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August 14, 2007

Michael D. Weeks, P.E., P.S.
TranSystems Corporation
5747 Perimeter Drive, Suite 240
Dublin, OH 43017

Re: **Bearing Capacity and Settlement Evaluation**
(Culvert at STA. 404+13)
SCI-823-0.00 Portsmouth Bypass
DLZ Job No.: 0121-3070.03
Document #0070

Dear Mr. Weeks:

This letter presents the findings of the preliminary evaluation of the proposed culvert at Station 404+13 on the above-referenced project. The findings of other culvert and embankment evaluations will be submitted in separate documents.

It is our understanding that a new culvert will be constructed at Station 404+13 for the above referenced project. The culvert will be a 96-inch Type A conduit, in accordance with ODOT Item 707.03 (Structural Plate Corrugated Steel Structures), approximately 386 feet long. Preliminary plans indicate the flow line of the culvert will be close to and nearly parallel to existing grade. It is therefore anticipated that the culvert will be constructed in accordance with ODOT CMS Item 603.05 Method B. The maximum cover over the culvert at this location is approximately 54 feet. The inlet and outlet of the culvert will be supported by headwalls flush with the face of the pipe. At the time of preparing this letter no further information was available regarding the culvert.

It should be noted that this preliminary evaluation is based upon the findings of three borings (C-19 through C-21) located along the proposed alignment of the culvert. The borings were advanced to depths ranging between 29 and 34 feet below the ground surface. Logs of the borings, a plan and profile drawing showing the approximate locations of the borings, a legend of the boring log terminology and general information regarding the drilling procedures are attached. The surveyed ground elevations at the boring locations are reported on the logs.

Exploration Findings

The borings generally encountered 24.3 to 28.0 feet of soil overlying sandstone bedrock. In boring C-19, the overburden soil generally consisted of cohesive soils (A-4a, A-4b, A-6a, A-7-6). The consistency of the soils varied from soft to hard but was predominantly stiff. In borings C-20 and C-21, the overburden consisted mostly of very loose to medium dense granular soil (A-

2-4, A-3, A-3a). Beneath the overburden soil, all the borings encountered soft to medium hard sandstone. The bedrock was weathered and fractured to varying degrees but generally improved in quality with depth.

Bearing Capacity Evaluation

The preliminary plans indicate that the invert elevations at the inlet and outlet of the proposed culvert are 674.45 and 663.10, respectively. The bottoms of the headwall footings were assumed to be 4 feet below the invert elevations to place them below the frost zone and prevent scour of the headwall (Ohio BDM Section 200). Based on the results of borings C-19 and C-21, the footings at the inlet and outlet will bear in medium stiff to stiff clay (A-7-6) and medium dense sand (A-3a), respectively. Footings bearing in these soils may be designed based on an allowable bearing pressure of 2,400 pounds per square foot (psf).

Settlement Evaluation

Soil parameters for use in the settlement calculations were estimated using correlations with SPT N-values, moisture content and Atterberg limits. Settlement below the centerline of the embankment was evaluated using the maximum cover of the embankment (54 feet) as the surcharge load and using the soil profile encountered in boring C-20.

The settlement analysis indicated that the soil below the embankment will yield a total settlement of 5.0 inches of which approximately 2.3 inches will occur in the granular layers during the construction of the embankment. The analysis indicated that 80% of the consolidation settlement (2.2 inches) will occur within 30 days after the end of the embankment construction while the time required to achieve the total consolidation settlement (2.7 inches) will be approximately six months. Secondary compression of the foundation soils beneath the embankment is estimated to produce approximately 0.7 inches of additional settlement over a period of a few years after construction.

Settlement at the ends of the culvert, due to the embankment loading, is expected to be one inch or less. Based on this information, and including the secondary consolidation estimate, differential settlement between the point of maximum embankment height and the inlet and outlet of the culvert is expected to be approximately 4.7 inches. The settlement analyses are attached.

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We appreciate having the opportunity to be of service to you on this project. Please do not hesitate to call if you have any questions concerning our preliminary findings.

Respectfully submitted,

DLZ OHIO, INC.

Wael Alkasawneh, P.E.
Geotechnical Engineer

Bryan Wilson, P.E.
Senior Geotechnical Engineer

STATE OF OHIO
BRYAN E. WILSON
E-57007
REGISTERED
PROFESSIONAL ENGINEER

Encl: As noted.

cc: J. Greg Brown, P.E. (TranSystems Corporation), File

GENERAL INFORMATION
DRILLING PROCEDURES AND LOGS OF BORINGS

Drilling and sampling were conducted in accordance with procedures generally recognized and accepted as standardized methods of investigation of subsurface conditions concerning geotechnical engineering considerations. Borings were drilled with either a truck-mounted or ATV-mounted drill rig.

Drive split-barrel sampling was performed in 1.5 foot increments at intervals not exceeding 5 feet. In the event the sampler encountered resistance to penetration of 6 inches or less after 50 blows of the drop hammer, the sampling increment was discontinued. Standard penetration data were recorded and one or more representative samples were preserved from each sampling increment.

In borings where rock was cored, NXM or NQ size diamond coring tools were used.

In the laboratory all samples were visually classified by a soils engineer. Moisture contents of representative fine-grained soil samples were determined. A limited number of samples, considered representative of foundation materials present, were selected for performance of grain-size analyses and plasticity characteristics tests. The results of these tests are shown on the boring logs.

The boring logs included in the Appendix have been prepared on the basis of the field record of drilling and sampling, and the results of the laboratory examination and testing of samples. Stratification lines on the boring logs indicating changes in soil stratigraphy represent depths of changes approximated by the driller, by sampling effort and recovery, and by laboratory test results. Actual depths to changes may differ somewhat from the estimated depths, or transitions may occur gradually and not be sharply defined. The boring logs presented in this report therefore contain both factual and interpretative information and are not an exact copy of the field log.

Although it is considered that the borings have disclosed information generally representative of site conditions, it should be expected that between borings conditions may occur which are not precisely represented by any one of the borings. Soil deposition processes and natural geologic forces are such that soil and rock types and conditions may change in short vertical intervals and horizontal distances.

Soil/rock samples will be stored at our laboratory for a period of six months. After this period of time, they will be discarded, unless notified to the contrary by the client.

LEGEND - BORING LOG TERMINOLOGY

Explanation of each column, progressing from left to right

1. Depth (in feet) - refers to distance below the ground surface.

2. Elevation (in feet) - is referenced to mean sea level, unless otherwise noted.

3. Standard Penetration (N) - the number of blows required to drive a 2-inch O.D., 1-3/8 inch I.D., split-barrel sampler, using a 140-pound hammer with a 30-inch free fall. The blows are recorded in 6-inch drive increments. Standard penetration resistance is determined from the total number of blows required for one foot of penetration by summing the second and third 6-inch increments of an 18-inch drive.

   50/n - indicates number of blows (50) to drive a split-barrel sampler a certain number of inches (n) other than the normal 6-inch increment.

4. The length of the sampler drive is indicated graphically by horizontal lines across the "Standard Penetration" and "Recovery" columns.

5. Sample recovery from each drive is indicated numerically in the column headed "Recovery".

6. The drive sample location is designated by the heavy vertical bar in the "Sample No., Drive" column.

7. The length of hydraulically pressed "Undisturbed" samples is indicated graphically by horizontal lines across the "Press" column.

8. Sample numbers are designated consecutively, increasing in depth.

9. Soil Description

   a. The following terms are used to describe the relative compactness and consistency of soils:

Granular Soils - Compactness

Terms	Blows/Foot Standard Penetration
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	over 50

Cohesive Soils - Consistency

Term	Unconfined Compression tons/sq.ft.	Blows/Foot Standard Penetration	Hand Manipulation
Very Soft	less than 0.25	below 2	Easily penetrated by fist
Soft	0.25 - 0.50	2 - 4	Easily penetrated by thumb
Medium Stiff	0.50 - 1.00	4 - 8	Penetrated by thumb w/ moderate effort
Stiff	1.0 - 2.0	8 - 15	Readily indented by thumb but not penetrated
Very Stiff	2.0 - 4.0	15 - 30	Readily indented by thumb nail
Hard	over 4.0	over 30	Indented with difficulty by thumb nail

   b. Color - If a soil is a uniform color throughout, the term is single, modified by such adjective as light and dark. If the predominant color is shaded by a secondary color, the secondary color precedes the primary color. If two major and distinct colors are swirled throughout the soil, the colors are modified by the term "mottled".

   c. Texture is based on the ODOT Classification System. Soil particle size definitions are as follows:

Description	Size	Description	Size
Boulders	Larger than 8"	Sand-Coarse	2.00 mm. to 0.42 mm.
Cobbles	8" to 3"	-Fine	0.42 mm. to 0.074 mm.
Gravel-Coarse	3" to 3/4"	Silt	0.074 mm. to 0.005 mm.
-Fine	3/4" to 2.00" mm.	Clay	Smaller than 0.005 mm.

   d. The main soil component is listed first. The minor components are listed in order of decreasing percentage of particle size.

e. Modifiers to main soil descriptions are indicated as a percentage by weight of particle sizes.

trace	- 0 to 10%
little	- 10 to 20%
some	- 20 to 35%
"and"	- 35 to 50%

f. The moisture content of cohesive soils (silts and clays) is expressed relative to plastic properties.

Term	Relative Moisture or Appearance
Dry	Powdery
Damp	Moisture content slightly below plastic limit
Moist	Moisture content above plastic limit, but below liquid limit
Wet	Moisture content above liquid limit

g. Moisture content of cohesionless soils (sands and gravels) is described as follows:

Term	Relative Moisture or Appearance
Dry	No moisture present
Damp	Internal moisture, but none to little surface moisture
Moist	Free water on surface
Wet	Voids filled with free water

10. Rock hardness and rock quality description.

a. The following terms are used to describe the relative hardness of the bedrock.

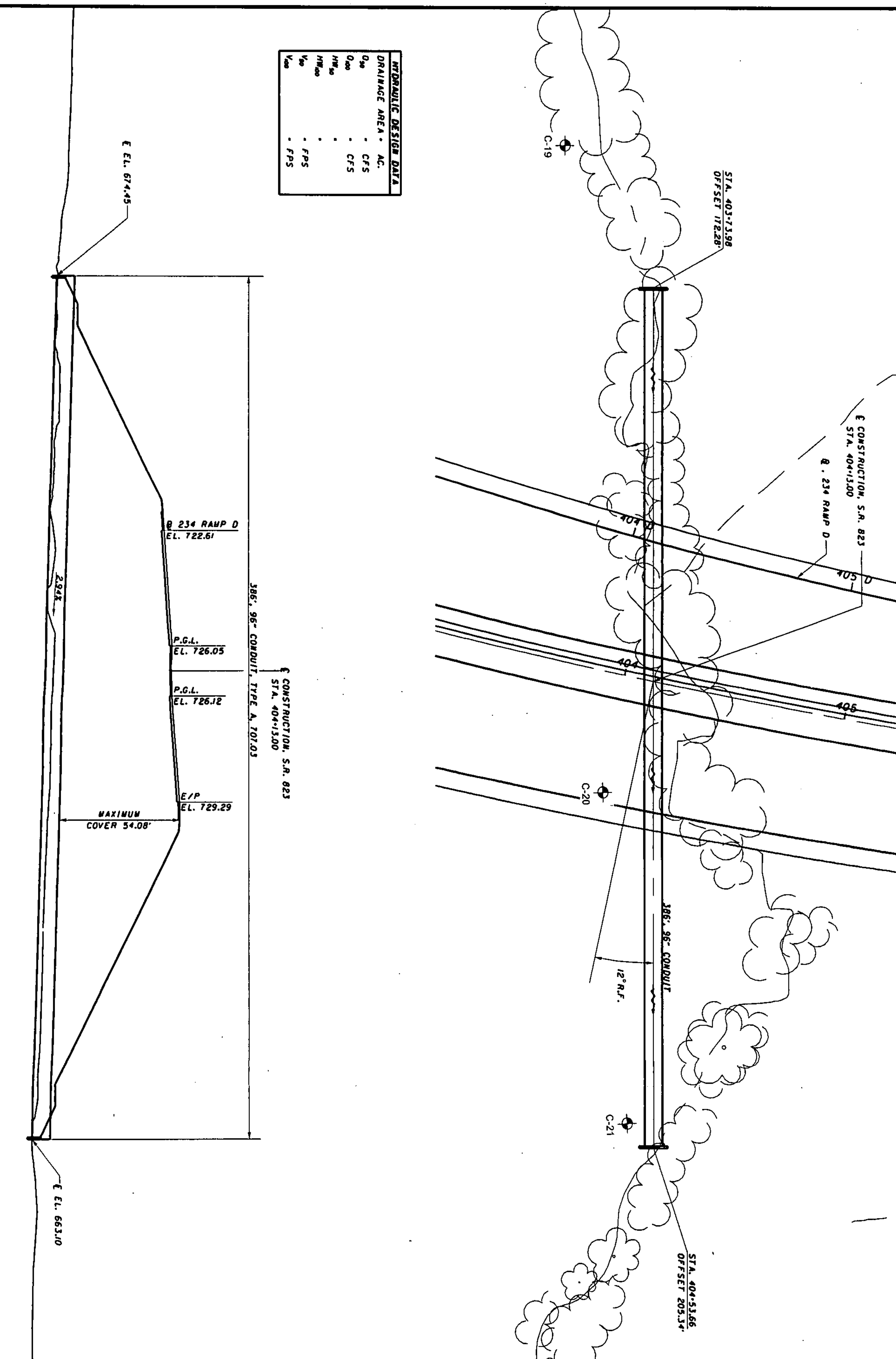
Term	Description
Very Soft	Difficult to indent with thumb nails; resembles hard soil but has rock structure
Soft	Resists indentation with thumb nail but can be abraded and pierced to a shallow depth by a pencil point.
Medium Hard	Resists pencil point, but can be scratched with a knife blade.
Hard	Can be deformed or broken by light to moderate hammer blows.
Very Hard	Can be broken only by heavy blows, and in some rocks, by repeated hammer blows.

b. Rock Quality Designation, RQD - This value is expressed in percent and is an indirect measure of rock soundness. It is obtained by summing the total length of all core pieces which are at least four inches long, and then dividing this sum by the total length of the core run.

11. Gradation - when tests are performed, the percentage of each particle size is listed in the appropriate column (defined in Item 9c).

12. When a test is performed to determine the natural moisture content, liquid limit moisture content, or plastic limit moisture content, the moisture content is indicated graphically.

13. The standard penetration (N) value in blows per foot is indicated graphically.



NOT FOR CONSTRUCTION

SCI-823-0.00	PHASE I HEADWALL LOCATION SUBMITTAL S.R. 823 STA. 404+13	CALCULATED JCB CHECKED HJS	HORIZONTAL SCALE IN FEET

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

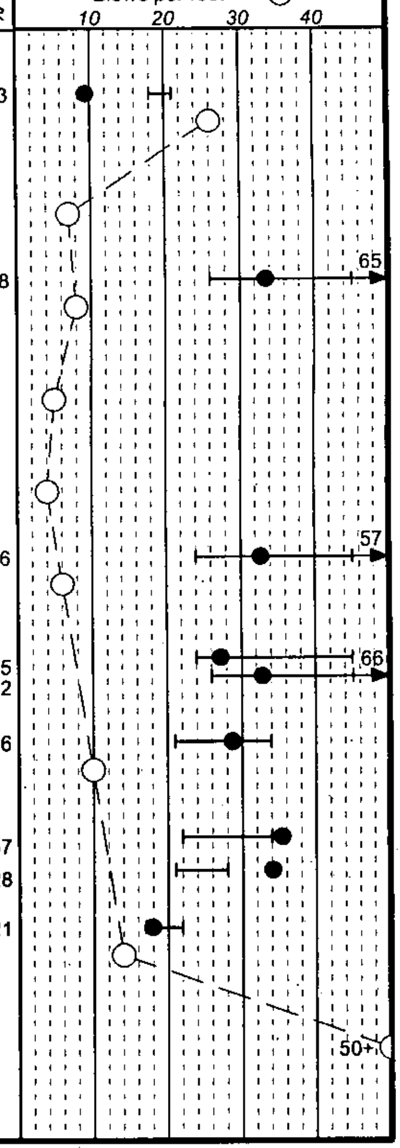
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-19 | Location: Sta. 403+22.2, 213.0 ft. LT of SR 823 CL | Date Drilled: 06/15/06

WATER OBSERVATIONS: Water seepage at: Not reported
Water level at completion: Not reported

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	679.2						Topsoil - 7"						
0.6	678.6	10 11 15	18	1		4.5+	Hard brown SANDY SILT (A-4a), little clay, little gravel; damp.	13	23	--	20	31	13
3.0	676.2	3 3 4	18	2		1.5	Stiff to very stiff brown and gray CLAY (A-7-6), trace to some silt, trace to little fine to coarse sand, trace gravel; (Varved); moist.						
		2 3 5	18	3		1.75		5	0	--	0	7	88
		1 2 3	18	4		1.0							
		1 2 2	18	5		1.0	@ 12.0', encountered thin layer of rock fragments.						
		2 3 3	18	6		1.5		2	0	--	0	12	86
				P-1b	P-1	2.25		1 1	5 3	-- --	8 4	31 20	55 72
18.5	660.7	7 6 4	18	8		0.5	Soft to medium stiff brown SILT AND CLAY (A-6a), trace fine sand; moist.	0	0	--	1	63	36
					P-2		@ 21.8', 4-inch thick fine sand layer; moist to wet .	0	0	--	1	62	37
22.5	656.7						Soft to medium stiff brown SILT (A-4b), trace to some fine sand, some clay; wet.	0	0	--	1	71	28
		1 2 12	22	10		0.5		1	9	--	24	45	21
24.5	654.7						Medium dense brown SANDY SILT (A-4a); contains sandstone fragments; damp to moist.						
		12 27 50/0	12	11									
27.0	652.2	Core	Rec	RQD	R-1		Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, argillaceous, laminated to very thinly bedded, moderately fractured, contains rust stains.						
30													

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○



FILE: 0121-3070-03 [4/20/2007 10:14 AM]

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-19 | Location: Sta. 403+22.2, 213.0 ft. LT of SR 823 CL | Date Drilled: 06/15/06

WATER OBSERVATIONS: Water seepage at: Not reported
Water level at completion: Not reported

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N) Natural Moisture Content, % - ● PL ⊢⊣ LL Blows per foot - ○ (10, 20, 30, 40)
30	649.2	60"	60"	36%										
32.0	647.2						Bottom of Boring - 32.0'							

FILE: 0121-3070-03 [4/20/2007 10:14 AM]

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

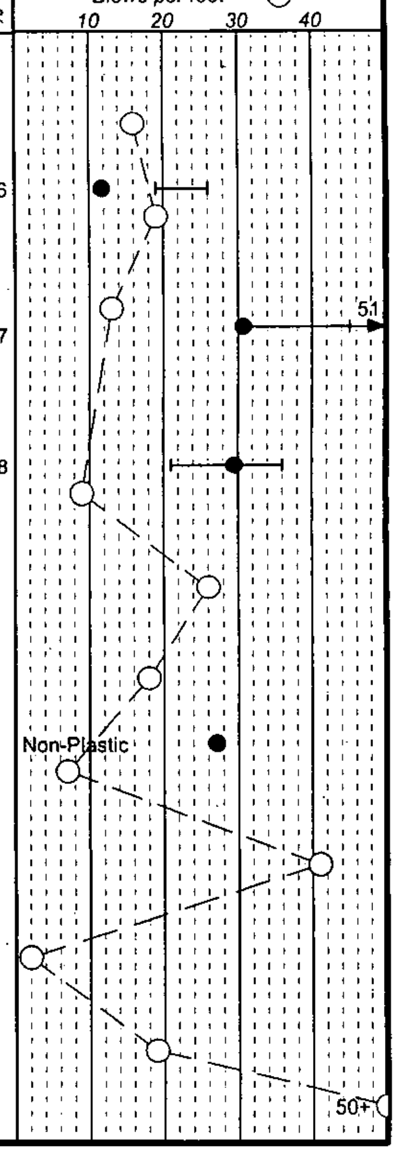
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-20 | Location: Sta. 404+01.2, 45.8 ft. RT of SR 823 CL | Date Drilled: 06/14/06

WATER OBSERVATIONS: Water seepage at: 20.0' - 27.5'
Water level at completion: 22.5' (prior to coring)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	671.2	7 8 8	9	1			Medium dense brown GRAVEL WITH SAND AND SILT (A-2-4); damp.						
3.0	668.2	7 11 8	16	2		4.5+	Hard brown SANDY SILT (A-4a), little clay, little fine gravel; damp.	12	25	--	15	32	16
		8 8 5	12	3		4.5+							
8.0	663.2				P-1		Stiff brown ELASTIC CLAY (A-7-5), little silt, trace fine sand; (Varved); damp to moist.	0	0	--	5	18	77
10.5	660.7	2 3 6	23	5		0.25	Soft brown SILT AND CLAY (A-6a), little fine to coarse sand, trace gravel; moist.	3	3	--	16	30	48
14.0	657.2	4 10 16	16	6			Medium dense brown FINE SAND (A-3), trace silty clay; damp.						
		7 9 9	21	7			@ 17.0', thin silty clay layer, encountered rock fragments.						
19.0	652.2	9 4 3	17	8			Very loose to loose brown COARSE AND FINE SAND (A-3a), little silty clay, trace gravel; moist to wet.	0	2	–	81	17	
		20 24 17	19.5	9			@ 21.0'-22.5', dense. @ 21.0', encountered rock fragments. @ 23.0', trace silty clay, wet.						
		1 1 1	16.5	10									
		7 8 11	24	11			@ 26.0'-27.5', medium dense.						
28.0	643.2						Severely weathered gray SANDSTONE.						
29.0	642.2	50/3	4	12			Soft to medium hard gray SANDSTONE.						
30													

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○



FILE: 0121-3070-03 [4/20/2007 10:14 AM]

Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-20 | Location: Sta. 404+01.2, 45.8 ft. RT of SR 823 CL | Date Drilled: 06/14/06

WATER OBSERVATIONS: Water seepage at: 20.0' - 27.5'
Water level at completion: 22.5' (prior to coring)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N) Natural Moisture Content, % - ● PL ⊢—⊣ LL Blows per foot - ○ 10 20 30 40
30	641.2	Core 60"	Rec 60"	RQD 85%	R-1		Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, argillaceous, laminated to very thinly bedded, moderately fractured, contains rust stains.							
34.0	637.2						Bottom of Boring - 34.0'							
35														
40														
45														
50														
55														
60														

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

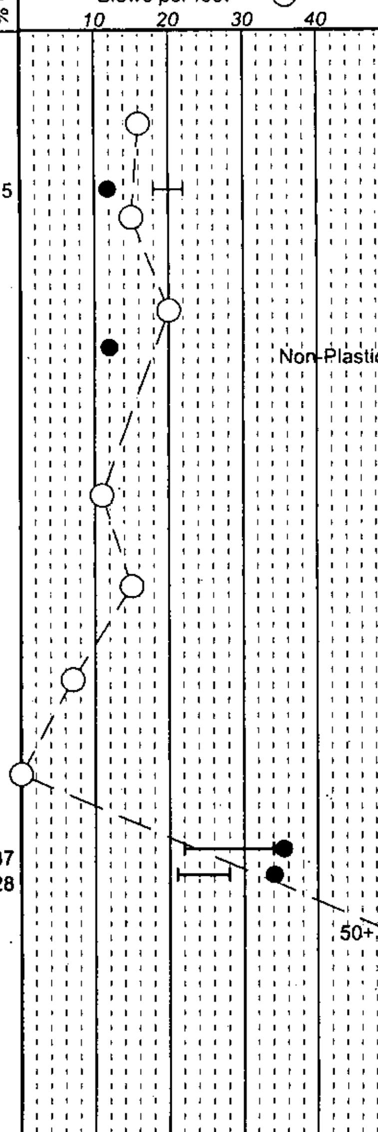
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-21 | Location: Sta. 404+41.6, 187.4 ft. RT of SR 823 CL | Date Drilled: 06/15/06

WATER OBSERVATIONS: Water seepage at: 13.5' - 24.0'
Water level at completion: Not reported

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	666.1						Topsoil - 8"						
0.7	665.4	6 6 10	15	1		4.5+	Hard brown SANDY SILT (A-4a), little clay, trace to little gravel, contains organic material; damp.						
		6 7 8	18	2		4.5+	@ 4.5', trace to little gravel.	9	25	--	21	30	15
5.5	660.6	5 10 10	18	3			Medium dense brown COARSE AND FINE SAND (A-3a), little to some silty clay; damp.						
					P-1			0	0	--	81	19	
		3 4 7	18	5									
		3 4 11	18	6									
15.0	651.1	3 5 2	15	7			Very loose to loose brown COARSE AND FINE SAND (A-3a), little to some silty clay; moist to wet. @ 16.0', moist to wet. @ 18.0', wet.						
		WOH	13	8									
20.5	645.6				P-2	0.25	Very soft to soft gray SILT AND CLAY (A-6a), trace fine sand; wet.	0	0	--	1	62	37
22.7	643.4	WOH 50/3	9	10			Very soft to soft gray SILT (A-4b), some clay, trace fine sand; wet.	0	0	--	1	71	28
24.3	641.8	Core 60"	Rec 59"	RQD 86%	R-1		Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, argillaceous, laminated to very thinly bedded, moderately fractured, contains rust stains.						
29.3	636.8						Bottom of Boring - 29.3'						

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○



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CLIENT	TranSystems Inc.	JOB NUMBER	0121-3070-03
PROJECT	Portsmouth Bypass	SHEET NO.	1 OF 2
SUBJECT	Culvert at Station 404+13	COMP. BY	BEW DATE 8/14/2007
	Bearing Capacity Analysis - Inlet	CHECKED BY	DATE

Base analysis on results of boring C-19.

From hand penetrometer measurements at and below footing elevation:

qu = 1.4 tsf

c = 1400 psf

Factor of Safety (FS) = 3 (ODOT BDM 202.2.3.1)

For cohesive foundation soil:

Meyerhof's Method

$q_u = S_c * c * N_c + q * N_q$ $q = \gamma * D$ **Can be neglected since footing depth is less than 5 ft**

Since footing Dimensions are not known assume $S_c = 1.0$. For $\phi = 0$, use $N_c = 5.14$ and $N_q = 1$

$q_a = q_u / FS$= 2398.7 psf

Use $q_a <$ 2399 psf

Base analysis on results of boring C-21.

qu =	0	tsf
c =	0	psf
ϕ =	34	degrees
Assume B =	2.5	ft
Assume γ =	120	pcf
Factor of Safety (FS) =	3	(ODOT BDM 202.2.3.1)

For cohesionless foundation soil:

Meyerhof's Method

$q_u = S_c{*}c{*}N_c{+}q{*}N_q{+}0.5\gamma{*}B{*}N_\gamma{*}S_\gamma$ Conservatively use buoyant unit weight in calculation.

$q = \gamma{*}D$

$S_\gamma =$ 1

$N\gamma =$ 31.10 for ϕ equal to 34 degrees

$Nq =$ 30.30 for ϕ equal to 34 degrees

$\mathbf{q_a = q_u/FS =}$ 2492

Use $\mathbf{q_{a\,<}}$ 2500 psf

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Client	TranSystems Inc.	JOB NUMBER	0121-3070.03
Project	Portsmouth Bypass	SHEET NO.	1 OF 4
Item	Culvert at STA. 404+13	COMP. BY	WMA DATE 5/1/07
	Based on Boring C-20	CHECKED BY	BEW DATE 8/14/07

Calculations Data

Boring	Sample	w	PL	LL	PI	Cc[1]	Cr[2]	e_o[3]
C-20	2	12	19	26	7	0.09	0.033	0.9571
C-20	3	31	31	51	20	0.27	0.065	0.9717
C-20	5	30	21	36	15	0.20	0.046	0.9780
					Average	**0.19**	**0.048**	**0.9689**
					Maximum	**0.27**	**0.065**	**0.9780**

1)Cc=PI/74
2)Cr=0.000463xLLxGs
3) Based on CR below

Boring	Sample	LL	C_v*(ft^2/day)	C_v*(ft^2/sec)
C-20	2	26	0.85	9.89E-06
C-20	3	51	0.12	1.45E-06
C-20	5	36	0.34	3.91E-06
		Minmum	**0.12**	**1.45E-06**
		Average	**0.44**	**5.08E-06**
		Maximum	**0.85**	**9.89E-06**

*Cv(ft2/day) = 9343.5*LL^(-2.8542) (Kulhawy and Mayne- 1990)

Typical Values
Source: Holtz and Kovacs (1981)/ Terzaghi, Peck and Mesri (1995)

Soil	C_α/C_c
Organic Silts	0.035-0.06
Amorphous and Fibrous Peat	0.035-0.085
Organic Clays and Silts	0.04-0.06
Granular Soils	0.01-0.03
Shale and mudstones	0.02-0.04
Silty Clay	0.03-0.06
Peat	0.05-0.07

Correlation Values-Source: Lamb and Whitman (1969)

w%	CR=(C_c/1+e_o)
9.983	2.389
11.785	2.547
14.487	3.016
17.099	3.825
19.816	4.892
25.352	6.931
28.328	8.079
34.174	10.369
42.400	13.490
51.139	16.388
79.829	23.326
152.740	33.469
341.288	46.114
501.494	52.174

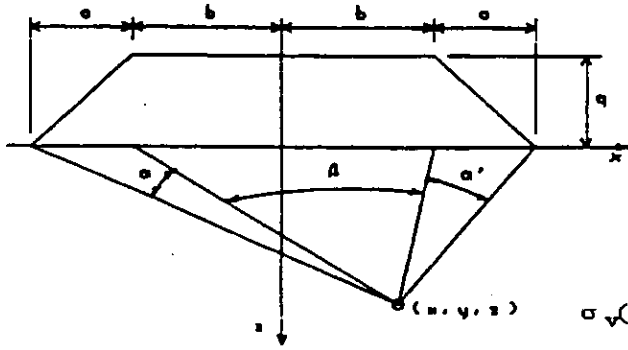
Correlation: CR=-4E-09w^4 + 5E-06w^3 - 0.0021w^2 + 0.4695w - 3.1337
R^2=0.9992

Boring	Sample	w	PL	LL	PI	LI	Consolidation*
C-20	2	12	19	26	7	-1.00	Overconsolidated
C-20	3	31	31	51	20	0.00	Overconsolidated
C-20	5	30	21	36	15	0.60	Overconsolidated

*Overconsolidated when LI<0.7
Ref: Soils and Foundations Workshop Reference Manual- NHI-00-045 (p. 6.11)

SETTLEMENT ANALYSIS - EMBANKMENT

Embankment Information:



Groundwater Table:	D=	13.0	ft			
Embankment Height:	H =	54	ft			
Fill Unit Weight:	γ_{emb} =	120	pcf	q =	6,480	psf
Width of Slope:	a =	118				
Top half-width of Emb:	b =	75				
Distance from CL:	x =	0				
Output Range:	z =	0	to	25	ft	

**See Data output Attached*

$$\sigma_v(z) := \left(\frac{q}{\pi a}\right)\left(a\cdot(\alpha(z)+\beta(z)+\alpha'(z)) + b\cdot(\alpha(z)+\alpha'(z)) + x\cdot(\alpha(z)-\alpha'(z))\right)$$

$$\beta(z) := \operatorname{atan}\left[\frac{(b-x)}{z}\right] + \operatorname{atan}\left[\frac{(b+x)}{z}\right] \qquad \alpha'(z) := \operatorname{atan}\left[\frac{(a+b-x)}{z}\right] - \operatorname{atan}\left[\frac{(b-x)}{z}\right] \qquad \alpha(z) := \operatorname{atan}\left[\frac{(a+b+x)}{z}\right] - \operatorname{atan}\left[\frac{(b+x)}{z}\right]$$

Reference: US Army Corps of Engineers EM 1110-1-1904 "Settlement Analysis", Table C-1

Soil Properties: *Settlement is calculated at mid-point of layer*

No.	Bot. of Layer		Soil Type	γ_{soil} (pcf)	σ'_c (psf)	σ'_o (psf)	$\Delta\sigma z$ (psf)	σ'_f (psf)	Cohesionless Soils C'	Cohesive Soils C_r	C_c	e_o
1	3.0	ft	Gravel/Sand	110	0	165	6,480	6,645	108.0	0.00	0.00	0.000
2	8.0	ft	Sandy Silt	110	7,500	605	6,480	7,085	0.0	0.03	0.09	0.950
3	10.5	ft	Clay	120	8,000	1,030	6,479	7,509	0.0	0.07	0.27	0.980
4	14.0	ft	Silt and Clay	120	8,000	1,390	6,477	7,867	0.0	0.05	0.20	0.980
5	28.0	ft	Gravel/Sand	110	0	1,871	6,465	8,335	60.0	0.00	0.00	0.000
6	0.0			0	0							
7	0.0			0	0							
8	0.0			0	0							
9	0.0			0	0							
10	0.0			0	0							

No.	Settlement:		Total Settlement
1	0.045	ft	
2	0.090	ft	**0.418 ft**
3	0.071	ft	
4	0.061	ft	
5	0.151	ft	**5.02 in**
6			
7			
8			
9			
10			

Reference: Geotechnical Engineering Principles and Practices; Coduto, 1999

Overconsolidated Soils - Case I ($\sigma'_0<\sigma'_c$) Eqn:11.24

$$(\delta_c)_{ult} = \Sigma\frac{C_r}{1+e_0}H\log\left(\frac{\sigma'_f}{\sigma'_0}\right)$$

Overconsolidated Soils - Case II ($\sigma'_0<\sigma'_c<\sigma_f$) Eqn:11.25

$$(\delta_c)_{ult} = \Sigma\left[\frac{C_r}{1+e_0}H\log\left(\frac{\sigma'_c}{\sigma'_0}\right) + \frac{C_c}{1+e_0}H\log\left(\frac{\sigma'_f}{\sigma'_c}\right)\right]$$

Normally Consolidated Soils ($\sigma'_0=\sigma'_c$) Eqn: 11.23

$$(\delta_c)_{ult} = \Sigma\frac{C_c}{1+e_0}H\log\left(\frac{\sigma'_f}{\sigma'_0}\right)$$

Cohesionless Soils ($\sigma'_0=\sigma'_c$)

$$(\delta_c)_{ult} = \Sigma\frac{1}{C'}H\log\left(\frac{\sigma'_f}{\sigma'_0}\right)$$

C' from FHWA Soils and Foundations Workshop Reference Manual, NHI-00-045 page 6-9, Figure 6-6.

SUBJECT	Client TranSystems, Inc.	JOB NUMBER	0121-3070.03
	Project SCI-823-0.00	SHEET NO.	3 OF 4
	Item Culvert at STA. 404+13	COMP. BY	WMA DATE 05/01/07
	Based on Boring C-20	CHECKED BY	BEW DATE 08/14/07

TIME RATE SETTLEMENT

Coeffecient of consolidation (c_v) = 5.08E-06 ft^2/s

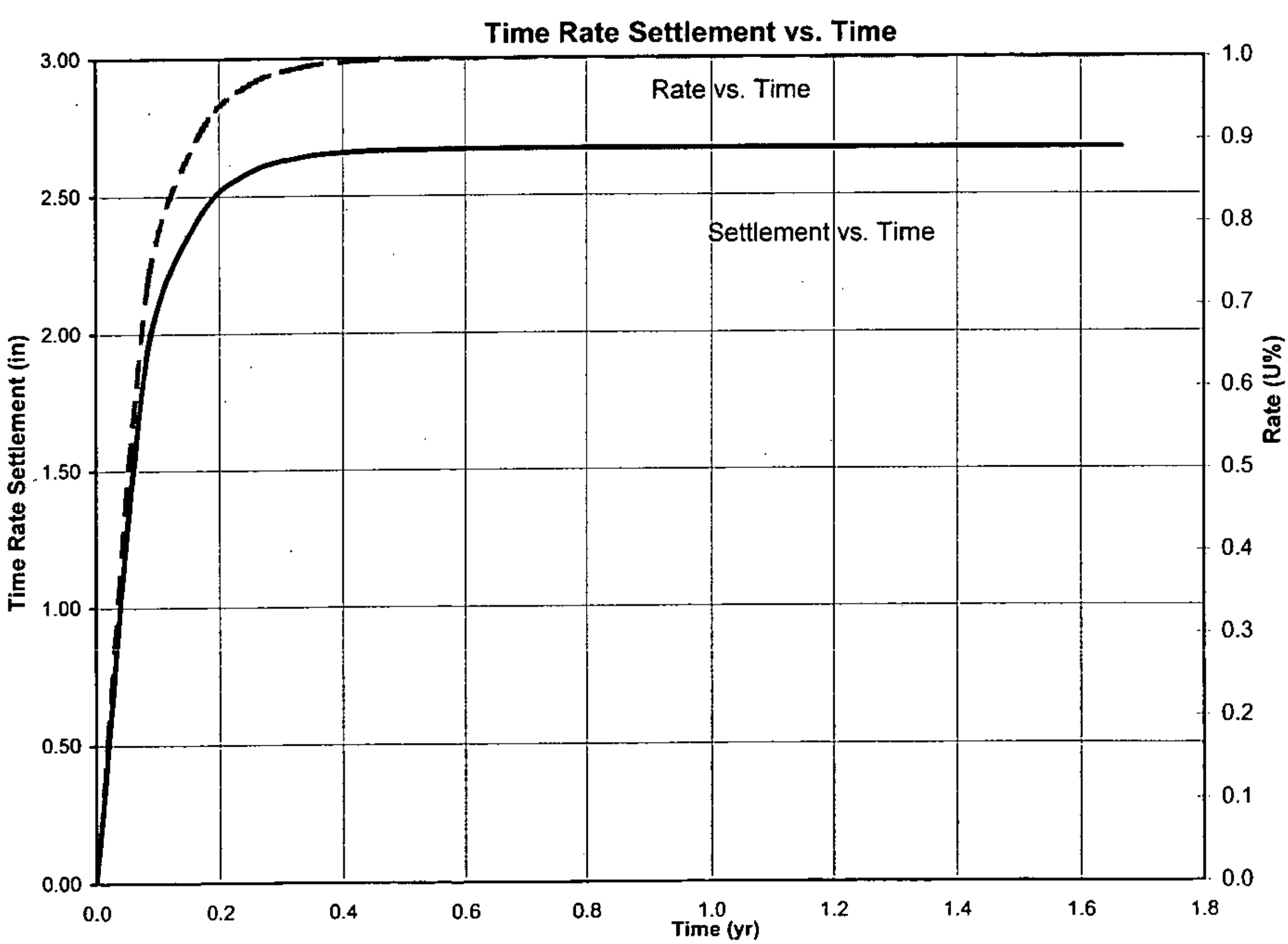
Assumed Life Time = 5 yrs

Drainage Path Condition = 1 (0 for single drainage; 1 for double drainage)

Thickness of Layer = 11 ft

Maximum Time Rate Settlement = 2.67 inches

Settlement at (U% =80%) = 2.14 inches 30 days after the end of construction



SECONDARY SETTLEMENT ANALYSIS - EMBANKMENT

Thickness (H) 11 ft

c_v = 5.08E-06 ft^2/s

T= 2.71 (assuming U=0.999)

t_p = 0.5 yrs = 187.05 days

Time to end of primary consolidation (t_p) = 0.5 yrs

No.	Soil	H(ft)	w(%)	C_a		S(inch)
1	Silt and Clay	11	24	0.0053		0.698
2						
3						

Total Secondary Settlement = 0.7 inches

Secondary Settlement*

$$(\delta_{secondary}) = C_\alpha H$$

$$t_p = \frac{T.H^2}{c_v} \; Assume \; U = 0.999$$

* Ref: Soils and Foundations Workshop Reference Manual- NHI-00-045 (p. 6.14)