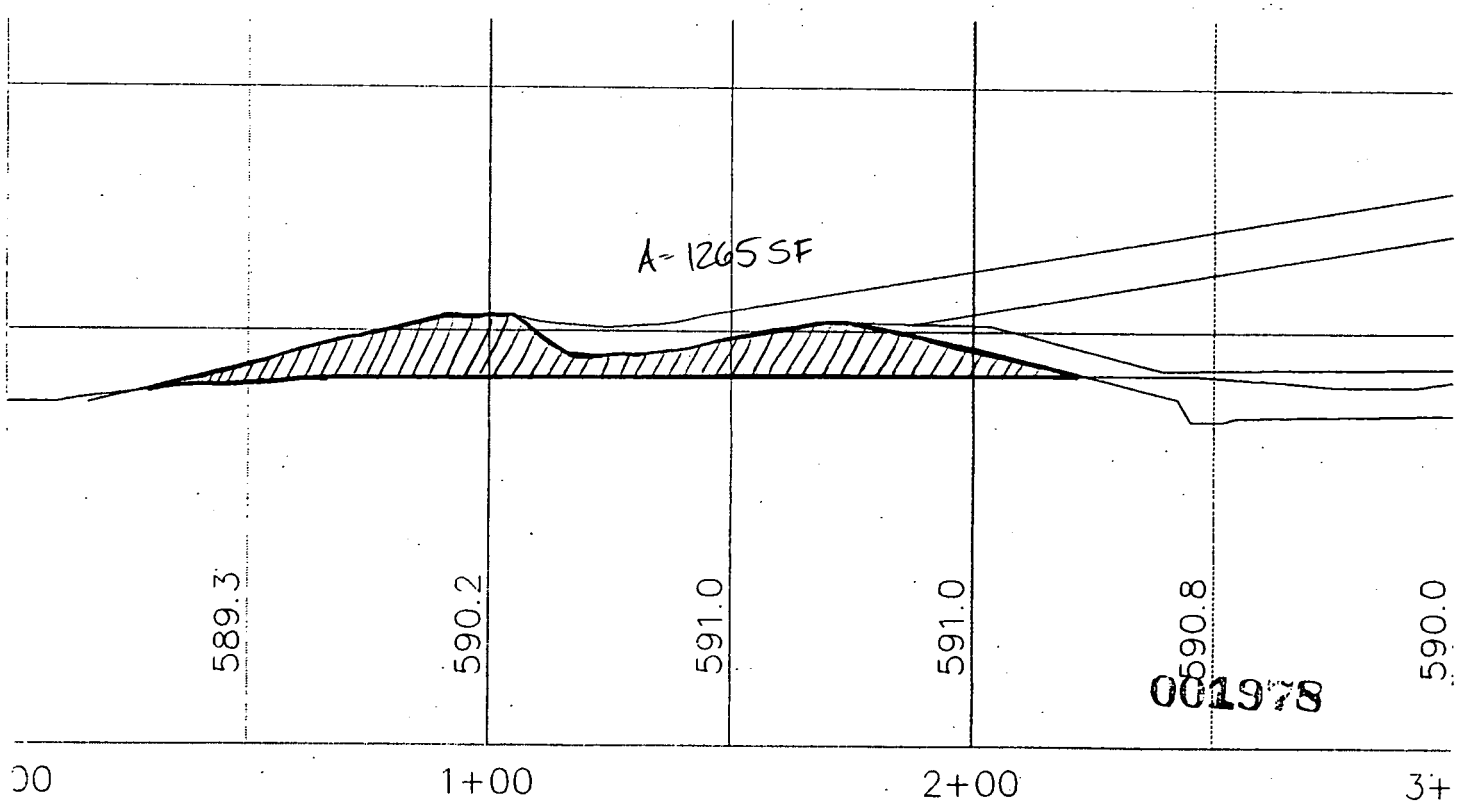
Scale: 1"=40'

Written by: Kara Olen / Dan Pass Date: 95 / 10 / 17 (YY MM DD) Reviewed by: PJS Date: 95 / 10 / 17 (YY MM DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11



CELL 5 (EAST)



CELL 5 (WEST)

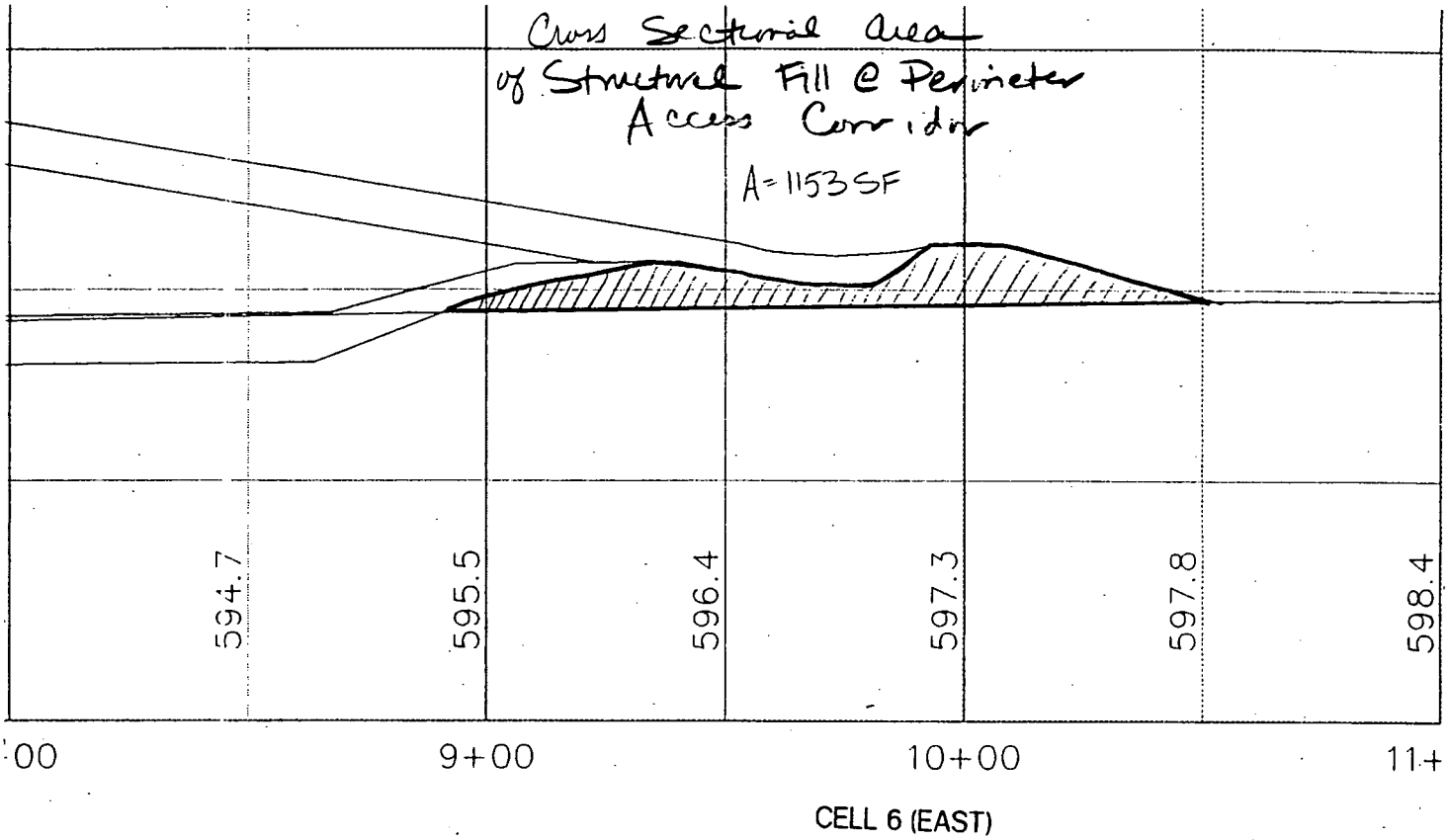
FIGURE 15

Scale 1"=40'

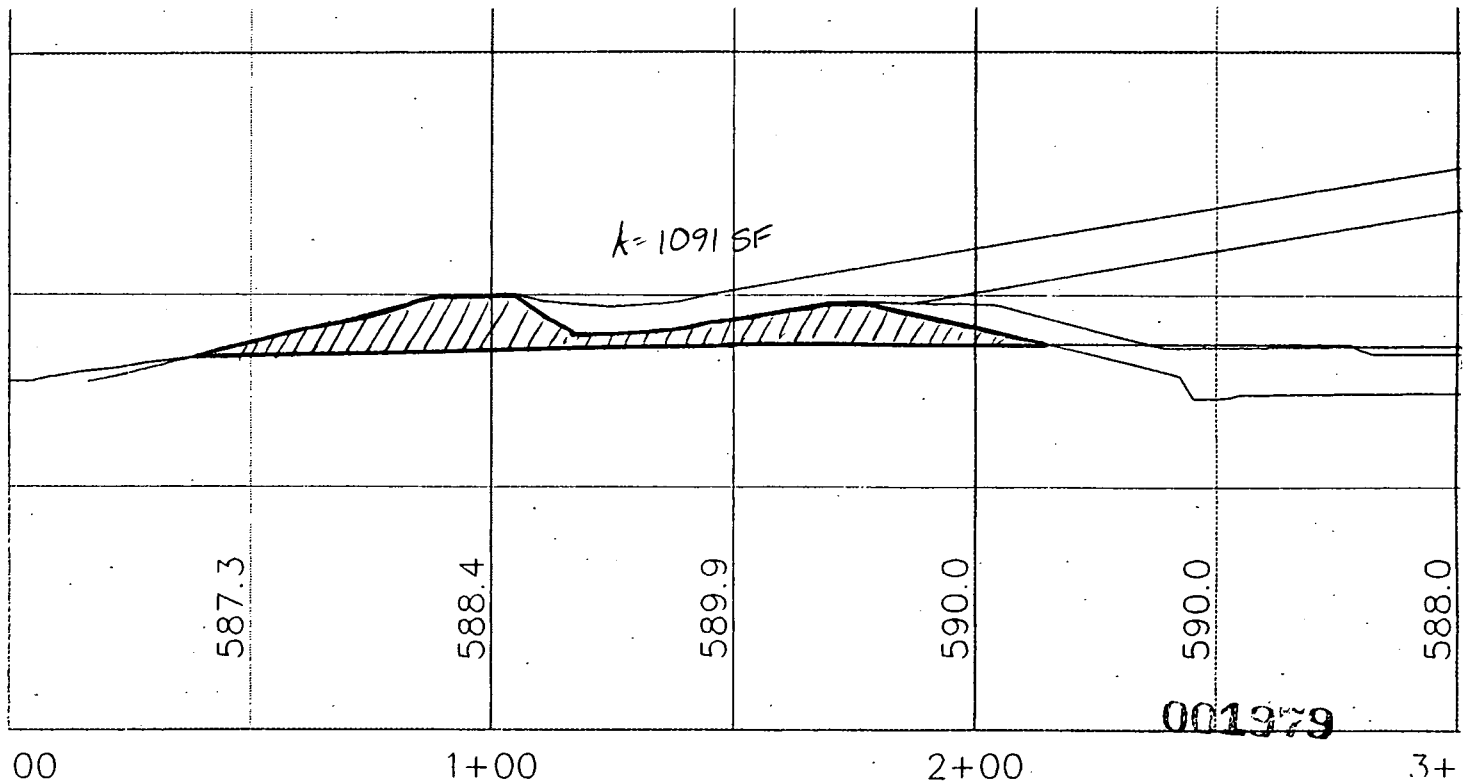
001978

Written by: Kara Olsen / Dan Pass Date: 95/10/17 (YY/MM/DD) Reviewed by: PJS Date: 95/10/17 (YY/MM/DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11



CELL 6 (EAST)



001979

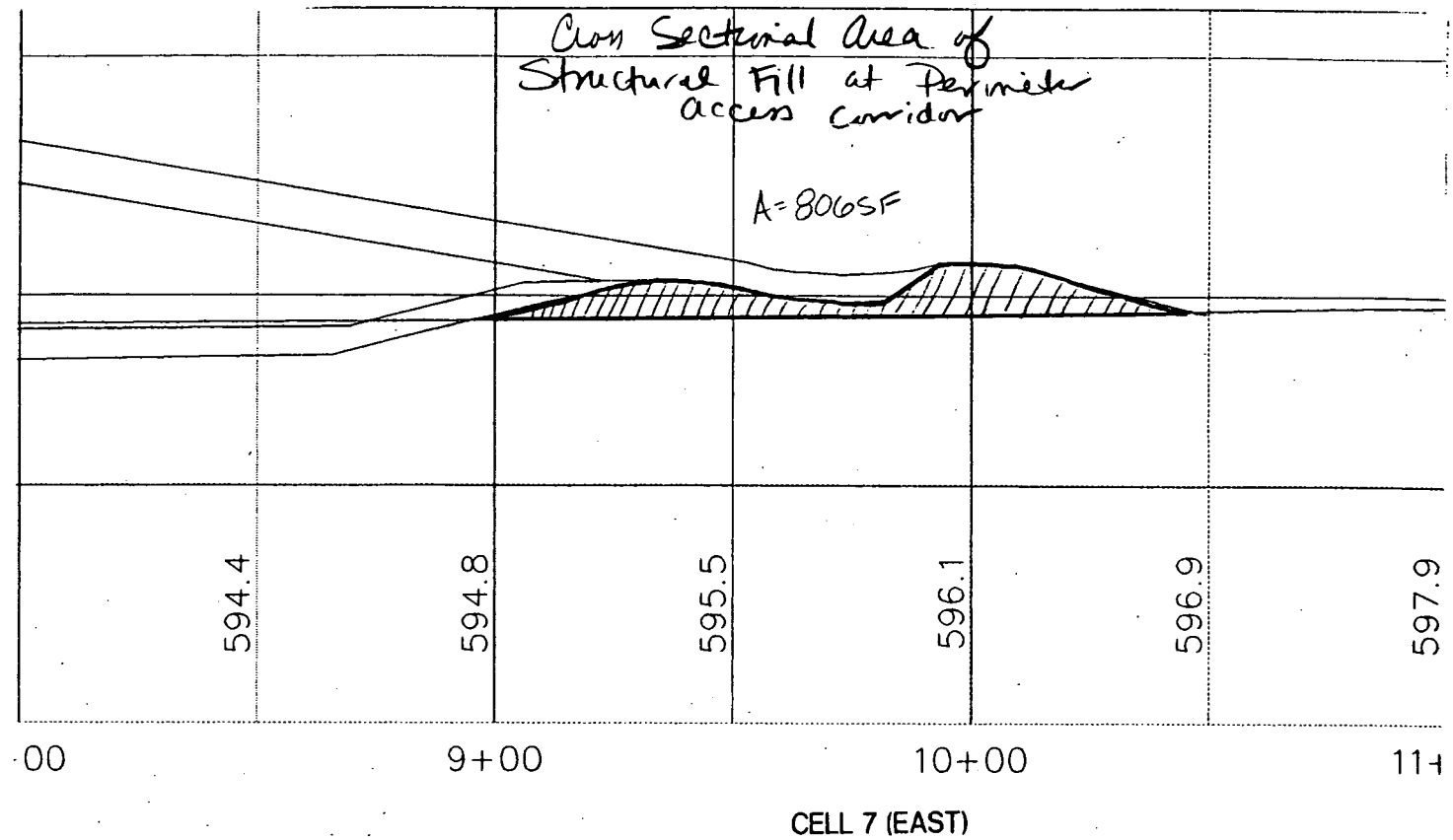
CELL 6 (WEST)

FIGURE 16

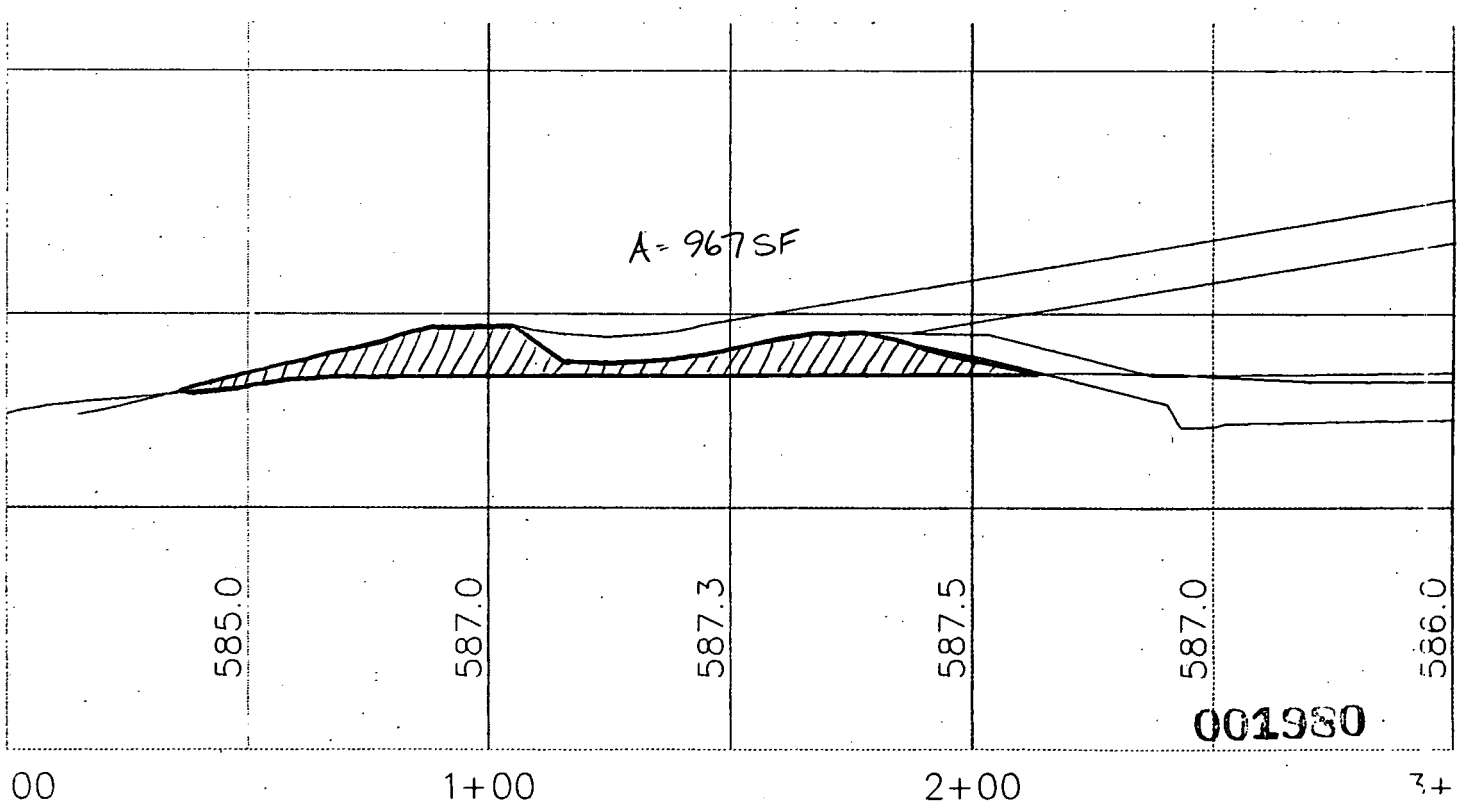
Scale 1"=40'

Written by: Kara Olson / Dan Pass Date: 95 / 10 / 17 (YY MM DD) Reviewed by: PJS Date: 95 / 10 / 17 (YY MM DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11



CELL 7 (EAST)



CELL 7 (WEST)

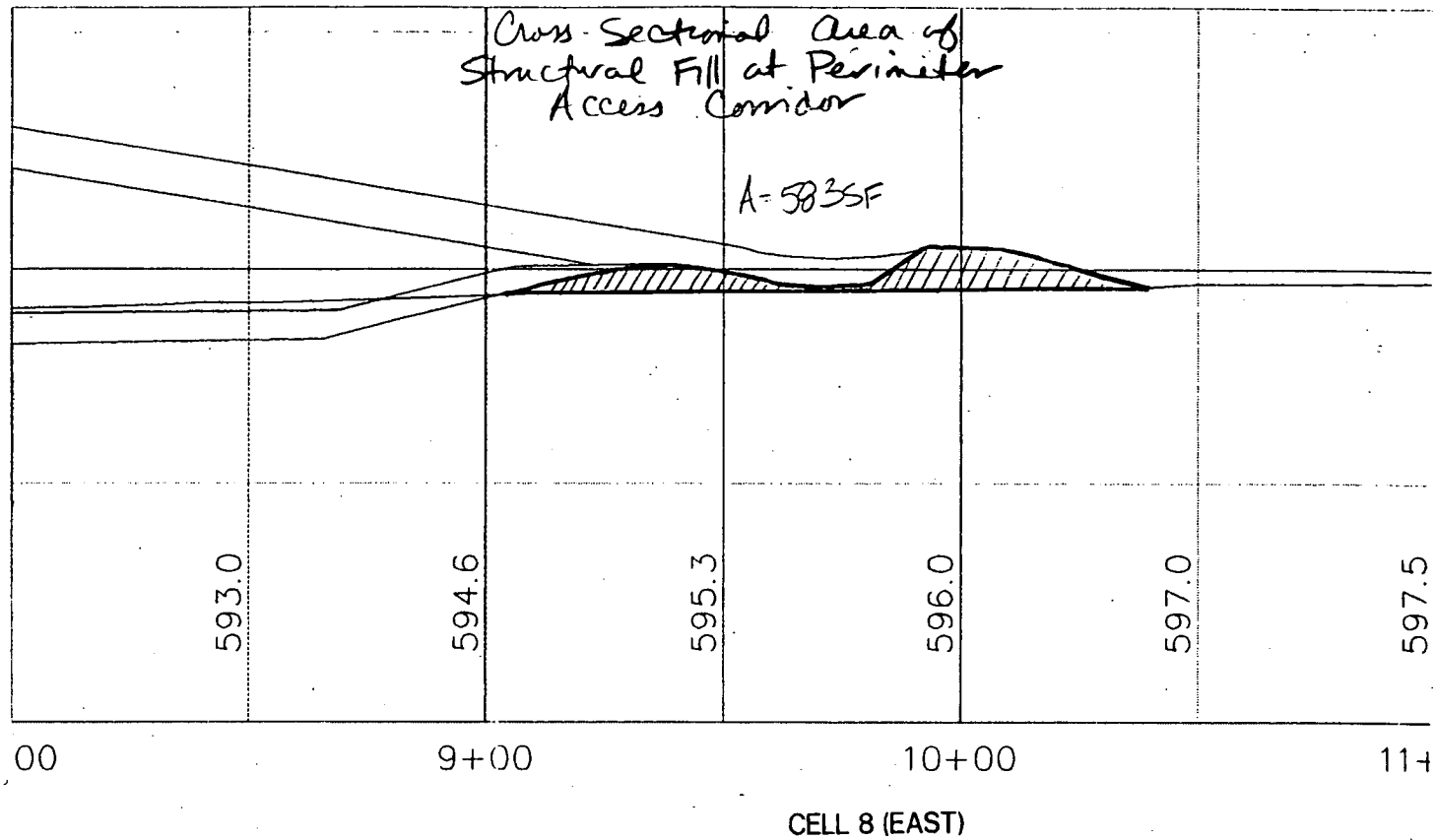
001980

FIGURE 17

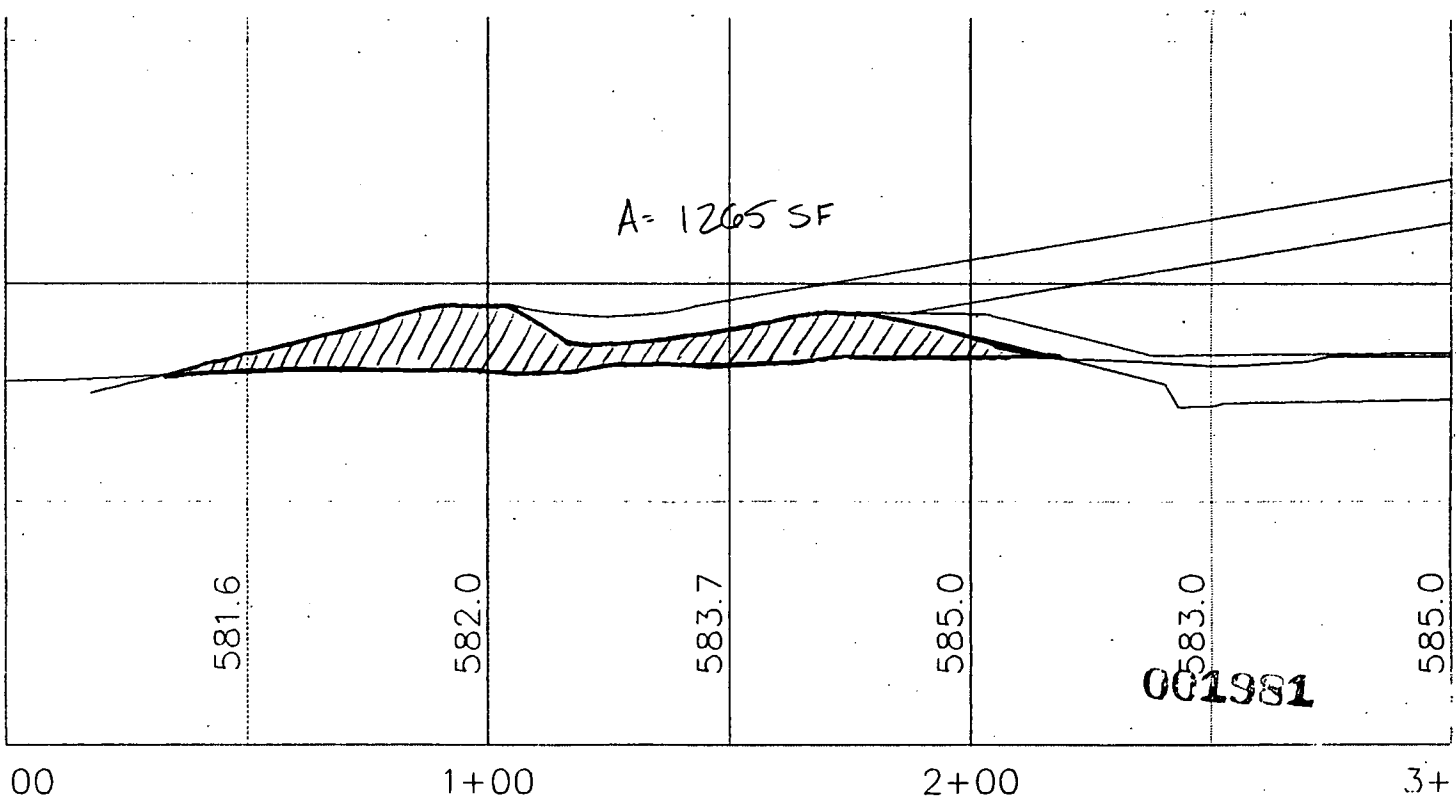
Scale 1"=40'

Written by: Kara Olen / Dan Pass Date: 95/10/17 (YY/MM/DD) Reviewed by: PJS Date: 95/10/17 (YY/MM/DD)

Client: Fernco Project: Fernald Project/Proposal No.: GE3900 Task No.: 8111



CELL 8 (EAST)



001981

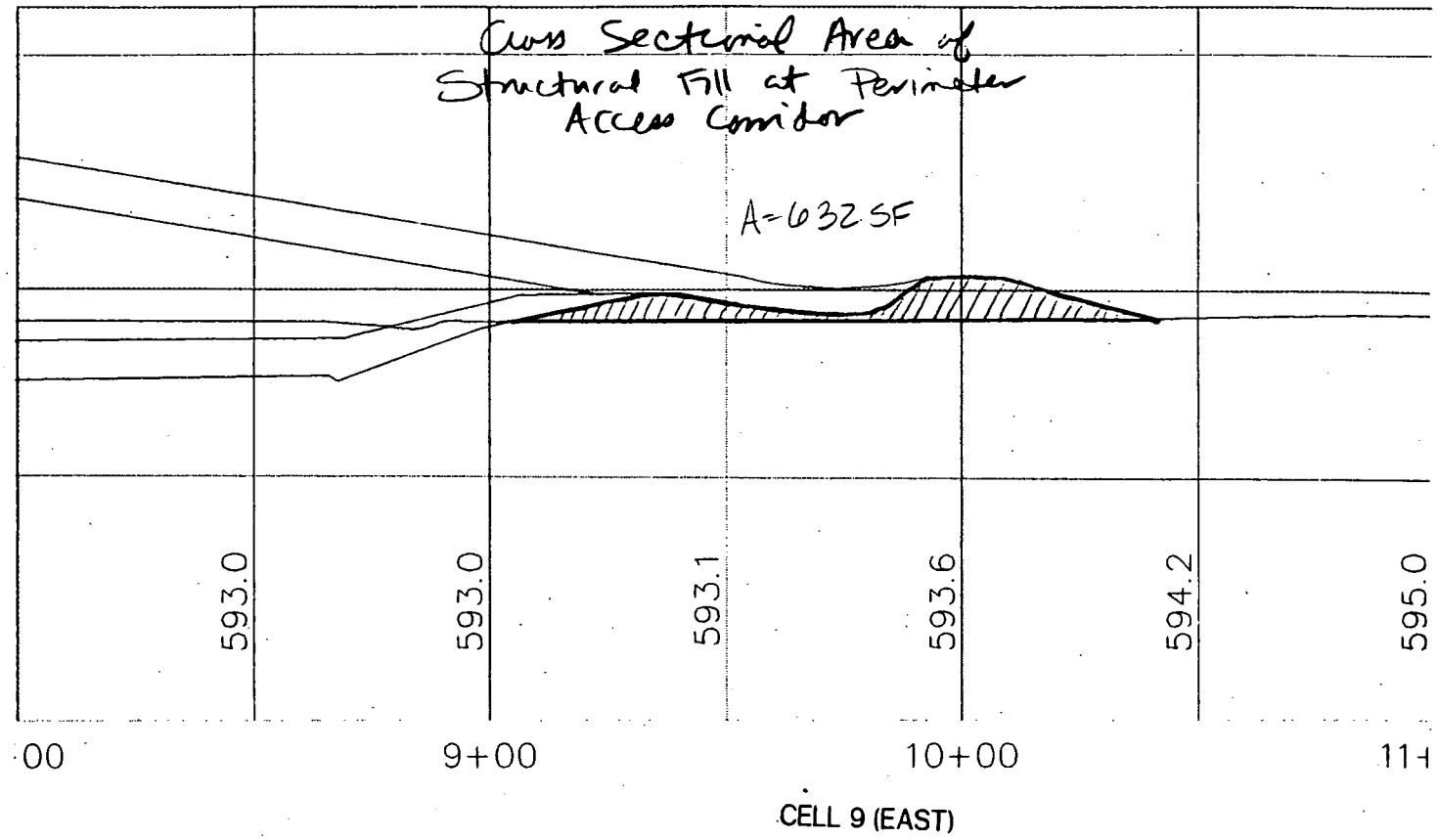
CELL 8 (WEST)

FIGURE 18

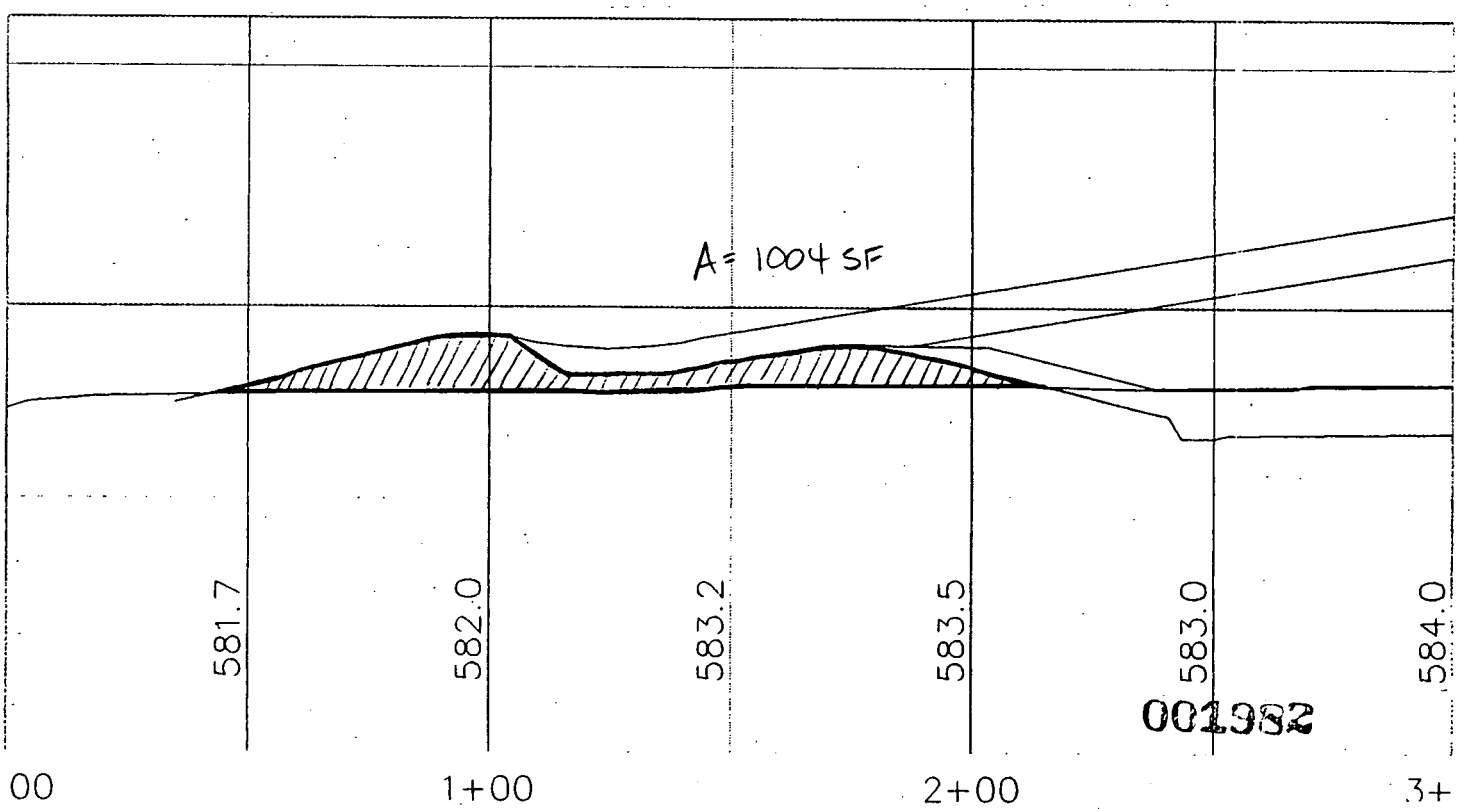
Scale 1"=40'

Written by: Kara Olen / Dan Pas Date: 95/10/17 (YY MM DD) Reviewed by: RJS Date: 95/10/17 (YY MM DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8,11



CELL 9 (EAST)



CELL 9 (WEST)

001982

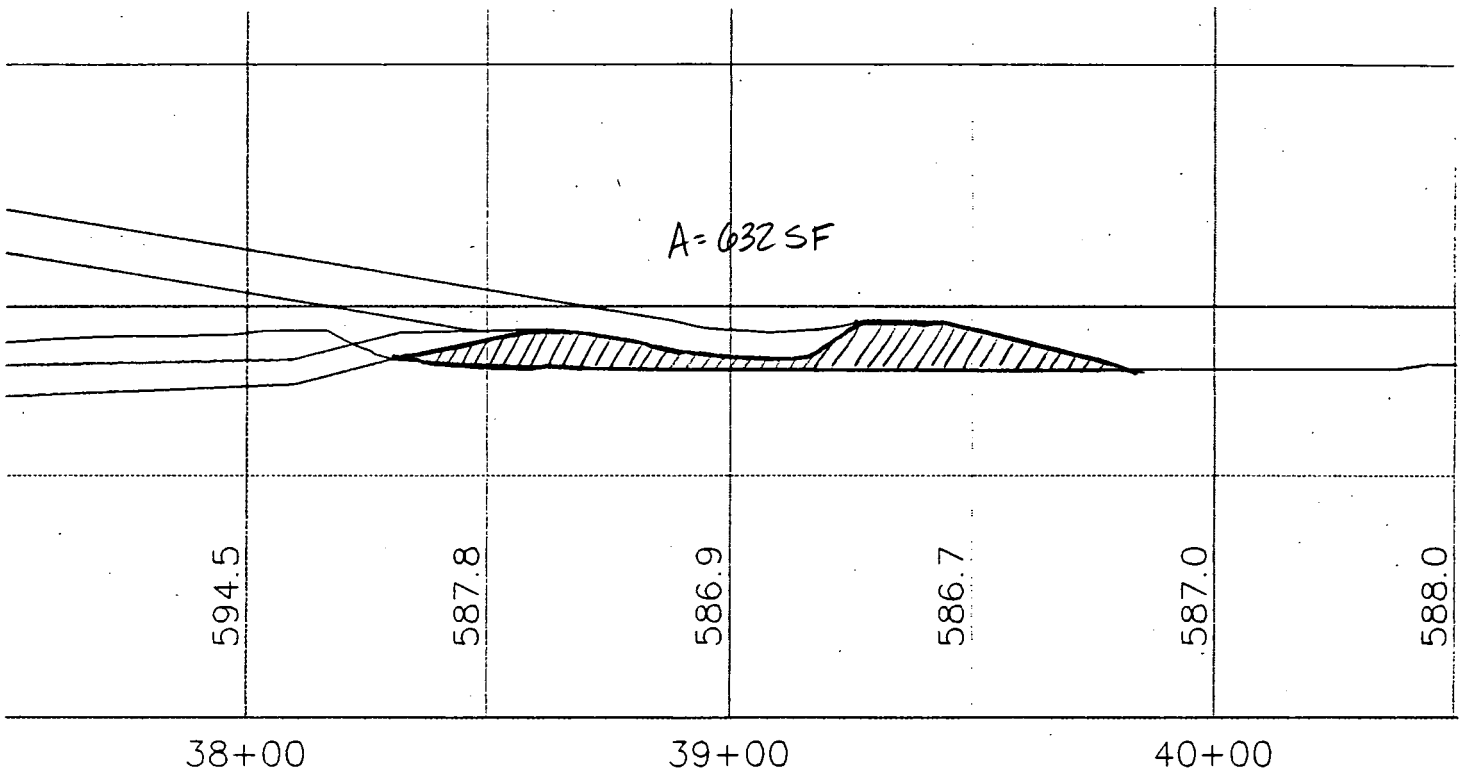
FIGURE 19

Scale: 1"=40'

Written by: Kara Olen / Dan Pass Date: 95/10/17 (YY/MM/DD) Reviewed by: PJS Date: 95/10/17 (YY/MM/DD)

Client: Fernald Project: Fernald Project/Proposal No.: GE3900 Task No.: 8.11

Cross Sectional Area of Structural Fill at Perimeter Access Corridor



CELL 9 (SOUTH)

001983

FIGURE 20

Scale 1" = 40'

327696

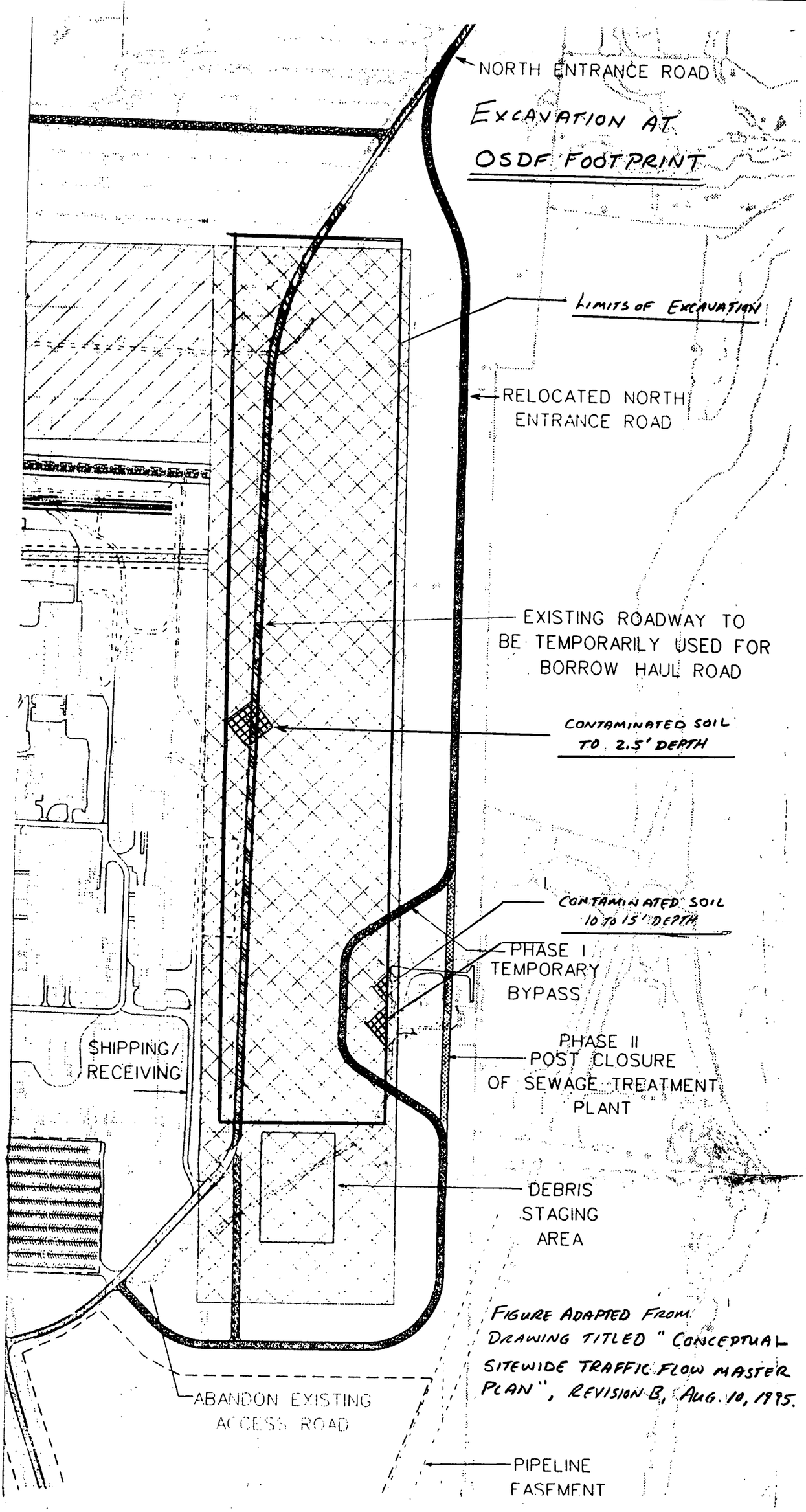


FIGURE ADAPTED FROM DRAWING TITLED "CONCEPTUAL SITEWIDE TRAFFIC FLOW MASTER PLAN", REVISION B, AUG. 10, 1995.

Kara Olsen / Dan Pass
Rm 10 / Ferrold / 623900 / 10/17
Pol Wind: PJS 95 10/18

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DOCUMENT NO.

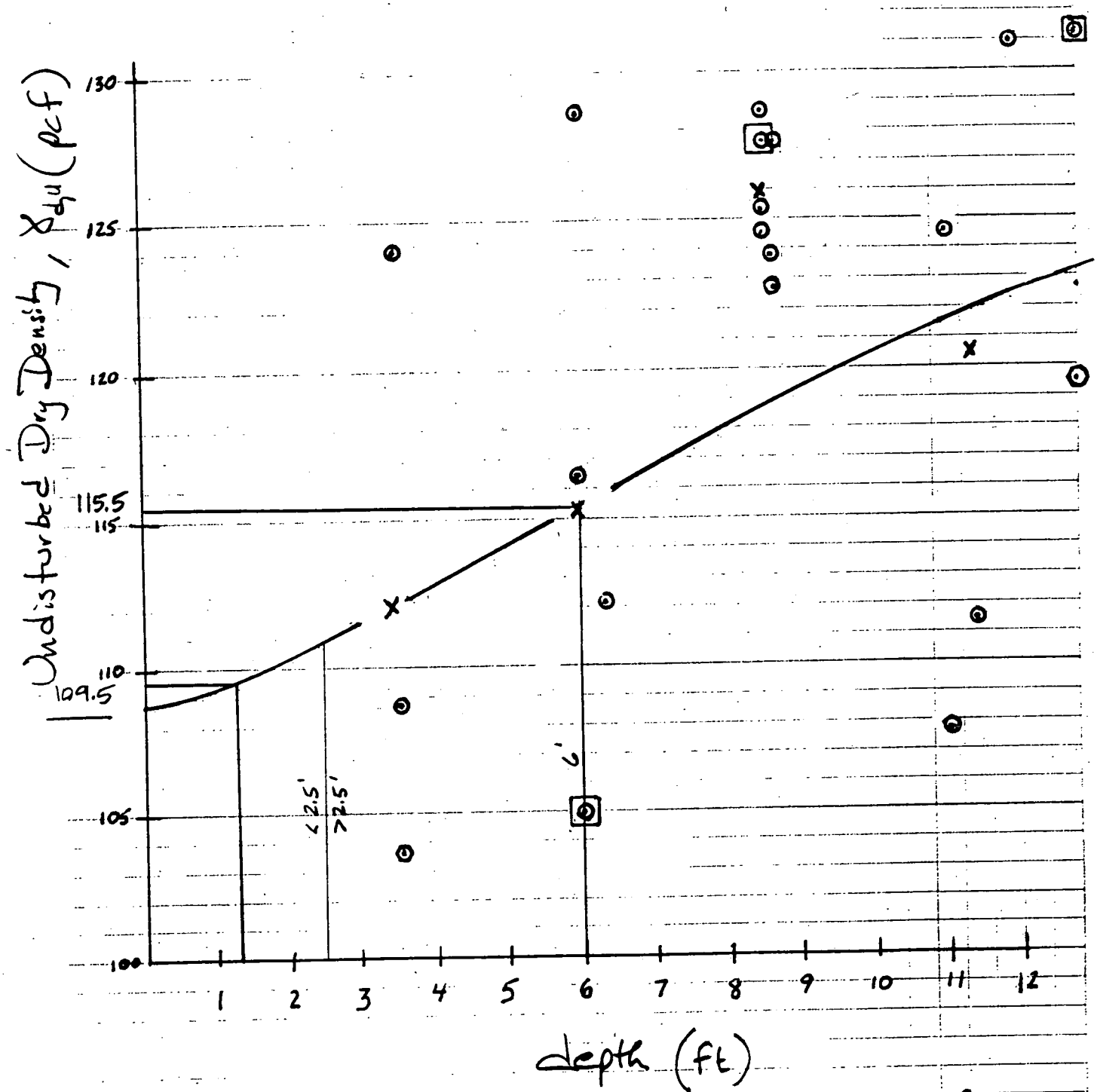
FIGURE 21

001984

450%

Written by: VANDER LINDE Date: 95/10/7 (YY/MM/DD) Reviewed by: PJS Date: 95/10/7 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

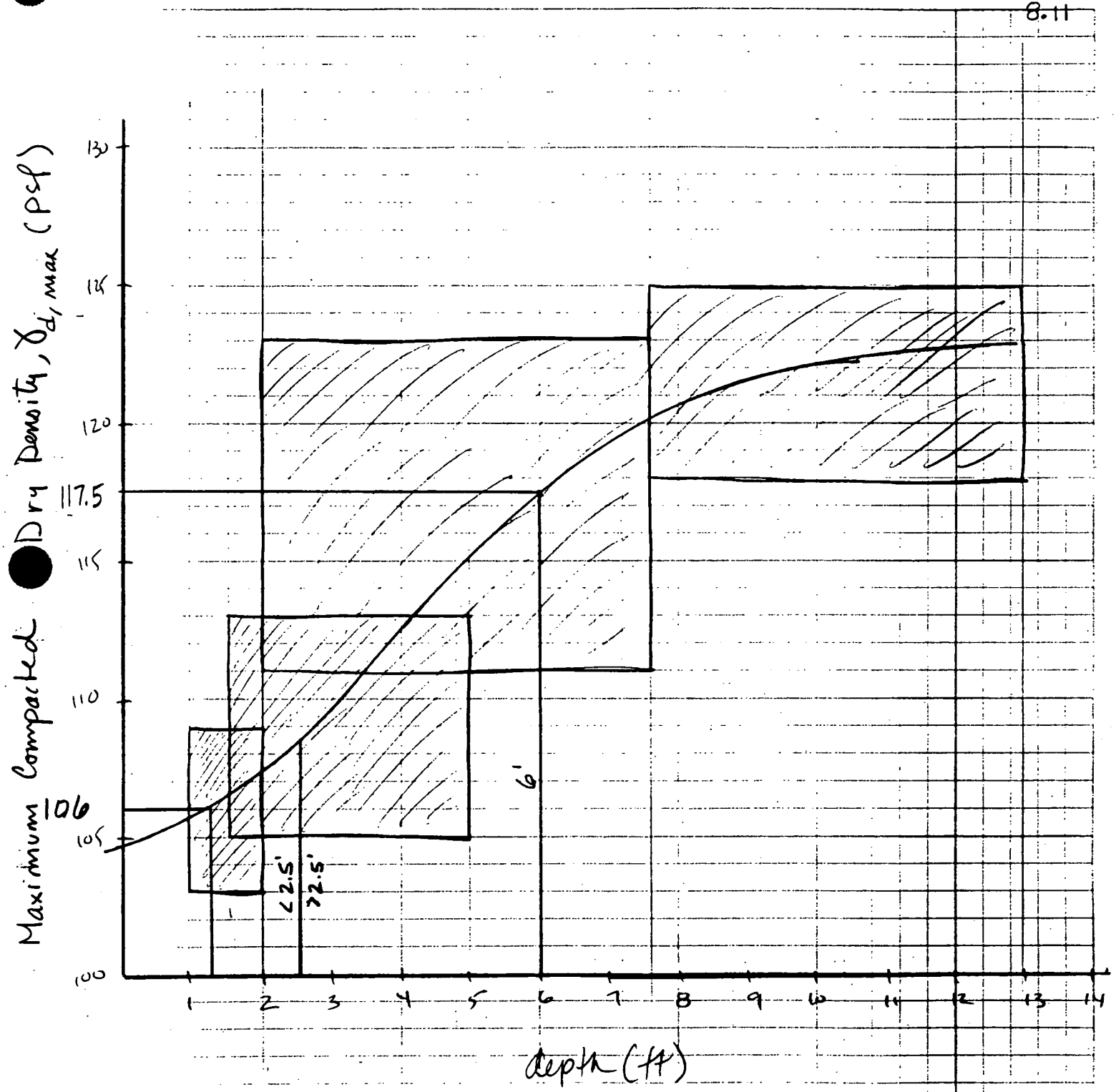


Ref.: Geotechnical Investigation Report, OSDF, Sept 1995, Table G-2

FIGURE 22

Written by: VANDERLINDE Date: 95/10/7 (YY MM DD) Reviewed by: PJS Date: ~~95/10/7~~ 95/10/12 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: ~~8.12~~ 8.11



Ref.: Geotechnical Investigation Report, OSDF, Sept 1995, pg 4-13 to 4-16 and Appendix I

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FIGURE 23

15.4 Borrow Area Capacity Verification

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: BORROW AREA CAPACITY VERIFICATION

Computations By: (Cognizant Engineer)
Signature: DANIEL PASS / BIN LI — Date: 10/17/95
Printed Name and Title: DANIEL PASS, STAFF ENGINEER / BIN LI, Asst. Proj. Engineer

Assumptions and Procedures Checked by: (Checker)
Signature — Date: 10/17/95
Printed Name and Title: DAVID W WARREN, STAFF ENGINEER

Computations Checked by:
Signature — Date: 10/17/95
Printed Name and Title: DAVID W WARREN, STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Daniel G. Pass / L. B. — Date: 10/17/95
Printed Name and Title: DANIEL PASS, STAFF ENGINEER / BIN LI, Asst. Proj. Engineer

Approved by: (PDP)
Signature — Date: 10/17/95
Printed Name and Title: Kara L. Olen, Asst. Project Engineer.

Approved by: (DTL and TETL)
Signature — Date: 20 Oct 95
Printed Name and Title: Kenneth W. Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Draft submittal to FERMCO				
0	30% Submittal	24 Oct 95	NA	NA	NA No changes
B	Preliminary Design - EPA Submittal	15 Dec 95			

Written by: DANIEL PASS Date: 15 Dec 1995 Reviewed by: [illegible] Date: 95-12-15

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 08.12

BORROW AREA CAPACITY VERIFICATION

EXECUTIVE SUMMARY

This calculation package was prepared to verify the volume of borrow material in the East Field Borrow Area as calculated by CADD. The CADD calculated volume is 873,756 cy. The verification is achieved by conducting end area method volume calculations using cross sections shown in Figures 2 to 7. Two volumes are presented.

The first volume is for verification of the CADD generated volume for the current borrow area grading plan. This volume represents the borrow available to construct the following earthwork components for 8 cells.

- Compacted Clay Liner
- Compacted Clay Cap
- Vegetative Soil Layer
- Seasonal Cover
- Structural Fill (for the perimeter access corridor)

The second volume represents an additional volume available in the event that the ninth (contingency) cell is constructed.

Written by: DAN PASS Date: 95 / 10 / 17 (YY MM DD) Reviewed by: DJD Date: 95 / 10 / 17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.12

KW 10/17/9

DATA COLLECTION AND VERIFICATION:

- The grading plan shown in Figure 1 and the cross sections shown in Figure 2 through 7 were obtained from the plan titled "Borrow Area Restoration Plan"

Procedure:

Verification of CADD volume

- Planimeter cross sectional borrow areas shown in Figure 2 through 7.
- Average adjacent areas and multiply this value by the distance between the stations (i. e., 100 ft) to obtain the volume of borrow between cross sections

Calculation of additional volume for a ninth cell:

- Delineate the grading limits showing from which additional volume will be obtained. These limits coincide with a 100 ft right of way.
- Extend current proposed grading to new limits.
- Calculate additional volume using the end area method.

Written by: DAN PASS Date: 95/10/17 (YY MM DD) Reviewed by: [illegible] Date: 95/10/17 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.:

BORROW AREA CAPACITY VERIFICATION CALCULATIONS:

VERIFY CADD VOLUME OF 873,756 CY. WITH END AREA METHOD.

1. A PLAN VIEW OF THE BORROW AREA SHOWING CROSS SECTION LINES IS SHOWN IN FIGURE 1.

2. CROSS-SECTIONS ARE SHOWN IN FIGURES 2 THROUGH 7.

3. A SUMMARY OF END AREA CALCULATION VALUES AND VOLUMES ARE SHOWN IN TABLE 1. TOTAL VOLUME IS 843,276 CY

4. COMPARE CADD AND END AREA VOLUMES

- CADD VOLUME IS 873,756 CY
- END AREA VOLUME IS 843,276 CY

END AREA VOLUME IS WITHIN 4% OF CADD VOLUME

CALCULATE VOLUME FOR POSSIBLE ADDITIONAL BORROW AREA

1. THE GRADING PLAN SHOWN IN FIGURE 1 IS FOR THE CONSTRUCTION OF 8 CELLS. IF AN ADDITIONAL NINETH CELL IS CONSTRUCTED ADDITIONAL BORROW VOLUME WILL BE REQUIRED.

2. OBTAIN ADDITIONAL BORROW VOLUME FROM EITHER SIDE OF THE SOUTH ACCESS RD AS SHOWN IN FIGURE 1. THE CROSS SECTIONS FOR THIS ADDITIONAL VOLUME ARE SHOWN WITH DOTTED LINES IN FIGURES 2 THROUGH 7.

3. THE ADDITIONAL VOLUME WAS CALCULATED USING THE END AREA METHOD. A SUMMARY OF END AREA CALCULATION VALUES AND VOLUMES FOLLOW. THE TOTAL ADDITIONAL VOLUME IS 37,107 CY

DW 95/10/17 4 3/C

Table 1 : Data and Calculated Volumes for Borrow Area Capacity Verification

Cross Section			Dist. Between	Volume	
Station	Area, sf	Avg. area, sf	Stations, ft	cf	cy
50	0				
		2,081	50	104,025	3,853
100	4,161				
		7,319	100	731,850	27,106
200	10,476				
		11,196	100	1,119,550	41,465
300	11,915				
		12,112	100	1,211,150	44,857
400	12,308				
		11,672	100	1,167,150	43,228
500	11,035				
		10,399	100	1,039,850	38,513
600	9,762				
		8,245	100	824,450	30,535
700	6,727				
		7,286	100	728,550	26,983
800	7,844				
		8,556	100	855,550	31,687
800A	9,267				
		10,206	100	1,020,600	37,800
900	11,145				
		11,802	100	1,180,150	43,709
1000	12,458				
		12,258	100	1,225,750	45,398
1100	12,057				
		12,115	100	1,211,450	44,869
1200	12,172				
		12,203	100	1,220,250	45,194
1300	12,233				
		12,623	100	1,262,250	46,750
1400	13,012				
		12,924	100	1,292,400	47,867
1500	12,836				
		13,998	100	1,399,750	51,843
1600	15,159				
		15,903	100	1,590,300	58,900
1700	16,647				
		15,112	100	1,511,200	55,970
1800	13,577				
		11,346	100	1,134,550	42,020
1900	9,114				
		6,729	100	672,850	24,920
2000	4,343				
		2,512	100	251,200	9,304
2100	681				
		341	40	13,620	504
2200	0				
		Total Volume is (cf, cy)		22,768,445	843,276

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FERMCO / OSDF
GE 3900 17 OCTOBER 95
Dan Russ

Written by: BL Date: 95/10/17 (YY/MM/DD) Reviewed by: DW Date: 95/10/17 (YY/MM/DD)

Client: Fernico Project: Fernald OSDF Project/Proposal No.: GE 3900 Task No.:

Volume Calculation

Station	End Area A_L (ft^2)	Volume (ft^3)	Volume (yd^3)
800	432		
		40450	1498.2
800A	377		
		42850	1587.0
900	480		
		47100	1744.4
1000	462		
		44100	1633.3
1100	420		
		39000	1444.4
1200	360		
		36000	1333.3
1300	360		
		39000	1444.4
1400	420		
		45750	1694.4
1500	495		
		45750	1694.4
1600	420		
		44800	1659.3
1700	476		
		44950	1664.8
1800	423		
		42150	1561.1
1900	420		
		29750	1101.9
2000	175		

Total A_L = 20060.9

Station	End Area A_R (ft^2)	Volume (ft^3)	Volume (yd^3)
300	78		
		8900	329.6
400	100		
		8750	324.1
500	75		
		7125	263.9
600	67.5		
		5857	217.6
700	50		
		4750	176.0
800	45		
		10000	370.4
800A	155		
		20250	750.0
900	250		
		30000	1111.1
1000	350		
		42000	1555.6
1100	490		
		50050	1853.7
1200	511		
		46550	1724.1
1300	420		
		39800	1474.1
1400	376		
		39500	1463.0
1500	414		
		37600	1392.6
1600	338		
		34900	1292.6
1700	360		
		35600	1318.5
1800	352		
		38600	1429.6
1900	420		

Total A_R = 17046.5

Total $A_L + A_R$ = 37107.4 yd^3

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Written By: RAA Date: 22 OCT 95 Reviewed by: Date:

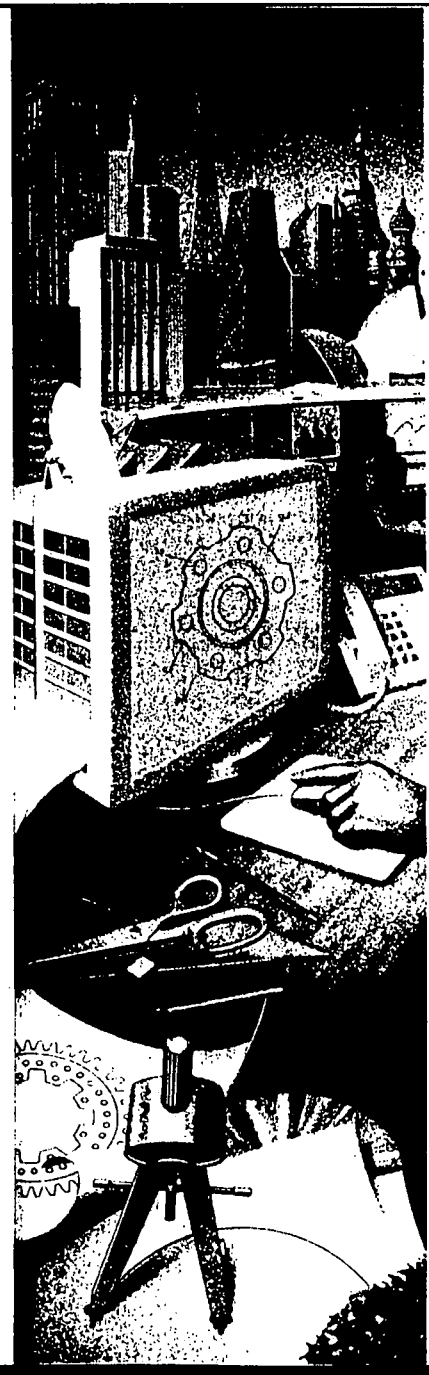
Client: Ferrosco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 11.1

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATIONS PACKAGE

1. Autodesk®, Inc., AutoCAD® Release 13 User's Guide, September 1994.

2. SOFTDESK®, Inc., SOFTDESK® Civil/Survey: Earthworks Reference Manual, Henner, NH, November 1994.



Autodesk.

AutoCAD® Release 13

USER'S GUIDE

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00105-010000-5020 September 15, 1994

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INTRODUCTION

AutoCAD is a full-featured program for computer-aided design (CAD). With the AutoCAD drafting system, you can prepare realistic, accurate two-dimensional drawings and three-dimensional models. The *AutoCAD User's Guide* describes AutoCAD's powerful features and their procedures with a step-by-step graphical approach. This introduction describes how to

- Use AutoCAD documentation
- Find information about AutoCAD
- Learn AutoCAD with the *AutoCAD User's Guide*
- Interpret the conventions in AutoCAD documentation

The *AutoCAD User's Guide* is complemented by several documents in the AutoCAD documentation set. To learn more about the complete set of AutoCAD Release 13 documentation, see the *AutoCAD Documentation Guide*.

Using AutoCAD Documentation

As a novice or experienced user, the best way to learn the details of AutoCAD's features is to use the *AutoCAD User's Guide* in conjunction with the *AutoCAD Command Reference*. After familiarizing yourself with a CAD concept and AutoCAD feature in the *User's Guide*, you can learn more details about a specific command using the *Command Reference*. The *Command Reference* is also available on line from the Help menu. It's a complete electronic version of the *Command Reference* and includes a glossary with more than 300 terms. With Help you can look up a command by name or by its placement on a menu or toolbar. Also, you can access Help with context-sensitive methods:

- For a command, enter **help** while the command is active or press F1 (Windows only)
- For a dialog box, select the dialog box Help button
- For a menu, select the menu name to open the menu, and then press F1 (Windows only).

If you're a novice user, you may want to take the *AutoCAD Quick Tour*, which introduces you to CAD concepts and AutoCAD features. Before starting with the *User's Guide*, you can get hands-on experience with the AutoCAD tutorial, *Learning AutoCAD*. If you're upgrading from an earlier release, you may want to look at *AutoCAD What's New in Release 13*, which is available on line from the Help menu.

Note For the latest changes to AutoCAD information and procedures, refer to the *readme.doc* file.

Using This Guide

The *User's Guide* describes the fundamental concepts and procedures first. Chapters 1 through 3 explain the basics. Beginners should understand these chapters before going further. Chapter 4 describes how to control the drawing display and chapter 5 explains editing methods. Chapters 6 through 10 explain two-dimensional drawing, followed by chapters 11 and 12, which describe the details of creating three-dimensional models. Chapters 13, 14, and 15 explain the specifics of using external databases, importing and exporting different file formats, and file management, respectively.

002007

Appendixes A, B, and C explain customizing toolbars, how to work with Windows applications, and standard libraries of fonts, PostScript patterns, and so on provided with AutoCAD. Appendix D explains compatibility issues you may encounter if you're upgrading from an older version of AutoCAD. The glossary (the printed version of the Help glossary) and index complete the *User's Guide*.

The *User's Guide* explains most AutoCAD features by introducing the drafting concept and feature, followed by procedural steps.

To calculate the area of an object

1 Start the AREA command using one of these methods:

Windows	From the Inquiry flyout on the Object Properties toolbar, choose Area.
DOS and UNIX	From the Assist menu, choose Inquiry. Then choose Area.

2 Enter **o** for Object.

3 Select an object.

command used for the same procedure

Command line equivalent AREA

other ways to do the same task

Alternate You also can use the DDMODIFY command to display an object's area and other information. If you use Windows, from the Object Properties toolbar, choose Properties. If you use DOS or UNIX, from the Modify menu, choose Properties.

information about similar features

Related Use the MASSPROP command to display additional information on solids and regions.

In most cases, the menu and the toolbar access (for Windows) are described in detail. However, as an experienced user, you may prefer to use the command line. The command line equivalent appears after the numbered steps. For detailed information about the command's options, see the *AutoCAD Command Reference*.

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Typographical Conventions

To orient you to AutoCAD features as they appear on the screen, specific terms are set in typefaces that distinguish them from the body text. Throughout AutoCAD documentation, the following conventions are used.

Formatting Conventions

Text element	*Example*
Keys you press on the keyboard The [↵] key is the same as [Enter] and [Return]	[Delete], [Esc]
Keys you press simultaneously on the keyboard	[Ctrl]+[C]
Menu items, prompts, and other text displayed on screen are in sans serif	From the File menu, choose Open. Command: **area** <First point>/Object/Add/Subtract:
Text you enter is in bold sans serif	At the Command prompt, enter **shape**
File names, names of directories, and instructions after prompt sequences are in italic	Select objects: *Use an object selection method* *disc.dwg* *c:\acad\support*
AutoCAD-named objects, such as layers, linetypes, and styles, and AutoCAD commands and system variables are in uppercase	SAVE, COPY, DWGNAME, BLIPMODE DISC-FRONT, DASHDOT, STANDARD
AutoLISP and C variables, sample code, and text in ASCII files are in monospaced font	`***POP1` The variable `pi` is preset to a value of pi
AutoLISP, ADS, and DIESEL function names are in bold monospaced font	**`command ads_command( )`**
Formal arguments specified in function definitions are in italic monospaced font	The *`string`* and *`mode`* arguments

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1

GETTING STARTED

This chapter lays the groundwork for learning and using AutoCAD. It provides basic, crucial information about the graphical and command interfaces. It explains how to set up the drawing environment and work effectively in that environment. Among other topics, this chapter covers

- Starting AutoCAD
- Getting help
- Using AutoCAD commands
- Specifying points in a coordinate system
- Setting up a new drawing
- Refreshing the screen display
- Moving around a drawing
- Working with named objects

For more details on AutoCAD features new to this release, see the on-line *AutoCAD What's New in Release 13*. To practice using commands together in exercises, see the on-line or printed tutorial, *Learning AutoCAD*.

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Softdesk® Civil/Survey

Earthworks Reference Manual

Softdesk, Inc.
7 Liberty Hill Road
Henniker, NH 03242 USA

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002009

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Chapter 1

Introduction

The Softdesk *Earthworks* module is a complete package for Civil Engineers and Surveyors. Softdesk *Earthworks* calculates cut and fill quantities for sites, roadways, and other applications. It can calculate total site volumes or localized subsite volumes as well as producing a proposed site surface using grading commands. The *Earthworks* module operates within the AutoCAD drawing editor.

How this Guide is Organized

As a reference text, this guide provides detailed explanations of the unique Softdesk *Earthworks* commands. Information on installation, system basics, Setup commands, and customization can be found in the respective chapters of the *Softdesk COGO Reference Manual*. Information on project management can be found in the respective chapter of the *Softdesk DTM Reference Manual*.

This reference manual is divided into the following sections.

- Chapter 1, *Introduction*, provides a summary of the topics covered in this guide. It also describes the conventions used in this guide.
- Chapter 2, *Earthworks Settings*, describes the settings used to manage the *Earthworks* project.
- Chapter 3, *Grading*, describes commands that produce the finished surface of a site.
- Chapter 4, *Volumes*, describes commands that define the total site for volume calculations and compute the volume between two surfaces.
- Chapter 5, *Earthwork Tools*, describes commands that manipulate *DTM* and *Earthworks* entities by their layers, and commands that set, import, and list information about Earthworks points.
- Appendix A, *Glossary*, defines common *DTM* and *Earthwork* terms.

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- Appendix B, *Revision History*, describes the changes made from the previous release of *Earthworks*.
- Appendix C, *File Listing*, contains a description of the files created by *Earthworks*.

For Unix and DOS installation and set up procedures for this module, see the *Softdesk Core Reference Manual.*

Requirements and Recommendations

This version of Earthworks operates on any true 386 or 486 compatible computer. The minimum hardware requirements for the software are as follows:

- 8MB of Ram, with 1MB of this memory containing 640K of conventional memory for AutoCAD Release 12 and 16MB of Ram with 1MB of this containing 640K of conventional memory for AutoCAD Release 13
- A floppy drive with a 3-1/2" high density drive. 5 1/4" high density drives are supported by special request only.
- The MAXV switch set to the amount of memory used by Softdesk and AutoCAD programs and data if using expanded memory.
- A 387 math coprocessor (486 computers have a built-in 387 coprocessor) is recommended, but not required.

The minimum software requirements for the software are as follows:

- DOS 5.0 or higher
- AutoCAD Release 12 or 13
- Softdesk *Core* Version 7.0
- Softdesk *COGO* Version 7.0
- Softdesk *DTM* Version 7.0

Conventions Used in this Guide

This section describes the format of the notations used in the Softdesk reference manuals. It is important to realize the distinctions between these conventions; to both expedite and ensure your comprehension of the material.

We have adopted some conventions that make descriptions more consistent and easier to understand.

Typographical Conventions

Throughout the manual we use different formatting to express different information. This section describes the typographical conventions used in this manual.

Formatting	Description
italic	Italicized text is used for filenames, file extensions, directory paths, manuals and module names. It is also used to represent variable data (data that may change from one instance to another).
`prompt text`	Text in this monospaced typeface represents text displayed on the computer screen, including prompts and the contents of ASCII text files.
bold	Bold text represents an action that you must make.
<Enter>	Text in angle brackets represents a key or keys on the computer keyboard.
{variable}	Italic text in curly brackets represents a variable value. The value displayed on your monitor may vary from one instance to another.
ZOOM	AutoCAD command names and system variable names are shown in all capital letters.
[Command]	Softdesk command names are shown with brackets.

In addition, the following formatting conventions are used to highlight important information:

Note: This denotes important information that you should keep in mind.

! This denotes a situation that may cause an error or a loss of data.

Menu Formats

Each menu reference in the manual contains the following information.

A menu location, or directory, is given to assist in locating the menu. This is given on the introductory menu page and is shown in the following form:

[Grading] → [Settings]

- Commands on the menu are described in the order in which they appear on the menu in the sections immediately following the menu path.

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Command Reference Formats

Each command contains a description of the command, including tips on how to most effectively use a command. The command description often describes techniques to make a command easier to use, and may include prerequisites.

The complete prompt sequence is given with brief explanations where required. Any dialogue boxes accompanying the command are displayed and explained as well.

Installation

For information about installing the software, refer to the *Softdesk Core Reference Manual.*

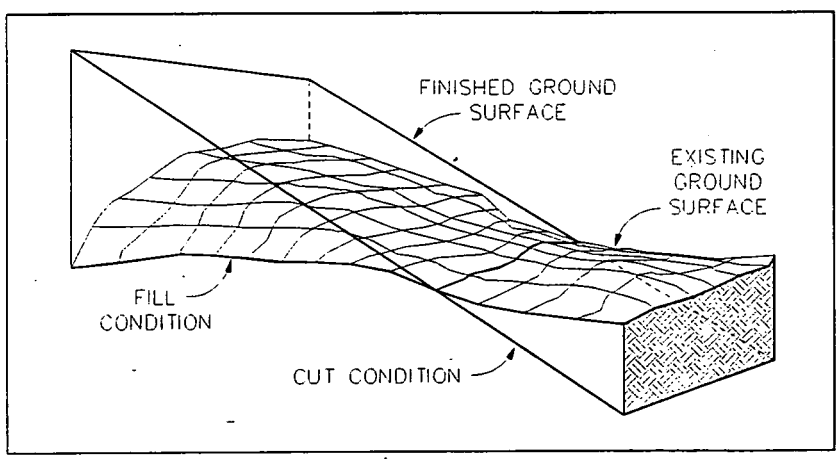
Changes From Previous Releases

The following sections contain information for previous users of the *Earthworks* module. For more information, see the Revision History appendix.

Defining Strata

One feature of *Earthworks* is the ability to define surface combinations and the associated volumetric differences as strata. Most commonly, a pairing of existing and finished ground surfaces and the resulting cut and/or fill, taken as a whole, may be referred to as a stratum.

The following illustration shows an example of a surface and a stratum.



Surface and Stratum

Multiple strata may also be defined with various types of combinations. For instance, an existing ground surface may be established, then one or more finished ground surfaces to compare with

that existing ground surface may be created. Surface pairings may then be defined as individual strata using the single existing ground surface and each of the multiple finished ground surfaces.

When calculating volumes, you will be prompted for the stratum to be used for those computations. Note that a TIN must have been created for each surface in the indicated stratum prior to executing any volumes calculations.

Average End Area Command Location

The [Average End Area] command of previous versions of *Earthworks* is now a type of calculation used to generate volumes. The explanation of the radio button that controls the type of section calculation can be found in the Volumes chapter.

Figure 1

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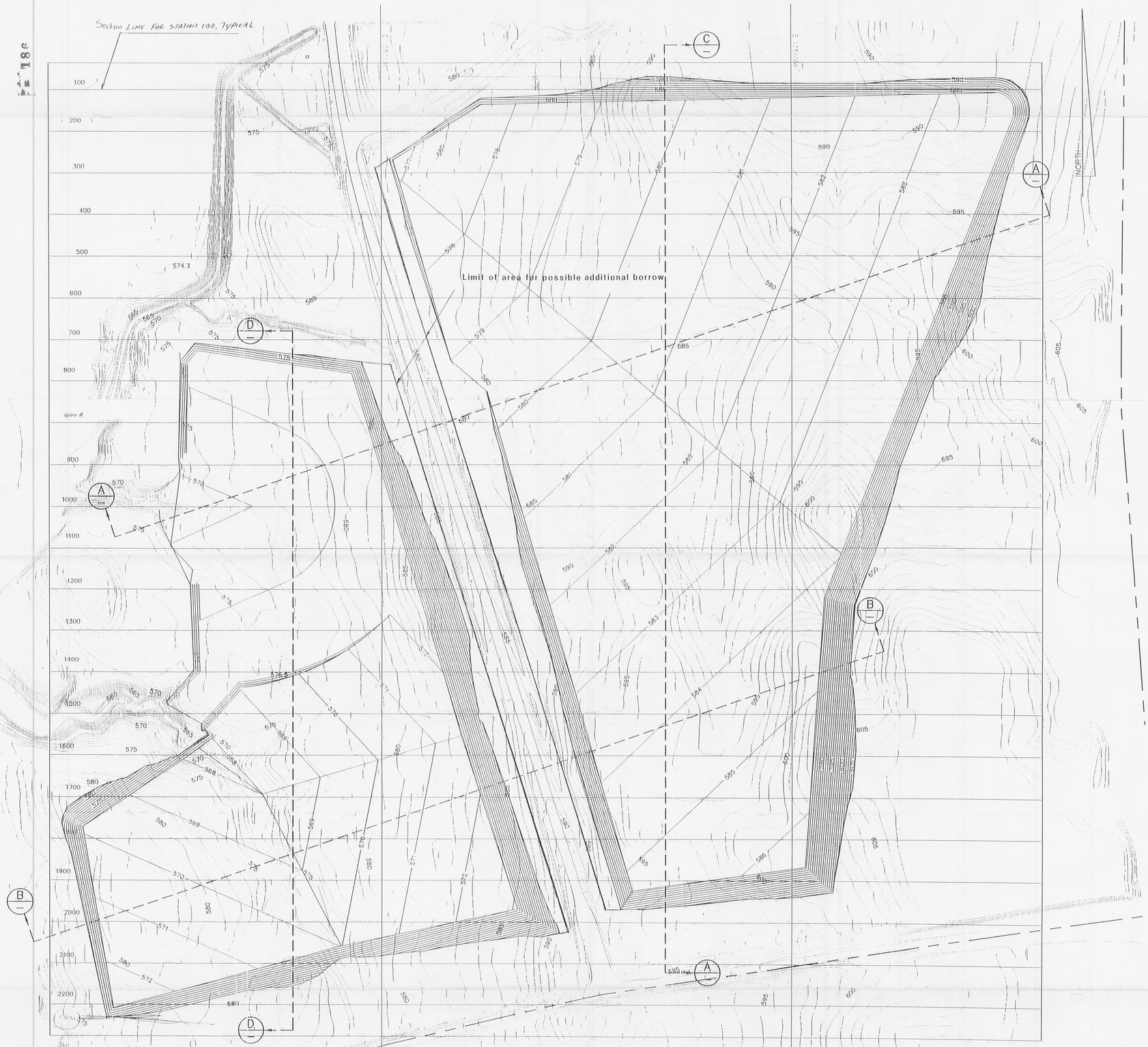

Subsite Volume Table: Unadjusted

Subsite	Stratum	Surf1	Surf2	Cut cubic yards	Fill cubic yards	Net cubic yards
EBRW						
	brw	exbrw	brw	569099.42	15.55	569083.86 (C)
WBRW						
	brw	exbrw	brw	304828.43	156.53	304671.89 (C)

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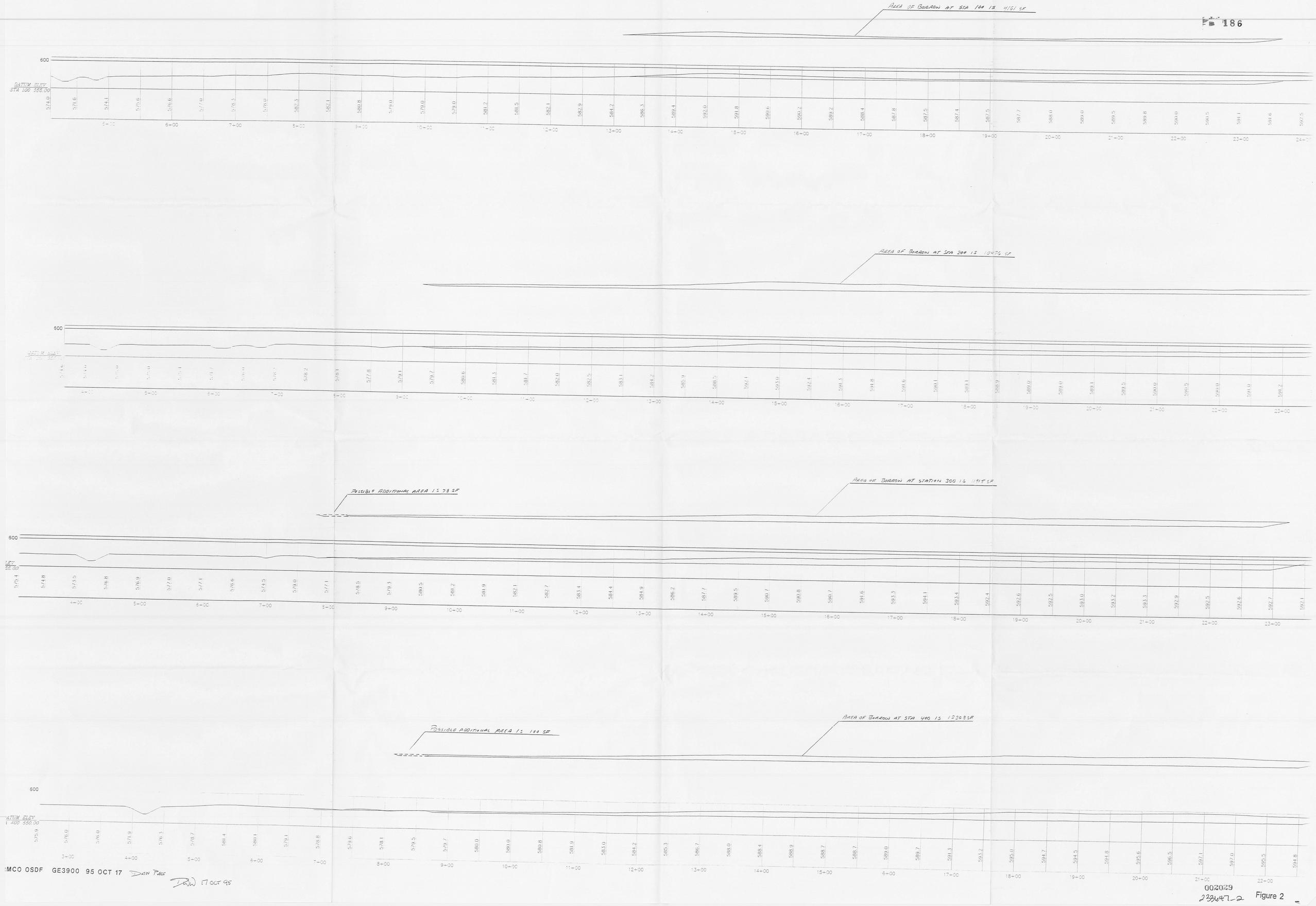

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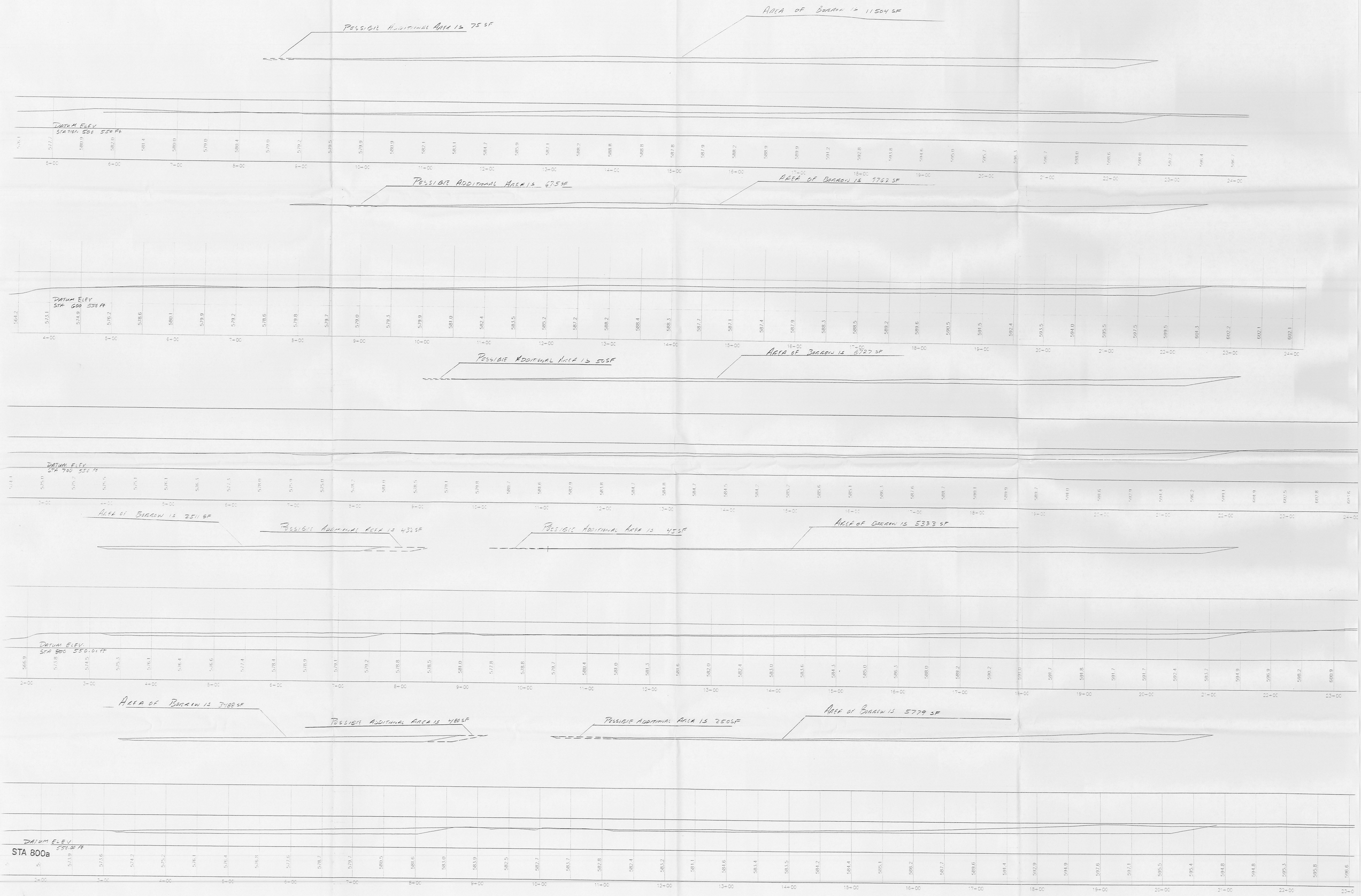
Figure 2



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233447_3 Figure 3

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Figure 4

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Figure 5

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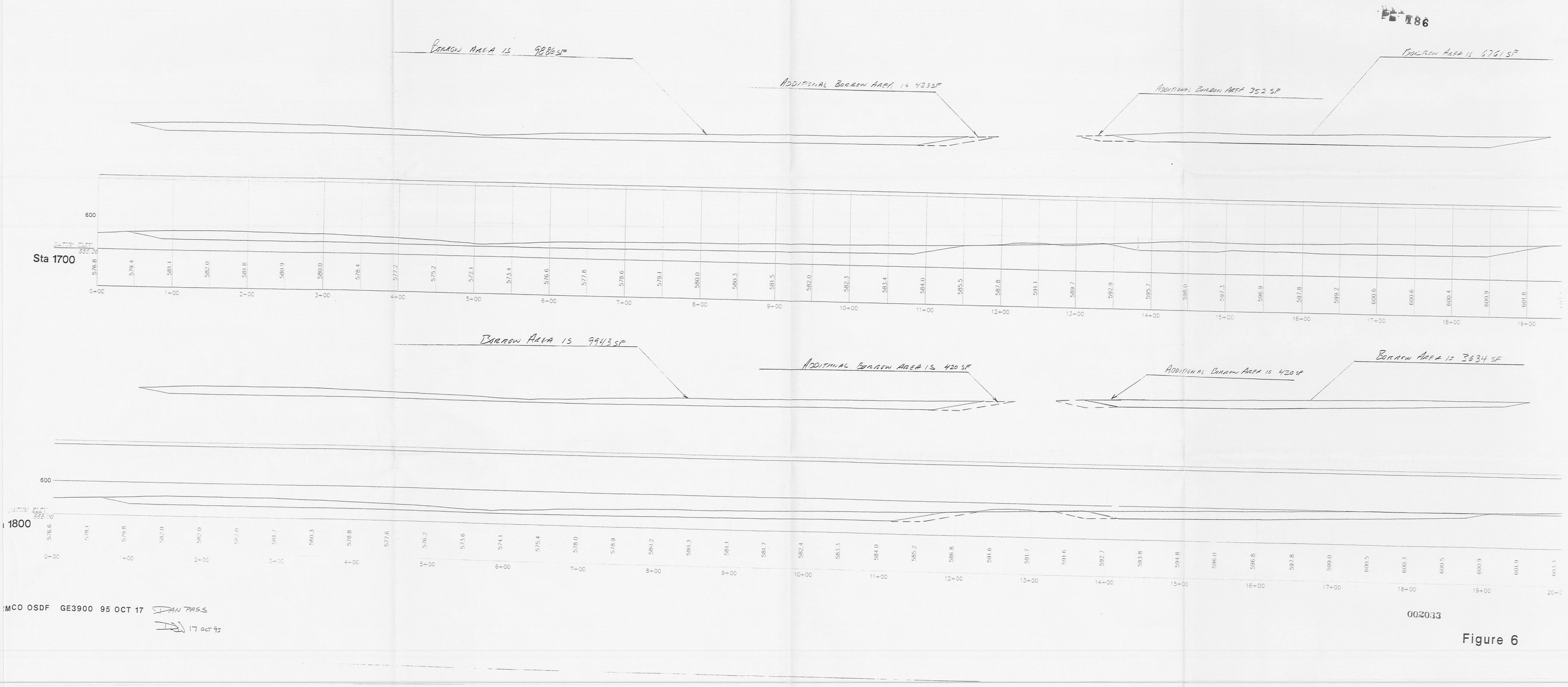

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Figure 6

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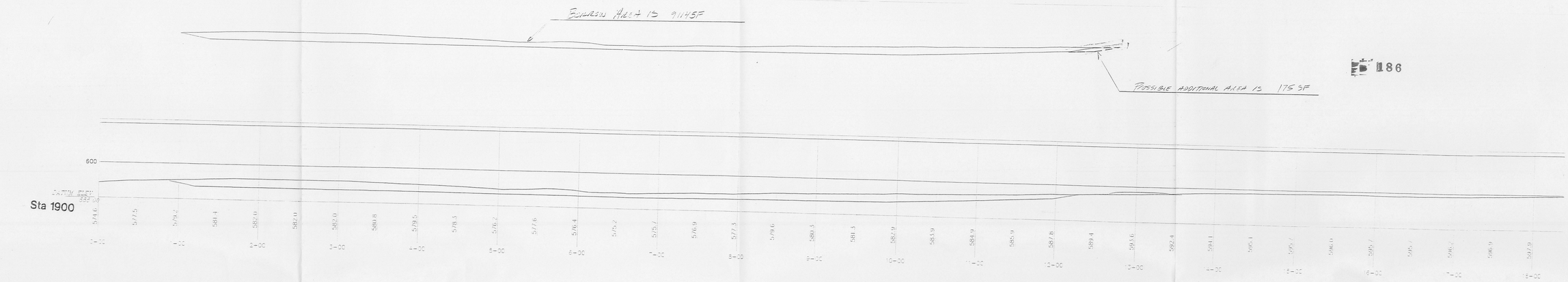

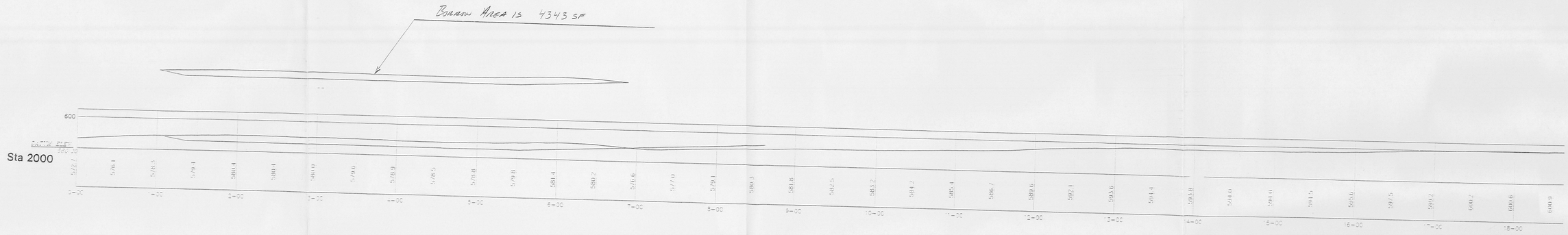

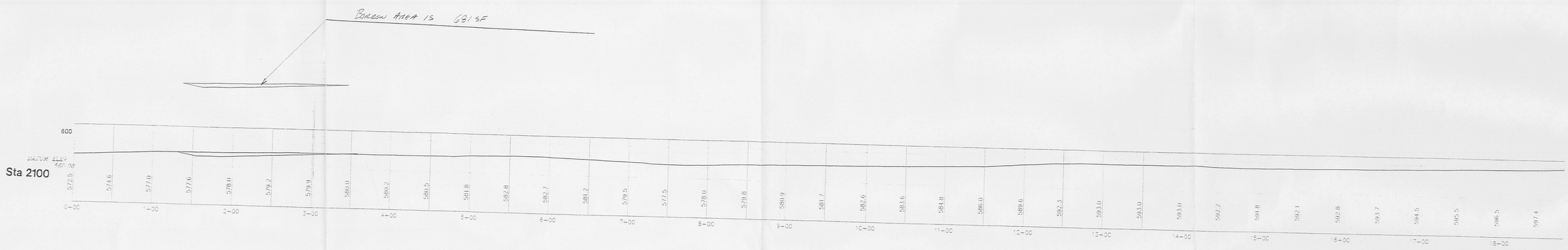

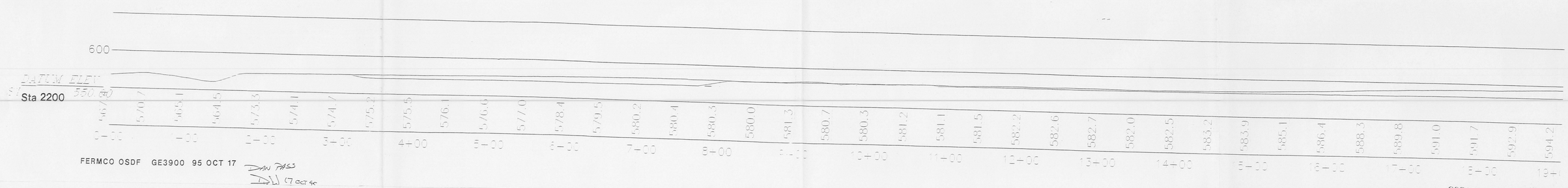

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Figure 7

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