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August 23, 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. 635+90)**
SCI-823-0.00 Portsmouth Bypass
DLZ Job No.: 0121-3070.03
Document #0085

Dear Mr. Weeks:

This letter presents the findings of the preliminary evaluation of the proposed culvert and embankment at Station 635+90 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 635+90 for the above referenced project. The culvert will be a 72-inch Type A conduit in accordance with ODOT Item 707.03 (Structural Plate Corrugated Steel Structures). Preliminary plans indicate the flow line of the culvert is at or slightly below and roughly 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 79 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 three borings (C-86 through C-88) located along the proposed alignment of the culvert. The borings were advanced to depths ranging between 17.5 and 24.5 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.

It should be noted that the reported as-drilled elevations of the borings (C-86 to C-88) drilled for the proposed culvert varied from the contours found on the topographic mapping. The variance in elevation was likely due to the steep valley slopes interfering with the reception required for the surveying equipment. The variations were estimated to be 14.6 to 19.2 feet. Representatives of Lockwood, Lanier, Mathias and Noland Inc (2LMN), who surveyed the borings, were made aware of the variance. They acknowledged the variance, but were unable to provide any correction to the as-drilled elevations, which were previously provided. Consequently, the existing ground surface elevations at the culvert borings were estimated based upon the contours found on the topographic mapping.

**Exploration Findings**

The borings encountered 12 to 18 feet of soil overlying siltstone and sandstone bedrock. The soil consisted mainly of stiff to hard cohesive soils (A-4a, A-4b, A-6a); however, boring C-86 encountered gravel with sand (A-1-b) to a depth of 8.5 feet. The underlying sandstone and siltstone bedrock was medium hard to hard, slightly weathered and fractured to varying degrees.

**Bearing Capacity Evaluation**

The preliminary plans indicate that the invert elevations at the inlet and outlet of the proposed culvert are 773.27 and 748.74, 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 stiff silt or medium dense sandy silt. Footings bearing in these materials may be designed based on allowable bearing capacity of up to 2,500 pounds per square foot (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 (79 feet) as the surcharge load and using the soil profile encountered in boring C-87.

The settlement analysis indicated that the soil below the embankment will yield a total settlement of 2.7 inches. The analysis indicated that 80% of the consolidation settlement (2.2 inches) will occur within two months after application of the embankment load (essentially during construction for an embankment this size), while the time required to achieve the total consolidation settlement (2.7 inches) will be approximately 10 months. Secondary compression of the foundation soils beneath the embankment is estimated to produce approximately 0.5 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 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 3.2 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

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.

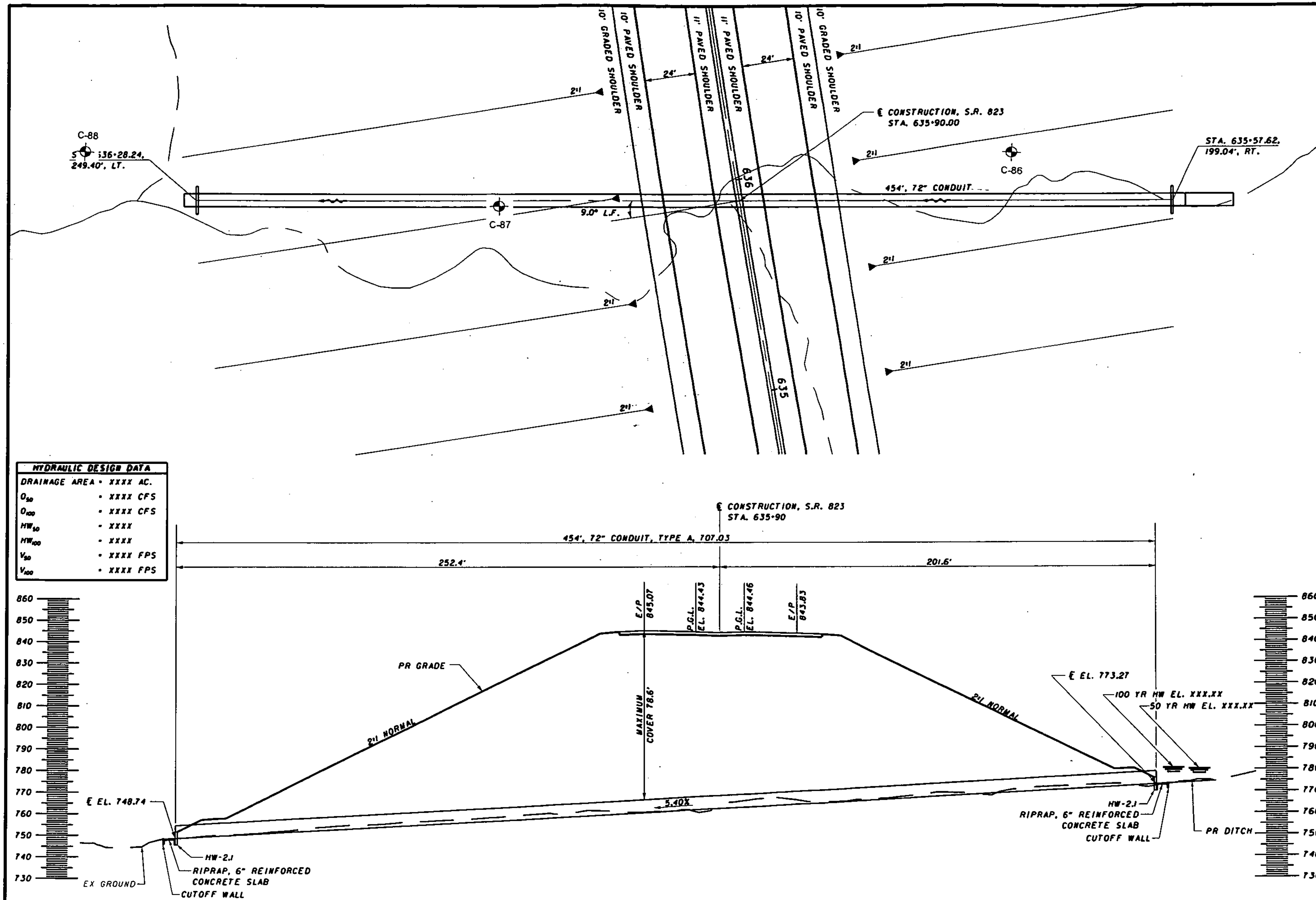
| Term | Description |
|---|---|
| Very Soft | Difficult to indent with thumb nails; resembles hard soil but has rock structure |
| Soft | Resists indentation with thumb nail but can be abraded and pierced to a shallow depth by a pencil point. |
| Medium Hard | Resists pencil point, but can be scratched 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.




**HYDRAULIC DESIGN DATA**

| | |
|---|---|
| DRAINAGE AREA | = XXXX AC. |
| $Q_{50}$ | = XXXX CFS |
| $Q_{100}$ | = XXXX CFS |
| $HW_{50}$ | = XXXX |
| $HW_{100}$ | = XXXX |
| $V_{50}$ | = XXXX FPS |
| $V_{100}$ | = XXXX FPS |

# CULVERT DETAIL
## S.R. 823 STA. 635+90

SCI-823-10.31

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

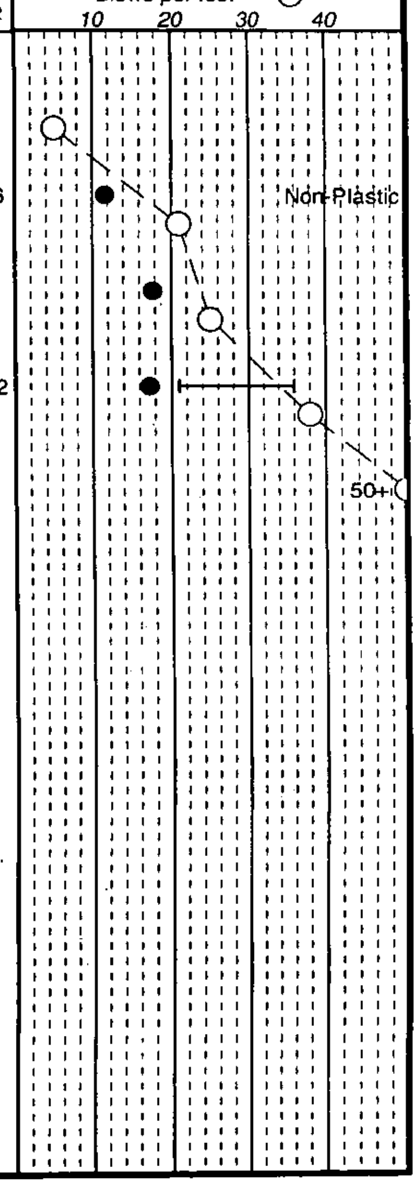
**Client:** TranSystems, Inc. | **Project:** SCI-823-0.00 | **Job No.** 0121-3070.03

**LOG OF: Boring C-86** | **Location:** Sta. 635+88.0, 122.4 ft. RT of SR 823 CL | **Date Drilled:** 01/23/07

**WATER OBSERVATIONS:** Water seepage at: 5.0' - 6.0'
Water level at completion: 11.1' (prior to coring)
7.7' (inside hollowstem augers)

| Depth (ft) | Elev. (ft) | Blows per 6" | Recovery (in) | Sample No. Drive | Sample No. Press / Core | Hand Penetrometer (tsf) / * Point-Load Strength (psi) | DESCRIPTION | % Aggregate | % C. Sand | % M. Sand | % F. Sand | % Silt | % Clay | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 772.5 | | | | | | | | | | | | | |
| 0.7 | 771.8 | | | | | | Topsoil - 8" | | | | | | | |
| | | 2 2 3 | 18 | 1 | | | Loose to dense brown GRAVEL WITH SAND (A-1-b), trace to little silty clay; contains sandstone fragments; damp to moist. | | | | | | | |
| | | 3 7 14 | 18 | 2 | | | | 59 | 12 | -- | 11 | 13 | 6 | Non-Plastic |
| | | 5 10 15 | 18 | 3 | | | | | | | | | | |
| 8.5 | 764.0 | 8 16 22 | 18 | 4 | | 1.0 | Medium stiff to stiff brown SILT AND CLAY (A-6a), trace to little fine to coarse sand, trace gravel; contains sandstone fragments; damp to moist. | 5 | 8 | -- | 5 | 50 | 32 | |
| | | 38 50/3 | 9 | 5 | | 1.0 | | | | | | | | 50+ |
| 12.0 | 760.5 | Core 84" | Rec 84" | RQD 72% | R1 | | Hard gray SILTSTONE interbedded with SANDSTONE; very fine to fine grained, slightly weathered, micaceous, argillaceous, laminated to very thinly bedded, slightly fractured. @ 12.0'-13.8', medium hard, brown, broken zone. @ 17.0'-18.0', broken zone. | | | | | | | |
| 19.0 | 753.5 | | | | | | Bottom of Boring - 19.0' | | | | | | | |

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



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

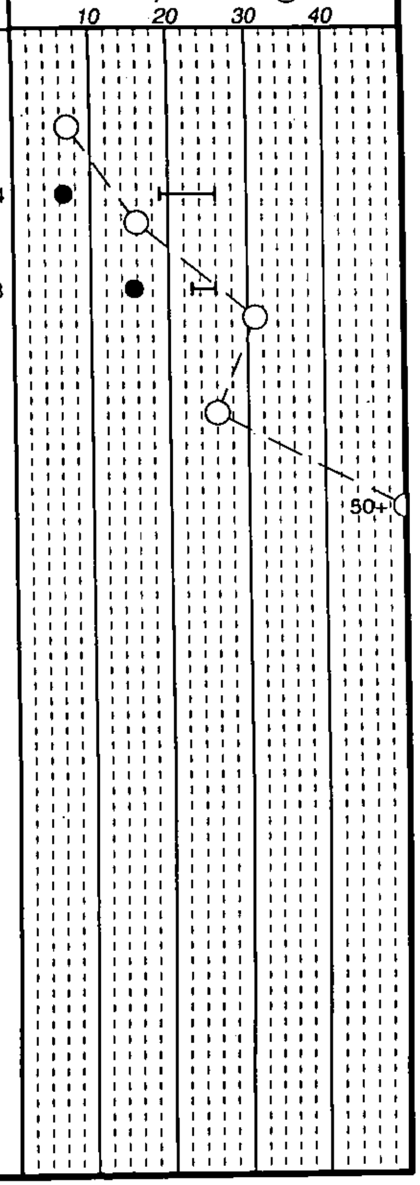
*Client:* TranSystems, Inc. | *Project:* SCI-823-0.00 | *Job No.* 0121-3070.03

**LOG OF: Boring C-87** | *Location:* Sta. 636+05.9, 105.2 ft. LT of SR 823 CL | *Date Drilled:* 01/24/07

*WATER OBSERVATIONS:* Water seepage at: 5.0'-6.0'
Water level at completion: 10.9' (prior to coring)
5.6' (inside hollowstem augers)

| Depth (ft) | Elev. (ft) | Blows per 6" | Recovery (in) | Sample No. Drive | Sample No. Press / Core | Hand Penetrometer (tsf) / * Point-Load Strength (psi) | DESCRIPTION | % Aggregate | % C. Sand | % M. Sand | % F. Sand | % Silt | % Clay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 757.5 | | | | | | Topsoil - 7" | | | | | | |
| 0.6 | 756.9 | | | | | | Very stiff to hard brown SANDY SILT (A-4a), some to "and" gravel, trace to little clay; contains sandstone fragments; damp to moist. | | | | | | |
| | | 2 3 4 | 18 | 1 | | -- | @ 1.0'-2.5', medium stiff. | | | | | | |
| | | 5 7 9 | 18 | 2 | | -- | | 29 | 16 | -- | 10 | 31 | 14 |
| | | 9 15 16 | 18 | 3 | | -- | | 45 | 11 | -- | 8 | 28 | 8 |
| | | 6 11 15 | 18 | 4 | | -- | | | | | | | |
| | | 10 14 50/3 | 15 | 5A 5B | | -- | | | | | | | |
| 12.0 | 745.5 | | | | | | Severely weathered brown SANDSTONE, argillaceous. | | | | | | |
| 12.5 | 745.0 | Core 60" | Rec 60" | RQD 83% | R1 | | Hard gray SILTSTONE interbedded with SANDSTONE; very fine to fine grained, slightly weathered, micaceous, argillaceous, laminated to very thinly bedded, slightly fractured. @ 13.0'-13.3', iron stained high angle fracture. @ 17.1'-17.2', high angle fracture. | | | | | | |
| 17.5 | 740.0 | | | | | | Bottom of Boring - 17.5' | | | | | | |

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




FILE: 0121-3070-03 | 11/13/2007 9:52 AM |

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

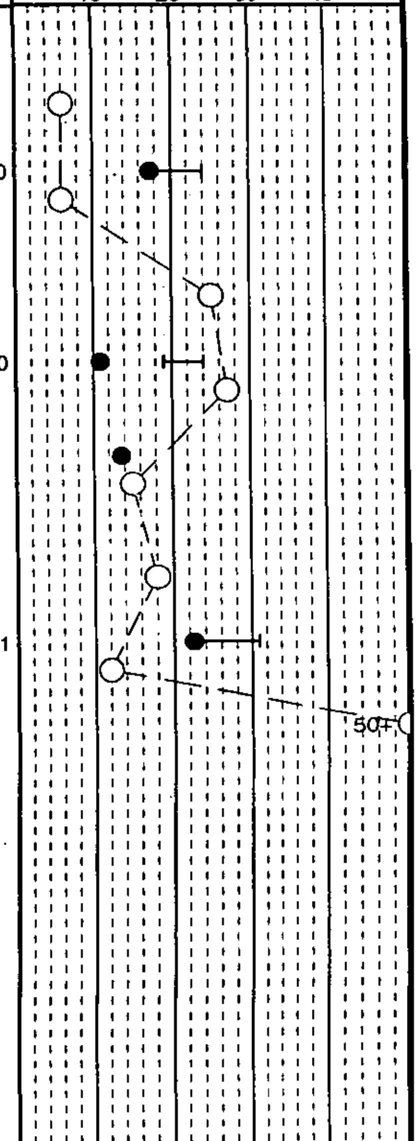
*Client:* TranSystems, Inc. | *Project:* SCI-823-0.00 | *Job No.* 0121-3070.03

**LOG OF: Boring C-88** | *Location:* Sta. 636+57.7, 284.3 ft. LT of SR 823 CL | *Date Drilled:* 01/24/07

*WATER OBSERVATIONS:* Water seepage at: None
Water level at completion: None (prior to coring)
6.0' (inside hollowstem augers)

| Depth (ft) | Elev. (ft) | Blows per 6" | Recovery (in) | Sample No. Drive | Sample No. Press / Core | Hand Penetrometer (tsf) / * Point-Load Strength (psi) | DESCRIPTION | % Aggregate | % C. Sand | % M. Sand | % F. Sand | % Silt | % Clay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 754.0 | | | | | | Topsoil - 9" | | | | | | |
| 0.8 | 753.2 | 2 3 3 | 18 | 1 | | -- | Stiff brown SILT (A-4b), little to some clay, little gravel, little fine to coarse sand; contains rock fragments; damp to moist. | | | | | | |
| | | 2 3 3 | 18 | 2 | | 1.75 | | 15 | 10 | -- | 4 | 51 | 20 |
| 5.5 | 748.5 | 4 10 15 | 18 | 3 | | -- | Very stiff brown SANDY SILT (A-4a), little to some gravel, trace to little clay; contains sandstone fragments; damp. | | | | | | |
| | | 7 13 14 | 18 | 4 | | -- | | 34 | 20 | -- | 10 | 27 | 10 |
| | | 8 8 7 | 18 | 5 | | -- | | | | | | | |
| | | 6 8 10 | 18 | 6 | | -- | | | | | | | |
| 16.0 | 738.0 | 4 5 7 | 18 | 7 | | -- | Stiff brown SILT (A-4b), some clay, little fine to coarse sand, trace gravel; damp to moist. | 1 | 5 | -- | 7 | 67 | 21 |
| 18.0 | 736.0 | 50/4 | 4 | 8 | | | Severely weathered gray SANDSTONE, argillaceous. | | | | | | |
| 19.5 | 734.5 | Core 60" | Rec 60" | RQD 96% | R1 | | Medium hard gray SILTSTONE interbedded with SANDSTONE; very fine to fine grained, slightly weathered, micaceous, argillaceous, thinly laminated to laminated, moderately to highly fractured. | | | | | | |
| 24.5 | 729.5 | | | | | | Bottom of Boring - 24.5' | | | | | | |

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○
10 20 30 40




FILE: 0121-3070-03 [ 11/13/2007 9:52 AM ]

Base analysis on results of boring C-88.

Assume qu = 1.5 tsf for stiff cohesive material

c = 1500 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 $N_q = 1$

$q_a = q_u / FS =$ 2570 psf

| Use $q_a <$ 2570 psf |
|---|

Base analysis on results of boring C-86.

qu = 0 tsf
c = 0 psf
$\phi$ = 34 degrees
Assume B = 2.5 ft
Assume $\gamma$ = 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 $\phi$ equal to 34 degrees

$Nq$ = 30.30 for $\phi$ equal to 34 degrees

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

Use $\mathbf{q_a} <$ 2500 psf

**DLZ**

| | | | | | |
|---|---|---|---|---|---|
| Client | TranSystems Inc. | JOB NUMBER | 0121-3070.03 | | |
| Project | Portsmouth Bypass | SHEET NO. | 1 | OF | 4 |
| Item | Culvert at STA. 635+90 | COMP. BY | WMA | DATE | 8/10/07 |
| | | CHECKED BY | BEW | DATE | 8/16/07 |

## Calculations Data

| Boring | Sample | w | PL | LL | PI | $Cc^1$ | $Cr^2$ | $e_o^3$ |
|---|---|---|---|---|---|---|---|---|
| C-86 | 4 | 18 | 21 | 36 | 15 | 0.20 | 0.046 | 0.9566 |
| C-87 | 2 | 9 | 19 | 26 | 7 | 0.09 | 0.033 | 0.8978 |
| C-87 | 3 | 16 | 23 | 26 | 3 | 0.04 | 0.033 | 0.9895 |
| C-88 | 2 | 18 | 18 | 24 | 6 | 0.08 | 0.031 | 0.9826 |
| C-88 | 4 | 11 | 19 | 24 | 5 | 0.07 | 0.031 | 0.9621 |
| C-88 | 7 | 23 | 23 | 31 | 8 | 0.11 | 0.039 | 0.9837 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | Average | 0.10 | 0.035 | 0.9620 |
| | | | | | Maximum | 0.20 | 0.046 | 0.9895 |

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

| Boring | Sample | LL | $C_v$*(ft²/day) | $C_v$*(ft²/sec) |
|---|---|---|---|---|
| C-86 | 4 | 36 | 0.34 | 3.91E-06 |
| C-87 | 2 | 26 | 0.85 | 9.89E-06 |
| C-87 | 3 | 26 | 0.85 | 9.89E-06 |
| C-88 | 2 | 24 | 1.07 | 1.24E-05 |
| C-88 | 4 | 24 | 1.07 | 1.24E-05 |
| C-88 | 7 | 31 | 0.52 | 5.99E-06 |
| | | | | |
| | | | | |
| | | | | |
| | | Minmum | 0.34 | 3.91E-06 |
| | | Average | 0.79 | 9.09E-06 |
| | | Maximum | 1.07 | 1.24E-05 |

*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 | $C_\alpha/C_c$ |
|---|---|
| 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-86 | 4 | 18 | 21 | 36 | 15 | -0.20 | Overconsolidated |
| C-87 | 2 | 9 | 19 | 26 | 7 | -1.43 | Overconsolidated |
| C-87 | 3 | 16 | 23 | 26 | 3 | -2.33 | Overconsolidated |
| C-88 | 2 | 18 | 18 | 24 | 6 | 0.00 | Overconsolidated |
| C-88 | 4 | 11 | 19 | 24 | 5 | -1.60 | Overconsolidated |
| C-88 | 7 | 23 | 23 | 31 | 8 | 0.00 | Overconsolidated |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

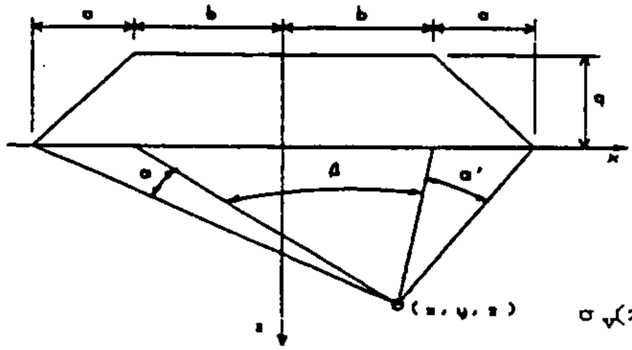
*Overconsolidated when LI<0.7
Ref: Soils and Foundations Workshop Reference Manual- NHI-00-045 (p. 6.11)

**DLZ**

| SUBJECT | | | |
|---|---|---|---|
| Client TranSystems, Inc. | JOB NUMBER 0121-3070.03 | | |
| Project SCI-823-0.00 | SHEET NO. 2 | OF | 4 |
| Item Culvert at STA.635+90 | COMP. BY WMA | DATE | 08/10/07 |
| Based on C-87 | CHECKED BY BEW | DATE | 08/16/07 |

## SETTLEMENT ANALYSIS - EMBANKMENT

**Embankment Informaiton:**




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Groundwater Table: | D= | 5.0 | ft | | | | |
| Embankment Height: | H = | 73 | ft | | | | |
| Fill Unit Weight: | $\gamma_{emb}$ = | 120 | pcf | | q = | 8,760 | psf |
| Width of Slope: | a = | 170 | | | | | |
| Top half-width of Emb: | b = | 57 | | | | | |
| Distance from CL: | x = | 0 | | | | | |
| Output Range: | z = | 0 | to | 20 | 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*

| | | | | | | | | | Cohesionless Soils | Cohesive Soils | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Bot. of Layer | | Soil Type | $\gamma_{soil}$ (pcf) | $\sigma'_c$ (psf) | $\sigma'_o$ (psf) | $\Delta\sigma z$ (psf) | $\sigma'_f$ (psf) | C' | $C_r$ | $C_c$ | $e_o$ |
| 1 | 12.0 | ft | Sandy Silt | 120 | 9,500 | 658 | 8,759 | 9,417 | 0.0 | 0.03 | 0.10 | 0.960 |
| 2 | 0.0 | | | 0 | 0 | | | | 0.0 | 0.00 | 0.00 | 0.000 |
| 3 | 0.0 | | | 0 | 0 | | | | 0.0 | 0.00 | 0.00 | 0.000 |
| 4 | 0.0 | | | 0 | 0 | | | | | | | |
| 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 | | | | | | | |

| No. | Settlement: | |
|---|---|---|
| 1 | 0.226 | ft |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

**Total Settlement**

**0.226 ft**

**2.7 in**

*Reference: Geotechnical Engineering Principles and Practices; Coduto, 1999*

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

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

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

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

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

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

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

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

DLZ

SUBJECT

| | | | | | | |
|---|---|---|---|---|---|---|
| Client | TranSystems, Inc. | JOB NUMBER | 0121-3007.03 | | | |
| Project | SCI-823-0.00 | SHEET NO. | 3 | OF | 4 | |
| Item | Culvert at STA.635+90 | COMP. BY | WMA | DATE | 08/10/07 | |
| Based on C-87 | | CHECKED BY | BEW | DATE | 08/16/07 | |

## TIME RATE SETTELMENT

Coeffecient of consolidation ($c_v$) = 3.9E-06 ft²/s

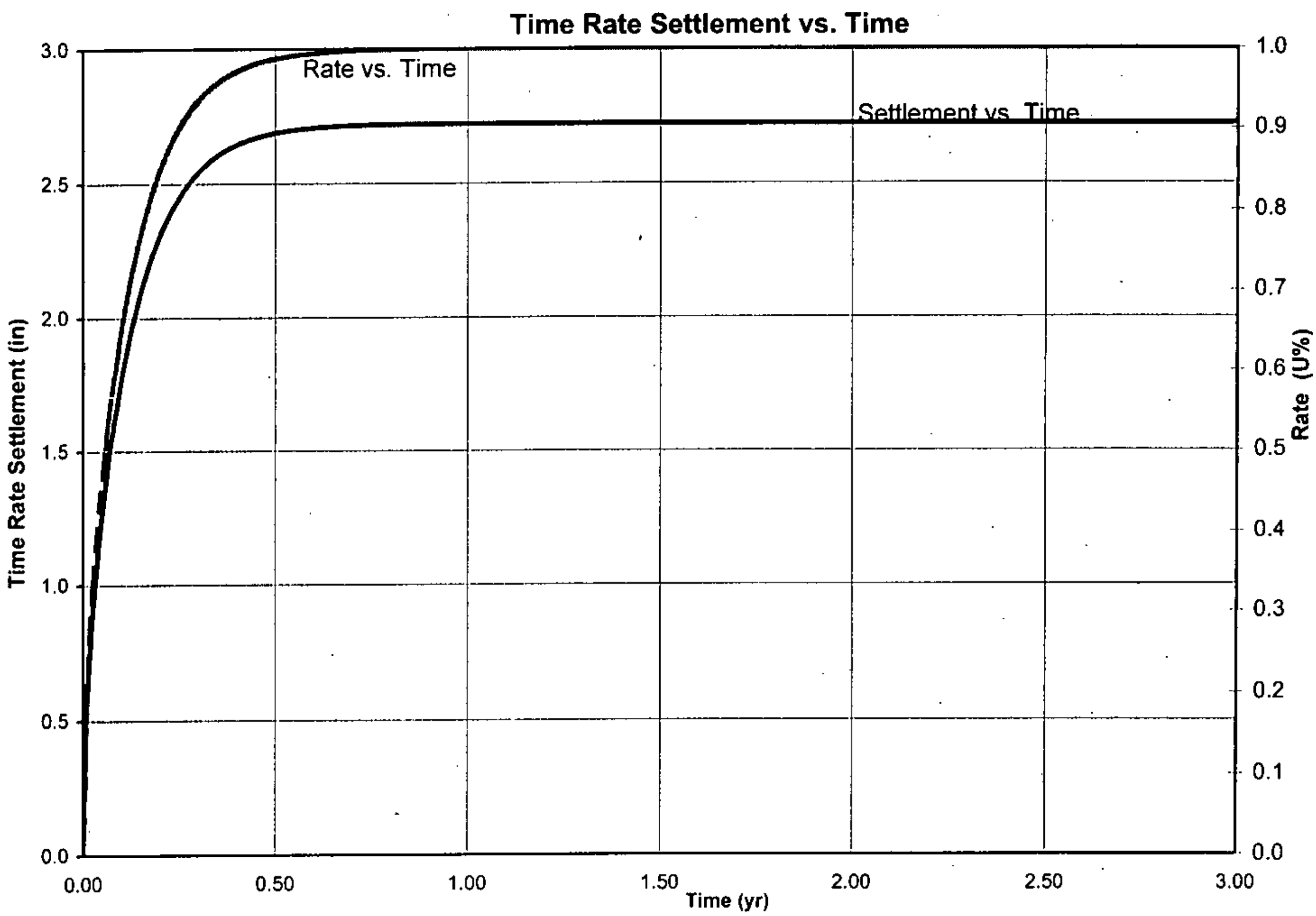
Assumed Life Time = 2 yrs

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

Thickness of Layer = 12.0 ft

Maximum Time Rate Settlement = 2.7 inches

Settlement at (U% =80%) = 2.17 inches 57 days after the end of construction



## SECONDARY SETTLEMENT ANALYSIS - EMBANKMENT

Thickness (H) 12 ft

$c_v$= 3.91E-06 $ft^2/s$

T= 2.71 (assuming U=0.999)

$t_p$= 0.79 yrs= 289 days

Time to end of primary consolidation ($t_p$) = 0.79 yrs

| No. | Soil | H(ft) | w(%) | $C_a$ | | S(inch) |
|---|---|---|---|---|---|---|
| 1 | Silt and Clay | 12 | 16 | 0.0037 | | 0.53 |
| 2 | | | | | | |
| 3 | | | | | | |

Total Secondary Settlement = 0.5 inches

Secondary Settlement*

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

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

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