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FINAL DESIGN
CALCULATION PACKAGE
ON-SITE DISPOSAL FACILITY

REVISION 0
VOLUME IV OF IV
MAY 1997

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

Fluor Daniel Fernald
Subcontract 95PS005028

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No. 02

740

FINAL DESIGN CALCULATION PACKAGE ON-SITE DISPOSAL FACILITY

Volume IV

May 1997
Revision 0

United States Department of Energy

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FINAL DESIGN PACKAGE
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On-Site Disposal Facility
Fernald Environmental Management Project

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COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: DRAINAGE CONTROL STRUCTURE EROSION RESISTANCE

Computations By: (Cognizant Engineer)
Signature [signature] Date 22 Feb 96
Printed Name and Title DAVID W W ARREN, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 23 Feb 96
Printed Name and Title Kenneth W Cargill, Associate

Computations Checked by:
Signature Daniel B. Wisialowski Date 23 FEB 96
Checked by:
Printed Name and Title DANIEL B. WISIALOWSKI, ASSISTANT PROJECT ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 23 Feb 96
Printed Name and Title DAVID W. WARREN, STAFF ENGINEER

Approved by: (PDP)
Signature [signature] Date 23 Feb 96
Printed Name and Title Kara L. Olen, Asst. Proj. Eng.

Approved by: (DTL and TETL)
Signature [signature] Date 23 Feb 96
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design	—	—	—	—
D	Intermediate Design - EPA Submittal	4 Apr 96	[initials]	—	—
G	Final Design Package	4 Oct 96	—	—	[initials]
C	Response to Final Design Cmts	5 May 97	—	—	[initials]

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Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

KC 23 Feb 96

DRAINAGE CONTROL STRUCTURE EROSION RESISTANCE

EXECUTIVE SUMMARY

Purpose

Determine if the planned grass and riprap linings in the OSDF north and east drainage channels (2000-year channels) will provide adequate resistance to erosion during the design storm.

Contents

- Executive Summary
- Calculation Procedure
- Collection and Verification of Data
- Calculations and Results

Findings

The Temple Method was used to evaluate the erosion resistance of the grass-lined portions of the OSDF north and east drainage channels for the 2000-year storm. Erosion resistance includes resistance to all forms of water erosion from channel flow, including formation of erosion gullies and scour. The calculation results indicate that strong and healthy proposed native-grass channel lining (SCS vegetal retardance class B) should survive the 2000-year storm without significant erosion.

The Safety Factors Method was used to evaluate the erosion resistance of the riprap-lined portions of the OSDF north and east drainage channels for the 2000-year storm. The calculation results indicate that the proposed riprap lining (mean diameter of 12 inches) should survive the 2000-year storm without significant erosion.

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Written by: _____ Date: ___/___/___ Reviewe

Client: FERMCO Project: OSDF

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EROSION RESISTANCE - OSDF NORTH AND EAST DRAINAGE CHANNELS

CALCULATION PROCEDURE

1. Evaluate resistance of the planned native-grass channel lining to erosion in the 2000-year storm using the Temple Method [Temple et al., 1987]

2. Evaluate resistance of the planned riprap channel lining to erosion in the 2000-year storm using the Safety Factors Method [NRC, 1990]

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DRAINAGE CONTROL STRUCTURE EROSION RESISTANCE

COLLECTION AND VERIFICATION OF DATA

1. **Design Flow and Channel Geometry**
2. **Temple Method**
3. **Safety Factors Method**

1. DESIGN FLOW AND CHANNEL GEOMETRY

Design flow parameters are taken from the OSDF calculations for stormwater runon/runoff and drainage control structures - northern area and eastern area [GeoSyntec, 1996a, 1996b], and are shown in Table 1. Flow parameters were calculated at several points, these points are shown in Figure 1. Note that the channel slope at all these points is 0.5 percent.

Channel cross-sections are shown in Figure 2. For the east drainage channel, the flow information given in Table 1 corresponds to idealized cross-sections, which are shown in Table 2.

The design flow per unit width is estimated by the following:

North Channel: see calculations
East Channel: Flow per unit width ~ total flow divided by the channel base width

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Table 1 - Peak Flows in East Drainage Channel for 2000-Year Storm. From GeoSyntec [1996a, 1996b]

	Point in Channel	Peak Flow Rate (cfs)	Peak Flow Depth (ft)	Peak Flow Velocity (fps)
East Channel:				
Light Cover	A	179.5	0.9	3.1
Moderate Cover		155.5	0.8	2.9
Heavy Cover		142.9	1.5	1.3
Light Cover	B	278.5	1.1	3.6
Moderate Cover		233.3	1.0	3.4
Heavy Cover		215.0	1.9	1.5
Light Cover	C	361.4	1.2	3.8
Moderate Cover		303.1	1.1	3.6
Heavy Cover		269.2	2.1	1.6
Light Cover	D	462.7	1.4	4.2
Moderate Cover		389.7	1.3	4.0
Heavy Cover		355.0	2.45	1.7
Light Cover	E	755.8	1.9	5.1
Moderate Cover		650.8	1.75	4.8
Heavy Cover		555.0	3.2	2.1
North Channel:				
Light Cover	F	68.3	1.8	3.3
Moderate Cover		63.5	1.8	3.2
Heavy Cover		63.5	2.7	1.3
Light Cover	G	397.8	3.5	5.2
Moderate Cover		351.8	3.3	5.0
Heavy Cover		336.2	5.3	2.0

From Calculation Package "Stormwater Runon/Runoff and Drainage Control Structures" Section B Vol. 4 of 4.

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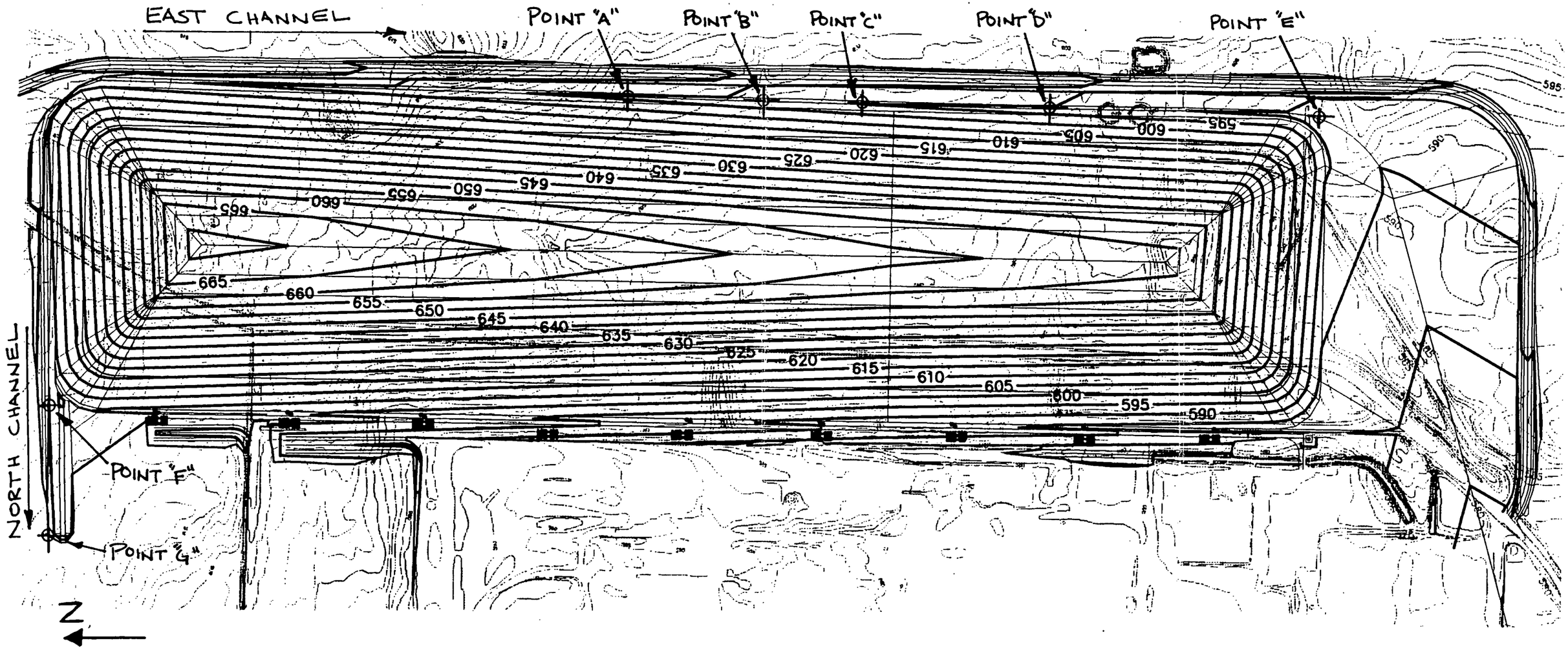

Figure 1 - OSDF Final Cover Grading Plan, Showing Points in the North and East Drainage Channels at Which Flow Parameters Were Evalulated. Modified from GeoSyntec [1996c]

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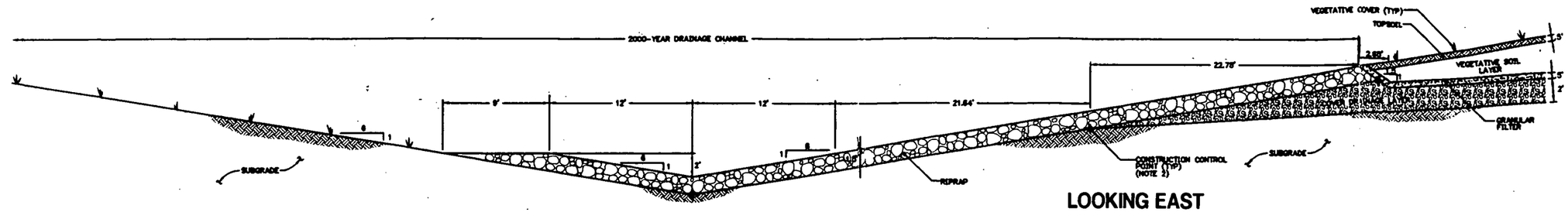
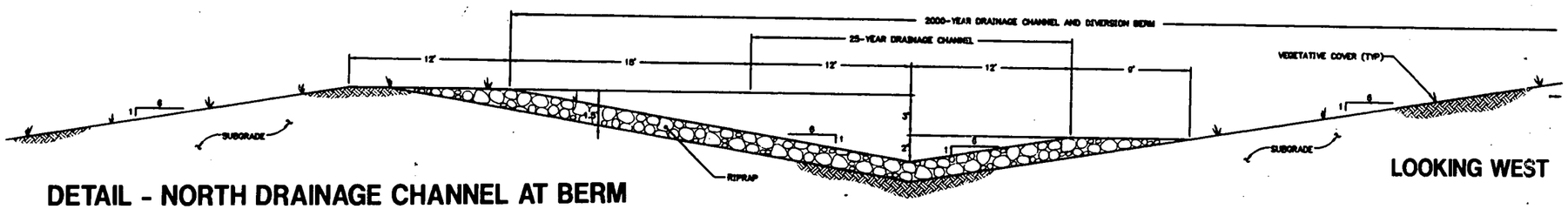


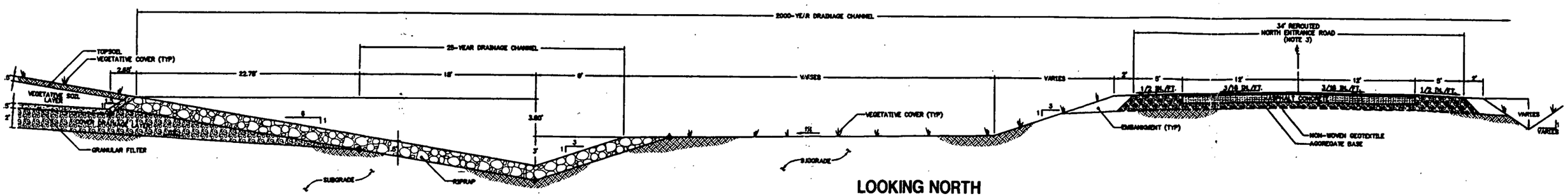
LOOKING EAST

DETAIL - NORTH DRAINAGE CHANNEL AT OSDF



LOOKING WEST

DETAIL - NORTH DRAINAGE CHANNEL AT BERM



LOOKING NORTH

DETAIL - EAST DRAINAGE CHANNEL

Figure 2 - Drainage Channel Details. Modified from GeoSyntec [1996c]

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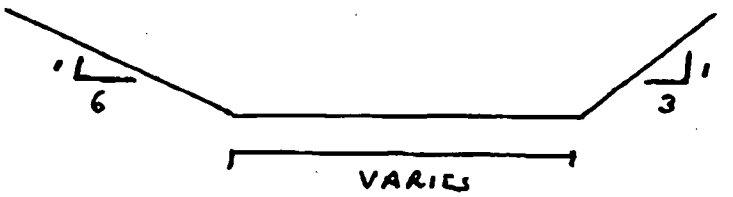
Table 2 - Idealized East Drainage Channel Geometry Used in Channel Sizing Calculations. From GeoSyntec [1996b]



POINT	WIDTH	X-C AREA	P_w
A	60 Ft	312	97
B	65 Ft	332	102
C	69 Ft	348	106
D	69 Ft	↓	↓
E	69 Ft		

2. TEMPLE METHOD

The Temple Method (more formally the Temple/USDA Method) is used to evaluate the erosion resistance of the grass-lined portions of the OSDF north and east drainage channels.

2.1 Allowable Shear Stress For Bare Soil (τ_a)

τ_a is calculated from the following equation [Temple et al., 1987]:

$$\tau_a = \tau_{ab} C_e^2 \geq 0.02 \text{ lb/ft}^2$$

Where: τ_{ab} = basic allowable shear stress (Section 2.1.1)
C_e = void ratio correction factor (Section 2.1.2)

2.1.1 Basic allowable shear stress, τ_{ab}

On-site soils are planned as the source of topsoil. Table 3 shows several index properties for on-site soils. From Table 3, most on-site soils classify as USCS Lean Clay (CL) and Sandy Lean Clay (CL). USCS CL corresponds to USDA *clay loam*, see line 11 in Table 4. Assuming a plasticity index (PI) ≤ 10 which is conservative (Table 3):

τ_{ab} = 0.03 psf ✓ (Figure 3, for CL)

2.1.2 Void ratio correction factor, C_e

Void ratio of the topsoil is estimated from porosity.

From Table 4, the porosity of clay loam or CL is: n = 0.464 ✓

Void ratio (e) is: e = n / (1-n) = 0.464 / (1-0.464) = 0.866 ✓

From Figure 4, void ratio correction factor is: C_e = 0.99 (for CL) ✓

2.2 Manning's Roughness Coefficient for Bare Soil (n_s)

For fine-grained soils, n_s = 0.0156 [Temple et al., 1987]

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Table 3 - Index Properties of Soils in the OSDF Area and North Borrow Area. Modified from Parsons [1995]

General Stratum	USCS Group Symbol	Dry Density (pcf)	Liquid Limit	Plasticity Index	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Specific Gravity (avg)
Brown Till (0-5 ft)	CL	95-125	21-50	7-32	0-12	1-43	35-63	18-48	2.72
Brown Till (5-10 ft)	CL	91-130	22-49	7-28	0-23	1-33	30-64	21-59	2.75
Brown Till (10-15 ft)	CL	107-131	19-43	4-23	0-25	1-41	2-65	18-58	2.78
Gray Till	CL	113-139	19-33	5-17	0-31	1-39	28-79	18-38	2.74
Brown or Gray Till	CL-ML	113-130	17-23	4-7	0-16	15-42	36-55	18-30	2.78
Brown Till	CH	102-105	50-57	23-38	0-2	3-14	38-61	34-48	2.70
Brown or Gray Till	GC	114-135	28	13	26	25	27	22	2.73
Gray Till	GM				40	38	17	5	2.80
Brown or Gray Till	ML	100-135	16-23	0-4	0-7	3-38	41-84	10-18	2.75
Brown or Gray Till	SM	113	NP-13	NP-1	0-15	43-71	13-42	4-20	2.73
Brown or Gray Till	SC	131	19-25	8-12	18-26	29-55	13-27	8-18	2.72
Brown or Gray Till	SC-SM	98-135	18-24	5-8	0-25	37-56	26-35	12-18	2.74
Brown Till	GC-GM	85-124	24	7	43	22	23	12	2.79
Great Miami Aquifer	SM				0-32	53-84	10-36	1-5	2.75
Great Miami Aquifer	SW-SM				16-37	54-76	4-10	1-3	2.74
Great Miami Aquifer	SP-SM				0-35	57-91	4-10	0-3	2.73

Notes: 1. Percent clay defined as those particles finer than 0.005mm (Reference ASTM D 422)
2. Density shown is for in-situ soils
3. NP is non-plastic

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Table 4 - Typical Porosities and USCS Classifications for Different USDA Soil 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/cy 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	1.0×10^{-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	3.3×10^{-1}

* Moderately Compacted

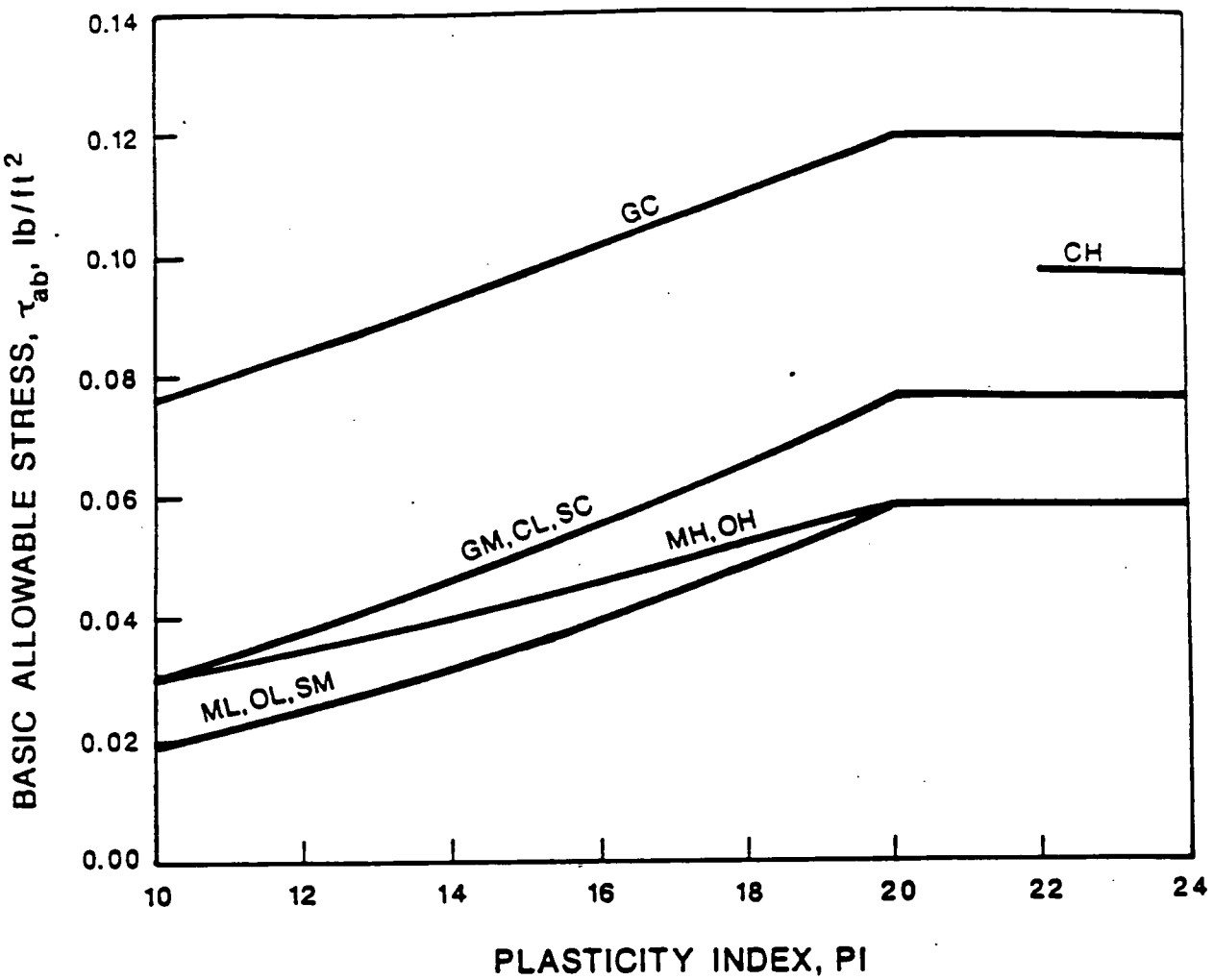

Figure 3 - Graph for Estimating τ_{ab}. From Temple et al. [1987]

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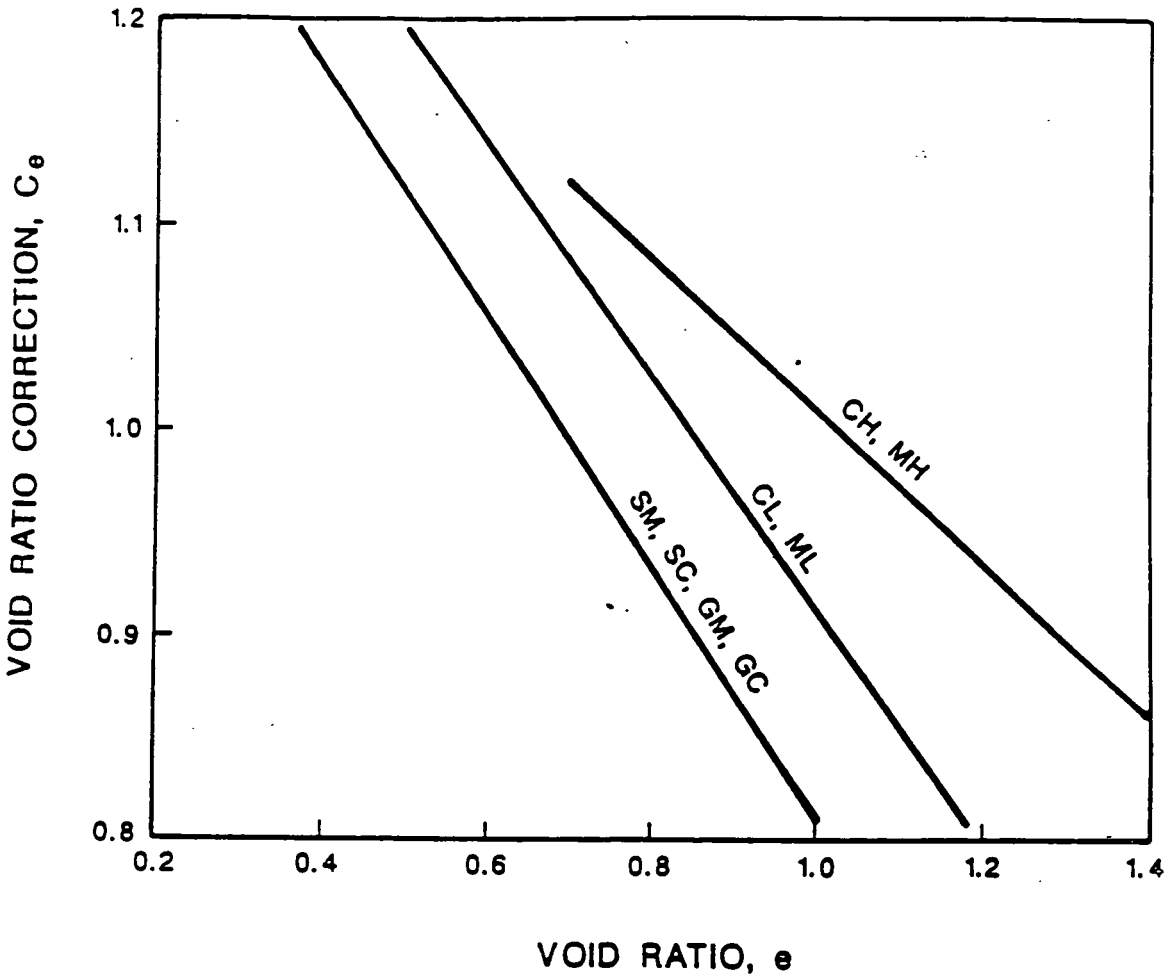

Figure 4 - Graph for Estimating C_e. From Temple et al. [1987]

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2.3 Vegetal Parameters (C_I and C_F)

The Retardance Curve Index, C_I, can be calculated with the following equation [Temple, 1987]:

$$C_I = 2.5(h\sqrt{M})^{1/3}$$

Where: h = representative stem length
M = stems per area

C_I can also be taken from Table 5 for good uniform stands of grass. Values for the Vegetal Cover Factor (C_F) for good uniform stands of grass also appear in Table 5. Values of C_I and C_F for good uniform stands of grass in each SCS vegetal retardance class are inferred from Table 5.

For uniform stands of grass other than "good" quality, C_F is changed following the guidance in Table 5, and C_I is changed by adjusting the stem density per the guidance in Table 5 and figuring the corresponding change in C_I from the equation above. For example, if the stem density changes by a factor of 2/3, C_I changes by a factor of $[(2/3)^{1/2}]^{1/3}$.

Preliminary recommended grasses for the OSDF final cover are shown in Table 6. According to Freshley [1996], SCS vegetal retardance class B should be attainable with native grasses on the OSDF final cover. Nevertheless, all vegetal retardance classes are analyzed to estimate the effect of less strong vegetation on erosion resistance.

2.4 Allowable Vegetal Stress (τ_{va})

$\tau_{va} = 0.75C_I$ [Temple et al., 1987]

2.5 Allowable Flow Per Unit Width (q) - Stability Controlled by Allowable Soil Stress

q is calculated from the following equations [Temple et al., 1987]:

$$q = \exp\frac{-b-\sqrt{b^2-4ac}}{2a}$$

$$a = 0.0133C_I$$

$$b = -0.0954C_I - 0.429$$

$$c = 0.297C_I - 0.5\ln(S) + 0.714\ln\left(\frac{\tau_a}{(1-C_F)n_s^2}\right) - 6.94$$

Where: S = slope (ft/ft)

The limits of q can be described as:
~~for~~ $0.0025\ C_I \le q \le 36$ cfs/ft

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Table 5 - Values of C_I and C_F for Good Uniform Stands of Grass. Modified from USDOE [1989]

SCS RETARDANCE CLASS	Cover	C_f	C_I[a]	Reference stem density (stems/square foot)[b]
A	Burmuda grass, 12-inch height	0.9	10.00	500
	Weeping lovegrass			500
B	Buffalo grass			400
	Kentucky bluegrass	0.87	7.64	350
	Blue gramma			350
C	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
D	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
E	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.

Ref. Temple et al., 1987.

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Table 6 - Prelimininary Recommended Grass Seed Mixes for Planting on the OSDF Final Cover. From Earth Systems Associates [1996]

Slope - Moisture Class	Species/Planting Period Class			
	Native Species / Apr. - May[1]		Pasture Species / Mar. 15 - May or Aug. - Sep.	
	Species[2]	lb/ac	Species	lb/ac
Wet Swales - Waterways	Big Bluestem Switchgrass	10 5	Reed Canary Grass Kentucky Bluegrass[3] Alsike Clover	8 10 5
Moist Slopes of 1% - 9%	Big Bluestem Indian grass Canada Wild Rye Switchgrass	5 5 1 3	Creeping Red Fescue Annual Ryegrass Kentucky Bluegrass[3] Alsike Clover	20 10 15 5
Dry Slopes of 10% - 17%	Big Bluestem Indian grass Canada Wild Rye Switchgrass	5 5 3 5	Creeping Red Fescue Annual Ryegrass Kentucky Bluegrass[3] Flat pea	20 10 10 5

[1]- Switchgrass should be frost seeded (Jan. - Feb.) by broadcasting into wintercover.
[2] - Species other than switchgrass planted by drilling during April - May.
[3] - Substitute Red Top on strongly acid sites.

2.6 Allowable Flow Per Unit Width (q) - Stability Controlled by Allowable Vegetal Stress

q is calculated from the following equations [Temple et al., 1987]:

$$q = \exp\frac{-b-\sqrt{b^2-4ac}}{2a}$$

$$a = 0.0133C_I$$

$$b = 1 - 0.0954C_I$$

$$c = 0.297C_I + 1.17\ln(S) - 1.67\ln(\tau_{va}) + 2.33$$

The limits of q can be described as:
~~for~~ $0.0025\ C_I \le q \le 36$ cfs/ft

2.7 Manning Roughness Coefficient (n)

Manning's n is calculated from the equation shown below [Temple et al., 1987], which was developed as a curve-fitting equation to the SCS vegetal retardance curves, shown in Figure 5. Manning's n is just used for information.

$$n = e^{0.01329C_I(\ln q)^2 - 0.09543C_I(\ln q) + 0.2971C_I - 4.16} \quad \text{for } 0.0025C_I \le q \le 36 \text{ cfs/ft}$$

Manning's n is calculated for the allowable flow, so q in the above equation is q calculated in Section 2.5 or 2.6. If $q < 0.0025C_I$, replace q with $0.0025C_I$ in the above equation. $q \le 36$ cfs/ft in all cases considered in these calculations.

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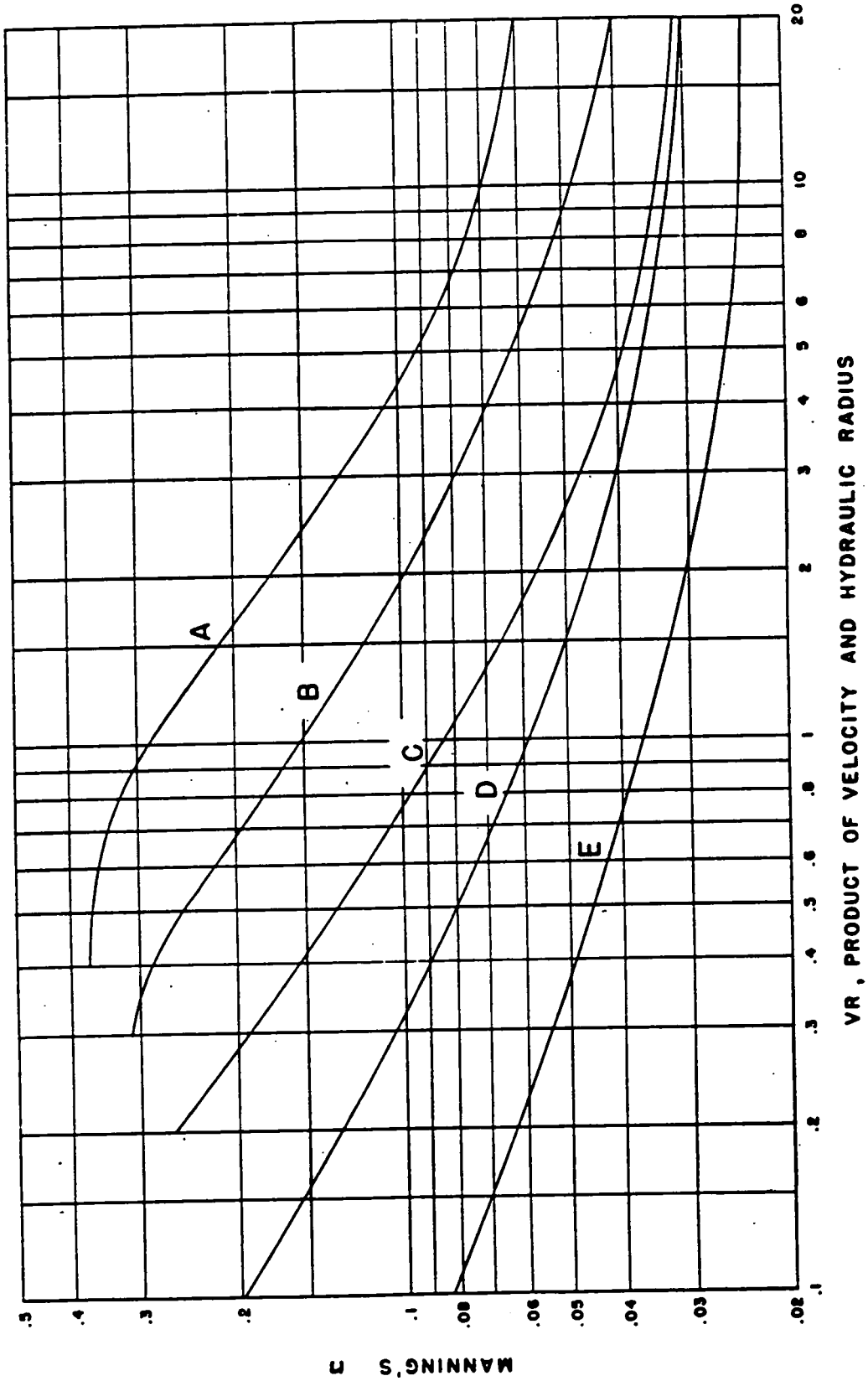

Figure 5 - Curves of Manning's n vs. VR for "Average Uniform Stands" of Grasses in Each SCS Vegetal Retardance Class. From USDA-SCS [1986]

2.8 Allowable Velocity (V)

Allowable velocity can be calculated from Manning's equation [Temple et al., 1987]. The allowable velocity is just used for information

$$V = q\left(\frac{1.49S^{1/2}}{qn}\right)^{3/5}$$

Where: q= allowable flow per unit width (Section 2.5 or 2.6)

3. SAFETY FACTORS METHOD

The Safety Factors Method is used to evaluate the erosion resistance of the riprap-lined portions of the OSDF north and east drainage channels. The factor of safety against riprap failure (SF) is calculated using the following equation [Abt et al., 1987]:

$$SF = \frac{\cos\theta \tan\phi}{\eta' \tan\phi + \sin\theta \cos\beta}$$

Where: θ = slope angle (angle of maximum side slope in channel)
ϕ = angle of repose of riprap
η' = factor calculated below
β = angle calculated below

A factor of safety greater than 1.5 is usually recommended for design against 100-year or smaller storms, and a factor of safety of 1.0 is generally recommended for design against the PMP [Abt et al., 1987]. From this information, a minimum factor of safety of 1.0 against erosion in the 2000-year storm should be reasonable.

3.1 Slope Angle (θ)

For the north and east drainage channels, the slope angle is the maximum angle of the channel sides (the place the riprap will most likely be unstable). The maximum side slope angle for the north drainage channel is 6H:1V or 9.56 degrees, and the maximum slope angle for the east drainage channel is 3H:1V or 18.4 degrees.

3.2 Angle of Repose of Riprap (ϕ)

The riprap angle of repose is estimated from Figure 6. For crushed stone riprap with a mean size of 12 inches, ϕ = 41 degrees is a conservative estimate from this figure.

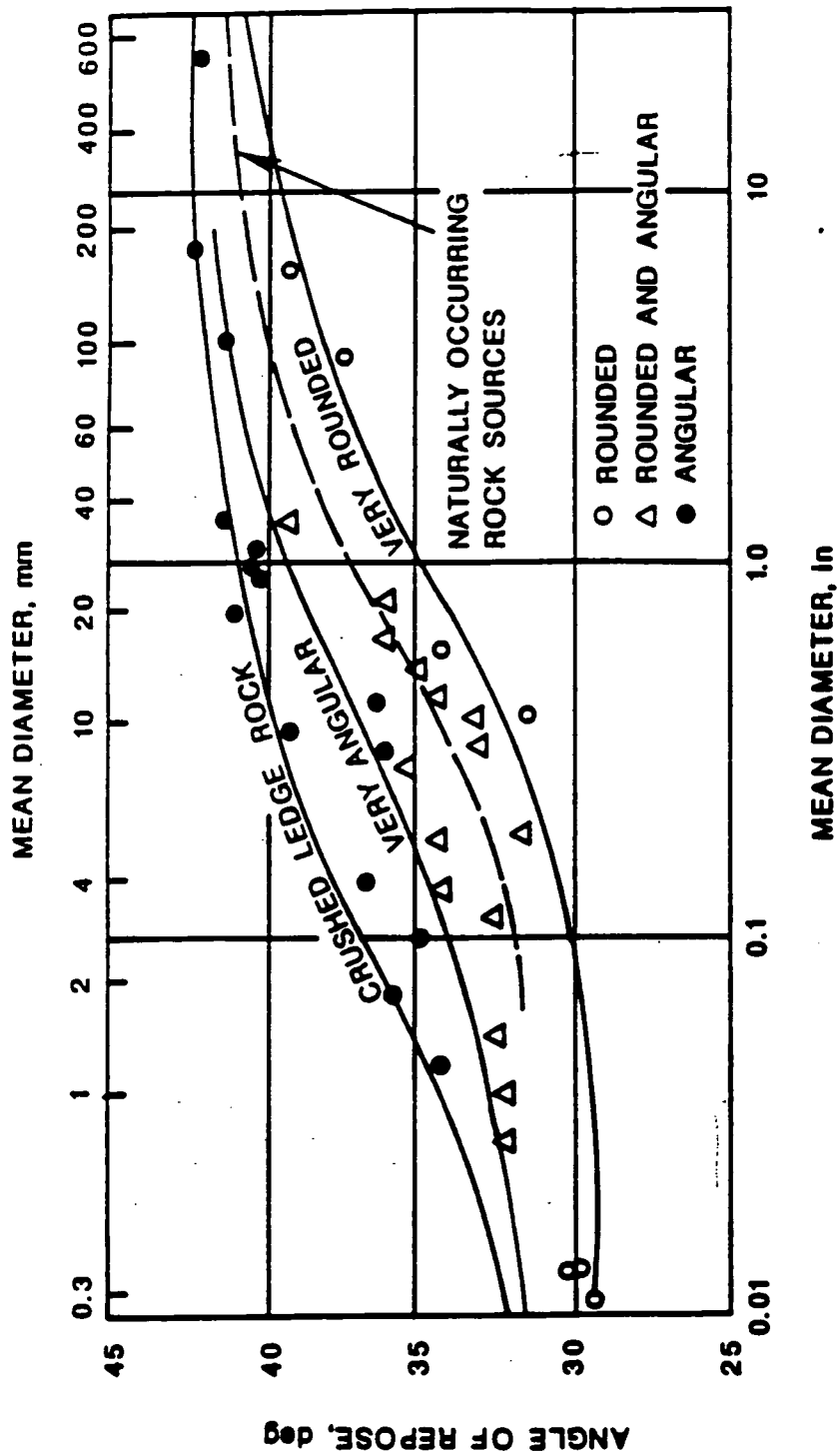

Figure 6 - Angle of Repose for Rock of Various Mean Diameters. From Abt et al. [1987]

3.3 Factor η'

η' is calculated from the following equation [Abt et al., 1987]:

$$\eta' = \eta\left[\frac{1+\sin(\lambda+\beta)}{2}\right] \qquad \text{With: } \eta = \frac{21\tau_o}{(G_s-1)\gamma_w D_{50}}$$

Where:
- λ = angle between horizontal and velocity vector (~zero for this channel)
- β = angle calculated in Section 3.4
- τ_o = shear stress applied by flow
- G_s = specific gravity of riprap ~ 2.65 [USDOE, 1989]
- γ_w = unit weight of water = 62.4 lb/ft^3
- D_{50} = mean size of riprap = 1 ft

3.3.1 Shear stress applied by flow (τ_o)

Shear stress applied by flow is calculated by the Duboys Formula [Abt et al., 1987]:

$$\tau_o = \gamma_w DS$$

Where:
- D = maximum flow depth
- S = channel slope = 0.5%

3.4 Angle β

β is calculated from the following equation [Abt et al., 1987]:

$$\beta = \tan^{-1}\left[\frac{\cos\lambda}{(2\sin\theta)/(\eta\tan\phi)+\sin\lambda}\right]$$

All terms have been previously defined

REFERENCES

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NRC - See U.S. Nuclear Regulatory Commission

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Written by: D. WARREN Date: 96/02/21 (YY/MM/DD) Reviewed by: DBW Date: 96/02/23 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

TEMPLE METHOD

ALLOWABLE SHEAR STRESS FOR BARE SOIL, τ_a

See Section 2.1 of Collection and Verification of Data (CVD)

$$\tau_a = \tau_{ab} C_e^2$$

$$\tau_{ab} = 0.03 \text{ psf (CL)} \qquad C_e = 0.99$$

$$\tau_a = (0.03)(0.99)^2 = 0.029 \text{ psf} \checkmark$$

MANNING'S ROUGHNESS COEFFICIENT FOR BARE SOIL, n_s

$n_s = 0.0156$ (Section 2.2 of CVD) ✓

VEGETAL PARAMETERS (C_I & C_F)

(See Section 2.3 of CVD)

FROM TABLE 5:

SCS RETARDANCE CLASS	STAND QUALITY	C_I	C_F
A	GOOD	10.00	0.90
	FAIR	9.35	0.72
B	GOOD	7.64	0.67
	FAIR	7.14	0.70
C	GOOD	5.60	0.75
	FAIR	5.23	0.60
D	GOOD	4.44	0.50
	FAIR	4.15	0.40
E	GOOD	2.88	0.50
	FAIR	2.69	0.40

$$C_I(\text{FAIR}) = \left(\sqrt{2/3}\right)^{1/3} C_I(\text{GOOD}) = 0.9347\, C_I(\text{GOOD})$$

$$C_F(\text{FAIR}) = 0.8\, C_F(\text{GOOD})$$

} TABLE

SHOULD BE ABLE TO GET GOOD CLASS B VEGETATION FROM NATIVE GRASSES [FRESHLEY, 1996].

✓

Written by: D. WARREN Date: 96/02/21 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

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FIND ALLOWABLE FLOW PER UNIT WIDTH (q)

1.) STABILITY CONTROLLED BY ALLOWABLE SOIL STRESS:
(Section 2.5 of CVD)

FOR GOOD CLASS B VEGETATION:

$a = 0.033\,C_I = 0.0133\,(7.64) = 0.1016$ ✓

$b = -0.0954\,C_I - 0.429 = -0.0954(7.64) - 0.429 = -1.16$ ✓

$$c = 0.297\,C_I - 0.5\ln(S) + 0.714\ln\left[\frac{\tau_a}{(1-C_F)\,n_s^2}\right] - 6.94$$

$$= 0.297\,(7.64) - 0.5\ln(0.005) + 0.714\ln\left[\frac{0.029}{(1-0.87)\,0.0156^2}\right] - 6.94$$

$c = 2.85$ ✓

$$q = \exp\left[\frac{-b - \sqrt{b^2 - 4ac}}{2a}\right] = \exp\left[\frac{1.16 - \sqrt{1.16^2 - 4(0.1016)(2.85)}}{2\,(0.1016)}\right]$$

$q = \underline{35.7}$ cfs/ft ✓

2.) STABILITY CONTROLLED BY ALLOWABLE VEGETAL STRESS
(Section 2.6 of CVD)

FOR GOOD CLASS B VEGETATION:

$a = 0.0133\,C_I = 0.1016$ (SAME AS ABOVE) ✓

$b = 1 - 0.0954\,C_I = 1 - 0.0954(7.64) = 0.271$ ✓

$c = 0.297\,C_I + 1.17\ln(S) - 1.67\ln(\tau_{VA}) + 2.33$

$= 0.297\,(7.64) - 1.17\ln(0.005) - 1.67\ln(5.73) + 2.33 = -4.515$ ✓

$$q = \exp\left[\frac{-b + \sqrt{b^2 - 4ac}}{2a}\right] = \exp\left[\frac{-0.271 + \sqrt{0.271^2 - 4(0.1016)(-4.515)}}{2\,(0.1016)}\right]$$

$q = \underline{236}$ cfs/ft ✓

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COMPARE ALLOWABLE FLOWS

STABILITY CONTROLLED BY:

SOIL STRESS → $q = 35.7$ cfs/ft

VEGETAL STRESS → $q = 236$ cfs/ft

ALLOWABLE SOIL STRESS CONTROLS → ALLOWABLE $q = 35.7$ cfs/ft ✓

COMPARE ALLOWABLE q TO ACTUAL q

ACTUAL q:

TAKE POINT "E" ON EAST SWALE

- CLASS B GRASS SHOULD BE AT LEAST MODERATE COVER - ASSUME "MODERATE" COVER → $Q = 650$ cfs (TABLE 1)
- SWALE BASE IS 69 ft WIDE (TABLE 2)

ASSUME ALL FLOW OCCURS ATOP SWALE BASE (CONSERVATIVE)

→ ACTUAL $q = \frac{650 \text{ cfs}}{69 \text{ ft}} = 9.42$ cfs/ft ✓

9.42 cfs/ft < ALLOWABLE $q = 35.7$ cfs/ft

→ GOOD CLASS B LINING SHOULD NOT ERODE IN 2000-YEAR STORM ✓

THIS MEANS EROSION GULLIES SHOULD NOT FORM IN LINER, SCOUR OF LINER SHOULD NOT OCCUR, ETC. IN THE 2000-YEAR STORM.

RESULTS OF EROSION RESISTANCE CALCULATIONS FOR ALL VEGETAL RETARDANCE CLASSES ARE SHOWN ON PAGES 28-29

MODERATE COVER FLOW CONDITIONS ARE ASSUMED FOR ALL POINTS - THIS SHOULD BE CONSERVATIVE (WITH GOOD CLASS "E" VEGETATION PRESENT)

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ROUGHNESS COEFFICIENT, n

(Section 2.7 in CVD)

$$n = \exp\left[0.01329\, C_I [\ln(q)]^2 - 0.09543\, C_I \ln(q) + 0.2971\, C_I - 4.16\right]$$

$$n = \exp\left\{(7.64)\left[0.01329[\ln(35.7)]^2 - 0.09543 \ln(35.7) + 0.2971\right] - 4.16\right\}$$

$n = 0.041$ ✓ (FOR GOOD CLASS B VEGETATION)

RESULTS ARE SHOWN ON PAGE 28.

ALLOWABLE VELOCITY (V)

(Section 2.8 of CVD)

$$V = q\left[\frac{1.49\, S^{1/2}}{q\, n}\right]^{0.6}$$

$$V = 35.7\left[\frac{1.49\ 0.005^{1/2}}{(35.7)(0.041)}\right]^{0.6} = 7.36\ \text{ft/sec}$$ ✓ (FOR GOOD CLASS B VEGETATION)

RESULTS ARE SHOWN ON PAGE 28.

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OSDF DRAINAGE CHANNELS - TEMPLE METHOD EVALUATION OF ALLOWABLE FLOW (q)

Channel Slope S = 0.5%

Soil grain roughness n_s = 0.0156

Allowable stress for bare soil τ_a = 0.029 psf

SCS Retardance Class	Stand Quality	Vegetal Parameters C_I	Vegetal Parameters C_F	Calculations For Allowable Flow Per Unit Width Stability Controlled By Allowable Soil Stress: a	b	c	Allow. flow, q (cfs/ft)		Manning n
A	Good	10.00	0.90	0.133	-1.383	3.736	#NUM!		#NUM!
A	Fair	9.35	0.72	0.124	-1.321	2.807	18.88		0.053
B	Good	7.64	0.87	0.102	-1.158	2.848	36.33		0.041
B	Fair	7.14	0.70	0.095	-1.110	2.093	10.63		0.044
C	Good	5.60	0.75	0.074	-0.963	1.775	9.27		0.036
C	Fair	5.23	0.60	0.070	-0.928	1.331	5.13		0.039
D	Good	4.44	0.50	0.059	-0.853	0.936	3.31		0.038
D	Fair	4.15	0.40	0.055	-0.825	0.720	2.54		0.039
E	Good	2.88	0.50	0.038	-0.704	0.473	2.01		0.031
E	Fair	2.69	0.40	0.036	-0.686	0.287	1.53		0.031

SCS Retardance Class	Stand Quality	Vegetal Parameters C_I	Vegetal Parameters C_F	Calculations For Allowable Flow Per Unit Width Stability Controlled By Allowable Vegetal Stress: a	b	c	Allow. flow, q (cfs/ft)		Manning n
A	Good	10.00	0.90	0.133	0.046	-4.264	242.7		0.089
A	Fair	9.35	0.72	0.124	0.108	-4.345	242.9		0.080
B	Good	7.64	0.87	0.102	0.271	-4.515	236.1		0.058
B	Fair	7.14	0.70	0.095	0.319	-4.551	231.5		0.053
C	Good	5.60	0.75	0.074	0.466	-4.602	207.1		0.040
C	Fair	5.23	0.60	0.070	0.501	-4.598	198.6		0.037
D	Good	4.44	0.50	0.059	0.576	-4.559	176.0		0.032
D	Fair	4.15	0.40	0.055	0.604	-4.533	166.3		0.030
E	Good	2.88	0.50	0.038	0.725	-4.300	114.6		0.024
E	Fair	2.69	0.40	0.036	0.743	-4.243	105.8		0.023

SCS Retardance Class	Stand Quality	RESULTS: **Minimum Allow. flow, q (cfs/ft)**	Allow. Velocity (fps)	Stability Controlled By
A	Good	*	*	-
A	Fair	**18.9**	4.87	Soil
B	Good	**36.3**	7.43	Soil
B	Fair	**10.6**	4.33	Soil
C	Good	**9.3**	4.62	Soil
C	Fair	**5.1**	3.47	Soil
D	Good	**3.3**	2.97	Soil
D	Fair	**2.5**	2.64	Soil
E	Good	**2.0**	2.76	Soil
E	Fair	**1.5**	2.46	Soil

*By inspection, good class A lining will have an allowable flow per unit width >36 cfs/ft

RESULTS OF TEMPLE METHOD

				EAST DRAINAGE CHANNEL					NORTH DRAINAGE CHANNEL	
			Point:	**A**	**B**	**C**	**D**	**E**	**F**	**G**
SCS Retardance Class	Stand Quality	**Minimum Allow. flow q (cfs/ft)**	Actual Q (cfs):	180	280	305	390	650	-	-
			Width (ft):	60	65	69	69	69	-	-
			Actual q (cfs/ft):	**3.0**	**4.3**	**4.4**	**5.7**	**9.4**	**0.89 ***	**6.0 ***
A	Good	**>36.3**		OK	OK	OK	OK	OK	OK	OK
A	Fair	**18.9**		OK	OK	OK	OK	OK	OK	OK
B	Good	**36.3**		OK	OK	OK	OK	OK	OK	OK
B	Fair	**10.6**		OK	OK	OK	OK	OK	OK	OK
C	Good	**9.3**		OK	OK	OK	OK	No	OK	OK
C	Fair	**5.1**		OK	OK	OK	No	No	OK	No
D	Good	**3.3**		OK	No	No	No	No	OK	No
D	Fair	**2.5**		No	No	No	No	No	OK	No
E	Good	**2.0**		No	No	No	No	No	OK	No
E	Fair	**1.5**		No	No	No	No	No	OK	No

*See following pages for calculation of actual q at points F and G.

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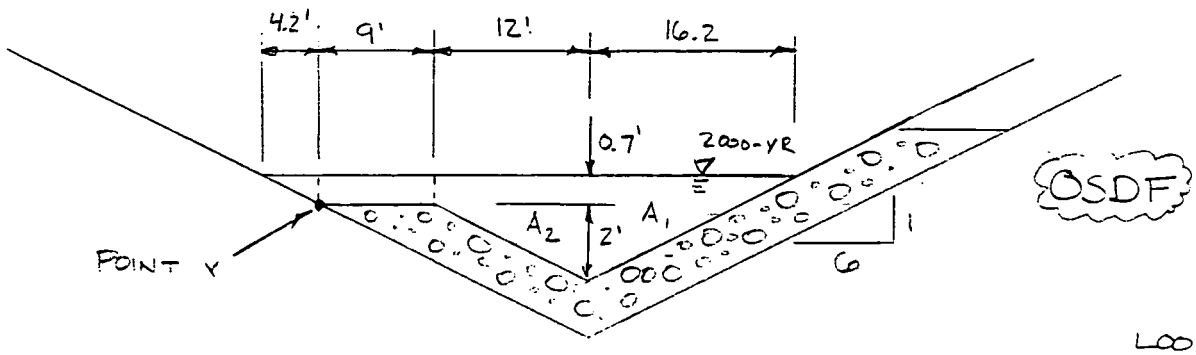


LOOKING EAST
N.T.S.

NORTH DRAINAGE CHANNEL AT POINT "F"
BEST COVER FLOW CONDITIONS *

$A_1 = \frac{1}{2}(2.7')(16.2') = 21.9\ ft^2$

$A_2 = \left(\frac{2.7'+0.7'}{2}\right)(12') = 20.4$

$A_3 = (0.7')(9.0') = 6.3$

$A_4 = \frac{1}{2}(0.7')(4.2') = 1.5$

$50.1\ ft^2$ ✓

AREA OF 1-FT WIDE STRIP AT POINT X:

$A_x = (1')(0.7') = 0.7\ ft^2$ ✓

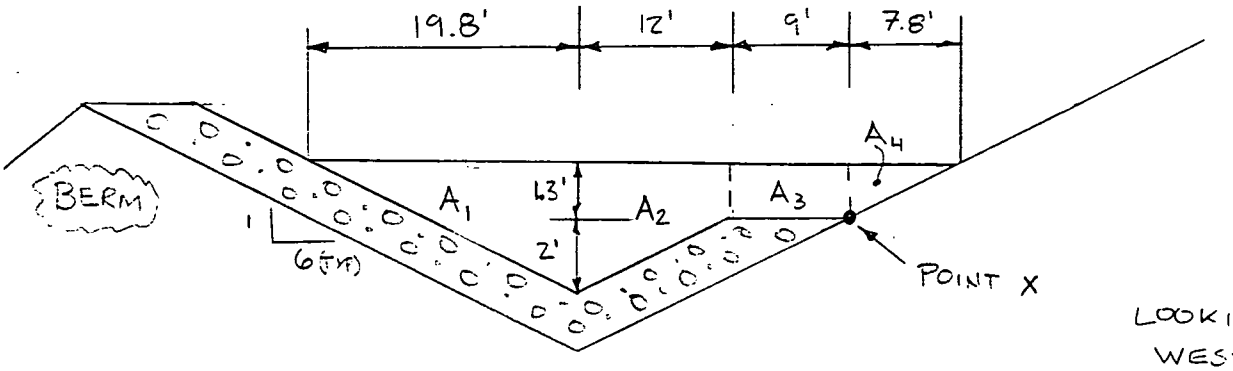
$$q_x = Q\frac{A_x}{A} = 63.5\ cfs\left(\frac{0.7\ ft^2}{50.1\ ft^2}\right) = 0.89\ cfs$$ ✓

FOR Q, SEE SECTION 1 OF CVD

* MODERATE COVER FLOW CONDITIONS NOT USED HERE BECAUSE MODERATE COVER FLOW DEPTH = 1.8 FT < 2 FT < HEIGHT OF RIPRAP LINING

Written by: D. WARREN Date: 96/02/21 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: OU DF Project/Proposal No.: GE3900 Task No.: 08.2



LOOKING WEST
N.T.S.

NORTH DRAINAGE CHANNEL AT POINT "G"
(MODERATE COVER FLOW CONDITIONS)*

$A_1 = \frac{1}{2}(3.3')(19.8') = 32.7\ ft^2$

$A_2 = \frac{3.3'+1.3'}{2}(12') = 27.6$

$A_3 = (1.3')(9') = 11.7$

$A_4 = \frac{1}{2}(1.3')(7.8') = 5.1$

$A = 77.1\ ft^2$

AREA OF A 1-FT WIDE STRIP AT POINT X:

$A_X = (1')(1.3') = 1.3\ ft^2$

$Q_X = Q\ \frac{A_X}{A} = 352\ cfs\ \frac{1.3\ ft^2}{77.1\ ft^2} = 5.9\ cfs \sim 6\ cfs/ft$

For [illegible] of CVD

* MODERATE COVER FLOW CONDITIONS SHOULD BE CONSERVATIVE WITH GOOD CLASS "B" VEGETATION PRESENT

Written by: D. WARREN Date: 96/02/21 (YY/MM/DD) Reviewed by: DBN Date: 96/02/23 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 28.2

SAFETY FACTORS METHOD

SEE SECTION 3 IN CVD

$$SF = \frac{\cos\theta \tan\phi}{\eta' \tan\phi + \sin\theta \cos\beta}$$

$\theta = \tan^{-1}\left(\frac{1}{3}\right) = 18.4°$ (MAX CHANNEL SIDE SLOPE) (CVD Section 3.1)

$\phi \sim 41°$ (CVD Section 3.2)

$\eta' = \eta \left[\frac{1 + \sin(\lambda + \beta)}{2}\right]$, $\eta = \frac{2\tau_0}{(G_s - 1)\gamma D_{50}}$ (CVD Section 3.3)

$\tau_0 = \gamma D S$ (CVD Section 3.3.1)

$\gamma = \gamma_{WATER} = 62.4$ pcf
$D \sim 6.2$ ft (SEE NEXT PAGE)
$S = 0.005$ ft/ft

MAX $\tau_0 = (62.4 \text{ pcf})(6.2 \text{ ft})(0.005 \text{ ft/ft}) = 1.934$ psf

$\tau_0 = 1.934$ psf
$G_s = 2.65$
$\gamma = 62.4$ pcf
$D_{50} = 1.0$ ft

$\longrightarrow \eta = \frac{2(1.934 \text{ psf})}{(2.65 - 1)(62.4 \text{ pcf})(1.0 \text{ ft})} = 0.395$ ✓

$$\beta = \tan^{-1}\left[\frac{\cos\lambda}{2\sin\theta / (\eta \tan\phi) + \sin\lambda}\right]$$ (CVD Section 3.4)

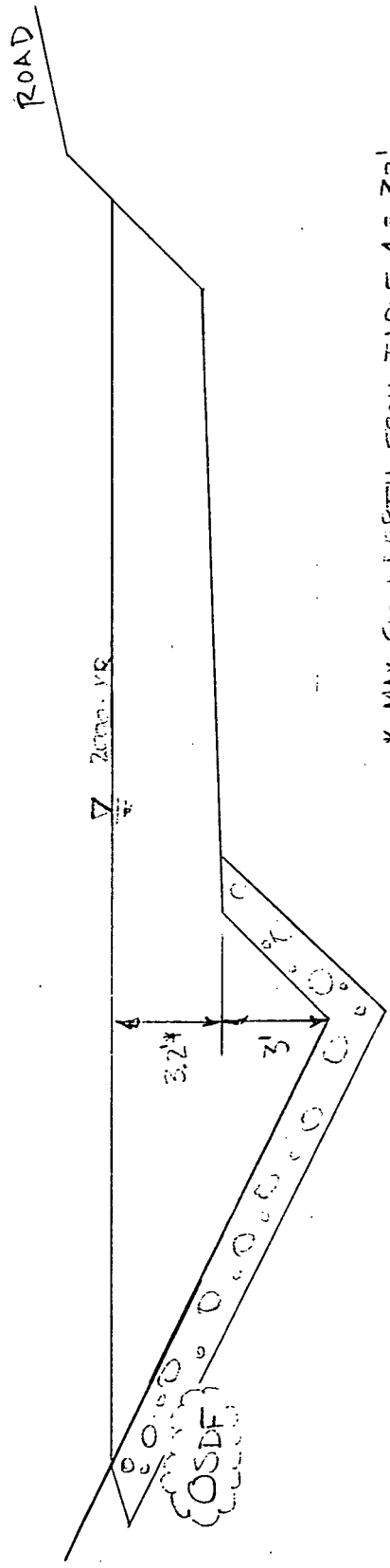
$\lambda = 0$ (CVD Section 3.3):

$$\beta = \tan^{-1}\left[\frac{\cos 0°}{2\sin 18.4° / (0.395 \tan 41°) + \sin 0°}\right]$$

$\beta = 28.5°$ ✓

Written by: D. WARREN Date: 96/02/21 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: CSDF Project/Proposal No.: GE3900 Task No.: 03.2



* MAX FLOW DEPTH FROM TABLE 1 = 3.2' OCCURS AT POINT "E" ("BEST CASE")

LOOKING NORTH
N.T.S.

EAST DRAINAGE CHANNEL

MAX FLOW DEPTH = 3.2' + 3' = 6.2'

THIS IS CONSERVATIVE - MAX FLOW DEPTH WILL ACTUALLY BE SHORTER DUE TO LOSS

THIS IS THE MAXIMUM FLOW DEPTH THAT WILL OCCUR IN THE NORTH AND EAST DRAINAGE CHANNELS.

Written by: D. WARREN Date: 96/02/21 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 05.2

$$\left.\begin{array}{l}\eta = 0.395 \\ \lambda = 0 \\ \beta = 28.5^\circ\end{array}\right\} \rightarrow \eta' = 0.395\left[\frac{1+\sin(0+28.5^\circ)}{2}\right]$$

$$\eta' = 0.292 \checkmark$$

$$\left.\begin{array}{l}\theta = 18.4^\circ \\ \phi = 41^\circ \\ \eta' = 0.292 \\ \beta = 28.5^\circ\end{array}\right\} \rightarrow SF = \frac{\cos 18.4^\circ \tan 41^\circ}{(0.292)\tan 41^\circ + \sin 18.4^\circ \cos 28.5^\circ}$$

$$SF = \boxed{1.55} \checkmark$$

$$SF = 1.55 > 1.0 \rightarrow \underline{\underline{OK}} \checkmark$$

RIPRAP LINING SHOULD NOT ERODE IN 2000-YEAR STORM

THIS MEANS GULLIES SHOULD NOT FORM IN RIPRAP LINING, SCOUR OF RIPRAP LINING SHOULD NOT OCCUR, ETC. IN THE 2000-YR STORM.

THIS IS THE WORST CASE HIGHEST FLOW DEPTH. SINCE THIS POINT ("E") IS OK, ALL OTHER POINTS SHOULD BE OK BY INSPECTION

Written by: DAVE WARREN Date: 22-Feb-96 Reviewed by: DBW Date: 23FEB96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

EROSION RESISTANCE: OSDF NORTH AND EAST DRAINAGE CHANNELS

DISCUSSION OF RESULTS

The potential for the grass-lined and riprap-lined portions of the OSDF north and east drainage channels to erode during the 2000-year storm was evaluated. The Temple Method was used to evaluate erosion potential of the grass-lined sections. The Safety Factors Method was used to evaluate erosion potential of the riprap-lined sections. The results of these calculations are shown on the previous pages. From these results, the following conclusions can be made:

- The calculations indicate that with a good stand of retardance class B vegetation (which should be achievable with native grasses), the grass-lined sections of the drainage channels should not significantly erode in the 2000-year storm.
- The calculations indicate that with 12-inch mean diameter riprap, the riprap-lined sections of the drainage channels should not significantly erode in the 2000-year storm.

"*Not significantly erode in the 2000-year storm*" includes resistance to erosion gullies developing, and resistance to scour occuring.

14. SUPPORT FACILITIES

14.1 Electrical Power Demand
14.2 Potable Water Demand
14.3 Sanitary Wastewater Discharge
14.4 Construction Water Demand
14.5 Decontamination Facility Water Demand
14.6 Decontamination Facility Pavement
14.7 Construction Admin Area Surfacing
14.8 Construction Haul Road
14.9 Leachate Transmission System Access Corridor

14.1 Electrical Power Demand

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: ELECTRICAL POWER DEMAND

Computations By: (Cognizant Engineer)
Signature: Brian D. Jacobson — Date: 15 JUNE 1996
Printed Name and Title: BRIAN D JACOBSON, Senior Staff Engineer

Assumptions and Procedures Checked by: (Checker)
Signature: Lawrence W Fly — Date: 17 JUNE 1996
Printed Name and Title: LAWRENCE W. FLY, PROJECT MANAGER

Computations Checked by:
Signature: Lawrence W Fly — Date: 17 JUNE 1996
Printed Name and Title: LAWRENCE W. FLY, PROJECT MANAGER

Computations Backchecked by: (Cognizant Engineer)
Signature: Brian D. Jacobson — Date: 18 JUNE 1996
Printed Name and Title: BRIAN D. JACOBSON, SENIOR STAFF ENGINEER

Approved by: (PDP)
Signature: Brian D Jacobson — Date: 24 June 96
Printed Name and Title: BRIAN D. JACOBSON, SENIOR STAFF ENGINEER

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 25 Jun 96
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
~~A~~	~~Intermediate Design~~				
F	Prefinal Design	18 June 96	BJ	KWF	25 Jun 96
G	Final Design Package	4 Oct 96			
C	Response to Final Design Cmts	5 May 97			

Written By : BRIAN D. JACOBSON Date: 18 JUNE 96 Reviewed by: [illegible] Date: 19 JUNE 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

ELECTRICAL POWER DEMAND

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this calculation package is to perform the required calculations to estimate the electrical power load and transformer sizing requirements for the following areas:

- Construction Administration Area;
  - North Side; and
  - South Side;
- Construction Work Area;
- Decontamination Facility; and
- Permanent Lift Station.

The calculations presented are representative calculations for anticipated power demands. Actual site development conditions at the time of construction may differ from these calculations, thus, the results should be reviewed before use for construction. Additionally, the calculation for the permanent lift station only includes components required by this design package, additional loads due to pumps and related instrumentation are to be calculated in a separate design package.

METHODS OF ANALYSIS

The load at each facility location will be estimated. A transformer will be selected for each location. The calculated loads will be compared to the capacity of the transformer at each location to evaluate the percentage of load rating utilized.

Written By : BRIAN D. JACOBSON Date: 18 JUNE 96 Reviewed by: [illegible] Date: 19 JUNE 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

CONCLUSIONS

- Construction Administration Area
  - North Side of Facility: One 75 KVA 1 phase 120/240 VAC transformer loaded at 67.3 percent of rating;
  - South Side of Facility: One 125 KVA 1 phase 120/240 VAC transformer loaded at 65.8 percent of rating;

- Construction Work Area: One 15 KVA 1 phase 120/240 VAC transformer loaded at 61.3 percent of rating;

- Decontamination Facility: One 10 KVA 1 phase 120/240 VAC transformer loaded at 54.0 percent of rating; and

- Permanent Lift Station: One 10 KVA 1 phase 120/240 VAC transformer loaded at 66.4 percent of rating.

Written By : BRIAN D. JACOBSON Date: — Reviewed by: Date:

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

ELECTRICAL POWER DEMAND
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CALCULATION PROCEDURES 1 of 4

DATA VERIFICATION 1 of 2

ANALYSIS RESULTS 1 of 6

Written By : BRIAN D. JACOBSON Date: 10 JUNE 96 Reviewed by: [illegible] Date: 12 JUNE 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

ELECTRICAL POWER DEMAND

CALCULATION PROCEDURE

INTRODUCTION

The purpose of this calculation package is to perform the required calculations to estimate the power demands and transformer loading at each of the following areas:

- Construction Administration Area;
  - North Side; and
  - South Side;
- Construction Work Area;
- Decontamination Facility; and
- Permanent Lift Station.

The location of each facility is presented in Figure 1.

METHOD OF ANALYSIS

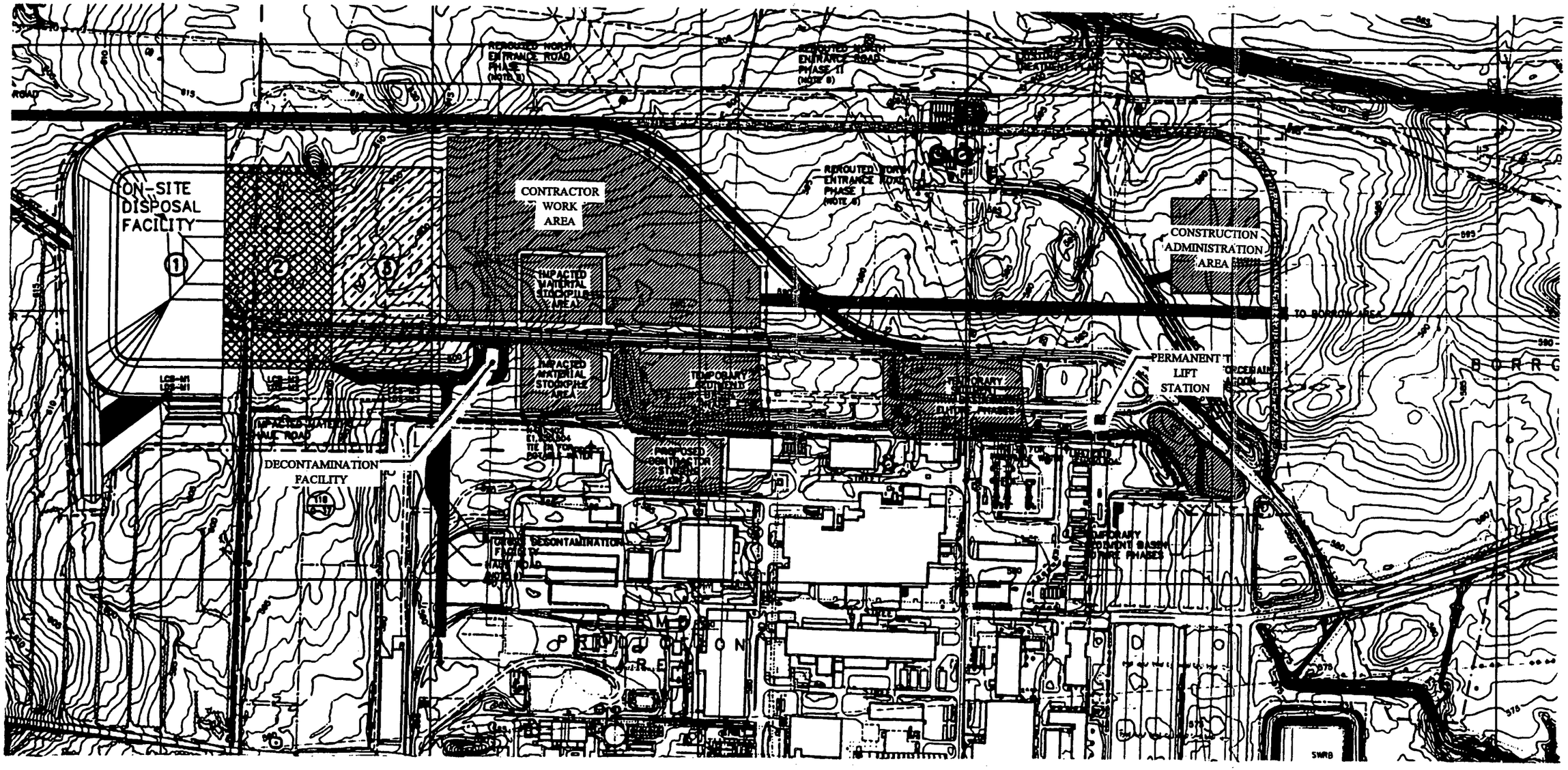
The following procedure will be used to calculate the design loads which will then be used to select the appropriately sized transformer.

- each load source will be evaluated and the appropriate volt-amperes value will be calculated; and
- each transformer will be selected based on the calculated load(s) such that the transformer loading will not exceed 75 percent of the rated value.

Written By : BRIAN D. JACOBSON Date: 10 JUNE 96 Reviewed by: RW Fry Date: 12 JUNE 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

FIGURE 1: FACILITY LOCATIONS



SOURCE: DRAWING G-2, PREFINAL DESIGN PACKAGE

Written By : BRIAN D. JACOBSON Date: 10 JUNE 96 Reviewed by: RWFry Date: 12 JUNE 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

Construction Administration Area

The construction administration will contain eight trailer units. Each trailer unit consists of two trailer modules, each 14-ft wide by 78 ft in length connected at the roof centerline. Each trailer module will be assumed to have a similar electrical demand. Shared non-continuous loads will be accounted for separately. The demand will include the following loads:

- Loads Calculated per Module
  - heat pump/air conditioning; and
  - general lighting, computers, appliances, etc.

- Loads Calculated per Trailer Unit
  - Lunch Area including microwave, mini refrigerator, coffee pots, etc.;
  - water heater; and
  - area lighting.

Construction Work Area

The following loads will be included:

- area lighting;
- breaker panel heater; and
- miscellaneous equipment/hand tool demands.

Decontamination Facility

The following load will be included:

- sump pump;
- 2 - convenience outlets; and
- area lighting.

[redacted]

Written By : BRIAN D. JACOBSON Date: 10 JUNE 96 Reviewed by: [illegible] Date: 12 JUNE 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

Permanent Lift Station

The following loads will be included:

- 2 - LIC level indicator controllers;
- control panel;
- alarm light;
- alarm siren;
- motor operated valve; and
- area lighting.

Written By : BRIAN D. JACOBSON Date: 13 JUNE 90 Reviewed by: RWFy Date: 14 JUNE 1990

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

ELECTRICAL POWER DEMAND

DATA VALIDATION

The loads at each location were estimated as follows:

Construction Administration Area	volt-amperes
• Loads Calculated per Module	
• heat pump/air conditioning	3500
• general lighting, computers, appliances, etc.	2300
• Loads Calculated per Trailer Unit	
• Lunch Area including microwave, mini refrigerator, coffee pots, etc.	1800
• water heater	2500
• area lighting (400 watt mercury vapor lights)	400

Construction Work Area	
• area lighting (400 watt mercury vapor lights)	400
• breaker panel heater	2000
• miscellaneous equipment/hand tool demands	6000

Decontamination Facility	
• pump (1 hp)	1000
• convenience oulet	2000
• area lighting (400 watt mercury vapor lights)	400

[redacted]

Written By : BRIAN D. JACOBSON Date: 13 JUNE 96 Reviewed by: RW Fry Date: 14 JUNE 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

Permanent Lift Station	volt-amperes
• LIC level indicator controller	120
• control panel	2000
• alarm light	1000
• alarm siren	1000
• motor operated valve	2000
• area lighting. (400 watt mercury vapor light)	400

Written By : BRIAN D. JACOBSON Date: 15 JUNE 96 Reviewed by: [illegible] Date: 17 JUNE 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

ELECTRICAL POWER DEMAND

ANALYSIS RESULTS

Written by: BRIAN JACOBSON Date: 96/06/15 (YY MM DD) Reviewed by: NWFy Date: 96/06/17 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

CONSTRUCTION ADMINISTRATION AREA

TRANSFORMER LOADINGS

ASSUMPTIONS:

1) The construction administration area contains 8 double-wide trailers.
2) All trailers have the same electrical demand requirements.
3) Two 14 foot by 78 foot modules attached at the roof center line form one trailer unit.

LOADS CALCULATED PER MODULE

	VOLT AMPERES
Heat Pump/Air Conditioning	3500
General Lighting and Appliances - 5 offices, computers, desk lights, etc	2300
TOTAL PER MODULE	5800

LOADS CALCULATED PER TRAILER UNIT

Module load x 2 = 5800 x 2	= 11,600
Non-continuous loads	
- Lunch area, Microwave, coffe pots, etc.	1800
- Water heater	2500
TOTAL PER TRAILER UNIT	15,900

[redacted]

Written by: BRIAN JACOBSON Date: 96/06/15 (YY MM DD) Reviewed by: RW Fry Date: 96/06/17 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

TOTAL DEMAND LOAD PER TRAILER UNIT

15,900 VOLT AMPERES ÷ 1000 = 15.9 kVA

15.9 kVA ÷ 240 VOLTS = 66.25 AMPERES

CONSTRUCTION ADMINISTRATION AREA – NORTH SIDE

(3) TRAILER UNITS × 15.9 kVA = 47.7 kVA

(7) 400 WATT MERCURY VAPOR LIGHTS @ 0.4 kVA — 2.8 kVA

50.5 kVA

TRANSFORMER FOR NORTH SIDE SHALL BE 75 kVA, 1 PHASE, 120/240 VAC LOADED AT 67.3 PERCENT OF RATING

CONSTRUCTION ADMINISTRATION AREA - SOUTH SIDE

(5) TRAILER UNITS × 15.9 kVA = 79.5 kVA

(7) 400 WATT MERCURY VAPOR LIGHTS @ 0.4 kVA — 2.8 kVA

82.3 kVA

TRANSFORMER FOR SOUTH SIDE SHALL BE 125 kVA, 1 PHASE, 120/240 VAC LOADED AT 65.8 PERCENT OF RATING

[redacted]

Written by: BRIAN JACOBSON Date: 96/06/15 (YY MM DD) Reviewed by: RWFry Date: 96/06/17 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

CONSTRUCTION WORK AREA

	VOLT AMPERES
(3) 400 WATT MERCURY VAPOR LIGHTS @ 0.4 KVA	1200
(1) BREAKER PANEL HEATER	2000
EQUIPMENT/HAND TOOLS	6000
	9,200

TOTAL DEMAND FOR CONSTRUCTION WORK AREA

9,200 VOLT AMPERES ÷ 1000 = 9.2 KVA

9.2 KVA ÷ 240 = 38 AMPERES

TRANSFORMER FOR CONSTRUCTION WORK AREA SHALL BE 15 KVA, 1 PHASE, 120/240 VAC LOADED AT 61.3 PERCENT OF RATING

[redacted]

Written by: BRIAN JACOBSON Date: 96/06/15 (YY MM DD) Reviewed by: [illegible] Date: 96/06/17 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE 3900 Task No.: 10.4

DECONTAMINATION FACILITY

POWER DEMAND

		VOLT-AMPERES
(1) SUMP PUMP		
1 hp · 746 watts/hp = 746 watts	say	1000
(2) Convenience outlets	2 · 2000 =	4000
(1) AREA LIGHT		400
		5400

5400 VOLT AMPERES ÷ 1000 = 5.4 KVA

5.4 KVA ÷ 240 VOLTS = 22.5 AMPS

TRANSFORMER FOR DECONTAMINATION FACILITY SHALL BE AT LEAST 10 KVA, 1 PHASE, 120/240 VAC LOADED AT 54.0 PERCENT OF RATING.

[redacted]

Written by: BRIAN JACOBSON Date: 96 / 06 / 15 (YY MM DD) Reviewed by: [illegible] Date: 96 / 06 / 17 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

PERMANENT LIFT STATION

TRANSFORMER LOADING

	VOLT-AMPERES
(2) LIC Level Indicator Controller x 120W	240
(1) Control Panel	2000
(1) alarm light	1000
(1) alarm siren	1000
(1) motor operated valve	2000
(1) 400 watt mercury vapor light	400
	6640

6640 VOLT AMPERES ÷ 1000 = 6.64 KVA

6.64 KVA ÷ 240 VOLTS = 27.7 AMPERES

TRANSFORMER FOR PERMANENT LIFT STATION SHALL BE AT LEAST 10 KVA, 1 PHASE, 120/240 VAC LOADED AT 66.4 PERCENT OF RATING.

IT SHOULD BE NOTED THAT ADDITIONAL DEMANDS MAY BE EXERTED DURING CONSTRUCTION. THE FINAL DESIGN SHOULD ALLOW FOR THESE LOADS

[redacted]

14.2 Potable Water Demand

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: POTABLE WATER DEMAND

Computations By: (Cognizant Engineer)
Signature [signature] Date 14 June 96
Printed Name and Title BRIAN D. JACOBSON, Senior Staff Engineer

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 10 JUNE 96
Printed Name and Title DENIS R SAUSSUS, STAFF ENGINEER

Computations Checked by:
Signature [signature] Date 17 JUNE 96
Printed Name and Title DENIS R SAUSSUS, STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 18 June 96
Printed Name and Title BRIAN D JACOBSON, SENIOR STAFF ENGINEER

Approved by: (PDP)
Signature [signature] Date 24 June 96
Printed Name and Title BRIAN D. JACOBSON, SENIOR STAFF ENGINEER

Approved by: (DTL and TETL)
Signature [signature] Date 25 June 96
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
~~A~~	~~Intermediate Design~~				
F	Prefinal Design Submitted to EPA	—	—	—	
G	Final Design Package	4 Oct 96	—	—	
C	Response to Final Design Cmts	5 May 97	—	—	

Written By : BRIAN D JACOBSON Date: 18 JUNE 96 Reviewed by: DENIS R SAUSSUS DRS Date: 19 JUNE 96

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

POTABLE WATER DEMAND

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this calculation package is to perform the required calculations to calculate the potable water demand at (i) the construction administration area for both consumption and fire protection, (ii) the tanker fill stations, and (iii) the decontamination facility.

METHODS OF ANALYSIS

The water demands at the following facility locations will be calculated:

- construction administration area potable water;
- construction administration area fire protection;
- tanker fill stations; and
- decontamination facility.

The head losses through the longest piping path will be calculated. This head will be used as the basis for the pressure requirement. The volume requirement will be based on the maximum expected demand at each location. The calculations are provided as representative calculations for the facilities. The calculations should be checked prior to construction of water lines to verify actual site conditions are accurately represented.

CONCLUSIONS

The construction administration area requires a potable water supply of 240 gallons per minute at a dynamic head of 140 feet.

The construction administration area requires a fire protection water supply of 500 gallons per minute at a dynamic head of 198 feet.

The tanker fill station and decontamination facility requires a water supply of 450 gallons per minute at a dynamic head of 177 feet.

The decontamination facility requires a water supply of 30 gallons per minute at a dynamic head of 105 feet.

[redacted] 68

Written By : BRIAN D JACOBSON Date: Reviewed by: DENIS R SAUSSUS DRS Date: 10 JUNE 96

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

POTABLE WATER DEMAND

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[redacted] 69

Written By : BRIAN D JACOBSON Date: 7 June 96 Reviewed by: DENIS R SAUSSUS DRS Date: 10 JUNE 96

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

POTABLE WATER DEMAND

CALCULATION PROCEDURE

[redacted]

POTABLE WATER SUPPLY DESIGN REQUIREMENTS FOR THE CONSTRUCTION ADMINISTRATION AREA CALCULATION PROCEDURE

PURPOSE OF ANALYSIS

The construction administration area is assumed to be comprised of approximately 8 double-wide trailers occupied by FERMCO, construction, GeoSyntec, and other personnel during all phases of the On-Site Disposal Facility construction through closure. These trailers may be supplied with potable water. This calculation is provided to evaluate the water demand if water is supplied to the trailers. The calculation should be checked prior to construction of water lines to verify actual site conditions.

To select the appropriate piping size and potable water supply requirement to deliver the water demand to these trailers, the head losses expected in the system must be calculated.

METHOD OF ANALYSIS

The following procedure was used to calculate the expected head loss in the system:

- the potable water supply shall be routed to the southeast corner of the construction administration area as indicated on Figure 1; the proposed potable water supply lines within the construction administration are and the trailers proposed layout are shown on Figure 2; the calculations will be based on the worst case flow and head loss which is the supply to Trailer #7;

- the potable water supply requirements are based on the "U.S. Water withdrawals and Water Consumption Standards" and are assumed to be 5,300 gallons per day with a peak demand of 240 gallons per minute; and

- the required pressure head is calculated using the conservation of energy equation:

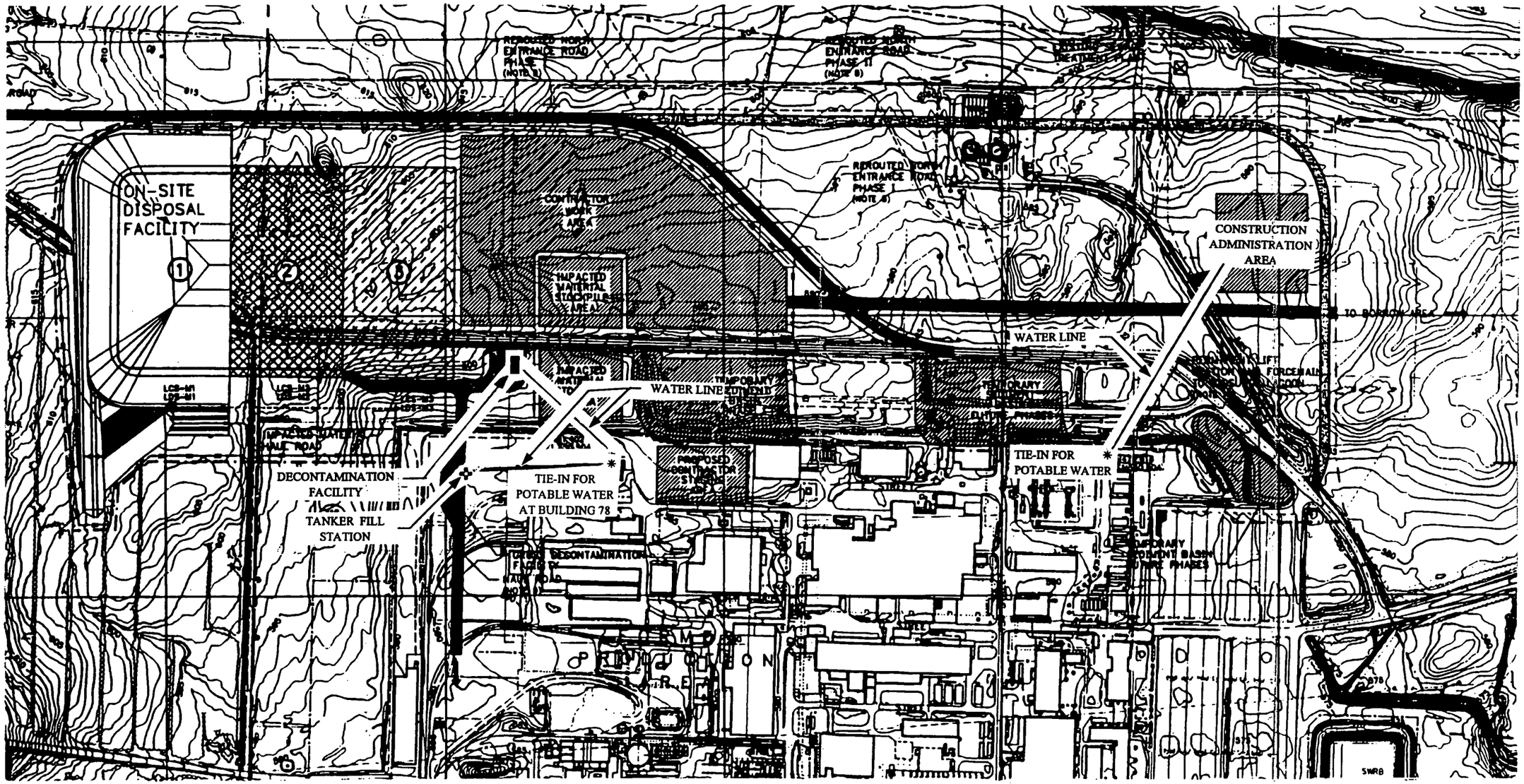
$$Z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Hp = Z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \Sigma h_{L1-2} \qquad (1)$$

where:

Written By : BRIAN D. JACOBSON Date: 7 June 96 Reviewed by: DENIS R SAUSSUS DRS Date: 10 JUNE 96

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

FIGURE 1: FACILITY LOCATIONS



SOURCE: DRAWING G-2, PREFINAL DESIGN PACKAGE

[redacted]

Written by: BRIAN JACOBSON Date: 96/06/07 (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96/06/10 (YY MM DD)

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

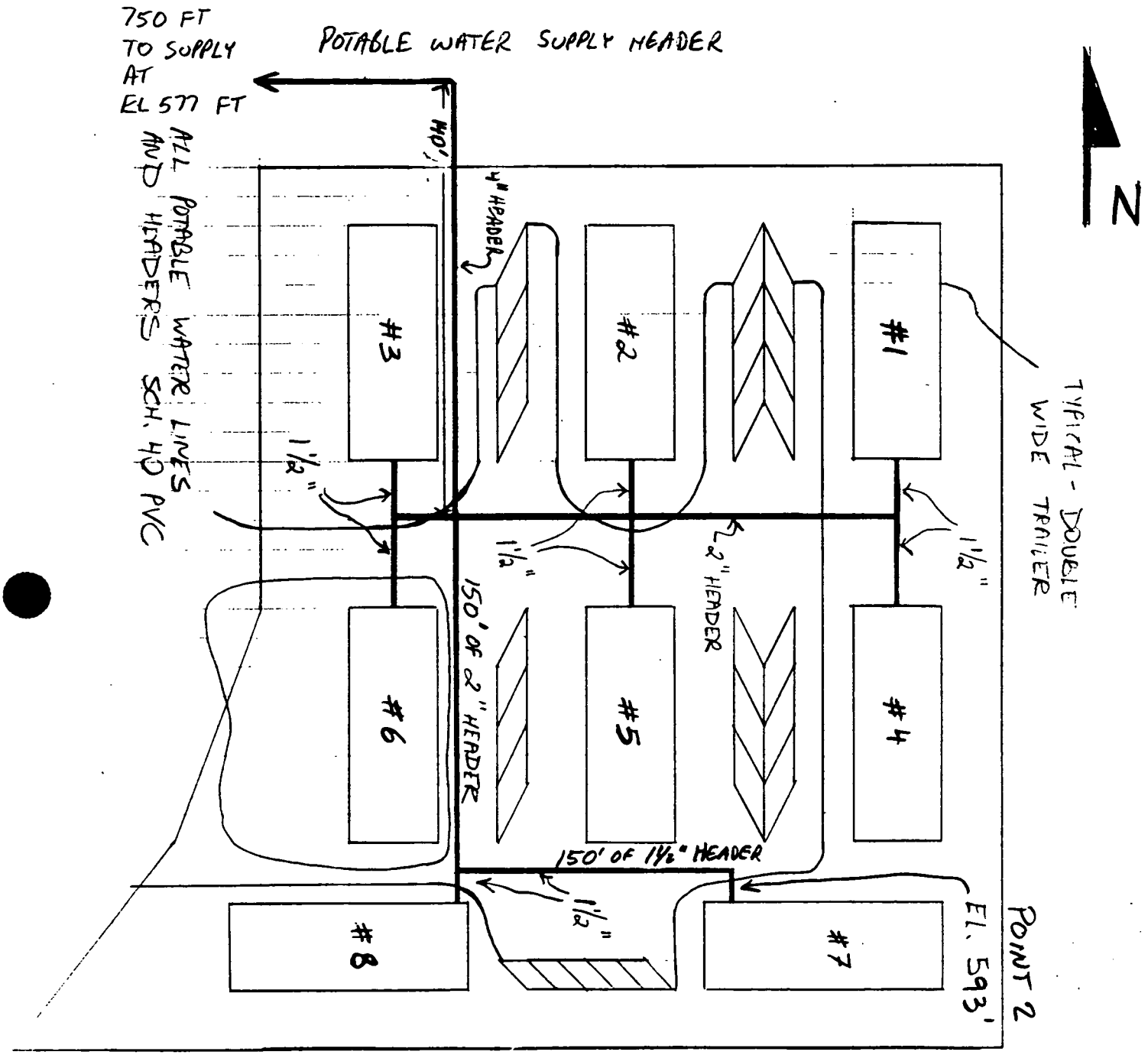


FIGURE 2

CONSTRUCTION ADMINISTRATION AREA

POTABLE WATER TO TRAILERS

[redacted]

Z_1	=	elevation at Point 1
P_1	=	pressure at Point 1
γ	=	unit weight of potable water
V_1	=	velocity at Point 1
g	=	acceleration due to gravity
Z_2	=	elevation at Point 2
P_2	=	pressure at Point 2
V_2	=	velocity at Point 2
H_p	=	pressure head provided by the potable water supply
Σh_{L1-2}	=	summation of frictional head losses between Points 1 and 2

The friction head loss due to the pipe is caused by:

- 890′ of 4" Sch. 40 PVC; ✓
- 150′ of 2" Sch. 40 PVC; and ✓
- 150′ of 1 1/2" Sch. 40 PVC. ✓

The friction head loss due to the fittings system is caused by:

- (1) 4" tee - line ✓
- (1) 4"/2" reducer ✓
- (1) 2" tee - branch ✓
- (1) 2"/1½" reducer ✓
- (1) 1½" regular flanged 90° elbow ✓

The friction loss in the pipe will be calculated using the Darcy-Weisbach formula:

$$h_f = f \frac{L}{D} \frac{V^2}{2g} \quad ✓ \qquad (2)$$

where:

h_f	=	friction head in pipe;
f	=	friction factor;
L	=	length of pipe;
V	=	velocity of the liquid = Q/A;
Q	=	flow rate;

A = area of pipe = $\frac{\pi}{4}(D)^2$;

D = inside diameter of pipe.

The friction factor is a function of Reynolds number (Re), and the relative roughness of pipe and will be determined using the chart developed by Moody. The parameters will be calculated as follows:

- the Reynolds number will be calculated as follows:

$$\mathrm{Re} = \frac{DV}{\nu} \tag{3}$$

where:

D = inside diameter of pipe;
V = velocity of the liquid; and
ν = kinematic viscosity of water.

- the relative roughness was calculated as follows:

k_s/D = equivalent sand roughness of pipe / inside diameter of pipe.

The friction loss in the fittings will be calculated using the following formula:

$$h_{L\ fittings} = \Sigma\ K_{fittings}\ \frac{V^2}{2g} \tag{4}$$

where:

$K_{fittings}$ = loss coefficient for each types of fitting; and
V = average velocity of liquid.

Written by: BRIAN D. JACOBSON Date: 7 June 96 Reviewed by: DENIS R SAUSSUS DRS Date: 10 JUNE 96

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

FIRE PROTECTION WATER SUPPLY DESIGN REQUIREMENTS FOR THE CONSTRUCTION ADMINISTRATION AREA CALCULATION PROCEDURE

PURPOSE OF ANALYSIS

A fire protection water supply may be required at the construction administration area during construction of the on-site disposal facility. This calculation is provided to evaluate the water demand if fire protection water is supplied to the trailers. The calculation should be checked prior to construction of water lines to verify actual site conditions are accurately represented.

The NFPA code requires a minimum primary supply of water for a fire protection system of at least 500 gpm with a residual pressure of 10 psi. Therefore, the worse case configuration is at H#2 (Hydrant #2 needs a supply of 500 gpm).

The head losses expected in the system will be calculated to select the appropriate piping size and the water supply pressure requirement.

METHOD OF ANALYSIS

The following procedure will be used to calculate the expected head loss in the system:

- the proposed fire protection primary supply lines within the Construction Administration Area are shown on Figure 3;
- the calculation will be based on the required flow rate through the longest pipe run, which would be the supply to Hydrant #2; ✓
- the fire protection primary water demand is taken from the NFPA code as being 500 gpm with a minimum 10 psi residual pressure; ✓
- the required pressure head is calculated using the conservation of energy equation:

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

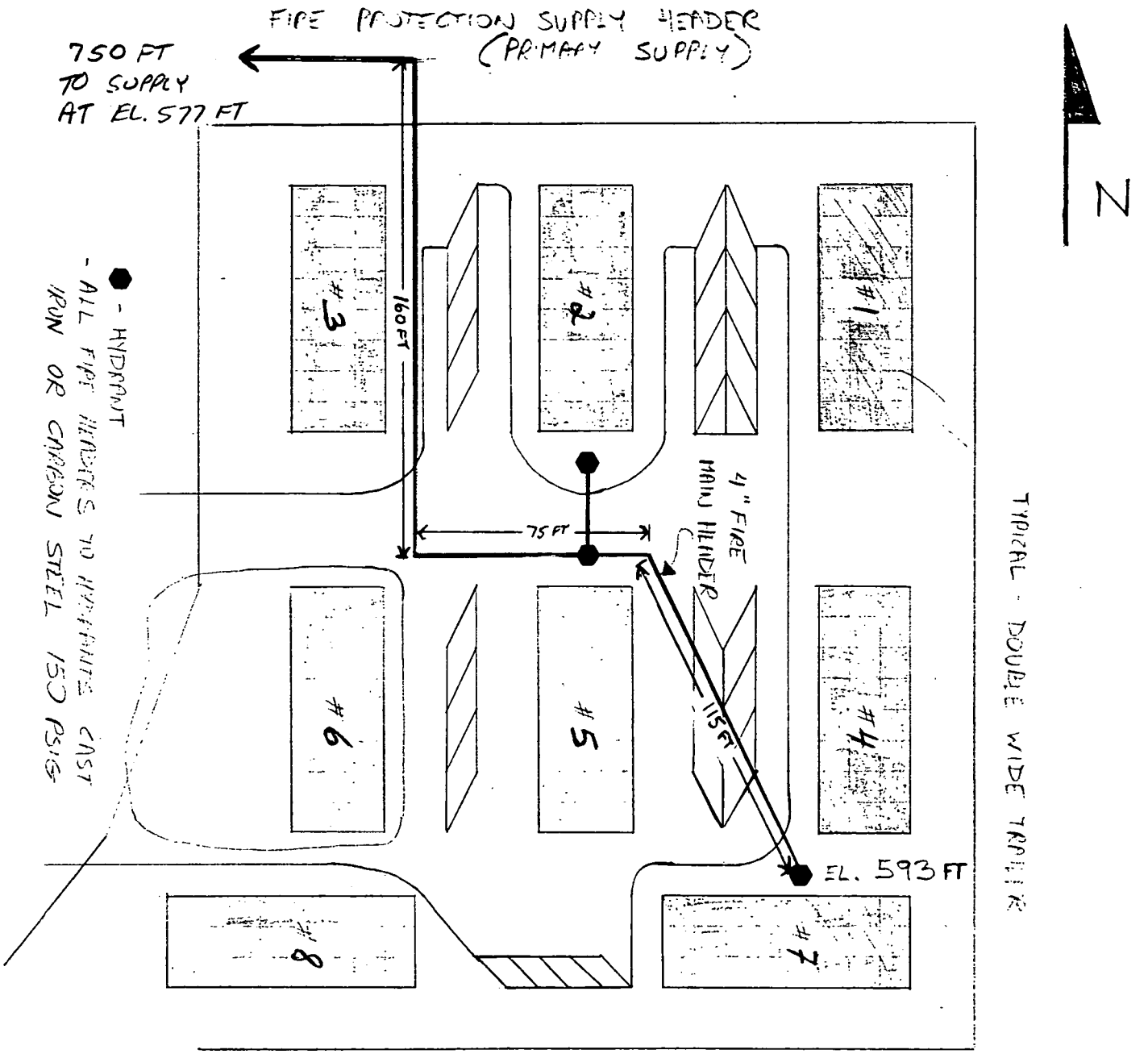


FIGURE 3

CONSTRUCTION ADMINISTRATION AREA
FIRE PROTECTION SYSTEM TO TRAILERS

[redacted]

$$Z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + H_p = Z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \Sigma h_{L_{1-2}} \quad (5)$$

where:

Z_1	=	elevation at Point 1;
P_1	=	pressure at Point 1
γ	=	unit weight of water;
V_1	=	velocity at Point 1;
H_p	=	elevation head provided by the fire protection water supply;
g	=	acceleration due to gravity;
Z_2	=	elevation at Point 2;
P_2	=	pressure at Point 2;
V_2	=	velocity at Point 2; and

$\Sigma h_{L_{1-2}}$ = summation of frictional losses between Point 1 and 2.

The friction head loss due to the pipe is caused by:

- 1100 ft of 4" carbon steel pipe.

The friction head loss due to the fittings are caused by:

- 1 - 4" 90° elbow;
- 1 - 4" tee; and
- 1 - 4" 45° elbow.

The friction loss in the pipe will be calculated using the Darcy-Weisbach formula:

$$h_f = f \frac{L}{D} \frac{V^2}{2g} \quad (6)$$

where:

h_f	=	friction head in pipe;
f	=	friction factor;

L = length of pipe;
V = average velocity of the liquid = Q/A;
Q = flow rate;
A = area of pipe = $\frac{\pi}{4}(D)^2$;
D = inside diameter of pipe.

The friction factor is a function of Reynolds number (Re), and the relative roughness of pipe and will be determined using the chart developed by Moody. The parameters will be calculated as follows:

- the Reynolds number will be calculated as follows:

$$\mathrm{Re} = \frac{DV}{\nu} \tag{7}$$

where:

D = inside diameter of pipe;
V = average velocity of the liquid; and
ν = kinematic viscosity of water.

- the relative roughness was calculated as follows:

k_s/D = equivalent sand roughness of pipe / inside diameter of pipe.

The friction loss in the fittings will be calculated using the following formula:

$$h_{L\ fittings} = \Sigma\ K_{fittings}\ \frac{V^2}{2g} \tag{8}$$

where:

$K_{fittings}$ = loss coefficient for each types of fitting; and
V = average velocity of liquid.

Written by: BRIAN D. JACOBSON Date: 7 Jun 96 Reviewed by: DENIS R SAUSSUS DRS Date: 10 JUNE 96

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

WATER SUPPLY DESIGN REQUIREMENTS FOR THE TANKER FILL STATIONS CALCULATION PROCEDURE

PURPOSE OF ANALYSIS

The tanker fill stations will require a supply of water during construction. This water will be needed for dust prevention and soil conditioning.

To select the appropriate piping size and water supply requirement, the head losses expected for the worst case scenario in this system must be calculated.

METHOD OF ANALYSIS

The following procedure was used to calculate the expected head loss in the system:

- the water supply may be routed to the two tanker fills from the supply header near Building 78; the proposed supply line is shown on Figure 1;
- the calculation will be based on the flow for the worst case scenario, which would be to supply the tanker fill station near the impacted material haul road;
- the water supply is taken from the demand estimates as being 450 gpm; and
- the required pressure head is calculated using the conservation of energy equation:

$$Z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + H_p = Z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \Sigma h_{L_{1-2}} \qquad (9)$$

where:

Z_1	=	elevation at Point 1;
P_1	=	pressure at Point 1
γ	=	unit weight of water;
V_1	=	velocity at Point 1;
H_p	=	elevation head provided by water supply;

g	=	acceleration due to gravity;
Z_2	=	elevation at Point 2;
P_2	=	pressure at Point 2;
V_2	=	velocity at Point 2; and

$\Sigma h_{L_{1-2}}$ = summation of frictional losses between Point 1 and 2.

The friction head loss due to the pipe is caused by:

- 600 ft of 6" carbon steel. ✓

The friction head loss due to the fittings are caused by:

- (3) 4" long radius flanged 90° elbow; and ✓
- (1) 4" globe valve. ✓

The friction loss in the pipe will be calculated using the Darcy-Weisbach formula:

$$h_f = f \frac{L}{D} \frac{V^2}{2g} \quad (10)$$

✓

where:

h_f	=	friction head in pipe;
f	=	friction factor;
L	=	length of pipe;
V	=	average velocity of the liquid = Q/A;
Q	=	flow rate;
A	=	area of pipe = $\frac{\pi}{4}(D)^2$;
D	=	inside diameter of pipe.

The friction factor is a function of Reynolds number (Re), and the relative roughness of pipe and will be determined using the chart developed by Moody. The parameters will be calculated as follows:

- the Reynolds number will be calculated as follows:

[redacted]

$$Re = \frac{DV}{\nu} \qquad (11)$$

where:

D	=	inside diameter of pipe;
V	=	average velocity of the liquid; and
ν	=	kinematic viscosity of water.

- the relative roughness was calculated as follows:

k_s/D	=	equivalent sand roughness of pipe / inside diameter of pipe.

The friction loss in the fittings will be calculated using the following formula:

$$h_{L\ fittings} = \Sigma\ K_{fittings} \frac{V^2}{2g} \qquad (12)$$

where:

$K_{fittings}$	=	loss coefficient for each types of fitting; and
V	=	average velocity of liquid.

POTABLE WATER SUPPLY DESIGN REQUIREMENTS FOR THE DECONTAMINATION FACILITY

CALCULATION PROCEDURE

PURPOSE OF ANALYSIS

The decontamination facility will require potable a water supply during cell construction. To select the appropriate piping size and supply requirement to deliver the potable water demand this location, the pipe head losses expected in the system must be calculated.

METHOD OF ANALYSIS

The following procedure was used to calculate the expected head loss in the system:

- the potable water supply at Building 78 which supplies the potable water header for the decontamination facility should have an adequate capacity to supply the anticipated flow; the proposed water line is shown on Figure 1; a detailed drawing of the system is presented in Figure 4. ✓

- the potable water demand is estimated to be 3600 gpd with a peak demand of 30 gpm in Calculation Package 14.5, "Decontamination Facility Water Demand"; and ✓

- the pressure head required at the supply is calculated using the conservation of energy

$$Z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + H_p = Z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \Sigma h_{L_{1-2}} \quad (13)$$

equation:
where:

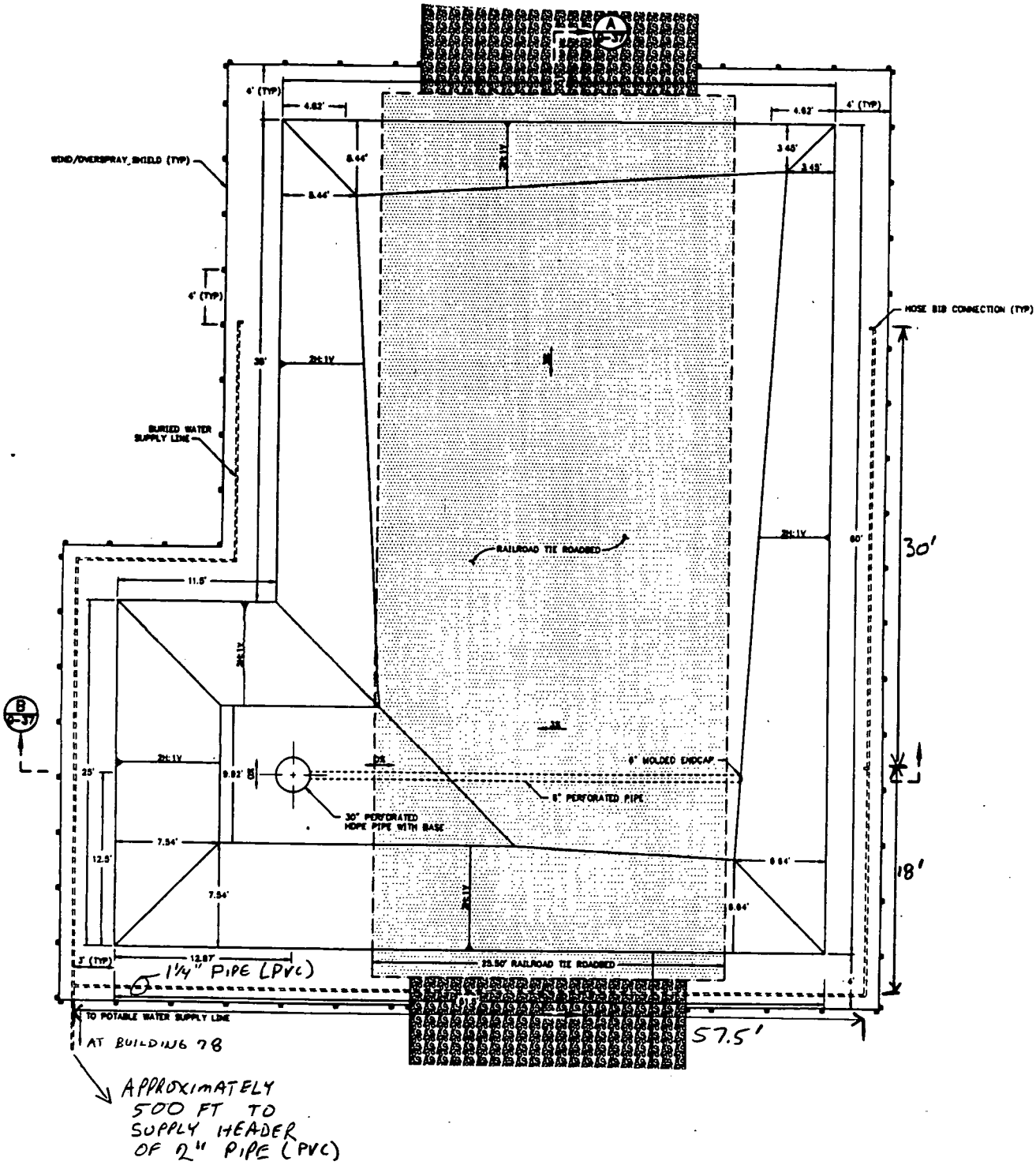
Z_1	=	elevation at Point 1
P_1	=	pressure at Point 1
γ	=	unit weight of raw water
V_1	=	velocity at point 1
g	=	acceleration due to gravity

Written by: BRIAN D. JACOBSON Date: 96/06/07 (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96/06/10 (YY MM DD)

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

FIGURE 4

DETAILED SYSTEM LAYOUT



APPROXIMATELY 500 FT TO SUPPLY HEADER OF 2" PIPE (PVC)

[redacted]

Z_2 = elevation at Point 2
P_2 = pressure at Point 2
V_2 = velocity at Point 2
H_p = pressure head provided by the water supply

$\Sigma h_{L_{1-2}}$ = summation of frictional losses between Point 1 and 2

The friction head loss due to the pipe is caused by:

- (2) 2" gate valves; ✓
- (2) 2" 45° elbows; ✓
- (1) 2" tee (branch); ✓
- (1) 2"x1-1/4" reducer; ✓
- (3) 1-1/4" 90° elbow; ✓
- (1) 1-1/4" tee (line); ✓
- (1) 3/4" hose bib; ✓

The friction head loss due to the fittings are caused by:

- 500 ft of 2" pipe. ✓
- 105.5 ft of 1-1/4" pipe. ✓

The friction loss in the pipe will be calculated using the Darcy-Weisbach formula:

$$h_f = f \frac{L}{D} \frac{V^2}{2g} \quad (14)$$

✓

where:

h_f = friction head in pipe;
f = friction factor;
L = length of pipe;

V = average velocity of the liquid = Q/A;

Q = flow rate;

A = area of pipe = $\frac{\pi}{4}(D)^2$;

D = inside diameter of pipe.

The friction factor is a function of Reynolds number (Re), and the relative roughness of pipe and will be determined using the chart developed by Moody. The parameters will be calculated as follows:

- the Reynolds number will be calculated as follows:

$$Re = \frac{DV}{\nu} \qquad (15)$$

where:

D = inside diameter of pipe;
V = average velocity of the liquid; and
ν = kinematic viscosity of water.

- the relative roughness was calculated as follows:

k_s/D = equivalent sand roughness of pipe / inside diameter of pipe.

The friction loss in the fittings will be calculated using the following formula:

$$h_{L\ fittings} = \Sigma\ K_{fittings}\ \frac{V^2}{2g} \qquad (16)$$

where:

$K_{fittings}$ = loss coefficient for each types of fitting; and
V = average velocity of liquid.

Written By : BRIAN D JACOBSON Date: 11 June 96 Reviewed by: DENIS R SAUSSUS DRS Date: 13 JUNE 96

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

POTABLE WATER DEMAND

DATA VERIFICATION

[redacted]

Written by: BRIAN D. JACOBSON Date: 11 June 96 Reviewed by: DENIS R SAUSSUS DRS Date: 13 JUNE 96

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

POTABLE WATER SUPPLY DESIGN REQUIREMENTS FOR THE CONSTRUCTION ADMINISTRATION AREA DATA VERIFICATION

Using the pipe routing to Trailer #7 as the worst case scenario for the calculation, the following values are established:

Q	=	240 gpm ✓
Z_1	=	580 ft elevation - 3 ft pipe burial = 577 ft ✓
Z_2	=	593 ft elevation + 6 ft to structure = 599 ft ✓
ν	=	kinematic viscosity of water @ 50° = 1.41×10^{-5} ft²/sec ✓

h_f terms

Inside Diameters:	1½"	=	0.125 ft	✓
	2"	=	0.167 ft	✓
	4"	=	0.333 ft	✓
Length of Pipes:	1½"	=	150 ft Sch. 40 PVC	✓
	2"	=	150 ft Sch. 40 PVC	✓
	4"	=	890 ft Sch. 40 PVC	✓

$\Sigma h_{L\ fittings}$ terms	K	Source	
(1) 4" tee - line	0.145	H	✓
(1) 4"/2" reducer	0.065	R	✓
(1) 2" tee - branch	0.85	H	✓
(1) 2"/1½" reducer	0.058	R	✓
(1) 1½" regular 90° elbow	0.4	H	✓

R = Roberson/Crow, Engineering Fluid Mechanics, Fourth ed., Houghton Miffin Co., Boston, Mass.
H = Pipe Friction Manual, 3rd ed., Hydraulic Institute, Cleaveland, Ohio, 1961

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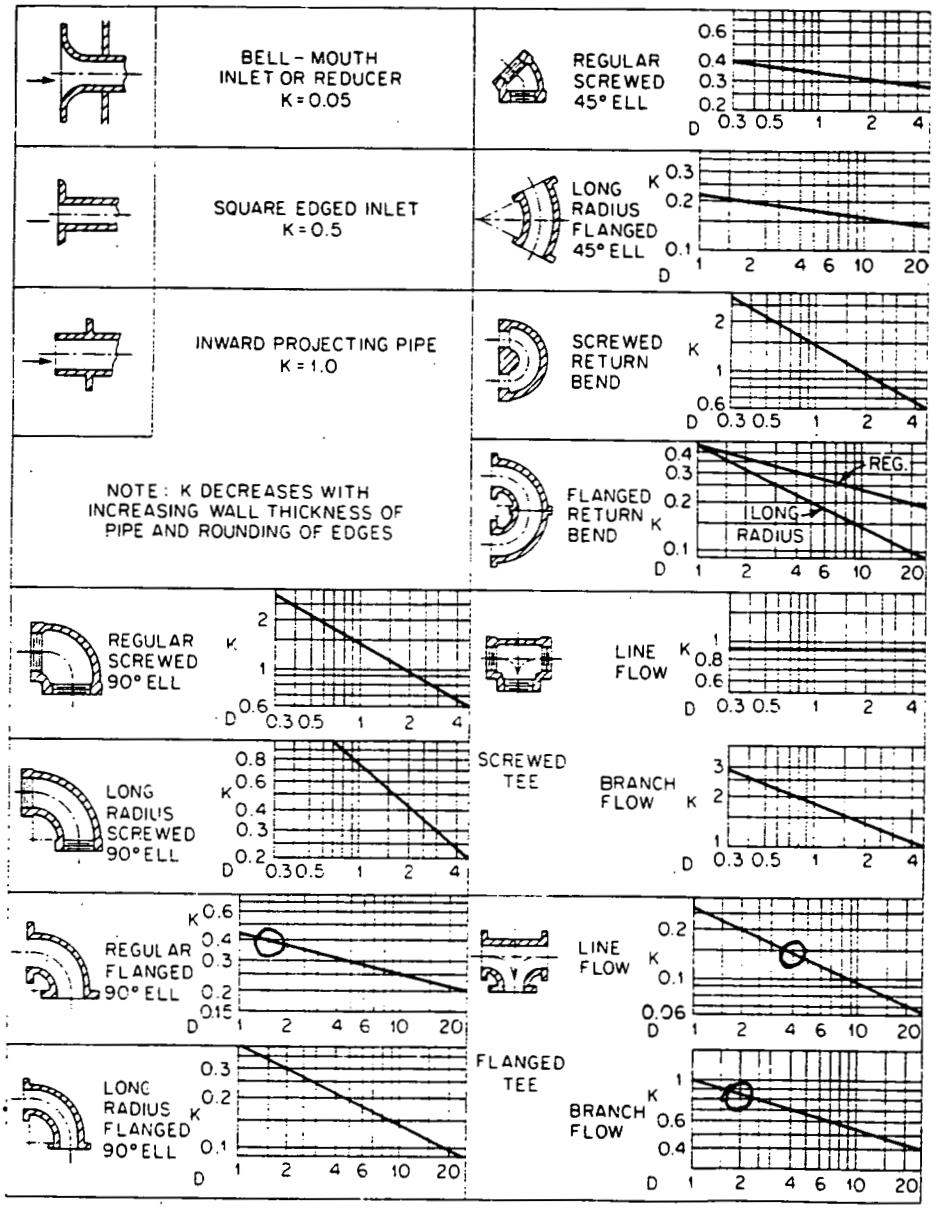
Client: FERMCO Project: Fernald OSDF Project/Proposal No.: 6E3900 Task No.: 8.6

FIGURE 5

Resistance Coefficients K for Valves and Fittings



$h = K \frac{V^2}{2g}$ FEET (METERS) OF FLUID

NOTE: D = nominal iron pipe size in inches (in × 25.4 = mm).

Source: *Pipe Friction Manual*, 3d ed., Hydraulic Institute, Cleveland, 1961.

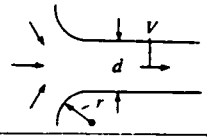
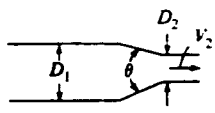
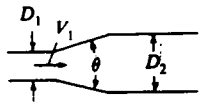
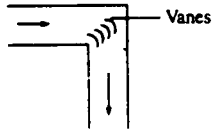
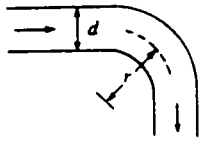
[redacted]

Written by: BRIAN JACOBSON Date: 961061/11 (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 961061/13 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GF3900 Task No.: 8.6

FIGURE 6

LOSS COEFFICIENTS FOR VARIOUS TRANSITIONS AND FITTINGS

Description	Sketch	Additional Data	K
Pipe entrance		r/d	K_r
		0.0	0.50
		0.1	0.12
$h_L = K_r V^2/2g$		>0.2	0.03
Contraction		D_2/D_1	K_C $\theta = 60°$ / K_C $\theta = 180°$
		0.0	0.08 / 0.50
		0.20	0.08 / 0.49
		0.40	0.07 / 0.42
		0.5 0.60	0.06 / 0.32
		0.75 0.80	0.05 / 0.18
$h_L = K_C V_2^2/2g$		0.90	0.04 / 0.10
Expansion		D_1/D_2	K_E $\theta = 10°$ / K_E $\theta = 180°$
		0.0	1.00
		0.20	0.13 / 0.92
		0.40	0.11 / 0.72
		0.60	0.06 / 0.42
$h_L = K_E V_1^2/2g$		0.80	0.03 / 0.16
90° miter bend		Without vanes	$K_b = 1.1$
		With vanes	$K_b = 0.2$
90° smooth bend		r/d	
		1	$K_b = 0.35$
		2	0.19
		4	0.16
		6	0.21
		8	0.28
		10	0.32

Threaded pipe fittings		
	Globe valve — wide open	$K_v = 10.0$
	Angle valve — wide open	$K_v = 5.0$
	Gate valve — wide open	$K_v = 0.2$
	Gate valve — half open	$K_v = 5.6$
	Return bend	$K_b = 2.2$
	Tee	
	straight-through flow	$K_t = 0.4$
	side-outlet flow	$K_t = 1.8$
	90° elbow	$K_b = 0.9$
	45° elbow	$K_b = 0.4$

BJ 10 Oct 1996

BJ 10 Oct 1996

Source: Roberson/Crowe, Engineering Fluid Mechanics, Fourth Edition, Houghton Mifflin Co. Boston, Mass.

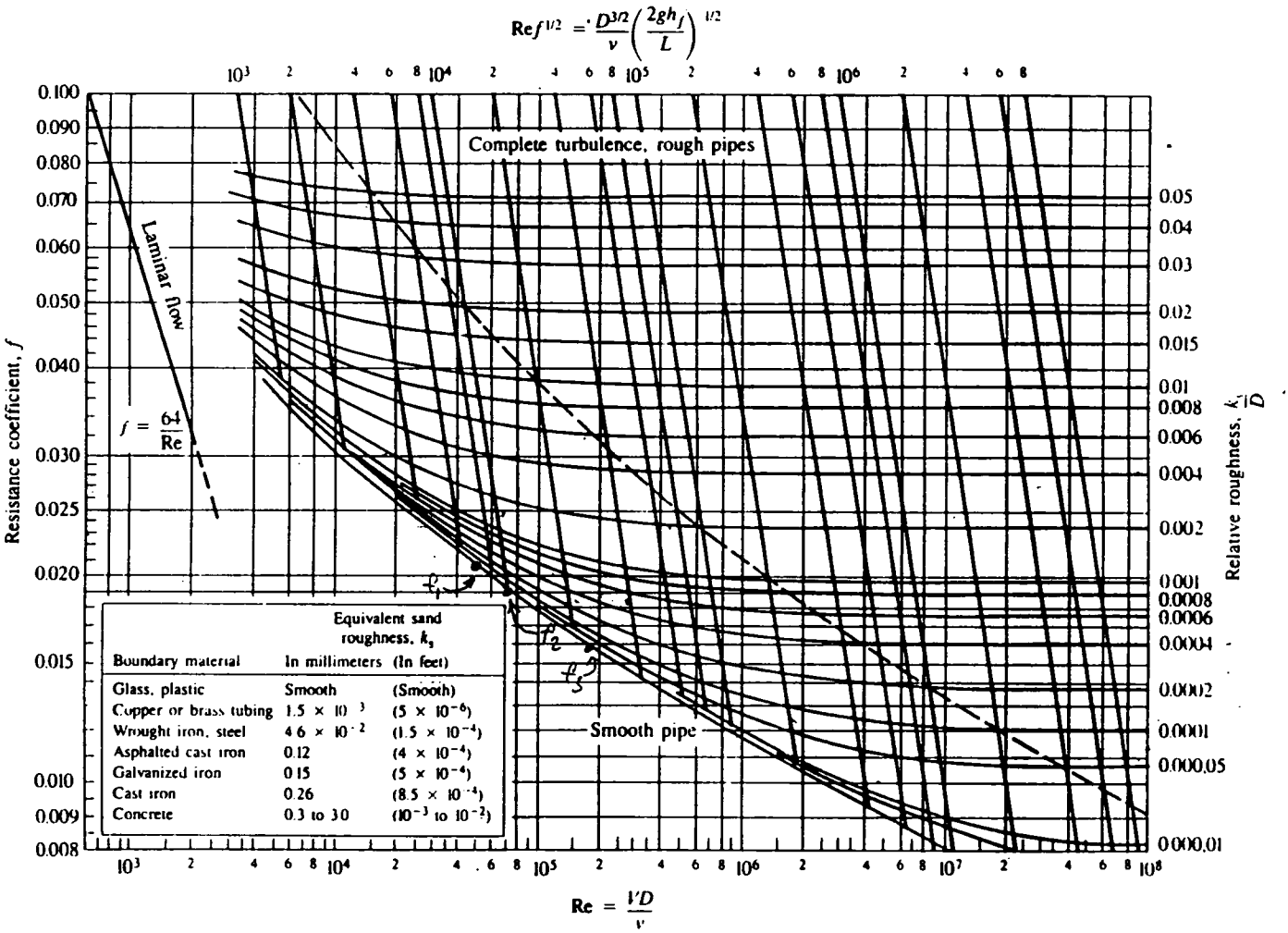
[redacted]

Written by: BRIAN JACOBSON Date: 96 / 06 / 11 (YY MM DD) Reviewed by: DENIS R. SAUSSUS DRS Date: 96 / 06 / 13 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 5.5

FIGURE 7

MOODY DIAGRAM



Written by: BRIAN D. JACOBSON Date: 11 June 96 Reviewed by: DENIS R SPAUSSUS DRS Date: 13 JUNE 96

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

FIRE PROTECTION WATER SUPPLY DESIGN REQUIREMENTS FOR THE CONSTRUCTION ADMINISTRATION AREA DATA VERIFICATION

Using the Hydrant #2 pipe routing as the worst case scenario, for the following values are established:

Q = 500 gpm = 1.11 ft^2/sec (NFPA code) ✓

Z_1 = 580 ft elevation - 3 ft pipe burial = 577 ft ✓
Z_2 = 593 ft elevation +3 ft to hydrant = 596 ft ✓
(elevations estimated from site development Drawing G-2)
ν = kinematic viscosity of water @ 50° = 1.41×10^{-5} ft^2/s ✓

h_f terms

Inside Diamer of Pipe: 4" = 0.333 ft (Carbon Steel) ✓
Length of Pipe: 1100 ft ✓

$\Sigma h_{L\ fittings}$ terms	K	Source	
(2) 4" 90° elbow	0.31	H	✓
(1) 4" tee	0.15	H	✓
(1) 4" 45° elbow	0.18	H	✓

k_s = 1.5E-4 ft (from table on Moody Chart)

H = Pipe Friction Manual, 3rd ed., Hydraulic Institute, Cleaveland, Ohio, 1961

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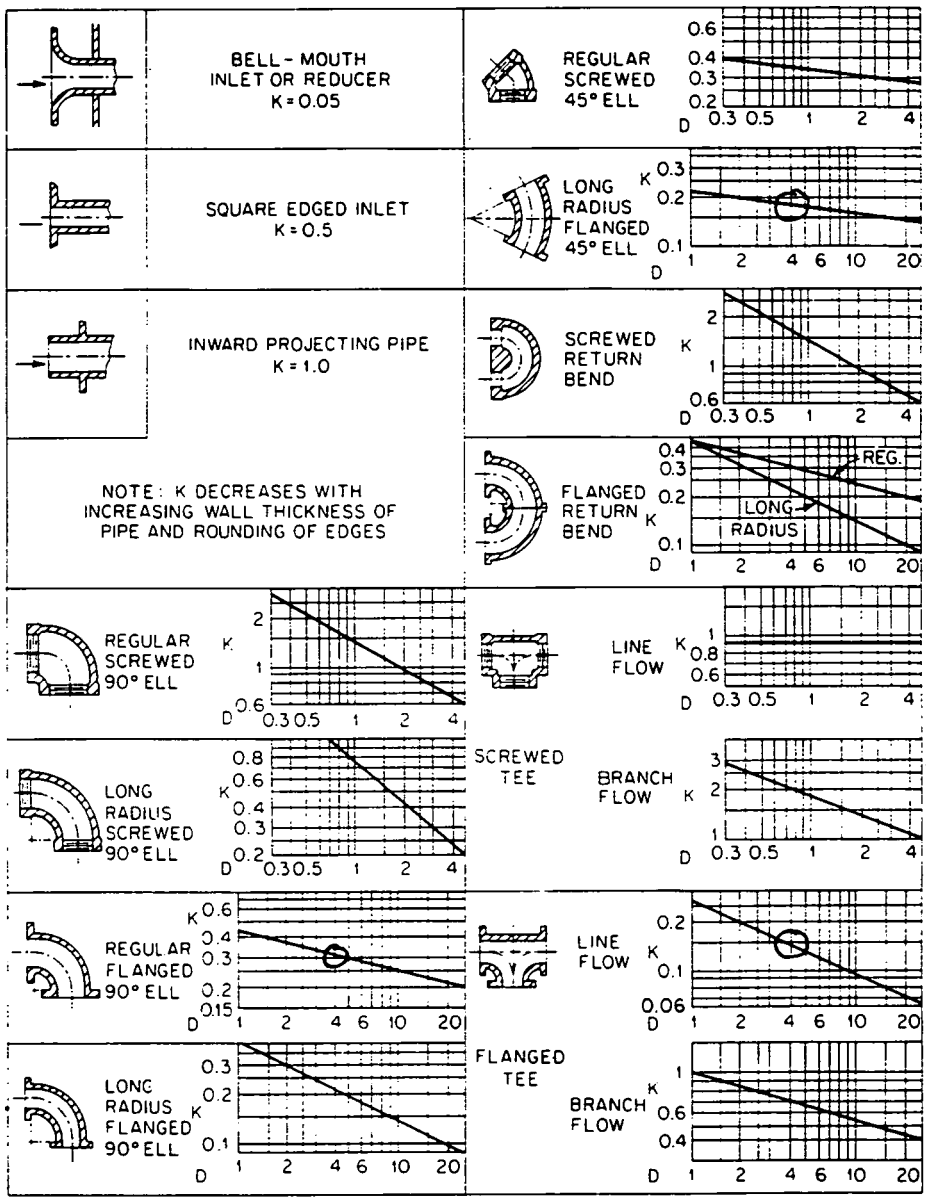
Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE 3900 Task No.: 8.6

FIGURE 8

Resistance Coefficients K for Valves and Fittings



$h = K \frac{V^2}{2g}$ FEET (METERS) OF FLUID

NOTE: D = nominal iron pipe size in inches (in × 25.4 = mm).

Source: *Pipe Friction Manual*, 3d ed., Hydraulic Institute, Cleveland, 1961.

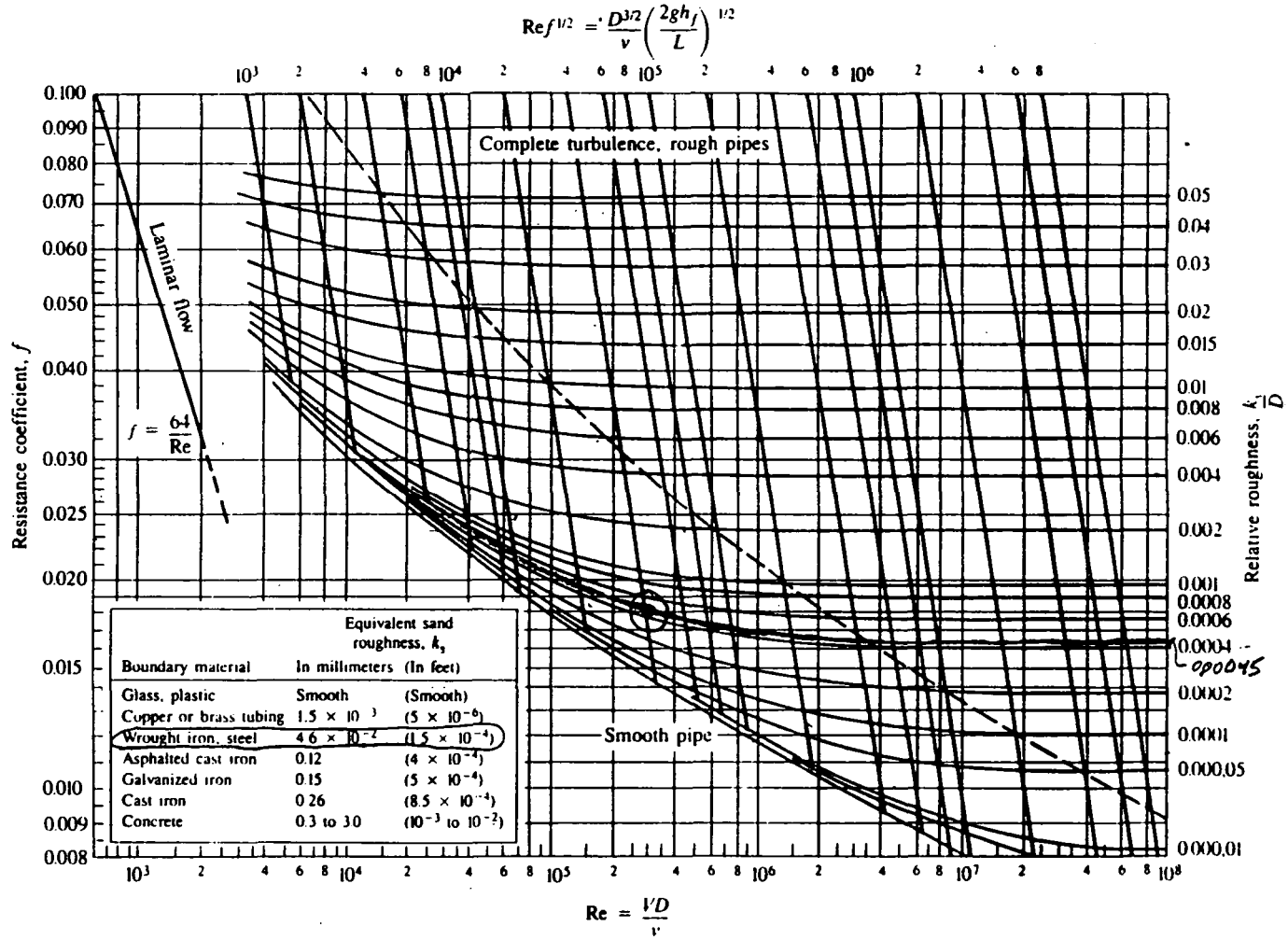
[redacted]

Written by: BRIAN JACOBSON Date: 96/06/11 (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96/06/13 (YY MM DD)

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

FIGURE 9

MOODY DIAGRAM



[redacted]

Written by: BRIAN D. JACOBSON Date: 11 June 96 Reviewed by: DENIS R SAUSSUS DRS Date: 13 JUNE 96

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

WATER SUPPLY DESIGN REQUIREMENTS FOR THE TANKER FILL STATIONS DATA VERIFICATION

Using the Tanker Fill Station near the impacted material haul road as the worst case scenario, the following values are established:

Q	=	450 gpm	✓
Z_1	=	elevation 587 ft	✓
Z_2	=	elevation 605 ft	✓
ν	=	kinematic viscosity of water @ 50° = 1.41×10^{-5} ft²/sec	✓

h_f terms

Inside Diameter of Pipe:	4" = 0.333 ft	✓
Length of Pipe:	600 ft	✓

$\Sigma h_{L\ fittings}$ terms	K	Source	
(3) 4" 90° elbow	0.31	H	✓
(1) 4" globe valve	10.0	R	✓

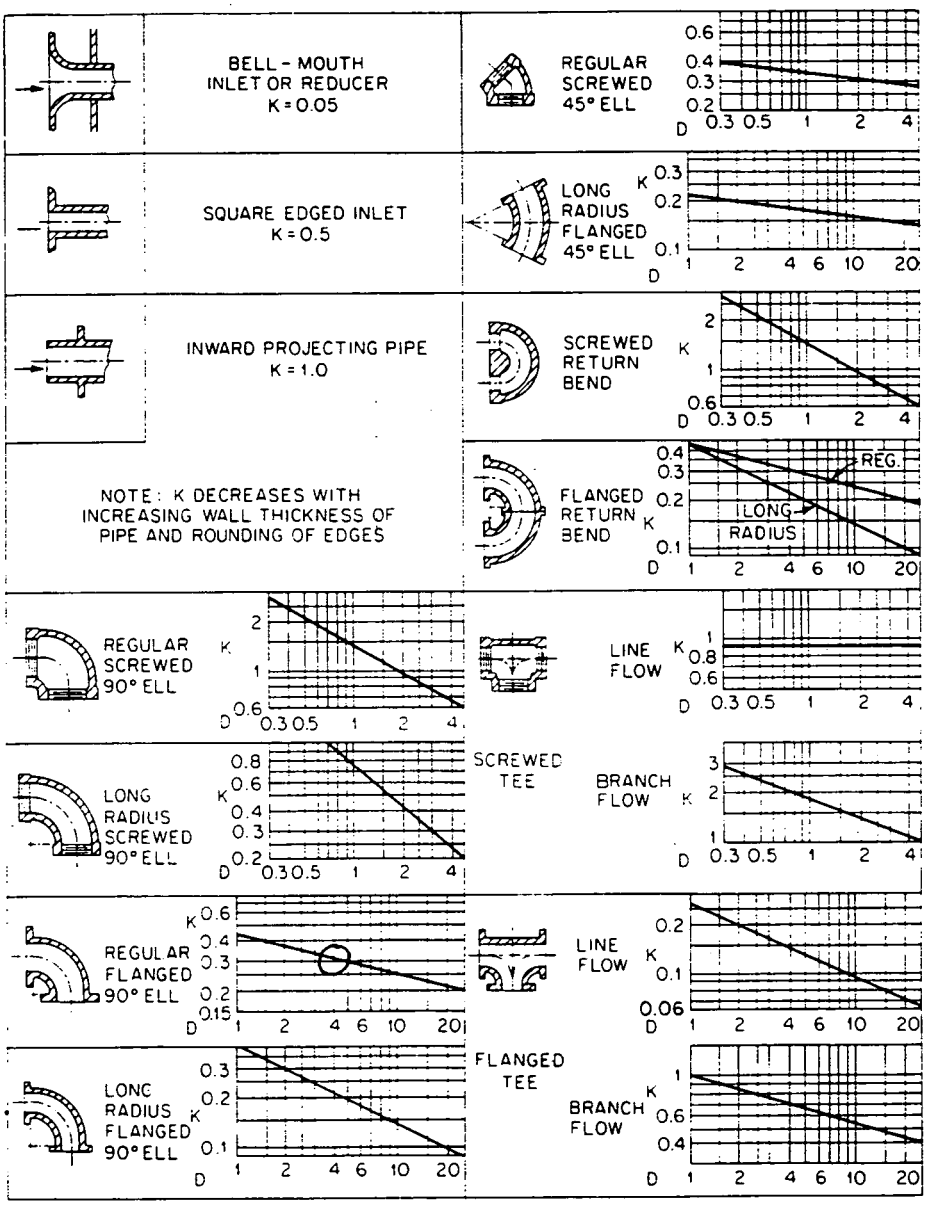
R = Roberson/Crow, Engineering Fluid Mechanics, Fourth ed., Houghton Miffin Co., Boston, Mass.
H = Pipe Friction Manual, 3rd ed., Hydraulic Institute, Cleaveland, Ohio, 1961

Written by: BRIAN JACOBSON Date: 96/06/11 (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96/06/13 (YY MM DD)

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

FIGURE 10

Resistance Coefficients K for Valves and Fittings



$h = K \frac{V^2}{2g}$ FEET (METERS) OF FLUID

NOTE: D = nominal iron pipe size in inches (in × 25.4 = mm).

Source: *Pipe Friction Manual*, 3d ed., Hydraulic Institute, Cleveland, 1961.

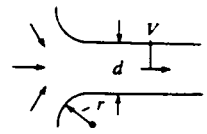
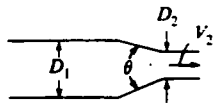
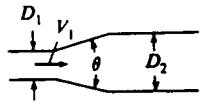
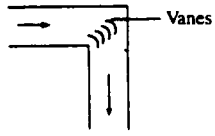
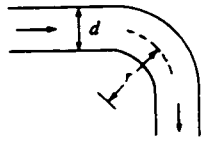
[redacted]

Written by: BRIAN JACOBSON Date: / / (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96 / 06 / 13 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE 3900 Task No.: 5.6

FIGURE 11

LOSS COEFFICIENTS FOR VARIOUS TRANSITIONS AND FITTINGS

Description	Sketch	Additional Data	K
Pipe entrance		r/d	K_e
		0.0	0.50
		0.1	0.12
$h_L = K_e V^2/2g$		>0.2	0.03
Contraction		D_2/D_1	K_C $\theta = 60°$ / K_C $\theta = 180°$
		0.0	0.08 / 0.50
		0.20	0.08 / 0.49
		0.40	0.07 / 0.42
		0.60	0.06 / 0.32
		0.80	0.05 / 0.18
$h_L = K_C V_2^2/2g$		0.90	0.04 / 0.10
Expansion		D_1/D_2	K_E $\theta = 10°$ / K_E $\theta = 180°$
		0.0	/ 1.00
		0.20	0.13 / 0.92
		0.40	0.11 / 0.72
		0.60	0.06 / 0.42
$h_L = K_E V_1^2/2g$		0.80	0.03 / 0.16
90° miter bend		Without vanes	$K_b = 1.1$
		With vanes	$K_b = 0.2$
90° smooth bend		r/d	
		1	$K_b = 0.35$
		2	0.19
		4	0.16
		6	0.21
		8	0.28
		10	0.32
Threaded pipe fittings	Globe valve — wide open	$K_v = 10.0$	
	Angle valve — wide open	$K_v = 5.0$	
	Gate valve — wide open	$K_v = 0.2$	
	Gate valve — half open	$K_v = 5.6$	
	Return bend	$K_b = 2.2$	
	Tee		
	straight-through flow	$K_t = 0.4$	
	side-outlet flow	$K_t = 1.8$	
	90° elbow	$K_b = 0.9$	
	45° elbow	$K_b = 0.4$	

Source: Roberson/Crow, Engineering Fluid Mechanics, Fourth Edition, Houghton Mifflin Co. Boston, Mass.

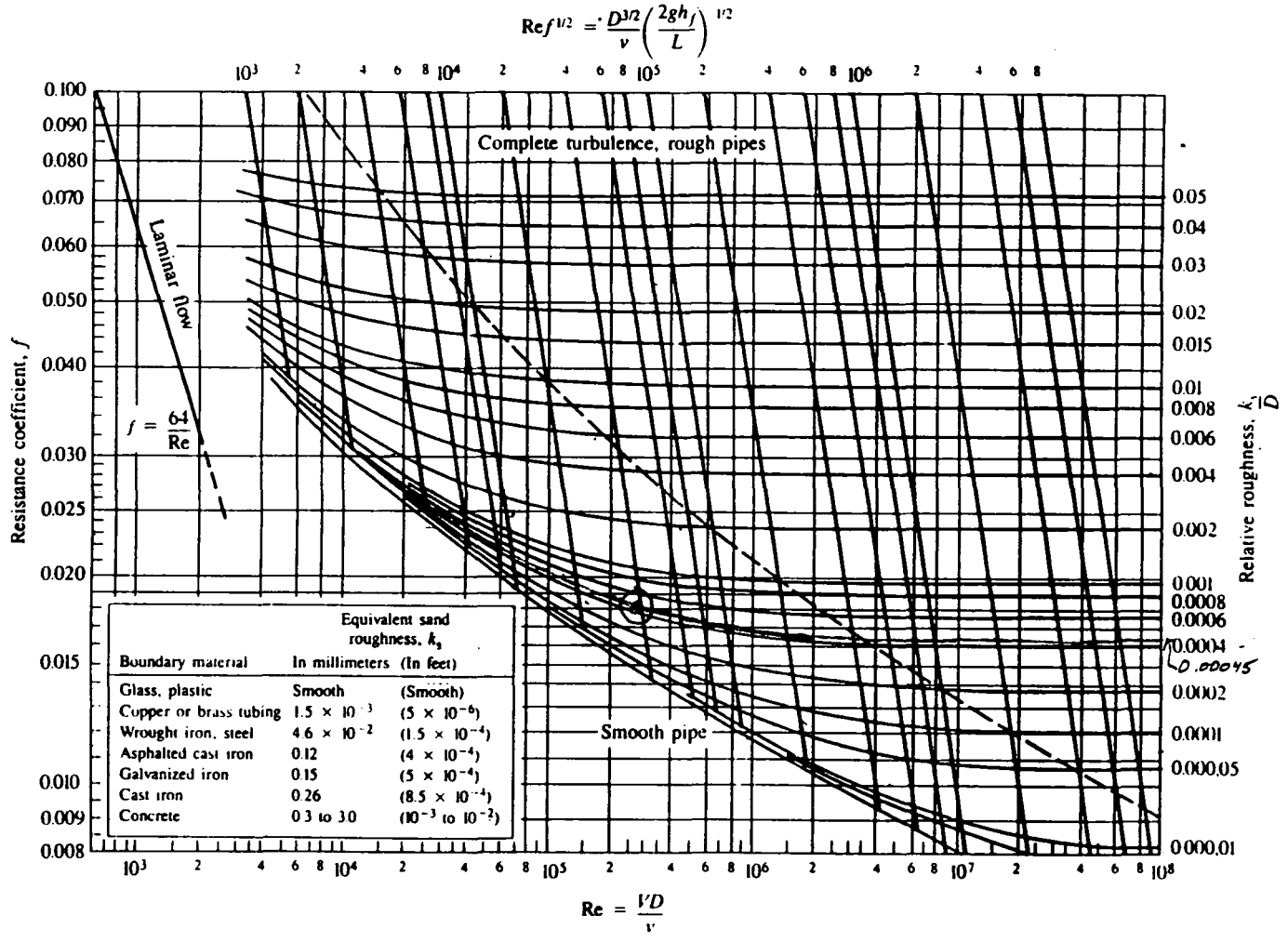
[redacted]

Written by: BRIAN JACOBSON Date: / / (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96 / 06 / 13 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 5.6

FIGURE 12

MOODY DIAGRAM



Boundary material	Equivalent sand roughness, k_s In millimeters	(In feet)
Glass, plastic	Smooth	(Smooth)
Copper or brass tubing	1.5×10^{-3}	(5×10^{-6})
Wrought iron, steel	4.6×10^{-2}	(1.5×10^{-4})
Asphalted cast iron	0.12	(4×10^{-4})
Galvanized iron	0.15	(5×10^{-4})
Cast iron	0.26	(8.5×10^{-4})
Concrete	0.3 to 3.0	$(10^{-3}$ to $10^{-2})$

[redacted]

Written by: BRIAN D. JACOBSON Date: 11 June 96 Reviewed by: DENIS R SAMSSUS DRS Date: 13 JUNE 96

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

POTABLE WATER SUPPLY DESIGN REQUIREMENTS FOR THE DECONTAMINATION FACILITY

DATA VERIFICATION

Using the required flows to the farthest fitting as the worst case basis for the calculation, the following values are established.

Q	=	30 gpm
Z_1	=	elevation 587 ft
Z_2	=	elevation 600 ft
ν	=	kinematic viscosity of water @ 50° = 1.41×10^{-5} ft²/sec

h_f terms

Inside Diameters:	1-1/4"	=	0.125 ft
	2"	=	0.167 ft
Length of Pipes:	1-1/4"	=	105.5 ft Sch. 40 PVC
	2"	=	500 ft Sch. 40 PVC

$\Sigma h_{L\ fitting}$ terms	K	Source
• (2) 2" gate valves	0.2	R
• (2) 2" 45° elbows	0.3	H
• (1) 2" tee (branch)	0.85	H
• (1) 2"x1-1/4" reducer	0.06	R
• (3) 1-1/4" 90° elbow	1.6	H
• (1) 1-1/4" tee (line)	0.9	H
• (1) 3/4" hose bib	10.0	R

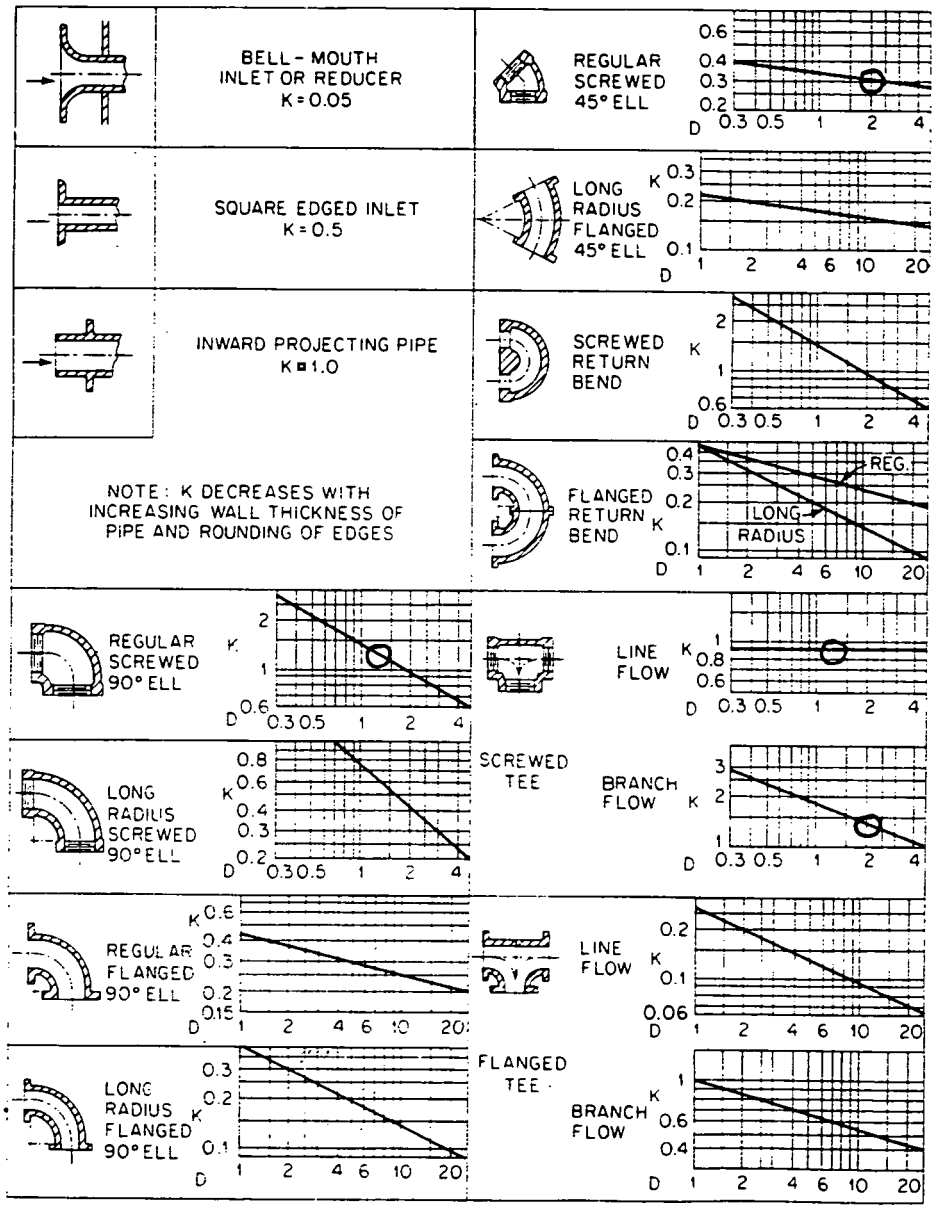
R = Roberson/Crow, Engineering Fluid Mechanics, Fourth ed., Houghton Miffin Co., Boston, Mass.
H = Pipe Friction Manual, 3rd ed., Hydraulic Institute, Cleaveland, Ohio, 1961

Written by: BRIAN D. JACOBSON Date: 96/06/11 (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96/06/13 (YY MM DD)

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

FIGURE 13

Resistance Coefficients K for Valves and Fittings



$h = K \frac{V^2}{2g}$ FEET (METERS) OF FLUID

NOTE: D = nominal iron pipe size in inches (in × 25.4 = mm).

Source: *Pipe Friction Manual*, 3d ed., Hydraulic Institute, Cleveland, 1961.

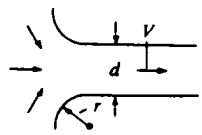
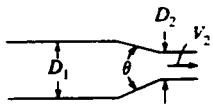
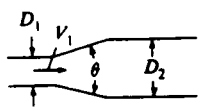
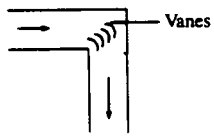
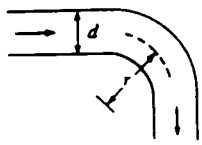
[redacted]

Written by: BRIAN JACOBSON Date: 96/06/11 (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96/06/13 (YY MM DD)

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

FIGURE 14

LOSS COEFFICIENTS FOR VARIOUS TRANSITIONS AND FITTINGS

Description	Sketch	Additional Data	K	
Pipe entrance		r/d	K_e	
		0.0	0.50	
		0.1	0.12	
$h_L = K_e V^2/2g$		>0.2	0.03	
Contraction		D_2/D_1	K_C $\theta = 60°$	K_C $\theta = 180°$
		0.0	0.08	0.50
		0.20	0.08	0.49
		0.40	0.07	0.42
		0.60	0.06	0.32
		0.80	0.05	0.18
$h_L = K_C V_2^2/2g$		0.90	0.04	0.10
Expansion		D_1/D_2	K_E $\theta = 10°$	K_E $\theta = 180°$
		0.0		1.00
		0.20	0.13	0.92
		0.40	0.11	0.72
		0.60	0.06	0.42
$h_L = K_E V_1^2/2g$		0.80	0.03	0.16
90° miter bend		Without vanes	$K_b = 1.1$	
		With vanes	$K_b = 0.2$	
90° smooth bend		r/d		
		1	$K_b = 0.35$	
		2	0.19	
		4	0.16	
		6	0.21	
		8	0.28	
		10	0.32	
Threaded pipe fittings	Globe valve — wide open	$K_v = 10.0$		
	Angle valve — wide open	$K_v = 5.0$		
	Gate valve — wide open	$K_v = 0.2$		
	Gate valve — half open	$K_v = 5.6$		
	Return bend	$K_b = 2.2$		
	Tee			
	straight-through flow	$K_t = 0.4$		
	side-outlet flow	$K_t = 1.8$		
	90° elbow	$K_b = 0.9$		
	45° elbow	$K_b = 0.4$		

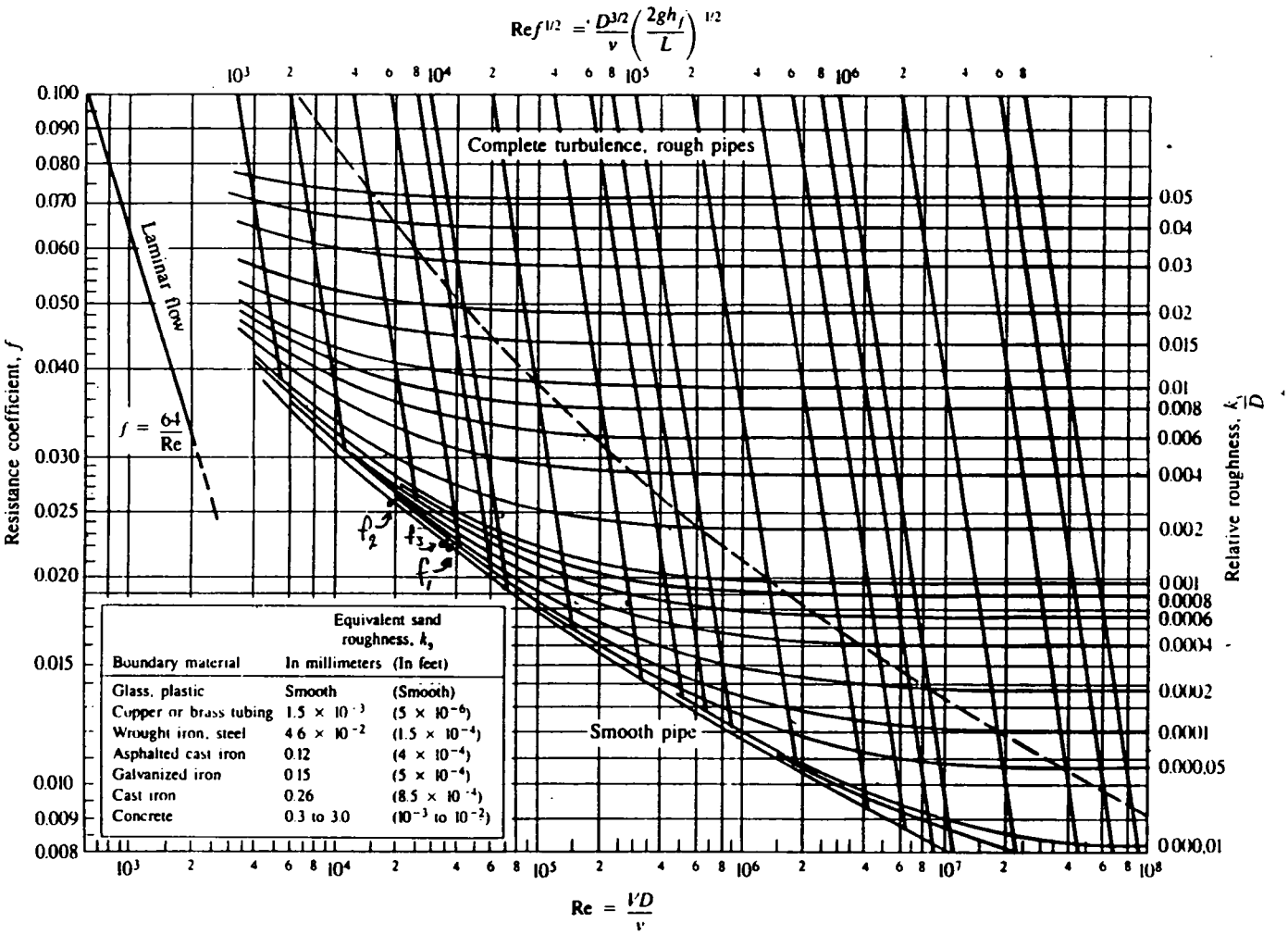
Source: Roberson/Crowe, Engineering Fluid Mechanics, Fourth Edition, Houghton Mifflin Co. Boston, Mass.

[redacted]

Written by: BRIAN D JACOBSON Date: 96/06/11 (YY MM DD) Reviewed by: DENIS R STRUSSUS DRS Date: 96/06/13 (YY MM DD)

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

FIGURE 15



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Written By : BRIAN D JACOBSON Date: 96/06/14 Reviewed by: DENIS R SAUSSUS DRS Date: 17 JUNE 96

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

POTABLE WATER DEMAND

ANALYSIS RESULTS

Written by: BRIAN JACOBSON Date: 96/06/14 (YY/MM/DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96/06/17 (YY/MM/DD)

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

POTABLE WATER SUPPLY DESIGN REQUIREMENTS

FOR THE CONSTRUCTION ADMINISTRATION AREA

ANALYSIS RESULTS

$V = \frac{Q}{A}$

1½" $V_1 = \frac{30\,gal}{min} \frac{1\,min}{60\,sec} \frac{1\,ft^3}{7.48\,gal} \frac{1}{(\pi/4)[0.125]^2} = 5.45\,ft/sec$ ✓

2" $V_2 = \frac{60\,gal}{min} \frac{1\,min}{60\,sec} \frac{1\,ft^3}{7.48\,gal} \frac{1}{(\pi/4)(0.167)^2} = 6.10\,ft/sec$ ✓

4" $V_3 = \frac{240\,gal}{min} \frac{1\,min}{60\,sec} \frac{1\,ft^3}{7.48\,gal} \frac{1}{(\pi/4)(0.333)^2} = 6.14\,ft/s$ ✓

$Re = \frac{VD}{\nu}$

1½" $Re_1 \quad \frac{5.45\,(0.125)}{1.41E-5} = 4.8E4$ ✓

2" $Re_2 \quad \frac{6.10\,(0.167)}{1.41E-5} = 7.2E4$ ✓

4" $Re_3 \quad \frac{6.14\,(0.333)}{1.41E-5} = 1.5E5$ ✓

$\frac{Ks}{D}$ = 1½ smooth pipe curve

2" smooth pipe curve

4" smooth pipe curve

FROM MOODY DIAGRAM

$f_1 = 0.021$ ✓

$f_2 = 0.019$ ✓

$f_3 = 0.016$ ✓

[redacted]

Written by: BRIAN JACOBSON Date: 96/06/14 (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96/06/17 (YY MM DD)

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

$$h_{f_1} = 0.021 \frac{150}{0.125} \frac{5.45^2}{2(32.2)} = 11.6 \text{ ft} \quad ✓$$

$$h_{f_2} = 0.019 \frac{150}{0.167} \frac{6.10^2}{2(32.2)} = 9.9 \text{ ft} \quad ✓$$

$$h_{f_3} = 0.016 \frac{890}{0.333} \frac{6.14^2}{2(32.2)} = 25.0 \text{ ft} \quad ✓$$

$$\Sigma h_{L,\,Fittings} = \left[\frac{(0.145)\,6.14^2 + (0.065+0.85)\,6.10^2 + (0.058+0.4)\,5.45^2}{2\,(32.2)} \right]$$

$$= 0.8 \text{ ft} \quad ✓$$

$$\Sigma h_{L\,1-2} = 11.6 + 9.9 + 25.0 + 0.8 = 47.3 \text{ ft} \quad ✓$$

$$H_p = 599 - 577 + 47.3 = 69.3 \text{ ft} \text{ - SAY } 70 \text{ ft} \quad ✓$$

CONCLUSION

A POTABLE WATER SUPPLY ENTERING THE CONSTRUCTION ADMINISTRATION AREA AT A RATE OF 240 gpm WILL INCUR A HEAD LOSS OF 70 FT IN THE WORST CASE SCENARIO. THE POTABLE WATER LINE MUST MAINTAIN A RESIDUAL PRESSURE OF 30 PSI (70 ft) FOR HEALTH REASONS. CONCLUDE THAT THE SUPPLY NEAR THE SUBSTATION MUST BE CAPABLE OF A FLOW OF 240 gpm AT A DYNAMIC HEAD OF 140 FT. ✓

[redacted]

Written by: BRIAN JACOBSON Date: 96/06/14 (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96/06/17 (YY MM DD)

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

FIRE PROTECTION WATER SUPPLY DESIGN REQUIREMENTS

FOR CONSTRUCTION ADMINISTRATION AREA

ANALYSIS RESULTS

$V = \frac{Q}{A} =$ 4" $V_1 = 500 \frac{gal}{min} \frac{1 min}{60 sec} \frac{1 ft^3}{7.48 gal} \frac{1}{(\pi/4)(0.333)^2} = 12.8 ft/s$ ✓

$Re = \frac{VD}{\nu}$ $R_1 = \frac{(12.8)(0.333)}{1.41E-5} = 3.0E5$ ✓

$\frac{K_s}{D} = \frac{1.5E-4}{0.333} = 4.5E-4$ ✓

FROM MOODY DIAGRAM

$f = 0.018$ ✓

$h_f = 0.018 \frac{1100}{0.333} \frac{(12.8)^2}{2(32.2)} = 151.3 FT$ ✓

$\Sigma h_{L, Fittings} = \frac{(2 \cdot 0.31 + 0.15 + 0.18) 12.8^2}{2(32.2)} = 2.4 FT$ ✓

$H_p = 596 - 577 + 151.3 + 2.4 = 172.7 FT$ SAY 175 FT ✓

[redacted]

Written by: BRIAN JACOBSON Date: 96/06/14 (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96/06/17 (YY MM DD)

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

CONCLUSION

A FIRE PROTECTION WATER SUPPLY ENTERING THE CONSTRUCTION ADMINISTRATION AREA AT A RATE OF 500 gpm WILL INCUR A HEAD LOSS OF 175 FT IN THE WORST CASE SCENARIO. THE FIRE PROTECTION WATER LINE MUST MAINTAIN A RESIDUAL PRESSURE OF 10 PSI (23 FT). CONCLUDE THAT THE SUPPLY NEAR THE SUBSTATION MUST BE CAPABLE OF A FLOW OF 500 gpm AT A DYNAMIC HEAD OF 198 FT. ✓

[redacted]

Written by: BRIAN JACOBSON Date: 96/06/14 (YY MM DD) Reviewed by: DENIS R STRUSSNS DRS Date: 96/06/17 (YY MM DD)

Client: FERNALD Project: Fernald OSDF Project/Proposal No.: GE5500 Task No.: 86

WATER SUPPLY DESIGN REQUIREMENTS FOR THE TANKER FILL STATIONS

ANALYSIS RESULTS

$V = \frac{Q}{A}$ 4" $V = \frac{450\,gal}{min} \frac{1\,min}{60\,sec} \frac{1\,ft^3}{7.48\,gal} \frac{1}{(\pi/4)(0.333)^2} = 11.5\ ft/s$ ✓

$Re = \frac{VD}{\nu}$ 4" $Re = \frac{(11.5)(0.333)}{1.41E-5} = 2.7E5$ ✓

$\frac{K_s}{D}$ 4" $= \frac{1.5E-4}{0.333} = 4.5E-4$ ✓

FROM MOODY DIAGRAM

$f = 0.018$ ✓

$h_f = 0.018 \frac{600}{0.333} \frac{(11.5)^2}{2(32.2)} = 66.6\ ft$ ✓

$\Sigma h_{L,fittings} = \frac{(3 \cdot 0.31 + 10.0)\,11.5^2}{2(32.2)} = 22.5\ ft$ ✓

$H_p = 605 - 587 + 66.6 + 22.5 = 107.1\ FT$ ✓

[redacted]

GEOSYNTEC CONSULTANTS

Written by: BRIAN JACOBSON Date: 96/06/14 (YY MM DD) Reviewed by: DENIS R SAUSSUS DRS Date: 96/06/17 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: E16

CONCLUSION

A WATER SUPPLY FOR THE TANKER FILL STATIONS AT A FLOW RATE OF 450 gpm WILL INCUR A HEAD LOSS OF 107 FT. IF POTABLE WATER IS USED, THEN A RESIDUAL PRESSURE OF 30 PSI (70FT) MUST BE MAINTAINED IN THE SUPPLY LINE. CONCLUDE THAT THE SUPPLY MUST BE CAPABLE OF A FLOW OF 450 gpm AT A DYNAMIC HEAD OF 177 FT. ✓

[redacted]

Written by: BRIAN D. JACOBSON Date: 96 / 06 / 14 (YY MM DD) Reviewed by: DENIS R SMUSSUS (DRS) Date: 96 / 06 / 17 (YY MM DD)

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

POTABLE WATER SUPPLY DESIGN REQUIREMENTS FOR THE DECONTAMINATION FACILITY

ANALYSIS RESULTS

$$V = \frac{Q}{A}$$

$$1\tfrac{1}{4}''_{20} = V_1 = \frac{20\,\text{gal}}{\text{min}} \cdot \frac{1\,\text{min}}{60\,\text{sec}} \cdot \frac{1\,\text{ft}^3}{7.48\,\text{gal}} \cdot \frac{1}{(\pi/4)\left[\frac{1.25\,\text{in}}{12\,\text{in/ft}}\right]^2}$$

$$= 5.22\ \text{ft/s} \quad ✓$$

$$1\tfrac{1}{4}''_{10} = V_2 = \frac{10\,\text{gal}}{\text{min}} \cdot \frac{1\,\text{min}}{60\,\text{sec}} \cdot \frac{1\,\text{ft}^3}{7.48\,\text{gal}} \cdot \frac{1}{(\pi/4)\left[\frac{1.25\,\text{in}}{12\,\text{in/ft}}\right]^2}$$

$$= 2.62\ \text{ft/s} \quad ✓$$

$$2''_{30} = V_3 = \frac{30\,\text{gal}}{\text{min}} \cdot \frac{1\,\text{min}}{60\,\text{sec}} \cdot \frac{1\,\text{ft}^3}{7.48\,\text{gal}} \cdot \frac{1}{\frac{\pi}{4}\left[\frac{2\,\text{in}}{12\,\text{in/ft}}\right]^2}$$

$$= 3.06\ \text{ft/s} \quad ✓$$

$$\mathcal{R}e = \frac{VD}{\nu} \qquad \mathcal{R}_1 = \frac{(5.22)\left(\frac{1.25}{12}\right)}{1.41\,E\text{-}5} = 3.9E4 \quad ✓$$

$$\mathcal{R}_2 = \frac{(2.62)\left(\frac{1.25}{12}\right)}{1.41E\text{-}5} = 1.9E4 \quad ✓$$

$$\mathcal{R}_3 = \frac{(3.06)\left(\frac{2}{12}\right)}{1.41E\text{-}5} = 3.6E4 \quad ✓$$

[redacted]

Written by: BRIAN D. JACOBSON Date: 96/06/14 (YY MM DD) Reviewed by: DENIS R STUSSUS (DRS) Date: 96/06/17 (YY MM DD)

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

$\frac{K_s}{D}$ = 1¼ = smooth pipe curve
2" = smooth pipe curve

FROM MOODY DIAGRAM

$f_1 = 0.0215$ ✓

$f_2 = 0.0255$ ✓

$f_3 = 0.0220$ ✓

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

$$h_{f_1} = 0.0215 \frac{755}{0.104} \frac{(5.22)^2}{2(32.2)} = 6.6 \text{ ft} \quad ✓$$

$$h_{f_2} = 0.0255 \frac{30}{0.104} \frac{(2.62)^2}{2(32.2)} = 0.8 \text{ ft} \quad ✓$$

$$h_{f_3} = 0.0220 \frac{500}{0.167} \frac{(3.06)^2}{2(32.2)} = 9.6 \text{ ft} \quad ✓$$

$$\Sigma h_{L,\text{FITTINGS}} = \frac{\left[(0.2+2(0.3)+0.85)3.06^2 + (0.06+1.6+0.9)5.22^2 + (2(1.6)+10)2.62^2\right]}{2(32.2)}$$

$$= 2.7 \text{ ft} \quad ✓$$

$$\Sigma h_{L\,1\text{-}2} = 6.6 + 0.8 + 9.6 + 2.7 = 19.7 \text{ ft} \quad ✓$$

$$H_p = 600 - 587 + 19.7 = 32.7 \text{ ft} = \text{SAY } 35 \text{ ft} \quad ✓$$

[redacted]

Written by: BRIAN D. JACOBSON Date: 96/06/14 (YY MM DD) Reviewed by: DENIS R STUSSUS DRS Date: 96/06/17 (YY MM DD)

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

CONCLUSION

A POTABLE WATER SUPPLY ENTERING THE DECONTAMINATION FACILITY AT A RATE OF 30 gpm WILL INCUR A HEAD LOSS OF 35 FT IN THE WORST CASE SCENARIO. THE POTABLE WATER LINE MUST MAINTAIN A RESIDUAL PRESSURE OF 30 PSI (70 FT) FOR HEALTH REASONS. CONCLUDE THAT THE SUPPLY AT BUILDING 78 MUST BE CAPABLE OF A FLOW OF 30 GPM AT A DYNAMIC HEAD OF 105 FT. ✓

[redacted]

14.3 Sanitary Wastewater Discharge

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: SANITARY WASTEWATER DISCHARGE

Computations By: (Cognizant Engineer)
Signature: Lawrence W Fly — Date: 2-23-96
Printed Name and Title: LAWRENCE W. FLY, PROJECT MANAGER

Assumptions and Procedures Checked by: (Checker)
Signature: Daniel B. Wisniewski — Date: 23 FEB 96
Printed Name and Title: DANIEL B. WISNIEWSKI, ASSISTANT PROJECT ENGINEER

Computations Checked by:
Signature: Daniel B. Wisniewski — Date: 23 FEB 96
Printed Name and Title: DANIEL B. WISNIEWSKI, ASSISTANT PROJECT ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Lawrence W Fly — Date: 2-23-96
Printed Name and Title: LAWRENCE W. FLY, PROJECT MANAGER

Approved by: (PDP)
Signature: Brian D. Jackson — Date: 24 FEB 96
Printed Name and Title: BRIAN D. JACOBSON, STAFF ENGINEER

Approved by: (PTL and TETL)
Signature: [illegible] — Date: 24 Feb 96
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A	Intermediate Design				
D	Intermediate Design - EPA Submitted	5 Apr 96			
G	Final Design Package	4 Oct 96			
O	Response to Final Design Cmts	5 May 97			

[redacted]

Written By : LAWRENCE W. FLY Date: 96/02/23 Reviewed by: DBW Date: 23FEB96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

SANITARY SEWER DISCHARGE

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this calculation package is to perform the required calculations to verify that the sanitary sewer lines in the construction administration area have adequate capacity for the expected loads.

METHODS OF ANALYSIS

The design will be compared with Uniform Plumbing Code and the Ohio Building Code for Modular units to ensure capacity requirements have been achieved.

CONCLUSIONS

The sanitary sewer layout proposed has adequate capacity and design to meet applicble codes and regulations.

[redacted]

GEOSYNTEC CONSULTANTS

Written By : _____ Date: _____ Re

Client: FERMCO Project: FERNALD OSDF

THIS PAGE IS INSERTED ONLY FOR CLARITY AND DOES NOT AFFECT THE NUMBERING SYSTEM OF THE REST OF THE PACKAGE

SANITARY SEWER DISCHARGE
TABLE OF CONTENTS

CALCULATION PROCEDURES	1 of 2
DATA VERIFICATION	1 of 3
ANALYSIS RESULTS	1 of 2

[redacted]

Written By : LAWRENCE W. FLY Date: 96/02/23 Reviewed by: DRM Date: 23FEB96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

SANITARY SEWER DISCHARGE

CALCULATION PROCEDURE

[redacted]

GEOSYNTEC CONSULTANTS

Written by: LAWRENCE W. FLY Date: 96/02/23 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: FERNAL OSDF Project/Proposal No.: GE 3900 Task No.: 10.4

EJ 23 Feb 1996

SANITARY SEWER OUTLET PIPING FOR THE CONSTRUCTION ADMINISTRATION AREA DESIGN REQUIREMENT

THE UNIFORM PLUMBING CODE AND THE OHIO BUILDING CODE REQUIREMENTS FOR MODULAR UNITS (DOUBLE WIDE TRAILERS) THAT HAVE A DOMESTIC WATER SUPPLY LINE OF 1 1/2" SHALL HAVE A SANITARY SEWER OUTLET PIPING OF 4" WITH 1/8" PER 1 FOOT SLOPE. THE 4" OUTLET SHALL TIE-IN TO A 6" HEADER WITH A MAXIMUM 3 TIE-INS.

∴ THEREFORE THE WORST CASE SANITARY SEWER DEMAND WOULD BE TRAILERS 1, 4 & 7 AND 3, 6 & 8 (SEE FIGURE 1) WHICH HAVE POTABLE WATER SUPPLIES OF 1 1/2" (SEE FIGURE 2)

[redacted]

Written By : LAWRENCE W. FLY Date: 96/02/23 Reviewed by: OBIN Date: 23 FEB 96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

SANITARY SEWER DISCHARGE

DATA VALIDATION

BJ
23 Feb 1996

[redacted]

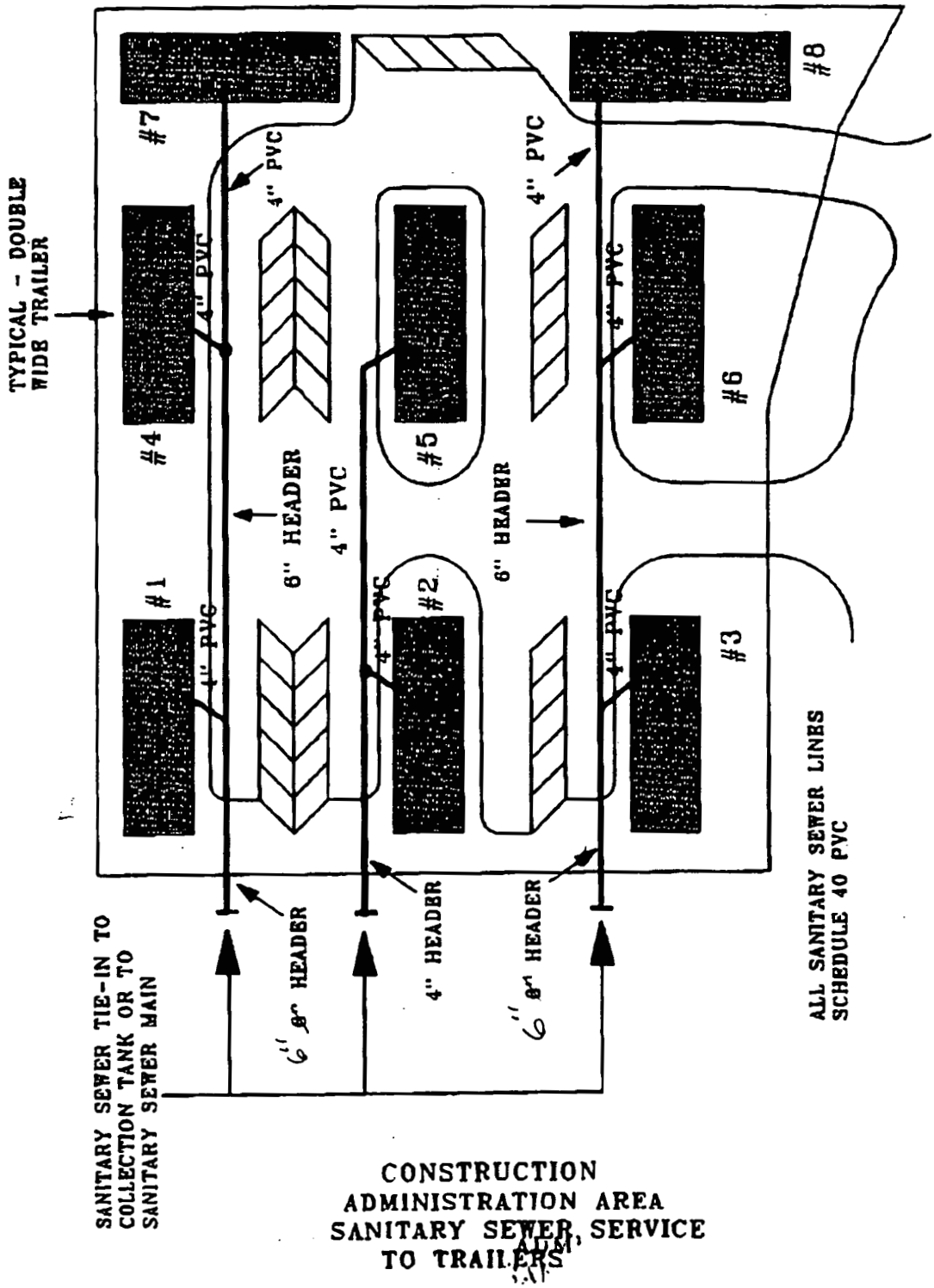
119

Written by: LAWRENCE W. FLV Date: 96/02/23 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

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

FIGURE 1

740



CONSTRUCTION ADMINISTRATION AREA SANITARY SEWER SERVICE TO TRAILERS

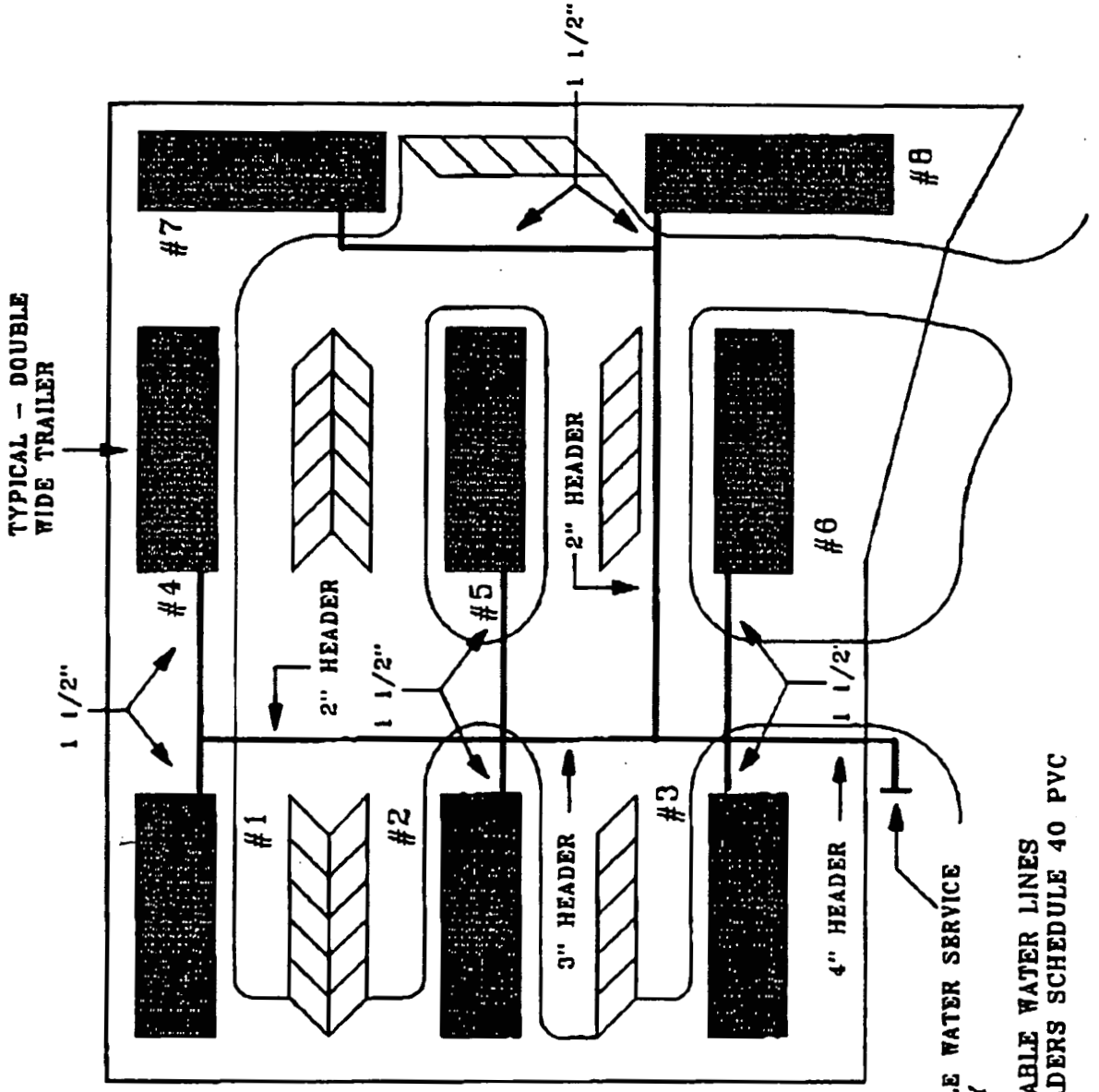
[redacted]

Written by: LAWRENCE W. FLY Date: 96/02/23 (YY MM DD) Reviewed by: DRW Date: 96/02/23 (YY MM DD)

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

FIGURE 2

740



ALL POTABLE WATER LINES AND HEADERS SCHEDULE 40 PVC

CONSTRUCTION ADMINISTRATION AREA POTABLE WATER SERVICE TO TRAILERS

[redacted]

GEOSYNTEC CONSULTANTS

Written By : LAWRENCE W. FLY Date: 96/02/23 Reviewed by: DBW Date: 23 FEB 96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

SANITARY SEWER DISCHARGE

ANALYSIS RESULTS

BJ
23 Feb 1996

[redacted]

Written by: LAWRENCE W. FLY Date: 96/02/23 (YY MM DD) Reviewed by: DBIN Date: 96/02/23 (YY MM DD)

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

740

THE SANITARY SEWER OUTLETS AS SHOWN ON FIGURE 1 SHOULD PROVIDE ADEQUATE SANITARY SEWER OUTLET DEMAND REQUIREMENTS

[redacted]

14.4 Construction Water Demand

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: CONSTRUCTION WATER DEMAND

Computations By: (Cognizant Engineer)	Signature	Kara L. Olen	21 Feb 96 Date
	Printed Name and Title	Kara L. Olen Asst. Proj Engr.	
Assumptions and Procedures Checked by: (Checker)	Signature	B.B. Mazanti	21 Feb 96 Date
	Printed Name and Title	B. B. Mazanti Consultant	
Computations Checked by: Checked by:	Signature	B.B. Mazanti	21 Feb 96 Date
	Printed Name and Title	B. B. Mazanti Consultant	
Computations Backchecked by: (Cognizant Engineer)	Signature	Kara L. Olen	22 Feb 96 Date
	Printed Name and Title	Kara L. Olen Asst. Proj Eng.	
Approved by: (PDP)	Signature	Kara L. Olen	22 Feb 96 Date
	Printed Name and Title	Kara L. Olen Asst Proj Engr	
Approved by: (DTL and TETL)	Signature	[illegible]	23 Feb 96 Date
	Printed Name and Title	Kenneth W Cargill Associate	

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design				
D	Intermediate Design - EPA Submittal	4 Apr 96	[illegible]		
G	Final Design Package	4 Oct 96			[illegible]
C	Response to Final Design Comts	5 May 97			[illegible]

Written by: K. Olen Date: 21 February 1996 Reviewed by: BBM Date: 2/21/96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE-3900 Task No.: 8.4

KL 23 Feb 96

CONSTRUCTION WATER DEMAND

EXECUTIVE SUMMARY

Purpose

The purpose of this calculation package is to estimate the construction water demand required to (i) control dust at the haul roads, (ii) control dust at the OSDF cells receiving waste, and (iii) achieve and maintain acceptable moisture contents for clay liner and clay cap material during construction.

Calculation Method

The water demand for dust control was calculated using the steps presented below.

- calculate the area of haul roads requiring dust control and the area of cells requiring dust control (during landfilling) or moisture maintenance (during construction);
- assume a number of sprays per day that the above areas will receive;
- assume a surficial depth of dry soil to be moistened;
- assume a percent increase in moisture content the dry soil will undergo per spray;
- based on the above assumptions, calculate the corresponding volume of water sprayed per square foot;
- multiply the volume of water sprayed per square foot by the number of sprays per day by the total area to be sprayed; and
- add the additional water demand required to moisture condition the clay materials prior to construction (obtained from *"Borrow Area Water Demand"* calculation)

Conclusions

A total of 96,400 gal/day are required to control dust at the haul roads and the OSDF cells receiving waste, and to achieve and maintain acceptable moisture contents for clay liner and clay cap material during cell construction.

CONSTRUCTION WATER DEMAND

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1.	Calculation Procedure	2/6
2.	Collection and Verification of Data	3/6
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Written by: K. Olen Date: 21 February 1996 Reviewed by: BMM Date: 2/21/96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE-3900 Task No.: 8.4

KL 23 Feb 96

CALCULATION PROCEDURE

Water demand for dust control was calculated using the following equation:

$$Q_d = [(A_1 n_1 + A_2 n_2 + A_3 n_3)\ q] + [Q_{mc}]$$

where:

Q_d	=	construction water demand (gal/day);
A_1	=	area of haul roads requiring dust control (ft^2);
n_1	=	number of sprays per day on haul roads;
A_2	=	area of landfilled material (i.e., impacted material) requiring dust control (ft^2);
n_2	=	number of sprays per day on landfilled material;
A_3	=	cell construction area requiring moisture maintenance (ft^2);
n_3	=	number of sprays per day on cell construction area;
q	=	volume of water sprayed per area (gal/spray/ft^2); and
Q_{mc}	=	quantity of water needed to moisture condition clay liner and clay cap materials (gal/day) (obtained directly from Calculation Package *"Borrow Area Water Demand"*)

Written by: K. Olen Date: 21 February 1996 Reviewed by: [illegible] Date: 2/21/96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE-3900 Task No.: 8.4

23 Feb 96

COLLECTION AND VERIFICATION OF DATA

Information regarding the layout of haul roads and OSDF cells is obtained from Sheet No. G-20: *Site Development Plan Early Stages* (see Figure 1). For the purposes of preparing this construction water demand estimate it will be assumed that landfilling of impacted material will be occurring in the first two cells and the third cell will be under construction. The data used in the construction water demand calculation are presented below.

- Area of Haul Roads (A_1):

Construction Access Road

length = 4200 ft (main road from borrow area to east side of Cells 1 to 3)
600 ft (stub road to Cell 3)
width = 40 ft

Impacted Material Haul Road

length = 800 ft (east-west portion)
700 ft (north-south portion)
width = 40 ft

Borrow Area Haul Road (conceptual layout, worst case longest length assumed)

length = 3500 ft
width = 18 ft

Total:

$$A_1 = (4200\text{ ft} + 600\text{ ft} + 800\text{ ft} + 700\text{ ft})(40\text{ ft}) + (3500\text{ ft})(18\text{ ft})$$

$$A_1 = 315{,}000\text{ sf}$$

- Area of Cells (A_2 and A_3)

Area of cells being actively landfilled (2 assumed)

$$A_2 = (400\text{ ft})(800\text{ ft})(2) = 640{,}000\text{ sf}$$

Area of cells under construction (1 assumed)

A_3 = (400 ft)(800 ft) = 320,000 sf

- Number of sprays per day (n)

It is assumed that on warm days the haul roads will sprayed three times per day to control dust, the cells being actively landfilled will be sprayed 2 times per day to control dust, and the cell under construction will be sprayed once per day over one half its area only to maintain the moisture content of the compacted clay. Therefore:

$n_1 = 3$

$n_2 = 2$

n_3 = (1 per day)(1/2 cell) = 0.5

- Rate of Spray

It is assumed that a 1-inch thick layer of dry soil exists on the surface to be sprayed. The moisture content of this layer is to be raised from ~~zero to~~ 4 percent.

γ_{dry} = 100 lbs/ft^3 (assumed dry unit weight of 1-inch thick layer of dry soil)

m = 0.04 (desired moisture content of 1-inch thick soil layer)

W_w = $(\gamma_{dry})(m)$
= (100 lbs/ft^3)(.04)
= 4 lbs/ft^3 (weight of water added per cubic foot dry soil)

V_s = (1 inch)(1/12 in/ft)(1 ft)(1 ft)
= .0833 ft^3 (volume of 1 inch thick layer of dry soil per square foot of area)

The corresponding rate of spray in gal/ft^2/spray is calculated from the above data.

- Water demand for moisture conditioning (Q_{mc})

Q_{mc} is obtained directly from *"Borrow Area Water Demand"* and equals 1000 gal/day.

Written by: K. Olen Date: 21 February 1996 Reviewed by: [illegible] Date: 2/21/96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE-3900 Task No.: 8.4

[illegible] 23 Feb 96

CONSTRUCTION WATER DEMAND CALCULATION

Water demand needed to control dust on the haul road, two active cells and one cell under construction is calculated below.

$$Q_d = [(A_1 n_1 + A_2 n_2 + A_3 n_3)\ q] + [Q_{mc}]$$

A_1	=	315,000 sf (area of haul roads)
n_1	=	3 (number of sprays per day on haul roads)
A_2	=	640,000 sf (area of landfilled material)
n_2	=	2 (number of sprays per day on landfilled material)
A_3	=	320,000 sf (area of cell under construction)
n_3	=	0.5 (number of sprays per day on cell under construction)
q	=	$(W_w)(V_s)$
	=	$(4\ lbs/ft^3)(0.0833\ ft^3)(7.48\ gal/ft^3)/(62.4\ lbs/ft^3)$
	=	.0399 gal/spray/ft^2 of area covered (volume of water sprayed per square foot of area)
Q_{mc}	=	1000 gal/day (water demand for moisture conditioning borrow soils)

Q_d = [(315,000)(3) + (640,000)(2) + (320,000)(0.5)][0.0399] + 1000

Q_d = 96,400 gal/day

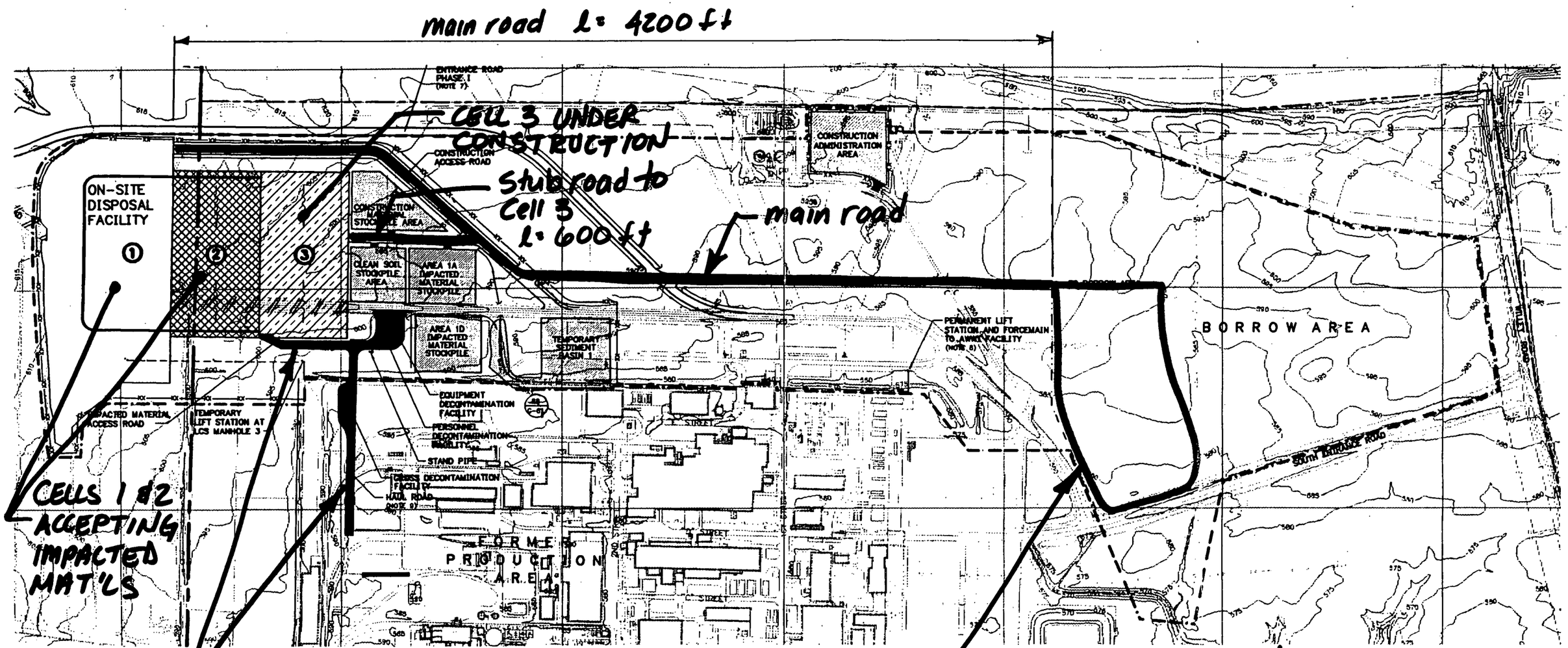
P. 740

6/6

fc 23 Feb 96

Written By: K. Olen Date: 21 Feb 96 Reviewed by: [illegible] Date: 2/21/96

Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 8.4



14.5 Decontamination Facility Water Demand

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: DECONTAMINATION FACILITIES WATER DEMAND

Computations By: (Cognizant Engineer)
Signature [signature] Date 2-19-96
Printed Name and Title BRIAN D. JACOBSON STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature Daniel B. Wisialowski Date 19 FEB 96
Printed Name and Title DANIEL B. WISIALOWSKI ASSISTANT PROJECT ENGINEER

Computations Checked by:
Signature Daniel B. Wisialowski Date 19 FEB 96
Printed Name and Title DANIEL B. WISIALOWSKI ASSISTANT PROJECT ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 2-19-96
Printed Name and Title BRIAN D JACOBSON STAFF ENGINEER

Approved by: (PDP)
Signature [signature] Date 19 Feb 96
Printed Name and Title Kara L. Olen Asst. Project Engineer

Approved by: (DTL and TETL)
Signature [signature] Date 21 Feb 96
Printed Name and Title Kenneth W Cargill Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design				
D	Intermediate Design - EPA Submittal Remove Personnel Decon Facility	4 Apr 96	[signature]	—	[signature]
G	Final Design Package	4 Oct 96	—	—	[signature]
O	Response to Final Design Cmts	5 May 97	—	—	[signature]

Written By : BRIAN D. JACOBSON Date: 96/2/19 Reviewed by: DBW Date: 19 FEB 96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

21 Feb 96

DECONTAMINATION FACILITIES WATER DEMAND

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

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 the decontamination trailer.~~ 4 Apr 96 JBJ 10 Oct 1996

METHOD OF ANALYSIS

The water demand for the truck decontamination facility was calculated based on expected usage.

~~The water demand for the showers in the Decontamination Trailer was calculated based on the expected usage.~~ 4 Apr 96 JBJ 10 Oct 1996

CONCLUSIONS

Truck Decontamination Pad

- water demand = 3600 gal/day

~~Showers in the Decontamination Trailer~~

- ~~water demand = 2250 gal/day~~ 4 Apr 96 JBJ 10 Oct 1996

~~Total Decontamination Water Demand~~

- ~~water demand = 5850 gal/day~~

GEOSYNTEC CONSULTANTS

Written by: _____ Date: _____ Revie

Client: FERMCO Project: OSDF

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DECONTAMINATION FACILITY WATER DEMAND

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		Page
1.	Calculation Procedure	2/8
2.	Data Verification	6/8
3.	Analysis Results	8/8

Written by: RJ Date: 96/2/19 (YY MM DD) Reviewed by: DBW Date: 96/02/19 (YY MM DD)

Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

21 Feb 96

DECONTAMINATION FACILITIES WATER DEMAND CALCULATION PROCEDURES

PURPOSE OF ANALYSIS

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 the truck decontamination pad;
- ~~Water demand for showers in the construction trailer.~~ 4 April 96

JBJ 1 Oct 1996

The decontamination pad plan is shown in Figure 1.

METHOD OF ANALYSIS

Truck Decontamination Pad

As presented in Figure 1, two pressure washers will be used on the decontamination pad. The water demand is calculated as follows:

$$Q_1 = n_1 \cdot q_1 \cdot T_1$$

Written by: BJ Date: 96/2/19 (YY MM DD) Reviewed by: DBW Date: 96/02/19 (YY MM DD)

Client: Fermco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

KC 21 Feb 96

Where:

n_1 = number of pressure washers

q_1 = discharge rate of a pressure washer, (gpm)

T_1 = total spray time in minutes / day

T_1 = Time per truck • Trucks per day

Showers in Decontamination Trailer

KC 4/Apr 96 ✓BJ 10 Oct 1996

As presented in Figure 2, there are 12 showers in a 30' x 10' construction trailer. The water demand is calculated as follows:

$$Q_2 = n_2 \cdot q_2 \cdot T_2$$ ✓✓

Where:

n_2 = number of showerheads

q_2 = discharge rate of a shower head, (gpm)

T_2 = total time showers in use per day, (min)

$$T_2 = n_s \cdot t_s$$

where

n_s = number of showers per day per head

t_s = length of each shower, (min)

Total Decontamination Water Demand

The total water demand for site decontamination facilities

$$Q_T = Q_1 + Q_2$$ ✓✓

KC 4/Apr 96 ✓BJ 10 Oct 1996

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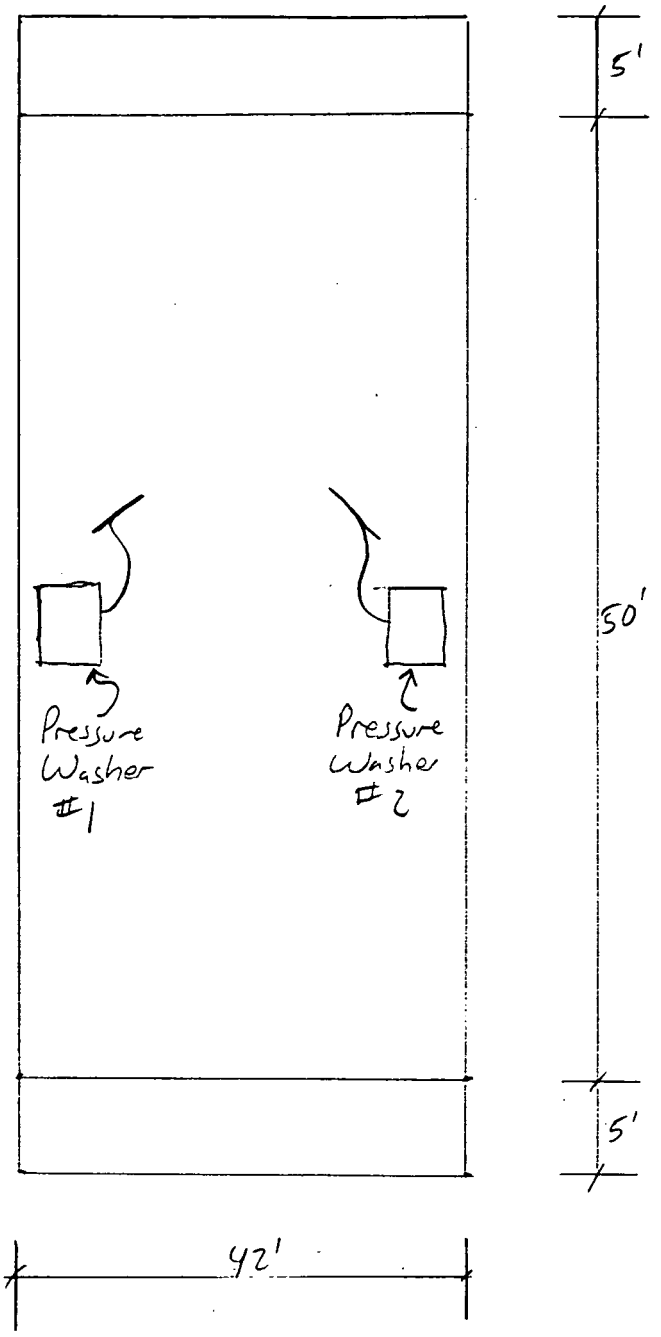
Written by: [illegible] Date: 96/2/19 (YY MM DD) Reviewed by: DBW Date: 96/02/19 (YY MM DD)

Client: Fermco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

FIGURE 1
PLAN OF DECONTAMINATION PAD

[illegible] 21 Feb 96



N.T.S.

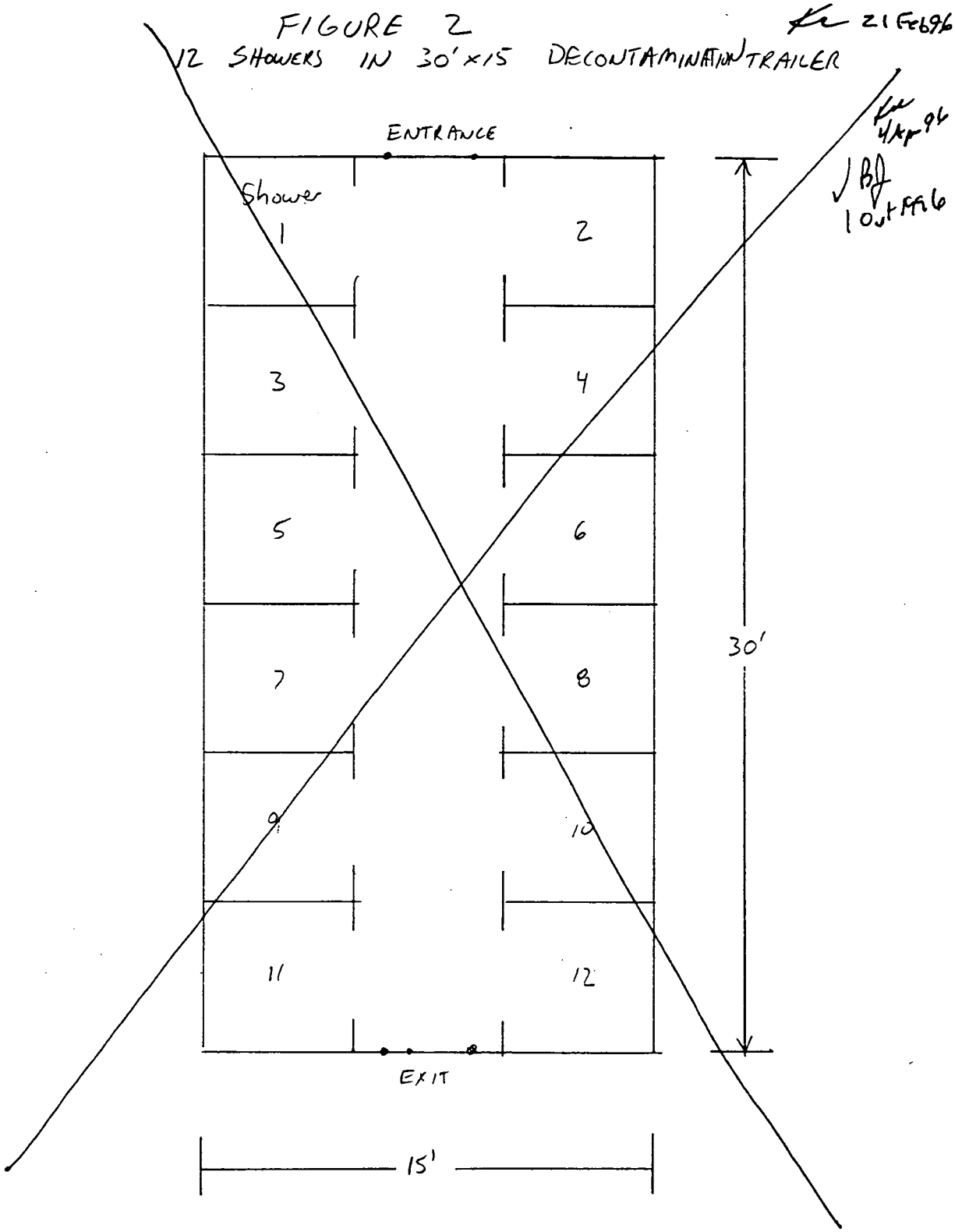
Written by: BJ Date: 96 / 2 / 19 (YY MM DD) Reviewed by: DBW Date: 96 / 02 / 19 (YY MM DD)

Client: Fermco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

FIGURE 2

12 SHOWERS IN 30' x 15 DECONTAMINATION TRAILER

21 Feb 96



4 Apr 96

BJ 10 Oct 1996

Written by: BDJ Date: 96/2/19 (YY/MM/DD) Reviewed by: DBW Date: 96/02/19 (YY/MM/DD)

Client: Fermco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

21 Feb 96

DECONTAMINATION FACILITIES
WATER DEMAND
DATA VERIFICATION

Truck Decontamination Pad

n_1 = number of pressure washers = 2 ✓✓

q_1 = discharge rate of each pressure washer = 10 gpm ✓✓
Manufacturers literature

T_1 = total spray time in minutes / day

t_r = trucks / day = 3 (Assume) ✓✓

t_t = time / truck = 60 min (Assume) ✓✓

Showers in Decontamination Trailer

Kw 4 Apr 96 VBJ 10 Oct 1996

n_2 = number of shower heads = 12 ✓✓

q_2 = discharge rate of shower head = 2.5 gpm ✓✓
Manufacturers literature

T_2 = total time showers in use per day

n_s = number of showers per day per head 5 (Assume) ✓✓

t_s = length of each shower (min) 15 (Assume) ✓✓

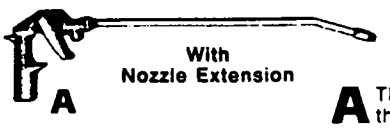
Written by: BDJ Date: 96/2/19 (YY/MM/DD) Reviewed by: DBW Date: 96/02/19 (YY/MM/DD)

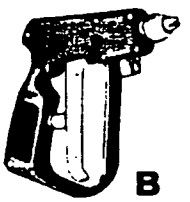
Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

21 Feb 96

High-Pressure Wash Guns

Add one of these guns to your pressure washer or high-pressure spray system for co[illegible] spray control. Water flow is automatically shut off when the trigger is released. **Maintenance** [illegible] (sold below) include replacement seals and internal parts that are prone to wear.





A The water flow bypasses the valve internals in this gun for reduced wear. Valve is nylon with Teflon packing. Includes an 18" extension with ⅛" fpt outlet and a brass nozzle with 40° spray angle. Other extensions sold below. Please see page 1156 (No. 3234K) for repl. spray nozzles.

B Manually lock the triggers of these guns in the off position when not in use. Include 25° spray nozzle, stainless steel shut-off needle, and bronze-filled Teflon seat. Replacement nozzle with 0°, 15°, or 25° spray angle is sold in accessory table below. Please specify spray angle desired.

C When you release the trigger, these guns a[illegible] matically are locked in the off posit[illegible] have ethylene propylene seals with a forge[illegible] valve housing.

The guns use the high-pressure nozzle [illegible] 3234K) sold separately on page 1156.

D A swivel connection at the water inlet [illegible] more movement with less wrist and [illegible] tigue. The gun has viton stem seals and a [illegible] brass body with stainless steel internal parts.

Spray nozzles (No. 3234K) are sold separa[illegible] page 1156.

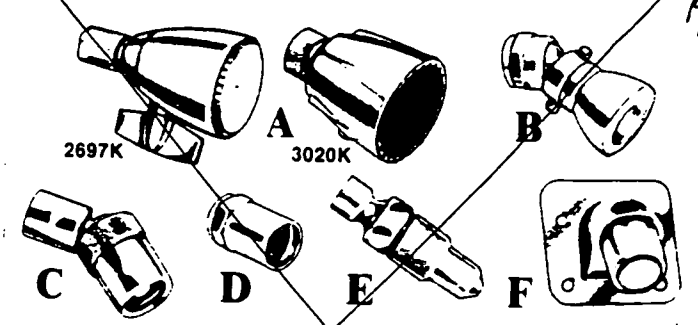
Key	Max. Flow	Max. Pres.	Max. Temp.	Connections Inlet	Connections Nozzle	Body Mat'l.
A	3.5 gpm	1000 psi	140° F	¼" NPT	11/16"-16 UN(M)	Zinc
B	5.0 gpm	1500 psi	200° F	¼" NPT	11/16"-16 THD	Nylon
B	6.0 gpm	2500 psi	300° F	⅜" NPT	11/16"-16 THD	Nylon
C	10.0 gpm	3000 psi	300° F	⅜" NPT	¼" NPT (F)	GRP■
C	10.0 gpm	3000 psi	300° F	⅜" NPT	⅜" NPT (F)	GRP■
D	10.0 gpm	4000 psi	300° F	⅜" NPT	⅜" NPT (F)	Nylon

■ Glass-reinforced plastic

ACCESSORIES

Nozzle Extensions	Fits Model	No.	NET EACH
24" Curved	A	3379K12	$16.60
36" Curved	A	3379K13	20.52
48" Curved	A	3379K14	26.83
18" Straight	B		
36" Straight	B		
Replacement Nozzle	B		

■ SHOWER HEADS ■



Kr 4 Apr 96

BDJ 10 Jt 1996

A **ADJUSTABLE SPRAY SHOWER HEADS—Adjust spray from needle pattern to a heavy wash.** Ball joint swivel adds flexibility. Flow rate is 2.5 gpm at 80 psi. Supply connection is ½" IPS female. Choose from chrome-plated brass head and chrome-plated ABS head.

Description

CHROME-PLATED BRASS HEAD

TIGHT SPRAY—1 9/16" DIAMETER FACE

Standard Connection

Tamperproof Connection

WIDE SPRAY—2¼" DIAMETER FACE

Standard Connection

Tamperproof Connection

CHROME-PLATED ABS HEAD—2" DIAMETER

Standard Connection

Written by: BDJ Date: 96/2/19 (YY MM DD) Reviewed by: DBW Date: 96/02/19 (YY MM DD)

Client: Fernco Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

21 Feb 96

DECONTAMINATION FACILITIES WATER DEMAND ANALYSIS RESULTS

Truck Decontamination Pad

$Q_1 = 2\,(10\,gpm)(3)(60\,min) = 3600\ gal/day$ ✓✓

~~Showers in Decontamination Trailer~~

~~$Q_2 = 12\,(2.5\,gpm)(5)(15\,min) = 2250\ gal/day$~~ ✓✓

✓bf 10 Oct 1996

~~Total Decontamination Water Demand~~

~~3600 gal/day + 2250 gal/day = 5850 gal/day~~ ✓✓

4 Apr 96

14.6 Decontamination Facility Pavement

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: EQUIPMENT DECONTAMINATION FACILITY PUMP DESIGN REQUIREMENT

Computations By: (Cognizant Engineer)
Signature [signature] Date 3 June 96
Printed Name and Title BRIAN D JACOBSON, SENIOR STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 5 JUN 96
Printed Name and Title DANIEL B. WISIALOWSKI, ASSISTANT PROJECT ENGINEER

Computations Checked by:
Signature [signature] Date 5 JUN 96
Printed Name and Title DANIEL B. WISIALOWSKI, ASSISTANT PROJECT ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 6 June 96
Printed Name and Title BRIAN D. JACOBSON, SENIOR STAFF ENGINEER

Approved by: (PDP)
Signature [signature] Date 7 June 96
Printed Name and Title BRIAN D. JACOBSON, SENIOR STAFF ENGINEER

Approved by: (DTL and TETL)
Signature [signature] Date 25 Jun 96
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
F	Prefinal Design EPA Submittal				
0	Response to Final Design Cmts	5 May 97	—	—	[illegible]

Written By : BRIAN D. JACOBSON Date: 96/06/07 Reviewed by: DBM Date: 10JUN96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

EXECUTIVE SUMMARY

EQUIPMENT DECONTAMINATION FACILITY PUMP DESIGN REQUIREMENTS

Purpose

The purpose of this calculation package is to estimate the equipment decontamination facility pump design requirements. Based in anticipated inflows, the total head required to pump water into the temporary gravity line, the pump capacity, and the excess capacity of the excavation to store soil from cleaning operations will be calculated.

Method of Analysis

The total head required by the pump to discharge liquid to the temporary gravity line was calculated using the following procedure:

- the configuration of the system was established; and
- the maximum elevation head in the temporary gravity line was calculated.

The pump capacity required to prevent overfilling of the equipment decontamination facility gravel layer was calculated using the following procedure:

- the volume of gravel in the equipment decontamination facility excavation was estimated;
- the void volume of the gravel was estimated;
- the flow rate into the sump was estimated based on both equipment cleaning operations and the 24-hour, 25-year storm event; and
- a pump capacity was selected to pump the liquid from the sump during one 8-hour work-day.

The excess capacity of the excavation to store soil from cleaning operations was calculated using the following procedure:

- the number of trucks per year was estimated;
- the projected life of the facility was determined; and
- the available volume of soil per truck was calculated.

Written By : BRIAN D. JACOBSON Date: ____ Reviewed by: DBW Date: 10 JUN 96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

Results

- The pump selected must be capable of delivering 20 gpm against a head of 25 ft.
- The facility is able to store up to 135 pounds of soil per truck decontaminated during the projected three-year life of the facility.

Written By : BRIAN D. JACOBSON Date: Reviewed by: DBW Date: 10 JUN 96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

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Data Verification	1 of 1
Analysis Results	1 of 3

Written By : BRIAN D. JACOBSON Date: 28 May 96 Reviewed by: DBW Date: 29 MAY 96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

EQUIPMENT DECONTAMINATION FACILITY PUMP DESIGN REQUIREMENTS

CALCULATIONS PROCEDURE

PURPOSE OF ANALYSIS

The purpose of this calculation package is to estimate the equipment decontamination facility pump design requirements and to verify the design life of the facility. The total head required to pump water into the temporary gravity line and the required pump capacity will be calculated. Drawings of the equipment decontamination facility are presented in Figure 1.

METHOD OF ANALYSIS

The largest hydrostatic head (i.e., elevation head) potentially present in the temporary gravity line occurs after the 24-hour, 25-year storm event when the liquid level in the impacted runoff catchment area is at a maximum. The sump pump selected must supply greater than the above hydrostatic head to ensure proper operation of the equipment decontamination facility after storm events. An elevation drawing of the leachate collection and transmission system up to the location of the equipment decontamination facility is presented in Figure 2.

The volume of gravel in the equipment decontamination facility excavation will be estimated based on the dimensions presented in Figure 1. The void space will be calculated by multiplying the total volume of gravel by the estimated porosity of the gravel.

The quantity of liquid which may enter the equipment decontamination facility during a 1-day period will be evaluated for both typical decontamination activities and during the 24-hour, 25-year storm event.

The pump size will be selected based on the higher of the above two numbers and with the constraint that all liquid can be removed during a typical 8-hour work-day.

The design life of the facility will be verified by calculating the available soil load to the gravel per truck. It should be noted that most of the contaminated soil should be removed in the active cell or at the gross decontamination area prior to final decontamination. Additionally, a substantial portion of the soil which is washed off of the equipment is expected to remain on the surface of the railroad tie roadbed and will be collected before it migrates into the gravel.

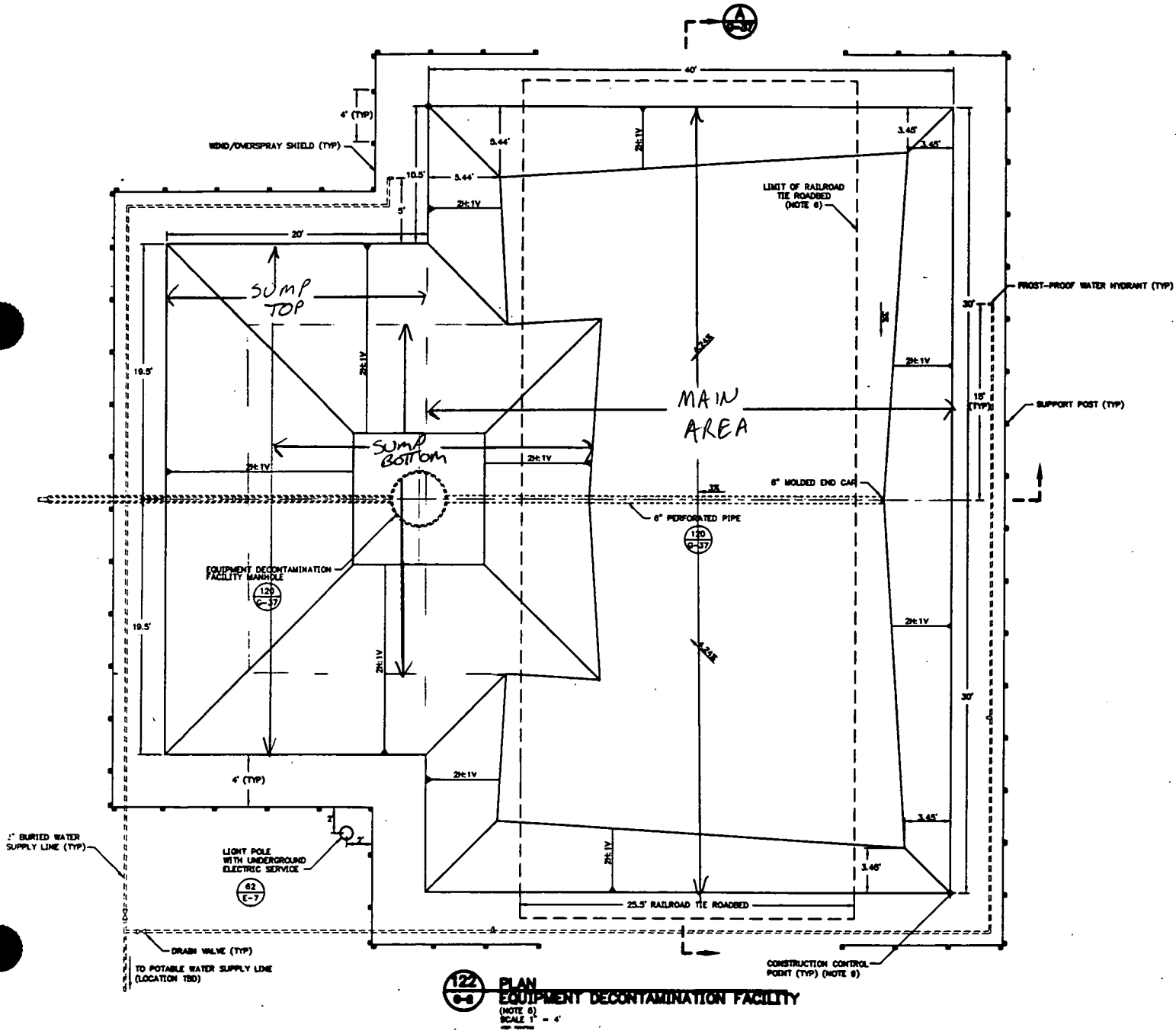
Written By : BRIAN D. JACOBSON Date: 28 May 96 Reviewed by: DBW Date: 29 MAY 96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

FIGURE 1

EQUIPMENT DECONTAMINATION FACILITY PUMP REQUIREMENTS

PLAN VIEW



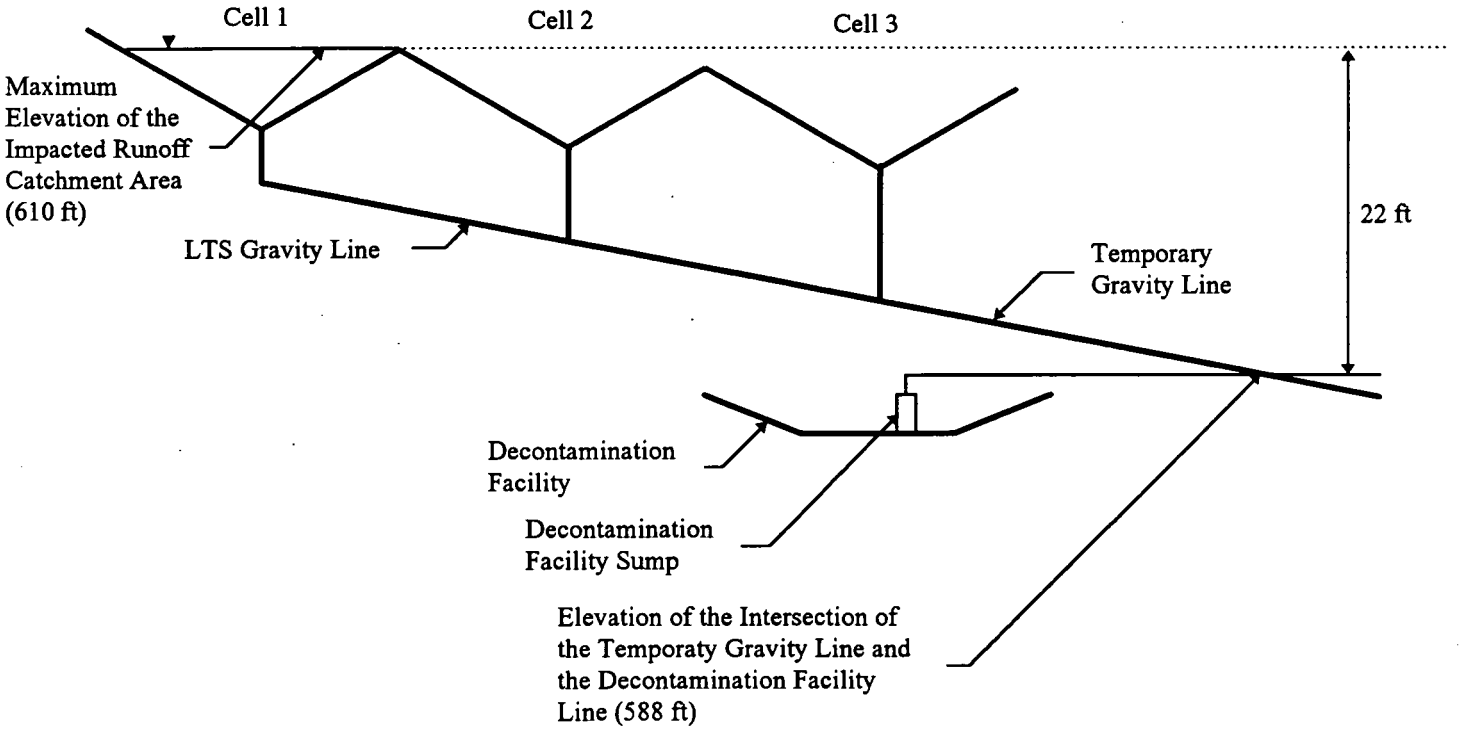
Written By : BRIAN D. JACOBSON Date: 28 May 96 Reviewed by: DBW Date: 29 MAY 96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

FIGURE 2

EQUIPMENT DECONTAMINATION FACILITY PUMP REQUIREMENTS

MAXIMUM HYDROSTATIC HEAD IN THE TEMPORARY GRAVITY LINE



Written By : BRIAN D. JACOBSON Date: Reviewed by: DBW Date: 3 JUN 96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 10.4

EQUIPMENT DECONTAMINATION FACILITY PUMP REQUIREMENTS

DATA VERIFICATION

Elevation of the maximum surface of the impacted runoff catchment area; 610 ft (minimum elevation of the intracellular berm from the Leachate Collection System Grading Plan, Drawing G-8 of the Prefinal Design Package, after allowing approximately 0.5 foot of freeboard)

Estimated elevation of the intersection of the decontamination line and the temporary gravity line; 588 ft
(calculated from the elevation of the Cell 3 manhole as shown on the Final Cover System Grading Plan, Drawing G-11 of the Prefinal Design Package, and the section of a typical manhole as shown on Leachate Transmission System Gravity Line and Manhole Mechanical Details I, Drawing M-4 of the Prefinal Design Package)

Porosity of the gravel layer; 0.3 (estimated)

Volume of water generated form decontamination activities; 3600 gal/day
(see Decontamination Water Demand Calculation)

Rainfall for the 24-hour, 25-year storm event; 4.7 in. (Table A1 of the 2000-yr flood and probable maximum flood site wide flood plain determination, calculation prepared by Parsons in November 1995)

Number of trucks per day; 2 trucks (estimated)

Number of work days per year; 175 days (estimated)

Design life of facility; 3 years (estimated)

Written by: BRIAN JACOBSON Date: 96/06/03 (YY MM DD) Reviewed by: DBW Date: 96/06/05 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

EQUIPMENT DECONTAMINATION FACILITY PUMP REQUIREMENTS

ANALYSIS RESULTS

MAXIMUM HYDROSTATIC HEAD

$610 - 588 = 22$ ft SAY 25 ft

VOLUME OF GRAVEL

MAIN AREA

AREA OF SURFACE

$60 \times 40 = 2400 \text{ ft}^2$

AREA OF BOTTOM

$$[60-(3.45+5.44)][40-(\frac{3.45+5.15}{2}+\frac{5.44+7.0}{2})] = 1507 \text{ ft}^2$$

AVERAGE DEPTH

$$\frac{3.45+5.44+5.15+7.0}{\frac{4}{2}} = 2.63$$

VOLUME

$$\frac{2400+1590}{2} \times 2.63 = \boxed{5138 \text{ ft}^3}$$

VOLUME (SUMP BOTTOM)

AREA OF SURFACE

$26.6 \times 26.6 = 707.6 \text{ ft}^2$

AREA OF BOTTOM $10 \times 10 = 100 \text{ ft}^2$

AVERAGE DEPTH $\frac{26.6}{2} - 5 = 8.3$ $\frac{8.3}{2} = 4.15$ ft

VOLUME

$$\frac{707.6 + 100}{2} \times 4.15 = \boxed{1676 \text{ ft}^3}$$

Written by: BRIAN JACOBSON Date: 96/06/03 (YY MM DD) Reviewed by: DBW Date: 96/06/05 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

VOLUME (SUMP TOP)

AREA OF SURFACE $39 \times 20 = 780\ ft^2$

AREA OF BOTTOM $26.6 \times 20 = 532\ ft^2$

AVERAGE DEPTH $= \frac{14.5 - 8.3}{2} = 3.1\ ft$

VOLUME $= \frac{780 + 532}{2} \times 3.1 = \boxed{2034\ ft^3}$

TOTAL VOLUME $= \boxed{8848\ ft^3}$

VOID SPACE IN GRAVEL

ESTIMATE POROSITY $= 0.3$

$8848 \times 0.3 = 2655\ ft^3$

$2655\ ft^3\ 7.48 \frac{gal}{ft^3} = 19{,}589\ gal$

VOLUME OF WATER GENERATED FROM DECONTAMINATION ACTIVITIES

$\boxed{3600\ gal/day}$ (FROM DECONTAMINATION WATER DEMAND CALCULATION PACKAGE)

VOLUME COLLECTED FROM 24-HOUR, 25-YEAR STORM EVENT

$\frac{4.7\ in}{12\ in/ft} (40 \times 60 + 39 \times 20) = 1246\ ft^3$

$1246\ ft^3\ 7.48 \frac{gal}{ft^3} = 9316\ gal$

Written by: BRIAN JACOBSON Date: 96/06/03 (YY MM DD) Reviewed by: DBN Date: 96/06/05 (YY MM DD)

Client: FERMCO Project: Fernald OSDF Project/Proposal No.: GE3900 Task No.: 10.4

COMPARE STORAGE CAPACITY WITH POTENTIAL INFLOWS

STORAGE CAPACITY DECONTAMINATION ACTIVITIES

19,589 gal >> 3600 gal ✓

STORAGE CAPACITY 24-HOUR, 25-YEAR STORM EVENT

19,589 gal > 9316 gal ✓

PUMP CAPACITY REQUIRED TO EMPTY SUMP IN 8-HOURS

$\frac{9316 \text{ gal}}{8 \text{hr} \cdot 60 \frac{\text{min}}{\text{hr}}}$ = 19.4 gal/min REQUIRED ✓

SAY 20 gpm PUMP REQUIRED ✓

CAPACITY AVAILABLE FOR SOIL COLLECTION

2655 ft^3 − 1246 ft^3 = 1409 ft^3 ✓

ALLOWABLE SOIL PER TRUCK

2 TRUCKS/DAY × 175 DAYS/YEAR = 350 TRUCKS/YEAR

350 TRUCKS/YEAR × 3 YEAR OPERATIONAL LIFE = 1050 TRUCKS

1409 ft^3 CAPACITY / 1050 TRUCKS = 1.34 ft^3/TRUCK

1.34 ft^3 × 100 pcf = 134 lb/truck SAY 135 lb ✓

14.7 Construction Admin Area Surfacing

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: CONSTRUCTION ADMINISTRATION AREA SURFACING

Computations By: (Cognizant Engineer)
Signature: Daniel G. Pass — Date: 2/15/96
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: B.B. Mazanti — Date: 2/20/96
Printed Name and Title: B.B. MAZANTI, Consultant

Computations Checked by:
Signature: B.B. Mazanti — Date: 2/20/96
Printed Name and Title: B.B. MAZANTI, Consultant

Computations Backchecked by: (Cognizant Engineer)
Signature: Daniel G. Pass — Date: 2/21/96
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Approved by: (PDP)
Signature: Kara L. Olen — Date: 22 Feb 96
Printed Name and Title: Kara L. Olen, Asst Proj. Engr.

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 22 Feb 96
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
AC (22 Feb 96)	Intermediate Design	—			
D	Intermediate Design-EPA Submitted	5 Apr 96	[illegible]	—	—
G	Final Design Package	4 Oct 96	—	—	[illegible]
O	Response to Final Design Comts	5 May 97	—	—	[illegible]

Written by: Daniel Pass Date: 15 February.96 Reviewed by: BTM Date: 2/20/96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

CONSTRUCTION ADMINISTRATION AREA SURFACING

EXECUTIVE SUMMARY

Purpose:

The purpose of this calculation is to design a typical pavement cross-section for the proposed Administration Area. The Administration Area will be used for trailers supporting construction of the OSDF and for associated passenger vehicles. The area will be relocated once during construction of the OSDF. The expected service life of the pavement ranges from 5 to 15 years.

Design Method:

Analysis is performed using an AASHTO method for design of low-volume flexible pavements (AASHTO, 1993). A performance period of 15 years is assumed.

Conclusions:

Flexible pavement cross-section:

- Surface course: 3 in. of Asphalt Concrete;
- Base course: 8 in. of ODOT spec. #304 Base Aggregate; and
- Prepared subgrade.

Subgrade:

- Fill sections: Compacted brown till to 100% of standard Proctor with a moisture content within 2% of optimum.
- Cut sections: Undisturbed brown till compacted to 100% of standard Proctor for a depth of 6 in.

GEOSYNTEC CONSULTANTS

Written by: _____ Date: _____ Review

Client: FERMCO Project: OSDF

THIS PAGE IS INSERTED ONLY FOR CLARITY AND DOES NOT AFFECT THE NUMBERING SYSTEM OF THE REST OF THE PACKAGE

CONSTRUCTION ADMIN AREA SURFACING

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2.	Collection and Verification of Engineering Data	3/11
3.	Calculations	5/11

Written by: Daniel Pass Date: 15 February 96 Reviewed by: [illegible] Date: 2/20/96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

Introduction:

An asphalt-surfaced pavement will be used for the construction administration area. The paved area is expected to provide a foundation for 2 construction trailers and a parking area for passenger vehicles. During the early and middle stages of OSDF construction the administration area will be located as shown in Figure 1. The administration area will be relocated for the final stage of OSDF construction.

An AASHTO method for design of low-volume flexible pavement is used to determine pavement layer thickness'. A design life of 15 years is assumed.

Procedure:

The AASHTO method used requires the selection of a structural number, SN from Table 1. The selected SN is then used to determine thickness' for the asphalt concrete and aggregate base layers of the pavement. The value of SN is selected based on the geographic location of the site and classifications of the expected traffic level and subgrade soil quality.

Step 1: Select a structural number, SN to be used for design from Table 1, based on the following input parameters.

- US climatic region, (See Figure 2).
- Traffic level, (See table provided in the section titled Collection and Verification of Engineering Data)
- Relative quality of road bed (or subgrade) material (Based on site specific testing of undisturbed and compacted brown till and Table 2).

The inherent reliability assumed by Table 1 is 75%. Inherent reliability, represents the probability that serviceability of the road will be maintained at an adequate level for the performance (or design) period considered. The reliability recommended for low-volume roads is between 50 and 80 percent (AASHTO, 1993).

Step 2: Determine design thickness' for asphalt concrete layer, D_{AC} and aggregate base layers, D_{BS} using the following equation.

$$SN = a_{AC}D_{AC} + a_{BS}D_{BS}$$

where,

a_{AC} = The structural coefficient for asphalt concrete

a_{BS} = The structural coefficient for aggregate base material.

The structural coefficient is a measure of the ability of a material to function as a structural component of the road.

Written by: Daniel Pass Date: 15 February.96 Reviewed by: BMM Date: 2/20/96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

Collection and Verification of Engineering Data:

1) US climatic region: Determined based on site location, see Figure 2.

US Climatic Region = II

2) Traffic level: Determine traffic level classification based on the expected 18 kip ESAL applications, W_{18}. and the following Table.

Traffic Level	W_{18}
High	700,000 to 1,000,000
Medium	300,000 to 600,000
Low	50,000 to 300,000

For calculation of w_{18} assume the following input parameters:

- Design Vehicle: Pickup Truck
- Single Axle Load: 2 kips
- Vehicles per day: 100
- Passages per day per vehicle: 4
- Axle load equivalency factor: 0.0004 [For terminal serviceability index of 2.5 and SN of 2 from Table 3 (AASHTO, 1993)]

3) Determine relative quality of roadbed material (subgrade).

The underlying subgrade is expected to include areas of undisturbed and compacted brown till.

- Undisturbed Brown Till:

  CPT results in the upper and lower horizon brown till were correlated to CBR values in Parsons (1995). The average CBR for CPT locations ranged between 4 to 5. The corresponding resilient modulus, M_R ranges between 4,800 to 6,000 psi.

- Compacted Brown Till:

  A CBR value of 8 was measured for brown till samples compacted to 100% of Standard Proctor in COE (1952). The corresponding resilient modulus M_R is 9,600 psi.

Assume, for design, a range of M_R between 4,800 to 6,000 psi as measured for undisturbed brown till. This range of M_R corresponds to a relative quality of roadbed soil of fair (see Table 2).

4) Inherent Reliability

- Assume as 75 percent.

5) Structural Coefficients, a_{AC}, a_{BS}

As recommended for the following materials in ODOT, 1992.

- Structural coefficient for asphalt concrete, a_{AC} = 0.35.
- Structural coefficient for #304 base aggregate, a_{BS} = 0.14.

Written by: DANIEL PASS Date: 96 / 2 / 15 (YY MM DD) Reviewed by: BBM Date: 96 / 02 / 20 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

CALCULATIONS:

STEP 1: SELECT AGGREGATE BASE THICKNESS FROM TABLE 1 GIVEN THE FOLLOWING INPUT PARAMETERS.

a) US CLIMATIC REGION = II

b) TRAFFIC LEVEL, BASED ON EXPECTED 18-KIP ESAL APPLICATIONS, W_{18}
W_{18} IS CALCULATED BASED ON EXPECTED TRAFFIC, AS FOLLOWS.

NUMBER OF SINGLE AXLE APPLICATIONS = 100 VEHICLES/DAY × 4 PASSAGES/(VEHICLE/DAY) × 365 days/YR × 15 YRS
= 2,190,000 APPLICATIONS

W_{18} = 2,190,000 × 0.0004 = 876 APPLICATIONS

EXPECTED W_{18} of ≈ 900 APPLICATIONS IS BELOW THE LOWER BOUND OF 50,000 FOR A TRAFFIC LEVEL OF LOW.

CONSERVATIVELY ASSUME A TRAFFIC LEVEL OF LOW.

c) RELATIVE QUALITY OF ROADBED SOIL IS FAIR

GIVEN THE ABOVE INPUT PARAMETERS SELECT FROM TABLE 1 A RANGE OF STRUCTURAL NUMBER BETWEEN 2.2 AND 2.8.

AS EXPECTED TRAFFIC (W_{18} ≈ 900) IS WELL BELOW THE RANGE SPECIFIED FOR A CLASSIFICATION OF LOW (50,000 TO 300,000) SELECT A SN of 2.2.

Written by: DANIEL PASS Date: 96/2/15 (YY MM DD) Reviewed by: [illegible] Date: 96/02/20 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

CALCULATIONS CONT'D:

STEP 2: DETERMINE DESIGN THICKNESS FOR THE ASPHALT CONCRETE AND BASE LAYERS OF PAVEMENT.

ASSUME THICKNESS OF ASPHALT CONCRETE AS 3 IN.

$SN = 2.2 = 0.35 \times 3\text{in} + 0.14 \times D_{BS}$

$\therefore$ THICKNESS OF BASE, $D_{BS} = 8.2\text{in}$.

THE DESIGN SECTION IS AS FOLLOWS:

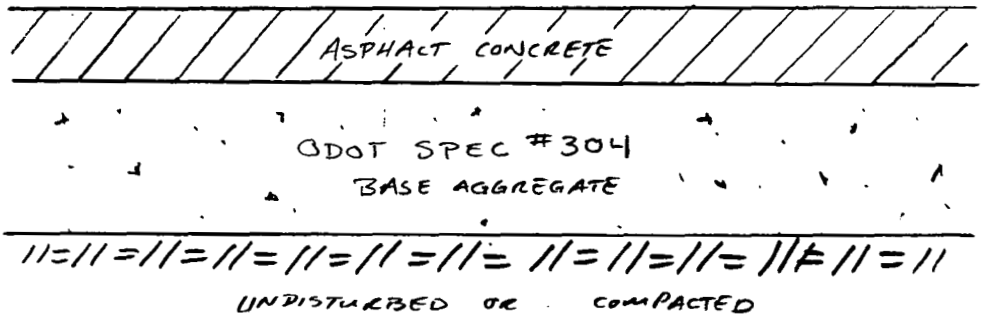
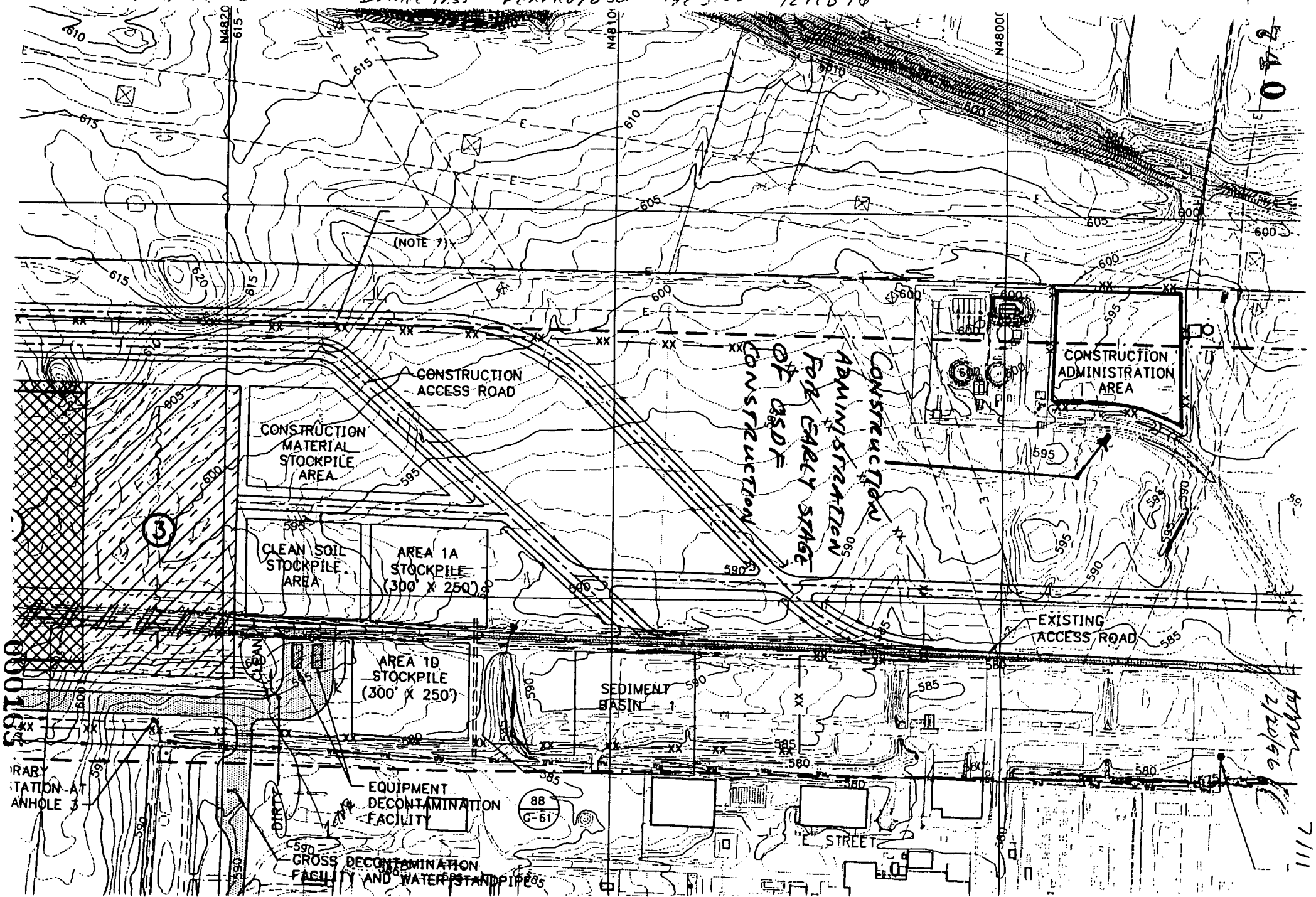


FIGURE 1 DANIEL PASS FCAMCO/OSCF GE 3900 12 FEB 96



2/20/96

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P- 740 8/11
bbm 2/20/96

TABLE 2: FOR DETERMINATION OF RELATIVE QUALITY OF ROADBED SOIL.

Table 4.2. Suggested Seasonal Roadbed Soil Resilient Moduli, M_R (psi), as a Function of the Relative Quality of the Roadbed Material

Relative Quality of Roadbed Soil	Season (Roadbed Soil Moisture Condition)			
	Winter (Roadbed Frozen)	Spring-Thaw (Roadbed Saturated)	Spring/Fall (Roadbed Wet)	Summer (Roadbed Dry)
Very good	20,000*	2,500	8,000	20,000
Good	20,000	2,000	6,000	10,000
Fair	20,000	2,000	4,500	6,500
Poor	20,000	1,500	3,300	4,900
Very poor	20,000	1,500	2,500	4,000

*Values shown are Resilient Modulus in psi.

TABLE 1: FOR DETERMINATION OF STRUCTURAL NUMBER

Table 4.7. Flexible Pavement Design Catalog for Low-Volume Roads: Recommended Ranges of Structural Number (SN) for Six U.S. Climatic Regions, Three Levels of Axle Load Traffic and Five Levels of Roadbed Soil Quality— Inherent Reliability: 75 percent

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climatic Region					
		I	II	III	IV	V	VI
Very good	High	2.6-2.7*	2.8-2.9	3.0-3.2	2.4-2.5	2.7-2.8	3.0-3.2
	Medium	2.3-2.5	2.5-2.7	2.7-3.0	2.1-2.3	2.4-2.6	2.7-3.0
	Low	1.6-2.1	1.8-2.3	2.0-2.6	1.5-2.0	1.7-2.2	2.0-2.6
Good	High	2.9-3.0	3.0-3.2	3.3-3.4	2.7-2.8	3.0-3.1	3.3-3.4
	Medium	2.6-2.8	2.7-3.0	3.0-3.2	2.4-2.6	2.6-2.9	2.9-3.2
	Low	1.9-2.4	2.0-2.6	2.2-2.8	1.8-2.3	2.0-2.5	2.2-2.8
Fair	High	3.2-3.3	3.3-3.4	3.4-3.5	3.0-3.2	3.2-3.3	3.4-3.5
	Medium	2.8-3.1	2.9-3.2	2.7-3.3	2.7-3.0	2.8-3.1	3.0-3.3
	Low	2.1-2.7	2.2-2.8	2.3-2.9	2.0-2.6	2.1-2.7	2.3-2.9
Poor	High	3.5-3.6	3.6-3.7	3.7-3.9	3.4-3.5	3.5-3.6	3.7-3.8
	Medium	3.1-3.4	3.2-3.5	3.4-3.6	3.0-3.3	3.1-3.4	3.3-3.6
	Low	2.4-3.0	2.4-3.0	2.5-3.2	2.3-2.8	2.3-2.9	2.5-3.2
Very poor	High	3.8-3.9	3.8-4.0	3.8-4.0	3.6-3.8	3.7-3.8	3.8-4.0
	Medium	3.4-3.7	3.5-3.8	3.5-3.7	3.3-3.6	3.3-3.6	3.4-3.7
	Low	2.6-3.2	2.5-3.3	2.6-3.3	2.5-3.1	2.5-3.1	2.6-3.3

*Recommended range of structural number (SN).

AASHTO, 1993

FERMCO GE3900 14 FEB 96 DANIEL PASS 00018C TABLES 1 AND 2

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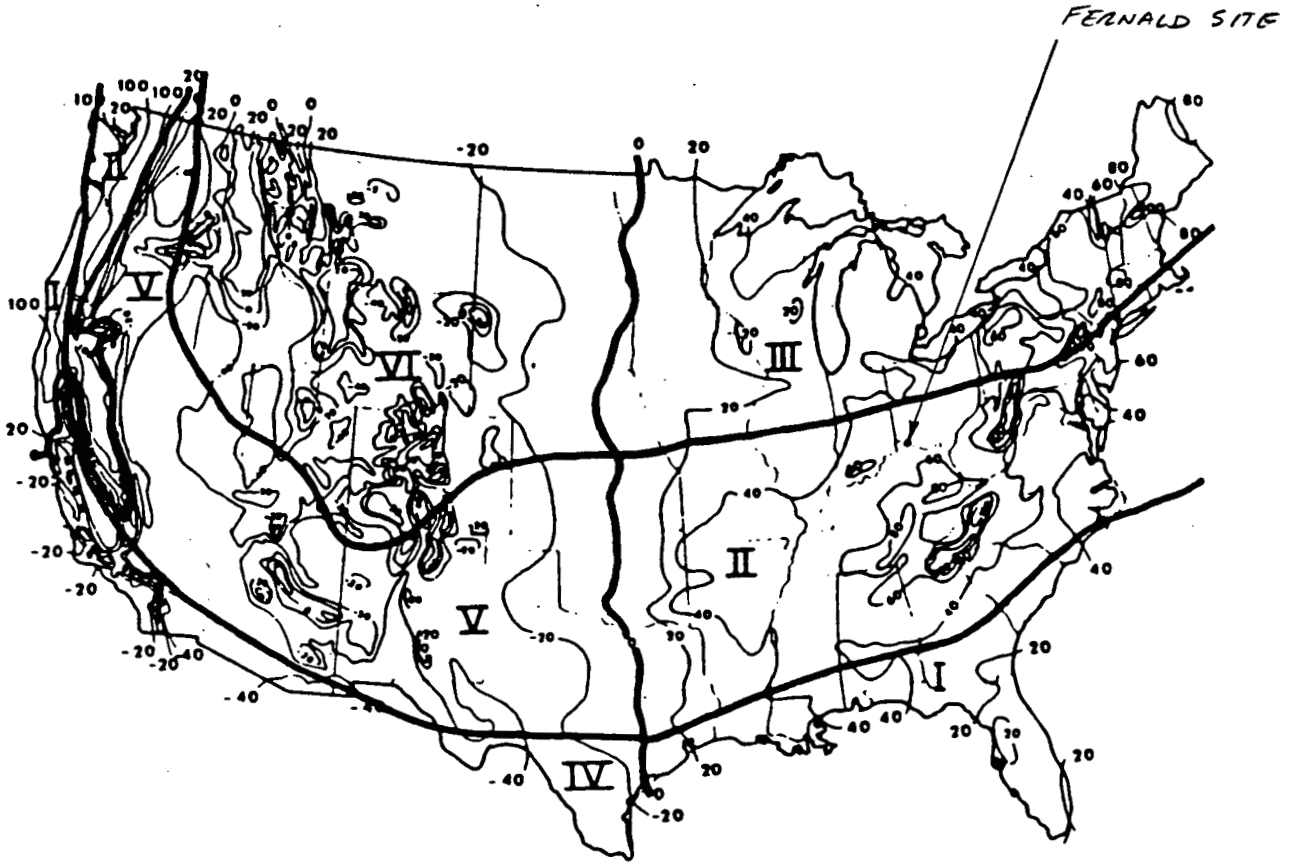

REGION	CHARACTERISTICS
I	Wet, no freeze
II	Wet, freeze - thaw cycling
III	Wet, hard-freeze, spring thaw
IV	Dry, no freeze
V	Dry, freeze - thaw cycling
VI	Dry, hard freeze, spring thaw

Figure 4.1. The Six Climatic Regions in the United States (*12*)

DANIEL PAGS FERMCO, OSDF GE3900 12 FEB 96

FIGURE 2

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Table D.4. Axle Load Equivalency Factors for Flexible Pavements, Single Axles and p_t of 2.5

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.3	9.5	7.9	6.8	7.0	7.8
32	13.9	12.8	10.5	8.8	8.9	10.0
34	18.4	16.9	13.7	11.3	11.2	12.5
36	24.0	22.0	17.7	14.4	13.9	15.5
38	30.9	28.3	22.6	18.1	17.2	19.0
40	39.3	35.9	28.5	22.5	21.1	23.0
42	49.3	45.0	35.6	27.8	25.6	27.7
44	61.3	55.9	44.0	34.0	31.0	33.1
46	75.5	68.8	54.0	41.4	37.2	39.3
48	92.2	83.9	65.7	50.1	44.5	46.5
50	112.	102.	79.	60.	53.	55.

AASHTO, 1993

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DANIEL PASS FERMCO OSOF GE 3900 15 FEB 96

TABLE 3

References:

1. American Association of State Highway and Transportation Officials (AASHTO). "*AASHTO Guide for Design of Pavement Structures*", AASHTO, Washington, D.C., 1993.

2. Ohio Department of Transportation (ODOT). "*Location and Design Manual, Volume 1 Roadway Design*", Revision October 1992, ODOT, Columbus, Ohio, 1992.

3. Parsons. "*Geotechnical Investigation Report, On-Site Disposal Facility*", Operable Unit 2, Project Order 140, Fernald Environmental Management Project, Rev. 0, Cincinnati, OH, 1995..

4. Department of the ARMY Corps of Engineers (COE), "*Report of Foundation Investigation Feed materials Production Center,- FERNALD, Ohio.*" Ohio River Division Laboratories, Mariemont, OHIO, 1952.

14.8 Construction Haul Road

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: CONSTRUCTION HAUL ROAD

Computations By: (Cognizant Engineer)
Signature: Daniel G. Pass — Date: 2/4/96
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: B. B. Mazanti — Date: 2/20/96
Printed Name and Title: B. B. MAZANTI, CONSULTANT

Computations Checked by:
Signature: B. B. Mazanti — Date: 2/20/96
Printed Name and Title: B. B. MAZANTI, Consultant

Computations Backchecked by: (Cognizant Engineer)
Signature: Daniel G. Pass — Date: 2/21/96
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Approved by: (PDP)
Signature: Kara L. Olen — Date: 22 Feb 96
Printed Name and Title: Kara L. Olen, Asst Proj. Engr.

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 23 Feb 96
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design				
D	Intermediate Design - EPA Submittal	5 Apr 96	[illegible]		
C	Response to Final Design Comts	5 May 97			[illegible]

GEOSYNTEC CONSULTANTS

Written by: Daniel Pass Date: 4 February 96 Reviewed by: ABM Date: 2/20/96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

KO 22 Feb 96

CONSTRUCTION HAUL ROAD EXECUTIVE SUMMARY

Purpose:

The purpose of this calculation is to design an aggregate-surfaced haul road for transport of borrow materials from the East Field Borrow area to the OSDF. The total volume of borrow expected for excavation and transport is 650,000 CY. Excavation and transport will be accomplished using scrapers.

Design Method:

Analyses are performed using an AASHTO method for design of aggregate-surfaced roads (AASHTO, 1993) and an ODOT method for design of flexible pavement roads (pavement thickness = 0). Analyses considered roadbed conditions during the normal period of operation and the spring-thaw period of operation. A design cross-section was selected based on calculations considering a performance period (or maintenance interval) of 1 to 2 weeks.

Conclusions:

Aggregate-surfaced road cross-section (top to bottom):

- Base: 9 in. of ODOT spec. #304 Base Aggregate;
- Subbase: 13 in. of ODOT spec. #310 Subbase Aggregate;
- Geotextile separator; and
- Prepared subgrade

Maintenance:

- Required Maintenance includes regrading of the road surface and the addition of aggregate to the base.
- Maintenance Intervals:
  Biweekly for normal period of operation.
  Weekly for spring-thaw period of operation.

Subgrade Requirements:

- Fill sections: Brown till compacted to 100% of Standard Proctor maximum dry density.
- Cut sections: Existing subgrade compacted to 100% of Standard Proctor maximum dry density.

Written by: Daniel Pass Date: 4 February 96 Reviewed by: BBM Date: 2/20/96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

KO 22Feb96

CONSTRUCTION HAUL ROAD

Contents: Page

1. Introduction 1

2. Calculation Procedure 2

3. Collection and Verification of Engineering Data 14

4. Calculations and Results 18

5. References 37

Introduction:

An aggregate-surfaced construction haul road will be used to transport borrow from the East Field borrow area to the OSDF where the borrow materials will be used in construction of : 1) the liner system; 2) the seasonal covers; 3) the final cover system; and 4) for other general fill operations. Scrapers will be used to excavate and to transport borrow material. An expected 650,000 cubic yards of borrow material will be transported over the haul road.

The haul road is divided into the following sections:

- From borrow area limit to OSDF: The location of this haul road is not expected to change after its construction; however, some portions will be removed at times in order to allow for progressive construction of the OSDF components. The total service life of the road will correspond to the expected period of OSDF construction (i.e., approximately 9 years).

- Within borrow area: The contractor will be responsible for design of the haul road within the borrow area.

Written by: Daniel Pass Date: 4 February.96 Reviewed by: [illegible] Date: 2/20/96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

KO 22 Feb96

Calculation Procedure:

The procedure used to design the construction haul road cross-section is based on two design methods: 1) the AASHTO method for design of low-volume aggregate-surfaced roads (AASHTO, 1993); and 2) the ODOT method for design or flexible pavement (ODOT, 1992). Calculations were performed using a performance period of two weeks. The performance period corresponds to the interval of time for which no road maintenance is required.

- For the AASHTO method, the traffic loading for a given performance period is represented in terms of 18-kip equivalent single axle load (ESAL) applications. The total number of 18-kip ESAL applications along with other input parameters are used with the design charts shown in Figures 1, 2 and 3 shown on pages 9, 10, and 11 respectively. A road section is determined which will be serviceable for the duration of the 2 week performance period.

- For the ODOT method, the traffic loading for a given performance period is also represented in terms of 18-kip Equivalent Single Axle Load (ESAL) applications. The method is a modification of the 1986 AASHTO method for flexible pavement design. The total number of 18-kip ESAL applications along with other input parameters are used with the design charts shown in Figures 4 and 5 shown on pages 12 and 13. A road cross-section is determined which will be serviceable for the duration of the 2 week performance period.

Analysis is also performed using both methods to determine the road cross-section requirements for spring-thaw conditions, assuming a performance period of 1 week.

Step 1: Determine the total 18-kip ESAL applications, $w_{Total\text{-}18}$ for a 2 week performance period. Scraper traffic to and from the OSDF are considered.

- The following are 18-kip ESAL applications corresponding to the different scraper traffic axle load types;

  -$w_{DL\text{-}18}$, for drive axle, loaded scraper traveling to the OSDF.
  -$w_{RL\text{-}18}$, for rear axle, loaded scraper traveling to the OSDF.
  -$w_{DE\text{-}18}$, for drive axle, empty scraper returning to the borrow area.
  -$w_{RE\text{-}18}$, for rear axle, empty scraper returning to the borrow area.

- The following equation is used to convert each expected scraper axle load type into an equivalent 18-kip ESAL axle load and to sum these loads over the performance period:

$$w_{DL,RL,DE,RE-18} = w_N \left(\frac{N_{DL,RL,DE,RE}}{18} \right)^{4.5} \qquad (1)$$

Where,

$w_{DL,RL,DE,RE-18}$ = the 18-kip ESAL applications for a given scraper axle load type.
w_N = the number scraper passages to (or from) the OSDF over the performance period.
$N_{DL,RL,DE,RE}$ = a given scraper single axle load type, kips
4.5 = coefficient determined from AASHTO axle load equivalency factors (for a terminal serviceability index, p_t of 2.5 and a pavement structural number of 2.5).
18 = an 18-kip equivalent single axle load, kips

- The total 18-kip ESAL applications, $w_{Total-18}$ is calculated for the performance period by summing 18-kip ESAL applications for each of the above scraper axle load types, as follows:

$$w_{Total-18} = w_{DL-18} + w_{RE-18} + w_{DE-18} + w_{RE-18} \qquad (2)$$

1.1 The single axle load, N, for each scraper axle load type is calculated using the following equation:

$$N_{DL,RL,DE,RE} = W_V L_{dist} \qquad (3)$$

Where,

$N_{DL,FL,DE,RE}$ = Single axle load for each scraper axle load type.
W_V = Weight of scraper and soil load (soil load = 0 for empty scraper), see Collection and Verification of Engineering Data.
L_{dist} = Load distribution for a given scraper axle load type, ratio.

1.2 Calculate the number of scraper passages to (or from) the OSDF, wN over the performance period, using the following equation:

$$w_N = \frac{V_{borrow}\left(1 + \frac{S}{100}\right)}{V_{S-Capacity}} \qquad (4)$$

Where,

V_{borrow} = Volume of borrow hauled during the performance period, BCY (bank cubic yards).
$V_{S\text{-}Capacity}$ = Capacity of scraper, LCY (loose cubic yards) of soil.
S = Swell, percentage increase in soil volume from Bank to Loose condition.

1.3 Calculate $w_{Total\text{-}18}$, to be input into the design charts, using equation 2 and inputs from equations 1, 3 and 4.

Step 2: Determine a design cross-section using the AASHTO design charts shown in Figures 1, 2 and 3 (AASHTO, 1993) and $w_{total\text{-}18}$ (calculated in step 1 section 3). Analyses are performed considering the normal period of operation (end of spring thaw to end of construction season) assuming a 2 week performance period and for the spring-thaw period of operation assuming a 1 week performance period. A final base layer thickness, $D_{BS\text{-}F}$ and a final subbase thickness, $D_{SB\text{-}F}$ is determined from the analyses.

2.1 Determine a base layer thickness, D_{BS}, based on an allowable serviceability loss and an allowable rut depth (see Figures 1 and 2) for both the normal period of operation and the spring-thaw period of operation .

a) Determine D_{BS} for the normal period of operation based on allowable serviceability loss, ΔPSI using Figure 1.

Figure 1 requirements:

- Allowable serviceability loss, ΔPSI calculated from selected values of: 1) an initial serviceability index (p_o); and 2) a terminal serviceability index (p_t).
- Resilient modulus of roadbed material, M_R
- Base modulus, E_{BS}
- Allowable 18-kip ESAL applications, W_{18psi}

The following explains how they are obtained.

ΔPSI is defined as the total change in serviceability index. The Serviceability Index is a measure of the ability of the road section to serve the type of traffic using the road.

Written by: Daniel Pass Date: 4 February.96 Reviewed by: Date: 2/20/96

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- ΔPSI is calculated as follows;

$$\Delta PSI = p_o - p_t \qquad (5)$$

Where,

p_o = the initial serviceability index, serviceability index at time of construction.
p_t = the terminal serviceability index, lowest serviceability index tolerated at the end of the performance period.

- Determine resilient modulus of roadbed material, M_R:

The roadbed material is expected to be either compacted brown till or existing brown till. Use lower value of the M_R values determined for compacted and undisturbed brown till material. Values of M_R, for compacted and undisturbed brown till material, are determined based on site specific CBR testing of brown till. (PARSONS, 1995 and COE, 1952). $M_R \alpha$ CBR

- Base Modulus, E_{BS}:

Use value recommended in ODOT, 1992 for #304, Aggregate Base (crushed stone).

- Allowable 18-kip ESAL applications , w_{18PSI}:

Corresponds to $w_{Total\text{-}18}$ calculated in step 1, section 3.

b) Determine D_{BS} for the normal period of operation based on RD using Figure 2.

Figure 2 requires selection of an allowable rut depth, RD and knowledge of

- Resilient Modulus of road bed material, M_R,
- Base Modulus, E_{BS}, and
- Allowable 18-kip ESAL applications, w_{18PSI}.

which are obtained in the above part a.

It is noted that in AASHTO, 1993 that a rut depth failure of an aggregate surfaced road refers to deformation of the pavement structure and roadbed support and not simply surface rutting of the base layer. Hence, after the specified allowable rut depth is reached, an addition of aggregate to the base will likely be required as well as grading of the road surface to regain the initial serviceability of the road.

c) Determine D_{BS} for spring-thaw operation period using the procedure from the above parts a and b. Performance period considered is 1 week.

Input parameter values are the same as determined for the above section 1 with the following exceptions.

- Allowable 18-kip ESAL applications , w_{18PSI}:

  Corresponds to 1/2 the $w_{Total\text{-}18}$ calculated in step 1, section 3. This value corresponds to a 1 week performance period.

- Determine Resilient Modulus of Roadbed Material, M_R for spring thaw conditions.:

  Assume value based on the value of M_R determined in the above part a.

2.2 Determine the required $D_{BS\text{-}R}$ value as the maximum value of D_{BS} determined in the above Section 1.

- Add 1 inch to D_{BS} for aggregate loss. Aggregate loss is a reduction of the base layer thickness due to traffic and erosion.

2.3 Select a final base thickness, $D_{BS\text{-}F}$ and convert the difference between D_{BS} and $D_{BS\text{-}F}$ to a required subbase thickness, D_{SB} using Figure 3.

Figure 3 requires selection of $D_{BS\text{-}F}$ and knowledge of

- Resilient Modulus of road bed material, M_R,
- Base Modulus, E_{BS}, and
- Allowable 18-kip ESAL applications, w_{18PSI}.
- Subbase Modulus, E_{SB}.

which are obtained in the above part a excepting for E_{SB} which is obtained as follows.

- Subbase Modulus, E_{SB}: Use value recommended in ODOT, 1992 for #310, subbase aggregate (bank run gravel).

Step 3: Calculate required section using the ODOT design method for flexible pavement design (ODOT, 1992).

3.1 Determine the design structure number, SN, using Figures 4 and 5 and the following input parameters. The SN is used in Equation 6 to determine the thickness of the road cross-section aggregate layers.

- Reliability, R (%): Reliability is the probability, that serviceability will be maintained at an adequate level for the performance period considered. This value will be assumed.

- Overall Standard Deviation, S_0: Overall Standard Deviation is a measure of the variability of input parameters. The value used is as recommended in ODOT, 1992.

- Estimated Total 18-kip ESAL Applications, w_{18}: Use values of w_{18} for 2 and 1 week performance periods as calculated for the AASHTO method.

- Effective Roadbed Soil Resilient Modulus, M_R (psi): Use values of M_R for normal and spring-thaw operating periods as calculated for the AASHTO method.

- Design Serviceability Loss, ΔPSI: Use value of ΔPSI determined for the AASHTO method.

- Structural Coefficients: The structural Coefficient for a soil is a measure of the relative ability of a material to function as a structural component of the road. Use Structural Coefficient recommended in ODOT, 1992 for aggregate base (ODOT spec. #304) and subbase (ODOT spec. #310)

- Asphalt pavement thickness: Assume as 0 ft for aggregate-surfaced road.

3.2 Select a Final Base Thickness, D_{BS-F}. Calculate a Required Subbase Thickness, D_{SB} using the following equation;

$$D_{SB} = \frac{\left(SN - a_{BS} D_{BS-F}\right)}{a_{SB}} \qquad (6)$$

Where,

a_{BS}, a_{SB} = Structural Coefficients for base and subbase aggregate, respectively.

Written by: Daniel Pass Date: 4 February.96 Reviewed by: BTOM Date: 2/20/96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

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Step 4: Determine a final design cross-section based on analysis in steps 1 to 3.

Select geotextile to act as separator between subbase and base.

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DESIGN CHART FOR AASHTO METHOD

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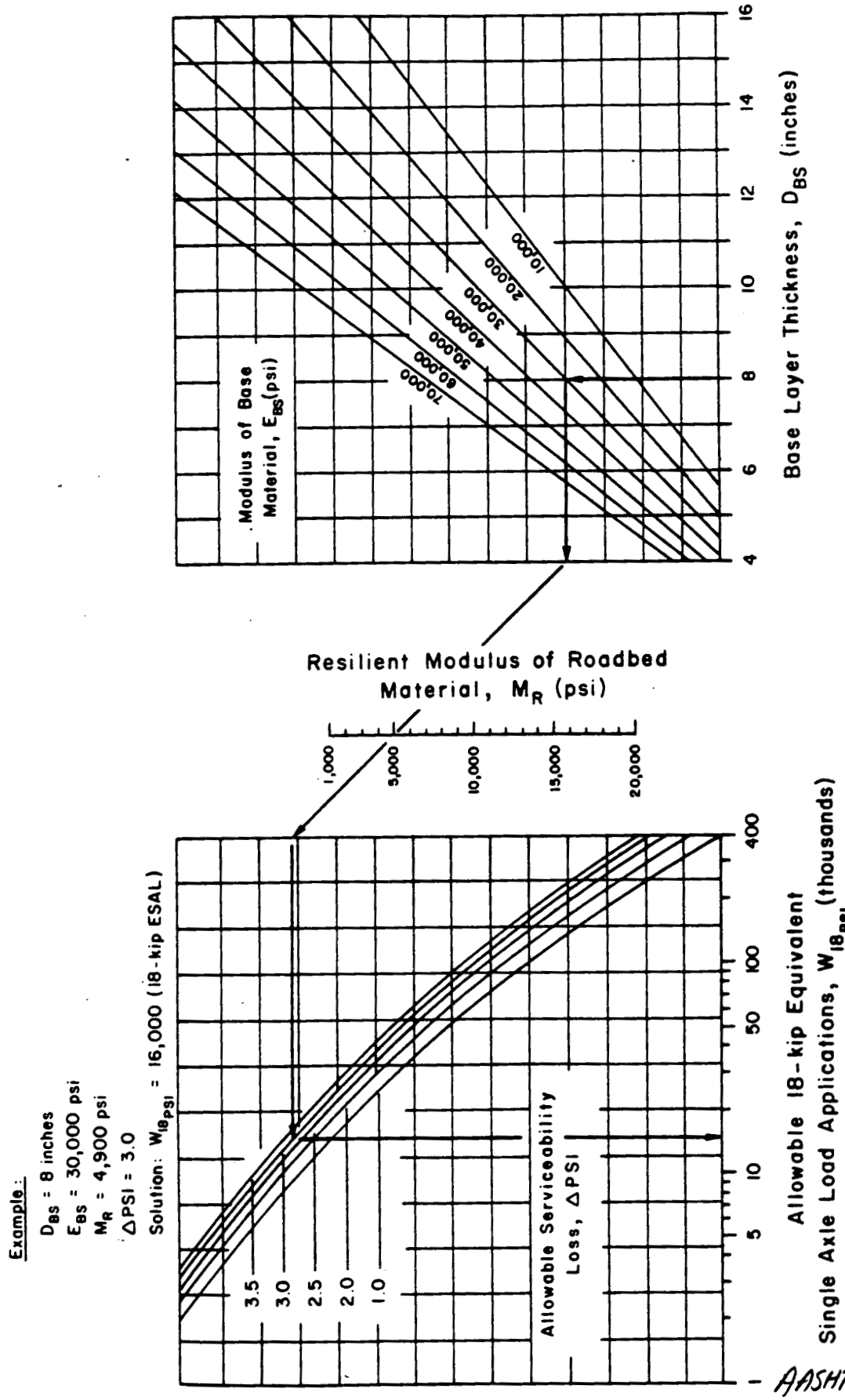

Figure 4.2. Design Chart for Aggregate-Surfaced Roads Considering Allowable Serviceability Loss

– AASHTO, 1993

DANIEL PASS FERMCO/OSDF GE3900 14 FEB 1996

000181 FIGURE 1

DESIGN CHART FOR AASHTO METHOD. — 10/37 2/20/96 KO 22 FEB 96

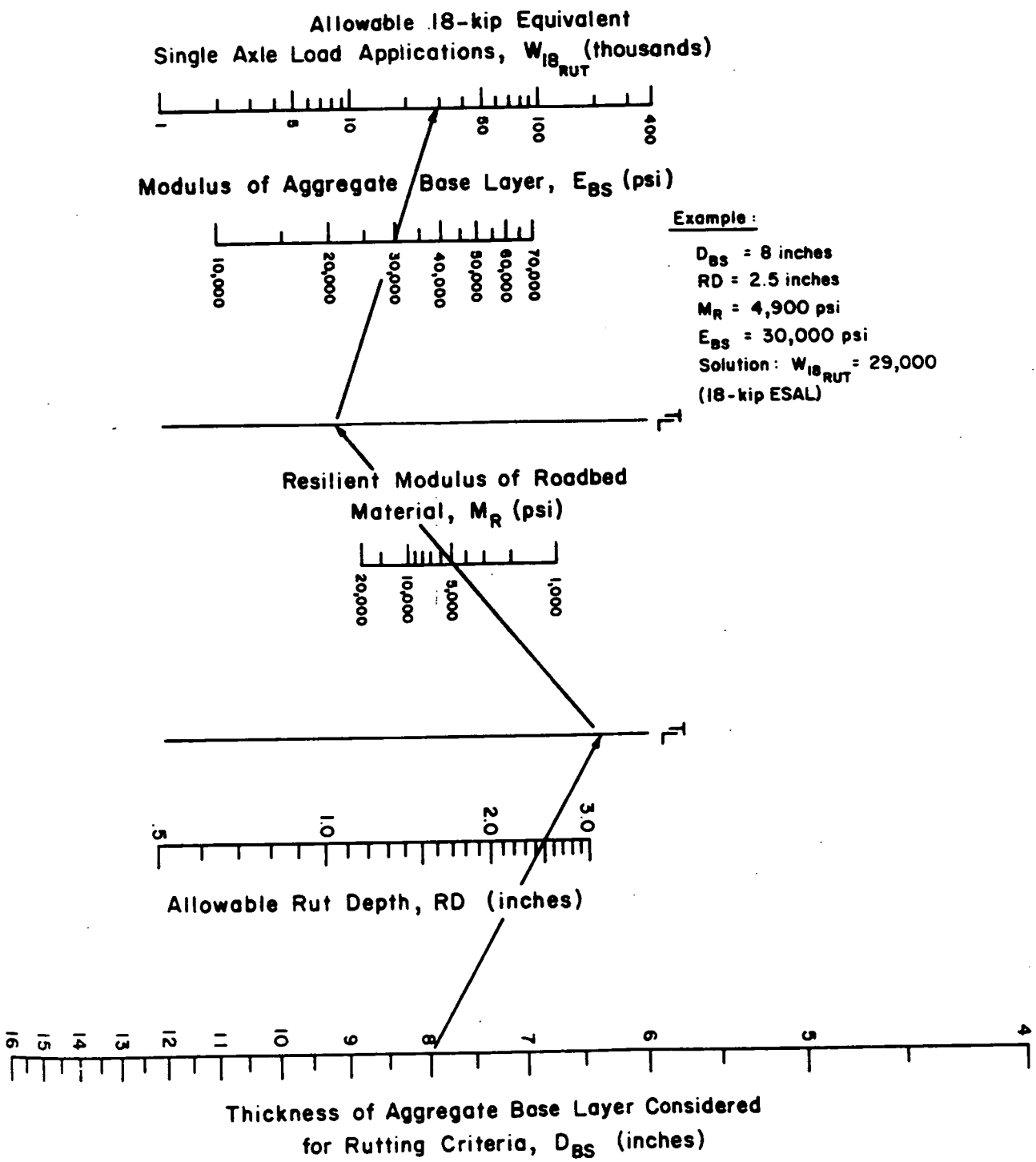

Figure 4.3. Design Chart for Aggregate-Surfaced Roads Considering Allowable Rutting

AASHTO, 1993

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000182 FIGURE 2

DESIGN CHART FOR AASHTO METHOD — 740 11/37 BTM 2/20/96 KO 22 Feb 96

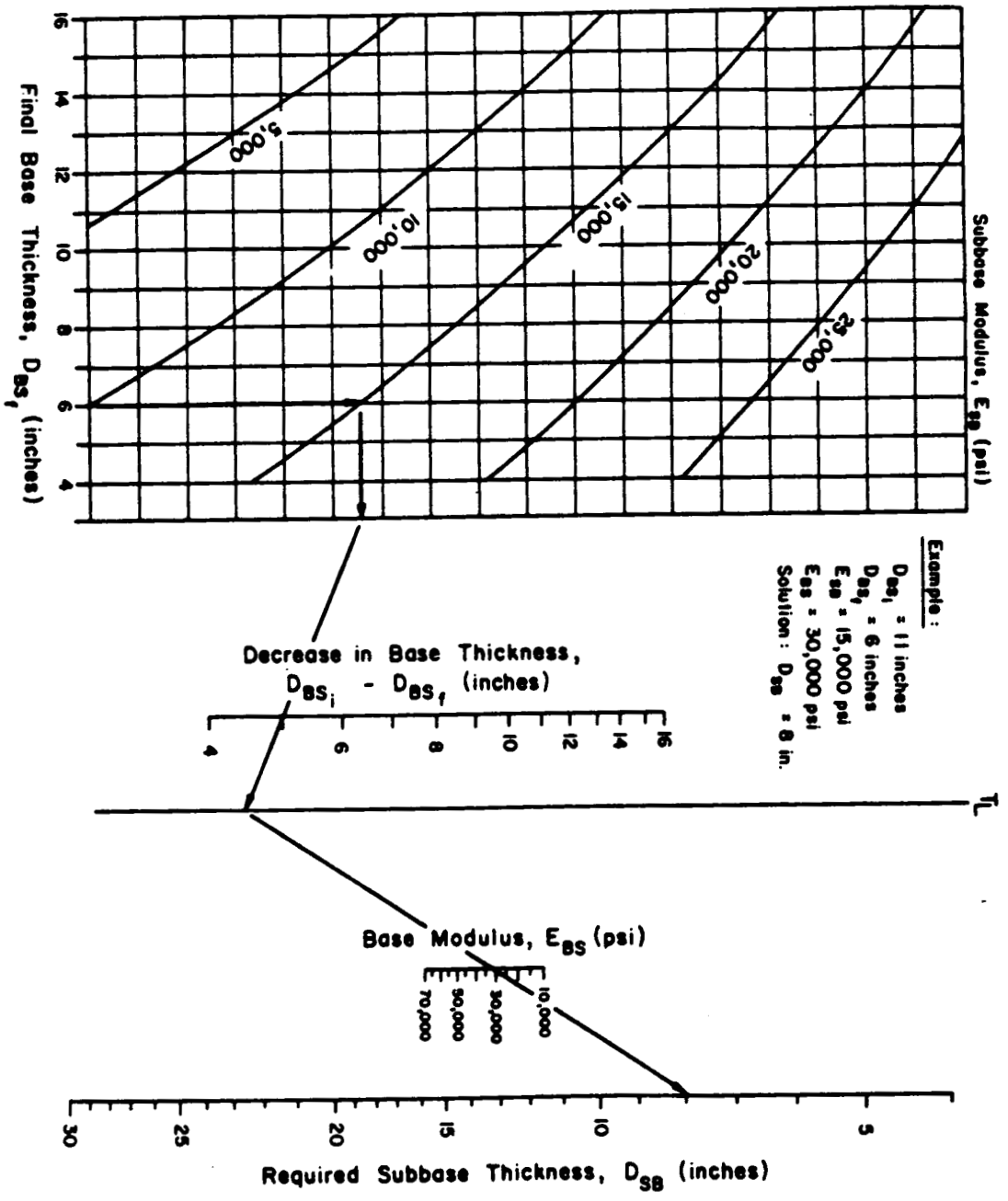

Figure 4.5. Chart to Convert a Portion of the Aggregate Base Layer Thickness To an Equivalent Thickness of Subbase

AASHTO, 1993

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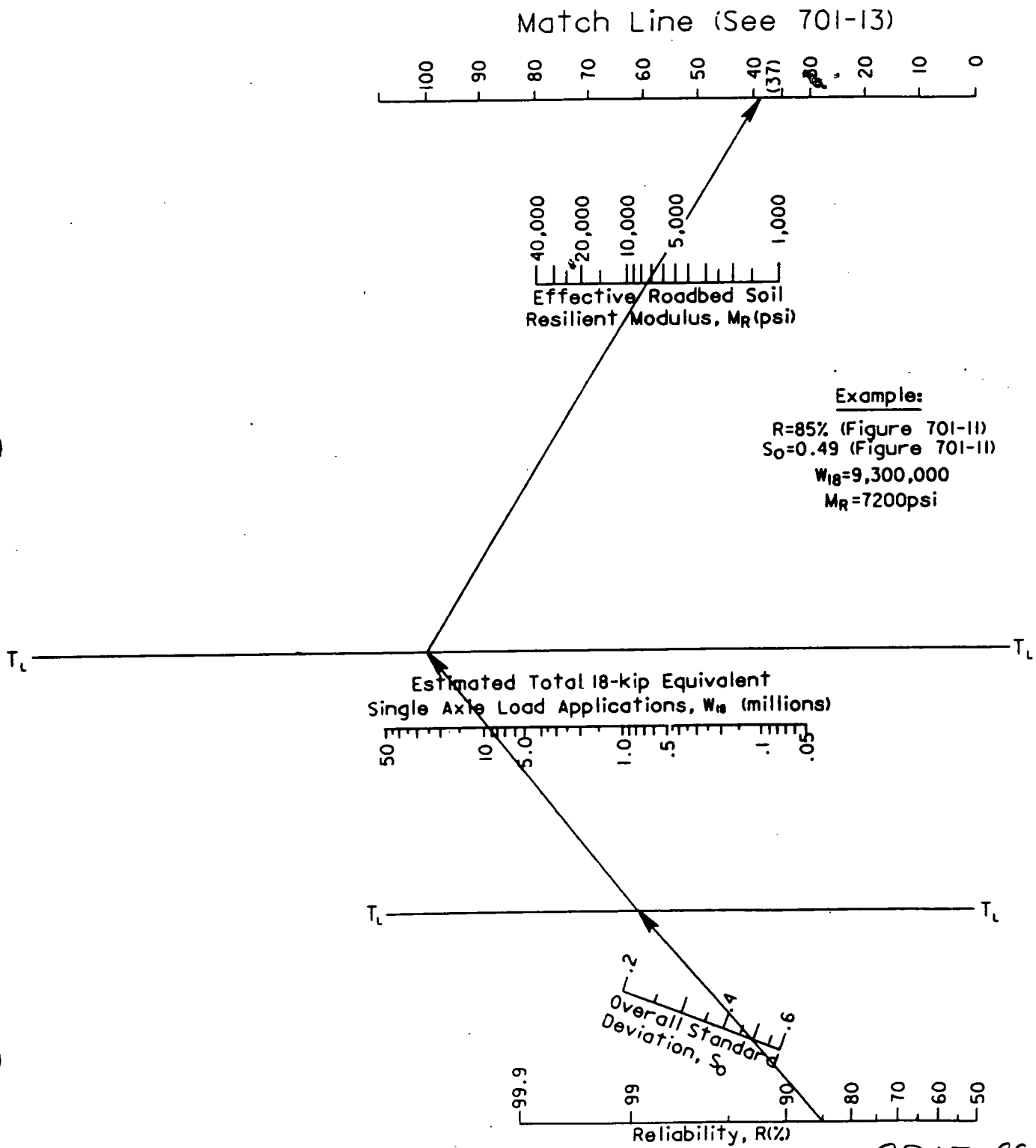
000183 FIGURE 3

DESIGN CHART FOR ODOT METHOD — 740 BBM October 1992 12/37 2/20/96 KO 22 Feb 96

FLEXIBLE PAVEMENT DESIGN CHART SEGMENT 1

701-12

REFERENCE SECTION
FLEXIBLE PAVEMENT DESIGN EXAMPLE - STEP 1



ODOT, 1992

DANIEL PASS FERMCO/OSOF GE3900 14 FEB 1996 000184 FIGURE 4

740

DESIGN CHART FOR ODOT METHOD

BMM 2/20/96 13/37

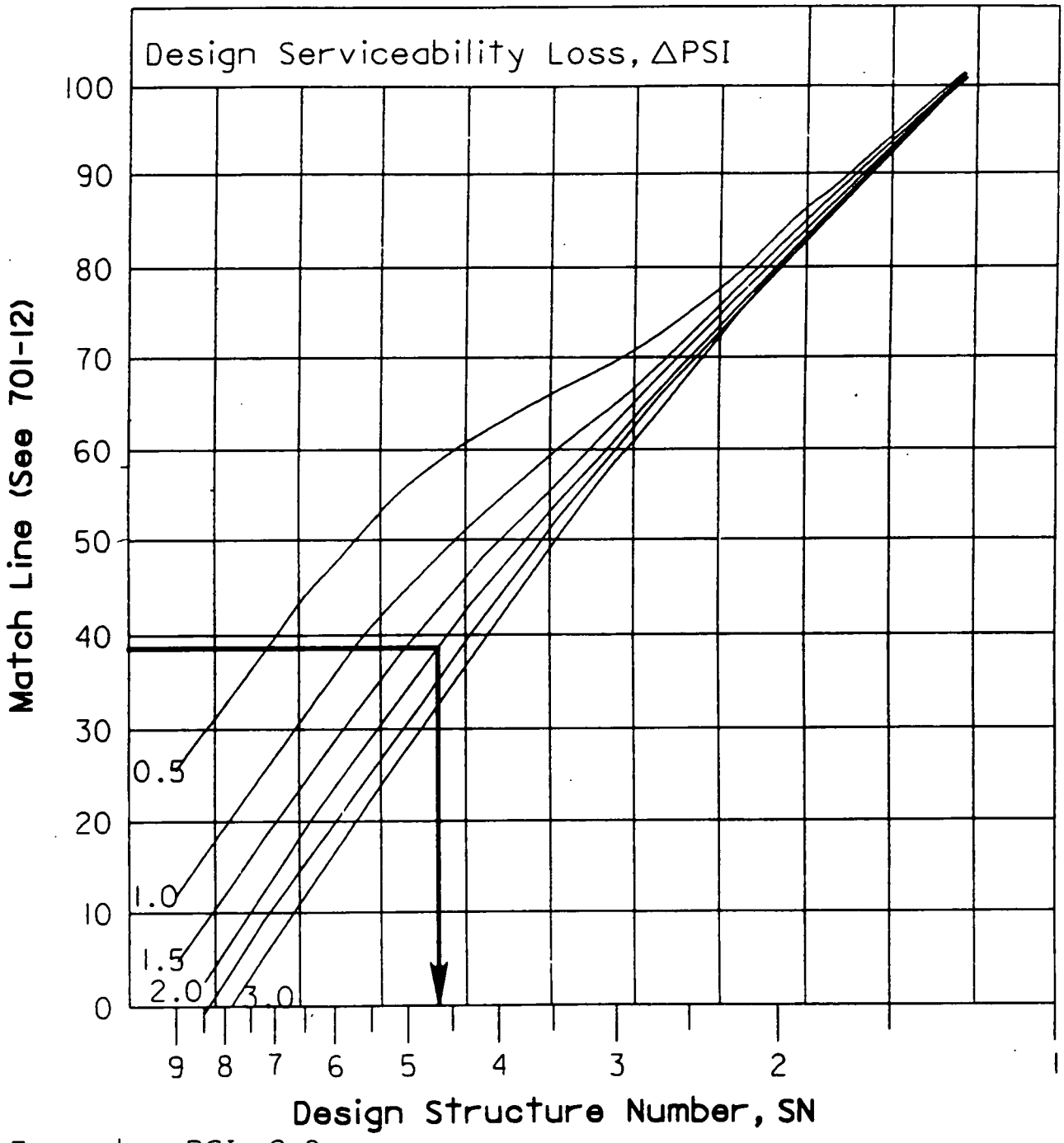
October 1992

KO 22 Feb 96

FLEXIBLE PAVEMENT DESIGN CHART SEGMENT 2

701-13

REFERENCE SECTION
FLEXIBLE PAVEMENT DESIGN EXAMPLE - STEP 1



Example: ΔPSI= 2.0

Solution: SN= 4.65

ODOT, 1992

DANIEL PASS, FERMICO/OSOF GE3900 14 FEB 1996 14 FEB 96

000185 FIGURE 5

Collection and Verification of Engineering Data:

Step 1: For determination of the total 18-kip Equivalent Single Axle Load applications, $w_{Total\text{-}18}$ for a 2 week performance period.

Design Vehicle:
The following table summarizes input parameters for the design vehicle - Cat 621E scraper. (Caterpillar, 1993)

Specifications for Caterpillar 621E Scraper.

Parameter		Value
Operating Weight		67.2 kip
Rated Load		48.0 kip
Weight Distribution		
Empty		
	Drive	68%
	Rear	32%
Loaded		
	Drive	53%
	Rear	47%
Scraper Capacity	Heaped	20 cy

- Capacity of Scraper, $V_{S\text{-}Capacity}$: The capacity of the scraper is determined to be controlled by the rated load, assuming a borrow unit weight of 135 PCF, swell of 25% and Rated load of 48.0 of kips. The capacity of the scraper is = 16.5 Loose CY.

Borrow area excavation:

- The total volume expected for excavation: From the design calculation titled "Borrow Area Capacity Verification"; V_{borrow} = 650,000 CY.

- Assume construction of OSDF occurs at a rate of one cell per year over a period of 9 years. Construction season is 9 months.

Borrow Clay Characteristics:

- Swell, S: Swell of clay borrow material from bank to loose condition is assumed as 25% (Caterpillar, 1993)

- Bank Unit Weight: 135 pcf from design parameter summary for design calculations.

Step 2: For determination of a design road cross-section using the AASHTO design method.

Allowable Serviceability Loss, ΔPSI:

- Initial Serviceability Index, p_o: Assume value of 4.2 (as recommended in general for flexible pavements in AASHTO, 1993)

- Terminal Serviceability Index, p_t : Assume value of 2.0 as recommended for rural roads (AASHTO, 1993)

Resilient Modulus of Roadbed Material, M_R:

- For normal period of operation (period after during spring-thaw to end of construction period): Use value of 5,400 psi based on correlation of cone penetration testing (CPT) test results to CBR (Parsons, 1995) for undisturbed upper and lower horizon brown till and using the following equation (ODOT, 1992);

$$M_R = 1200CBR \qquad (7)$$

CBR values from correlation by Parsons averaged between 4 and 5. CPT soundings were conducted at locations within the borrow area and OSDF battery limits.

- For spring thaw period of operation: assume a 50% reduction in M_R from normal period of operation.

Note: Values of M_R for compacted brown till are expected to be higher than values of M_R for undisturbed brown till: Two test programs for compacted brown till were considered:

- PARSONS, 1995 testing program: Upper horizon brown till samples were compacted to 95 % of standard Proctor. Measured values of CBR ranged from 1.95 to 4.4. The corresponding M_R range is 2,340 to 5,280 psi.

- US Corps, 1952 Testing program: Brown till samples were compacted to 100% of standard Proctor. Measured value of CBR was 8. The corresponding value of M_R is 9,600 psi.

The average value of M_R for upper horizon brown till compacted to 95% of standard Proctor (i.e., 3) is lower than the M_R value of undisturbed brown till selected for design. On this basis compacted brown till used for road fill must be compacted using a higher compactive effort (i.e., 100% of standard Proctor or higher). The lower horizon brown till exhibits a higher measured maximum dry density than the upper horizon material. (GeoSyntec, 1996).

Base Modulus, E_{BS}: = Assume 30,000 psi as recommended by ODOT, 1992 for ODOT spec. 304, Aggregate Base.

Allowable $w_{18\text{-}PSI}$: Calculated using p_0 and p_t .

Allowable rut depth: Assume 3 in. given that use of the road will largely be confined to off-highway vehicles.

Subbase Modulus, E_{SB}: = Assume 15,000 psi as recommended by ODOT, 1992 for ODOT spec. 310, Aggregate Subbase.

Step 3: For determination of design cross-section using the ODOT method (ODOT, 1992).

- Reliability, R: 50 to 80% is recommended for low volume roads; Assume value of 70%.
- Overall Standard Deviation, S_0: Assume value of 0.49 as recommended for flexible pavements in ODOT, 1992.
- Estimated Total 18-kip ESAL Applications, w_{18}: Obtain from calculation in Step 1, section 3.
- Effective Roadbed Soil Resilient Modulus, M_R: Use values determined for AASHTO method; for normal operating and spring thaw periods; 5,400 psi, and 2,700 psi, respectively.
- Design Serviceability Loss, ΔPSI : Use value determined for AASHTO method, 0.22.

$$\Delta PSI = p_o - p_i = 4.2 - 2.0 = 2.2$$

Written by: Daniel Pass Date: 4 February.96 Reviewed by: [illegible] Date: 2/20/96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

KO 22 Feb 96

- Structural Coefficients: Use values recommended in ODOT, 1992 for materials selected for base and subbase, as follows;

  Aggregate base (#304) = 0.14, recommended in ODOT, 1992.
  subbase (#310) = 0.11, recommended in ODOT, 1992.

- Asphalt pavement thickness: Assume = 0 ft for aggregate-surfaced road.

Written by: DANIEL PASS Date: 96/2/14 (YY MM DD) Reviewed by: [illegible] Date: 96/02/20 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

CALCULATIONS AND RESULTS: INPUT PARAMETERS ARE TAKEN FROM THE COLLECTION AND VERIFICATION SECTION.

STEP 1: DETERMINE THE TOTAL 18-KIP EQUIVALENT SINGLE LOAD APPLICATIONS, $W_{TOTAL-18}$ FOR A 2 WEEK PERFORMANCE PERIOD. SCRAPER TRAFFIC TO AND FROM THE OSDF ARE CONSIDERED.

1.1) CALCULATE THE SINGLE AXLE LOAD, N FOR EACH SCRAPER AXLE LOAD TYPE USING THE FOLLOWING EQUATION:

$$N_{DL,RL,DE,RE} = W_V L_{dist}$$

W_V, FOR LOADED SCRAPER = OPERATING WEIGHT + RATED LOAD

= 67.2 KIP + 48.0 KIP

= 115.2 KIP

W_V, FOR EMPTY SCRAPER = 67.2 KIP.

- N_{DL}, DRIVE AXLE, LOADED SCRAPER TRAVELLING TO THE OSDF

  = 115.2 KIP × 0.53

  = 61.1 KIP

- N_{RL}, REAR AXLE, LOADED SCRAPER TRAVELLING TO THE OSDF

  = 115.2 KIP × 0.47

  = 54.1 KIP

- N_{DE}, DRIVE AXLE, EMPTY SCRAPER RETURNING TO THE BORROW AREA

  = 67.2 KIP × 0.68

  = 45.7 KIP

Written by: DANIEL PASS Date: 96/2/14 Reviewed by: [illegible] Date: 96/02/20

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

STEP 1, CONT'D: DETERMINE TOTAL 18-KIP ESAL APPLICATION, $W_{TOTAL-18}$

1.1 CONT'D) CALCULATION OF SINGLE AXLE LOAD, N.

- N_{RE}, REAR AXLE, EMPTY SCRAPER RETURNING TO THE BORROW AREA.

$$= 67.2 \text{ kip} \times 0.32$$

$$= 21.5 \text{ kips}$$

1.2) CALCULATE THE NUMBER OF SCRAPER PASSAGES TO (OR FROM) THE OSDF, W_N OVER THE PERFORMANCE PERIOD, USING THE FOLLOWING EQUATION;

$$W_N = \frac{V_{BORROW}\left(1 + \frac{S}{100}\right)}{V_{S\text{-}CAPACITY}}$$

$$W_N = \frac{650{,}000 \text{ cy}\left(1 + \frac{25\%}{100}\right)}{16.5 \text{ cy}}$$

$$= 49{,}242 \text{ APPLICATIONS/SCRAPE AXLE LOAD TYPE}^{*}$$

1.3) CALCULATE $W_{TOTAL-18}$ TO BE INPUT INTO DESIGN CHARTS USING THE FOLLOWING EQUATIONS;

$$W_{DL,RL,DE,RE-18} = W_N \left(\frac{N_{DL,RL,DE,RE}}{18}\right)^{4.5}$$

$$W_{TOTAL-18} = W_{DL-18} + W_{RL-18} + W_{DE-18} + W_{RE-18}$$

* NUMBER OF APPLICATIONS FOR PERFORMANCE PERIOD OF 2 WEEKS.

$$W_{N-2WKS} = 49{,}242 \times \frac{1}{9_{YRS}} \times \frac{1}{39 \text{ WKS}} \times 2 = 281 \text{ APPLICATIONS}$$

Written by: DANIEL PASS Date: 96 / 2 / 14 (YY MM DD) Reviewed by: [illegible] Date: 96 / 02 / 20 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

STEP 1, CONT'D: DETERMINE TOTAL 18-KIP ESAL APPLICATIONS.

1.3, CONT'D) CALCULATE $W_{TOTAL-18}$

$$W_{DL-18} = 281 \left(\frac{61.1\,kip}{18}\right)^{4.5}$$

$$= 68,733$$

$$W_{RL-18} = 281 \left(\frac{54.1\,kip}{18}\right)^{4.5}$$

$$= 39,753$$

$$W_{DE-18} = 281 \left(\frac{45.7\,kip}{18}\right)^{4.5}$$

$$= 18,604$$

$$W_{RE-18} = 281 \left(\frac{21.5\,kip}{18}\right)^{4.5}$$

$$= 625$$

$$W_{TOTAL-18} = 127,996 \text{ APPLICATIONS}$$

Written by: DANIEL PASS Date: 96 / 2 / 14 (YY MM DD) Reviewed by: [illegible] Date: 96/02/20 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

STEP 2: DETERMINE A DESIGN ROAD CROSS-SECTION USING AASHTO DESIGN CHARTS.

2.1) DETERMINE REQUIRED AGGREGATE BASE LAYER THICKNESS, D_{BS} BASE ON ALLOWABLE SERVICEABILITY LOSS, ΔPSI AND ALLOWABLE RUT DEPTH, RD.

a) DETERMINE D_{BS} BASED ON ΔPSI

- $\Delta PSI = P_o - P_t$

  $= 4.2 - 2.0$

  $= 2.2$

- RESILIEND MODULUS OF ROADBED MATERIAL, M_R

  $= 5,400$ psi

- BASE MODULUS, $E_{BS} = 30,000$ psi
- ALLOWABLE 18-KIP ESAL APPLICATIONS, W_{18PSI}

  $= 127,996$ APPLICATIONS

FROM FIGURE 6 AND ABOVE INPUT PARAMETERS

$D_{BS} = 17$ IN

b) DETERMINE D_{BS} BASED ON RD = 3 IN.

FROM FIGURE 7 AND ABOVE INPUT PARAMETERS

$D_{BS} = 11$ IN.

Written by: DANIEL PASS Date: 96/2/14 (YY/MM/DD) Reviewed by: [illegible] Date: 96/02/20 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

STEP 2, CONT'D: DETERMINE A DESIGN ROAD CROSS-SECTION USING AASHTO DESIGN CHARTS.

2.1, CONT'D) DETERMINE REQUIRED AGGREGATE BASE LAYER THICKNESS, D_{BS}

C) DETERMINE D_{BS} FOR SPRING-THAW OPERATION PERIOD BASED ON ΔPSI AND RD. ONE WEEK PERFORMANCE PERIOD.

ALLOWABLE 18-KIP ESAL APPLICATIONS, $W_{18\,psi}$

= 127,996/2

= 63,998 APPLICATIONS.

RESILIENT MODULUS FOR ROADBED MATERIAL, M_R

= 5,400 psi/2

= 2,700 psi

FROM FIGURE 8 AND ABOVE INPUT PARAMETERS (AND FROM PART'a) FOR $\Delta PSI = 2.2$.

D_{BS} = 16 IN.

FROM FIGURE 9 AND ABOVE INPUT PARAMETERS (AND FROM PART b) FOR RD. = 3 IN.

D_{BS} = 12 IN.

2.2) DETERMINE REQUIRED D_{BS} AS MAXIMUM VALUE FROM ABOVE SECTION 1

MAXIMUM D_{BS} = 17 IN

ADD 1 IN FOR AGGREGATE LOSS

∴ REQUIRED D_{BS} = 18 IN.

Written by: DANIEL PASS Date: 96/2/14 (YY MM DD) Reviewed by: [illegible] Date: 96/02/20 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

STEP 2. CONT'D: DETERMINE A DESIGN ROAD-CROSS-SECTION USING AASHTO DESIGN CHARTS.

2.3) SELECT A FINAL BASE THICKNESS, D_{BS-F} AND CONVERT THE DIFFERENCE BETWEEN D_{BS} AND D_{BS-F} TO A REQUIRED THICKNESS OF SUBBASE, D_{SB}

USE FINAL BASE THICKNESS, D_{BS-F} = 9 IN.

$D_{BS} - D_{BS-F}$ = 18 IN - 9 IN = 9 IN.

SUBBASE MODULUS = 15,000 psi

FROM FIGURE 10 ABOVE INPUT PARAMETERS AND INPUT PARAMETERS FROM SECTION 1.

D_{SB} = 12.5 IN.

STEP 3: CALCULATE REQUIRED SECTION USING THE DOT DESIGN METHOD FOR FLEXIBLE PAVEMENT DESIGN (ODOT, 1992)

3.1) DETERMINE THE DESIGN STRUCTURE NUMBER, SN

RELIABILITY, R = 70%

OVERAL STANDARD DEVIATION, S_0 = 0.49

ESTIMATED TOTAL 18 KIP ESAL APPLICATIONS, W_{18} = 127,996

EFFECTIVE ROADBED SOIL RESILIENT MODULUS, M_R = 5,400

DESIGN SERVICEABILITY LOSS, ΔPSI = 0.22

FROM FIGURES 11 AND 12 AND ABOVE INPUT PARAMETERS

SN = 2.4

3.2) SELECT FINAL BASE THICKNESS, D_{BS-F}. CALCULATE REQUIRED SUBBASE THICKNESS, D_{SB} USING THE FOLLOWING EQUATION

$$SN = a_{BS} D_{BS-F} + a_{SB} D_{SB}$$

SN = 2.4

Written by: DANIEL PASS Date: 96/2/14 (YY/MM/DD) Reviewed by: [illegible] Date: 96/02/20 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

STEP 3 CONT'D: CALCULATE REQUIRED SECTION USING THE DOT DESIGN METHOD.

3.2, CONT'D) SELECT FINAL BASE THICKNESS AND CALCULATE D_{SB}

$a_{BS} = 0.14$

$a_{SB} = 0.11$

$D_{BS-F} = 9$ IN

FROM ABOVE EQUATION $D_{SB} = 10.5$ IN

3.3) FOR SPRING-THAW OPERATION PERIOD, SEE FIGURES 13 AND 14.

ESTIMATED TOTAL 18-KIP ESAL APPLICATION, $W_{18} = 63,998$

EFFECTIVE ROADBED SOIL RESILIENT MODULUS, $M_R = 2,700$

$SN = 2.7$

GIVEN $D_{BS-F} = 9$ IN.

$D_{SB} = 13$ IN.

STEP 4: DETERMINE FINAL DESIGN CROSS SECTION BASED ON ANALYSIS IN STEPS 1 TO 3.

RESULTS FROM STEPS 1 TO 3 AS FOLLOWS

	D_{BS-F}	D_{SB}
AASHTO METHOD	9 IN	12.5 IN
ODOT METHOD	9 IN	13.0 IN

USE LARGEST CROSS-SECTION DETERMINED FROM AASHTO AND ODOT METHODS

DESIGN CROSS-SECTION 9 IN 13 IN

Written by: DANIEL PASS Date: 96/2/14 (YY MM DD) Reviewed by: BRM Date: 96/02/20 (YY MM DD)

Client: FERMCO Project: GE3900 Project/Proposal No.: GE3900 Task No.: 10.2

STEP 4 CONT'D: DETERMINE FINAL DESIGN CROSS-SECTION

SELECTION OF GEOTEXTILE SEPARATOR

FOR LONG TERM PERFORMANCE AND CONSTRUCTION LOADS USE GEOTEXTILE WITH A HIGH TO VERY HIGH DEGREE OF FABRIC SURVIVABILITY. SEE TABLE 1 FOR GEOTEXTILE PROPERTIES.

- DESIGN CROSS-SECTION SHOWN IN FIGURE 15.

DETERMINATION OF D_{BS} FOR ΔPSI 740 26/37

(NORMAL OPERATING PERIOD) 2/20/96

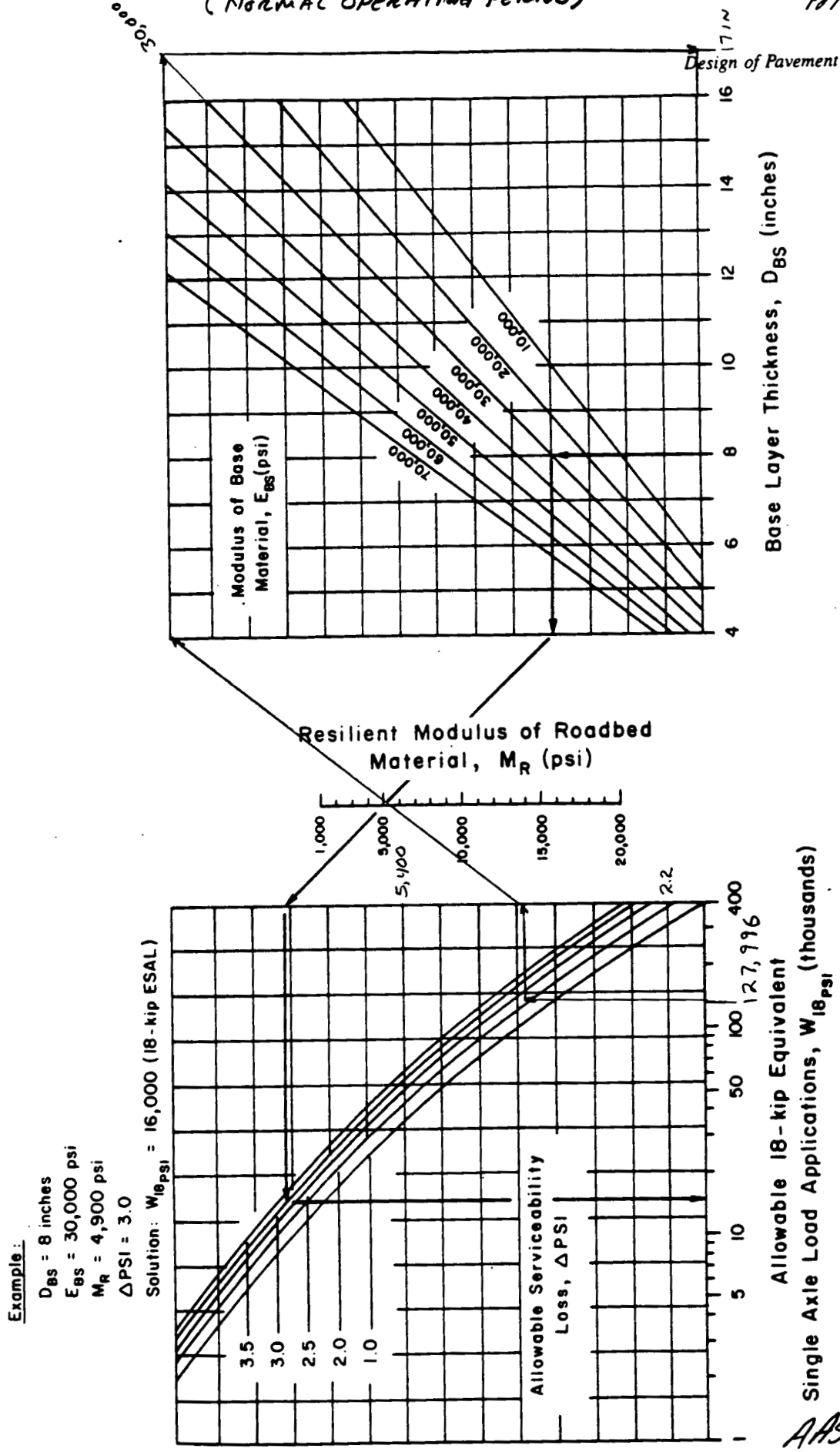


Figure 4.2. Design Chart for Aggregate-Surfaced Roads Considering Allowable Serviceability Loss

AASHTO, 1993

DANIEL PASS FERMCO OSDF GE3900 14 FEB 1996 000198 FIGURE 6

DETERMINATION OF D_{BS} FOR RD

(NORMAL OPERATING PERIOD)

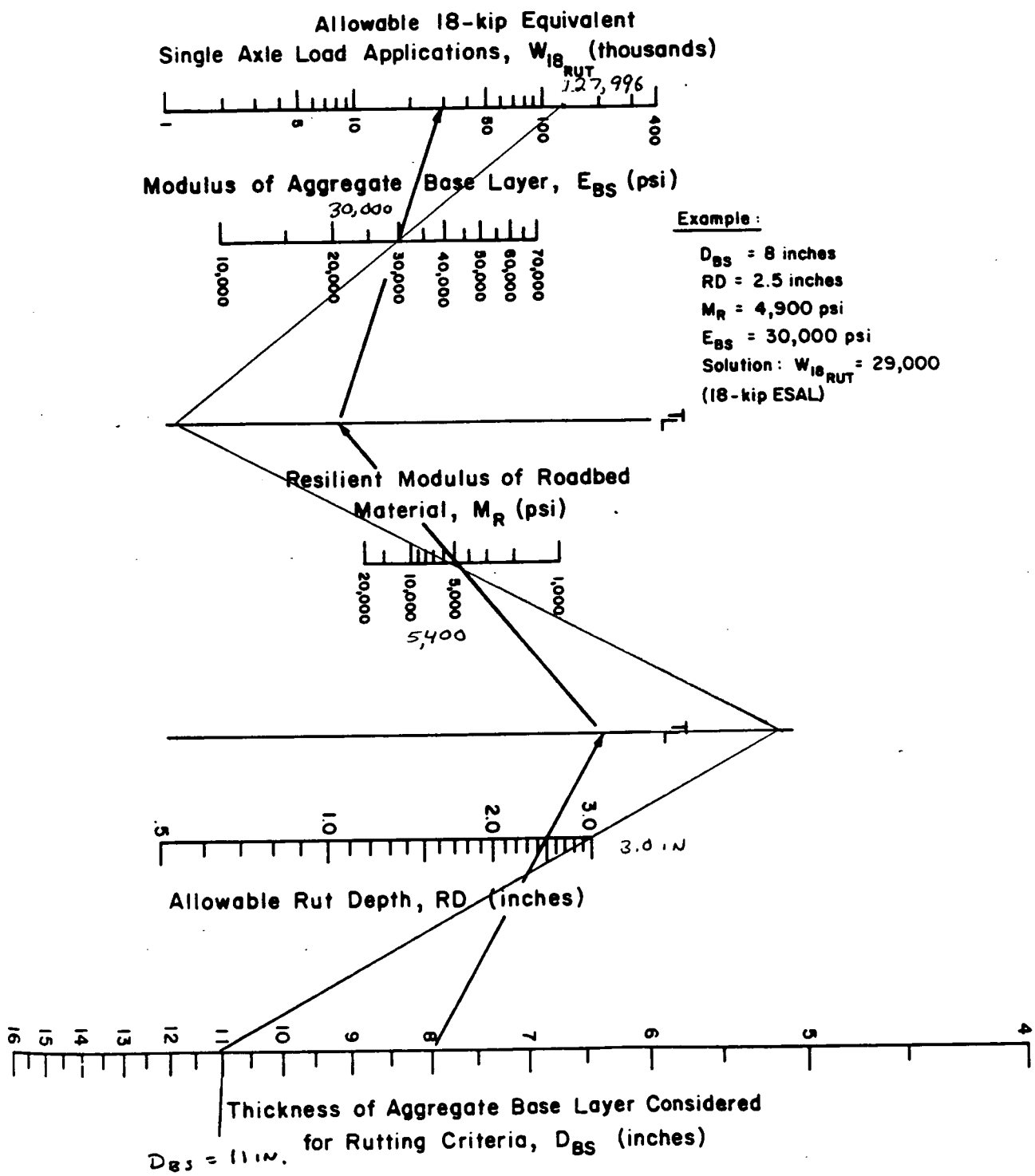


Figure 4.3. Design Chart for Aggregate-Surfaced Roads Considering Allowable Rutting

AASHTO, 1993

DETERMINATION OF D_{BS} FOR ΔPSI
(SPRING-THAW OPERATING PERIOD)

740 28/37
2/20/96

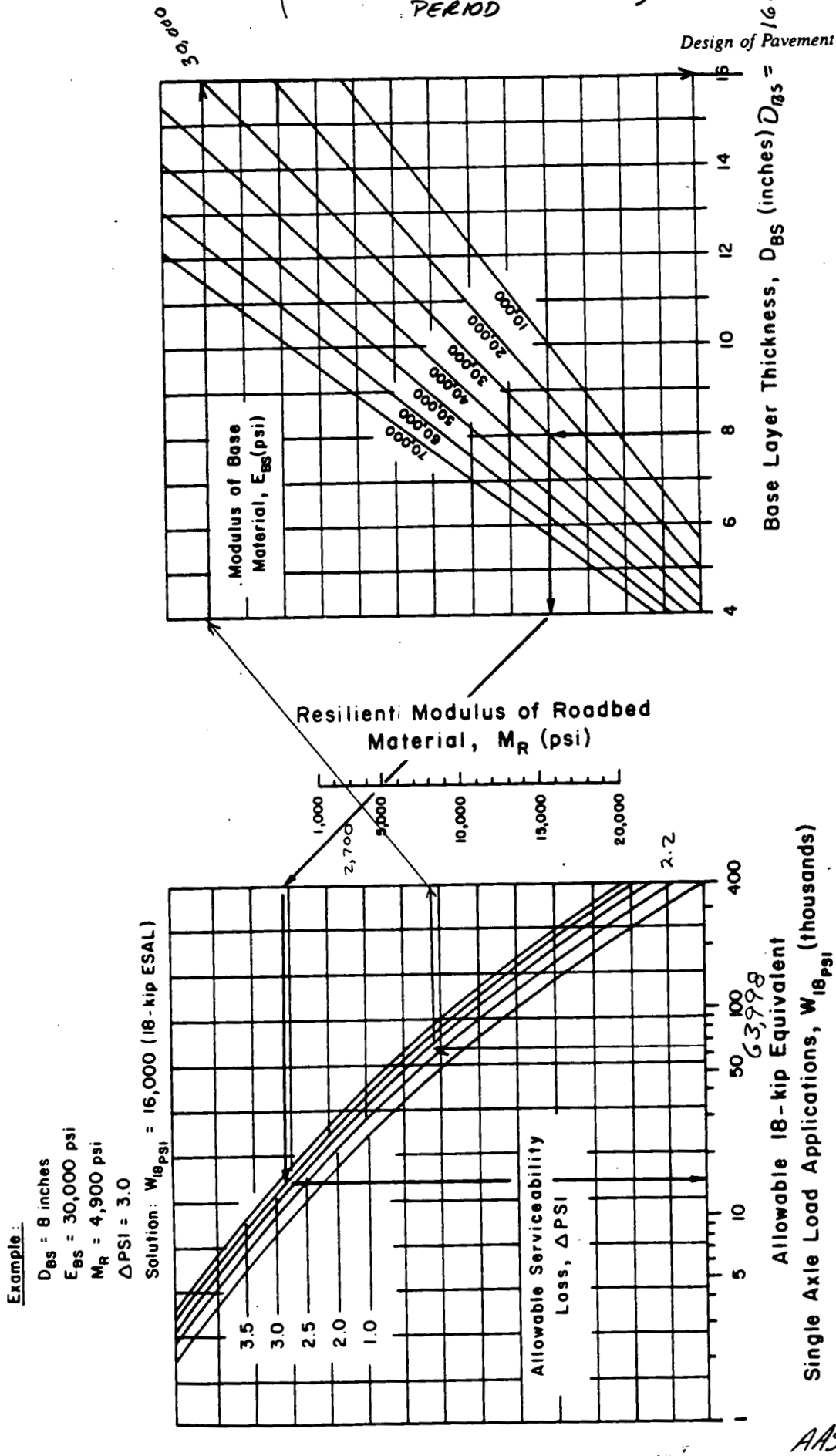


Figure 4.2. Design Chart for Aggregate-Surfaced Roads Considering Allowable Serviceability Loss

AASHTO, 1993
FIGURE 8

DANIEL PASS FERMCO/OSDF GE 3900 14 FEB 1996

000200

DETERMINATION OF D_{BS} FOR RD
(SPRING-THAW OPERATING PERIOD)

740 29/37
2/20/96

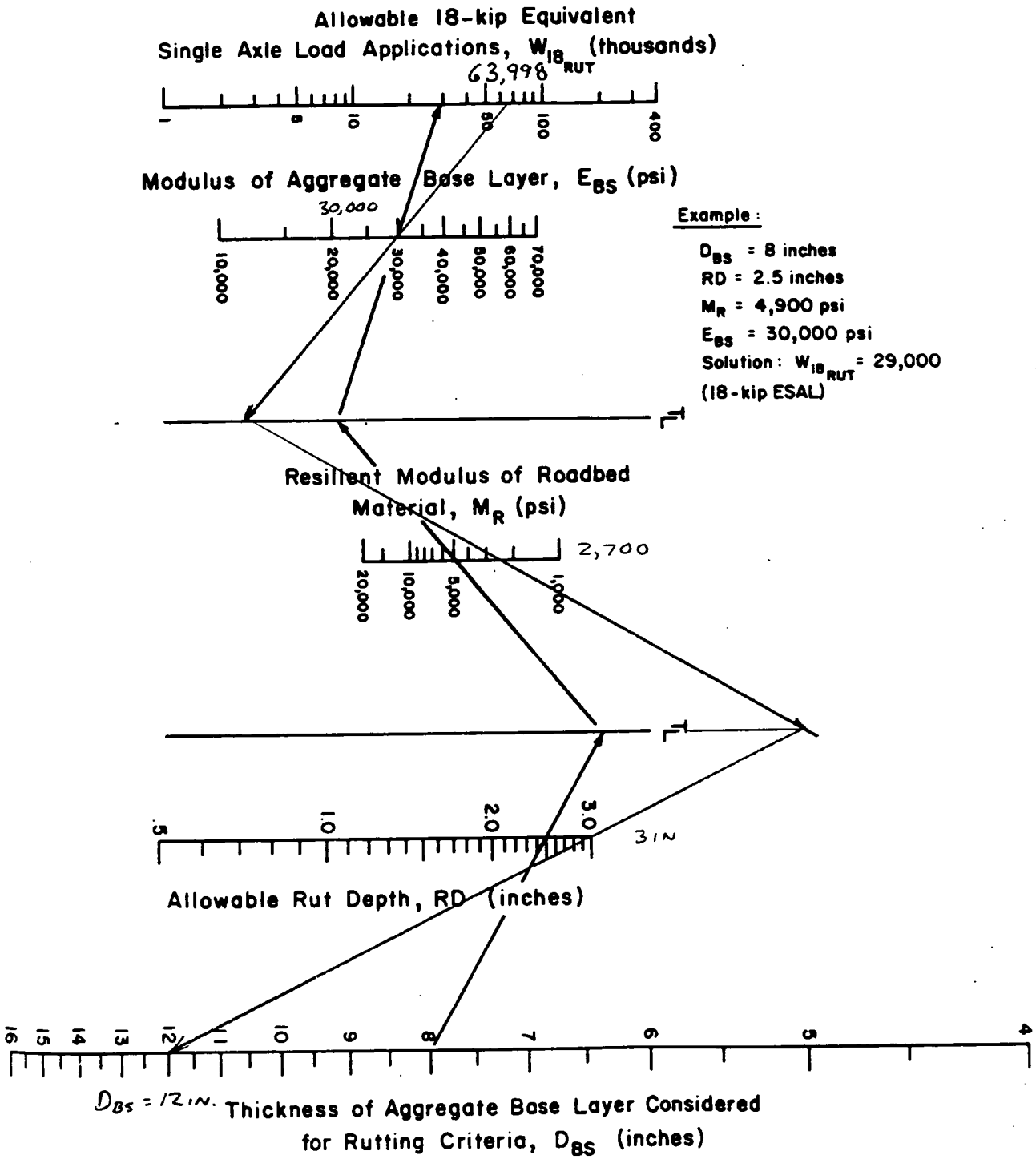


Figure 4.3. Design Chart for Aggregate-Surfaced Roads Considering Allowable Rutting

AASHTO, 1993

DANIEL DASS FERMCO OSDF GE 3900 14 FEB 96

000201 FIGURE 9

DETERMINATION of D_{SB} FOR D_{BS-F} 740 30/37 2/20/96

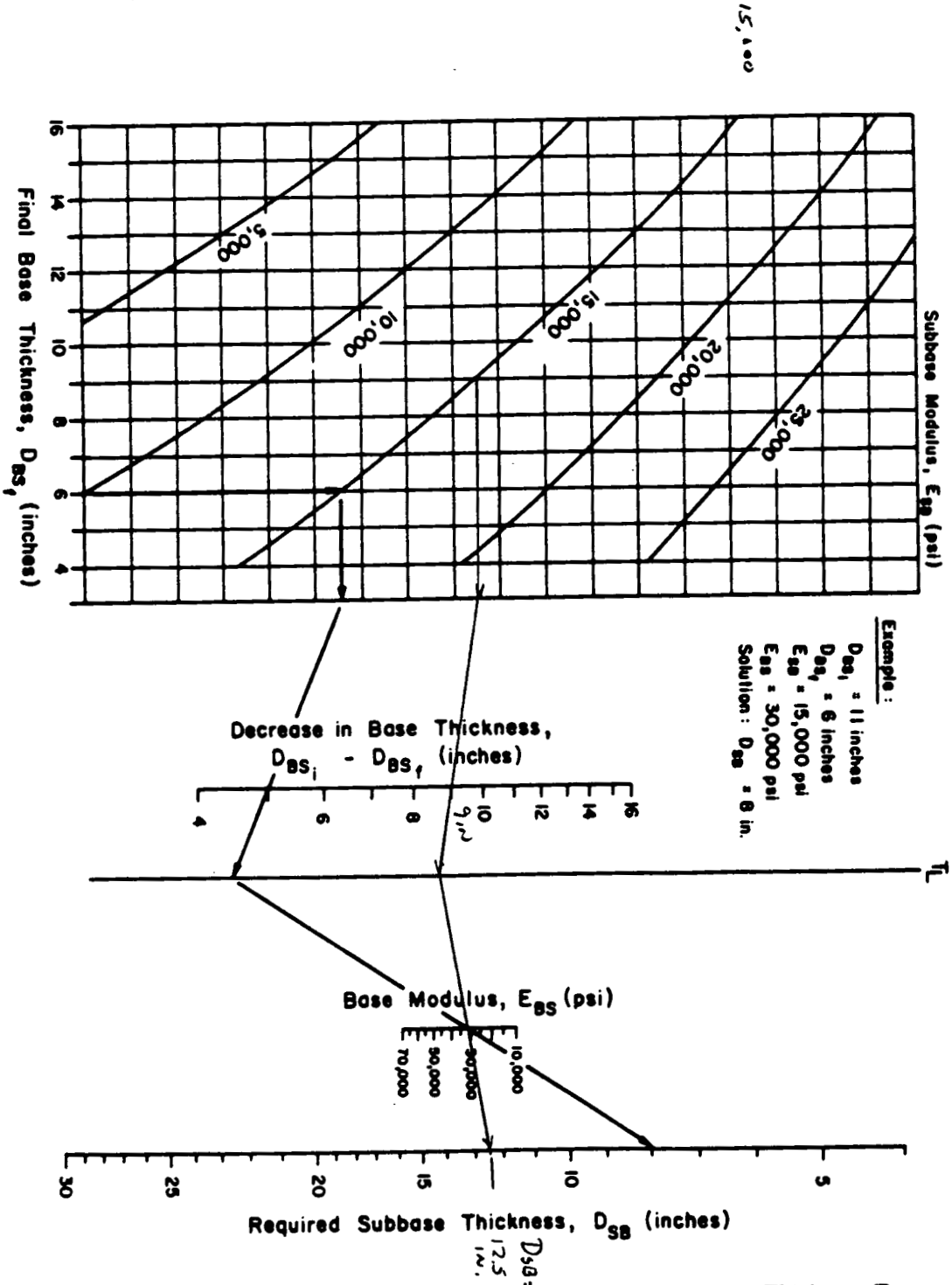


Figure 4.5. Chart to Convert a Portion of the Aggregate Base Layer Thickness To an Equivalent Thickness of Subbase

AASHTO, 1993

DANIEL PASS FERMCO OSDF GE3900 14 FEB 96 000202 FIGURE 10

DETERMINE SN FOR NORMAL PERIOD OF OPERATION 31/37

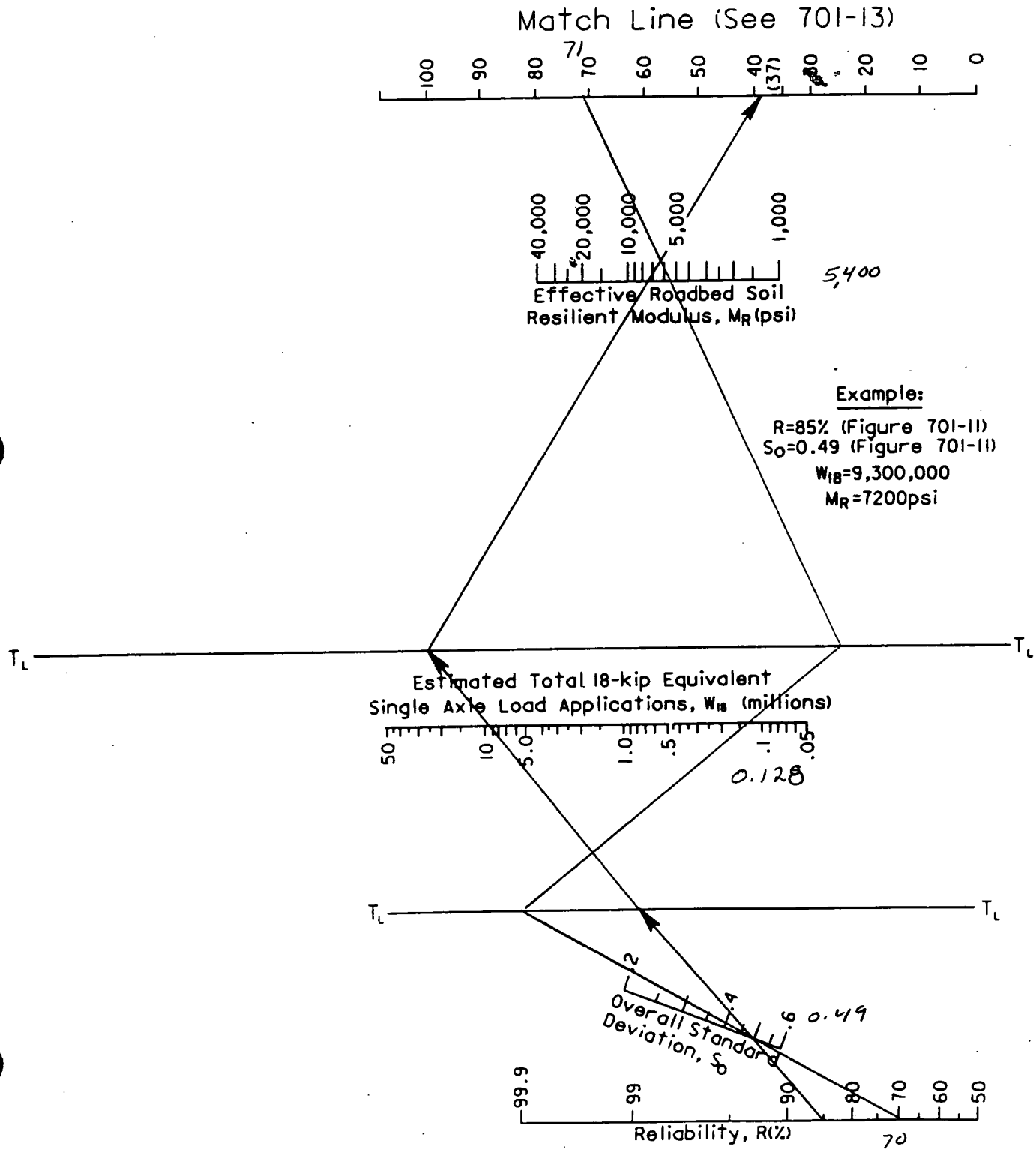
October 1992

RTOM 2/20/96

FLEXIBLE PAVEMENT DESIGN CHART SEGMENT 1

701-12 740

REFERENCE SECTION
FLEXIBLE PAVEMENT DESIGN
EXAMPLE - STEP 1



000203 ODOT, 1992

DANIEL PASS FERMCO OSDF GE3900 14 FEB 96

FIGURE 11

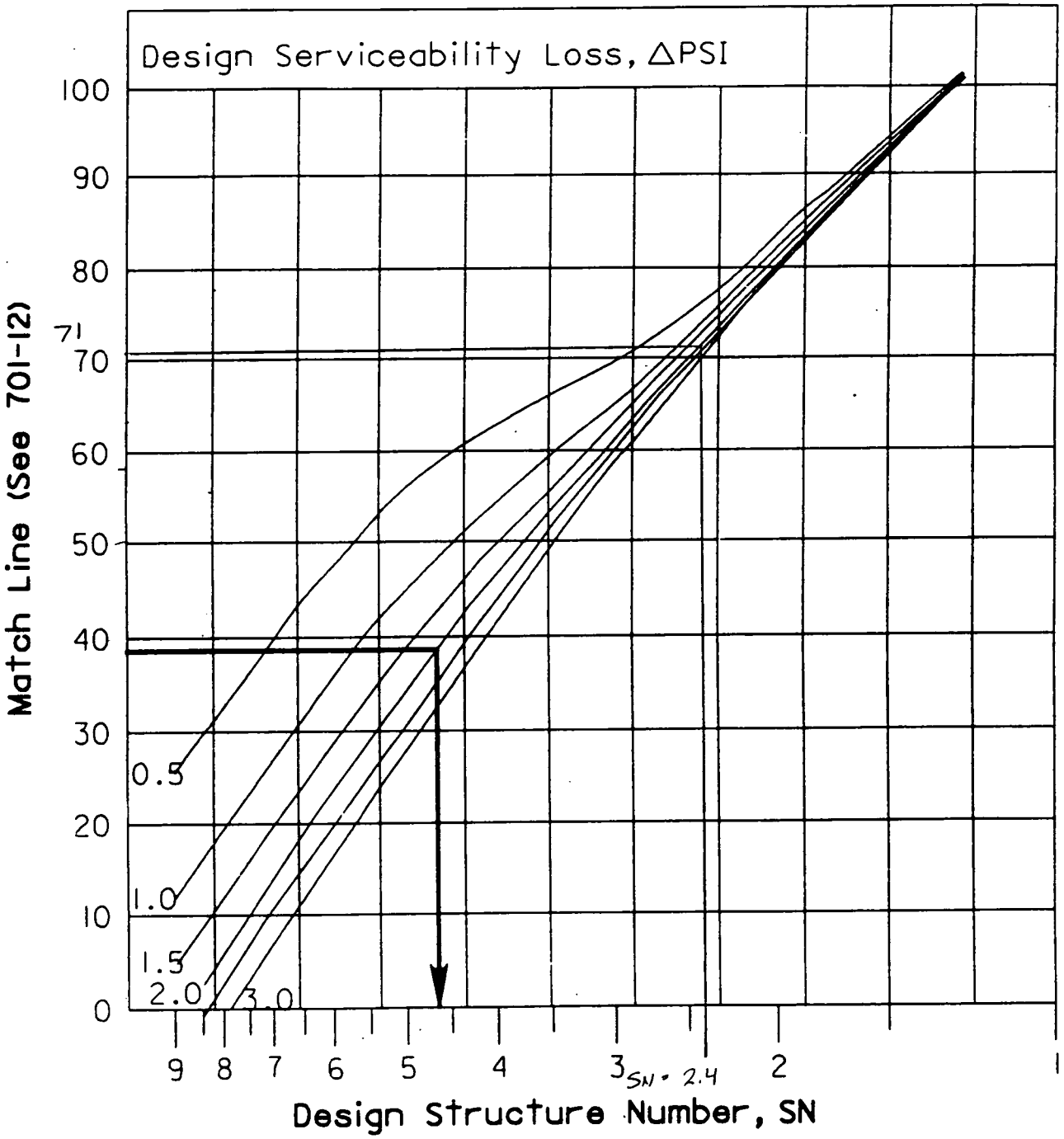
740 DETERMINE SN FOR NORMAL PERIOD OF OPERATION 32/37 RTM 2/20/96

October 1992

FLEXIBLE PAVEMENT DESIGN CHART SEGMENT 2

701-13

REFERENCE SECTION
FLEXIBLE PAVEMENT DESIGN EXAMPLE - STEP 1



Example: ΔPSI= 2.0

Solution: SN= 4.65

ODOT, 1992

000204

FIGURE 12

DANIEL PASS FERMCO OSDF GE3900 14 FEB 96

DETERMINE SN FOR SPRING THAW OPERATION PERIOD 33/37

October 1992

740

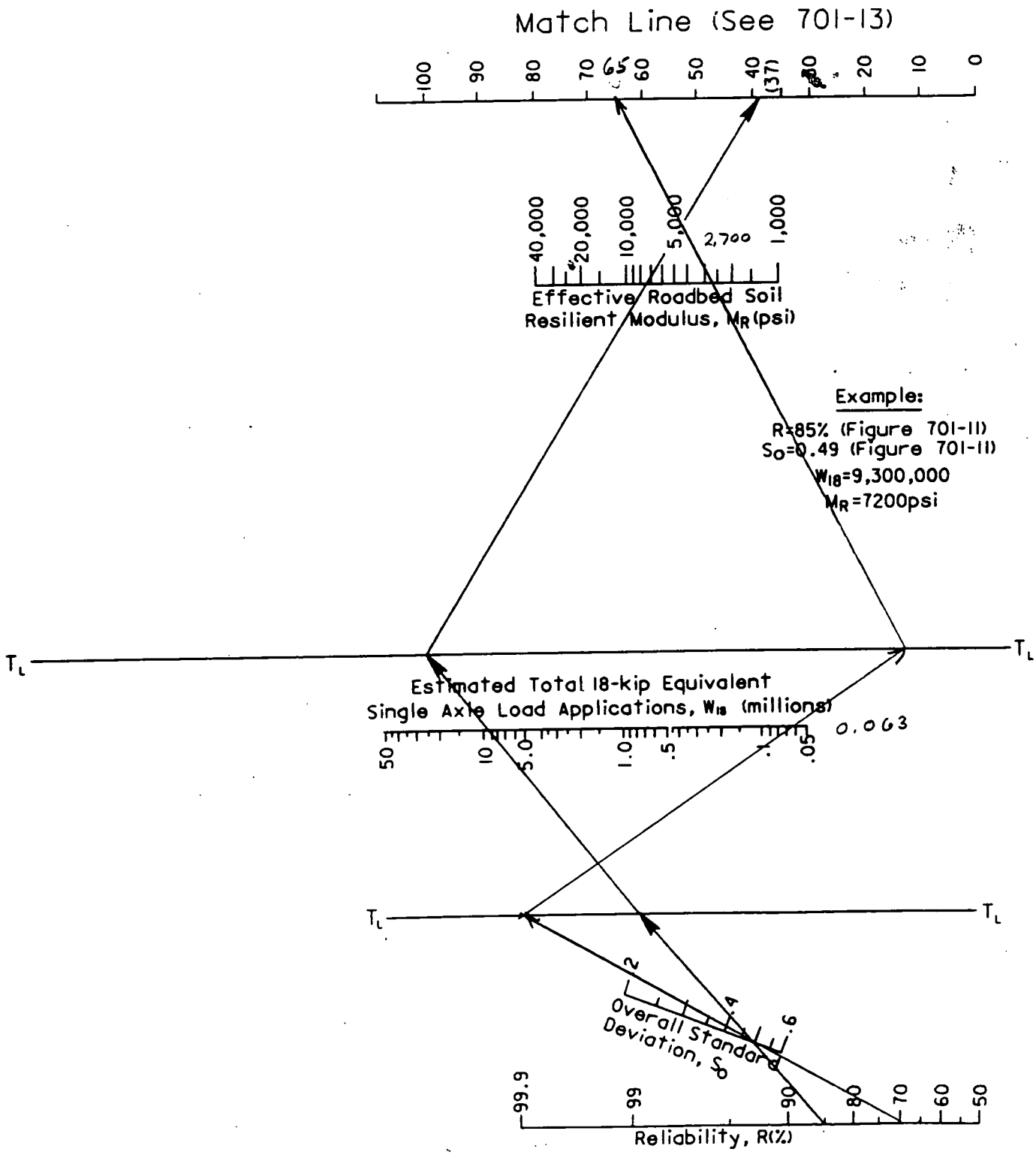
2/20/96

FLEXIBLE PAVEMENT DESIGN CHART SEGMENT 1

701-12

REFERENCE SECTION

FLEXIBLE PAVEMENT DESIGN EXAMPLE - STEP 1



ODOT, 1992

DANIEL PASS FEXMCO OSDF GE3900 14 FEB 96

000205

FIGURE 13

DETERMINE SN FOR SPRING-THAW OPERATION PERIOD 34/37

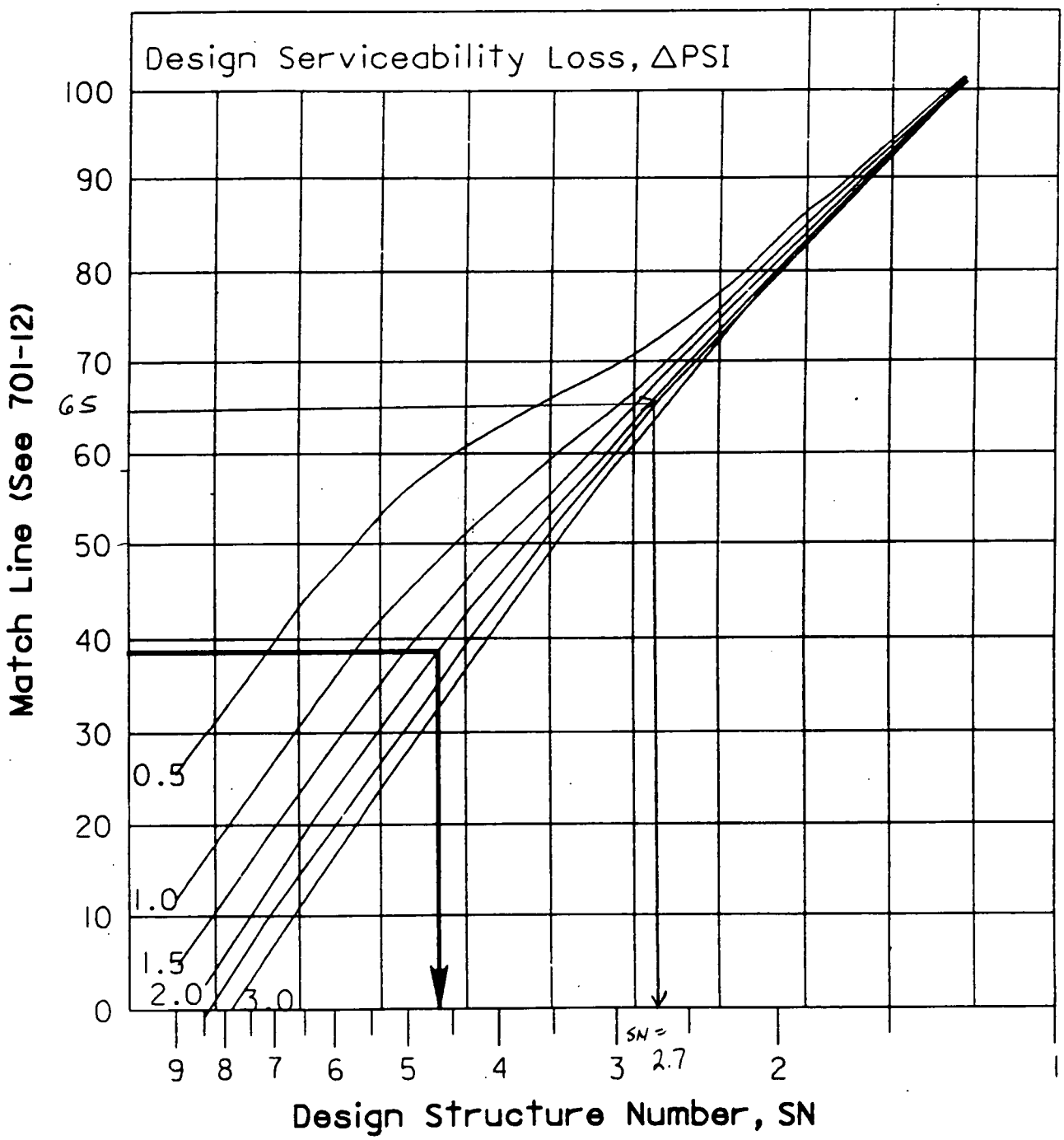
740 October 1992

PRINT 2/20/96

FLEXIBLE PAVEMENT DESIGN CHART SEGMENT 2

701-13

REFERENCE SECTION
FLEXIBLE PAVEMENT DESIGN EXAMPLE - STEP 1



Example: ΔPSI= 2.0

Solution: SN= 4.65

ODOT, 1992

DANIEL PASS FERMCO 050F GE390U 14 FEB 96

000206 FIGURE 14

Written by: DAN PASS Date: 96 / 2 / 14 (YY MM DD) Reviewed by: [illegible] Date: 96 / 02 / 20 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

CONSTRUCTION MATERIAL HAUL ROAD

DESIGN CROSS-SECTION

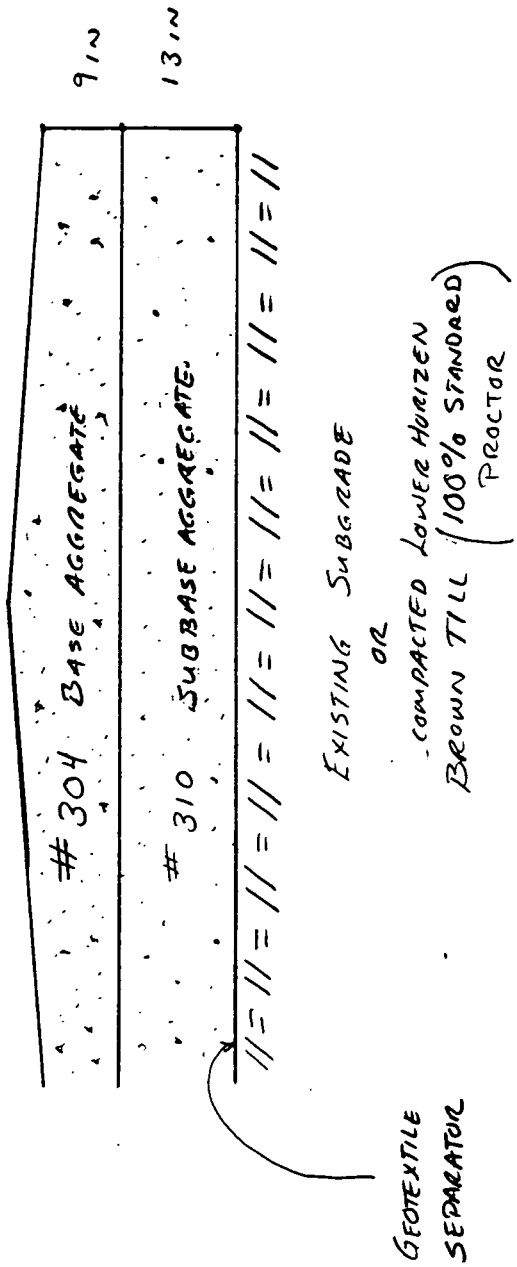


FIGURE 15

Table 4. Minimum[1] geotextile properties required for survivability [FHWA, 1985]

Required Degree of Fabric Survivability	Grab Strength (minimum values) (lbs.)	Puncture Strength[2] (lbs)	Burst Strength[3] (psi)	Trap[4] Tear (lbs)
Very High	270	110	430	75
High	180	75	290	50
Moderate	130	40	210	40
Low	90	30	145	30

[1] All values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the minimum value in this table). Note: these values are normally 20% lower than manufacturer's reported typical values.

[2] ASTM D-751-68, Tension Testing Machine with ring clamp, steel ball replaced with a 5/16-inch diameter solid steel cylinder with flap tip centered within the ring clamp.

[3] ASTM D-751-68, Diaphragm Test Method.

[4] ASTM D-1117, either principal direction.

FWHA, 1989

DAWIEC TASS FERMCO/OSDF GE3900 14 FEB 96

000208 TABLE 1

References:

1. American Association of State Highway and Transportation Officials (AASHTO). "*AASHTO Guide for Design of Pavement Structures*", AASHTO, Washington, D.C., 1993.

2. Caterpillar, "*Caterpillar Performance Handbook*", 24th ed., Peoria, Illinois, 1995.

3. Federal Highway Administration (FHWA), "Geotextile Engineering Workshop, Design Examples", FHWA, Washington, D.C., January 1989.

4. GeoSyntec, "*Draft Test Pad Work Plan, On-Site Disposal Facility*", Revision B, GeoSyntec Consultants, Atlanta, GA, January 1996.

5. Ohio Department of Transportation (ODOT). "*Location and Design Manual, Volume 1 Roadway Design*", Revision October 1992, ODOT, Columbus, Ohio, 1992.

6. Parsons. "*Geotechnical Investigation Report, On-Site Disposal Facility*", Operable Unit 2, Project Order 140, Fernald Environmental Management Project, Rev. 0, Cincinnati, OH, 1995..

7. Department of the ARMY Corps of Engineers, "*Report of Foundation Investigation Feed materials Production Center,- FERNALD, Ohio.*" Ohio River Division Laboratories, Mariemont, OHIO, 1952.

14.9 Leachate Transmission System Access Corridor

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: LEACHATE TRANSMISSION SYSTEM ACCESS CORRIDOR

Computations By: (Cognizant Engineer)
Signature: Daniel G Pass — Date: 2/13/96
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: B B Mazanti — Date: 2/20/96
Printed Name and Title: B. B. MAZANTI, Consultant

Computations Checked by:
Signature: B B Mazanti — Date: 2/20/96
Printed Name and Title: B. B. MAZANTI, Consultant

Computations Backchecked by: (Cognizant Engineer)
Signature: Daniel G. Pass — Date: 2/21/96
Printed Name and Title: DANIEL PASS, STAFF ENGINEER

Approved by: (PDP)
Signature: Kara L Olen — Date: 22 Feb 96
Printed Name and Title: Kara L. Olen, Asst. Proj Eng.

Approved by: (DTL and TETL)
Signature: K W Cargill — Date: 22 Feb 96
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
AC	Intermediate Design				
D	Intermediate Design - EPA Submittal	5 Apr 96			
G	Final Design Package	4 Oct 96			
C	Response to Final Design Cmts	5 May 97			

Written by: Daniel Pass Date: 13 February 96 Reviewed by: MMM Date: 2/20/96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

LEACHATE TRANSMISSION SYSTEM ACCESS CORRIDOR

EXECUTIVE SUMMARY

Purpose:

The purpose of this calculation is to design a typical road cross-section for the proposed Leachate Transmission System Access Corridor. The road will be aggregate-surfaced and is designed to allow access by vehicles used for pumping out the LTS manholes (on an emergency basis) and for providing routine maintenance to the manholes. The expected service life of the road is approximately 40 years, corresponding to the active life of the facility plus a 30 year post-closure period.

Design Method:

Analyses are performed using an AASHTO method for design of aggregate-surfaced roads (AASHTO, 1993). A performance period of 20 years is assumed.

Conclusions:

Aggregate-surfaced road cross-section (top to bottom):

- Base: 6 in. of ODOT spec. #304 Base Aggregate;
- Subbase: 6 in. of ODOT spec. #310 Subbase Aggregate;
- Geotextile separator; and
- Prepared subgrade..

Rehabilitation:

- At the end of the 20 year performance period rehabilitation of the road is expected. Rehabilitation of the road may include regrading the roadway surface and addition of base aggregate.

Subgrade:

- Compacted brown till to 100% of Standard Proctor.

GEOSYNTEC CONSULTANTS

Written by: _____ Date: _____ Reviewe

Client: FERMCO Project: OSDF

THIS PAGE IS INSERTED ONLY FOR CLARITY AND DOES NOT AFFECT THE NUMBERING SYSTEM OF THE REST OF THE PACKAGE

LEACHATE TRANSMISSION SYSTEM ACCESS CORRIDOR

TABLE OF CONTENTS

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1.	Calculation Procedure	1/9
2.	Collection and Verification of Engineering Data	2/9
3.	Calculations	4/9

Written by: Daniel Pass Date: 13 February 96 Reviewed by: [illegible] Date: 2/20/96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

Introduction:

An aggregate surfaced road will be used to service the OSDF manholes during the assumed 10-year active life and 30-year post closure maintenance of the facility. The road is located along the west side of the OSDF. Expected traffic includes water tank trucks for pumping out the leachate manholes on an emergency basis, and passenger vehicles for routine maintenance.

An AASHTO method for design of low-volume roads is used to determine the required base and subbase layer thicknesses. A performance period of 20 years is assumed which corresponds to the interval of time before rehabilitation of the road will be required. Rehabilitation may include regrading of the road and the addition of aggregate.

Procedure:

An AASHTO method for design of low-volume aggregate-surfaced roads (AASHTO, 1993) is used. The method entails the selection of aggregate base layer thickness from a design table based on the geographic location of the site and classification of the expected traffic level and subgrade (road bed material) quality. A portion of the base layer is then converted to an equivalent thickness of subbase.

Step 1: Select recommended aggregate base thickness from Table 1, based on the following:

1) US climatic region, Figure 1;

2) Traffic level; and

3) Relative quality of road bed soil.

Step 2: Convert a portion of the recommended aggregate base thickness to an equivalent thickness of subbase using the design chart shown in Figure 2 (AASHTO, 1992), based on the following:

1) Final base thickness D_{bs};

2) Subbase modules, E_{sb}; and

3) Base modulus, E_{bs}.

Written by: Daniel Pass Date: 13 February 96 Reviewed by: [illegible] Date: 2/20/96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

Collection and Verification of Engineering Data:

1) US climatic region, using site location and Figure 1.

Site location, Fernald Ohio

US Climatic Region = II

2) Traffic level, based on expected traffic ad the following classification (AASHTO, 1993).

Traffic Level	Number of 18-kip ESAL Applications
High	60,000 to 100,000
Medium	30,000 to 60,000
Low	10,000 to 30,000

a) For calculation of 18 kip ESAL application, W_{18}, assume the following traffic:

- Water Tank Truck:

  -double axle

  -2 passages per week

  -4,000 gallon capacity

  -4 ton truck

  -50% load distribution to each axle

  Truck weight = 4,000 gal x 8.345lb/gal x 1kip/1000lb + 8kip
  = 41.4 kip

- Passenger Vehicle:

  -Pickup truck

-2 passages/day

-2 kip axle load

-Axle load equivalency factor: 0.0004 [For terminal serviceability index of 2.5 and SN of 2 from Table 3 (AASHTO, 1993)]

3) Relative Quality of Road Bed Soil:

Road bed material expected to be brown till compacted to 100 percent Standard Proctor.

CBR tests conducted by Parsons, 1995, measured CBR values from 1.95 to 4.4 averaging 3 for upper horizon brown till samples compacted to 95 percent Standard Proctor (poor classification).

CBR tests conducted by Corps of Engineers, 1952, measured CBR values ~~for~~ of 8 for brown till samples compacted to 100 percent Proctor (fair to good classification).

Conservatively assume the relative quality of roadbed soil as poor.

4) Modulus for Base and Subbase:

As recommended in ODOT, 1992.

Aggregate base, ODOT Spec. #304, E_{bs} = 30,000 psi
Subbase, ODOT Spec. #310, E_{bs} = 15,000 psi

Written by: DANIEL PASS Date: 96 / 2 / 13 (YY MM DD) Reviewed by: [illegible] Date: 96 / 02 / 20 (YY MM DD)

Client: FERMIO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

CALCULATIONS:

STEP 1: SELECT AGGREGATE BASE THICKNESS FROM TABLE 1 GIVEN THE FOLLOWING INPUT PARAMETERS.

a) US CLIMATIC REGION = II

b) TRAFFIC LEVEL, BASED ON EXPECTED 18-KIP ESAL APPLICATIONS, W_{18}. W_{18} IS CALCULATED BASED ON EXPECTED TRAFFIC, AS FOLLOWS.

- VALUE OF W_{18} FOR WATER TANK TRAFFIC

NUMBER OF SINGLE AXLE APPLICATIONS = 2 PASSAGES/WK × 52 WKS/YR × 20 YRS × 2 AXLES = 4,160 APPLICATIONS

$$W_{18} = 4{,}160 \left(\frac{41.4\text{kip}/2}{18}\right)^{4.5} = 7{,}802 \text{ APPLICATIONS}$$

- VALUE OF W_{18} FOR PICKUP TRUCK TRAFFIC

NUMBER OF SINGLE AXLE APPLICATIONS = 2 PASSAGES/DAY × 365 DAYS/YR × 20 YRS × 2 AXLES = 29,200 APPLICATIONS

$$W_{18} = 29{,}200 \times 0.0004 = 12$$

EXPECTED W_{18} = 7,802 + 12 = 7,814 APPLICATIONS

EXPECTED W_{18} OF 7,814 CORRESPONDS TO A LOW TRAFFIC LEVEL

c) RELATIVE QUALITY OF ROADBED MATERIAL = POOR.

GIVEN THE ABOVE INPUT PARAMETERS SELECT FROM TABLE 1 AN AGGREGATE BASE THICKNESS OF 10 IN.

Written by: DANIEL PASS Date: 96 / 2 / 13 (YY MM DD) Reviewed by: [illegible] Date: 96 / 02 / 20 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

STEP 2: CONVERT A PORTION OF AGGREGATE BASE THICKNESS TO AN EQUIVALENT THICKNESS OF SUBBASE. GIVEN THE FOLLOWING: SEE FIGURE 2

FINAL BASE THICKNESS = 6 IN.

DECREASE IN BASE THICKNESS = 4 IN.

SUBBASE MODULUS = 15,000 psi

BASE MODULUS = 30,000 psi

∴ REQUIRED SUBBASE THICKNESS ≈ 6.4 IN.

ROUND THICKNESS DOWN TO 6 IN, GIVEN THAT EXPECTED TRAFFIC OF ≈ 8,000 18-KIP ESAL IS BELOW RANGE FOR LOW TRAFFIC LEVEL (10,000 TO 30,000)

DESIGN SECTION AS FOLLOWS,

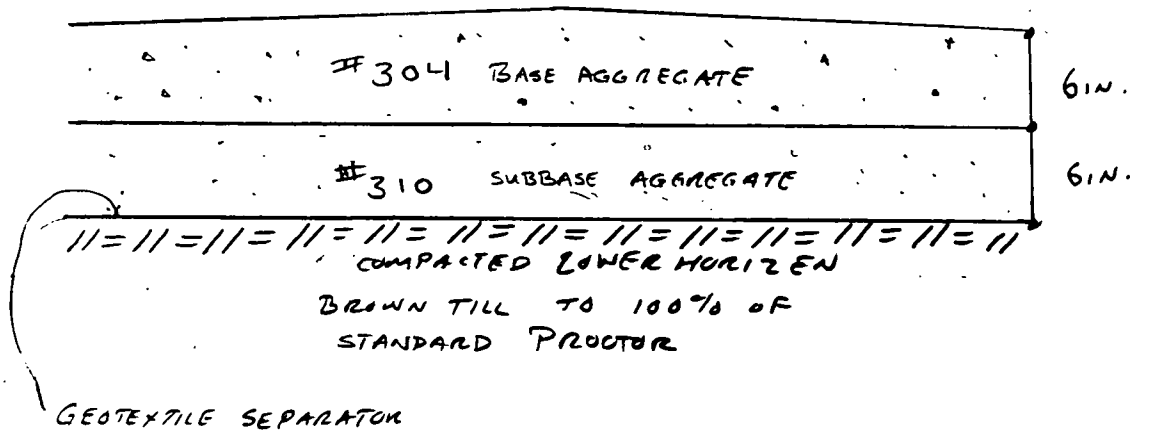

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Table 4.10. Aggregate Surfaced Road Design Catalog: Recommended Aggregate Base Thickness (in Inches) for the Six U.S. Climatic Regions, Five Relative Qualities of Roadbed Soil and Three Levels of Traffic

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climatic Region					
		I	II	III	IV	V	VI
Very good	High	8*	10	15	7	9	15
	Medium	6	8	11	5	7	11
	Low	4	4	6	4	4	6
Good	High	11	12	17	10	11	17
	Medium	8	9	12	7	9	12
	Low	4	5	7	4	5	7
Fair	High	13	14	17	12	13	17
	Medium	11	11	12	10	10	12
	Low	6	6	7	5	5	7
Poor	High	**	**	**	**	**	**
	Medium	**	**	**	15	15	**
	Low	9	10	9	8	8	9
Very poor	High	**	**	**	**	**	**
	Medium	**	**	**	**	**	**
	Low	11	11	10	8	8	9

*Thickness of aggregate base required (in inches).

**Higher type pavement design recommended.

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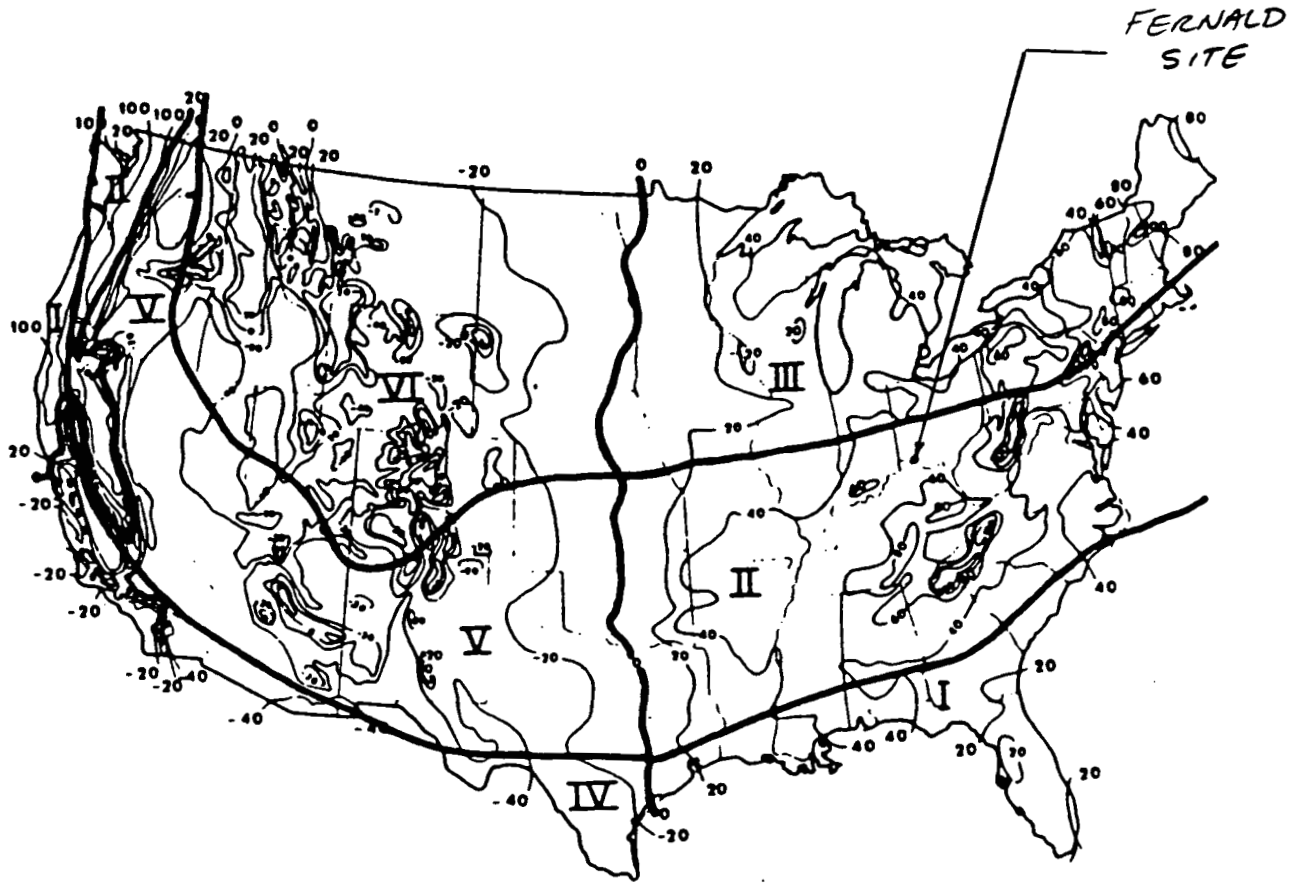
DANIEL PASS FERMCO/OSDF GE3900 13 FEB 96 000219 TABLE 1



REGION	CHARACTERISTICS
I	Wet, no freeze
II	Wet, freeze-thaw cycling
III	Wet, hard-freeze, spring thaw
IV	Dry, no freeze
V	Dry, freeze-thaw cycling
VI	Dry, hard freeze, spring thaw

Figure 4.1. The Six Climatic Regions in the United States (*12*)

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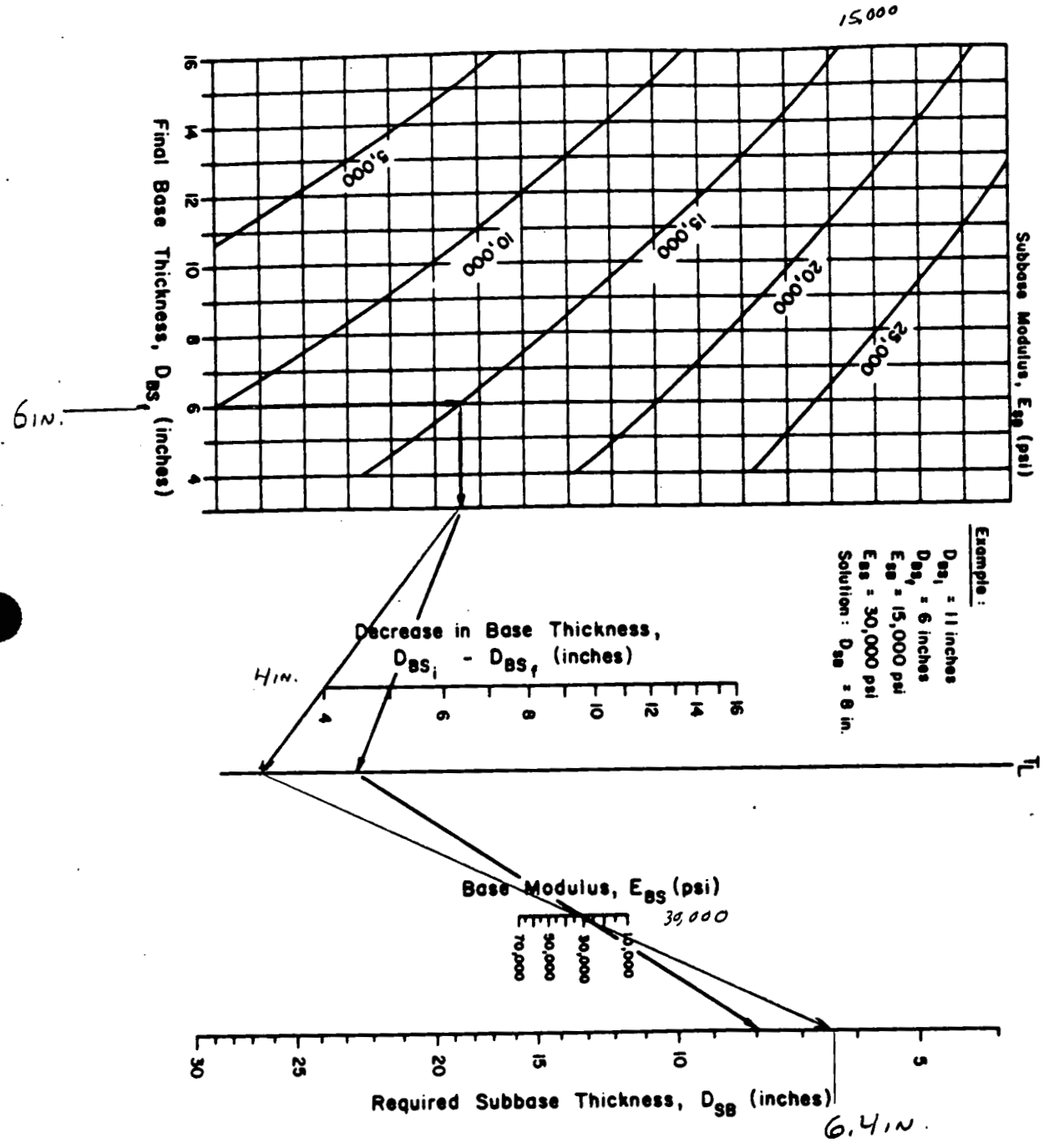

Figure 4.5. Chart to Convert a Portion of the Aggregate Base Layer Thickness To an Equivalent Thickness of Subbase

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DANIEL PASS FERMCO/OSDF GE3900 13FEB96

FIGURE 2

References:

1. American Association of State Highway and Transportation Officials (AASHTO). "*AASHTO Guide for Design of Pavement Structures*", AASHTO, Washington, D.C., 1993.

2. Ohio Department of Transportation (ODOT). "*Location and Design Manual, Volume 1 Roadway Design*", Revision October 1992, ODOT, Columbus, Ohio, 1992.

3. Parsons. "*Geotechnical Investigation Report, On-Site Disposal Facility*", Operable Unit 2, Project Order 140, Fernald Environmental Management Project, Rev. 0, Cincinnati, OH, 1995..

4. Department of the ARMY Corps of Engineers (COE), "*Report of Foundation Investigation Feed materials Production Center,- FERNALD, Ohio.*" Ohio River Division Laboratories, Mariemont, OHIO, 1952.

SECTION 15

15. BORROW AREA

15.1 Borrow Area Required Volume
15.2 Borrow Area Capacity Verification
15.3 Borrow Area Water Demand
15.4 Stormwater Runoff Routing
15.5 Borrow Area Sediment Basin

15.1 Borrow Area Required Volume

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: BORROW AREA REQUIRED VOLUME

Computations By: (Cognizant Engineer)
Signature [signature] Date 22 Feb 1996
Printed Name and Title Peter J. Prommer, Senior Staff Engineer

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 22 Feb 1996
Printed Name and Title PAUL J. SABATINI, SR. STAFF ENGINEER

Computations Checked by:
Signature [signature] Date 22 Feb 1996
Printed Name and Title PAUL. J. SABATINI, SR. STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 23 Feb 1996
Printed Name and Title Peter J. Prommer, Senior Staff Engineer

Approved by: (PDP)
Signature [signature] Date 23 Feb 96
Printed Name and Title Kara L. Olen, Asst. Proj. Engr.

Approved by: (DTL and TETL)
Signature [signature] Date 23 Feb 96
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design	—	—	—	—
D	For change in contingency volume	3 APRIL 96	D. Pass	K. Olen	[signature] 4 Apr 96
G	Final Design Package	4 Oct 96	—	—	[signature]
O	Response to Final Design Cmts	5 May 97	—	—	[signature]

Written By: PJP Date: 21 Feb 1996 Reviewed by: PJS Date: 96-2-22

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

BORROW AREA REQUIRED VOLUME

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this package is to evaluate the bank/unbulked volume of borrow material required for the FEMP On-Site Disposal Facility (OSDF) East Field Borrow Area (Borrow Area). This borrow material will be used to construct selected earthwork components of the 8 OSDF cells. These components include: (i) compacted clay liner; (ii) compacted clay cap; (iii) vegetative soil layer; and (iv) compacted fill. On-site borrow material will be obtained from the brown till soils within the OSDF foot-print excavation and the Borrow Area.

METHODS OF ANALYSIS

The required Borrow Area volume is calculated by the following four-step procedure:

Step 1: Estimate the shrinkage/bulking factor (SBF) of the borrow material.

Step 2: Calculate the bank/unbulked net volume of borrow material available from the OSDF foot-print.

Step 3: Calculate the bank/unbulked volume of material required for the selected earthwork components of the OSDF and the minimum contingency volume.

Step 4: Calculate the bank/unbulked volume of borrow material required from the Borrow Area.

The volume of borrow material required from the Borrow Area is then compared with the actual volume of the Borrow Area to evaluate whether a minimum ~~10%~~ contingency volume is provided. The

17.5% ΔD, DGP 2 APRIL 96 ✓ KO

Written By : PJP Date: 21 Feb 1996 Reviewed by: PJS Date: 96-2-22

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

contingency volume is provided for the following reasons: (i) construction of a ninth OSDF contingency cell if disposal volumes are larger than anticipated; (ii) to backfill to subgrade elevations beneath the footprint of the OSDF in the event that additional excavation of impacted material is necessary; and (iii) if insufficient volumes of suitable impacted material are available to complete the construction of a component of the liner or cover system.

CONCLUSIONS

The shrinkage/bulk factor for the brown till is calculated to be 0.955 (i.e., 0.955 ft^3 of in situ brown till material is required to construct 1.000 ft^3 of compacted material). This implies the bank/unbulked brown till will undergo a net increase in volume of approximately 4.7 percent once compacted in-place as part of the OSDF liner/cover system.

The required bank/unbulked volume was calculated to be 433,567 yd^3 for the Borrow Area. There is 590,834 yd^3 of material available in the Borrow Area, an excess of 157,267 yd^3 of material for use in constructing specific earthwork components of the OSDF. This excess corresponds to a 19.5% contingency volume; this exceeds the minimum required contingency of ~~10%~~.

17.5% ✓ KO

ΔD, DGP
2 APRIL 96

BORROW AREA REQUIRED VOLUME

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2.	Collection and Verification of Data	1/7
3.	Calculation Results	1/4

Written By: PJP Date: 21 Feb 1996 Reviewed by: PJS Date: 96 2-23

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

BORROW AREA REQUIRED VOLUME

CALCULATION PROCEDURES

INTRODUCTION

The purpose of this package is to present the calculation procedures necessary to evaluate the bank/unbulked volume of borrow material required from the FEMP On-Site Disposal Facility (OSDF) Borrow Area. This borrow material will be used to construct selected earthwork components of the 8 OSDF cells. These components include: (i) compacted clay liner; (ii) compacted clay cap; (iii) vegetative soil layer; and (iv) compacted fill. Borrow material will be obtained from the brown till soils within the OSDF foot-print excavation and the Borrow Area.

METHODS OF ANALYSIS

REQUIRED BORROW AREA VOLUME

A four-step procedure is used to calculate the required bank/unbulked volume of the Borrow Area. Herein, bank/unbulked volume refers to the in-place volume of borrow material prior to excavation from the ground. Compacted volume refers to the volume of borrow material after compaction. This procedure is described below.

Step 1: Estimate the shrinkage/bulking factor (SBF) of the borrow material.

For the calculations performed herein, the SBF is defined as the ratio of the total volume of the bank/unbulked borrow material to that of the compacted borrow material. This can be written as:

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$$SBF = \frac{V_{bank\ /\ unbulked}}{V_{compacted}} = \frac{1 + e_{bank\ /\ unbulked}}{1 + e_{compacted}} \quad (1)$$

where $V_{bank/unbulked}$ = total volume of bank/unbulked borrow material;

$V_{compacted}$ = total volume of compacted borrow material;

$e_{bank/unbulked}$ = void ratio of bank/unbulked borrow material; and

$e_{compacted}$ = void ratio of compacted borrow material.

The void ratio of the bank/unbulked and compacted borrow material can be calculated using the following equation [Holtz and Kovacs, 1981]:

$$\rho_d = \rho_s / (1 + e) \quad (2)$$

where ρ_d = dry density;

ρ_s = density of solids; and

e = void ratio.

Values for the dry density and density of solids for the bank/unbulked and compacted borrow material are reported in the Data Verification package.

Step 2: Calculate the bank/unbulked net volume of borrow material available from the OSDF foot-print excavation.

Borrow material for the OSDF will be obtained from the OSDF foot-print excavation and from the Borrow Area. The upper 1-ft of soil in the OSDF foot-print is anticipated to be impacted and cannot be used as borrow material. The bank/unbulked volume of impacted material is therefore given by:

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$$V_{impacted} = (\text{Area of OSDF foot-print}) \times (1 \text{ ft}) \quad (4)$$

The bank/unbulked volume of borrow material from the OSDF foot-print excavation (minus any portion of this material that is considered to be impacted material) can be written as:

$$V_{net\ FP} = V_{gross\ FP} - V_{impacted} \quad (5)$$

where $V_{net\ FP}$ = net bank/unbulked volume of borrow material from the OSDF foot-print excavation;

$V_{gross\ FP}$ = gross bank/unbulked volume of borrow material from the OSDF foot-print excavation (including impacted material); and

$V_{impacted}$ = bank/unbulked volume of impacted material not suitable for use as borrow material.

The value for $V_{gross\ FP}$ is reported in the Data Verification package.

Step 3: Calculate the bank/unbulked volume of material required for the selected earthwork components of the OSDF and the minimum REQUIRED contingency volume. AD, DGP 2 APRIL 96 (KO)

The SBF is used to calculate the total bank/unbulked volume of borrow material required to construct the OSDF. In addition to this volume, a minimum contingency volume ~~equal to 10 percent of the total bank/unbulked required borrow volume~~ OD, DGP 2 APRIL 96 must be provided. This contingency borrow volume is PJS 3 OCT 96 provided for the following reasons: (i) construction of an OSDF contingency cell if disposal volumes are larger than anticipated; (ii) to backfill to subgrade elevations beneath the footprint of the OSDF in the event that additional excavation of impacted material is necessary; and (iii) if insufficient volumes of suitable impacted material are available to complete the construction of a component of the liner or cover

system. The total bank/unbulked volume of borrow material required to construct the selected earthwork components is given by the following equation:

$$V_{\text{required bank / unbulked}} = V_{\text{required compacted}}(\text{SBF}) \qquad (6)$$

where $V_{\text{required bank/unbulked}}$ = total volume of bank/unbulked borrow material required for the 8 cell OSDF; and

$V_{\text{required compacted}}$ = total volume of compacted borrow material required for the 8 cell OSDF.

~~The minimum bank/unbulked contingency volume, $V_{\text{contingency}}$, required is given by the following calculation:~~

$$\cancel{V_{\text{contingency}} = (V_{\text{required bank/unbulked}})(0.1) \qquad (7)}$$

SEE PAGE 4a. AD, DGP 2 APRIL 96

Step 4: Calculate the bank/unbulked volume of borrow material required from the Borrow Area.

The bank/unbulked volume of borrow material required from the Borrow Area is the difference between the required total bank/unbulked volume of borrow material (Step 3) and the bank/unbulked volume of borrow material available from the OSDF foot-print excavation (Step 2). This calculation is given by the following equation:

$$V_{BA} = V_{\text{required bank / unbulked}} - V_{\text{net FP}} \qquad (8)$$

where V_{BA} = required bank/unbulked volume of Borrow Area material.

Written By : DGP Date: 2 April96 Reviewed by: Date:

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

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The minimum bank/unbulked contingency volume, $V_{contingency}$, required for a nine cell OSDF is given by the following calculation:

$$V_{contingency} = (V_{9cell} + \left(\frac{25\%}{100}\right)(V_{contour\ compacted} + V_{IMprotective\ compacted} + V_{seasonal\ compacted}))(SBF) \quad (7)$$

where, V_{9cell} = Volume of compacted borrow material required for construction of a 9 cell OSDF above that required for construction of an 8 cell OSDF;

$V_{contour\ compacted}$ = Compacted volume of the contouring layer for a 9 cell OSDF;

$V_{IMprotective\ compacted}$ = Compacted volume of the impacted material component of the protective layer;

$V_{seasonal\ compacted}$ = Compacted volume of the seasonal cover for a 9 cell OSDF; and

25%, conservatively selected to represent the percentage of the impacted material components which may need to be replaced with borrow in the event that there is an insufficient amount of impacted material available.

The minimum required bank/unbulked contingency volume ($V_{contingency}$) as a percentage of the total volume of bank/unbulked borrow material required for the 8 cell OSDF ($V_{required\ bank/unbulked}$) is calculated as follows:

$$V_{\%contingency} = 100\%\left(\frac{V_{contingency}}{V_{requiredbank/unbulked}}\right) \quad (7a)$$

Written By: PJP Date: 21 Feb 1996 Reviewed by: PJS Date: 96-2-23

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

BORROW AREA VOLUME COMPARISON

The available bank/unbulked Borrow Area volume is calculated by taking the Borrow Area volume from the "Borrow Area Capacity Verification" Calculation Package and subtracting the volume of top soil from the Borrow Area foot print which will be stripped and stockpiled. This can be written as:

$$V_{BA\ available} = V_{BA\ capacity} - V_{top\ soil} \qquad (9)$$

where $V_{BA\ available}$ = available bank/unbulked Borrow Area volume;
$V_{BA\ capacity}$ = Borrow Area volume from the "Borrow Area Capacity Verification" Calculation Package; and
$V_{top\ soil}$ = volume of top soil in the Borrow Area foot print.

The volume of top soil from the Borrow Area foot print is given by:

$$V_{top\ soil} = (\text{area of Borrow Area foot print}) \times (\text{top soil depth}) \qquad (10)$$

The bank/unbulked volume of borrow material required from the Borrow Area is compared with the available bank/unbulked Borrow Area volume to evaluate whether the minimum ~~10 percent~~ contingency volume is provided.

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REFERENCES

Holtz, R.D. and Kovacs, W.D. (1981). *An Introduction to Geotechnical Engineering*. Prentice Hall, Englewood Cliffs, 733 p.

Written By: PJP Date: 21 Feb 1996 Reviewed by: PJS Date: 96 2-22

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

BORROW AREA REQUIRED VOLUME

DATA VERIFICATION

INTRODUCTION

The purpose of this package is to present the data necessary to evaluate the bank/unbulked volume of borrow material required from the FEMP On-Site Disposal Facility (OSDF) Borrow Area. This borrow material will be used to construct selected earthwork components of the 8 OSDF cells. These components include: (i) compacted clay liner; (ii) compacted clay cap; (iii) vegetative soil layer; and (iv) compacted fill. Borrow material will be obtained from the brown till soils within the OSDF foot-print excavation and the Borrow Area.

REQUIRED BORROW AREA VOLUME

The data necessary to calculate the required borrow area volume is presented in the same four-step outline used in the Calculation Procedures section of this calculation package. This outline is described below:

Step 1: Data for estimating the shrinkage/bulking factor (SBF) of the borrow material.

In situ and compacted soil properties of the on-site brown till material were obtained from soil sample laboratory test results shown in Appendix G of Parsons [1995] and preliminary data tables [Parsons, preliminary data 1996] for samples retrieved from 0 to 15 feet below the ground surface of the OSDF foot print and Borrow Area. Figures 1 and 2 present the brown till in situ and maximum dry density data.

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BROWN TILL SOIL DATA

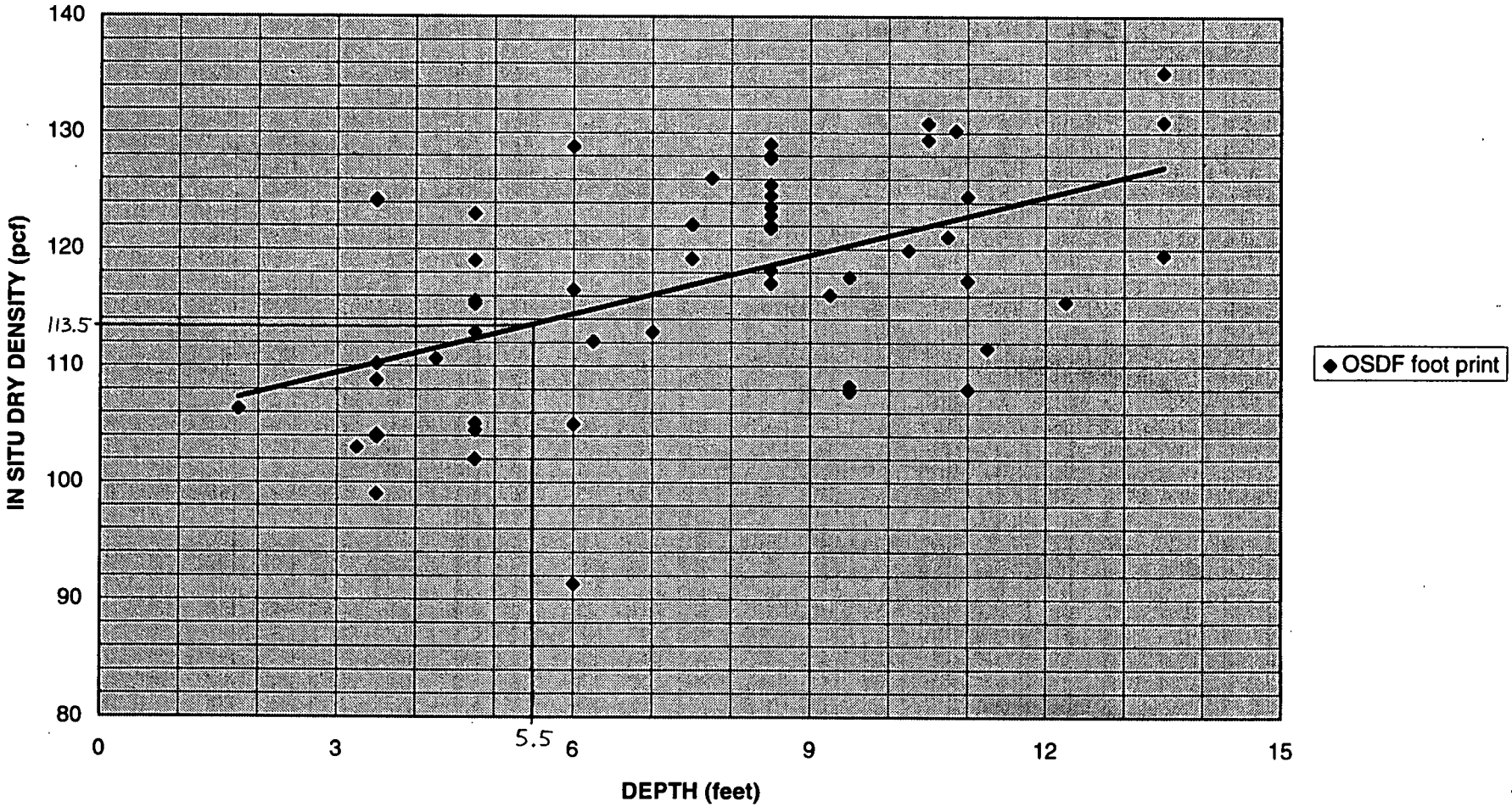

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Figure 1. Brown Till In Situ Dry Density Data

[data obtained from Parsons, 1995]

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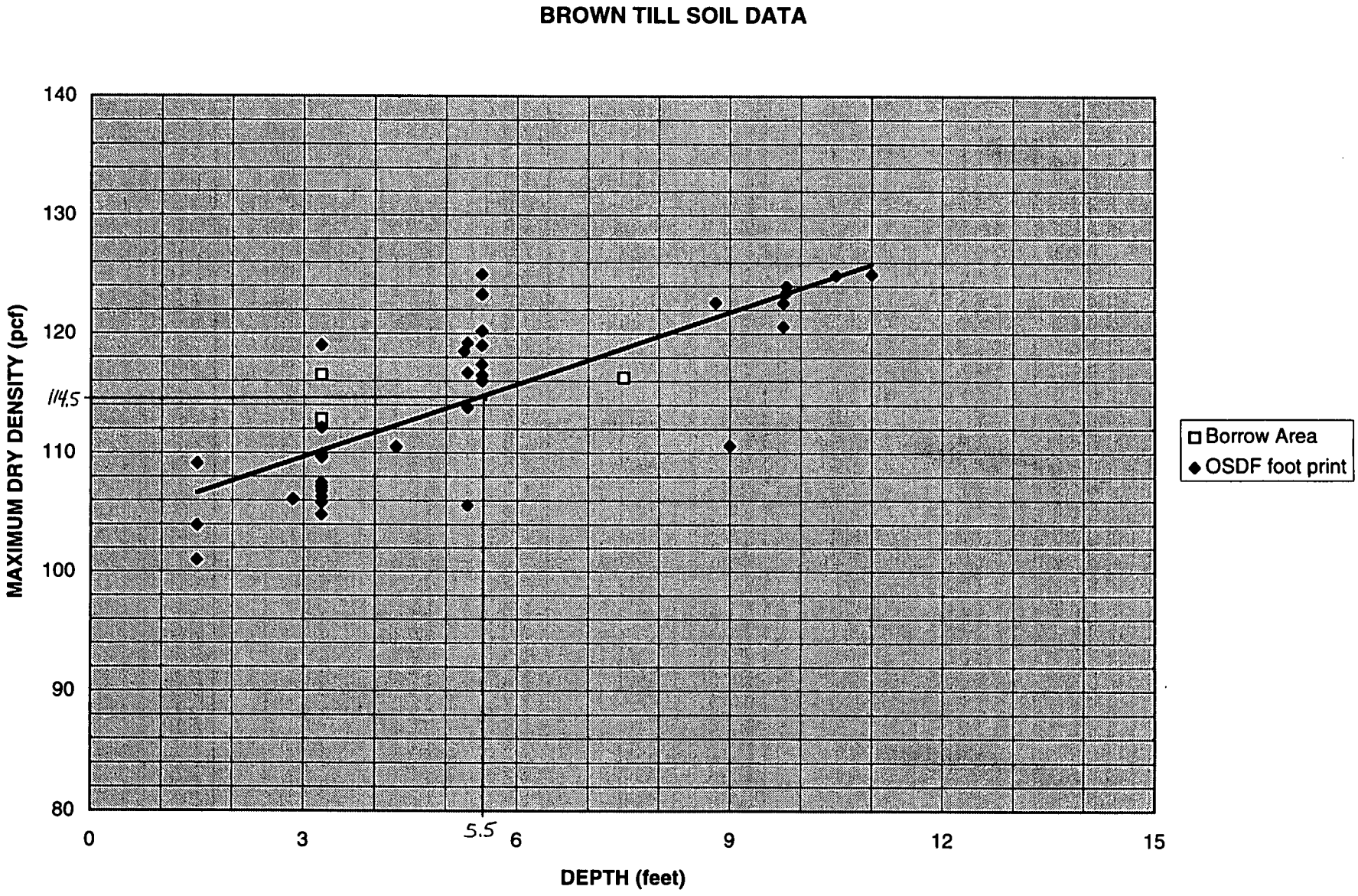

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Figure 2. Brown Till Maximum Dry Density Data

[data obtained from Parsons, 1995 and 1996]

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Based on the geologic cross-sections through the OSDF (see Sheets X-13 through X-15 of the Intermediate Design Drawings), it is reasonable to assume that the borrow material from the OSDF foot-print excavation will come primarily from depths ranging from 1 to 10 feet below the ground surface. Based on the Intermediate Design Drawings Borrow Area excavation boundaries and excavation elevations, it is anticipated that approximately 80% of the borrow material from the Borrow Area will come from depths ranging from 0.5 to 10 feet below ground surface (the remaining 20% of the borrow material from the Borrow Area is anticipated to come from depths ranging from 10 to 16 feet below the ground surface). Based on the drawing information, it is assumed that the majority of the borrow material will be excavated from the OSDF foot-print excavation and the Borrow Area from depths ranging from 1 to 10 feet below the ground surface.

A representative brown till borrow material soil property is estimated using the best-fit lines plotted on Figures 1 and 2. Using the 5.5-foot depth (half-way between the 1- to 10-foot depth) value gives the following estimate for the brown till bank/unbulked and maximum standard Proctor compacted dry density ($\rho_{d\ (bank/unbulked)}$ and $\rho_{d\ (maximum)}$, respectively):

- $\rho_{d\ (bank/unbulked)}$ = 113.5 pcf
- $\rho_{d\ (maximum)}$ = 114.5 pcf

A weighted average compacted dry density is estimated using the following information:

(1) The compacted dry density for the compacted clay liner and cap is estimated to be 97% of $\rho_{d\ (maximum)}$ standard Proctor based on the data reported in Parsons [1995 and preliminary data 1996].

(2) The compacted dry density for the vegetative cover and compacted fill are 90% and 95%, respectively, of $\rho_{d\ (maximum)}$ standard Proctor based on the CQA Plan.

(3) The volume of compacted material required to build 8 cells of the OSDF (obtained from the "Earthwork Required Volume" Calculation Package) are reported below.

- compacted clay liner = 297,231 yd^3

- compacted clay cap = 194,582 yd^3
- vegetative soil = 232,166 yd^3
- compacted fill = 124,437 yd^3

Based on this information, the weighted average compacted dry density is 94.8% of $\rho_{d(maximum)}$. Thus, the borrow material average compacted dry density is:

$$\rho_{d\ (compacted)} = (0.948)(114.5\ pcf) = 108.5\ pcf$$

The density of solids for the borrow material is the specific gravity multiplied by the unit weight of water. The specific gravity for the borrow material is assumed to be 2.70 and the unit weight of water is 62.4 pcf. Thus, the density of solids for the borrow material is:

$$\rho_s = (2.70)(62.4\ pcf) = 168.5\ pcf$$

Step 2: Data to calculate the bank/unbulked net volume of borrow material available from the OSDF foot-print excavation.

A total volume of 559,325 yd^3 will be excavated from the OSDF foot-print area (obtained from the "Earthwork Required Volume" Calculation Package). This volume is decreased to account for the impacted material that will be stripped from the OSDF foot-print area and disposed of in the OSDF. The following data and assumptions are used to calculate this decreased volume:

- the approximate surface area of the impacted material to be removed is 114.4 acres (see Sheet G-1, "Impacted Material Removal Plan Within Battery Limit" of the Intermediate Design Drawings); and
- the impacted material depth is assumed to be 1 ft below the ground surface.

Written By: PJP Date: 21 Feb 1996 Reviewed by: RJS Date: 96 2-22

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

Step 3: Data to calculate the bank/unbulked volume of material required for the selected earthwork components of the OSDF and the minimum contingency volume.

The quantities of compacted material required to build 8 cells of the OSDF are presented in Step 1. The total required volume of compacted material is:

$$V_{\text{required compacted}} = (297{,}231 + 194{,}582 + 232{,}166 + 124{,}437) = 848{,}416 \text{ yd}^3$$

SEE PAGE 6a. √ (KO) DD, DGP 2 APRIL 96

Step 4: Data to calculate the bank/unbulked volume of borrow material required from the Borrow Area.

No additional data is required for this calculation.

BORROW AREA VOLUME COMPARISON

The actual bank/unbulked Borrow Area volume is calculated by CADD and is hand calculated in the "Borrow Area Capacity Verification" Calculation Package. The volume calculated by CADD is:

$$V_{\text{BA capacity}} = 630{,}199 \text{ yd}^3$$

The foot-print area of the Borrow Area is estimated with a planimeter to be 48.8 acres based ~~off~~ on RJS 96 2-22 the Intermediate Design Drawings. The assumed top soil depth in the Borrow Area is 0.5 ft.

Written By : DGP Date: 2 April 1996 Reviewed by: Date:

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

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The quantities of compacted material used in the calculation of the minimum required bank/unbulked contingency volume ($V_{contingency}$) are obtained from the "Earthwork Required Volume" calculation package are listed below:

- Additional volume for a 9th cell = 99,779 yd^3
- Contouring layer for 9 cells = 98,532 yd^3
- Impacted material component of the protective layer for 9 cells = 63,374 yd^3
- Seasonal cover for 9 cells = 28,744 yd^3

Written By: PJP Date: 21 Feb 1996 Reviewed by: PJS Date: 96 2-22

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

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Construction Quality Assurance Plan (Revision C). (1996). FEMP On-Site Disposal Facility, prepared for FERMCO by GeoSyntec Consultants.

Intermediate Design Drawings (60% Submittal). (1996). FEMP On-Site Disposal Facility, prepared for FERMCO by GeoSyntec Consultants, February.

Parsons. (1995). *Geotechnical Investigation Report, On-Site Disposal Facility*, Operable Unit 2, Project Order 140, Revision 0, prepared for FERMCO for the Fernald Environmental Management Project, Subcontract No. 2-21487, December.

Parsons. (preliminary data 1996). Preliminary results of borrow area sampling and testing program.

Written by: PJP Date: 96 / 02 / 21 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 22 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: G-E3900 Task No.: 8.11

BORROW AREA REQUIRED VOLUME

CALCULATION RESULTS

Required Borrow Area Volume

Step 1: Estimate SBF

- $SBF = \frac{1 + e_{bank/unbulked}}{1 + e_{compacted}}$

- Calculate e

$$\rho_d = \frac{\rho_s}{1+e}$$

$$\rho_d(1+e) = \rho_s \checkmark$$

- $$e = \frac{\rho_s}{\rho_d} - 1$$

$$\rho_{s_{bank/unbulked}} = \rho_{s_{compacted}} = 168.5 \text{ pcf}$$

$$\rho_{d_{bank/unbulked}} = 113.5 \text{ pcf}$$

- Need to calculate the weighted average $\rho_{d_{compacted}}$

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Written by: PJP Date: 96 / 02 / 21 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 22 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

Weighted Average $\rho_{d_{compacted}}$

	Weighting Factor Req'd Compacted Vol.			
Clay Liner	297,231 yd³	×	97% $\gamma_{d_{max}}$	= (288,314 yd³) $\gamma_{d_{max}}$
Clay Cap	194,582	×	97% $\gamma_{d_{max}}$	= (188,745) $\gamma_{d_{max}}$
Vegetative Soil	232,166	×	90% $\gamma_{d_{max}}$	= (208,949) $\gamma_{d_{max}}$
Compacted Fill	124,437	×	95% $\gamma_{d_{max}}$	= (118,215) $\gamma_{d_{max}}$
	848,416 yd³			(804,223 yd³) $\gamma_{d_{max}}$

$$\rho_{d_{compacted}} = \frac{(804{,}223\ yd^3)\,\gamma_{d_{max}}}{848{,}416\ yd^3} = 94.8\%\ \gamma_{d_{max}}$$

$$= (0.948)(114.5\ pcf)$$

$$\rho_{d_{compacted}} = 108.5\ pcf$$

- Substitute and solve for e

$$e_{bank/unbulked} = \frac{168.5\ pcf}{113.5\ pcf} - 1 = 0.48$$

$$e_{compacted} = \frac{168.5}{108.5} - 1 = 0.55$$

- Substitute and solve for SBF

$$SBF = \frac{1 + 0.48}{1 + 0.55}$$

$$\underline{SBF = 0.955} \quad \text{or} \quad \left(\frac{1}{0.995} - 1\right) 100\% = 4.7\%$$ bulking of bank/unbulked material when compacted

* 0.955 ft³ of bank/unbulked borrow is required to construct 1 ft³ compacted borrow

Written by: PJP Date: 96 / 02 / 21 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 22 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

Step 2: Calculate $V_{net\ FP}$

- $V_{impacted}$ = (Area of OSDF foot-print) (1 ft)

$$= \left(114.4 \text{ acres} \cdot \frac{43{,}560 \text{ ft}^2}{1 \text{ acre}}\right)(1 \text{ ft})\left(\frac{1 \text{ yd}^3}{27 \text{ ft}^3}\right)$$

$V_{impacted} = 184{,}565 \text{ yd}^3$ ✓

- $V_{net\ FP} = V_{gross\ FP} - V_{impacted}$

$$= 559{,}325 \text{ yd}^3 - 184{,}565 \text{ yd}^3$$

$V_{net\ FP} = 374{,}760 \text{ yd}^3$ ✓

Step 3: Calculate $V_{required\ bank/unbulked}$ and minimum $V_{contingency}$

- $V_{required\ bank/unbulked} = V_{required\ compacted}$ (SBF)

$$= (846{,}416 \text{ yd}^3)(0.955)$$

$V_{required\ bank/unbulked} = 808{,}327 \text{ yd}^3$ ✓

- ~~$V_{contingency} = (808{,}327 \text{ yd}^3)(0.1)$~~

~~$= 80{,}833 \text{ yd}^3$~~ ✓

AD, DGP 2 APRIL 96

$V_{CONTINGENCY} = 0.955(99{,}779 \text{ yd}^3 + 0.25(98{,}532 \text{ yd}^3 + 63{,}374 \text{ yd}^3 + 28{,}744 \text{ yd}^3)) = 140{,}807 \text{ yd}^3$

$V\%_{CONTINGENCY} = \frac{140{,}807 \text{ yd}^3}{808{,}327 \text{ yd}^3} \times 100\% = 17.4\% \approx 17.5\%$

✓ (RO)

4/8/96

Written by: DJP Date: 96 / 02 / 21 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 22 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

Step 4: Calculate V_{BA}

- $V_{BA} = V_{required\ bank/unbulked} - V_{net\ FP}$

$= 808,327 - 374,760$

$V_{BA} = 433,567\ yd^3$ ✓

Borrow Area Volume Comparison

- $V_{top\ soil} = (48.8\ acres)\left(\frac{43,560\ ft^2}{1\ acre}\right)(0.5\ ft)\left(\frac{1\ yd^3}{27\ ft^3}\right)$

$V_{top\ soil} = 39,365\ yd^3$ ✓

- $V_{BA\ available} = 630,199\ yd^3 - 39,365\ yd^3$

$V_{BA\ available} = 590,834\ yd^3$ ✓

- additional available volume $= V_{BA\ available} - V_{BA}$

$= 590,834\ yd^3 - 433,567\ yd^3$

$= 157,267\ yd^3$ ✓

AD, DGP 2 APRIL 96

$\frac{157,267}{808,327} \times 100\% = \underline{19.5\%\ \text{contingency}} > \cancel{10\%}\ 17.5\%$ ✓ minimum required contingency ✓ (KO)

Written by: DAVE WARREN Date: 21-Feb-96 Reviewed by: PJS Date: 96-2-22

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.11

COLLECTION AND VERIFICATION OF DATA

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CADD VOLUME ESTIMATE

Pages A1 through A17 from Autodesk [1994].
Pages A18 through A34 from Softdesk [1994]

REFERENCES

Autodesk, Inc., "*Autocad® Release 13 User's Guide*", Autodesk, Inc., San Rafael, CA, Sep 1994, 644 p.

Softdesk, Inc., "*SOFTDESK® Civil/Survey: Earthworks Reference Manual*", Softdesk, Inc., Hanner, NH, Nov 1994, 168 p.

For documentation of computer programs see

1.2 Computer Program Validation

15.2 Borrow Area Capacity Verification

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: BORROW AREA CAPACITY VERIFICATION

Computations By: (Cognizant Engineer)
Signature [signature] Date 21 Feb 96
Printed Name and Title DAVID W. WARREN, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 96-2-22
Printed Name and Title PAUL J. SABATINI, SENIOR STAFF ENGINEER

Computations Checked by:
Signature [signature] Date 96-2-22
Printed Name and Title PAUL J. SABATINI, SENIOR STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 23 Feb 96
Printed Name and Title DAVID WARREN, STAFF ENGINEER

Approved by: (PDP)
Signature [signature] Date 23 Feb 96
Printed Name and Title Kara L. Olen, Asst. Proj. Eng.

Approved by: (DTL and TETL)
Signature [signature] Date 23 Feb 96
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design	—	—	—	—
D	Intermediate Design - EPA Submittal	4 Apr 96	[illegible]	—	—
0	Response to Final Design Cmts	5 May 97	—	—	[illegible]

Written by: DAVE WARREN Date: 21-Feb-96 Reviewed by: PJS Date: 96-2-22

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.11

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 630,199 cubic yards (cy or yd^3). The verification is achieved by conducting contour-area method volume calculations using areas measured from elevation contours shown on the *East Field Borrow Area Restoration Plan* [GeoSyntec, 1996]. Using the contour-area method, a volume of 628,988 cubic yards was calculated. The difference between this calculated volume and that from CADD is approximately 0.2 percent. Therefore, the CADD calculated volume is considered to be reasonably accurate. This volume represents the borrow available to construct the following earthwork components for 8 cells (where sufficient materials for these components are not available from the OSDF footprint):

- compacted clay liner;
- compacted clay cap;
- vegetative soil layer; and
- compacted fill.

REFERENCES

GeoSyntec Consultants, "*On-Site Disposal Facility - Intermediate Design Package*", (Design Drawings), GeoSyntec Consultants, Atlanta, GA, Feb 1996.

BORROW AREA CAPACITY VERIFICATION

TABLE OF CONTENTS

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3.	Calculations	1/7

Written by: DAVE WARREN Date: 21-Feb-96 Reviewed by: PJS Date: 96 2-22

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.11

BORROW AREA CAPACITY VERIFICATION

CALCULATION PROCEDURES

Estimate the volume of material removed from development of the East Field Borrow Area using the contour-area method, as detailed in the steps below.

1. Estimate plane areas of material removed at specific elevations

Estimate the plane areas of borrow material removed at one-foot elevation increments by measuring areas enclosed by the contour lines on Figure 1. Measure these areas with a planimeter.

2. Estimate volumes of "slices"

The total volume of borrow material removed can be divided into "slices" whose tops and bottoms correspond to planes at specific elevations. Estimate the volume of borrow material removed in a "slice" of height 'Δz' by using one of the following formulas:

For volume of material in a "slice" whose bottom is the plane bounded by the uppermost contour in a section:

$$V_z = \tfrac{1}{3} A_z \Delta z \qquad \text{(i.e., volume of a pyramid)}$$

where: V_z = volume of material removed between elevation 'z' and 'z+Δz'
A_z = plane area of material removed at elevation 'z'
Δz = elevation increment between contours (= 1 ft)

For volume of material in a "slice" whose top is the plane bounded by the contour at elevation 'z+Δz' and whose bottom is the plane bounded by the contour at elevation 'z':

$$V_z = \frac{A_z + A_{z+\Delta z}}{2} \Delta z \qquad \text{(i.e., "average-end-area" volume)}$$

Where: $A_{z+\Delta z}$ = plane area of material removed at elevation 'z+Δz'

Note that the average-end-area volume is <u>not</u> the true volume of the estimated slice. Equations for the true volume of the estimated slice, or *prismoidal volume*, can be found in most surveying texts. The average-end-area volume is accurate enough for the purposes of this calculation, and for most earthwork volume estimates [Wolf and Brinker, 1989].

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Written by: DAVE WARREN Date: 21-Feb-96 Reviewed by: PJS Date: 96 2-22

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.11

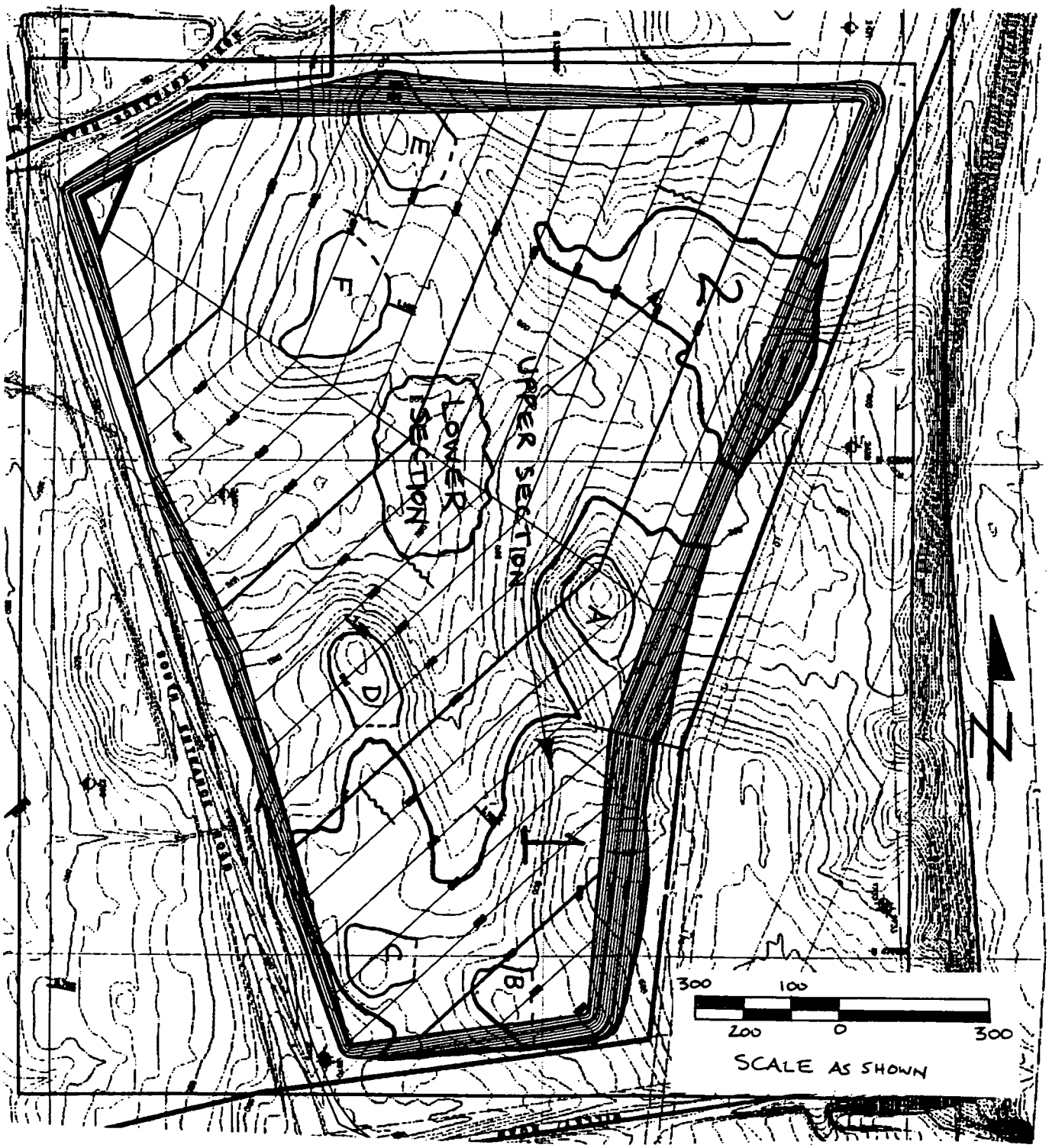


Figure 1 - East Field Borrow Area Restoration Plan. Modified from GeoSyntec [1996]

Several knolls exist within the borrow area. Volumes that include a plane area bounded by the uppermost contour below a knoll must be handled in the following manner. Slices whose bottoms coincide with this plane area must be divided into two portions: the part inside and below the knoll, and the part outside the knoll. Slices whose tops coincide with this plane area can be handled as one volume. This is shown in Figure 2.

3. Sum volumes of slices to get total volume

4. Compare contour-area method volume to volume from CADD

Compare the volume estimated from the contour-area method calculations to the volume estimated from CADD. If both volume estimates are reasonably close (within ~5 percent of each other), the CADD volume is considered to be accurate. Otherwise, one or both of the volumes is/are inaccurate.

REFERENCES

GeoSyntec Consultants, "*On-Site Disposal Facility - Intermediate Design Package*", (Design Drawings), GeoSyntec Consultants, Atlanta, GA, Feb 1996.

Wolf, P.R., and Brinker, R.C., "*Elementary Surveying*", 8th ed., Harper and Row Publishers, New York, NY, 1989, 696 p.

KO 23 Feb 96

Written by: DWW Date: 96 / 03 / 21 Reviewed by: PJS Date: 96 / 2 / 22

Client: FERMCO Project: OSDF Project/Proposal No.: GE3000 Task No.: 08.1

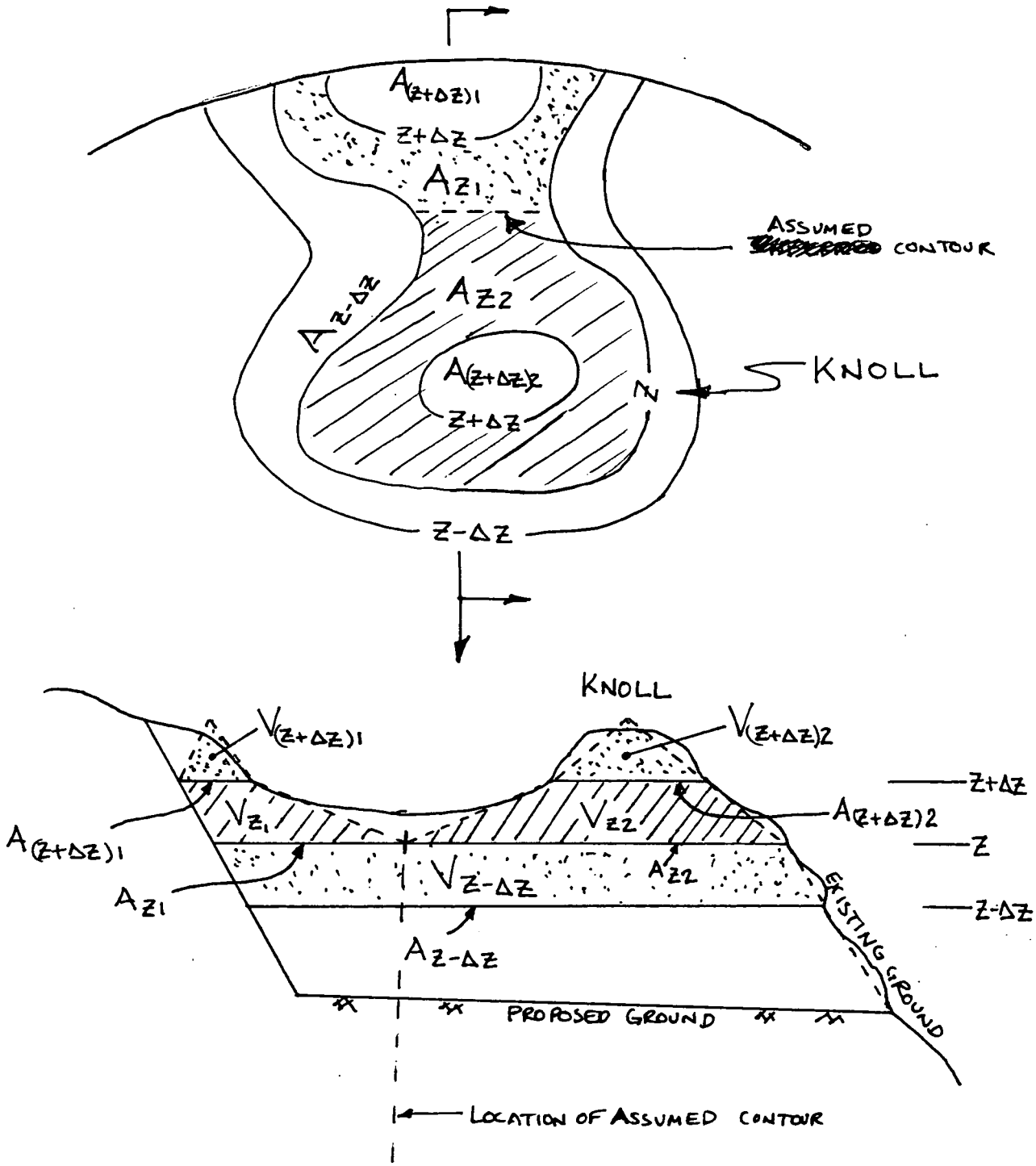


Figure 2 - Procedure for Calculating Volumes Directly Above and Below Knolls

Written by: DAVE WARREN Date: 21-Feb-96 Reviewed by: PJS Date: 96-2-22

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.11

BORROW AREA CAPACITY VERIFICATION

COLLECTION AND VERIFICATION OF DATA

The existing and proposed layouts of the East Field borrow area (Figure 1) were obtained from the drawing entitled "*Borrow Area Restoration Plan*" [GeoSyntec, 1996]. This drawing was used to prepare both the CADD and the manual borrow area capacity estimates.

The estimated volume of borrow material from CADD is 630,199 yd^3. Documentation for the CADD software used to prepare the CADD borrow area capacity estimate is attached in Appendix A.

REFERENCES

GeoSyntec Consultants, "*On-Site Disposal Facility - Intermediate Design Package*", (Design Drawings), GeoSyntec Consultants, Atlanta, GA, Feb 1996.

GEOSYNTEC CONSULTANTS

Written by: DAVE WARREN Date: 21-Feb-96 Reviewed by: PJS Date: 96-2-22

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.11

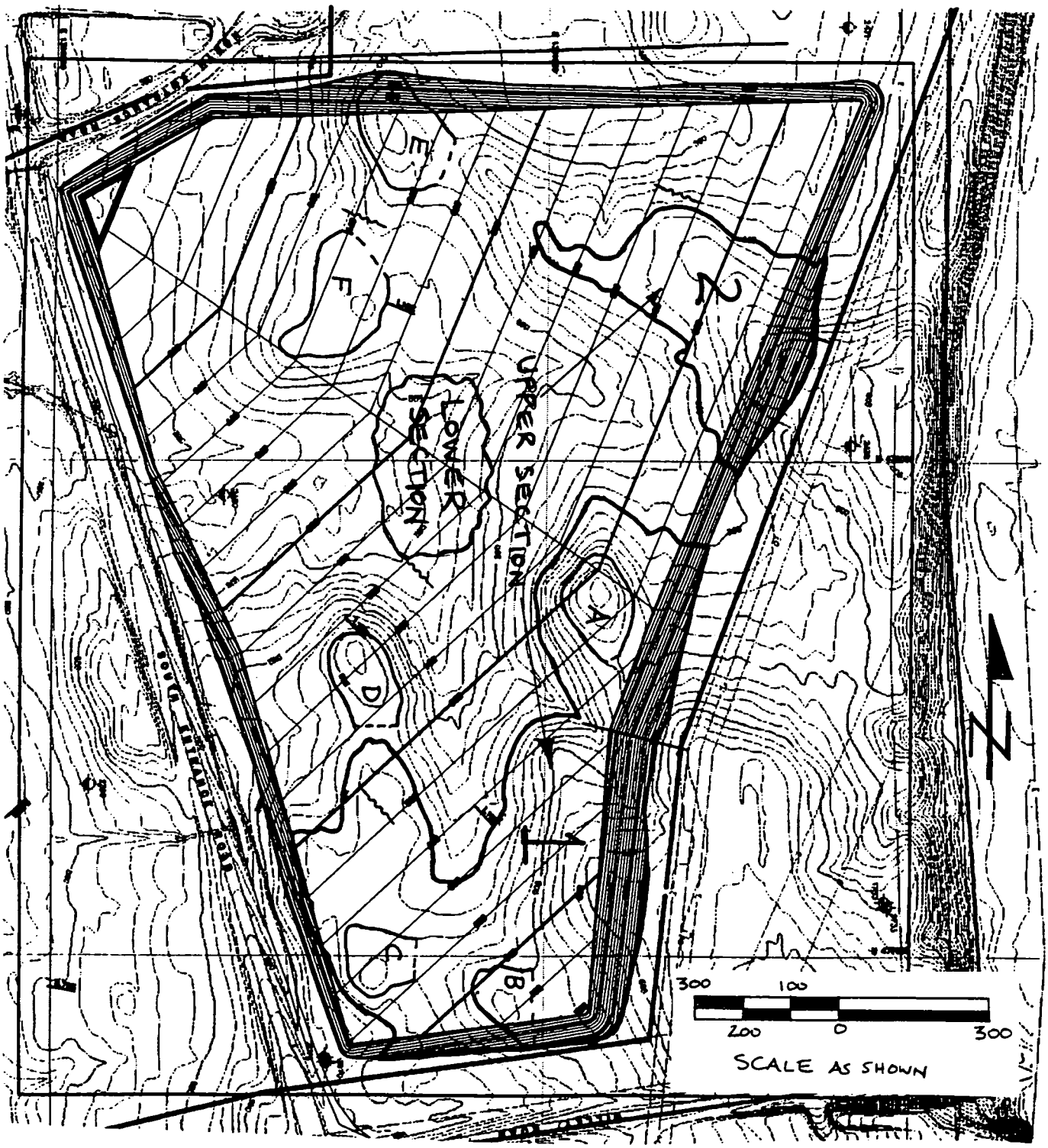


Figure 1 - East Field Borrow Area Restoration Plan. Modified from GeoSyntec [1996]

Written by: D. WAREEN Date: 96/02/21 (YY MM DD) Reviewed by: PJS Date: 96/2/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.11

BORROW AREA CAPACITY VERIFICATION - CALCULATIONS

VERIFY BORROW AREA VOLUME FROM CADD - 630,199 yd^3

USE CONTOUR-AREA METHOD: MEASURE AREA OF MATERIAL REMOVED AT EACH ELEVATION CONTOUR. VOLUME IS CALCULATED AS FOLLOWS:

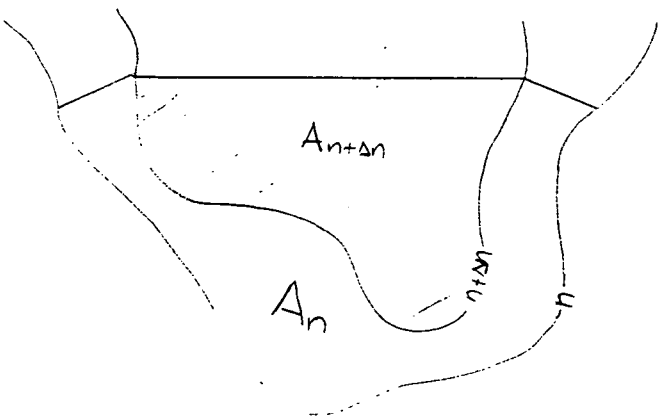
$$V_{n,n+\Delta n} = \left[\frac{A_n + A_{n+\Delta n}}{2}\right]\Delta n$$

WHERE: $V_{n,n+\Delta n}$ = VOLUME OF MATERIAL BETWEEN ELEVATION "n" & ELEVATION "n+Δn"

A_n = AREA OF MATERIAL AT ELEVATION n

$A_{n+\Delta n}$ = AREA OF MATERIAL AT ELEVATION n+Δn

Δn = ELEVATION DIFFERENCE BETWEEN ADJACENT AREAS (i.e. CONTOUR INTERVAL)



NOTE: VOLUME AT THE HIGHEST CONTOUR IN AN AREA IS ESTIMATED AS THE VOLUME OF A PYRAMID OF HEIGHT Δn, CALCULATED AS FOLLOWS:

$$V = \frac{1}{3} A_n \Delta n$$

Written by: D. WARREN Date: 96 / 02 / 21 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.11

AREAS OF MATERIAL REMOVED AT EACH CONTOUR ARE MEASURED FROM FIGURE 1 WITH A PLANIMETER

ABOVE ELEVATION 595ft, BORROW MATERIAL WILL BE REMOVED FROM TWO MAIN SEITIONS (SECTIONS 1 & 2 IN FIGURE 1).

SIX SMALL KNOLLS EXIST IN THE BORROW AREA (KNOLLS A - F IN FIGURE 1).

FOR CONTOUR PLANES THAT ARE AT THE BOTTOM OF A KNOLL, SUCH AS CONTOUR 'Z' IN FIGURE 2:

$$A_Z = A_{Z1} + A_{Z2}$$

A_{Z1} = AREA AT ELEV. Z OUTSIDE KNOLL
A_{Z2} = AREA AT ELEV. Z IN KNOLL

$$V_{Z1} = \left[\frac{A_{Z1} + A_{(Z+\Delta Z)1}}{2}\right] \Delta Z$$

$$V_{Z2} = \left[\frac{A_{Z2} + A_{(Z+\Delta Z)2}}{2}\right] \Delta Z$$

$$V_{Z-\Delta Z} = \left[\frac{A_{Z-\Delta Z} + A_{Z1} + A_{Z2}}{2}\right] \Delta Z$$

[redacted]

GEOSYNTEC CONSULTANTS

Written by: DAVE WARREN Date: 21-Feb-96 Reviewed by: PJS Date: 16-2-22

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.11

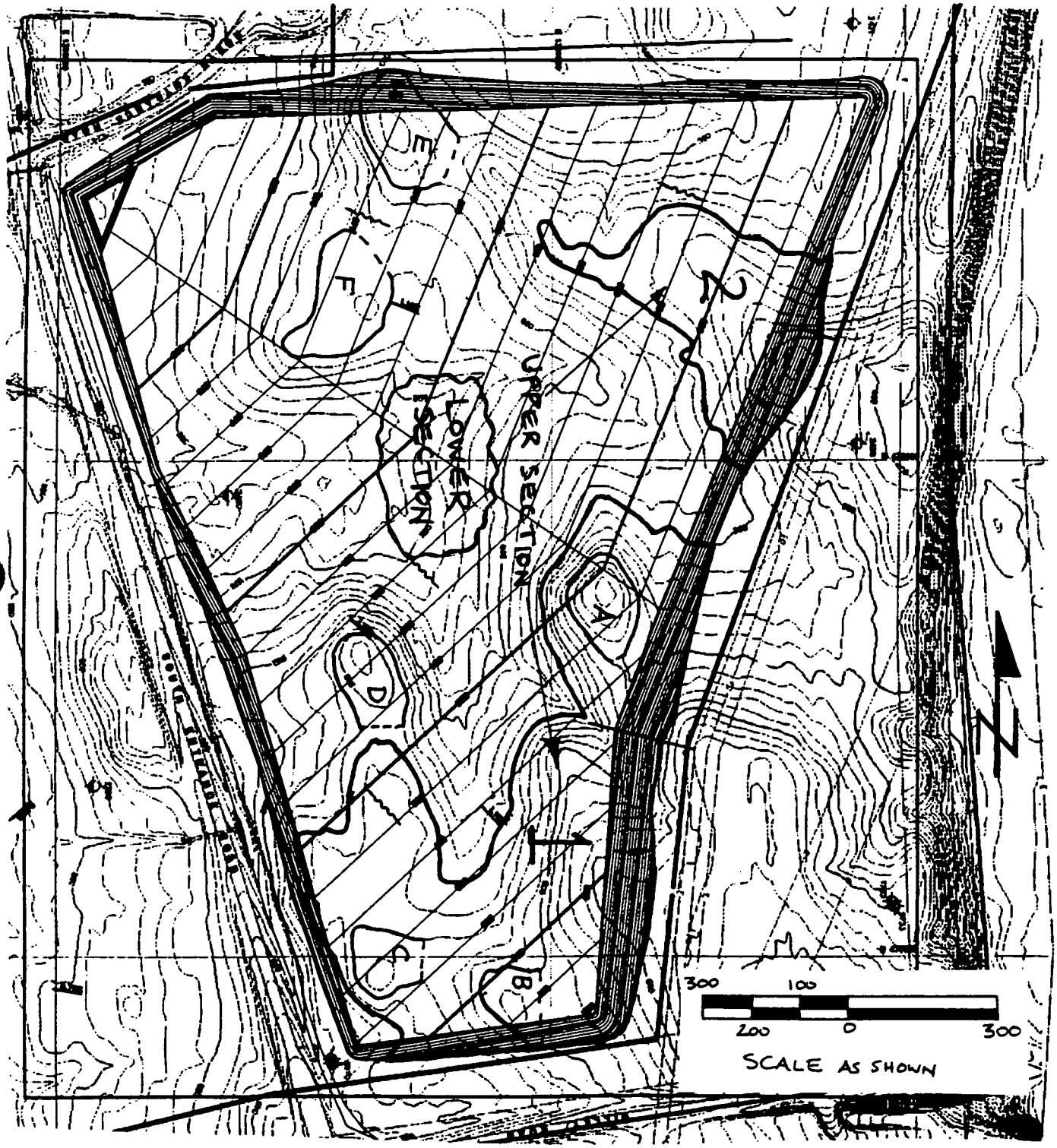


Figure 1 - East Field Borrow Area Restoration Plan. Modified from GeoSyntec [1996]

Written by: D. WARREN Date: 96 / 02 / 21 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.11

RESULTS:

VOLUME FROM CALC: 630,199 yd^3

VOLUME FROM MANUAL MEASUREMENT: 628,968 yd^3

DIFFERENCE BETWEEN ESTIMATES: 0.2 %

THE TWO ESTIMATES ARE NEAR EQUAL

THEREFORE, CADD VOLUME IS OK

DETAILS FOR THE MANUALLY MEASURED VOLUME ESTIMATE ARE SHOWN ON THE FOLLOWING PAGES

REFERENCES

GeoSyntec Consultants, "*On-Site Disposal Facility - Intermediate Design Package*", (Design Drawings), GeoSyntec Consultants, Atlanta, GA, Feb 1996.

[redacted]

D. WARREN 21 FEB 96 740.5/7

PJS 22 Feb 96

02/11/96

CALCULATION OF BORROW AREA VOLUME

Elevation (ft MSL)	Area (ft^2)	Δ Elev. (ft)	Volume (ft^3)	
Upper Section 1 - South End				
606	6,800	1	2,267	
605	16,800	1	11,800	
604	27,000	1	21,900	
603	40,700	1	33,850	
602	56,900	1	48,800	
601	80,300	1	68,600	
600*	107,600	1	93,950	*Does not include knoll A or B
600	144,800	0	0	
599	180,800	1	162,800	
598	208,400	1	194,600	
597*	242,900	1	225,650	*Does not include knoll C
597	259,100	0	0	
596	341,200	1	300,150	
595	404,900	1	373,050	
Upper Section 2 - North End				
603	3,320	1	1,107	
602	7,600	1	5,460	
601	11,350	1	9,475	
600	16,800	1	14,075	
599	23,500	1	20,150	
598	36,900	1	30,200	
597	55,000	1	45,950	
596	83,600	1	69,300	
595	121,200	1	102,400	

Continued on Next Page

CALCULATION OF BORROW AREA VOLUME

Elevation (ft MSL)	Area (ft^2)	Δ Elev. (ft)	Volume (ft^3)	
Lower Section				
595	526,100			
594*	628,100	1	577,100	*Does not include knoll D
594	649,300	0	0	
593	754,600	1	701,950	
592	851,400	1	803,000	
591*	943,900	1	897,650	*Does not include knoll E
591	976,100	0	0	
590	1,048,600	1	1,012,350	
589	1,085,300	1	1,066,950	
588*	1,101,100	1	1,093,200	*Does not include knoll F
588	1,135,800	0	0	
587	1,148,500	1	1,142,150	
586	1,064,100	1	1,106,300	
585	940,600	1	1,002,350	
584	839,750	1	890,175	
583	756,800	1	798,275	
582	683,400	1	720,100	
581	625,200	1	654,300	
580	543,050	1	584,125	
579	490,400	1	516,725	
578	396,500	1	443,450	
577	300,000	1	348,250	
576	214,300	1	257,150	
575	142,000	1	178,150	
574	83,000	1	112,500	
573	35,800	1	59,400	
572	8,350	1	22,075	
567	3,500	5	29,625	

Continued on Next Page

CALCULATION OF BORROW AREA VOLUME

Elevation (ft MSL)	Area (ft^2)	Δ Elev. (ft)	Volume (ft^3)
Knoll A			
603	1,400	1	467
602	7,400	1	4,400
601	13,150	1	10,275
600	20,900	1	17,025
Knoll B			
601	2,250	1	750
600	16,300	1	9,275
Knoll C			
598	2,800	1	933
597	16,200	1	9,500
Knoll D			
596	1,850	1	617
595	10,800	1	6,325
594	21,200	1	16,000
Knoll E			
593	3,600	1	1,200
592	15,700	1	9,650
591	32,200	1	23,950
Knoll F			
589	1,900	1	633
588	34,700	1	18,300

Total (ft^3): 16,982,133
Total (yd^3): 628,968 ✓

Total From CADD (yd^3): 630,199 ✓

Difference Between
Manual and CADD Volumes: 0.20% ✓

15.3 Borrow Area Water Demand

[redacted]

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: BORROW AREA WATER DEMAND

Computations By: (Cognizant Engineer)
Signature [signature] Date 23 Feb 1996
Printed Name and Title Peter J. Prommer, Senior Staff Engineer

Assumptions and Procedures Checked by: (Checker)
Signature Paul J. Sabatini Date 24 Feb 1996
Printed Name and Title PAUL J. SABATINI, SENIOR STAFF ENGINEER

Computations Checked by:
Signature Paul J. Sabatini Date 24 Feb 1996
Printed Name and Title PAUL J. SABATINI, SENIOR STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 24 Feb 1996
Printed Name and Title Peter J. Prommer, Senior Staff Engineer

Approved by: (PDP)
Signature [signature] Date 24 Feb 96
Printed Name and Title Kara L Olen, Asst Proj Engr.

Approved by: (DTL and TETL)
Signature [signature] Date 24 Feb 96
Printed Name and Title Kenneth W Cargill

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design	24 Feb 1996	[illegible]	PJS	[illegible] 24 Feb 96
D	Intermediate Design - EPA Submittal	4 Apr 96	[illegible]	—	—
G	Final Design Package	4 Oct 96	—	—	[illegible]
O	Response to Final Design Comts	5 May 97	—	—	[illegible]

Written By : PJP Date: 23 Feb 1996 Reviewed by: PJS Date: 96 2-24

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

BORROW AREA WATER DEMAND

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this package is to evaluate the water demand for moisture conditioning of on-site borrow materials during the construction of the compacted clay liner and cap of the FEMP On-Site Disposal Facility (OSDF). Soil removed for use as borrow material will also be used to construct the vegetative soil layer and compacted fill components of the OSDF. Moisture requirements only exist, however, for the compacted clay liner and cap material (as discussed in the Data Verification portion of this calculation package). For this reason, the calculation considers moisture conditioning requirements for the compacted clay liner and cap material only. The borrow material used for the compacted clay liner and cap components will be obtained from the brown till soils within the OSDF foot-print excavation and the East Field Borrow Area (Borrow Area).

METHODS OF ANALYSIS

The water demand for moisture conditioning is calculated for the compacted clay liner and cap by:

1) calculating the average mass of water per cubic foot of in situ soil;
2) calculating the average mass of water per cubic foot of compacted soil for various established moisture-density relationships;
3) comparing the mass of water of the in situ soil with the mass of water calculated for the established moisture-density relationships for compacted soil; and
4) calculating the water demand for moisture conditioning.

Written By : PJP Date: 23 Feb 1996 Reviewed by: PJS Date: 96 2-24

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

CONCLUSIONS

A total of approximately 334,300 gallons of water will be required for the moisture conditioning of borrow soils during construction of the compacted clay liner and compacted clay cap for 8 cells of the OSDF. This corresponds to approximately 1,000 gallons per clay liner/cover construction day of water required for moisture conditioning.

BORROW AREA WATER DEMAND

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Written By : PJP Date: 22 Feb 1996 Reviewed by: PJS Date: 96 2-24

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.4

BORROW AREA WATER DEMAND

CALCULATION PROCEDURES

INTRODUCTION

The purpose of this package is to present the calculation procedures necessary to estimate the water demand for moisture conditioning of on-site borrow materials during the construction of the compacted clay liner and cap of the FEMP On-Site Disposal Facility (OSDF).

METHODS OF ANALYSIS

The procedures described below are used to calculate the water demand for moisture conditioning borrow soils for the construction of the compacted clay liner and compacted clay cap of the OSDF. In the calculations performed, it is assumed that the borrow soils do not gain or lose moisture during excavation or during compaction.

1) Calculate the average mass of water per cubic foot of soil.

From Holtz and Kovacs [1981]:

$$M_w = w\, M_s \qquad (1)$$

and

$$M_s = \rho_d\, V_T \qquad (2)$$

where w = soil moisture content;

M_w = mass of water in the soil;

M_s = mass of solids in the soil;

[redacted]

Written By: PJP Date: 22 Feb 1996 Reviewed by: PJS Date: 96 2-24

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.4

ρ_d = dry density of the soil; and

V_T = total volume of soil.

Substituting Equation (2) into Equation (1) yields:

$$M_w = w\,\rho_d\,V_T \tag{3}$$

or

$$M_w = w\,\rho_d \text{ for } V_T = 1\ ft^3 \tag{4}$$

2) Using Equation (4), calculate $M_{w\ in\ situ}$ and $M_{w\ compacted}$ for $V_T = 1\ ft^3$.

$M_{w\ in\ situ}$ is calculated as:

$$M_{w\ in\ situ} = w_{in\ situ}\,\rho_{d\ in\ situ}$$

where $M_{w\ in\ situ}$ = mass of water in the in situ soil;

$w_{in\ situ}$ = in situ soil moisture content; and

$\rho_{d\ in\ situ}$ = dry density of the in situ soil.

$M_{w\ compacted}$ is calculated for the two compacted moisture-density conditions described in the Data Verification portion of this calculation package as:

$$M_{w\ compacted} = w_{compacted}\,\rho_{d\ compacted}$$

where $M_{w\ compacted}$ = mass of water in the compacted soil;

$w_{compacted}$ = compacted soil moisture content; and

$\rho_{d\ compacted}$ = dry density of the compacted soil.

[redacted]

Written By : PJP Date: 22 Feb 1996 Reviewed by: PJS Date: 96-2-24

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3) Compare the value of $M_{w\ in\ situ}$ with that of $M_{w\ compacted}$ for the two additional moisture-density conditions.

If $M_{w\ in\ situ} \geq M_{w\ compacted}$; no additional water is required.

If $M_{w\ in\ situ} < M_{w\ compacted}$; additional water is required.

If additional water is required, it is calculated as:

$$M_{w\ additional} = (\text{Volume of compacted clay liner and cap})\ (M_{w\ compacted} - M_{w\ in\ situ}) \quad (5)$$

where $M_{w\ additional}$ = the total mass of water that must be added to the compacted clay liner and cap.

REFERENCES

Holtz, R.D. and Kovacs, W.D. (1981). *An Introduction to Geotechnical Engineering*. Prentice Hall, Englewood Cliffs, 733 p.

[redacted]

Written By : PJP Date: 22 Feb 1996 Reviewed by: RJS Date: 96 2-24

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

BORROW AREA WATER DEMAND

DATA VERIFICATION

INTRODUCTION

The purpose of this package is to present the data necessary to estimate the water demand for moisture conditioning of on-site borrow materials during the construction of the compacted clay liner and cap of the FEMP On-Site Disposal Facility (OSDF). The borrow material used for the compacted clay liner and cap components will be obtained from the brown till soils within the OSDF foot-print excavation and the Borrow Area.

CRITICAL EARTHWORK COMPONENT

The CQA Plan was reviewed to obtain required moisture contents for the various earthwork components to be constructed from on-site borrow materials (i.e., compacted clay liner and cap, vegetative soil layer, and compacted fill). This review indicated the following:

- The required moisture content range and compacted dry density performance criteria for the compacted clay liner and cap will be established based on results from the Test Pad construction.
- The vegetative soil layer and compacted fill have no required moisture content range. Therefore, water demand associated with these components is not considered herein.

The CQA Plan review indicates that the compacted clay liner and cap are the critical earthwork components with regard to water demand. The vegetative soil layer and compacted fill will be moisture conditioned to ensure workability and strength, however, it is expected that these materials will be dried

[redacted]

rather than wetted to achieve these conditions. Therefore, the water demand for these components is not considered herein.

REQUIRED DATA

The data required to estimate the water demand for moisture conditioning is described in this section. These data include:

- in situ moisture content ($w_{in\ situ}$) and in situ dry density ($\rho_{d\ in\ situ}$);
- compacted moisture content ($w_{compacted}$) and compacted dry density ($\rho_{d\ compacted}$);
- optimum moisture content of the brown till soil; and
- volumes of the compacted clay liner and compacted clay cap.

Information on and values for these data are described below.

- $w_{in\ situ}$ and $\rho_{d\ in\ situ}$

  In situ moisture contents and dry densities of the on-site brown till material were obtained from soil sample laboratory test results from Appendix G of Parsons [1995] and preliminary data tables [Parsons, preliminary data 1996]. Figures 1 and 2 present the brown till in situ moisture content and dry density data.

  The average or representative brown till moisture content and dry density is estimated using the best-fit lines plotted on Figures 1 and 2. Based on the geologic cross-sections through the OSDF (see Sheets X-13 through X-15 of the Intermediate Design Drawings), it is reasonable to assume that the borrow material from the OSDF foot-print excavation will come primarily from depths ranging from 1 to 10 feet below the ground surface. Also, based on the Intermediate Design Drawings Borrow Area excavation boundaries and excavation elevations, it is anticipated that approximately 80% of the borrow material

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BROWN TILL SOIL DATA

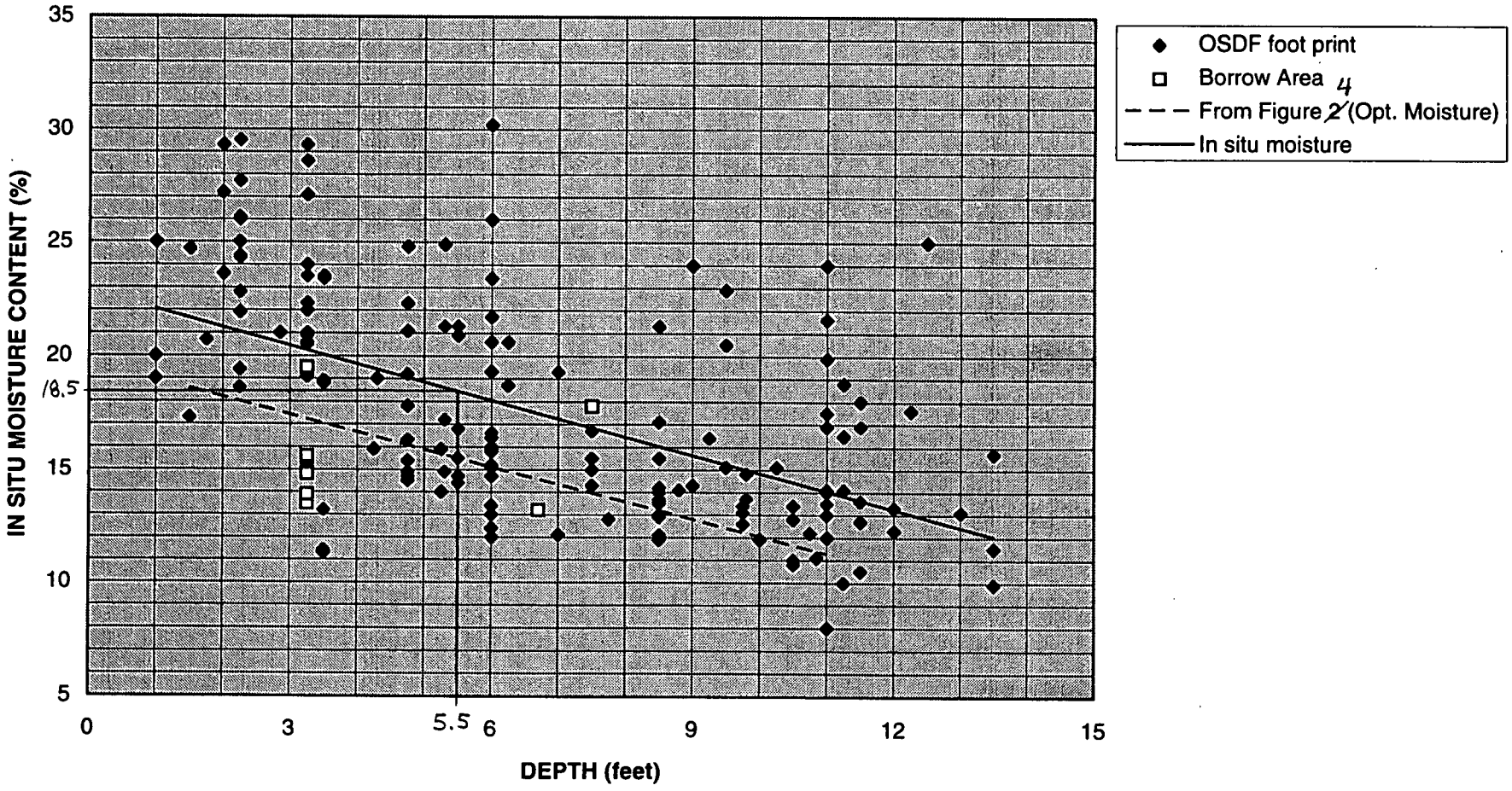

Figure 1. Brown Till In Situ Moisture Content Data

[data obtained from Parsons, 1995 and 1996]

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BROWN TILL SOIL DATA

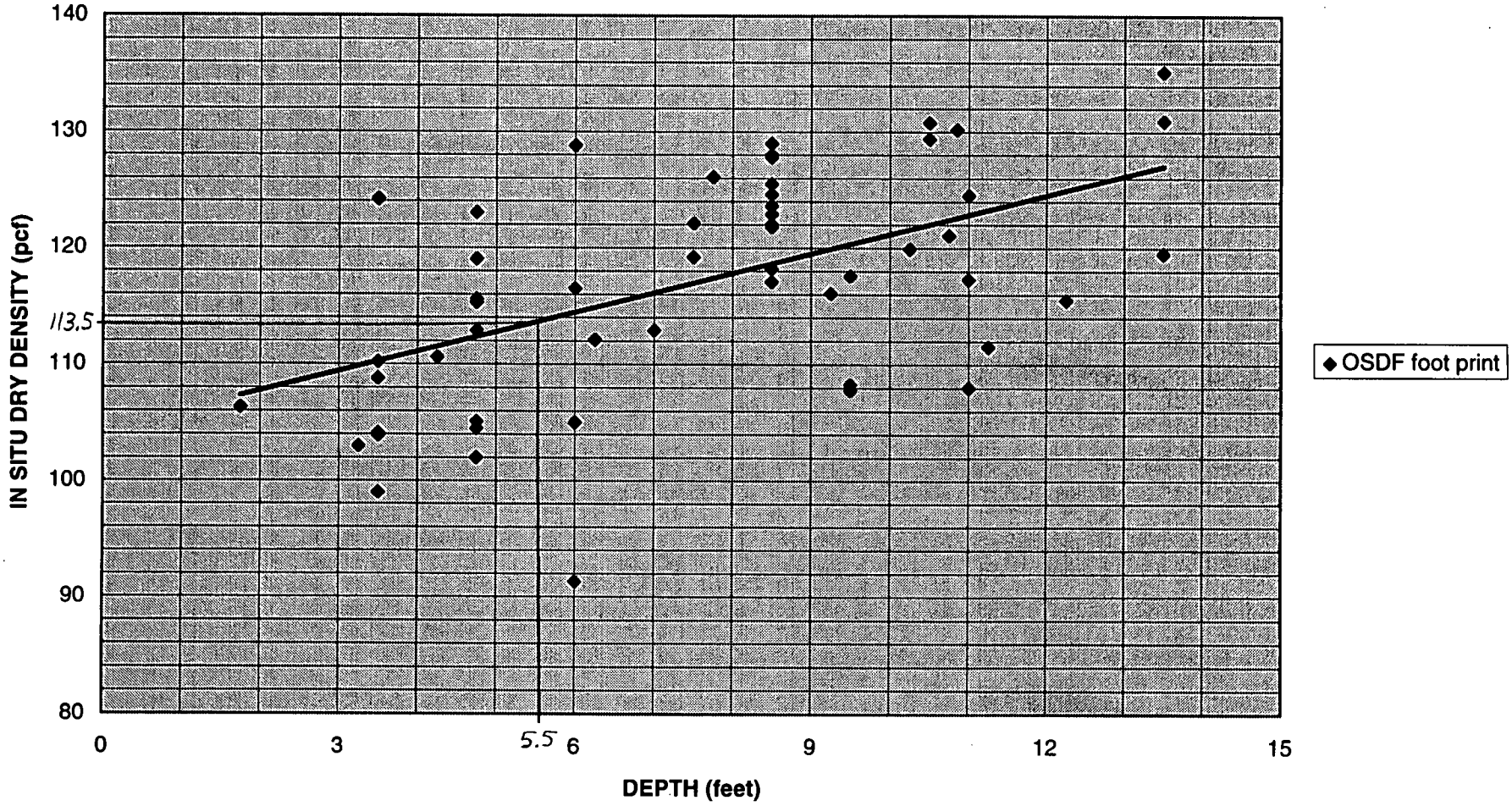

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Figure 2. Brown Till In Situ Dry Density Data

[data obtained from Parsons, 1995]

from the Borrow Area will come from depths ranging from 0.5 to 10 feet below ground surface. Based on this information, it is assumed that the majority of the borrow material will be excavated from the OSDF foot-print excavation and the Borrow Area from depths ranging from 1 to 10 feet below the ground surface. Using the 5.5-foot depth (half-way between the 1- to 10-foot depth) value gives the following estimate for the brown till in situ moisture content and dry density:

$w_{in\ situ} = 18.5\ \%$

$\rho_{d\ in\ situ} = 113.5$ pcf

- $w_{compacted}$ and $\rho_{compacted}$

The assumed values for the compacted water content and compacted dry density of the brown till soils were selected to be consistent with the conditions necessary to achieve a hydraulic conductivity of 1×10^{-7} cm/s. The actual performance criteria for the compacted clay components will be established based on the results of testing performed as part of the Test Pad construction. The selected values of moisture and dry density at which the specified hydraulic conductivity should be achievable are:

- 95% of $\rho_{d\ maximum}$ at +4% of optimum moisture content; and
- 98% of $\rho_{d\ maximum}$ at +2% of optimum moisture content.

Compacted maximum dry densities of the on-site brown till material were obtained from soil sample laboratory test results from Appendix G of Parsons [1995] and preliminary data tables [Parsons, preliminary data 1996] Figures 3 presents the brown till maximum dry density data.

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BROWN TILL SOIL DATA

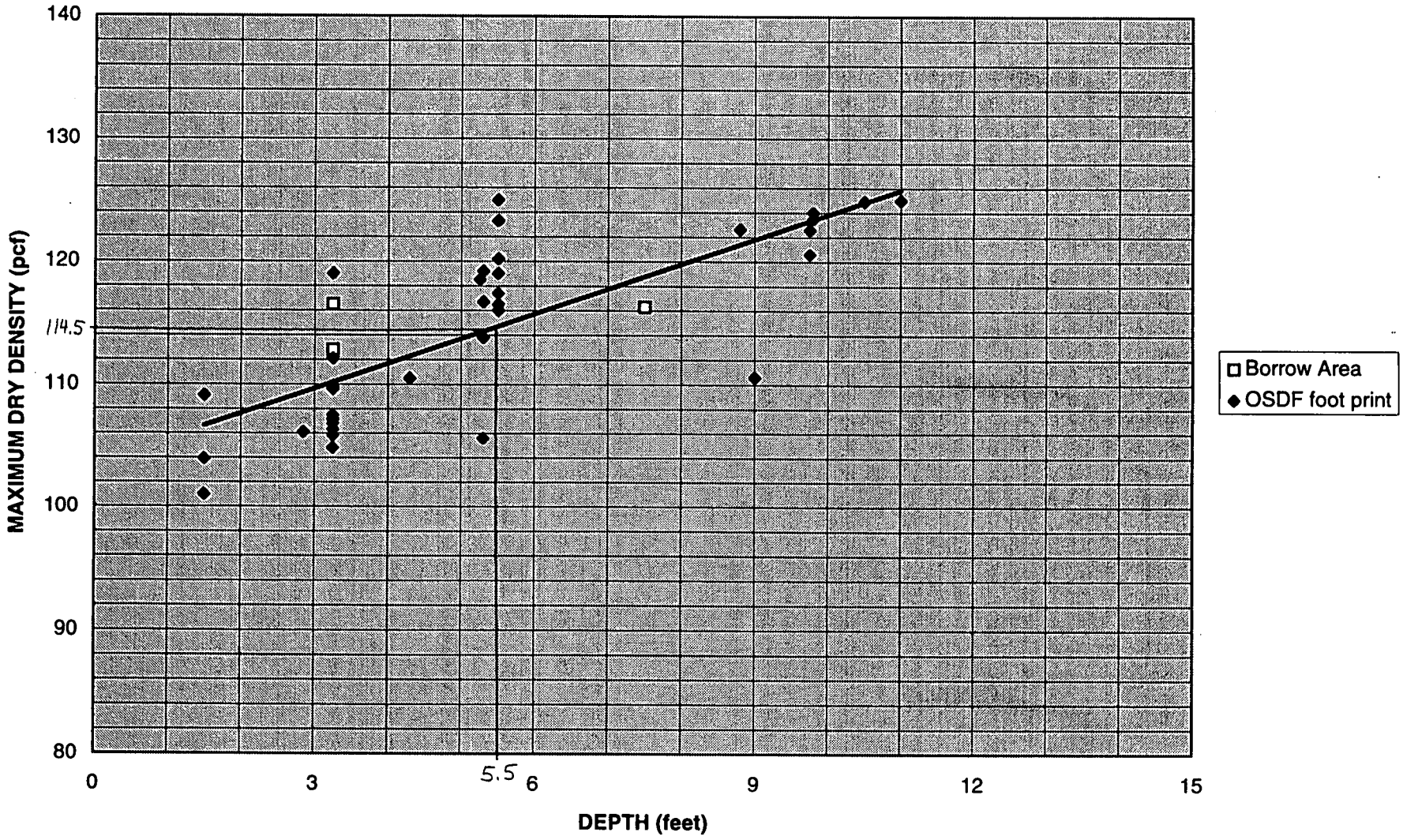

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Figure 3. Brown Till Maximum Dry Density Data

[data obtained from Parsons, 1995 and 1996]

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The average or representative brown till maximum dry density is estimated using the best-fit line plotted on Figure 3. Using the 5.5-foot depth (half-way between the 1- to 10-foot depth) value gives the following estimate for the brown till maximum dry density:

$$\rho_{d\ maximum} = 114.5 \text{ pcf}$$

For the 95% of $\rho_{d\ maximum}$ at +4% of optimum moisture content:

$$\rho_{d\ compacted} = (0.95)(114.5) = 108.8 \text{ pcf}$$

For the 98% of $\rho_{d\ maximum}$ at +2% of optimum moisture content:

$$\rho_{d\ compacted} = (0.98)(114.5) = 112.2 \text{ pcf}$$

- optimum moisture content

The optimum moisture content used for the calculations performed herein was obtained from laboratory test results on the brown till soil [Appendix G of Parsons, 1995] and preliminary data tables [Parsons, preliminary data 1996]. Figure 4 presents the brown till optimum moisture content data.

The average or representative brown till optimum moisture content is estimated using the best-fit line plotted on Figure 4. Using the 5.5-foot depth (half-way between the 1- to 10-foot depth) value gives the estimate of 15.5% for the brown till optimum moisture content.

Figure 4 also shows the best-fit line for the in situ moisture content. This line is nearly parallel to the optimum moisture content best-fit line. The in situ moisture content is

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BROWN TILL SOIL DATA

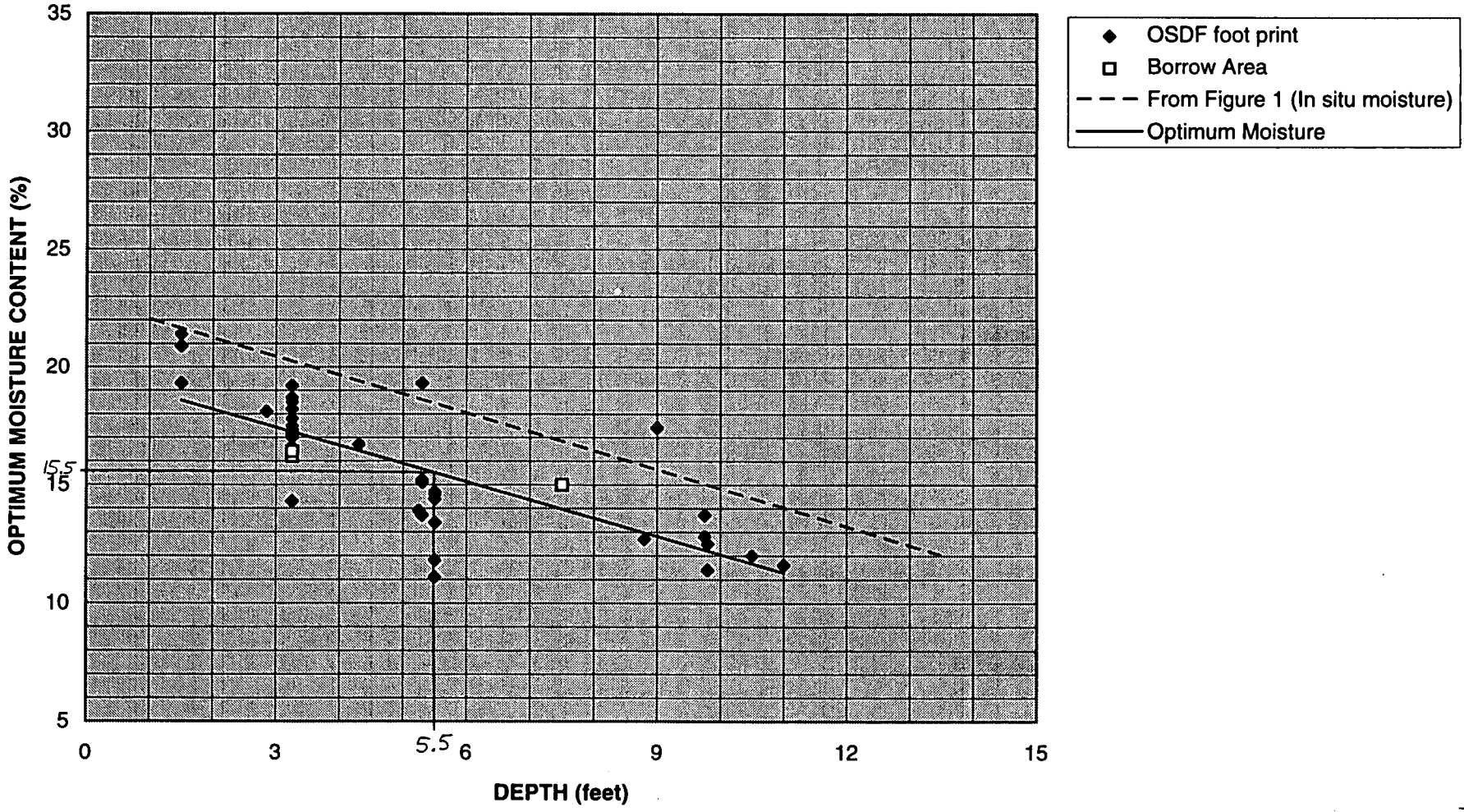

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Figure 4. Brown Till Optimum Moisture Content Data

[data obtained from Parsons, 1995 and 1996]

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approximately 3% greater than the optimum moisture content for the range of moisture contents shown on the figure.

For the 95% of $\rho_{d\ maximum}$ at +4% of optimum moisture content:

$$w_{compacted} = \text{optimum moisture content} + 4\% = 15.5 + 4 = 19.5\%$$

For the 98% of $\rho_{d\ maximum}$ at +2% of optimum moisture content:

$$w_{compacted} = \text{optimum moisture content} + 2\% = 15.5 + 2 = 17.5\%$$

- Volumes of the compacted clay liner and compacted clay cap
  - compacted clay liner = 297,231 yd^3
  - compacted clay cap = 194,582 yd^3

[redacted]

Written By : PJP Date: 22 Feb 1996 Reviewed by: PJS Date: 96-2-24

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.11

REFERENCES

Construction Quality Assurance Plan (Revision C). (1996). FEMP On-Site Disposal Facility, prepared for FERMCO by GeoSyntec Consultants.

Intermediate Design Drawings (60% Submittal). (1996). FEMP On-Site Disposal Facility, prepared for FERMCO by GeoSyntec Consultants, February.

Parsons. (1995). *Geotechnical Investigation Report, On-Site Disposal Facility*, Operable Unit 2, Project Order 140, Revision 0, prepared for FERMCO for the Fernald Environmental Management Project, Subcontract No. 2-21487, December.

Parsons. (preliminary data 1996). Preliminary results of borrow area sampling and testing program.

[redacted]

GEOSYNTEC CONSULTANTS

Written by: PJP Date: 96 / 02 / 23 (YY MM DD) Reviewed by: RJS Date: 96 / 2 / 24 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.4

BORROW AREA WATER DEMAND

CALCULATION RESULTS

* Assume no moisture is gained or lost during excavation and compaction.

- Given equation:

$$M_w = w \rho_d \text{ per unit volume}$$

- $M_{w_{in\ situ}}$

$$M_{w_{in\ situ}} = w_{in\ situ}\, \rho_{d\,insitu} \quad \text{for } V_T = 1\,ft^3$$
$$= (0.185)(113.5\,pcf)$$
$$\underline{M_{w_{in\ situ}} = 21.0 \text{ pound for } V_T = 1\,ft^3}$$

- $M_{w_{compacted}}$

$$M_{w_{compacted}} = w_{compacted}\, \rho_{d\,compacted} \quad \text{for } V_T = 1\,ft^3$$

[redacted]

Written by: PJP Date: 96 / 02 / 23 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 24 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.4

$M_{w_{compacted(98\%)}} \rightarrow$ use $w_{compacted} = w_{opt} + 2\%$

$\rho_{d_{compacted}} = 98\% \, \rho_{d_{maximum}}$

$M_{w_{compacted(98\%)}} = (15.5\% + 2\%)(0.98 \cdot 114.5 pcf)$

$M_{w_{compacted(98\%)}} = 19.64$ pounds for $V_T = 1 ft^3$ ✓

$M_{w_{compacted(95\%)}} \rightarrow$ use $w_{compacted} = w_{opt} + 4\%$

$\rho_{d_{compacted}} = 95\% \, \rho_{d_{maximum}}$

$M_{w_{compacted(95\%)}} = (15.5\% + 4\%)(0.95 \cdot 114.5 pcf)$

$M_{w_{compacted(95\%)}} = 21.21$ pounds for $V_T = 1 ft^3$ ✓

- compare $M_{w_{compacted}}$ with $M_{w_{in\ situ}}$

$M_{w_{compacted(98\%)}} < M_{w_{in\ situ}}$

$19.64 < 21.0$

∴ no additional water required

$M_{w_{compacted(95\%)}} > M_{w_{in\ situ}}$

$21.21 > 21.0$

∴ additional water required ✓

[redacted]

Written by: PJP Date: 96 / 02 / 23 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 24 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.4

- Calculate the additional water required for the case where brown till soil is compacted to 95% $\rho_{d\,maximum}$

$$M_{w_{additional}} = (297,231\ yd^3 + 194,582\ yd^3)\left(\frac{27\ ft^3}{1\ yd^3}\right)\left(0.21\ \frac{lb}{ft^3}\right)$$

$= 2,789,000$ pounds of water is required

$$\text{gallons} = (2,789,000\ \text{pounds})\left(\frac{7.48\ \text{gallons}}{1\ ft^3}\right)\left(\frac{1\ ft^3}{62.4\ \text{pounds}}\right)$$

$= 334,300$ gallons of water for the compacted clay liner and cap over the time of construction of the 8 cells of the OSDF

- Assume 1 cell is constructed each year
- Assuming a cell cap and liner are being constructed simultaneously during a 2 month construction period
- Assume 22 construction days a month

total quantity of water required for the construction of the clay liner and cap components for a single cell $= \frac{334,300\ \text{gallons}}{8\ \text{cells}} = 41,790$ gallons

Water demand per day when both a cell clay liner and cap are being constructed $= \frac{41,790\ \text{gallons}}{(2\ \text{months})\left(\frac{22\ \text{const. days}}{1\ \text{month}}\right)} = 950$ gallons

Assume 1,000 gallons

Maximum water demand for moisture conditioning is 1,000 gallons per clay liner/cap construction day.

[redacted]

15.4 Stormwater Runoff Routing

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: STORMWATER RUNOFF ROUTING

Computations By: (Cognizant Engineer)
Signature Daniel G. Pass — Date 23 FEB 96
Printed Name DANIEL PASS
and Title STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature Daniel B. Wisialowski — Date 23 FEB 96
Printed Name DANIEL B. WISIALOWSKI
and Title ASSISTANT PROJECT ENGINEER

Computations Checked by:
Signature Daniel B. Wisialowski — Date 24 FEB 96
Printed Name DANIEL B. WISIALOWSKI
and Title ASSISTANT PROJECT ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature Daniel G. Pass — Date 24 FEB 96
Printed Name DANIEL G. PASS
and Title STAFF ENGINEER

Approved by: (PDP)
Signature Kara Olen — Date 24 Feb 96
Printed Name Kara L. Olen
and Title Asst. Prj Eng.

Approved by: (DTL and TETL)
Signature [illegible] — Date 24 Feb 96
Printed Name Kenneth W Cargill
and Title

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design				
D	IDP-EPA Submittal / ADDED SENTANCE TO P. 3 OF CALCULATION PROCEDURES	28 MAR 96	DGP	K. Olen	[illegible] 8 Apr 96
E	Response to Final Design Comts	5 May 97			[illegible]

Written by: DGP Date: 23 FEB 96 Reviewed by: DBW Date: 24 FEB 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

BORROW AREA STORMWATER RUNOFF ROUTING

EXECUTIVE SUMMARY

Purpose:

The East Field Borrow area, located in the southeast corner of the FEMP site, will be developed as a borrow source for construction of the OSDF. This calculation is used to demonstrate, for a 25-year 24-hour design storm, that the peak runoff rate discharged after development does not exceed the peak runoff rate discharged prior to development. Permanent drainage structures are designed to convey runoff from the design storm west of the South Access road for discharge into Paddy's Run.

Design Approach:

Peak flow rates are calculated using the TR-55 computer program (USDA, 1986a). Permanent stormwater structures include one culvert at the northwest corner of the borrow area and two drainage channels which collect runoff from the borrow area and discharge to the culvert and one drainage channel from the culvert to Paddy's Run. The culvert is designed using a procedure from AISI, 1987; the drainage channels are designed using Manning's equation. The design storm used for analysis and design is the 25-year 24-hour storm event.

Findings:

The peak flow rate calculated for post-development conditions (96 cfs) does not exceed that for pre-development conditions (106 cfs).

Design for permanent stormwater structures:

CMP Culvert and riprap apron:

- Culvert size: 48 in
- Outlet velocity: 7.6 ft/sec
- Length of riprap apron: 20 ft
- Riprap size: ODOT type D

Drainage Channels:

- Cross-section shape: trapezoidal AND V-DITCH
- Side slopes: 3H:1V
- Maximum channel depth: ~~1.8~~ ft 2.2 ft
- Maximum flow velocity: ~~4.7 ft/sec~~ 4.72 ft/sec

Written by: DGP Date: 28 MARCH 96 Reviewed by: Date:

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

STORMWATER RUNOFF ROUTING

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APPENDIX A: Computer Software Used to Prepare Calculations Package

Written by: DGD Date: 1 FEB 96 Reviewed by: DBW Date: 23 FEB 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

BORROW AREA STORMWATER RUNOFF ROUTING

CALCULATION PROCEDURE

The following procedure is used to demonstrate, for a 25-year 24-hour design storm, that the peak runoff rate discharged after development does not exceed the peak runoff rate discharged prior to development. In addition, permanent drainage structures are designed to convey runoff from the design storm west of the South Access road for discharge into Paddy's Run.

The TR-55 computer program is used to evaluate peak flow rates for pre- and post-development conditions and to evaluate inflow rates for the culvert and drainage channels (Step 1). Permanent drainage structures are designed in step 2.

Step 1: Evaluate the required peak flow rates using the PC program TR-55 (USDA, 1986). The peak flow rates are required for the following conditions:

- Borrow area for pre-development conditions. (See Figure 1)
- Borrow area for post-development conditions. (See Figure 2)
- Drainage area for the permanent culvert (Culvert 1). (See Figure 3)
- Drainage area for the permanent drainage Channel 3 which is the same as for Culvert1 (See Figure 3)
- Drainage area for the permanent drainage channels (Channels 1 and 2). (See Figure 3)

The following input parameters are input to the TR-55 program and are evaluated for each of the above conditions.

1.1 Identify precipitation parameters:

- The 25-yr, 24-hr storm rainfall depth obtained from Parsons, 1995.
- The SCS 24-hour Rainfall Distribution Type based on guidance in USDA, 1986b.

1.2 Measure the drainage area and subareas.

- Delineate the drainage area.
- Divide the drainage area into subareas and measure the size of each subarea using a planimeter.

1.3 Select a runoff curve number, CN for each subarea based on the following parameters and guidance given in USDA, 1986b:

- Select the Hydrologic Soil Group, HSG of expected surficial soils based on guidance in USDA, 1986b, USDA, 1980 and USDA, 1992.
- Select a Ground Cover Type, based on guidance given in USDA, 1986b.

1.4 Define flow path parameters for each subarea. Flow path parameters are used to calculate a time of concentration for each subarea. Drainage is generally from East to West and all flow ultimately discharges to Paddy's Run.

Define flow paths for each subarea. Each flow path is divided into flow path segments. Each flow path segment is associated with one of the following flow regimes; 1) sheet flow, 2) shallow concentrated flow and 3) open channel flow. The required input parameters are as follows.

Sheet flow regime:

- Assume a length of sheet flow up to 300 ft.
- Select a surface code (within the TR55 program) based on ground cover. The surface code corresponds to Manning's coefficient.
- Calculate the average slope for the flow path segment.

Shallow concentrated flow:

- Select a surface code (within the TR-55 program) which corresponds to a paved or unpaved condition.
- Calculate an average slope for the flow path segment.

Open channel flow:

- Assume a V-section for natural swales.
- Select a Manning's coefficient based on guidance in Chow (1959)
- Calculate an average slope for the flow path segment.
- Calculate an area of flow for a V-shaped swale, a using the following equation:

$$a = \frac{(z_1 + z_2)}{2} d^2 \qquad [1]$$

Where:
z_1 = Side slope of one side of the swale (in./in.)
z_2 = Side slope of one side of the swale (in./in.)
d = the depth of the swale (ft), as show in Figure 2.

- Calculate the wetted perimeter, p_w,. for the depth of flow using the following equation:

$$p_w = \left(d^2 + (z_1 d)^2\right)^{1/2} + \left(d^2 + (z_2 d)^2\right)^{1/2} \qquad [2]$$

1.5 For each condition, run the TR-55 computer program using the above listed input parameters (See Data Collection and Verification section). Values of q_p (flow rate in cfs) are obtained directly from TR-55 output.

Step 2: Size permanent stormwater structures. The required stormwater structures include;

- a CMP culvert (Culvert 1) to convey borrow area runoff across the south access road;
- a channel (Channel 1) along the north perimeter of the borrow area;
- a channel (Channel 2) along the west perimeter of the borrow area.
- a channel (Channel 3) from the culvert to Paddy's Run.

The above stormwater structures are located as shown in Figure 3.

2.1 CMP Culvert 1: Culvert1 is sized using the design charts shown in Figure 4 (AISI, 1983). The outlet velocity, V is calculated using Manning's equation and the design chart shown in Figure 5. If the value of V for the culvert exceeds a permissible velocity (V_a for the receiving area) outlet protection will be required. A riprap apron will be sized to provide outlet protection for the culvert using the design chart shown in Figure 6. THE STRUCTURAL ANALYSIS FOR CULVERT 1 WAS PERFORMED AS PART OF THE "BORROW AREA SEDIMENT BASIN" CALCULATION. ✓

2.1.1 The required culvert diameter, D is sized using Figure 4 in the following iterative procedure. Inlet control conditions are assumed. ΔD 28 MAR 96 DGP

1) Calculate an allowable headwater depth, HW_a. The allowable headwater depth is the height of the road embankment above the culvert invert at the culvert inlet less 6 in. of required freeboard.

2) Select a trial culvert diameter, D_t.

3) Select the ratio HW/D_t from the design chart shown in Figure 4 using the following input parameters.

- Trial culvert diameter, D_t (in.)
- Discharge, Q (cfs) which is the inflow rate, q_p to the culvert calculated in step 1.
- Culvert entrance type which is selected.

4) Calculate a value of HW from the ratio HW/D_t.
5) If the value of HW is less than the value of HW_a then the trial culvert diameter, D_t is sufficient, otherwise reselect D_t and repeat steps 2 through 5.

2.1.2 Assess whether or not outlet protection will be required. The allowable outlet velocity, V_a is defined in the GeoSyntec (1996). The outlet velocity, V for Culvert 1 is calculated using Manning's equation, the design chart shown in Figures 5 with the following procedure;

1) Calculate the flow rate, Q_f, for the culvert flowing full using Manning's equation as follows;

$$Q_f = A\frac{1.486}{n}R^{2/3}S^{1/2}$$

where:

A = the cross sectional area of flow (ft^2);
R = the hydraulic radius (ft), which is equal to a/p_w;
S = the culvert slope (ft/ft);
n = the Manning's coefficient for CMP (USDA-SCS, 1986); and

2) Calculate the ratio, Q/Q_f:

3) Select the ratio, V/V_f from the design chart shown in Figure 5 using the ratio Q/Q_f .

4) Calculate V from the ratio V/V_f.

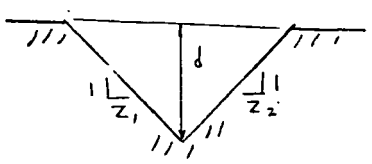
If the value of V is less than the value of V_a then outlet protection is not required; otherwise design a riprap apron using the procedure in section 2.3.

2.1.3 Size a riprap apron to provide outlet protection for culvert 1. The riprap apron is sized using the design chart shown in Figure 6 (VDRC, 1992). The geometry of the riprap apron is also shown in Figure 6.

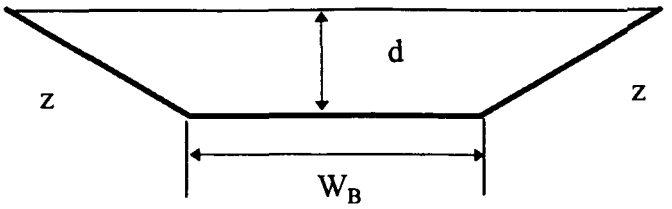
The design chart shown in Figure 6 is used with the following input parameters to select a minimum apron length, La and a riprap size, d_{50}. ;

- Culvert diameter, D (in.)
- Discharge, Q (cfs)

2.2: The drainage channels (Channels 1, 2 and 3; shown in Figure 3)) are sized to convey peak inflow rates, q_p without erosion of the channel bed. The cross-sectional geometry of the channel is assumed as shown in the following figure.



CHANNEL 1 AND 2
TYPICAL CROSS-SECTION



CHANNEL 3
Typical drainage channel cross-section

2.2.1 The channels are sized using the following iterative procedure.

1) Assume a cross-sectional shape and values for sideslope and bottom width. The required freeboard is 6 in. (GeoSyntec, 1996);

2) Calculate the slope of the channel bed from Figure 3.

3) Calculate a channel depth, d which will convey q_p with a value of $V < V_a$ using the following equations;

$$q = A\frac{1.486}{n}R^{2/3}S^{1/2} \qquad [4]$$

CHANNEL 3

$$A = \frac{(W_B + dz)}{2}d \qquad [5]$$

$$w_p = W_B + 2\left(d^2 + (zd)^2\right)^{1/2} \qquad [6]$$

CHANNELS 1 AND 2

$$A = \frac{(z_1 + z_2)d^2}{2}$$

$$w_p = \left(d^2 + (z_1 d)^2\right)^{1/2} + \left(d^2 + (z_2 d)^2\right)^{1/2}$$

Where:

q = the peak flow rate (cfs);
A = the cross-sectional area for the channel (ft^2),.
n = the Manning's roughness coefficient, based on guidance in Chow (1959)
R = the hydraulic radius (ft) $R=a/w_p$
S = the channel bed slope, (ft/ft);
W_B = the bottom width of the channel(ft); assumed
z = the side slope of the channel (in./in.); assumed

4) Select a trial value of d.

5) Calculate the value of q.

6) If the value of q exceeds the value of q_p the channel with a depth of d is sufficient to convey the design flow; otherwise repeat steps 1 and 2.

2.2.1 Evaluate the erosion resistance of each channel. Channel velocities are not to exceed a permissible channel velocity, V_a as defined in (GeoSyntec, 1996). Calculate the flow velocity, v_s at the peak flow rate, q_p for each channel using the following equation;

$$v_s = \frac{q_p}{a_p} \qquad [7]$$

Where,

a_p = the cross-sectional area of flow at the peak flow rate, ft^2.

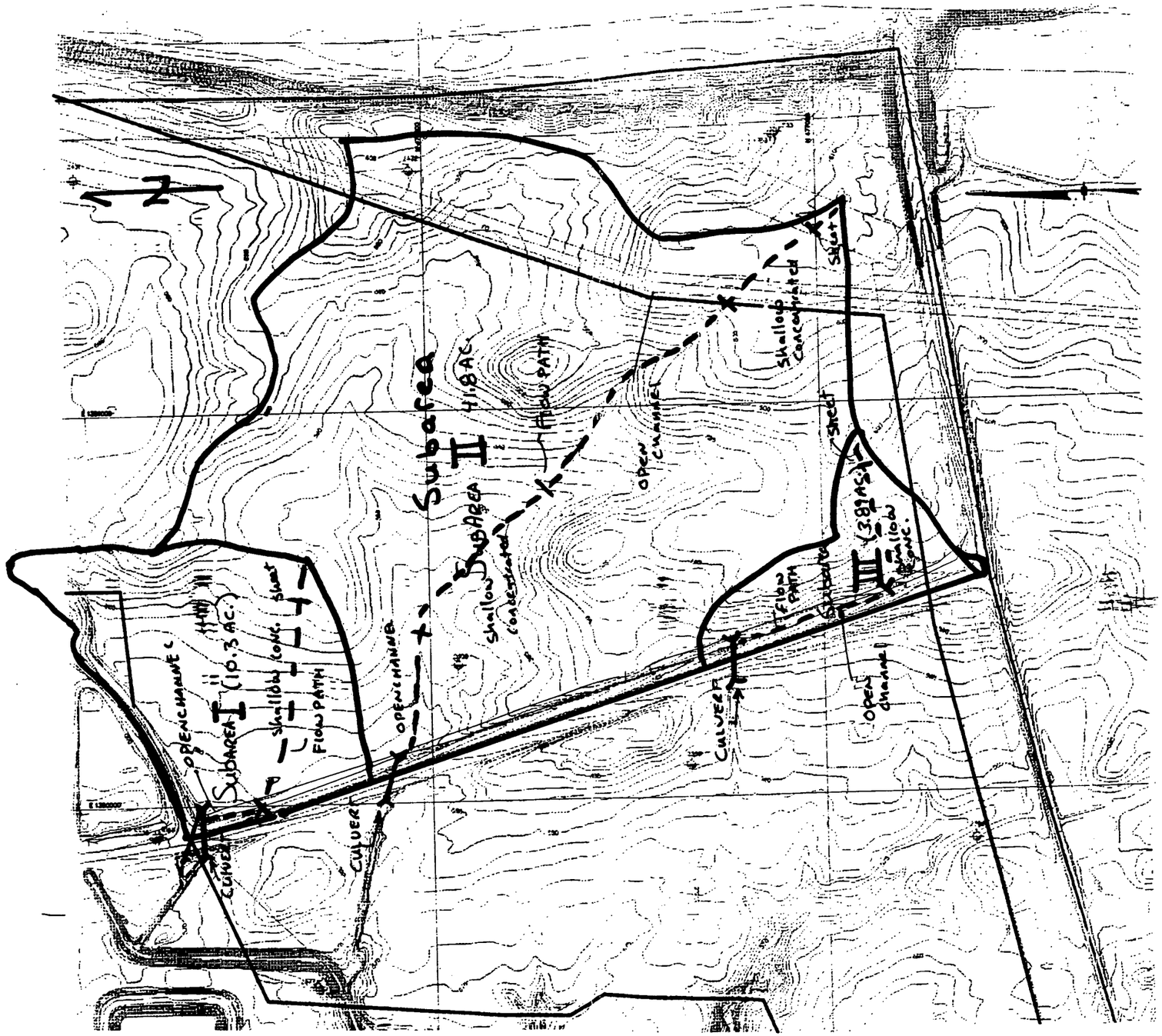
If the value of V_s is less than V_a then erosion of the channel bed is not anticipated, otherwise, revise the channel dimensions and recalculate V_s.

740 KO 24 Feb 96 7/13

Written By: DGP Date: 1 FEB 96 Reviewed by: DBW Date: 23 FEB 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

WATER SHED FOR PRE-DEVELOPMENT CONDITIONS



LEGEND

I SUBAREA NAME

FLOW PATH

DIVISION BETWEEN SUBAREAS

CULVERT

OPENCHANNEL FLOW REGIME

300 ft
SCALE

FIGURE 1

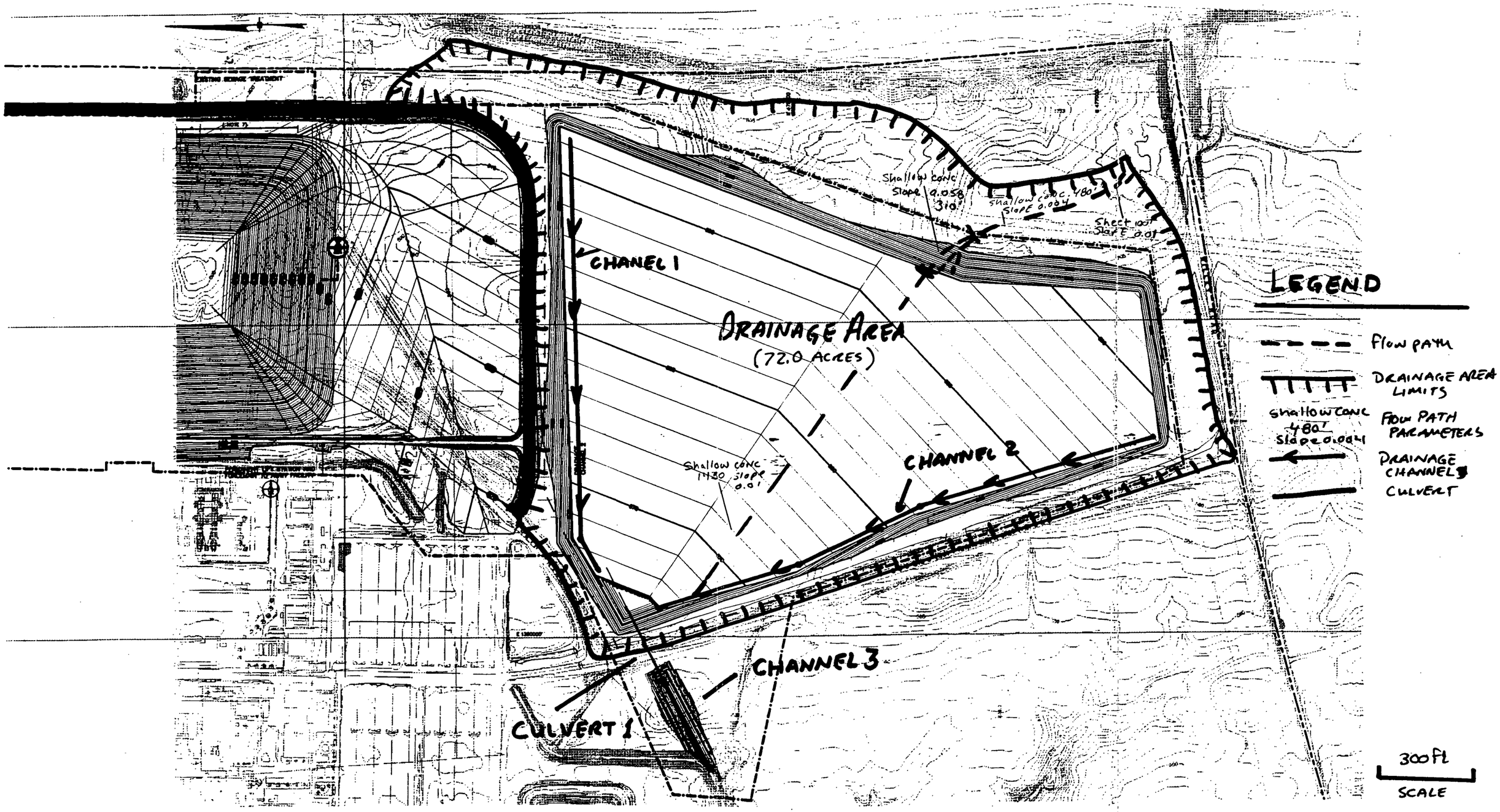
740

KO 24 FEB 96
8/13

Written By: DSP Date: 1 FEB 96 Reviewed by: DBW Date: 23 FEB 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

WATERSHED FOR POST-DEVELOPMENT CONDITIONS



000296

FROM DESIGN DRAWING TITLED "BORROW AREA RESTORATION PLAN"

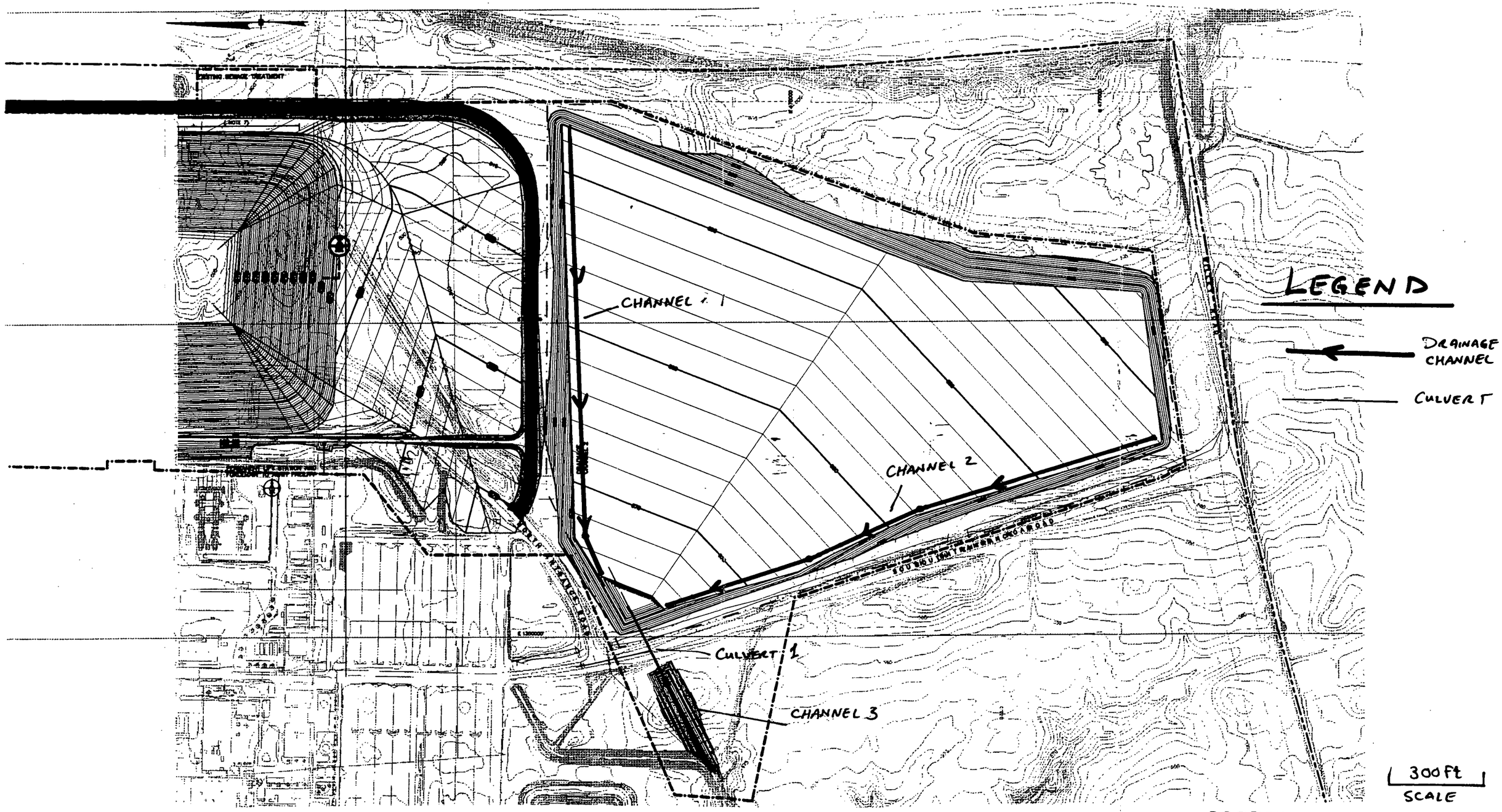
FIGURE 2

740 KO 24 FEB96 9/13

Written By: DGP Date: 1FEB96 Reviewed by: DBW Date: 23FEB96

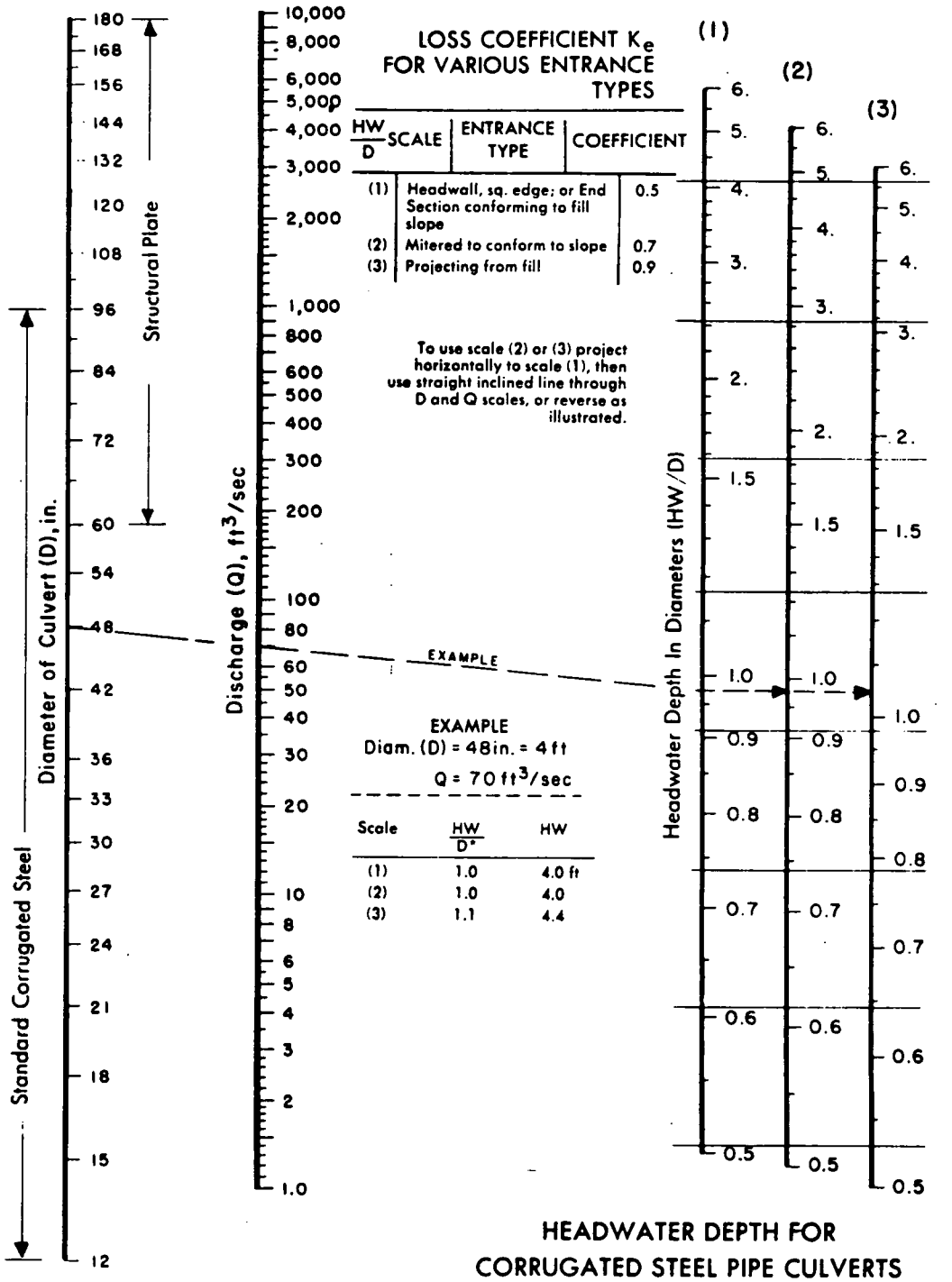
Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

LOCATIONS OF PERMANENT STORMWATER STRUCTURES



000297 FIGURE 3

FROM DESIGN DRAWING TITLED "BIRCOW AREA RESTORATION PLAN"



HEADWATER DEPTH FOR CORRUGATED STEEL PIPE CULVERTS WITH INLET CONTROL

FHWA HEC 5

Figure 4-28 *Inlet control* nomograph for corrugated steel *pipe* culverts. The manufacturers recommended keeping *HW/D* to a maximum of 1.5 and preferably to no more than 1.0.

Written by: DCP Date: 96/12/17 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3700 Task No.: 8.11

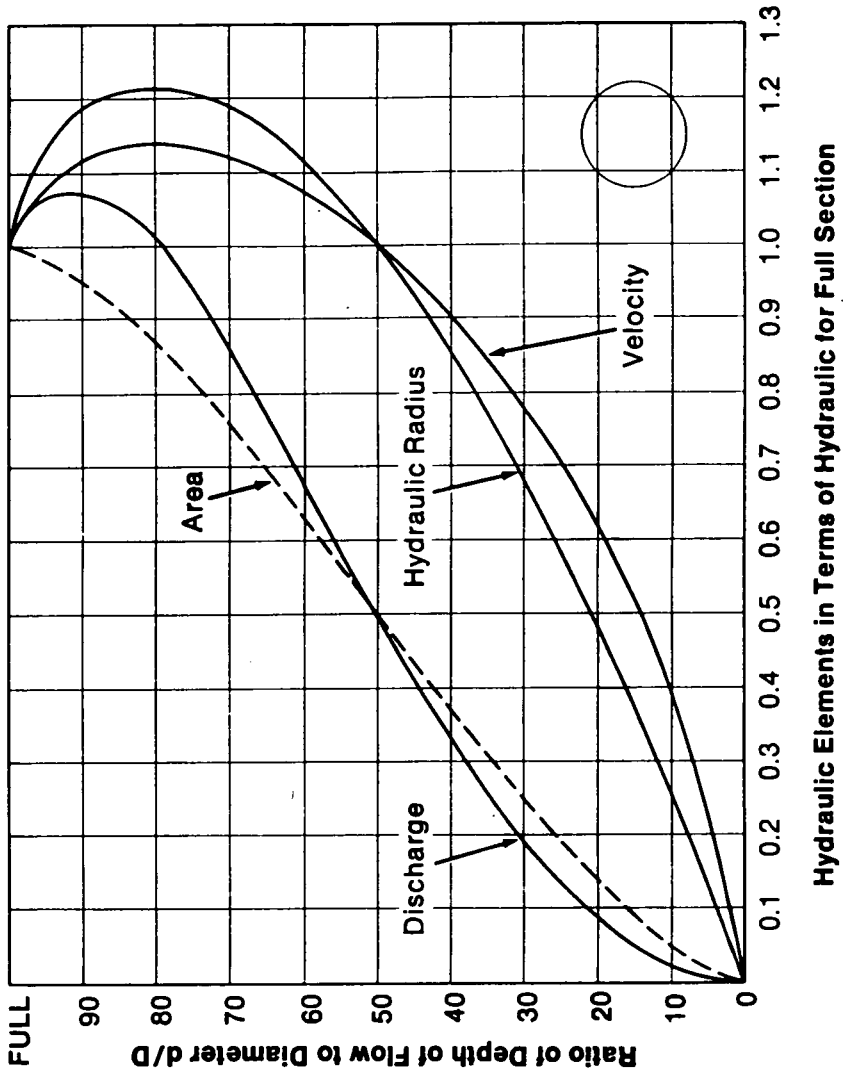


Figure 4-37 Hydraulic elements graph for circular corrugated steel pipe.

FIGURE 5

Written by: DGP Date: 96/2/1 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

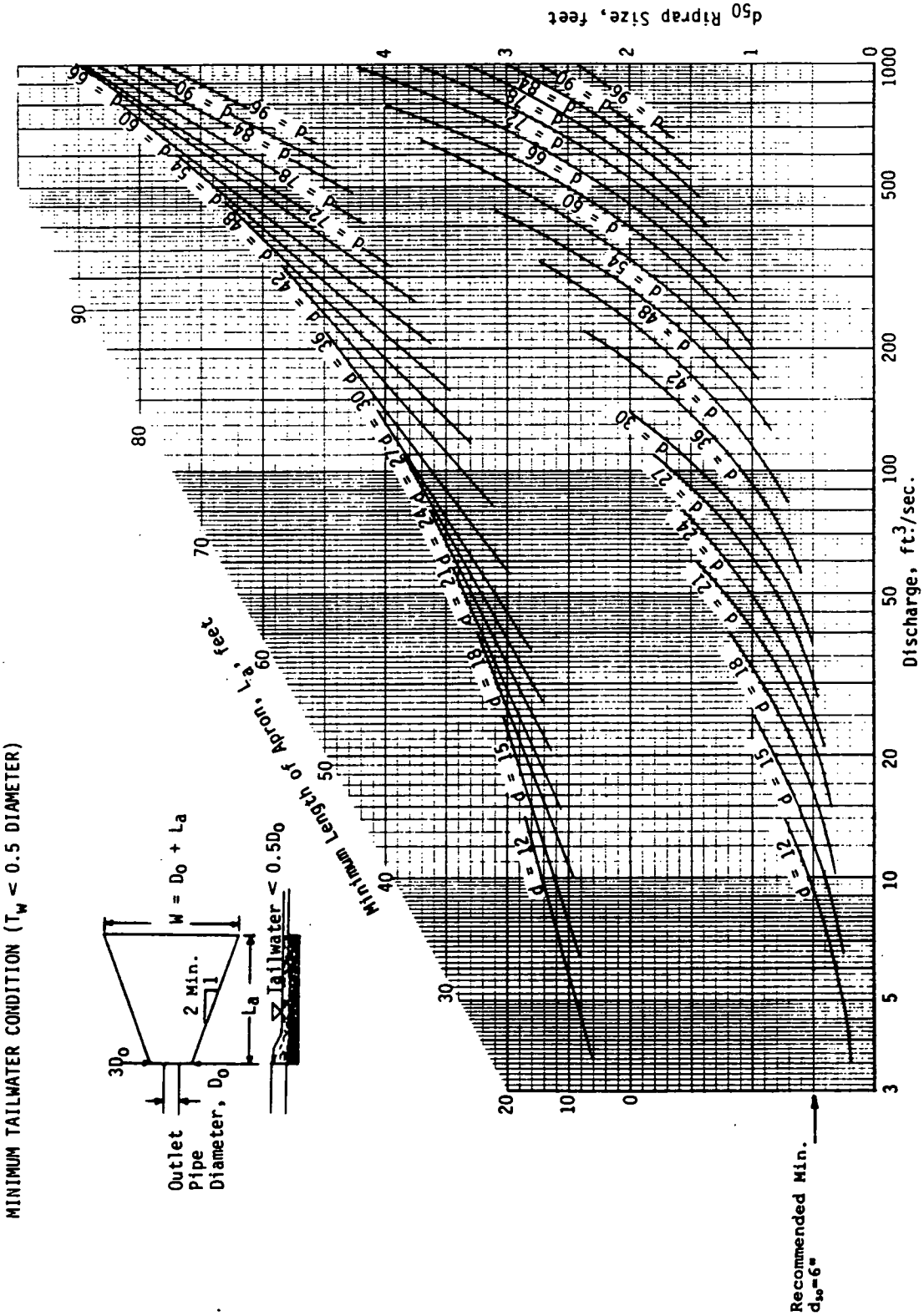


FIGURE 6

References:

1. American Iron and Steel Institute (AISI), "*Handbook of Steel Drainage & Highway Construction Products*", 3rd edition., AISI, Washington, DC, 1983.

2. Chow, Ven Te (Chow), "*Open-Channel Hydraulics*", New York, NY, 1959.

3. GeoSyntec Consultants, "Design Criteria Package, On-Site Disposal Facility", Revision ~~B~~ C, GeoSyntec Consultants, Atlanta Georgia, February 1996.

4. Parsons (Parsons),"*2000-Year Flood and Probable Maximum Flood, Site-wide Flood Plain Determination, Operable Unit 2*", Revision 0, Parsons, Cincinnati, Ohio, 1995.

5. United States Department of Agriculture, Soil Conservation Service (USDA), "*Soil Survey of Butler County, Ohio*", USDA, Washington, DC, January 1980.

6. United States Department of Agriculture, Soil Conservation Service (USDA), "*Soil Service of Hamilton County, Ohio*", USDA, Washington, DC, August 1992.

7. United States Department of Agriculture, Soil Conservation Service, Engineering Division (USDA), "*TR-55 Microcomputer Program System*", USDA, Washington, DC, 1986a.

8. United States Department of Agriculture, Soil Conservation Service, Engineering Division (USDA), "*Urban Hydrology for Small Watersheds*" USDA Technical release 55, Washington, DC, 1986b.

9. Virginia Department of Conservation and Recreation - Division of Soil and Water Conservation (VDCR), "*Virginia Erosion and Sediment Control Handbook*", VDCR, Richmond, Virginia, 1992.

Written by: DGP Date: 20 FEB 96 Reviewed by: DBW Date: 23 FEB 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

Borrow Area Stormwater Runoff Routing

Data Verification

Step 1: The input parameters required by TR-55 are as follows;

1.1 Precipitation Parameters: TR-55 requires rainfall depths for 2-yr.-24-hr. and design storm (i.e.. the 25-yr.,-24-hr.) events and the SCS 24-hour rainfall distribution type as part of the program input parameters.

a) Rainfall Depth: Values of rainfall depth were obtained from Parsons (1995), See Table 1:

- 2 yr.-24 hr. storm event = 2.55 in.
- 25 yr.-24 hr. storm event = 4.70 in.

b) SCS 24-hour Rainfall Distribution Type: The SCS 24-hour Rainfall Distribution Type was obtained from USDA-SCS (1986b) based on the geographic location of the FERNALD site, see Figure 1.

- SCS 24-hour rainfall distribution is type II

1.2 Drainage area and subareas:

Pre-development conditions: The topography of the borrow area for pre-development conditions is shown in Figure 1 of the Calculation Procedures. Elevation contours are based on a 1992 site flyover, provided by FERMCO.

Post-development conditions: The topography of the borrow area for post-development conditions is shown in Figure 2 of the calculation procedures.

Input parameters are listed in the following Tables.

Drainage Areas for pre-development conditions (Figure 1 of the Calculation Procedures).

Subarea Name	Area (acres)
I	10.3
II	41.8
III	3.86

Drainage Areas for post-development conditions and for permanent drainage structures (Figure 2 of the Calculation Procedures and Figures 2 through 4).

Area Name	Area (acres)
1	72.0
Culvert 1, Channel 3	72.0
Channel 1	25.7
Channel 2	46.3

1.2. Runoff Curve Number: TR-55 uses input data related to soil type and cover conditions to obtain a SCS curve number, CN for each drainage area. These values are presented below

a) 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.

- Pre-development Conditions: Tables 2a through 2d (USDA, 1986b) lists the names of surficial soils located within the borrow area watershed and their associated HSG classifications. The distribution of these soils across the site is shown in Figure 5 (Parsons, 1992). Surface soils within the borrow area classify as group B for approximately 60% of the total drainage area and as group C for the remaining 40%.

HSG Classifications for Borrow area surficial soils.

Map Symbol	Soil Name	Hydrologic Soil Group
FeA, FdA	Fincastle Silt Loam	C
MoE2	Miamian-Hennepin Silt Loams	C
RdA	Raub Silt Loam	C
XfA, XfB2	Xenia Silt Loam	B

- Post-development Conditions: The existing borrow area topsoil will be stockpiled for use in restoration of the borrow area. Thus, the post-development topsoil will be a mix of the existing topsoil. Geotechnical studies indicates that the upper soil layer (brown Till) has a higher sand content with depth. On this basis, it is assumed that the post-development topsoil will be better draining than the pre-development topsoil.

- HSG Classifications for pre-development and post-development conditions: Conservatively assume a HSG classification of C for pre-development and post-development conditions.

b) Ground Cover Type and Hydrologic Condition: Descriptions of vegetal cover within the borrow watershed area were obtained from aerial photographs of the site.

- Pre-development conditions: The existing vegetal cover for the borrow area. is grassland (US Dept. of Energy, 1994) (See Figure 6). Grasses are long and in good condition.

- Post-development Conditions: - The borrow area will be re-seeded. 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):

Borrow area ground cover, type and hydrologic condition[1]

Condition	Ground Cover Type	Hydrologic Condition
Pre-development	Pasture, Grassland or Range	Good
Post-development	Pasture, Grassland or Range	Good
[1]Obtained from USDA (1986a), See Table 3.		

1.4 Flow path parameters for each subarea:

Summary of flow path data and TR-55 calculated time of concentration.

	Time of Concentration							
Drainage area	Sheet Flow		Shallow Conc. Flow		Open Channel Flow			
	Length, ft	Slope	Length, ft	Slope	Length, ft	Slope	Area, ft^2	WP, ft
Pre-development								
subarea I	100	0.0125	330	0.0242	125	0.014	24	40.1
			185	0.0108	125	0.014	67.5	90
subarea II	100	0.01	320	0.0141	680	0.0265	126	103
			505	0.0119	340	0.0103	18	60
subarea III	100	0.0357	320	0.025	450	0.0122	52.3	55.1
Post-development	100	0.01	310	0.058				
(Whole drainage area)			1910'	0.008				
Culvert 1, Channel 3	100	0.01	310	0.058				
			1910'	0.008				
Channel 1	100	0.003	170	0.094				
			1450	0.011				
Channel 2	100	0.01	310	0.058				
			1910'	0.008				

[1] Slope is a weighted average for two flow path segments.

Manning's coefficients for sheet (input as TR-55 Surface Code) and open channel flow are listed in the following tables.

TR-55 Surface Code

Condition	Surface description	Manning's Coefficient[1]	TR-55 Surface Code[2]
Pre-development	Range (natural)	0.13	E
Post-development	Range (natural)	0.13	E

[1]Obtained from USDA (1986a), See Table 4.
[2]Obtained from USDA (1986b), TR-55 computer program

Manning's coefficients for open channel flow

Condition	Channel type	Channel Description	Manning Coefficient, n
Pre-development	Flood plain, pasture and no brush	High grass	0.035[1]
Post-development	Flood plain, pasture and no brush	High grass	0.035[1]
Drainage channels	Channel, straight and uniform[1]	grass	0.033[2]

[1]See Table 5 (Chow, 1959); [2]See Table 6 (Chow, 1959)

Written by: DGP Date: 20 FEB 96 Reviewed by: DBW Date: 23FEB96

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

Step 2: Size permanent stormwater structures:

2.1 Input parameters for design of Culvert1 are as follows

- Culvert type: Corrugated metal pipe;
- Culvert Slope: S = 0.8 %;
- Culvert Manning's Coefficient: n = 0.023; (USDA, 1986)
- End Type: headwall at inlet end; and
- Permissible Velocity: V_a = 5 ft/sec (GeoSyntec, 1996).

2.2 Input parameters for design of Channel1 and Channel2 are as follows;

- Cross-sectional shape: ~~Trapezoidal~~ V-DITCH
- Channel lining: Grass
- Manning's Roughness Coefficient, n 0.033
- Bottom width: W_B ~~= 3 ft~~ 0 ft
- Slope of Channel bed: S=0.011.
- Sideslope: z = 3; slope = 3H:1V
- Permissible Velocity: V_a = 5 ft/sec (GeoSyntec, 1996).

2.3 Input parameters for Channel 3

- Cross-sectional shape: Trapezoidal
- Channel lining: Grass
- Manning's Roughness Coefficient, n 0.033
- Bottom width: W_B = 5 ft
- Slope of Channel bed: S=0.005.
- Sideslope: z = 3; slope = 3H:1V
- Permissible Velocity: V_a = 5 ft/sec (GeoSyntec, 1996)
- Depth: 6 to 17 ft..

RAINFALL DEPTHS FOR 2 AND 25-YR 24-HR STORM EVENTS

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	2-YR 24-H
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	25-YR 24-H
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			

PARSONS, 1985

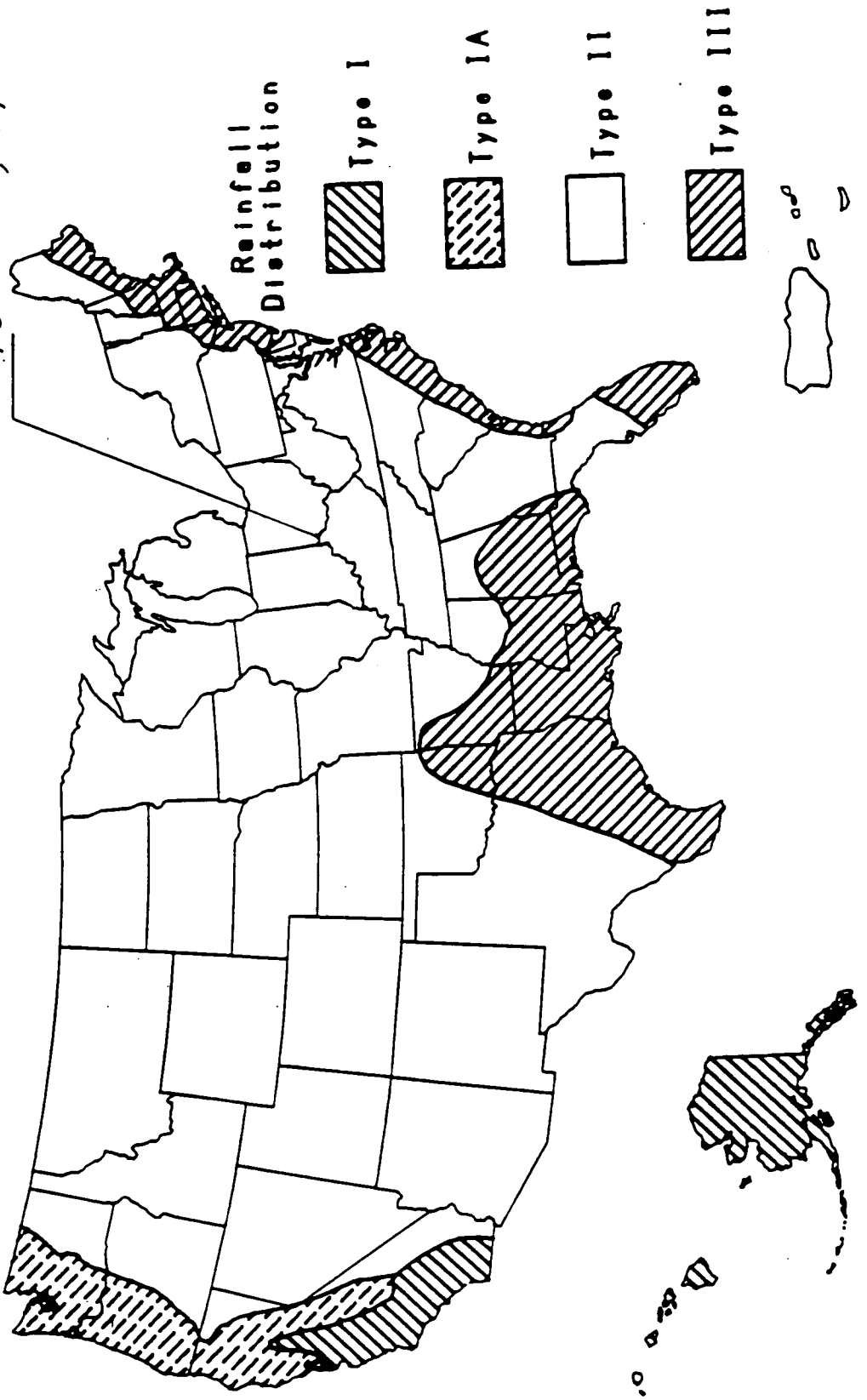
TABLE 1

000308

Written by: DGP Date: 96 / 2 / 20 (YY MM DD) Reviewed by: DBW Date: 96 / 02 / 23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

SCS 24-Hour RAINFALL DISTRIBUTION TYPE FEMP SITE, TYDE II



(210-VI-TR-55, Second Ed., June 1986)

USDA, 1986b FIGURE 1

740 KOM FEB96 9/22

Written By: DGP Date: 20 FEB 96 Reviewed by: DBW Date: 23 FEB 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

DRAINAGE AREA FOR CULVERT 1 AND CHANNEL 3

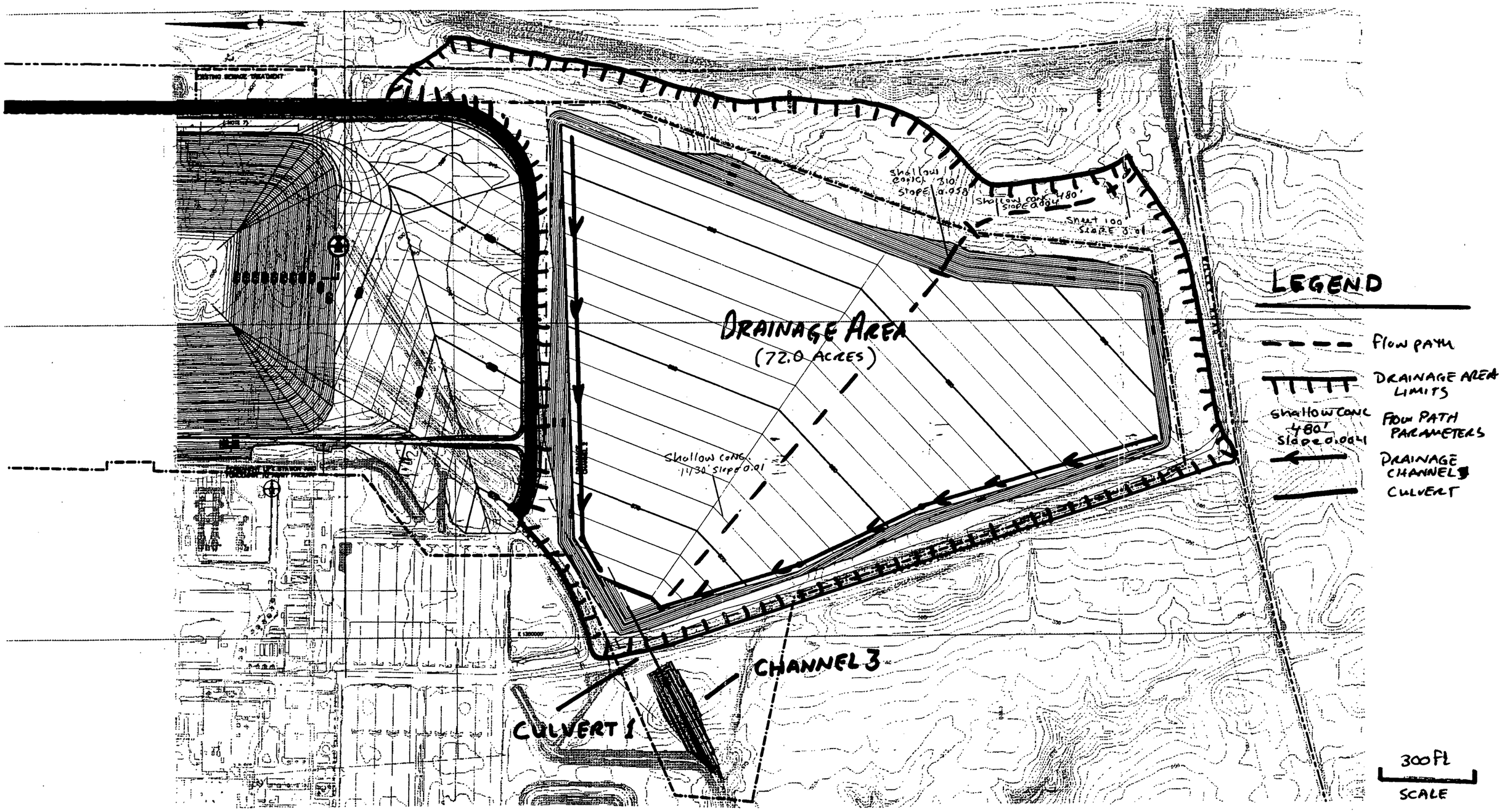


FIGURE 2

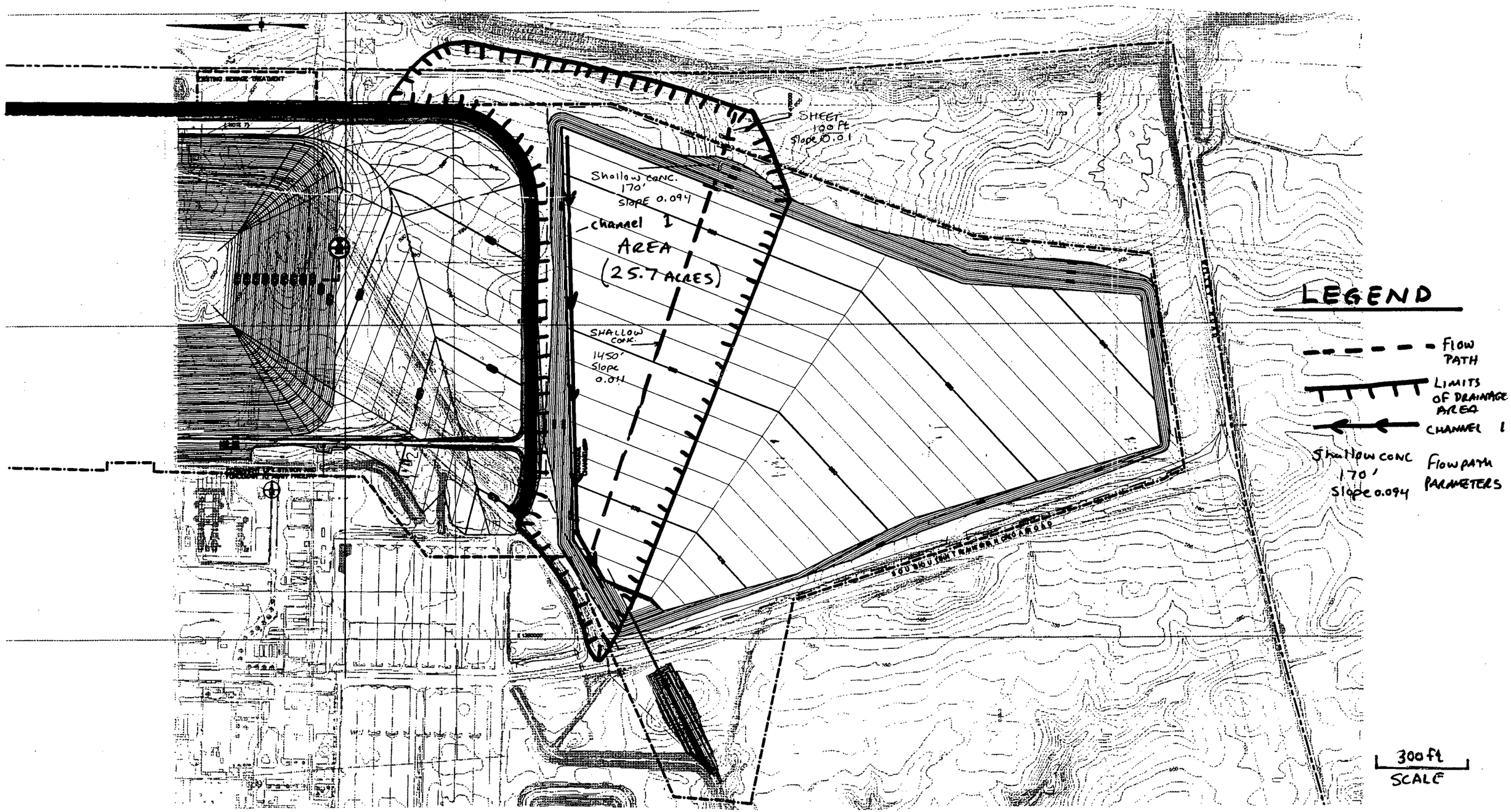
FROM DESIGN DRAWING TITLED "BORROW AREA RESTORATION PLAN"

740 KO 24 FEB 96
10/22

Written By: DGP Date: 20FEB96 Reviewed by: DBW Date: 23FEB96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

DRAINAGE AREA FOR CHANNEL 1



FROM DESIGN DRAWING TITLED "BORROW AREA RESTORATION PLAN"

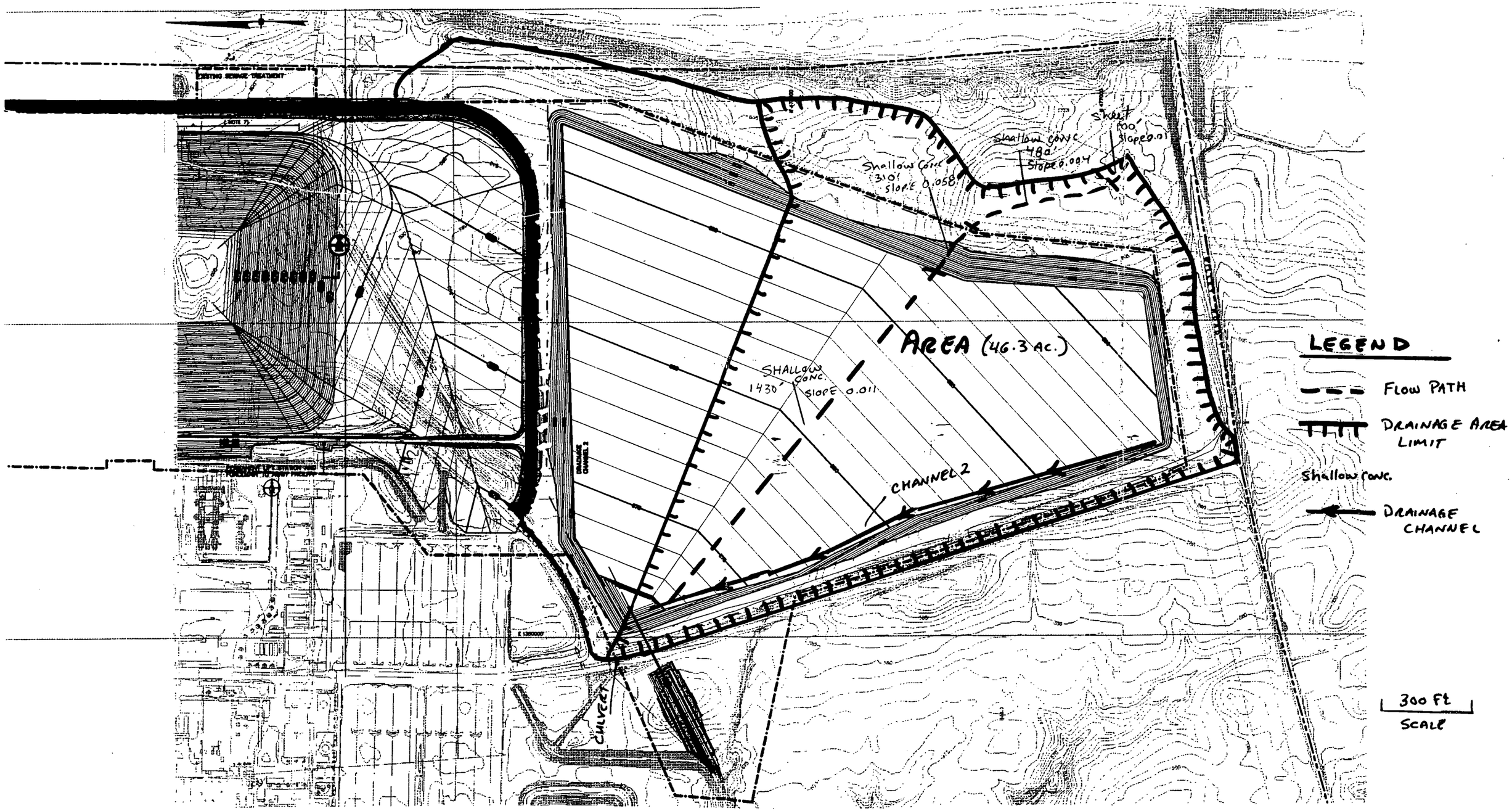
FIGURE 3

GEOSYNTEC CONSULTANTS Page 11 of 22

Written By: DGP Date: 20 FEB 96 Reviewed by: DBW Date: 23 FEB 96

Client: FERMCO Project: GSDF Project/Proposal No.: GE3900 Task No.: 8.11

WATERSHED FOR CHANNEL 2



000312 FIGURE 4

FROM DESIGN DRAWING TITLED "BORROW AREA RESTORATION PLAN"

Written by: DGP Date: 96 / 2 / 20 (YY MM DD) Reviewed by: DBW Date: 96 / 02 / 23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

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	FORNDALE	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	FATINA	B	FIELDING	B	FLOER	D	FORT MEADE	A
FAIN	C	FATTIG	C	FIELDON	B/D	FLOKE	D	FORT MOTT	A
FAIN, MOIST	B	FAUNCE	A	FIFER	D	FLON	B/D	FORT ROCK	C
FAIRBANKS	B	FAUNSDALE	D	FIFIELD	C	FLONATON	A	FORTANK	C
FAIRBURN	D	FAUQUIER	C	FILION	D	FLONOT	B	FORTESCUE	C/D
FAIRCHILD	C	FAUSSE	D	FILIRAN	D	FLOODWOOD	B	FORTUNA	D
FAIRDALE	B	FAVRET	C	FILLMORE	D	FLORAMONE	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, DEPRESSIONAL	D	FOSSILON	D
FAIRMOUNT	D	FAYWOOD	C	FINGEROCK	D			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	FIPADA	C	FLOYD	B	FOURNE	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, DEPRESSIONAL	D	FIRESTEEL	B	FLUKER	C	FOXCREEK	D
FALFURRIAS	A			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	E	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	D	FOLDAHL	B	FRANCIS	A
FALONA	D	FELTON	B	FISHLAKE	D	FOLEY	D	FRANCISCAN	C
FALSEM	A	FELTONIA	B	FISHPOT	C	FOLLET	D	FRANCISQUITO	C
FALULA	D	FENCE	B	FISHROCK	D	FONSENG	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	E	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	FORBAP	D	FRAVAL, GRAVELLY	B
FAPS	C	FERGUS	B	FIVES	B	FORBES	C	FRAZER	C
FARAWAY	D	FERN CLIFF	B	FIVESPRINGS	C	FORRESVILLE	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 RAINFALL	C	FERNOW	B	FLAMING	A	FORDUN	D	FREE	B/D
		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
FARNSWORTH	D	FERRIS	D	FLANLY	B	FORESMAN	B	FREEDOM, SALINE	B
FARNTON	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

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.

USDA, 1986

TABLE 2a

Written by: DGP Date: 96/2/20 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

continued: Hydrologic soil groups for United States soils

MCDERMOTT	A	MECKLENBURG	C	MEPDEN	D	MIKIM, WET	C	MINNEOSA	B
MCDOLE	B	MECOSTA	A	MEPECITH	B	SUBSTRATUM		MINNEQUA	C
MCDONALD	C	MEDA	B	MEPETA	C	MIKKALO	C	MINNETONKA	D
MCDONALDSVILLE	C/D	MEDAND	D	MERGEL	B	MILACA	C	MINNETONKA, SILTY	C/D
MCDUFF	C	MEDARY	C	MERIDIAN	B	MILAN	B	SUBSTRATUM	
MCELMO	C	MEDBURN	A	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	F	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	MEERS	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	C
MCGUFFEY	D	MEISS	C	MESABA	C	MILLHEIM	C	MIPPON	C
MCGUIRE	B	MEKINOCK	D	MESCAL	C	MILLHI	D	MIRABAL	C
MCHENRY	B	MELAKWA	C	MESCALERO	C	MILLHOPPER	A	MIRACLE	C
MCILWAINE	B	MELAND	C	MESEI	C	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	C	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	MISSISSOUDI	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	MITIVANGA	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	MINAR	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	MOAND	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	C	MINESINGER	C	MOCA	D
MEADOWBROOK	B/D	MENTO	C	MIERMILL	C	MINETA	C	MOCARRY	D
MEADOWCREEK	C	MENTOR	B	MIERUF	B	MINGO	C	MOCHO	B
MEADOWLAKE	C	MENZEL	B	MIESEN	C	MINGUS	D	MOCKLEP	B
MEADOWVILLE	B	MEOUON	C	MIFFLIN	B	MINIDOKA	C	MOCMONT	B
MEANS	C	MER ROUGE	B	MIGEON	B	MINKLER	D	MOCTILEME	C
MEARES	D	MERCED	D	MIGUEL	D	MINLITH	D	MODA	D
MECAN	B	MERCEDES	D	MIKE	D	MINNEMA	C	MODALE	C
MECHANICSBURG	C	MERCER	C	MIKESELL	C	MINNEISKA	B	MODENA	B
MECKESVILLE	C	MERCEY	C	MIKIM	B	MINNEOPA	B	MODESTO	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.

USDA, 1986

TABLE 26

Written by: DCD Date: 96/2/26 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.11

continued: Hydrologic soil groups for United States soils

POGUONOCK	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	PREWITT	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	PRIDMAN	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	PRIN	D	PURNER	D	RABER	C	RANDS	C
PORTIA	C	PRINEAUX	C	PUROB	D	RABIDEUX	B	RANDSBURG	D
PORTINO	C	PRINER	D	PURSLEY	B	RABUN	B	RANGEE	D
PORTLAND	D	PRINGMAR	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	RANSON	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 SUBSTRATUM	C	RAPATEE	D
POSEN	B	PROCHASKA	A/D	PUU OO	A			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	PROMO	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
POTANUS	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 SUBSTRATUM	C	RAGNEL	B	RASSET	B
POTOMAC	A	PROVIG	C			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	RAHN	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 SUBSTRATUM	B
POWELL	C	PUETT	D	QUEALY	D	RAIRDENT	B		
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
POWMENT	C	PUGSLEY	C	QUEMADO	C	RAKIED	C	RAVENNA	C
POWWAMKEE	B	PUHI	B	QUENZER	D	RALEIGH	D	RAVENSWOOD	C
POWWATKA	C	PUMIMAU	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	RAVAM	C
POYNOR	B	PULANTAT	C	QUICKSELL	C	RALPHSTON	B	RAVE	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	C	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 SUBSTRATUM	C	RAYNE	B
PREATORSON	B	PUMEL, NONGRAVELLY	C	QUILT	D			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.

USDA, 1986

TABLE 2C

Written by: DGP Date: 96 / 2 / 20 (YY MM DD) Reviewed by: DBN Date: 96 / 02 / 23 (YY MM DD)

Client: FEEMCO Project: OSOF Project/Proposal No.: GE3900 Task No.: 8.11

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	C	XERXES	D	YENRAB	A
WINDER	B/D	WITHEE	C	WOOFUS	D	XICA	C	YEOMAN	B
WINDER, DEPRESSIONAL	D	WITHERBEE	A/D	WOOLPER	C	XINE	C	YEOPIN	B
		WITHERELL	D	WOOLSEY	B	XIPE	D	YERINGTON	A
WINDMAN	B	WITHERS	C	WOOLSTALF	B	XIPE, MODERATELY WET	C	YERMO	B
WINDICREEK	A	WITT	B	WOOLSTED	B			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	YAMANA	C	YIPOR	B
WINDWHISTLE, WARM	B	WIXOM	B	WORDEN	C	YAMARA	C	YLIG	C
WINDY	B	WOCKLEY	C	WORF	D	YAMHE	C	YOBE	C
WINDYPOINT	B	WODA	D	WORFKA	D	YAMOLA	B	YOCHUM	C
WINEG	B	WODEN	B	WORFMAN	D	YAMOO	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	WOMLY	B	WORK, GRAVELLY	B	YAKIMA	B	YOMURT	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	WRTMAN	D	YAMO	B	YONGES	D
WINKEL	D	WOLFEY	C	WRTMAN, SANDY	A	YAMSAY	D	YONNA	D
WINKLEMAN	C	WOLFPEN	A	WOYOKA	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	WRAYMA	D	YANKTON	B	YORKTREE	C
WINLO	D	WOLOT	B	WREDAM	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 SUBSTRATUM	D
WINNESHIEK	B	WOOD RIVER	D	WRIGHTSBORO	C	YARCO	D		
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	YAUMANNAH	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, DRAINED	C	WYARD	B	YEARY	C	YUKO	D
WINTERS	C			WYARNO	B	YEATES HOLLOW	B	YUKON	D
WINTERSBURG	C	WOODLAWN	B	WYATT	C	YEATES HOLLOW, LOAMY SUBSTRATUM, STONY	C	YULEE	D
WINTERSET	C	WOODLEAF	C	WYCOLO	C			YUNES	D
WINTHROP	A	WOODLY	B	WYE	B			YUNQUE	C
WINTLEY	B	WOODLYN	D	WYEAST	D	YEATES HOLLOW, LOAMY SUBSTRATUM	C	YURM	D
WINTON	C	WOODMANSIE	B	WYETH	B			YUTRUE	D
WINTONER	B	WOODMERE	B	WYEVILLE	C	YEATES HOLLOW, STONY	C	YUVAS	D
WINU	C	WOODMONT	C	WYICK	D			ZAAR	D
WINZ	D	WOODPASS	B	WYKEHAM	B	YEATES HOLLOW, NONSTONY	C	ZABA	B
WIOTA	B	WOODROCK	C	WYKOFF	B			ZACA	D
WIPPLE	C	WOODROW	B	WYMAN	B	YEATES HOLLOW, DRY	C	ZACHARIAS	B
WIRT	B	WOODROW, SALINE-ALKALI	C	WYMORE	D	YEATES HOLLOW, COBBLY	C	ZACHARY	C
WISCON	D			WYNOMERE	B			ZACK	D
WISE	C	WOODROW, OCCASIONALLY FLOODED	C	WYNN	B	YEATON	C	ZADOG	A/D
WISEMAN	A			WYNNVILLE	C	YECROSS	A	ZADVAR	D
WISPLAT	D			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.

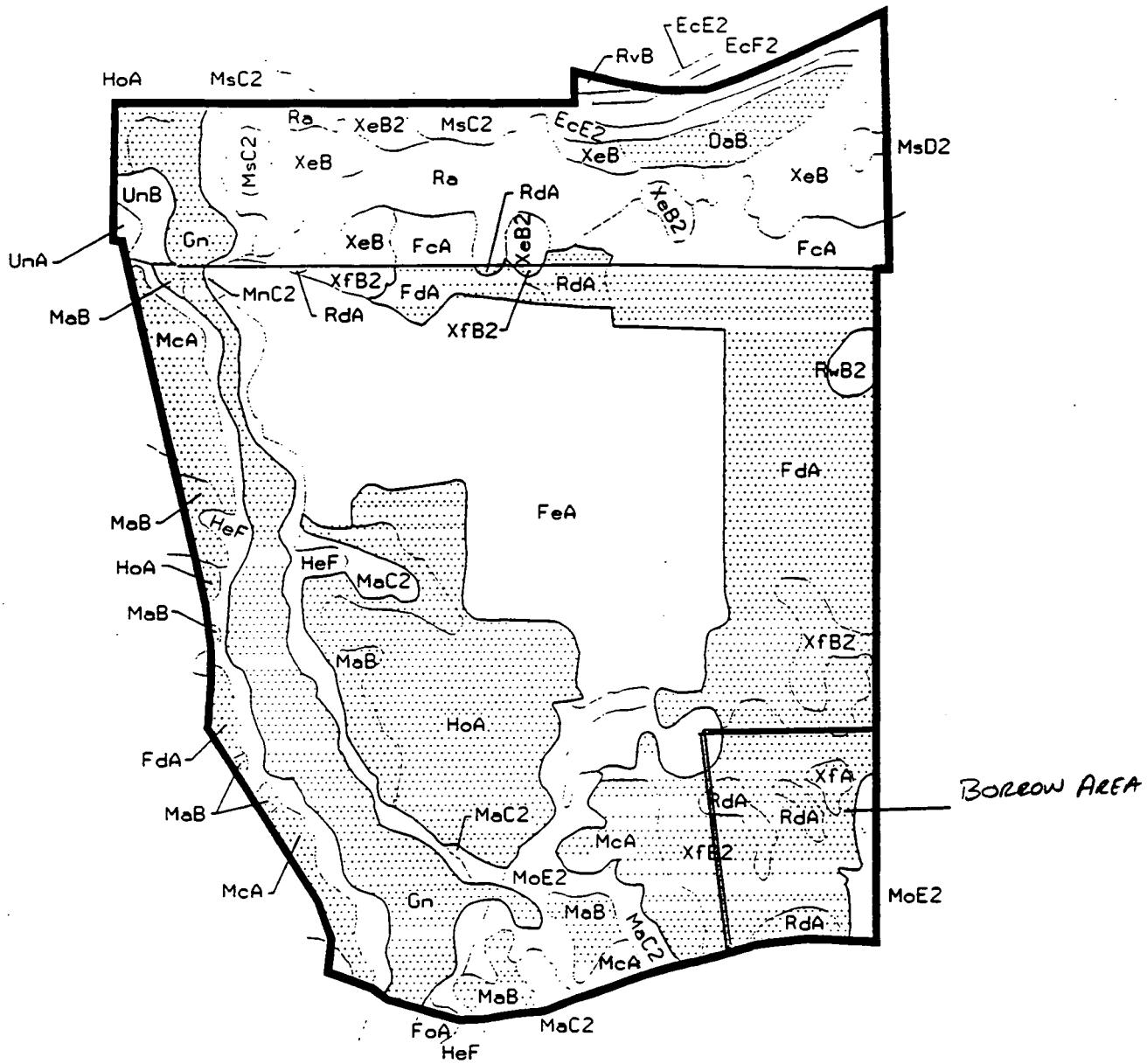
USDA, 1986b

TABLE 2d

Written by: DGP Date: 96/2/20 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

SURFICIAL SOILS IN THE BORROW AREA



LEGEND:

PRIME AGRICULTURAL LAND

FEMP BOUNDARY

NOTE:

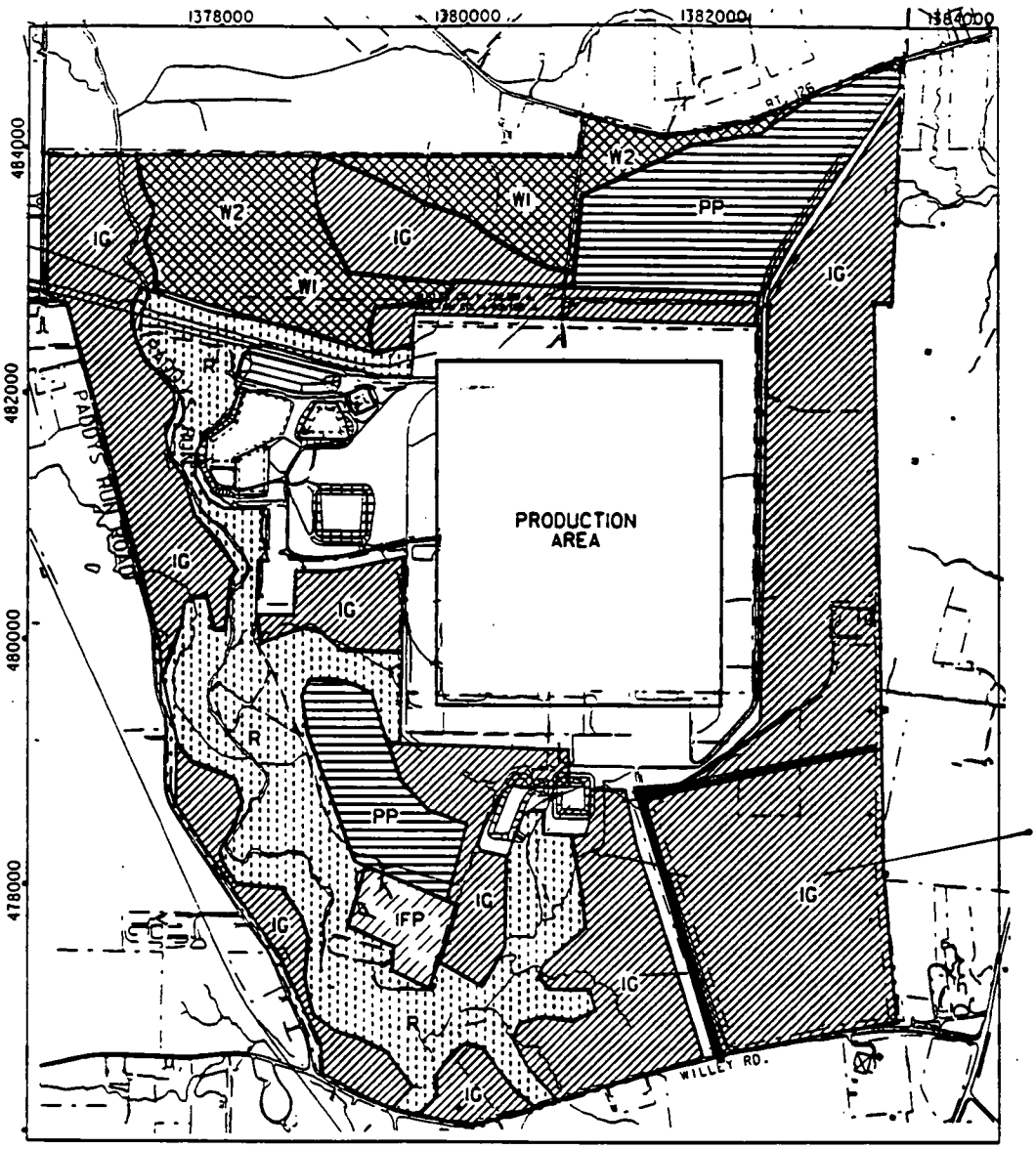
SOURCE: USDA 1980, 1982

DOE, 1995

FIGURE 5

Written by: DGP Date: 96/2/20 (YY MM DD) Reviewed by: DRW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11



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.

GROUND COVER FOR BORROW AREA

DOE, 1995

FIGURE 6

Written by: DGP Date: 96/2/20 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

COVER TYPE AND HYDROLOGIC CONDITION

Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
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.

USDA, 1986

TABLE 3

Written by: DGP Date: 96/2/20 (YY/MM/DD) Reviewed by: DBW Date: 96/02/23 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

MANNING'S COEFFICIENT 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.

(210-VI-TR-55, Second Ed., June 1986)

USDA, 1986b

TABLE 4

Written by: DCP Date: 96 / 2 / 20 (YY MM DD) Reviewed by: DBN Date: 96 / 02 / 23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

MANNING'S COEFFICIENT FOR CHANNEL FLOW
EXISTING DRAINAGE SWALES

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

CHOW, 1959

TABLE 5

Written by: DGP Date: 96/2/20 (YY MM DD) Reviewed by: DBW Date: 96/02/23 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

MANNING'S COEFFICIENT FOR OPEN CHANNEL FLOW FOR PERMANENT DRAINAGE CHANNELS.

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

CHOW, 1959

TABLE 6

References:

1. Chow, Ven Te (Chow), "*Open-Channel Hydraulics*", New York, NY, 1959.

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3. Parsons. "*Geotechnical Investigation Report, On-Site Disposal Facility*", Operable Unit 2, Project Order 140, Fernald Environmental Management Project, Rev. 0, Cincinnati, OH, 1995..

4. United States Department of Agriculture, Soil Conservation Service (USDA), "*Engineering Field Manual for Conservation Practices*", USDA, Washington, DC, November, 1986.

5. United States Department of Agriculture, Soil Conservation Service (USDA), "*Soil Survey of Butler County, Ohio*", USDA, Washington, DC, January 1980.

6. United States Department of Agriculture, Soil Conservation Service (USDA), "*Soil Service of Hamilton County, Ohio*", USDA, Washington, DC, August 1992.

7. United States Department of Agriculture, Soil Conservation Service, Engineering Division (USDA), "*TR-55 Microcomputer Program System*", USDA, Washington, DC, 1986a.

8. United States Department of Agriculture, Soil Conservation Service, Engineering Division (USDA), "*Urban Hydrology for Small Watersheds*" USDA Technical release 55, Washington, DC, 1986b.

9. United States Department of Energy (DOE), "*Remedial Investigation Report for Operable Unit 5*", Vol. 1 of 5, Revision Draft Final, DOE, March 1995.

Written by: DGP Date: 96/2/23 (YY MM DD) Reviewed by: DJW Date: 96/02/24 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

CALCULATIONS:

STEP 1: ESTIMATE PEAK FLOW RATES, q_p FOR THE FOLLOWING:

1) PRE-DEVELOPMENT CONDITIONS;
2) POST-DEVELOPMENT CONDITIONS;
3) DESIGN OF CULVERT 1;
4) DESIGN OF CHANNEL 1; AND
5) DESIGN OF CHANNEL 2.
6) DESIGN OF CHANNEL 3.

TR-55 INPUT PARAMETERS FOR EACH OF THE ABOVE ARE PRESENTED IN THE DATA VERIFICATION SECTION. VALUES OF q_p CALCULATED USING TR55 ARE PRESENTED IN THE FOLLOWING TABLE.

VALUES OF q_p FROM TR-55, FOR 25-YR, 24-HR STORM EVENT.

CONDITION OR STRUCTURE	q_p (CFS)	
PRE-DEVELOPMENT	106	✓
POST-DEVELOPMENT	96	✓
CULVERT 1/CHANNEL 3	96	✓
CHANNEL 1	35	✓
CHANNEL 2	62	✓

THE ABOVE RESULTS DEMONSTRATE THAT THE POST-DEVELOPMENT DISCHARGE (q_p) FROM THE BORROW PIT IS LESS THAN THE PRE-DEVELOPMENT DISCHARGE (q_p). THE DESIGN CRITERIA REQUIREMENT TO THAT EFFECT IS THUS SATISFIED.

PERMANENT STORMWATER STRUCTURES (i.e., CULVERT 1, CHANNELS 1, 2 AND 3) ARE SIZED USING VALUES OF q_p FROM THE ABOVE TABLE. (SEE STEP 2)

Written by: DGP Date: 96/2/23 (YY MM DD) Reviewed by: DBW Date: 96/02/24 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

CALCULATIONS, CONT'D:

STEP 2: DESIGN THE FOLLOWING PERMANENT STORMWATER STRUCTURES TO CONVEY PEAK INFLOW RATES, q_P PRESENTED IN STEP 1.

- CULVERT 1: LOCATED AT THE NORTH END OF THE SOUTH ACCESS RD AND USED TO DISCHARGE RUNOFF FROM THE BORROW AREA.
- CHANNEL 1: LOCATED ALONG THE NORTH PERIMETER EDGE OF THE BORROW AREA AND USED TO CONVEY RUNOFF TO CULVERT 1.
- CHANNEL 2: LOCATED ALONG THE WEST PERIMETER EDGE OF THE BORROW AREA AND USED TO CONVEY RUNOFF TO CULVERT 2.
- CHANNEL 3: DOWNGRADIENT OF CULVERT 1 TO PADDY'S RUN

2.1) DESIGN OF CULVERT 1: A CORRUGATED METAL PIPE (CMP) IS USED. THE DESIGN INFLOW RATE, q_P FOR CULVERT 1 IS 96 CFS.

2.1.1) SELECT A CULVERT DIAMETER, D: AS FOLLOWS;

1. CALCULATE THE ALLOWABLE HEADWATER DEPTH, HW_a

   THE HEIGHT OF THE ROAD EMBANKMENT ABOVE THE CULVERT INVERT IS APPROXIMATELY 15 ft AS SHOWN IN FIGURE 3 OF THE CALCULATION PROCEDURES.

   GIVEN A REQUIRED FREEBOARD OF 0.5 ft; $HW_a \approx 14.5$ ft.

2. SELECT A TRIAL CULVERT DIAMETER OF 48 IN.

3. FROM THE DESIGN CHART SHOWN IN FIGURE 1 WITH THE FOLLOWING PARAMETER VALUES SELECT A VALUE FOR HW/D

   - D = 48 IN
   - Q (i.e. q_P) = 96 CFS
   - HEAD WALL ENTRANCE TYPE

   FROM FIGURE 1 $HW/D = 1.28$ ✓

Written by: DGP Date: 96/2/23 (YY MM DD) Reviewed by: DBW Date: 96/02/24 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3500 Task No.: 8.11

CALCULATIONS, CONT'D:

STEP 2, CONTINUED: DESIGN OF PERMANENT STORMWATER STRUCTURES

2.1 CONT'D) DESIGN OF CULVERT 1

2.1.1 CON'D) SELECTION OF CULVERT DIAMETER, D

4. CALCULATE THE HEADWATER DEPTH, HW FOR THE TRIAL CULVERT.

$$HW = 1.28 \times D = 1.28 \times 48\,in. = 61.4\,in = \underline{5.1\,ft}$$ ✓

5. THE CALCULATED VALUE OF HW IS LESS THAN THE ALLOWABLE HEADWATER DEPTH OF 14.5 ft. ✓ THEREFORE THE TRIAL CULVERT DIAMETER IS SUFFICIENT TO CONVEY THE DESIGN FLOW RATE.

2.1.2) EVALUATE WHETHER OR NOT OUTLET PROTECTION WILL BE REQUIRED. OUTLET PROTECTION WILL BE REQUIRED IF THE CULVERT OUTLET VELOCITY, V EXCEEDS AN ALLOWABLE OUTLET VELOCITY OF 5 ft/sec (GEOSYNTEC, 1996)

1. CALCULATE THE FLOW RATE, Q_f FOR THE CULVERT FLOWING FULL. USE MANNING'S EQUATION WITH THE FOLLOWING PARAMETER VALUES:

THE AREA OF FLOW, a $\quad a = \frac{\pi D^2}{4}$

$$a = \frac{3.14 \times (4ft)^2}{4}$$

$$= 12.6\,ft^2$$ ✓

THE HYDRAULIC RADIUS, r $\quad r = a/w_p \quad w_p = 3.14 \times 4ft = 12.6\,ft$

$$= 12.6\,ft^2 / 12.6\,ft$$

$$= 1$$ ✓

THE CULVERT SLOPE, S = 0.8% = 0.008

MANNINGS COEFFICIENT FOR RCP = 0.023.

Written by: DGP Date: 96/2/23 (YY MM DD) Reviewed by: DBN Date: 96/02/24 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3960 Task No.: 8.11

STEP 2 CONT'D: DESIGN PERMANENT STORMWATER STRUCTURES

2.1 CONT'D) DESIGN CULVERT 1

2.1.2 CONT'D) EVALUATE WHETHER OR NOT OUTLET PROTECTION IS REQUIRED.

1. USING THE ABOVE PARAMETER VALUES CALCULATE Q_f

$$Q_f = \frac{12.6\ ft^2\ 1.49\ (1)^{2/3}(0.008)^{1/2}}{0.023}$$

$$= 73\ cfs$$

2. CALCULATE Q/Q_f

$$Q/Q_f = 96/73 = 1.32$$

3. CALCULATE OUTLET VELOCITY, V AS FOLLOWS;

$$V = Q/a = 96/12.6\ ft^2$$

$$= 7.6\ ft/sec \checkmark$$

THE OUTLET VELOCITY FOR CULVERT 1 (7.6 ft/sec) EXCEEDS THE ALLOWABLE VELOCITY FOR THE RECIEVING AREA (5 ft/sec). THUS, OUTLET PROTECTION IS REQUIRED.

2.1.3) SIZE A RIPRAP APRON TO PROVIDE OUTLET PROTECTION FOR CULVERT 1.

USING THE DESIGN CHART SHOWN IN FIGURE 3 AND THE FOLLOWING PARAMETER VALUES SELECT A MINIMUM LENGTH OF APRON, L_a AND A d_{50} RIPRAP SIZE.

DISCHARGE = 96 CFS
CULVERT DIAMETER = 48 IN.

Written by: DGP Date: 96/2/23 (YY/MM/DD) Reviewed by: DBW Date: 96/02/29 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

STEP 2, CONT'D: DESIGN PERMANENT STORMWATER STRUCTURES

2.1, CONT'D) DESIGN CULVERT 1

2.1.3, CONT'D) SIZE RIPRAP APRON

FROM FIGURE 3

THE MINIMUM LENGTH OF APRON, L_a = 20 ft ✓

THE d_{50} RIP RAP SIZE, = 0.6 ft ✓

SELECT ODOT SPEC. TYPE D RIPRAP

2.2) DESIGN OF PERMANENT DRAINAGE CHANNELS; CHANNELS 1, 2 AND 3:

2.2.1) CALCULATE THE REQUIRED DEPTHS, d FOR CHANNELS 1, 2 AND 3 USING THE FOLLOWING PARAMETER VALUES AND EQUATIONS;

- CROSS-SECTIONAL SHAPE: V-DITCH
- SIDE SLOPE, Z: Z_1 = 3H:1V; Z_2 = 6H:1V
- MANNINGS ROUGHNESS COEFFICIENT, n: 0.033
- BOTTOM WIDTH, W_B: 0 ft
- PEAK INFLOW RATE, q
  - CHANNEL 1: 35 CFS
  - CHANNEL 2: 62 CFS
- SLOPE OF CHANNEL BED, S: 0.011

$$q = a\frac{1.486}{n}R^{2/3}S^{1/2}$$

$$a = \tfrac{1}{2}(Z_1+Z_2)\,d^2$$

$$W_p = d\left(\sqrt{Z_1^2+1}+\sqrt{Z_2^2+1}\right)$$

CHANNEL 3 (TRAPEZOIDAL)

CHANNEL 3: 96 CFS

BOTTOM WIDTH: 5 ft

SLOPE, S: 0.005

$$q = a\frac{1.486}{n}R^{2/3}S^{1/2}$$

$$a = \frac{(W_B + dZ)}{2}\,d$$

$$W_p = W_B + 2\left(d^2+(Zd)^2\right)^{1/2}$$

THE REQUIRED DEPTHS ARE AS FOLLOWS; (INCLUDING A 6 IN. FREEBOARD)

CHANNEL	d, IN		W_B	Z_1	Z_2	
CHANNEL 1	1.4 ft	✓	0	6	3	✓
CHANNEL 2	1.8 ft	✓	0	6	3	✓
CHANNEL 3	2.2 ft	✓	5 ft	3	3	

Written by: DGP Date: 96/2/23 (YY MM DD) Reviewed by: DBW Date: 96/02/24 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

STEP 2, CONT'D: DESIGN PERMANENT DRAINAGE STRUCTURES

2.2, CONT'D: DESIGN OF PERMANENT DRAINAGE CHANNELS

2.2.2: EVALUATE DRAINAGE CHANNELS FOR EROSION RESISTANCE

DETERMINE FLOW VELOCITIES, V_s FOR EACH CHANNEL USING THE FOLLOWING EQUATION.

$$V_s = q_p / a$$

AND THE FOLLOWING PARAMETER VALUES

q_p (CFS)

CHANNEL 1: 35 CFS
CHANNEL 2: 62 CFS
CHANNEL 3: 96 CFS

a (ft^2) FOR THE ABOVE FLOW RATES

CHANNEL 1: 9.33 ft^2
CHANNEL 2: 14.58 ft^2
CHANNEL 3: ~~15.97 ft^2~~ 24.8 ft^2

CALCULATED VALUES OF V_s ARE AS FOLLOWS:

CHANNEL 1: 3.75 ft/sec ✓

CHANNEL 2: 4.33 ft/sec ✓

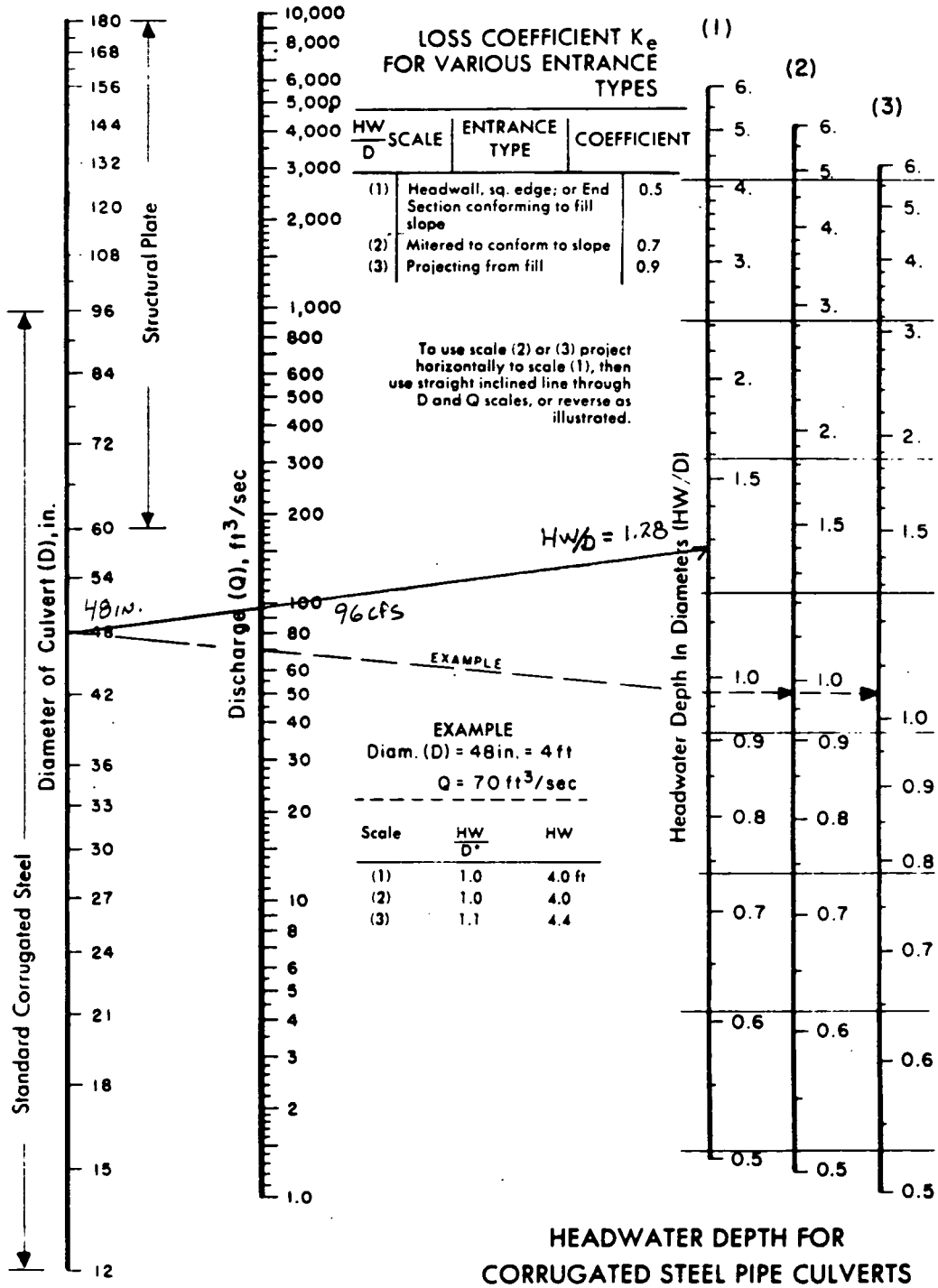
CHANNEL 3: ~~6.03 ft/sec~~ ✓ 3.86 ft/sec

FLOW VELOCITIES FOR CHANNELS 1, 2 AND 3 DO NOT EXCEED THE MAXIMUM PERMISSIBLE VELOCITY FOR GRASS LINED CHANNELS OF 5 ft/sec. THUS, NO EROSION PROTECTION FEATURES ARE REQUIRED.

Written by: DGP Date: 96/2/23 (YY MM DD) Reviewed by: DBW Date: 96/02/24 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

SELECTION OF CULVERT DIAMETER



HEADWATER DEPTH FOR CORRUGATED STEEL PIPE CULVERTS WITH INLET CONTROL

FHWA HEC 5

Figure 4-28 *Inlet control* nomograph for corrugated steel *pipe* culverts. The manufacturers recommended keeping *HWID* to a maximum of 1.5 and preferably to no more than 1.0.

FIGURE 4

Written by: DGP Date: 96/12/23 (YY MM DD) Reviewed by: DBWN Date: 96/12/24 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

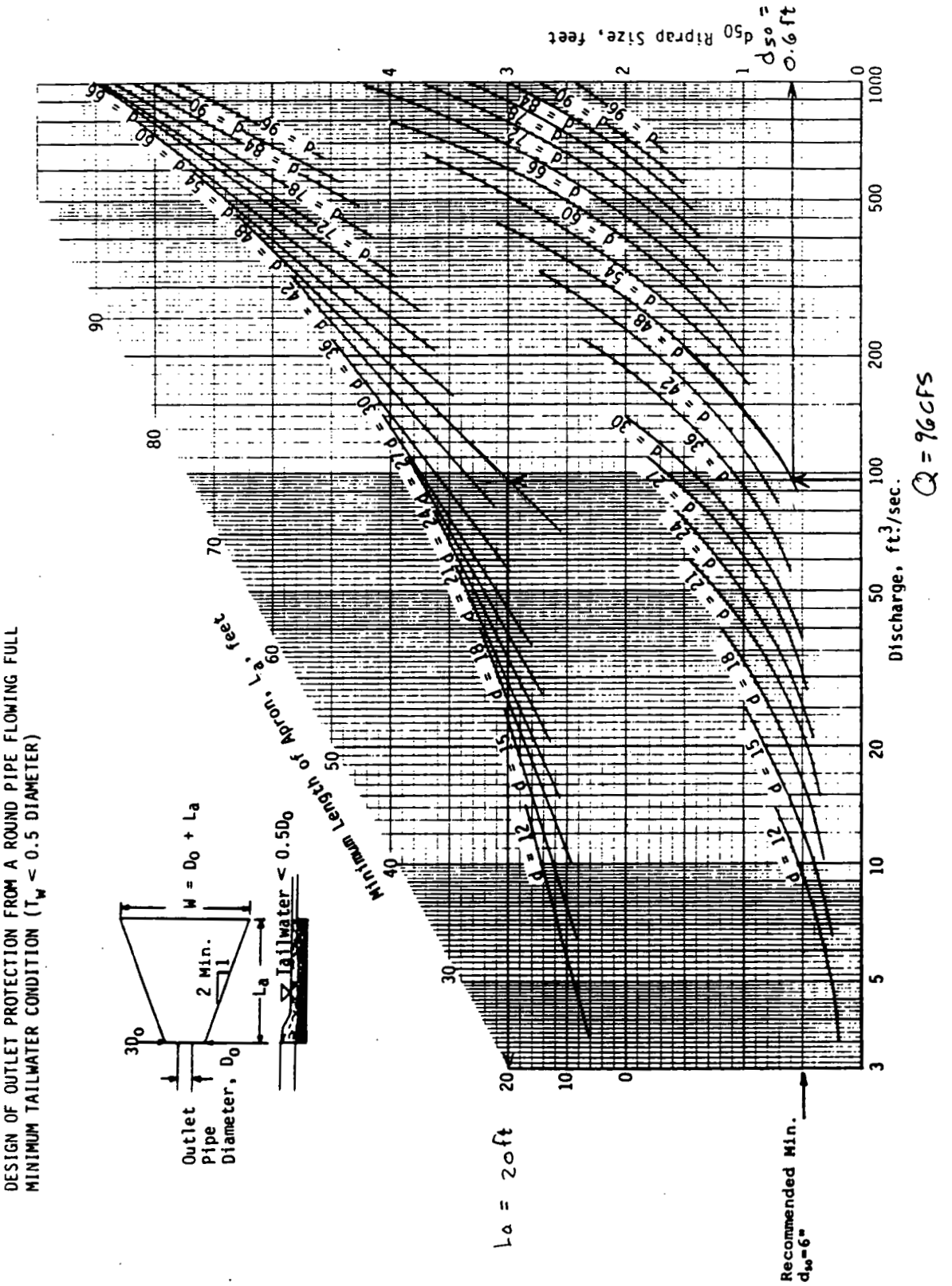


FIGURE 6

TABULAR HYDROGRAPH METHOD Version 2.00

Project : Fermco OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DSW Date: 96-02-24
Subtitle: East Field Borrow Area: Pre-Developement Conditions

Total watershed area: 0.103 sq mi Rainfall type: II Frequency: 25 years

Subareas

	I	II	III
Area(sq mi)	0.02*	0.07*	0.01*
Rainfall(in)	4.7	4.7	4.7
Curve number	74*	74*	74*
Runoff(in)	2.13	2.13	2.13
Tc (hrs)	0.31*	0.44*	0.21*
(Used)	0.30	0.40	0.20
TimeToOutlet	0.00	0.00	0.00
Ia/P	0.15	0.15	0.15
(Used)	0.15	0.15	0.15

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) I	II	III
11.0	3	1	2	0
11.3	4	1	3	0
11.6	5	1	4	0
11.9	13	3	8	2
12.0	27	7	16	4
12.1	55	14	32	9
12.2	91	22P	59	10P
12.3	106P	22	78P	6
12.4	96	16	77	3
12.5	71	10	59	2
12.6	51	7	42	2
12.7	37	5	31	1
12.8	28	4	23	1
13.0	19	3	15	1
13.2	15	2	12	1
13.4	12	2	9	1
13.6	11	2	8	1
13.8	10	2	7	1
14.0	10	2	7	1
14.3	7	1	6	0
14.6	6	1	5	0
15.0	6	1	5	0
15.5	5	1	4	0
16.0	5	1	4	0
16.5	4	1	3	0
17.0	4	1	3	0
17.5	4	1	3	0
18.0	4	1	3	0
19.0	4	1	3	0
[illegible]0	3	1	2	0
[illegible].0	2	0	2	0
26.0	0	0	0	0

THE PEAK DISCHARGE RATE FOR THE BORROW AREA FOR PRE-DEVELOPMENT CONDITIONS = 106 cfs

P - Peak Flow * - value(s) provided from TR-55 system routines

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

Project : Fermco OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBN Date: 2/13/96
Subtitle: East Field Borrow Area: Pre-Developement Conditions
Subarea : I

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

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

Project : Fermco OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Pre-Developement Conditions
Subarea : 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

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

Project : Fermco OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Pre-Developement Conditions
Subarea : III

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: III TOTAL DRAINAGE AREA: 3.86 Acres WEIGHTED CURVE NUMBER: 74

740

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : Fermco OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Pre-Developement 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 - III

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	0.025	u					0.035
Open Channel		450	.0122		.035	52.3	55.1		0.028

Time of Concentration = 0.21*
=====

--- 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

TABULAR HYDROGRAPH METHOD Version 2.00

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Post-Development Condition

Total watershed area: 0.112 sq mi Rainfall type: II Frequency: 25 years

---------- Subareas ----------

	I
Area(sq mi)	0.11*
Rainfall(in)	4.7
Curve number	74*
Runoff(in)	2.13
Tc (hrs)	0.63*
(Used)	0.75
TimeToOutlet	0.00
Ia/P	0.15

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) I
11.0	2	2
11.3	3	3
11.6	4	4
11.9	6	6
12.0	8	8
12.1	13	13
12.2	22	22
12.3	40	40
12.4	63	63
12.5	84	84
12.6	96P	96P
12.7	95	95
12.8	86	86
13.0	60	60
13.2	42	42
13.4	30	30
13.6	23	23
13.8	19	19
14.0	16	16
14.3	13	13
14.6	11	11
15.0	9	9
15.5	8	8
16.0	7	7
16.5	6	6
17.0	6	6
17.5	6	6
18.0	5	5
19.0	5	5
20.0	4	4
22.0	3	3
26.0	0	0

THE PEAK DISCHARGE RATE FROM THE BORROW AREA FOR POST-DEVELOPMENT CONDITIONS = 96 CFS

P Peak Flow * - value(s) provided from TR-55 system routines

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Post-Development Condition
Subarea : I

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	72(74)	-
Total Area (by Hydrologic Soil Group)				72	

SUBAREA: I TOTAL DRAINAGE AREA: 72 Acres WEIGHTED CURVE NUMBER: 74

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Post-Development Condition

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	0.01	e					0.241
Shallow Concent'd		310	0.058	u					0.022
Shallow Concent'd		1910	0.008	u					0.368

Time of Concentration = 0.63*
=====

--- 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

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DRW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Culvert at Outlet

Total watershed area: 0.112 sq mi Rainfall type: II Frequency: 25 years

---------- Subareas ----------

	I
Area(sq mi)	0.11*
Rainfall(in)	4.7
Curve number	74*
Runoff(in)	2.13
Tc (hrs)	0.63*
(Used)	0.75
TimeToOutlet	0.00
Ia/P	0.15

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) I
11.0	2	2
11.3	3	3
11.6	4	4
11.9	6	6
12.0	8	8
12.1	13	13
12.2	22	22
12.3	40	40
12.4	63	63
12.5	84	84
12.6	96P	96P
12.7	95	95
12.8	86	86
13.0	60	60
13.2	42	42
13.4	30	30
13.6	23	23
13.8	19	19
14.0	16	16
14.3	13	13
14.6	11	11
15.0	9	9
15.5	8	8
16.0	7	7
16.5	6	6
17.0	6	6
17.5	6	6
18.0	5	5
19.0	5	5
20.0	4	4
22.0	3	3
26.0	0	0

PEAK INFLOW RATE TO CULVERT 1 = 96 CFS

P Peak Flow * - value(s) provided from TR-55 system routines

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Culvert at Outlet
Subarea : I

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	72(74)	-
Total Area (by Hydrologic Soil Group)				72	

SUBAREA: I TOTAL DRAINAGE AREA: 72 Acres WEIGHTED CURVE NUMBER: 74

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 21 FEB 96
Subtitle: East Field Borrow Area: Culvert at Outlet

---------- 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	0.01	e					0.241
Shallow Concent'd		310	0.058	u					0.022
Shallow Concent'd		1910	0.008	u					0.368

Time of Concentration = 0.63*
=====

--- 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

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 29 FEB 96
Subtitle: East Field Borrow Area: Permanent Drainage Channel #1

Total watershed area: 0.040 sq mi Rainfall type: II Frequency: 25 years

---------- Subareas ----------

	Chan1
Area(sq mi)	0.04*
Rainfall(in)	4.7
Curve number	74*
Runoff(in)	2.16
Tc (hrs)	0.64*
(Used)	0.75
TimeToOutlet	0.00
Ia/P	0.15

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) Chan1
11.0	1	1
11.3	1	1
11.6	2	2
11.9	2	2
12.0	3	3
12.1	5	5
12.2	8	8
12.3	15	15
[illegible]	23	23
[illegible]	31	31
12.6	35P	35P
12.7	34	34
12.8	31	31
13.0	22	22
13.2	15	15
13.4	11	11
13.6	8	8
13.8	7	7
14.0	6	6
14.3	5	5
14.6	4	4
15.0	3	3
15.5	3	3
16.0	3	3
16.5	2	2
17.0	2	2
17.5	2	2
18.0	2	2
19.0	2	2
20.0	1	1
22.0	1	1
[illegible]	0	0

PEAK INFLOW RATE TO DRAINAGE CHANNEL #1 = 35 CFS

P Peak Flow * - value(s) provided from TR-55 system routines

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Permanent Drainage Channel #1
Subarea : Chan1

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	25.7(74)	-
Total Area (by Hydrologic Soil Group)				25.7	

SUBAREA: Chan1 TOTAL DRAINAGE AREA: 25.7 Acres WEIGHTED CURVE NUMBER: 74

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Permanent Drainage Channel #1

---------- Subarea #1 - Chan1 ----------

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	.003	e					0.391
Shallow Concent'd		170	.094	u					0.010
Shallow Concent'd		1450	0.011	u					0.238

Time of Concentration = 0.64*
=====

--- 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

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Permanent Channel #2

Total watershed area: 0.072 sq mi Rainfall type: II Frequency: 25 years

---------- Subareas ----------

	I
Area(sq mi)	0.07*
Rainfall(in)	4.7
Curve number	74*
Runoff(in)	2.16
Tc (hrs)	0.63*
(Used)	0.75
TimeToOutlet	0.00
Ia/P	0.15

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) I
11.0	2	2
11.3	2	2
11.6	3	3
11.9	4	4
12.0	5	5
12.1	8	8
12.2	15	15
12.3	26	26
12.4	41	41
12.5	55	55
12.6	62P	62P
12.7	62	62
12.8	56	56
13.0	39	39
13.2	27	27
13.4	20	20
13.6	15	15
13.8	12	12
14.0	10	10
14.3	8	8
14.6	7	7
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
20.0	3	3
22.0	2	2
26.0	0	0

THE PEAK INFLOW RATE TO CHANNEL #2 = 62 CFS

P Peak Flow * - value(s) provided from TR-55 system routines

740

RUNOFF CURVE NUMBER COMPUTATION

Version 2.00

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: OBW Date: 24 FEB 96
Subtitle: East Field Borrow Area: Permanent Channel #2
Subarea : I

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
			Acres (CN)		
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	good	-	-	46.3(74)	-
Total Area (by Hydrologic Soil Group)				46.3	

SUBAREA: I TOTAL DRAINAGE AREA: 46.3 Acres WEIGHTED CURVE NUMBER: 74

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : FERMCO OSDF Pr#GE3900 Tsk#8.1 User: DGP Date: 02-17-96
County : Hamilton State: OH Checked: DBW Date: 2A FEB 96
Subtitle: East Field Borrow Area: Permanent Channel #2

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	0.01	e					0.241
Shallow Concent'd		310	0.058	u					0.022
Shallow Concent'd		1910	0.008	u					0.368

Time of Concentration = 0.63*
=====

--- 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

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.

For documentation of computer programs see

1.2 Computer Program Validation

15.5 Borrow Area Sediment Basin

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: BORROW AREA SEDIMENT BASIN

Computations By: (Cognizant Engineer)
Signature: Patrick Rhodes — Date: 3 APRIL 1996
Printed Name and Title: PATRICK RHODES, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: Daniel G. Pass — Date: 3 APRIL 96
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Computations Checked by:
Signature: Daniel G. Pass — Date: 3 APRIL 96
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Patrick B. Rhodes — Date: 3 APRIL 1996
Printed Name and Title: PATRICK RHODES, STAFF ENGINEER

Approved by: (PDP)
Signature: Kara Olen — Date: 5 April 1996
Printed Name and Title: Kara L. Olen, Asst Proj Engr.

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 5 Apr 96
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
D	Intermediate Design - EPA Submitted				
G	Final Design Package	4 Oct 96			
O	Response to Final Design Comb	5 May 97			

GE3900-8.2/28/F9630107

BORROW AREA SEDIMENT BASIN

EXECUTIVE SUMMARY

The borrow area sediment basin (Sediment Basin No. 4) for the On-Site Disposal Facility Project was designed as a Class III Temporary Sediment Basin according to *"Water Management and Sediment Control for Urbanizing Areas"* (USDA-SCS, 1987). Sediment Basin No. 4 is located in the north west corner of the East Field Borrow Area (borrow area). Sediment Basin No. 4 will be used to catch sediment laden-stormwater run-off during all stages of borrow activities. The basin is designed to impound 27,000 ft^3 of sediment and pass the 25-year, 24-hour design storm. The principal spillway outlet for the sediment basin will utilize a 36 in. CMP segment at the spillway riser connected to a 48 in. CMP which will run under the South Entrance Road and discharge to Drainage Channel 3 and ultimately to Paddys Run. When the borrow area activities are completed and the sediment basin is decommissioned, the riser and 38 in. CMP will be removed ~~on~~ and the 48 in. diameter pipe will then be used as the permanent culvert for this area. This design is cost effective since the pipe will serve two functions and will have to be constructed only once.

The computer program "HydroCAD™ Stormwater Modeling System" [Applied Microcomputer Systems, 1993] (HydroCAD™), was used to calculate the design storm runoff, storm volume, and storm routing. HydroCAD™ uses the hydrologic modeling methods presented in Technical Release 20 (TR-20) [USDA-SCS, 1975] and TR-55 [USDA-SCS, 1986a]. HydroCAD™ has the ability to completely model a storm through several hydrologic features. A description of HydroCAD™ is located in Appendix A.

BORROW AREA SEDIMENT BASIN

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CALCULATION PROCEDURES

The design of Sediment Basin #4 started by modeling the hydrologic conditions within HydroCAD™. The model was set up as a drainage area (subcatchment) flowing into a basin. The drainage area is defined by the existing and proposed topographical features that divert stormwater to the basin. The stormwater run-off conditions in the drainage area were then described by runoff curve numbers that corresponded to the hydrologic soil groups, and the surficial conditions. The Contractor will be limited to only 10 acres of disturbed soil area at one time. The disturbed area in the drainage area will be assumed as 15 acres to allow for this 10 acres plus an extra 5 acres that may not have vegetation fully established (from the previous disturbed soil area). A weighted average runoff curve number (CN), based on the acreage of each soil type, was calculated for the drainage area using the following equation:

$$CN = \sum (CN_A \bullet Area_A) \ / \ Total\ Area$$

CN_A	=	Runoff curve number that corresponds to the hydrologic soil group and surficial condition for a subarea
$Area_A$	=	Area of the subarea
Total Area	=	Sum of all subareas (total area of drainage area)

The next step in HydroCAD™ is to calculate the time of concentration (T_c). T_c is defined as the time required for runoff to travel from the most hydrologically distant point of the watershed (drainage area) to the point of collection (basin). This longest flow path is divided up into flow segments. The T_c is calculated by summing the travel time (T_t) for each consecutive flow segment along the drainage area's flow path. The T_t calculations start by identifying the flow types along the flow path. The following equations were used to calculate travel times for the different flow types in the Basin #4 drainage area:

TR-55 Sheet Flow

$$T_t = \frac{.007(nL)^{0.8}}{P_2^{0.5} s^{0.4}}$$

[Applied Microcomputer Systems, HydroCAD™ Manual 1993]

T_t	=	Travel time (hours)
n	=	Manning's coefficient for sheet flow
L	=	Flow length (feet)
P_2	=	2-year, 24-hour rainfall (inches)

s = Land slope (ft/ft)

TR-55 Shallow Concentrated Flow/Upland Method

$$T_t = \frac{L}{3600V} \quad where\ V = K_v\sqrt{s}$$

[Applied Microcomputer Systems, HydroCAD™ Manual, 1993]

T_t = Travel time (hours)
L = Flow length (feet)
V = Average velocity (fps)
K_v = Velocity factor
s = Land slope (ft/ft)

Channel Flow

$$T_t = \frac{L}{3600V} \quad where\ V = \frac{1.486 r^{2/3} s^{1/2}}{n} \quad and\ r = \frac{a}{P_w}$$

[Applied Microcomputer Systems, HydroCAD™ Manual, 1993]

T_t = Travel time (hours)
L = Flow length (feet)
V = Average velocity (fps)
s = Channel slope (ft/ft)
n = Manning's coefficient for sheet flow
r = Hydraulic radius (feet)
a = Cross sectional flow area (sq - feet)
P_w = Wetted perimeter (feet)

HydroCAD™ will prompt the user to input the following variables in order to calculate the T_c.

Sheet Flow

- Surface type; which yields a Manning's coefficient for sheet flow
- Flow length (ft)
- 2-year, 24-hour rainfall (in.)
- Land slope (ft/ft)

Shallow Concentrated Flow/Upland Method

- Flow length (ft)
- Surface type (paved or unpaved)
- Average land slope (ft/ft)

Open Channel Flow

- Manning's coefficient for open channel flow
- Channel length (ft)
- Channel slope (ft/ft)
- Channel and flow geometry

The travel times (T_t) for each of the flow segments are calculated and summed to yield the T_c for the drainage area's flow path.

HydroCAD™ uses the USDA-SCS TR-20 procedure to calculate the storm runoff. USDA-SCS TR-20 method is a unit hydrograph method that utilizes the following inputs: curve number, storm rainfall, storm type, and the unit hydrograph (which is supplied by the HydroCAD™ program).

The storm runoff is generated by performing a convolution of the unit hydrograph. The storm is divided into a series of rainfall bursts of duration $D = 2/15\ T_c$. The runoff volume during any duration (D) at time t can be calculated by:

$$dQ = Q_{t+D} - Q_t$$

For each burst, the unit hydrograph defines how this volume of runoff (dQ) will occur overtime. The runoff from the entire storm is calculated by summing the hydrographs resulting from each rainfall burst. The runoff ~~from the~~ flows into the basin and is routed down stream.

The next step in the basin design is the sediment storage. The sediment storage calculation is based on the amount of disturbed area within the drainage area. The basin is then positioned and sized to hold this volume below the principal spillway crest. According to Ohio USDA-SCS, the minimum design volume of sediment storage required is 1,800 cubic feet per acre of disturbed area. The following equation, which is based on the volume of a truncated pyramid, was used to calculate the cumulative volume under the principal spillway (actual sediment volume).

$$V = \Sigma \left[\frac{1}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right) \times (E_1 - E_2) \right]$$

V = Cumulative volume under the principal spillway (ft^3)
A_1 = Upper elevation area of each interval (ft)
A_2 = Lower elevation area of each interval (ft)
E_1 = Upper elevation (ft)
E_2 = Lower elevation (ft)

This volume must be greater than the design sediment volume.

The basin hydraulic calculations begin with routing the design storm through the basin without utilizing the actual sediment storage (volume under principal spillway crest). The principal spillway is designed to pass a minimum of the 2-year, 24-hour storm with a pipe diameter equal to or greater than 8 in. The principal spillway will be composed of 3 main components: a riser structure, a low flow structure, and an outlet pipe. The riser is an open-ended CMP circular pipe with a trash rack anti-vortex top. The low flow structure is a capped 8 in. diameter CMP circular perforated pipe which is parallel to the riser and is connected with a 90 degree elbow. The riser and low flow structure both flow into a circular CMP outlet pipe which discharges to the flow down stream.

The principal spillway flow is calculated by summing the actual flows of each structure at a given elevation or head. For each structure different flow types must be calculated because the limiting flow must be used as the actual flow.

The low flow structure was modeled as a series of vertical circular orifices (perforations) and as a pipe. The lower of the two was selected as the low flow discharge through the low flow structure. The following equations were used:

- Vertical Circular Orifice

$$Q = Ca\sqrt{2gh}$$

[Brater and King, 1976]

Q = Flow (cfs)
C = Discharge coefficient
a = Submerged area (sq-feet)
g = Gravitation constant
h = Head above center at orifice (feet) given by:

h = H-r (if fully submerged)
h = H/2 (if partially submerged)
H = Head above invert (feet)
r = Radius

- Pipe Flow

$$Q = a\sqrt{\frac{2gh}{1 + K_m + K_p L}}$$

[USDA-SCS, Eng. Field Manual, Nov. 1986b]

a = Pipe area
g = Gravitational constant
H = Elevation head difference (ft)
K_m = Coefficient of minor loses
L = Pipe length (ft)
K_p = Pipe friction coefficient

$$K_p = \frac{5087\ n^2}{d_i^{4/3}}$$

[USCS, Eng. Field Manual, Nov. 1986b]

n = Manning's number
d_i = Inside diameter of the pipe

The riser structure is modeled as a sharp crested weir. Since the riser is circular, there are no end contractions and the crest length is equal to the pipe circumference. The equation for flow over a sharp crested weir is:

- Sharp Crested Weir

$$Q = C\,L_e\,H^{3/2} \qquad where\ C = 3.27 + .4\,\frac{H}{P}$$

(Brater and King, 1976)

C = Weir coefficient
L_e = Effective crest length ($2\pi r$)(feet)
H = Head (above invert elevation)(feet)
P = Crest height (feet above approach channel)

The outlet pipe was modeled as a vertical circular orifice and as a pipe.

- Vertical circular orifice
  (see low flow structure, previous page)

- Pipe Flow

$$Q = a\sqrt{\frac{2gh}{1 + K_m + K_t + K_p L}}$$

[USDA-SCS, Eng. Field Manual, Nov. 1986b]

a = Pipe area
g = Gravitational constant
H = Elevation head difference (ft)
K_m = Coefficient of minor loses
L = Pipe length (ft)
K_p = Pipe friction coefficient
K_t = Coefficient transition loss (36" pipe to 48" pipe)

$$K_p = \frac{5087\,n^2}{d_i^{4/3}}$$

[USCS, Eng. Field Manual, Nov. 1986b]

n = Manning's number
d_i = Inside diameter of the pipe

The flows at each head increment were summed for the structure to yield a total outflow for the principal spillway. This outflow will be compared to the inflow from the drainage area and a stage-storage relationship will be calculated in HydroCAD™. The maximum storage elevation of the stage-storage relationship is the elevation of the basin corresponding to the required stormwater storage volume and needed to route the design storm.

Flood routing through the basin utilizing just the principal and no emergency spillway will be used in the design of Basin #4. The borrow area within itself is a basin and would retain the stormwater in the area with no emergency spillway required.

Basin #4 is located in an all cut area so no berm (around the basin) will be constructed. One foot of free board was added to the 25-year storm water elevation.

The principal spillway riser structure base was designed with a minimum factor of safety of 1.1 to protect against flotation. Because concrete will be used as the base material, the following formula was used to calculate the minimum amount of concrete needed. The volume of concrete needed to protect against flotation is:

$$V = 0.62\ HD^2 - \frac{HW_R}{87.6}$$ [USDA-SCS, March 1987]

V = Volume of concrete
H = Riser height (ft)
D = Diameter of riser (ft)
W_R = Riser weight (lb/ft)

The outlet pipe extends 13 ft out into the pond so that the 36 in. to 48 in. diameter CMP extender could be constructed, and so that when the pond is made permanent, ~~a headwall~~ outlet protection can be constructed easily. The above equation will be used to protect against flotation of the pipe extending out of the cut slope.

Anti-seep collars are required for all outlet pipes that are located within a berm where the distance between the top of the outlet pipe to the crest of the berm is 5 ft or greater. Anti-seep collars are installed along the outlet pipe to protect the embankment from seepage forces. The anti-seep collars should increase the flow length along a pipe by a minimum of 15 percent and will be installed approximately 25 ft apart. Four foot projection collars will be used for this design. The following equation was used to solve for the number of collars.

$$N = .075 \frac{L}{V}$$ [USDA-SCS, March 1987]

V = Collar radius (ft)
L = Length of pipe (ft)
N = Numbered of collars

The outlet pipe will discharge approximately the lowest elevation at the downstream toe of the berm. Riprap rock placed on a geotextile filter will be used for the outlet protection. The outlet protection apron will be dimensioned and the riprap sized according to Figure 5 in the calculations with:

$$W = D_o + L_a$$ [USDA-SCS, March 1987]

W = Downstream width of protection
D_o = Pipe diameter
L_a = Length of protection apron along the channel

If the basin outlets into an existing channel, then the riprap shall extend up the side of the channel to the maximum ~~tailwater~~ tailwater elevation.

The pipe structural stability must be checked in order to specify the type and thickness of CMP. The pipe structural stability calculations follow those provided in "The Handbook of Steel Drainage and Highway Construction Products" [AISI, 1983]. The procedures for the structural design are:

1) Make needed assumptions concerning pipe backfill.

2) Calculate design pressures.

$$P_v = DL + LL$$

P_v = Design pressure (psf)
DL = Dead load pressure (psf)
LL = Live load pressure (psf)

3) Calculate ring compression on pipewall.

$$C = P_v + \frac{S}{2}$$

C = Ring compression (lb/ft)
P_v = Design pressure (lb/ft$_2$)
S = Span (ft) = Pipe diameter (ft)

4) Calculate allowable wall stress.

$$f_a = \frac{33{,}000}{2K} \; for \; D/r < 294$$

f_a = Allowable wall stress (lb/in^2)
D = Pipe diameter (in.)
r = Radius of gyration (in.)
K = Load factor based on backfill density

5) Calculate wall thickness.

$$A = \frac{C}{f_a}$$

A = Required wall area (in^2/ft)
C = Ring compression (lb/ft)
f_a = Allowable wall stress (lb/in^2)

Find a CMP section with a wall thickness that has an area that is greater than or equal to the required wall thickness.

6) Check handling stiffness.

$$FF = \frac{D^2}{EI}$$

FF = Flexibility factor
D = Pipe diameter (in.)
E = Modulus of elasticity (lb/in^2)
I = Moment of inertia ($in^4/in.$)

In steps 5 and 6, check to insure all pipe assumptions were correct based on these calculations.

DATA VERIFICATION

Drainage Area

The drainage area for Basin #4 is shown in Figure 1. It will be assumed that during borrow activities, the contractor may expose up to 10 ares 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 acres of the previous 10 acres of exposed soil have established vegetation for a conservative total of 15 acres of exposed bare soil. The total area is 72.0 acres, 15 of which are disturbed and 57 are undisturbed. Also shown on Figure 1 is the maximum drainage path within the subarea. The drainage path flow segments are defined as:

Flow Type	Length (ft)	Slope (ft/ft)
Sheet Flow, fallow (n = .05)	100	.01
Shallow Concentrated, Unpaved (Kv = 16.1345)	480	.004
Shallow Concentrated, Unpaved (Kv = 16.1345)	310	.058
Shallow Concentrated, Unpaved (Kv = 16.1345)	1,430	.01

Runoff Curve Number

The soil types within the drainage area are defined on Figure 2, which is a composite soil map of Hamilton and Butler counties [USDA-SCS, Aug. 1952, USDA-SCS, Jan. 1980]. The hydrologic soil groups (HSG) are based on the soil type and can be found in TR-55, Exhibit A-1 [USDA-SCS, 1986a] and the runoff curve numbers are from Table 2-2 of TR-55.

Symbol	Name	Total Area	HSG
FdA	Fincastle Silt Loam	9.0	C
XFA	Xenia Silt Loam	3.5	B
XFB2	Xenia Silt Loam	52.0	B
RdA	Raub Loam	7.5	C
		72.0	

Condition	Cover Type	HSG	Runoff Curve Number
Disturbed	Fallow, Bare Soil	B	86
Disturbed	Fallow, Bare Soil	C	91
Undisturbed	Pasture, Poor	B	79
Undisturbed	Pasture, Poor	C	86

Pasture at poor condition was used to describe the undisturbed areas since the actual use of these areas will be variable during the borrow area activities. This assumption is considered to be conservative.

Rainfall Depths for Designs Storms

The following design storm events are needed in the design of Sediment Basin #4. The rainfall depths were taken from Table 1 [Parsons, 1995].

2 Year - 24 Hour = 2.552 in.
25 Year - 24 Hour = 4.7 in.

The rainfall distribution for all design storms in this area is a Type II distribution (see Figure 3).

Basin Sediment Volume

The design sediment volume is to be stored between the elevations of 567 ft and 571 ft. The surface areas for the actual storage are as follows:

Elevation (ft)	Area (sf)
567	782
568	3,344
569	7,524
570	13,308
571	20,793

The areas were provided by AutoCAD, and were checked with a planimeter using the design drawing titled "Borrow Area Grading Plan."

Principal Spillway

The principal spillway is designed with a CMP riser connected to a CMP outlet pipe. A trash rack anti-vortex device will be placed at the top of the riser. The low flow structure is an 8 in. perforated CMP pipe that is connected to the riser. The following coefficients were used in the design equations.

Low Flow Structure

- Vertical Orifice

  $C = 0.6$ [Applied Microcomputer Systems, HydroCAD™ Manual]

- Pipe Flow

  $n = 0.023$ [USDA-SCS Eng. Field Manual, Nov. 1986]
  $K_m = 1$ [USDA-SCS Eng. Field Manual, Nov. 1986]
  $K_p = 0.168$ [USDA-SCS Eng. Field Manual, Nov. 1986]
  $L = 8$ ft

Riser Structure

- Sharp Crested Weir

  $C = 3.27 + 4\ H/R$ [Applied Microcomputer Systems, HydroCAD™ Manual]

Outlet Pipe

- Vertical Orifice

  $C = 0.6$ [Applied Microcomputer Systems, HydroCAD™ Manual]

- Pipe Flow

n	=	0.023	[USDA-SCS Eng. Field Manual, Nov. 1986]
K_m	=	1	[USDA-SCS Eng. Field Manual, Nov. 1986]
K_p	=	0.0226	[USDA-SCS Eng. Field Manual, Nov. 1986]
K_t	=	0.4	[Modern Sewer Design, 1980, American Iron and Steel Inst. (AISI)]
L	=	13 ft	

Pipe Structural Analysis

Soil unit weight = 120 lb/ft^3
Height of fill (from x-section on drawings) = 11 ft

Assume 85% standard density (this assumption is considered to be conservative)

Pipe diameter	=	4 ft	
K	=	0.86	[AISI, 1983]
E	=	30×10^6 lb/in^2	[AISI, 1983]
I	=	0.0227 in^4/ft (> 0.00189 in^4/in.)	

The recommended maximum value of FF for factory-made pipe is 0.0433 (AISI, 1983).

Riser Base

W_r	=	24 lb/ft (1/2 + published W_r, this assumption is considered to be conservative)	[AISI, 1983]
$H_{(riser)}$	=	4 ft	
$H_{(outlet)}$	=	Length of outlet 13 ft	

CALCULATIONS

Curve Number

The actual or weighted curve number (CN) is a weighted average based on the amount of area that each hydrologic soil group (HSG) occupies. Since the location of the disturbed ~~are~~ area will be variable during the borrow are activities, two different weighted curve numbers will be developed. One for the runoff from disturbed area and one for runoff from undisturbed area.

$$CN = \Sigma\ (CN_A \bullet Area_A)\ /\ Total\ Area$$

Disturbed

$$CN = [(91 \times 16.5ac) + (86 \times 55.5ca)\ /\ 72.0ac$$
$$CN = 87$$

Undisturbed

$$CN = [(86 \times 16.5ac) + (79 \times 55.5ac)\ /\ 72.0ac$$
$$CN = 81$$

Storm Runoff

The output from the HydroCAD™ models simulations are located in Appendix B. The results are summarized in the following table.

Storm	Peak Runoff (cfs)	Storm Volume (AC ft)
2-year - 24-hour	64.70	5.82
25-year - 24-hour	174.2	15.56

Design Sediment Volume

V = 1800 cf/Acre of Disturbed Soil × Area of Disturbed Soil (in acres)

V = 1800 cf/ac × 15.0 ac = 27,000 cf

Actual Sediment Volume

$$V = \Sigma \left[\frac{1}{3}(A_1 + A_2 + \sqrt{A_1 A_2}) \times (E_1 - E_2) \right]$$

Elevation (ft)	Area (sf)	Volume (cf)	Cumulative Volume (cf)
567	782	--	--
568	3,344	1,914	1,914
569	7,524	5,295	7,209
570	13,308	10,279	17,488
571	20,793	16,912	34,400

E_1-E_2 = 1 ft for each interval

Sediment Cleanout

Sediment shall be cleaned out of the basin when the available sediment capacity has been reduced to 60 percent of the design sediment volume.

Cleanout volume = 27,000 cf × 0.6 = 16,200 cf

This corresponds to an approximate volume cleanout elevation of (see table above) 569.4 ft

Principal Spillway

VSDA-SCS (1986)
PBR 3 OCT 1996

The design is based on a 36 in. diameter outlet circular CMP connected to an expander connected to a 48 in. diameter circular CMP. According to ~~Ohio SCS~~ guidelines, the cross sectional area of the riser should be at least 1.3 times the cross sectional area of the outlet pipe.

$$A_{riser} > 1.3\ A_{outlet}$$

$$\pi(2\ ft)^2 > 1.3\ \pi(1.5\ ft^2)$$

$$12.57\ ft^2 > 9.19\ ft^2$$

A 48 in. riser will work with a 36 in. outlet.

The riser will have an 8 in. diameter perforated CMP pipe for a low flow structure. The following calculations will present the methodology used in each column of Table 2. Table 2 was prepared using the spreadsheet program Microsoft Excel 5.0. Elevations used in the following calculations were obtained from the design drawing titled "Temporary Sediment Basin 4."

Low Flow Discharge Rate

8 in. diameter perforated CMP - 1-1/2 in. diameter perforations on each side (vertical spacing is 8 in.). The flow is summed over the perforations as the level water rises.

- Orifice Flow (Vertical Circular)

  Head = elevation of bottom of rise - elevation of perforation series

  The following equation is used to calculate the flow into one set of 2 perforations.

$$Q = Ca\sqrt{2gh}$$

C = .6
a = cross-sectional area of 2 perforations. $2\pi r^2 = 2\pi(1.5\ in.\ x\ 0.5\ x\ 1\ ft/12\ in.)^2 = 0.0123\ ft^2$
h = Head (H)

g = Gravitational constant (32.2 ft/s^2)

- Pipe Capacity

$$Q = a\sqrt{\frac{2gh}{1 + K_m + K_p L}}$$

a = Pipe area = πr^2 = π(8 in. x 0.5 x 1 ft/12 in.)^2 = 0.349 ft^2
g = Gravitational constant (32.2 ft/s^2)
h = Head (ft)
K_m = Coefficient of minor loses (1)
L = Pipe length (8 ft)
K_p = Pipe friction coefficient (.168)

$$K_p = \frac{5087\ n^2}{d_i^{4/3}}$$

n = Manning's number (.023)
d_i = Pipe inside diameter (8 in.)

- Low Flow Discharge

The lower of either the orifice flow or pipe capacity is used as the low flow discharge.

Principal Spillway Discharge Rate

48 in. diameter CMP riser connected to a 36 in. diameter CMP outlet.

- Weir Flow (Sharp Crested)

Head = principal spillway crest (571) minus pool elevation.

$$Q = C\ L_e\ H^{3/2}$$

H = Head
P = Crest height = 4 ft
L_e = Effective crest length = $2\pi r$ = $2\pi(2\text{ ft})$ = 12.57 ft
C = Weir coefficient = 3.27 + 0.4 H/P

- Pipe Inlet

  - Head for pipe inlet = pool elevation - (pipe inlet centerline elevation)
    = pool elevation - 568.5 ft

  - Pipe Inlet (Vertical Orifice)

$$Q = Ca\sqrt{2gh}$$

C = 0.6
a = $\pi r^2 = \pi(1.5\text{ ft})^2 = 7.07\text{ ft}^2$
g = Gravitational constant (32.2 ft/s^2)
h = Pipe inlet head

The weir and orifice flows were checked with Table 3.

- Full Flow (Pipe Flow)

  - Head for pipe full flow = pool elevation - pipe outlet centerline elevation
    = pool elevation - 566 ft

$$Q = a\sqrt{\frac{2gh}{1 + K_m + K_t + K_pL}}$$

a = Pipe area = $\pi r^2 = \pi(1.5\text{ ft})^2 = 7.07\text{ ft}$
h = Head (ft)
g = Gravitational constant (32.2 ft/s^2)
K_m = Coefficient of minor loses (1)
L = Pipe length (13 ft)
K_t = Coefficient transition loss (0.4)

K_p = Pipe friction coefficient = (0.0226)

$$K_p = \frac{5087\ n^2}{d_i^{4/3}}$$

n = Manning's number (.023)
d_i = Pipe inside diameter (36 in.)

The pipe flows were checked with Table 4.

- Limiting Q

This is an if statement written to yield the lower of either the pipe inlet Q or the full flow Q:

- Principal Discharge

This column's cells are set up as if statements that return the minimum value of either riser structure weir flow or the limiting pipe flow, plus the low flow structure discharge.

Rate for Principal Spillway

This column is the actual principal discharge. The maximum principal discharge (flow through the principal spillway) is 83 cfs at the maximum storm water elevation of 574.2.

Berm Crest

Basin #4 was constructed in a cut area, so no berm was required.

Riser Base

The minimum factor of safety against riser flotation is 1.1. The riser is 16 gauge aluminum-coated CMP. The base is concrete with #4 steel reinforcing bars on 12 in. center to center spacings each way.

$$Volume\ of\ concrete = 0.62\ HD^2 - \frac{H\ W_r}{87.6}$$

Riser

$H_{(riser)}$ = Height of riser (4 ft)
D = Diameter of riser (4 ft)
W_r = Weight per foot of riser (24 lb/ft)

$$V = 38.6\ ft^3$$

Outlet Pipe

$H_{(outlet)}$ = Length of pipe extending into basin (13 ft)
D = Diameter of outlet pipe (4 ft)
W_r = Weight per foot of riser (24 lb/ft)

$$V = 125.4\ ft^3$$

Total minimum volume of concrete required.

$$V_{total} = 38.6\ ft^3 + 125.4\ ft^3$$
$$= 164\ ft^3$$

V_{actual} = Volume of base design

$$V_{actual} = 9.5\ ft \times 9.5\ ft \times 2\ ft$$
$$V_{actual} = 180.5\ ft^3 < 164\ ft^3$$

Use a 9.5 ft × 9.5 ft × 2 ft concrete base with #4 bars 12 in. O.C. each way.

Anti-Seep Collar

The design of the anti-seep collar is supposed to increase the flow length by 15 percent along the outlet pipe; 4.6 ft extension collars will be used. The minimum number of collars is:

$$N = .075\frac{L}{V}$$

V = Collar projection (4.6 ft)
L = Outlet pipe length in berm (245 ft)
N = Minimum number of collars = 4

The radius of the anti-seep collar is the distance from the outer edge of the outlet pipe to the outer edge of the collar. Square collars will be used for this design.

Outlet Protection

PBR 30CT 1996

Using Figure 4 (from the USDA-SCS ~~Guidelines, March~~ (1987)) and a maximum outflow of 83 cfs from Table 2, the d_{50} of the riprap will be at least .6 ft (10 in.) (use ODOT Class C) and L_a (length) shall be a minimum of 24 ft. The minimum width at the end of the apron is calculated as:

$$W = D_o + L_a$$

D_o = 3 ft
L_a = 24 ft
W = 27 ft

The minimum width is 27 ft unless the outlet pipe outlets into a channel in which case the apron will conform to the channel. This design is considered to be conservative since the outlet pipe is the 48-inch diameter pipe.

Pipe Structural Analysis

This analysis method was taken from "Handbook of Steel Drainage and Highway Construction Products" [AISI, 1983].

1) Assume 85% standard density (less than specified 95%). This assumption is considered to be conservative.

   Unit weight = 120 lb/ft^3

Height of overfill pipe = 11 ft

2 2/3 × 1/2 in. 16 gauge CMP (0.064 in. thick)

2) Design Pressure, P_u

$$P_u = DL + LL$$

DL = 120 lb/ft^3 × 11 ft = 1,320 lb/ft^2
LL = Negligible for cover greater than 8 ft

P_u = 1,320 psf + 0 = 1,320 psf/ft^2

3) Ring Compression, C (Used in Step 5)

$$C = P_u \frac{S}{2}$$

S = Span (ft) = pipe diameter = 4 ft
P_u = Design pressure (lb/ft^2)

C = 1,320 lb/ft^2 × 4 ft/2
C = 2,640 lb/ft

4) Allowable Wall Stress, f_a (Used in Step 5)

$$f_a = \frac{33{,}000}{2K} \text{ for } D/r < 294$$

D = Pipe diameter (in.)
r = Radius of gyration
K = 0.86 for 85% standard density

f_a = 19,186 lb/in.^{2}

5) Wall Thickness Criteria

$$A = \frac{C}{f_a}$$

A = Required wall area (in.^{2}/ft)
C = Ring compression (step 3) (lb/ft)
f_a = Allowable wall stress (step 4) (lb/in.^{2})

A = 0.1376 in.^{2}/ft

The wall area for a 16 gauge CMP (0.064 in. thick) of 0.775 in.^{2}/ft exceeds the required wall area (0.1376 in.^{2}/ft) and thus the wall thickness criteria is satisfied.

6) Handling Stiffness Criteria

$$FF = \frac{D^2}{EI} < .0433$$

FF = Flexibility factor
D = Diameter (in.)
E = Modulus of elasticity (30×10^6 lb/in.^{2})
I = Moment of inertia (in.^{4}/in); (0.0227 in.^{4}/ft)/(12 in/ft) = 0.00189 in.^{4}/in.

FF = 0.0406 < 0.0433; therefore 2 2/3 × 1/2 in. 16 gauge is ok.

The value of FF (0.0406) is less than the recommended maximum value of FF (0.0433) and thus the handing stiffness criteria is satisfied.

References

American Iron and Steel Institute, *Handbook of Steel Drainage & Highway Construction Products*, Washington, D.C., 1983.

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Brater, E.F. and King, H.W., *Handbook of Hydraulics*, 1976.

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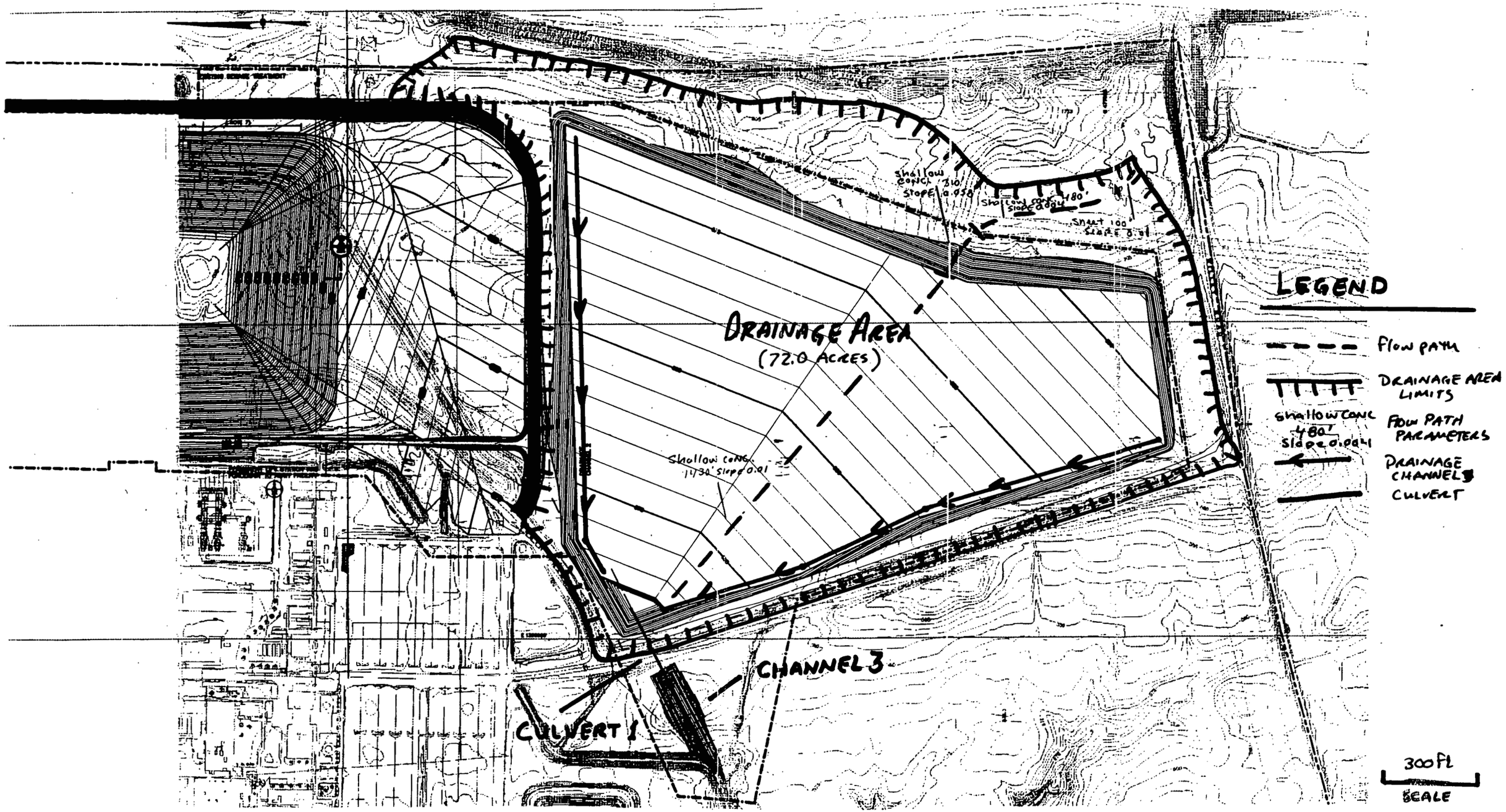
DGP 3 APRIL 96
P Chadwick 3 APRIL 1996 740/474

Written By: DGP Date: 20 FEB 96 Reviewed by: DBW Date: 23 FEB 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.11

DRAINAGE AREA FOR SEDIMENT BASIN 4



FROM DESIGN DRAWING TITLED "BORROW AREA RESTORATION PLAN"

FIGURE 1

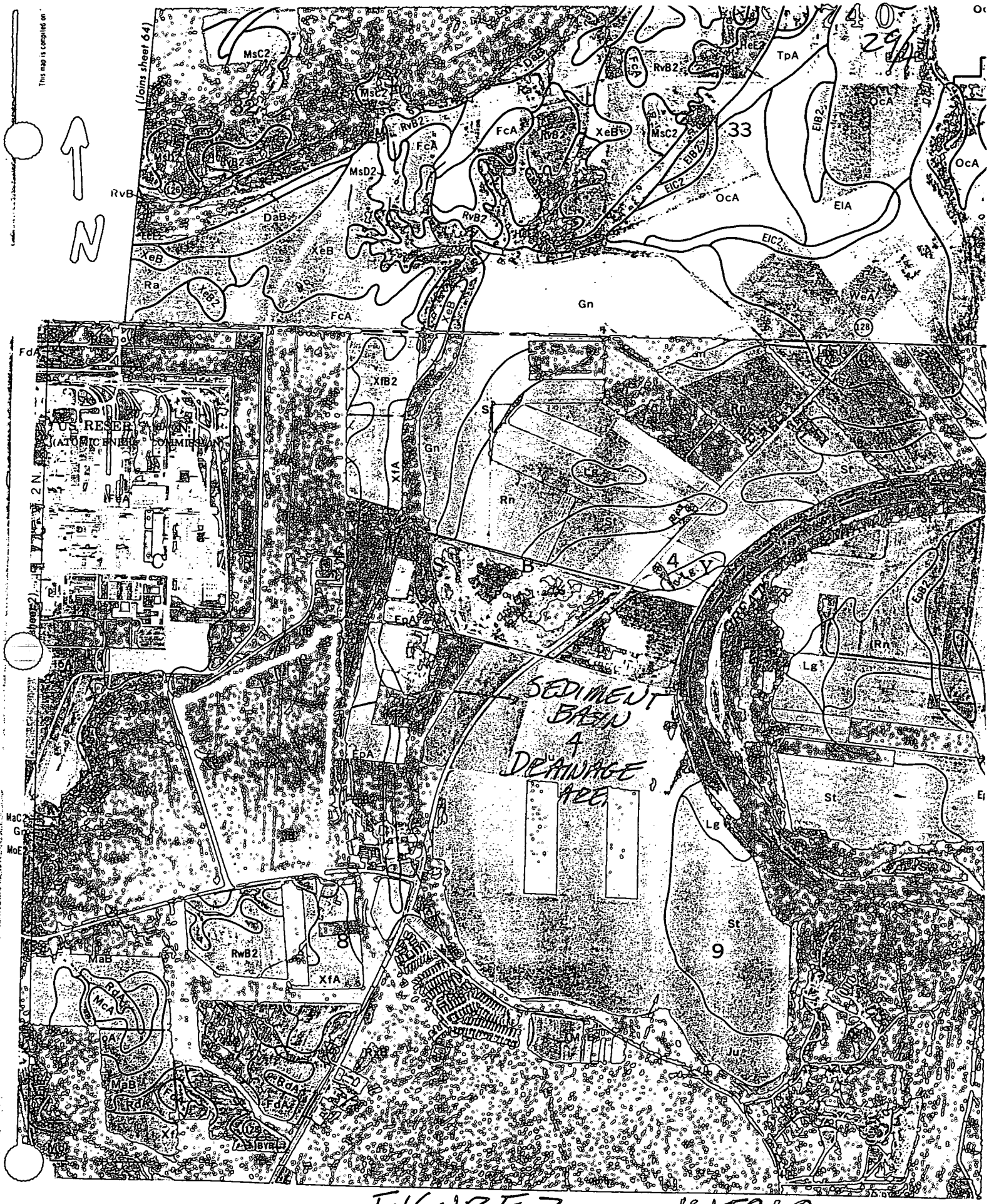


FIGURE 2 1:15840

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[USDA-SCS 8/57 : USDA-SCS 1/80]

TABLE 2

SEDIMENT BASIN 4 SPILLWAY - STAGED DISCHARGE - 48 IN RISER/ 36 IN OUTLET PIPE INTO 48" OUTLET PIPE

POOL ELEVATION	LOW FLOW DISCHARGE RATE				PRINCIPAL SPILLWAY DISCHARGE RATE								
	ORIFICE FLOW*		PIPE CAPACITY	LOW FLOW DISCHARGE	WIER FLOW		36" PIPE CAPACITY					PRINCIPAL DISCHARGE	
	HEAD (FT)	Q (CFS)	Q (CFS)	(CFS)	HEAD (FT)	Q (CFS)	HEAD (FT)	Pipe Inlet Q (CFS)	HEAD (FT)	Full Flow Q (CFS)	Limiting Q (CFS)	(CFS)	
567.00	0.00	0.00	0.00	0.00			-1.50	0.00	1.00	34.56	0.00	0.00	BOTTOM OF SEDIMENT BASIN
567.67	0.67	0.10	1.25	0.10			-0.83	0.00	1.67	44.62	0.00	0.10	
568.33	1.33	0.23	1.77	0.23			-0.17	0.00	2.33	52.79	0.00	0.23	
569.00	2.00	0.40	2.17	0.40			0.50	24.06	3.00	59.86	24.06	0.40	
569.67	2.67	0.59	2.50	0.59			1.17	36.76	3.67	66.18	36.76	0.59	
570.33	3.33	0.81	2.80	0.81			1.83	46.08	4.33	71.94	46.08	0.81	
571.00	4.00	1.04	3.06	1.04	0.00	0.00	2.50	53.81	5.00	77.28	53.81	1.04	CREST OF PRIMARY SPILLWAY
571.10	4.10	1.19	3.10	1.19	0.10	1.30	2.60	54.88	5.10	78.05	54.88	2.48	
571.20	4.20	1.29	3.14	1.29	0.20	3.69	2.70	55.92	5.20	78.81	55.92	4.98	
571.30	4.30	1.37	3.18	1.37	0.30	6.80	2.80	56.95	5.30	79.56	56.95	8.17	
571.40	4.40	1.43	3.21	1.43	0.40	10.51	2.90	57.96	5.40	80.31	57.96	11.93	
571.50	4.50	1.46	3.25	1.46	0.50	14.73	3.00	58.95	5.50	81.05	58.95	16.19	
571.60	4.60	1.48	3.29	1.48	0.60	19.43	3.10	59.92	5.60	81.78	59.92	20.91	
571.70	4.70	1.50	3.32	1.50	0.70	24.56	3.20	60.88	5.70	82.51	60.88	26.06	
571.80	4.80	1.51	3.36	1.51	0.80	30.10	3.30	61.82	5.80	83.23	61.82	31.61	
571.90	4.90	1.53	3.39	1.53	0.90	36.03	3.40	62.75	5.90	83.95	62.75	37.55	
572.00	5.00	1.54	3.43	1.54	1.00	42.32	3.50	63.67	6.00	84.66	63.67	43.87	
572.10	5.10	1.56	3.46	1.56	1.10	48.97	3.60	64.57	6.10	85.36	64.57	50.54	
572.20	5.20	1.58	3.49	1.58	1.20	55.97	3.70	65.46	6.20	86.05	65.46	57.55	
572.25	5.25	1.59	3.51	1.59	1.25	59.59	3.75	65.91	6.25	86.40	65.91	61.19	
572.30	5.30	1.60	3.53	1.60	1.30	63.30	3.80	66.34	6.30	86.75	66.34	64.90	
572.40	5.40	1.62	3.56	1.62	1.40	70.95	3.90	67.21	6.40	87.43	67.21	68.83	
572.50	5.50	1.63	3.59	1.63	1.50	78.92	4.00	68.07	6.50	88.11	68.07	69.70	
572.60	5.60	1.64	3.62	1.64	1.60	87.20	4.10	68.91	6.60	88.79	68.91	70.56	
572.70	5.70	1.66	3.66	1.66	1.70	95.78	4.20	69.75	6.70	89.46	69.75	71.40	
572.80	5.80	1.67	3.69	1.67	1.80	104.66	4.30	70.57	6.80	90.12	70.57	72.24	
572.90	5.90	1.68	3.72	1.68	1.90	113.83	4.40	71.39	6.90	90.78	71.39	73.07	
573.00	6.00	1.70	3.75	1.70	2.00	123.30	4.50	72.20	7.00	91.44	72.20	73.90	
573.10	6.10	1.71	3.78	1.71	2.10	133.04	4.60	72.99	7.10	92.09	72.99	74.71	
573.20	6.20	1.73	3.81	1.73	2.20	143.07	4.70	73.78	7.20	92.74	73.78	75.51	
573.30	6.30	1.74	3.84	1.74	2.30	153.37	4.80	74.56	7.30	93.38	74.56	76.31	
573.40	6.40	1.76	3.88	1.76	2.40	163.95	4.90	75.34	7.40	94.01	75.34	77.09	
573.50	6.50	1.77	3.91	1.77	2.50	174.80	5.00	76.10	7.50	94.65	76.10	77.87	
573.60	6.60	1.79	3.94	1.79	2.60	185.93	5.10	76.86	7.60	95.28	76.86	78.65	
573.70	6.70	1.80	3.96	1.80	2.70	197.31	5.20	77.61	7.70	95.90	77.61	79.41	
573.80	6.80	1.81	3.99	1.81	2.80	208.97	5.30	78.35	7.80	96.52	78.35	80.17	
573.90	6.90	1.83	4.02	1.83	2.90	220.88	5.40	79.09	7.90	97.14	79.09	80.92	
574.00	7.00	1.84	4.05	1.84	3.00	233.06	5.50	79.82	8.00	97.75	79.82	81.66	
575.00	8.00	1.87	4.33	1.87	4.00	368.89	6.50	86.77	9.00	103.68	86.77	88.64	
576.00	9.00	1.93	4.60	1.93	5.00	529.60	7.50	93.21	10.00	109.29	93.21	95.13	
577.00	10.00	1.99	4.84	1.99	6.00	714.66	8.50	99.23	11.00	114.63	99.23	101.22	
578.00	11.00	2.08	5.08	2.08	7.00	923.86	9.50	104.90	12.00	119.72	104.90	106.98	

NOTE: SHADED AREAS INDICATED THAT OUTLET PIPE FLOWING UNDER PRESSURE OR MAXIMUM DESIGN POOL ELEVATION HAS BEEN EXCEEDED

* SEE TABLE BELOW

LOW FLOW RISER ORIFICE FLOW - 2 PERFORATIONS ON 8" VERITICLE CENTERS

EL.	HEAD (ft)		FLOW (cfs)					Σ (cfs)
567.00	0.00	0.00						0.00
567.67	0.67	0.10	0.00					0.10
568.33	1.33	0.14	0.10	0.00				0.23
569.00	2.00	0.17	0.14	0.10	0.00			0.40
569.67	2.67	0.19	0.17	0.14	0.10	0.00		0.59
570.33	3.33	0.22	0.19	0.17	0.14	0.10	0.00	0.81
571.00	4.00	0.24	0.22	0.19	0.17	0.14	0.10	1.04
571.10	4.10	0.24	0.24	0.22	0.19	0.17	0.14	1.19
571.20	4.20	0.24	0.24	0.24	0.22	0.19	0.17	1.29
571.30	4.30	0.25	0.24	0.24	0.24	0.22	0.19	1.37
571.40	4.40	0.25	0.25	0.24	0.24	0.24	0.22	1.43
571.50	4.50	0.25	0.25	0.25	0.24	0.24	0.24	1.46
571.60	4.60	0.25	0.25	0.25	0.25	0.24	0.24	1.48
571.70	4.70	0.26	0.25	0.25	0.25	0.25	0.24	1.50
571.80	4.80	0.26	0.26	0.25	0.25	0.25	0.25	1.51
571.90	4.90	0.26	0.26	0.26	0.25	0.25	0.25	1.53
572.00	5.00	0.26	0.26	0.26	0.26	0.25	0.25	1.54
572.10	5.10	0.27	0.26	0.26	0.26	0.26	0.25	1.56
572.20	5.20	0.27	0.27	0.26	0.26	0.26	0.26	1.58
572.25	5.25	0.27	0.27	0.27	0.26	0.26	0.26	1.59
572.30	5.30	0.27	0.27	0.27	0.27	0.26	0.26	1.60
572.40	5.40	0.27	0.27	0.27	0.27	0.27	0.26	1.62
572.50	5.50	0.28	0.27	0.27	0.27	0.27	0.27	1.63
572.60	5.60	0.28	0.28	0.27	0.27	0.27	0.27	1.64
572.70	5.70	0.28	0.28	0.28	0.27	0.27	0.27	1.66
572.80	5.80	0.28	0.28	0.28	0.28	0.27	0.27	1.67
572.90	5.90	0.29	0.28	0.28	0.28	0.28	0.27	1.68
573.00	6.00	0.29	0.29	0.28	0.28	0.28	0.28	1.70
573.10	6.10	0.29	0.29	0.29	0.28	0.28	0.28	1.71
573.20	6.20	0.29	0.29	0.29	0.29	0.28	0.28	1.73
573.30	6.30	0.30	0.29	0.29	0.29	0.29	0.28	1.74
573.40	6.40	0.30	0.30	0.29	0.29	0.29	0.29	1.76
573.50	6.50	0.30	0.30	0.30	0.29	0.29	0.29	1.77
573.60	6.60	0.30	0.30	0.30	0.30	0.29	0.29	1.79
573.70	6.70	0.31	0.30	0.30	0.30	0.30	0.29	1.80
573.80	6.80	0.31	0.31	0.30	0.30	0.30	0.30	1.81
573.90	6.90	0.31	0.31	0.31	0.30	0.30	0.30	1.83
574.00	7.00	0.31	0.31	0.31	0.31	0.30	0.30	1.84
575.00	8.00	0.33	0.31	0.31	0.31	0.31	0.30	1.87
576.00	9.00	0.35	0.33	0.31	0.31	0.31	0.31	1.93
577.00	10.00	0.37	0.35	0.33	0.31	0.31	0.31	1.99
578.00	11.00	0.39	0.37	0.35	0.33	0.31	0.31	2.08

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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.

TABLE 1

DGP 3 APRIL 96
I, Rhodes 3 APRIL 1986 32/44

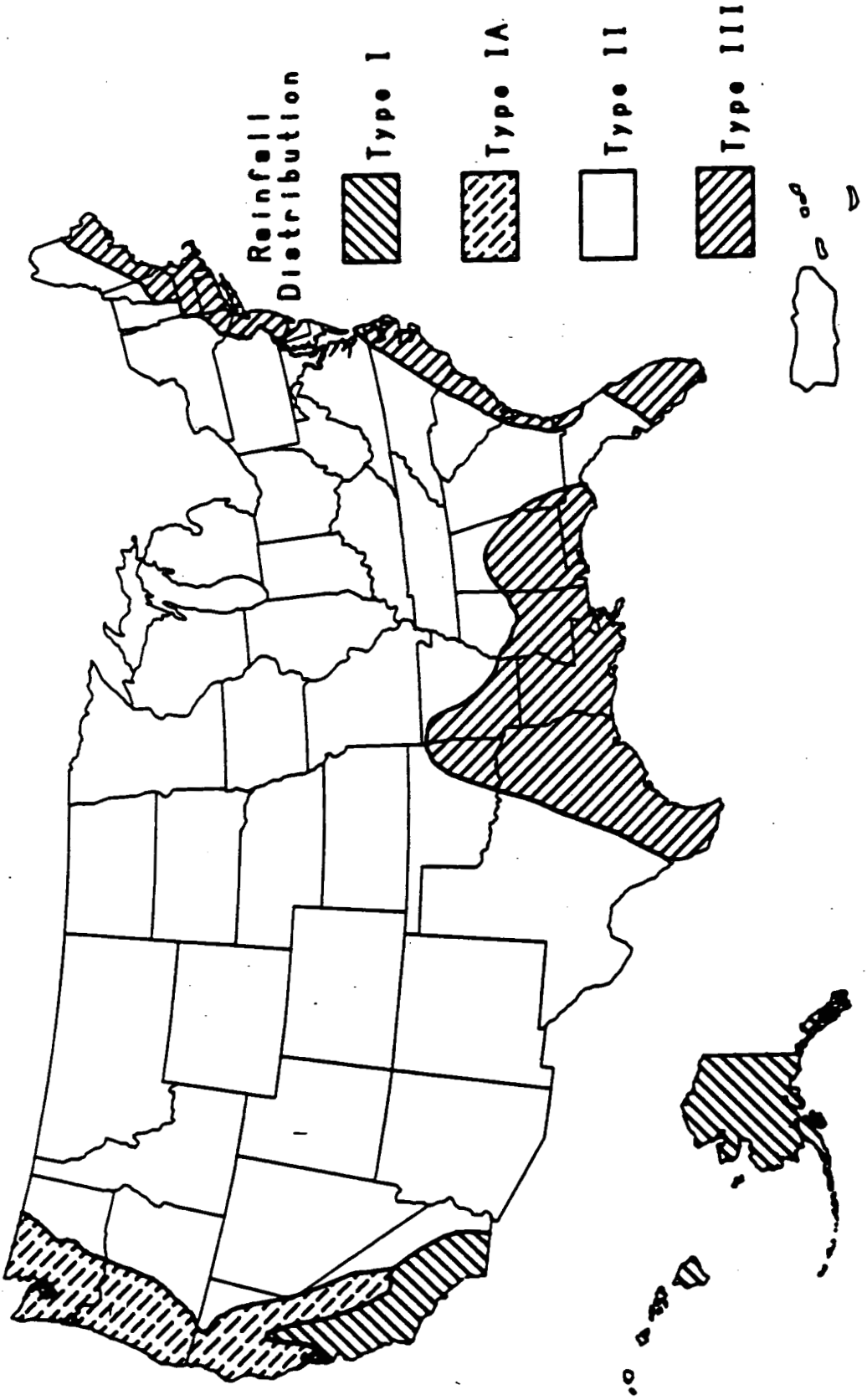

FIGURE 3

HEAD DISCHARGE TABLE FOR CORRUGATED METAL PIPE
DROP INLETS
(Orifice Control Conditions at Crest of Riser or Entrance to Barrel)

Dia. Inches	Head in Feet																
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
12	4.1	5.0	5.8	6.3	7.1	7.7	8.2	8.7	9.1	9.6	10.0	10.4	10.8	11.2	11.6	11.9	12.3
15	6.7	8.2	9.5	10.6	11.6	12.6	13.4	14.3	15.0	15.8	16.5	17.1	17.8	18.4	19.0	19.6	20.2
18	10.1	12.3	14.3	16.0	17.5	18.9	20.2	21.4	22.5	23.6	24.7	25.7	26.7	27.6	28.5	29.4	30.2
21	13.8	17.0	19.6	21.9	24.0	25.9	27.7	29.4	31.0	32.5	33.9	35.3	36.6	37.9	39.2	40.4	41.6
24		22.5	26.1	29.2	32.0	34.5	36.8	39.0	41.1	43.1	45.0	46.9	48.6	50.3	52.0	53.6	55.1
30		35.2	40.8	45.4	49.9	53.8	57.5	61.0	64.3	67.4	70.4	73.3	76.1	78.7	81.3	83.8	86.2
36	Weir		58.7	65.7	71.9	77.8	82.9	87.9	92.7	97.2	101.5	105.7	109.7	113.5	117.2	120.8	124.4
42	Flow		79.8	88.2	97.7	105.5	112.6	119.5	125.9	132.1	137.9	143.6	149.0	154.2	159.3	164.2	169.0
48	Controls			115.0	125.5	136.0	145.2	154.0	162.3	170.2	177.8	185.0	192.1	198.7	205.3	211.6	217.8

Chart for determining inlet proportions and required head over inlet

TABLE 3

DGP 3 APRIL 96
Filed 3 APRIL 1996
33/44

FROM US-SCS
ENG FIELD MANUAL
(NOV 1986)

Sheet 3 of 3

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DGP 3 APRIL 96 740
B. Rodan 3 APRIL 1996 34/44

PIPE FLOW CHART (Full flow assumed)

For Corrugated Metal Pipe Inlet $K_e + K_b = 1.0$ and 70 feet of Corrugated Metal Pipe Conduit n = 0.025. Note correction factors for other pipe lengths.

H \ Dia.	12"	15"	18"	21"	24"	30"	36"	42"
2	2.84	4.92	7.73	11.30	15.60	26.60	40.77	58.12
3	3.48	6.03	9.47	13.84	19.10	32.58	49.93	71.19
4	4.02	6.96	10.94	15.98	22.06	37.62	57.66	82.20
5	4.49	7.78	12.23	17.87	24.66	42.06	64.46	91.90
6	4.92	8.52	13.40	19.57	27.01	46.07	70.60	100.65
7	5.32	9.21	14.47	21.14	29.19	49.77	76.28	108.75
8	5.68	9.84	15.47	22.60	31.19	53.19	81.53	116.23
9	6.03	10.44	16.41	23.97	33.09	56.43	86.49	123.30
10	6.36	11.00	17.30	25.26	34.88	59.48	91.16	129.96
11	6.67	11.54	18.14	26.50	36.59	62.39	95.63	136.33
12	6.96	12.05	18.95	27.68	38.21	65.16	99.87	142.37
13	7.25	12.55	19.72	28.81	39.77	67.83	103.96	148.21
14	7.52	13.02	20.47	29.90	41.27	70.39	107.88	153.80
15	7.78	13.48	21.19	30.95	42.72	72.85	111.66	159.18
16	8.04	13.92	21.88	31.96	44.12	75.24	115.32	164.40
17	8.29	14.35	22.55	32.94	45.48	77.55	118.87	169.46
18	8.53	14.77	23.21	33.90	46.80	79.81	122.33	174.39
19	8.76	15.17	23.84	34.83	48.08	81.99	125.67	179.15
20	8.99	15.56	24.46	35.73	49.33	84.12	128.93	183.80
21	9.21	15.95	25.07	36.62	50.55	86.21	132.13	188.36
22	9.43	16.32	25.65	37.47	51.73	88.22	135.21	192.76
23	9.64	16.69	26.23	38.32	52.90	90.21	138.27	197.12
24	9.85	17.05	26.80	39.14	54.04	92.15	141.24	201.35
25	10.05	17.40	27.35	39.95	55.15	94.05	144.15	205.50
L	Correction Factors For Other Pipe Lengths							
40	1.23	1.22	1.20	1.19	1.16	1.14	1.13	1.11
50	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07
60	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.03
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	0.95	0.95	0.95	0.96	0.96	0.96	0.97	0.97
90	0.90	0.91	0.91	0.92	0.92	0.93	0.94	0.94
100	0.86	0.87	0.88	0.89	0.89	0.90	0.91	0.92

Pipe flow chart for corrugated metal pipe drop inlet spillway

TABLE 4

FROM US-SCS ENG FIELD MANUAL (NOV 1986)

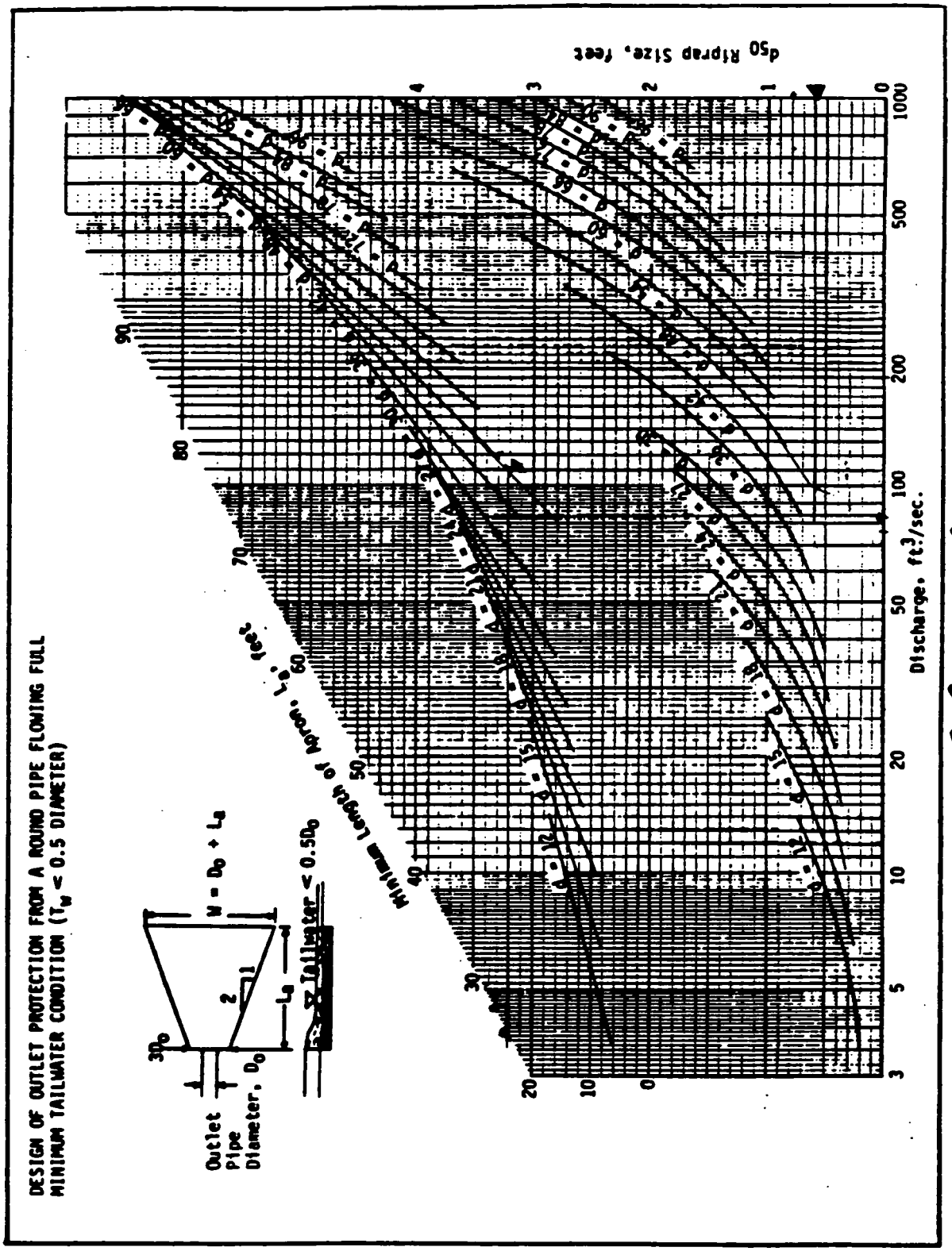
DESIGN OF OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL
MINIMUM TAILWATER CONDITION (T_w < 0.5 DIAMETER)
Outlet Pipe Diameter, D_o
$3D_o$
$W = D_o + L_a$
2
1
L_a
T_w < $0.5D_o$
Minimum Length of Apron, L_a, feet
Discharge, ft^3/sec.
d_{50} Riprap Size, feet
FIGURE 4

Figure 3

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATION PACKAGE HydroCAD™ STORMWATER MODELING SYSTEM

Applied Microcomputer Systems, *"HydroCAD™ Stormwater Modeling System"*, version 3.10, Chocorva, NH, 1993.

For documentation of computer programs see

1.2 Computer Program Validation

61/68
37/44
Attach 3 Appx

APPENDIX B

HYDROCAD™ OUTPUT

Data for **SEDIMENT BASIN 4 - BORROW AREA - 25 YEAR STORM**
TYPE II 24-HOUR RAINFALL= 4.7 IN
Prepared by Applied Microcomputer Systems
HydroCAD 4.51 000663 (c) 1996 Applied Microcomputer Systems

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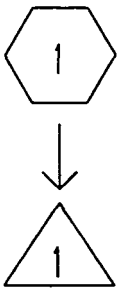
W ERSHED ROUTING ==========



PCLA 0 April 1996
DGP 3APR1996

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SUBCATCHMENT 1 **SEDIMENT BASIN 4 - BORROW AREA**

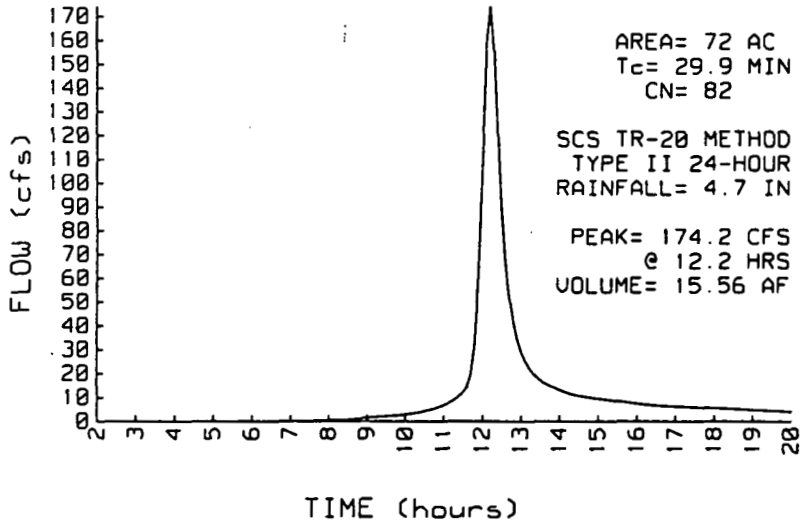
PEAK= 174.2 CFS @ 12.20 HRS, VOLUME= 15.56 AF

ACRES	CN
15.00	87
57.00	81
72.00	82

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
SPAN= 2-20 HRS, dt=.1 HRS

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	6.0
Fallow n=.05 L=100' P2=2.6 in s=.01 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	7.8
Unpaved Kv=16.1345 L=480' s=.004 '/' V=1.02 fps		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	1.3
Unpaved Kv=16.1345 L=310' s=.058 '/' V=3.89 fps		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	14.8
Unpaved Kv=16.1345 L=1430' s=.01 '/' V=1.61 fps		
	Total Length= 2320 ft Total Tc=	29.9

SUBCATCHMENT 1 RUNOFF
SEDIMENT BASIN 4 - BORROW AREA



40/44

POND 1 **SEDIMENT BASIN 4 - BORROW AREA**

Qin = 174.2 CFS @ 12.20 HRS, VOLUME= 15.56 AF
Qout= 83.13 CFS @ 12.53 HRS, VOLUME= 15.45 AF, ATTEN= 52%, LAG= 20.0 MIN

ELEVATION (FT)	AREA (SF)	INC.STOR (CF)	CUM.STOR (CF)
567.0	782	0	0
568.0	3344	2063	2063
569.0	7524	5434	7497
570.0	13308	10416	17913
571.0	20793	17051	34964
572.0	30565	25679	60643
573.0	42773	36669	97312
574.0	85418	64096	161407
575.0	144176	114797	276204
576.0	215775	179976	456180
577.0	299975	257875	714055
578.0	395843	347909	1061964

STOR-IND METHOD
PEAK STORAGE = 185089 CF
PEAK ELEVATION= 574.2 FT
FLOOD ELEVATION= 577.5 FT
START ELEVATION= 571.0 FT
SPAN= 2-20 HRS, dt=.1 HRS
Tdet= 48 MIN (14.65 AF)

#	ROUTE	INVERT	OUTLET DEVICES
1	P	567.0'	**48" RISER - 36" INTO 48" OUTLET**

ELEV(FT)	DISCH(CFS)
567.0	0.00
569.0	.40
570.3	.81
571.0	1.04
571.1	2.48
571.2	4.98
571.5	16.19
572.0	43.87
572.5	69.70
573.0	73.90
573.5	77.87
574.0	81.66
575.0	88.64
576.0	95.13
577.0	101.22

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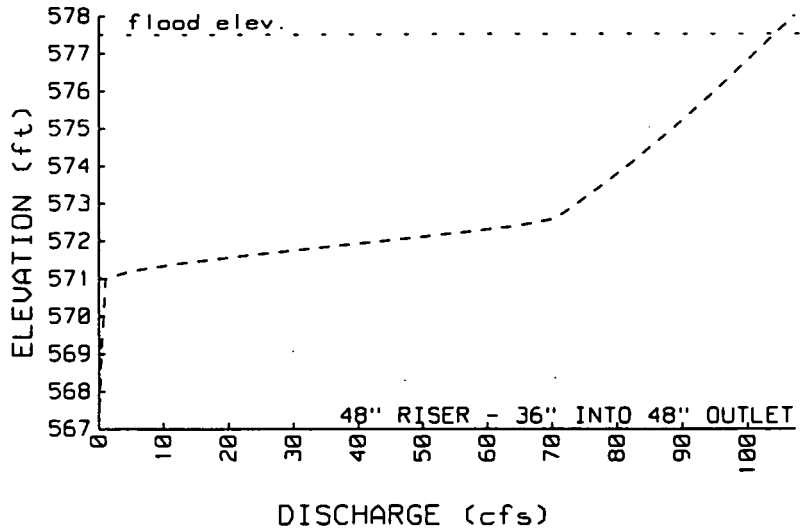
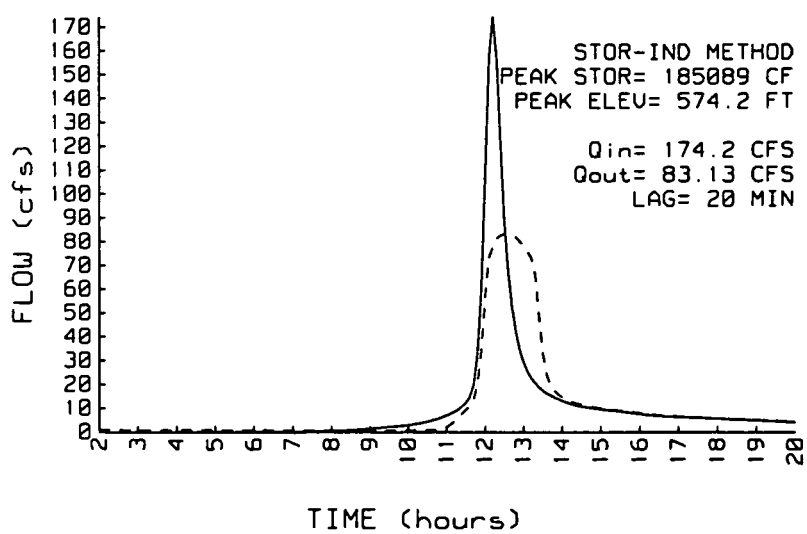
POND 1 DISCHARGE
SEDIMENT BASIN 4 - BORROW AREA



POND 1 INFLOW & OUTFLOW
SEDIMENT BASIN 4 - BORROW AREA



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SUBCATCHMENT 1 **SEDIMENT BASIN 4 - BORROW AREA**

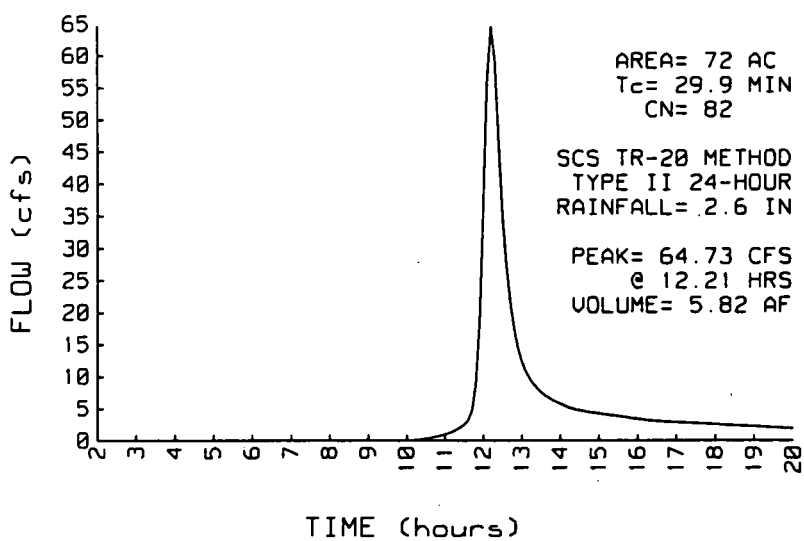
PEAK= 64.73 CFS @ 12.21 HRS, VOLUME= 5.82 AF

ACRES	CN
15.00	87
57.00	81
72.00	82

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 2.6 IN
SPAN= 2-20 HRS, dt=.1 HRS

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	6.0
Fallow n=.05 L=100' P2=2.6 in s=.01 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	7.8
Unpaved Kv=16.1345 L=480' s=.004 '/' V=1.02 fps		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	1.3
Unpaved Kv=16.1345 L=310' s=.058 '/' V=3.89 fps		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	14.8
Unpaved Kv=16.1345 L=1430' s=.01 '/' V=1.61 fps		
	Total Length= 2320 ft Total Tc=	29.9

SUBCATCHMENT 1 RUNOFF
SEDIMENT BASIN 4 - BORROW AREA



43/44

PC 1 **SEDIMENT BASIN 4 - BORROW AREA**

Qin = 64.73 CFS @ 12.21 HRS, VOLUME= 5.82 AF
Qout= 50.96 CFS @ 12.38 HRS, VOLUME= 5.79 AF, ATTEN= 21%, LAG= 9.9 MIN

ELEVATION (FT)	AREA (SF)	INC.STOR (CF)	CUM.STOR (CF)
567.0	782	0	0
568.0	3344	2063	2063
569.0	7524	5434	7497
570.0	13308	10416	17913
571.0	20793	17051	34964
572.0	30565	25679	60643
573.0	42773	36669	97312
574.0	85418	64096	161407
575.0	144176	114797	276204
576.0	215775	179976	456180
577.0	299975	257875	714055
578.0	395843	347909	1061964

STOR-IND METHOD
PEAK STORAGE = 65568 CF
PEAK ELEVATION= 572.1 FT
FLOOD ELEVATION= 577.5 FT
START ELEVATION= 571.0 FT
SPAN= 2-20 HRS, dt=.1 HRS
Tdet= 72.5 MIN (4.99 AF)

#	ROUTE	INVERT	OUTLET DEVICES
1	P	567.0'	**48" RISER - 36" INTO 48" OUTLET**

ELEV(FT)	DISCH(CFS)
567.0	0.00
569.0	.40
570.3	.81
571.0	1.04
571.1	2.48
571.2	4.98
571.5	16.19
572.0	43.87
572.5	69.70
573.0	73.90
573.5	77.87
574.0	81.66
575.0	88.64
576.0	95.13
577.0	101.22

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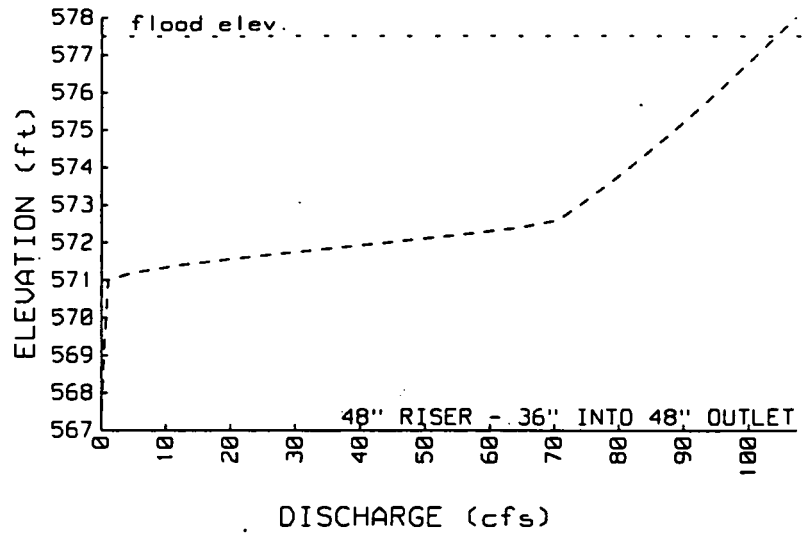
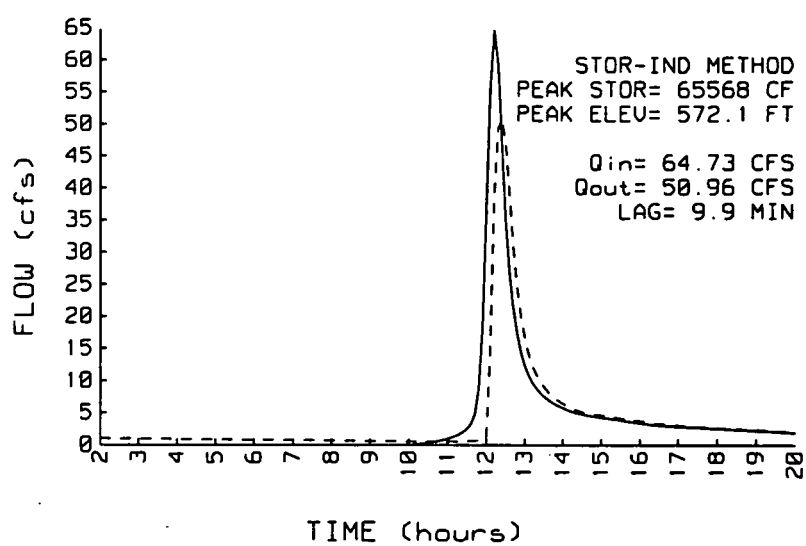
POND 1 DISCHARGE
SEDIMENT BASIN 4 - BORROW AREA



POND 1 INFLOW & OUTFLOW
SEDIMENT BASIN 4 - BORROW AREA



SECTION 16

000397

16. IMPACTED MATERIALS MANAGEMENT

16.1 Impacted Material Haul Road
16.2 Impacted Runoff from Haul Road
16.3 OSDF Methane Generation
16.4 OSDF Radon 222 Release

16.1 Impacted Material Haul Road

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: IMPACTED MATERIAL HAUL ROAD

Computations By: (Cognizant Engineer)
Signature: Daniel G. Pass — Date: 12 FEB 96
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: David W. Warren — Date: 24 Feb 96
Printed Name and Title: DAVID W. WARREN, STAFF ENGINEER

Computations Checked by:
Signature: David W. Warren — Date: 25 Feb 96
Printed Name and Title: DAVID W. WARREN, STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Daniel G. Pass — Date: 25 FEB 96
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Approved by: (PDP)
Signature: [illegible] — Date: 25 Feb 96
Printed Name and Title: Kenneth W Cargill, Associate

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 25 Feb 96
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design	25 FEB 96	DGP	DWW	[illegible] 25 Feb 96
D	Intermediate Design - EPA Submittal	5 Apr 96	[illegible]	—	—
G	Final Design Package	4 Oct 96	—	—	[illegible]
O	Response to Final Design Cmts	5 May 97	—	—	[illegible]

Written by: DGP Date: 23 FEB 96 Reviewed by: DRW Date: 25 Feb 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

IMPACTED MATERIAL HAUL ROAD EXECUTIVE SUMMARY

Purpose:

The purpose of this calculation is to design an aggregate-surfaced haul road for transport of impacted material from the battery limit to the OSDF for placement. This road will connect with roads from the operable units. The total volume of impacted rubble is 274,615 unbulked cubic yards (CY) and of impacted soil is 2,360,251 bank CY is expected for transport. Transport will be accomplished using articulated trucks.

Design Method:

Analyses are performed using an AASHTO method for design of aggregate-surfaced roads (AASHTO, 1993) and an ODOT method for design of flexible pavement roads (pavement thickness = 0). Analyses considered roadbed conditions during the normal period of operation and the spring-thaw period of operation. A design cross-section was selected based on calculations considering a performance period (or maintenance interval) of 1 to 2 weeks.

Conclusions:

Aggregate-surfaced road cross-section (top to bottom):

- Base: 9 in. of ODOT spec. #304 Base Aggregate;
- Subbase: 15 in. of ODOT spec. #310 Subbase Aggregate;
- Geotextile separator; and
- Prepared subgrade

Maintenance:

- Required Maintenance includes regrading of the road surface and the addition of aggregate to the base.
- Maintenance Intervals:
  Biweekly for normal period of operation.
  Weekly for spring-thaw period of operation.

Subgrade Requirements:

- Fill sections: Brown till compacted to 100% of Standard Proctor maximum dry density.
- Cut sections: Existing subgrade compacted to 100% of Standard Proctor maximum dry density.

Written by: DGP Date: 17 JAN 96 Reviewed by: DWW Date: 25 Feb 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

IMPACTED MATERIAL HAUL ROAD

25 Feb 96

Contents:

1. Introduction 1/16

2. Calculation Procedure 2/16

3. Collection and Verification of Engineering Data 1/5

References 5/5

4. Calculations and Results 1/14

~~5. References~~

Introduction:

An aggregate-surfaced impacted material haul road will be used to transport impacted material from the operable units to the OSDF for placement. A mix of 20 and 40 ton articulated trucks will be used to transport impacted material. An expected 274,615 unbulked cubic yards (CY) of impacted rubble and 2,360,251 bank CY of impacted ~~rubble~~ Soil will be transported over the haul road.

The haul road is divided into the following sections:

1. From the battery limit to the OSDF: The location of this haul road is expected to change for each of the OSDF stages, the haul road for a preceding phase will be removed in order to allow for progressive construction of OSDF components. The road for each stage will be kept in service for approximately 3 years (corresponding to the expected length of a stage). The location of the haul road for the early stage of OSDF construction is shown in Figure 1.

2. From Operable units to the OSDF battery limit: Parsons is responsible for design of the haul road outside the OSDF battery limits (PARSONS, 1996).

Written by: DGP Date: 17 JAN 96 Reviewed by: DJW Date: 25 Feb 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

25 Feb 96

Calculation Procedure:

The procedure used to design the impacted haul road cross-section is based on two design methods: 1) the AASHTO method for design of low-volume aggregate-surfaced roads (AASHTO, 1993); and 2) the ODOT method for design or flexible pavement (ODOT, 1992). Calculations were performed using a performance period of two weeks. The performance period corresponds to the interval of time for which no road maintenance is required.

- For the AASHTO method, the traffic loading for a given performance period is represented in terms of 18-kip equivalent single axle load (ESAL) applications. The total number of 18-kip ESAL applications along with other input parameters are used with the design charts shown in Figures 2, 3 and 4. A road section is determined which will be serviceable for the duration of the 2 week performance period.

- For the ODOT method, the traffic loading for a given performance period is also represented in terms of 18-kip Equivalent Single Axle Load (ESAL) applications. The method is a modification of the 1986 AASHTO method for flexible pavement design. The total number of 18-kip ESAL applications along with other input parameters are used with the design charts shown in Figures 5 and 6. A road cross-section is determined which will be serviceable for the duration of the 2 week performance period.

Analysis is also performed using both methods to determine the road cross-section requirements for spring-thaw conditions, assuming a performance period of 1 week.

Step 1: Estimate the total 18-kip ESAL applications, $w_{Total\text{-}18}$ for a 2 week performance period. Truck traffic to and from the OSDF are considered. A traffic mix of 75% 20 ton and 25% 40 ton trucks is assumed.

- The following are 18-kip ESAL applications corresponding to the different truck traffic axle load types;

  -$w_{FL\text{-}18}$, for front axle,
  20 and 40 ton trucks hauling impacted rubble to the OSDF; and
  20 and 40 ton trucks hauling impacted soil to the OSDF.
  -$w_{RL\text{-}18}$, for rear axle,
  20 and 40 ton trucks hauling impacted rubble to the OSDF; and
  20 and 40 ton trucks hauling impacted soil to the OSDF.
  -$w_{FE\text{-}18}$, for front axle, empty 20 or 40 ton truck returning to the operable units.
  -$w_{RE\text{-}18}$, for rear axle, empty 20 or 40 ton truck returning to the operable units.

- The following equation (AASHTO, 1993) is used to convert each expected truck axle load type into an equivalent 18-kip ESAL axle load and to sum these loads over the performance period:

$$w_{FL,RL,FE,RE-18} = w_N \left(\frac{N_{FL,FE,RL,RE}}{18} \right)^{4.5} \qquad (1)$$

Where,

$w_{FL,RL,FE,RE-18}$ = the 18-kip ESAL applications for a given truck axle load type.
w_N = the number truck passages to (or from) the OSDF over the performance period.
$N_{FL,RL,FE,RE}$ = a given truck single axle load type, kips
4.5 = coefficient determined from AASHTO axle load equivalency factors (for a terminal serviceability index, p_t of 2.5 and a pavement structural number of 2.5).
18 = an 18-kip equivalent single axle load, kips

- The total 18-kip ESAL applications, $w_{Total-18}$ is calculated for the performance period by summing 18-kip ESAL applications for each of the above truck axle load types, as follows:

$$w_{Total-18} = w_{FL-18} + w_{RE-18} + w_{FE-18} + w_{RE-18} \qquad (2)$$

1.1 The single axle load, N, for each truck axle load type is calculated using the following equation (Caterpillar, 1995):

$$N_{FL,RL,FE,RE} = W_V L_{dist} \qquad (3)$$

Where,

$N_{FL,FL,FE,RE}$ = Single axle load for each truck axle load type.
W_V = Weight of truck and rated load (soil load = 0 for empty truck), see Collection and Verification of Engineering Data (CVED).
L_{dist} = Load distribution for a given truck axle load type, ratio (See CVED).

1.2 Calculate the number of truck passages to (or from) the OSDF, w_N over the performance period, using the following equations:

For 20 ton truck applications:

$$w_{N20-R} = 0.55\frac{V_R\left(1+\frac{S_R}{100}\right)}{V_{20}} \qquad (4a)$$

$$w_{N20-S} = 0.55\frac{V_S\left(1+\frac{S_S}{100}\right)}{V_{20}} \qquad (4b)$$

For 40 ton truck applications:

$$w_{N40-R} = 0.45\frac{V_R\left(1+\frac{S_R}{100}\right)}{V_{40}} \qquad (4c)$$

$$w_{N40-S} = 0.45\frac{V_S\left(1+\frac{S_S}{100}\right)}{V_{40}} \qquad (4d)$$

Where,

0.55,0.45 = coefficients for percentage of material transported by a given truck, based on truck capacity and traffic mix.
w_{N20-R} = number of axle load applications for 20 ton truck hauling rubble.
w_{N20-S} = number of axle load applications for 20 ton truck hauling soil.
w_{N40-R} = number of axle load applications for 40 ton truck hauling rubble.
w_{N40-S} = number of axle load applications for 40 ton truck hauling soil.
V_R = Total volume of rubble to be placed in OSDF (unbulked CY).
V_S = Total volume of soil to be placed in OSDF (bank CY).
S_R = Swell of rubble from unbulked to bulked condition.
S_S = Swell of soil from bank to loose condition.
V_{20} = Capacity of 20 ton truck at rated load (CY).
V_{40} = Capacity of 40 ton truck at rated load (CY).

1.3 Calculate $w_{Total\text{-}18}$ (for placement of all impacted material; i.e. performance period of 9 years), using equation 2 and inputs from equations 1, 3 and 4. Calculate the 18-kip ESAL applications for performance periods of 1 and 2 weeks which correspond to spring-thaw and normal periods of operation, respectively.

Step 2: Select a design cross-section using the AASHTO design charts shown in Figures 2, 3 and 4 (AASHTO, 1993) and $w_{Total\text{-}18}$ (calculated in section 1.3). Analyses are performed considering the normal period of operation (end of spring thaw to end of placement season) assuming a 2 week performance period and for the spring-thaw period of operation assuming a 1 week performance period. A final base layer thickness, $D_{BS\text{-}F}$, and a final subbase thickness, $D_{SB\text{-}F}$, is determined from the analyses.

2.1 Estimate the required base layer thickness, D_{BS}, based on an allowable serviceability loss and an allowable rut depth (see Figures 2 and 3) for both the normal period of operation and the spring-thaw period of operation .

a) Select, for the normal period of operation, D_{BS} from Figure 2 based on allowable serviceability loss, ΔPSI .

Figure 2 requirements:

- Allowable serviceability loss, ΔPSI calculated from selected values of: 1) an initial serviceability index (p_o); and 2) a terminal serviceability index (p_t).
- Resilient modulus of roadbed material, M_R
- Base modulus, E_{BS}
- Allowable 18-kip ESAL applications, W_{18psi}

The following explains how they are obtained.

ΔPSI is defined as the total change in serviceability index. The Serviceability Index is a measure of the ability of the road section to serve the type of traffic using the road.

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- ΔPSI is calculated as follows (AASHTO, 1993);

$$\Delta PSI = p_o - p_t \qquad (5)$$

where,

p_o = the initial serviceability index, serviceability index at time of construction.
p_t = the terminal serviceability index, lowest serviceability index tolerated at the end of the performance period.

- Estimate the resilient modulus of roadbed material, M_R:

The roadbed material is expected to be either compacted brown till or existing brown till. Use lower value of the M_R values determined for compacted and undisturbed brown till material. Values of M_R, for compacted and undisturbed brown till material, are determined based on site specific CBR testing of brown till. (PARSONS, 1995 and COE, 1952). $M_R \alpha$ CBR

- Base Modulus, E_{BS}:

Use value recommended in ODOT (1992) for #304, Aggregate Base (crushed stone).

- Allowable 18-kip ESAL applications , w_{18PSI}:

Corresponds to $w_{Total\text{-}18}$ calculated in step 1, section 3.

b) Select, for the normal period of operation, from Figure 3 a value of D_{BS} based on RD.

Figure 3 requires selection of an allowable rut depth, RD and knowledge of:

- Resilient Modulus of road bed material, M_R,
- Base Modulus, E_{BS}, and
- Allowable 18-kip ESAL applications, w_{18RD}.

which are obtained in the above part a.

A rut depth failure of an aggregate surfaced road refers to deformation of the pavement structure and roadbed support and not simply surface rutting of the base layer (AASHTO, 1993). Hence, after the specified allowable rut depth is reached, an addition of aggregate to the base will likely be required as well as grading of the road surface to regain the initial serviceability of the road.

c) Estimate D_{BS} for spring-thaw operation period using the procedure from the above parts a and b.

Input parameter values are the same as determined for the above section 1 with the following exceptions.

- Allowable 18-kip ESAL applications; w_{18PSI}:

  Corresponds to 1/2 the $w_{Total-18}$ calculated in step 1, section 3. This value corresponds to a 1-week instead of a 2 week performance period.

- Calculate Resilient Modulus of Roadbed Material, M_R for spring thaw conditions.:

  Calculate M_R based on the value of M_R assumed in the above part a.

2.2 Select the required D_{BS-R} value as the maximum value of D_{BS} determined in the above 2.1.

- Add 1 inch to D_{BS} for aggregate loss. Aggregate loss is a reduction of the base layer thickness due to traffic and erosion (AASHTO, 1993).

2.3 Select a final base thickness, D_{BS-F} and convert the difference between D_{BS} and D_{BS-F} to a required subbase thickness, D_{SB} using Figure 4.

Figure 4 requires selection of D_{BS-F} and knowledge of

- Resilient Modulus of road bed material, M_R,
- Base Modulus, E_{BS}, and
- Allowable 18-kip ESAL applications, w_{18PSI}.
- Subbase Modulus, E_{SB}.

which are obtained in the above part a, excepting E_{SB} which is obtained as follows.

- Subbase Modulus, E_{SB}: Use value recommended in ODOT (1992) for #310, subbase aggregate (bank run gravel).

Step 3: Calculate required section using the ODOT design method for flexible pavement design (ODOT, 1992). 25 Feb 96

3.1 Select a design structure number, SN, using Figures 5 and 6 and the following input parameters. The SN is used in Equation 6 to determine the thickness of the road cross-section aggregate layers.

- Reliability, R (%): Reliability is the probability that serviceability will be maintained at an adequate level for the performance period considered. This value will be assumed.

- Overall Standard Deviation, S_0: Overall Standard Deviation is a measure of the variability of input parameters. The value used is as recommended in ODOT (1992).

- Estimated Total 18-kip ESAL Applications, w_{18}: Use values of w_{18} for 2 and 1 week performance periods as calculated in Step 1.

- Effective Roadbed Soil Resilient Modulus, M_R (psi): Use values of M_R for normal and spring-thaw operating periods as calculated for the AASHTO method.

- Design Serviceability Loss, ΔPSI: Use value of ΔPSI determined for the AASHTO method.

- Structural Coefficients: The structural coefficient for a soil is a measure of the relative ability of a material to function as a structural component of the road. Use Structural Coefficient recommended in ODOT (1992) for aggregate base (ODOT spec. #304) and subbase (ODOT spec. #310)

- Asphalt pavement thickness: Assume zero for aggregate-surfaced road.

3.2 Select a Final Base Thickness, D_{BS-F}. Calculate a Required Subbase Thickness, D_{SB} using the following equation;

$$D_{SB} = \frac{(SN - a_{BS} D_{BS-F})}{a_{SB}} \qquad (6)$$

Where,

a_{BS}, a_{SB} = Structural Coefficients for base and subbase aggregate, respectively.

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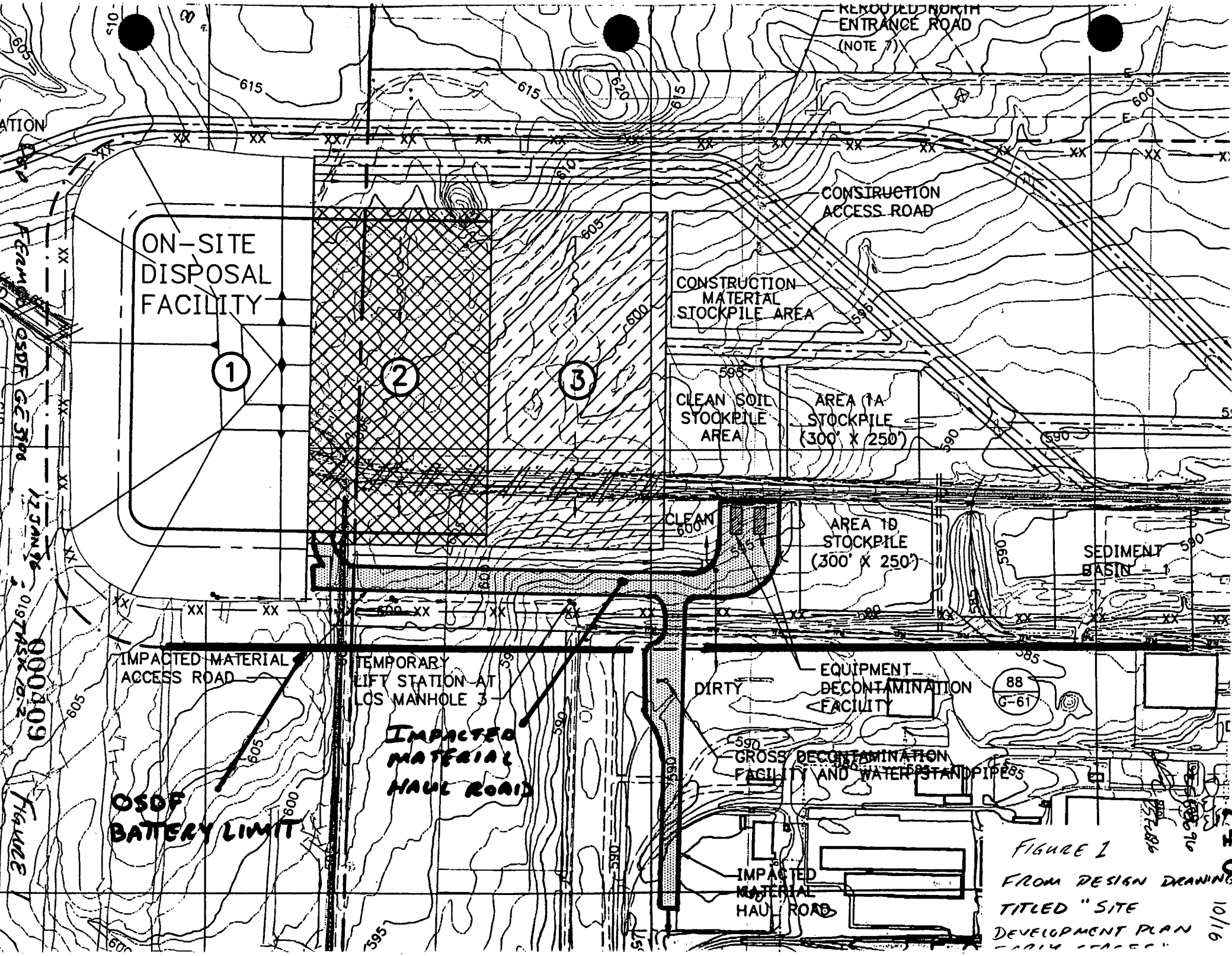
Step 4: Select a final design cross-section based on analysis in Steps 1 to 3.

Select geotextile to act as separator between subbase and base.


REROUTED NORTH ENTRANCE ROAD (NOTE 7)
CONSTRUCTION ACCESS ROAD
ON-SITE DISPOSAL FACILITY
1
2
3
CONSTRUCTION MATERIAL STOCKPILE AREA
CLEAN SOIL STOCKPILE AREA
AREA 1A STOCKPILE (300' X 250')
CLEAN
AREA 1D STOCKPILE (300' X 250')
SEDIMENT BASIN - 1
IMPACTED MATERIAL ACCESS ROAD
TEMPORARY LIFT STATION AT LOS MANHOLE 3
IMPACTED MATERIAL HAUL ROAD
DIRTY
EQUIPMENT DECONTAMINATION FACILITY
88
G-61
GROSS DECONTAMINATION FACILITY AND WATER STANDPIPE
OSDF BATTERY LIMIT
IMPACTED MATERIAL HAUL ROAD
OSDF GC 3704
12 JAN 96
FIGURE 1
FROM DESIGN DRAWING TITLED "SITE DEVELOPMENT PLAN
10/16
240

740

DJW 25Feb96 11/16

DESIGN CHART FOR AASHTO METHOD

KC 25Feb94

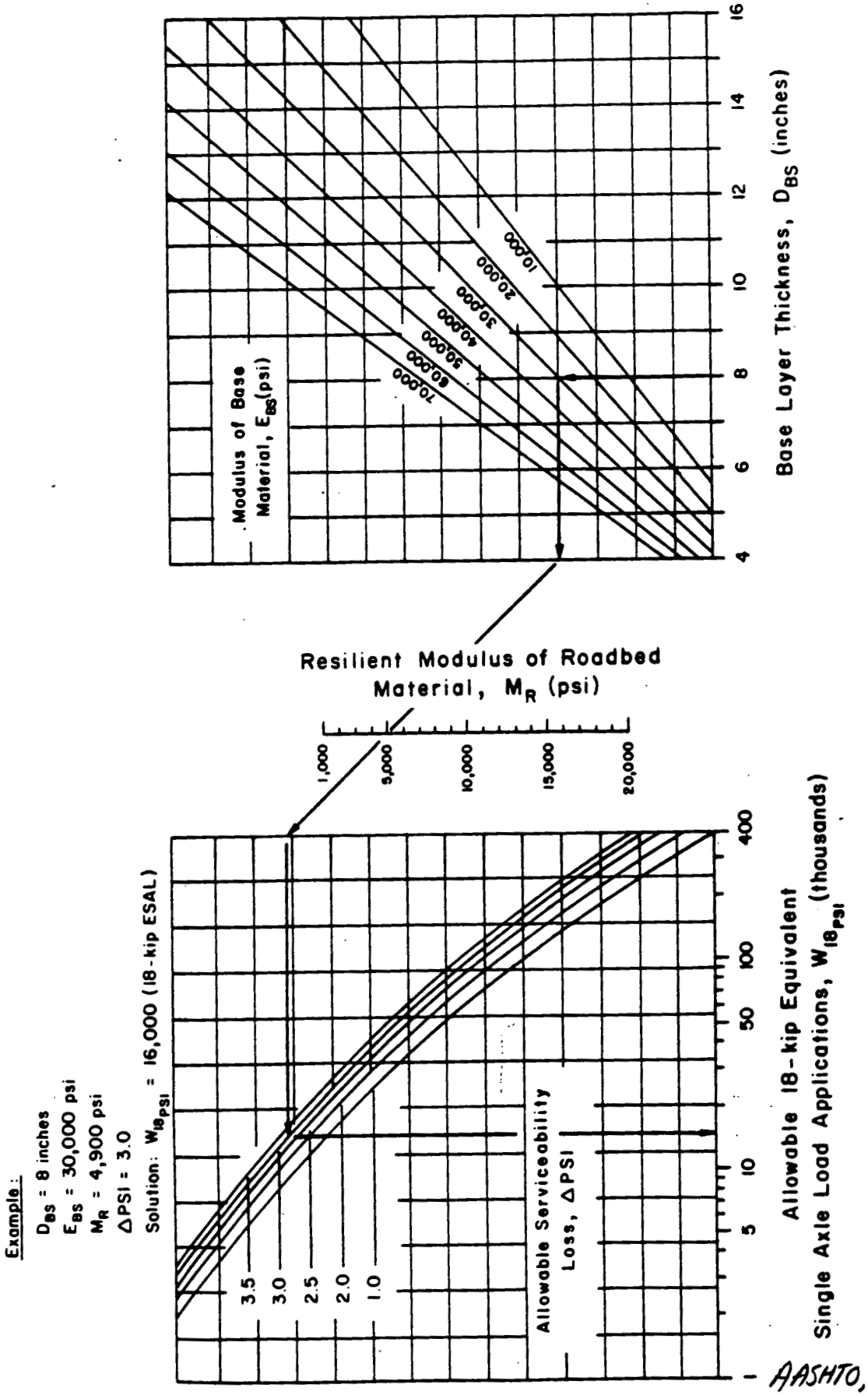


Figure 4.2. Design Chart for Aggregate-Surfaced Roads Considering Allowable Serviceability Loss

– AASHTO, 1993

DANIEL PASS FERMCO/OSDF GE3900 17JAN96 000410 FIGURE 2

DESIGN CHART FOR AASHTO METHOD

740 25Feb96 12/16

25Feb96

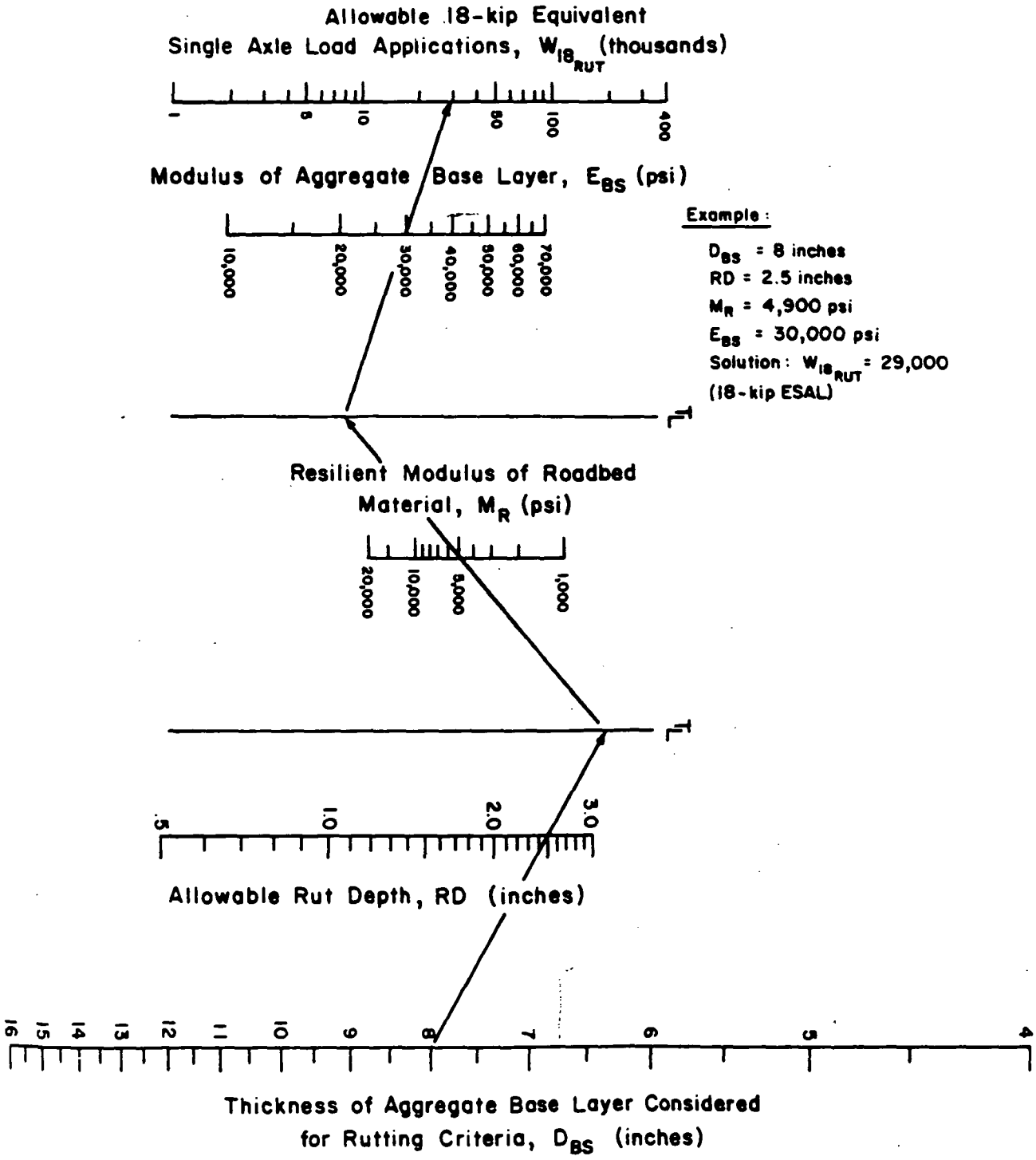


Figure 4.3. Design Chart for Aggregate-Surfaced Roads Considering Allowable Rutting

DANIEL PASS FERMIO/OSDF GE3900 17 JAN 96 000411 AASHTO, 1993 FIGURE 3

DESIGN CHART FOR AASHTO METHOD

740 13/16

25Feb96

25Feb96

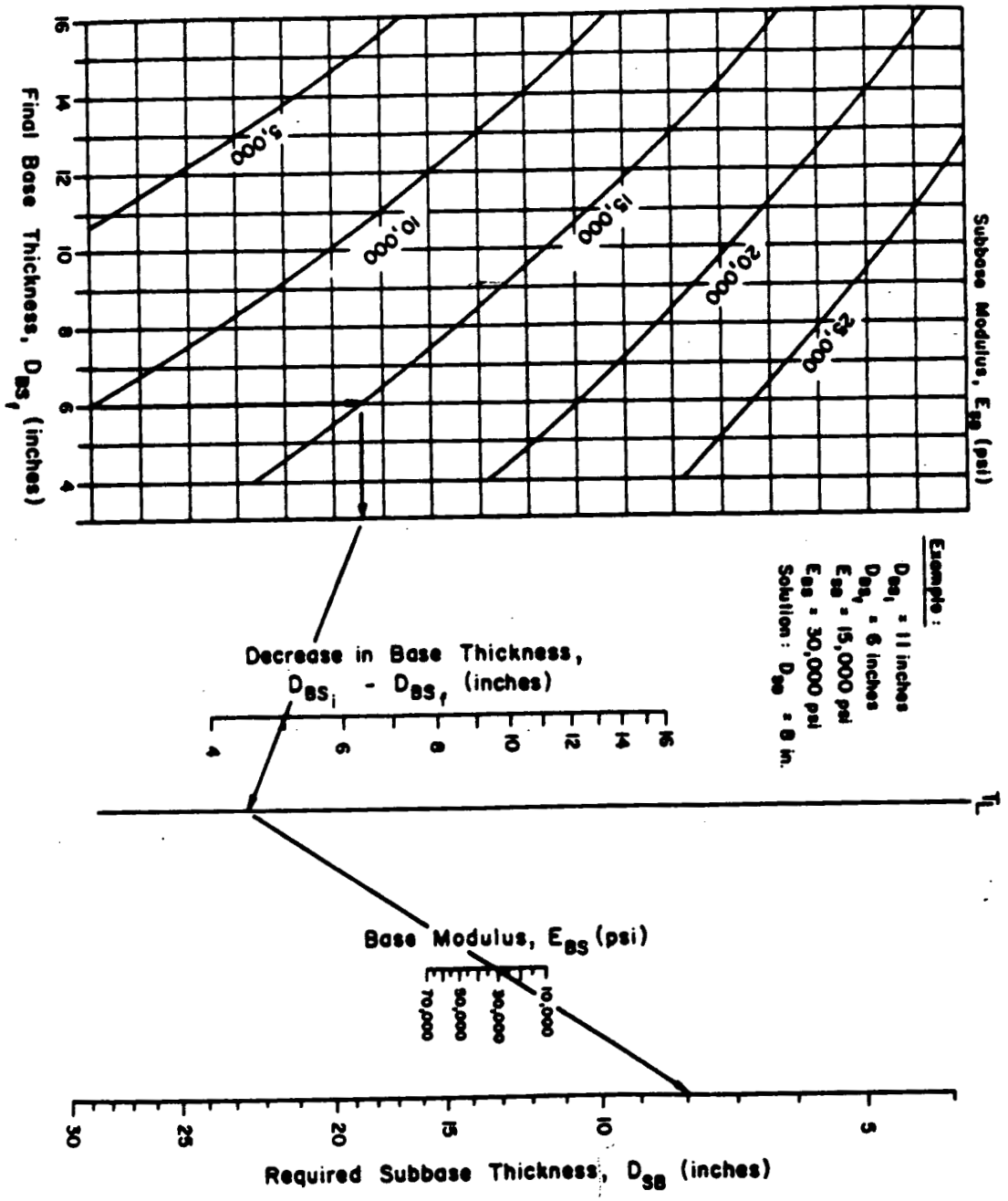


Figure 4.5. Chart to Convert a Portion of the Aggregate Base Layer Thickness To an Equivalent Thickness of Subbase

17 ~~14~~ JAN 96

AASHTO, 1993

DANIEL PASS FERMCO/OSDF GE 3900

000412

FIGURE 4.

DESIGN CHART FOR ODOT METHOD 740 25Feb96 14/16

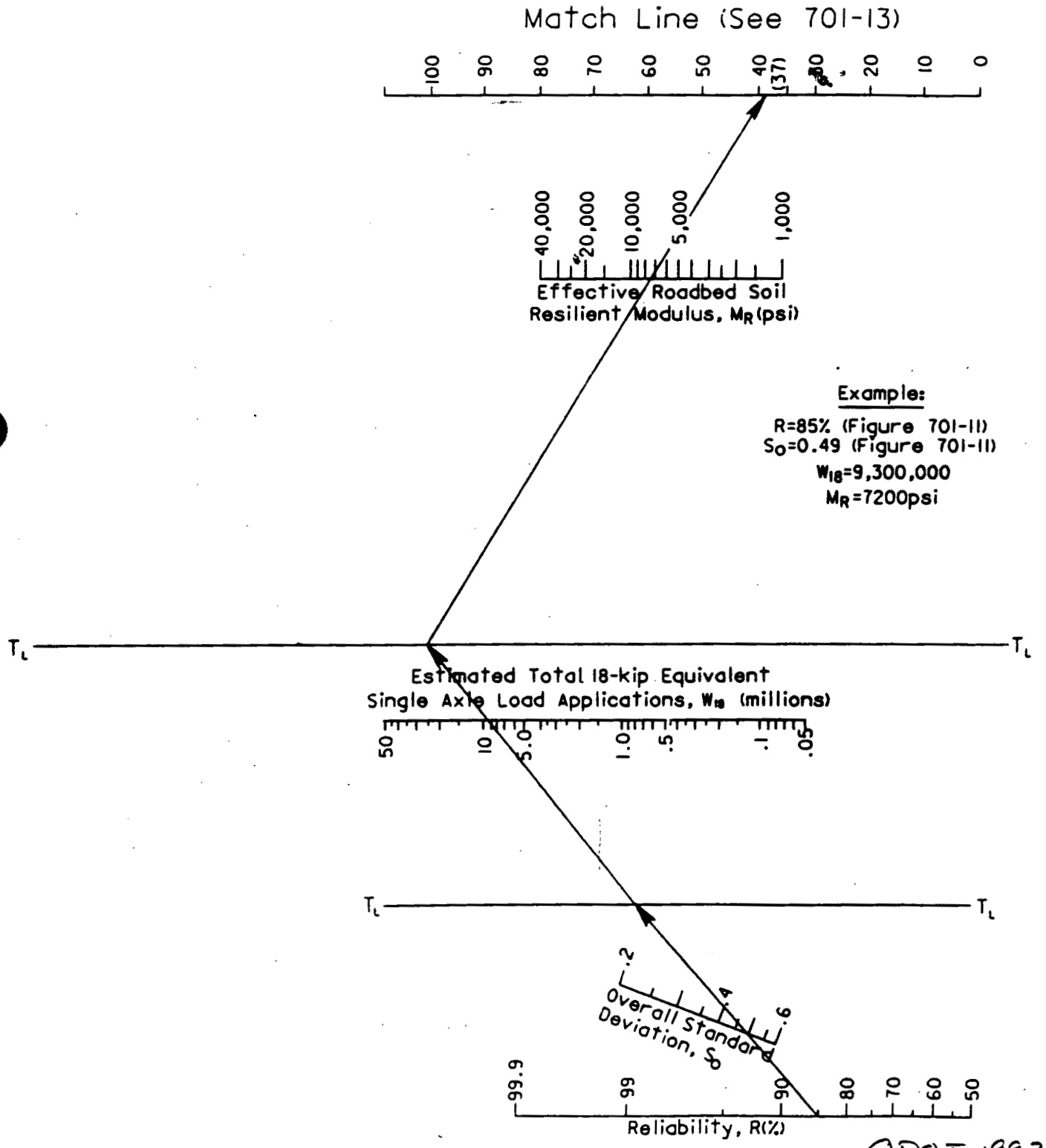
October 1992

FLEXIBLE PAVEMENT DESIGN CHART SEGMENT 1

701-12

REFERENCE SECTION
FLEXIBLE PAVEMENT DESIGN EXAMPLE - STEP 1

25Feb96



ODOT, 1992

DANIEL PASS FERMCO/ODOT GE3900 17 ~~14~~ FEB 96

000413

FIGURE 5

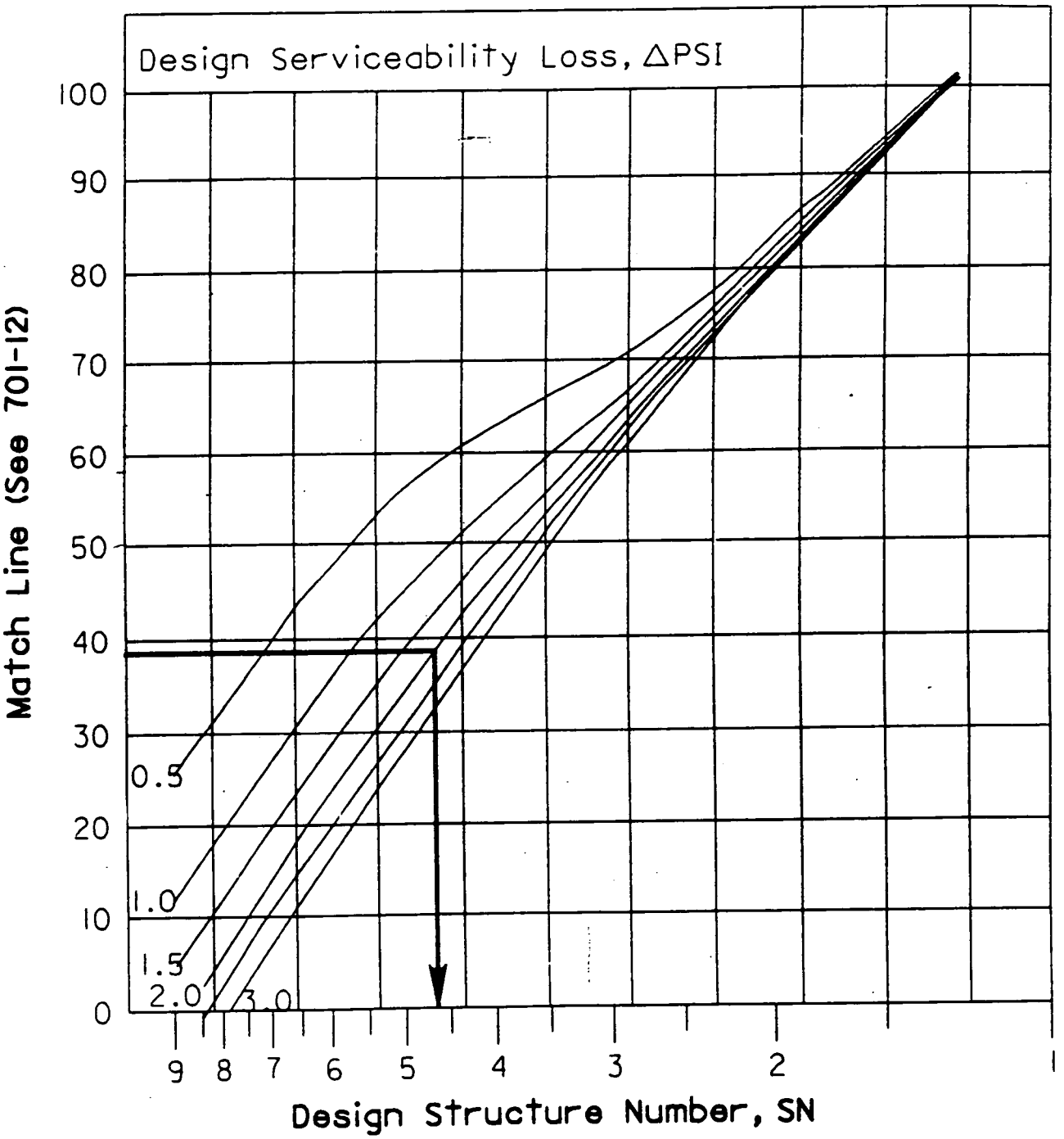
DESIGN CHART FOR ODOT METHOD 740 25 Feb 96 15/16

October 1992 25 Feb 96

FLEXIBLE PAVEMENT DESIGN CHART SEGMENT 2

701-13

REFERENCE SECTION
FLEXIBLE PAVEMENT DESIGN EXAMPLE - STEP 1



Example: ΔPSI = 2.0

Solution: SN = 4.65

ODOT, 1992

DANIEL PASS, FERMICO/OSOF GE3900 17 FEB. 1996 14 FEB 96 000414 FIGURE 6

References:

1. FERMCO, "*$276 Million Plan*", Revision 1, Fernald Environmental Management Corporation, Fernald, Ohio,1995.

2. American Association of State Highway and Transportation Officials (AASHTO). "*AASHTO Guide for Design of Pavement Structures*", AASHTO, Washington, D.C., 1993.

3. Caterpillar, "*Caterpillar Performance Handbook*", 24th ed., Caterpillar, Peoria, Illinois, 1995.

4. US Army Corps of Engineers (COE), "*Report of Foundation Investigation, Feed Materials Production Center,- Fernald, Ohio.*" Ohio River Division Laboratories, Mariemont, OH, 1952.

5. Federal Highway Administration (FHWA), "*Geotextile Engineering Workshop, Design Examples*", FHWA, Washington, D.C., January 1996.

6. GeoSyntec, "*Draft Test Pad Work Plan, On-Site Disposal Facility*", Revision B, GeoSyntec Consultants, Atlanta, GA, January 1996a.

7. GeoSyntec, "*Preliminary Design OSDF Support Plans - Impacted Material Placement Plan*", Revision C, GeoSyntec Consultants, Atlanta, GA, February 1996b.

8. GeoSyntec, "*Preliminary Design Calculation Package, Design Paramter Summary*", Revision C, GeoSyntec Consultants, Atlanta, GA, February 1996c

9. Ohio Department of Transportation (ODOT). "*Location and Design Manual, Volume 1 Roadway Design*", Revision October 1992, ODOT, Columbus, Ohio, 1992.

10. Parsons. "*Geotechnical Investigation Report, On-Site Disposal Facility*", Operable Unit 2, Project Order 140, FERNALD Environmental Management Project, Rev. 0, Cincinnati, OH, 1995.

11. Parsons, "*Haul Road and Rerouted North Entrance Road Design and Construction Calculations*", Operable Unit 2, Project Order 158, FERNALD Environmental Management Project, Rev. Draft, January 1996.

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Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

FC 25Feb96

Data Verification

Step 1: Estimate the total 18-kip Equivalent Single Axle Load applications, $w_{Total\text{-}18}$, for a 2 week performance period.

Design Vehicle:
The following table summarizes input parameters for the design vehicles - Cat D20D (20 ton) and D40D (40 ton) articulated trucks. (Caterpillar, 1993)

Specifications for 20 and 40 ton trucks.

Parameter		20 Ton truck	40 ton truck
Operating Weight		33.1 kip	61.8 kip
Rated Load		40 kip	80 kip
Weight Distribution:			
Empty			
	Front	67%	62%
	Rear	33%	38%
Loaded			
	Front	45%	39%
	Rear	55%	61%
Capacity		12.7CY (Struck)	29.3 CY (Struck)

- Capacity of design vehicles: Assume load is struck.

20 ton truck hauling rubble: The weight of the rubble hauled in a 20 ton truck is controlled by the struck capacity, assuming a concrete unit weight of 150 PCF, swell of 100% and struck capacity of 12.7 Loose CY. The capacity of the truck is = 19.6 kip.

20 ton truck hauling soil: The weight of soil hauled in a 20 ton truck is controlled by the struck capacity, assuming a soil unit weight of 135 PCF, swell of 25% and struck capacity of 12.7 Loose CY. The capacity of the truck is = 28.3 kip.

40 ton truck hauling rubble: The weight of rubble hauled in a 40 ton truck is controlled by the struck capacity, assuming a concrete unit weight of 150 PCF, swell of 100% and a struck capacity of 29.3 Loose CY. The capacity of the truck is = 44.8 kip.

40 ton truck hauling soil: The weight of soil hauled in a 40 ton truck is controlled by the struck capacity, assuming a soil unit weight of 135 PCF, swell of 25% and a struck capacity of 29.3 Loose CY. The capacity of the truck is = 64.4 kip.

Impacted Material to be placed:

- Total volume of expected impacted soil from the $276 Million Plan (FERMCO, 1995): V_s=2,360,251 Bank CY.
- Total volume of expected impacted rubble from the $276 Million Plan: V_R=274,615 Unbulked CY.
- Assume total volume of impacted material is placed at a constant rate over a 9 year period. Placement season is 9 months per year.

Impacted Material Characteristics:

- Swell, S: Swell of impacted rubble from unbulked to bulked condition is assumed as 100% (GeoSyntec, 1996b)
- Swell, S: Swell of impacted soil from bank to loose condition is assumed as 25% (Caterpillar, 1993b)
- Unbulked Unit Weight of impacted rubble: 150 pcf assumed as typical for concrete.
- Bank Unit Weight of soil: 135 pcf (GeoSyntec, 1996c).

Step 2: For determination of a design road cross-section using the AASHTO design method.

Allowable Serviceability Loss, ΔPSI:

- Initial Serviceability Index, p_o: Assume p_0 4.2 (recommended for flexible pavements [AASHTO, 1993])
- Terminal Serviceability Index, p_t : Assume p_t = 2.0 (recommended for rural roads [AASHTO, 1993])

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Resilient Modulus of Roadbed Material, M_R:

- For normal period of operation (period from end of spring-thaw to end of placement period): Use value of 5,400 psi based on correlation of cone penetration testing (CPT) results to CBR results (Parsons, 1995) for undisturbed upper and lower horizon brown till and using the following equation (ODOT, 1992):

$$M_R = 1200CBR \qquad (7)$$

  CBR values from correlation by Parsons average between 4 and 5. CPT soundings were conducted at locations within the East Field borrow area and OSDF battery limits.

- For spring thaw period of operation: assume a 50% reduction in M_R from normal period of operation.

Note: Values of M_R for compacted brown till are expected to be higher than values of M_R for undisturbed brown till. This is based on the results of two test programs:

- PARSONS' (1995) testing program: Upper horizon brown till samples were compacted to 95% of standard Proctor. Measured values of CBR ranged from 1.95 to 4.4. The corresponding M_R range is 2,340 to 5,280 psi.

- US Army Corps of Engineers' (1952) testing program: Brown till samples were compacted to 100% of standard Proctor. Measured value of CBR was 8. The corresponding value of M_R is 9,600 psi.

The average value of M_R for upper horizon brown till compacted to 95% of standard Proctor (3,600 psi) is lower than the M_R value of undisturbed brown till selected for design. On this basis compacted brown till used for road fill must be compacted using a higher compactive effort (i.e., 100% of standard Proctor or higher). The lower horizon brown till exhibits a higher measured maximum dry density than the upper horizon material. (GeoSyntec, 1996a).

Base Modulus, E_{BS}: Assume 304, Aggregate Base, E_{SB}=30,000 psi (ODOT, 1992)..

Allowable $w_{18\text{-}PSI}$: Calculated using p_0 and p_t.

Allowable rut depth: Assume 3 in. (The road will largely be confined to off-highway vehicles).

Subbase Modulus, E_{SB}: Assume ODOT spec. 310, Aggregate Subbase, E_{SB} 15,000 psi (ODOT, 1992)

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Step 3: For determination of design cross-section using the ODOT method (ODOT, 1992).

- Reliability, R: 50% to 80% is recommended for low volume roads; Assume value of 70%.

- Overall Standard Deviation, S_0: Assume value of 0.49 as recommended for flexible pavements in ODOT, 1992.

- Estimated Total 18-kip ESAL Applications, w_{18}: Obtain from calculation in Step 1.3.

- Effective Roadbed Soil Resilient Modulus, M_R: Use values estimated in step 2; for normal operating and spring thaw periods; M_R = 5,400 psi, and 2,700 psi, respectively.

- Design Serviceability Loss, ΔPSI.

$$\Delta PSI = p_o - p_i = 4.2 - 2.0 = 2.2 \text{ (Step 2)}$$

- Structural Coefficients: Use values recommended in ODOT (1992) for materials selected for base and subbase, as follows;

  Aggregate base (#304) = 0.14.
  Subbase (#310) = 0.11.

- Asphalt pavement thickness: Assume zero for aggregate-surfaced road.

Written by: DGP Date: 2 FEB 96 Reviewed by: DWW Date: 25 Feb 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.4

25 Feb 96

References:

1. FERMCO, "*$276 Million Plan*", Revision 1, Fernald Environmental Management Corporation, Fernald, Ohio,1995.

2. American Association of State Highway and Transportation Officials (AASHTO). "*AASHTO Guide for Design of Pavement Structures*", AASHTO, Washington, D.C., 1993.

3. Caterpillar, "*Caterpillar Performance Handbook*", 24th ed., Caterpillar, Peoria, Illinois, 1995.

4. US Army Corps of Engineers (COE), "*Report of Foundation Investigation, Feed Materials Production Center,- Fernald, Ohio.*" Ohio River Division Laboratories, Mariemont, OH, 1952.

5. Federal Highway Administration (FHWA), "*Geotextile Engineering Workshop, Design Examples*", FHWA, Washington, D.C., January 1996.

6. GeoSyntec, "*Draft Test Pad Work Plan, On-Site Disposal Facility*", Revision B, GeoSyntec Consultants, Atlanta, GA, January 1996a.

7. GeoSyntec, "*Preliminary Design OSDF Support Plans - Impacted Material Placement Plan*", Revision C, GeoSyntec Consultants, Atlanta, GA, February 1996b.

8. GeoSyntec, "*Preliminary Design Calculation Package, Design Paramter Summary*", Revision C, GeoSyntec Consultants, Atlanta, GA, February 1996c

9. Ohio Department of Transportation (ODOT). "*Location and Design Manual, Volume 1 Roadway Design*", Revision October 1992, ODOT, Columbus, Ohio, 1992.

10. Parsons. "*Geotechnical Investigation Report, On-Site Disposal Facility*", Operable Unit 2, Project Order 140, FERNALD Environmental Management Project, Rev. 0, Cincinnati, OH, 1995.

11. Parsons, "*Haul Road and Rerouted North Entrance Road Design and Construction Calculations*", Operable Unit 2, Project Order 158, FERNALD Environmental Management Project, Rev. Draft, January 1996.

Written by: DGP Date: 96/2/12 (YY/MM/DD) Reviewed by: DWW Date: 96/02/25 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

CALCULATIONS AND RESULTS: INPUT PARAMETERS ARE TAKEN FROM THE DATA VERIFICATION SECTION.

STEP 1: CALCULATE THE TOTAL 18-KIP EQUIVALENT SINGLE AXLE LOAD APPLICATIONS, W_{18-J}: FOR 1 AND 2 WEEK PEFORMANCE PERIODS, TRUCK TRAFFIC TO AND FROM THE OSDF ARE CONSIDERED. W_{18-1WK} AND W_{18-2WK}

1.1) CALCULATE THE SINGLE AXLE LOAD, N FOR EACH TRUCK AXLE LOAD TYPE USING THE FOLLOWING EQUATION:

$$N_{DL,RL,DE,RE} = W_V L_{DIST}$$

a) CALCULATE TRUCK WEIGHTS; W_V

20 TON TRUCK WITH RUBBLE LOAD = OPERATING WEIGHT + LOAD CAPACITY

= 33.1 kip + 19.6 kip

= 52.7 kip

20 TON TRUCK WITH SOIL LOAD = 33.1 kip + 28.3 kip

= 61.4 kip

40 TON TRUCK WITH RUBBLE LOAD = 61.8 kip + 44.8 kip

= 106.6 kip

40 TON TRUCK WITH SOIL LOAD = 61.8 kip + 64.4 kip

= 126.2 kip

b) CALCULATE SINGLE AXLE LOADS, N

N_{FL}, FRONT AXLE, 20 TON TRUCK WITH RUBBLE LOAD

= 52.7 kip × 0.45

= 23.7 kip

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STEP 1, CONT'D: CALCULATE W_{18-1WK} AND W_{18-2WK}

1.1, CONTD) CALCULATE N

SINGLE AXLE LOADS, N FOR EACH TRUCK AXLE LOAD TYPE ARE CALCULATED AS IN THE ABOVE EXAMPLE AND ARE PRESENTED IN THE FOLLOWING TABLE.

SINGLE AXLE LOADS, N FOR TRAFFIC.

TRUCK - LOAD	Wv - kip TRUCK WEIGHT,	AXLE	LOAD - Ldist DISTRIBUTION	CALCULATED SINGLE AXLE LOAD, N (kip)
20 TON - Rubble	52.7 kip	FRONT	45%	23.7
		REAR	55%	29.0
- Soil	61.4 kip	FRONT	45%	27.6
		REAR	55%	33.8
EMPTY	33.1 kip	FRONT	67%	22.2
		REAR	33%	10.9
40 TON - Rubble	106.6 kip	FRONT	39%	41.6
		REAR	61%	65.0
Soil	126.2 kip	FRONT	39%	49.2
		REAR	61%	77.0
EMPTY	61.8 kip	FRONT	62%	38.3
		REAR	38%	23.5

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STEP 1, CONT'D: CALCULATE $W_{18\text{-}1WK}$ AND $W_{18\text{-}2WK}$

1.2) CALCULATE THE NUMBER OF PASSAGES AS FOLLOWS:

a) FOR 20 TON TRUCKS:

RUBBLE LOAD: $W_{N20\text{-}R} = 0.55 \dfrac{V_R(1+S_R)}{V_{20}}$

SOIL LOAD: $W_{N20\text{-}S} = 0.55 \dfrac{V_S(1+S_S)}{V_{20}}$

b) FOR 40 TON TRUCKS:

Rubble Load: $W_{N40\text{-}R} = 0.45 \dfrac{V_R(1+S_R)}{V_{40}}$

SOIL LOAD: $W_{N40\text{-}S} = 0.45 \dfrac{V_S(1+S_R)}{V_{40}}$

RESULTS ARE PRESENTED IN THE FOLLOWING TABLE:

NUMBER OF PASSAGES FOR TRAFFIC.

TRUCK-LOAD	TRUCK CAPACITY (CY) $V_{20,40}$	MATERIAL VOL (CY) V_R, V_S	SWELL S_R, S_S	# OF PASSAGES W_N
20 TON - RUBBLE	12.7	274,615 UNBULKED	100%	23,786 ✓
- SOIL	12.7	2,360,251 BANK	25%	127,769 ✓
- EMPTY	—	—	—	151,555 ✓
40 TON - RUBBLE	29.3	274,615 UNBULKED	100%	8,435 ✓
SOIL	29.3	2,360,251 BANK	25%	45,312 ✓
EMPTY	—	—	—	53,747 ✓

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Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

STEP 1, CONTD: CALCULATE $W_{18\text{-}1WK}$ AND $W_{18\text{-}2WK}$

1.3) CALCULATE the TOTAL 18-KIP ESAL APPLICATIONS, $W_{TOTAL\text{-}18}$ FOR TRAFFIC USING THE FOLLOWING EQUATION:

$$W_{18} = W_N \left(\frac{N}{18}\right)^{4.3}$$

$W_{TOTAL\text{-}18}$ = SUM OF W_{18} FOR ALL AXLE LOAD TYPES.

VALUES OF W_N ARE FROM the TABLE IN SECTION 1.2.
VALUES OF N ARE FROM THE TABLE IN SECTION 1.1.
RESULTS ARE PRESENTED IN THE FOLLOWING TABLE.

18-KIP ESAL APPLICATIONS FOR PLACEMENT OF ALL IMPACTED MATERIAL.

TRUCK-LOAD	AXLE	# OF PASSAGES, W_N	SINGLE AXLE LOAD, N	18-KIP ESAL, W_{18}
20 TON - RUBBLE	FRONT	23,786	23.7	77,637 ✓
	REAR		29.0	184,910 ✓
- SOIL	FRONT	127,769	27.6	802,908 ✓
	REAR		33.8	1,919,091 ✓
- EMPTY	FRONT	151,555	22.2	373,436 ✓
	REAR		10.9	17,532 ✓
40 ton - Rubble	FRONT	8,435	41.6	309,396 ✓
	REAR		65.0	2,108,340 ✓
SOIL	FRONT	45,312	49.2	3,419,727 ✓
	REAR		77.0	23,466,676 ✓
EMPTY	FRONT	53,747	38.3	1,381,775 ✓
	REAR		23.5	169,151 ✓

TOTAL $W_{TOTAL\text{-}18}$ = 34,230,588 ✓

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Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

STEP 1, CONT'D: CALCULATE $W_{18\text{-}1WK}$ AND $W_{18\text{-}2WK}$

1.3, CONT'D) CALCULATE $W_{TOTAL\text{-}18}$

CALCULATE W_{18} FOR PERFORMANCE PERIODS OF 1 WEEK AND 2 WEEKS AS FOLLOWS

$$W_{18\text{-}1WK} = W_{TOTAL\text{-}18} \Big/ \left(\#\text{ WKS FOR PLACEMENT OF ALL IMPACTED MATERIALS}\right)$$

$$W_{18\text{-}1WK} = 34{,}230{,}588 / (9 \text{ YRS} \cdot 3 \text{ QUARTERS} \cdot 13 \text{ WEEKS/QUARTER})$$

$$= 97{,}523 \approx 98{,}000$$

$$W_{18\text{-}2WK} = 97{,}523 \times 2$$

$$= 195{,}046 \approx 195{,}000$$

STEP 2: DESIGN A TYPICAL ROAD CROSSSECTION USING THE AASHTO DESIGN METHOD

2.1) DETERMINE THE REQUIRED AGGREGATE BASE LAYER THICKNESS, D_{BS} BASED ON ANALYSIS FOR NORMAL PERIODS OF OPERATION AND THE SPRING-THAW PERIOD OF OPERATION

NORMAL PERIOD OF OPERATION:

a) DETERMINE D_{BS} BASED ON AN ALLOWABLE SERVICABILITY LOSS ΔPSI

- $\Delta PSI = P_0 - P_t$

  $= 4.2 - 2.0$

  $= 2.2$

- RESILIENT MODULUS OF ROADBED MATERIAL, $M_R = 5400$ psi
- BASE MODULUS; $E_{BS} = 30{,}000$ psi
- ALLOWABLE 18-KIP EASL APPLICATIONS, $W_{18\text{-}2WKS} \approx 195{,}000$

FROM FIGURE 1 AND THE ABOVE PARAMETER VALUES, $D_{BS} = 18.5$ IN

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STEP 2, CONT'D: DESIGN A CROSS SECTION USING AASHTO METHOD

2.1, CONT'D) DETERMINE D_{BS}

b) DETERMINE D_{BS} BASED ON AN ALLOWABLE RUT DEPTH, RD

RD = 3 IN

FROM FIGURE 2 AND THE INPUT PARAMETERS IN 2.1.a

D_{BS} = 14.5 IN. ✓

SPRING THAW PERIOD OF OPERATION:

c) DETERMINE D_{BS} FOR SPRING-THAW OPERATION PERIOD BASED ON ΔPSI AND RD. A ONE WEEK PERFORMANCE PERIOD IS ASSUMED.

- ALLOWABLE 18-KIP ESAL APPLICATIONS, W_{18} PSI

  ~ 98,000 APPLICATIONS

- RESILIENT MODULUS FOR ROADBED MATERIAL, M_R

  = 5,400 PSI/2

  = 2,700 PSI ✓

FROM FIGURE 1 AND THE ABOVE INPUT PARAMETERS (AND PARAMETERS FROM 2.1.a

D_{BS} = 18.0 IN. ✓

FROM FIGURE 2 AND THE ABOVE INPUT PARAMETERS (AND PARAMETERS FROM 2.1.b

D_{BS} = 15.3 IN ✓

2.2) SELECT FROM SECTION 2.1 THE LARGEST VALUE OF D_{BS}. DETERMINE A REQUIRED D_{BS}.

MAX D_{BS} = 18.5 IN ✓

ADD 1 IN FOR AGGREGATE LOSS; REQUIRED D_{BS} = 19.5 IN ✓

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STEP 2, CONT'D: DESIGN A CROSSSECTION USING THE AASHTO METHOD

2.3) ASSUME A FINAL BASE THICKNESS, D_{BS-F} AND CONVERT THE DIFFERENCE BETWEEN D_{BS} AND D_{BS-F} TO AN EQUIVALENT THICKNESS OF SUBBASE, D_{SB}.

- ASSUME D_{BS-F} AS 9 IN.
- $D_{BS} - D_{BS-F} = 19.5 - 9 \text{ IN} = 10.5 \text{ IN}$ ✓
- SUBBASE MODULUS, $E_{SB} = 15{,}000$ psi
- FROM FIGURE 3 THE ABOVE PARAMETERS AND PARAMETERS FROM 2.1 THE EQUIVALENT THICKNESS OF SUBBASE IS 12.2 in ✓

STEP 3: SELECT A DESIGN CROSS SECTION USING THE ODOT DESIGN METHOD (ODOT, 1992)

SELECT A DESIGN STRUCTURAL NUMBER, SN USING FIGURES 4 AND 5 WITH THE FOLLOWING PARAMETER VALUES.

RELIABILITY, $R = 70\%$
OVERALL STANDARD DEVIATION, $S_0 = 0.49$
ESTIMATED TOTAL 18-KIP ESAL APPLICATIONS, W_{18}
NORMAL PERIOD OF OPERATION $W_{18-2WK} \sim 195{,}000$
STRING-THAW PERIOD OF OPERATION $W_{18-1WK} \sim 98{,}000$
EFFECTIVE ROADBED RESILIENT MODULUS, M_R
NORMAL PERIOD OF OPERATION, $M_R = 5{,}400$
STRING-THAW PERIOD OF OPERATION, M_R 2,700
DESIGN SERVICABILITY LOSS, $\Delta PSI = 2.2$

3.1) SELECT SN FOR NORMAL PERIOD OF OPERATION

FROM FIGURES 4 AND 5.

$SN \sim 2.6$, SELECT $SN = 2.7$ ✓

3.2) ASSUME A FINAL BASE THICKNESS, D_{BS-F}. CALCULATE THE REQUIRED SUBBASE THICKNESS, D_{SB} USING THE FOLLOWING EQUATION

$$D_{SB} = \frac{SN - a_{BS} D_{BS-F}}{a_{SB}}$$

Written by: DGP Date: 96/2/12 Reviewed by: DWW Date: 96/02/25

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

STEP 3, CONT'D: DESIGN A CROSS-SECTION USING THE ODOT METHOD.

3.2 CONT'D) ASSUME D_{BS-F} AND CALCULATE D_{SB}

$a_{BS} = 0.14$

$a_{SB} = 0.11$

$D_{BS-F} = 9$ IN

FROM THE ABOVE EQUATION $D_{SB} = 13.1$ IN ✓

3.3) SELECT A SN FOR THE SPRING-THAW PERIOD OF OPERATION.

FROM FIGURES 4 AND 5 AND

$W_{18} = 97{,}523$

$M_R = 2{,}700$ psi

$SN = 3.0$

$\therefore D_{BS} = 15.8$ IN ≈ 16 IN. ✓ (FOR SPRING THAW OPERATION)

STEP 4: SELECT A FINAL CROSS-SECTION BASED ON DESIGN SECTIONS SELECTED USING THE AASHTO AND ODOT METHODS. (STEPS 2 AND 3)

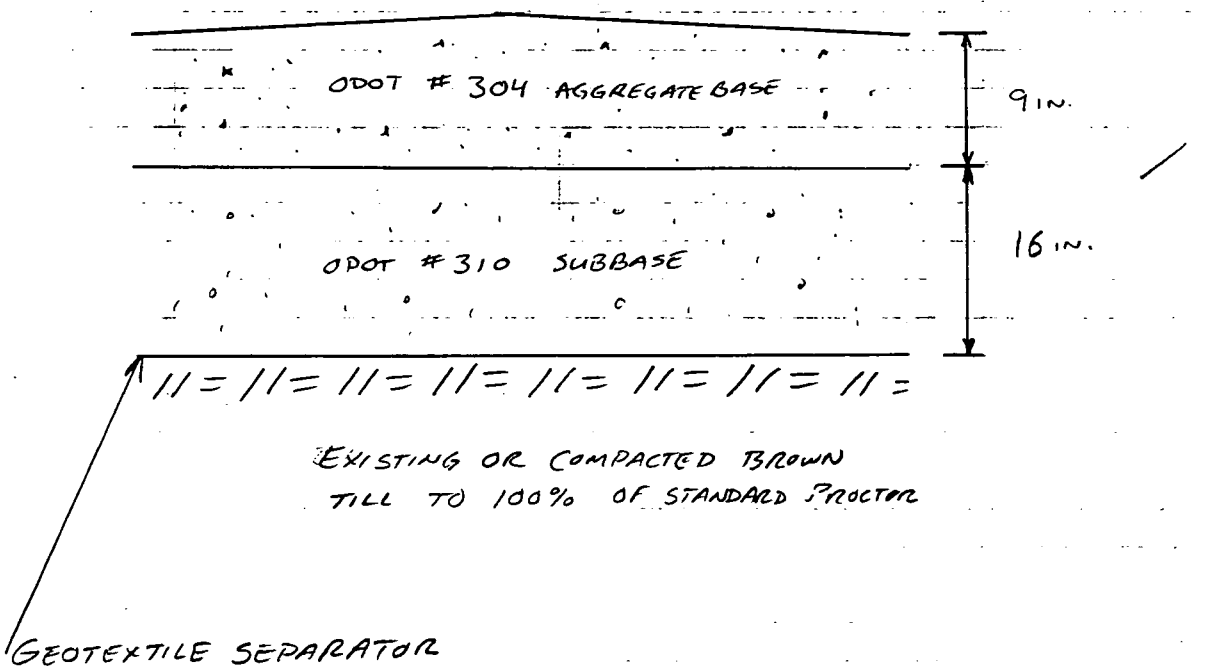
METHOD	D_{BS-F}	D_{SB}	
AASHTO METHOD	9	13.0 IN.	✓ NORMAL OPERATION
ODOT METHOD	9	16.0 IN.	✓ SPRING-THAW

Written by: DGP Date: 96 / 2 / 12 (YY MM DD) Reviewed by: DWW Date: 96 / 02 / 25 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 10.2

STEP 4, CONT'D: SELECT A FINAL CROSS-SECTION

SELECT THE FOLLOWING CROSS-SECTION:



Example:

D_{BS} = 8 inches
E_{BS} = 30,000 psi
M_R = 4,900 psi
ΔPSI = 3.0
Solution: $W_{18_{PSI}}$ = 16,000 (18-kip ESAL)

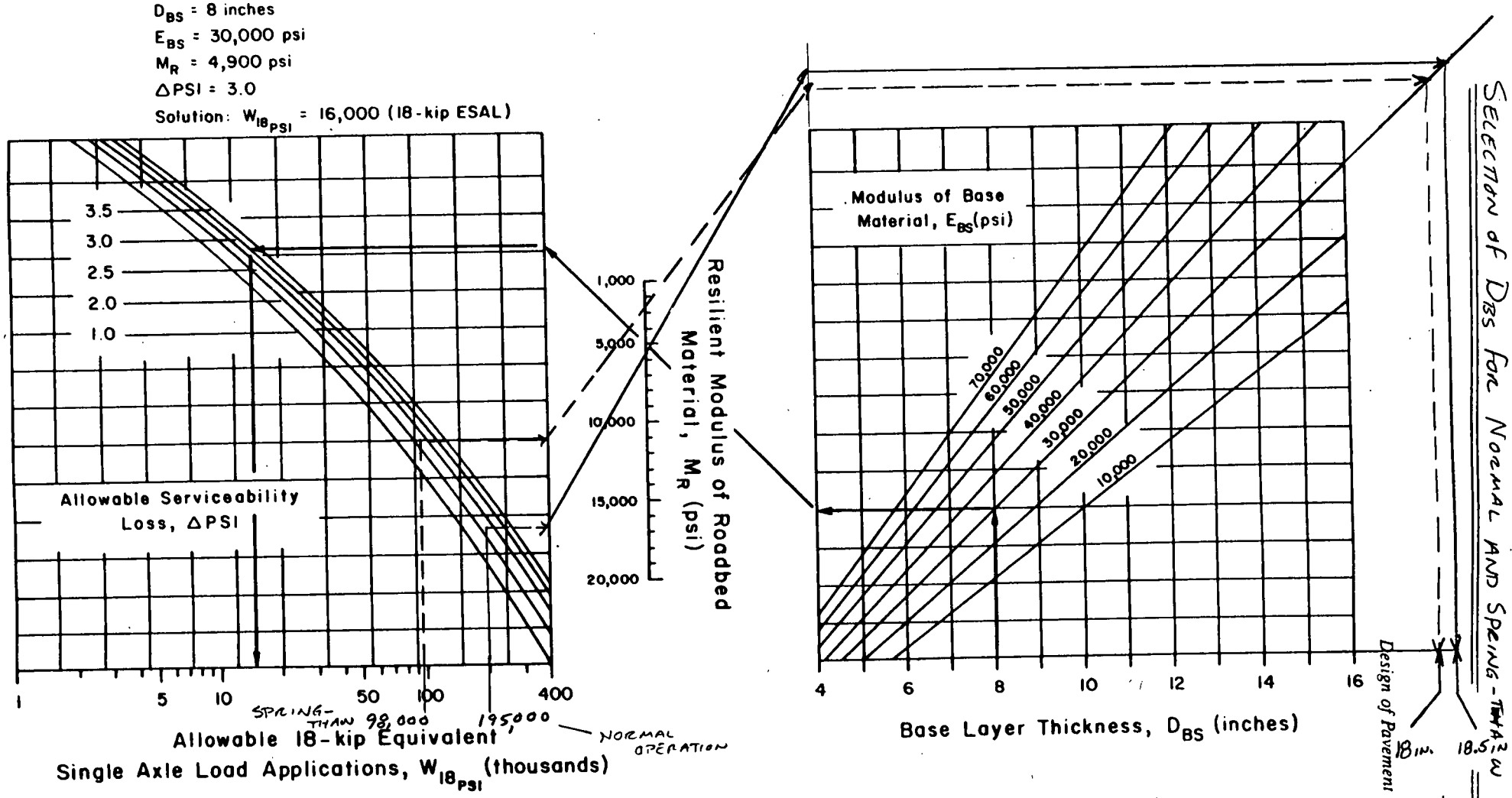


Figure 4.2. Design Chart for Aggregate-Surfaced Roads Considering Allowable Serviceability Loss

FROM AASHTO, 1993

000430

FIGURE 1

DANIEL PASS FERMCO, OSDF, GE3900 TASK #10.2 12 FEB96

10/14

740

SELECTION OF D_{BS} FOR NORMAL AND SPRING-THAW OPERATION AND RD = 3IN.

11/14/6 DWW 25 FEB 96

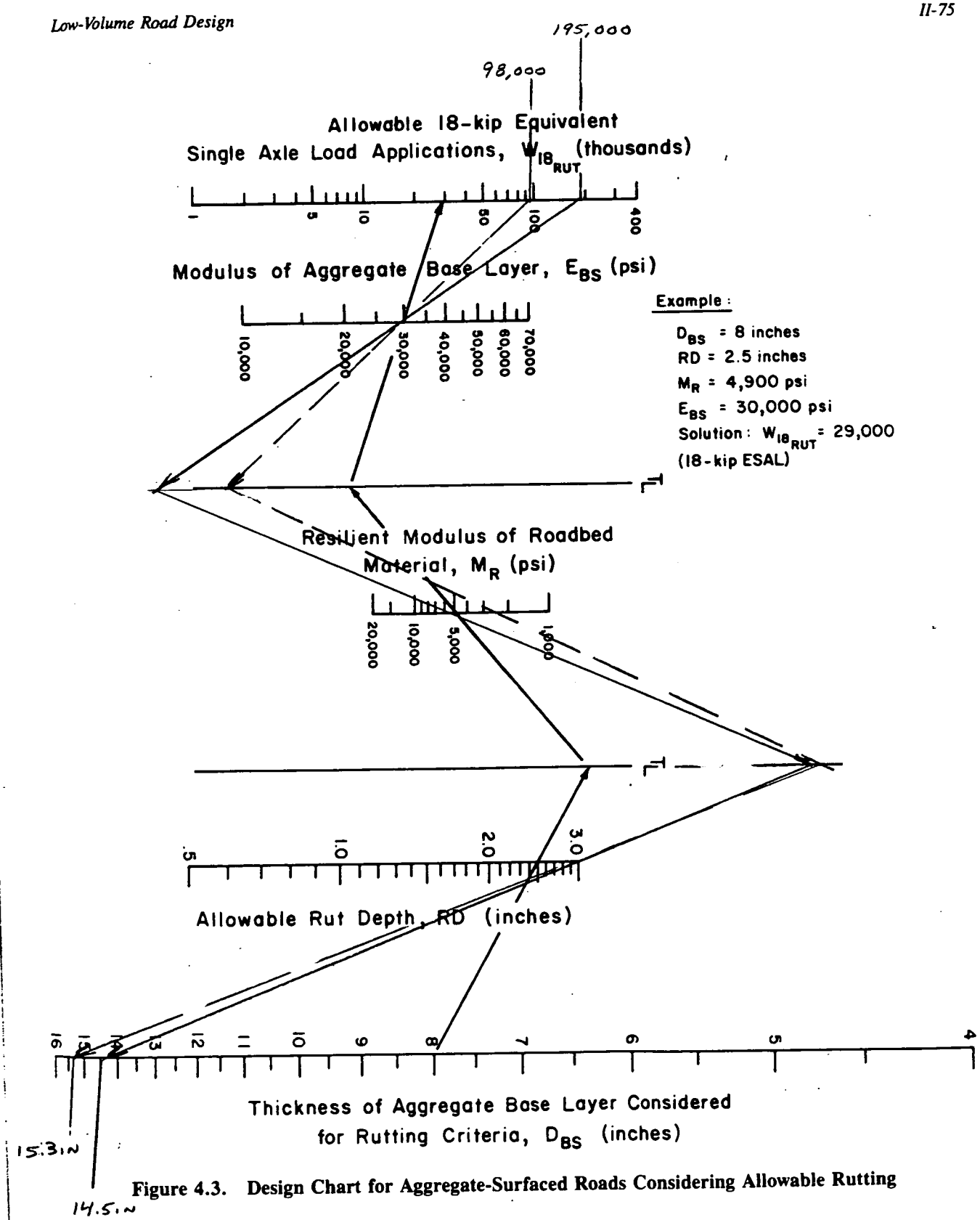


Figure 4.3. Design Chart for Aggregate-Surfaced Roads Considering Allowable Rutting

FROM AASHTO, 1993

000431

DANIEL PASS FERMCO, OSDF GE3900 12 FEB 96 TASK 910.2 FIGURE 2

740 12/14

SELECTION OF D_{SB} FOR AASHTO METHOD

DWW 25Feb96

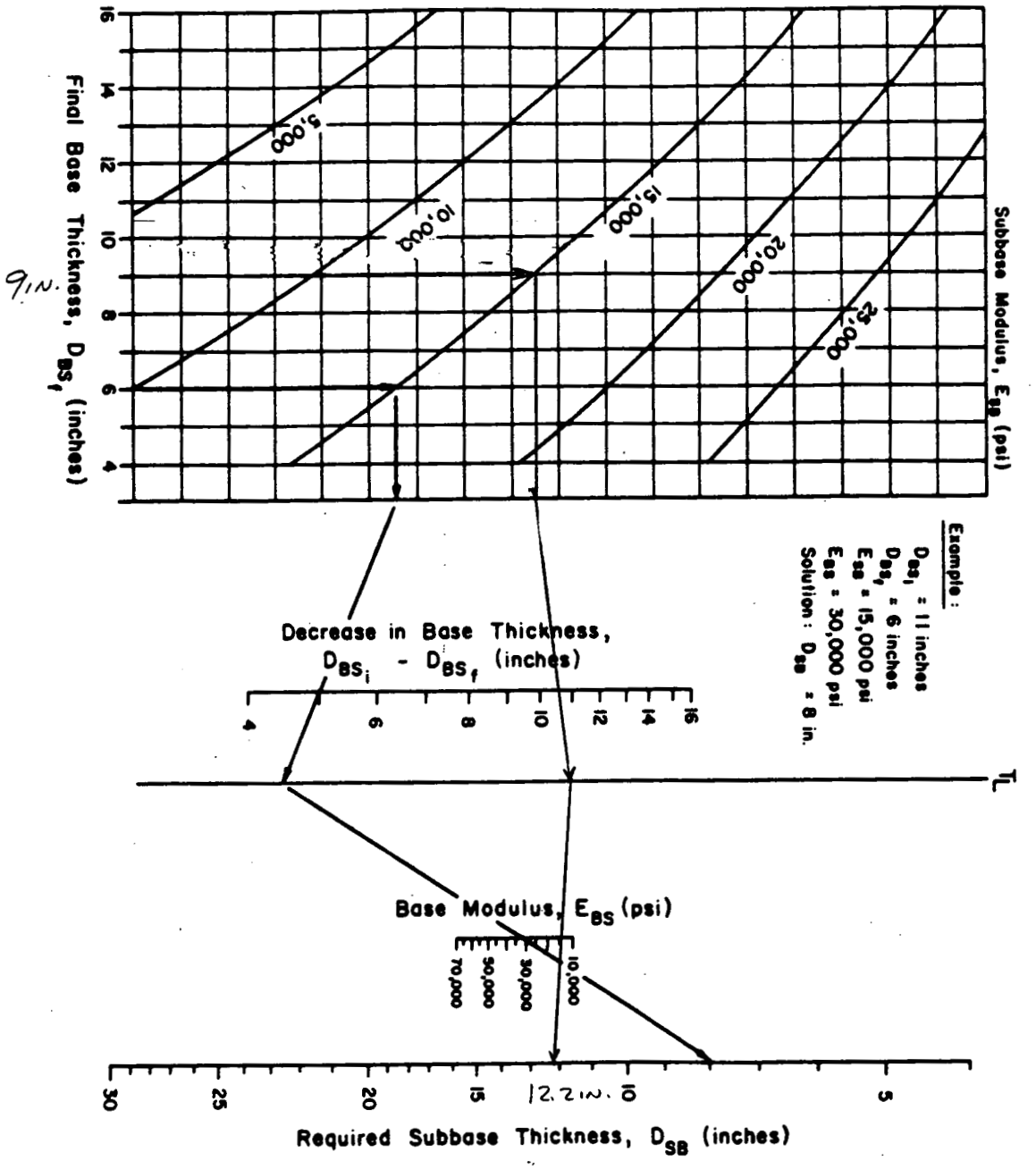


Figure 4.5. Chart to Convert a Portion of the Aggregate Base Layer Thickness To an Equivalent Thickness of Subbase

FROM AASHTO, 1993

DANIEL PASS FERMCO OSDF GE 3900 12 FEB 96

000132 FIGURE 3

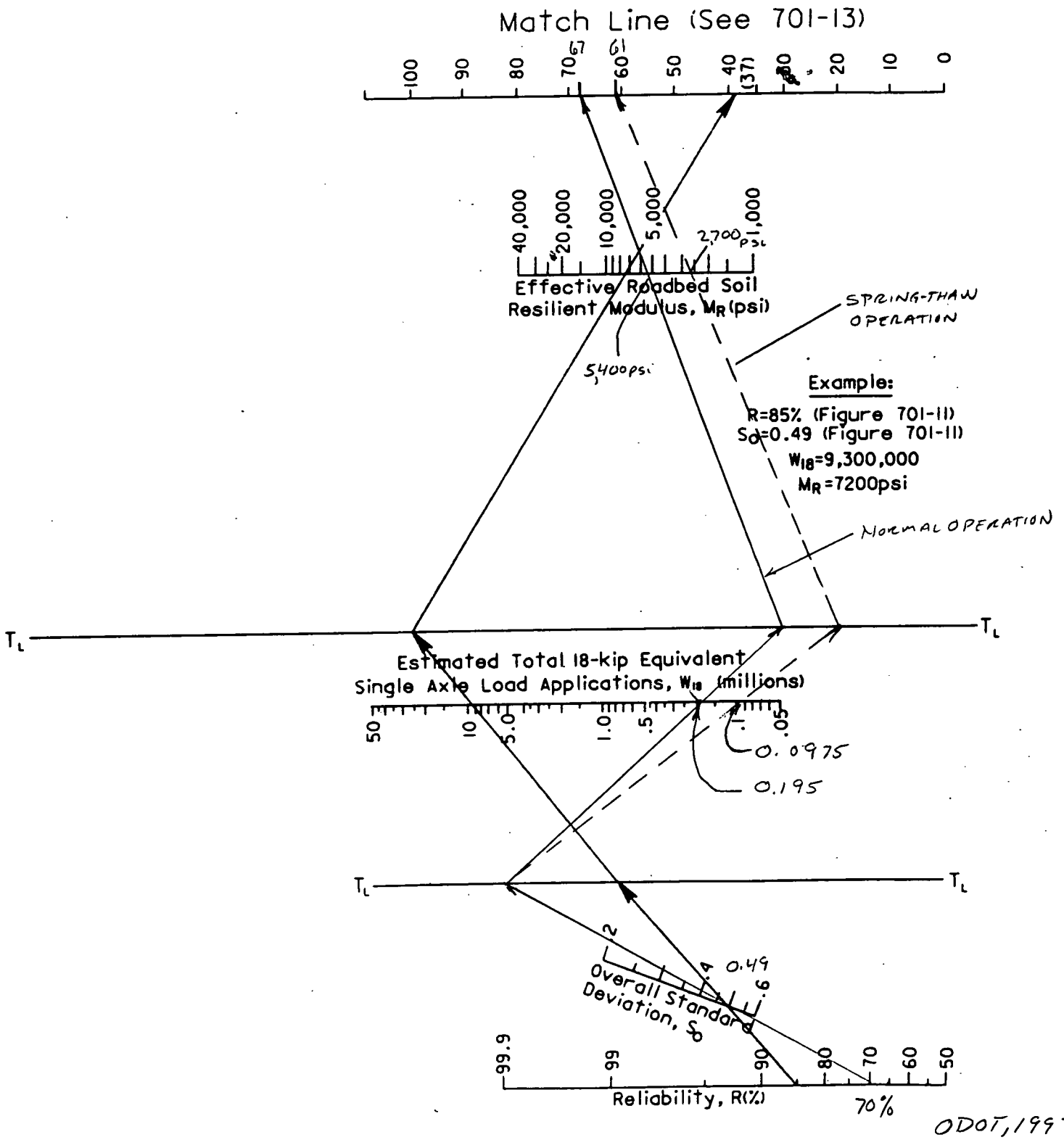
SELECT SN FOR NORMAL AND SPRING-THAW OPERATION 740 13/14

October 1992 DWW 25 Feb 96

FLEXIBLE PAVEMENT DESIGN CHART SEGMENT 1

701-12

REFERENCE SECTION
FLEXIBLE PAVEMENT DESIGN EXAMPLE - STEP 1



ODOT, 1992

DGP FERMCO 0SDFGE3900 12 FEB 96

000133

FIGURE 4

SELECT SN FOR NORMAL AND SPRING-THAW OPERATION

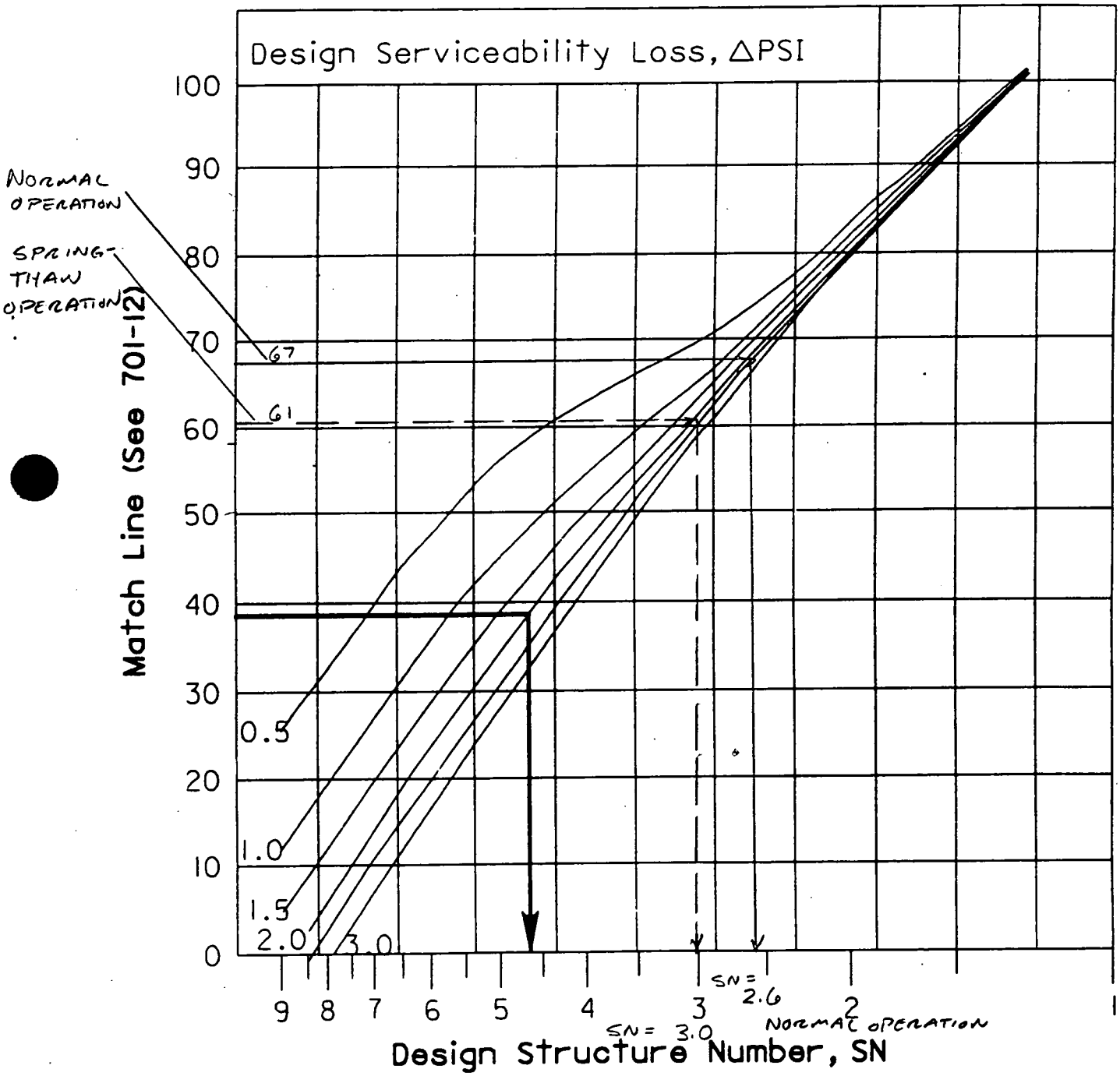
October 1992

DWW 25Feb96

FLEXIBLE PAVEMENT DESIGN CHART SEGMENT 2

701-13

REFERENCE SECTION
FLEXIBLE PAVEMENT DESIGN EXAMPLE - STEP 1



Example: ΔPSI = 2.0

Solution: SN = 4.65

DGP FERMCO ODOT GE 3900 12 FEB 96

000131

ODOT, 1992
FIGURE 5

16.2 Impacted Runoff from Haul Road

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: IMPACTED MATERIALS MANAGEMENT -

IMPACTED RUNOFF FROM HAUL ROAD

Computations By: (Cognizant Engineer)
Signature: [signature] Date: 19 Feb 96
Printed Name and Title: ROBERT S COBLE II, SENIOR STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: [signature] Date: 20 Feb 96
Printed Name and Title: ERIC S. STEINHAUSER, SENIOR PROJECT ENGINEER

Computations Checked by:
Signature: [signature] Date: 22 Feb 96
Printed Name and Title: ERIC S. STEINHAUSER, SENIOR PROJECT ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: [signature] Date: 22 Feb 96
Printed Name and Title: ROBERT S. COBLE II, SENIOR STAFF ENGINEER

Approved by: (PDP)
Signature: [signature] Date: 22 Feb 96
Printed Name and Title: ERIC S. STEINHAUSER, SENIOR PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature: [signature] Date: 23 Feb 96
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
~~K~~ AC 23 Feb 96	Intermediate Design	—	—	—	—
D	Intermediate Design - EPA Submitted	5 Apr 96	[signature]	—	—
0	Response to Final Design Cmts	5 May 97	—	—	[signature]

GE3900-08.1/F9630076

Written by: Asc Date: 19 / Feb / 96 Reviewed by: [illegible] Date: 22 / Feb / 96

lient: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

[illegible] 23 Feb 96

IMPACTED MATERIALS MANAGEMENT

IMPACTED RUNOFF FROM HAUL ROAD

EXECUTIVE SUMMARY

Purpose of Analysis

The purpose of this analysis is to calculate the amount of impacted runoff from the haul road from a 25-year, 24-hour design storm event. The design of the haul road must contain the impacted runoff within the haul road and divert it into the former production area. The haul road will be constructed with a berm on either side to contain the runoff.

Method of Analysis

Stormwater Runoff: The amount of impacted runoff was calculated using the computer program "HydroCAD™ Stormwater Modeling System" (HydroCAD™). This program uses the hydraulic modeling methods presented in USDA-SCS Technical Releases 20 and 55.

Drainage Control Structures: The height of the containment berms to be constructed adjacent to the haul road was evaluated using HydroCAD™.

Conclusions

The peak runoff from the haul road due to a 25-year, 24-hour design storm event is 33 cfs. The impacted runoff can be controlled with a 1 ft containment berm constructed adjacent to the road.

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Written by: _____ Date: ___/___/___ Reviewed by: _____ Date: ___/___/___

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.2

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Appendix A - HydroCAD Stormwater modeling System (Manual) 1 of 1

Written by: RJC Date: 19 / Feb / 96 Reviewed by: AJS Date: 20 / Feb / 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

IMPACTED MATERIALS MANAGEMENT

23 Feb 96

IMPACTED RUNOFF FROM HAUL ROAD

CALCULATION PROCEDURES

Purpose

The purpose of this document is to present the procedures used to calculate the impacted runoff from the haul road and to calculate the maximum depth of flow of runoff along the haul road containment berm. The calculations are performed in accordance with, and to verify compliance with, the DCP. The DCP requirement relevant to these calculations is:

- the freeboard along the containment berms should be at least 6 in. during the design storm event; and
- drainage control structures shall be designed to contain runoff from the 25-yr, 24-hr storm event.

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Scope

The procedures presented in this document will be used to perform the following calculations for the drainage area and design storm event:

- runoff quantities; and
- maximum depth of flow along the containment berms.

Calculation Procedures

General

The computer program "HydroCAD™ Stormwater Modeling System" [Applied Microcomputer Systems, 1993] (HydroCAD™), will be used to calculate quantities, and maximum depth of flow along the containment berms. HydroCAD™ uses the hydrologic modeling methods presented in Technical Release 20 (TR20) [USDA-SCS, 1975] and TR55 [USDA-SCS, 1986a]. (See Appendix A for information related to HydroCAD™.)

Written by: RJC Date: 19/Feb/96 Reviewed by: ASS Date: 20/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

FC 23 Feb 96

Stormwater Runon and Runoff Quantities

The procedure for calculating stormwater runoff quantities consists of the following steps.

1. Define the drainage area to be analyzed. These data are presented in the design verification document.

2. Define the runoff curve number. This value is presented in the design verification document.

3. Define the parameters associated with the surface-water flow segments for the drainage area. The flow segments consist of sheet flow and open channel flow. The engineering parameters needed to define these flow segments are listed below:

   - for sheet flow:

     - surface type which yields a Manning's coefficient for sheet flow;
     - the flow length (ft);
     - slope of land (ft/ft);

   - for open channel flow:

     - Manning's coefficient for open channel flow;
     - channel length (ft);
     - channel slope (ft/ft); and
     - pertinent channel geometry (e.g., side slopes (H:V) and depth (ft) or cross-sectional area (ft^2), and wetted perimeter (ft)).

   These data are also presented in the data verification document.

4. Calculate the amount of runoff for the drainage area, the design storm event, and the vegetative cover type. The data defined in Steps 1 through 3 are used as input to HydroCAD™. HydroCAD™ uses the data to develop a "runoff hydrograph" as described below.

   a. Calculate the Time of Concentration (T_c) for a drainage area. The Tc represents the time required for stormwater to travel from the most hydrologically distance point of

a drainage area to the point of interest. Tc is calculated by summing the individual travel time (T_t) for each flow segment define in a drainage area.

Travel time for each flow segment is calculated as follows:

for sheet flow:

$$T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5} S^{0.4}}$$

where: T_t = Travel time for sleet flow (hours);
n = Manning's coefficient for sheet flow, based on surface types;
L = flow length (ft);
P_2 = amount of rainfall from a 2-year, 24-hour design storm event (in.); and
S = slope of land (ft/ft).

for open channel flow:

$$T_t = \frac{nL}{(3600)(1.486) r^{0.67} S^{0.5}}$$

where: T_t = Travel time for open channel flow (hours);
n = Manning's coefficient for open channel flow;
L = channel length (ft)
r = hydraulic radius (ft) = a/Pw;
a = cross-sectional area of flow (ft^2);
P_w = wetted perimeter (ft);
S = channel slope (ft).

b. Develop a unit hydrograph for the project site. The unit hydrograph is a dimensionless curve that represents the runoff distribution resulting from 1 in. of rainfall excess over the drainage area during a specified period of time. To develop a unit hydrograph, HydroCAD™ uses the CN value and the anticipated rainfall distribution. HydroCAD™ develops the runoff hydrograph by summing the amount of runoff calculated over a series of discrete time intervals during the storm event. The amount of runoff is calculated as follows:

Written by: RSC Date: 19/Feb/96 Reviewed by: MSS Date: 20/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

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$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (Q = \text{zero if } P < 0.\cancel{1}2S)$$

where: Q = amount of runoff (in.);
P = cumulative rainfall (in.);
S = potential maximum retention after run off begins (in.);
S = 1000/CN - 10
CN = runoff curve number.

The discrete time interval or duration during which runoff calculations are performed is calculated as follows:

$$D = \frac{2}{15} Tc$$

where: D = duration (hours); and
T_c = time of concentration (hours).

5. The resulting runoff hydrograph provides the runoff quantities for the storm event as well as the peak runoff quantity.

Maximum Depth of Flow in Drainage Channels

The procedures for calculating the maximum depth of flow along a containment berm consists of the following steps.

1. Define the dimensions and geometry of the containment berm. This information is presented in the data verification document.

2. Develop a discharge versus depth curve for the drainage berm by calculating the flow rate for various flow depths within the drainage berms based on the berm geometry. Flow rate is calculated as follows:

$$Q = \frac{1.486 a r^{0.67} s^{0.5}}{n}$$

where: Q = flow rate (cfs);
a = cross-section area of flow (ft^2);

23 Feb 95

r = hydraulic radius (ft) = a/P_w;
P_w = wetted perimeter (ft);
s = channel slope (ft/ft); and
n = Manning's coefficient for open channel flow.

3. Verify that the drainage berm satisfies the design criteria.

References

Applied Microcomputer Systems, "HydroCAD™ Stormwater Modeling System," version 3.10, Chocorna, NH, 1993.

Chow, "Open Channel Hydraulics," 1959

USDA-SCS, "Computer Program for Project Formulation, Hydrology", Technical Release 20 (TR20), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., May 1982.

USDA - SCS "National Engineering Handbook, Section 4 - Hydrology," Washington, DC, Mar 1985.

USDA-SCS, *"Urban Hydrology for Small Watersheds"*, Technical Release 55 (TR55), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 2nd Edition, 1986a.

USDA-SCS, *"Engineering Field Manual for Conservation Practices"*, U.S. Department of Agriculture, Soil conservation Service, Washington, D.C., 1986b.

USDA-SCS, *"Water Management and Sediment Control for Urbanizing Areas"*, U.S. Department of Agriculture, Soil Conservation Services, Washington, D.C., 1987.

Written by: RSC Date: 19 Feb 96 Reviewed by: HSS Date: 20 Feb 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

23 Feb 96

IMPACTED MATERIALS MANAGEMENT

IMPACTED RUNOFF FROM HAUL ROAD

DATA VERIFICATION

PURPOSE

The purpose of this document is to present the engineering data used to calculate the amount of impacted runoff from the haul road. The impacted runoff will be contained on the haul road using containment berms and will be diverted into the former production area.

The data presented in this document are used to satisfy the requirement presented in the DCP. The DCP requirement relevant to the data verification are:

- the drainage control structures shall be designed to contain runoff from the 25-year, 24-hour design storm event; and
- the freeboard along the containment berms should be at least 6 in. during the design storm.

SCOPE

The data presented in this document will be used to perform the following calculations:

- runoff quantities; and
- maximum depth of flow along the containment berms.

PARAMETERS FOR DESIGN

General

Data required to perform the calculations include: (i) rainfall information (i.e., quantities, durations, distribution); and (ii) drainage area information (i.e., drainage channel dimensions and geometries, Manning's coefficients for sheet flow and open channel flow, soil and vegetative cover types). Engineering data will be obtained from site-specific studies and published engineering texts.

Written by: Asc Date: 13/Feb/96 Reviewed by: SSS Date: 20/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

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Rainfall Information

Rainfall Quantities and Durations

Rainfall quantities for specific design storm events were summarized by Parsons [1995] and are presented in Table 1. Rainfall for the design storm required by the DCP or by the calculation method include:

Storm Event	Rainfall (in.)
2-Year, 24-Hour	2.55
25-Year, 24-Hour	4.7

Rainfall Distribution

According to USDA-SCS [1986a], storm events that occur in the area of the OSDF site will have a Type II storm distribution, see Figure 1. Rainfall intensities for a Type II, 24-hour storm are shown on Figure 2.

Drainage Area Data

Drainage Areas

The drainage area is shown on Figure 3.

Drainage Flow Types

Surface water flow within a drainage area is characterized as a series of flow segments. The flow segments will consist of sheet flow, and open channel flow. The engineering parameters needed to define these flow segments, along with the reference source for the data, is listed below:

- for sheet flow:
  - surface type which yields a Manning's coefficient for sheet flow, Table 2 [USDA-SCS, 1986a];
  - flow length (ft), Figure 3;
  - slope of land (ft/ft);

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- for open channel flow:
  - Manning's coefficient for open channel flow, Figure 3 [USDA-SCS, 1986b and Chow, 1959];
  - channel length (ft), Figure 3;
  - channel slope (ft/ft);
  - pertinent channel geometry (e.g., side slopes (H:V) and depth (ft) or cross-sectional area (ft^2), and wetted perimeter (ft)), Figure 4.

Hydrologic Soil Group (HSG)

The soil types found within the OSDF watershed are illustrated in Figure 5 [USDA-SCS, 1992]. The HSG classification for each soil type identified were obtained from Table 4 [USDA-SCS, 1986a]. Soils found within the OSDF watershed and their associated HSG are:

SCS Map Designator	Soil Name	HSG Group
FcA	Fincastle	C
FdA	Fincastle	C

Vegetative Cover Type

The HSGs identified within the drainage are subdivided by vegetative cover type. Vegetative cover types recognized by Technical Release 55 [USDA-SCS, 1986a] (i.e., the hydrology model used in these calculations) are presented in Table 5 [USDA-SCS, 1986a]. The impacted material haul road will be gravel.

Runoff Curve Number

The Runoff Curve Number (CN) is a factor used to account for the influence that each of the HSG, vegetative cover type, and hydrologic condition and treatment have on the amount of runoff. The CN value for the analysis is 89, see Table 5 [USDA-SCS, 1986a].

The Manning's n value for gravel-lined channels is 0.022, see Table 4. [Chow 1959].

Summary

A summary of the drainage area data is presented in Table 6.

FC 23Feb90

REFERENCES

Chow, *"Open Channel Hydraulics"*, 1959.

GeoSyntec Consultants, *"Design Criteria Package"*, document in preparation.

USDA-SCS, *"National Engineering Handbook, Section 4 - Hydrology"*, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Mar 1985.

USDA-SCS, *"Urban Hydrology for Small Watersheds"*, Technical Release 55 (TR-55), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Jun 1986a.

USDA-SCS, *"Engineering Field manual for Conservation Practices"*, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Nov 1986b.

USDA-SCS, *"Water Management and Sediment Control for Urbanizing Areas'*, U.S. Department of Agriculture, Soil Conservation Services, Washington, D.C., 1987.

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TABLE 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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555 20Feb96

23Feb96

Table 2 .—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.

(210-VI-TR-55, Second Ed., June 1986)

TABLE 3. MANNING'S COEFFICIENTS

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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TABLE 4, continued: Hydrologic soil groups for United States soils

EYOTA	A	FARRAGUT	C	FETTIC	D	FLATIRON	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	E	FORSEY	B
FADOLL	B	FASHING	D	FIDDYMENT	D	FLEVSIE	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, DEPRESSIONAL	D	FOSSILON	D
FAIRMOUNT	D	FAYWOOD	C	FINGEROCK	D			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	C
FAIRWAY	C	FEATHERSTONE	D	FINNERTY	D	FLORITA	B	FOUR STAR	C
FAIRYDELL	C	FEDJI	A	FIND	B	FLOTAG	B	FOUR STAR, DRAINED	B
FAIRYLAWN	D	FEDORA	B/D	FINDL	C	FLOWELL	C	FOURCHE	B
FAJAROO	C	FEDSCREEK	B	FIONE	B	FLOWEREE	B	FOURLOG	D
FALAYA	D	FELAN	B	FIFADA	C	FLOYD	B	FOURNE	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, DEPRESSIONAL	D	FIRESTEEL	B	FLUKER	C	FOXCREEK	D
FALFURRIAS	A			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	FELTMAN	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	FISHRUCK	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	FORDIRAN	C	FREDONYER	C
FARLOW, HIGH RAINFALL	C	FERNOW	B	FLAMING	A	FORDUM	D	FREE	B/D
		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
FARNSWORTH	D	FERRIS	D	FLANLY	B	FORESMAN	B	FREEDOM, SALINE	B
FARNTON	D	FERROBURRO	D	FLASHER	D	FORESTBURG	A	FREEHOLD	B
FARNHAM	B	FERROM	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

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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Table 5.—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 2-2a).					

[1] Average runoff condition.
[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.
[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 based on the impervious area (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 the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

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TABLE 6

INPUT PARAMETERS

25-YEAR STORM EVENT

		Sheet Flow			Open Channel Flow						
Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Bottom Width (ft)	Right Slope	Left Slope
2.6	89	26	0.002	Gravel	2,000	0.022	1	0.0002	50	3:1	3:1

Channel slope is considered conservative for this calculation. Actual slope will be greater, which will tend to result in a shallower flow.

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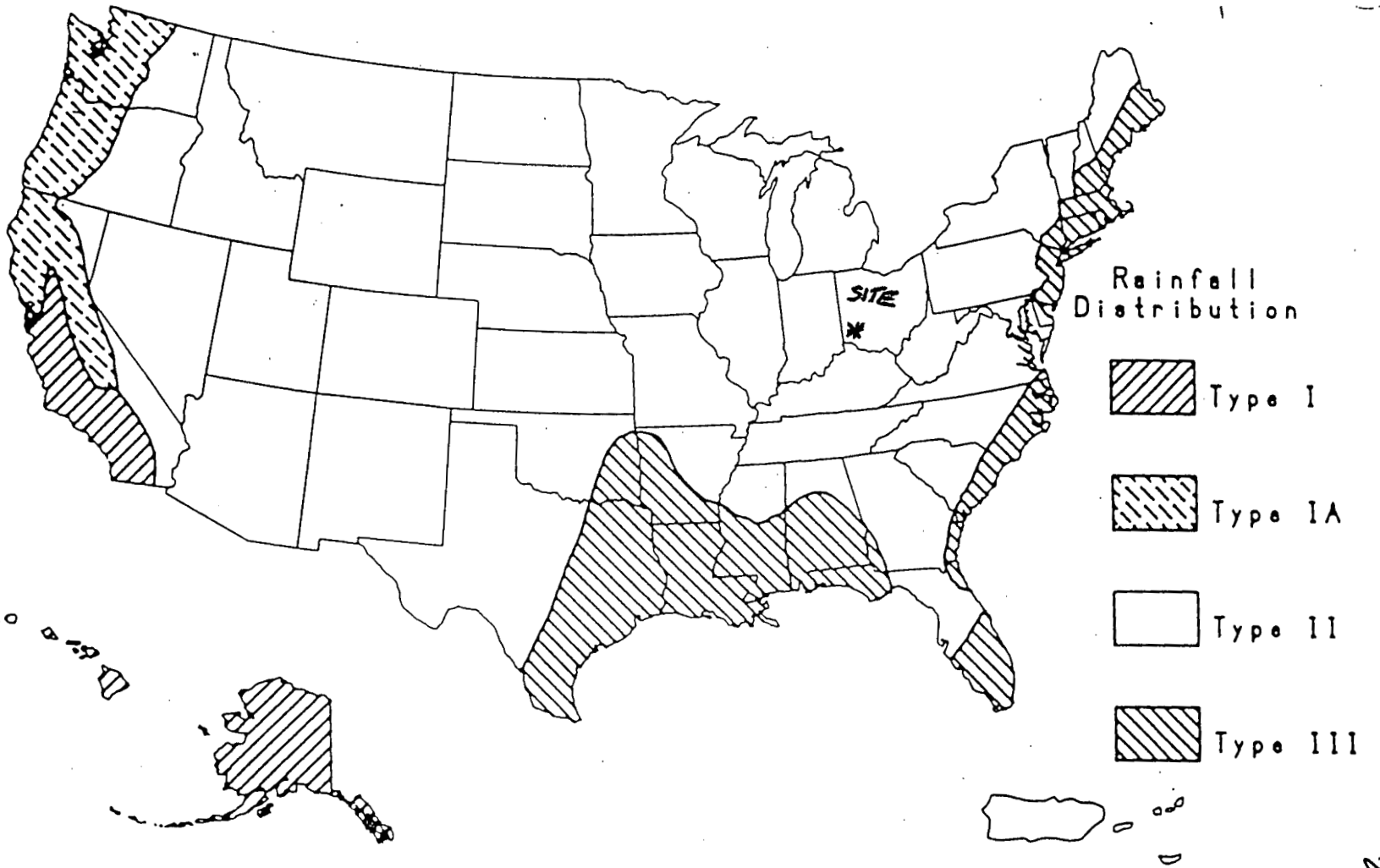

Figure 4 —Approximate geographic boundaries for SCS rainfall distributions.

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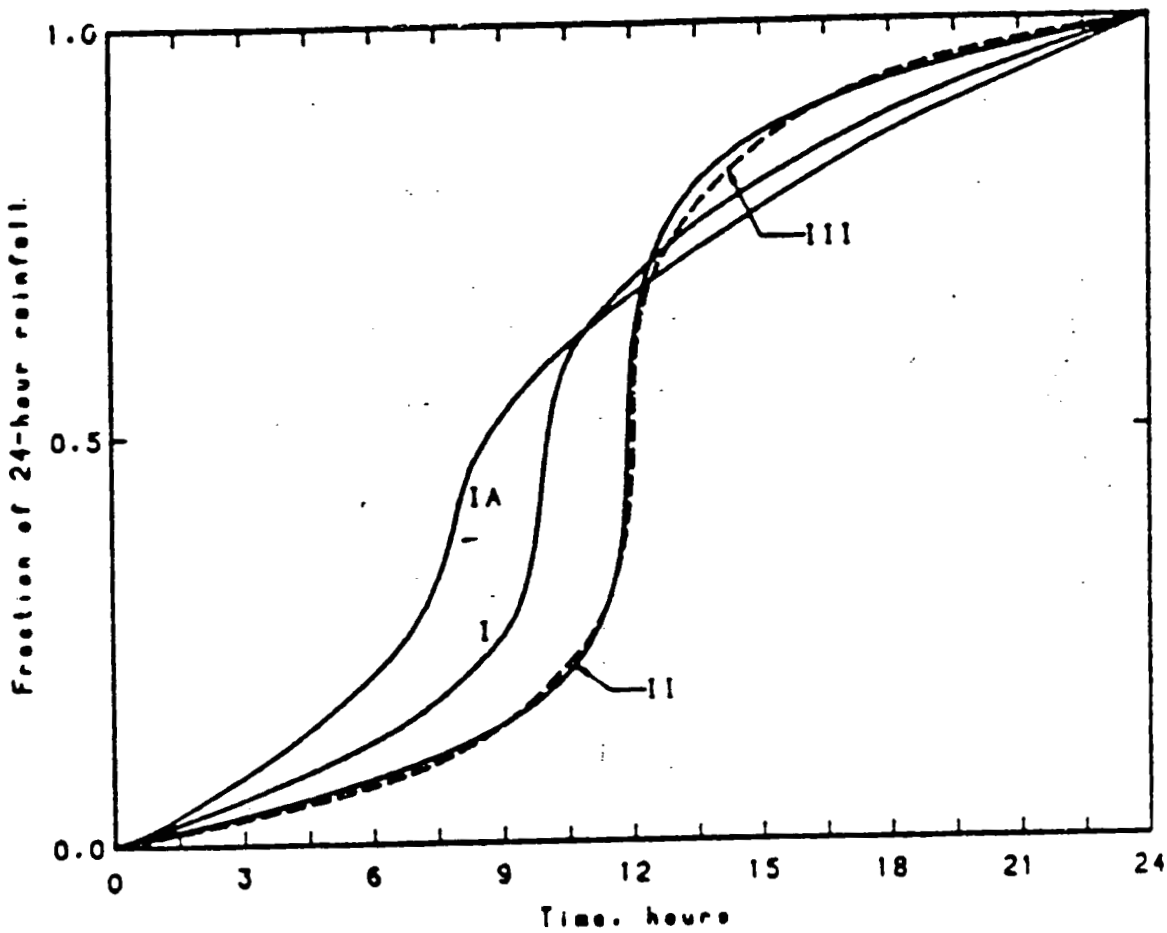

Figure 2 .—SCS 24-hour rainfall distributions.

(210-VI-TR-55, Second Ed., June 1986)

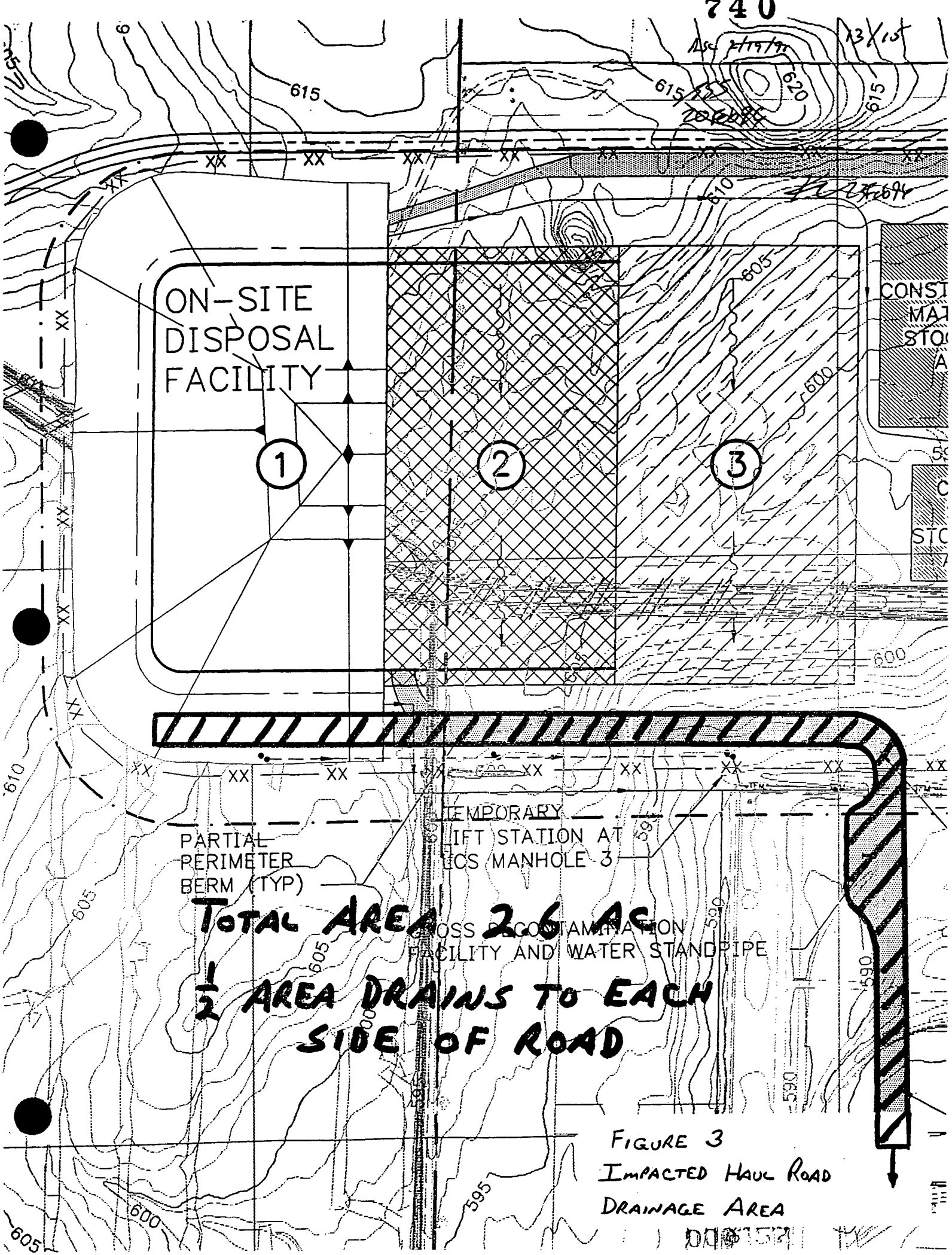

FIGURE 3
IMPACTED HAUL ROAD
DRAINAGE AREA

Written by: RSC Date: 19 / Feb / 96 (YY MM DD) Reviewed by: GSS Date: 96 / 02 / 20 (YY MM DD)

Client: Fellco Project: OSDF Project/Proposal No.: GR 3500 Task No.: 08.1

KL 23 Feb 96

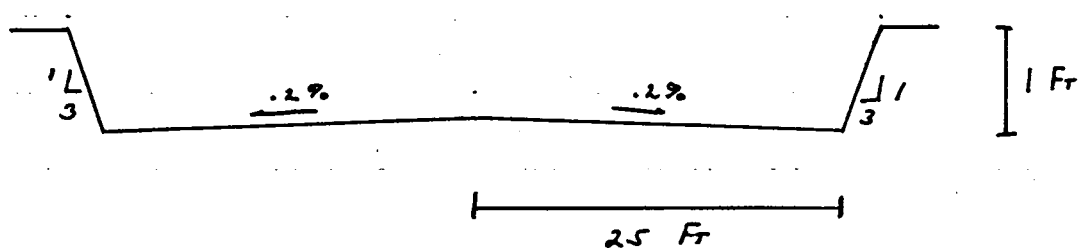

FIGURE 4. IMPACTED MATERIAL HAUL ROAD AND PERIMETER BERM CROSS-SECTION

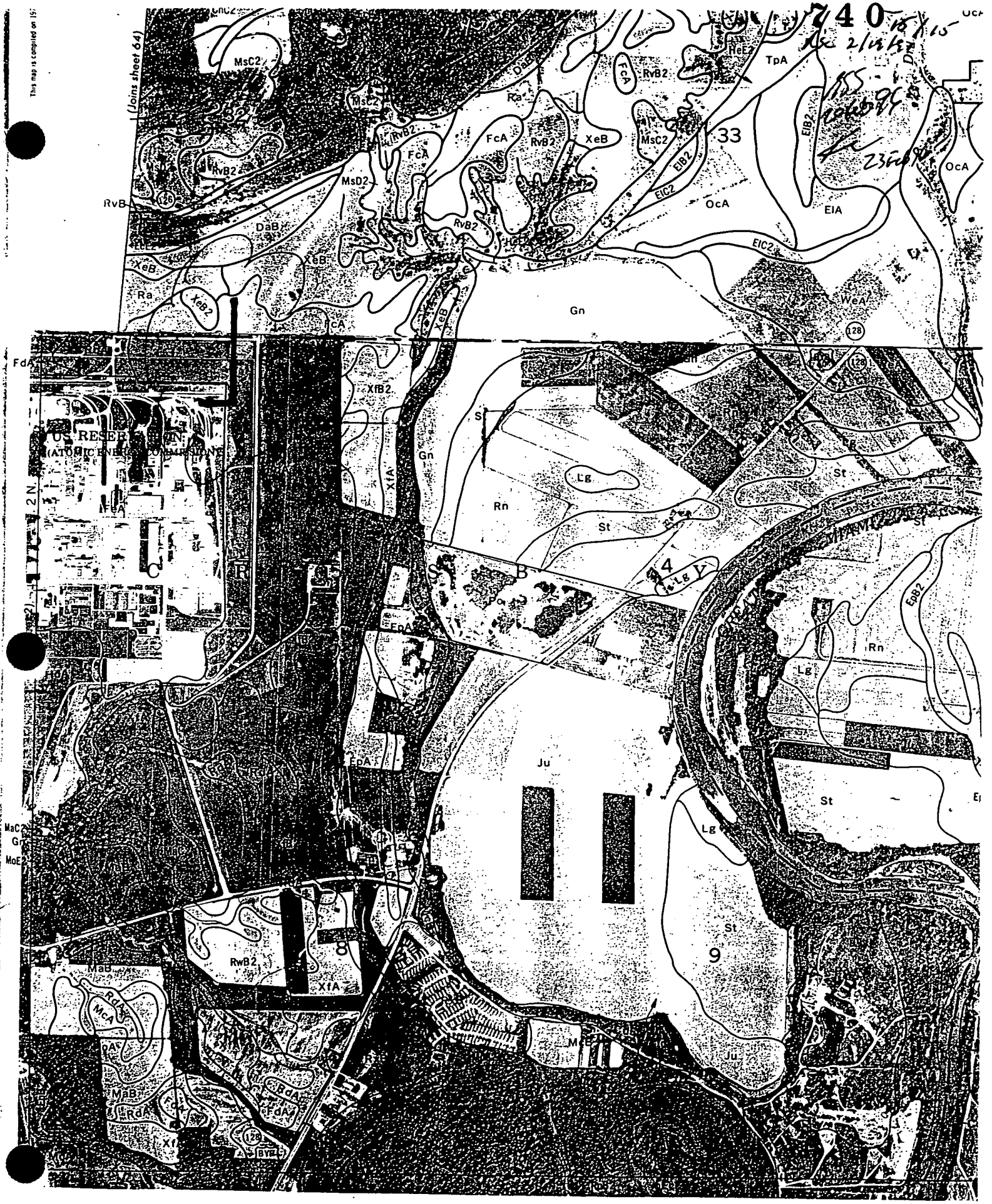

FIGURE 5. HYDROLOGIC SOIL GROUPS

Written by: ASC Date: 19/Feb/96 Reviewed by: SSS Date: 22/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

IMPACTED MATERIALS MANAGEMENT

IMPACTED RUNOFF FROM HAUL ROAD

CALCULATIONS

Purpose

The purpose of this document is to provide the engineering calculations used in the design of the impacted material haul road for the On-Site Disposal Facility (OSDF).

Scope

The calculation procedures used in this document are presented in the calculations procedures document. The data used in the calculations is presented in the data verification document.

The calculations consists of: (i) a summary of the input data; (ii) a summary of the calculation results; and (iii) the calculations (i.e., worksheets, computer runs).

Calculations

Summary of Input Data

A summary of the HydroCAD™ input data is presented in Table 1.

Summary of Calculation Results

The peak runoff from the haul road due to a 25-year, 24-hour design storm event is 33 cfs. Maximum flow depth on the haul road will not exceed 0.2 ft. Therefore, the 1-ft high containment berms will be sufficient to contain the runoff from a 25-year, 24-hour design storm event.

TABLE 1

INPUT PARAMETERS

25-YEAR STORM EVENT

		Sheet Flow			Open Channel Flow						
Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Bottom Width (ft)	Right Slope	Left Slope
2.6	89	26	0.002	Gravel	2,000	0.022	1	0.0002	50	3:1	3:1

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DRAINAGE AREA MAPS

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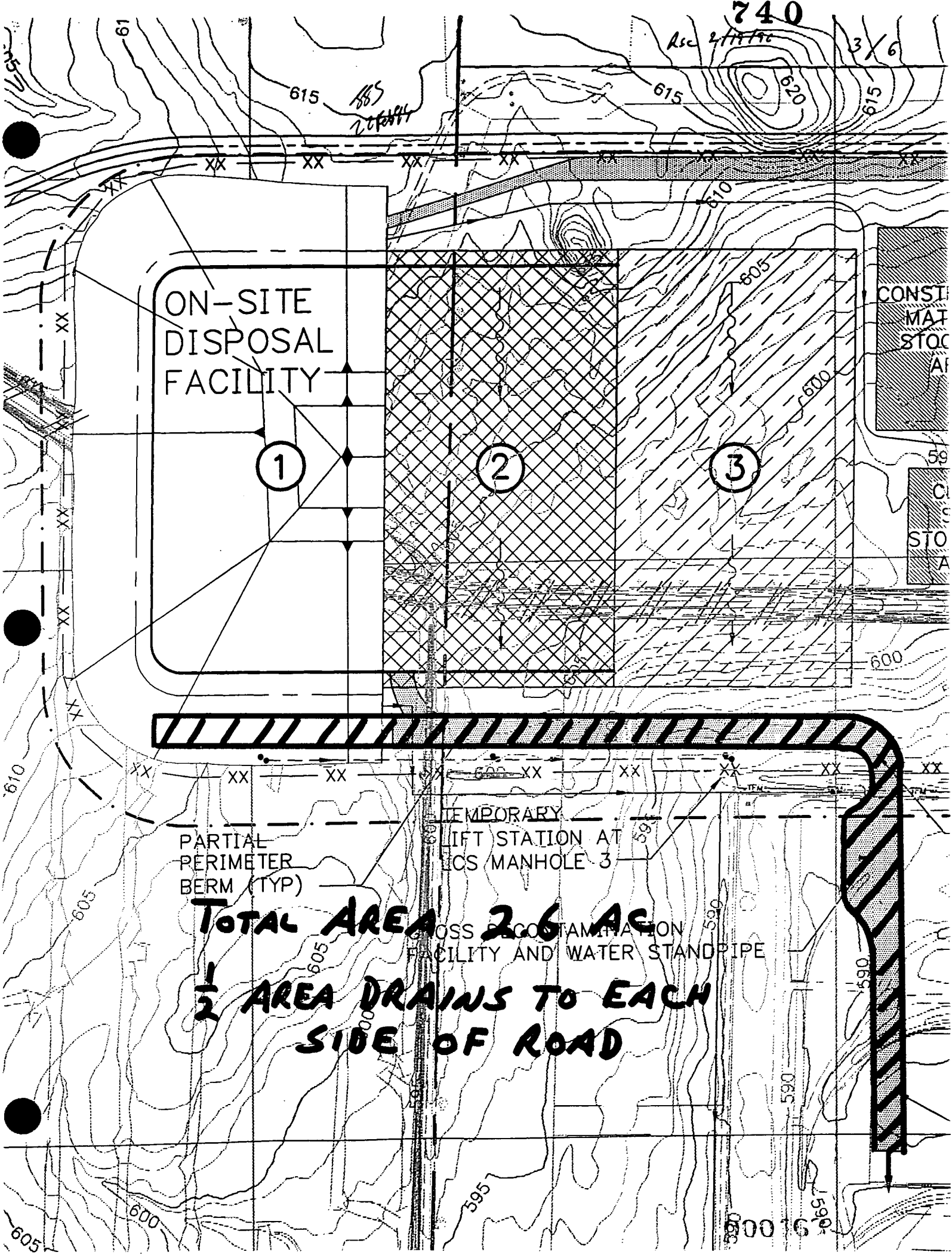
ON-SITE
DISPOSAL
FACILITY
1
2
3
CONSTR
MAT
STOC
AR
TEMPORARY
LIFT STATION AT
CS MANHOLE 3
PARTIAL
PERIMETER
BERM (TYP)
CROSS CONTAMINATION
FACILITY AND WATER STANDPIPE
TOTAL AREA 2.6 AC
1/2 AREA DRAINS TO EACH
SIDE OF ROAD
615
620
610
605
600
595
590

HYDROCAD™ RUNS

RUNON/RUNOFF

Data for **IMPACTED MATERIAL HAUL ROAD RUNOFF DEPTH**
Prepared by GeoSyntec Consultants 19 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

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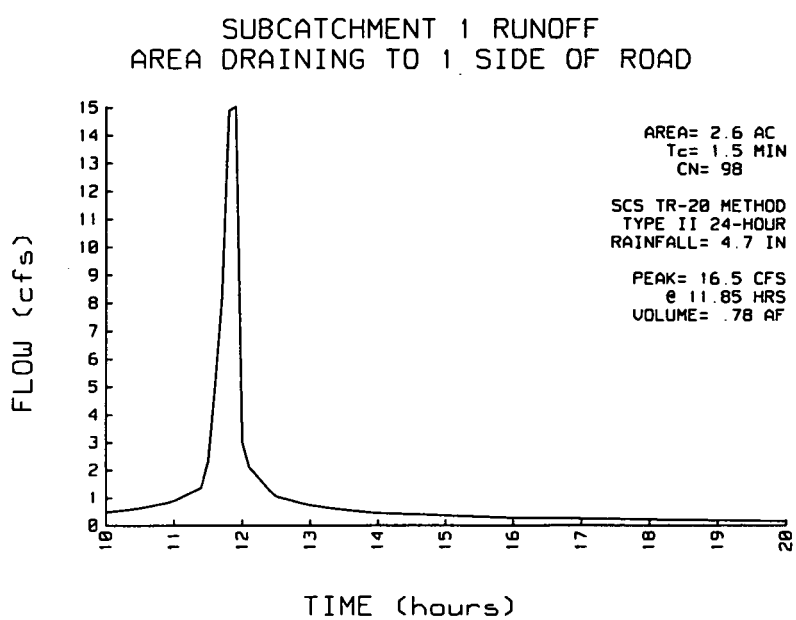
SUBCATCHMENT 1 **AREA DRAINING TO 1 SIDE OF ROAD**

ACRES	CN
2.60	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 16.5 CFS @ 11.85 HRS
VOLUME= .78 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**FLOW FROM CENTER LINE OF ROAD**	1.5
Smooth surfaces n=.011 L=26' P2=2.6 in s=.001 '/'		



HYDROCAD™ RUNS

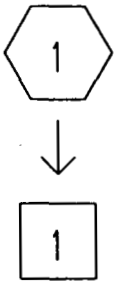
DRAINAGE CHANNEL ROUTING

Data for **IMPACTED MATERIAL HAUL ROAD RUNOFF DEPTH**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

19 Feb 96

TSS 22Feb94

WATERSHED ROUTING ==========



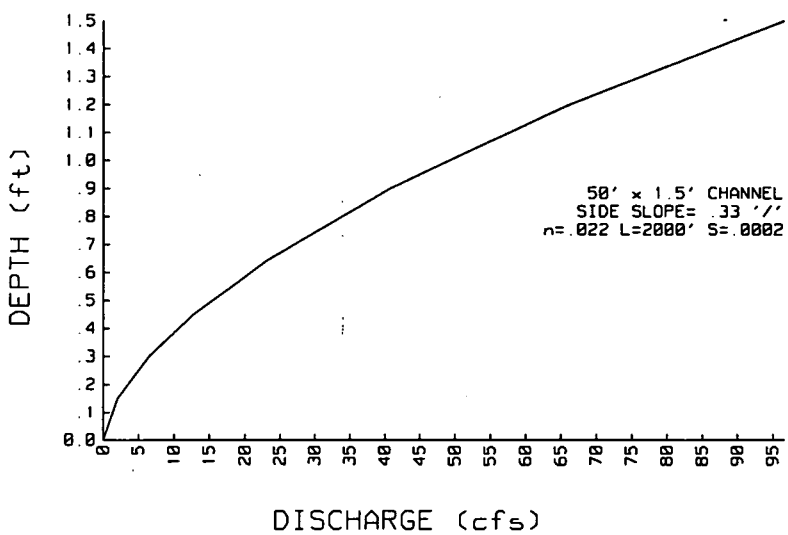
REACH 1 **CURB DEPTH FOR RUNOFF FLOWING LENGTH OF RD**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	7.6	2.0
.3	15.3	6.5
.5	23.1	12.7
.6	33.5	23.3
.9	47.5	40.7
1.2	64.4	66.2
1.5	81.8	96.6

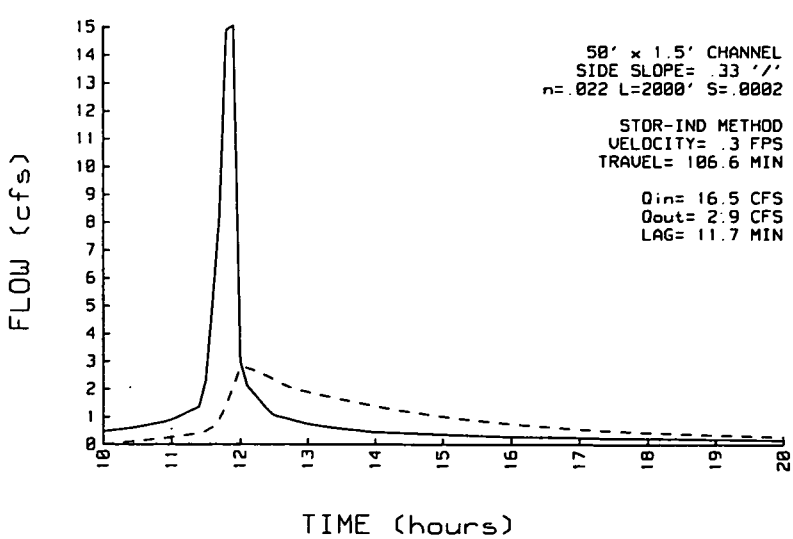
50' x 1.5' CHANNEL
SIDE SLOPE= .33 '/'
n= .022
LENGTH= 2000 FT
SLOPE= .0002 FT/FT

STOR-IND METHOD
MAX. DEPTH= .18 FT
PEAK VELOCITY= .3 FPS
TRAVEL TIME = 106.6 MIN
Qin = 16.5 CFS @ 11.85 HRS
Qout= 2.9 CFS @ 12.05 HRS
ATTEN= 83 % LAG= 11.7 MIN
IN/OUT= .78 / .73 AF

REACH 1 DISCHARGE
CURB DEPTH FOR RUNOFF FLOWING LENGTH OF RD



REACH 1 INFLOW & OUTFLOW
CURB DEPTH FOR RUNOFF FLOWING LENGTH OF RD



APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATION PACKAGE HydroCAD™ STORMWATER MODELING SYSTEM

Applied Microcomputer Systems, *"HydroCAD™ Stormwater Modeling System"*, version 3.10, Chocorva, NH, 1993.

For documentation of computer programs see

1.2 Computer Program Validation

16.3 OSDF Methane Generation

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: OSDF METHANE GENERATION

Computations By: (Cognizant Engineer)
Signature: Thomas B. Maier — Date: 6 APR 96
Printed Name and Title: Thomas B. Maier, Asst. Project Eng

Assumptions and Procedures Checked by: (Checker)
Signature: [illegible] — Date: 06 Apr 96
Printed Name and Title: Kenneth W Cargill, Associate

Computations Checked by: (Checker)
Signature: [illegible] — Date: 06 Apr 96
Printed Name and Title: Kenneth W Cargill, Associate

Computations Backchecked by: (Cognizant Engineer)
Signature: Thomas B. Maier — Date: 6 APR 96
Printed Name and Title: Thomas B. Maier, Asst. Project Eng.

Approved by: (PDP)
Signature: [illegible] — Date: 08 Apr 96
Printed Name and Title: Kenneth W Cargill, Associate

Approved by: (DTL and TETL)
Signature: Rudolph Bonaparte — Date: 8 April 96
Printed Name and Title: Rudolph Bonaparte, Principal

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
D	Intermediate Design - EPA Submitted				
G	Final Design Package	4 Oct 96	—	—	[illegible]
O	Response to Final Design Cmts	5 May 97	—	—	[illegible]

GE3900-10.2/Methane.cal

Written by: JM Date: 6 APR 96 Reviewed by: KC Date: 06/04/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

OSDF METHANE GENERATION

EXECUTIVE SUMMARY

Purpose

The purposes of this analysis are to: (i) estimate a reasonable range of methane and total landfill gas generation rates within the On-Site Disposal Facility (OSDF); (ii) evaluate the potential health and safety impacts of the generated gas; and (iii) evaluate the potential effects of the generated gas on the OSDF final cover system.

Procedure

The following procedure was used to estimate methane and total landfill gas generation within the OSDF:

- estimate the weight, volume, and volumetric concentration of organic material that will be placed in the OSDF;
- estimate the rate at which the organic material will be placed in the OSDF;
- estimate the total methane generation potential of the OSDF;
- estimate the weight of typical municipal solid waste (MSW) equivalent to the estimated weight of organic material;
- estimate the methane and total landfill gas generated within the OSDF over time using a model developed for MSW (i.e., the United States Environmental Protection Agency's Landfill Air Emissions Estimation Model (EPA LAEEM), also know as the Scholl Canyon or first order methane generation model);
- use a simple landfill gas balance model to aid in evaluating health and safety impacts and potential effects on the final cover system; and

- evaluate the results of the landfill gas balance model.

Conclusion

1. Conservative methane and total landfill gas generation rates were calculated; the calculated peak annual methane generation rate is 1.56×10^4 ft^3/yr.

2. The landfill gas balance model shows that this gas generation rate does not cause the buildup of any significant gas pressure against the OSDF final cover system. Thus, methane generation should not have any adverse impact on the OSDF final cover system.

3. The OSDF may generate enough methane to cause methane to migrate through the OSDF leachate collection, and possibly leak detection, pipes. All outlet points from these pipes should be periodically monitored. Should methane be detected at concentrations approaching 25 percent of the methane lower explosive limit in any confined space, then mitigation measures, such as venting, should be implemented.

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Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

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Written by: SM Date: 6 APR 96 Reviewed by: FC Date: 06/04/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

RB 6 April 96

OSDF METHANE GENERATION

CALCULATION PROCEDURES

Purpose

The purpose of this document is to present the procedures used to calculate methane generation within the OSDF and to evaluate health and safety impacts and potential effects on the final cover system. The calculations are performed in accordance with, and to verify compliance with, the Design Criteria Package.

Scope

The procedures presented in this document are used to:

- conservatively estimate a methane generation rate that can be expected within the OSDF; and
- perform a simple landfill gas balance model to aid in estimating the effect of the generated gas on the final cover system.

Calculation Procedures

A. Procedure Outline

The calculation procedure used is comprised of the following steps:

- estimate the organic content of the OSDF;
- estimate the rate at which organic material will be placed in the OSDF;
- estimate the total methane generation potential of the OSDF;

- estimate the rate of methane generation within the OSDF;
- use a simple landfill gas balance model to aid in evaluating the effect of the generated gas on health and safety and on the final cover system; and
- evaluate the results of the landfill gas balance model.

Each of the steps is described below.

B. Organic Content

The following procedure was used to estimate the weight, volume, and volumetric concentration of organic material that will be placed in the OSDF:

- identify sources or organic material and approximate volume of each source;
- estimate the volume, unit weight, and organic content of each source containing organic material;
- calculate a weight and volume of organic material from each source containing organics;
- estimate how much of the organic material will be placed in Cells 1 through 3 and how much will be placed in Cells 4 through 8; and
- calculate a volumetric concentration of organic material.

C. Rate of Placement of Organic Material

For planning purposes, it was assumed that Cells 1 through 3 will be filled in five years and that Cells 4 through 8 will be filled in an additional five years. This assumption was combined with the organic weight and distribution estimates previously developed to estimate the weight of organic material that will be placed in the OSDF each year.

D. Methane Generation Potential

A value for methane generation potential (L_o), in units of cubic feet of methane per megagram of municipal solid waste (MSW) (ft^3/Mg), was obtained from a literature search.

E. Methane Generation Rate

1. Methane Generation Rate Constant

The rate of methane generation has been reported to be directly proportional to organic concentration [Amaral and Knowles, 1994]. A methane generation rate constant (k), in units of 1/year, was estimated by comparing the concentration of organic material in the OSDF to that of typical MSW. The methane generation rate constant used for the OSDF is lower than the rate constant applicable to MSW landfills.

2. Methane Generation Over Time

The annual volume of methane generated within the OSDF for 100 years after waste placement begins was estimated using the following equation:

$$Q = \sum kL_o M_i (e^{-kt_i})$$

where:

Q = methane generated (ft^3/yr at 20°C and 1 atm)
k = methane generation rate constant (1/yr)
L_o = methane generation potential (ft^3/Mg of MSW)
M_i = mass of MSW placed in year i
t_i = age of waste placed in year i

This equation is used in the EPA's Landfill Air Emissions Estimate model [USEPA, 1991] and is also referred to as the Scholl Canyon or first order methane generation model. GeoSyntec has used a spreadsheet to implement this equation and has verified that the spreadsheet results are identical to the results of the EPA model.

F. Landfill Gas Balance Model

The simple landfill gas balance consists of the following equations:

1. Total Landfill Gas (LFG) Generated = 2 x Methane Generated (assuming LFG is 50% CH_4)

2. Emission to Atmosphere Prior to Completion of Final Cover = Landfill Gas Generated

3. Emission to Atmosphere After Completion of Final Cover = Landfill Gas Diffused

4. Landfill Gas Stored = Landfill Gas Generated - Landfill Gas Diffused

5. Air-Filled Void Space = (Total OSDF Volume)(porosity)(saturation)

6. Landfill Pressure = (Initial Pressure) $\left[\dfrac{\text{Cumulative Storage + Air-Filled Void Space}}{\text{Air-Filled Void Space}}\right]$

G. Evaluation of Landfill Pressure

1. To evaluate the potential for generated gas to affect the final cover system by causing uplift or cracking, the calculated landfill pressure is compared to the vertical stress at the base of the final cover system due to the weight of the final cover system.

2. The evaluation of health and safety concerns is addressed at the end of the calculations and in the executive summary.

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References

Amaral, J.A. and Knowles, R., "Methane Metabolism in a Temperate Swamp", *Applied and Environmental Microbiology, Volume 60*, 1995, pp. 3,945-3,951.

USEPA, "*Landfill Air Emissions Estimation Model User's Manual*", Document EPA-600/8-90-085a, Research Triangle Park, NC, April 1991, 27 p.

GEOSYNTEC CONSULTANTS

Written by: [illegible] Date: 6 [illegible] 96 Reviewed by: [illegible] Date: 06/04/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

RB 6 April 96

OSDF METHANE GENERATION

DATA VERIFICATION

Purpose

The purpose of this document is to present the engineering data used to calculate the methane generation within the OSDF.

Scope

The data presented in this document will be used to:

- prepare estimates of the volume of methane that will be generated within the OSDF over time; and
- evaluate the potential for the generated gas to cause cracking or uplift of the final cover system or to cause health and safety concerns.

Parameters for Design

A. General

Engineering data were obtained from site-specific information and engineering texts.

B. Organic Content

1. Sources of Organic Material

Information regarding sources of organic material was obtained from Table 7-3 of the Draft Operable Unit 5 (OU5) Feasibility Study, which is attached, and from discussion with design team members regarding the amount of grubbing waste expected to be placed in the 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.

The identified sources of organic material are as follows:

Component	Source	Volume (yd^3)
Solid Waste Landfill Material(MSW)	OU2	18,000
Windows, Wood, Insulation	OU3	58,571
Grubbing Waste	200 acres of the site	161,333 (assuming an average thickness of 0.5 ft)

2. Unit Weight and Organic Content

Component	Unit Weight	Source
MSW (refuse only)	50 lb/ft^3	[NAVFAC DM-7.3, 1983]
Windows, Wood, Insulation (Wood only)	50 lb/ft^3	G_s = 0.7 (Ranges from 0.12 to 0.74 for various woods [Merritt, 1983])
Grubbing Waste (mostly soil)	110 lb/ft^3	Typical for Silty Clay [NAVFAC DM-7.1, 1986]

Component	Organic Content	Source
MSW	50%	[Franklin Associates, 1992]
Wood	100%	Conservative assumption
Grubbing Waste	1%	Estimate

C. Rate of Placement of Organic Material

For planning purposes, it is assumed that Cells 1 through 3 will be filled in five years and that Cells 4 through 8 will be filled in an additional five years. This assumption is combined with the organic weight and distribution estimates previously developed to estimate the weight of organic material that will be placed in the OSDF each year.

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D. Methane Generation Potential, L_o

A theoretical maximum value for methane generation potential for organic material (L_o = 420 liters/kg) was obtained from Thorneloe et al. [1993]. A typical value for the methane generation potential of MSW (L_o = 125 liters/kg) was obtained from USEPA [1994]. A minimum methane generation potential for typical MSW (L_o = 38.6 liters/kg) was obtained from Pacey [1989] as reported in Thorneloe et al. [1993]. The minimum methane generation potential for MSW is believed to be conservative for estimating the methane generation potential for the OSDF.

E. Methane Balance Model

To estimate the air-filled void space in the OSDF, the following data were used.

Parameter	Value	Source
Total Air Space	27.5×10^6 yd ^{3}	Calculation Package 2.1, required OSDF volume
Average Porosity	0.445	Calculation Package 7.1, porosity of impacted material.
Average Saturation	0.88	Calculation Package 7.1, calculated from porosity and moisture content of impacted material

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RB 6 April 96

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USEPA, "Municipal Solid Waste Landfills," *Compilation of Air Pollutant Emission Factors*, Document AP-42, fifth edition, Research Triangle Park, NC, 1994, pp. 2.4-1 to 2.4-13.

Written by: [illegible] Date: 6 Apr 98 Reviewed by: [illegible] Date: 06/04/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

OSDF METHANE GENERATION

CALCULATIONS

Purpose

The purpose of this document is to present engineering calculations used to estimate methane generation within the OSDF and to evaluate its potential affects on the final cover system and on health and safety.

Scope

The calculation procedures used in this document are presented in the calculations procedures document. The data used in the calculations are presented in the data verification document.

Calculations

Estimate Weight Of Organic Material In OSDF

A. Sources of Organic Material:

1. The 18,000 yd^3 of MSW has an average age of 30 years, and therefore has expended most of its methane generation potential. Assume that the original organic content was 50% and that 25% of the original remains (i.e., 12.5%). (18,000 yd^3) (1,350 lb/yd^3) (.125 organic content) = 3.04×10^6 lbs. ✓

2. Assume the 58,571 yd^3 of windows, wood, and insulation is 30% wood (i.e., 17,571 yd^3) and has a unit weight of 0.7×62.4 lb/ft^3 = 43.7 lb/ft^3 (i.e., 1,180 lbs/yd^3). (17,571 yd^3) (1,180 lbs/yd^3) = 2.07×10^7 lbs. ✓

3. Assume grubbing waste is top 6-in. of a 200-ac area and is 1% organic by weight: (200 ac. x 43,560 ft^2/ac) (0.5 ft) (110 lb/ft^3) (.01 organic content) = 4.79×10^6 lbs. ✓

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Written by: JM Date: 6/APR/96 Reviewed by: JC Date: 06/04/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

Table 1: Organic Material

Component	Organic Weight (lbs)	Organic Weight (Mg)	Organic Volume (yd^3)
MSW	3.04×10^6	1.38×10^3 ✓	2,250 (12.5%) ✓
Wood	2.07×10^7	9.41×10^3 ✓	17,571 (30%) ✓
Grubbing Waste	4.79×10^6	2.18×10^3 ✓	1,613 (1%) ✓
Total	**2.85×10^7**	**1.30×10^4** ✓	**21,434** ✓

B. **Filling Rate**

1. Cells 1 Through 3

Assume all MSW and half of wood and grubbing waste goes into Cells 1-3 in first five years; then total organic weight in Cells 1-3 is:

$$1.38 \times 10^3 + (0.5)(9.41 \times 10^3 + 2.18 \times 10^3) = 7{,}175 \text{ Mg}$$ ✓

Organic material filling rate: 7,175 Mg/5 yr = 1,435 Mg/yr
Equivalent MSW Filling rate: 2 x 1,435 Mg/yr = 2,870 Mg/yr ✓
(assuming MSW is 50% organic)

2. Cells 4 Through 8

Total organic weight in Cells 4-9: $1.30 \times 10^4 - 7.175 \times 10^3 = 5{,}825$
Organic material filling rate: $5{,}825 \times 10^3$ Mg/5 yr = $1{,}165 \times 10^3$ Mg/yr
Equivalent MSW filling rate: 2 x 1,165 Mg/yr = 2,330 Mg/yr ✓
(assuming MSW is 50% organic)

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Written by: JM Date: 6 APR/96 Reviewed by: JC Date: 06/04/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

ESTIMATE OF METHANE GENERATION

I. Total Methane Generation Potential

A. Consider a Theoretical Maximum Based on Stoichiometric Conversion

This is a highly conservative upper bound presented only to define the physical limit of the methane generation potential.

1. From Thornloe et al. [1993]:

   Methane generation potential of cellulose is 415 liters CH_4/dry kg and of hemicellulose 424 liters CH_4/dry kg; these materials account for most of the methane generation potential of MSW. Use an average value of 420 liters/kg (14,830 ft^3/Mg) for the following calculation.

2. Conservatively assume that the estimated organic content of the OSDF (i.e., 1.30 x 10^4 Mg, moist, from Table 1) is all cellulose and hemicellulose and has a moisture content of 90% (dry wt. basis)

$$Dry\ Weight = \frac{1.30 \times 10^4\ Mg}{1 + 0.9} \times 10^3\ \frac{kg}{Mg} = 6.84 \times 10^6\ kg,\ dry\ organic\ material$$

CH_4 Potential = (6.84 x 10^6 kg) (420 liters CH^4/dry kg)
= 2.87 x 10^9 liters

3. Convert to LFG industry standard temperature (20°C): (at constant pressure)

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{(2.87 \times 10^9 l)(293°K)}{(273°K)(28.32\ l/ft^3)} = 1.09 \times 10^8\ ft^3$$

The theoretical maximum methane generation is 109 x 10^6 ft^3.

B. Consider a Typical MSW Material

The methane generation potential for typical MSW is 4,411 ft^3/Mg (125 liters/kg) [USEPA, 1994].

C. Consider a Lower Bound MSW Material

1. A lower bound methane potential of MSW measured during a field study [Pacey, 1989] was 38.6 liters CH_4/dry kg refuse. Applying this to the OSDF results in the total methane potential shown below.

$$\frac{(7.15 \times 10^6\ kg)(38.6\ l/kg)(293°\ K)}{(273°\ K)(28.32\ l/ft^3)} = 10.46 \times 10^6 ft^3\ CH_4$$ ✓

2. Convert 38.6 liters/kg to units of ft^3/Mg
(38.6 liters/kg) (10^3 kg/Mg)/(28.32 liters/ft^3) = 1,363 ft^3/Mg ✓

D. Consider OSDF Impacted Material

1. The total methane generation potential will be less than typical MSW (which in turn is only about one-third to one-quarter of the theoretical maximum based on a stoichiometric conversion) because of the lower temperatures, decreased moisture availability, and less vigorous methanogenic bacteria community in the OSDF compared to a MSW landfill.

2. It is believed to be conservative to assume that the OSDF methane generation potential is equal to the lower-bound MSW methane generation potential of 1,363 ft^3/Mg reported above.

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II. Concentration of Organic Material (use volume basis)

A. Methane generation rate is directly proportional to organic concentration [Amaral and Knowles, 1994]. Therefore, compare the organic content of the OSDF to that of typical MSW and, in the next step, reduce the methane generation rate expected for the OSDF accordingly.

B. Organic Contents

1. Organic content of typical MSW: Assume 50% organic [Franklin Associates, 1992]

2. Organic Content of Cells 1-3

Using the volumes of organic material from Table 1 and the distribution of organics described under "Filling Rate", the volume of organic material in cells 1-3 is estimated as follows.

Organic volume: 2,250 + 0.5 (17,571 + 1,613) = 11,842 yd^3
Cells 1-3 account for approximately 30% of the total volume of the OSDF (i.e., 27.5 x 10^6 yd^3)
Total Volume: 27.5 x 10^6 yd^3 ÷ 3 = 9.2 x 10^6 yd^3
Organic Content: (11,842 yd^3/9.2 x 10^6 yd^3) x 100% = 0.13% (< 1/300th of typical MSW) ✓

3. Organic Content of Cells 4-8

Organic Volume: 21,434 yd^3 - 11,842 yd^3 = 9,592 yd^3
Total Volume: 27.5 x 10^6 - 9.2 x 10^6 = 18.3 x 10^6 yd^3
Organic Content: (9,592/18.3 x 10^6 yd^3) x 100% = 0.05% (1/1000th of typical MSW) ✓

~~Knowles, 1994]~~. The organic concentration in the OSDF will be about 1/300th to 1/1000th of the organic concentration of a MSW landfill. It is unknown whether the proportionality is linear, but it is believed to be conservative to assume the linearity exists. The actual methane generation rate may be lower than predicted by a linear proportionality because of the lower temperatures, decreased moisture availability, and less vigorous methanogenic bacteria community in the OSDF compared to a typical MSW landfill.

- Provisions are included in the impacted material placement plan that are intended to achieve as uniform a distribution of organic material throughout the OSDF as is operationally feasible.

- Based on the factors discussed, it is believed to be conservative to assume that the actual methane generation rate in the OSDF is 1/100th of that for typical MSW.

- A typical MSW methane generation rate constant value is: k=0.04 1/yr [USEPA, 1994].

- Therefore, a conservative value for the methane generation rate constant for the OSDF is k=0.0004 1/yr. This value is used for the subsequent calculations.

II. Methane Generation Rate

Method: Use a methane generation model developed for MSW (i.e., the EPA Landfill Air Emissions Estimation Model [EPA,1991]) as implemented by a spreadsheet developed by GeoSyntec. Computer output from the EPA model is attached to show that the spreadsheet provides identical results.

Assumptions: Assumptions for filling rate (10 years) and equivalent weight of MSW in the OSDF were presented previously. To simplify the calculation, the same methane generation rate constant is used for waste in all cells of the OSDF.

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Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

Analysis: Methane generation is calculated using the methane generation potential and the methane generation rate constant selected for the OSDF as presented above (i.e., L_o = 1,363 ft^3/Mg and k = 0.0004 1/yr). The spreadsheet was used to model a period of 100 years; results from years 1 through 30 are printed on the attached spreadsheet; results from years 1 through 100 are plotted on the attached graph.

Results: The maximum annual methane generation rate is 1.42×10^4 ft^3 CH_4/yr. ✓

GE3900-10.2/Methane.cal

OUTPUT FROM EPA MODEL FOR VERIFICATION OF SPREADSHEET MODEL 21/42

740

SM 6 APR 96

Model Parameters

==========

Lo : 4411.000000 ft^3 / Mg ***** Note : Default value not used ****

k : 0.004000 1/yr ***** Note : Default value not used ****

KC 6 Apr 96

NMOC : 0.000000 ppmv ***** Note : Default value not used ****

Methane : 50.000000 % volume

Carbon Dioxide : 50.000000 % volume

Parameters for verification

Landfill Parameters

==========

Year Opened : 1996 Current Year : 2027 Year Closed: 2006

Capacity : 26000.000000 Mg

Average Acceptance Rate : 838.709677 Mg/year

Average Acceptance Rate Required from

Current Year to Closure Year : 0.000000 Mg/year

Model Parameters

==========

Year	Refuse In Place (Mg)	Methane Emission Rate (Mg/yr)	(Cubic Ft/yr)
1997	2.870E+003	9.566E-001	5.064E+004
1998	5.740E+003	1.909E+000	1.011E+005
1999	8.610E+003	2.858E+000	1.513E+005
2000	1.148E+004	3.804E+000	2.013E+005
2001	1.435E+004	4.745E+000	2.512E+005
2002	1.668E+004	5.503E+000	2.913E+005
2003	1.901E+004	6.258E+000	3.312E+005
2004	2.134E+004	7.009E+000	3.710E+005
2005	2.367E+004	7.758E+000	4.107E+005
2006	2.600E+004	8.504E+000	4.501E+005
2007	2.600E+004	8.470E+000	4.483E+005
2008	2.600E+004	8.436E+000	4.465E+005
2009	2.600E+004	8.402E+000	4.448E+005
2010	2.600E+004	8.369E+000	4.430E+005
2011	2.600E+004	8.335E+000	4.412E+005
2012	2.600E+004	8.302E+000	4.394E+005
2013	2.600E+004	8.269E+000	4.377E+005
2014	2.600E+004	8.236E+000	4.359E+005
2015	2.600E+004	8.203E+000	4.342E+005
2016	2.600E+004	8.170E+000	4.325E+005

These values are identical to those calculated using GeoSyntec's spreadsheet

VERIFICATION OF SPREADSHEET MODEL.

OSDF METHANE GENERATION
Spreadsheet Implementation of EPA's Landfill Air Emissions Estimation Model
Parameters for verification

Project No. GE3900
Task No. 10.2
Prepared by T. Maier
5-Apr-96

Lo = 4411 cf/Mg Potential Methane Generation Capacity (of equivalent MSW weight in the OSDF)
k = 0.004 1/yr Methane Generation Rate Constant

Year	Refuse in Place (Mg)	Mass of Waste Placed Each Year of Ten Year Filling Period (Mg)										Total Methane (cf)	Total LFG (cf)
		2870	2870	2870	2870	2870	2330	2330	2330	2330	2330		
		Methane Emissions per Waste Unit per Year (cf)											
1	2870	5.06E+04										5.064E+04	1.01E+05
2	5740	5.04E+04	5.06E+04									1.011E+05	2.02E+05
3	8610	5.02E+04	5.04E+04	5.06E+04								1.513E+05	3.03E+05
4	11480	5.00E+04	5.02E+04	5.04E+04	5.06E+04							2.013E+05	4.03E+05
5	14350	4.98E+04	5.00E+04	5.02E+04	5.04E+04	5.06E+04						2.512E+05	5.02E+05
6	16680	4.96E+04	4.98E+04	5.00E+04	5.02E+04	5.04E+04	4.11E+04					2.913E+05	5.83E+05
7	19010	4.94E+04	4.96E+04	4.98E+04	5.00E+04	5.02E+04	4.09E+04	4.11E+04				3.312E+05	6.62E+05
8	21340	4.92E+04	4.94E+04	4.96E+04	4.98E+04	5.00E+04	4.08E+04	4.09E+04	4.11E+04			3.710E+05	7.42E+05
9	23670	4.90E+04	4.92E+04	4.94E+04	4.96E+04	4.98E+04	4.06E+04	4.08E+04	4.09E+04	4.11E+04		4.107E+05	8.21E+05
10	26000	4.88E+04	4.90E+04	4.92E+04	4.94E+04	4.96E+04	4.05E+04	4.06E+04	4.08E+04	4.09E+04	4.11E+04	4.501E+05	9.00E+05
11	26000	4.87E+04	4.88E+04	4.90E+04	4.92E+04	4.94E+04	4.03E+04	4.05E+04	4.06E+04	4.08E+04	4.09E+04	4.483E+05	8.97E+05
12	26000	4.85E+04	4.87E+04	4.88E+04	4.90E+04	4.92E+04	4.01E+04	4.03E+04	4.05E+04	4.06E+04	4.08E+04	4.465E+05	8.93E+05
13	26000	4.83E+04	4.85E+04	4.87E+04	4.88E+04	4.90E+04	4.00E+04	4.01E+04	4.03E+04	4.05E+04	4.06E+04	4.448E+05	8.90E+05
14	26000	4.81E+04	4.83E+04	4.85E+04	4.87E+04	4.88E+04	3.98E+04	4.00E+04	4.01E+04	4.03E+04	4.05E+04	4.430E+05	8.86E+05
15	26000	4.79E+04	4.81E+04	4.83E+04	4.85E+04	4.87E+04	3.97E+04	3.98E+04	4.00E+04	4.01E+04	4.03E+04	4.412E+05	8.82E+05
16	26000	4.77E+04	4.79E+04	4.81E+04	4.83E+04	4.85E+04	3.95E+04	3.97E+04	3.98E+04	4.00E+04	4.01E+04	4.394E+05	8.79E+05
17	26000	4.75E+04	4.77E+04	4.79E+04	4.81E+04	4.83E+04	3.93E+04	3.95E+04	3.97E+04	3.98E+04	4.00E+04	4.377E+05	8.75E+05
18	26000	4.73E+04	4.75E+04	4.77E+04	4.79E+04	4.81E+04	3.92E+04	3.93E+04	3.95E+04	3.97E+04	3.98E+04	4.359E+05	8.72E+05
19	26000	4.71E+04	4.73E+04	4.75E+04	4.77E+04	4.79E+04	3.90E+04	3.92E+04	3.93E+04	3.95E+04	3.97E+04	4.342E+05	8.68E+05
20	26000	4.69E+04	4.71E+04	4.73E+04	4.75E+04	4.77E+04	3.89E+04	3.90E+04	3.92E+04	3.93E+04	3.95E+04	4.325E+05	8.65E+05
21	26000	4.67E+04	4.69E+04	4.71E+04	4.73E+04	4.75E+04	3.87E+04	3.89E+04	3.90E+04	3.92E+04	3.93E+04	4.307E+05	8.61E+05
22	26000	4.66E+04	4.67E+04	4.69E+04	4.71E+04	4.73E+04	3.86E+04	3.87E+04	3.89E+04	3.90E+04	3.92E+04	4.290E+05	8.58E+05
23	26000	4.64E+04	4.66E+04	4.67E+04	4.69E+04	4.71E+04	3.84E+04	3.86E+04	3.87E+04	3.89E+04	3.90E+04	4.273E+05	8.55E+05
24	26000	4.62E+04	4.64E+04	4.66E+04	4.67E+04	4.69E+04	3.83E+04	3.84E+04	3.86E+04	3.87E+04	3.89E+04	4.256E+05	8.51E+05
25	26000	4.60E+04	4.62E+04	4.64E+04	4.66E+04	4.67E+04	3.81E+04	3.83E+04	3.84E+04	3.86E+04	3.87E+04	4.239E+05	8.48E+05
26	26000	4.58E+04	4.60E+04	4.62E+04	4.64E+04	4.66E+04	3.79E+04	3.81E+04	3.83E+04	3.84E+04	3.86E+04	4.222E+05	8.44E+05
27	26000	4.56E+04	4.58E+04	4.60E+04	4.62E+04	4.64E+04	3.78E+04	3.79E+04	3.81E+04	3.83E+04	3.84E+04	4.205E+05	8.41E+05
28	26000	4.55E+04	4.56E+04	4.58E+04	4.60E+04	4.62E+04	3.76E+04	3.78E+04	3.79E+04	3.81E+04	3.83E+04	4.189E+05	8.38E+05
29	26000	4.53E+04	4.55E+04	4.56E+04	4.58E+04	4.60E+04	3.75E+04	3.76E+04	3.78E+04	3.79E+04	3.81E+04	4.172E+05	8.34E+05
30	26000	4.51E+04	4.53E+04	4.55E+04	4.56E+04	4.58E+04	3.73E+04	3.75E+04	3.76E+04	3.78E+04	3.79E+04	4.155E+05	8.31E+05

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EMISSIONS CALCULATED FOR OSDF

OSDF METHANE GENERATION
Spreadsheet Implementation of EPA's Landfill Air Emissions Estimation Model

Project No. GE3900
Task No. 10.2
Prepared by T. Maier
5-Apr-96

Lo = 1363 cf/Mg Potential Methane Generation Capacity (of equivalent MSW weight in the OSDF)
k = 0.0004 1/yr Methane Generation Rate Constant

Year	Refuse in Place (Mg)	Mass of Waste Placed Each Year of Ten Year Filling Period (Mg)										Total Methane (cf)	Total LFG (cf)
		2870	2870	2870	2870	2870	2330	2330	2330	2330	2330		
		Methane Emissions per Waste Unit per Year (cf)											
1	2870	1.56E+03										1.565E+03	3.13E+03
2	5740	1.56E+03	1.56E+03									3.129E+03	6.26E+03
3	8610	1.56E+03	1.56E+03	1.56E+03								4.692E+03	9.38E+03
4	11480	1.56E+03	1.56E+03	1.56E+03	1.56E+03							6.255E+03	1.25E+04
5	14350	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03						7.817E+03	1.56E+04
6	16680	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.27E+03					9.085E+03	1.82E+04
7	19010	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.27E+03	1.27E+03				1.035E+04	2.07E+04
8	21340	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.27E+03	1.27E+03	1.27E+03			1.162E+04	2.32E+04
9	23670	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03		1.288E+04	2.58E+04
10	26000	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.415E+04	2.83E+04
11	26000	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.414E+04	2.83E+04
12	26000	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.414E+04	2.83E+04
13	26000	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.413E+04	2.83E+04
14	26000	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.413E+04	2.83E+04
15	26000	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.412E+04	2.82E+04
16	26000	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.411E+04	2.82E+04
17	26000	1.55E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.26E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.411E+04	2.82E+04
18	26000	1.55E+03	1.55E+03	1.56E+03	1.56E+03	1.56E+03	1.26E+03	1.26E+03	1.27E+03	1.27E+03	1.27E+03	1.410E+04	2.82E+04
19	26000	1.55E+03	1.55E+03	1.55E+03	1.56E+03	1.56E+03	1.26E+03	1.26E+03	1.26E+03	1.27E+03	1.27E+03	1.410E+04	2.82E+04
20	26000	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.56E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.27E+03	1.409E+04	2.82E+04
21	26000	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.409E+04	2.82E+04
22	26000	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.408E+04	2.82E+04
23	26000	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.407E+04	2.81E+04
24	26000	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.407E+04	2.81E+04
25	26000	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.406E+04	2.81E+04
26	26000	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.406E+04	2.81E+04
27	26000	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.405E+04	2.81E+04
28	26000	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.405E+04	2.81E+04
29	26000	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.404E+04	2.81E+04
30	26000	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.55E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.404E+04	2.81E+04

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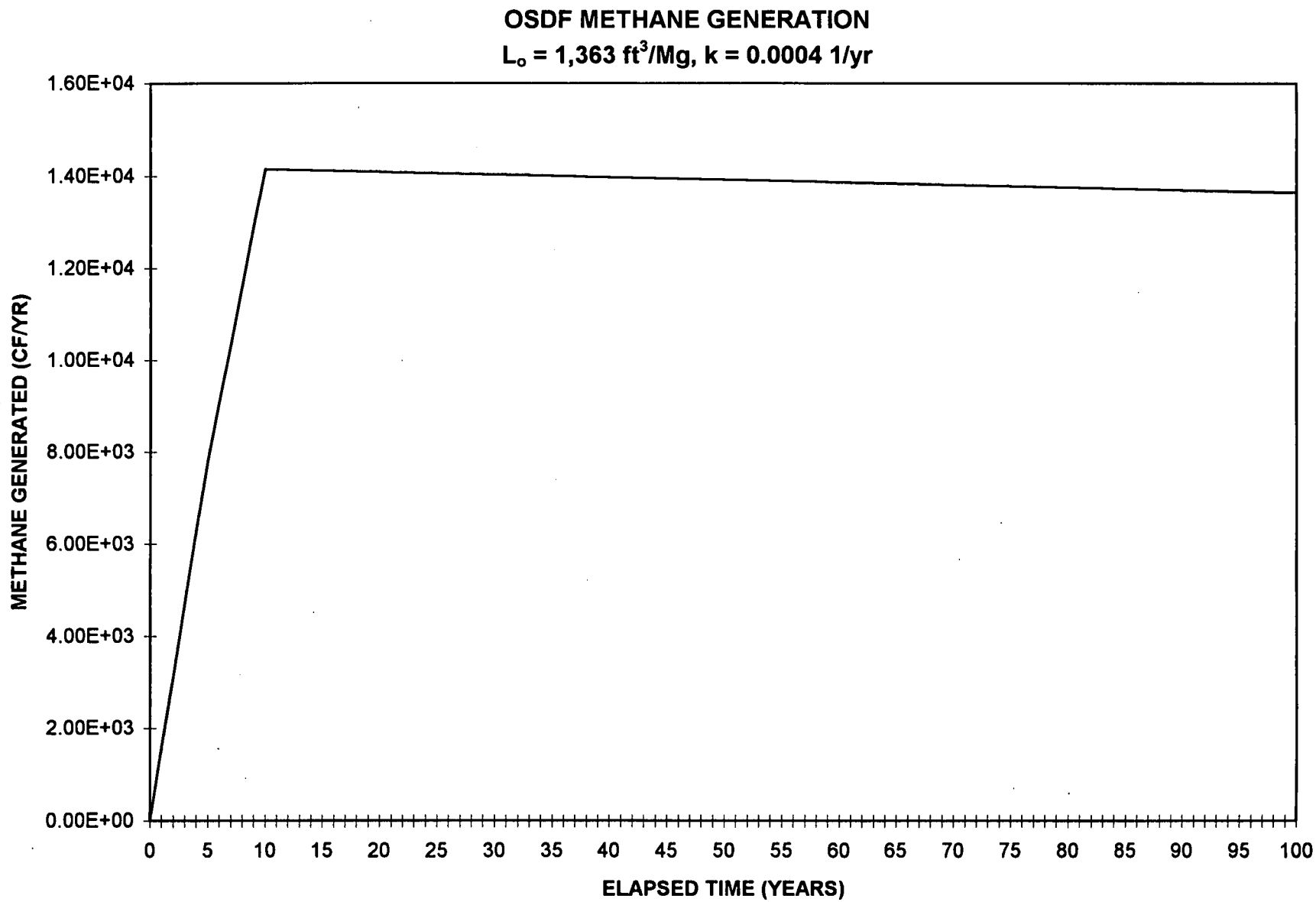

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Written by: JM Date: 6 APR 1 96 Reviewed by: [illegible] Date: 06/04/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

LANDFILL GAS BALANCE MODEL

Objective: Evaluate the likelihood of health and safety problems occurring and the potential for cap geomembrane uplift occurring by using a simple landfill gas (LFG) balance model.

Description: The LFG balance model is described by the following equation:

LFG Generated = LFG Collected + LFG Emitted to Atmosphere + LFG Oxidized + LFG Lost + LFG Stored

Assumptions:

1. LFG Collected = 0 , no gas collection system
   LFG Lost = 0 , the geosynthetic liner will effectively prevent subsurface gas migration
   LFG Oxidized = 0
   LFG Emitted to Atmosphere = LFG Diffused

   For this calculation, the relevant parameter is total LFG losses from the landfill interior. Assume the only losses are due to diffusion through the geomembrane cap. Ignore oxidation of the methane portion of LFG because this can only occur after methane has entered oxygenated soils (i.e., soils above the geomembrane cap. The purpose of this model is to estimate internal landfill pressure, therefore the fate of methane that leaves the landfill interior is not considered. It is possible that all of the methane that diffuses through the geomembrane cap will be oxidized in the cover soils and that none of it will be emitted to the atmosphere, as discussed in the attached narrative.

   The simplified LFG balance model is :

   LFG Generated = LFG Diffused + LFG Stored

Written by: JM Date: 6 APR 96 Reviewed by: [illegible] Date: 06/04/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

2. Assume the pressure in the landfill is initially 1 atm and the pressure change can be calculated using the ideal gas law based on the amount of landfill gas stored in the landfill.

3. LFG Diffused = Flux through Geomembrane Cap

   Methane flux through geomembrane cap = 0.003 g/m^2.day [Bogner and Scott, 1995]

   This value is the lowest reported measured methane flux rate at the surface of an MSW landfill. It is conservatively assumed that no carbon dioxide diffuses because data on carbon dioxide flux rate are not available.

Calculations:

1. Pressure in Landfill

   Use PV = nRT

   where:
   - p = pressure (atm)
   - v = volume (liters)
   - n = number of moles (dimensionless)
   - R = 0.0821 liter atm/mole °K
   - T = temperature (°K)

$$\frac{P_1V_1}{P_2V_2} = \frac{n_1RT_1}{n_2RT_2}$$

Assume for the OSDF $T_1=T_2$, $V_1=V_2$

$$P_2 = \frac{P_1n_2}{n_1}$$

Volume of 1 mole of any gas at STP = 22.4 liters

T = 0°C

Written by: JM Date: 6 APR / 96 Reviewed by: [illegible] Date: 06/04/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

Volume at 20°C:

$$\frac{24.04\ l/mole}{28.32\ l/ft^3} = 0.8489\ ft^3/mole \quad at\ 20°C$$

2. Diffused Landfill Gas

$$n_1 = \frac{Vi}{0.8489},\ n_2 = \frac{Vi + \Delta V}{0.8489},\ use\ \ volumes\ \ calculated\ \ at\ \ STP\ \ by\ \ EPA\ \ LAEEM$$

$$P_2 = P_1 \frac{\left[\frac{Vi + \Delta V}{0.8489}\right]}{\left[\frac{Vi}{0.8489}\right]} = \frac{P_1(Vi + \Delta V)}{Vi},\ where\ \ all\ \ volumes\ \ are\ \ at\ \ STP$$

Assume methane flux through geomembrane is 0.003 g/m^2 day
1g CH_4 = 1/16 mole (gram atomic weight of CH_4 is 16)

$$V = \frac{nRT}{P} = \frac{(1/16)(0.0821)(293)}{(1)} = 1.50\ liters$$

$$\frac{1.50\ liters}{28.32\ liters/ft^3} = 0.053\ ft^3/g \quad CH_4\ at\ 20°C,\ 1\ atm$$

Assume surface area of cap is 64 acres.

Flux = (.003 g/m^2 day) (.053 ft^3/g) (64 ac x 43,560 ft^3/ac) (.3048 m/ft)^2
= 41 standard ft^3 CH_4/day

GE3900-10.2/Methane.cal

GeoSyntec Consultants

Written by: JM Date: 6 Apr / 96 Reviewed by: [illegible] Date: 06/04/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

41 ft^3/day x 365.25 day/yr = 15,000 ft^3/yr ✓

Total diffused landfill gas: 15,000 ft^3/yr

3. Landfill Gas Balance Calculation
   See attached spreadsheet.

JM 6 APR 96 740 29/42

KC 6 Apr 96

OSDF METHANE GENERATION
LANDFILL GAS BALANCE MODEL

Project No. GE3900
Task No. 10.2
Prepared by T. Maier
5-Apr-96

Methane generation was calculated using parameters for low end of expected range for the OSDF (Lo = 1363 cf/Mg, k = 0.0004 1/yr)

Air Filled Void Space Estimatation

Total air space	7.43E+08	cf	2.75E+07 cy
Ave. porosity	0.445		
1 - Ave. saturation	0.12	(Ave. saturation is 0.88)	
Air filled void space	3.96E+07	cf	

Emission, Storage, and Pressure Calculation

Year	Methane Generated (cf)	Gas Generated (cf)	Gas Emitted (cf)	Gas Diffused (cf)	Gas Stored (cf)	Cumulative Storage (cf)	Pressure (atm)
1	1.56E+03	3.13E+03	3.13E+03				1.000
2	3.13E+03	6.26E+03	6.26E+03				1.000
3	4.69E+03	9.38E+03	9.38E+03				1.000
4	6.26E+03	1.25E+04	1.25E+04				1.000
5	7.82E+03	1.56E+04	1.56E+04				1.000
6	9.08E+03	1.82E+04	1.82E+04				1.000
7	1.04E+04	2.07E+04	2.07E+04				1.000
8	1.16E+04	2.32E+04	2.32E+04				1.000
9	1.29E+04	2.58E+04	2.58E+04				1.000
10	1.41E+04	2.83E+04	2.83E+04				1.000
11	1.41E+04	2.83E+04		1.50E+04	1.33E+04	1.33E+04	1.0003
12	1.41E+04	2.83E+04		1.50E+04	1.33E+04	2.66E+04	1.0007
13	1.41E+04	2.83E+04		1.50E+04	1.33E+04	3.98E+04	1.0010
14	1.41E+04	2.83E+04		1.50E+04	1.33E+04	5.31E+04	1.0013
15	1.41E+04	2.82E+04		1.50E+04	1.32E+04	6.63E+04	1.0017
16	1.41E+04	2.82E+04		1.50E+04	1.32E+04	7.95E+04	1.0020
17	1.41E+04	2.82E+04		1.50E+04	1.32E+04	9.28E+04	1.0023
18	1.41E+04	2.82E+04		1.50E+04	1.32E+04	1.06E+05	1.0027
19	1.41E+04	2.82E+04		1.50E+04	1.32E+04	1.19E+05	1.0030
20	1.41E+04	2.82E+04		1.50E+04	1.32E+04	1.32E+05	1.0033
21	1.41E+04	2.82E+04		1.50E+04	1.32E+04	1.46E+05	1.0037
22	1.41E+04	2.82E+04		1.50E+04	1.32E+04	1.59E+05	1.0040
23	1.41E+04	2.81E+04		1.50E+04	1.31E+04	1.72E+05	1.0043
24	1.41E+04	2.81E+04		1.50E+04	1.31E+04	1.85E+05	1.0047
25	1.41E+04	2.81E+04		1.50E+04	1.31E+04	1.98E+05	1.0050
26	1.41E+04	2.81E+04		1.50E+04	1.31E+04	2.11E+05	1.0053
27	1.41E+04	2.81E+04		1.50E+04	1.31E+04	2.24E+05	1.0057
28	1.40E+04	2.81E+04		1.50E+04	1.31E+04	2.37E+05	1.0060
29	1.40E+04	2.81E+04		1.50E+04	1.31E+04	2.50E+05	1.0063
30	1.40E+04	2.81E+04		1.50E+04	1.31E+04	2.64E+05	1.0066

Written by: JM Date: 6/APR/95 Reviewed by: K Date: 06/04/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

4. Evaluation of Landfill Gas Balance Model

The generated landfill gas expected to have no effects on the final cover system if the difference between the internal landfill pressure and atmospheric pressure remains substantially less than the vertical stress at the base of the final cover system due to the weight of the final cover system. The vertical stress at the base of the final cover system is calculated below. The thicknesses of the cover system layers were obtained from the design drawings and the unit weights of the cover system materials were obtained from Calculation Package 1.1.

Cap Layer	Thickness (ft)	Unit Weight (pcf)	Vertical Stress Due to Layer (psf)
Topsoil	0.5	125	62.5
Vegetative Soil	1.75	125	218.8
Granular Filter	0.5	125	62.5
Biointrusion Layer	3.0	125	375.0
Cover Drainage Layer	1.0	125	125.0
Clay Cap	2.0	130	260.0
		TOTAL	**1,103.8 PSF (0.52 atm)**

Total vertical pressure on cap = 1 atm + 0.52 atm = 1.52 atm

- Comparison of the calculated internal landfill pressure to the vertical stress at the base of the final cover system shows that there is no potential for the generated gas to affect the final cover system.

- The OSDF may generate enough methane to cause methane to migrate through the OSDF leachate collection, and possibly leak detection, pipes. All outlet points from

these pipes should be periodically monitored. Should methane be detected at concentrations approaching 25 percent of the methane lower explosive limit in any confined space, then mitigation measures, such as venting, should be implemented.

References

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Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 10.2

OSDF METHANE GENERATION

NARRATIVE

Evaluation of Environmental Impacts on Landfill Gas Generation

GE3900-10.2/Methane.cal

1. INTRODUCTION

The purpose of this document is to provide a technical basis for the gas management activities design criteria presented in the *Design Criteria Package*. The following topics are addressed: (i) the biological process of methanogenesis; (ii) environmental impacts on landfill gas generation; and (iii) potential modifications to landfill construction and operating practices.

2. METHANOGENESIS

The biological generation of gaseous methane, commonly known as methanogenesis, is mediated by a class of bacteria known as methanogenic bacteria or methanogens. Methanogens are primitive bacteria that form methane as the endproduct of an anaerobic respiratory mechanism. Some of the more common methanogenic bacterial genera include *Methanobacterium, Methanobrevibacter, Methanosphaera, Methanococcus,* and *Methanosarcina* [Atlas, 1984]. Within each genus, several species exist which are capable of mediating methanogenesis.

Methanogenesis is an obligately anaerobic process; that is, it will not occur in the presence of oxygen, but has the possibility to occur wherever the oxygen content of the surrounding environment is low. In nature, anaerobic microzones may exist in which methanogenesis can occur shielded from the inhibitory effect of oxygen. Common anaerobic environments include the mammalian gastrointestinal tract, swamps, salt marshes, and landfills.

At the molecular level (i.e., in pure culture), methane is formed by the reduction (i.e., hydrogen addition) of oxidized forms of carbon, principally carbon dioxide, formate, acetate, methanol, methylamines, and other, simple carbohydrates [Atlas, 1984]. However, in nature, these substances rarely occur naturally in substantial quantities. Invariably, the action of other bacterial populations is responsible for the initial metabolism of more complicated carbon sources (i.e., lignocellulose, hemicellulose, etc.) to a simpler form that is more easily assimilated by methanogenic bacteria. This action is frequently mediated aerobically or under microaerophilic (i.e., low oxygen) conditions. The metabolized carbon is then translocated to an anaerobic zone where various anaerobic processes, including methanogenesis, will occur.

3. ENVIRONMENTAL IMPACTS ON LANDFILL GAS GENERATION

3.1 Introduction

The purpose of this section is to discuss the environmental factors that control the rate of gas generation due to biological activity. In Section 3.2, the environmental factors conducive to the growth of soil bacteria in general are summarized. In Section 3.3, the most critical environmental factors that can limit the rate of methanogenesis are discussed. In Section 3.4, the most critical environmental factors that can limit the rate of carbon dioxide generation are discussed.

3.2 Environmental Factors Influencing Microbial Activity

Several environmental factors have been identified that impact overall microbial activity in soils. These factors are as follows:

- available soil water;
- oxygen availability;
- redox potential;
- pH;
- nutrient availability; and
- temperature.

A brief discussion of the impacts of these factors follows.

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Available Soil Water

Optimum moisture levels for microbial activity are 25 to 85 percent of soil water holding capacity [Sims et al., 1989] Soil water is important for bacterial growth in that it is required for growth of bacteria, serves as a transport medium for nutrients and organic constituents, and also affects soil aeration by physically displacing oxygen [Sims et al., 1989], thereby accelerating the attainment of anaerobic conditions.

Oxygen Availability

Oxygen availability determines the degree to which aerobic or anaerobic processes will predominate in a given environment. Generally, when the air filled pore space of soil is less than 1 percent, anaerobic conditions exist [Sims et al., 1989].

Redox Potential

This factor, which correlates to the oxygen content of the soil, determines which processes will predominate in a given environment. Generally, when the redox potential is less than 50 millivolts, anaerobic bacterial growth is promoted [Sims et al., 1989]. However, some species of anaerobic bacteria, specifically methanogens, require more reducing conditions than 50 millivolts to effectively grow.

Soil pH

A general range conducive to bacterial growth is 5.5 to 8.5 [Sims et al., 1989]. Specific types of bacteria will grow better under a narrower range of pH conditions. The optimum pH range for methanogenesis is 6.8 to 7.9; methane production decreases sharply with pH less than about 6.5 [Thorneloe et al., 1993, p. 366].

Nutrient Levels

Bacterial growth is largely dependent on nutrient levels required for organic carbon metabolism. The chief types of nutrients required for microbial growth are nitrogen and phosphorus. A suggested ratio of these nutrients to carbon is a C:N:P ratio of 120:10:1 [Sims et al., 1989]. This ratio is generally recommended for aerobic, high rate applications, however, and will vary widely depending on the populations under consideration and the organic constituents to be degraded.

Temperature

Most bacteriological processes will occur most rapidly in the mesophilic (15-45°C) temperature range [Sims et al., 1989]. Biological activity slows dramatically at temperatures less than 4°C and halts completely at temperatures less than 0°C [Sims et al., 1989].

3.3 Environmental Factors Influencing Methanogenesis

In naturally anaerobic environments, methanogenesis will always occur to some degree. The rate at which methane is produced is largely regulated by the concomitant effects of several environmental factors, predominantly:

- oxygen availability;
- competitive inhibition from sulfate reducing and denitrifying bacteria; and
- carbon availability.

In addition, consumption of methane by methanotrophic bacteria in aerobic zones can reduce the emission of methane to the atmosphere. The effects of these environmental factors are described individually below.

Oxygen Content

Oxygen availability is the single most critical environmental factor that is limiting to methanogenesis rates. Methanogenesis will not occur to a significant degree in aerobic or oxygen enriched environments. The interior of a landfill is a predominantly anaerobic environment, and, therefore, no oxygen inhibition is expected within the OSDF.

Competitive Inhibition

Some other types of anaerobic respiration include denitrification, sulfate reduction, iron reduction, and manganese reduction. All of the above processes are more energetically favorable than is methanogenesis, and, consequently, bacterial populations responsible for the execution of these reactions compete with methanogens for available carbon and hydrogen. In many natural environments, the two principal types of competing anaerobic respiratory processes are denitrification and sulfate reduction. Thus, when nitrates and/or sulfates are present in excess in the environment of interest and anaerobic conditions exist, denitrifying and/or sulfate reducing bacteria will likely proliferate at the expense of methanogens, thereby inhibiting methanogenesis. An oversupply of nitrates and/or sulfates is not expected in the interior of a landfill, and thus competitive inhibition of methanogenesis is not expected to be significant within the OSDF.

Carbon Availability

A critical environmental factor regulating the production of methane in ecosystems is the availability of extractable metabolizable (i.e., labile) organic carbon [Kelly and Chynoweth, 1981]. In several studies performed on swamp and peat bog systems, high rates of methanogenesis were correlated to high levels of labile organic carbon [Amaral and Knowles, 1994] and also to high levels of easily decomposed vegetation [Amaral and Knowles, 1994]. Because the mechanism of methanogenesis does not typically vary with environment, similar correlations should be expected in landfill environments (i.e., the level of labile organic carbon should be correlated with the rate of methanogenesis).

Methane Consumption

It is important to note that, from a biological standpoint, anaerobic environments, while usually physically separate and distinct from aerobic environments, actively interact with aerobic environments. The interaction frequently involves the generation of one compound or group of compounds by one type of microbial group as a metabolic byproduct, which is subsequently used as a primary substrate by another group of bacteria. For example, in many swamp and marsh sediment systems, an aerobic layer overlays an anaerobic one at the soil:air interface. Frequently, complex carbon sources found in nature, such as cellulose and lignocellulose, are aerobically oxidized in the aerobic zone to simpler carbohydrates, such as acetate. These soluble carbohydrates are then translocated to the anaerobic zone to be used as a carbon and energy source for methanogenesis, sulfate reduction, or another type of anaerobic respiration. The exchange is two way in that compounds produced as a byproduct of anaerobic respiration (e.g., sulfide from sulfate reduction, methane from methanogenesis, nitrogen from denitrification, etc.) can be used by aerobic species in the aerobic zone. Similarly, certain species of methanotrophic bacteria, including *Methylobacter, Methylosinus* and *Methylomonas* species, have the capability to oxidize methane and other single carbon compounds to carbon dioxide and water in the presence of oxygen [Atlas, 1984]. This phenomenon can occur at landfill sites. In bench-scale studies conducted on landfill site soils from a United Kingdom landfill, the type of cover soils affording the maximum rates of methane oxidation, and hence the lowest rates of methane evolution, were investigated; the most effective cover soils in this regard were coarse sandy soils, the methanotrophic bacterial populations of which exhibited low affinity and high capacity methane oxidation kinetics when exposed to methane in a laboratory microcosm [Knightly, et. al. 1995]. In this study, the efficiency of the coarse soil types relative to the finer grained clays and sands was attributed largely to establishment of a significantly active methanotrophic community in the upper coarse grained cover soils that consumed oxygen as methane was oxidized, thereby preventing the permeation of oxygen to the lower, finer grained soils and maintaining their anaerobicity [Knightly, et. al. 1995].

3.4 Environmental Factors Influencing Carbon Dioxide Generation

Carbon dioxide is generated as a byproduct of various types of respiration, both aerobic and anaerobic. Carbon dioxide is formed when organic carbon is oxidized during respiratory processes. In a landfill, the predominant respiratory mechanism generating carbon dioxide is methanogenesis. Therefore, factors that mitigate methane generation, with the exception of oxygen introduction and competitive inhibition by other anaerobic species, would also tend to mitigate carbon dioxide production. The most critical limiting factor for carbon dioxide generation is the availability of carbon.

4. POTENTIAL MODIFICATIONS TO LANDFILL CONSTRUCTION AND OPERATING PRACTICES

Several factors regarding landfill construction and operating practices may be implemented that can mitigate the generation and release of methane from the landfill. These practices are grouped according to the parameter influencing the rate of methane synthesis and are summarized below.

Oxygen Availability

Because the injection of oxygen into a landfill could present a fire hazard and would be very costly, it is not feasible to use oxygen injection to suppress methanogenesis.

Carbon Availability

As noted by Amaral and Knowles [1994], methanogenesis rates are directly proportional to the concentration of labile organic carbon in the environment. The amount of potentially utilizable carbon proposed for disposal in the landfill is small relative to the total capacity of the landfill. By strategically spreading out the carbon (principally woody material) inside the landfill, the availability of the carbon to methanogenic bacteria may be somewhat restricted, and thus methanogenesis rates may be suppressed. The degree to which methanogenesis rates are suppressed, if any, will depend on the specific bacterial populations present in the landfill.

Because this is a relatively easy procedure to implement, it is recommended for this landfill.

Competitive Inhibition

As noted previously, other types of anaerobic respiration, specifically sulfate reducing and denitrifying bacteria, are much more energetically favorable than is methanogenesis, and in many cases, sulfate reducing bacteria and denitrifying bacteria are able to outcompete methanogens for available hydrogen and organic carbon. The potential for other types of anaerobic growth can be maximized by ensuring that sufficient electron acceptors relevant to the type of respiration under consideration (i.e., nitrate for denitrifiers, sulfate for sulfate reducers) is supplied. It would be very difficult to exogenously supply nitrates and sulfates in sufficient concentration to ensure that denitrifying and sulfate reducing bacteria will be able to overgrow the methanogens. Therefore, mitigation of methanogenesis by this procedure is not recommended.

Methane Consumption

As previously noted, certain methanotrophic species of bacteria are capable of aerobically oxidizing methane produced in underlying soil layers [Knightly, et. al., 1995]. This relationship has been demonstrated to exist between refuse and cover soils in landfills [Knightly, et. al., 1995]. By selecting the type of cover soils appropriately, the consumption of methane in this layer will be maximized. This procedure can be implemented fairly easily and is recommended. It should be noted that because the rates of methane oxidation will be dependent on site-specific environmental factors, bench and/or pilot-scale studies should be undertaken to ascertain rates of methane oxidation relative to methane production at the site under consideration.

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OSDF METHANE GENERATION

APPENDIX A

Landfill Air Emissions Estimation Model Documentation

For documentation of computer programs see

1.2 Computer Program Validation

GE3900-10.2/Methane.cal

16.4 OSDF Radon 222 Release

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: OSDF RADON 222 RELEASE

Computations By: (Cognizant Engineer)
Signature [signature] Date 6 APR 96
Printed Name and Title David N. Scotti, Assistant Project Geologist

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 6 Apr 96
Printed Name and Title Kenneth W Cargill, Associate

Computations Checked by:
Signature [signature] Date 6 Apr 96
Printed Name and Title Kenneth W Cargill, Associate

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 6 APR 96
Printed Name and Title David N. Scotti, Assistant Project Geologist

Approved by: (PDP)
Signature [signature] Date 08 Apr 96
Printed Name and Title Kenneth W Cargill, Associate

Approved by: (DTL and TETL)
Signature [signature] Date 8 April 96
Printed Name and Title Rudolph Bonaparte, Principal

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
ED	Intermediate Design - EPA Submittal				
G	Final Design Package	4 Oct 96	—	—	[signature]
O	Response to Final Design Cmts	5 May 97	—	—	[signature]

OSDF RADON 222 RELEASE

EXECUTIVE SUMMARY

Purpose of Analysis

The purpose of this analysis is to estimate radon emission rates from the On-Site Disposal Facility (OSDF). The estimated emission rates can then be compared to the regulatory limit to evaluate regulatory compliance. In general, regulatory compliance requires prevention of emission of radon at rates that: (i) exceed an average release rate of 20 picoCuries per square meter per second (pCi/m^2/s); or (ii) increase the average annual concentration of radon at or above any location outside the disposal site by more than 0.5 pCi per litre (pCi/l) (ARAR: 40 CFR § 192.02(b)).

Method of Analysis

Radon emission rates were calculated using the computer program "Radiation Attenuation Effectiveness and Cover Optimization with Moisture Effects (RAECOM)". This program is a one-dimensional, steady-state radon diffusion program which calculates the radon fluxes and concentrations in multilayer waste material and cover systems, and estimates radon emission rates from the cover systems.

Conclusions

Estimated radon emission rates were compared to the regulatory limit. Based on the estimates, release of radon to atmosphere will not: (i) exceed an average release rate of 20 pCi/m^2/s; or (ii) increase the average annual concentration of radon at or above any location outside the disposal site by more than 0.5 pCi per litre (pCi/l) (ARAR: 40 CFR § 192.02(b)).

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OSDF RADON 222 RELEASE

CALCULATION PROCEDURES

Purpose

The purpose of this document is to present the procedures used to calculate the release of radon from the OSDF both prior to and after construction of the final cover system. The calculations are performed in accordance with, and to verify compliance with, the DCP. The DCP requirements relevant to these calculations are:

- the radon emission rate shall be estimated using the computer code RAECOM [U.S. Nuclear Regulatory Commission (NRC), 1984a] (Appendix A); and
- the release of radon to atmosphere will not: (i) exceed 20 percent of the regulatory-established average release rate of 20 pCi/m^2/s; or (ii) increase the average annual concentration of radon at or above any location outside the disposal site by more than 0.5 pCi per litre (pCi/l) (ARAR: 40 CFR § 192.02(b)).

Scope

The procedures presented in this document will be used to prepare emission estimates for the release of radon from the OSDF prior to and after construction of the final cover system.

Calculation Procedures

Radon-222 will be generated within the OSDF due to the radioactive decay of U-238, via the decay series of Th-234, Pa-234, U-234, Th-230, and Ra-~~236~~ 226. Radon-222 is an inert, heavier-than-air, radioactive gas which will have the potential to migrate within the OSDF. For the purpose of this calculation, it is assumed that the radioactive production of Radon-222 from U-238 has achieved equilibrium and therefore the specific activity of Radon-222 is the same as U-238 (i.e., secular

equilibrium, as defined by Friedlander et al. [1981], is established within the OSDF). This assumption results in the most conservative (i.e., highest) estimate of radon emission rate.

Assuming secular equilibrium, the activity of Radon-222 will be determined by, and will be equal to the activity of U-238, which has the longest half-life (approximately 4.55 billion years) of the decay series, and is much longer than the half-life of Radon-222 (approximately 3.8 days). Estimates of Radon-222 emission rates from the waste materials without the attenuating capacity of the final cover system can then be based on the average U-238 concentration of the waste material. Based on discussions with FERMCO, the average U-238 concentration of the waste material is expected to be only about ten percent of the OSDF waste acceptance criteria (WAC) of 346 picoCuries per gram (pCi/g) of U-238, or 34.6 pCi/g.

The first step in estimating radon emission rates from the OSDF is to calculate the moisture saturation of the waste material and the layers of the cover system. The moisture saturation is calculated as follows:

$$m = \frac{W_{vi}}{n}$$

where:
- m = moisture saturation of the waste material;
- W_{vi} = volumetric water content; and
- n = porosity of the waste material.

The diffusion coefficient of the waste material may then be derived from Figure 1 (from NRC [1984b]), which represents the correlation between moisture saturation and radon diffusion coefficients.

The radon flux rate from the waste material may then be estimated using the procedures for estimating radon flux from bare uranium-mill tailings presented in the document titled "Radon Attenuation Handbook for Uranium-Mill Tailings Cover Design" [NRC, 1984b]. The flux rate from the waste material is calculated as follows:

$$J_t = 10^4 R p E \sqrt{\lambda D_t} \tanh\left[\sqrt{(\lambda)(1/D_t)} \; X_t\right]$$

4 Oct 96

where:
- J_t = radon flux from the waste material (pCi/m^2/s);
- R = specific activity of radon in the waste material (pCi/g);
- p = dry bulk density of the waste material (g/cm^3);
- E = radon emanation coefficient (dimensionless);
- λ = decay constant of radon (2.1×10^{-6} s^{-1});
- D_t = diffusion coefficient for radon in the total pore space (cm^2/s); and
- X_t = thickness of the waste material (cm).

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The computer program "RAECOM" [NRC, 1984a] will then be used to estimate radon emission rates from the OSDF given the radon flux once the final cover system is constructed. RAECOM uses the radon diffusion modeling methods presented in the document titled "Radon Attenuation Handbook for Uranium-Mill Tailings Cover Design" [NRC, 1984b]. The procedure for calculating attenuated rates of radon emission (i.e., with the final cover system in place) using this model consists of the following steps.

1. Establish the thickness of each layer of the OSDF final cover system.

2. Estimate the porosity of each layer of the OSDF final cover system.

3. Estimate the moisture content (dry-weight percent) of each layer of the OSDF final cover system.

4. Calculate the radon diffusion coefficient for each layer of the final cover system based on a correlation to moisture saturation.

5. Estimate radon emission rates using the estimations and calculations made in steps 1 through 5 as input parameters for RAECOM.

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OSDF RADON 222 RELEASE

DATA VERIFICATION

Purpose

The purpose of this document is to present the engineering data used to calculate the radon emission rates from the OSDF. The radon flux rate from the impacted waste materials will be calculated first (without the attenuating capacity of the final cover system), and then the attenuating capacity of the final cover system will be used to estimate radon emission rates. The final cover system consists of the following layers:

- topsoil layer;
- vegetative soil layer;
- granular filter layer;
- biointrusion barrier;
- cover drainage layer;
- 1.5 - mm thick high density polyethylene (HDPE) geomembrane cap;
- geosynthetic clay liner (GCL); and
- compacted clay cap.

Radon release from waste material placed within the OSDF will be attenuated by these layers. For purposes of this analysis, the attenuation capacity of the HDPE geomembrane cap is neglected.

The data presented in this document are used to demonstrate that the requirements presented in the DCP are satisfied. The DCP requirements relevant to the data verification are:

- the radon emission rate shall be estimated using the computer code RAECOM [NRC, 1984a]; and

- the release of radon to atmosphere will not:(i) exceed 20 percent of the regulatory-established average release rate of 20 pCi/m^2/s; or (ii) increase the average annual concentration of radon at or above any location outside the disposal site by more than 0.5 pCi/l (ARAR: 40 CFR § 192.02(b)).

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Scope

The data presented in this document will be used to prepare emission estimates for the release of radon from the OSDF prior to and after construction of the final cover system.

Parameters for Design

General

Data required to estimate radon emission rates include: (i) cover system individual layer thicknesses; (ii) specific activity of radon in the waste material; (iii) dry bulk density of the waste material; (iv) radon emanation coefficient; (v) decay constant of radon; (vi) radon diffusion coefficients for each layer of the final cover system; (vii) thickness of the waste material; (viii) volumetric water content; (ix) porosity of each layer of the OSDF final cover system; (x) moisture content (dry-weight percent) of each layer of the final cover system; and (xi) radon concentration and flux of the cover materials. Engineering data will be obtained from site-specific information and published engineering texts.

Cover System Thickness

The components of the final cover system and the individual thickness of each of these components are specified in the DCP and are:

Cover Layer	Thickness (mm)[1]
Topsoil Layer	150
Vegetative Soil Layer	530
Granular Filter Layer	150
Biointrusion Barrier	910
Cover Drainage Layer	300
GCL	3.0
Compacted Clay Cap	610

Note: [1]Thicknesses of the final cover system layers are entered into the RAECOM model in units of centimeters (cm).

Specific Activity of Radon in the Waste Material

For this analysis, it is assumed that the specific activity of radon in the waste material (R) is equivalent to the average U-238 concentration of the waste material (secular equilibrium is established). Based on discussions with FERMCO, the average U-238 concentration of the waste material is expected to be only about ten percent of the WAC, or 34.6 pCi/g.

Dry Bulk Density of the Waste Material

As presented in the design calculation package, it is assumed that the impacted waste material will have an average total unit weight of 125 pounds per cubic foot (pcf). The dry bulk density (p) of the waste material will be based on this value.

Radon Emanation Coefficient

The radon emanation coefficient (E) is a dimensionless value that is used in calculating the radon flux from the waste material. This value represents the fraction of the radon generated that is free to diffuse in the pore spaces (NRC, 1984b). While it has been shown that the radon emanation coefficient can vary considerably with moisture and with different waste materials, a value of 0.2 represents a reasonable average for calculation purposes (NRC, 1984b). A value of 0.2 will be used in calculating the radon flux from the waste material.

Decay Constant of Radon

A value of $2.1 \times 10^{-6} s^{-1}$ is given by the NRC (1984b) for the decay constant of radon (λ).

Radon Diffusion Coefficients

Radon diffusion coefficients (D_i) for each layer are based on a correlation with the moisture saturation (m) values of the materials as presented in Figure 1 (from NRC [1984b]). The diffusion coefficients for each layer were derived from this figure and are provided in Table 1.

Thickness of the Waste Material

The total thickness of the impacted waste material varies across the OSDF. Based on the Design Drawings, the average impacted waste material thickness (X_i) is estimated to be 34 ft.

Volumetric Water Content

The volumetric water content (W_{vi}) is used to calculate moisture saturation given the porosity of the material. The volumetric water content for the waste material and each layer of the final cover system, except for the GCL, was taken from OSDF Calculation Package 7.1. The volumetric water content for the GCL is estimated based on information presented in Bonaparte et al. [1995].

Porosity

The values for porosity of each layer of the final cover system are the same as the values used in the leachate generation calculations (i.e., Calculation Package 7.1), with the exception that the porosity value provided for the GCL is based on technical literature regarding hydrated GCLs [Bonaparte et al., 1995]. The porosity values are considered to be conservative values for this analysis and are provided in Table 1.

Moisture Content

Increasing moisture causes lower diffusion coefficients. The values of moisture content of each layer of the final cover system are the same as those values used in the leachate generation calculations, with the exception that the moisture content value provided for the GCL is based on technical literature regarding hydrated GCLs [Bonaparte et al., 1995]. The moisture content values are provided in Table 1.

Radon Concentration and Flux of the Cover Materials

For each layer of the final cover system, the radon concentration and flux from the cover materials is set equal to zero. The cover materials are considered to contain no background concentrations of radon.

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OSDF RADON 222 RELEASE

CALCULATIONS

Purpose

The purpose of this document is to provide the engineering calculations used in estimating radon emission rates from the final cover system of the On-Site Disposal Facility (OSDF).

Scope

The calculation procedures used in this document are presented in the calculations procedures document. The data used in the calculations are presented in the data verification document.

The calculations consist of : (i) a summary of the input data; (ii) a summary of the calculation results; and (iii) the calculations (i.e., worksheets, RAECOM computer output sheets).

Calculations

Summary of Input Data

A summary of the RAECOM [NRC, 1984a] input parameters is presented in Table 1. The radon emission estimates were computed given an input value of 4.48 pCi/m^2/s for the radon flux from the waste material, which corresponds to an average specific activity of radon of 34.6 pCi/g in the waste material (FERMCO RUN 1). For comparison, the RAECOM model was also run for each of the following input values:

- radon flux = 44.8 pCi/m^2/s; which corresponds to a specific activity of radon of 346 pCi/g (WAC) (FERMCO RUN 2);
- radon flux = 3,275 pCi/m^2/s; the maximum radon flux that will be attenuated by the cover system to attain a radon emission rate below 4 pCi/m^2/s (FERMCO RUN 3);

- radon flux = 16,376 pCi/m^2/s; the maximum radon flux that will be attenuated by the cover system to attain a radon emission rate below 20 pCi/m^2/s (FERMCO RUN 4); and

- number of layers = 8; used to estimate the radon exit concentration (pCi/l) below the surface to evaluate compliance with the regulatory limit (FERMCO RUN 5).

Summary of Calculation Results

Given an average specific activity of radon in the waste material of 34.6 pCi/g, the radon emission rate from the impacted material without any attenuation by the OSDF final cover system is conservatively calculated to be 4.48 pCi/m^2/s. This is a conservative estimate of the flux rate, prior to construction of the final cover system, because it is based on the assumption that secular equilibrium has been established. Because of the extremely long half-life of U-238 (approximately 4.55 billion years), actual equilibration will take many years, and thus the actual radon flux rate will be lower than the calculated equilibrium value.

The calculated value of 4.48 pCi/m^2/s is below the regulatory limit of 20 pCi/m^2/s. The attenuating capacity of the final cover system reduces the radon emission rate to 4.7353 x 10^{-3} pCi/m^2/s. The radon exit concentration is estimated to be 0.13587 pCi/l, and thus is not expected to increase the average annual concentration of radon at or above any location outside the disposal site by more than 0.5 pCi/l. Accordingly, the estimated radon emission rates from the OSDF are in compliance with the regulatory requirements.

Calculations

The calculations are provided on the attached worksheets and RAECOM computer output sheets.

CALCULATION OF MOISTURE SATURATION (m)

Moisture Saturation (m) is the ratio of volumetric water content to porosity of the material, and may be calculated as follows:

$$m = \frac{W_{vi}}{n}$$

where: m = moisture saturation of the waste material;
W_{vi} = volumetric water content; and
n = porosity of the waste material.

For the impacted waste material and each layer of the final cover system, except the GCL, the values for W_{vi} and porosity are defined by OSDF Calculation Package 7.1.

Example Calculation for Impacted Waste Material:

$$m = (0.3930)/(0.4450)$$

$$m = 0.88$$

For the GCL, moisture content is calculated based on information presented by Bonaparte et al. [1995]. Bonaparte et al. [1995] defines water content of the GCL at saturation to be approximately 150%, and long-term moisture content to be 50% - 100%. For purposes of this analysis, 100% is chosen because the GCL overlies the clay cap which is saturated and provides a moisture source.

Example Calculation for GCL:

$$m = (\text{moisture content}) / (\text{moisture content at saturation})$$

$$m = (100)/(150)$$

$$m = 0.67$$

CALCULATION OF FLUX (J_t) OF THE OSDF WASTE MATERIAL

Average, specific activity of radon in the waste material = 34.6 pCi/g.

From NRC [1984B], radon flux from the waste material is calculated as follows:

$$J_t = 10^4 \, R \, p \, E \sqrt{\lambda D_t} \, \tanh\left[\sqrt{(\lambda)(1/D_t)} \, X_t\right]$$

where:
- J_t = radon flux from the waste material (pCi/m²/s);
- R = specific activity of radon in the waste material (pCi/g);
- p = dry bulk density of the waste material (g/cm³);
- E = radon emanation coefficient (dimensionless);
- λ = decay constant of radon (2.1×10^{-6} s^{-1});
- D_t = diffusion coefficient for radon in the total pore space (cm²/s); and
- X_t = thickness of the waste material (cm).

First, convert dry bulk density of the waste material (p) in pounds per cubic foot (pcf) to grams per cubic centimeter (g/cm³) as follows:

125 pcf=(125 lbs. / ft³)(0.45359 kg / 1 lb.)(1,000 g / 1 kg)(1 ft³ / 28.31685 l)(0.001 l / 1 cm³) =

2.00 g/cm³ ✓

Then calculate radon flux as follows:

$$J_t = 10^4 (34.6 \text{ pCi/g})(2.0 \text{ g/cm}^3)(0.2)\sqrt{(2.1\times10^{-6}\text{s}^{-1})(5\times10^{-4} \text{ cm}^2\text{s}^{-1})} \, \tanh\left[\sqrt{\frac{(2.1\times10\text{-}6\text{s-}1)}{(5\times10\text{-}4 \text{ cm}^2\text{s-}1)}} \, (1036 \text{ cm})\right]$$

J_t = 4.48 pCi/m²/s ✓

TABLE 1

RAECOM INPUT PARAMETERS[1]

Final Cover System	Layer No.	Layer Thickness (cm)	Diffusion Coefficient (cm^2/s)	Porosity (dimensionless)	Randon Concentration ($pCi/m^2/s$)	Moisture Content (dry wt. %)	Moisture Saturation (dimensionless)
Topsoil Layer	7	15	0.01	0.3980	0.0	0.1247	0.50
Vegetative Soil Layer	6	53	0.005	0.4000	0.0	0.1786	0.71
Granular Filter Layer	5	15	0.03	0.4370	0.0	0.1172	0.40
Biointrusion Barrier	4	91	0.08	0.3500	0.0	0.0183	0.09
Cover Drainage Layer	3	30	0.07	0.3970	0.0	0.0248	0.10
Geosynthetic Clay Liner	2	1	0.005	0.8049	0.0	1.00	0.67
Compacted Clay Cap	1	61	0.0003	0.4270	0.0	0.2484	0.90
Impacted Material	-	1036	0.0005	0.4450	4.48	0.2626	0.88

Notes: [1] See Data Verification portion of the calculation package for basis of RAECOM input parameters.

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FIGURE 1

COMPARISON OF MEASURED RADON DIFFUSION COEFFICIENTS WITH A SIMPLE CORRELATION FUNCTION ASSUMING DIFFERENT POROSITIES

6 Apr 96

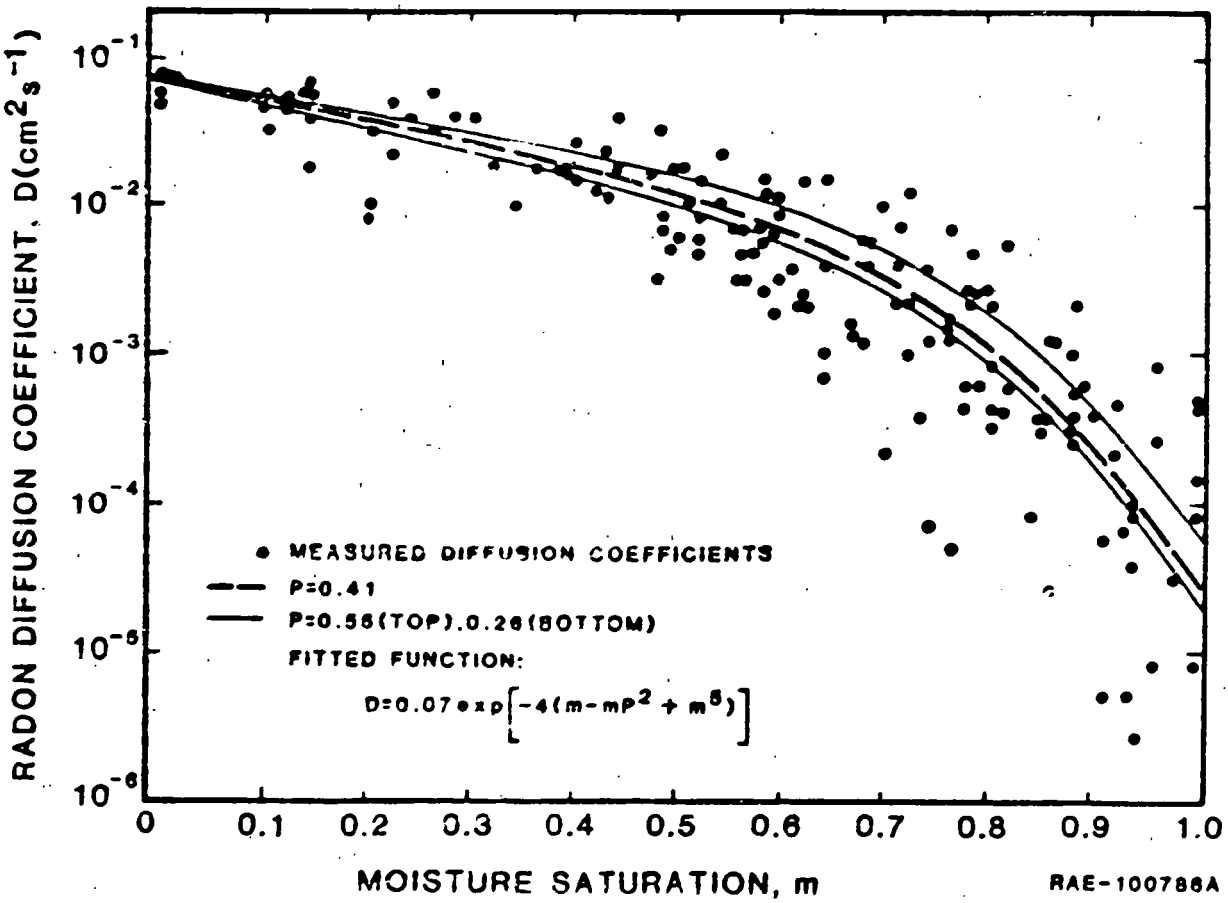

FIGURE 10. COMPARISON OF MEASURED RADON DIFFUSION COEFFICIENTS WITH A SIMPLE CORRELATION FUNCTION ASSUMING DIFFERENT POROSITIES.

RAECOM COMPUTER OUTPUT SHEETS

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RAECOM INPUT VALUES

RAECOM - FERMCO RUN 1

7,4.48,0.,0,0.,.001
61., .0003, .4270, .0, 24.84
1., 0.005, 0.8049, .0, 1.
30.,.07,.3970,.0, 2.48
91., .08, .35,.0, 1.83
15., .03, .4370,.0, 11.72
53., .005, .4, .0, 17.86
15., .01, .3980, .0, 12.47

RAECOM - FERMCO RUN 2

7,44.8,0.,0,0.,.001
61., .0003, .4270, .0, 24.84
1., 0.005, 0.8049, .0, 1.
30.,.07,.3970,.0, 2.48
91., .08, .35,.0, 1.83
15., .03, .4370,.0, 11.72
53., .005, .4, .0, 17.86
15., .01, .3980, .0, 12.47

RAECOM - FERMCO RUN 3

7,3275.,0.,0,0.,.001
61., .0003, .4270, .0, 24.84
1., 0.005, 0.8049, .0, 1.
30.,.07,.3970,.0, 2.48
91., .08, .35,.0, 1.83
15., .03, .4370,.0, 11.72
53., .005, .4, .0, 17.86
15., .01, .3980, .0, 12.47

RAECOM - FERMCO RUN 4

7,16376.,0.,0,0.,.001
61., .0003, .4270, .0, 24.84
1., 0.005, 0.8049, .0, 1.
30.,.07,.3970,.0, 2.48
91., .08, .35,.0, 1.83
15., .03, .4370,.0, 11.72
53., .005, .4, .0, 17.86
15., .01, .3980, .0, 12.47

RAECOM - FERMCO RUN 5

8,4.48,0.,0,0.,.001
61., .0003, .4270, .0, 24.84
1., 0.005, 0.8049, .0, 1.
30.,.07,.3970,.0, 2.48
91., .08, .35,.0, 1.83
15., .03, .4370,.0, 11.72
53., .005, .4, .0, 17.86
14., .01, .3980, .0, 12.47
1., .01, .3980, .0, 12.47

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RAECOM - FERMCO RUN 1

********** INPUT PARAMETERS **********

NUMBER OF LAYERS :	7	
RADON FLUX INTO LAYER 1 :	4.48	pCi/m²/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	.0000	pCi/m²/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm²/sec)	POROSITY	SOURCE (pCi/cm³/sec)	MOISTURE (dry wt. percent)
1	61.	3.0000E-04	.4270	0.0000E+00	24.84
2	1.	5.0000E-03	.8049	0.0000E+00	1.00
3	30.	7.0000E-02	.3970	0.0000E+00	2.48
4	91.	8.0000E-02	.3500	0.0000E+00	1.83
5	15.	3.0000E-02	.4370	0.0000E+00	11.72
6	53.	5.0000E-03	.4000	0.0000E+00	17.86
7	15.	1.0000E-02	.3980	0.0000E+00	12.47

***** RESULTS OF RADON DIFFUSION CALCULATION *****

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m²/sec)	EXIT CONC. (pCi/liter)	MIC
1	61.	5.2440E-02	1.8515E+01	.3340
2	1.	5.1518E-02	5.3874E+01	.9952
3	30.	3.9638E-02	4.5153E+01	.9247
4	91.	1.2469E-02	3.7195E+01	.9321
5	15.	8.7215E-03	2.6655E+01	.6983
6	53.	4.8477E-03	1.3415E+00	.4647
7	15.	4.7353E-03	0.0000E+00	.6231

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RAECOM - FERMCO RUN 2

**********INPUT PARAMETERS **********

NUMBER OF LAYERS :	7	
RADON FLUX INTO LAYER 1 :	44.8	pCi/m²/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	.0000	pCi/m²/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm²/sec)	POROSITY	SOURCE (pCi/cm³/sec)	MOISTURE (dry wt. percent)
1	61.	3.0000E-04	.4270	0.0000E+00	24.84
2	1.	5.0000E-03	.8049	0.0000E+00	1.00
3	30.	7.0000E-02	.3970	0.0000E+00	2.48
4	91.	8.0000E-02	.3500	0.0000E+00	1.83
5	15.	3.0000E-02	.4370	0.0000E+00	11.72
6	53.	5.0000E-03	.4000	0.0000E+00	17.86
7	15.	1.0000E-02	.3980	0.0000E+00	12.47

***** RESULTS OF RADON DIFFUSION CALCULATION *****

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m²/sec)	EXIT CONC. (pCi/liter)	MIC
1	61.	5.2450E-01	1.8419E+02	.3340
2	1.	5.1533E-01	5.3588E+02	.9952
3	30.	3.9720E-01	4.4881E+02	.9247
4	91.	1.2750E-01	3.6863E+02	.9321
5	15.	9.0387E-02	2.6373E+02	.6983
6	53.	5.4723E-02	1.5379E-01	.4647
7	15.	5.4710E-02	0.0000E+00	.6231

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RAECOM - FERMCO RUN 3

********** INPUT PARAMETERS **********

NUMBER OF LAYERS :	7	
RADON FLUX INTO LAYER 1 :	.328E+04	pCi/m²/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	.0000	pCi/m²/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm²/sec)	POROSITY	SOURCE (pCi/cm³/sec)	MOISTURE (dry wt. percent)
1	61.	3.0000E-04	.4270	0.0000E+00	24.84
2	1.	5.0000E-03	.8049	0.0000E+00	1.00
3	30.	7.0000E-02	.3970	0.0000E+00	2.48
4	91.	8.0000E-02	.3500	0.0000E+00	1.83
5	15.	3.0000E-02	.4370	0.0000E+00	11.72
6	53.	5.0000E-03	.4000	0.0000E+00	17.86
7	15.	1.0000E-02	.3980	0.0000E+00	12.47

***** RESULTS OF RADON DIFFUSION CALCULATION *****

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m²/sec)	EXIT CONC. (pCi/liter)	MIC
1	61.	3.8342E+01	1.3465E+04	.3340
2	1.	3.7672E+01	3.9174E+04	.9952
3	30.	2.9036E+01	3.2810E+04	.9247
4	91.	9.3205E+00	2.6948E+04	.9321
5	15.	6.6075E+00	1.9279E+04	.6983
6	53.	4.0004E+00	1.1242E+01	.4647
7	15.	3.9994E+00	0.0000E+00	.6231

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RAECOM - FERMCO RUN 4

********** INPUT PARAMETERS **********

NUMBER OF LAYERS :	7	
RADON FLUX INTO LAYER 1 :	.164E+05	pCi/m²/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	.0000	pCi/m²/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm²/sec)	POROSITY	SOURCE (pCi/cm³/sec)	MOISTURE (dry wt. percent)
1	61.	3.0000E-04	.4270	0.0000E+00	24.84
2	1.	5.0000E-03	.8049	0.0000E+00	1.00
3	30.	7.0000E-02	.3970	0.0000E+00	2.48
4	91.	8.0000E-02	.3500	0.0000E+00	1.83
5	15.	3.0000E-02	.4370	0.0000E+00	11.72
6	53.	5.0000E-03	.4000	0.0000E+00	17.86
7	15.	1.0000E-02	.3980	0.0000E+00	12.47

***** RESULTS OF RADON DIFFUSION CALCULATION *****

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m²/sec)	EXIT CONC. (pCi/liter)	MIC
1	61.	1.9172E+02	6.7328E+04	.3340
2	1.	1.8837E+02	1.9588E+05	.9952
3	30.	1.4519E+02	1.6406E+05	.9247
4	91.	4.6605E+01	1.3475E+05	.9321
5	15.	3.3040E+01	9.6402E+04	.6983
6	53.	2.0003E+01	5.6215E+01	.4647
7	15.	1.9998E+01	0.0000E+00	.6231

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RAECOM - FERMCO RUN 5

********** INPUT PARAMETERS **********

NUMBER OF LAYERS :	8	
RADON FLUX INTO LAYER 1 :	4.48	pCi/m²/sec
SURFACE RADON CONCENTRATION :	.000	pCi/liter
BARE SOURCE FLUX (Jo) FROM LAYER 1 :	.0000	pCi/m²/sec

LAYER	THICKNESS (cm)	DIFF COEFF (cm²/sec)	POROSITY	SOURCE (pCi/cm³/sec)	MOISTURE (dry wt. percent)
1	61.	3.0000E-04	.4270	0.0000E+00	24.84
2	1.	5.0000E-03	.8049	0.0000E+00	1.00
3	30.	7.0000E-02	.3970	0.0000E+00	2.48
4	91.	8.0000E-02	.3500	0.0000E+00	1.83
5	15.	3.0000E-02	.4370	0.0000E+00	11.72
6	53.	5.0000E-03	.4000	0.0000E+00	17.86
7	14.	1.0000E-02	.3980	0.0000E+00	12.47
8	1.	1.0000E-02	.3980	0.0000E+00	12.47

***** RESULTS OF RADON DIFFUSION CALCULATION *****

LAYER	THICKNESS (cm)	EXIT FLUX (pCi/m²/sec)	EXIT CONC. (pCi/liter)	MIC
1	61.	5.2449E-02	1.8426E+01	.3340
2	1.	5.1532E-02	5.3610E+01	.9952
3	30.	3.9714E-02	4.4902E+01	.9247
4	91.	1.2729E-02	3.6888E+01	.9321
5	15.	9.0147E-03	2.6394E+01	.6983
6	53.	5.4251E-03	1.1554E-01	.4647
7	14.	5.4081E-03	1.3587E-01	.6231
8	1.	5.4075E-03	0.0000E+00	.6231

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATION PACKAGE RADIATION ATTENUATION EFFECTIVENESS AND COVER OPTIMIZATION WITH MOISTURE EFFECTS (RAECOM)

NRC, "*Radon Attenuation Effectiveness and Cover Optimization with Moisture Effects (RAECOM)*", Computer Program prepared by Rogers and Associates Engineering, Salt Lake City, Utah, for the U.S. Nuclear Regulatory Commission, Washington, D.C., 1984.

For documentation of computer programs see

1.2 Computer Program Validation

17. HORIZONTAL MONITORING WELL

17.1 Differential Settlement and Tensile Strain
17.2 Structural Stability

17.1 Differential Settlement and Tensile Strain

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: HORIZONTAL MONITORING WELL - SETTLEMENT AND TENSILE STRAIN

Computations By: (Cognizant Engineer)
Signature: Mark H. Gleason — Date: 27 Jun 96
Printed Name and Title: MARK H. GLEASON, Project Engineer

Assumptions and Procedures Checked by: (Checker)
Signature: [illegible] — Date: 13 May 97
Printed Name and Title: Kenneth W Cargill, Associate

Computations Checked by:
Signature: [illegible] — Date: MAY 1 2 1997
Printed Name and Title: GANESH GOPALAKRISHNAN, STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Mark H. Gleason — Date: 12 May 1997
Printed Name and Title: MARK H. GLEASON, Project Engineer

Approved by: (PDP)
Signature: Mark H. Gleason — Date: 12 May 1997
Printed Name and Title: MARK H. Gleason, Project Engineer

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 13 May 97
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	Response to Final Design Comts	13 May 97	—	—	[illegible]

GEOSYNTEC CONSULTANTS

Written by: MARK GLEASON Date: 97/5/12 (YY MM DD) Reviewed by: GG Date: 97/5/12 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

HORIZONTAL MONITORING WELL

TOTAL AND DIFFERENTIAL SETTLEMENT

EXECUTIVE SUMMARY

Purpose: This calculation package contains analyses for the total and differential settlement of the OSDF compacted clay liner overlying the horizontal monitoring wells to be installed at the site. The differential settlement will result from the different compressibility of the granular pipe bedding materials and the compacted soil backfill vs. the undisturbed brown till.

Procedure: The elastic and consolidation settlement of the OSDF foundation soils are calculated using elastic and consolidation theory equations.

The differential settlement between the center of the trench and the sides of the trench is calculated. The tensile strain at the OSDF compacted clay liner is calculated from the differential settlement

Analysis: Two points are selected along the horizontal monitoring well that represent the locations of maximum and minimum material thickness between the well and the compacted clay liner.

Material properties established in previous settlement and slope stability calculations are used.

Maximum allowable tensile strain in the compacted clay liner is 0.5%.

Results: Point A: Maximum differential settlement = 0.089 ft
Maximum tensile strain = 0.4%

Point B: Maximum differential settlement = 0.056 ft
Maximum tensile strain = 0.31%

The maximum allowable tensile strain of 0.5% is not exceeded. Therefore, the conditions are acceptable.

GEOSYNTEC CONSULTANTS

Written by: M. Gleason Date: 96/6/27 (YY MM DD) Reviewed by: GG 5/12/97 Date: / / (YY MM DD)

Client: Fernald Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

13 May 97

HORIZONTAL MONITORING WELL

TOTAL AND DIFFERENTIAL SETTLEMENT

PURPOSE: The purpose of this document is to provide the engineering calculations for total and differential settlement of the compacted clay liner overlying the horizontal monitoring well. Differential settlement will be a result of differential compressibility of the granular pipe bedding materials and compacted soil backfill and the surrounding undisturbed brown fill. On calculating differential settlements, calculate the resulting tensile strain that is induced in the compacted clay component of the OSDF Liner System.

PROCEDURE: Calculate the elastic and consolidation settlement of the foundation soils due to the load imposed by the OSDF. Use widely known equations from elastic and consolidation theory. For this analysis, settlement is dependent upon material properties, and the load imposed by the OSDF

GEOSYNTEC CONSULTANTS

Written by: M. Gleason Date: 96 / 6 / 27 (YY MM DD) Reviewed by: GG 5/12/97 Date: / / (YY MM DD)

Client: Fernco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring Well – Settlement 13 May 97

Procedures cont.

For the geometry shown in Figures 1, 2, and 3 calculate the total settlement at the bottom of the compacted clay for a point in the center of the trench and for a point adjacent to the trench.

Use the material properties described in the data verification section of this package and the methods described below.

Settlement of Cohesive Soils

Total Settlement $S_t = S_i + S_p + S_s$

where S_i = elastic settlement (immediate)
S_p = primary consolidation settlement (time and surcharge dependent)
S_s = secondary compression settlement (time dependent)

Elastic Settlement, S_i, (or Δh_i for each layer)

$$\Delta h_i = (\Delta\sigma_v / M) H_o$$

where $\Delta\sigma_v$ = additional vertical stress due to OSDF
M = Constrained modulus
H_o = initial layer thickness

Written by: M. Gleason Date: 96/6/27 (YY MM DD) Reviewed by: GG 5/12 Date: / / (YY MM DD)

Client: Fernco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring Well - Settlement BMay 97

Procedures cont.

Constrained Modulus, M

$$M = \frac{E_{ut}(1-\nu)}{(1+\nu)(1-2\nu)}$$

where E_{ut} = Undrained Tangent Modulus
ν = Poisson's Ratio

Undrained Tangent Modulus, E_{ut} (Duncan and Chang)

$$E_{ut} = K P_a (\sigma_c / p_a)^n \left[1 - R_f (\sigma_1 - \sigma_3)/(2 S_u)\right]^2$$

where p_a = atmospheric pressure (2117 psf)
K, n, R_f = modulus parameters
$\sigma_c = \sigma_3$ = minor principal stress (total stress)
σ_1 = Major principal stress = σ_v (total stress)
S_u = undrained shear strength

Primary Consolidation Settlement S_p (or Δh_p for each layer)

$$\Delta h_p = C_r \frac{H_o}{1+e_o} \log \frac{\sigma_p}{\sigma_{vo}} + C_c \frac{H_o}{1+e_o} \log \frac{\sigma_{vo} + \Delta\sigma_v}{\sigma_p}$$

where C_c = coefficient of compression
C_r = coefficient of recompression
e_o = initial void ratio
σ_{vo} = initial vertical effective stress
$\Delta\sigma_v$ = additional vertical effective stress
σ_p = past maximum pressure due to overconsolidation or dessication
H_o = initial layer thickness.

Written by: M. Gleason Date: 96/6/27 (YY MM DD) Reviewed by: GG 5/12 Date: / / (YY MM DD)

Client: Fernco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring well - Settlement 13 May 97

Procedures, cont.

Secondary Compression settlement, S_s (or Δh_s for each layer)

$$\Delta h_s = C_\alpha \frac{H_0}{1+e_p} \log(t_2/t_1)$$

where C_α = secondary compression index
H_0 = initial layer thickness
e_p = void ratio at the start of secondary compression.
$\log t_2/t_1$ = time ratio t_2/t_1 where t_1 is the time from loading to the end of primary consolidation (i.e. 90% of primary) and t_2 is a future time of interest
Assume t_1 = 10 yrs t_2 = 1000 yrs.

SETTLEMENT OF COHESIONLESS SOILS

GRANULAR SETTLEMENT IS ELASTIC AND IMMEDIATE

$$\Delta h_s = \left(\frac{\Delta\sigma_v}{M}\right) H_0$$

where Δh_s = elastic settlement of sand layer
$\Delta\sigma_v$ = additional vertical effective stress
M = Constrained Modulus
H_0 = initial layer thickness

$$M = \frac{E_t(1-\nu)}{(1+\nu)(1-2\nu)}$$

where E_t = Elastic tangent Modulus
ν = Poisson's Ratio

Written by: M. Gleeson Date: 96 / 6 / 27 (YY MM DD) Reviewed by: GG 12 May 97 Date: / / (YY MM DD)

Client: Fermco Project: OSDF Project/Proposal No.: GF 3900 Task No.: 24.1

Horizontal Monitoring Well - Settlement 13 May 97

Procedures cont.

Cohesionless soils

Elastic Tangent Modulus

$$E_t = K p_a \left(\bar{\sigma}_3 / p_a\right)^n \left[1 - R_f (1-\sin\phi)(\bar{\sigma}_1 - \bar{\sigma}_3) / (2\bar{\sigma}_3 \sin\phi)\right]^2$$

where p_a = atmospheric pressure (2117 psf)

$\bar{\sigma}_1$ = Major principal effective stress

$\bar{\sigma}_3$ = Minor principal effective stress

$\bar{\phi}$ = effective stress angle of internal friction

K, n, R_f = hyperbolic model parameters

For Total Settlements calculated at each point, calculate differential settlement and tensile strain

Differential Settlement, Δ_s

$$\Delta_s = \Delta h_B - \Delta h_A$$

where Δh_B = total settlement at Point B

Δh_A = total settlement at Point A

Tensile Strain, ε

$$\varepsilon\% = \frac{(L^2 + \Delta_s^2)^{1/2} - L}{L} \times 100$$

where Δ_s = differential settlement

L = Original distance between center line of trench and edge of trench (1 ft)

GEOSYNTEC CONSULTANTS

Written by: M. Gleason Date: 91 / 6 / 27 (YY MM DD) Reviewed by: CG 13 May 97 Date: / / (YY MM DD)

Client: Femco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring Well - Settlement 13 May 97

DATA VERIFICATION

GEOMETRY

For Points A & B on Figure 1 and 2

Point A

Overburden at Point A = 22 ft (liner, cover, impacted Mat'l)

Trench Backfill - assumed to be to base of compacted clay liner = 8 ft

Granular Backfill = 2 ft

Assume that material beyond limits of trench is undisturbed brown till

Point B

Overburden = 30 ft
Trench backfill = 2 ft
Granular backfill = 2 ft

Assume that material beyond limits of trench is undisturbed brown till

MATERIAL PROPERTIES

Overburden - Liner System, Impacted Materials, and Cover System
- Assume average unit weight $\gamma = 125$ pcf from Foundation Settlement Calculation

Granular backfill material in trench will be the same stone as the Leachate Collection and Leachate Detection corridor materials

Written by: M. Gleason Date: 96/6/27 (YY MM DD) Reviewed by: GG 12 May 97 Date: / / (YY MM DD)

Client: Fernald Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring Well - Settlement 13 May 97

DATA VERIFICATION

Granular Backfill - GW or GP for USCS classification from Specification § 02710

Assume the following properties

- $\gamma = 135$ pcf $\bar{\phi} = 35°$

For $\bar{\sigma}_1$ and $\bar{\sigma}_3$ Assume $\sigma_3 = K_o \sigma_1$

$K_o = 1 - \sin\bar{\phi}$ (Jaky, 1944)

$\therefore \bar{\sigma}_3 = 0.426\,\bar{\sigma}_1$

Elastic Parameters K, n, R_f

Estimate $K = 300 + 900\,\phi_{rel}$ (Kulhawy & Mayne)

$\phi_{rel} = (\bar{\phi}_{tc} - 25°)/(45 - 25)$ (Kulhawy & Mayne)

for $\phi = 35°$ $\phi_{rel} = 0.5$

$K = 300 + 450 = 750$

TABLE 5-6 of Kulhawy & Mayne

For GP soils $n = 1/3$ $R_f = 0.8$

for GW soils $n = 1/3$ $R_f = 0.7$

For analysis use $n = 1/3$ $R_f = 0.75$

Estimate Poisson's Ratio

$\nu_d = 0.1 + 0.3\,\phi_{rel}$

$\nu = 0.1 + 0.3(0.5) = 0.25$

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Written by: M. Gleason Date: 96/6/27 (YY/MM/DD) Reviewed by: GG 12 May 97 Date: / / (YY/MM/DD)

Client: Fermco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring well - Settlement 13 May 97

DATA VERIFICATION

TRENCH BACKFILL MATERIAL.

Assume that trench backfill material will be on-site borrow consisting predominantly of silty clay soils.

Trench backfill will meet the requirements of compacted fill as described in Specification Section 02200.

Trench backfill will be compacted in 1 ft lifts at 95 percent of standard Proctor optimum per ASTM D698.

Assume Trench backfill material properties will be similar to compacted clay material properties identified in Foundation Settlement Calculation Package

Trench Backfill Properties

$\gamma = 130$ pcf	$K = 150$
$e_0 = 0.43$	$n = 1$
$C_c = 0.13$	$R_f = 0.9$
$C_r = 0.035$	$\nu = 0.475$
$C_\alpha = 0.0015$	$S_u = 1200$ psf
$\sigma_p = 1000$ psf	
$e_p = 0.32$	

Written by: M. Gleason Date: 96/6/27 (YY MM DD) Reviewed by: CG 12 May '97 Date: / / (YY MM DD)

Client: Fernow Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring Well - Settlement 13 May 97

Data Verification

Undisturbed Brown Till

Material Properties obtained from page 10 of 70 of Foundation Settlement Calculation

$\gamma = 135$ pcf	$e_p = 0.22$
$e_0 = 0.29$	$K = 175$
$C_c = 0.075$	$n = 1$
$C_r = 0.015$	$R_f = 0.9$
$C_\alpha = 0.0015$	$\nu = 0.475$
$OCR = 1.7$	$S_u = 1200$ psf

- Assume the perched water table does not effect these calculations
- Assume that ring deflection of the HDPE pipe does not effect these calculations
- For overburden loads, use height of material overlying point in question. Ignore possible influence of variations in OSDF geometry for each point. Based on the location and depth of these points (A & B) the influence of geometry will be minimal (Refer to Foundation Settlement Influence Factors at small depths)

Written by: M. Gleeson Date: 96/6/27 (YY MM DD) Reviewed by: CG 12 May 97 Date: / / (YY MM DD)

Client: Fermilab Project: OSDF Project/Proposal No.: GF 3900 Task No.: 24.1

Horizontal Monitoring Well - Settlement

CALCULATIONS

For Each Point there are 2 cases Case 1 is for over the horizontal monitoring well trench. Case 2 is in undisturbed ground.

	POINT A		POINT B	
MATERIAL	CASE 1	CASE 2	CASE 1	CASE 2
overburden	22 ft	22 ft	30 ft	30 ft
Compacted fill	8 ft	—	2 ft	—
Granular fill	2 ft	—	2 ft	—
Undisturbed Brown Till	—	10 ft	—	4 ft

POINT A

CASE 1

Layer 1 8 ft of compacted fill

$\gamma = 130$ pcf
$e_o = 0.43$
$C_c = 0.13$
$C_r = 0.035$
$C_\alpha = 0.0015$

$\sigma_p = 1000$ psf
$e_p = 0.32$
$K = 150$
$n = 1$
$R_f = 0.9$

$\nu = 0.475$
$s_u = 1700$ psf

$s_u = 1200$ psf

Midpoint @ 4 ft
overburden : 2

$\Delta\sigma_v = 22\text{ ft} \times 125\text{ pcf} = 2750$ psf

$\sigma_1 = 4\text{ ft}\,(130\text{ pcf}) = 520$ psf

Assume $\sigma_3 = 0.8\,\sigma_1$ for immediate loading $\therefore \sigma_3 = 416$ psf

$$E_{ut} = K p_a \left(\sigma_c/p_a\right)^n \left[1 - R_f(\sigma_1 - \sigma_3)/2s_u\right]^2$$

$$E_{ut} = 150(2117)\left(416/2117\right)^1 \left[1 - 0.9(520 - 416)/2(1200)\right]^2$$

$$E_{ut} = 57{,}628 \text{ psf}$$

Written by: M. Eckerson Date: 96/6/27 (YY MM DD) Reviewed by: CG 12 May 97 Date: / / (YY MM DD)

Client: Fermio Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring well - Settlement

CALCULATIONS

POINT A CASE 1 Layer 1

$$M = \frac{E_{ut}(1-\nu)}{(1+\nu)(1-2\nu)} = \frac{-57628\,(1-0.475)}{1.475\,(1-0.95)} = 410{,}230 \text{ psf}$$

$$\Delta h_{i1} = \left(2750 \text{ psf} / 410{,}230\right) 8\text{ft} = 0.05 \text{ ft}$$

$$\Delta h_{p1} = C_r \frac{H_0}{1+e_0} \log \frac{\sigma_p}{\sigma_0} + C_c \frac{H_0}{1+e_0} \log \frac{\sigma_{vo} + \Delta\sigma_v}{\sigma_p}$$

$$= 0.035 \frac{8\text{ft}}{1+0.43} \log \frac{1000}{520} + 0.13 \frac{8}{1+0.43} \log \frac{520+2750}{1000}$$

$$\Delta h_{p1} = 0.055 + 0.374 \text{ ft} = 0.429 \text{ ft}$$

$$\Delta h_{si} = C_\alpha \frac{H_0}{1+e_p} \log t_2/t_1$$

$$= 0.0015 \frac{8}{1+0.32} \log 1000/10$$

$$\Delta h_{si} = 0.018 \text{ ft}$$

$$\Delta h_1 = 0.05 \text{ ft} + 0.429 \text{ ft} + 0.018 \text{ ft} = 0.497 \text{ ft}$$

Written by: M. Gleason Date: 96/6/27 (YY/MM/DD) Reviewed by: CG 12 May 97 Date: / / (YY/MM/DD)

Client: Femco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring Well - Settlement

CALCULATIONS

POINT A CASE 1 Layer 2

Layer 2 · 2ft of Granular Material

$\gamma = 135$ $\phi = 35°$ $\nu = 0.25$ $\sigma_1 = 8(130) + 1(135) = 1175$ psf

$K = 750$ $n = 1/3$ $R_f = 0.75$ $\sigma_3 = (1-\sin\phi)\sigma_1 = 500$ psf

$$E_t = K p_a \left(\sigma_3/p_a\right)^n \left[1 - R_f (1-\sin\phi)(\sigma_1-\sigma_3) / 2\sin\phi\,\sigma_3\right]^2$$

$$E_t = 750(2117)\left(500/2117\right)^{1/3}\left[1 - 0.75(.426)(675)/2\sin\phi(500)\right]^2$$

$E_t = 382,155$ psf

$$M = \frac{E_t(1-\nu)}{1+\nu(1-2\nu)} = \frac{382155(.75)}{1.25(0.5)} = 458,590 \text{ psf}$$

$$\Delta h_2 = \left(\Delta\sigma_v/M\right)h_0 = \left(2750/458590\right)2\text{ft} = 0.012 \text{ ft}$$

TOTAL SETTLEMENT AT POINT A

CASE 1 = 0.497ft + 0.012 ft

CASE 1 $\Delta h_A = 0.509$ ft

Written by: M. Gleason Date: 96 / 6 / 27 (YY MM DD) Reviewed by: GG 12 May '97 Date: / / (YY MM DD)

Client: Fernco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.1

Horizontal Monitoring well - Settlement

Calculations

Point A CASE 2 - UNDISTURBED SOIL

Layer 1 5 ft of undisturbed brown till

$\gamma = 135$ $OCR = 1.7$ $S_u = 1200$ psf

$e_0 = 0.29$ $e_p = 0.22$

$C_c = 0.075$ $K = 175$ $\Delta\sigma_v = 2750$ psf

$C_r = 0.015$ $n = 1$

$C_\alpha = 0.0015$ $R_f = 0.9$ $\sigma_1 = (2.5ft)(135pcf) = 338$ psf

$\sigma_p = \sigma_1 \times 1.7 = 575$ $\sigma_3 = 0.8\sigma_1 = 270$ psf

$$E_{ut} = 175(2117)\left(270/2117\right)^1\left[1 - 0.9(338-270)/2(1200)\right]^2$$

$E_{ut} = 44870$ psf

$$M = \frac{44870\text{psf}\ (1-0.475)}{1.475\ (1-0.95)} = 319420\text{psf}$$

$$\Delta h_{i1} = \left(2750\text{psf}/319420\text{psf}\right)5ft = 0.043\ ft$$

$$\Delta h_{p1} = 0.015\ \frac{5ft}{1+0.29}\log 1.7 + 0.075\ \frac{5ft}{1+0.29}\log\frac{2750+338}{(338\times 1.7)}$$

$$\Delta h_{p1} = 0.013 + 0.212\ ft = 0.225$$

$$\Delta h_{s2} = 0.0015\ \frac{5}{1+.22}\log 1000/10 = 0.012\ ft$$

Layer 1 settlement

$$\Delta h_1 = (0.043 + 0.225 + 0.012)\ ft$$

$$\Delta h_1 = 0.28\ ft$$

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Client: Fernco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring Well · Settlement

Calculations

Point A CASE 2

Layer 2 5ft of undisturbed till

$\Delta\sigma_v = 2750$ psf $\sigma_1 = (7.5\text{ft})(135\text{pcf}) = 1013$ psf

$\sigma_3 = 810$ psf $\sigma_p = 1013 \times 1.7 = 1720$ psf

$$E_{ut} = 175(2117)\left(810/2117\right)^1 \left[1 - 0.9(1013-810)/2(1200)\right]^2$$

$E_{ut} = 120{,}990$ psf

$$M = \frac{120{,}990\text{ psf}\ (1-0.475)}{1.475\ (1-0.95)} = 861{,}284\text{ psf}$$

$$\Delta h_{i2} = \left(2750\text{ psf}/861{,}284\text{ psf}\right) 5\text{ft} = 0.016\text{ ft}$$

$$\Delta h_{p2} = 0.015\ \frac{5}{1+0.29}\log 1.7 + 0.075\ \frac{5}{1+.29}\log\left(\frac{2750+1013}{1720}\right)$$

$$\Delta h_{p2} = 0.013 + 0.099\text{ ft} = 0.112\text{ ft}$$

$$\Delta h_{s2} = 0.0015\ \frac{5}{1+.22}\log 1000/10 = 0.012\text{ ft}$$

Layer 2 settlement

$$\Delta h_2 = (0.016 + 0.112 + 0.012)\text{ ft} = 0.14\text{ ft}$$

TOTAL SETTLEMENT AT POINT A CASE 2

$\Delta h_1 + \Delta h_2 = 0.28\text{ ft} + 0.14\text{ ft}$

CASE 2 $\Delta h_A = 0.42$ ft

Written by: M. Gleason Date: 96/6/27 Reviewed by: CG 12 May '97 Date: / /

Client: Fernow Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring well - Settlement

Calculations

POINT B CASE 1 - 2ft compacted fill
2 ft granular soil

Layer 1 2 ft of compacted fill — use same material properties as for Point A

$\Delta\sigma_v = 30\,ft \times 125\,pcf = 3750\,psf$

$\sigma_1 = 1\,ft \times 130\,pcf = 130\,pcf$ $\sigma_3 = 0.8\sigma_1 = 104\,psf$

$E_{ut} = 150(2117)(104/2117)^{1}[1 - 0.9(130-104)/2(1200)]^{2}$

$E_{ut} = 15,300\,psf$

$M = \dfrac{15300(1-.475)}{1.475(1-0.95)} = 108,900\,psf$

$\Delta h_{i1} = (3750\,psf/108\,900)\,2\,ft = 0.069\,ft$

$\Delta h_{p1} = 0.035\,\dfrac{2\,ft}{1+0.43}\log\dfrac{1000}{130} + 0.13\,\dfrac{2}{1+.43}\log\dfrac{3750+130}{1000}$

$\Delta h_{p1} = (0.043 + 0.107)\,ft = 0.150\,ft$

$\Delta h_{s1} = 0.0015\,\dfrac{2}{1+.32}\log 1000/10 = 0.005\,ft$

POINT B CASE 1

LAYER 1 $\Delta h_1 = (.069 + .150 + .005)\,ft$

$\Delta h_1 = 0.224\,ft$

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Written by: M. Gleeson Date: 96 / 6 / 27 (YY MM DD) Reviewed by: CCG 12 May 97 Date: / / (YY MM DD)

Client: Fermco Project: GIDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring well - Settlement

CALCULATIONS

POINT B CASE 1

Layer 2 2ft of granular fill $\Delta\sigma_v = 3750$ psf

$\sigma_1 = 2(130) + 1(135) = 395$ psf

$\sigma_3 = (1 - \sin 35)\,\sigma_1 = 168$ psf

Material properties from Point A Layer 2

$$E_t = 750(2117)\left(168/2117\right)^{1/3}\left[1 - 0.75(.426)(395-168)/2\sin\phi(168)\right]^2$$

$E_t = 265{,}400$ psf

$$M = \frac{265{,}400(1-0.25)}{1.75\ (1-0.5)} = 318{,}470 \text{ psf}$$

$$\Delta h_2 = \left(3750/318{,}470\right)2\text{ft} = 0.024 \text{ ft}$$

POINT B CASE 1 SETTLEMENT

$\Delta h_B = 0.024\text{ft} + 0.224\text{ft}$

$\Delta h_{B\ CASE\ 1} = 0.248$ ft

Written by: M. Gleason Date: 91 6 27 (YY MM DD) Reviewed by: CG 12 May '97 Date: / / (YY MM DD)

Client: Fernco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring Well - Settlement

CALCULATIONS

POINT B CASE 2

Layer - 4 ft of undisturbed Brown Till

$\Delta\sigma_v = 3750$ psf $\sigma_1 = 2$ ft $(135) = 270$ psf $\sigma_p = 1.7(270) = 459$ psf

$\sigma_3 = .8\sigma_1 = 216$ psf

use Material Properties for Brown Till

$$E_{ut} = 175(2117)\left(\frac{208}{2117}\right)^1\left[1 - 0.9(270-216)/2(1200)\right]^2$$

$$E_{ut} = 35{,}000 \text{ psf}$$

$$M = \frac{35{,}000(0.525)}{1.475(0.05)} = 249{,}150 \text{ psf}$$

$$\Delta h_i = \left(\frac{3750}{249{,}150}\right)4\text{ft} = 0.060 \text{ ft}$$

$$\Delta h_p = 0.015\,\frac{4}{11.29}\log 1.7 + 0.075\,\frac{4}{1.29}\log\left(\frac{3750+260}{442}\right)$$

$$\Delta h_p = 0.011 \text{ ft} + 0.223 \text{ ft} = 0.234 \text{ ft}$$

$$\Delta h_s = 0.0015\,\frac{4}{1+.22}\log 1000/10 = 0.010 \text{ ft}$$

POINT B CASE 2 SETTLEMENT

$$\Delta h_{B\,CASE\,2} = 0.304 \text{ ft}$$

GEOSYNTEC CONSULTANTS

Written by: M. Gleason Date: 96/6/27 (YY MM DD) Reviewed by: CG 12 May '97 Date: / / (YY MM DD)

Client: Fernco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring Well - Settlement

CALCULATIONS

DIFFERENTIAL SETTLEMENT & TENSILE STRAIN SEE FIGURE 3 page 23 of 23

POINT A

CASE 1 $\Delta h_1 = 0.509$ ft

CASE 2 $\Delta h_2 = 0.420$ ft

Differential settlement $\Delta s = 0.089$ ft

TENSILE STRAIN

FOR 2 ft wide trench ASSUME CASE 1 AT MIDDLE OF TRENCH AND CASE 2 AT EDGE OF TRENCH. MINIMUM POSSIBLE L = 1 ft.

$$\varepsilon = \frac{(L^2 + \Delta s^2)^{1/2} - L}{L} \times 100$$

$$\varepsilon = \frac{(1^2 + (0.089)^2)^{1/2} - 1}{1} \times 100$$

$$\varepsilon = \frac{1.00395 - 1}{1} \times 100$$

$\varepsilon = 0.4\%$ STRAIN

MAXIMUM ACCEPTABLE = 0.5%

CONDITION is acceptable and conservative as the strain is at the base of the compacted clay liner.

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Client: Fernico Project: OSDF Project/Proposal No.: GF 3900 Task No.: 24.1

Horizontal Monitoring Well - Settlement

Calculations

Differential Settlement & Strain (see Figure 3 page 23 of 23)

POINT B

CASE 1 $\Delta h = 0.248$ ft CASE 2 $\Delta h = 0.304$ ft

$\Delta s = 0.304 - 0.248 = 0.056$ ft

For this case, the trench material settle less than the undisturbed brown till

TENSILE STRAIN

$L = 1$ ft

$$\varepsilon = \frac{(1\text{ ft}^2 + 0.056\text{ ft}^2)^{1/2} - 1\text{ ft}}{1\text{ ft}} \times 100$$

$\varepsilon = 0.31$ % strain

Maximum acceptable strain is 0.5 %

∴ Condition is acceptable.

Written by: M. Gleason Date: 96/6/27 Reviewed by: CG 12 May 97 Date: / /

Client: Fermco Project: OSDF Project/Proposal No.: GE 3980 Task No.: 24.1

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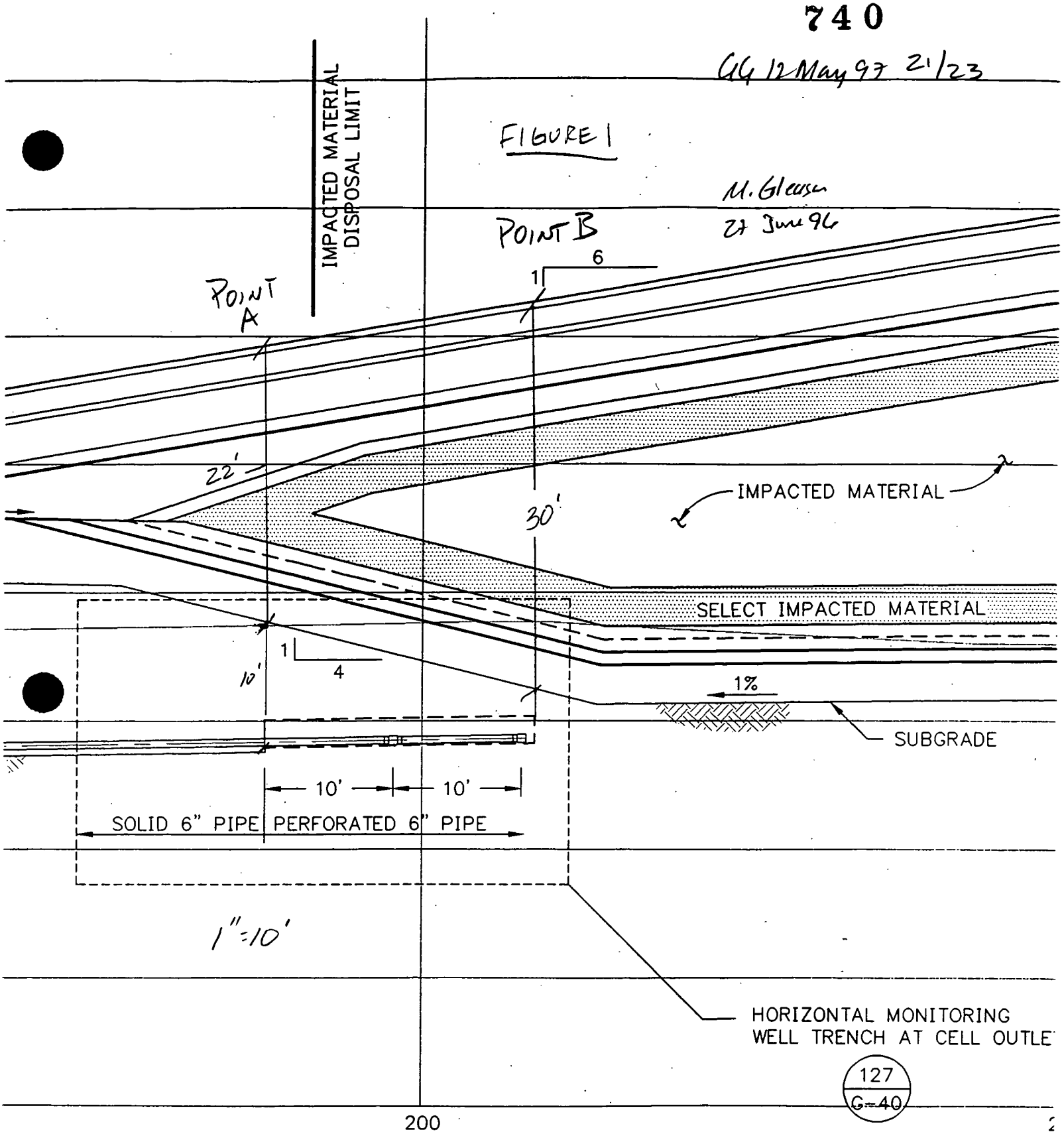
GG 12 May 97 21/23

FIGURE 1

M. Gleason
27 June 96

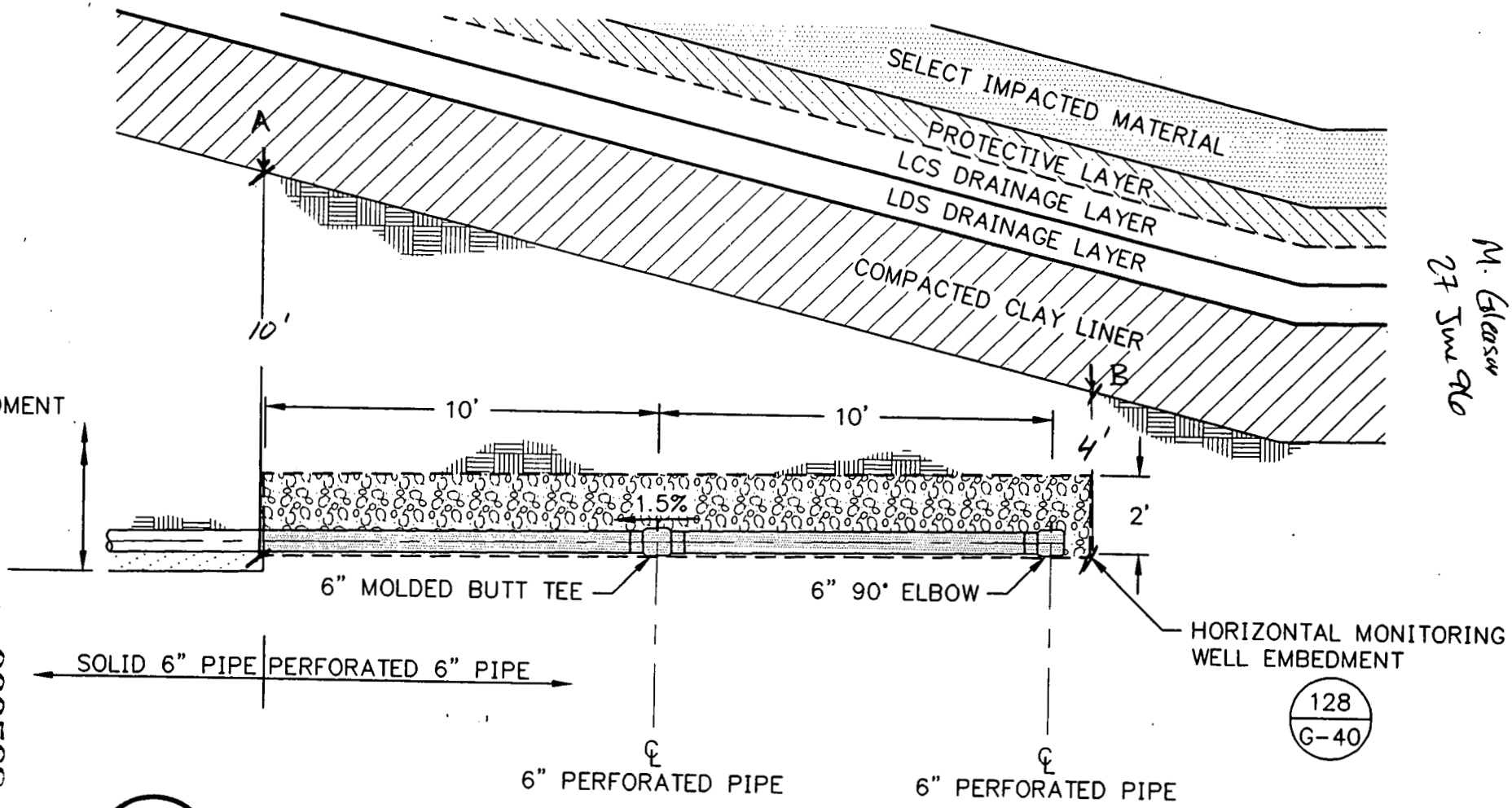


DRAWING G-40 OF SECTION E
REVISION F

200 G-40 550 250

FIGURE 2

DRAWING G-40 OF REVISION F



M. Gleason 27 Jun 96

GG 12 May 97 2/22/23

240

000568

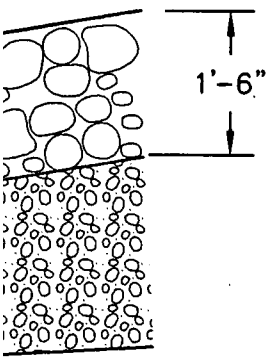
127
G-40

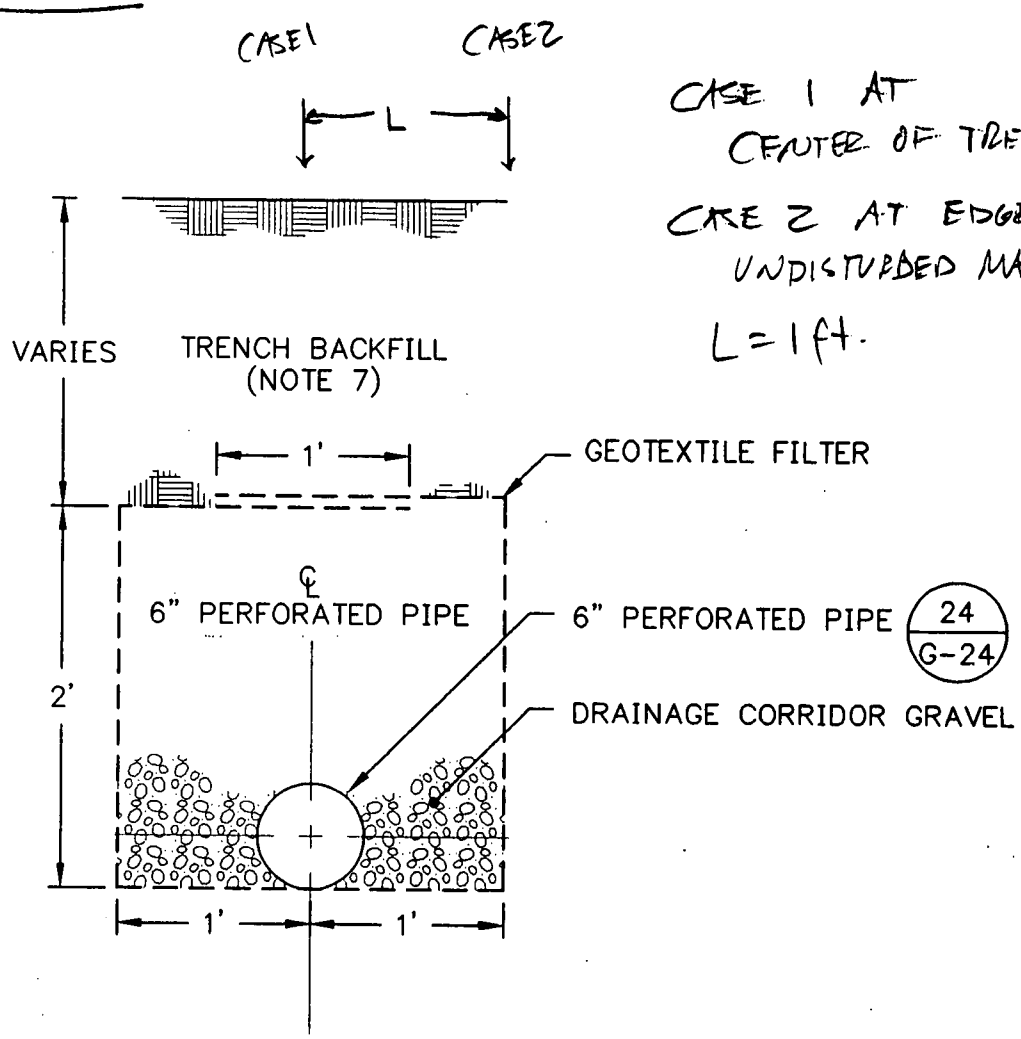
DETAIL
HORIZONTAL MONITORING WELL TRENCH AT CELL OUTLET

SCALE: 1" = 4'

XREF: F96XF609

FIGURE 3





CASE 1 AT CENTER OF TRENCH

CASE 2 AT EDGE OF UNDISTURBED MATERIAL

L = 1 ft.

DRAWING G-40 OF REVISION F

M. Gleason 27 Jun 96

GG, 12 May '97

23/23

740

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G-40

DETAIL
HORIZONTAL MONITORING WELL EMBEDMENT

SCALE: 1" = 1'

XREF: F96XF611

000569

17.2 Structural Stability

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: HORIZONTAL MONITORING WELL - STRUCTURAL STABILITY

Computations By: (Cognizant Engineer)
Signature: Mark H. Gleason — Date: 26 Jan 96
Printed Name and Title: MARK H. GLEASON, PROJECT ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: [signature] — Date: 13 May 97
Printed Name and Title: Kenneth W Cargill, Associate

Computations Checked by:
Signature: [signature] — Date: MAY 1 2 1997
Printed Name and Title: GANESH GOPALAKRISHNAN, STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Mark H. Gleason — Date: 12 May 1997
Printed Name and Title: MARK H. GLEASON, PROJECT ENGINEER

Approved by: (PDP)
Signature: Mark H. Gleason — Date: 12 May 1997
Printed Name and Title: MARK H. GLEASON, PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature: [signature] — Date: 13 May 97
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	Response to Final Design Comts	13 May 97	—	—	[signature]

Written by: M. Gleason Date: 97 / 5 / 12 (YY MM DD) Reviewed by: CG 12 May '97 Date: / / (YY MM DD)

Client: FEEMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

HORIZONTAL MONITORING WELL

STRUCTURAL STABILITY

EXECUTIVE SUMMARY

Purpose: This calculation package contains analyses for the structural stability of the horizontal monitoring well pipe that is to be installed beneath each cell of the OSDF. The calculations are performed to demonstrate that the pipe is able to withstand the OSDF load with acceptable factor of safety.

Procedure: Calculate factors of safety for the pipe for construction conditions, and for post-closure conditions. The calculations address the following failure mechanisms: (i) wall crushing; (ii) wall buckling; and (iii) excessive ring deflection.

Use ASCE design methods and methods recommended by various manufacturers to calculate factors of safety. Compare calculated factors of safety to manufacturer's recommended minimums.

Analysis: Based on the anticipated loads during construction and the overburden load during the post-closure period, the post-closure period represents the peak loading condition. The failure mechanisms stated above are analyzed for this case.

Results: The following results are calculated

CASE	CALCULATED Factor of Safety	Manufacturer's Recommended Minimum Factor of Safety
Wall Crushing	9.8	2.0
Wall Buckling	8.2	2.0
Ring Deflection	2.7	1.0

The conditions are acceptable.

Written by: M. Gleason Date: 96/6/26 (YY MM DD) Reviewed by: GG 12 May 97 Date: / / (YY MM DD)

Client: FEEMIO Project: OSDF Project/Proposal No.: GF 3900 Task No.: 24.1

13 May 97

HORIZONTAL MONITORING WELL

STRUCTURAL STABILITY

PURPOSE: The purpose of this calculation package is to present the calculations for the structural stability of the horizontal monitoring well pipes that will be installed beneath each cell of the OSDF. Perform calculations to demonstrate that the horizontal monitoring well pipe is able to withstand the loads applied on it with an adequate factor of safety.

PROCEDURE: Failure mechanisms that are calculated include: (i) wall crushing; (ii) wall buckling; and (iii) excessive ring deflection. Stresses in the horizontal monitoring well pipe will be estimated for: (i) construction conditions (i.e., stresses due to traffic when a minimum of 2ft of soil overlie the pipe; and (ii) post closure condition (i.e., stresses due to over burden materials.

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Horizontal Monitoring Well - Structural Stability 13 May 97

Procedure cont.

Construction Condition Pipe Stress is a result of traffic load and soil over burden and is expressed by:

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

where:
- σ_{ic} : stress on the pipe
- γ_p : average unit weight of overburden materials
- D_p : thickness of overburden materials
- B_c : outer pipe diameter
- C_s : load coefficient (TABLE 1)
- P : concentrated load
- F_{ic} : impact factor accounting for dynamic loads
- L_{ic} : effective length of pipe

C_s is a function of $\frac{B_c}{2D_p}$ and $\frac{L_{ic}}{2D_p}$ (TABLE 1)

Post Closure condition pipe stress is due to the overburden materials above the pipe (i.e, backfill materials, compacted soil, liner system materials, impacted materials, and the final cover system) This stress is calculated as

$$\sigma_{ic} = \gamma_p D_p$$

where
- σ_{ic} = stress on the pipe
- γ_p = average unit weight of overburden materials
- D_p = thickness of overburden materials

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Client: FEEMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring Well - Structural Stability 13 May 97

Procedure, cont.

WALL CRUSHING

Wall crushing occurs when the external vertical pressure on the pipe wall exceeds the compressive strength of the pipe material. The factor of safety against pipe crushing is calculated using the following equation:

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

where: FS_{ws} = factor of safety against wall crushing
σ_y = compressive yield strength of the pipe.
SDR = Standard Dimension ratio of the pipe
σ_{max} = maximum stress applied to the pipe.

WALL BUCKLING

Wall buckling occurs when the external vertical pressure exceeds the critical buckling pressure of the pipe/bedding aggregate system. The factor of safety against wall buckling is calculated using the following:

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

where FS_{wb} = factor of safety against 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
SDR = standard dimension ratio of the pipe

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Horizontal Monitoring well - Structural Stability 13 May 97

Procedure cont.

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 must be less than the allowable ring deflection. The factor of safety for ring deflection is calculated using the following equation:

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

where:

FS_{RD} = factor of safety against ring deflection

Δ_R = allowable ring deflection in percent change of the original pipe diameter

E' = modulus of soil reaction for pipe bedding

σ_{max} = maximum stress applied to the pipe.

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Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

HORIZONTAL MONITORING WELL - STRUCTURAL STABILITY KC 13 May 97

DATA VERIFICATION

PIPES

The horizontal monitoring well will be 6 inch SDR-11 HDPE pipe. For installation details see Figures 1 and 2 obtained from the Reactor F Construction Drawings, Drawing 6-40.

Geometric Characteristics of 6 in SDR-11 HDPE pipe are:

- outer diameter B_c = 6.625 in
- wall thickness t = 0.602 in
- inner diameter B_i = 5.421 in
- mean radius r = 3.01 in

The characteristics of the pipes, as estimated from Phillips 66 Manufacturer's Literature are:

- Modulus of elasticity = 2.74×10^6 psf
- compressive yield strength = 216,000 psf = σ_y
- allowable ring deflection = 2.7 percent.

Material Properties

Average unit weight of final cover system, liner system, impacted material, and trench backfill material is assumed to be 125 pcf based on the Foundation Settlement Calculation Package.

Thickness of overburden materials

Construction Condition 2 ft - conservative

Post Closure Condition 35 ft maximum - Section E Dwg 6-40 (Figure 3)

Modulus of soil reaction - for drainage corridor gravel use E' = 3,000 psi = 432,000 psf (Phillips 66)

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Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring well - Structural Stability 13 May 97

Data Verification cont.

Construction Vehicles

Total load = 35 tons
wheel load = 20,000 lb = P

Dynamic Impact Factor Fic = 1.5
(for dynamic loads - ASCE 1979)

Other

Effective Pipe Length, Lic = 3 ft

Allowable Ring Deflection, Δe = 2.7 percent

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Written by: M. Gleason Date: 96/6/26 (YY/MM/DD) Reviewed by: GG 12 May 97 Date: / / (YY/MM/DD)

Client: FEMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

Horizontal Monitoring well Structural Stability

CALCULATIONS FOR STRUCTURAL STABILITY

CONSTRUCTION CONDITIONS

$L_{ic} = 3ft$

$D_p = 2ft$

$B_c = 6.625 in = 0.55ft$

$\frac{L_{ic}}{2D_p} = 0.75$

$\frac{B_c}{2D_p} = 0.138$

FROM TABLE 1 $C_s = 0.138$ (INTERPOLATION)

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

$$= 125(2) + 0.138 \frac{20,000\ 1.5}{(3ft)(0.55)}$$

$$\underline{\sigma_{ic} = 2760\ psf}$$

POST CLOSURE CONDITIONS

· Stress applied to pipe is due to overburden only

$$\sigma_{ic} = \gamma_p D_p$$

$$= 125\ (35\ ft)$$

$$\underline{\sigma_{ic} = 4375\ psf}$$

POST CLOSURE CONDITIONS REPRESENT WORST CASE

CONTINUE CALCULATIONS USING $\sigma_c = 4375$ psf

Written by: M. Gleason Date: 96/6/26 (YY MM DD) Reviewed by: GG 12 May '97 Date: / / (YY MM DD)

Client: Fernico Project: OSDF Project/Proposal No.: GE 3900 Task No.: 24.1

HORIZONTAL MONITORING WELL -

CALCULATIONS

WALL CRUSHING

$$FS_{wc} = \frac{2\sigma_y}{(SDR-1)\sigma_{max}} = \frac{2(216{,}000\,psf)}{(11-1)(4375\,psf)}$$

$$FS_{wc} = 9.8$$

Manufacturer's Minimum Recommended $FS_{wc} = 2$ - ok

WALL BUCKLING

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

$$= \frac{1.2}{4375}\left[\frac{(432{,}000\,psf)(2.74\times10^6\,psf)}{11^3}\right]^{1/2}$$

$$FS_{wb} = 8.2$$

Manufacturer's minimum Recommended $FS = 2$ - ok

RING DEFLECTION

$$FS_{RD} = \frac{\Delta_R E'}{100\,\sigma_{max}} = \frac{2.7(432{,}000)}{100(4375)}$$

$$FS_{RD} = 2.7$$

Manufacturer's minimum Recommended $FS = 1$ - ok.

Written by: M. Gleason Date: 96 / 06 / 26 (YY MM DD) Reviewed by: GG 12 May 97 Date: / / (YY MM DD)

Client: Fernco Project: OSDF Project/Proposal No.: GE3900 Task No.: 24.1

References

ASCE, "Design and Construction of Sanitary Storm Sewers," Manual and Report on Engineering Practice No. 37, American Society of Civil Engineers, New York, 1979.

Chevron Chemical Company, "Plexco/Spirolite Engineering Manual, 2. System Design", Chevron Chemical Company, Bensenville, IL, Aug 1994, 76p.

Phillips 66, "Driscopipe System Design," Manufacturer's Literature, No 1160-88, A17, Phillips 66, 1988.

Phillips 66, "Driscopipe Systems Design," Manufacturer's Literature, No - 1089-91 A17 Phillips 66 1991.

Uni-Bell PVC Pipe Association, "Handbook of PVC Pipe, Design and Construction," Uni-Bell Plastic Pipe Association, 1991

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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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GRAVEL

EDMENT

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ARY

PACKAGE

REV. NO.	DATE	DESCRIPTION	DES BY	DR BY	CHK BY	RVW BY	APP BY
F	25.06.96	PREFINAL SUBMITTAL TO EPA					

SCALE AS SHOWN

OWNER/FACILITY:

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

CLIENT:

FERNALD ENVIRONMENTAL RESTORATION MANAGEMENT CORPORATION

PROJECT:

ON-SITE DISPOSAL FACILITY

TITLE:

HORIZONTAL MONITORING WELL DETAILS

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

SEAL

GEOSYNTEC CONSULTANTS
1100 LAKE HEARN DRIVE
ATLANTA, GEORGIA 30342 USA

FERMCO PROJECT NO.: 20100
FERMCO SUBCONTRACT NO.: 95PS005028
FERMCO DRAWING NO.: 90X-6000-G-001707
GEOSYNTEC PROJECT NO.: GE3900-13.1
GEOSYNTEC DOCUMENT NO.: F96-F166
SHEET NO.: G-40
REVISION NO.: F

E

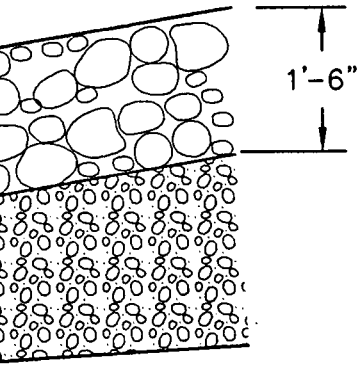
M. Bierasp 26 June 96

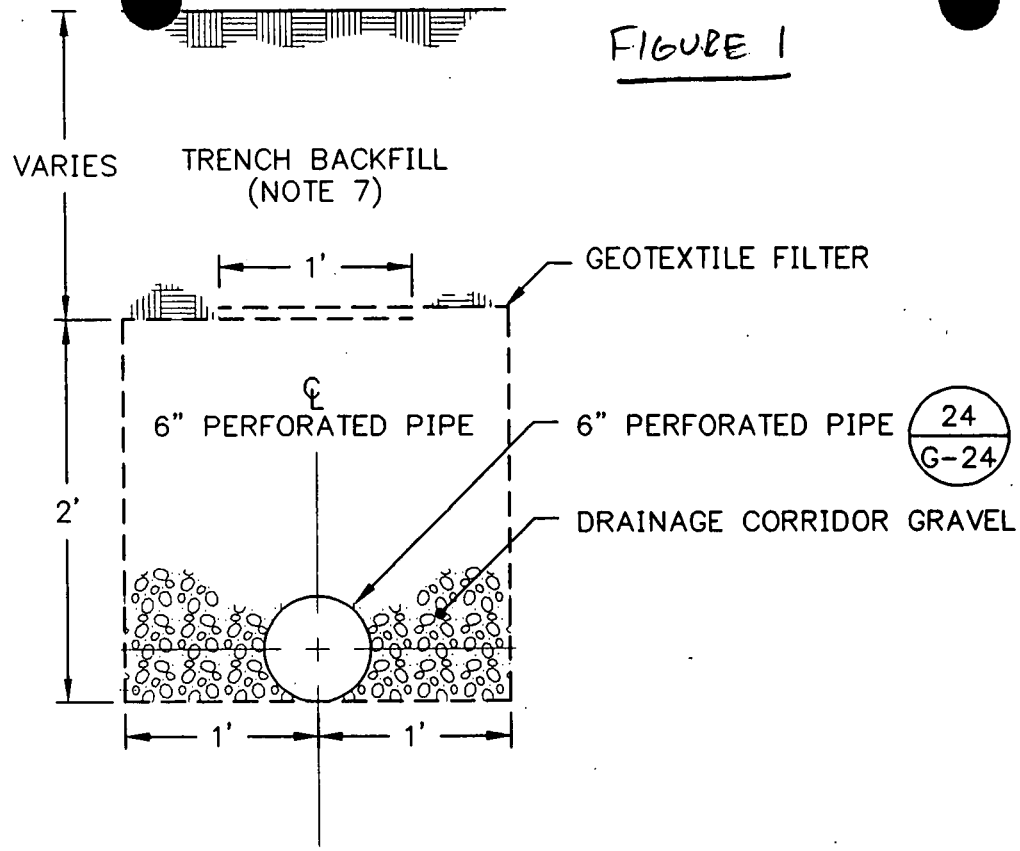
GG 12 May 97

740

11/14

FIGURE 1





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G-40

DETAIL
HORIZONTAL MONITORING WELL EMBEDMENT

SCALE: 1" = 1'

XREF: F96XF611

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26 Jun 96

GL 12 May 97

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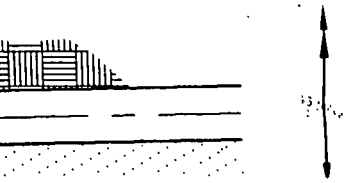
RED LATERAL



PIPE EMBEDMENT
(NOTE 3)

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M-6

PRELIM.

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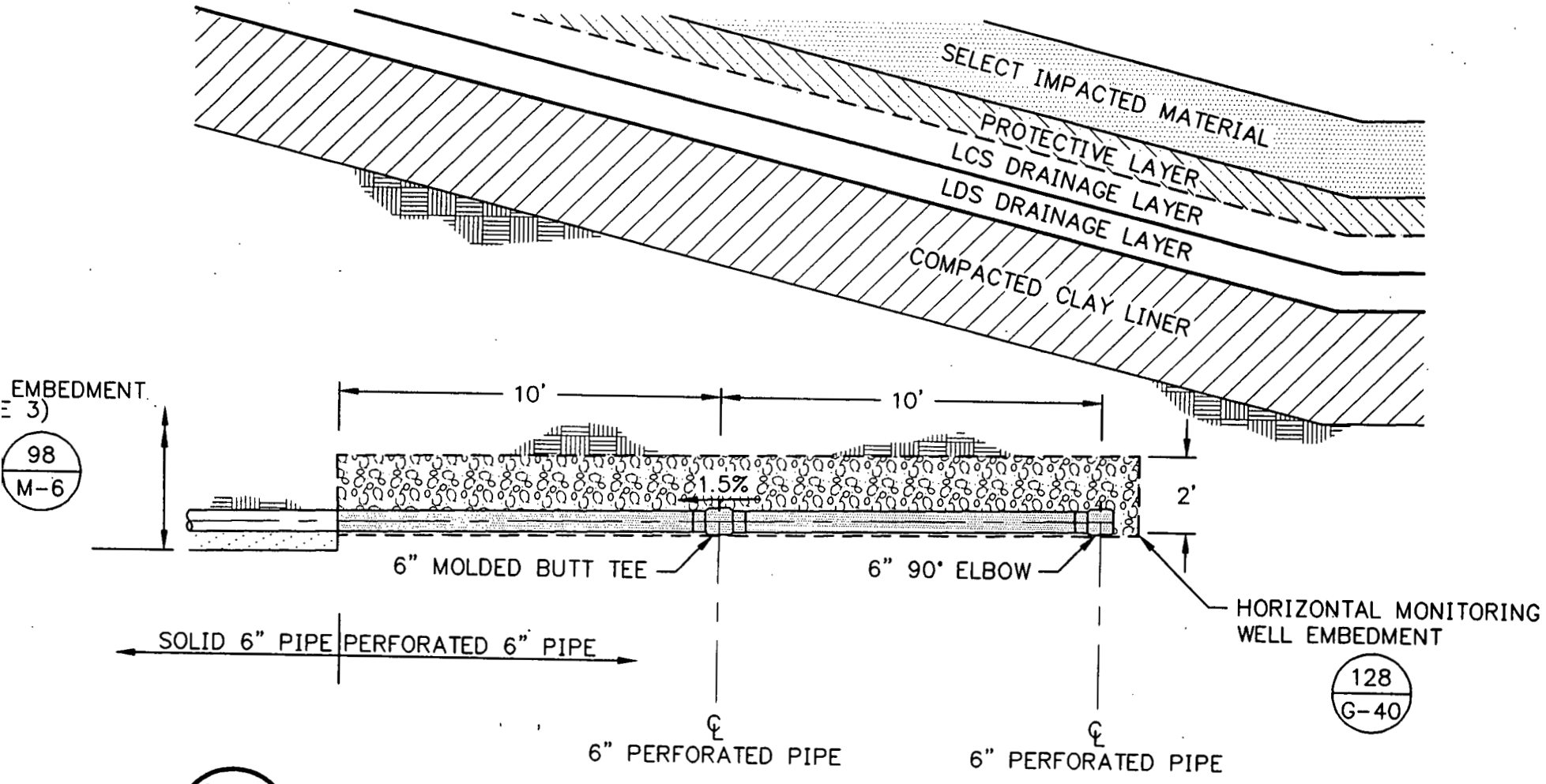
12/14

FIGURE 2



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G-40

DETAIL
HORIZONTAL MONITORING WELL TRENCH AT CELL OUTLET

SCALE: 1" = 4'

XREF: F96XF609

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26 Jun 96

GG, 12 May 97

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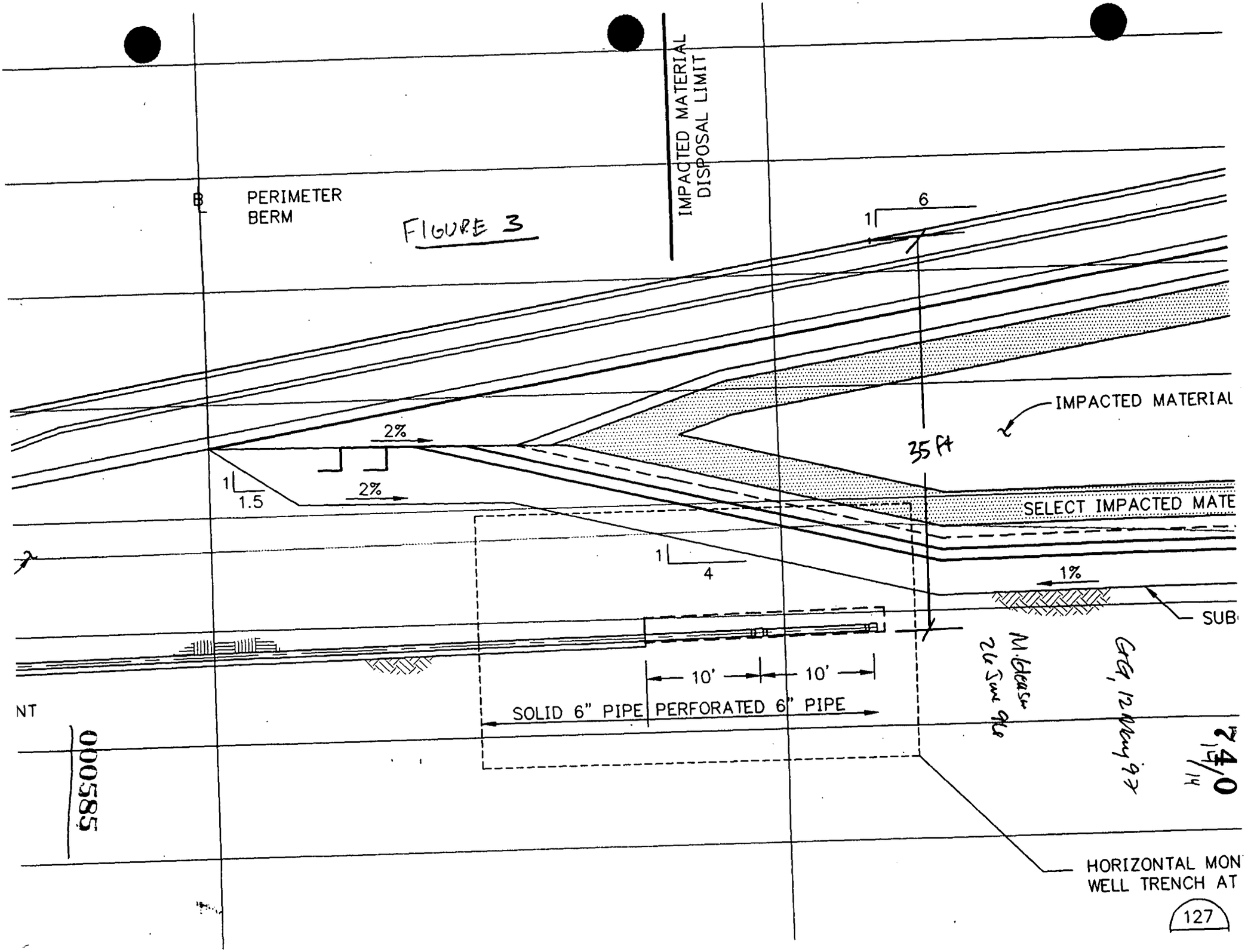
13/14


PERIMETER BERM
FIGURE 3
IMPACTED MATERIAL DISPOSAL LIMIT
6
1
IMPACTED MATERIAL
35 ft
2%
2%
1
1.5
SELECT IMPACTED MATE
1
4
1%
SUB
10'
10'
SOLID 6" PIPE
PERFORATED 6" PIPE
HORIZONTAL MON
WELL TRENCH AT
NT
000585
M. Glasser
26 June 96
GG, 12 May 97
240
14
127