



August 20, 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. 412+07)
SCI-823-0.00 Portsmouth Bypass
DLZ Job No.: 0121-3070.03
Document #0080

Dear Mr. Weeks:

This letter presents the findings of the preliminary evaluation of the proposed culvert and embankment at Station 412+07 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 412+07 for the above referenced project. The culvert will be a 72-inch Type A conduit in accordance with ODOT Item 707.03 (Reinforced Concrete Pipe, Epoxy Coated). Preliminary plans indicate the flow line of the culvert varies from approximately 0 to 8 feet below 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 47 feet. The inlet and outlet of the culvert will be supported by headwalls flush with the face of the pipe at each end. At the time of preparing this letter no further information was available regarding the culvert.

It should be noted that the results of this evaluation are based upon the findings of two borings (C-51 and C-52) located along the proposed alignment of the culvert. The borings were advanced to depths ranging between 15 and 53.5 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

Boring C-51 encountered 5.5 feet of hard sandy silt (A-4a) over soft to medium hard sandstone bedrock. However, beneath eight feet of hard sandy silt, boring C-52 encountered medium stiff to very stiff clay (A-7-6) and silt (A-4b) to a depth of 42 feet. The consistency decreased with depth and soft zones were encountered below 25 feet depth. Beneath the cohesive soils, very

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dense sand (A-3a) was encountered to a depth of 48.5 feet where medium hard sandstone was encountered.

Bearing Capacity Evaluation

The preliminary plans indicate that the invert elevations at the inlet and outlet of the proposed culvert are 699.00 and 677.00, 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 the borings, footings at this depth will bear in weathered bedrock at the inlet and stiff clay soils at the outlet. Footings bearing in the stiff clay may be designed based on allowable bearing capacity of up to 1,700 pounds per square foot (psf). Footings bearing on the sandstone bedrock may be designed based on an allowable bearing capacity not greater than 20,000 psf.

Settlement Evaluation

Soil parameters for use in the settlement calculations were estimated using correlations with moisture content and Atterberg limits. Settlement below the centerline of the embankment was evaluated using the maximum cover of the embankment (approximately 47.3 feet) as the surcharge load and using the soil profile encountered in boring C-52.

The settlement analysis indicated that the soil below the embankment will yield a total settlement of 9.6 inches. The analysis indicated that 80% of the consolidation settlement (7.7 inches) will occur within 7.5 years days after the embankment construction while the time required to achieve the total consolidation settlement (9.6 inches) will be approximately 37.5 years. Secondary compression of the foundation soils beneath the embankment is estimated to produce approximately 3.3 inches of additional settlement in the years following completion of the primary consolidation. Consolidation times can be shortened by means of wick drains installed through the compressible foundation layers within the embankment footprint prior to construction of the embankment. Recommendations for the use of wick drains have been provided in the Report of Subsurface Investigation for the Shumway Hollow Road Interchange, dated November 29, 2006, presented separately.

Settlement at the ends of the culvert due to the embankment loading is expected to be insignificant. Based on the preceding information, and including the secondary consolidation estimate, differential settlement between the center of the embankment and the inlet and outlet of the culvert is expected to be approximately 12.9 inches. Since appreciable settlement is anticipated, consideration should be given to cambering the flow line of the culvert. 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



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

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

Cohesive Soils - Consistency

<u>Term</u>	<u>Unconfined Compression tons/sq.ft.</u>	<u>Blows/Foot Standard Penetration</u>	<u>Hand Manipulation</u>
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:

<u>Description</u>	<u>Size</u>	<u>Description</u>	<u>Size</u>
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.

<u>Term</u>	<u>Relative Moisture or Appearance</u>
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:

<u>Term</u>	<u>Relative Moisture or Appearance</u>
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.


<u>Term</u>	<u>Description</u>
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.

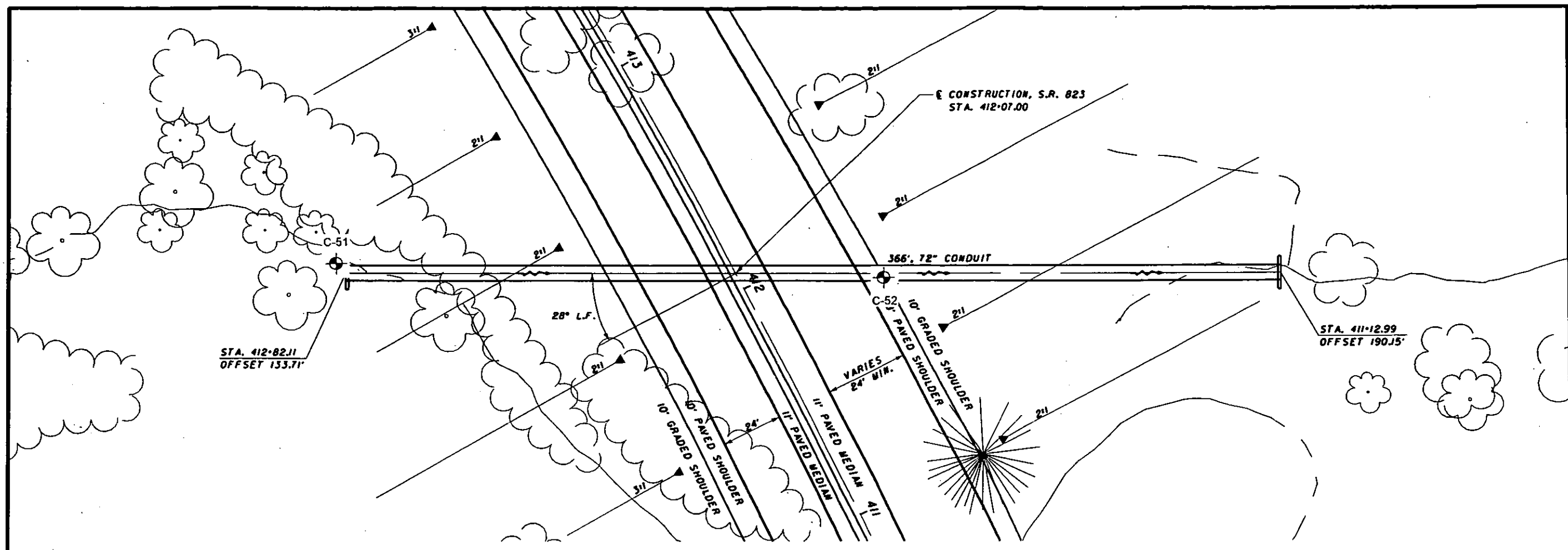


 HORIZONTAL SCALE IN FEET

 0 10 20

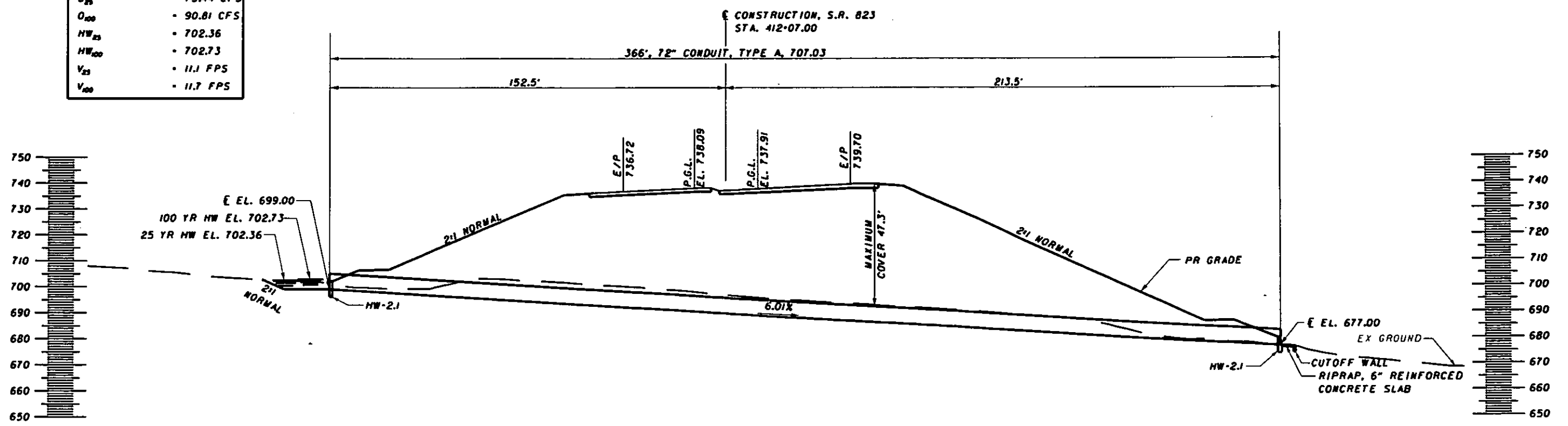
 MDC

 HJS



HYDRAULIC DESIGN DATA

DRAINAGE AREA	- 22.00 AC.
Q_{25}	- 75.44 CFS
Q_{100}	- 90.81 CFS
HW_{25}	- 702.36
HW_{100}	- 702.73
V_{25}	- 11.1 FPS
V_{100}	- 11.7 FPS



CULVERT DETAIL
 S.R. 823 STA. 412+07

SCI-823-0.00



Client: TranSystems, Inc.

Project: SCI-823-0.00

Job No. 0121-3070.03

LOG OF: Boring C-51

Location: Sta. 412+84.1, 130.5 ft. LT of SR 823 CL

Date Drilled: 09/06/06

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No.		Hand Penetrometer (tsf) / * Point-Load Strength (psi)	WATER OBSERVATIONS: Water seepage at: None Water level at completion: None (prior to coring) 0.8' (includes drilling water)	GRADATION						STANDARD PENETRATION (N) Natural Moisture Content, % - ● PL ——— LL Blows per foot - ○ 10 20 30 40				
				Drive	Press / Core			% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay					
0	701.1						Topsoil - 11" Hard brown SANDY SILT (A-4a), trace to little clay; damp.											
0.9	700.2	9			1	4.5+												
		10	14															
		7			2	4.5+												
5		12	13				Soft to medium hard brown SANDSTONE; fine grained, highly weathered to decomposed.											
5.5	695.6	50/4	3		3	-												
		50/3	3		4	-												
10.0	691.1						Medium hard brown SANDSTONE; very fine grained, highly weathered, thinly bedded to medium bedded, highly fractured. @ 13.0', 13.2', 13.6', 13.9', high angle fractures. @ 13.9'-14.4', broken zone. @ 14.4', becomes gray.											
		Core 60"	Rec 60"	RQD 46%	R-1													
15.0	686.1						Bottom of Boring - 15.0'											
20																		
25																		
30																		

Client: TranSystems, Inc.

Project: SCI-823-0.00

Job No. 0121-3070.03

LOG OF: Boring C-52

Location: Sta. 411+80.1, 51.9 ft. RT of SR 823 CL

Date Drilled: 09/06/06 to 09/07/06

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No.		Hand Penetrometer (tsf) / * Point-Load Strength (psi)	WATER OBSERVATIONS: Water seepage at: 43.5' - 44.0' Water level at completion: None (prior to coring) 53.5' (includes drilling water)	GRADATION						STANDARD PENETRATION (N) Natural Moisture Content, % - ● PL ————— LL Blows per foot - ○ 10 20 30 40				
				Drive	Press / Core			% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay					
0	692.8																	
0.8	692.0	7				4.5+	Topsoil - 10"											
		15 13	14		1		Very stiff to hard brown SANDY SILT (A-4a), trace to little clay, damp.											
		9				3.0	@ 3.5'-5.0', trace gravel, contains trace organic material.											
5		18 22	16		2		@ 6.0'-7.5', little gravel.											
		5				3.0												
		10 17	15		3													
8.0	684.8					2.5	Stiff to very stiff mottled brown and gray CLAY (A-7-6), little to some silt, trace fine to coarse-sand, trace gravel; damp.											
		3				2.0	@ 11.0', becomes brown, varved, moist.											
		5	9	17	4													
10		2				1.5												
		4	6	18	5		@ 16.0', becomes gray.											
		3				1.5												
		5	5	18	6													
15		2				1.25												
		4	5	18	7		@ 23.5'-25.0', trace fine sand.											
		2				1.0												
		3	4	18	8													
20		2				1.0												
		3	3	18	9													
		2				1.0												
		4	5	18	10													
25		2				0.25	Very soft to soft reddish brown CLAY (A-7-6), trace fine sand, little to some silt, moist.											
25.5	667.3	WOH				0.5	@ 28.5', becomes gray.											
		2	4	18	11													
		2																
		3	4	18	12													
30		2																
		3	4	18														
		4																

FILE: 0121-3070-03 [11/12/2007 10:11 AM]

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

LOG OF: Boring C-52 Location: Sta. 411+80.1, 51.9 ft. RT of SR 823 CL Date Drilled: 09/06/06 to 09/07/06

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No.		Hand Penetrometer (tsf)	DESCRIPTION	GRADATION						STANDARD PENETRATION (N)		
				Drive	Press / Core			% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	Natural Moisture Content, %	Blows per foot	
30	662.8						WATER OBSERVATIONS: Water seepage at: 43.5' - 44.0' Water level at completion: None (prior to coring) 53.5' (includes drilling water)									
32.0	660.8					1.0		Very soft to soft gray CLAY (A-7-6), trace fine sand, little to some silt, moist.								
35		50/3	2	13			Medium stiff light brown SILT (A-4b), trace fine sand, little to some clay, moist. @ 33.7', encountered possible cobble.									
40		2 4 6	18	14		0.5	@ 38.5'-40.0', gray, moist to wet.									
42.0	650.8						Very dense brown COARSE AND FINE SAND (A-3a), little to some silty clay, trace to little gravel; moist.									
45		50/5	5	15												
48.5	644.3						Medium hard gray SANDSTONE; fine grained, slightly weathered, micaceous, thinly bedded to medium bedded, moderately fractured. @ 48.5'-50.0', broken and decomposed zone.									
50		Core 60"	Rec 60"	RQD 35%	R-1											
53.5	639.3						Bottom of Boring - 53.5'									
55																
60																

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



CLIENT TranSystems Inc.
PROJECT Portsmouth Bypass
SUBJECT Culvert at Station 412+07
Bearing Capacity Analysis

JOB NUMBER 0121-3070-03
SHEET NO. 1 OF 1
COMP. BY BEW DATE 8/20/2007
CHECKED BY _____ DATE _____

Base analysis on results of boring C-52.

From hand penetrometer measurements:

$$q_u = 1 \text{ tsf}$$

$$c = 1000 \text{ psf}$$

$$\text{Factor of Safety (FS)} = 3 \quad (\text{ODOT BDM 202.2.3.1})$$

For cohesive foundation soil:

Meyerhof's Method

$$q_u = S_c \cdot c \cdot N_c + q \cdot N_q \quad q = \gamma \cdot D \quad \text{Can be neglected since footing depth is less than 5 ft}$$

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

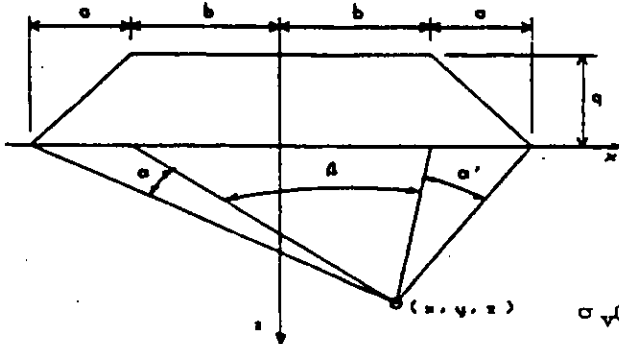
$$q_a = q_u / \text{FS} = 1713.3 \text{ psf}$$

Use $q_a < 1713$ psf for footings in stiff/medium stiff clay at culvert outlet.

At culvert inlet, use presumptive allowable bearing of 20,000 psf for footings bearing in sandstone bedrock.

SETTLEMENT ANALYSIS - EMBANKMENT

Embankment Informaiton:



Groundwater Table: D= 43.0 ft
 Embankment Height: H = 47.3 ft
 Fill Unit Weight: $\gamma_{emb} = 120$ pcf $q = 5,676$ psf
 Width of Slope: a = 117
 Top half-width of Emb: b = 66
 Distance from CL: x = 0
 Output Range: z = 0 to 45 ft

*See Data output Attached

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

$$\beta(z) := \text{atan} \left[\frac{(b-x)}{z} \right] + \text{atan} \left[\frac{(b+x)}{z} \right]$$

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

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

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

Cohesionless

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'_r (psf)	Soils			
								C'	C_r	C_c	e_o
1	8.0 ft	Sandy Silt	120	6,500	480	5,676	6,156	0.0	0.04	0.15	0.960
2	20.0 ft	Clay	120	7,500	1,680	5,671	7,351	0.0	0.07	0.42	0.960
3	32.0 ft	Clay	120	9,000	3,120	5,645	8,765	0.0	0.07	0.42	0.960
4	42.0 ft	Silt	120	10,100	4,440	5,591	10,031	0.0	0.07	0.42	0.960
5	0.0		0	0							
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							

Reference: Geotechnical Engineering Principles and Practices; Coduto, 1999

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

$$(\delta_c)_{ult} = \sum \frac{C_r}{1+e_o} H \log \left(\frac{\sigma'_f}{\sigma'_o} \right)$$

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

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

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

$$(\delta_c)_{ult} = \sum \frac{C_c}{1+e_o} H \log \left(\frac{\sigma'_f}{\sigma'_o} \right)$$

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

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

No. Settlement:

Total Settlement

1 0.181 ft

2 0.286 ft

0.800 ft

3 0.200 ft

4 0.132 ft

9.6 in

5

6

7

8

9

10



SUBJECT

Client TranSystems, Inc.

JOB NUMBER 0121-3070.03

Project SCI-823-0.00

SHEET NO. 3 OF 4

Item Culvert at STA.412+07

COMP. BY WMA DATE 08/10/07

Based on Boring C-52

CHECKED BY BEW DATE 08/20/07

TIME RATE SETTLEMENT

Coefficient of consolidation (c_v) =

1.02E-06 ft²/s

Assumed Life Time =

20 yrs

Drainage Path Condition =

1 (0 for single drainage; 1 for double drainage)

Thickness of Layer =

42.0 ft

Maximum Time Rate Settlement =

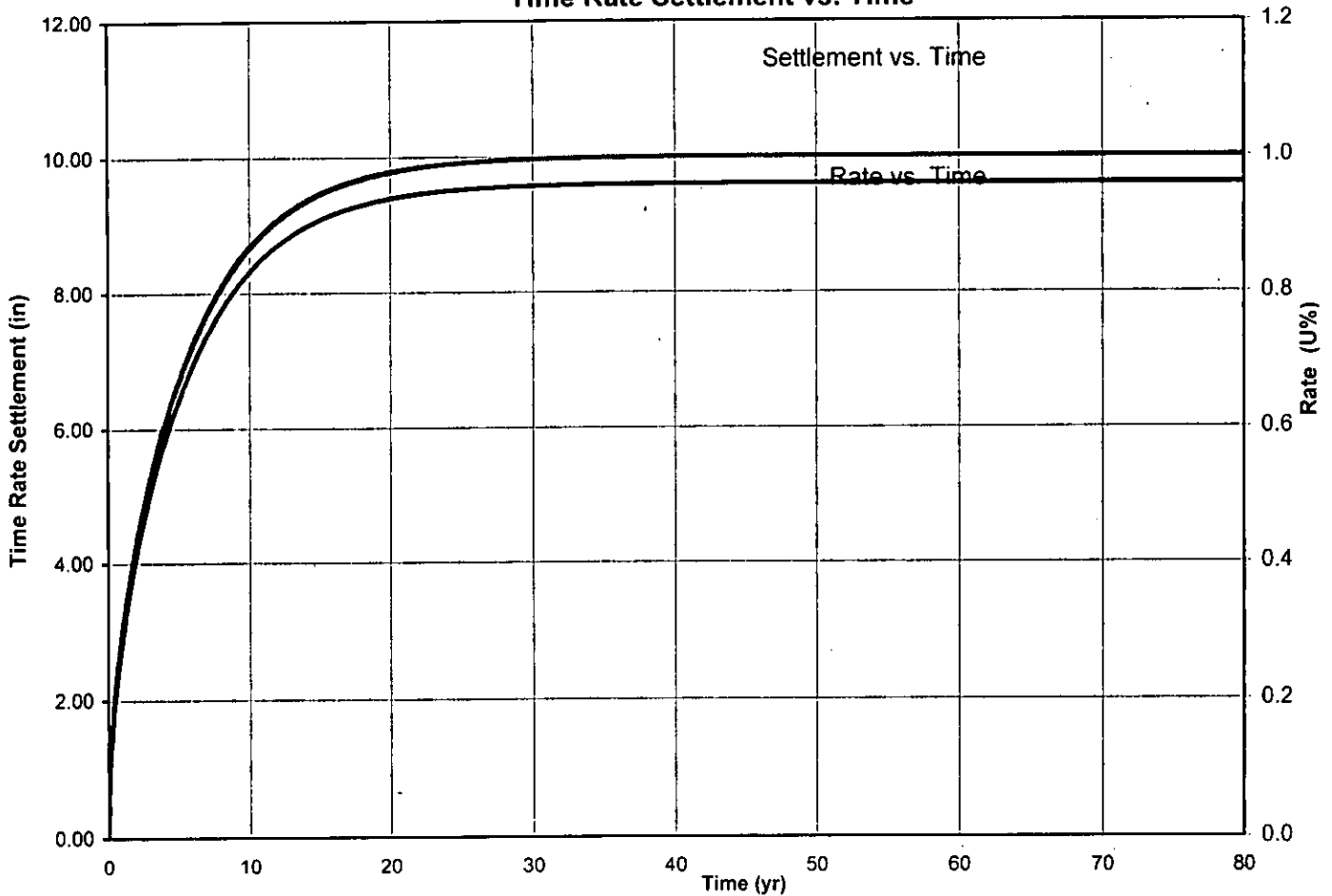
9.6 inches

Settlement at (U% =80%) =

7.68 inches

2790 days after the end of construction

Time Rate Settlement vs. Time





SUBJECT

Client TranSystems Inc.

JOB NUMBER

0121-3070.03

Project Portsmouth Bypass

SHEET NO.

4 OF 4

Item Culvert at STA. 412+07

COMP. BY

WMA

DATE

08/10/07

Based on Boring C-52

CHECKED BY

BEW

DATE

08/20/07

SECONDARY SETTLEMENT ANALYSIS - EMBANKMENT

Thickness (H) 42 ft

$c_v = 1.02E-06$ ft²/s

T = 2.71 (assuming U=0.999)

$t_p = 37.4$ yrs

Time to end of primary consolidation (t) = 37.4 yrs

No.	Soil	H(ft)	w(%)	C_a	S(inch)
1	Silt and Clay	42	30	0.0064	3.25
2					
3					

Total Secondary Settlement = 3.3 inches

Secondary Settlement*

$$(\delta_{secondary}) = C_a H$$

$$t_p = \frac{T \cdot H^2}{c_v} \text{ Assume } U = 0.999$$

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