SCHOOL OF CIVIL AND
ENVIRONMENTAL ENGINEERING
OKLAHOMA STATE UNIVERSITY

FINAL REPORT

PERFORMANCE OF EXPERIMENTAL APPROACH EMBANKMENTS AT SALT FORK RIVER BRIDGES ON U.S. 177

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16. ABSTRACT

In an effort to address the bump at the end of the bridge problem, ODOT has undertaken an experimental construction research project to evaluate five different approach embankment construction methods. The research is being conducted at a relocation project in which three new bridges are being constructed to relocate a two-mile section of U.S. 177 north of Stillwater, Oklahoma. Five of the six approach embankments are approximately the same height and the foundation soils are relatively uniform, consisting of fine to medium dense sands.

Materials and construction methods used for the five approach embankments in the study include: unclassified borrow placed by contractor's discretion (i.e., equipment)—this serves as the control for the research study; geotextile reinforced approach embankment using a nonwoven geotextile and granular backfill (i.e., concrete sand); controlled low strength material; dynamically compacted granular backfill; and flooded and vibrated granular backfill.

During and following construction, all five approach embankments and bridge abutments were instrumented to evaluate the performance of the approach embankments and interaction with the abutment walls. Specific instruments and the parameters they monitored included: total pressure cells on the back of the abutment walls to monitor lateral earth pressures caused by the approach embankments; amplified liquid settlement gages beneath the approach embankments to monitor settlement; inclinometer casings with telescoping couplings to monitor lateral displacement and settlement within the approach embankment and foundation materials; piezometers to monitor pore water pressures; and surface survey points to monitor total surface movement.

In terms of settlement, the flooded and vibrated granular backfill appears to be performing the best. Lateral earth pressure values are closest to the predicted values for the geotextile reinforced backfill. The CLSM is performing well with respect to settlement. The dynamically compacted granular backfill embankment has the highest amount of settlement. The least expensive embankment construction was the control section which had a total cost of $1500. The most expensive was the geotextile reinforced backfill at $25,000. The remaining embankments cost in the range of $14,500 to $16,000.

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(Study No. 2195)

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NOTICE

SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units					Approximate Conversions from SI Units				
Symbol	When You Know	Multiply by	To Find	Symbol	Symbol	When You Know	Multiply by	To Find	Symbol
		Length					Length		
in.	inches	25.40	millimeters	mm	mm	millimeters	0.0394	inches	in.
ft	feet	0.3048	meters	m	m	meters	3.281	feet	ft
yd	yards	0.9144	meters	m	m	meters	1.094	yards	yd
mi	miles	1.609	kilometers	km	km	kilometers	0.6214	miles	mi
		Area					Area		
$in.^2$	square inches	645.2	square millimeters	mm^2	mm^2	square millimeters	0.00155	square inches	$in.^2$
ft^2	square feet	0.0929	square meters	m^2	m^2	square meters	10.764	square feet	ft^2
yd^2	square yards	0.8361	square meters	m^2	m^2	square meters	1.196	square yards	yd^2
ac	acres	0.4047	hectares	ha	ha	hectares	2.471	acres	ac
mi^2	square miles	2.590	square kilometers	km^2	km^2	square kilometers	0.3861	square miles	mi^2
		Volume					Volume		
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.0338	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.2642	gallons	gal
ft^3	cubic feet	0.0283	cubic meters	m^3	m^3	cubic meters	35.315	cubic feet	ft^3
yd^3	cubic yards	0.7645	cubic meters	m^3	m^3	cubic meters	1.308	cubic yards	yd^3
		Mass					Mass		
oz	ounces	28.35	grams	g	g	grams	0.0353	ounces	oz
lb	pounds	0.4536	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.1023	short tons (2000 lb)	T
		Temperature (exact)					Temperature (exact)		
°F	degrees Fahrenheit	(°F-32)/18	degrees Celsius	°C	°C	degrees Celsius	9/5+32	degrees Fahrenheit	°F
		Force and Pressure or Stress					Force and Pressure or Stress		
lbf	poundforce	4.448	Newtons	N	N	Newtons	0.2248	poundforce	lbf
$lbf/in.^2$	poundforce per square inch	6.895	kilopascals	kPa	kPa	kilopascals	0.1450	poundforce per square inch	$lbf/in.^2$

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ABSTRACT

Differential settlement at bridge abutments is a persistent problem for transportation agencies. Relatively small differential movements produce the "bump at the end of the bridge," which results in ride discomfort and a potential hazard for motorists. Heavy vehicle traffic may accelerate the damage to approach slabs and bridge decks because of the dynamic forces. Additional maintenance may be required to prevent deterioration of the approach fill and abutment system.

In an effort to address the bump at the end of the bridge problem, ODOT has undertaken an experimental construction research project to evaluate five different approach embankment construction methods. The research is being conducted at a relocation project in which three new bridges are being constructed to relocate a two-mile section of U.S. 177 north of Stillwater, Oklahoma. Five of the six approach embankments are approximately the same height and the foundation soils are relatively uniform, consisting of fine to medium dense sands. The topography in the alluvial valley is level with no significantly varying geologic features. The relatively uniform conditions provide an excellent opportunity to evaluate approach embankment material and construction methods.

Materials and construction methods used for the five approach embankments in the study include: unclassified borrow placed by contractor's discretion (i.e., equipment)—this serves as the control for the research study; geotextile reinforced approach embankment using a nonwoven geotextile and granular backfill (i.e., concrete sand); controlled low strength material; dynamically compacted granular backfill; and flooded and vibrated granular backfill.

During and following construction, all five approach embankments and bridge abutments were instrumented to evaluate the performance of the approach embankments and interaction with the abutment walls. Specific instruments and the parameters they monitored included: total pressure cells on the back of the abutment walls to monitor lateral earth pressures caused by the approach embankments; amplified liquid settlement gages beneath the approach embankments to monitor settlement; inclinometer casings with telescoping couplings to monitor lateral displacement and settlement within the approach embankment and foundation materials; piezometers to monitor pore water pressures; and surface survey points to monitor total surface movement.

The instruments were monitored during construction and for approximately 18 months since completion of the approach embankment construction, including approximately 9 months under traffic loading.

In terms of settlement, the flooded and vibrated granular backfill appears to be performing the best. Even though settlement values are higher than predicted, it has the least settlement of any of the approach embankments. It has not developed a bump at the end of the bridge, and settlement is uniform along the centerline and the offset wheel path. The flooded and vibrated granular backfill also shows the expected trend in terms of lateral earth pressure. The lateral earth pressures are higher than expected, but the distribution has the expected linear increase with depth.

Lateral earth pressure values are closest to the predicted values for the geotextile reinforced backfill. This embankment is performing the second best in terms of settlement, but a bump is beginning to develop at this embankment. A bump is also beginning to develop at the control section using unclassified borrow.

The CLSM is performing well with respect to settlement. The surface settlement point data show that at a distance of 5 ft behind the abutment wall, there are 0.036 ft of settlement at the wheel path closest to centerline and 0.030 ft of settlement at the offset wheel path. No bump has started to develop at this approach embankment. In addition, the controlled low strength material is exerting very little pressure on the back of the abutment wall. The settlement according to the settlement gages is high, second only to dynamically compacted granular backfill. A greater amount of settlement is expected with this type of embankment construction because of the weight of material.

The dynamically compacted granular backfill embankment has the highest amount of settlement. Although it has the greatest amount of settlement, it does not yet have a significant bump at the abutment wall. This embankment is exerting less pressure on the abutment wall than the flooded and vibrated granular bakcfill which can be directly related to the construction method because both are constructed of the same type of backfill material.

The least expensive embankment construction was the control section which had a total cost of $1500. The most expensive was the geotextile reinforced backfill at $25,000. The remaining embankments cost in the range of $14,500 to $16,000. Although the control was by far the least expensive construction, it posed the conventional construction problems related to compaction requirements. The unclassified borrow material used for this embankment is generally not as good as the material used in the other options, and since it has not performed as well as some of the other approach embankments, the added expense for embankment materials may be justified.

CHAPTER 1

INTRODUCTION

Background

Differential settlement at bridge abutments is a persistent problem for transportation agencies. Relatively small differential movements produce the "bump at the end of the bridge," which results in ride discomfort and a potential hazard for motorists. Heavy vehicle traffic may accelerate the damage to approach slabs and bridge decks because of the dynamic forces. Additional maintenance may be required to prevent deterioration of the approach fill and abutment system.

Differential settlement problems are usually attributed to excessive consolidation of the embankment and foundation soils or inadequate compaction of the approach embankment or both. Other factors that may influence the problem include soil erosion from improper surface or subsurface drainage, frost heave, or swelling soils. The Colorado Department of Highways (1) studied 20 sites within their state and concluded that the primary causes of bridge approach settlement are one or more of the following:

- Time-dependent consolidation of embankment foundation.
- Time-dependent consolidation of approach embankment.
- Poor compaction of abutment backfill caused by restricted access of compaction equipment.
- Erosion of soil at the abutment face.
- Poor drainage of embankment and abutment backfill.

The approach slab design and type of abutment and foundation may also affect performance.

In Oklahoma, the Oklahoma Department of Transportation (ODOT) sponsored research (2–10) surveyed 52 state and federal transportation agencies that have had problems with bridge approach settlement, and the survey results were similar to the conclusions from the Colorado Department of Highways study. Of the causes listed in the study, consolidation of the embankment or foundation materials was considered the most significant.

Most bridge approach embankments are constructed using conventional soil compaction methods. Soils from roadway excavations or borrow pits are commonly used. A major problem develops with approach embankment construction when conventional compaction equipment tries to compact the soil near the abutment wall and wing walls. The result is a nonuniformly compacted material that is more susceptible to differential settlement. The alternative to using conventional compaction methods is "hand" compaction using small scale vibratory or impact compaction machines. This becomes labor intensive and requires additional care to ensure uniformity and level of compaction.

Purpose of Research

In an effort to address the bump at the end of the bridge problem, ODOT has undertaken an experimental construction research project to evaluate five different approach embankment construction methods. The research is being conducted at a relocation project in which three new bridges are being constructed to relocate a two-mile section of U.S. 177 north of Stillwater, Oklahoma. Five of the six approach embankments are approximately the same height and the foundation soils are relatively uniform, consisting of fine to medium dense sands. The topography in the alluvial valley is level with no significantly varying geologic features. The relatively uniform conditions provide an excellent opportunity to evaluate approach embankment material and construction methods.

Materials and construction methods used for the five approach embankments in the study include:

- Unclassified borrow placed by contractor's discretion (i.e., equipment). This serves as the control for the research study.
- Geotextile reinforced approach embankment using a nonwoven geotextile and granular backfill (i.e., concrete sand).
- Controlled low strength material.
- Dynamically compacted granular backfill.
- Flooded and vibrated granular backfill.

During and following construction, all five approach embankments and bridge abutments were instrumented to evaluate the performance of the approach embankments and interaction with the abutment walls. Specific instruments and the parameters they monitored included:

- Total pressure cells on the back of the abutment walls to monitor lateral earth pressures caused by the approach embankments.
- Amplified liquid settlement gages beneath the approach embankments to monitor settlement.
- Inclinometer casings with telescoping couplings to monitor lateral displacement and settlement within the approach embankment and foundation materials.
- Piezometers to monitor pore water pressures.
- Surface survey points to monitor total surface movement.

The instruments were monitored during construction and for approximately 18 months since completion of the approach embankment construction, including approximately 9 months under traffic loading.

The major emphasis of this report is the description of the construction, monitoring, and general performance of the different approach embankments.

CHAPTER 2

REVIEW OF APPROACH EMBANKMENT CONSTRUCTION AND PERFORMANCE

Causes

The bump at the end of the bridge has been a persistent problem for transportation agencies for decades. Achieving a smooth transition from the approach embankment to the bridge deck is a common problem which has no simple solution. The bump is caused by differential settlement between the bridge abutment wall and the approach embankment. Generally, the approach embankment moves vertically downward with respect to the abutment wall resulting in a number of problems. The bump causes discomfort to motorists, unnecessary wear and tear to vehicles, and can be hazardous (11). In addition to these problems, it can result in expensive roadway repairs, such as patching or mudjacking (12). Repairs take time as well as money and often cause one or more lanes of traffic to be closed for a period of time. Shutting down traffic lanes always has the potential for causing dangerous and costly accidents. Finally, the bridge structure is typically not designed for the type of impact loading that can result from an uneven roadway.

The first step in solving a problem is attempting to determine the source of the problem. Settlement of the approach embankment has a variety of possible causes. The two major causes of settlement are settlement of the foundation material under the approach embankment and settlement within the fill mass (13). According to the Colorado Department of Highways (1), bridge approach settlement can be attributed to one or more of the following factors:

- time dependent consolidation of the embankment foundation,
- time dependent consolidation of the approach embankment,
- poor compaction of the abutment backfill caused by restricted access of standard compaction equipment,
- erosion of the soil at the abutment face, and
- poor drainage of the embankment and abutment backfill.

In 1985, the University of Oklahoma (OU) began investigating approach embankment settlement in conjunction with the Oklahoma Department of Transportation (ODOT). Through an extensive survey and literature review, OU found approach embankment settlement is a problem in Oklahoma as well as in many other states (2). Better approach embankment settlement prediction methods were needed. In 1987, OU began a study of 758 bridge approaches in Oklahoma. Information relating to construction, maintenance, and materials for these approaches was collected; 83% of the approaches surveyed experienced settlement (3).

In 1993, OU published a statistical model for predicting bridge approach settlement. The model was based on field tests at 29 sites in Oklahoma and several equations were developed to predict settlement (4, 8, 9). The factors determined to significantly affect approach settlement included age of approach, embankment height, traffic count, foundation soil thickness, embankment soil characteristics, and foundation soil characteristics. The skewness of the approach was found to be negligible with respect to approach settlement and the embankment and foundation soil characteristics were found to have the greatest influence on approach settlement.

In 1995, OU published a computer program called FEABAS (10). The program utilized a finite element analysis procedure to predict settlement. The program predicted both the consolidation settlement of the foundation soil under an approach embankment and the settlement of the actual embankment.

When analyzed, the procedures followed for the construction of the bridge structure and approach embankment, it becomes apparent why the approach embankment settles with respect to the abutment wall. The foundation materials for the bridge are generally subjected to substantially more analysis than the material used in approach embankments. Often, the foundation material's ability to support the approach embankment load is determined from just a few samples, while the foundation material for the bridge is analyzed extensively (14). In addition, the bridge is usually founded on spread footings, drilled shafts, or driven piles. As a result, very little or no settlement is expected from the bridge structure. On the other hand, the approach embankment has problems associated with settlement within the fill, settlement of the foundation material, and the possibility that some unknowns exist with regard to the foundation material.

Reducing Settlement

Precautions should be taken to reduce the settlement of the approach embankment. Four elements that must be considered when designing an approach embankment are the embankment foundation, backfill material, drainage system for the embankment, and construction practices (13). Although this research project deals with varying the construction method and backfill material to reduce approach embankment settlement problems, there are other ways of reducing settlement.

When the foundation material for the approach embankment is a cause for concern, it is often because the material is a soft, compressible soil. Differential settlement often occurs between the bridge abutment and the approach embankment when the foundation material is compressible (15), and post-construction consolidation of soft foundation soils is the major cause of settlement (16). Several options are available when this is the case. First, it may be possible to remove some or all of the compressible material. This may only be practical if the problem soil is near the surface and does not extend to unreasonable depths. Another option is to preload the foundation material, which causes consolidation to occur at a faster rate. This is done with the expectation that the majority of consolidation will occur before the approach slab is paved. This generally increases earthwork costs and may require a significant amount of time to elapse before paving. When primary consolidation is the main concern, wick drains may be used to provide an exit path for water in the foundation. This generally allows primary consolidation to occur at a much quicker rate. To reduce loading on the embankment material, a lightweight material can be used for the fill area. When large amounts of settlement are expected within the existing material, the approach can be founded on driven piles. This has been shown to be an effective alternative for providing a smooth transition between the roadway and the bridge deck. Generally, the depth of the pile decreases with increasing distance from the structure. Dynamic compaction can be used to consolidate the foundation if the foundation material is a loose, coarse-grained deposit.

After the foundation material for the approach embankment has been analyzed, it is necessary to examine the backfill itself. Settlement within the fill is caused by volume change, which may be caused by consolidation, shrinking and swelling of the soil, or ice and frost action within the fill. Most state highway agencies specify that a select material be used for the approach fill. Soft clay is not a good choice because it may take years for consolidation of the material to occur. Granular materials with a high permeability and a low void ratio are preferred because compression occurs within a few months after the embankment is constructed, generally before the approach embankment is paved.

It is necessary to provide good drainage in and around the approach embankment. The backfill should be designed to remove any hydrostatic pressure from the back of the abutment wall. Erosion of the soil around and under the approach embankment can cause settlement. Surface and subsurface drainage must be provided, and the slope under the bridge deck should be protected from erosion. As with any construction project, good quality control should be practiced during construction. Poor construction procedures or inadequate compaction of the backfill material can lead to settlement.

The above information discusses ways to reduce approach embankment settlement by considering the embankment foundation, the backfill material, the drainage system for the embankment , and construction practices. The primary focus of this research is to reduce approach embankment settlement by varying the backfill material and the construction method for five different approach embankments. This research project is unique in nature. Instead of dealing with a number of variables when attempting to reduce settlement, only the backfill material and construction are considered. By using five sites that are similar in foundation material and abutment wall height, any movement measured after construction can be attributed to one of these two variables.

CHAPTER 3

SITE CHARACTERIZATION

Site characterization is essential to develop adequate and appropriate construction plans to fit the need of a particular project. For the US 177 bridge replacement project, a thorough investigation of the foundation materials was conducted to characterize the soil and develop parameters for design. This chapter discusses the general topography of the site, tests performed for site characterization, and concludes with recommendations for design and construction developed from the geotechnical investigation.

Topography

General topographic description of the site is an alluvial valley surrounded by low rolling hills with moderate slopes. Aerial photography reveals mottled phototones and land uses for grain crops and grazing. Fine grained soils are the predominant surface soil in this area.

Site description is based on the 1970 Soil Conservation Service Noble County Soil Survey (17) and the 1974 Kay County Survey (18). The southern-most portion of the project is classified as Miller clay with 0-1% slopes. It is characterized as a compressible and unstable soil that floods because of slow percolation (low permeability). At the south abutment of bridge A (A1), Yahola silt loam (SM, SC, ML, CL) with 0-1% slopes is encountered. It is poor as roadfill because of low strength, but does drain favorably. The Yahola group also lies on the north bank of the Salt Fork River and continues northward approximately to the south abutment of bridge B. From there, the Port silt loam formation (classified as ML, CL) with 0-1% slopes extends northward past the north embankment of bridge C. This material has favorable drainage and is fair as roadfill. It is compressible and deemed unstable for use as embankment material. Near the south abutment of bridge C, a band of Port silty clay loam lies within the Port silt loam formation. It has low strength and shrink-swell behavior, making it fair as roadfill material. As an embankment material, it is unstable and compressible. North of the Port silt loam and extending to the northern end of the project lies a Dougherty-Eufaula complex soil (SM, CL) that is characterized with moderate seepage and susceptibility to wind erosion.

In-Situ Testing

Three in-situ tests were run for the geotechnical investigation at the US 177 project: the Standard Penetration Test, the Cone Penetration Test, and the Dilatometer Test.

Standard Penetration Test

The Standard Penetration Test (SPT) is a widely used test that correlates results to determine soil type. A split spoon sampler (or split barrel) with a sample length capacity of 1.5 ft (0.5 m) is driven into a soil deposit. To maintain uniformity, the sampler dimensions are kept constant with a 2-in. (51 mm) outside diameter and a 1-3/8 in. (35 mm) inside diameter. A 140 lb (64 kg) weight drives the sampler with 30 in. (75 cm) drops so the energy is known. The number of blows to drive the sampler 18 in. (45.7 cm) into the ground is recorded and the blow count, N, is the number of blows for the last 1 ft of the drive.

The blow count along with visual identification and laboratory results were used to describe the density of cohesionless soils and the consistency of cohesive soils. Density and consistency descriptions were used to help delineate soil strata or confirm uniformity. Other correlations with N values used were, for cohesionless soils, relative density and bearing capacity, and for cohesive soils, shear strength.

Cone Penetration Test

The Cone Penetration Test (CPT) was used to define the soil profile and soil properties. As the cone penetrates, the tip resistance and sleeve friction are measured continuously and used to define the friction ratio. Sleeve friction is a function of grain size for granular soils and cohesion for fine-grained soils. Friction ratio and tip resistance values are used to define soil type based on empirical correlations.

Dilatometer Test

The Dilatometer Test (DMT) is an in-situ test used to define soil strata. The device attaches to the end of the same type of extension rods used for the CPT. It is a flat plate 96 mm (3.78 in.) wide, 240 mm (9.45 in.) long, and 15 mm (0.59 in.) thick. The penetrating end of the plate is tapered. One side of the plate contains a stainless steel membrane 0.2 mm (0.0079 in.) thick and 60 mm (2.36 in.) in diameter. Pneumatic pressure from a source on the ground surface is applied through a tube to the membrane. When the membrane expands outward 0.05 mm (0.00197 in.) and then 1.10 mm (0.433 in.) total (so an additional 1.05 mm), the applied pressure values are recorded. With these pressure values various indexes were calculated, which correlate with other empirical data. From this, estimates of the soil type, density, Ko values (earth pressure ratio), and the overconsolidation ratio were made.

In-Situ Test Soundings

The original geotechnical investigation plan for the bridge replacement project called for subsurface exploration and in situ testing of the pier and abutment foundation material. The pier foundation investigation involved primarily SPT and split spoon sampling. Investigation for the foundation originally included 8 CPT soundings, one DMT sounding, one SPT boring, and one continuous pushtube boring. The configuration of these tests at each abutment is shown in Figure 1. During the actual investigation, changes were made. CPT number eight as shown in the figure was dropped and replaced with another DMT run near CPT number seven. A triangle represents a pressuremeter test location that was originally planned but omitted during the investigation. This configuration ensured that accurate profiles were estimated, which was especially important when attempting to reduce differential settlement between the bridge and approach embankment.

In-Situ Test Comparisons

Dr. Jim Nevels, Jr., ODOT geotechnical engineer, prepared the foundation report for the US 177 project site. The following information is taken from his report (19).

Comparisons

With the SPT, CPT, and DMT performed in such close proximity at this particular project site, profile comparison can confirm the relative accuracy of these procedures. CPT-5 (from Figure 1) test results and DMT data from near CPT-5 were chosen from each of the trial embankments for comparison. For bridges A and B, boring logs (including SPT N values and laboratory test results) were chosen from stations within 1 ft (0.3 m) of the north abutment wall station. Bridge C investigation sites did not correlate as closely to the abutment locations, but tests from stations nearest the abutment walls were chosen.

Soil types within a profile are determined differently for each in-situ test. The SPT boring log gives soil descriptions straight from visual inspection that are substantiated with laboratory data. With the DMT, a series of steps is required to be able to estimate soil type. After following procedures to get the material index and dilatometer modulus, soil descriptions and unit weights can be estimated. The DMT device used by the Oklahoma Department of Transportation (ODOT) has software that automatically calculates values and gives a soil description.

Profile estimation from the CPT is not automated. First, major differences in soil strata were determined by visually assessing pattern changes in the friction ratio (sleeve friction/tip resistance) versus depth plot. Once these basic strata were established, average friction ratio values and tip resistance values for each strata were graphically determined. Third, plots of friction ratio versus tip resistance were used to estimate a soil description. For this particular exercise, plots from Robertson and Campanella (20) were used.

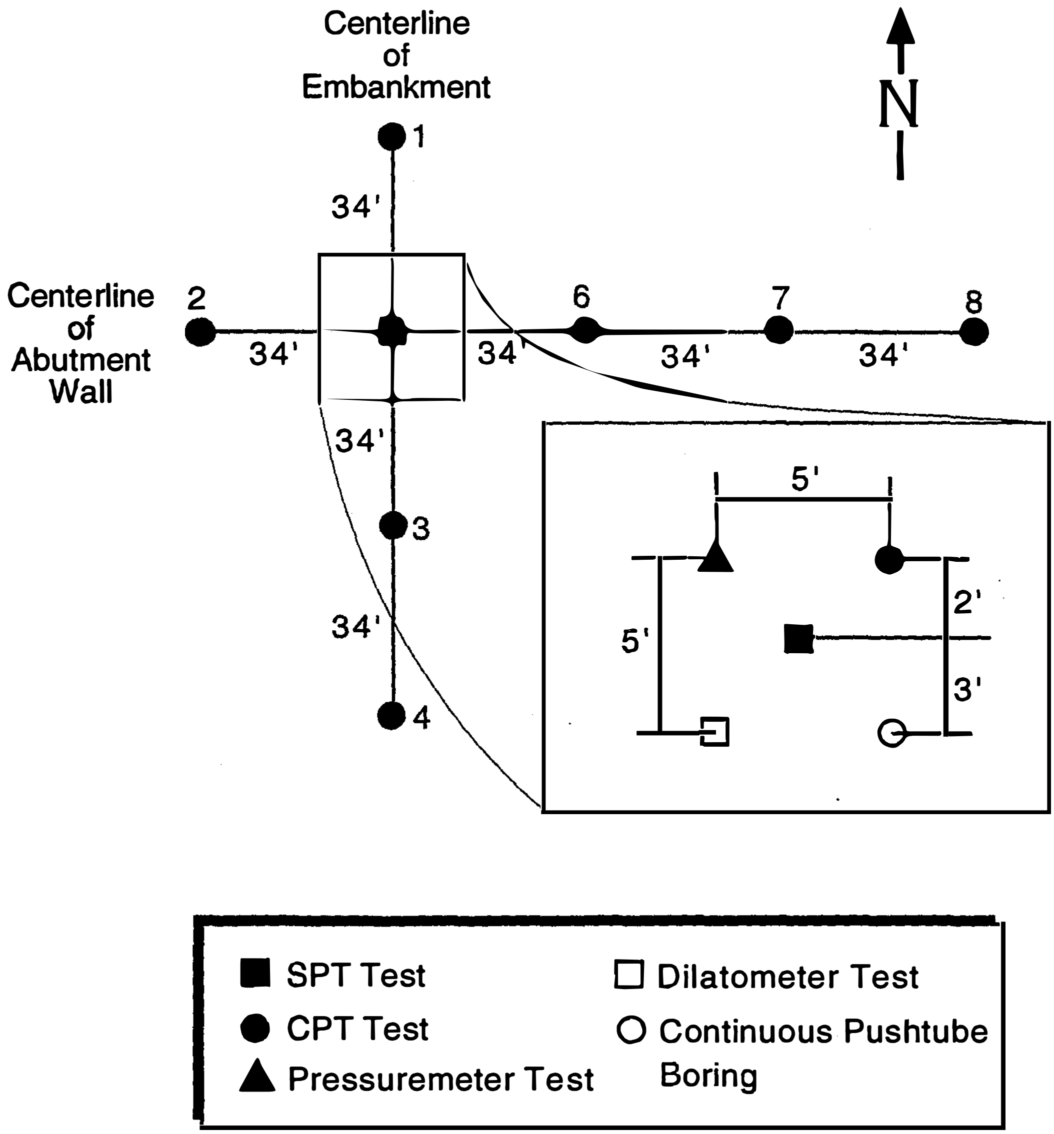

Figure 1. In-Situ Test Locations at U.S. 177 Project Site (19)

Comparison of abutments A2, B1, B2, C1, and C2 are shown in Figures 2 through 6, respectively. Since the SPT boring involves direct observation and testing, it is considered the control for a comparison basis. Detail improved when going from the CPT to the DMT. This comparison helps verify the legitimacy and relative accuracy of the CPT and DMT in-situ tools if the right correlations are made. However, variations in the descriptions demonstrate the variability inherent in empirical methods.

Ten-year settlement was calculated for all abutments except for the south abutment of bridge A. Two sets of calculations were made—one based on CPT data and the other based on DMT data. For CPT-based settlement calculations, the Schmertmann method (21) for ten-year settlement was calculated by converting electric cone resistance (q_c) to an equivalent elastic modulus. The DMT settlement was calculated by applying the appropriate modulus from the dilatometer with elastic theory (22). The calculations were similar at the north abutment of bridge A with both methods effectively predicting 0.8 in. (2.0 cm). The north abutment of bridge C gave the most variation with the CPT method predicting 0.7 in. (1.8 cm) and DMT predicting 1.9 in. (4.8 cm). Complete settlement estimates, as published in the foundation report, are presented in Table 1.

Soils at Site

Generally, the soils are Quaternary Period Alluvium deposits from the Salt Fork of the Arkansas River. This material varies from gravel and sand to silt and clay.

Bridge A

Soils at bridge A are predominantly clays and silts. Plasticity indexes (PI) from the 20s to the 30s are common. One 2.5 ft (0.8 m) thick layer of highly plastic clays with PI values ranging from 37 to 46 and SPT N values of zero were located just south of the south abutment wall. Clay areas were abundant on the south end of the project. The Noble County Soil Survey reported consistent trends of more clayey soils in the southern portion of the project. Moving north, the soils became less plastic and more silty, consistent with the Survey maps. At the northern end of bridge A, PI values decreased to the teens and low 20s. SPT N values generally ranged from four to seven in these silty and silty sand regions.

Bridge B

Soil types at bridge B were coarser than those at bridge A. Most soils were silt and sand combinations with significant strata of sand. Silts and sandy silts had SPT N values ranging from five to seven. Most of these soils were nonplastic, but a few had PI values as high as 15. Soils with more sand and silty sands had higher SPT N values of 20. Locations with poorly graded sands had SPT N values of 11-20, both of which were classified as loose to medium dense, based on SPT correlations.

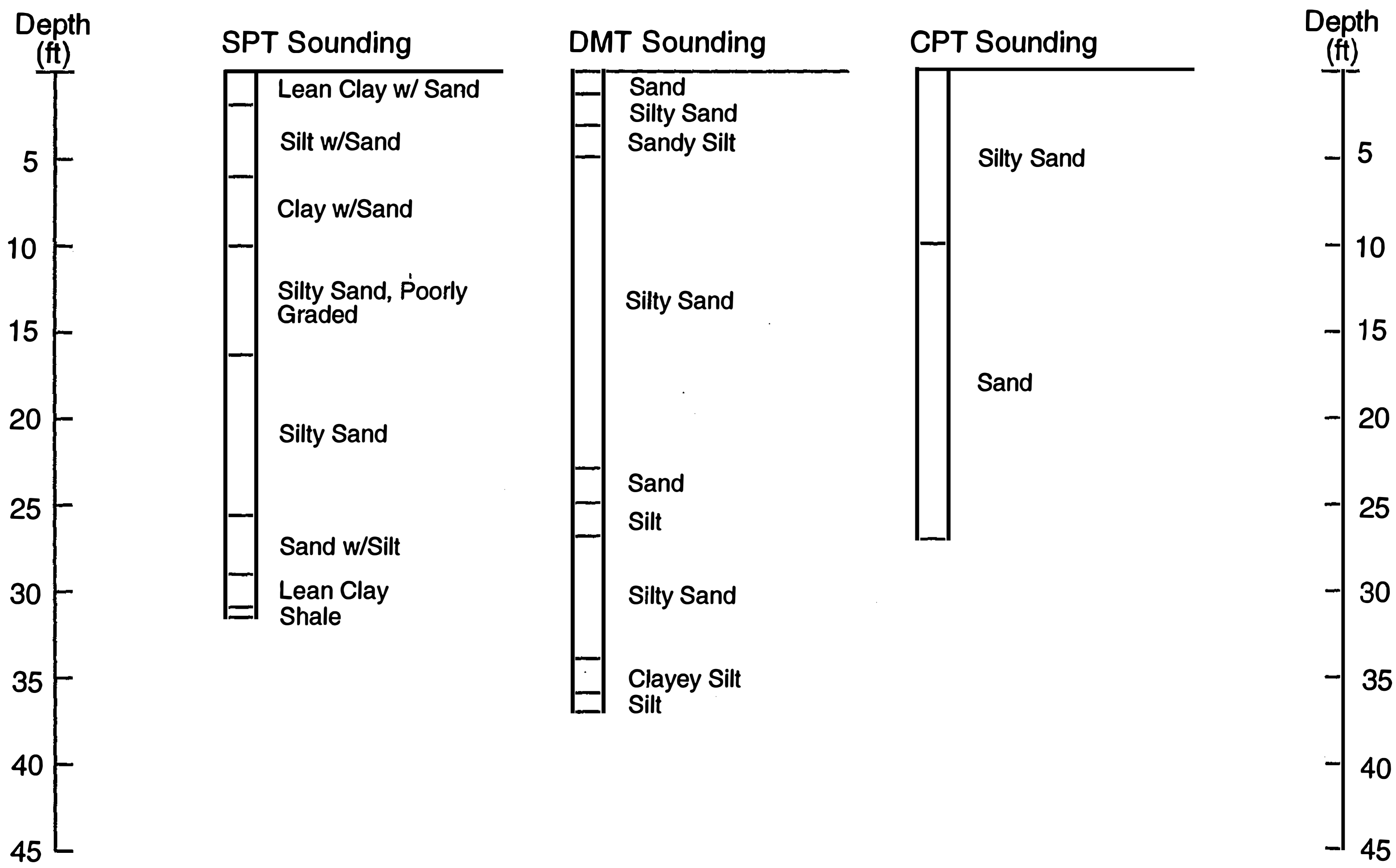

Figure 2. Soil Profile Based on In Situ Testing at Abutment A2

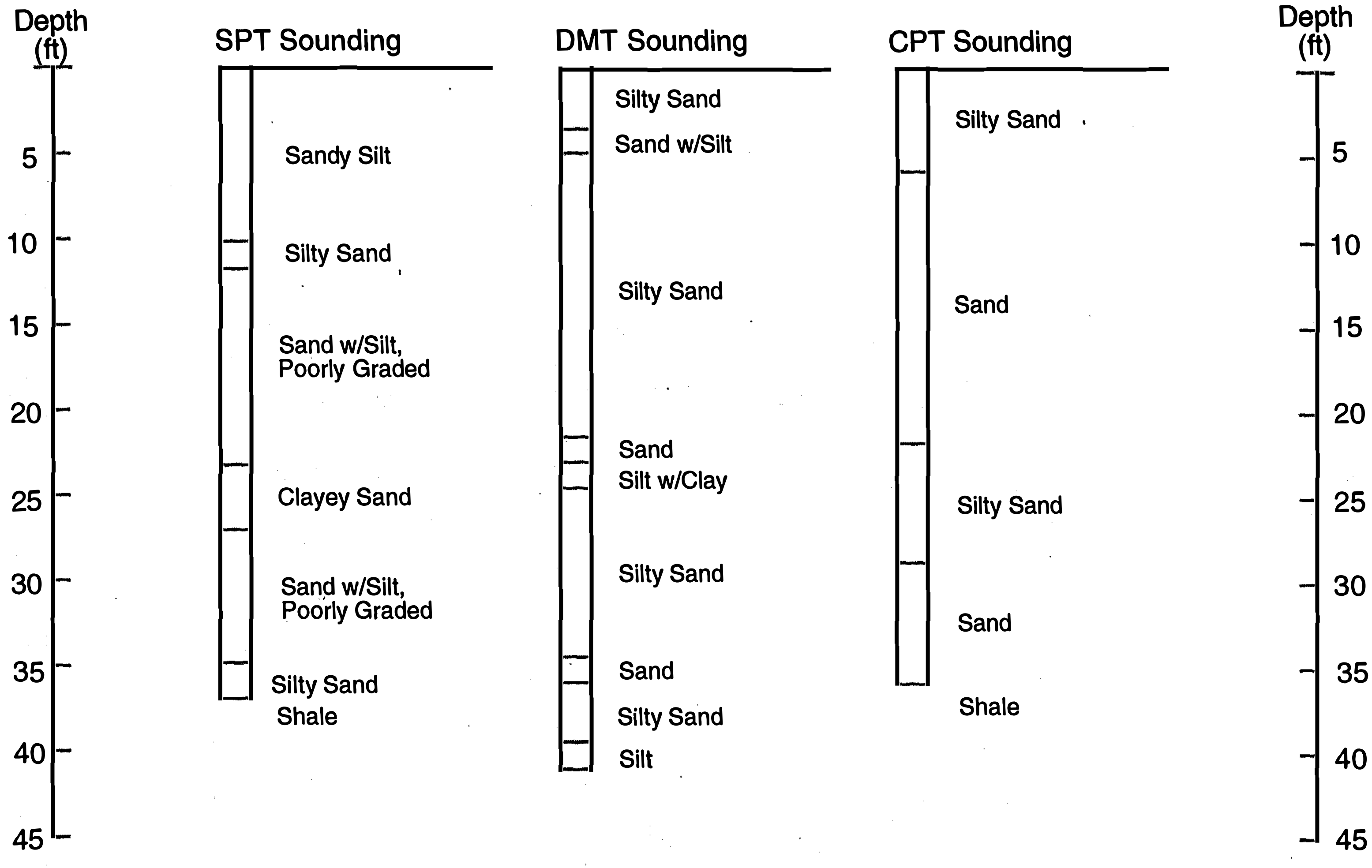

Figure 3. Soil Profile Based on In Situ Testing at Abutment B1

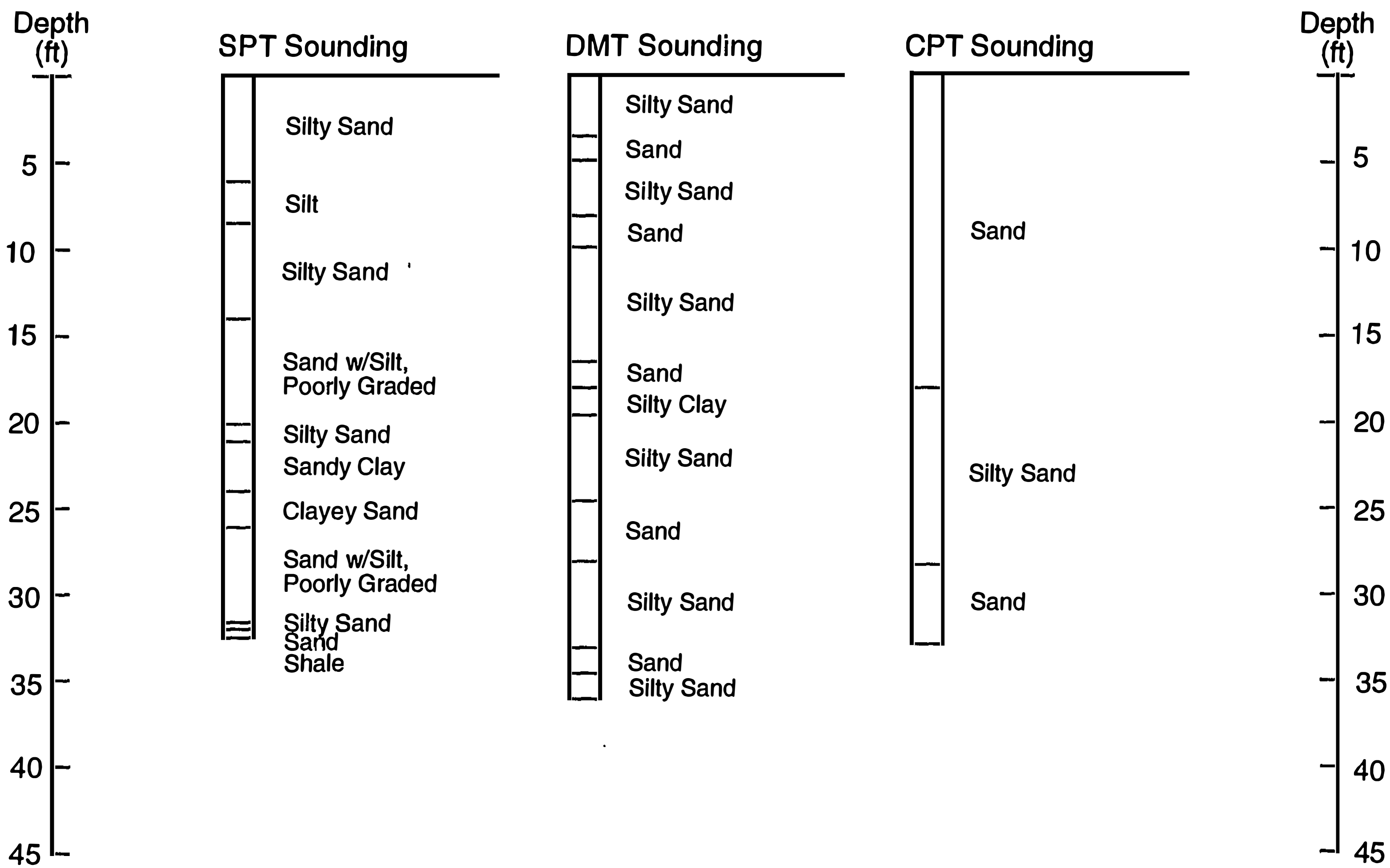

Figure 4. Soil Profile Based on In Situ Testing at Abutment B2

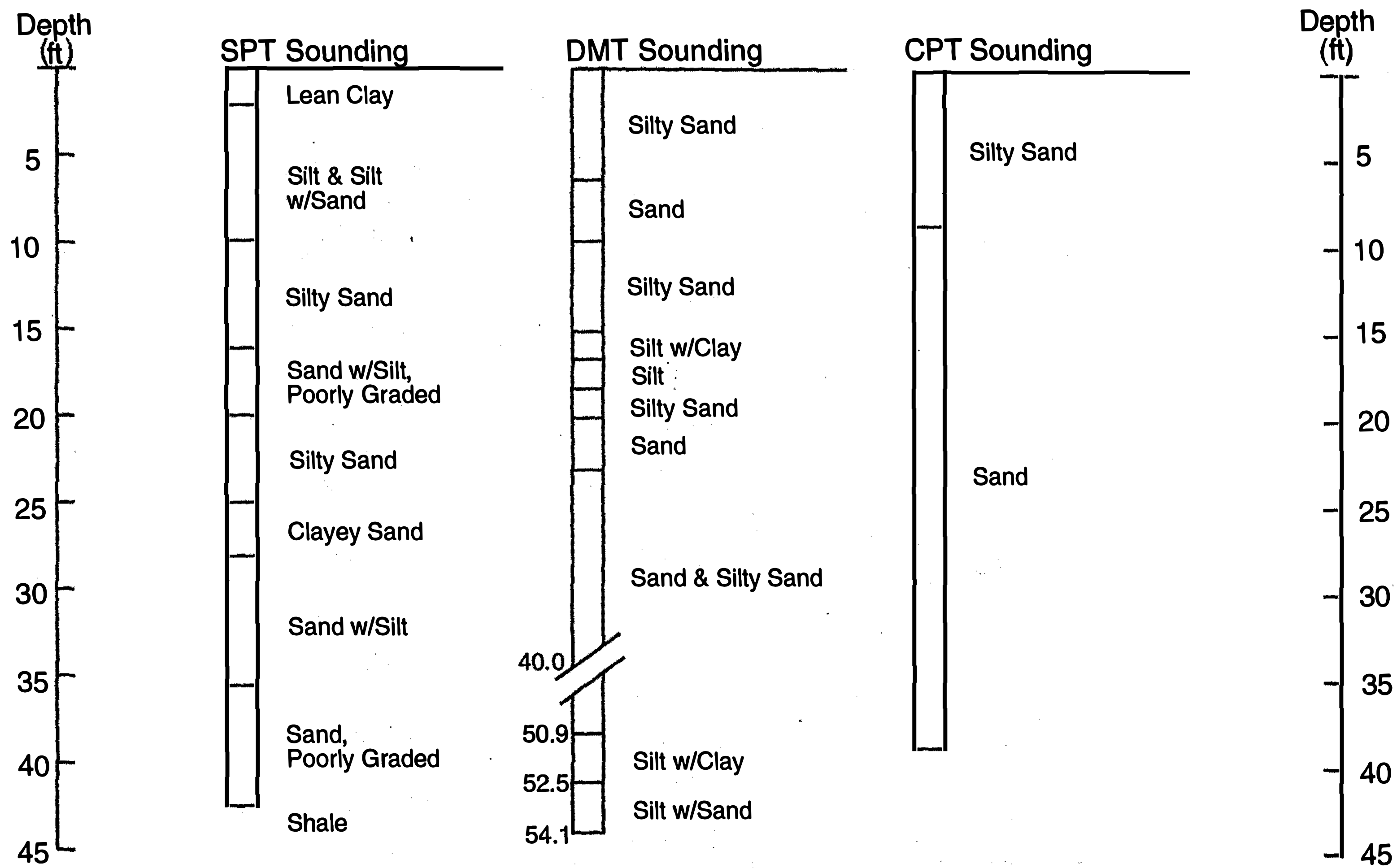

Figure 5. Soil Profile Based on In Situ Testing at Abutment C1

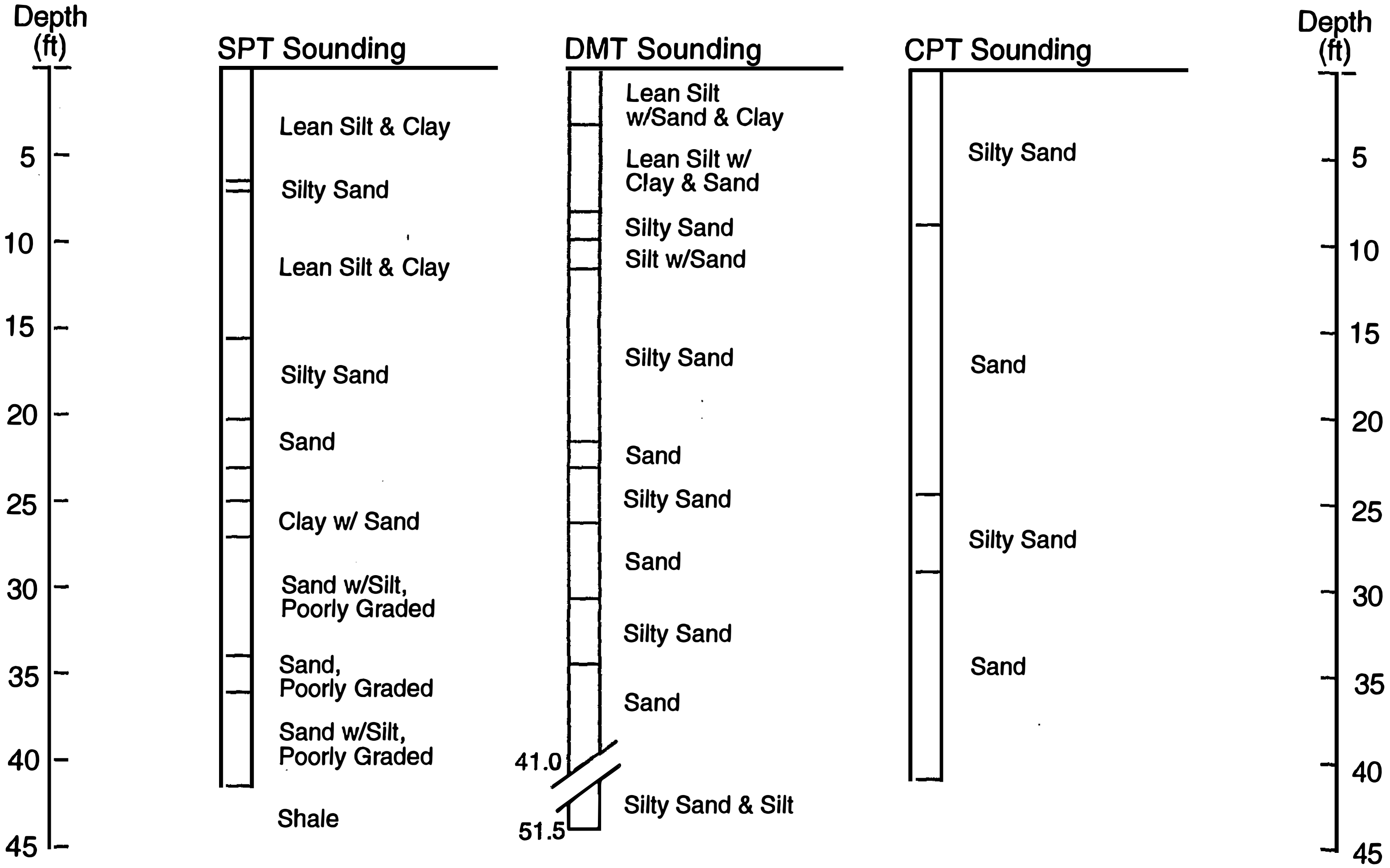

Figure 6. Soil Profile Based on In Situ Testing at Abutment C2

Table 1. Settlement Estimates From U.S. 177 Geotechnical Investigation (19)

Bridge Abutment		Settlement (in.)	
A2			
	CPT-2	0.958	
	CPT-5	1.135	Avg = 0.962
	CPT-6	0.794	
	DMT-1	0.840	
B1			
	CPT-2	0.289	
	CPT-5	0.340	Avg = 0.329
	CPT-6	0.359	
	DMT-1	0.732	
B2			
	CPT-2	1.306	
	CPT-5	0.728	Avg = 0.961
	CPT-6	0.849	
	DMT-1	1.024	
C1			
	CPT-2	0.860	
	CPT-5	0.837	Avg = 0.818
	CPT-6	0.757	
	DMT-1	1.365	
C2			
	CPT-2	1.053	
	CPT-5	0.937	Avg = 0.909
	CPT-6	0.737	
	DMT-1	1.859	

Bridge C

Bridge C soils were combinations of silt, poorly graded sand, and clay. The material descriptions commonly changed in 6 in. (15.2 cm) intervals. Overall, the SPT N values were low and plasticity was either nonexistent or low. All but one clay was classified as lean. This only "fat" clay was at the north end of bridge C. This 9 ft (2.7 m) thick layer at station 194+98, right of centerline, was not tested and is only documented with material description. Typical silts had SPT N values between 3 and 11 and were nonplastic. Sands appeared to be loose with SPT N values of 1 to 7. Combinations of silt and sand were common that had low SPT N values and low to zero PI values.

Bedrock

The bedrock at the U.S. 177 project site was shale with isolated lenses of limestone. Permian Age shale of the Wellington Formation made up the top 10 to 15 ft (3.0 to 4.6 m) of the bedrock and was described as reddish-gray in color, soft and weathered. Depth to shale varied among the bridges with the foundation report showing depth to bedrock at bridges A, B, and C is 25, 36, and 40 ft (7.6, 11.0, 12.2 m), respectively. This upper portion had lower Rock Quality Designation (RQD) values than the underlying material. RQD's for the Wellington formation varied from 48.6 to 62 and then 83 at bridges A, B, and C, respectively. Unconfined compressive strengths (UCS) for this top formation ranged from 540 tsf (51710 KPa) at bridge A to values below 10 tsf (958 KPa) at bridge C.

Beneath the Wellington Formation lies the Oscar Group, also known as the Wellington-Admire Unit. This structure was characterized as mainly shale with layers of limestone and fine-grained Arkosic sandstone. Borings showed the shale as dark gray to grayish red shale that was silty to clayey. RQD values were in the 90s for bridge A and bridge B, but in the upper 50s for bridge C. UCS values were much higher in the Oscar Group with values up to 1063 tsf (101,790 KPa) at bridge A, but mostly averaging 530 tsf (50750 KPa), and 22.8 tsf (2185 KPa) and lower at bridge C. No UCS data for any bridge B borings were reported. Bridges A and B showed limestone generally 50 ft (15.2 m) below the surface with limestone interbedded in the shale at about 45 ft (13.7 m). The limestone bed was about 10 ft (3.0 m) thick and varied between bridge A and bridge B. Geologic mapping showed the Herrington limestone unit at the project site, so the foundation report suggested the possibility of this limestone from the Herrington Formation. Bridge C borings showed no limestone present.

Crews drilled 93 ft (28.3 m) near the north end of bridge A to determine if any other limestone units existed. One 0.15 ft (4.6 cm) thick layer was encountered at 82.3 ft (25.1 m) below the ground surface. Shale was the only other bedrock material encountered.

Water levels in the borings were at depths of 2 to12 ft (0.6 to 3.7 m). Isolated gravel pits may exist within the valley that may bear significant water. Nearby wells yield 20 to 150 gallons (75.7 to 567.8 L) per hour from the alluvium. Visual investigation of the bedrock cores suggested that no significant water bearing zones existed in the bedrock formations.

Summary

This investigation report concluded that drilled shafts should be used for the bridge foundations and driven piles be used for the abutment wall foundations. The slurry displacement method was recommended for the drilled shafts due to the loose granular material and its depth below the water table. These recommendations were followed with the installation of drilled shaft bridge piers and driven piles for the abutment walls.

CHAPTER 4

APPROACH EMBANKMENT CONSTRUCTION AND INSTALLATION OF INSTRUMENTATION

The objective of the experimental approach embankments was to reduce or eliminate the "bump at the end of the bridge" by decreasing the vertical settlement of each backfill and lateral stress exerted on abutment and wing walls. This was done by constructing backfills that were well-drained and generally self-supportive to act as an incompressible single mass. Instrumentation for each of the abutment walls and backfills was chosen to monitor lateral movement of the abutment wall and the backfill, lateral stresses exerted upon the abutment wall, settlement, and pore water pressure.

Instrumentation

Each abutment was instrumented with total pressure cells, amplified liquid settlement gages, piezometer, inclinometer casings with telescoping couplings, and surface settlement points.

Total Pressure Cells

Lateral stresses exerted on each abutment wall were measured using total pressure cells embedded at the centerline of the back of the abutment wall. Three cells were spaced 3 ft (0.91 m) apart vertically. The cells used were 9 in. (22.9 cm) diameter, stainless steel covered rubber membranes, Figure 7, that measure total lateral earth stress. A transducer converted the lateral pressure to a pneumatic pressure that was measured by the Pressure Indicator in psi. For reading, the Pressure Indicator applied air pressure through the input tube which eventually built up pressure greater than the pressure exerted by the backfill. An equilibrium state for the membrane was achieved by balancing the applied pressure on the membrane with the measured pressure being the total lateral stress.

The pressure cells were installed on the face of the abutment wall so that they were flush with the wall surface. When the forms for the abutment wall were constructed, blockouts for the pressure cells and the tubing that leads to the control box were constructed, Figure 8. To complete the installation, the cells and tubing were connected and mortared in place, Figure 9.

Amplified Liquid Settlement Gages

Settlement was measured using amplified liquid settlement gages. One gage was placed on the centerline and one ten ft west of centerline, both 2 ft (0.61 m) below the base of the abutment wall and 6 ft (1.8 m) behind the abutment wall. The gages were fixed on 18 in. by 18 in. (45.7 cm by 45.7 cm) metal plates. When settlement occurred, the buried gage moved and the head relative to a reference reservoir located on the west wingwall was measured.

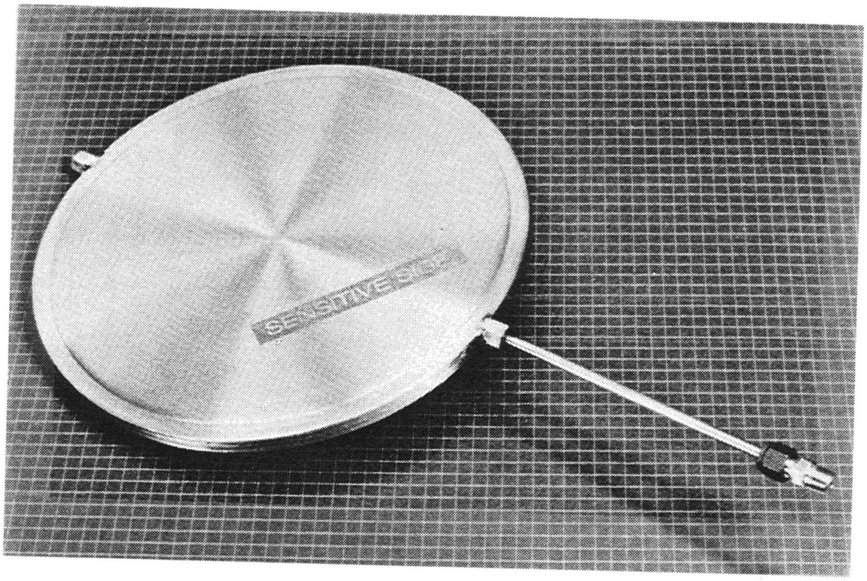

Figure 7. Total Pressure Cells Used to Monitor Lateral Earth Pressure on Abutment Walls

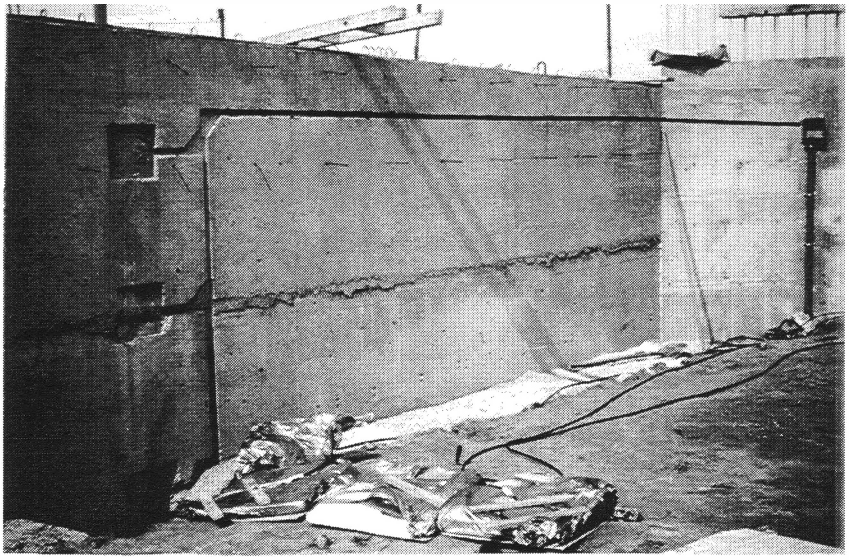

Figure 8. Blockouts on Back of Abutment Wall
for Total Pressure Cells and Tubing

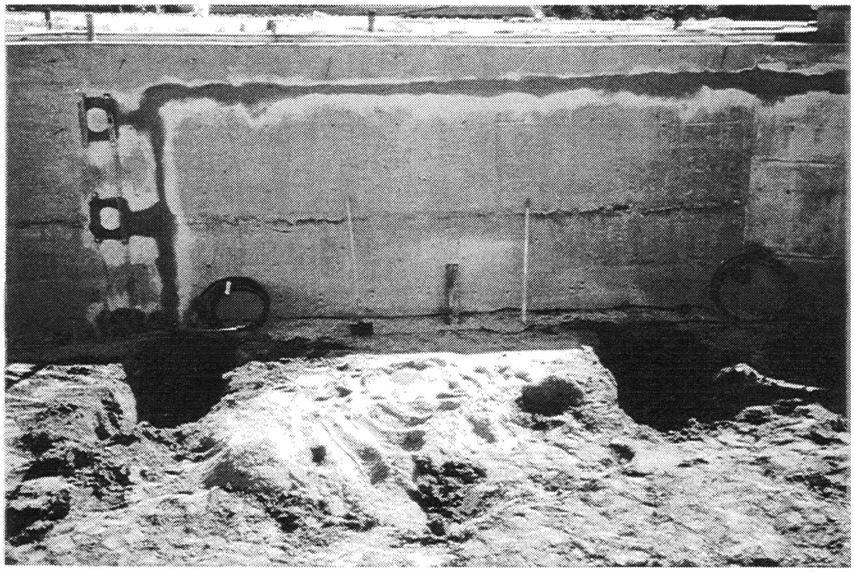

Figure 9. Total Pressure Cells Installed in Back of Abutment Wall

The settlement gage is composed of three main parts: the transducer, the reservoir, and the tubing. The transducer is a sensing unit designed to provide continuous reading and be installed at the point of settlement measurement. The reservoir is at a fixed location on the wingwall at a higher elevation than the transducer. The tubing supplies fluid and air needed to read the transducer using the Pressure Indicator. Settlement is measured when a balance of the hydraulic head of the ethylene-glycol and regulated pneumatic pressure from the pressure indicator is achieved. Readings are in units of psi head that can be converted to a linear vertical distance.

The settlement gages were placed in 2 ft by 2 ft (0.61 m by 0.61 m) holes, Figure 10, and covered with sand. Excess tubing was laid in the hole to provide extra length during settlement. Inside the backfill area, the tubing was placed in a plastic conduit that ran from the centerline settlement gage to the offset gage, to the west wingwall, and then up to the junction box.

On the outside of the west wingwall, locking steel security boxes, Figure 11, cover a terminal box and tubing from the settlement gages and pressure cells. The terminal box, Figure 12, houses labeled connections to the instrument tubing for access with the Pressure Indicator. This terminal box is placed directly above a plastic conduit that leads to the inside of the wingwall to the junction box. From there, the tubing for the amplified liquid settlement gages and total pressure cells splits to reach its respective instruments.

The Pressure Indicator is a portable device the size of a small suitcase used to measure settlement from the amplified liquid settlement gages and total lateral earth pressure from the total pressure cells, Figure 13. It contains a supply of nitrogen used as the controlled air pressure source for the input connections of settlement gages and pressure cells. All readings are taken when the flow meter in the Pressure Indicator reads 0.1 SCFH (standard cubic ft per hour). A flow meter is also used for hookup to the outlet side of the instrument being read to confirm a continuous flow of air from the Pressure Indicator to the measuring device and back to the Pressure Indicator. This ensures proper air flow for accurate readings. A digital liquid crystal display pressure gage measures applied pressure which is then recorded onto data sheets.

Piezometers

While settlement gages and pressure cells were installed before backfill placement, instrumentation for the water pressure, lateral movement, and additional settlement were installed after each backfill was completed. One open-tube piezometer was installed on the centerline in each experimental backfill 12 ft (3.7 m) from the abutment wall to depths of 40 ft (12.2 m). PVC pipe with 1.5 in. (3.8 cm) outside diameter was used for the riser. Groundwater depth was measured by placing a water level indicator down the tube attached to a calibrated cord. When the tip of the indicator reached water, a simple electrical circuit was formed that triggered an alarm to sound and the depth of the ground water was measured by the calibrated cord and recorded.

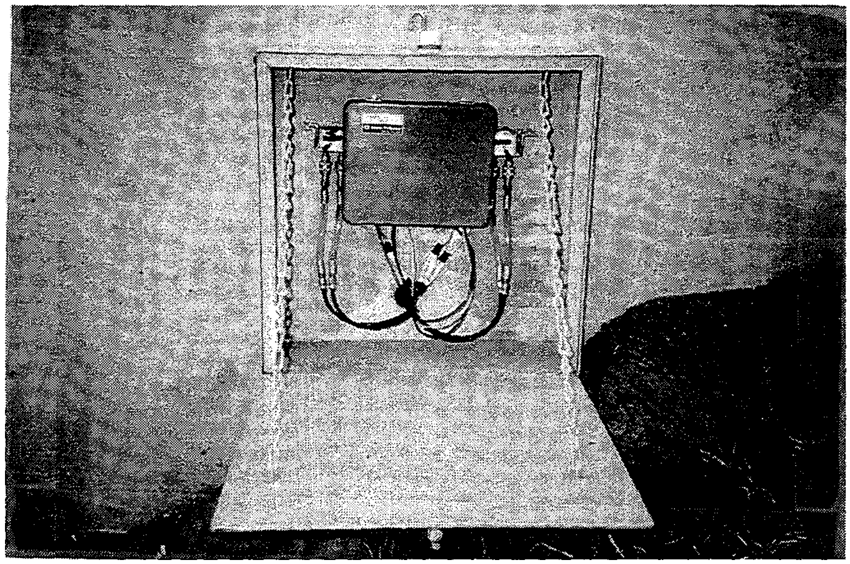

Figure 11. Steel Security Box Used to Protect Terminal Box

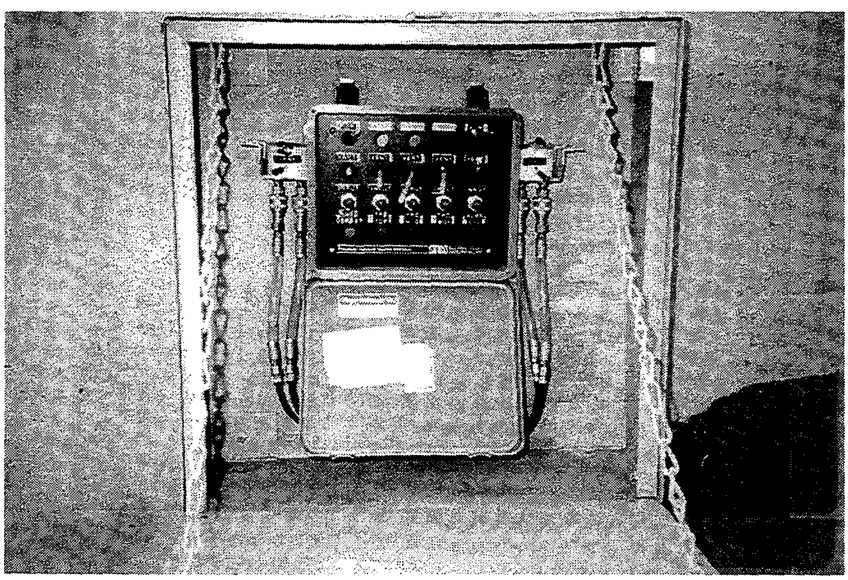

Figure 12. Terminal Box for Amplified Liquid Settlement Gages and Total Pressure Cells

Figure 10. Installation of Amplified Liquid Settlement Gages

Figure 13. Pressure Indicator

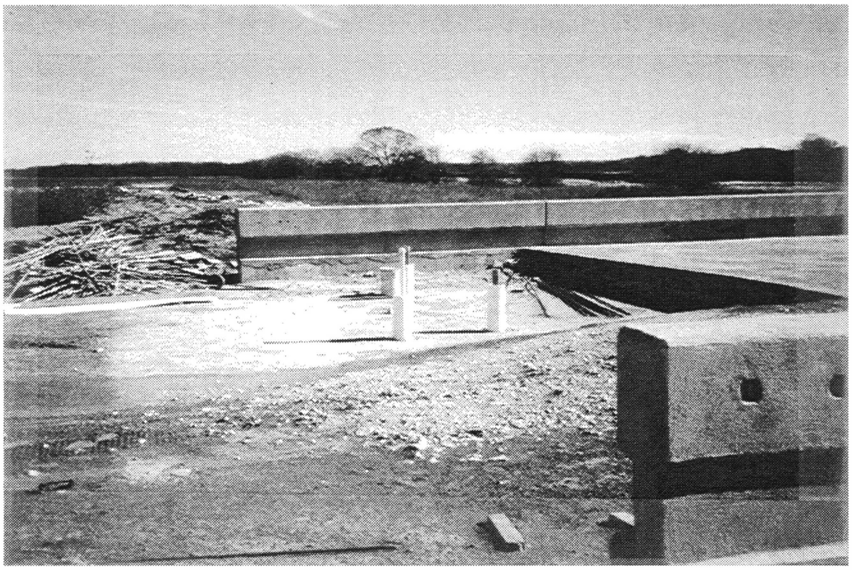

Figure 14. Typical Installation of Inclinometer Casings
and Piezometer Riser Pipe

Inclinometer Casing With Telescoping Couplings

To measure lateral movement, three inclinometer casings were installed at the end of each bridge. One, in the abutment wall itself on centerline, was installed before the wall was poured. The other two inclinometers were installed on the centerline and 10 ft (3.05 m) west of centerline and 9 ft (2.7 m) from the back of the abutment wall in the backfill after construction. Figure 14 shows the installed inclinometers and piezometer. The inclinometer casings are 2.75 in. (7.0 cm) diameter tubes that extend to depths ranging from 50 ft to 58 ft (15.2 m to 17.7 m) as noted in Appendix A.

Both lateral movement and settlement data were obtained from these inclinometer installations. For lateral movement, the casing is designed for an inclinometer probe with four grooves spaced 90° apart on the inside of the casing. The inclinometer probe is a stainless steel cylinder 1 in. (2.54 cm) in diameter and 2 ft (0.61 m) long housing two accelerometers. The accelerometers are positioned at right angles of one another and measured tilt in degrees with reference to the vertical. To take a reading, a pulley assembly was attached to the top of the inclinometer casing to facilitate the lowering and raising of the inclinometer attached to a control cable. Spring loaded wheels on the outside of the inclinometer guided the device as it was pulled by hand upward through the tubing and stopped every 2 ft (0.61 m) for a reading. The probe was next rotated 180° to measure movement in the other direction so that movement in two perpendicular planes was measured, one perpendicular to the abutment wall (plane A) and one parallel to the abutment wall (plane B). When readings were taken, data were recorded by a DataMate, an electronic memory device attached to the inclinometer.

The data were analyzed using the DataMate Manager and DigiPro software on a personal computer. For analysis, movement within the two planes was detected by comparison of any data set with the initial readings taken at the time of installation. A_O and B_O are designations for the positive direction for planes A and B, respectively. The A_O direction always is toward the plane formed by the back side of the abutment wall while B_O is always 90° to the right of A_O. When standing over the backfill inclinometer casing, A_O direction is facing the abutment wall. When standing over the abutment wall inclinometer casing, A_O is toward the backfill. The backfill A_O direction for abutments A2, B2, and C2 is south, while the backfill A_O direction for B1 and C1 is north. Referenced from the bridge for the abutment wall casing, the A_O direction at A2, B2, and C2 is north, while the A_O direction for B1 and C1 is south.

Settlement was the other parameter measured with the inclinometer casings set in the backfill (the casing in the abutment wall was read for lateral measurement only). Telescoping joints were installed at different depths along the backfill inclinometer casings. A specially designed hook was lowered down the casing and pulled upward. As it was pulled up, it caught the bottom lip of the top piece of casing in the telescoping coupling. The hook was attached to a measuring tape that allows depth readings with reference from the top of the casing. As distances from one joint to the other changed, isolated strata of settlement were delineated.

Surface Settlement Points

Settlement is measured in another way with the surface settlement points. These points were installed on the surface of the asphalt pavement once paving was completed. Elevations at the time of installation will be recorded and then compared to subsequent elevations measured when readings for all the instruments were taken. The configuration of the surface settlement points will be a 4 point by 4 point grid with 5 ft (1.5 m) spacing. The configuration will run from the west wingwall to the centerline, and from the abutment wall 20 ft (6.1 m) away from the bridge.

Appendix A contains plan and profile drawings of as-built instrumentation of each backfill. Table 2 is a summary of the approach embankments and instrumentation.

Approach Embankment Construction

The purpose of this research project was to monitor the performance of the four experimental approach embankments and compare their performance to one another and an identically instrumented control section constructed using typical materials and methods. The following is a discussion of the construction of five backfills involved in this research (23, 24, 25).

Drainage

Drainage for each of the backfills followed standard ODOT specifications. A perforated PVC pipe was buried along the inside base of the abutment wall and covered with granular material. A solid PVC pipe connected the east end of each perforated drain pipe and ran through the base of the east wingwall and down the embankment where it drained beneath the bridge. For A2 and B2, the pipe was covered with coarse pipe underdrain material which was covered with filter sand. Since the other trial sections used granular material, the PVC pipe cover was all coarse pipe underdrain material, with no filter sand material.

North of Bridge A (A2)

The approach embankment for the north end of bridge A was the control section for this research. The method of construction was not specified to represent a typically constructed backfill. The contractor used unclassified borrow and achieved the specified densities.

On Thursday, April 27, 1995, backfilling began. The initial method of compaction the contractor used was inadequate. At first, a 4-ton cube of concrete with side dimensions of approximately 4 ft (1.2 m) was dropped from heights of 5 ft (1.5 m) as a sort of dynamic

Table 2. Backfill and Instrumentation Summary

South of Bridge A, A1—unclassified borrow (not considered in this study)
North of Bridge A, A2—unclassified borrow (control section)
South of Bridge B, B1—geotextile reinforced granular backfill
North of Bridge B, B2—controlled low strength backfill
South of Bridge C, C1—dynamically compacted granular backfill
North of Bridge C, C2—flooded and vibrated granular backfill

		A1	A2	B1	B2	C1	C2
Total Pressure Cells in Centerline Abutment Walls		3	3	3	3	3	3
Amplified liquid settlement gages beneath approach embankment	Centerline	1	1	1	1	1	1
	Offset	0	1	1	1	1	1
Inclinometer casing in abutment wall		1	1	1	1	1	1
Inclinometer casing with telescoping couplings through approach embankment	Centerline	1	1	1	1	1	1
	Offset	0	1	1	1	1	1
Open tube piezometer through embankment centerline		1	1	1	1	1	1
Surface Settlement Points		16	16	16	16	16	16

compaction. Density requirements were not met. The next day, backfill compaction was completed using a Case 1150C tracked front end loader with a full scoop and simply driving over the 1 ft (0.3 m) lifts as shown in Figure 15. The loader passed over the backfill twice, once in a direction parallel to the abutment wall and once parallel to the centerline. The area approximately 2 ft (0.6 m) away from the walls was compacted using a walk behind pad vibrator, Figure 16. The following Monday was rainy and work resumed on Tuesday, May 2. Because of a series of rain days, the backfill compaction was finally completed on Wednesday, May 10, with a construction time of 4 days and a cost of $1500.

South of Bridge B (B1)

The approach embankment behind the south abutment of Bridge B was a geotextile reinforced wall. This technique was chosen because of its ability to support its own weight. Tension on the folded portion of the geotextile was resisted by the pressure of the overlying lift, creating essentially a free-standing structure supported by its own weight. Theoretically this would keep all lateral stress from the abutment walls and both wingwalls. Settlement was minimized by densification of each lift assuring a well-compacted backfill.

Preliminary steps were required before the nonwoven geotextile was placed. First, the excavation had to be level and the 5:1 incline toward the south (i.e., away from the abutment wall) had to be defined. A base lift of granular material was placed as a level and densified base for the geotextile wall. Then, as shown in Figure 17, 4 ft x 12 ft x 2 in. (1.2 m x 2.4 m x 5.1 cm) panels of collapsible honeycomb cardboard were wrapped with plastic to be longitudinally attached to the abutment and wing walls. Steel rods were used at the base of the panels to hold them against the wall. These bars were removed as the backfill was placed. At first, only the bottom row of cardboard spacers was set with the second row set as construction of the geotextile wall progressed upward. The panels were left in place and were collapsed prior to paving by wetting the cardboard. When collapsed, space between the walls and the face of the geotextile structure will allow tension to further develop and improve the free-standing characteristics of the structure. Once the excavation was detailed, the base layer placed, and the first row of wrapped honeycomb cardboard spacers were set, construction began.

Construction geotextile reinforced granular backfill began on Monday, May 22, and consisted basically of repeating five steps for each of the eight lifts: lay the textile, place and spread the sand, water, compact, and fold over the flaps. Figure 18 shows the placement of the geotextile. Laying the geotextile was similar to laying carpet. Rolls of textile 12 ft (3.7 m) wide were rolled in the direction perpendicular to the face of the wall (north to south). Excess fabric (approximately 6 ft (1.8 m)) was temporarily attached to the abutment and wing walls to later

Figure 15. Compaction of Unclassified Borrow for Approach Embankment at North Abutment, Bridge A

Figure 16. Compaction of Granular Backfill Adjacent to Abutment Wall at North Abutment, Bridge A

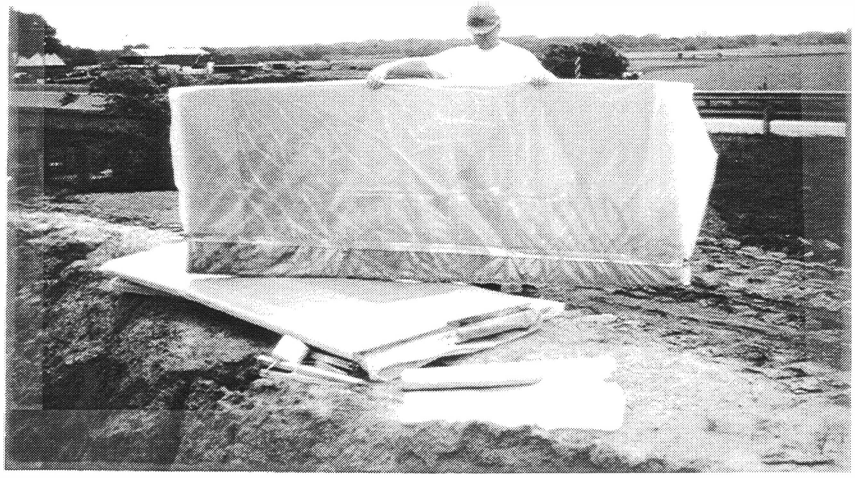

Figure 17. Wrapped Cardboard Spacer for Geotextile Reinforced Backfill, South Abutment, Bridge B

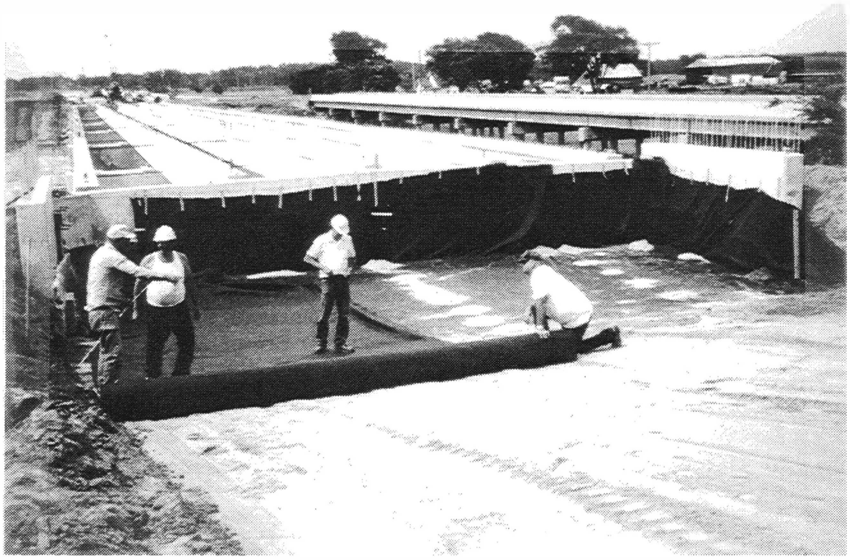

Figure 18. Placement of Geotextile Layer, South Abutment, Bridge B

be folded back onto the granular material. The width of the backfill along with the excess required for construction of the wall required that a total of four strips of textile had to be placed. Overlap seams were chosen instead of sewn ones. These 3 ft to 6 ft (0.91 m to 1.8 m) overlaps helped to create a strong seam through friction. Since the backfill area was about 40 ft wide (39 ft 8 in. or 12.1 m), the fourth strip overlapped much more than the 2 ft (0.61 m) minimum. Shovelfuls of granular backfill were placed near the edge of the fabric to help keep the honeycomb cardboard from blowing in the wind.

Next, the sand was placed using a tracked front end loader, Figure 19. The front end loader dumped sand from the south to the north to avoid direct contact to the geotextile by the machinery. Once all the material was placed, a total of six men distributed the material to create a 12 in. (30.5 cm) thick loose lift.

Compaction with a walk-behind vibrator followed, Figure 20. The weather had been rainy during the week and the sand was already moist, but to reach saturation extra moisture was applied using a water truck. A five horsepower walk-behind pad vibrator achieved adequate densities with one, or sometimes two, passes. Density readings were taken with a Troxler nuclear density/moisture gage. After density was achieved, a small mound descending away from the wall was pushed up using concrete spreaders around the perimeter of the three walls. The flaps were then brought down from hanging on the walls and laid on top of this grade as seen in Figure 21.

This process continued until eight lifts were completed, Figure 22, on Thursday, June 1. With an average of four men for spreading and the equipment mentioned, completion took 104 man-hours. The time for each lift gradually increased since the area of the lift increased with the slope of the backfill volume. The estimated cost was approximately $25,000 for installation over a 5-day period.

North of Bridge B (B2)

Controlled low strength material (CLSM) was placed behind the north abutment wall of bridge B. This backfill supports itself since the fill acts like a single unit upon curing. Self-support theoretically eliminates lateral wall stress and the relatively high strength of 300 psi (2069 KPa) for base materials helped reduce settlement of the approach embankment.

Construction of the CLSM approach embankment was simple and fast. First, the excavation was cleaned out, Figure 23, and the faces of the two exposed pressure cells covered with plastic for protection (the lowest pressure cell was covered with the granular drainage material as was the case with all four test sections). Then forms were built on the north side of the backfill area. The contractor built the forms so that the outside corners of the fill were deeper than the rest at the edge for strengthening. Excavation and form work construction took 8 man-hours total.

Figure 19. Placement of Granular Backfill on Geotextile,
South Abutment, Bridge B

Figure 20. Compaction of Granular Backfill,
South Abutment, Bridge B

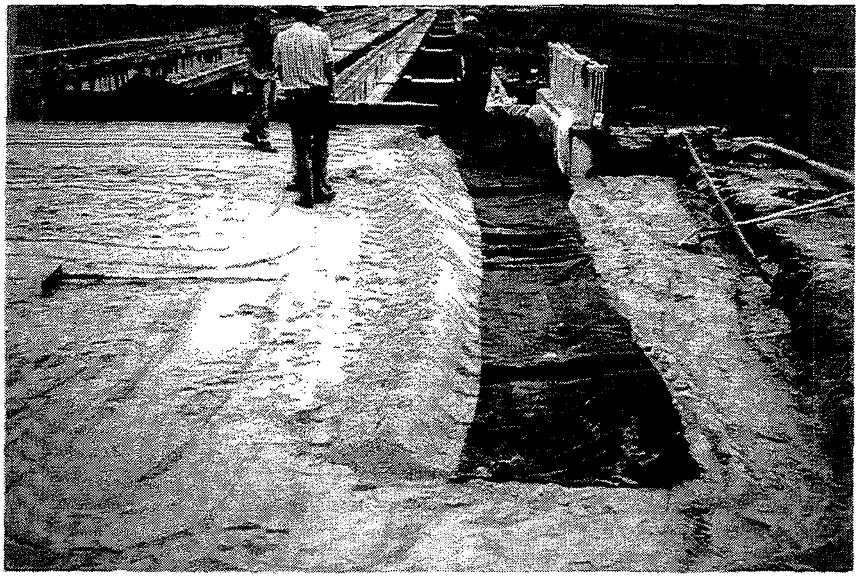

Figure 21. Trench in Granular Backfill for Roll-Back of Geotextile, South Abutment, Bridge B

Figure 22. Placement of Final Lift for Geotextile Reinforced Wall, South Abutment, Bridge B

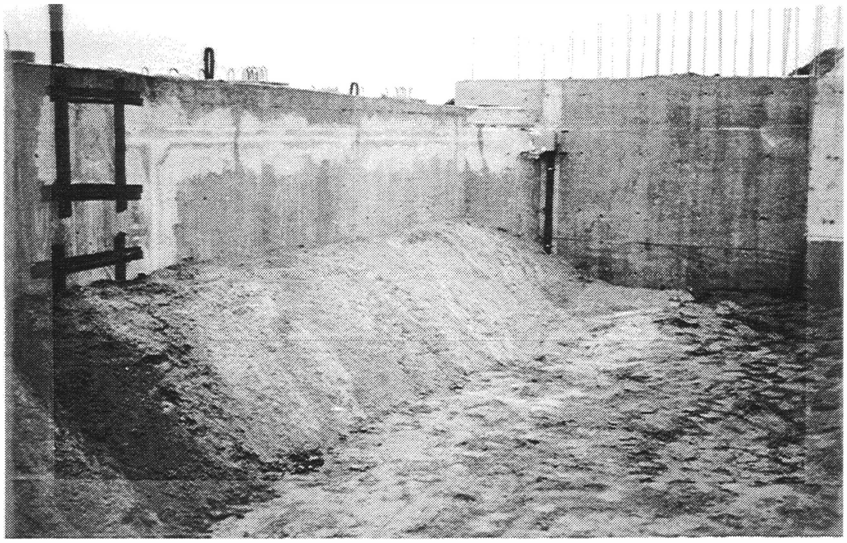

Figure 23. CLSM Approach Embankment Area After Initial Preparation, North Abutment, Bridge B

Figure 24. Placement of CLSM, North Abutment, Bridge B

Pouring the CLSM backfill involved ready-mix concrete trucks backing up to the forms and releasing the backfill material down the chute directly into the excavated volume, Figure 24. Two trucks were able to simultaneously unload. Twenty-three loads of nine cubic yards each were dumped for a total of 207 cubic yards (158.3 m^3) in 4.5 hours on Friday, May 12. Figure 25 shows the completed backfill. Besides pouring, the only labor involved was using a vibrator near the abutment wall-wingwall corners and leveling with a concrete float. Total time for this construction was 2 days at a cost of $14,560.

South of Bridge C (C1)

Dynamically compacted granular backfill was placed at the south abutment of bridge C. Dense and confined sand will have high shear strength and with effective densification, both settlement and lateral earth pressures were minimized.

The construction began on Friday, May 12, and ended on Thursday, May 18. Lifts of granular backfill 2 ft (0.6 m) thick were spread and then sprayed with water, Figure 26. Then a tracked crane dropped a 4 ft (1.2 m) cube of concrete as shown in Figure 27. The weight of the cube was estimated at 4 tons (3629 kg). It was dropped from heights of 8 ft (2.4 m). The drop configuration was from the edge of the wing wall to the center and from the abutment wall back. Impact areas overlapped half of the previous impact. This procedure followed through the next three lifts. Control of the drop height and pattern improved after the first lift was completed which resulted in more consistent heights closer to the specifications and efficient overlapping. A walk behind pad vibrator densified the perimeter and then densities were taken. If density was sufficient, material for the next lift was brought in with a front-end loader. A final "ironing" pass was used to compact the surface materials, Figure 28.

One main concern with this method was the movement of the abutment and wing walls, so there were no drops closer than 2 ft (0.61 m) from the walls. Transits set up about 100 ft (30.5 m) from the backfill focused on wall marking to detect lateral movement. None occurred until the second lift while movement was greatest during compaction of the third and fourth lifts. Total movement of the abutment wall was 0.01 ft (0.305 cm) away from the backfill (north), while the west wingwall moved 0.01 ft (0.305 cm) west and the east wingwall moved 0.02 ft (0.610 cm) east.

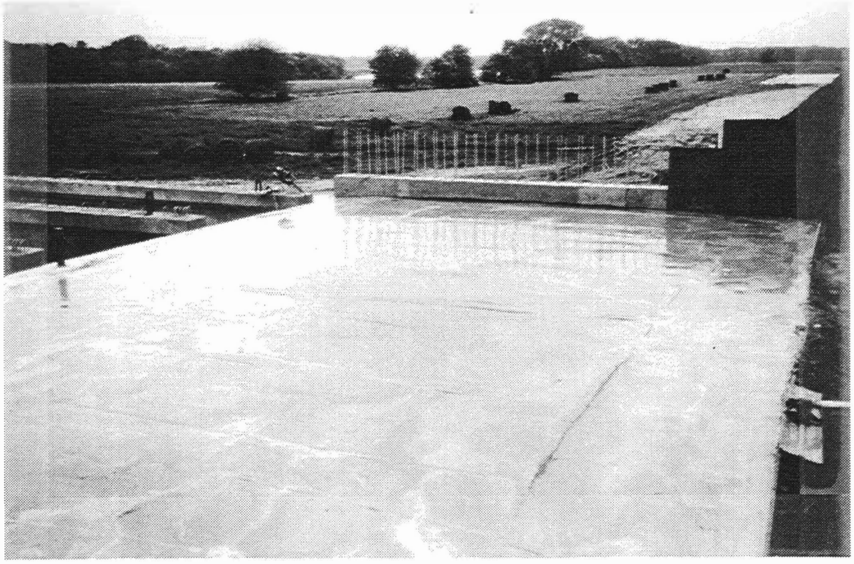

Figure 25. Completed CLSM Backfill, North Abutment, Bridge B

Figure 26. Placement of Granular Backfill for Dynamic Compaction,
South Abutment, Bridge C

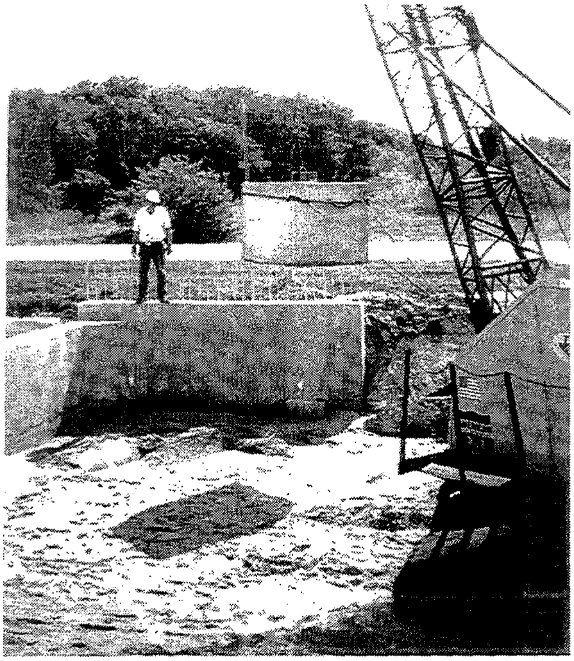

Figure 27. Dynamic Compaction of Granular Backfill, South Abutment, Bridge C

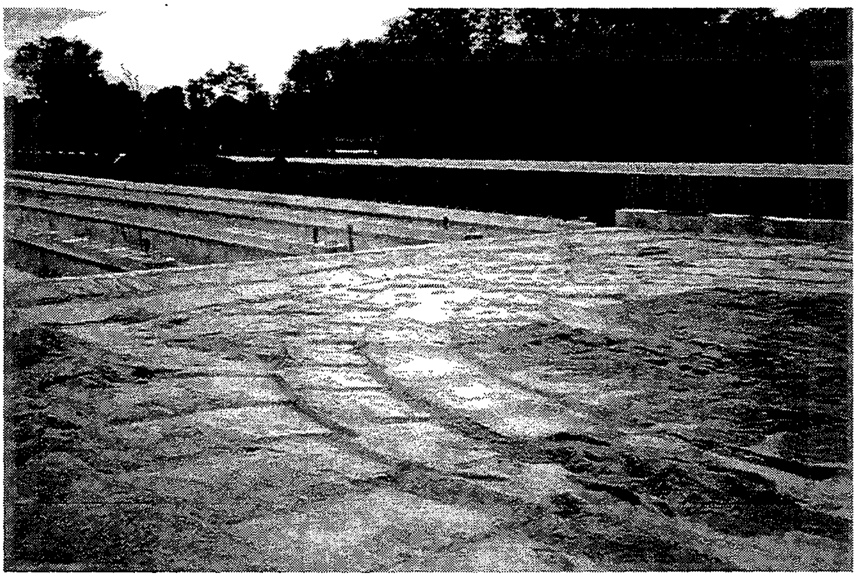

Figure 28. Final "Ironing" Pass to Compact Surface Soils, South Abutment, Bridge C

Cost for south backfill of bridge C dynamic compaction was $15,000 with construction taking 5 days. Workers included a crane operator and a spotter. Equipment used was a crane, front end loader, and walk behind pad vibrator.

North of Bridge C (C2)

The north abutment of bridge C was backfilled with granular material, then flooded and vibrated. The same reasoning was used here as with the south side of bridge C in that as sand density increases, so will its shear strength and bearing capacity.

Figure 29 shows the construction that began on Friday, May 12, with the placement of the first 4 ft (1.2 m) lift. First, the granular material was placed and spread with a front end loader. Then the lift was flooded with water from a water truck and a hand-held concrete vibrator was inserted to the approximate depth of the lift at approximate 1 ft (0.6 m) spacing over the whole backfill area to create a 1 ft (0.6 m) grid pattern, Figure 30. Densities were then checked using a Troxler density/moisture gage. The first round of testing after completion of the first lift revealed that the densities were low. On the following Monday, vibration of the first lift was repeated and all subsequent densities were sufficient. The second 4 ft (1.2 m) lift was placed and the backfill was flooded and vibrated twice and completed on Tuesday, May 16.

Equipment used was one loader, one vibrator, and a water truck. The construction time was 2 days and the cost was estimated at $16,000.

Summary

Table 3 shows a summary of the cost and time of construction for each of the backfills. Construction times are approximate due to the variation in the rate of productivity of the workforce and a "learning curve" for the new and different techniques. This unfamiliarity with certain construction methods was to be expected and was most prevalent on B1, the geotextile reinforced granular backfill, since it was definitely the most unique and labor intensive.

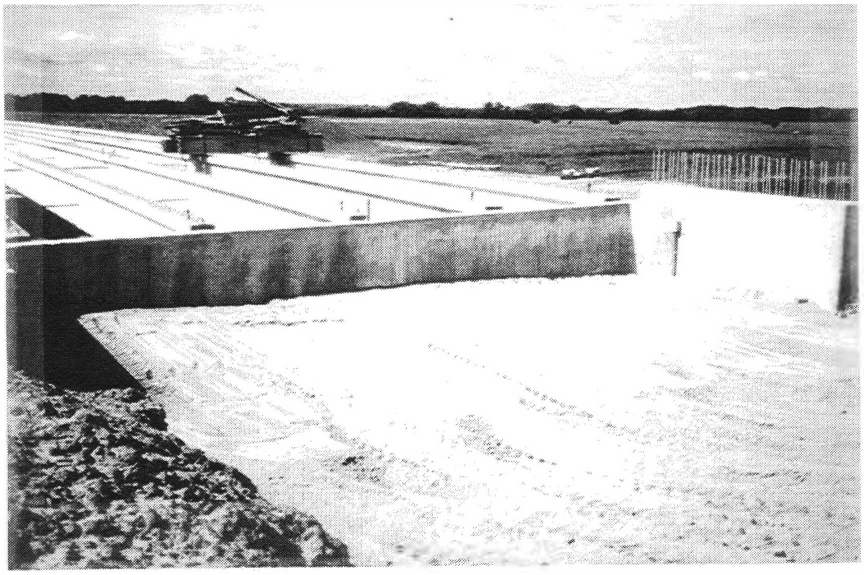

Figure 29. Placement of Granular Backfill for Flooding and Vibrating, North Abutment, Bridge C

Figure 30. Flooding and Vibration of First Lift of Granular Backfill, North Abutment, Bridge C

Table 3. Cost and Time of Construction Summary

	Quantities	Estimated Cost	Construction Days	Equipment
A2	300 yd^3	$ 1,500	4	Loader, walk-behind pad vibrator
B1	375 yd^3 fill 2230 yd^2 textile	$25,000	5	Loader, walk-behind pad vibrator, concrete spreaders, water truck
B2	207 yd^3	$14,560	2	Concrete trucks, concrete vibrator
C1	306 yd^3	$15,000	5	Crane, concrete block, walk-behind pad vibrator, water truck
C2	306 yd^3	$16,000	2	Water truck, concrete vibrator

CHAPTER 5

DATA PRESENTATION

The instruments in each backfill were read on a periodic basis. The instrumentation data are included in Appendix B. The graphs for lateral earth pressure, lateral earth movement, settlement, and groundwater levels are included in Appendix C.

North of A, A2

Total Pressure Cells

The top total pressure cell shows 1.3 psi exerted on the back of the abutment wall. The plot for the top cell has two distinct peaks. The peaks occur in the summer months, while the valleys occur in the winter months. The data appear to be approaching another peak. The increase in pressure during the summer months is likely due to expansion of the bridge deck. When the deck expands, it pushes on the wall and causes an increase in pressure on the back of the abutment wall. The opposite is true in the winter months. The bridge deck shrinks with the decrease in temperature which decreases the pressure on the back of the wall.

The middle total pressure cell has a pressure of 1.6 psi. The data show the same trend as the top total pressure cell, but the difference between the low and the high values of the middle cell is not nearly as great as the difference between the low and high values of the top cell. The contraction and expansion characteristics of the bridge deck cause the same decrease and increase in pressure on the middle of the wall. The effect is not as great because the middle cell is farther away from the bridge deck.

The bottom total pressure cell is experiencing a constant decreasing trend in pressure exerted on the wall. The pressure on the bottom of the wall rose immediately after construction, but has since decreased steadily. The pressure has gone from a high value of 2.2 psi to only 0.3 psi. The bottom cell is far enough away from the bridge deck that the contraction and expansion characteristics of the bridge deck do not appear to have any effect on the pressure.

The expectation for active lateral earth pressure distribution would be increasing pressure with depth. The pressure increases from the top cell to the middle cell, then decreases to a low value at the bottom cell. The low value is not likely due to reader error because the bottom cell has shown a consistent decrease in pressure since August, 1995. Construction plans required the granular backfill be placed in the area immediately behind the abutment wall. Arching of the granular material in front of the bottom cell could be contributing to the low pressure value.

Lateral Earth Movement

Lateral movement of the backfill and the abutment wall was measured using an inclinometer. Both the centerline and offset inclinometer casings are fixed in the shale. The anticipated direction of movement is south, toward the abutment wall. This is the case for the centerline, offset, and abutment wall inclinometer casings for this embankment. The magnitudes of movement are small. The top of the centerline casing has moved 0.3 in., the top of the offset casing has moved 0.4 in., and the top of the abutment wall casing has moved 0.12 in, all relative to the bottom of the casing.

In the direction parallel to the face of the abutment wall, the centerline and offset inclinometer casings have moved east toward the centerline of the roadway. The centerline casing has moved 0.06 in. at the top of the casing. The offset casing has moved 0.12 in. at the top of the casing. The casing in the abutment wall has moved west 0.05 in. toward the wingwall.

Amplified Liquid Settlement Gages

The centerline amplified liquid settlement gage data plot exhibits the expected trend. The settlement occurred within the first ten months after construction and has leveled off. The centerline amplified liquid settlement gage shows that 0.332 ft. of settlement have occurred since construction of the approach embankment.

The offset liquid settlement gage data plot shows the same trend as the centerline liquid settlement gage. The settlement for the offset is 0.247 ft. The amplified liquid settlement gages indicate settlement below the backfill, i.e., settlement of the embankment and foundation strata.

Inclinometer Telescoping Couplings

Table 4 summarizes the settlement for each individual stratum according to the centerline and offset inclinometer telescoping coupling readings.

Table 4. Inclinometer Telescoping Coupling Settlement Summary for A2

ΔH (ft)	Centerline	Offset
Δ (R4-R1)	0.080	0.155
Δ (R4-R2)	0.075	0.080
Δ (R4-R3)	0.074	0.085
$\Delta H_{backfill}$	0.005	0.075
$\Delta H_{embankment}$	0.001	–0.005
$\Delta H_{foundation}$	0.074	0.085

The centerline backfill settlement is 0.005 ft, the centerline embankment settlement is 0.001 ft, and the centerline foundation settlement is 0.074 ft. All three plots* show an initial increase in settlement after construction was complete. Since October 1995, settlement values have remained essentially constant.

The offset backfill has exhibited 0.075 ft. of settlement since construction. The settlement shown on the data plot is leveling off. The offset embankment has settled –0.005 ft. The data plot shows a sudden increase in settlement in October 1995, which could be attributed to rivet shear in the second telescoping coupling. The offset foundation has exhibited 0.085 ft of settlement. The settlement plot shows significant variation in the readings for the foundation settlement.

Surface Settlement Points

The surface settlement point data were evaluated for both wheel paths of the average vehicle. The wheel path closest to centerline is composed of reading points 4, 8, 12, and 16. The offset wheel path is composed of reading points 2, 6, 10, and 14. The centerline wheel path has settled 0.03 ft at a location 5 ft behind the abutment wall, and 0.061 ft at a location 20 ft behind the abutment wall. The plot for this wheel path indicates a slight dip at reading point 8 and a significant dip at reading point 16. This means that the approach embankment is settling more with increasing distance from the abutment wall, i.e., a bump at the end of the bridge has developed.

The offset wheel path has settled 0.058 ft at a location 5 ft behind the abutment wall and 0.043 ft. at a distance 20 ft behind the abutment wall. The plot shows that a depression has developed at reading point 14, and a bump at the end of the bridge is beginning to develop for this approach.

South of B, B1

Total Pressure Cells

The top total pressure cell shows 0.2 psi exerted on the back of the wall. The total pressure versus time plot shows two distinct peaks in pressure. These peaks occur in the summer, which can be attributed to expansion of the bridge deck with the increase in temperature. This expansion causes the pressure on the back of the wall to increase, as explained earlier.

The middle total pressure cell shows 0.5 psi on the back of the abutment wall. Shortly after construction, the pressure reached 2.4 psi, but it decreased and has remained at 0.5 psi since that time. The middle cell shows no variation of pressure with temperature change.

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*Refers to data plots in Appendix C.

According to the bottom total pressure cell, the total pressure on the bottom of the wall is 1.7 psi. There are fluctuations in the plot, but the pressure on the bottom of the wall has shown a general downward trend since the pressure peaked at 8.8 psi shortly after construction.

On May 2, 1996, the cardboard that was placed against the abutment wall for construction purposes was flooded and collapsed. This caused an initial increase in pressure of 0.1 psi on the top cell and 0.2 psi on the middle cell. These values are such small increases that the change is not significant. There was an immediate decrease in pressure on the bottom cell of 1.8 psi. This indicates that the cardboard structure collapsed as planned.

This embankment shows an increase in lateral earth pressure with depth. The increase in pressure from the top to the middle cell is slight, especially in the summer months when the pressure in the top cell can increase to 0.5 psi. The backfill for this embankment was designed to be self-supporting. In theory, the backfill should never come in contact with the abutment wall. Since the backfill is in contact with the abutment wall, it is necessary to identify possible reasons for the problem. The geotextile fabric in the embankment could be creeping, which would put the backfill into contact with the wall. Also, the density of the sand within the backfill could be insufficient. The average relative densities for the eight layers was only 25.8%, which correlates to a loose material. This indicates that even though the required standard Proctor-based densities were met, the relative densities should have been higher. The densities were specified using the standard Proctor test which is not a good test for cohesionless soils.

Lateral Earth Movement

The centerline inclinometer casing shows movement toward the bridge (north), which is the expected direction of movement. The centerline casing has moved 0.25 in. at the top of the casing. The offset casing has exhibited movement both toward and away from the abutment wall. The plot of lateral displacement is variable, but the magnitude of movement is less than 0.07 in. The inclinometer casing in the abutment wall indicates that the abutment wall is moving south toward the backfill. The indication from the casing in the abutment wall may be misleading. The bottom of the casing in the abutment wall is not fixed. The casing could actually be moving toward the bridge but be tilted toward the backfill at the top of the casing. The casing would tilt toward the backfill if it began moving toward the bridge because the bridge deck would prohibit the top of the casing from moving toward the bridge. The abutment wall casing has moved 0.08 in. at the top of the casing.

All three of the casings show westward movement in the direction parallel to the wall. The magnitudes of movement are very small. The centerline casing has moved 0.015 in., the offset casing has moved 0.25 in., and the cumulative movement of the abutment wall is zero.

Amplified Liquid Settlement Gages

The centerline amplified liquid settlement gage data plot shows 0.264 ft of settlement. The settlement increased rapidly after construction then began leveling off in February 1996.

The offset amplified liquid settlement gage data plot shows a settlement of 0.214 ft. The plot of settlement versus time shows a downward trend, and settlement appears to be continuing under the offset gage.

Inclinometer Telescoping Couplings

Table 5 summarizes the settlement for each individual stratum according to the centerline and offset inclinometer telescoping coupling readings.

Table 5. Inclinometer Telescoping Coupling Settlement Summary for B1

ΔH (ft)	Centerline	Offset
Δ (R4-R1)	0.057	0.126
Δ (R4-R2)	0.018	0.028
Δ (R4-R3)	0.016	0.016
$\Delta H_{backfill}$	0.039	0.098
$\Delta H_{embankment}$	0.002	0.012
$\Delta H_{foundation}$	0.016	0.016

The centerline backfill has experienced 0.039 ft of settlement, the centerline embankment has settled 0.002 ft since construction, and the centerline foundation has settled 0.016 ft since construction. All three centerline plots showed higher settlement values during the period of July 1995, to May 1996. Since May 1996, the settlement readings have been consistently lower. This could be attributed to reader error since different people read the depths on different dates.

The offset backfill has settled 0.098 ft. There was a sudden increase to this value in May 1996, and has remained at this value since that time. The offset embankment has settled 0.012 ft and appears to be remaining constant. The offset foundation has settled 0.016 ft and is also remaining constant. Both the embankment and foundation settlements have exhibited a very gradual increase over time and appear to have leveled off.

The foundation layer shows the same amount of settlement (0.016 ft) for both the centerline and the offset inclinometer. Also, the embankment layer has settled very little according to both inclinometer readings. The majority of settlement appears to be in the backfill, which again indicates that densities required for the backfill were not as high as they should have been. Elastic settlement of the sand in the backfill could be contributing to the backfill settlement.

Surface Settlement Points

As with embankment A2, the surface settlement data were evaluated for both of the wheel paths. The wheel path closest to centerline is composed of reading points 4, 8, 12, and 16. The offset wheel path is composed of reading points 2, 6, 10, and 14. The centerline wheel path has settled 0.053 ft. at a distance of 5 ft. behind the abutment wall, and has settled 0.022 ft. at a distance of 20 ft. behind the wall. It has significantly more settlement near the abutment wall.

The offset wheel path has settled 0.058 ft. at a distance of 5 ft. behind the wall, and has settled 0.048 ft. at a distance of 20 ft. behind the wall. This wheel path has settled uniformly, and while it has a little more settlement near the abutment wall (0.01 ft.), it is not as significant as the differential settlement for the centerline wheel path.

The bump at the end of the bridge has started to develop at this approach. This indicates that although the required densities were achieved during construction of this embankment, the required densities were not great enough to eliminate a bump at the transition between the bridge approach and deck.

North of B, B2

Total Pressure Cells

There are 0.4 psi of pressure exerted on the back of the abutment wall at the top cell. There was an initial peak in the pressure at the top cell shortly after construction, but the value has remained constant at 0.4 psi since March 1996. The initial peak could be a result of the hydrostatic pressure of the wet controlled low strength material shortly after construction.

The middle total pressure cell measures 0.1 psi of pressure on the back of the abutment wall. The pressure on the middle cell reached a peak of 2.8 psi shortly after construction but has stayed below 0.5 psi since May 1995. The plot has small peak values of 0.5 psi in the summer months. The peaks could be due to thermal expansion of the bridge deck or the backfill itself during summer months, but if this were the case, the same trend would be exhibited in the top pressure cell.

The pressure on the bottom total pressure cell is 0.9 psi. The pressure has increased from an average value of 0.7 psi before May 1996, to recent values in the 0.8–1.0 psi range. The sand covering the lower cell to protect the drain could be putting pressure on the lower cell.

Like the geotextile reinforced embankment, this backfill was designed to be self supporting. Nothing was placed between the controlled low strength material and the abutment wall during construction so the material is in contact with the wall. The pressure is higher than expected. This could be attributed to movement of the controlled low strength material toward the abutment wall as the pressure is fairly uniform (less than 1 psi) along the face of the abutment wall.

Lateral Earth Movement

The data from the centerline inclinometer show the casing has moved 0.2 in. toward the bridge at the top of the casing. At a depth of 5 ft, the movement toward the bridge reduces to 0.00 in. The larger indication of movement at the top of the casing is inconsistent with the rest of the data, so 0.00 in. is a better assessment of actual movement. The offset inclinometer data show 0.06 in. of movement toward the bridge at the top of the casing. The abutment wall casing has moved 0.02 in. toward the bridge at the top of the casing. The middle section of this casing has moved 0.06 in. toward the backfill. This is probably due to an error in the reference data set because the subsequent data sets show the movement toward the backfill.

In a direction parallel to the abutment wall, the centerline casing has moved 0.01 in. east. The offset casing has moved 0.03 in. west toward the wingwall. The data for the abutment wall in this direction also indicate that the initial data set is incorrect. The data show that the top of the casing has moved east 0.15 in. If the reference and the June data sets were ignored, movement would only be 0.02 in. west.

Amplified Liquid Settlement Gages

The centerline amplified liquid settlement gage shows a settlement of 0.348 ft. The settlement showed an increase following construction and has since leveled off.

The offset amplified liquid settlement gage has 0.143 ft of settlement. Although there are some variations in the plot, it has shown a general increase in settlement since construction. Settlement is still occurring according to the offset amplified liquid settlement gage data.

Inclinometer Telescoping Couplings

Table 6 summarizes the settlement for each individual stratum according to the centerline and offset inclinometer telescoping coupling readings. The centerline backfill has consistently shown upward movement since construction. This is difficult to explain as there is no plausible reason for upward movement. The indication of upward movement could be due to inconsistent installation of the inclinometer casing. The entire tube may have been pushed down further than it should have been during construction which would have altered the bottom reading. The embankment settlement also has some negative settlement values, but the average settlement is 0.000 ft. The foundation settlement is 0.050 ft.

Table 6. Inclinometer Telescoping Coupling
Settlement Summary for B2

ΔH (ft)	Centerline	Offset
Δ (R4-R1)	–0.080	0.028
Δ (R4-R2)	0.050	0.090
Δ (R4-R3)	0.050	0.040
$\Delta H_{backfill}$	–0.130	–0.062
$\Delta H_{embankment}$	0.000	0.050
$\Delta H_{foundation}$	0.050	0.040

The offset backfill settlement is –0.062 ft. As before, the negative value is difficult to explain. The embankment settlement is 0.050 ft, and the foundation settlement is 0.040 ft. Both the embankment and the foundation settlement values are questionable because, over time, the plots show upward movement of the embankment.

Surface Settlement Points

The surface settlement data for the two vehicle wheel paths were evaluated. The wheel path closest to centerline is composed of reading points 4, 8, 12, and 16. The offset wheel path is composed of reading points 2, 6, 10, and 14. The centerline wheel path has had 0.036 ft of settlement at a distance of 5 ft behind the abutment wall, and 0.013 ft of settlement at a distance of 20 ft behind the wall. The most settlement has occurred at reading points 4 and 12, 5 ft and 15 ft behind the wall, respectively. This means there is a small dip at each of these points.

The offset wheel path has had 0.030 ft of settlement 5 ft behind the abutment wall, and 0.041 ft of settlement 20 ft behind the wall. The settlement for this wheel path is more uniform than the settlement for the centerline wheel path. The change in surface elevation increases with distance from the abutment wall.

South of C, C1

Total Pressure Cells

The pressure on the top cell peaked after construction and immediately decreased to a value of 0.1 psi. It has remained at 0.1 psi since that time.

The pressure on the middle cell is 1.8 psi. The plot shows two definite peaks in total pressure on the middle cell. One peak is in July 1995, and the other is in October 1996.

The pressure on the bottom cell is 2.4 psi. The plot for the bottom total pressure cell also shows peaks in July 1995, and October 1996. The variations in pressure on the middle and bottom cell are probably due to seasonal temperature variations. Expansion of the bridge deck in the summer months causes more pressure on the back of the wall. The lack of cyclic behavior in the top cell suggests the soil is not as dense near the top cell as it is near the middle and bottom cells. The soil around the top cell could be arching which would result in less pressure on the top cell.

Lateral Earth Movement

The top of the centerline casing has moved 0.12 in. toward the bridge. The offset casing has moved 0.12 in. toward the bridge. The abutment wall casing has moved 0.20 in. away from the bridge. This could indicate the abutment wall has moved toward the bridge but is tilted into the backfill at the top of the wall because of the bridge deck, as explained earlier.

In a direction parallel to the abutment wall, the centerline casing has shown small movements in both the east and west directions. It has moved 0.15 in. west at the top of the casing. The offset casing has moved 0.06 in. east at the top of the casing. The abutment wall casing has moved west 0.25 in.

Amplified Liquid Settlement Gages

The centerline settlement gage stopped functioning properly in May 1996. Prior to that time, 0.364 ft of settlement had occurred and settlement appeared to be continuing.

The offset settlement gage shows that 0.343 ft of settlement have occurred. The plot appears to be approaching a constant value, but a small amount of additional settlement will likely occur before it does.

Inclinometer Telescoping Couplings

Table 7 summarizes the settlement for each individual stratum according to the centerline and offset inclinometer telescoping coupling readings. According to the centerline inclinometer telescoping coupling readings, the backfill stratum has settled 0.028 ft. The embankment has settled 0.005 ft. The foundation has settled 0.050 ft.

Table 7. Inclinometer Telescoping Coupling Settlement Summary for C1

ΔH (ft)	Centerline	Offset
Δ (R4-R1)	0.083	0.265
Δ (R4-R2)	0.055	0.050
Δ (R4-R3)	0.050	0.085
$\Delta H_{backfill}$	0.028	0.215
$\Delta H_{embankment}$	0.005	–0.035
$\Delta H_{foundation}$	0.050	0.085

According to the offset telescoping coupling readings, the backfill has settled 0.215 ft, the embankment has settled –0.035 ft, and the foundation has settled 0.085 ft. Again, the negative value for the embankment settlement raises questions about the reliability of the inclinometer data. For both the centerline and offset inclinometer readings, the foundation has exhibited a large amount of settlement and the embankment has exhibited little settlement. However, the large difference between the centerline and offset values for settlement of the backfill is questionable.

Surface Settlement Points

The wheel path closest to centerline consists of reading points 4, 8, 12, and 16. At a distance of 5 ft behind the abutment wall, 0.027 ft of settlement has occurred, and 0.012 ft of settlement has occurred 20 ft behind the abutment wall. Initially, there was a dip in the pavement at reading point 12, and the pavement was flat between points 8 and 4. Now, the dip extends from point 12 to point 8 before coming back up to point 4. Point 8 has settled 0.044 ft which is the largest amount of settlement for this wheel path.

The offset wheel path consists of reading points 2, 6, 10, and 14. At a point 5 ft behind the abutment wall, 0.039 ft of settlement has occurred. At a point 20 ft behind the abutment wall, 0.027 ft of settlement has occurred.

North of C, C2

Total Pressure Cells

The top total pressure cell had an initial peak in pressure of 0.6 psi. Then pressure decreased to 0.1 psi, where it remained constant until October 1996. It then began increasing and recently reached a value of 0.3 psi.

The middle total pressure cell has shown a steady increase in pressure since construction. The total pressure is 1.6 psi. The pressure appears to be approaching a constant value.

The bottom cell has also been increasing steadily since construction and has reached a value of 3.4 psi. It also appears to be reaching a constant value.

Of the five embankments, C2 is the most consistent with expectations in terms of pressure distribution. The wall has a nearly linear pressure distribution from the top cell to the bottom cell.

Lateral Earth Movement

The centerline inclinometer casing has moved 0.15 in. toward the bridge, The offset inclinometer casing has moved 0.10 in. toward the bridge. The abutment wall casing has moved 0.08 in. toward the bridge.

In a direction parallel to the abutment wall, the centerline casing has moved 0.03 in. east. The top of the offset casing has moved 0.01 in. west. The abutment wall casing has moved 0.25 in. west.

Amplified Liquid Settlement Gages

The gages both had questionable readings in February 1997. The readings could be the result of insufficient flow in the system.

Settlement for the centerline amplified liquid settlement gage is 0.200 ft. The settlement is approaching a constant value.

Settlement for the offset gage is 0.071 ft. The plot for the offset gage is variable.

Inclinometer Telescoping Couplings

Table 8 summarizes the settlement for each individual stratum according to the centerline and offset inclinometer telescoping coupling readings.

Table 8. Inclinometer Telescoping Coupling Settlement Summary for C2

ΔH (ft)	Centerline	Offset
Δ (R4-R1)	0.045	0.315
Δ (R4-R2)	0.038	0.035
Δ (R4-R3)	0.026	0.040
$\Delta H_{backfill}$	0.007	0.280
$\Delta H_{embankment}$	0.012	–0.005
$\Delta H_{foundation}$	0.026	0.040

According to the centerline telescoping coupling, the backfill has settled 0.007 ft. The settlement seems to have reached a constant value since the total settlement value (Δ (R4-R1)) has remained at 0.045 ft since May 1996. The embankment has settled 0.012 ft, which is also a constant value. The foundation has settled 0.026 ft. The plot for the foundation settlement has not leveled off and some additional settlement may occur.

The offset inclinometer telescoping coupling indicates that the backfill has settled 0.280 ft. The settlement was gradually decreasing after construction but experienced a significant increase in May 1996. This could indicate that the rivet in the first telescoping coupling sheared in May 1996. The embankment settlement has been gradually increasing since construction, and settlement appears to have stopped at –0.005 ft. The foundation settlement has also been decreasing since construction and it seems to have stopped at 0.040 ft. The settlement indicated by the offset inclinometer readings is significantly greater than the settlement indicated by the centerline inclinometer readings. There is also a negative value of settlement for the embankment indicated by the offset inclinometer which suggests that these readings are unreliable.

Surface Settlement Points

The wheel path closest to centerline contains reading points 4, 8, 12, and 16. For this wheel path, 0.033 ft of settlement has occurred at a point 5 ft behind the abutment wall, and 0.041 ft of settlement has occurred at a point 20 ft behind the abutment wall. A slight bump is developing at reading point 12.

The offset wheel path contains reading points 2, 6, 10, and 14. At a point 5 ft behind the abutment wall, 0.053 ft of settlement has occurred. At a point 20 ft behind the abutment wall, 0.049 ft of settlement has occurred. Settlement is uniform along this wheel path.

CHAPTER 6

DISCUSSION OF RESULTS

Performance

Total Pressure Cells

The pressure on the back of the abutment walls was measured at three heights using total pressure cells. The theoretical lateral earth pressure values were predicted for both active and at-rest conditions by Benson (24). The active lateral earth pressures were calculated using the Rankine formula:

$$\sigma_a = K_a * \gamma * H$$

where

σ_a = active lateral earth pressure

K_a = Rankine active earth pressure coefficient = $\tan^2(45 - \phi/2)$

ϕ = angle of internal friction

γ = dry density

H = depth of interest

At-rest earth pressures were calculated using the Jaky at-rest coefficient $K_o = 1 - \sin\phi$, where $\sigma_o = Ko * \gamma * H$. Table 9 gives a comparison between the theoretical values of earth pressure estimated by Benson and the actual measured values.

The measured values of lateral earth pressure do not correlate well with the estimated values. The estimated active lateral earth pressures for embankment B1 are the closest to the actual measured values. The Rankine active lateral earth pressure closely approximates the actual conditions for this embankment. The Rankine active conditions and at-rest conditions underestimate lateral earth pressure conditions for embankments C1 and C2. The measured values at A2 are also higher than the estimated values with the exception of the bottom total pressure cell. Although pressures were higher than expected for C2, the abutment wall has the expected linear pressure distribution. Compaction efforts could have caused excess pressure to be exerted on the back of the abutment wall C1 if the concrete cube was dropped too close to the face of the abutment wall. This should not be the case, as a walk-behind pad vibrator was used within 2 ft of the abutment wall and wingwalls. Also, the observed effect of temperature on pressures could be causing measured pressures to be higher than estimated pressures.

Lateral Earth Movement

All approach embankments show the same general trend for lateral earth movement as indicated by the inclinometers. The backfill area is moving toward the bridge which is the expected direction of movement. In the direction parallel to the abutment wall, embankments

Table 9. Lateral Earth Pressure Values, Predicted and Measured

	A2	B1	B2	C1	C2
H_1, ft	2.19	1.86	1.55	0.96	0.96
σ_a, psi	0.40	0.50	‡	0.10	0.10
σ_o, psi	0.60	0.80	‡	0.20	0.20
$\sigma_{measured}$, psi	1.30†	0.20†	0.50	0.10	0.30
H_2, ft	5.19	4.86	4.55	3.96	3.96
σ_a, psi	0.80	1.40	‡	0.50	0.50
σ_o, psi	1.40	2.00	‡	0.60	0.90
$\sigma_{measured}$, psi	1.60†	0.50	0.10†	1.80†	1.60
H_3, ft	7.66	7.86	7.55	6.96	6.96
σ_a, psi	1.30	2.20	‡	0.90	0.90
σ_o, psi	2.00	3.20	‡	1.50	1.60
$\sigma_{measured}$, psi	0.30	1.70	0.90	2.40†	3.40

H_1 = depth to top cell, H_2 = depth to middle cell, and H_3 = depth to bottom cell.

†Total pressure cell data fluctuate with seasonal temperature change.

‡Pressures not calculated because ϕ value for controlled low strength material is unknown.

have shown small amounts of movement. There has been movement toward the centerline of the roadway and toward the wingwall west of the roadway. The westward movement is more common and has greater magnitudes than the eastward movement. As settlement occurs, the embankment tends to spread. Since the inclinometers are installed either on the centerline or west of centerline, the movement is mostly west. The movement to the west is also influenced by the presence of spur dikes at three of the locations.

Settlement

Settlement was measured by the amplified liquid settlement gages, the inclinometer telescoping couplings, and the surface settlement points. Table 10 summarizes the settlement data for the control embankment and the four experimental approach embankments.

Table 10. Summary of Measured Settlement Data

ΔH	A2	B1	B2	C1	C2
Amplified Liquid Settlement Gage Data, ΔH in ft					
Centerline	0.332	0.264	0.348	0.364	0.200
Offset	0.247	0.214	0.143	0.343	0.071
Difference	0.085	0.050	0.205	0.021	0.129
Inclinometer Data, ΔH in ft					
Centerline					
Backfill	0.005	0.039	−0.130	0.028	0.007
Embankment	0.001	0.002	0.000	0.005	0.012
Foundation	0.074	0.016	0.050	0.050	0.026
Offset					
Backfill	0.075	0.098	−0.062	0.215	0.280
Embankment	−0.005	0.012	0.050	−0.035	−0.005
Foundation	0.085	0.016	0.040	0.085	0.040

The amplified liquid settlement gages indicate that settlement was greater under the centerline of the approach embankments than under the offset. This is true in all cases. Embankment C2 had the least settlement for both the centerline and the offset. The centerline settlement was 0.200 ft and the offset settlement was 0.071 ft. Embankment C1 settled the most, with 0.364 ft of centerline settlement and 0.343 ft of offset settlement. Although C1 had the most settlement, it had the lowest differential settlement, 0.021 ft, between the centerline and the offset of any of the five embankments. C2 had a large differential settlement of 0.129 ft, second only to B2, which had a differential settlement of 0.205 ft.

The amplified liquid settlement gage data are more reliable than the settlement data obtained from the inclinometer telescoping couplings. The data from the inclinometer telescoping couplings show upward movement of the approach embankment in some cases, which is not a likely occurrence. One reason for data error is reader variability. The depth to the various telescoping couplings in the inclinometer casing was not read by the same person each time data were recorded, which may have caused some mistakes in the measurements. In addition, differences of a hundredth of a foot could be easily misread by simply reading the measuring tape at an angle instead of level. Also, to accurately measure settlement, the top rivet in the telescoping coupling must shear. This appears to have happened in only two cases, the second telescoping coupling of A2 and the first telescoping coupling of C2. Conversely, the amplified liquid settlement gage data were gathered using calibrated instruments which are considered more reliable. The decision to measure settlement using the inclinometer telescoping couplings was a good idea in theory, but it is highly variable and is not a good backup system for determining settlement.

Even though settlement data from the inclinometer telescoping couplings are questionable, trends can be detected. In all cases, the total settlement for the centerline inclinometer was less than the settlement for the offset inclinometer. For both the centerline and the offset inclinometer, B2 showed upward movement of the backfill. Although this is unlikely, it is probable that very little or no settlement occurred within the backfill of this embankment.

The surface settlement data give a good indication of whether or not a bump has started to develop at the end of the bridge. At embankments A2 and B1, the bump has started to develop, and there has been traffic on the road for less than one year.

Table 11 compares the values of settlement estimated by Schwidder (23) to the actual values of settlement according to the amplified liquid settlement gages for each approach embankment.

Table 11. Comparison of Estimated Settlement Values to Measured Settlement Values

ΔH, ft	A2	B1	B2	C1	C2
Measured Values					
Centerline	0.332	0.264	0.348	0.364	0.200
Offset	0.247	0.214	0.143	0.343	0.071
Estimated Values	0.250	0.187	0.203	0.179	0.143

The estimated values of settlement are lower than the actual values of settlement according to the centerline amplified liquid settlement gages in all cases. The estimated value for A2 is the same as the offset value. The estimated value for B1 is close to the offset value. The estimated settlements give reasonable indications of the actual settlement, based on the material properties of the approach embankment assumed at the time.

Groundwater Levels

The plots of groundwater table elevation versus time (Appendix C) showed the same trend for all of the embankments. The groundwater table rose approximately 8 ft above normal levels in July 1995, during the record rainfalls of that summer. The levels then returned to and have remained at normal levels. The variations in the groundwater level do not appear to have any effect on either settlement or lateral earth pressure. If groundwater had a noticeable effect on lateral earth pressure, it would indicate that drainage systems for the approach embankments were not functioning properly and there was water in the backfill.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In terms of settlement, C2 appears to be performing the best. Even though settlement values are higher than predicted, it has the least settlement of any of the approach embankments. It has not developed a bump at the end of the bridge, and settlement is uniform along the centerline and the offset wheel path. The only real concern is the large amount of differential settlement (0.120 ft) between the centerline and the offset, which is not an extremely high value but is the largest of any of the embankments. C2 also shows the expected trend in terms of lateral earth pressure. Lateral earth pressures are higher than expected, but the distribution has the expected linear increase with depth.

Lateral earth pressure values are closest to the predicted values for B1. Embankment B1 is performing the second best in terms of settlement, but a bump is beginning to develop at this embankment. A bump is also beginning to develop at A2.

B2 is performing well with respect to settlement. The surface settlement point data show that at a distance of 5 ft behind the abutment wall, there are 0.036 ft of settlement at the wheel path closest to centerline and 0.030 ft of settlement at the offset wheel path. No bump has started to develop at this approach embankment. In addition, the controlled low strength material is exerting very little pressure on the back of the abutment wall. The settlement according to the settlement gages is high, second only to C1. A greater amount of settlement is expected with this type of embankment construction because of the weight of material. The controlled low strength material exerts more weight on the foundation material than either the compacted granular backfill or unclassified borrow. The embankment has experienced little lateral movement.

Embankment C1 has the highest amount of settlement for both centerline and offset according to the amplified liquid settlement gage data. Although it has the greatest amount of settlement, it does not yet have a significant bump at the abutment wall. C1 is exerting less pressure on the abutment wall than C2, which can be directly related to the construction method because C1 and C2 are constructed of the same backfill material.

The least expensive embankment construction was A2. The total cost for A2 was $1500. The most expensive was B1 at $25,000. The remaining embankments cost in the range of $14,500 to $16,000. Although A2 was by far the least expensive construction, it poses the conventional construction problems related to compaction requirements. The unclassified borrow material used for this embankment is generally not as good as the material used in the other options, and A2 has not performed as well as some of the other approach embankments. Therefore, the added expense of embankment B2, C1, or C2 may be justified.

Recommendations

The conclusions concerning the performance of the different approach embankment construction methods showed that no single construction method performed consistently better than any other method. Instead, the data confirm that each of the approach embankments has advantages and limitations with regard to materials, construction procedures, and performance. With this in mind the following paragraphs present recommendations that should be considered to help reduce construction problems and improve performance of future approach embankments.

The geotextile reinforced wall is, conceptually, an excellent option for addressing both settlement and lateral earth pressures; however, some problems arose with the materials used in the construction and construction method. To alleviate these problems, the geotextile selected should have as low a creep tendency as possible. Perhaps a woven geotextile would be more appropriate. The geotextile roll-back on the top of each layer should be more uniformly tensioned and anchored in some way to hold the tension. To achieve better compaction of the granular backfill, the soil should be placed in thinner lifts and compacted with a small vibratory drum roller. Finally, a relative density specification should be used for compaction control rather than a Proctor specification.

Dynamic compaction is an effective way to achieve density in granular backfill; however, care should be taken to use the minimal amount of energy necessary to achieve the desired results. Soil should be placed on the outside of the wing wall to at least two-thirds of the height of the wall and wing wall movement monitored throughout the dynamic compaction process. Following the ironing pass, the compacted material should be covered with a layer (≈ 4 to 6 in. thick) of controlled low strength material to protect the surface materials.

Flooding and vibration of backfill is also an effective means of compacting granular materials. A larger vibrating probe (i.e., rather than a conventional concrete vibrator) would be helpful. Following compaction, the granular backfill should be covered with a layer (≈ 4 to 6 in. thick) of controlled low strength material.

Controlled low strength materials, although considerably more expensive, has significant advantages with regard to speed and simplicity of CLSM placement. Use of the material does require some additional preparation time to assure good placement conditions. Quality control testing to monitor consistency of the mix is important. Some major advantages of CLSM are its resistance to erosion and firm consistency to resist internal settlement. One concern about CLSM involves increased loading on the pile foundation due to bonding of the CLSM to the abutment wall and wing walls. Evaluation of this concept should be addressed in some future use.

The use of "unclassified borrow" for approach embankment backfill allows a wide variety of materials to be used in an important area like the approach embankment. The options for backfill construction materials should be reduced to granular backfill or select material placed in thin lifts with careful quality control. If the selected material has less than 10% fines, a relative density specification should be used for quality control.

More attention should be paid to differences between plan drawings and what is (or can be) actually constructed in the field. This was particularly prevalent in the control section approach embankment.

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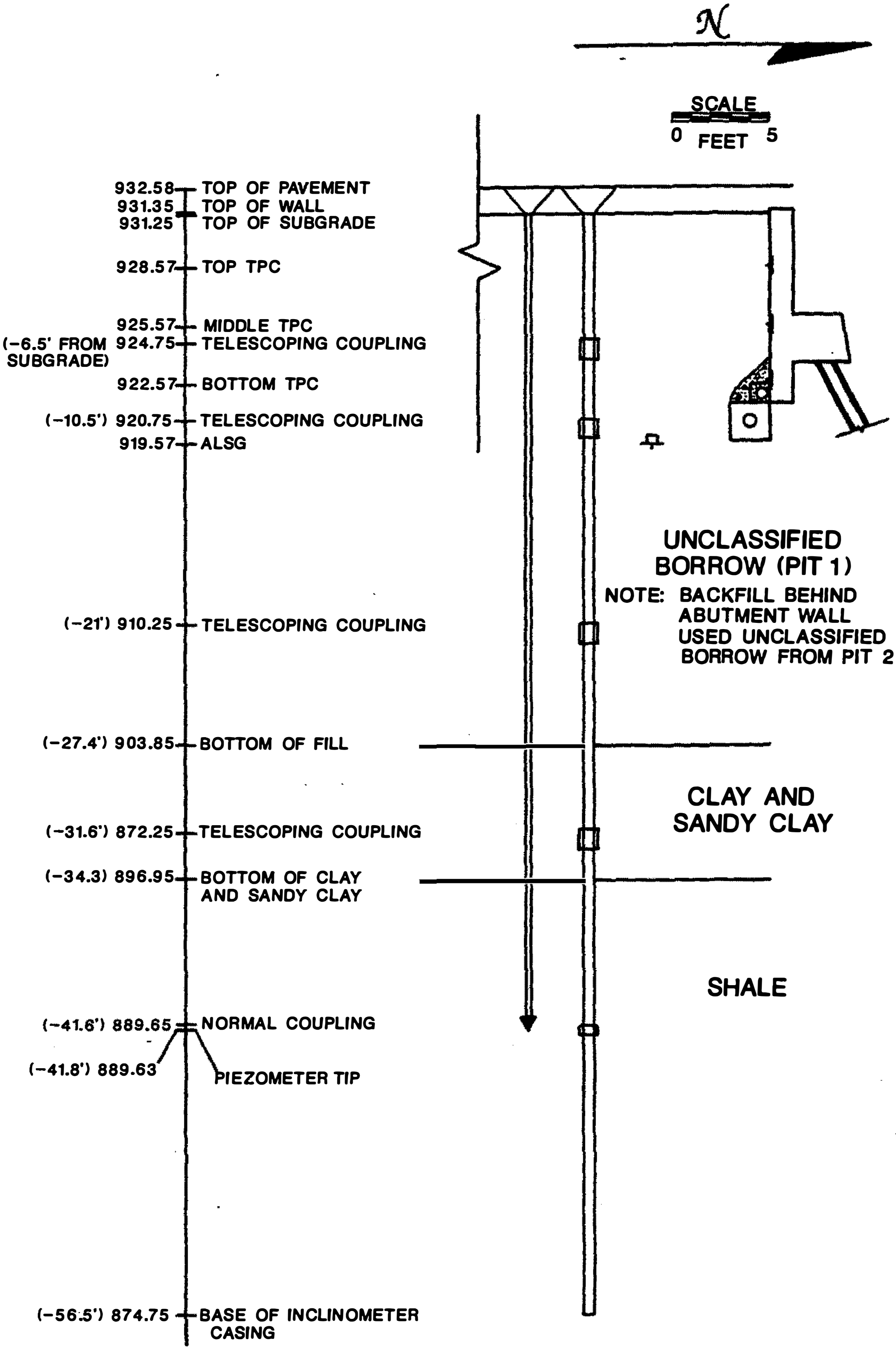
APPENDIX A

AS-BUILT INSTRUMENT LOCATIONS FOR ALL APPROACH EMBANKMENTS

APPENDIX A1

Instrument Locations for Approach Embankment A1



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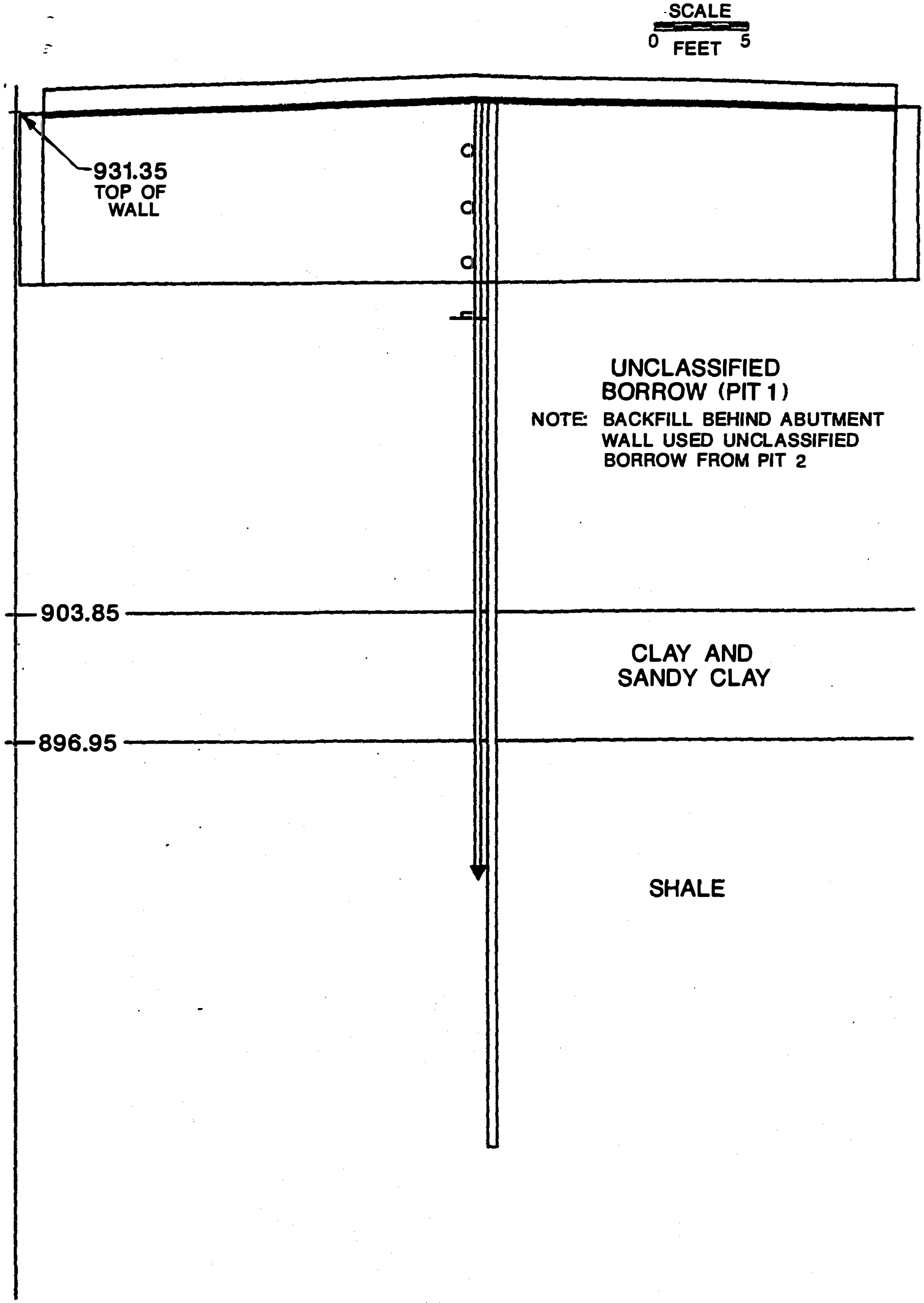

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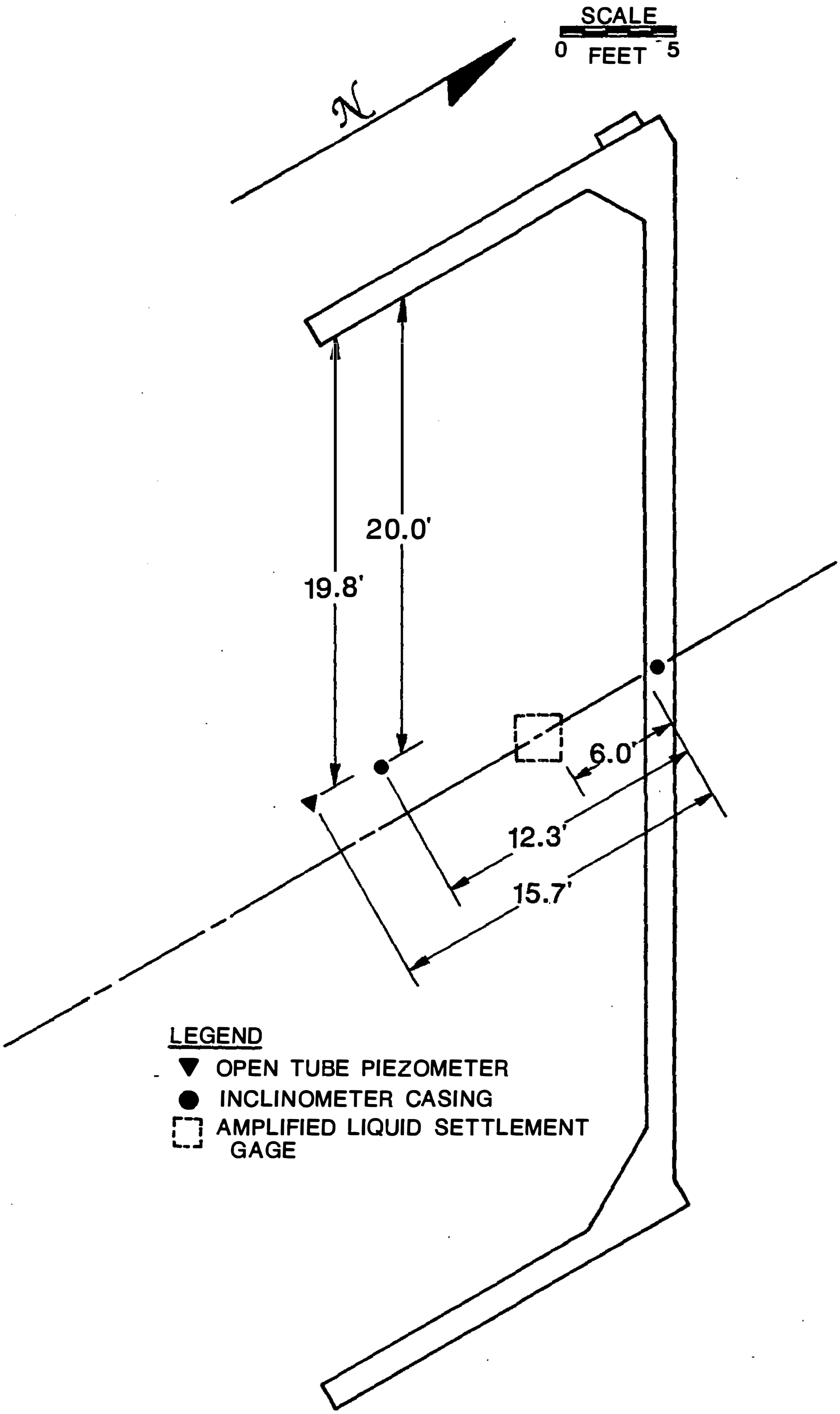

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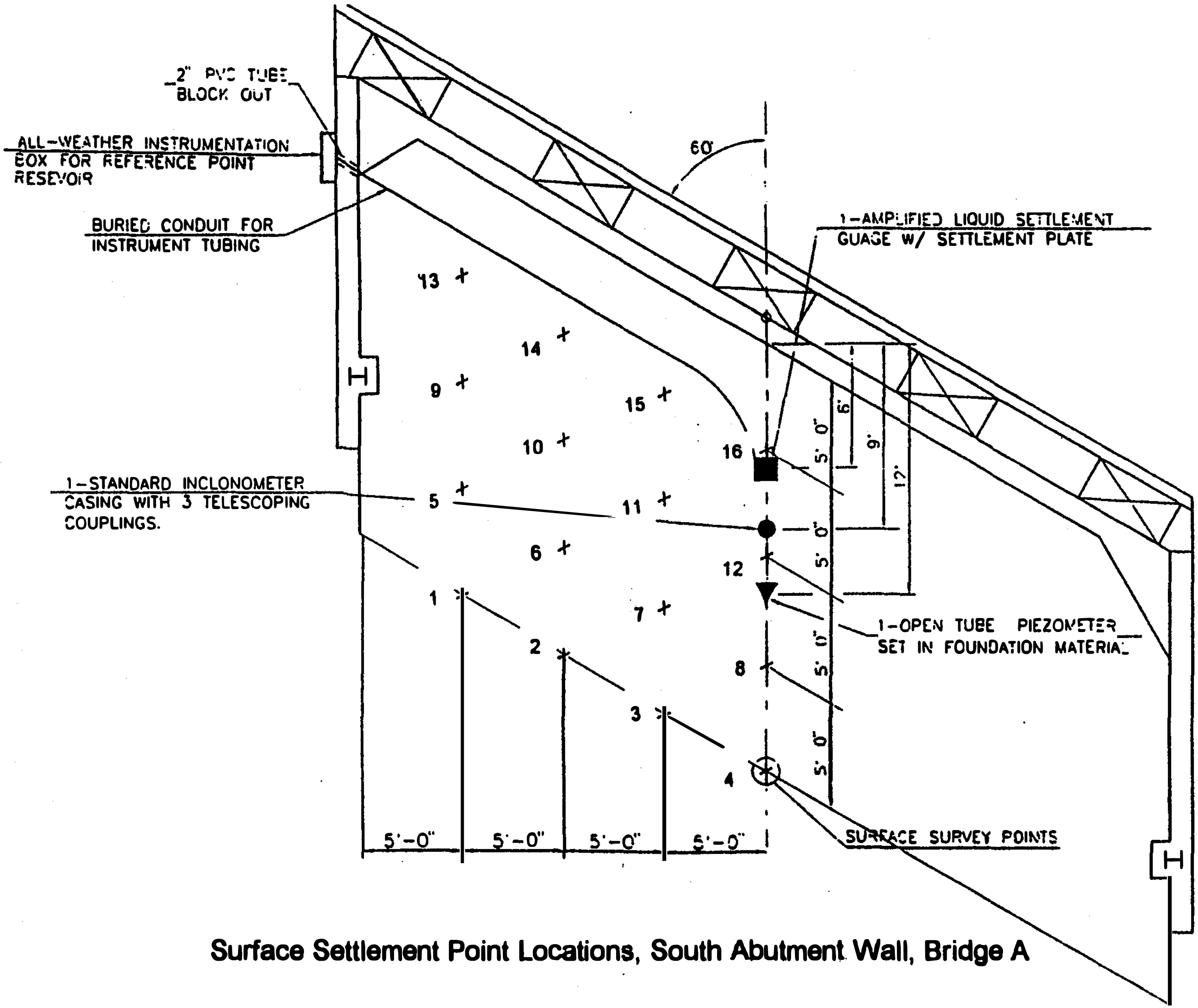
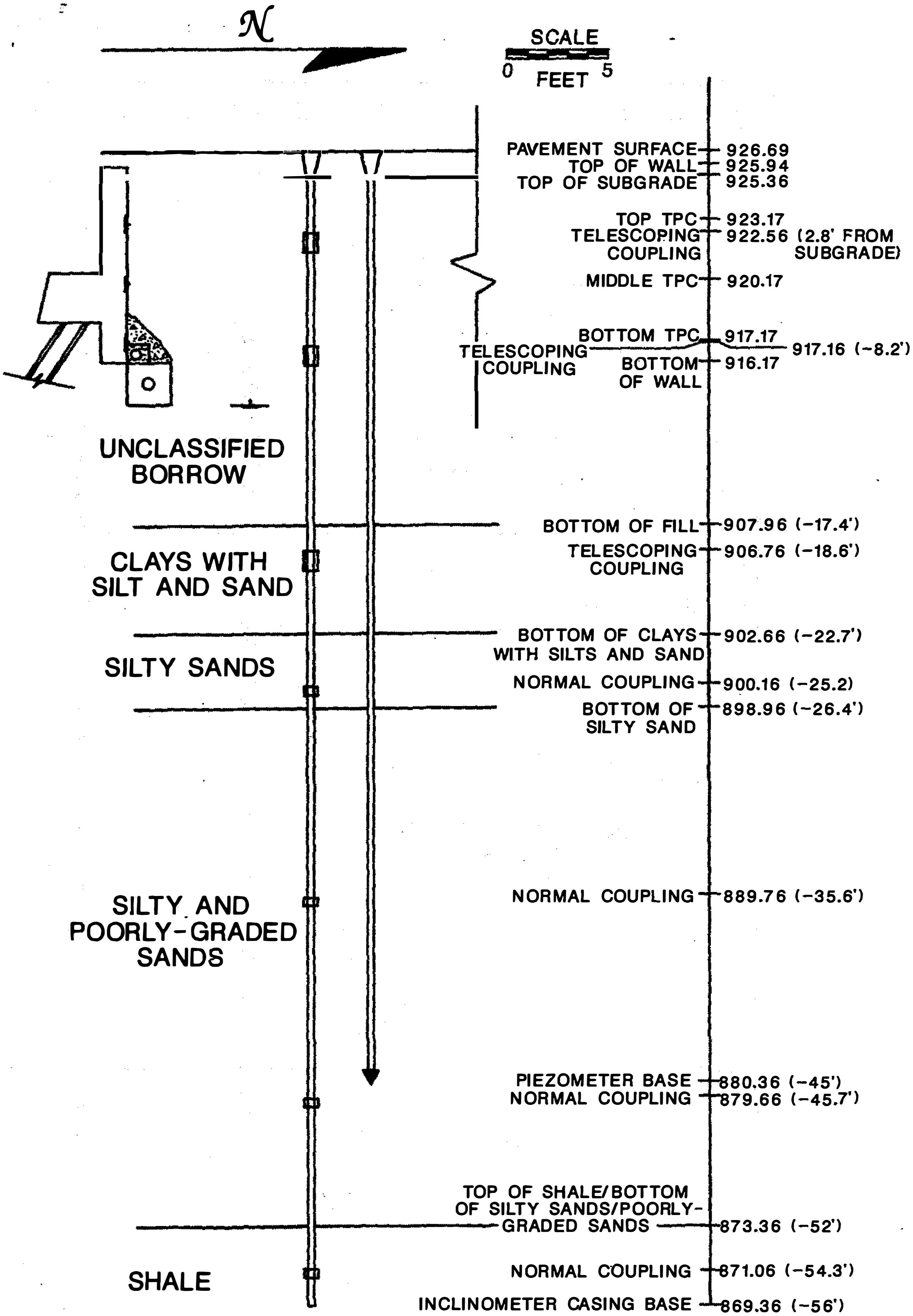


Surface Settlement Point Locations, South Abutment Wall, Bridge A

APPENDIX A2

Instrument Locations for Approach Embankment A2



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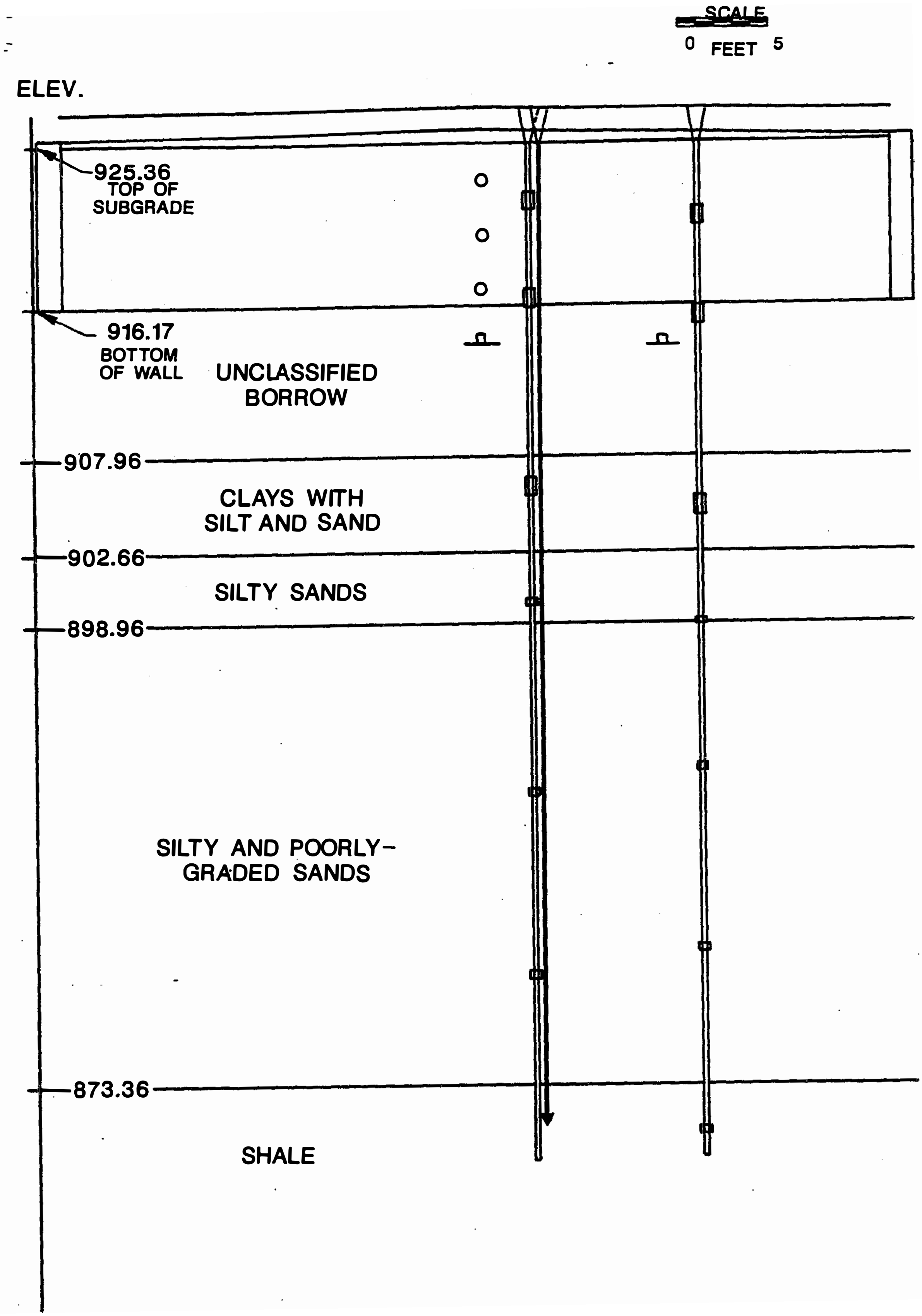

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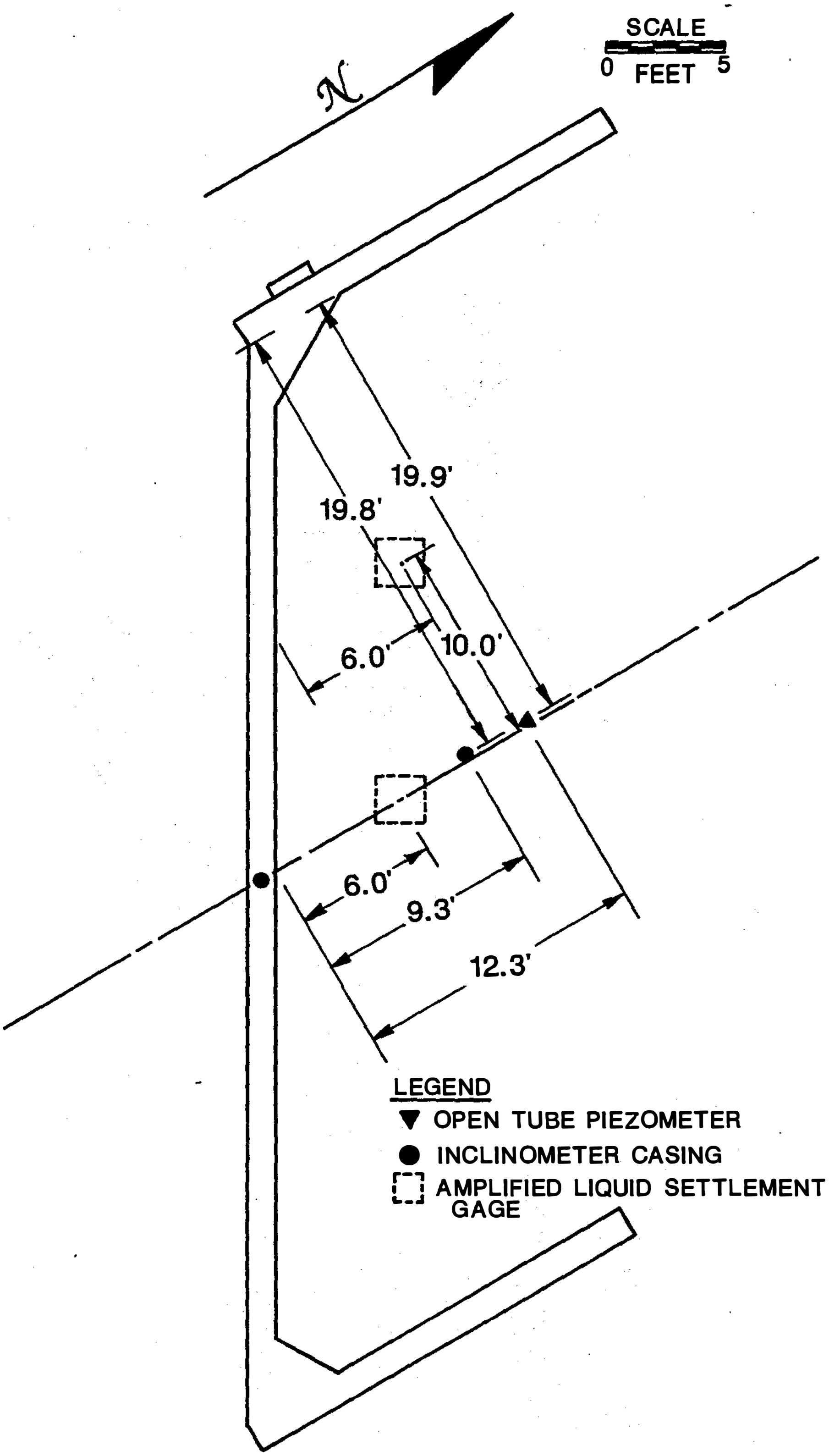

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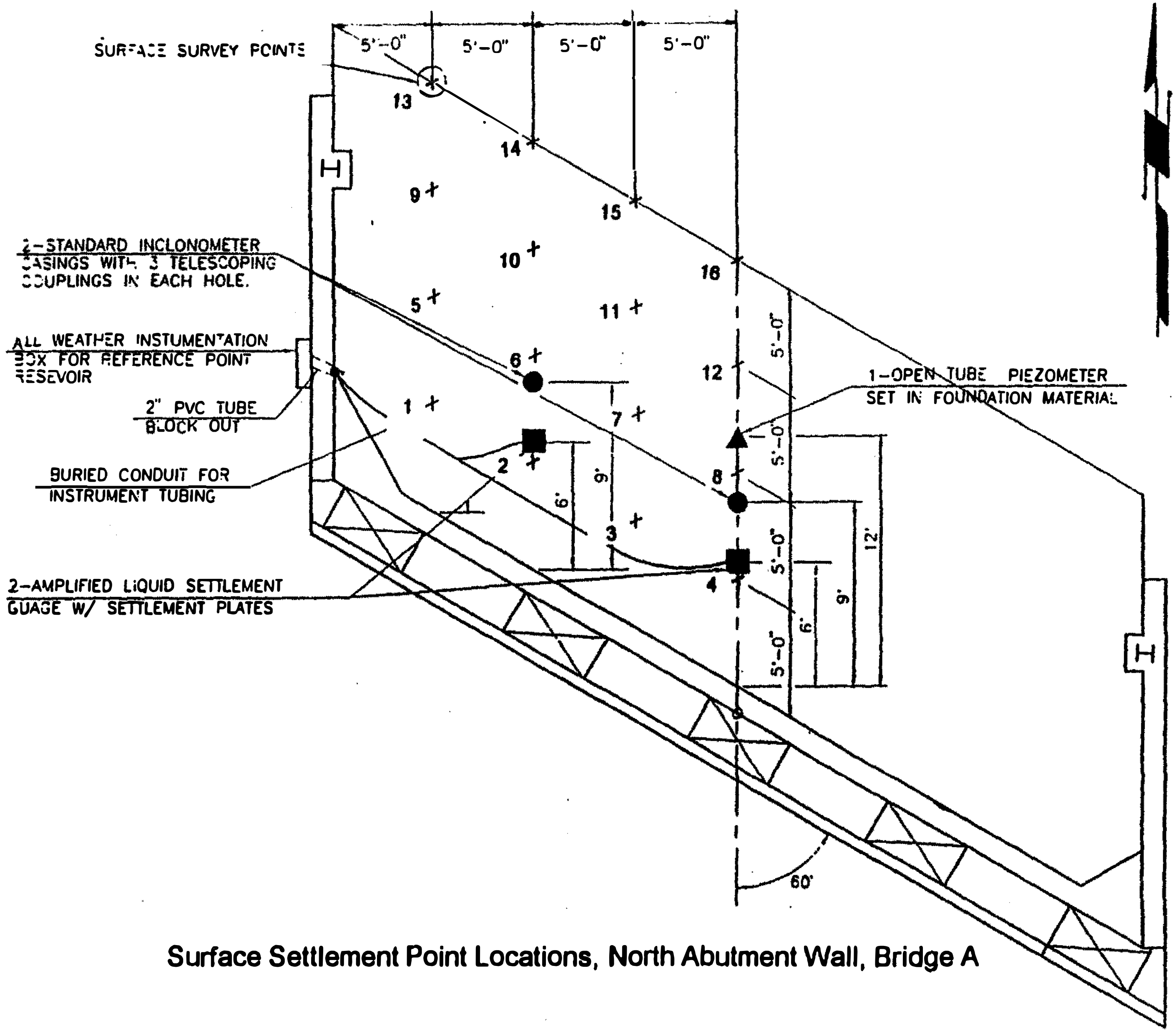
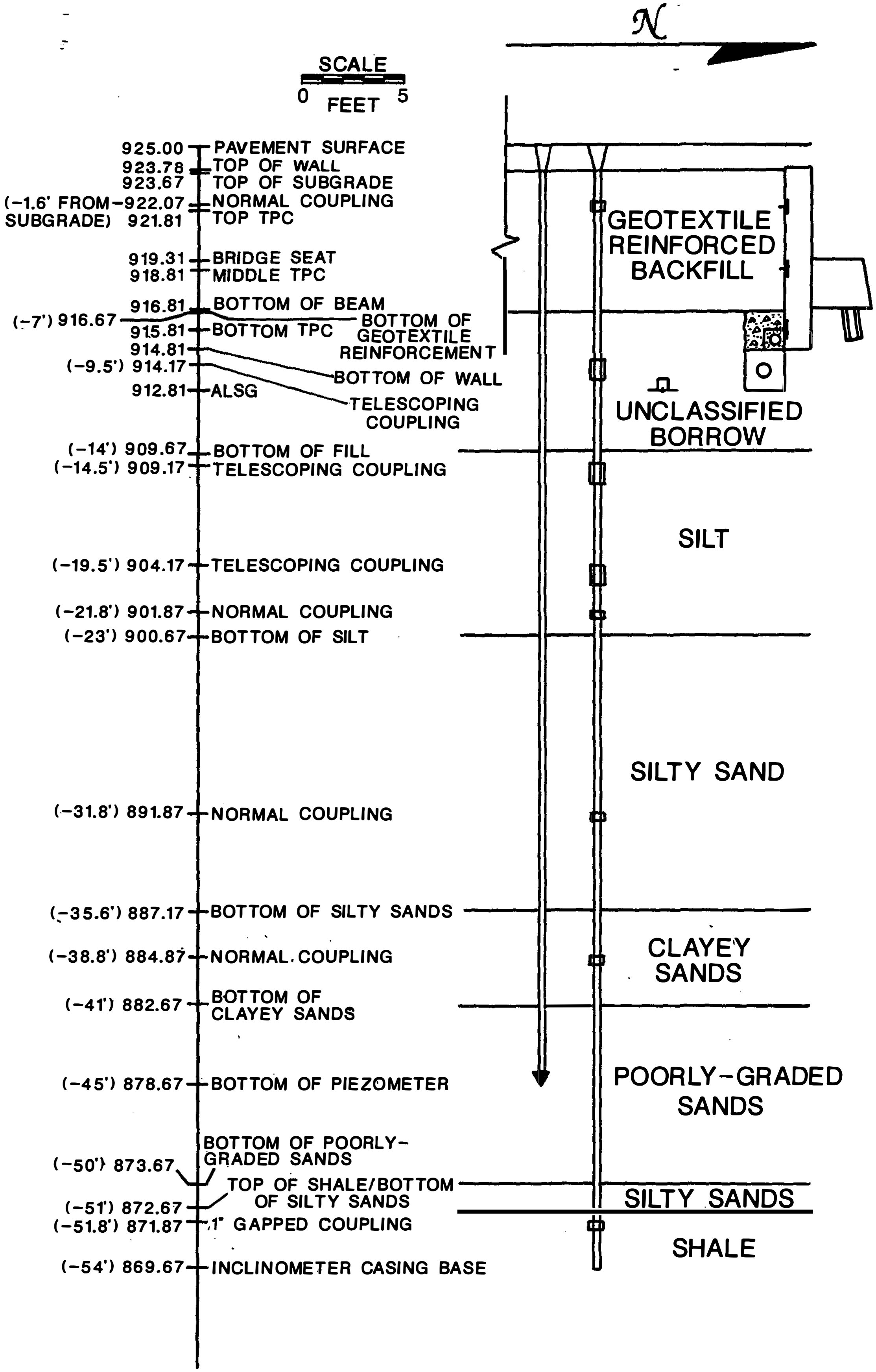


Surface Settlement Point Locations, North Abutment Wall, Bridge A

APPENDIX A3

Instrument Locations for Approach Embankment B1



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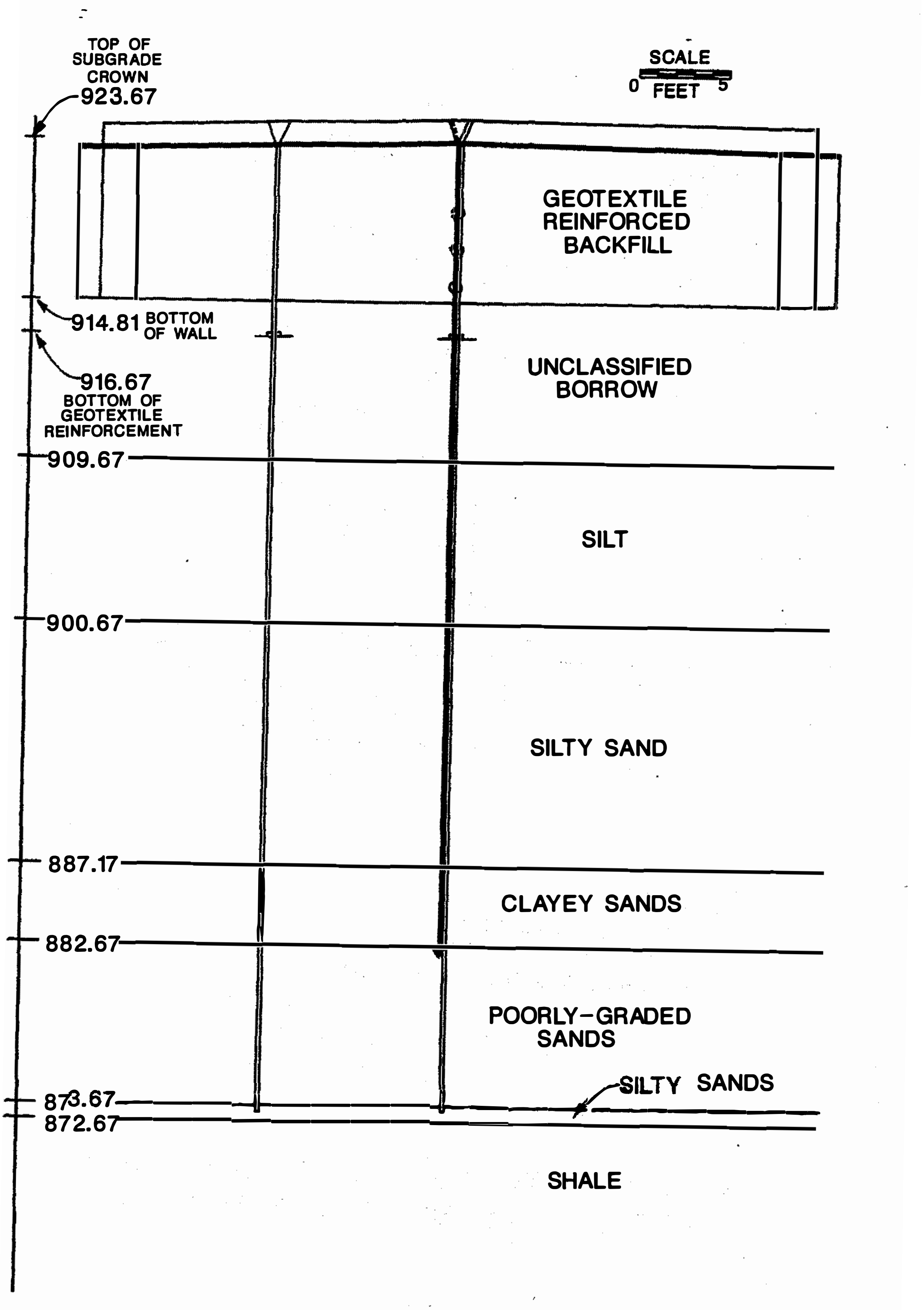

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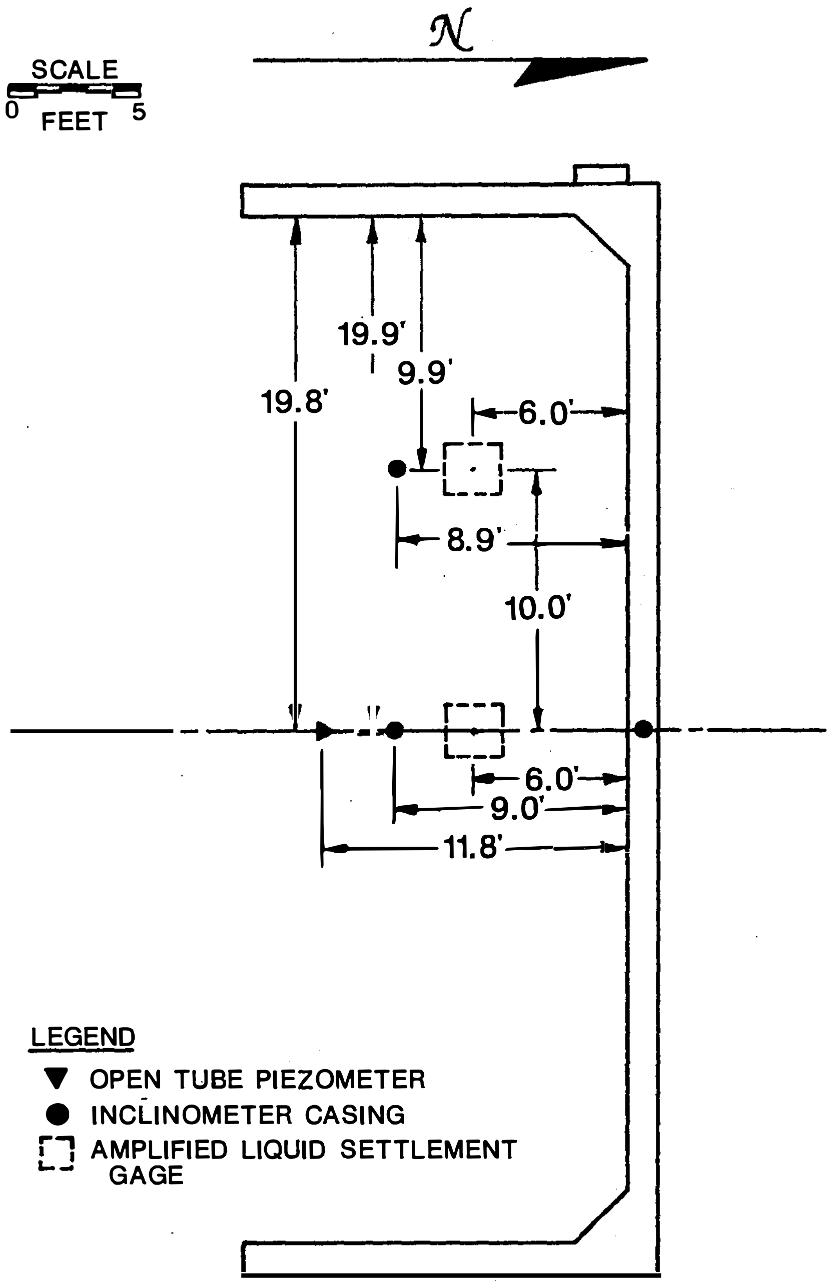

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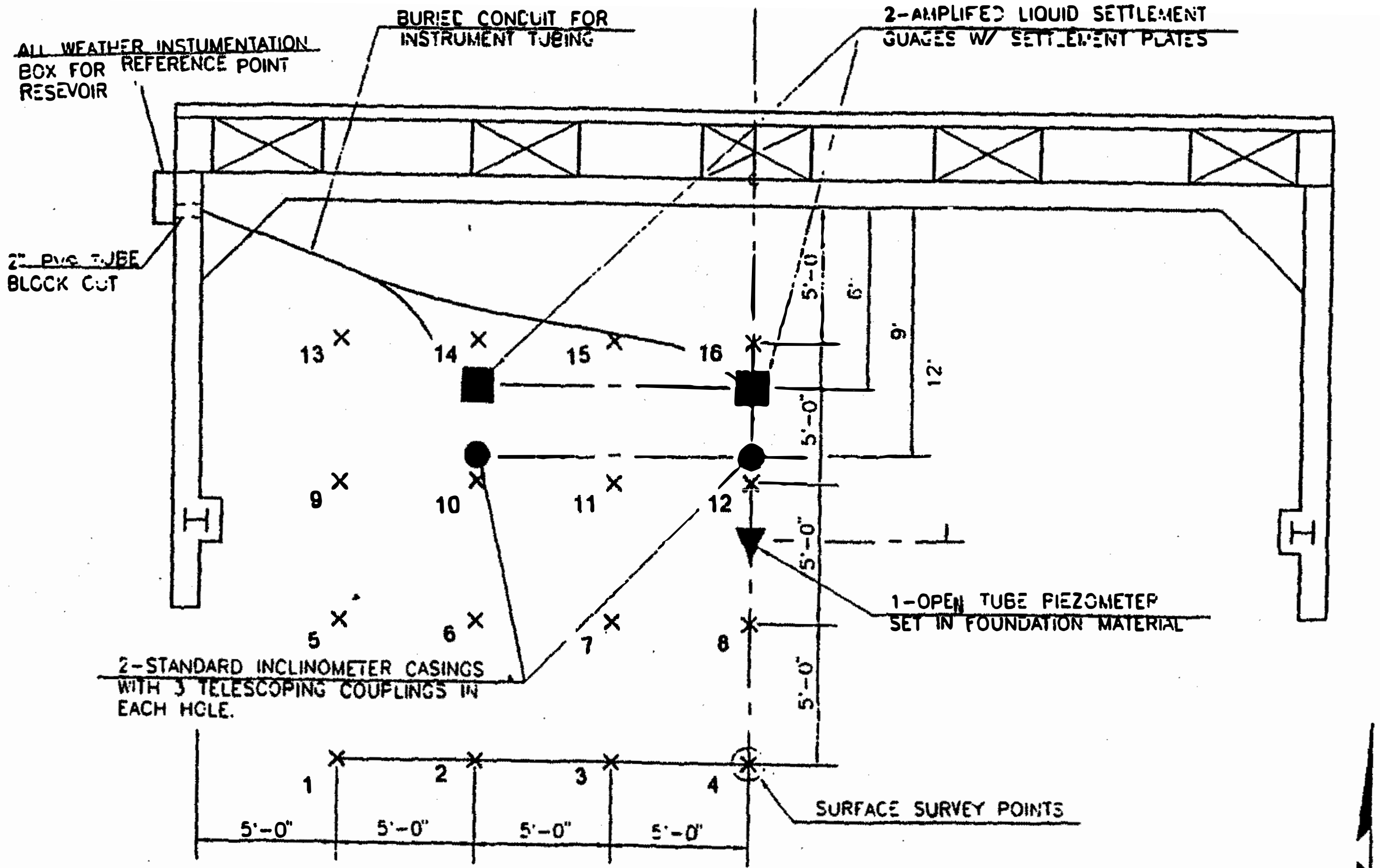
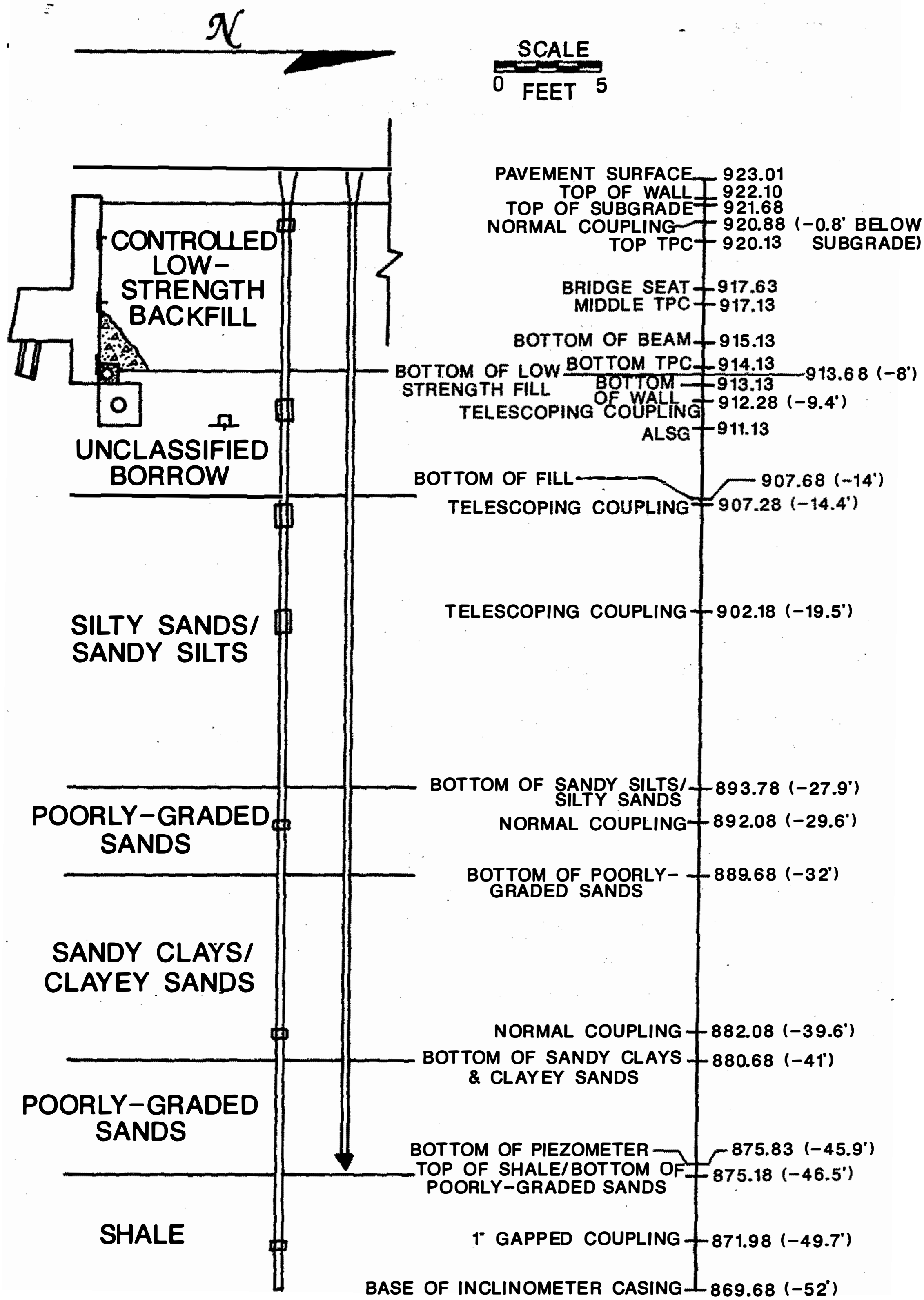


Surface Settlement Point Locations, South Abutment Wall, Bridge B

APPENDIX A4

Instrument Locations for Approach Embankment B2



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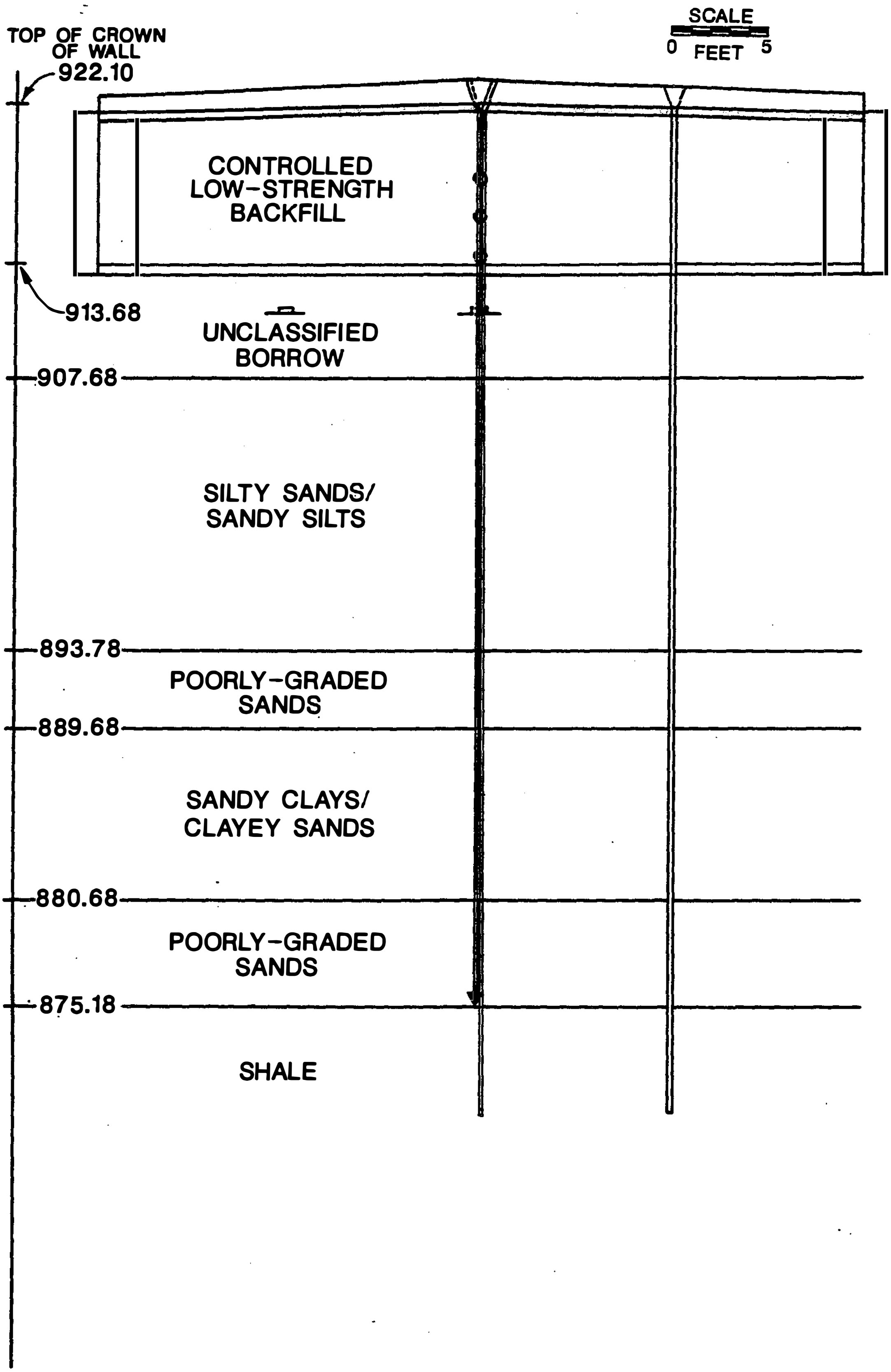

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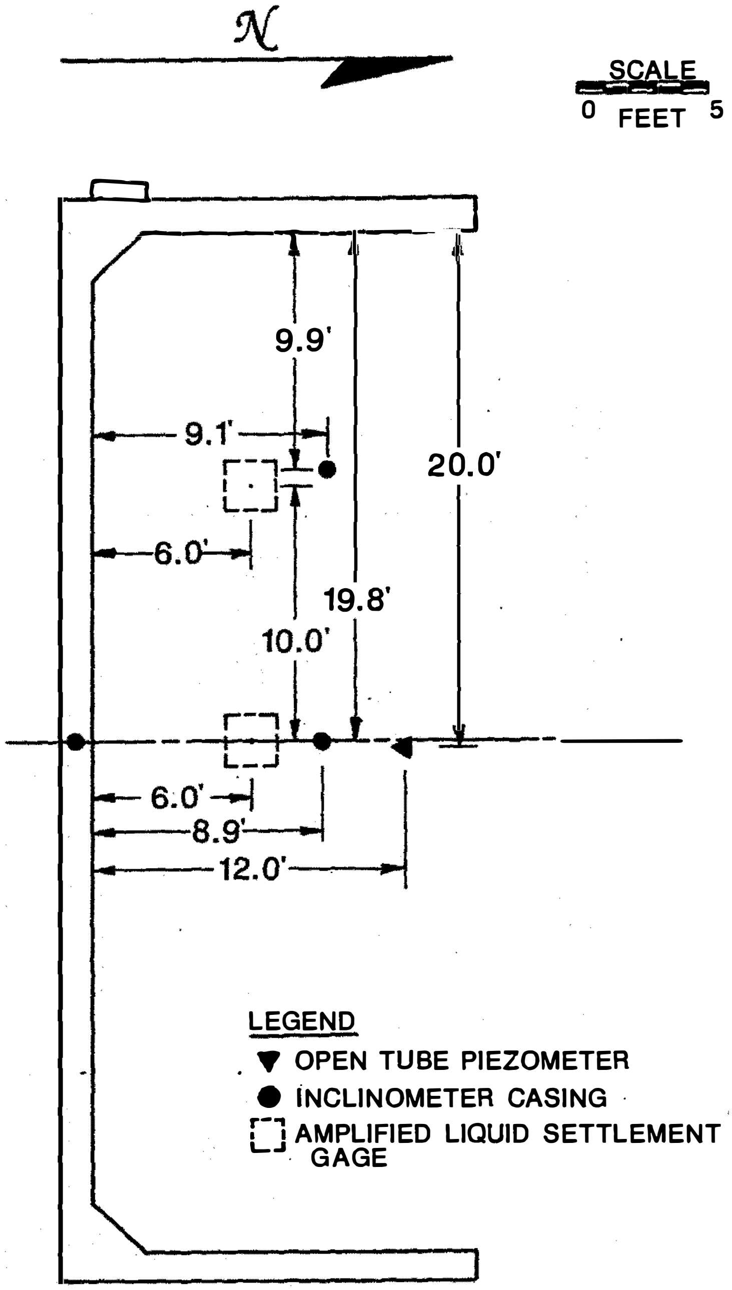

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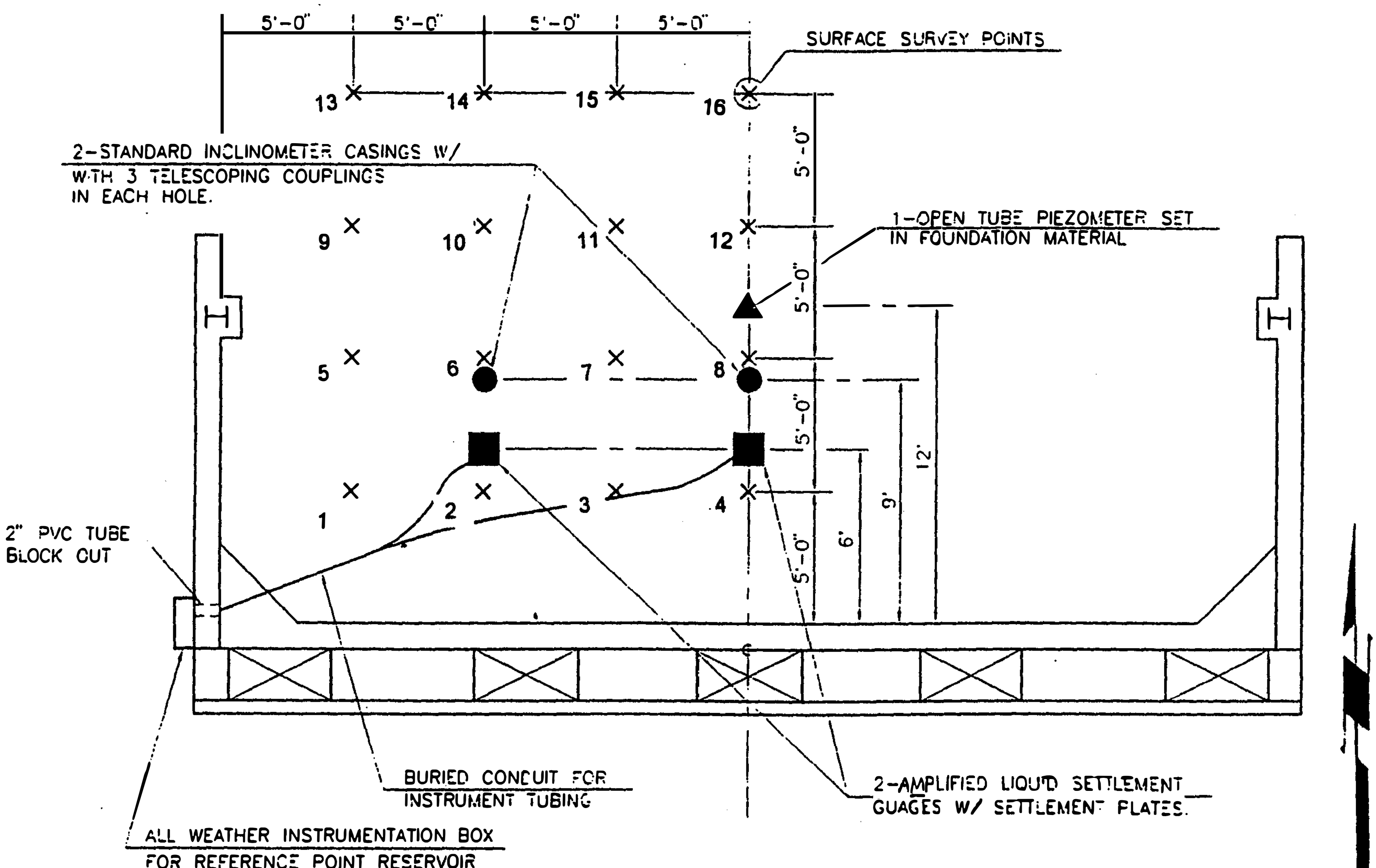
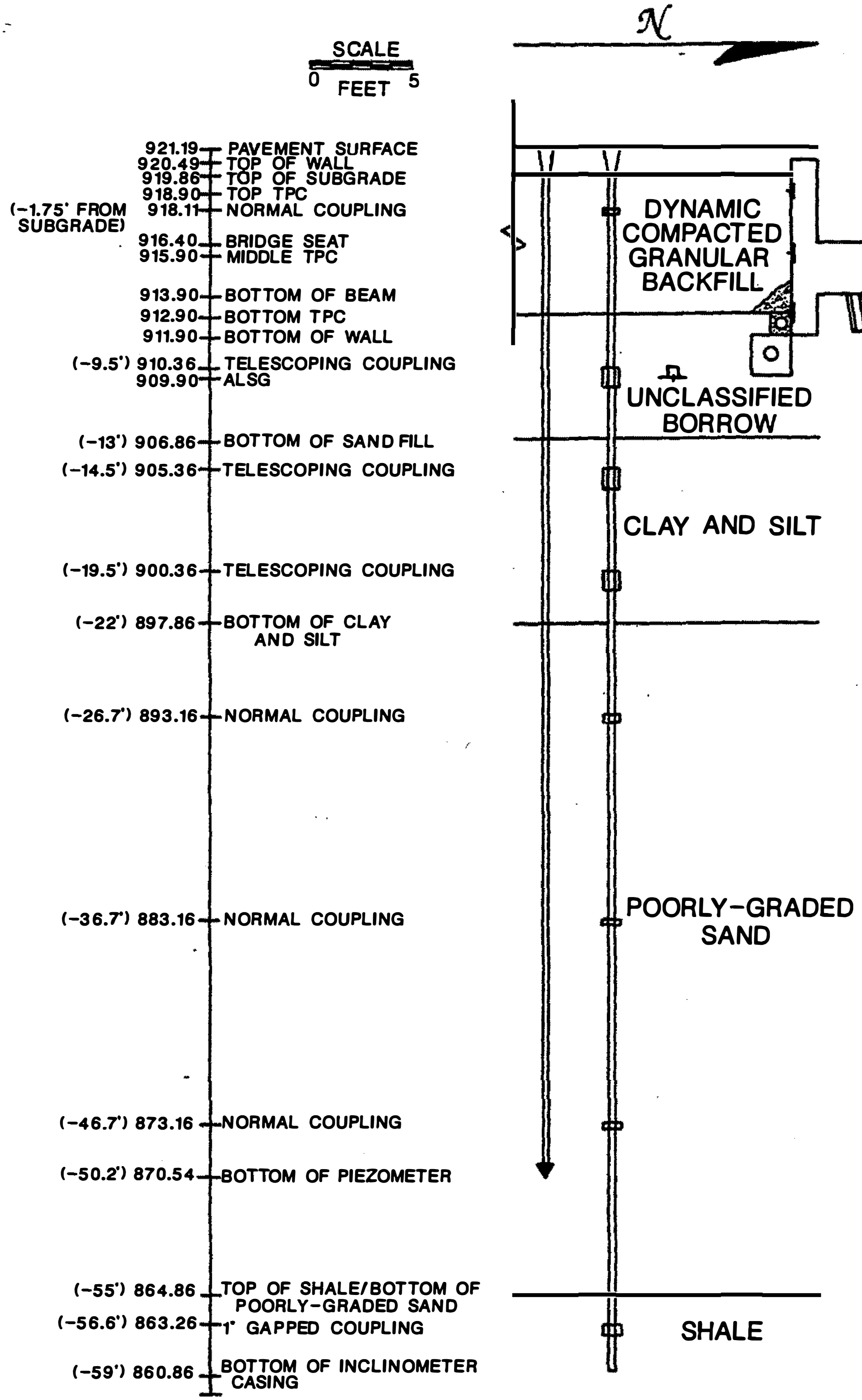


Surface Settlement Point Locations, North Abutment Wall, Bridge B

APPENDIX A5

Instrument Locations for Approach Embankment C1



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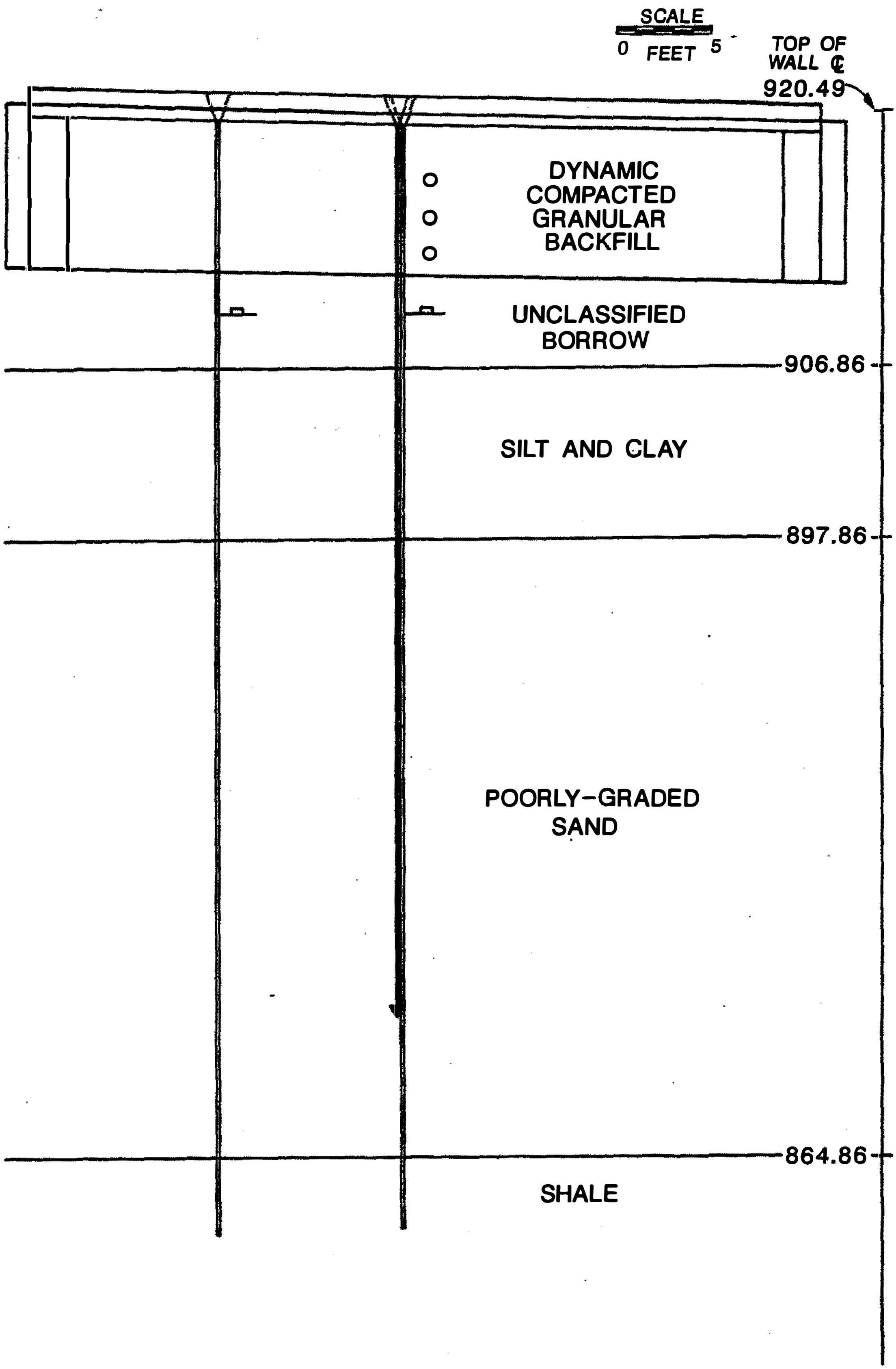

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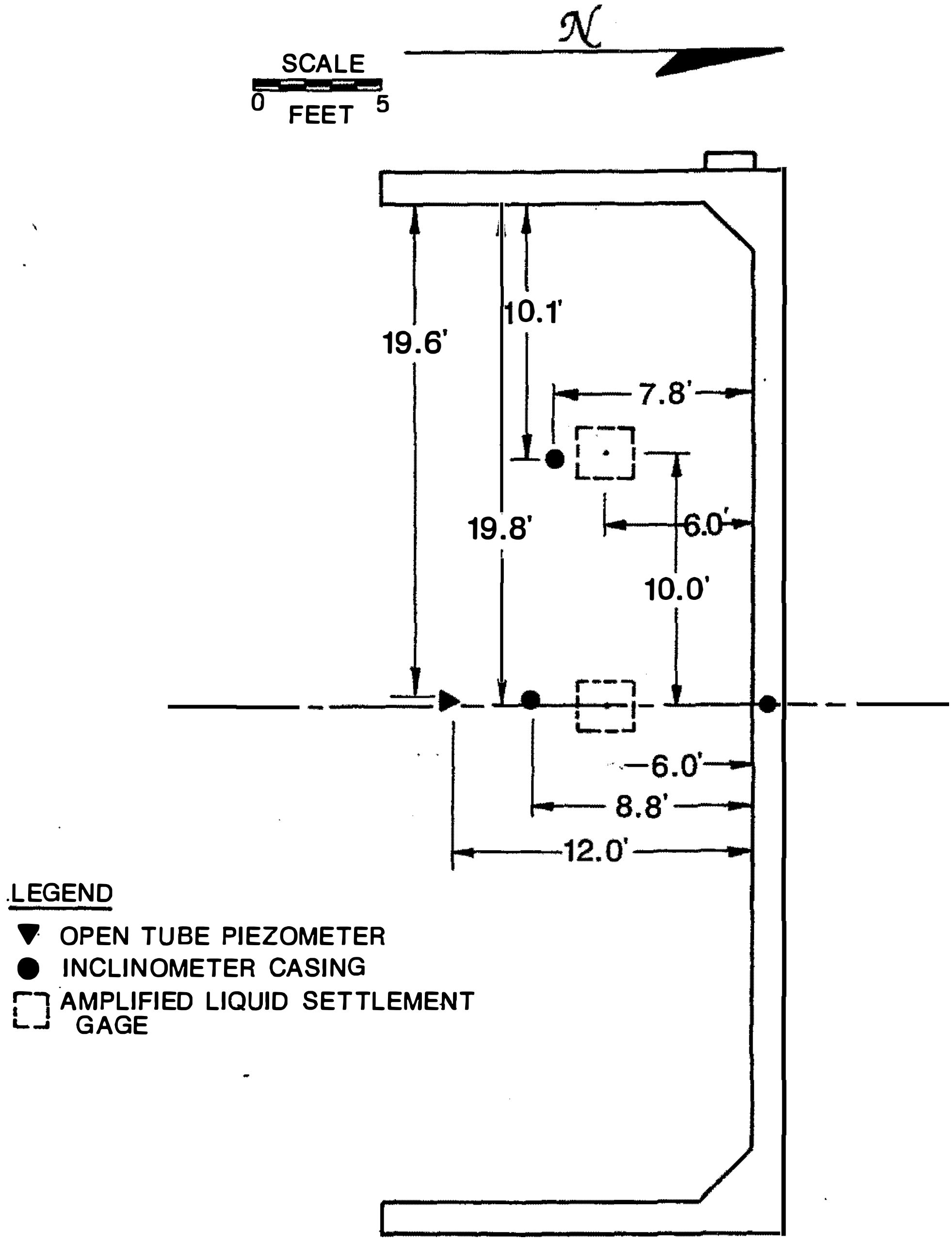
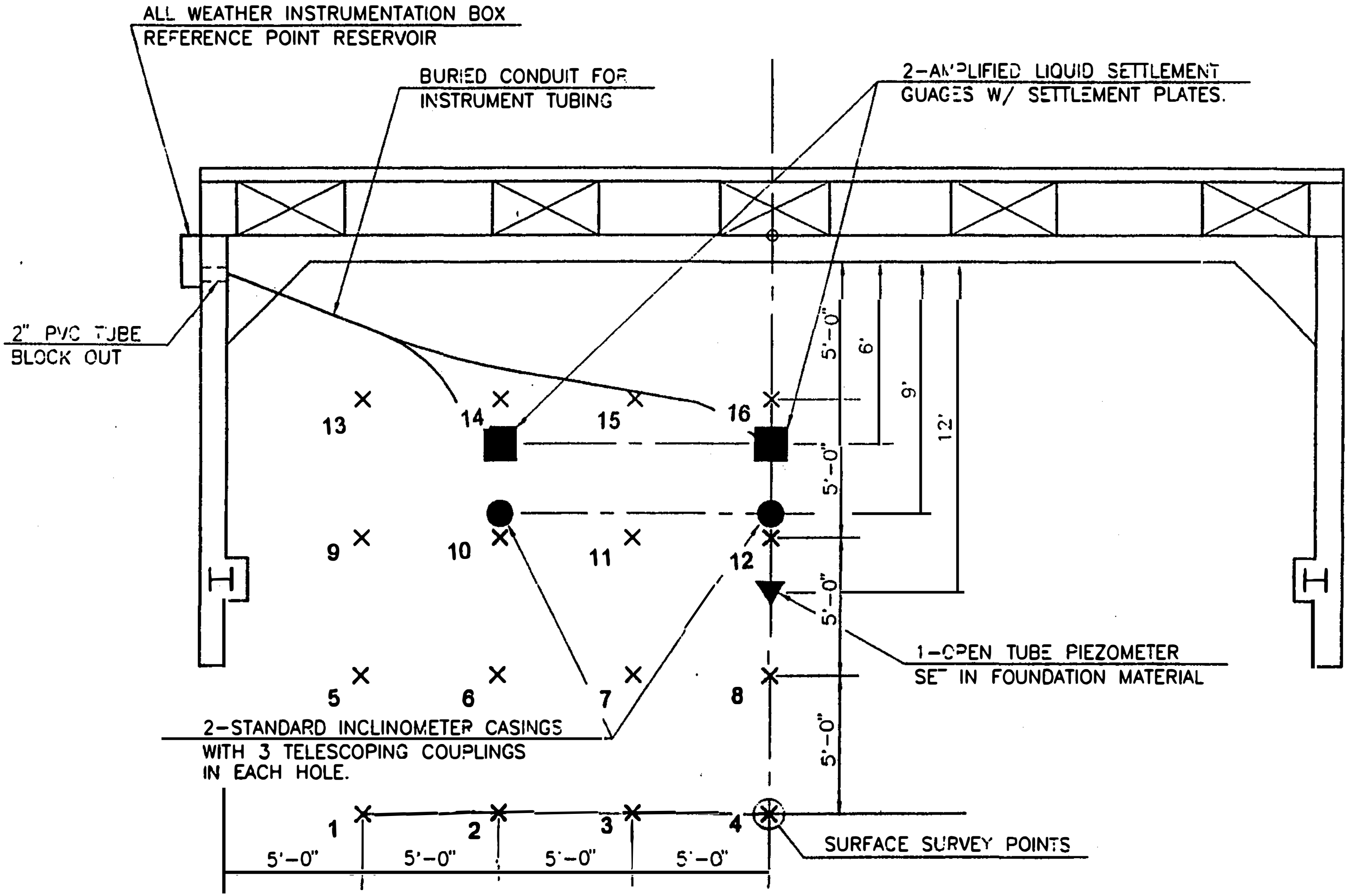


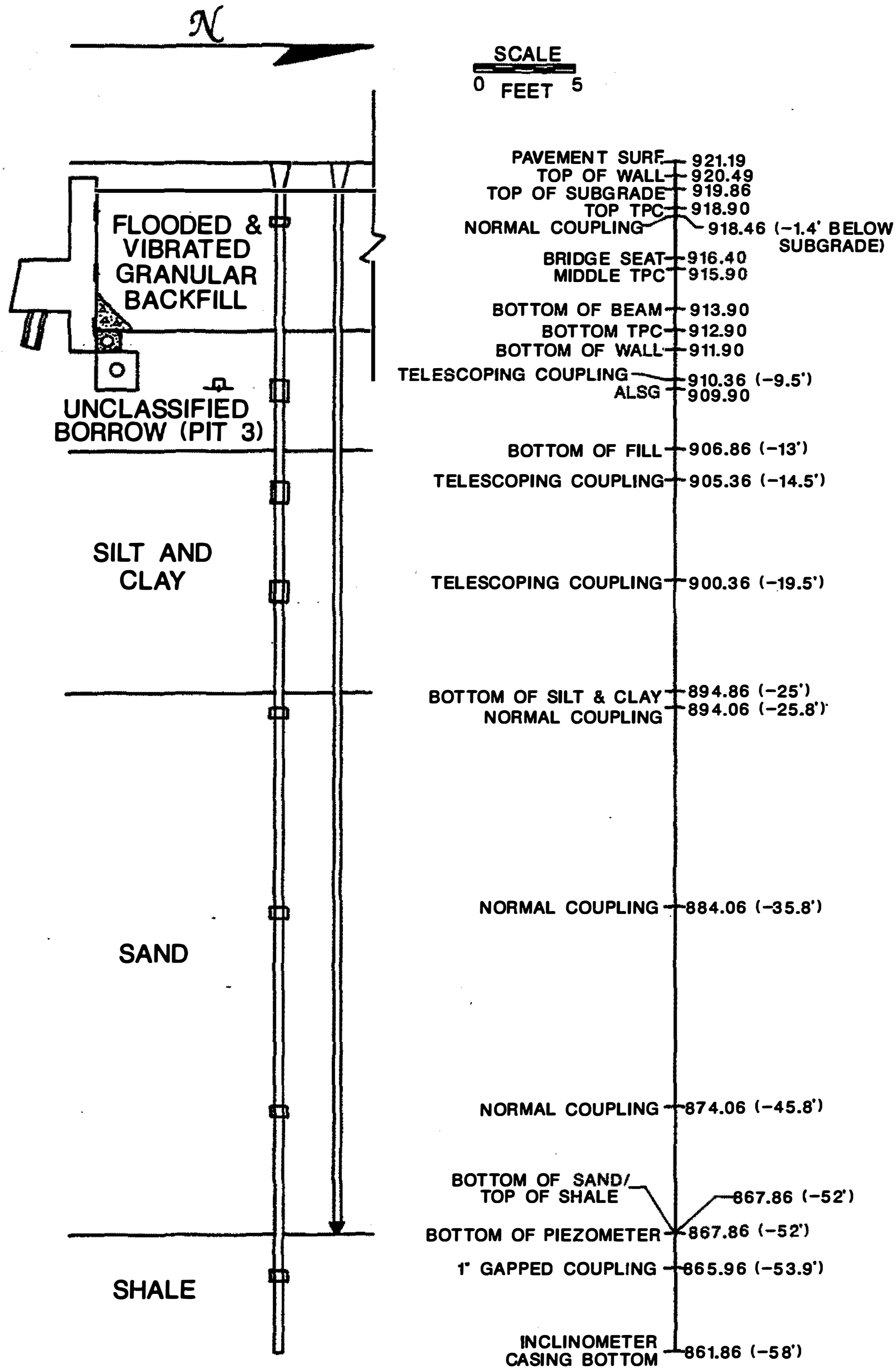
PLAN SECTION, SOUTH ABUTMENT WALL,
BRIDGE C, AS-BUILT CONDITIONS



Surface Settlement Point Locations, South Abutment Wall, Bridge C

APPENDIX A6

Instrument Locations for Approach Embankment C2



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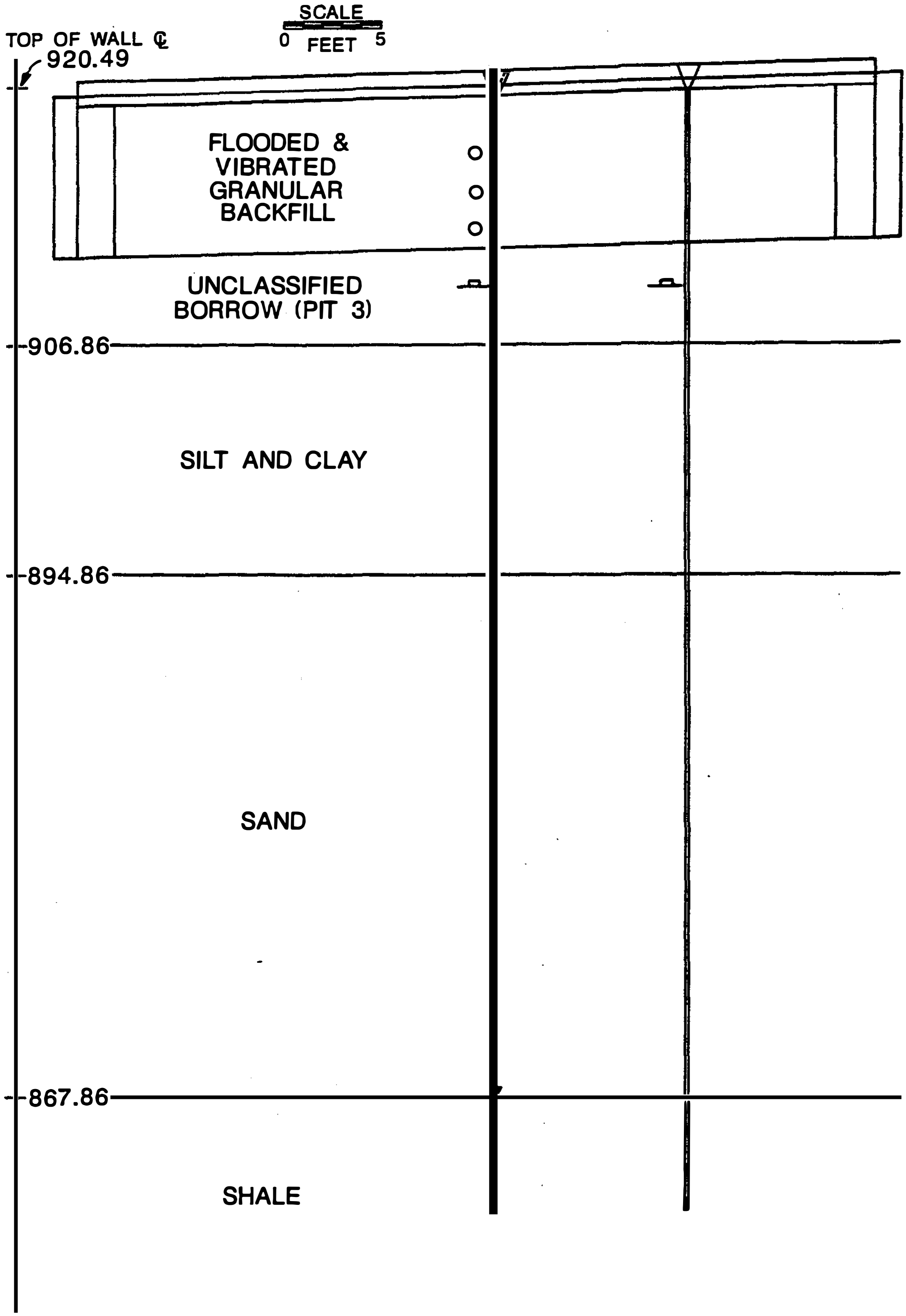

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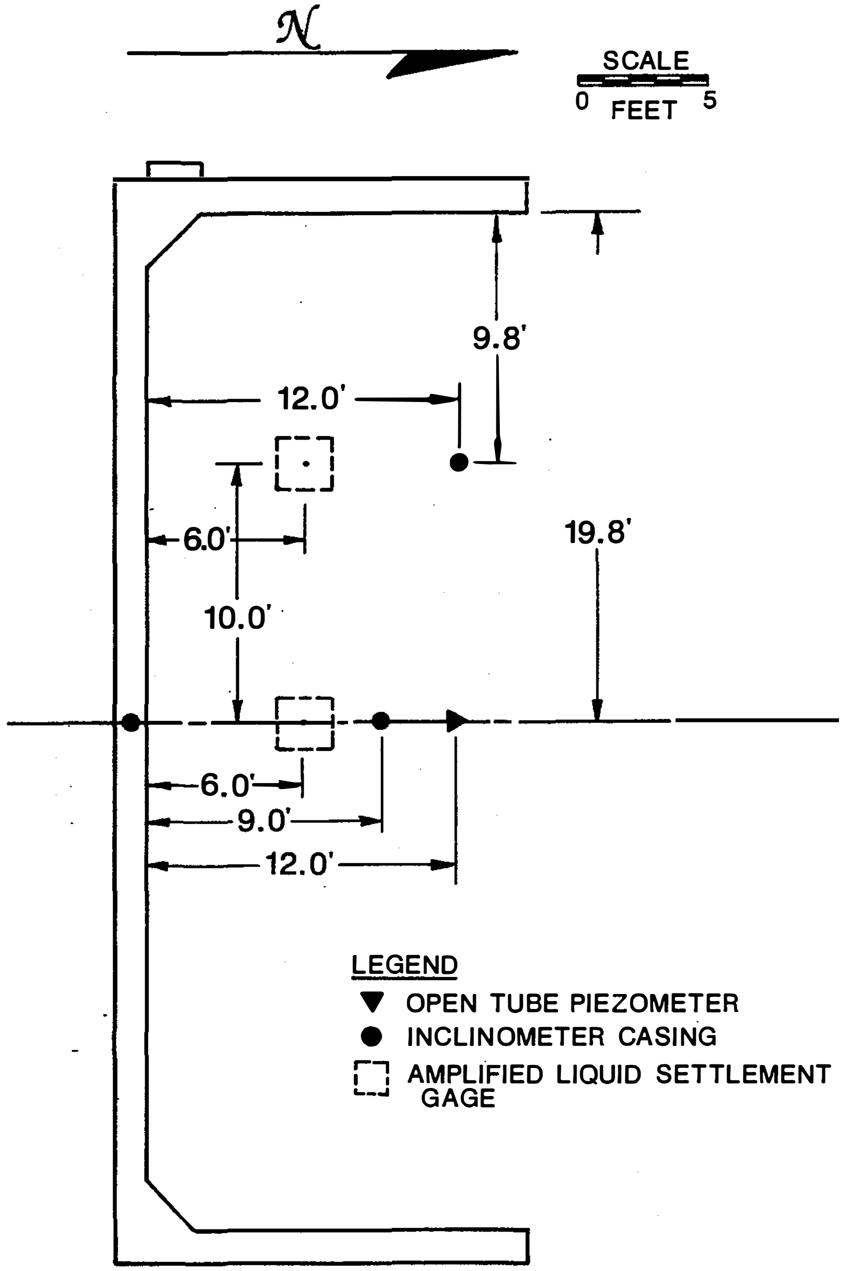
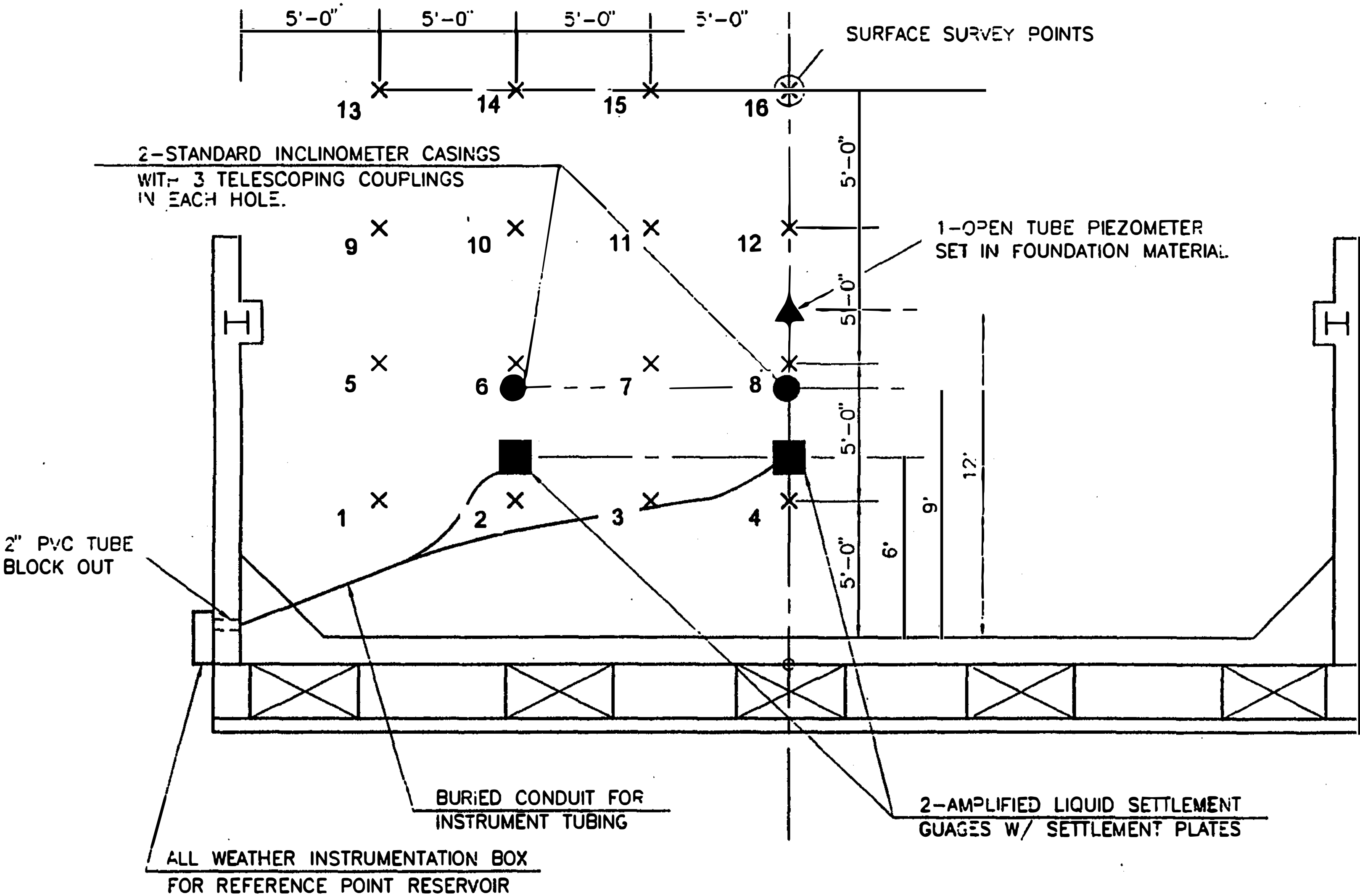


PLAN SECTION, NORTH ABUTMENT WALL, BRIDGE C, AS-BUILT CONDITIONS



Surface Settlement Point Locations, North Abutment Wall, Bridge C

APPENDIX B

MEASURED INSTRUMENTATION DATA FOR ALL APPROACH EMBANKMENTS

APPENDIX B1

Instrumentation Data for Approach Embankment A1

ODOT US177 Approach Embankment Evaluation

Bridge A, South Abutment Wall (Unclassified Borrow)

Total Pressure Cells:

	Tubing Length	Date Installed	Test Pressures 5 psi	50 psi	100 psi
Top - SN 44196	34'	5/4/95	4.56	49.50	99.63
Middle - SN 44203	37'	5/4/95	4.90	50.03	100.03
Bottom - SN 44210	40'	5/4/95	4.40	49.49	99.33

Date	Time	TPC Readings (psi) Top w/flow	Top w/o flow	Middle w/flow	Middle w/o flow	Bottom w/flow	Bottom w/o flow	Remarks
5/5/95		0.0	0.0	0.3	0.0	0.2	0.0	Initial readings by WCC, no backfill
6/19/95	AM	0.7	0.4	0.4	0.2	0.9	0.7	No backfill, drain cov. mat'l over bottom TPC
7/7/95	10:25 AM	0.9	0.6	0.5	0.3	1.0	0.7	No backfill, drain cov. mat'l over bottom TPC
7/14/95	9:40 AM	1.0	0.5	0.5	0.2	0.7	0.1	No backfill, drain cov. mat'l over bottom TPC
7/26/95	1:30 PM	0.6	0.3	2.3	2.1	2.7	2.5	Backfill placed
8/9/95	11:35 AM	0.1	0.0	2.0	1.2	2.0	1.2	
9/1/95	11:35 AM	0.3	0.1	2.8	2.6	2.7	2.5	Equip. parked adj. to wall for several weeks
9/20/95	2:25 PM	0.1	0.0	2.9	2.7	2.7	2.5	
10/11/95	2:15 PM	0.1	0.0	1.8	1.7	2.5	2.3	
11/3/95	8:50 AM	0.1	0.0	2.6	2.4	2.3	2.1	
11/22/95	9:00 AM	0.1	0.0	1.9	1.7	2.3	2.1	
12/20/95	10:00 AM	0.0	0.0	1.8	1.7	2.0	1.8	
1/11/96	9:00 AM	0.1	0.0	1.3	1.2	2.0	1.9	
2/8/96	1:00 PM	0.1	0.0	1.3	1.1	2.0	1.9	
2/29/96	1:00 PM	0.0	0.0	3.1	2.9	2.7	2.5	
3/28/96	12:30 PM	0.0	0.0	3.1	3.0	2.8	2.7	
4/23/96	10:00 AM	0.1	0.0	3.9	3.8	3.4	3.3	
5/21/96	8:00 AM	1.3	1.0	4.8	4.6	3.9	3.8	
6/11/96	2:00 PM	0.7	0.4	4.5	*	4.1	4.0	Highway opened to traffic
8/6/96	2:00 PM	1.3	1.0	5.3	*	4.3	4.2	*Cell won't hold pressure for no flow
10/31/96	1:25 PM	0.5	0.2	4.8	4.7	2.5	2.1	
12/16/96	11:35 AM	0.2	0.1	3.8	3.6	2.2	2.1	
2/27/97	11:50 AM	0.2	0.1	3.6	3.3	2.8	2.6	

ODOT US177 Approach Embankment Evaluation

Bridge A, South Abutment Wall (Unclassified Borrow)

Amplified Liquid Settlement Gages:

	Tubing Length	Date Installed	As Built Elevation Top of Plate	Top of Fluid
Centerline - SN 44224	40'	5/4/95	919.55'	930.72'
			Initial Head = 11.17'	

Calibration for: Centerline

$$\text{Head(ft)} = \frac{\text{Reading} - (-3.415 \text{ psi})}{8.425 \text{ psi / ft}}$$

ALSG Readings, Heads, & ΔH

Date	Time	CL Reading psi	CL Head ft	ΔH ft	Remarks
5/5/95		90.7	11.171	-	Initial readings by WCC, no backfill, reference reading (datum)
6/19/95	AM	90.6	11.159	-0.012	No backfill
7/7/95	10:25 AM	90.7	11.171	0.000	No backfill
7/14/95	9:40 AM	90.8	11.183	0.012	No backfill
7/26/95	1:30 PM	91.4	11.254	0.083	Backfill placed
8/9/95	11:35 AM	91.6	11.278	0.107	
9/1/95	11:35 AM	91.6	11.278	0.107	Equip. parked over backfill
9/20/95	1:25 PM	91.6	11.277	0.106	
10/11/95	2:15 PM	92.0	11.325	0.154	
11/3/95	8:50 AM	92.0	11.325	0.154	
11/22/95	9:00 AM	92.1	11.337	0.166	
12/20/95	10:00 AM	92.4	11.373	0.202	
1/11/96	9:00 AM	91.6	11.278	0.107	
2/8/96	1:00 PM	92.0	11.325	0.154	
2/29/96	1:00 PM	92.0	11.325	0.154	
3/28/96	12:30 PM	91.4	11.254	0.083	
4/23/96	9:50 AM	91.9	11.313	0.142	
5/21/96	8:10 AM	91.8	11.301	0.130	
6/11/96	2:00 PM	92.2	11.349	0.178	Highway opened to traffic
8/6/96	1:00 PM	91.8	11.301	0.130	
10/31/96	1:25 PM	91.3	11.242	0.071	
12/16/96	11:35 AM	92.5	11.385	0.214	
2/27/97	11:50 AM	92.5	11.385	0.214	

ODOT US177 Approach Embankment Evaluation

Bridge A, South Abutment Wall (Unclassified Borrow)

Inclinometer Telescoping Couplings - Centerline: Installed 7/25/95

Casing Elevation (top=2.60' above GS): 933.50' As Built → 931.94' After Paving

GS Elevation 930.92' **Pavement Elevation** 932.46'

Reference Coupling 54.08' Depth → 876.84' Elevation **Bottom of Casing** 56.5'

Readings, Changes, & ΔH Values

Date	Time	Level 1 (Top)			Level 2			Level 3			Level 4			Level 5 (Bottom)		
		Reading R1, ft	R5 - R1 ft	ΔH ft	Reading R2, ft	R5 - R2 ft	ΔH ft	Reading R3, ft	R5 - R3 ft	ΔH ft	Reading R4, ft	R5 - R4 ft	ΔH ft	Reading R5, ft	ΔR5 ft	ΔH ft
7/26/95	1:30 PM	9.125	47.555	-	13.140	43.540	-	23.650	33.030	-	34.160	22.520	-	56.680	-	-
8/9/95	11:35 AM	9.125	47.550	0.005	13.140	43.535	0.005	23.645	33.030	0.000	34.150	22.525	-0.005	56.675	0.005	0.005
9/1/95	11:35 AM	9.125	47.538	0.017	13.140	43.523	0.017	23.640	33.023	0.007	34.147	22.516	0.004	56.663	0.017	0.017
9/20/95	1:25 PM	9.120	47.545	0.010	13.137	43.528	0.012	23.640	33.025	0.005	34.147	22.518	0.002	56.665	0.015	0.015
10/11/95	2:15 PM	9.125	47.535	0.020	13.140	43.520	0.020	23.640	33.020	0.010	34.145	22.515	0.005	56.660	0.020	0.020
11/3/95	8:50 AM	9.115	47.550	0.005	13.130	43.535	0.005	23.633	33.032	-0.002	34.137	22.528	-0.008	56.665	0.015	0.015
11/22/95	9:00 AM	9.115	47.538	0.017	13.130	43.523	0.017	23.630	33.023	0.007	-	-	-	56.653	0.027	0.027
12/20/95		9.110	47.535	0.020	13.120	43.525	0.015	23.625	33.020	0.010	34.237	22.408	0.112	56.645	0.035	0.035
1/11/96	9:00 AM	9.110	47.535	0.020	13.120	43.525	0.015	23.623	33.022	0.008	34.133	22.512	0.008	56.645	0.035	0.035
2/8/96	1:00 PM	9.110	47.525	0.030	13.123	43.512	0.028	23.623	33.012	0.018	34.133	22.502	0.018	56.635	0.045	0.045
2/29/96	1:00 PM	9.109	47.531	0.024	13.120	43.520	0.020	23.624	33.016	0.014	34.130	22.510	0.010	56.640	0.040	0.040
3/28/96	12:50 PM	9.110	47.527	0.028	13.120	43.517	0.023	23.620	33.017	0.013	34.133	22.504	0.016	56.637	0.043	0.043
4/23/96	9:50 AM	9.110	47.525	0.030	13.123	43.512	0.028	23.625	33.010	0.020	34.133	22.502	0.018	56.635	0.045	0.045
5/21/96	8:10 AM	9.110	47.500	0.055	13.115	43.495	0.045	23.615	32.995	0.035	34.120	22.490	0.030	56.610	0.070	0.070
6/11/96	2:00 PM	9.110	47.500	0.055	13.120	43.490	0.050	23.619	32.991	0.039	34.108	22.502	0.018	56.610	0.070	0.070
8/6/96	2:00 PM	9.110	47.487	0.068	13.120	43.477	0.063	23.623	32.974	0.056	34.117	22.480	0.040	56.597	0.083	0.083
10/31/96	1:25 PM	9.105	47.480	0.075	13.110	43.475	0.065	23.616	32.969	0.061	34.105	22.480	0.040	56.585	0.095	0.095
12/16/96	11:35 AM	9.100	47.493	0.062	13.107	43.486	0.054	23.615	32.978	0.052	34.100	22.493	0.027	56.593	0.087	0.087
2/27/97	11:50 AM	9.103	47.482	0.073	13.105	43.480	0.060	23.610	32.975	0.055	34.100	22.485	0.035	56.585	0.095	0.095

ODOT US177 Approach Embankment Evaluation

Bridge A, South Abutment Wall (Unclassified Borrow)

Piezometer:

Standpipe Elevation	932.93'	→	931.93'
*As Built ► (Top=2.05 ft above GS)	(As Built)		(After Paving)

GS Elevation 930.92'
(Top of Subgrade)

Pavement Elevation 932.46'
(Top of Pavement)

Tip Elevation 888.92'

Tip Depth 42.0'

Groundwater Depth = Piezometer Reading + 0.53' (0.53' = Diff. between standpipe and pavement)
(Below Top of Pavement)

Groundwater Elevation = Standpipe Elevation (931.93') - Piezometer Reading

Piezometer Data

Date	Time	Reading ft	GW Depth ft	GW Elev. ft	Remarks
7/25/95	PM	-	-	-	Installed piezometer
7/26/95	1:30 PM	37.93	35.88	897.62	Initial reading by OSU
8/9/95	11:35 AM	33.63	31.58	901.92	
9/1/95	11:35 AM	38.78	36.73	896.77	
9/20/95	1:25 PM	40.18	38.13	895.37	
10/11/95	2:15 PM	40.64	38.59	894.91	
11/3/95	8:50 AM	41.08	39.03	894.47	
11/22/95	9:00 AM	41.30	39.25	894.25	
12/20/95		41.20	39.15	894.35	Surveyed elevations established
1/11/96	9:00 AM	41.12	39.07	894.43	
2/8/96	1:00 PM	41.17	39.12	894.38	
2/29/96	1:00 PM	41.48	39.43	894.07	
3/28/96	12:50 PM	41.42	39.37	894.13	
4/23/96	10:00 AM	41.60	39.55	893.95	
5/21/96	8:10 AM	40.88	41.41	891.05	Use new standpipe elev., changed reference for depth
6/11/96	2:00 PM	40.17	40.70	891.76	Highway opened to traffic
8/6/96	1:00 PM	40.12	40.65	891.81	
10/31/96	1:25 PM	39.51	40.04	892.42	
12/16/96	11:35 AM	38.845	39.38	893.09	
2/27/97	11:50 AM	36.687	37.22	895.24	

ODOT US177 Approach Embankment Evaluation

Bridge A, South Abutment Wall (Unclassified Borrow), Surface Setlement Points

Date		6/12/96		8/6/96		10/31/96		2/28/97		
		Reading	Elevation	Reading	Elevation	Reading	Elevation	Reading	Elevation	
BM		W E	934.30	W E	934.30	W E	934.30	W E	934.30	
BS		2.5	-	2.570	-	3.418	-	3.138	-	
HI		936.80	-	936.87	-	937.72	-	937.438	-	
FS	1	4.80	932.00	4.882	931.988	5.754	931.964	5.480	931.958	
	2	4.69	932.11	4.787	932.083	5.644	932.074	5.366	932.072	
	3	4.61	932.19	4.695	932.175	5.548	932.170	5.273	932.165	
	4	4.52	932.28	4.604	932.266	5.455	932.263	5.183	932.255	
	5	4.80	932.00	4.874	931.996	5.748	931.970	5.473	931.965	
	6	4.69	932.11	4.783	932.087	5.639	932.079	5.364	932.074	
	7	4.61	932.19	4.690	932.180	5.542	932.176	5.278	932.160	*2/27/1997
	8	4.53	932.27	4.614	932.256	5.469	932.249	5.200	932.238	
	9	4.79	932.01	4.866	932.004	5.739	931.979	5.463	931.975	
	10	4.68	932.12	4.775	932.095	5.632	932.086	5.356	932.082	
	11	4.59	932.21	4.674	932.196	5.529	932.189	5.254	932.184	
	12	4.52	932.28	4.615	932.255	5.466	932.252	5.195	932.243	
	13	4.80	932.00	4.879	931.991	5.750	931.968	5.463	931.975	
	14	4.68	932.12	4.784	932.086	5.638	932.080	5.364	932.074	
	15	4.58	932.22	4.675	932.195	5.530	932.188	5.258	932.180	
	16	4.50	932.30	4.588	932.282	5.445	932.273	5.173	932.265	

*Settlement Reading Point is missing.

APPENDIX B2

Instrumentation Data for Approach Embankment A2

ODOT US177 Approach Embankment Evaluation

Bridge A, North Abutment Wall (Control Section-Unclassified Borrow)

Total Pressure Cells:

	Tubing Length	Date Installed	Test Pressures 5 psi	50 psi	100 psi
Top - SN 44201	34'	4/25/95	5.10	50.18	100.50
Middle - SN 44207	37'	4/25/95	5.37	50.41	100.51
Bottom - SN 44213	40'	4/25/95	5.34	50.41	100.47

Date	Time	TPC Readings (psi) Top w/flow	w/o flow	Middle w/flow	w/o flow	Bottom w/flow	w/o flow	Remarks	
4/25/95	PM	0.0	-	0.0	-	0.0	-	No Backfill	T=40 degrees C
4/27/95	AM	0.0	-	0.0	-	0.1	-	No Backfill	T=50 degrees C
4/27/95	5:35 PM	0.0	-	0.0	-	0.0	-	No Backfill	T=60 degrees C
4/28/95	8:50 AM	0.0	-	0.0	-	0.0	-		T=50 degrees C
4/28/95	3:30 PM	0.1	0.0	0.7	0.4	1.3	1.5		T=60 degrees C
5/1/95	AM	0.1	0.0	0.4	0.0	0.8	0.7		
5/10/95	AM	0.2	0.1	1.7	1.6	1.3	1.2	Unclassified Borrow Backfill Complete	
5/15/95	AM	0.4	0.2	1.3	1.2	1.2	1.1		
5/19/95	AM	0.3	0.1	1.5	1.4	1.3	1.2		
5/31/95	PM	0.2	0.0	1.6	1.5	1.5	1.4		
6/19/95	AM	1.0	0.9	1.7	1.7	2.1	2.0	W. side of approach used for access to bridge	
6/28/95	PM	0.9	0.8	1.9	1.8	2.1	2.0		
7/7/95	10:50 AM	1.3	1.3	2.0	1.9	2.2	2.1		
7/14/95	10:05 AM	1.6	1.5	2.1	2.0	2.2	2.1		
7/26/95	12:40 PM	1.3	1.2	2.2	2.1	2.1	2.0		
8/9/95	7:35 AM	1.3	1.2	2.1	2.0	1.9	1.8		
9/1/95	7:45 AM	1.6	1.5	2.3	2.2	2.2	2.1		
9/20/95	2:25 PM	1.0	0.9	2.2	2.1	2.0	1.9	T = 21 degrees C	
10/11/95	3:15 PM	1.5	1.4	1.6	1.5	1.8	1.7	T = 34 degrees C	
11/3/95	9:45 AM	0.7	0.5	2.2	2.1	1.9	1.8		
11/22/95	10:00 AM	0.7	0.6	1.8	1.8	1.8	1.7		
12/20/95	10:30 AM	0.5	0.4	1.6	1.5	1.5	1.4		
1/11/96	10:00 AM	0.6	0.5	1.4	1.3	1.5	1.4		
2/8/96	2:00 PM	1.1	1.0	1.1	1.0	1.4	1.3		
2/29/96	2:00 PM	1.1	1.0	2.0	1.9	1.5	1.4		
3/28/96	1:00 PM	1.1	1.0	1.8	1.7	1.5	1.4		
4/23/96	9:00 AM	1.1	1.0	2.1	2.0	1.5	1.4		
5/21/96	8:30 AM	1.9	1.8	2.3	2.2	1.8	1.7		
6/11/96	1:00 PM	2.1	2.0	1.6	1.5	1.4	1.3	Highway Opened to Traffic	
8/6/96	2:00 PM	2.4	2.3	1.9	1.8	1.1	1.0		
10/31/96	12:45 PM	1.6	1.4	2.0	1.9	0.6	0.5		
12/16/96	11:00 AM	1.1	1.0	1.8	1.7	0.4	0.3		
2/27/97	11:10 AM	1.3	1.2	1.6	1.5	0.3	0.2		

ODOT US177 Approach Embankment Evaluation

Bridge A, North Abutment Wall (Control Section-Unclassified Borrow)

Amplified Liquid Settlement Gages:	Tubing Length	Date Installed	As Built Elevation Top of Plate	As Built Elevation Top of Fluid
Centerline - SN 44217	40'	4/28/95	914.21'	925.10'
			Initial Head = 10.89'	
Offset - SN 44223	30'	4/28/95	914.12'	925.11'
			Initial Head = 10.99'	

Calibration for: Centerline

Head(ft) Reading - (-5.24 psi)
8.44 psi / ft

Offset

Head(ft) Reading - (-2.08 psi)
8.50 psi / ft

ALSG Readings, Heads, & ΔH

Date	Time	CL Reading psi	CL Head ft	CL ΔH ft	OFS Reading psi	OFS Head ft	OFS ΔH ft	Remarks
4/28/95	7:45 AM	87.6	11.000	-	91.5	11.009	-	Reference Reading (Datum)
4/28/95	11:10 AM	87.2	10.953	-0.047	91.5	11.009	0.000	
4/28/95	3:15 PM	87.7	11.012	0.012	91.5	11.009	0.000	
5/1/95	8:25 AM	87.6	11.000	0.000	91.4	10.998	-0.011	
5/10/95	AM	87.7	11.012	0.012	91.7	11.033	0.024	Unc. Borrow Backfill complete
5/12/95	AM	88.2	11.071	0.071	91.5	11.009	0.000	
5/19/95	AM	87.9	11.036	0.036	91.4	10.998	-0.011	
5/31/95	PM	88.5	11.107	0.107	91.6	11.021	0.012	
6/19/95	AM	88.7	11.130	0.130	92.1	11.080	0.071	
6/28/95	PM	88.9	11.154	0.154	92.1	11.080	0.071	
7/7/95	10:50 AM	88.8	11.142	0.142	91.8	11.045	0.036	
7/14/95	10:05 AM	88.2	11.071	0.071	91.7	11.033	0.024	
7/26/95	12:40 PM	89.0	11.166	0.166	92.0	11.068	0.059	
8/9/95	7:35 AM	88.5	11.107	0.107	91.7	11.033	0.024	
9/1/95	7:45 AM	88.8	11.142	0.142	91.9	11.056	0.047	
9/20/95	2:25 PM	89.1	11.178	0.178	92.2	11.092	0.083	T = 21 degrees C
10/11/95	3:15 PM	89.5	11.225	0.225	94.4	11.351	0.342	
11/3/95	9:45 AM	89.4	11.213	0.213	92.5	11.127	0.118	
11/22/95	10:00 AM	89.6	11.237	0.237	92.8	11.162	0.153	
12/20/95	10:30 AM	89.9	11.273	0.273	93.0	11.186	0.177	
1/11/96	10:00 AM	90.3	11.320	0.320	93.1	11.198	0.189	
2/8/96	2:00 PM	90.6	11.355	0.355	93.1	11.198	0.189	
2/29/96	2:00 PM	90.0	11.284	0.284	93.0	11.186	0.177	
3/28/96	1:00 PM	90.1	11.296	0.296	93.1	11.198	0.189	
4/23/96	9:00 AM	90.0	11.284	0.284	93.2	11.209	0.200	
5/21/96	8:30 AM	89.8	11.261	0.261	93.0	11.186	0.177	
6/11/96	1:00 PM	90.0	11.284	0.284	93.1	11.198	0.189	Highway Opened to Traffic
8/6/96	2:00 PM	89.8	11.261	0.261	92.8	11.162	0.153	
10/31/96	12:45 PM	89.5	11.225	0.225	92.7	11.151	0.142	
12/16/96	11:00 AM	90.2	11.308	0.308	93.5	11.245	0.236	
2/27/97	11:10 AM	90.4	11.332	0.332	93.6	11.256	0.247	

ODOT US177 Approach Embankment Evaluation

Bridge A, North Abutment Wall (Control Section-Unclassified Borrow)

Inclinometer Telescoping Couplings - Centerline: Installed 5/16/95

Casing Elevation (top=1.83' above GS): 927.41' As Built → 926.64' After Paving

GS Elevation 925.58' **Pavement Elevation** 926.99'

Reference Coupling 53.74' Depth → 871.84' Elevation **Bottom of Casing** 55.34'

Readings, Changes, & ΔH Values

Date	Time	Level 1 (Top)			Level 2			Level 3			Level 4 (Bottom)			Remarks
		Reading R1, ft	R4 - R1 ft	ΔH ft	Reading R2, ft	R4 - R2 ft	ΔH ft	Reading R3, ft	R4 - R3 ft	ΔH ft	Reading R4, ft	ΔR4 ft	ΔH ft	
6/1/95	PM	4.113	51.407	-	9.634	45.886	-	20.124	35.396	-	55.520	-	-	Omit this Data set
6/19/95	PM	4.103	51.469	0.000	9.634	45.938	0.000	20.134	35.438	0.000	55.572	0.000	0.000	Reference Reading (Datum)
6/28/95	PM	4.115	51.375	0.094	9.630	45.860	0.078	20.125	35.365	0.073	55.490	0.082	0.082	
7/7/95	10:50 AM	4.110	51.460	0.009	9.635	45.935	0.003	20.125	35.445	-0.007	55.570	0.002	0.002	
7/14/95	9:40 AM	4.110	51.380	0.089	9.640	45.850	0.088	20.130	35.360	0.078	55.490	0.082	0.082	
7/26/95	12:40 PM	4.105	51.455	0.015	9.633	45.927	0.011	20.125	35.435	0.003	55.560	0.012	0.012	
8/9/95	7:55 AM	4.110	51.450	0.019	9.635	45.925	0.013	20.125	35.435	0.003	55.560	0.012	0.012	
9/1/95	7:45 AM	4.105	51.245	0.224	9.640	45.710	0.228	20.230	35.120	0.318	55.350	0.222	0.222	
9/20/95	2:25 PM	4.100	51.370	0.099	10.060	45.410	0.528	20.127	35.343	0.095	55.470	0.102	0.102	
10/11/95	3:15 PM	4.105	51.445	0.024	9.637	45.913	0.025	20.130	35.420	0.018	55.550	0.022	0.022	
11/3/95	9:45 AM	4.097	51.448	0.021	9.625	45.920	0.018	20.120	35.425	0.013	55.545	0.027	0.027	
11/22/95	10:00 AM	4.100	51.370	0.099	9.625	45.845	0.093	20.125	33.345	0.093	55.470	0.102	0.102	
12/20/95	10:30 AM	4.100	51.370	0.099	9.620	45.850	0.088	20.120	35.350	0.088	55.470	0.102	0.102	
1/11/96	10:00 AM	4.095	51.372	0.097	9.627	45.840	0.098	20.117	35.350	0.088	55.467	0.105	0.105	
2/8/96	2:00 PM	4.100	51.367	0.102	9.630	45.837	0.101	20.120	35.347	0.091	55.467	0.105	0.105	
2/29/96	2:00 PM	4.094	51.446	0.023	9.629	45.911	0.027	20.119	5.421	0.017	55.540	0.032	0.032	
3/28/96	1:00 PM	4.100	51.365	0.104	9.627	45.838	0.100	20.120	35.345	0.093	55.465	0.107	0.107	*(-0.29) for diff. b/w cutoff*
4/23/96	10:30 AM	4.095	51.365	0.104	9.625	45.835	0.103	20.113	35.347	0.091	55.460	0.112	0.112	*length and ext.*
5/21/96	8:30 AM	4.385	51.360	0.109	9.913	45.832	0.106	20.410	35.335	0.103	55.745	0.117	0.117	New reference (top) using ext.

6/11/96	1:00 PM	4.393	51.417	0.052	9.910	45.900	0.038	20.408	35.402	0.036	55.810	0.052	0.052	Highway opened to traffic
8/6/96	2:00 PM	4.394	51.416	0.053	9.915	45.895	0.043	20.407	35.403	0.035	55.810	0.052	0.052	
10/31/96	12:45 PM	4.385	51.345	0.124	9.903	45.827	0.111	20.400	35.330	0.108	55.730	0.132	0.132	
12/16/96	11:00 AM	4.385	51.420	0.049	9.905	45.900	0.038	20.403	35.402	0.036	55.805	0.057	0.057	
2/27/97	11:10 AM	4.390	51.410	0.059	9.903	45.897	0.041	20.403	35.397	0.041	55.800	0.062	0.062	

ODOT US177 Approach Embankment Evaluation

Bridge A, North Abutment Wall (Control Section-Unclassified Borrow)

Inclinometer Telescoping Couplings - Offset: Installed 5/18/95

Casing Elevation (top=1.95' above GS): 927.54' As Built → 926.52' After Paving

GS Elevation 925.59' **Pavement Elevation** 926.69'

Reference Coupling 53.65' Depth → 871.94' Elevation **Bottom of Casing** 55.22'

Readings, Changes, & ΔH Values

Date	Time	Level 1 (Top)			Level 2			Level 3			Level 4 (Bottom)			Remarks
		Reading R1, ft	R4 - R1 ft	ΔH ft	Reading R2, ft	R4 - R2 ft	ΔH ft	Reading R3, ft	R4 - R3 ft	ΔH ft	Reading R4, ft	ΔR4 ft	ΔH ft	
6/1/95	PM	5.103	50.437	-	10.582	44.958	-	21.051	34.489	-	55.540	-	-	Omit this Data set
6/19/95	PM	5.103	50.500	0.000	10.582	45.021	0.000	21.051	34.552	0.000	55.603	0.000	0.000	Reference Reading (Datum)
6/28/95	PM	5.100	50.495	0.005	10.580	45.015	0.006	21.050	34.545	0.007	55.595	0.008	0.008	
7/7/95	10:50 AM	5.105	50.495	0.005	10.585	45.015	0.006	21.050	34.550	0.002	55.600	0.003	0.003	
7/14/95	9:40 AM	5.100	50.500	0.000	10.580	45.020	0.001	21.050	34.550	0.002	55.600	0.003	0.003	
7/26/95	12:40 PM	5.105	50.490	0.010	10.583	45.012	0.009	21.050	34.545	0.007	55.595	0.008	0.008	
8/9/95	7:55 AM	5.105	50.490	0.010	10.580	45.015	0.006	21.050	34.545	0.007	55.595	0.008	0.008	
9/1/95	7:45 AM	5.105	50.490	0.010	10.583	45.012	0.009	21.047	34.548	0.004	55.595	0.008	0.008	
9/20/95	2:25 PM	5.103	50.420	0.080	10.577	44.946	0.075	21.045	34.478	0.074	55.523	0.080	0.080	
10/11/95	3:15 PM	5.107	50.483	0.017	10.580	45.010	0.011	21.047	34.543	0.009	55.590	0.013	0.013	
11/3/95	9:45 AM	5.095	50.488	0.012	10.573	45.010	0.011	21.040	34.543	0.009	55.583	0.020	0.020	
11/22/95	10:00 AM	5.095	50.428	0.072	10.567	44.956	0.065	21.040	34.483	0.069	55.523	0.080	0.080	
12/20/95	10:30 AM	5.125	50.485	0.015	10.595	45.015	0.006	21.065	34.545	0.007	55.610	0.007	-0.007	
1/11/96	10:00 AM	5.095	50.428	0.072	10.563	44.960	0.061	21.033	34.490	0.062	55.523	0.080	0.080	
2/8/96	2:00 PM	5.095	50.428	0.072	10.567	44.956	0.065	21.035	34.488	0.064	55.523	0.080	0.080	
2/29/96	2:00 PM	5.095	50.425	0.075	10.563	44.957	0.064	21.030	34.490	0.062	55.520	0.083	0.083	
3/28/96	1:00 PM	5.093	50.427	0.073	10.565	44.955	0.066	21.033	34.487	0.065	55.520	0.083	0.083	*(-0.16) for diff. b/w cutoff*
4/23/96	10:30 AM	5.093	50.422	0.078	10.565	44.950	0.071	21.137	34.378	0.174	55.515	0.088	0.088	*length and ext.*
5/21/96	8:30 AM	5.245	50.405	0.095	10.700	44.950	0.071	21.165	34.485	0.067	55.650	0.113	0.113	New reference (top) using ext.

6/11/96	1:00 PM	5.254	50.288	0.212	10.600	44.942	0.079	21.064	34.478	0.074	55.542	0.221	0.221	Highway opened to traffic
8/6/96	2:00 PM	5.267	50.283	0.217	10.607	44.943	0.078	21.075	34.475	0.077	55.550	0.213	0.213	
10/31/96	12:45 PM	5.250	50.345	0.155	10.588	45.007	0.014	21.056	34.539	0.013	55.595	0.168	0.168	
12/16/96	11:00 AM	5.250	50.340	0.160	10.585	45.005	0.016	21.053	34.537	0.015	55.590	0.173	0.173	
2/27/97	11:10 AM	5.250	50.345	0.155	10.585	45.010	0.011	21.050	34.545	0.007	55.595	0.168	0.168	

ODOT US177 Approach Embankment Evaluation

Bridge A, North Abutment Wall (Control Section-Unclassified Borrow)

Piezometer:

	Standpipe Elevation	928.10'	926.65'
*As Built ►	(Top=2.44 ft above GS)	(As Built)	(After Paving)

GS Elevation 925.66'
(Top of Subgrade)

Pavement Elevation 926.99'
(Top of Pavement)

Tip Elevation 880.66'

Tip Depth 45.0'

Groundwater Depth = Piezometer Reading + 0.34'
(Below Top of Pavement)

Groundwater Elevation = Standpipe Elevation (926.65') - Piezometer Reading

Date	**Time**	**Piezometer Data** Reading ft	GW Depth ft	GW Elev. ft	**Remarks**
5/17/95	PM	-	-	-	Installed piezometer
5/23/95	AM	33.50	31.06	894.60	Initial reading by OSU
5/31/95	AM	31.65	29.21	896.45	
6/19/95	PM	29.60	27.16	898.50	
6/28/95	PM	30.55	28.11	897.55	
7/7/95	10:25 AM	30.38	27.94	897.72	
7/14/95	9:40 AM	31.39	28.95	896.71	
7/26/95	12:40 PM	31.90	29.46	896.20	
8/9/95	7:55 AM	27.90	25.46	900.20	
9/1/95	7:45 AM	31.80	29.36	896.30	
9/20/95	2:25 PM	33.41	30.97	894.69	
10/11/95	3:15 PM	33.96	31.52	894.14	
11/3/95	9:45 AM	34.52	32.08	893.58	
11/22/95	10:00 AM	34.72	32.28	893.38	
12/20/95	10:30 AM	34.96	32.52	893.14	
1/11/96	10:00 AM	35.09	32.65	893.01	
2/8/96	2:00 PM	35.33	32.89	892.77	
2/29/96	2:00 PM	35.465	33.025	892.64	
3/28/96	1:00 PM	35.57	33.13	892.53	
4/23/96	10:30 AM	35.73	33.29	892.37	
5/21/96	8:30 AM	34.51	34.85	892.14	Use new standpipe elev., changed reference for depth
6/11/96	1:00 PM	33.95	34.29	892.70	Highway opened to traffic
8/6/96	2:00 PM	33.47	33.81	893.18	
10/31/96	12:45 PM	33.175	33.515	893.48	
12/16/96	11:00 AM	32.750	33.090	893.90	
2/27/97	11:10 AM	32.485	32.825	894.17	

ODOT US177 Approach Embankment Evaluation

'Bridge A, North Abutment Wall (Control Section-Unclassified Borrow), Surface Settlement Points

Date		6/12/96		8/6/96		10/31/96		2/27/97	
		Reading	Elevation	Reading	Elevation	Reading	Elevation	Reading	Elevation
BM		W		W		W		W	
		E	929.06	E	929.06	E	929.06	E	929.06
BS		2.42	-	2.730	-	3.448	-	3.252	-
HI		931.48	-	931.79	-	932.51	-	932.312	-
FS	1	4.80	926.68	5.110	926.680	5.842	926.666	5.650	926.662
	2	4.67	926.81	5.024	926.766	5.746	926.762	5.560	926.752
	3	4.55	926.93	4.889	926.901	5.613	926.895	5.422	926.890
	4	4.46	927.02	4.787	927.003	5.512	926.996	5.322	926.990
	5	4.81	926.67	5.127	926.663	5.860	926.648	5.665	926.647
	6	4.70	926.78	5.053	926.737	5.778	926.730	5.590	926.722
	7	4.59	926.89	4.923	926.867	5.644	926.864	5.452	926.860
	8	4.50	926.98	4.835	926.955	5.556	926.952	5.364	926.948
	9	4.83	926.65	5.147	926.643	5.878	926.630	5.702	926.610
	10	4.72	926.76	5.058	926.732	5.785	926.723	5.590	926.722
	11	4.60	926.88	4.930	926.860	5.655	926.853	5.464	926.848
	12	4.50	926.98	4.820	926.970	5.543	926.965	5.354	926.958
	13	4.85	926.63	4.162	927.628	5.887	926.621	5.715	926.597
	14	4.73	926.75	5.073	926.717	5.796	926.712	5.605	926.707
	15	4.62	926.86	4.947	926.843	5.670	926.838	5.480	926.832
	16	4.50	926.98	4.823	926.967	5.543	926.965	5.393	926.919

APPENDIX B3

Instrumentation Data for Approach Embankment B1

ODOT US177 Approach Embankment Evaluation

Bridge B, South Abutment Wall (Geotextile Reinforced Wall)

Total Pressure Cells:

	Tubing Length	Date Installed	Test Pressures 5 psi	50 psi	100 psi
Top - SN 44197	34'	4/25/95	4.95	49.93	99.94
Middle - SN 44202	37'	4/25/95	5.06	50.22	100.29
Bottom - SN 44212	40'	4/25/95	5.43	50.50	100.52

Date	Time	TPC Readings (psi) Top w/flow	Top w/o flow	Middle w/flow	Middle w/o flow	Bottom w/flow	Bottom w/o flow	Remarks
5/5/95	10:00 AM	0.1	0.0	0.1	0.0	0.5	0.3	Initial Readings by WCC, T = 60 degrees C
5/23/95	2:00 PM	0.3	0.2	0.4	0.3	2.1	2.0	During plcmt. of 4th lift, b/fill above lower TPC
5/31/95	PM	0.5	0.4	1.8	1.7	4.5	4.4	After compaction of G.R. wall (i.e. 8 lifts)
6/19/95	AM	0.9	0.8	2.0	1.9	6.9	6.8	
6/28/95	PM	0.7	0.6	1.6	1.4	6.5	6.4	
7/7/95	11:45 AM	0.7	0.6	1.8	1.7	7.0	6.9	
7/14/95	11:10 AM	0.8	0.6	2.1	2.0	7.8	7.7	
7/26/95	10:45 AM	1.0	0.9	2.4	2.2	8.8	8.7	
8/9/95	8:40 AM	0.7	0.6	1.9	1.7	6.3	6.2	
9/1/95	8:30 AM	0.5	0.4	1.9	1.8	7.5	7.4	
9/20/95	3:35 PM	0.6	0.5	1.5	1.3	7.5	7.4	T = 21 degrees C
10/11/95	3:55 PM	0.4	0.3	0.9	0.7	6.4	6.4	T = 32 degrees C
11/3/95	11:00 AM	0.4	0.3	1.1	1.0	8.4	8.3	
11/22/95	11:00 AM	0.3	0.1	0.6	0.5	6.1	6.0	
12/20/95	11:30 AM	0.2	0.1	0.4	0.3	5.9	5.8	
1/11/96	12:00 PM	0.1	0.0	0.3	0.2	4.1	4.0	
2/8/96	3:00 PM	0.1	0.0	0.1	0.0	3.6	3.5	
2/29/96	3:00 PM	0.4	0.3	0.6	0.5	6.5	6.4	
3/28/96	2:00 PM	0.2	0.1	0.4	0.3	5.6	5.5	
4/23/96	11:30 AM	0.4	0.3	0.7	0.6	5.8	5.7	
5/2/96	8:10 AM	0.4	0.2	0.4	0.3	5.4	5.3	Before Flooding of Cardboard (not on plot)
5/2/96	10:00 AM	0.5	0.4	0.6	0.5	3.6	3.5	After Flooding of Cardboard (plotted)
5/21/96	9:00 AM	0.3	0.2	0.6	0.5	4.2	4.1	
6/11/96	12:30 PM	0.5	0.3	0.6	0.5	3.4	3.3	Highway Opened to Traffic
8/6/96	AM	0.4	0.2	0.6	0.4	4.4	4.2	
10/31/96	10:50 AM	0.3	0.1	0.6	0.5	4.1	4.0	
12/16/96	10:20 AM	0.2	0.0	0.5	0.4	2.6	2.5	
2/27/97	10:40 AM	0.2	0	0.5	0.4	1.7	1.6	

ODOT US177 Approach Embankment Evaluation

Bridge B, South Abutment Wall (Geotextile Reinforced Wall)

Amplified Liquid Settlement Gages:			**As Built Elevation**	
	Tubing Length	**Date Installed**	**Top of Plate**	**Top of Fluid**
Centerline - SN 44215	40'	4/25/95	912.95'	923.49'
			Initial Head = 10.54'	
Offset - SN 44220 10' wide	30'	4/25/95	912.94'	923.49'
			Initial Head = 10.55'	

Calibration for: Centerline — Head(ft) Reading - (-2.49 psi) / 8.33 psi / ft

Offset — Head(ft) Reading - (-3.44 psi) / 8.40 psi / ft

ALSG Readings, Heads, & ΔH

Date	Time	CL Reading psi	CL Head ft	CL ΔH ft	OFS Reading psi	OFS Head ft	OFS ΔH ft	Remarks
5/4/95	11:20 AM	85.6	10.575	-	86.0	10.648	-	Initial Readings by WCC, T = 65 degrees C
5/23/95	2:00 PM	86.0	10.623	0.048	86.4	10.695	0.047	During plcmt. of 4th lift, b/fill above lower TPC
5/31/95	PM	86.4	10.671	0.096	86.6	10.719	0.071	After compaction of G.R. wall (i.e. 8 lifts)
6/19/95	AM	86.7	10.707	0.132	86.7	10.731	0.083	
6/28/95	PM	86.7	10.707	0.132	86.8	10.743	0.095	
7/7/95	11:45 AM	86.6	10.695	0.120	86.6	10.719	0.071	
7/14/95	11:10 AM	86.5	10.683	0.108	86.4	10.695	0.047	
7/26/95	10:45 AM	86.5	10.683	0.108	86.5	10.707	0.059	
8/9/95	8:40 AM	86.4	10.671	0.096	86.4	10.695	0.047	
9/1/95	8:30 AM	86.3	10.569	0.006	86.3	10.683	0.035	
9/20/95	3:35 PM	86.7	10.707	0.132	86.5	10.707	0.059	
10/11/95	3:55 PM	87.1	10.755	0.180	87.0	10.767	0.119	
11/3/95	11:00 AM	86.8	10.719	0.144	86.7	10.731	0.083	
11/22/95	11:00 AM	87.3	10.779	0.204	87.1	10.779	0.131	
12/20/95	11:30 AM	87.3	10.779	0.204	87.2	10.790	0.142	
1/11/96	12:00 PM	87.6	10.815	0.240	87.6	10.838	0.190	
2/8/96	3:00 PM	88.0	10.863	0.288	87.7	10.850	0.202	
2/29/96	3:00 PM	87.9	10.851	0.276	87.0	10.767	0.119	
3/28/96	2:00 PM	87.7	10.827	0.252	87.4	10.814	0.166	
4/23/96	11:00 AM	87.8	10.839	0.264	86.9	10.757	0.109	
5/21/96	9:00 AM	87.2	10.767	0.192	86.5	10.707	0.059	
6/11/96	12:30 PM	87.6	10.815	0.240	87.2	10.790	0.142	Highway opened to traffic
8/6/96	PM	87.0	10.743	0.168	86.9	10.757	0.109	
10/31/96	10:50 AM	87.0	10.743	0.168	87.1	10.779	0.131	
12/16/96	10:20 AM	87.8	10.839	0.264	87.7	10.850	0.202	
2/27/97	10:40 AM	87.8	10.839	0.264	87.8	10.862	0.214	

ODOT US177 Approach Embankment Evaluation

Bridge B, South Abutment Wall (Geotextile Reinforced Wall)

Inclinometer Telescoping Couplings - Centerline: Installed 6/3/95

Casing Elevation (top=2.0' above GS)	925.15' As Built	→	924.66' After Paving
GS Elevation	923.15'	**Pavement Elevation**	924.98'
Reference Coupling	51.23' Depth	→	871.92' Elevation
Bottom of Casing	53.22'		

Readings, Changes, & ΔH Values

Date	Time	Level 1 (Top)			Level 2			Level 3			Level 4 (Bottom)			Remarks
		Reading R1, ft	R4 - R1 ft	ΔH ft	Reading R2, ft	R4 - R2 ft	ΔH ft	Reading R3, ft	R4 - R3 ft	ΔH ft	Reading R4, ft	ΔR4 ft	ΔH ft	
6/6/95	PM	10.874	42.354	-	15.874	37.354	-	20.874	32.354	-	53.228	-	-	Omit this Data set
6/19/95	AM	10.874	42.427	0.000	15.900	37.401	0.000	20.895	32.406	0.000	53.301	0.000	0.000	Reference Reading (Datum)
6/28/95	PM	10.880	42.390	0.037	15.870	37.400	0.001	20.865	32.405	0.001	53.270	0.031	0.031	
7/7/95	11:45 AM	10.880	42.390	0.037	15.875	37.395	0.006	20.870	32.400	0.006	53.270	0.031	0.031	
7/14/95	11:10 AM	10.885	42.390	0.037	15.880	37.395	0.006	20.870	32.405	0.001	53.275	0.026	0.026	
7/26/95	10:45 AM	10.880	42.335	0.092	15.870	37.345	0.056	20.865	32.350	0.056	53.215	0.086	0.086	
8/9/95	8:40 AM	10.883	42.392	0.035	15.875	37.400	0.001	20.870	32.405	0.001	53.275	0.026	0.026	
9/1/95	8:30 AM	10.883	42.390	0.037	15.873	37.400	0.001	20.867	32.406	0.000	53.273	0.028	0.028	
9/20/95	3:35 PM	10.880	42.327	0.100	15.870	37.337	0.064	20.863	32.344	0.062	53.207	0.094	0.094	
10/11/95	3:55 PM	10.883	42.384	0.043	15.873	37.394	0.007	20.865	32.402	0.004	53.267	0.034	0.034	
11/3/95	11:00 AM	10.870	42.335	0.092	15.865	37.340	0.061	20.855	32.350	0.056	53.205	0.096	0.096	
11/22/95	11:00 AM	10.870	42.387	0.040	15.865	37.392	0.009	20.857	32.400	0.006	53.257	0.044	0.044	
12/20/95	11:30 AM	10.865	42.390	0.037	15.857	37.398	0.003	20.855	32.400	0.006	53.255	0.046	0.046	
1/11/96	12:00 PM	10.865	42.338	0.089	15.860	37.343	0.058	20.853	32.350	0.056	53.203	0.098	0.098	
2/8/96	3:00 PM	10.865	42.332	0.095	15.857	37.340	0.061	20.853	32.344	0.062	53.197	0.104	0.104	
2/29/96	3:00 PM	10.868	42.337	0.090	15.855	37.350	0.051	20.855	32.350	0.056	53.205	0.096	0.096	
3/28/96	2:00 PM	10.870	42.330	0.097	15.857	37.343	0.058	20.853	32.347	0.059	53.200	0.101	0.101	*(-0.03) for diff. b/w cutoff*
4/23/96	11:30 AM	10.863	42.384	0.043	15.855	37.392	0.009	20.850	32.397	0.009	53.247	0.054	0.054	*length and ext.*
5/21/96	9:00 AM	10.900	42.325	0.102	15.893	37.332	0.069	-	-	-	53.225	0.106	0.106	New reference (top) using ext.

6/11/96	12:30 PM	10.905	42.375	0.052	15.895	37.385	0.016	20.887	32.393	0.013	53.280	0.051	0.051	Highway opened to traffic
8/6/96	AM	10.908	42.372	0.055	15.897	37.383	0.018	20.890	32.390	0.016	53.280	0.051	0.051	
10/31/96	10:50 AM	10.905	42.370	0.057	15.895	37.380	0.021	20.890	32.385	0.021	53.275	0.056	0.056	
12/16/96	10:20 AM	10.905	42.370	0.057	15.893	37.382	0.019	20.885	32.390	0.016	53.275	0.056	0.056	
2/27/97	10:40 AM	10.920	42.370	0.057	15.907	37.383	0.018	20.900	32.390	0.016	53.290	0.041	0.041	

ODOT US177 Approach Embankment Evaluation

Bridge B, South Abutment Wall (Geotextile Reinforced Wall)

Inclinometer Telescoping Couplings - Offset: Installed 6/5/95

Casing Elevation (top=2.0' above GS): 925.08' As Built → 924.53' After Paving

GS Elevation 923.08' **Pavement Elevation** 924.98'

Reference Coupling 51.29' Depth → 871.79' Elevation **Bottom of Casing** 53.25'

Readings, Changes, & ΔH Values

Date	Time	Level 1 (Top)			Level 2			Level 3			Level 4 (Bottom)			Remarks
		Reading R1, ft	R4 - R1 ft	ΔH ft	Reading R2, ft	R4 - R2 ft	ΔH ft	Reading R3, ft	R4 - R3 ft	ΔH ft	Reading R4, ft	ΔR4 ft	ΔH ft	
6/6/95	PM	10.884	42.406	-	15.895	37.395	-	20.884	32.406	-	53.290	-	-	Omit this Data set
6/19/95	AM	10.884	42.396	0.000	15.874	37.406	0.000	20.874	32.406	0.000	53.280	0.000	0.000	Reference Reading (Datum)
6/28/95	PM	10.995	42.405	-0.009	15.975	37.425	-0.019	20.960	32.440	-0.034	53.400	0.120	-0.120	
7/7/95	11:45 AM	10.875	42.420	-0.024	15.900	37.395	0.011	20.890	32.405	0.001	53.295	0.015	-0.195	
7/14/95	11:10 AM	10.880	42.600	-0.204	15.967	37.513	-0.107	20.958	32.522	-0.116	53.480	0.200	-0.200	(?) data
7/26/95	10:45 AM	10.880	42.375	0.021	15.900	37.355	0.051	20.890	32.365	0.041	53.255	0.025	0.025	
8/9/95	8:40 AM	10.883	42.422	-0.026	15.903	37.402	0.004	20.895	32.410	-0.004	53.305	0.025	-0.025	
9/1/95	8:30 AM	10.885	42.415	-0.019	15.905	37.395	0.011	20.893	32.407	-0.001	53.300	0.020	-0.020	
9/20/95	3:35 PM	10.877	42.413	-0.017	15.900	37.390	0.016	20.890	32.400	0.006	53.290	0.010	-0.010	
10/11/95	3:55 PM	10.880	42.420	-0.024	15.905	37.395	0.011	20.893	32.407	-0.001	53.300	0.020	-0.020	
11/3/95	11:00 AM	10.873	42.412	-0.016	15.895	37.390	0.016	20.883	32.402	0.004	53.285	0.005	-0.005	
11/22/95	11:00 AM	10.867	42.418	-0.022	15.893	37.392	0.014	20.833	32.452	-0.046	53.285	0.005	-0.005	
12/20/95	11:30 AM	10.860	42.420	-0.024	15.885	37.395	0.011	20.877	32.403	0.003	53.280	0.000	0.000	
1/11/96	12:00 PM	10.863	42.417	-0.021	15.885	37.395	0.011	20.875	32.405	0.001	53.280	0.000	0.000	
2/8/96	3:00 PM	10.860	42.415	-0.019	15.880	37.395	0.011	20.875	32.400	0.006	53.275	0.005	0.005	
2/29/96	3:00 PM	10.865	42.417	-0.021	15.887	37.395	0.011	20.879	32.403	0.003	53.282	0.002	-0.002	
3/28/96	2:00 PM	10.865	42.415	-0.019	15.890	37.390	0.016	20.877	32.403	0.003	53.280	0.000	0.000	*(-0.10) for diff. b/w cutoff*
4/23/96	11:00 AM	10.870	42.367	0.029	15.890	37.347	0.059	20.880	32.357	0.049	53.237	0.006	-0.006	*length and ext.*
5/21/96	9:00 AM	10.970	42.217	0.179	15.857	37.330	0.076	-	-	-	53.187	0.193	0.193	New reference (top) using ext.

6/11/96	12:30 PM	10.977	42.265	0.131	15.864	37.378	0.028	20.852	32.390	0.016	53.242	0.138	0.138	Highway opened to traffic
8/6/96	AM	10.982	42.270	0.126	15.872	37.380	0.026	20.863	32.389	0.017	53.252	0.128	0.128	
10/31/96	10:50 AM	10.970	42.272	0.124	15.864	37.378	0.028	20.852	32.390	0.016	53.242	0.138	0.138	
12/16/96	10:20 AM	10.967	42.228	0.168	15.857	37.338	0.068	20.847	32.348	0.058	53.195	0.085	0.085	
2/27/97	10:40 AM	10.963	42.270	0.126	15.855	37.378	0.028	20.843	32.390	0.016	53.233	0.147	0.147	

ODOT US177 Approach Embankment Evaluation

Bridge B, South Abutment Wall (Geotextile Reinforced Wall)

Piezometer:

	Standpipe Elevation	925.13'	924.66'
*As Built ►	(Top=1.90 ft above GS)	(As Built)	(After Paving)

GS Elevation (Top of Subgrade)	923.23'	**Pavement Elevation** (Top of Pavement)	924.98'
Tip Elevation	878.23'	**Tip Depth**	45.0'

Groundwater Depth = Piezometer Reading - 0.32'
(Below Top of Pavement)

Groundwater Elevation = Standpipe Elevation (924.66') - Piezometer Reading

Piezometer Data

Date	Time	Reading ft	GW Depth ft	GW Elev. ft	Remarks
6/3/95	PM	-	-	-	Installed piezometer
6/5/95	AM	23.60	21.70	901.53	Initial reading by OSU
6/19/95	AM	26.55	24.65	898.58	
6/28/95	AM	26.74	24.84	898.39	
7/7/95	11:30 AM	26.60	24.70	898.53	
7/14/95	9:40 AM	26.89	24.99	898.24	
7/26/95	10:45 AM	27.55	25.65	897.58	
8/9/95	8:40 AM	24.30	22.40	900.83	
9/1/95	8:30 AM	26.65	24.75	898.48	
9/20/95	3:35 PM	28.11	26.21	897.02	
10/11/95	3:55 PM	28.845	26.95	896.29	
11/3/95	11:00 AM	29.54	27.64	895.59	
11/22/95	11:00 AM	29.92	28.02	895.21	
12/20/95	11:30 AM	30.40	28.50	894.73	
1/11/96	12:00 PM	30.63	28.73	894.50	
2/8/96	3:00 PM	30.97	29.07	894.16	
2/29/96	3:00 PM	31.17	29.27	893.96	
3/28/96	2:00 PM	31.39	29.49	893.74	
4/23/96	11:30 AM	34.61	32.71	890.52	
5/21/96	9:00 AM	31.31	30.99	893.35	Use new standpipe elev., changed reference for depth
6/11/96	12:30 PM	31.11	30.79	893.55	Highway opened to traffic
8/6/96	AM	31.05	30.73	893.61	
10/31/96	10:50 AM	30.580	30.26	894.08	
12/16/96	10:20 AM	30.063	29.74	894.60	
2/27/97	10:40 AM	31.70	31.38	892.96	

ODOT US177 Approach Embankment Evaluation

Bridge B, South Abutment Wall (Geotextile Reinforced Wall), Surface Settlement Points

Date		6/12/96		8/6/96		10/31/96		2/28/97		
		Reading	Elevation	Reading	Elevation	Reading	Elevation	Reading	Elevation	
BM		W	927.16	W	927.16	W	927.16	W	927.16	
		E		E		E	927.17	E		
BS		2.42	-	2.878	-	3.215	-	3.138	-	
HI		929.58	-	930.038	-	930.38	-	930.298	-	
FS	1	4.73	924.85	5.198	924.840	5.560	924.815	5.487	924.811	
	2	4.65	924.93	5.145	924.893	5.488	924.887	5.416	924.882	
	3	4.57	925.01	5.048	924.990	5.395	924.980	5.324	924.974	
	4	4.47	925.11	4.944	925.094	5.283	925.092	5.210	925.088	
	5	4.78	924.80	5.240	924.798	5.600	924.775	5.527	924.771	
	6	4.68	924.90	5.180	924.858	5.520	924.855	5.447	924.851	
	7	4.58	925.00	5.063	924.975	5.408	924.967	5.337	924.961	
	8	4.51	925.07	4.992	925.046	5.330	925.045	5.257	925.041	
	9	4.78	924.80	5.262	924.776	5.608	924.767	5.537	924.761	
	10	4.69	924.89	5.196	924.842	5.536	924.839	5.464	924.834	
	11	4.58	925.00	5.074	924.964	5.420	924.955	5.348	924.95	
	12	4.54	925.04	5.047	924.991	5.381	924.994	5.309	924.989	
	13	4.77	924.81	5.245	924.793	5.606	924.769	5.531	924.767	
	14	4.70	924.88	5.208	924.830	5.547	924.828	5.476	924.822	
	15	4.60	924.98	5.097	924.941	5.442	924.933	5.368	924.93	
	16	4.55	925.03	5.025	925.013	5.368	925.007	5.321	924.977	*2/27/1997

*Settltment Reading Point is missing.

APPENDIX B4

Instrumentation Data for Approach Embankment B2

ODOT US177 Approach Embankment Evaluation

Bridge B, North Abutment Wall (Controlled Low Strength Backfill)

Total Pressure Cells:

	Tubing Length	Date Installed	Test Pressures 5 psi	50 psi	100 psi
Top - SN 44198	34'	4/27/95	4.95	49.96	100.00
Middle - SN 44204	37'	4/27/95	5.14	49.90	100.02
Bottom - SN 44208	40'	4/27/95	4.60	50.20	100.42

Date	Time	TPC Readings (psi) Top w/flow	w/o flow	Middle w/flow	w/o flow	Bottom w/flow	w/o flow	Remarks
5/5/95		0.3	0	0.1	0	0.1	0	Initial Readings by WCC, no backfill
5/12/95	1:30 PM	0.0	0	0.9	0.8	1.7	1.5	After placement of ~ 1/2 CLSB
5/12/95	4:00 PM	1.4	1.0	2.8	2.7	2.4	2.2	After placement of all CLSB
5/16/95	9:20 AM	0.5	0.2	0.4	0.3	2	1.8	4 days after CLSB pour
5/31/95	AM	0.4	0.2	0.5	0.5	1.7	1.6	
6/16/95	PM	0.5	0.2	0.3	0.2	0.7	0.6	
6/28/95	PM	0.3	0.0	0.4	0.2	0.6	0.4	
7/7/95	12:35 PM	0.6	0.3	0.4	0.2	0.5	0.4	
7/14/95	1:25 PM	0.7	0.4	0.1	0.0	0.4	0.3	
7/26/95	10:00 AM	0.6	0.3	0.1	0.0	0.5	0.3	
8/9/95	9:15 AM	0.4	0.1	0.1	0.0	0.5	0.3	
9/1/95	9:10 AM	0.5	0.1	0.5	0.3	0.4	0.2	
9/22/95	12:10 PM	0.3	0.0	0.3	0.2	0.7	0.5	T = 13 degrees C
10/12/95	2:35 PM	0.4	0.0	0.0	0.0	0.7	0.6	
11/3/95	1:20 PM	0.5	0.1	0.3	0.2	0.9	0.8	
11/22/95	12:00 PM	0.5	0.1	0.1	0.0	0.8	0.7	
12/20/95	12:00 PM	0.5	0.0	0.0	0.0	0.7	0.5	
1/11/96	2:00 PM	0.4	0.2	0.1	0.0	0.5	0.4	
2/8/96	4:00 PM	0.2	0.0	0.0	0.0	0.4	0.3	
2/29/96	4:00 PM	0.4	0.3	0.1	0.0	0.7	0.6	
3/28/96	2:15 PM	0.4	0.3	0.1	0.0	0.7	0.6	
4/23/96	12:00 PM	0.4	0.1	0.3	0.2	0.6	0.5	
5/21/96	9:30 AM	0.1	0.0	0.2	0.1	0.6	0.5	
6/11/96	11:30 AM	0.3	0.1	0.4	0.3	1.1	1.0	Highway Opened to Traffic
8/6/96	AM	0.4	0.0	0.5	0.4	1.0	0.8	
10/31/96	10:15 AM	0.4	0.0	0.3	0.2	1.1	1.0	
12/16/96	9:50 AM	0.5	0.1	0.1	0.0	1.0	0.9	
2/27/97	9:50 AM	0.5	0.0	0.1	0.0	0.8	0.7	

ODOT US177 Approach Embankment Evaluation

Bridge B, North Abutment Wall (Controlled Low Strength Backfill)

Amplified Liquid Settlement Gages:	**Tubing Length**	**Date Installed**	**As Built Elevation Top of Plate**	**As Built Elevation Top of Fluid**
Centerline - SN 44216	40'	4/28/95	911.14'	921.73'
			Initial Head = 10.59'	
Offset - SN 44219 10' wide	30'	4/28/95	911.15'	921.67'
			Initial Head = 10.52'	

Calibration for: Centerline

Head(ft) Reading - (-4.33 psi) / 8.35 psi / ft

Offset

Head(ft) Reading - (-6.445 psi) / 8.395 psi / ft

ALSG Readings, Heads, & ΔH

Date	**Time**	**CL Reading psi**	**CL Head ft**	**CL ΔH ft**	**OFS Reading psi**	**OFS Head ft**	**OFS ΔH ft**	**Remarks**
5/5/95		84.4	10.626	-	84.4	10.821	-	Initial Readings by WCC, no backfill (datum)
5/12/95	1:30 PM	85.2	10.722	0.096	84.3	10.809	-0.012	After placement of ~ 1/2 CLSB
5/12/95	4:00 PM	85.4	10.746	0.120	84.3	10.809	-0.012	After placement of all CLSB
5/16/95	9:20 AM	85.5	10.758	0.132	84.3	10.809	-0.012	4 days after CLSB pour
5/31/95	AM	85.6	10.770	0.144	84.4	10.821	0.000	
6/16/95	PM	85.6	10.770	0.144	84.5	10.833	0.012	
6/28/95	PM	85.6	10.770	0.144	84.5	10.833	0.012	
7/7/95	12:35 PM	85.5	10.758	0.032	84.5	10.833	0.012	
7/14/95	1:25 PM	85.7	10.782	0.156	84.5	10.833	0.012	
7/26/95	10:00 AM	85.7	10.782	0.156	84.5	10.833	0.012	
8/9/95	9:15 AM	86.0	10.818	0.192	84.5	10.833	0.012	
9/1/95	9:10 AM	85.9	10.806	0.180	84.4	10.821	0.000	
9/22/95	12:10 PM	86.2	10.842	0.216	84.6	10.845	0.024	
10/12/95	2:35 PM	84.0	10.578	0.048	84.4	10.821	0.000	
11/3/95	1:20 PM	86.0	10.818	0.192	84.8	10.869	0.048	
11/22/95	12:00 PM	86.5	10.878	0.252	85.0	10.893	0.072	
12/20/95	12:00 PM	86.6	10.890	0.264	85.2	10.917	0.096	
1/11/96	2:00 PM	87.0	10.938	0.312	85.4	10.940	0.199	
2/8/96	4:00 PM	86.9	10.926	0.300	85.3	10.929	0.108	
2/29/96	4:00 PM	86.7	10.902	0.276	85.2	10.917	0.096	
3/28/96	2:15 PM	86.8	10.914	0.288	85.1	10.905	0.084	
4/23/96	12:00 PM	87.1	10.950	0.324	85.0	10.893	0.072	
5/21/96	9:30 AM	86.2	10.842	0.216	84.6	10.845	0.024	
6/11/96	11:30 AM	86.9	10.926	0.300	85.2	10.917	0.096	Highway opened to traffic
8/6/96	AM	86.2	10.842	0.216	84.7	10.857	0.036	
10/31/96	10:15 AM	86.4	10.866	0.240	84.6	10.845	0.024	
12/16/96	9:50 AM	87.2	10.962	0.336	85.5	10.952	0.131	
2/27/97	9:50 AM	87.3	10.974	0.348	85.6	10.964	0.143	

ODOT US177 Approach Embankment Evaluation

Bridge B, North Abutment Wall (Controlled Low Strength Backfill)

Inclinometer Telescoping Couplings - Centerline Installed 5/22/95

Casing Elevation (top=1.97' above GS) 923.84' As Built → 922.87' After Paving

GS Elevation 921.87' **Pavement Elevation** 923.19'

Reference Coupling 48.95' Depth → 872.93' Elevation **Bottom of Casing** 51.07'

Readings, Changes, & ΔH Values

Date	Time	Level 1 (Top)			Level 2			Level 3			Level 4 (Bottom)			Remarks
		Reading R1, ft	R4 - R1 ft	ΔH ft	Reading R2, ft	R4 - R2 ft	ΔH ft	Reading R3, ft	R4 - R3 ft	ΔH ft	Reading R4, ft	ΔR4 ft	ΔH ft	
6/1/95	PM	10.863	40.052	0.000	15.780	35.135	0.000	20.822	30.093	0.000	50.915	0.000		Reference Reading (Datum)
6/16/95	AM	10.874	40.802	-	15.895	35.781	-	20.936	30.740	-	51.676	-	-	Omit this Data set
6/28/95	AM	10.870	40.055	-0.003	15.885	35.040	0.095	20.825	30.100	-0.007	50.925	0.010	-0.010	
7/7/95	12:35 PM	11.270	40.030	0.022	16.215	35.085	0.050	21.260	30.040	0.053	51.300	0.385	-0.385	
7/14/95	1:25 PM	10.770	40.170	-0.118	15.785	35.155	-0.020	20.850	30.090	0.003	50.940	0.025	-0.025	
7/26/95	10:00 AM	10.770	40.155	-0.103	15.780	35.145	-0.010	20.830	30.095	-0.002	50.925	0.010	-0.010	
8/9/95	9:15 AM	10.765	40.160	-0.108	15.780	35.145	-0.010	20.830	30.095	-0.002	50.925	0.010	-0.010	
9/1/95	9:10 AM	10.767	40.160	-0.108	15.785	35.142	-0.007	20.835	30.092	0.001	50.927	0.012	-0.012	
9/22/95	12:10 PM	10.762	40.095	-0.043	15.780	35.077	0.058	20.825	30.032	0.061	50.857	0.058	0.058	
10/12/95	2:35 PM	10.767	40.100	-0.048	15.783	35.084	0.051	20.833	30.034	0.059	50.867	0.048	0.048	
11/3/95	1:20 PM	10.755	40.160	-0.108	15.770	35.145	-0.010	20.820	30.095	-0.002	50.915	0.000	0.000	
11/22/95	12:00 PM	10.753	40.097	-0.045	15.775	35.075	0.060	20.823	30.027	0.066	50.850	0.065	0.065	
12/20/95	12:00 PM	10.750	40.160	-0.108	15.770	35.140	-0.005	20.817	30.093	0.000	50.910	0.005	0.005	
1/11/96	2:00 PM	10.747	40.166	-0.114	15.767	35.146	-0.011	20.817	30.096	-0.003	50.913	0.002	0.002	
2/8/96	4:00 PM	10.747	40.106	-0.054	15.763	35.090	0.045	20.813	30.040	0.053	50.853	0.062	0.062	
2/29/96	4:00 PM	10.749	40.164	-0.112	15.764	35.149	-0.014	20.813	30.100	-0.007	50.913	0.002	0.002	
3/28/96	2:15 PM	10.750	40.160	-0.108	15.765	35.145	-0.010	20.815	30.095	-0.002	50.910	0.005	0.005	*(-0.04) for diff. b/w cutoff*
4/23/96	12:00 PM	10.750	40.100	-0.048	15.767	35.083	0.052	20.815	30.035	0.058	50.850	0.065	0.065	*length and ext.*
5/21/96	9:30 AM	10.825	40.100	-0.048	15.840	35.085	0.050	20.890	30.035	0.058	50.925	0.030	-0.030	New reference (top) using ext.

6/11/96	11:30 AM	10.800	39.988	0.064	15.798	34.990	0.145	20.851	29.937	0.156	50.788	0.167	0.167	Highway opened to traffic
8/6/96	AM	10.803	40.137	-0.085	15.803	35.137	-0.002	20.850	30.090	0.003	50.940	0.015	0.015	
10/31/96	10:15 AM	10.798	40.142	-0.090	15.795	35.145	-0.010	20.848	30.092	0.001	50.940	0.015	0.015	
12/16/96	9:50 AM	10.790	40.150	-0.098	15.793	35.147	-0.012	20.843	30.097	-0.004	50.940	0.015	0.015	
2/27/97	9:50 AM	10.790	40.090	-0.038	15.795	35.085	0.050	20.845	30.035	0.058	50.880	0.075	0.075	

ODOT US177 Approach Embankment Evaluation

Bridge B, North Abutment Wall (Controlled Low Strength Backfill)

Inclinometer Telescoping Couplings - Offset: Installed 5/24/95

Casing Elevation (top=2.0' above GS): 923.84' As Built → 922.56' After Paving

GS Elevation 921.84' **Pavement Elevation** 923.19'

Reference Coupling 49.05' Depth → 872.79' Elevation **Bottom of Casing** 51.17'

Readings, Changes, & ΔH Values

Date	Time	Level 1 (Top)			Level 2			Level 3			Level 4 (Bottom)			Remarks
		Reading R1, ft	R4 - R1 ft	ΔH ft	Reading R2, ft	R4 - R2 ft	ΔH ft	Reading R3, ft	R4 - R3 ft	ΔH ft	Reading R4, ft	ΔR4 ft	ΔH ft	
6/1/95	PM	10.593	40.458	-	15.624	35.427	-	20.478	30.573	-	51.051	-	-	Omit this Data set
6/16/95	AM	10.488	40.521	0.000	15.530	35.479	0.000	20.488	30.521	0.000	51.009	0.000	0.000	Reference Reading (Datum)
6/28/95	PM	10.490	40.520	0.001	15.525	35.485	-0.006	20.480	30.530	-0.009	51.010	0.001	-0.001	
7/7/95	12:35 PM	10.490	40.510	0.011	15.525	35.475	0.004	20.480	30.520	0.001	51.000	0.009	0.009	
7/14/95	1:25 PM	10.495	40.565	-0.044	15.525	35.535	-0.056	20.490	30.570	-0.049	51.060	0.051	-0.051	
7/26/95	10:00 AM	10.490	40.565	-0.044	15.630	35.425	0.054	20.480	30.575	-0.054	51.055	0.046	-0.046	
8/9/95	9:15 AM	10.490	40.520	0.001	15.527	35.483	-0.004	20.490	30.520	0.001	51.010	0.001	-0.001	
9/1/95	9:10 AM	10.490	40.520	0.001	15.530	35.480	-0.001	20.485	30.525	-0.004	51.010	0.001	-0.001	
9/22/95	12:10 PM	10.485	40.515	0.006	15.520	35.480	-0.001	20.480	30.520	0.001	51.000	0.009	0.009	
10/12/95	2:35 PM	10.487	40.568	-0.047	15.523	35.532	-0.053	20.485	30.570	-0.049	51.055	0.046	-0.046	
11/3/95	1:20 PM	10.480	40.570	-0.049	15.517	35.533	-0.054	20.475	30.575	-0.054	51.050	0.041	-0.041	
11/22/95	12:00 PM	10.480	40.520	0.001	15.513	35.487	-0.008	20.487	30.513	0.008	51.000	0.009	0.009	
12/20/95	12:00 PM	10.475	40.570	-0.049	15.505	35.540	-0.061	20.467	30.578	-0.057	51.045	0.036	-0.036	
1/11/96	2:00 PM	10.470	40.527	-0.006	15.610	35.387	0.092	20.465	30.532	-0.011	50.997	0.012	0.012	
2/8/96	4:00 PM	10.487	40.570	-0.049	15.520	35.537	-0.058	20.480	30.577	-0.056	51.057	0.048	-0.048	
2/29/96	4:00 PM	10.483	40.516	0.005	15.505	35.494	-0.015	20.465	30.534	-0.013	50.999	0.010	0.010	
3/28/96	2:15 PM	10.473	40.517	0.004	15.510	35.480	-0.001	20.469	30.521	0.000	50.990	0.019	0.019	*(-0.05) for diff. b/w cutoff*
4/23/96	12:00 PM	10.475	40.515	0.006	15.507	35.483	-0.004	20.573	30.417	0.104	50.990	0.019	0.019	*length and ext.*
5/21/96	9:30 AM	10.525	40.315	0.206	15.380	35.460	0.019	20.355	30.485	0.036	50.840	0.219	0.219	New reference (top) using ext.

6/11/96	11:30 AM	10.531	40.237	0.284	15.490	35.278	0.201	20.196	30.572	-0.051	50.768	0.291	0.291	Highway opened to traffic
8/6/96	AM	10.533	40.237	0.284	15.393	35.377	0.102	20.205	30.565	-0.044	50.770	0.289	0.289	
10/31/96	10:15 AM	10.637	40.105	0.416	15.491	35.251	0.228	20.306	30.436	0.085	50.742	0.317	0.317	
12/16/96	9:50 AM	10.520	40.247	0.274	15.380	35.387	0.092	20.195	30.572	-0.051	50.767	0.292	0.292	
2/27/97	9:50 AM	10.525	40.250	0.271	15.385	35.390	0.089	20.195	30.580	-0.059	50.775	0.284	0.284	

ODOT US177 Approach Embankment Evaluation

Bridge B, North Abutment Wall (Controlled Low Strength Backfill)

Piezometer:

Standpipe Elevation 924.55' (As Built) → 922.88' (After Paving)

*As Built ► (Top=2.72 ft above GS)

GS Elevation 921.83' (Top of Subgrade)

Pavement Elevation 923.19' (Top of Pavement)

Tip Elevation 875.83'

Tip Depth 46.0'

Groundwater Depth = Piezometer Reading - 0.31'
(Below Top of Pavement)

Groundwater Elevation = Standpipe Elevation (922.88') - Piezometer Reading

Date	Time	Piezometer Data Reading ft	GW Depth ft	GW Elev. ft	Remarks
5/24/95	PM	-	-	-	Installed piezometer
6/1/95	PM	29.13	26.41	895.42	Initial reading by OSU
6/2/95	PM	29.00	26.28	895.55	
6/16/95	AM	26.15	23.43	898.40	
6/28/95	AM	25.62	22.90	898.93	
7/7/95	12:35 PM	25.48	22.76	899.07	
7/14/95	1:25 PM	25.50	22.78	899.05	
7/26/95	10:00 AM	26.00	23.28	898.55	
8/9/95	9:15 AM	23.40	20.68	901.15	
9/1/95	9:10 AM	23.96	21.24	900.59	
9/22/95	12:10 PM	26.20	23.48	898.35	
10/12/95	2:35 PM	26.93	24.21	897.62	
11/3/95	1:20 PM	27.63	24.91	896.92	
11/22/95	12:00 PM	28.12	25.40	896.43	
12/20/95	12:00 PM	28.69	25.97	895.86	
1/11/96	2:00 PM	29.01	26.29	895.54	
2/8/96	4:00 PM	29.40	26.68	895.15	
2/29/96	4:00 PM	29.61	26.89	894.94	
3/28/96	2:15 PM	29.88	27.16	894.67	
4/23/96	12:00 PM	30.12	27.40	894.43	
5/21/96	9:30 AM	28.66	28.35	894.22	Use new standpipe elev., changed reference for depth
6/11/96	11:30 AM	28.63	28.32	894.25	Highway opened to traffic
8/6/96	AM	28.76	28.45	894.12	
10/31/96	10:15 AM	28.33	28.02	894.55	
12/16/96	9:50 AM	27.770	27.46	895.11	
2/27/97	9:50 AM	28.00	27.69	894.88	

ODOT US177 Approach Embankment Evaluation

Bridge B, North Abutment Wall (Controlled Low Strength Backfill), Surface Settlement Points

Date		6/12/96		8/6/96		10/31/96		2/28/97		
		Reading	Elevation	Reading	Elevation	Reading	Elevation	Reading	Elevation	
BM		W	925.26	W	925.26	W	925.26	W	925.26	
		E		E		E	925.26	E		
BS		0.75	-	2.734	-	3.238	-	3.114	-	
HI		926.01	-	927.994	-	928.498	-	928.374	-	
FS	1	3.05	922.96	5.033	922.961	5.554	922.944	5.428	922.946	
	2	2.97	923.04	4.982	923.012	5.487	923.011	5.364	923.01	
	3	2.89	923.12	4.888	923.106	5.397	923.101	5.273	923.101	
	4	2.82	923.19	4.814	923.180	5.322	923.176	5.220	923.154	*2/27/1997
	5	3.12	922.89	5.089	922.905	5.606	922.892	5.483	922.891	
	6	3.03	922.98	5.045	922.949	5.554	922.944	5.430	922.944	
	7	2.94	923.07	4.933	923.061	5.444	923.054	5.322	923.052	
	8	2.88	923.13	4.882	923.112	5.390	923.108	5.267	923.107	
	9	3.14	922.87	5.126	922.868	5.642	922.856	5.518	922.856	
	10	3.05	922.96	5.062	922.932	5.569	922.929	5.446	922.928	
	11	2.96	923.05	4.963	923.031	5.472	923.026	5.349	923.025	
	12	2.89	923.12	4.895	923.099	5.400	923.098	5.293	923.081	*2/27/1997
	13	3.14	922.87	5.132	922.862	5.643	922.855	5.520	922.854	
	14	3.06	922.95	5.074	922.920	5.585	922.913	5.465	922.909	
	15	2.98	923.03	4.977	923.017	5.485	923.013	5.363	923.011	
	16	2.90	923.11	4.892	923.102	5.398	923.100	5.277	923.097	

*Settlement Reading Point is missing.

APPENDIX B5

Instrumentation Data for Approach Embankment C1

ODOT US177 Approach Embankment Evaluation

Bridge C, South Abutment Wall (Dynamic Compaction of Granular Backfill)

Total Pressure Cells:

	Tubing Length	Date Installed	Test Pressures 5 psi	50 psi	100 psi
Top - SN 44199	34'	5/1/95	4.62	49.64	99.55
Middle - SN 44206	37'	5/1/95	5.00	50.00	100.10
Bottom - SN 44209	40'	5/1/95	4.90	49.90	100.04

Date	Time	TPC Readings (psi) Top w/flow	Top w/o flow	Middle w/flow	Middle w/o flow	Bottom w/flow	Bottom w/o flow	Remarks
5/5/95		0.0	0.0	0.1	0.0	0.1	0.0	Initial Readings by WCC, no backfill
5/15/95	AM	0.0	0.0	0.0	0.0	0.5	0.4	After placing 1st lift, before dyn. compaction
5/15/95	1:00 PM	0.0	0.0	0.0	0.0	0.8	-	After 1st lift compaction (2 ft)
5/15/95	3:00 PM	0.0	0.0	0.8	0.7	1.4	1.3	After 2nd lift compaction (4 ft)
5/17/95	11:40 AM	0.0	0.0	1.6	1.4	1.9	1.8	After 3rd lift compaction (6 ft)
5/17/95	PM	0.5	0.4	2.6	2.5	2.6	2.5	After 4th lift compaction (8 ft)
5/19/95	AM	0.9	0.8	2.7	2.6	2.7	2.6	
5/31/95	AM	0.2	0.1	1.7	1.6	2.7	2.6	
6/16/95	AM	0.3	0.1	1.9	1.8	2.5	2.4	
6/28/95	AM	0.1	0.0	2.0	1.9	2.7	2.6	
7/7/95	2:20 PM	0.4	0.2	1.6	1.5	2.7	2.6	
7/14/95	2:15 PM	0.4	0.3	2.2	2.1	2.9	2.8	
7/26/95	9:25 PM	0.1	0.0	2.7	2.6	3.2	3.1	
8/9/95	10:00 AM	0.1	0.0	2.0	1.9	2.8	2.7	
9/1/95	9:55 AM	0.1	0.0	2.8	2.7	3.0	3.0	
9/22/95	1:40 PM	0.1	0.0	1.9	1.8	3.0	2.9	T = 15 degrees C
10/12/95	3:05 PM	0.4	0.3	0.8	0.7	2.2	2.1	
11/3/95	2:05 PM	0.1	0.0	1.5	1.3	2.8	2.7	
11/22/95	2:00 PM	0.1	0.0	0.6	0.5	2.2	2.1	
12/20/95	1:30 PM	0.1	0.0	1.0	0.8	2.5	2.4	
1/11/96	3:00 PM	0.1	0.0	0.3	0.2	2.0	1.9	
2/8/96	5:00 PM	0.1	0.0	0.3	0.1	1.2	1.1	
2/29/96	4:00 PM	0.2	0.1	1.7	1.6	1.5	1.4	
3/28/96	3:00 PM	0.0	0.0	1.3	1.2	1.4	1.4	
4/23/96	1:15 PM	0.1	0.0	1.5	1.4	1.6	1.5	
5/21/96	10:00 AM	0.1	0.0	1.9	1.8	2.2	2.1	
6/11/96	10:30 AM	0.1	0.0	1.4	1.3	2.4	2.3	Highway Opened to Traffic
8/6/96	9:30 AM	0.0	0.0	1.5	1.4	2.7	2.6	
10/31/96	8:30 AM	0.2	0.1	2.2	2.1	3.2	3.1	
12/16/96	9:00 AM	0.1	0.0	2.0	1.8	3.0	2.9	
2/27/97	9:05 AM	0.2	0.1	1.8	1.6	2.4	2.3	

ODOT US177 Approach Embankment Evaluation

Bridge C, South Abutment Wall (Dynamic Compaction of Granular Backfill)

Amplified Liquid Settlement Gages:	**Tubing Length**	**Date Installe**	**As Built Elevation Top of Plate**	**Top of Fluid**
Centerline - SN 44214	40'	5/1/95	909.91'	920.85'
			Initial Head = 10.94'	
Offset - SN 44218	30'	5/1/95	909.88'	920.86'
10' wide			Initial Head = 10.98'	

Calibration for: Centerline — Head(ft) Reading - (-3.855 psi) / 8.505 psi / ft

Offset — Head(ft Reading - (-3.30 psi) / 8.18 psi / ft

ALSG Readings, Heads, & ΔH

Date	Time	CL Reading psi	CL Head ft	CL ΔH ft	OFS Reading psi	OFS Head ft	OFS ΔH ft	Remarks
5/5/95		90.2	11.059	-	86.6	10.990	-	Initial Readings by WCC, no backfill
5/15/95	AM	90.2	11.059	0.000	86.5	10.978	-0.012	After placing 1st lift, before dyn. compaction
5/15/95	1:00 PM	89.8	11.012	-0.047	86.5	10.978	-0.012	After 1st lift compaction (2 ft)
5/15/95	3:00 PM	90.9	11.141	0.082	86.9	11.027	0.037	After 2nd lift compaction (4 ft)
5/17/95	11:40 AM	91.3	11.188	0.129	86.8	11.015	0.025	After 3rd lift compaction (6 ft)
5/17/95	PM	91.3	11.188	0.129	86.8	11.015	0.025	After 4th lift compaction (8 ft)
5/19/95	AM	91.0	11.153	0.094	86.7	11.002	0.012	
5/31/95	AM	92.0	11.270	0.211	87.4	11.088	0.098	Prob w/cCL SG, won't hold pressure at 0.1,
6/16/95	AM	91.1	11.165	0.106	87.4	11.088	0.098	used 0.2 reading
6/28/95	AM	91.2	11.176	0.117	87.6	11.112	0.122	Used interpolation to get CL reading at 0.1
7/7/95	2:20 PM	91.0	11.153	0.094	87.5	11.100	0.110	Used interpolation to get CL reading at 0.1
7/14/95	2:15 PM	91.0	11.153	0.094	87.3	11.076	0.186	Used interpolation to get CL reading at 0.1
7/26/95	9:25 PM	91.0	11.153	0.094	87.4	11.088	0.098	Problem with CL SG has stopped
8/9/95	10:00 AM	91.2	11.176	0.117	87.5	11.100	0.110	
9/1/95	9:55 AM	91.0	11.153	0.094	87.6	11.112	0.122	
9/22/95	1:40 PM	91.3	11.188	0.129	87.8	11.137	0.147	
10/12/95	3:05 PM	91.7	11.235	0.176	88.0	11.161	0.171	
11/3/95	2:05 PM	91.8	11.247	0.188	87.9	11.149	0.159	
11/22/95	2:00 PM	92.2	11.294	0.235	88.3	11.198	0.208	
12/20/95	1:30 PM	92.3	11.306	0.247	88.6	11.235	0.245	
1/11/96	3:00 PM	92.7	11.353	0.294	88.9	11.271	0.281	
2/8/96	5:00 PM	92.7	11.353	0.294	88.9	11.271	0.281	
2/29/96	4:00 PM	92.8	11.364	0.305	88.9	11.271	0.281	
3/28/96	3:00 PM	92.5	11.329	0.270	88.6	11.234	0.244	
4/23/96	1:15 PM	93.3	11.423	0.364	88.9	11.271	0.281	CL SG - high volume of air bubbles in line
5/21/96	10:00 AM	76.5	-	-	88.4	11.210	0.220	CL ALSG has stopped functioning properly.
6/11/96	10:30 AM	70.7	-	-	88.7	11.247	0.257	Gage will be read but no data reduction carrie
8/6/96	9:30 AM	62.4	-	-	88.0	11.161	0.171	out.
10/31/96	8:30 AM	54.9	-	-	88.2	11.186	0.196	
12/16/96	9:00 AM	63.3	-	-	89.1	11.296	0.306	
2/27/97	9:05 AM	56.5	-	-	89.400	11.333	0.343	

ODOT US177 Approach Embankment Evaluation

Bridge C, South Abutment Wall (Dynamic Compaction of Granular Backfill)

Inclinometer Telescoping Couplings - Centerline: Installed 5/25/95

Casing Elevation (top=2.04' above GS) 922.49' As Built → 921.21' After Paving

GS Elevation 920.45' **Pavement Elevation** 921.65'

Reference Coupling 54.99' Depth → 865.46' Elevation **Bottom of Casing** 57.11'

Readings, Changes, & ΔH Values

Date	Time	Level 1 (Top)			Level 2			Level 3			Level 4 (Bottom)			Remarks
		Reading R1, ft	R4 - R1 ft	ΔH ft	Reading R2, ft	R4 - R2 ft	ΔH ft	Reading R3, ft	R4 - R3 ft	ΔH ft	Reading R4, ft	ΔR4 ft	ΔH ft	
6/2/95	AM	10.874	46.156	-	16.061	40.969	-	20.863	36.167	-	57.030	-	-	Omit this data set
6/16/95	PM	10.884	46.104	-	15.968	41.020	-	20.863	36.125	-	56.988	-	-	Omit this data set
6/28/95	AM	10.885	46.150	0.000	15.960	41.075	0.000	20.860	36.175	0.000	57.035	0.000	0.000	Reference Reading(Datum)
7/7/95	2:20 PM	10.885	46.155	-0.005	15.970	41.070	0.005	20.860	36.180	-0.005	57.040	0.005	-0.005	
7/14/95	2:15 PM	10.890	46.150	0.000	15.970	41.070	0.005	20.865	36.175	0.000	57.040	0.005	-0.005	
7/26/95	9:25 PM	10.890	46.150	0.000	15.967	41.073	0.002	20.865	36.175	0.000	57.040	0.005	-0.005	
8/9/95	10:00 AM	10.890	46.105	0.045	15.970	41.025	0.050	20.867	36.128	0.047	56.995	0.040	0.040	
9/1/95	9:55 AM	10.887	46.158	-0.008	15.970	41.075	0.000	20.867	36.178	-0.003	57.045	0.010	-0.010	
9/22/95	1:40 PM	10.880	46.105	0.045	15.960	41.025	0.050	20.855	36.130	0.045	56.985	0.050	0.050	
10/12/95	3:05 PM	10.880	46.157	-0.007	15.960	41.077	0.002	20.857	36.180	-0.005	57.037	0.002	-0.002	
11/3/95	2:05 PM	10.980	46.050	0.100	15.953	41.077	0.002	20.850	36.180	-0.005	57.030	0.005	0.005	
11/22/95	1:00 PM	10.875	46.108	0.042	15.955	41.028	0.047	20.850	36.133	0.042	56.983	0.052	0.052	
12/20/95	1:30 PM	10.870	46.155	-0.005	15.947	41.078	-0.003	20.845	36.180	-0.005	57.025	0.010	0.010	
1/11/96	3:00 PM	10.867	46.108	0.042	15.943	41.032	0.043	20.843	36.132	0.043	56.975	0.060	0.060	
2/8/96	5:00 PM	10.870	46.105	0.045	15.943	41.032	0.043	20.840	36.135	0.040	59.975	0.060	0.060	
2/29/96	4:00 PM	10.871	46.102	0.048	15.945	41.028	0.047	20.843	36.130	0.045	56.973	0.062	0.062	
3/28/96	3:00 PM	10.870	46.109	0.041	15.945	41.034	0.041	20.843	36.136	0.039	59.979	0.056	0.056	*(+0.16) for diff. b/w cutoff*
4/23/96	1:15 PM	10.875	46.105	0.045	15.943	41.037	0.038	20.847	36.133	0.042	56.980	0.055	0.055	*length and ext.*
5/21/96	10:00 AM	10.720	46.093	0.057	15.787	41.026	0.049	20.685	36.128	0.047	56.813	0.062	0.062	New reference (top) using ext.

6/11/96	10:30 AM	10.722	46.061	0.089	15.728	41.055	0.020	20.612	36.171	0.004	56.783	0.092	0.092	Highway opened to traffic
8/6/96	9:30 AM	10.728	46.012	0.138	15.725	41.015	0.060	20.618	36.122	0.053	56.740	0.135	0.135	
10/31/96	8:30 AM	10.715	46.020	0.130	15.717	41.018	0.057	20.613	36.122	0.053	56.735	0.140	0.140	
12/16/96	9:00 AM	10.740	46.070	0.080	15.740	41.070	0.005	20.637	36.173	0.002	56.810	0.065	0.065	
2/27/97	9:05 AM	10.715	46.067	0.083	15.710	41.072	0.003	20.605	36.177	-0.002	56.782	0.093	0.093	

ODOT US177 Approach Embankment Evaluation

Bridge C, South Abutment Wall (Dynamic Compaction of Granular Backfill)

Inclinometer Telescoping Couplings - Offset: Installed 5/30/95

Casing Elevation (top=2.05' above GS) 922.61' As Built → 921.37' After Paving

GS Elevation 920.56' **Pavement Elevation** 921.65'

Reference Coupling 56.11' Depth → 864.45' Elevation **Bottom of Casing** 58.17'

Readings, Changes, & ΔH Values

Date	Time	Level 1 (Top) Reading R1, ft	Level 1 R4 - R1 ft	Level 1 ΔH ft	Level 2 Reading R2, ft	Level 2 R4 - R2 ft	Level 2 ΔH ft	Level 3 Reading R3, ft	Level 3 R4 - R3 ft	Level 3 ΔH ft	Level 4 (Bottom) Reading R4, ft	Level 4 ΔR4 ft	Level 4 ΔH ft	Remarks
6/2/95	AM	10.874	47.281	-	15.874	42.281	-	20.988	37.167	-	58.155	-	-	Omit this Data set
6/16/95	PM	10.884	47.240	0.000	15.884	42.240	0.000	20.894	37.230	0.000	58.124	0.000	0.000	Reference Reading (Datum)
6/28/95	AM	10.885	47.230	0.010	15.875	42.240	0.000	20.890	37.225	0.005	58.115	0.009	0.009	
7/7/95	2:20 PM	10.890	47.230	0.010	15.880	42.240	0.000	20.895	37.225	0.005	58.120	0.004	0.004	
7/14/95	2:15 PM	10.890	47.225	0.015	15.885	42.230	0.010	20.895	37.220	0.010	58.115	0.009	0.009	
7/26/95	9:25 AM	10.890	47.230	0.010	15.885	42.234	0.006	20.897	37.223	0.007	58.120	0.004	0.004	
8/9/95	10:00 AM	10.890	47.165	0.075	15.885	42.170	0.070	20.895	37.160	0.070	58.055	0.069	0.069	
9/1/95	9:55 AM	10.895	47.225	0.015	15.885	42.235	0.005	20.900	37.220	0.010	58.120	0.004	0.004	
9/22/95	1:40 PM	10.885	47.160	0.080	15.880	42.165	0.075	20.890	37.155	0.075	58.045	0.079	0.079	
10/12/95	3:05 PM	10.885	47.202	0.038	15.857	42.230	0.010	20.870	37.217	0.013	58.087	0.037	0.037	
11/3/95	2:05 PM	10.880	47.140	0.100	15.850	42.170	0.070	20.863	37.157	0.073	58.020	0.194	0.194	
11/22/95	2:30 PM	10.880	47.140	0.100	15.953	42.067	0.173	20.865	37.155	0.075	58.020	0.104	0.104	
12/20/95	1:30 PM	10.875	47.135	0.105	15.840	42.170	0.070	20.855	37.155	0.075	58.010	0.114	0.114	
1/11/96	3:00 PM	10.870	47.145	0.095	15.843	42.172	0.068	20.855	37.160	0.070	58.015	0.109	0.109	
2/8/96	5:00 PM	10.873	47.200	0.040	15.845	42.228	0.012	20.855	37.218	0.012	58.073	0.051	0.051	
2/29/96	4:00 PM	10.975	47.103	0.137	15.842	42.236	0.004	20.859	37.219	0.011	58.078	0.046	0.046	
3/28/96	3:00 PM	10.877	47.200	0.040	15.849	42.228	0.012	20.860	37.217	0.013	58.077	0.047	0.047	*(-0.02) for diff. b/w cutoff*
4/23/96	1:15 PM	10.880	47.195	0.045	15.847	42.228	0.012	20.860	37.215	0.015	58.075	0.049	0.049	*length and ext.*
5/21/96	10:00 AM	10.885	46.952	0.288	15.675	42.162	0.078	20.683	37.154	0.076	57.837	0.307	0.307	New reference (top) using ext.

6/11/96	10:30 AM	10.891	47.007	0.233	15.675	42.223	0.017	20.690	37.208	0.022	57.898	0.246	0.246	Highway opened to traffic
8/6/96	9:30 AM	10.897	47.003	0.237	15.682	42.218	0.022	20.797	37.103	0.127	57.900	0.244	0.244	
10/31/96	8:30 AM	10.888	46.945	0.295	15.673	42.160	0.080	20.688	37.145	0.085	57.833	0.311	0.311	
12/16/96	9:00 AM	10.885	46.945	0.295	15.673	42.157	0.083	20.787	37.043	0.187	57.830	0.314	0.314	
2/27/97	9:05 AM	10.910	47.010	0.230	15.693	42.227	0.013	20.707	37.213	0.017	57.920	0.224	0.224	

ODOT US177 Approach Embankment Evaluation

Bridge C, South Abutment Wall (Dynamic Compaction of Granular Backfill)

Piezometer:

Standpipe Elevation	922.89'	→	921.28'
*As Built ► (Top=2.35 ft above GS)	(As Built)		(After Paving)

GS Elevation (Top of Subgrade)	920.54'	**Pavement Elevation** (Top of Pavement)	921.65'
Tip Elevation	870.54'	**Tip Depth**	50.0'

Groundwater Depth = Piezometer Reading - 0.37'
(Below Top of Pavement)

Groundwater Elevation = Standpipe Elevation (921.28') - Piezometer Reading

Date	Time	Piezometer Data Reading ft	GW Depth ft	GW Elev. ft	Remarks
5/25/95	PM	-	-	-	Installed piezometer
6/2/95	AM	23.95	21.60	898.94	Initial reading by OSU
6/16/95	PM	19.00	16.65	903.89	
6/28/95	AM	19.88	17.53	903.01	
7/7/95	2:20 PM	19.40	17.05	903.49	
7/14/95	2:15 PM	19.84	17.49	903.05	
7/26/95	9:25 AM	20.00	17.65	902.89	
8/9/95	10:00 AM	17.30	14.95	905.59	
9/1/95	9:55 AM	19.38	17.03	903.51	
9/22/95	1:40 PM	19.65	17.30	903.24	
10/12/95	3:05 PM	20.30	17.95	902.59	
11/3/95	2:05 PM	20.99	18.64	901.90	
11/22/95	2:30 PM	21.45	19.10	901.44	
12/20/95	1:30 PM	22.00	19.65	900.89	
1/11/96	3:00 PM	22.40	20.05	900.49	
2/8/96	5:00 PM	22.90	20.55	899.99	
2/29/96	4:00 PM	23.19	20.84	899.70	
3/28/96	3:00 PM	23.61	21.26	899.28	
4/23/96	1:15 PM	23.77	21.42	899.12	
5/21/96	10:00 AM	22.87	22.50	898.41	Use new standpipe elev., changed reference for depth
6/11/96	10:30 AM	23.21	22.84	898.07	Highway opened to traffic
8/6/96	9:30 AM	23.96	23.59	897.32	
10/31/96	8:30 AM	23.96	23.59	897.32	
12/16/96	9:00 AM	22.885	22.52	898.40	
2/27/97	9:05 AM	22.175	21.81	899.11	

ODOT US177 Approach Embankment Evaluation

Bridge C, South Abutment Wall (Dynamic Compaction of Granular Backfill), Surface Settlement Points

Date		6/12/96		8/6/96		10/31/96		2/28/97		
		Reading	Elevation	Reading	Elevation	Reading	Elevation	Reading	Elevation	
BM		W	924.65	W	924.65	W	924.65	W	924.65	
		E	923.46	E		E	923.46	E		
BS		2.26	-	3.044	-	3.145	-	3.243	-	
HI		925.72	-	927.694	-	927.795	-	927.893	-	
FS	1	3.65	922.07	5.623	922.071	5.755	922.040	5.848	922.045	
	2	3.81	921.91	5.798	921.896	5.911	921.884	6.010	921.883	
	3	4.00	921.72	5.983	921.711	6.102	921.693	6.198	921.695	
	4	4.18	921.54	6.162	921.532	6.266	921.529	6.365	921.528	
	5	3.63	922.09	5.602	922.092	5.726	922.069	5.823	922.070	
	6	3.79	921.93	5.785	921.909	5.898	921.897	5.997	921.896	
	7	4.00	921.72	5.982	921.712	6.096	921.699	6.195	921.698	
	8	4.18	921.54	6.173	921.521	6.281	921.514	6.397	921.496	*2/27/1997
	9	3.63	922.09	5.605	922.089	5.734	922.061	5.832	922.061	
	10	3.79	921.93	5.788	921.906	5.895	921.900	5.998	921.895	
	11	4.00	921.72	5.985	921.709	6.100	921.695	6.200	921.693	
	12	4.20	921.52	6.192	921.502	6.304	921.491	6.404	921.489	
	13	3.64	922.08	?	#VALUE!	5.734	922.061	5.843	922.050	
	14	3.78	921.94	5.778	921.916	5.887	921.908	5.992	921.901	
	15	3.97	921.75	5.950	921.744	6.067	921.728	6.169	921.724	
	16	4.12	921.60	6.110	921.584	6.219	921.576	6.320	921.573	

*Settlement Reading Point is missing.

APPENDIX B6

Instrumentation Data for Approach Embankment C2

ODOT US177 Approach Embankment Evaluation

Bridge C, North Abutment Wall (Flooding and Vibration of Granular Backfill)

Total Pressure Cells:

	Tubing Length	Date Installed	Test Pressures 5 psi	50 psi	100 psi
Top - SN 44200	34'	5/2/95	5.11	50.05	100.20
Middle - SN 44205	37'	5/2/95	4.92	50.00	100.05
Bottom - SN 44211	40'	5/2/95	5.40	50.46	100.59

Date	Time	TPC Readings (psi) Top w/flow	Top w/o flow	Middle w/flow	Middle w/o flow	Bottom w/flow	Bottom w/o flow	Remarks
5/5/95		0.0	0.0	0.0	0.0	0.5	0.3	nitial readings by WCC, drain cov. mat'l over bottom TP
5/12/95	AM	0.2	0.0	0.1	0.0	0.7	0.0	After 1st flood.& vib. of 1st lift, b/fill below mid.TPC
5/12/95	AM	0.0	0.0	0.0	0.0	0.9	0.1	After 2nd flood.& vib. of 1st lift, b/fill below mid.TPC
5/16/95	9:00 AM	0.6	0.4	0.7	0.5	1.5	0.9	After placing 2nd lift, b/fill to top, flood. & vib. underway
5/17/95	10:00 AM	0.2	0.1	0.4	0.2	2.0	1.4	After flooding and vibrating complete
5/19/95	AM	0.4	0.3	0.9	0.7	2.1	1.6	
5/31/95	AM	0.3	0.2	0.3	0.2	2.0	1.8	
6/16/95	AM	0.3	0.2	0.3	0.2	2.0	1.8	
6/28/95	AM	0.2	0.0	0.3	0.1	2.1	1.9	
7/7/95	3:05 PM	0.1	0.0	0.0	0.0	1.5	1.1	Top and middle TPC readings are "?"
7/14/95	3:00 PM	0.1	0.0	0.1	0.0	1.8	1.2	Top and middle TPC readings are "?"
7/26/95	8:35 AM	0.1	0.0	1.2	1.0	2.3	1.6	
8/9/95	10:45 AM	0.1	0.0	0.9	0.7	2.0	1.6	
9/1/95	10:40 AM	0.1	0.1	1.4	1.3	2.3	1.8	
9/22/95	3:10 PM	0.1	0.0	0.8	0.7	2.4	2.2	
10/12/95	3:45 PM	0.0	0.0	0.3	0.1	1.7	1.5	
11/3/95	2:50 PM	0.3	0.0	1.5	1.4	3.1	2.7	
11/22/95	1:00 PM	0.1	0.0	0.9	0.8	2.7	2.6	
12/20/95	2:00 PM	0.0	0.0	1.0	0.9	2.7	2.5	
1/11/96	4:00 PM	0.1	0.1	0.4	0.3	1.7	1.6	
2/8/96	5:00 PM	0.0	0.0	0.2	0.1	1.5	1.3	
2/29/96	4:00 PM	0.1	0.0	1.5	1.4	3.3	3.2	
3/28/96	3:30 PM	0.1	0.0	1.3	1.2	3.0	2.9	
4/23/96	12:35 PM	0.1	0.0	1.3	1.2	3.2	3.1	
5/21/96	10:00 AM	0.0	0.0	1.5	1.3	2.7	2.5	
6/11/96	8:45 AM	0.1	0.0	1.5	1.4	2.4	2.2	Highway Opened to Traffic
8/6/96	8:45 AM	0.1	0.0	1.5	1.4	2.8	2.6	
10/31/96	8:15 AM	0.2	0.1	1.6	1.5	3.4	3.2	
12/16/96	8:15 AM	0.2	0.1	1.7	1.6	3.6	3.4	
2/27/97	8:05 AM	0.3	0.2	1.6	1.5	3.3	3.1	

ODOT US177 Approach Embankment Evaluation

Bridge C, North Abutment Wall (Flooding and Vibration of Granular Backfill)

Amplified Liquid Settlement Gages:	Tubing Length	Date Installe	As Built Elevation Top of Plate	Top of Fluid
Centerline - SN 44221	40'	5/2/95	909.91'	920.88'
			Initial Head = 10.97'	
Offset - SN 44222 10' wide	30'	5/2/95	909.87'	920.90'
			Initial Head = 11.03'	

Calibration for: Centerline

Head(ft) Reading - (-4.405 psi)
8.455 psi / ft

Offset

Head(ft)= Reading - (-3.50 psi)
8.48 psi / ft

ALSG Readings, Heads, & ΔH

Date	Time	CL Reading psi	CL Head ft	CL ΔH ft	OFS Reading psi	OFS Head ft	OFS ΔH ft	Remarks
5/5/95		~~90.2~~	~~11.147~~		~~90.3~~	~~11.061~~		Initial readings by WCC, drain cov. mat'l over bottom TP
5/12/95	AM	90.0	11.123	0.000	90.0	11.026	0.000	After 1st flooding & vib. of 1st lift on 5/11
5/12/95	AM	90.5	11.182	0.059	91.1	11.156	0.130	After 2nd flooding & vib. of 1st lift on 5/12
5/16/95	9:00 AM	90.3	11.158	0.035	89.2	10.932	-0.094	After placing 2nd lift, b/fill to top, flood. & vib. underway
5/17/95	10:00 AM	89.8	11.099	-0.024	90.1	11.038	0.012	After flooding and vibrating complete
5/19/95	AM	90.3	11.158	0.035	90.2	11.050	0.024	
5/31/95	AM	90.8	11.218	0.095	89.8	11.002	-0.024	
6/16/95	AM	90.4	11.170	0.047	89.0	10.908	-0.118	
6/28/95	AM	90.8	11.218	0.095	90.0	11.026	0.000	
7/7/95	3:05 PM	90.8	11.218	0.095	89.8	11.002	-0.024	
7/14/95	3:00 PM	90.8	11.218	0.095	89.9	11.014	-0.012	
7/26/95	8:35 AM	90.5	11.182	0.059	89.8	11.002	-0.024	
8/9/95	10:45 AM	90.7	11.206	0.083	89.8	11.002	-0.024	
9/1/95	10:40 AM	90.8	11.218	0.095	89.9	11.014	-0.012	
9/22/95	3:10 PM	91.0	11.241	0.118	89.8	11.002	-0.024	
10/12/95	3:45 PM	91.1	11.253	0.130	89.6	10.979	-0.047	
11/3/95	2:50 PM	91.1	11.253	0.130	90.2	11.050	0.024	
11/22/95	1:00 PM	91.3	11.277	0.154	90.8	11.120	0.094	
12/20/95	2:00 PM	91.5	11.300	0.177	90.5	11.085	0.059	
1/11/96	4:00 PM	91.8	11.336	0.213	90.9	11.132	0.106	
2/8/96	5:00 PM	91.7	11.324	0.201	90.8	11.120	0.094	
2/29/96	5:00 PM	91.8	11.378	0.255	90.3	11.061	0.035	
3/28/96	3:30 PM	91.6	11.312	0.189	89.9	11.014	-0.012	
4/23/96	12:35 PM	-	-	-	90.3	11.061	0.035	Misread - not on plot.
5/2/96	9:00 AM	91.5	11.300	0.177	90.4	11.073	0.047	
5/21/96	10:00 AM	91.5	11.300	0.177	90.2	11.050	0.024	
6/11/96	8:45 AM	91.6	11.312	0.189	90.4	11.073	0.047	Highway opened to traffic
8/6/96	8:45 AM	91.1	11.253	0.130	89.8	11.002	-0.024	
10/31/96	8:15 AM	91.7	11.324	0.201	90.6	11.097	0.071	
12/16/96	8:15 AM	92.3	11.395	0.272	91.1	11.156	0.130	
2/27/97	8:05 AM	72.2	9.060	-2.063	58.3	7.288	-3.738	(?) Readings, not enough flow?

ODOT US177 Approach Embankment Evaluation

Bridge C, North Abutment Wall (Flooding and Vibration of Granular Backfill)

Inclinometer Telescoping Couplings - Centerline Installed 6/1/95

Casing Elevation (top=1.91' above GS) — 922.38' As Built → 921.35' After Paving

GS Elevation 920.47' — **Pavement Elevation** 921.68'

Reference Coupling 55.27' Depth → 865.20' Elevation — **Bottom of Casing** 57.22'

Readings, Changes, & ΔH Values

Date	Time	Level 1 (Top)			Level 2			Level 3			Level 4 (Bottom)			Remarks
		Reading R1, ft	R4 - R1 ft	ΔH ft	Reading R2, ft	R4 - R2 ft	ΔH ft	Reading R3, ft	R4 - R3 ft	ΔH ft	Reading R4, ft	ΔR4 ft	ΔH ft	
6/5/95	AM	10.853	46.323	-	15.843	41.333	-	20.853	36.323	-	57.176	-	-	Omit this data set
6/16/95	AM	10.858	46.328	0.000	15.843	41.343	0.000	20.853	36.333	0.000	57.186	0.000	0.000	Reference Reading(Datum)
6/28/95	AM	10.860	46.315	0.013	15.845	41.330	0.013	20.850	36.325	0.008	57.175	0.011	0.011	
7/7/95	3:05 PM	10.860	46.315	0.013	15.845	41.330	0.013	20.855	36.320	0.013	57.175	0.011	0.011	
7/14/95	3:00 PM	10.865	46.315	0.013	15.845	41.335	0.008	20.850	36.330	0.003	57.180	0.006	0.006	
7/26/95	8:35 AM	10.865	46.315	0.013	15.850	41.330	0.013	20.855	36.325	0.008	57.180	0.006	0.006	
8/9/95	10:45 AM	10.865	46.315	0.013	15.850	41.330	0.013	20.853	36.327	0.006	57.180	0.006	0.006	
9/1/95	10:40 AM	10.865	46.312	0.016	15.850	41.327	0.016	20.853	36.324	0.009	57.177	0.009	0.009	
9/22/95	3:10 PM	10.860	46.307	0.021	15.845	41.322	0.021	20.845	36.322	0.011	57.167	0.019	0.019	
10/12/95	3:45 PM	10.860	46.267	0.061	15.845	41.282	0.061	20.847	36.280	0.053	57.127	0.059	0.059	
11/3/95	2:50 PM	10.853	46.310	0.018	15.943	41.220	0.123	20.837	36.326	0.007	57.163	0.023	0.023	
11/22/95	1:00 PM	10.850	46.307	0.021	15.837	41.320	0.023	20.840	36.137	0.016	57.157	0.029	0.029	
12/20/95	2:00 PM	10.845	46.408	-0.080	15.827	41.426	-0.083	20.925	36.328	0.005	57.253	0.067	-0.067	
1/11/96	4:00 PM	10.845	46.265	0.063	15.827	41.283	0.060	20.830	36.280	0.053	57.110	0.076	0.076	
2/8/96	5:00 PM	10.843	46.307	0.021	15.825	41.325	0.018	20.827	36.323	0.010	57.150	0.036	0.036	
2/29/96	5:00 PM	10.845	46.302	0.026	15.825	41.322	0.021	20.828	36.319	0.014	57.147	0.039	0.039	
3/28/96	3:30 PM	10.845	46.300	0.028	15.825	41.320	0.023	20.825	36.320	0.013	57.145	0.041	0.041	
4/23/96	12:35 PM	10.849	46.258	0.070	15.827	41.280	0.063	20.830	36.277	0.056	57.107	0.079	0.079	
5/21/96	10:00 AM	10.850	43.290	0.038	15.830	41.310	0.033	20.830	36.310	0.023	57.140	0.046	0.046	New reference (top) using ext.

6/11/96	8:45 AM	10.852	46.288	0.040	15.830	41.310	0.033	20.830	36.310	0.023	57.140	0.046	0.046	Highway opened to traffic
8/6/96	8:45 AM	10.858	46.282	0.046	15.835	41.305	0.038	20.830	36.310	0.023	57.140	0.046	0.046	
10/31/96	8:15 AM	10.850	46.280	0.048	15.828	41.302	0.041	20.825	36.305	0.028	57.130	0.056	0.056	
12/16/96	8:15 AM	10.847	46.283	0.045	15.825	41.305	0.038	20.823	36.307	0.026	57.130	0.056	0.056	
2/27/97	8:05 AM	10.840	46.285	0.043	15.820	41.305	0.038	20.813	36.312	0.021	57.125	0.061	0.061	

ODOT US177 Approach Embankment Evaluation

Bridge C, North Abutment Wall (Flooding and Vibration of Granular Backfill)

Inclinometer Telescoping Couplings - Offset: Installed 6/2/95

Casing Elevation (top=2.04' above GS) — 922.65' As Built → After Paving

GS Elevation 920.61' — **Pavement Elevation**

Reference Coupling 55.23' Depth → 865.38' Elevation — **Bottom of Casing** 57.17'

Readings, Changes, & ΔH Values

Date	Time	Level 1 (Top)			Level 2			Level 3			Level 4 (Bottom)			Remarks
		Reading R1, ft	R4 - R1 ft	ΔH ft	Reading R2, ft	R4 - R2 ft	ΔH ft	Reading R3, ft	R4 - R3 ft	ΔH ft	Reading R4, ft	ΔR4 ft	ΔH ft	
6/5/95	AM	10.884	46.385	0.000	15.884	41.385	0.000	20.905	36.364	0.000	57.269	0.000	0.000	Reference Reading (Datum)
6/16/95	AM	10.884	46.323	-	15.884	41.323	-	20.915	36.292	-	57.207	-	-	Omit this Data set
6/28/95	AM	10.911	46.389	-0.004	15.915	41.385	0.000	20.940	36.360	0.004	57.300	0.031	-0.031	
7/7/95	3:05 PM	10.890	46.380	0.005	15.885	41.385	0.000	20.915	36.355	0.009	57.270	0.001	-0.001	
7/14/95	3:00 PM	10.890	46.380	0.005	15.895	41.375	0.010	20.920	36.350	0.014	57.270	0.001	-0.001	
7/26/95	8:35 AM	10.885	46.385	0.000	15.890	41.380	0.005	20.915	36.355	0.009	57.270	0.001	-0.001	
8/9/95	10:45 AM	10.890	46.380	0.005	15.890	41.380	0.005	20.915	36.355	0.009	57.270	0.001	-0.001	
9/1/95	10:40 AM	10.927	46.396	-0.011	15.933	41.390	-0.005	20.960	36.363	0.001	57.323	0.054	-0.054	
9/22/95	3:10 PM	10.877	46.323	0.062	15.885	41.315	0.070	20.910	36.290	0.074	57.200	0.069	0.069	
10/12/95	3:45 PM	10.890	46.370	0.015	15.893	41.367	0.018	20.910	36.350	0.014	57.260	0.009	0.009	
11/3/95	2:50 PM	10.875	46.395	-0.010	15.880	41.390	-0.005	20.920	36.450	-0.086	57.270	0.001	-0.001	
11/22/95	1:00 PM	10.870	46.323	0.062	15.875	41.318	0.067	20.903	36.290	0.074	57.193	0.076	0.076	
12/20/95	2:00 PM	10.865	46.415	-0.030	15.870	41.410	-0.025	20.900	36.380	-0.016	57.280	0.011	-0.011	
1/11/96	4:00 PM	10.865	46.380	0.005	15.870	41.375	0.010	20.895	36.350	0.014	57.245	0.024	0.024	
2/8/96	5:00 PM	10.865	46.378	0.007	15.870	41.373	0.012	20.895	36.348	0.016	57.243	0.026	0.026	
2/29/96	5:00 PM	10.869	46.376	0.009	15.870	41.375	0.010	20.899	36.346	0.018	57.245	0.024	0.024	
3/28/96	3:30 PM	10.867	46.313	0.072	15.870	41.310	0.075	20.899	36.281	0.083	57.180	0.089	0.089	
4/23/96	12:35 PM	10.870	46.310	0.075	15.873	41.307	0.078	20.900	36.280	0.084	57.180	0.089	0.089	
5/21/96	10:00 AM	10.880	46.097	0.288	15.615	41.362	0.023	20.640	36.337	0.027	56.977	0.292	0.292	New reference (top) using ext.

6/11/96	8:45 AM	10.890	46.010	0.375	15.602	41.298	0.087	20.628	36.272	0.092	56.900	0.369	0.369	Highway opened to traffic
8/6/96	8:45 AM	10.898	46.080	0.377	15.613	41.365	0.020	20.740	36.238	0.126	56.978	0.291	0.291	
10/31/96	8:15 AM	10.917	46.068	0.317	15.635	41.350	0.035	20.660	36.325	0.039	56.985	0.284	0.284	
12/16/96	8:15 AM	10.885	46.070	0.315	15.605	41.350	0.035	20.630	36.325	0.039	56.955	0.314	0.314	
2/27/97	8:05 AM	10.890	46.070	0.315	15.605	41.355	0.030	20.630	36.330	0.034	56.960	0.309	0.309	

ODOT US177 Approach Embankment Evaluation

Bridge C, North Abutment Wall (Flooding and Vibration of Granular Backfill)

Piezometer:

	Standpipe Elevation	923.12'	→ 921.31'
*As Built ►	(Top=2.63 ft above GS)	(As Built)	(After Paving)

GS Elevation 920.49' (Top of Subgrade)

Pavement Elevation 921.68' (Top of Pavement)

Tip Elevation 875.49'

Tip Depth 45.0'

Groundwater Depth = Piezometer Reading - 0.37'
(Below Top of Pavement)

Groundwater Elevation = Standpipe Elevation (921.31) - Piezometer Reading

Date	Time	Piezometer Data Reading ft	GW Depth ft	GW Elev. ft	Remarks
6/1/95	PM	-	-	-	Installed piezometer
6/16/95	AM	19.05	16.42	904.07	
6/28/95	AM	19.44	16.81	903.68	
7/7/95	3:05 PM	18.94	16.31	904.18	
7/14/95	3:00 PM	19.36	16.73	903.76	
7/26/95	8:35 AM	19.60	16.97	903.52	
8/9/95	10:45 AM	17.40	14.77	905.72	
9/1/95	10:40 AM	18.98	16.35	904.14	
9/22/95	3:10 PM	19.24	16.61	903.88	
10/12/95	3:45 PM	19.85	17.22	903.27	
11/3/95	2:50 PM	20.47	17.84	902.65	
11/22/95	1:00 PM	20.87	18.24	902.25	
12/20/95	2:00 PM	21.35	18.72	901.77	
1/11/96	4:00 PM	21.73	19.10	901.39	
2/8/96	5:00 PM	22.19	19.56	900.93	
2/29/96	5:00 PM	22.60	19.97	900.52	
3/28/96	3:30 PM	22.89	20.26	900.23	
4/23/96	12:35 PM	23.10	20.47	900.02	
5/21/96	10:00 AM	21.79	21.42	899.52	Use new standpipe elev., changed reference for depth
6/11/96	8:45 AM	22.17	21.80	899.14	Highway opened to traffic
8/6/96	8:45 AM	23.02	22.65	898.29	
10/31/96	8:15 AM	23.14	22.77	898.17	
12/16/96	8:15 AM	21.937	21.57	899.37	
2/27/97	8:05 AM	21.02	20.65	900.29	

ODOT US177 Approach Embankment Evaluation

Bridge C, North Abutment Wall (Flooding and Vibration of Granular Backfill), Surface Settlement Points

Date		6/12/96		8/6/96		10/31/96		2/28/97		
		Reading	Elevation	Reading	Elevation	Reading	Elevation	Reading	Elevation	
BM		W	924.78	W	924.78	W	924.78	W	924.78	
		E	923.56	E	923.56	E	923.56	E		
BS		2.18	-	2.70	-	2.78	-	2.537	-	
HI		925.74	-	927.48	-	927.56	-	927.317	-	
FS	1	3.60	922.14	5.340	922.140	5.435	922.125	5.197	922.120	
	2	3.74	922.00	5.520	921.960	5.605	921.955	5.370	921.947	
	3	3.88	921.86	5.650	921.830	5.735	921.825	5.500	921.817	
	4	4.05	921.69	5.810	921.670	5.895	921.665	5.660	921.657	
	5	3.64	922.10	5.385	922.095	5.475	922.085	5.265	922.052	*2/27/1997
	6	3.79	921.95	5.565	921.915	5.655	921.905	5.418	921.899	
	7	3.93	921.81	5.685	921.795	5.770	921.790	5.560	921.757	*2/27/1997
	8	4.13	921.61	5.890	921.590	5.983	921.577	5.747	921.570	
	9	3.69	922.05	5.442	922.038	5.535	922.025	5.318	921.999	*2/27/1997
	10	3.84	921.90	5.605	921.875	5.695	921.865	5.462	921.855	
	11	3.97	921.77	5.730	921.750	5.825	921.735	5.587	921.730	
	12	4.14	921.60	5.890	921.590	5.975	921.585	5.745	921.572	
	13	3.73	922.01	5.484	921.996	5.575	921.985	5.360	921.957	*2/27/1997
	14	3.88	921.86	5.646	921.834	5.740	921.820	5.506	921.811	
	15	4.01	921.73	5.767	921.713	5.867	921.693	5.627	921.690	
	16	4.15	921.59	5.915	921.565	6.000	921.560	5.768	921.549	

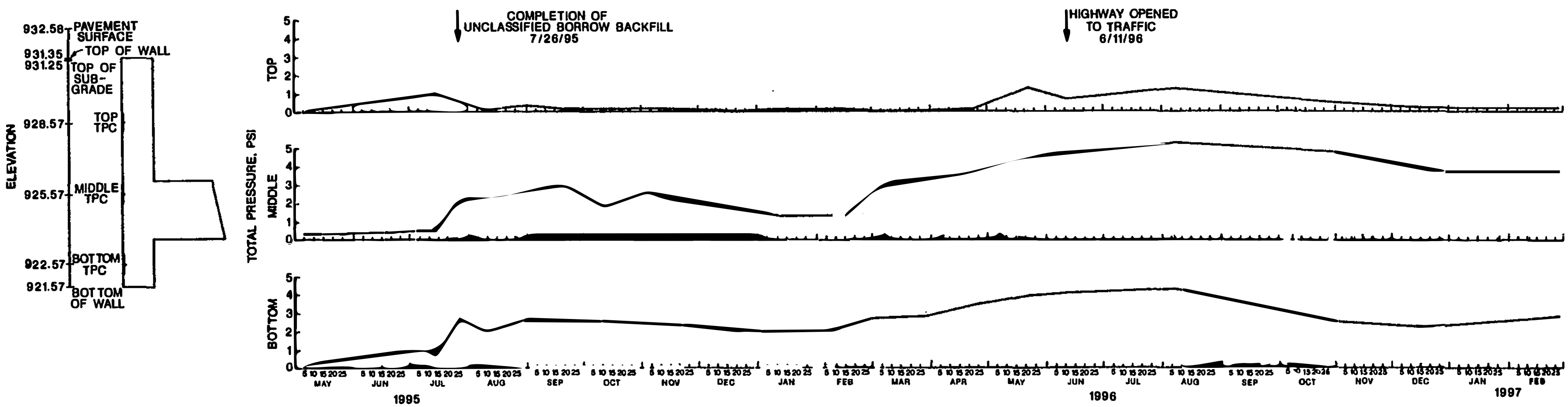
*Settlement Reading Point is missing.

APPENDIX C

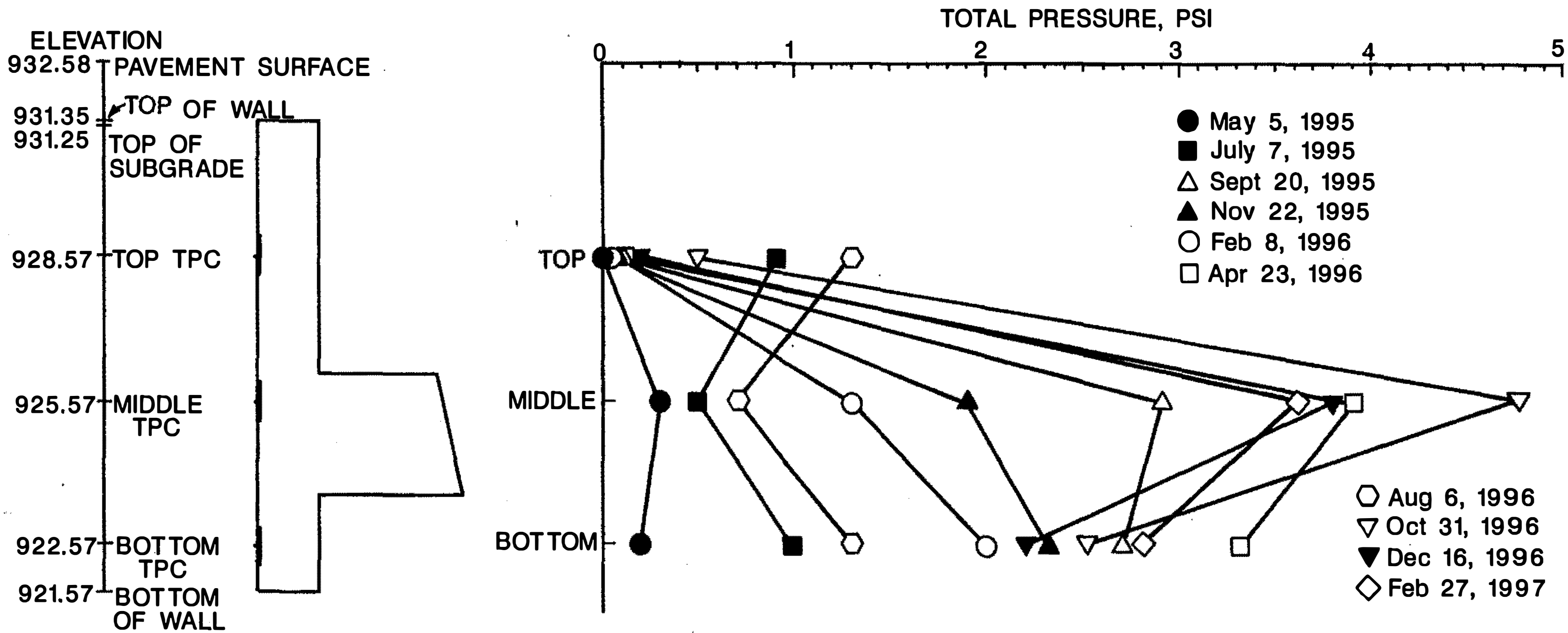
INSTRUMENTATION DATA PLOTS FOR ALL APPROACH EMBANKMENTS

APPENDIX C1

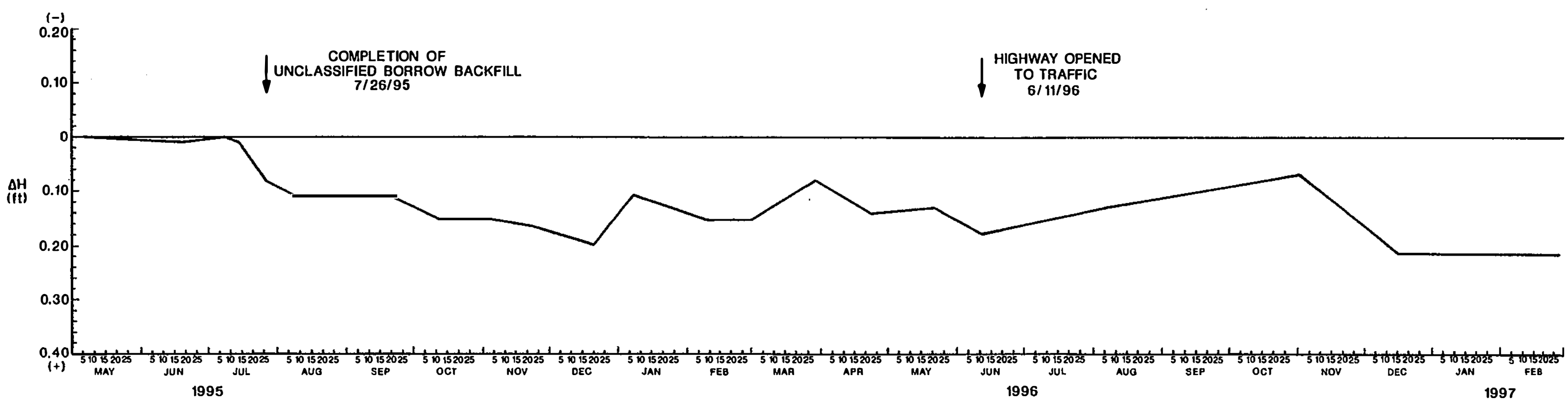
Data Plots for Approach Embankment A1



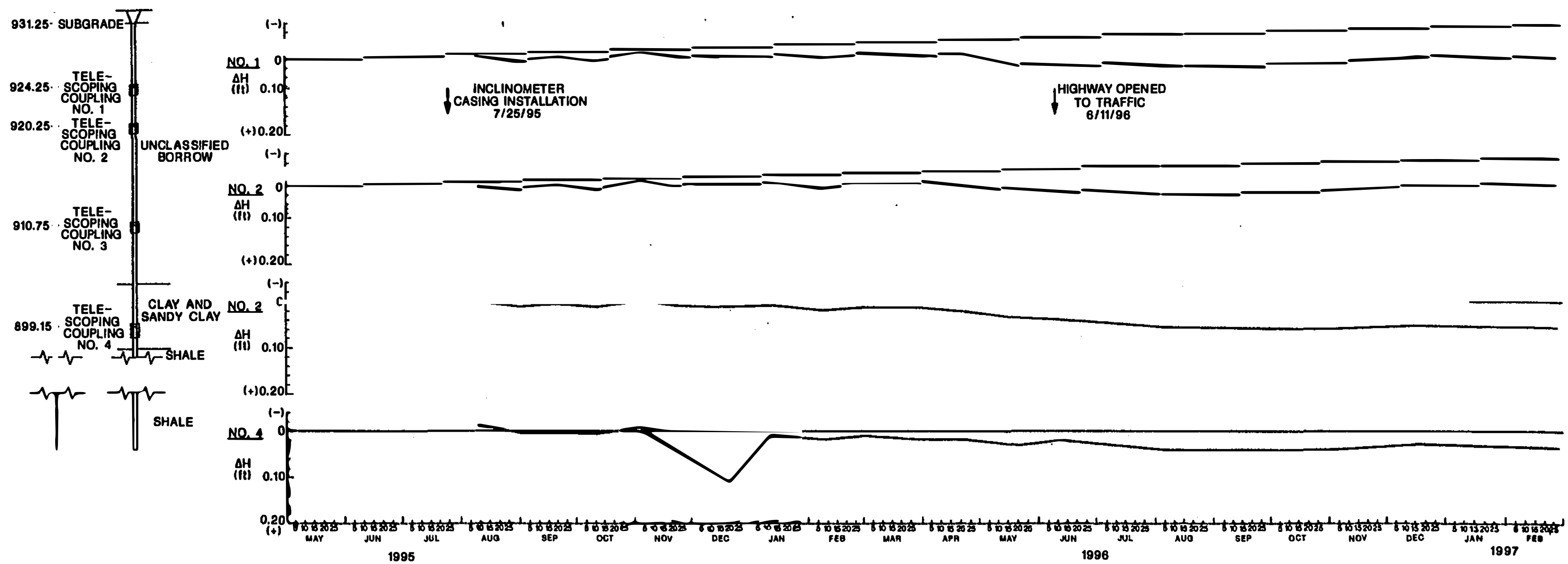
TOTAL PRESSURE CELL DATA (TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE A



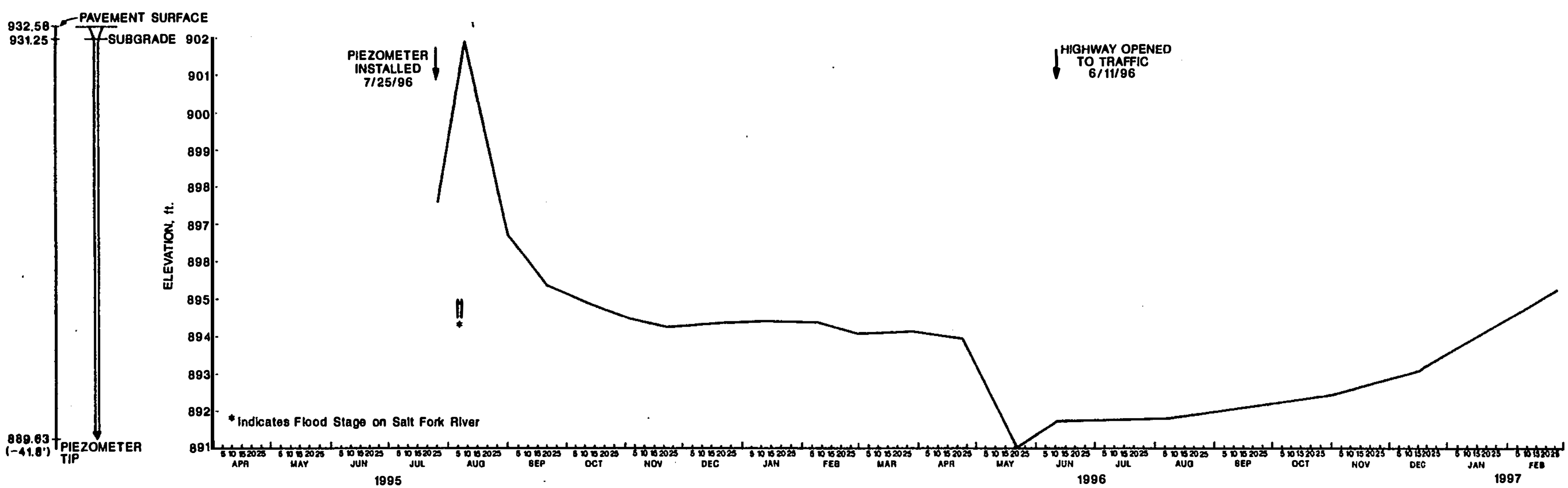
TOTAL PRESSURE CELL DATA (PROFILE) SOUTH ABUTMENT WALL, BRIDGE A



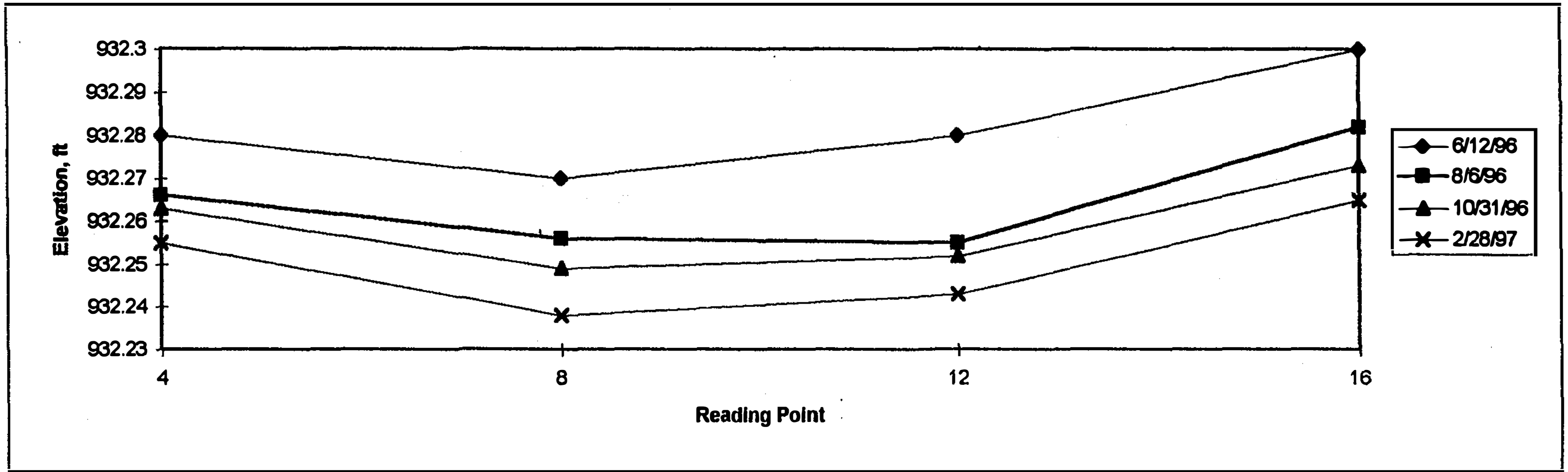
SETTLEMENT FROM AMPLIFIED LIQUID SETTLEMENT
GAGE, (℄) SOUTH ABUTMENT WALL, BRIDGE A

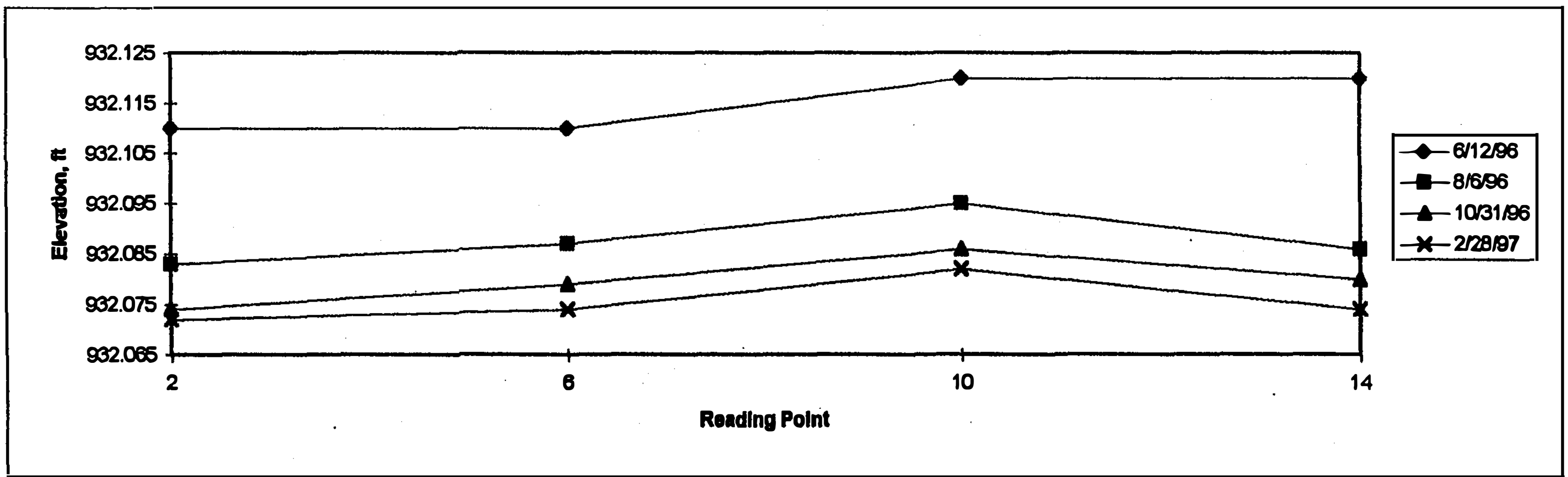


SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE A

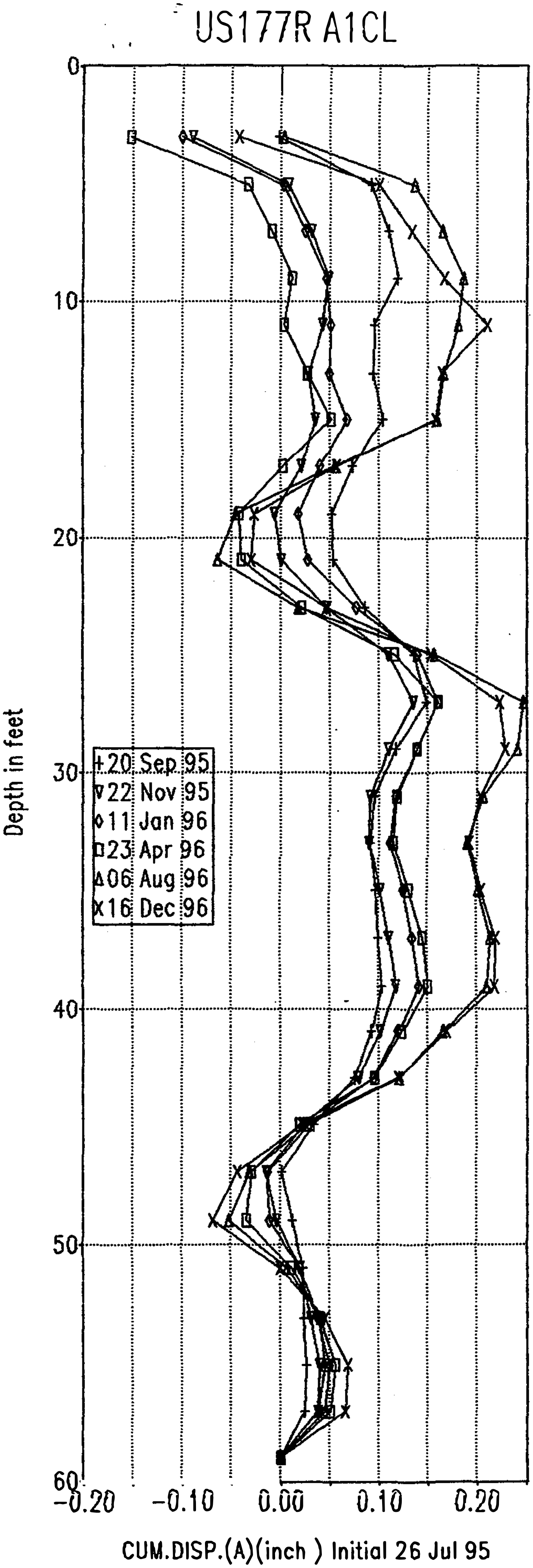


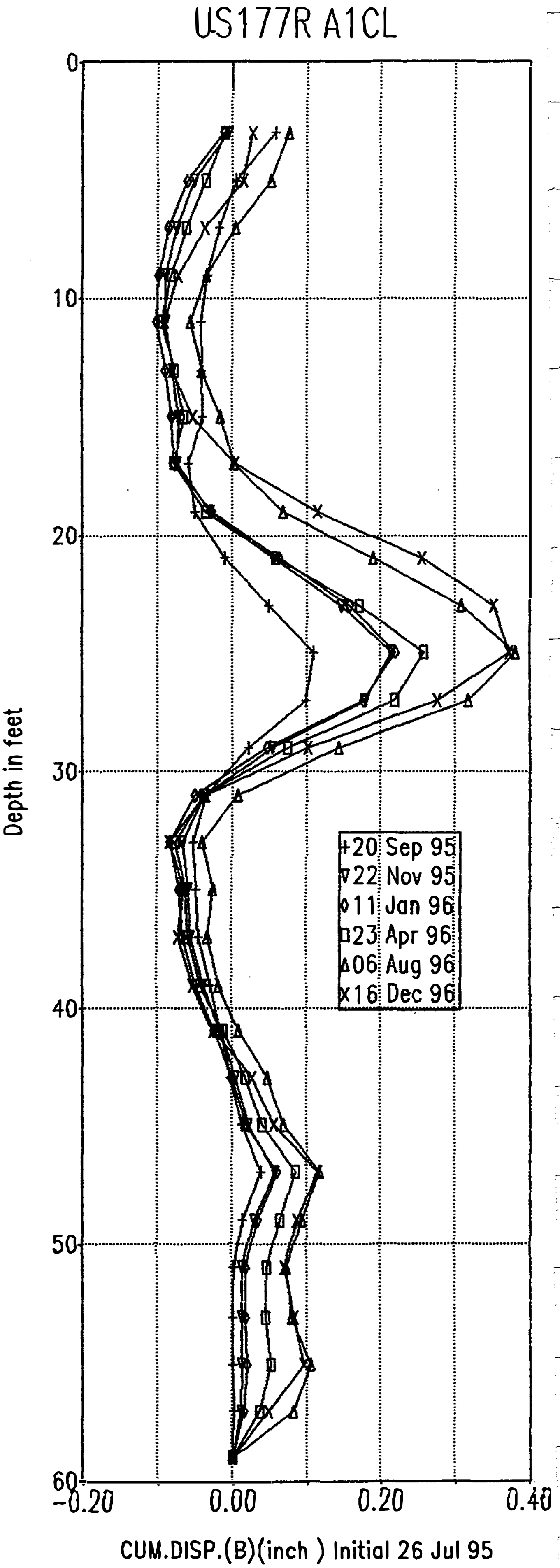
GROUNDWATER TABLE ELEVATION (TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE A

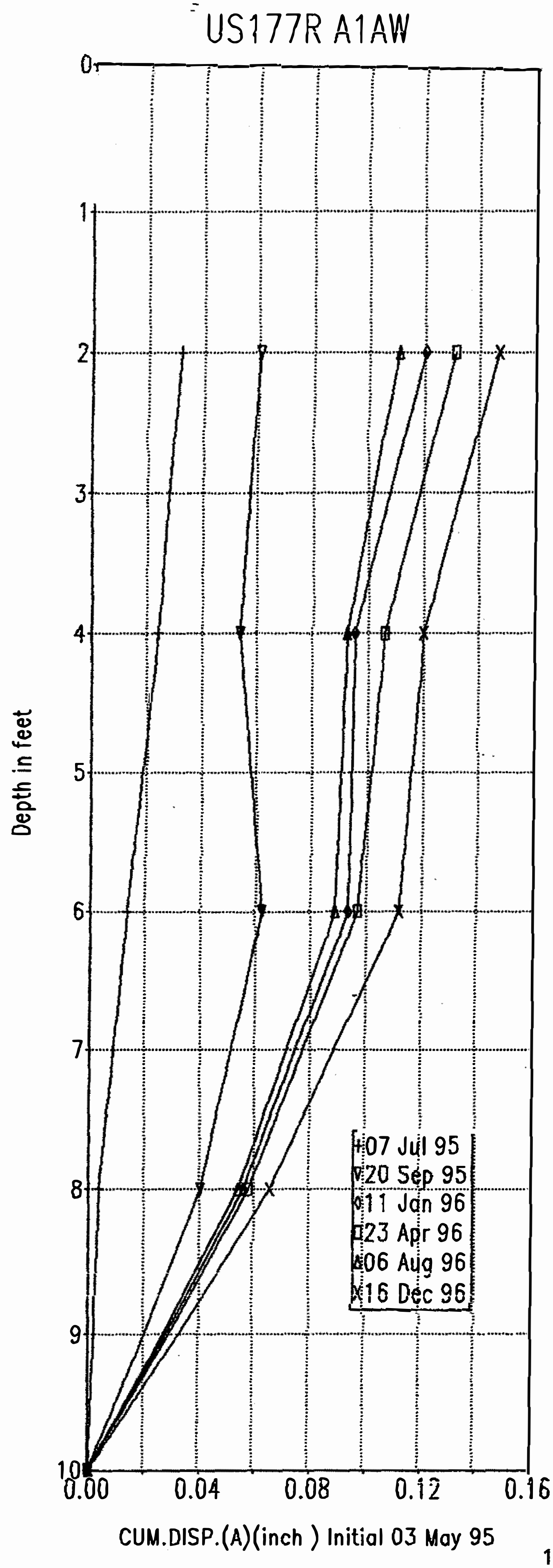


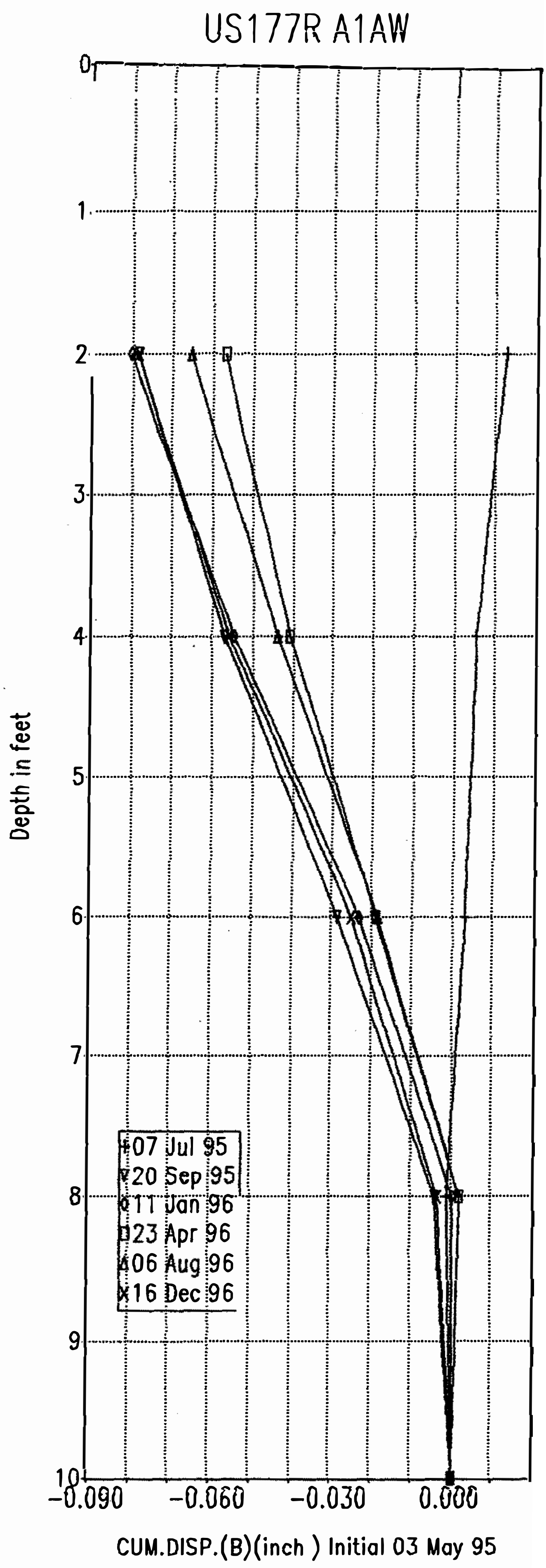


Surface Settlement Point Data, South Abutment Wall, Bridge A


US177R A1CL
Depth in feet
0
10
20
30
40
50
60
-0.20
-0.10
0.00
0.10
0.20
+20 Sep 95
∇22 Nov 95
◊11 Jan 96
□23 Apr 96
Δ06 Aug 96
X16 Dec 96
CUM.DISP.(A)(inch) Initial 26 Jul 95

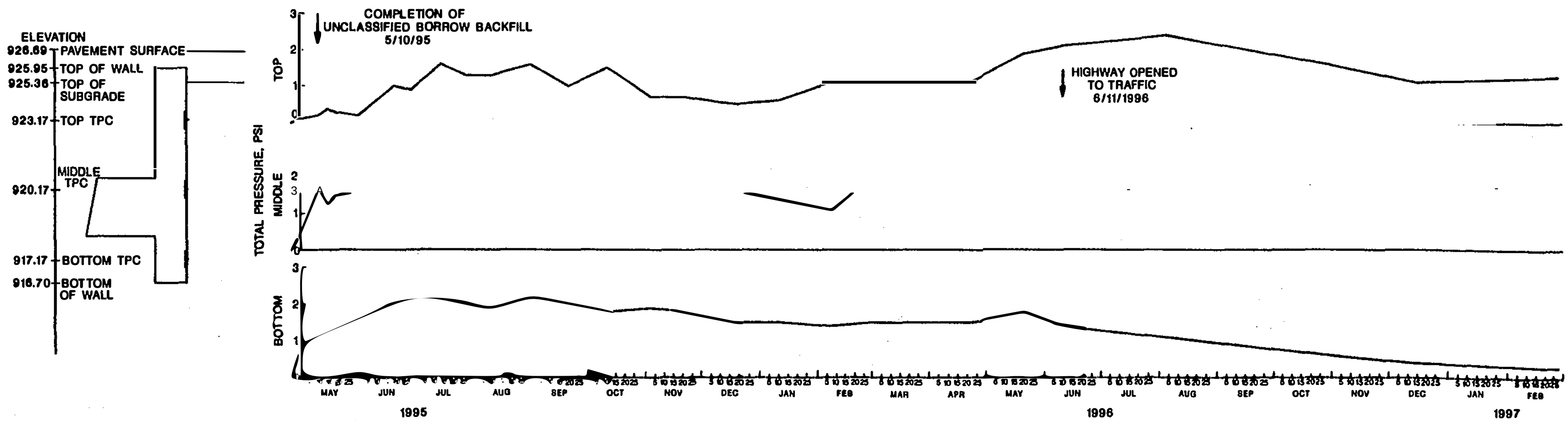

US177R A1CL
Depth in feet
0
10
20
30
40
50
60
-0.20
0.00
0.20
0.40
+20 Sep 95
∇22 Nov 95
◊11 Jan 96
□23 Apr 96
Δ06 Aug 96
X16 Dec 96
CUM.DISP.(B)(inch) Initial 26 Jul 95


US177R A1AW
Depth in feet
0
1
2
3
4
5
6
7
8
9
10
0.00
0.04
0.08
0.12
0.16
07 Jul 95
20 Sep 95
11 Jan 96
23 Apr 96
06 Aug 96
16 Dec 96
CUM.DISP.(A)(inch) Initial 03 May 95

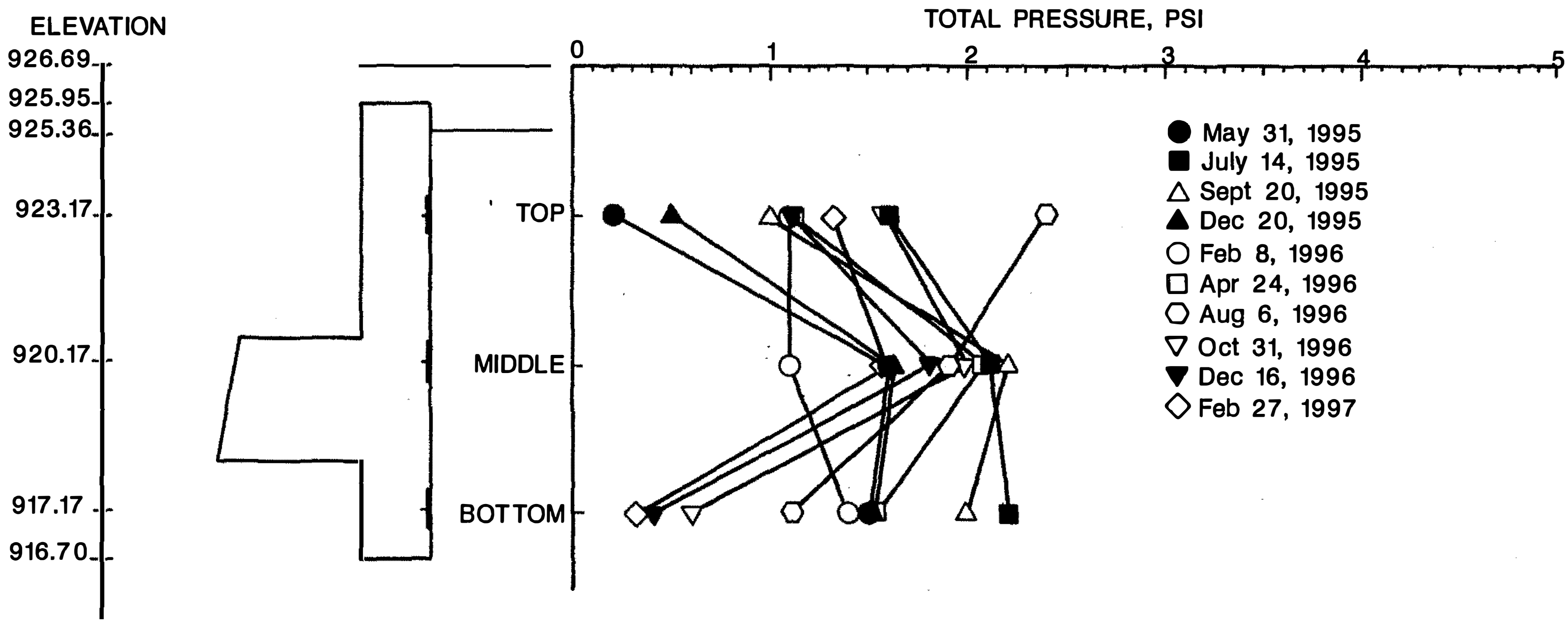

US177R A1AW
Depth in feet
0
1
2
3
4
5
6
7
8
9
10
-0.090
-0.060
-0.030
0.000
07 Jul 95
20 Sep 95
11 Jan 96
23 Apr 96
06 Aug 96
16 Dec 96
CUM.DISP.(B)(inch) Initial 03 May 95

APPENDIX C2

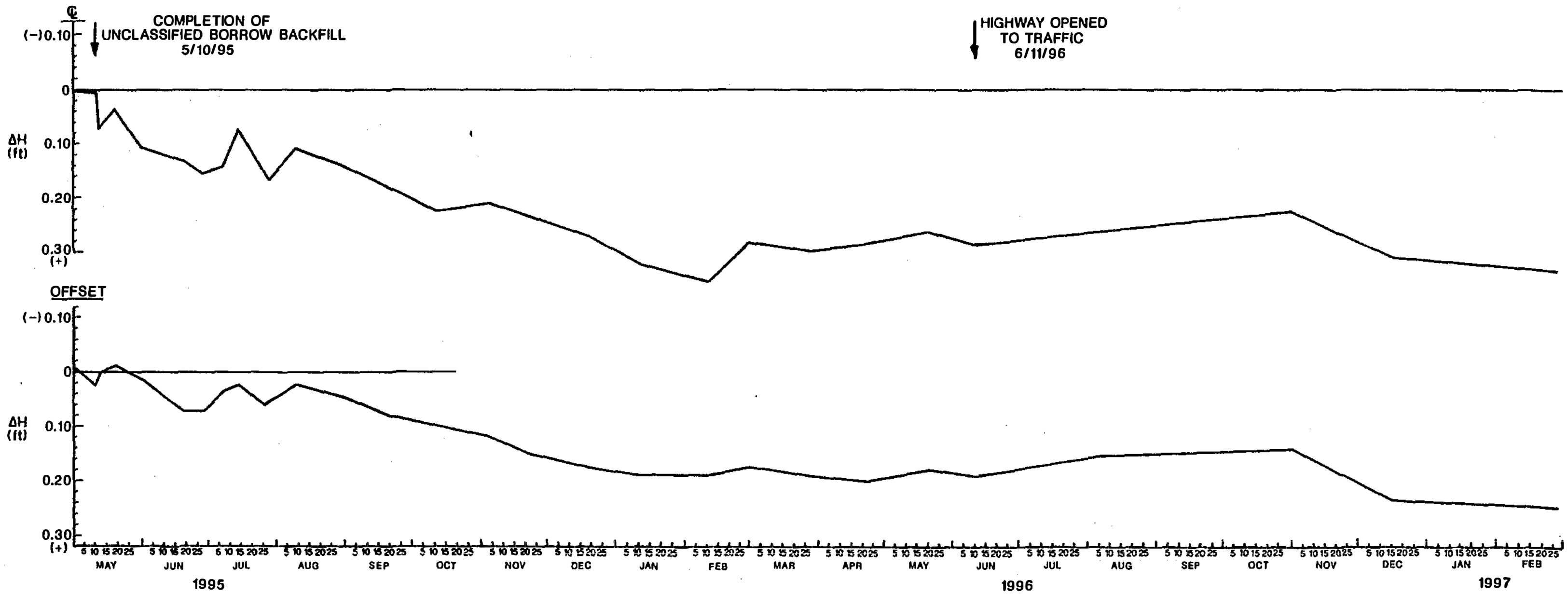
Data Plots for Approach Embankment A2



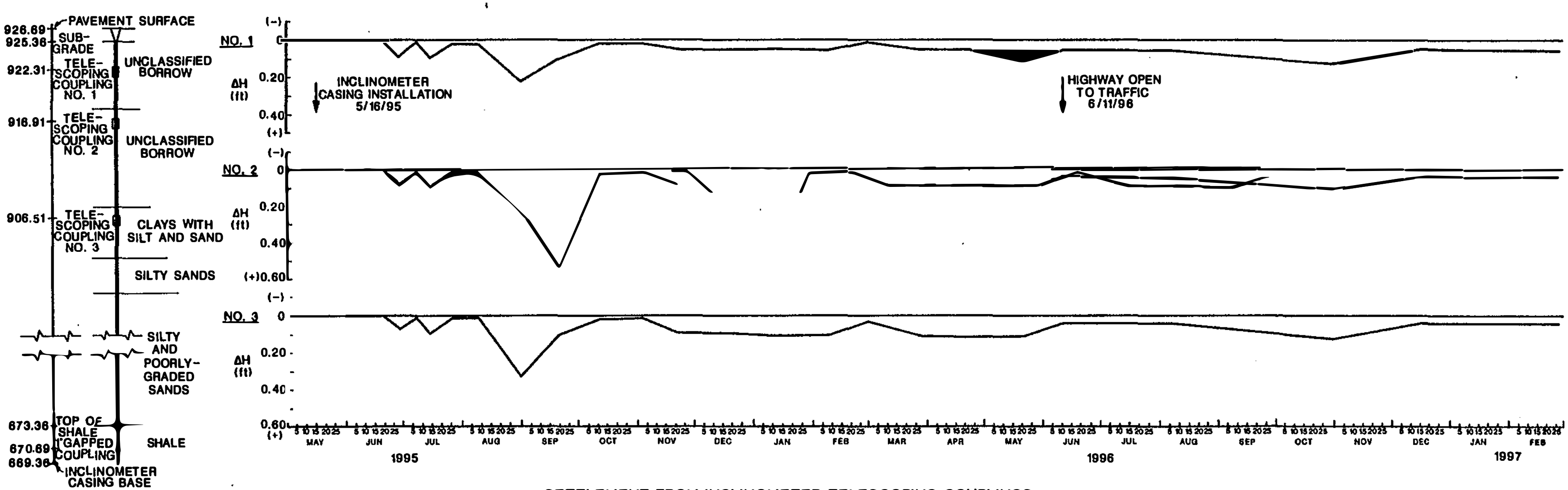
TOTAL PRESSURE CELL DATA (TIME PLOT) NORTH ABUTMENT WALL, BRIDGE A



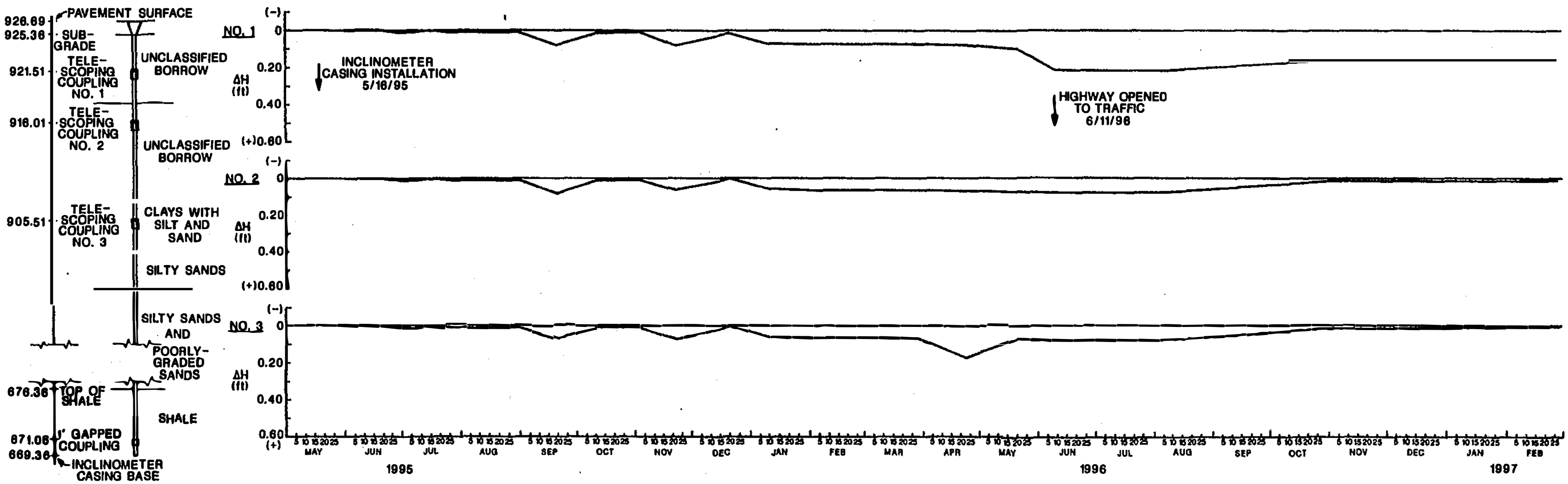
TOTAL PRESSURE CELL DATA (PROFILE) NORTH ABUTMENT WALL, BRIDGE A



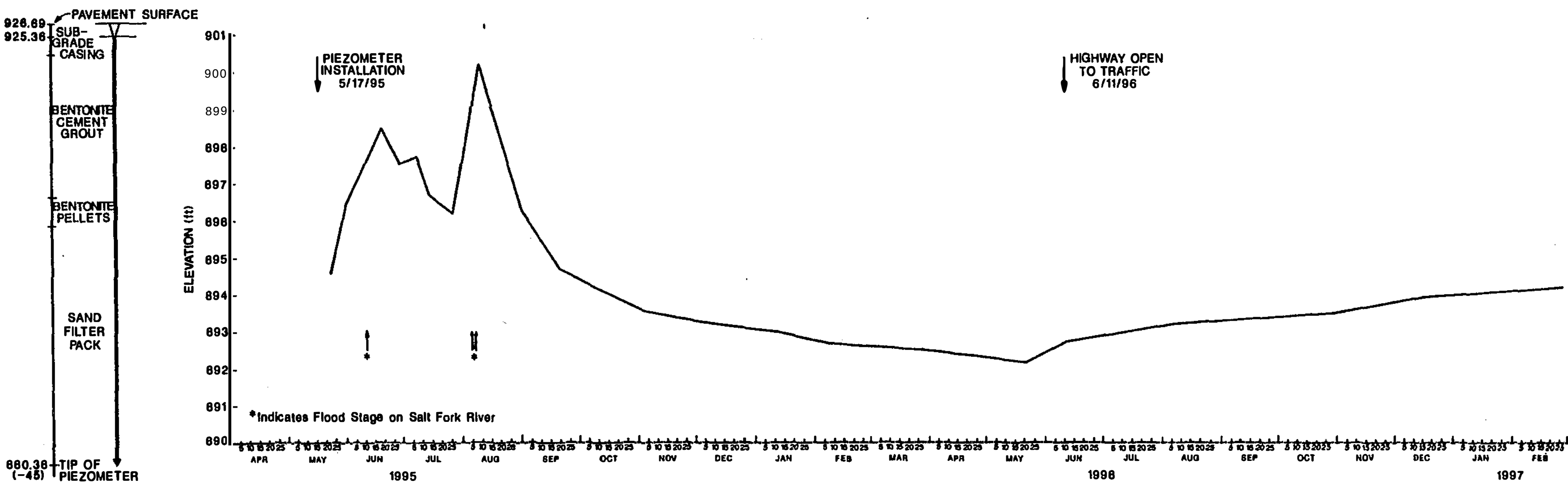
SETTLEMENT FROM AMPLIFIED LIQUID SETTLEMENT
GAGES NORTH ABUTMENT WALL, BRIDGE A



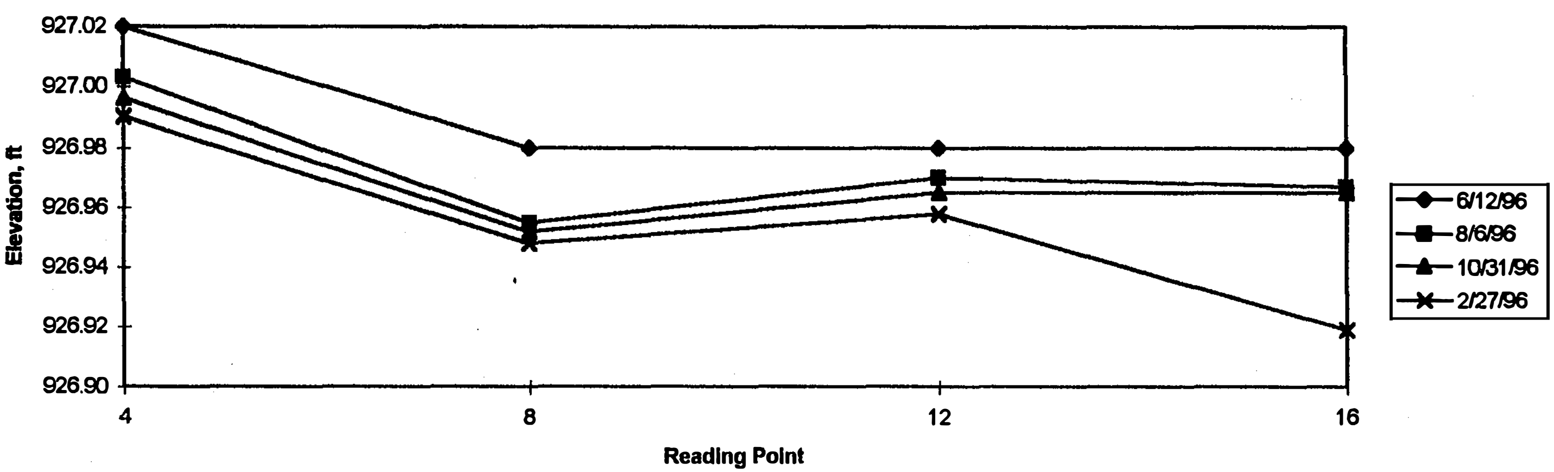
SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) CENTERLINE, NORTH ABUTMENT WALL, BRIDGE A

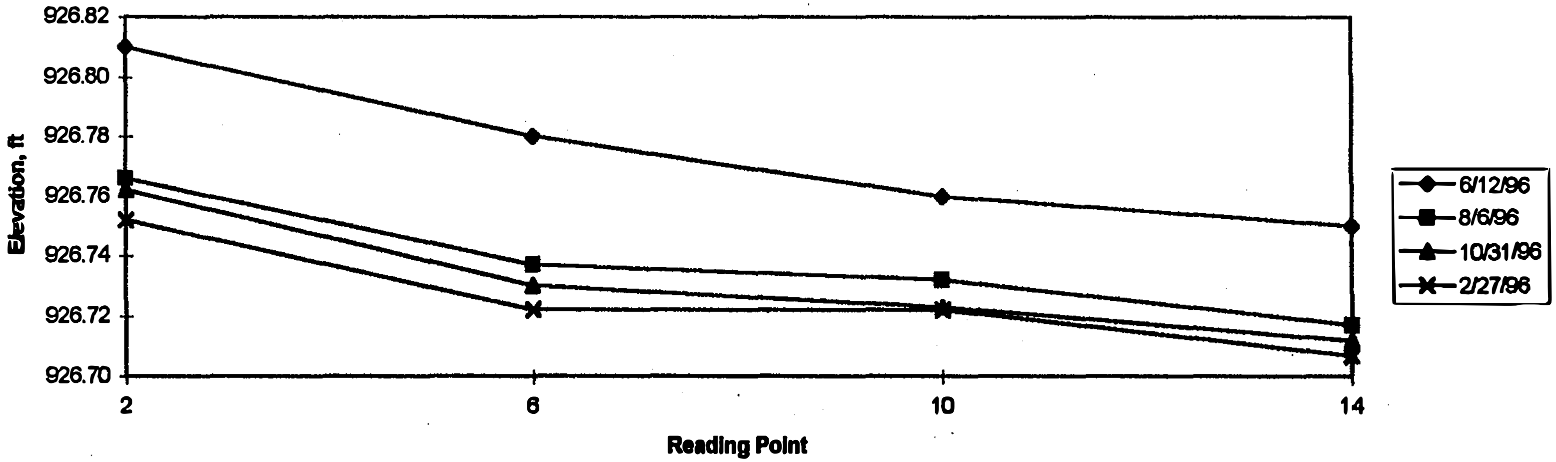


SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) OFFSET, NORTH ABUTMENT WALL, BRIDGE A

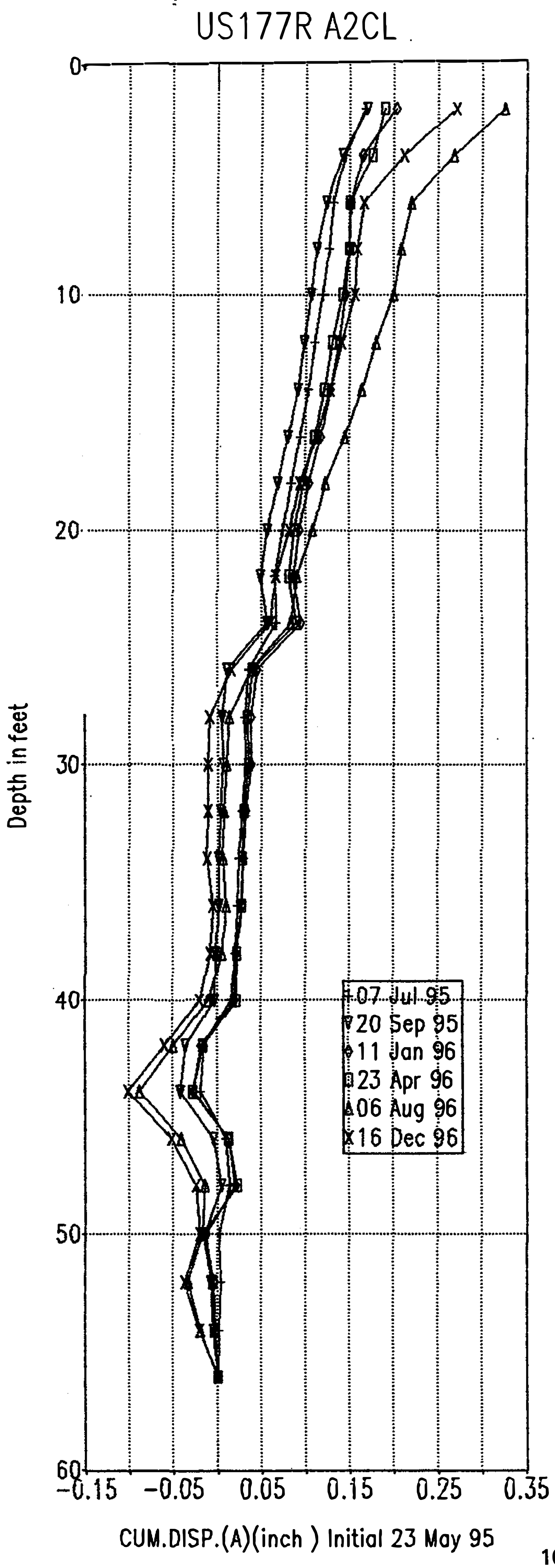


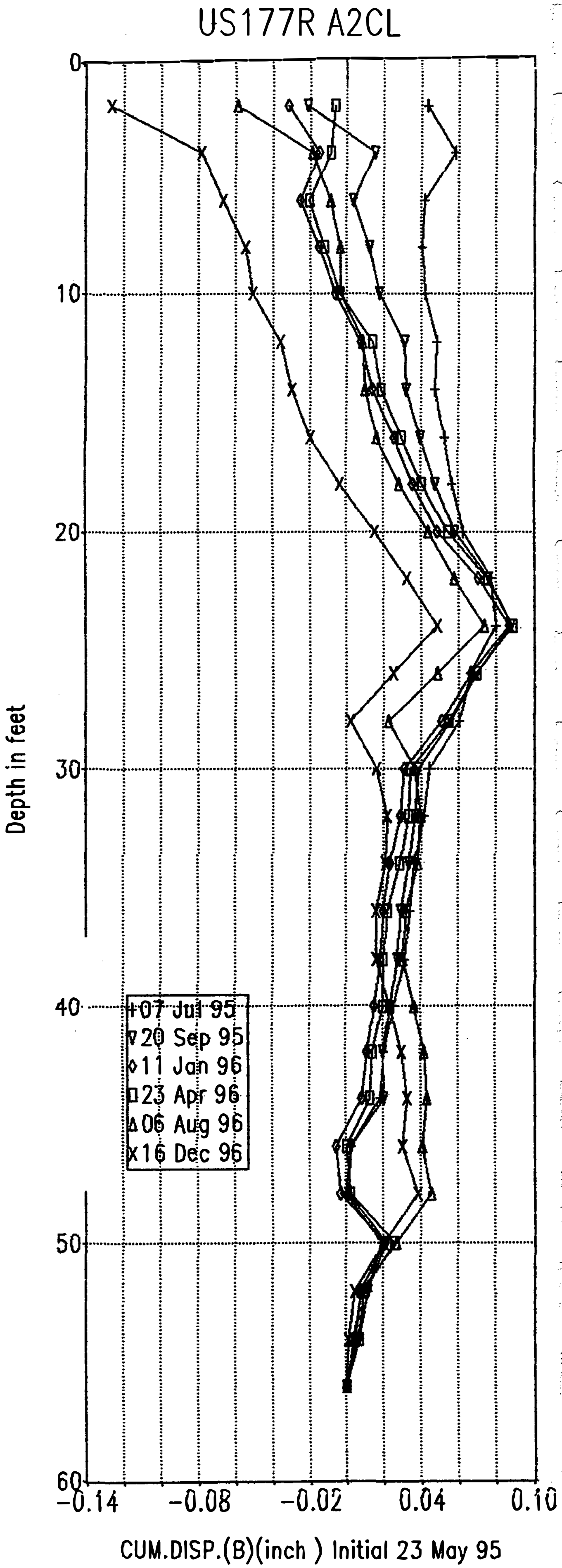
GROUNDWATER TABLE ELEVATION (TIME PLOT) NORTH ABUTMENT WALL, BRIDGE A

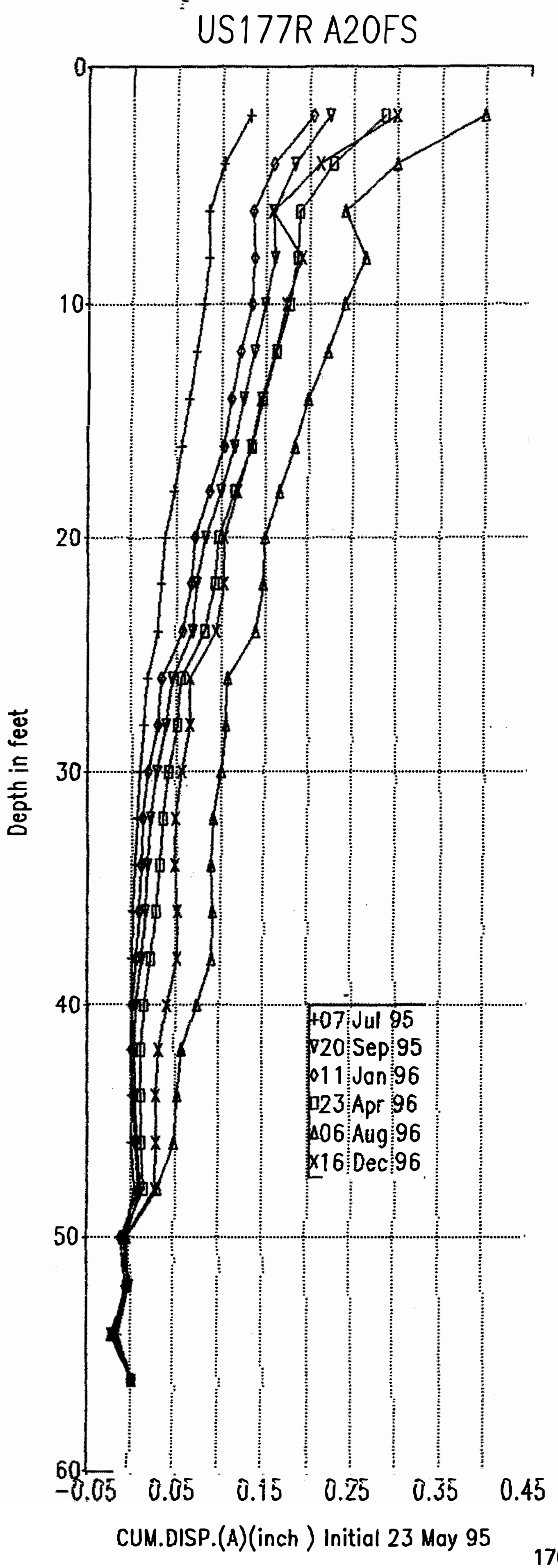


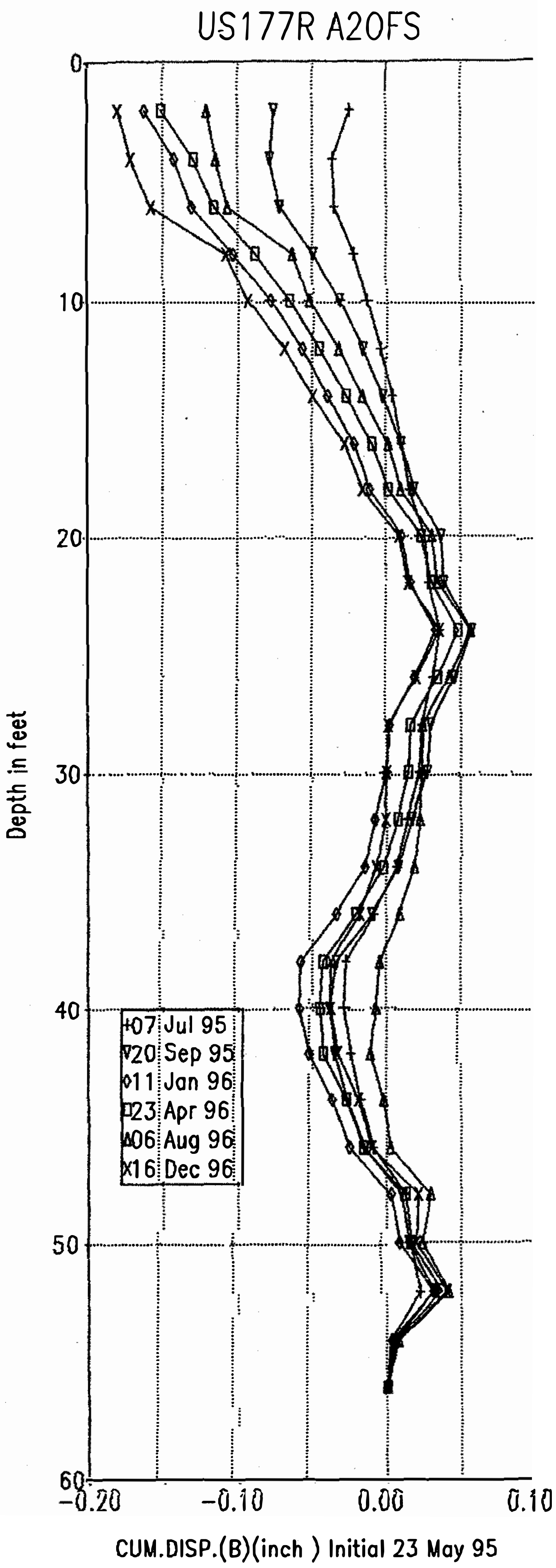


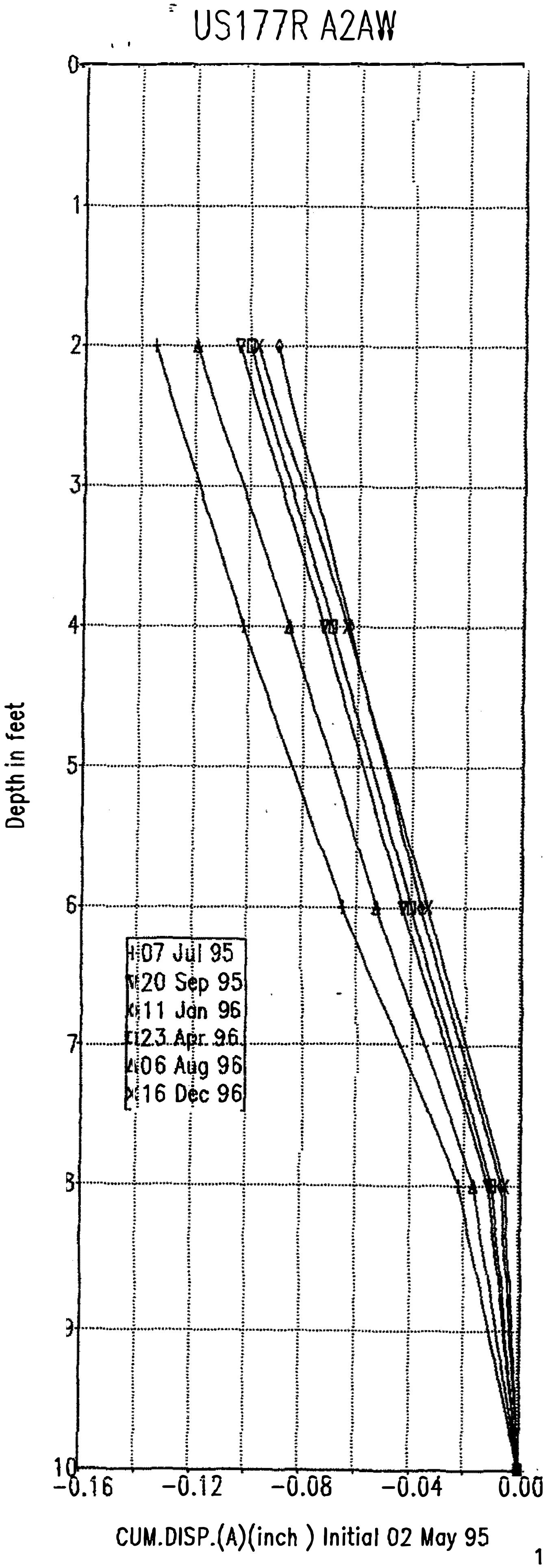
Surface Settlement Point Data, North Abutment Wall, Bridge A

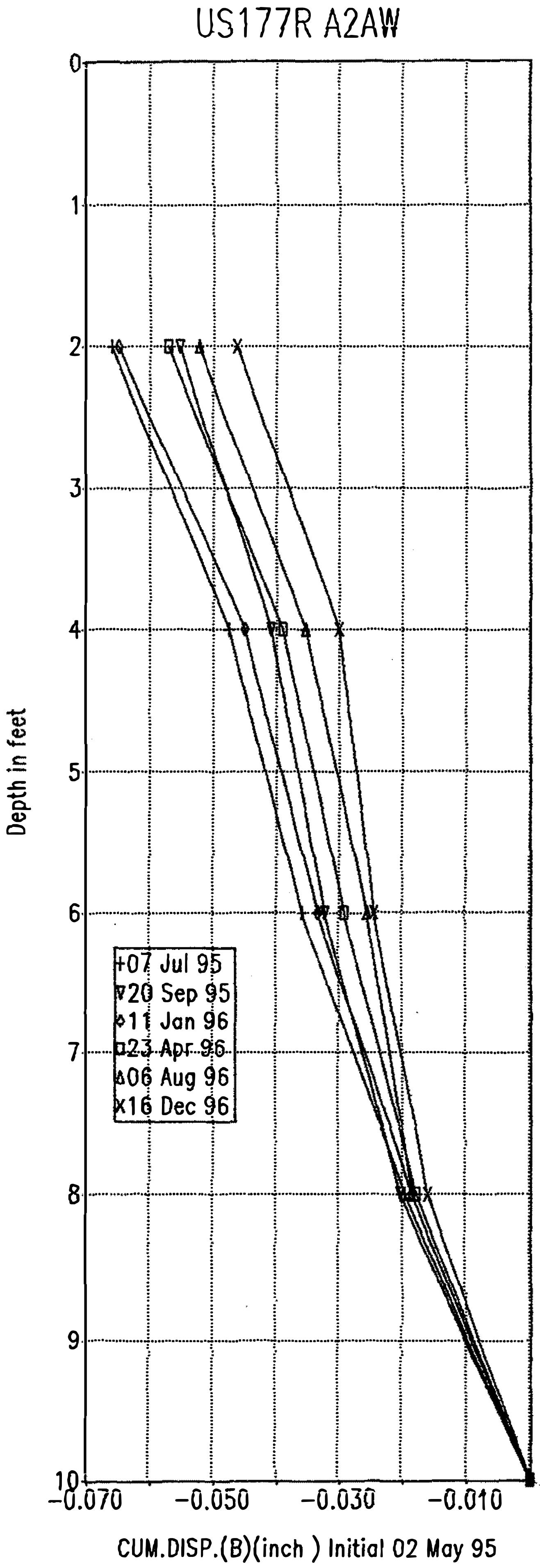

US177R A2CL
Depth in feet
0
10
20
30
40
50
60
-0.15
-0.05
0.05
0.15
0.25
0.35
07 Jul 95
20 Sep 95
11 Jan 96
23 Apr 96
06 Aug 96
16 Dec 96
CUM.DISP.(A)(inch) Initial 23 May 95


US177R A2CL
Depth in feet
0
10
20
30
40
50
60
-0.14
-0.08
-0.02
0.04
0.10
07 Jul 95
20 Sep 95
11 Jan 96
23 Apr 96
06 Aug 96
16 Dec 96
CUM.DISP.(B)(inch) Initial 23 May 95


US177R A20FS
Depth in feet
CUM.DISP.(A)(inch) Initial 23 May 95
07 Jul 95
20 Sep 95
11 Jan 96
23 Apr 96
06 Aug 96
16 Dec 96
0
10
20
30
40
50
60
-0.05
0.05
0.15
0.25
0.35
0.45

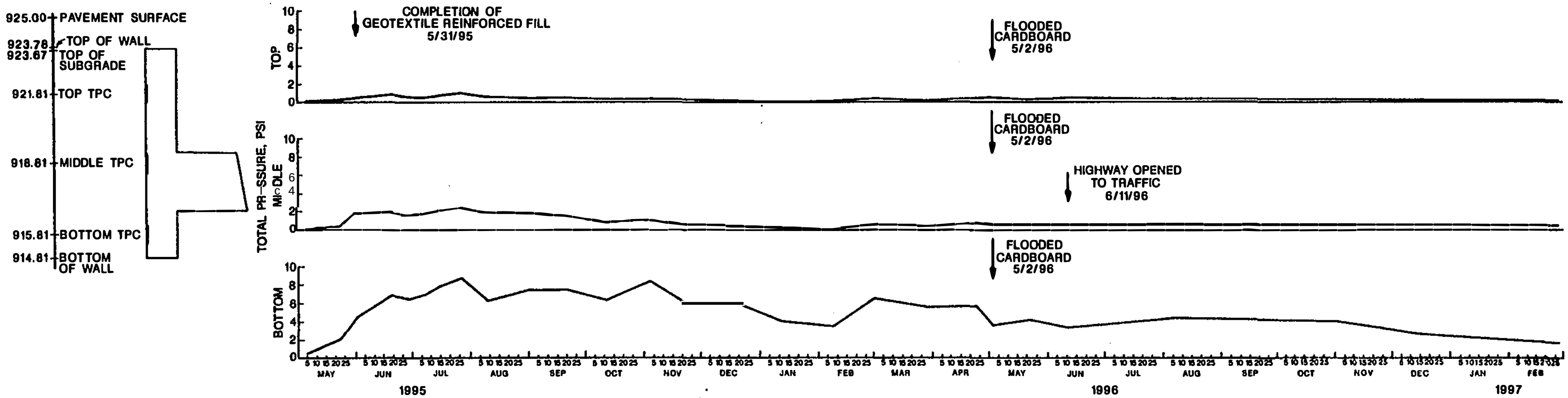

US177R A20FS
Depth in feet
CUM.DISP.(B)(inch) Initial 23 May 95
07 Jul 95
20 Sep 95
11 Jan 96
23 Apr 96
06 Aug 96
16 Dec 96
0
10
20
30
40
50
60
-0.20
-0.10
0.00
0.10


US177R A2AW
Depth in feet
07 Jul 95
20 Sep 95
11 Jan 96
23 Apr 96
06 Aug 96
16 Dec 96
CUM.DISP.(A)(inch) Initial 02 May 95

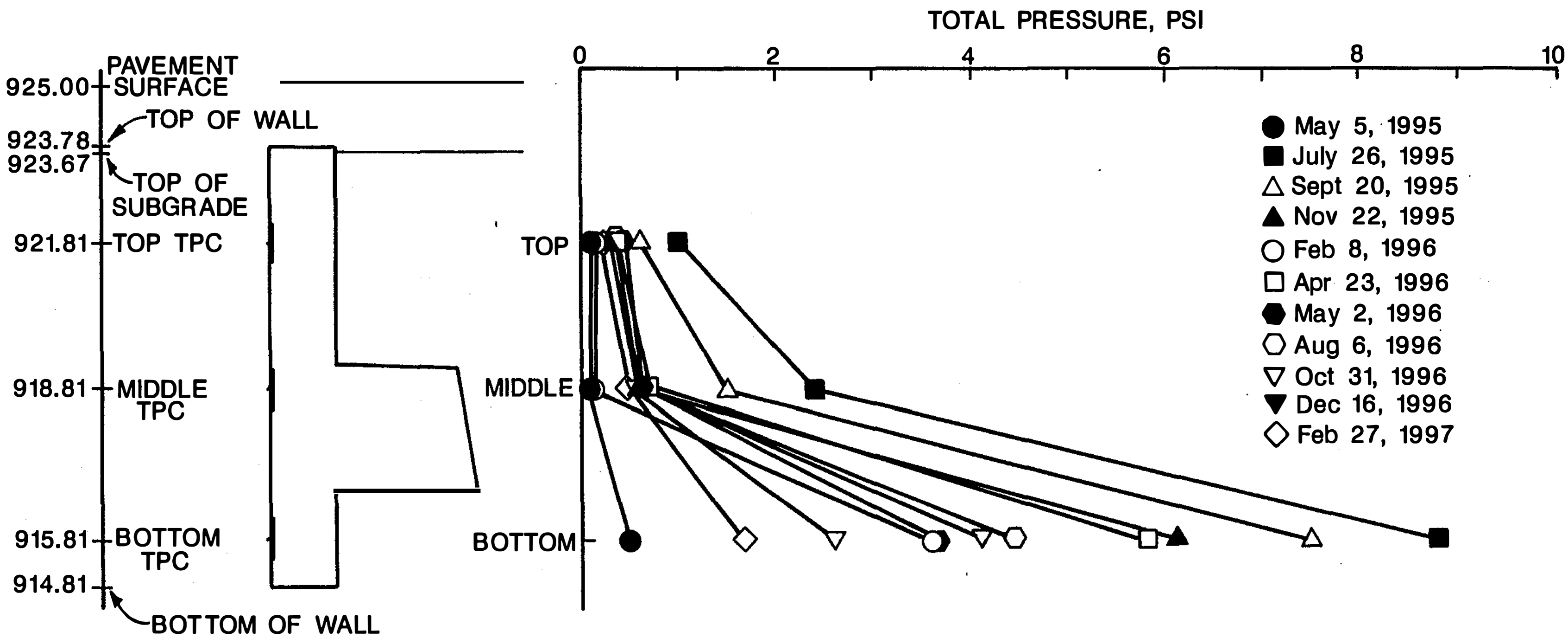

US177R A2AW
Depth in feet
+07 Jul 95
▽20 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
×16 Dec 96
CUM.DISP.(B)(inch) Initial 02 May 95

APPENDIX C3

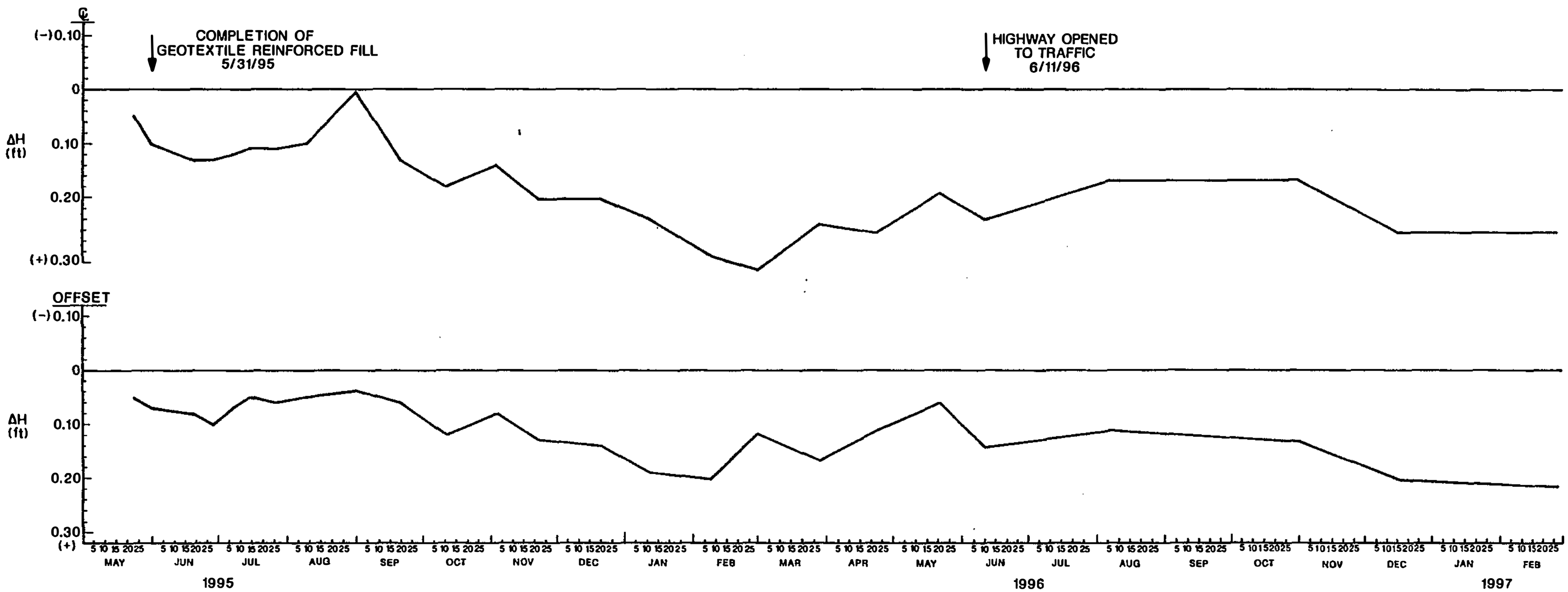
Data Plots for Approach Embankment B1



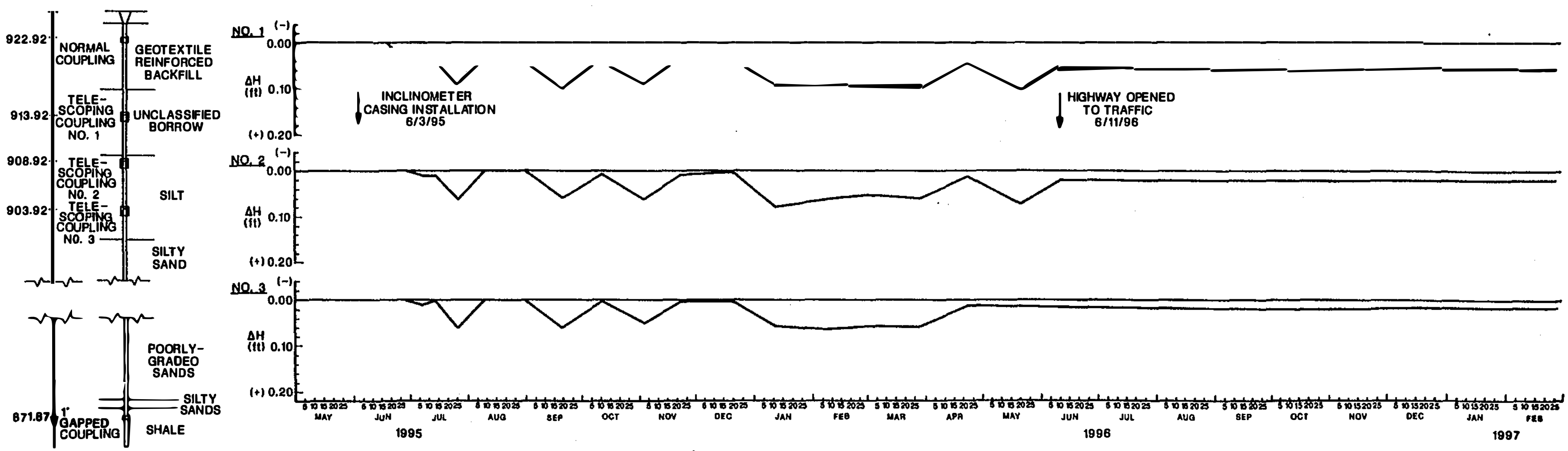
TOTAL PRESSURE CELL DATA (TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE B



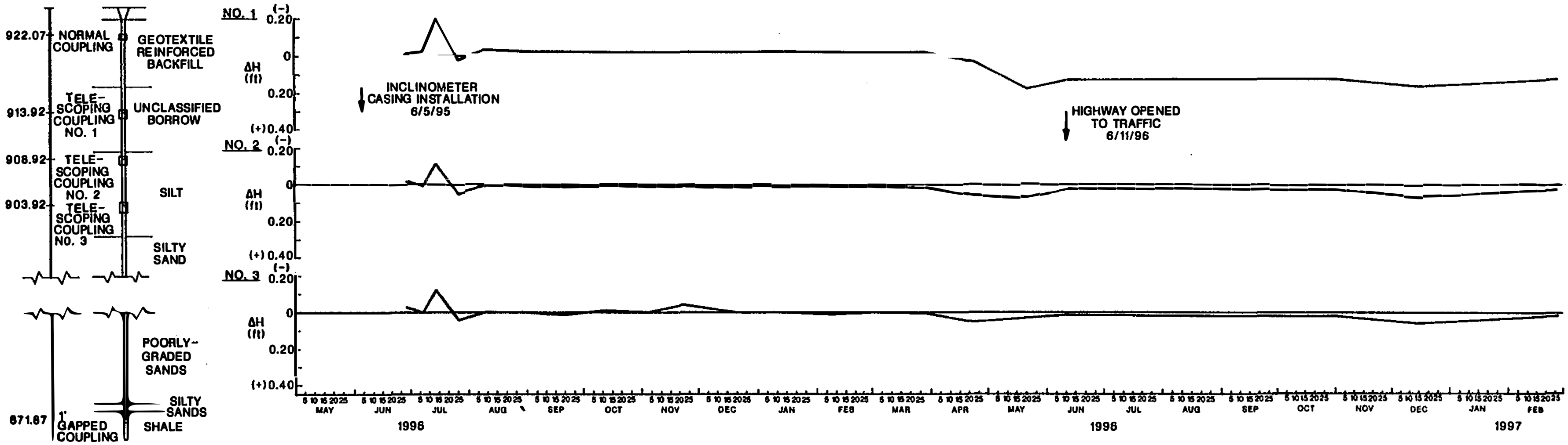
TOTAL PRESSURE CELL DATA (PROFILE) SOUTH ABUTMENT WALL, BRIDGE B



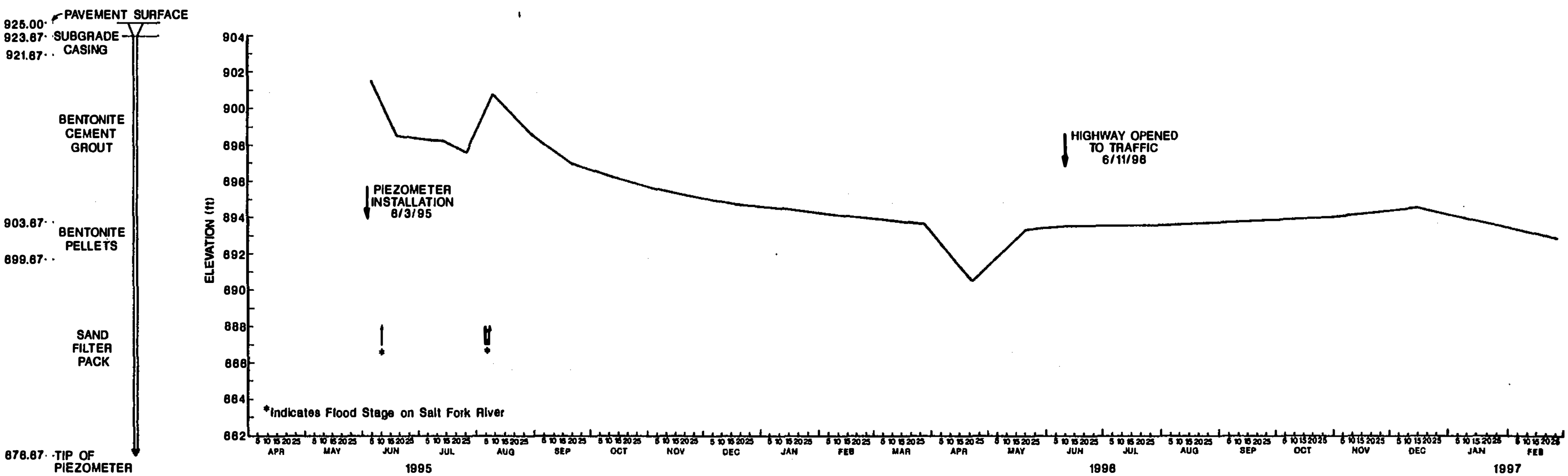
SETTLEMENT FROM AMPLIFIED LIQUID SETTLEMENT
GAGES SOUTH ABUTMENT WALL, BRIDGE B



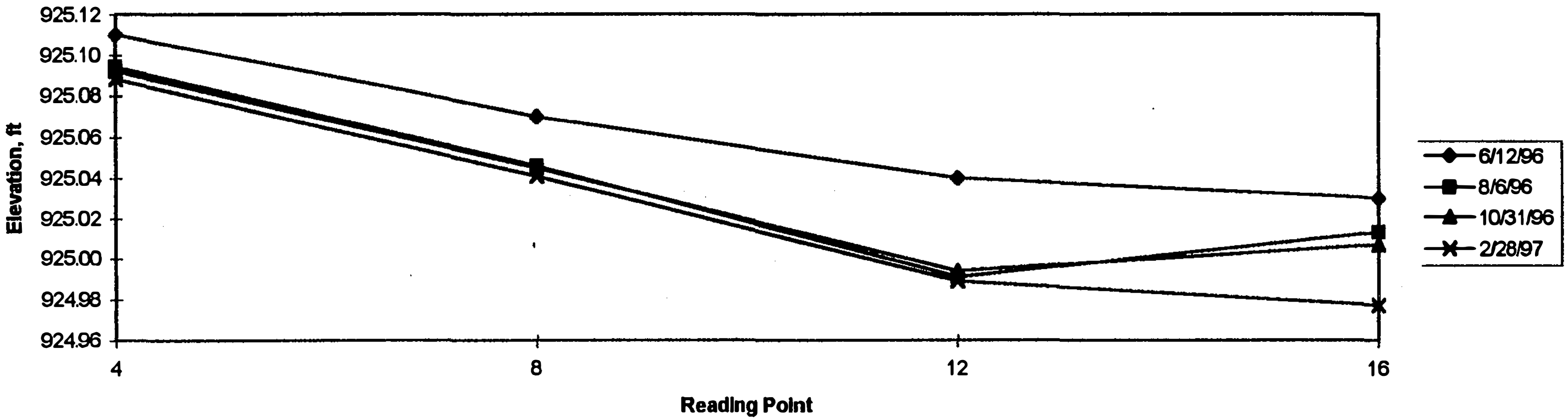
SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) CENTERLINE, SOUTH ABUTMENT WALL, BRIDGE B

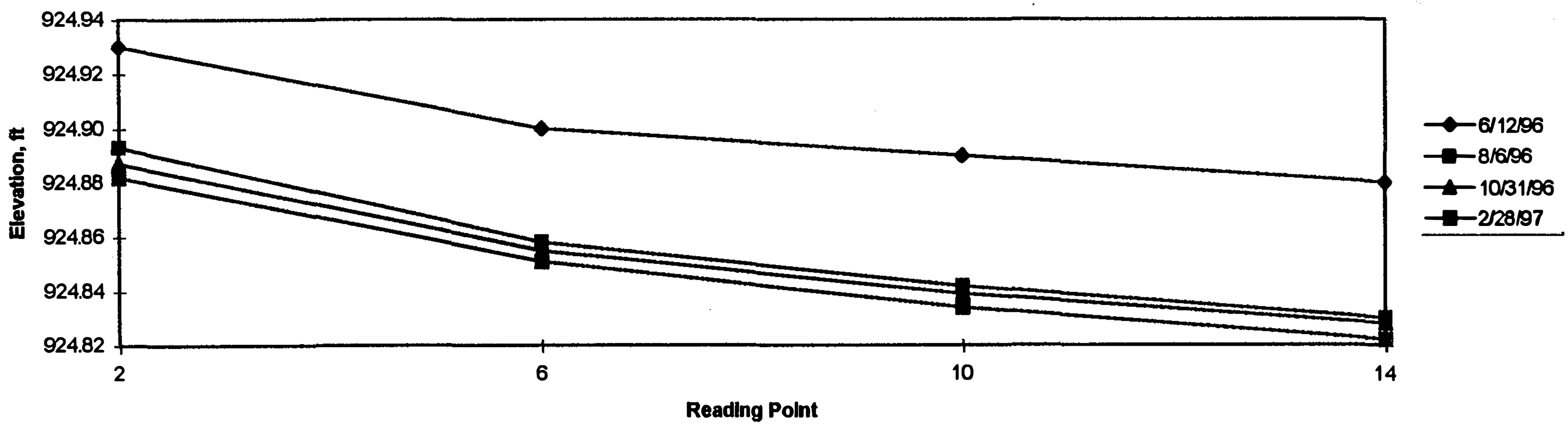


SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) OFFSET, SOUTH ABUTMENT WALL, BRIDGE B

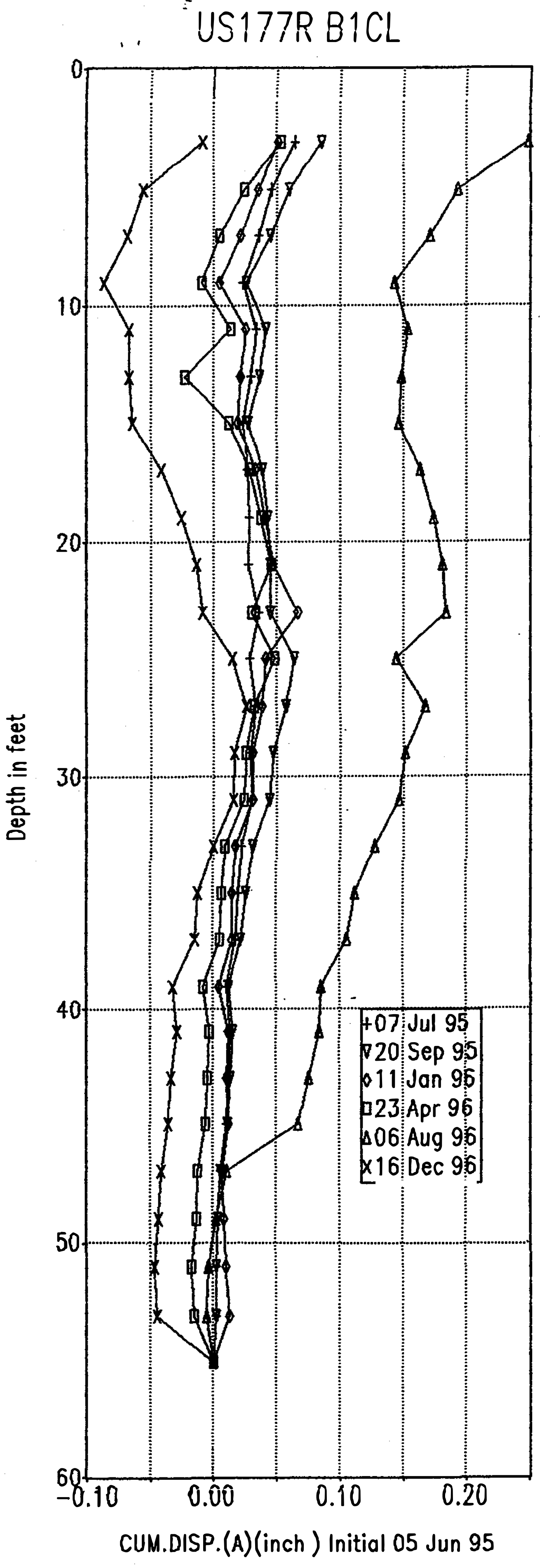


GROUNDWATER TABLE ELEVATION (TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE B

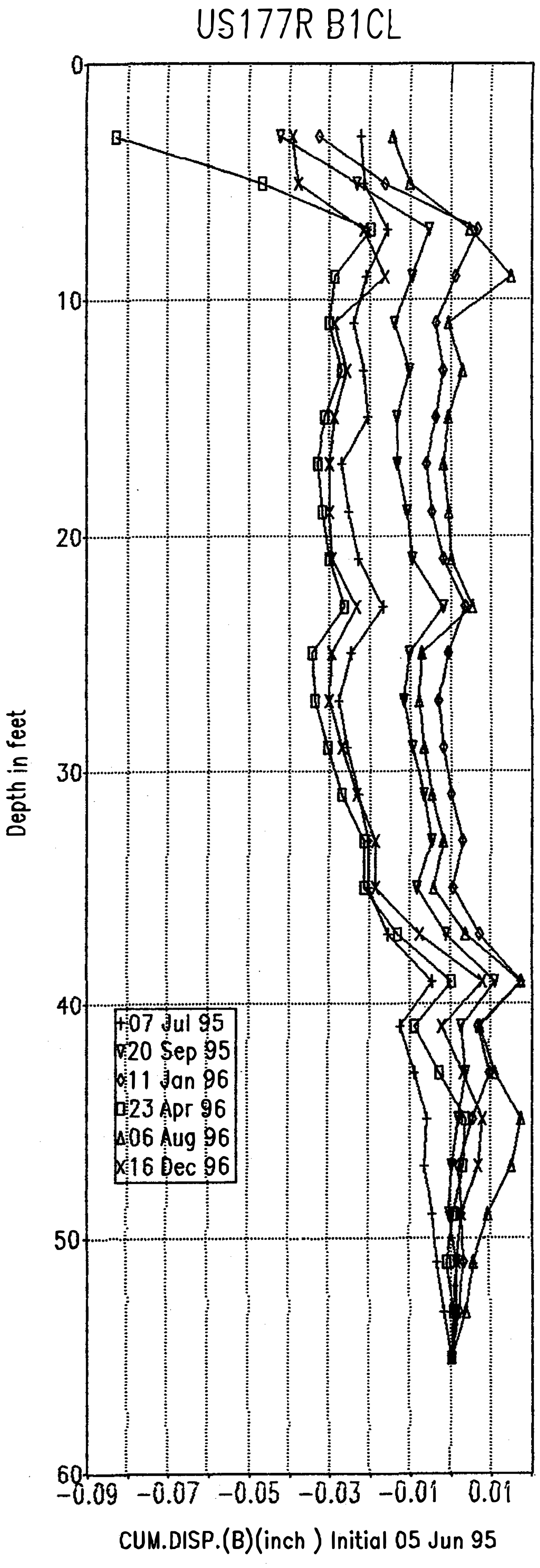




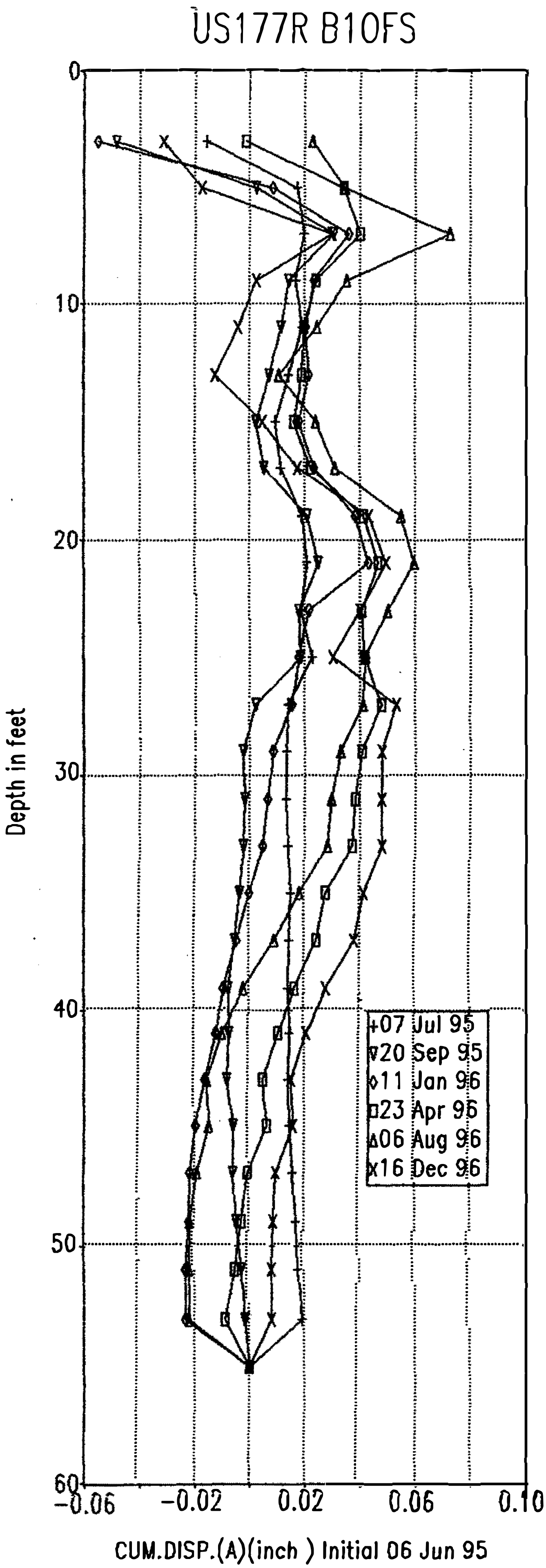
Surface Settlement Point Data, South Abutment Wall, Bridge B

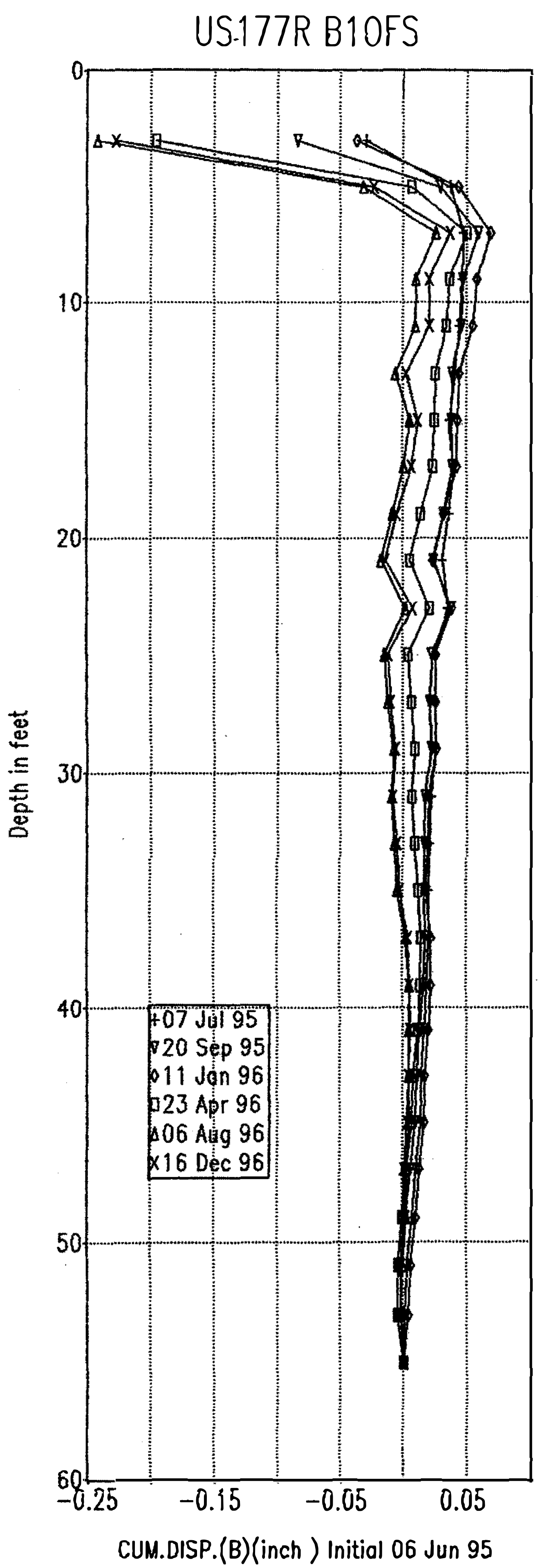


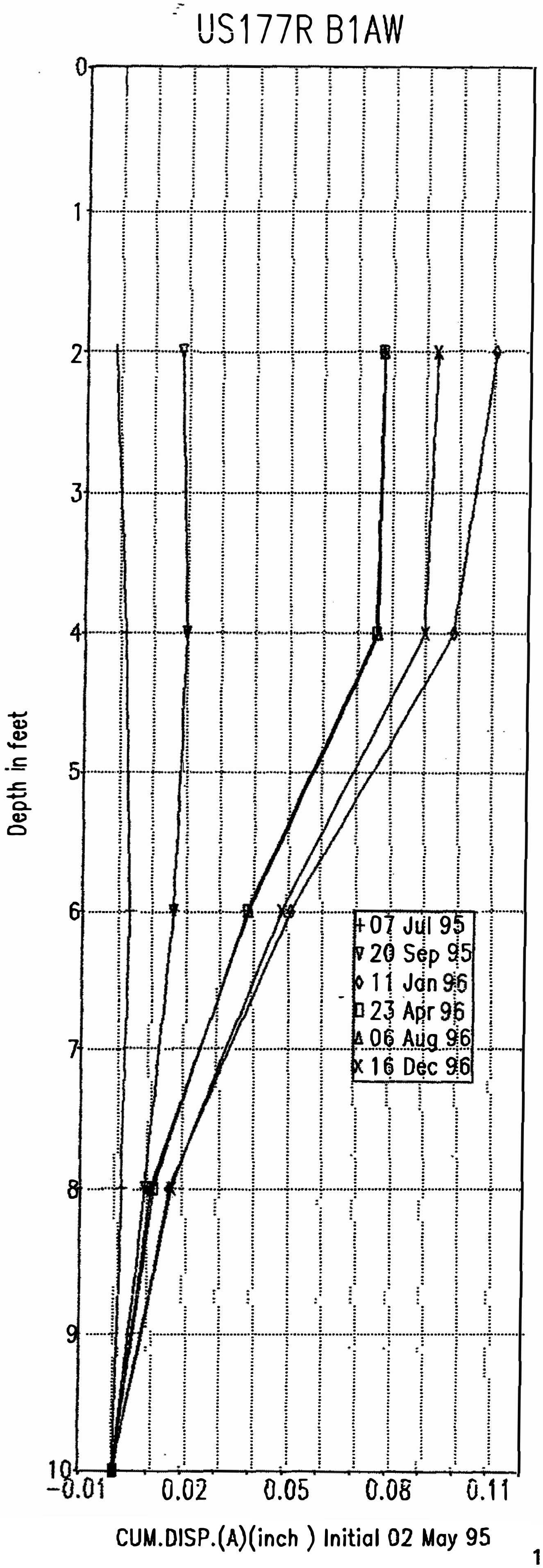
US177R B1CL
Depth in feet
0
10
20
30
40
50
60
-0.10
0.00
0.10
0.20
CUM.DISP.(A)(inch) Initial 05 Jun 95
+07 Jul 95
▽20 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96

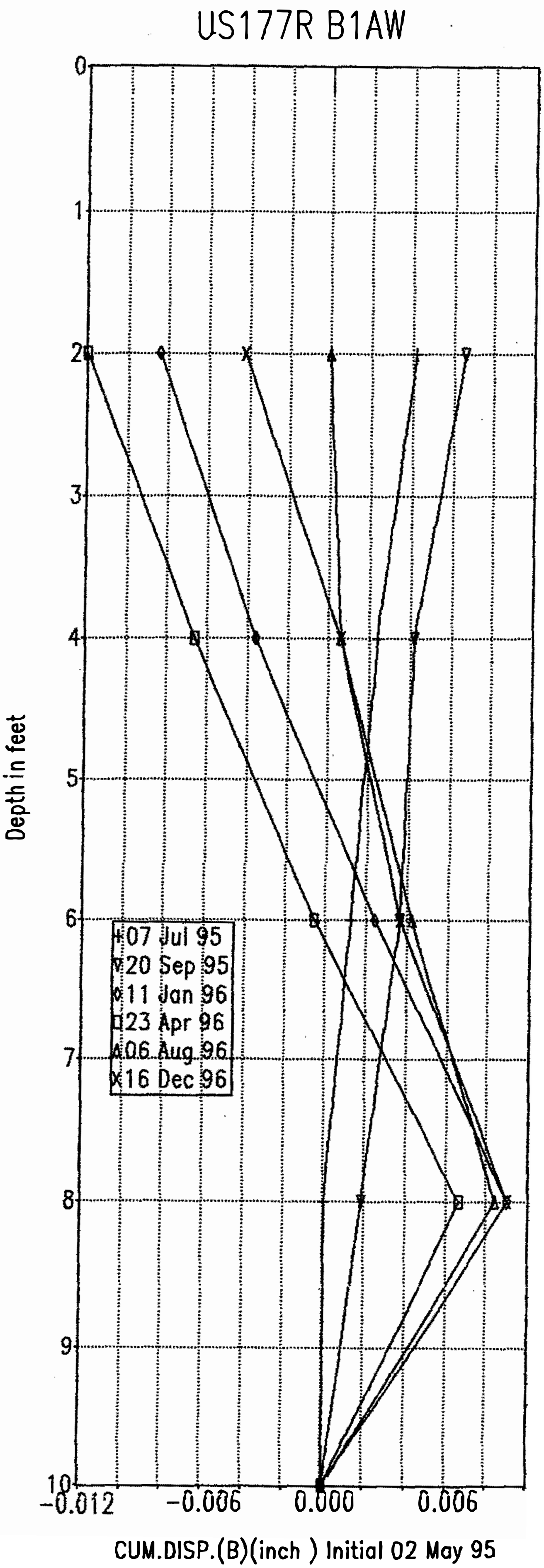


US177R B1CL
Depth in feet
0
10
20
30
40
50
60
-0.09
-0.07
-0.05
-0.03
-0.01
0.01
CUM.DISP.(B)(inch) Initial 05 Jun 95
+07 Jul 95
▽20 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96


US177R B10FS
Depth in feet
CUM.DISP.(A)(inch) Initial 06 Jun 95
+07 Jul 95
▽20 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96

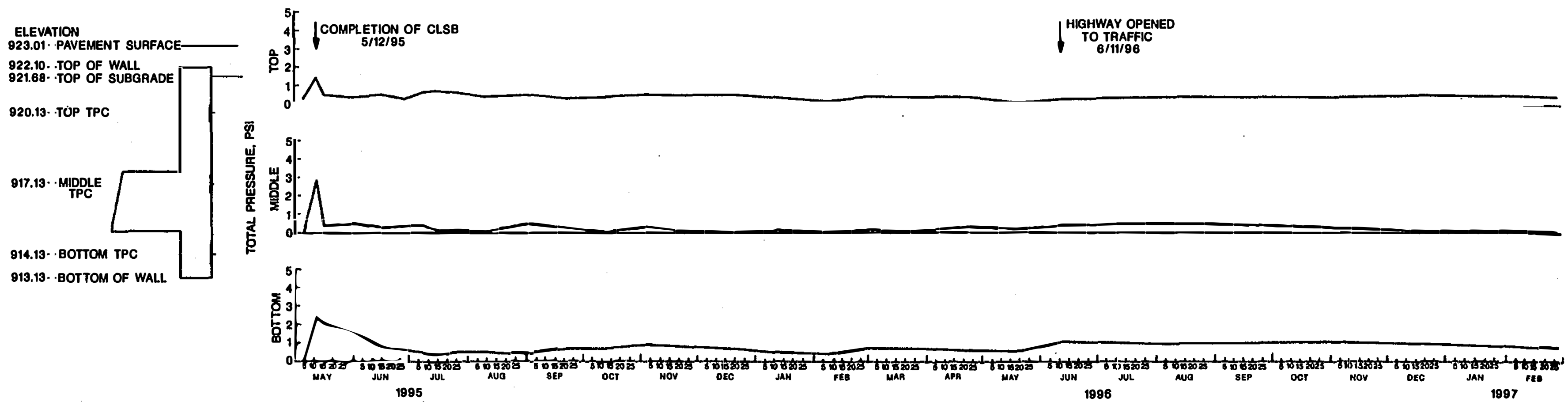

US177R B10FS
Depth in feet
CUM.DISP.(B)(inch) Initial 06 Jun 95
+07 Jul 95
▽20 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96


US177R B1AW
Depth in feet
0
1
2
3
4
5
6
7
8
9
10
-0.01
0.02
0.05
0.08
0.11
+07 Jul 95
▽20 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96
CUM.DISP.(A)(inch) Initial 02 May 95

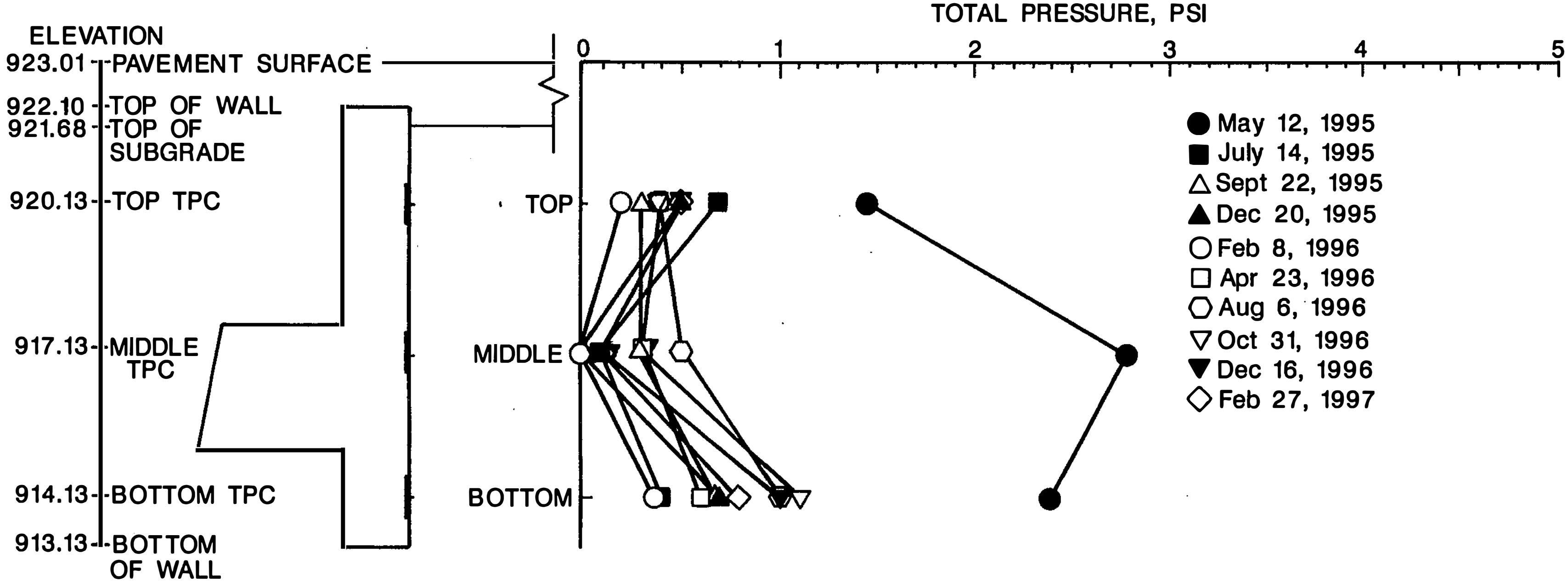

US177R B1AW
Depth in feet
0
1
2
3
4
5
6
7
8
9
10
-0.012
-0.006
0.000
0.006
+07 Jul 95
▽20 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96
CUM.DISP.(B)(inch) Initial 02 May 95

APPENDIX C4

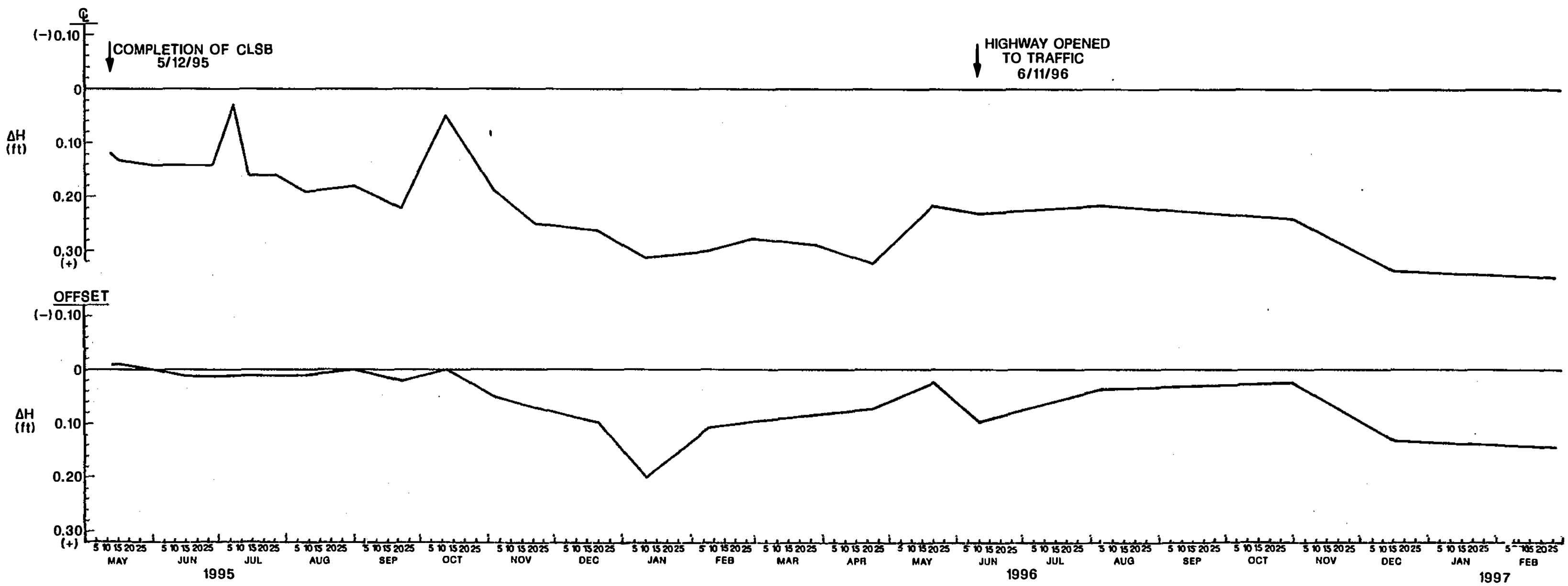
Data Plots for Approach Embankment B2



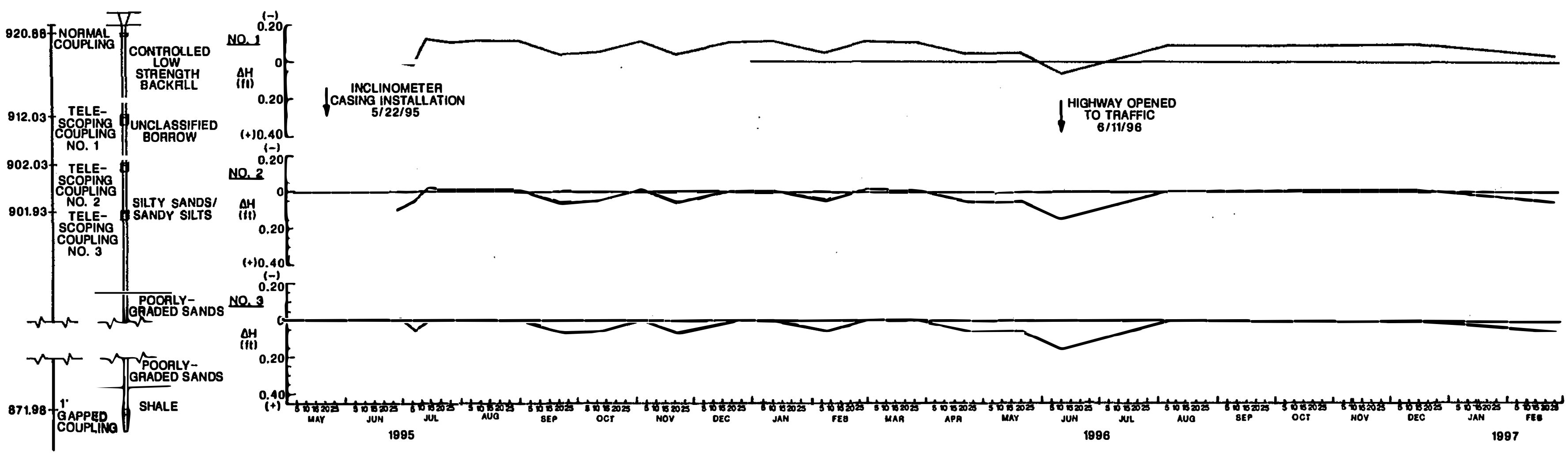
TOTAL PRESSURE CELL DATA (TIME PLOT) NORTH ABUTMENT WALL, BRIDGE B



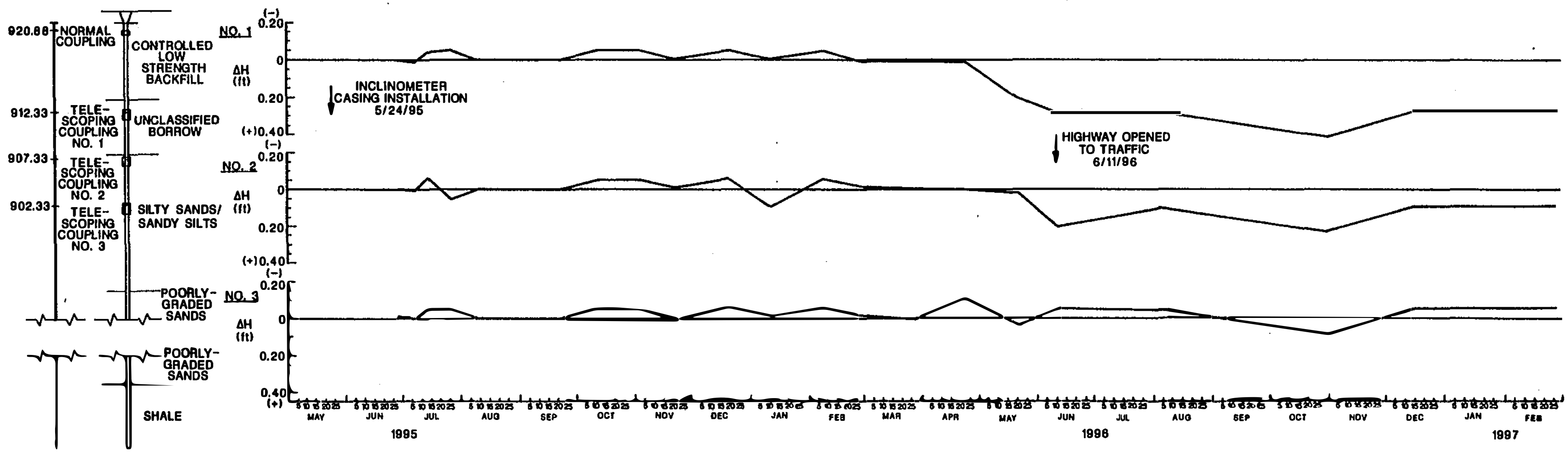
TOTAL PRESSURE CELL DATA (PROFILE) NORTH ABUTMENT WALL, BRIDGE B



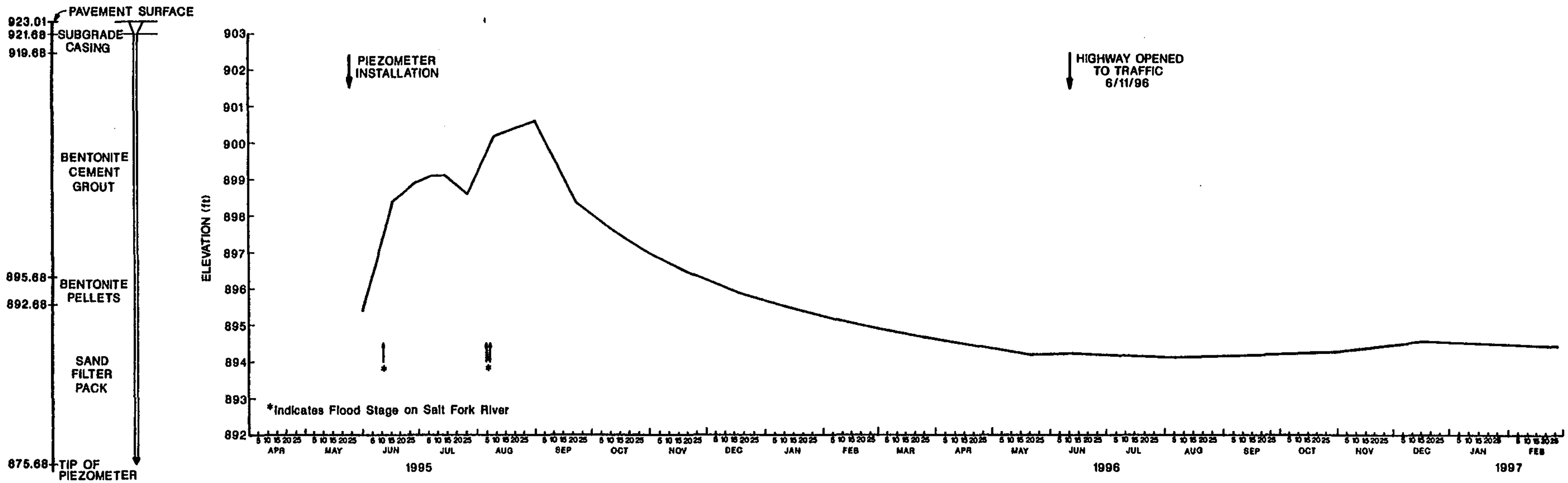
SETTLEMENT FROM AMPLIFIED LIQUID SETTLEMENT
GAGES NORTH ABUTMENT WALL, BRIDGE B



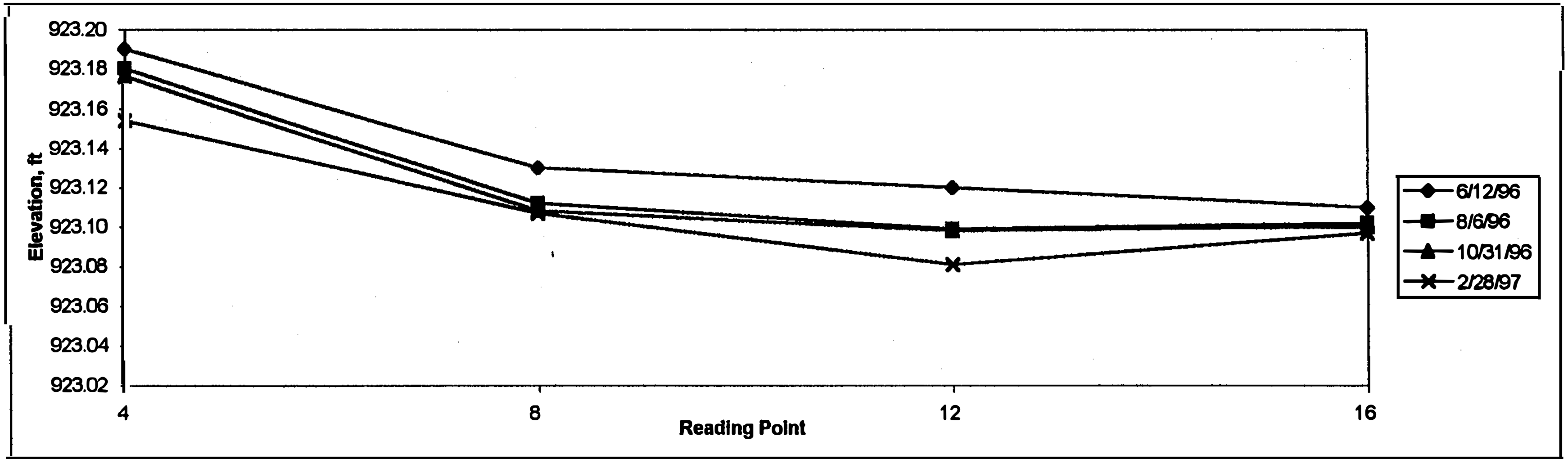
SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) CENTERLINE, NORTH ABUTMENT WALL, BRIDGE B

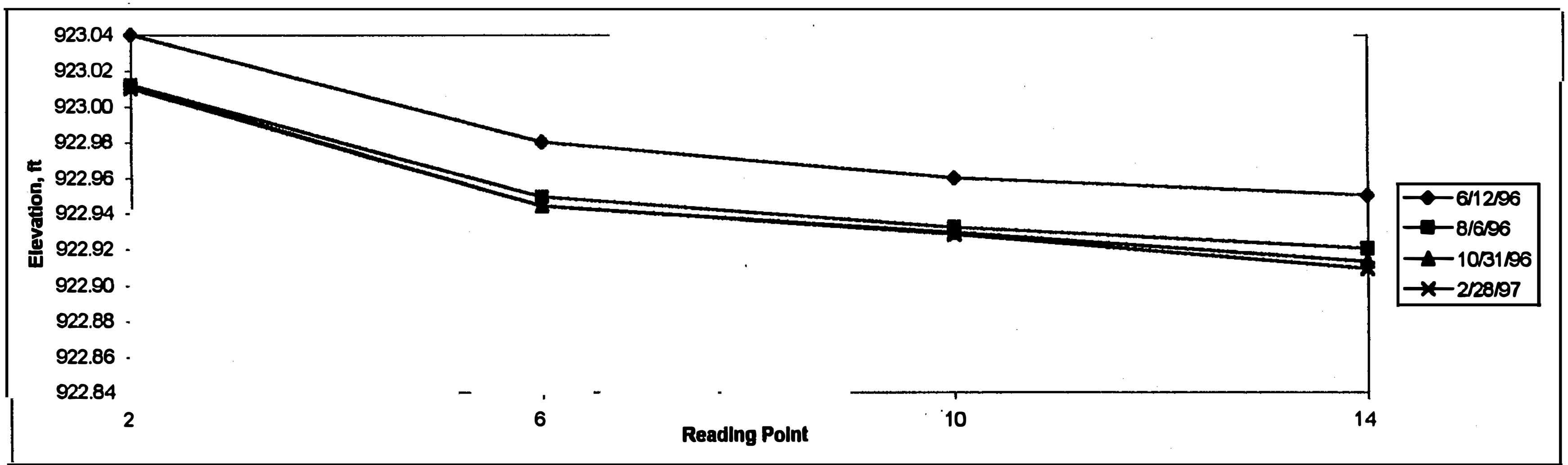


SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) OFFSET, NORTH ABUTMENT WALL, BRIDGE B

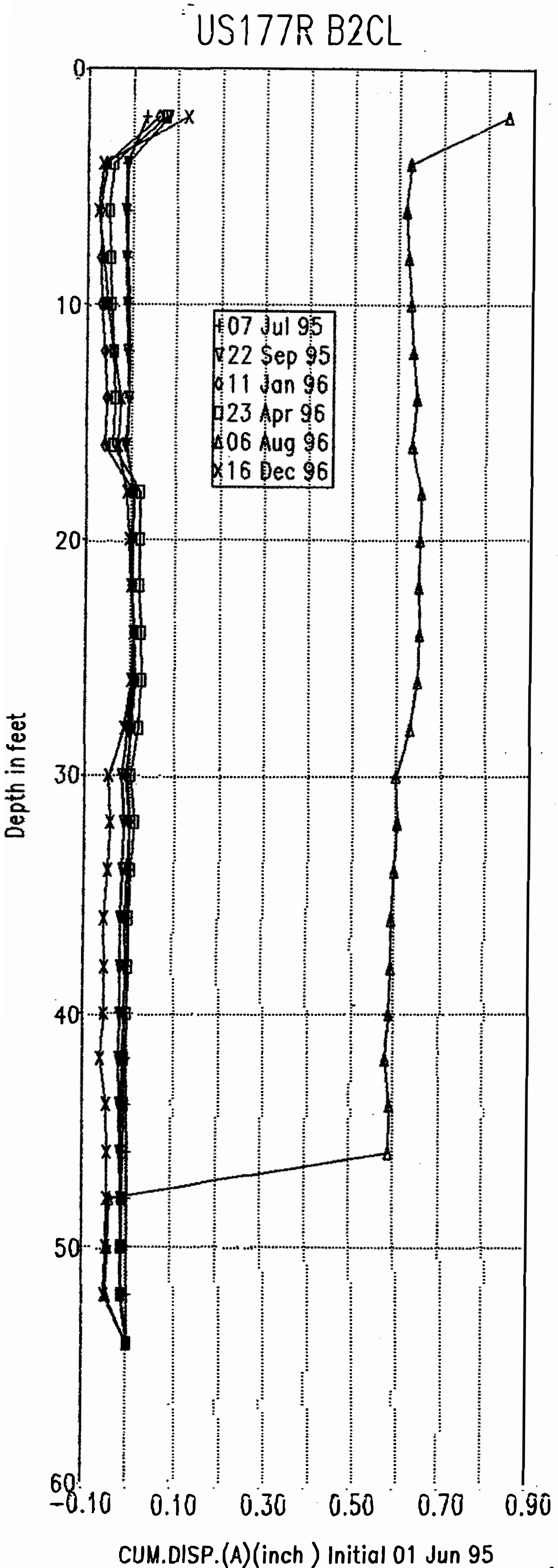


GROUNDWATER TABLE ELEVATION (TIME PLOT) NORTH ABUTMENT WALL, BRIDGE B

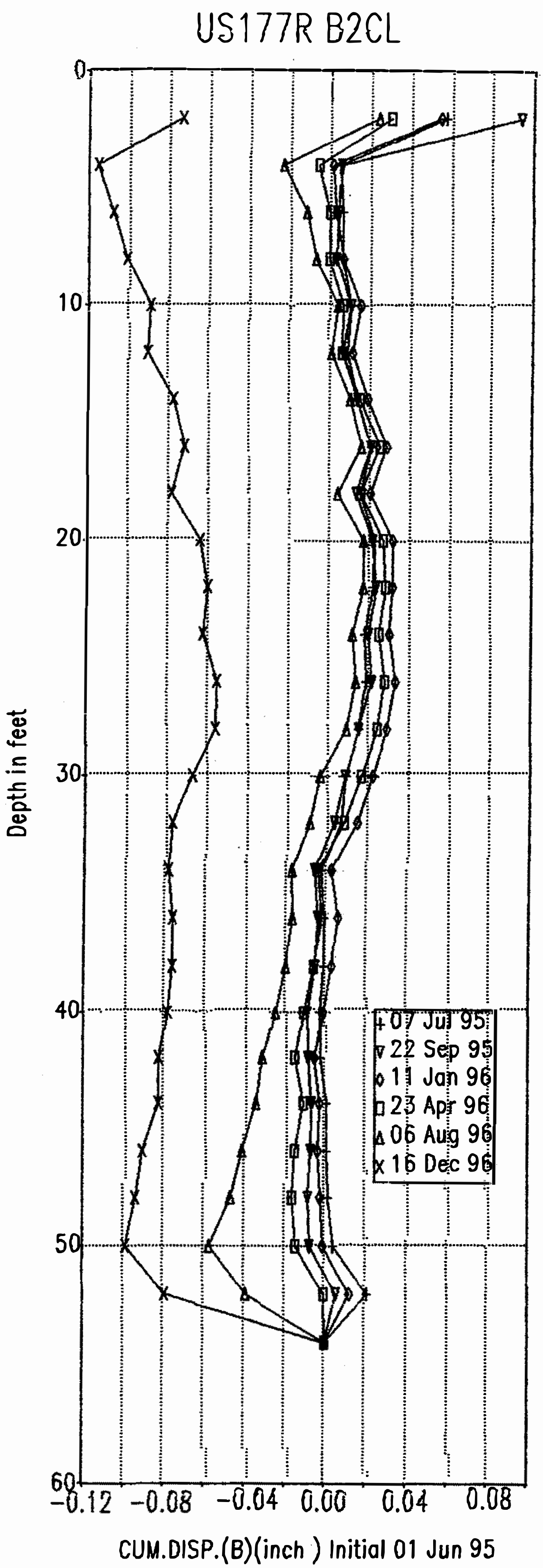




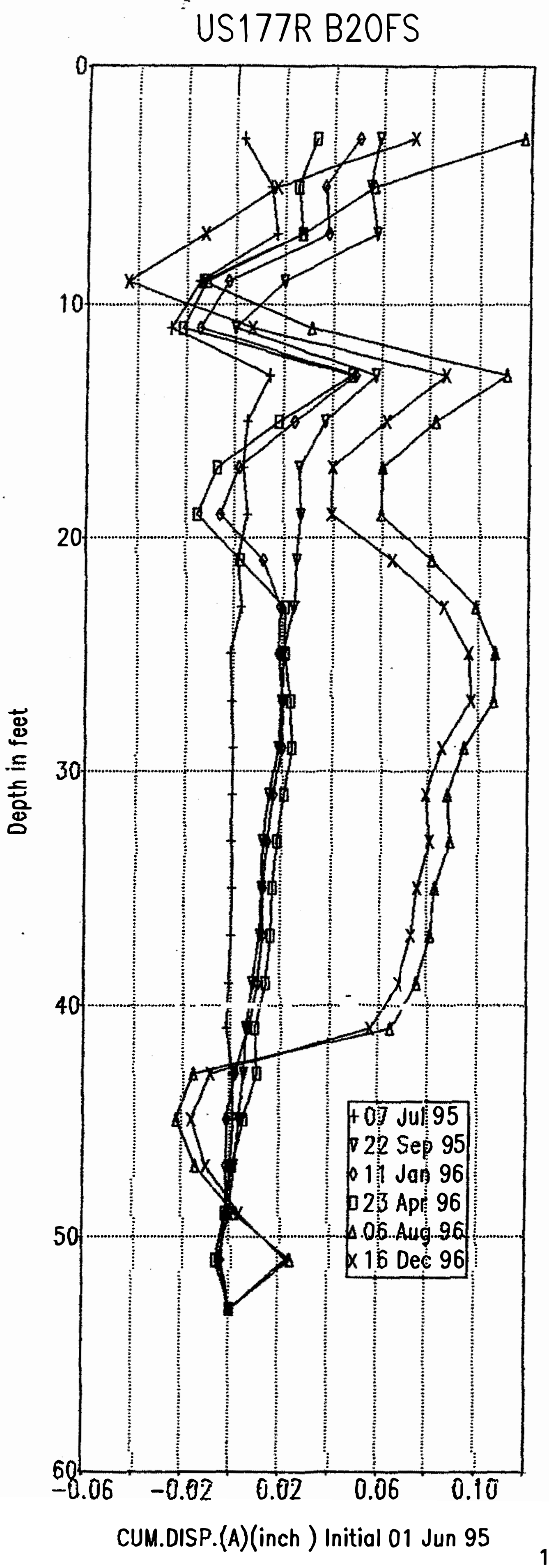
Surface Settlement Point Data, North Abutment Wall, Bridge B



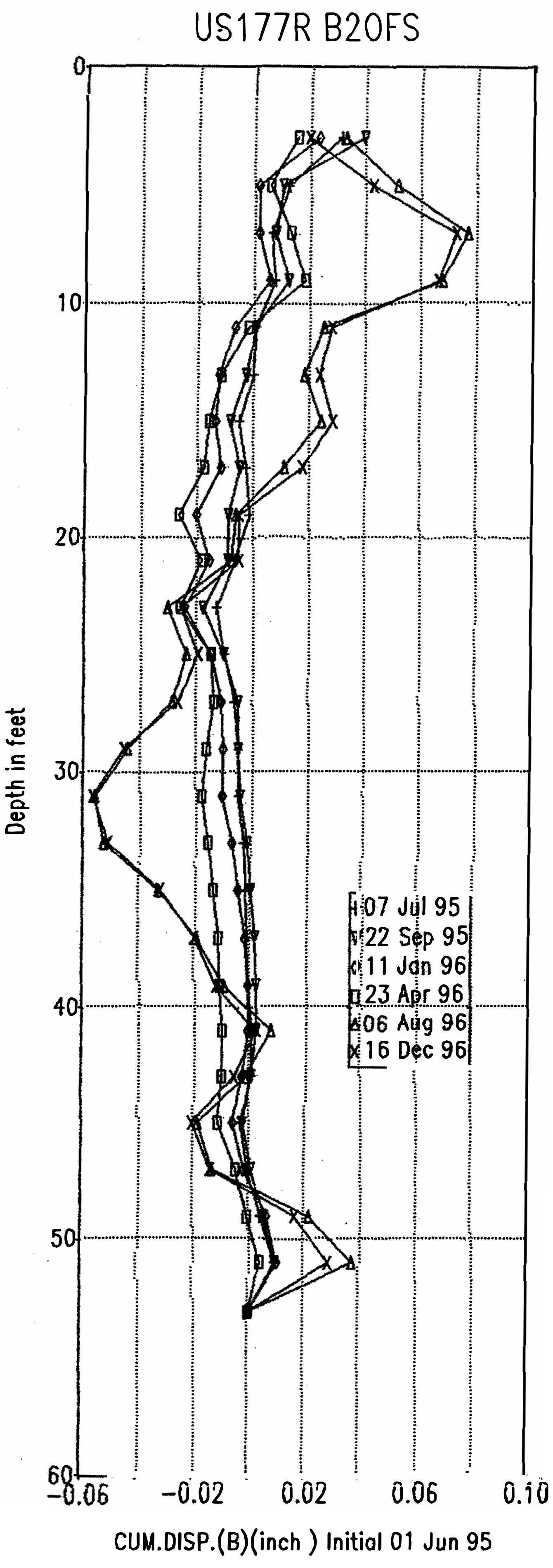
US177R B2CL
Depth in feet
0
10
20
30
40
50
60
-0.10
0.10
0.30
0.50
0.70
0.90
07 Jul 95
22 Sep 95
11 Jan 96
23 Apr 96
06 Aug 96
16 Dec 96
CUM.DISP.(A)(inch) Initial 01 Jun 95



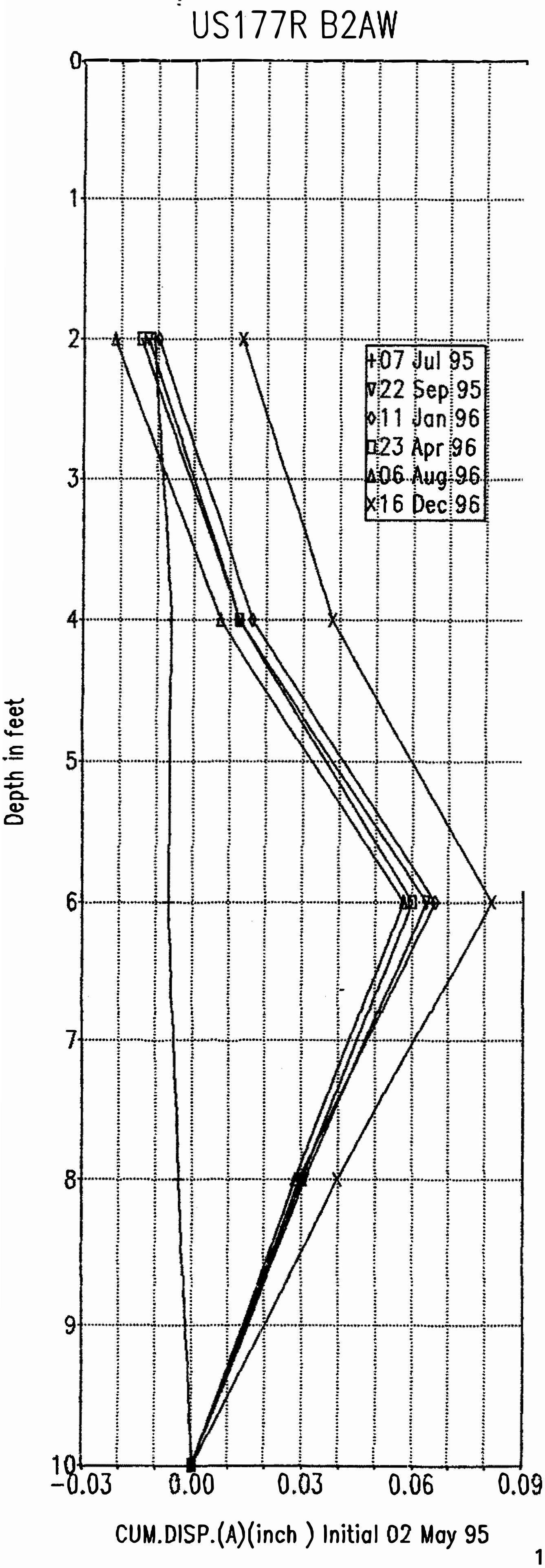
US177R B2CL
Depth in feet
0
10
20
30
40
50
60
-0.12
-0.08
-0.04
0.00
0.04
0.08
07 Jul 95
22 Sep 95
11 Jan 96
23 Apr 96
06 Aug 96
16 Dec 96
CUM.DISP.(B)(inch) Initial 01 Jun 95

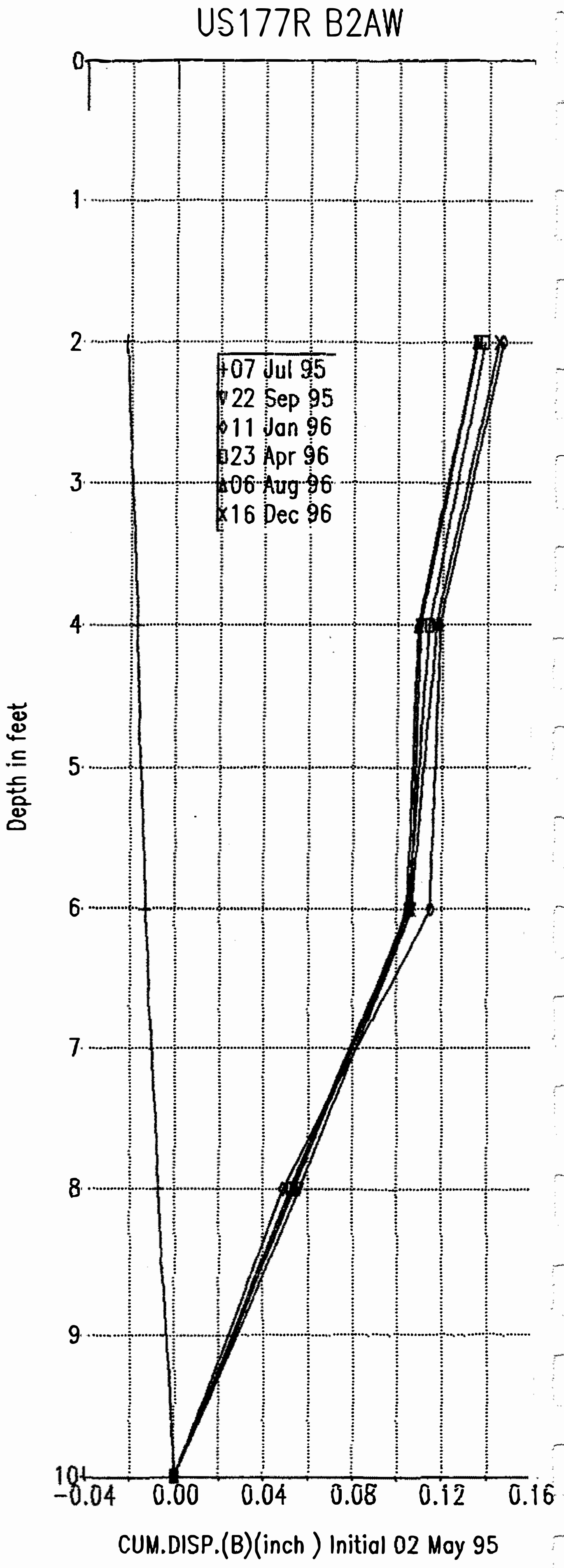


US177R B20FS
Depth in feet
0
10
20
30
40
50
60
-0.06
-0.02
0.02
0.06
0.10
07 Jul 95
22 Sep 95
11 Jan 96
23 Apr 96
06 Aug 96
16 Dec 96
CUM.DISP.(A)(inch) Initial 01 Jun 95



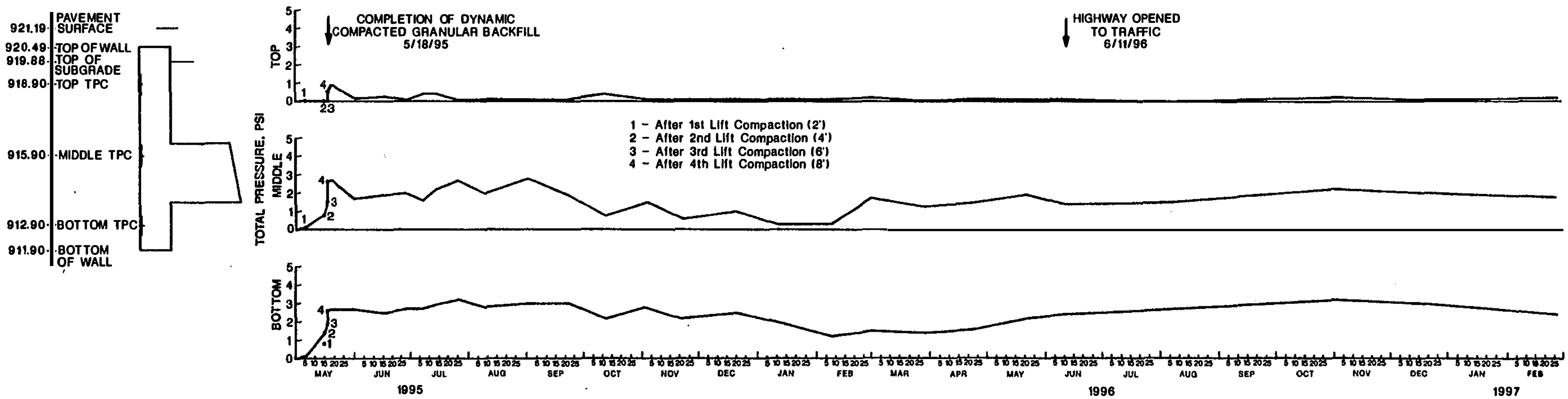
US177R B20FS
Depth in feet
0
10
20
30
40
50
60
-0.06
-0.02
0.02
0.06
0.10
07 Jul 95
22 Sep 95
11 Jan 96
23 Apr 96
06 Aug 96
16 Dec 96
CUM.DISP.(B)(inch) Initial 01 Jun 95


US177R B2AW
Depth in feet
0
1
2
3
4
5
6
7
8
9
10
-0.03
0.00
0.03
0.06
0.09
+07 Jul 95
∇22 Sep 95
◊11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96
CUM.DISP.(A)(inch) Initial 02 May 95

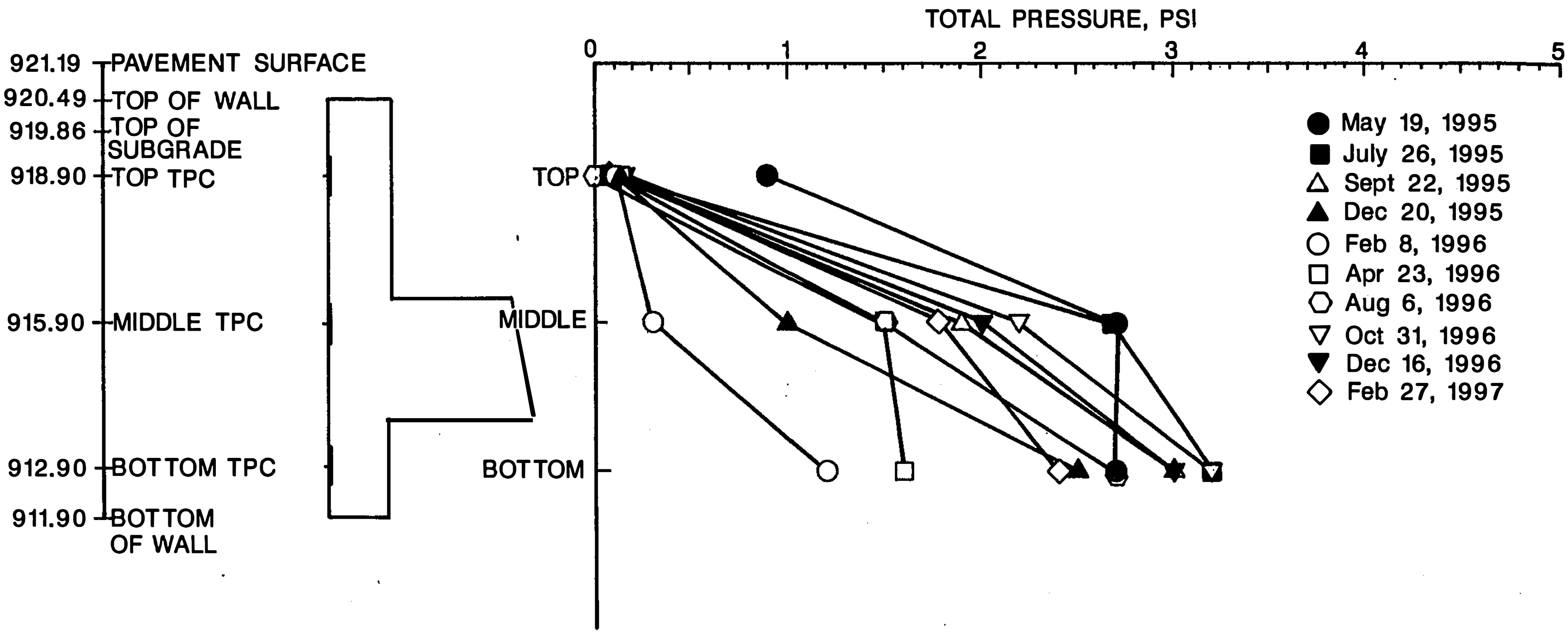

US177R B2AW
Depth in feet
0
1
2
3
4
5
6
7
8
9
10
-0.04
0.00
0.04
0.08
0.12
0.16
+07 Jul 95
∇22 Sep 95
◊11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96
CUM.DISP.(B)(inch) Initial 02 May 95

APPENDIX C5

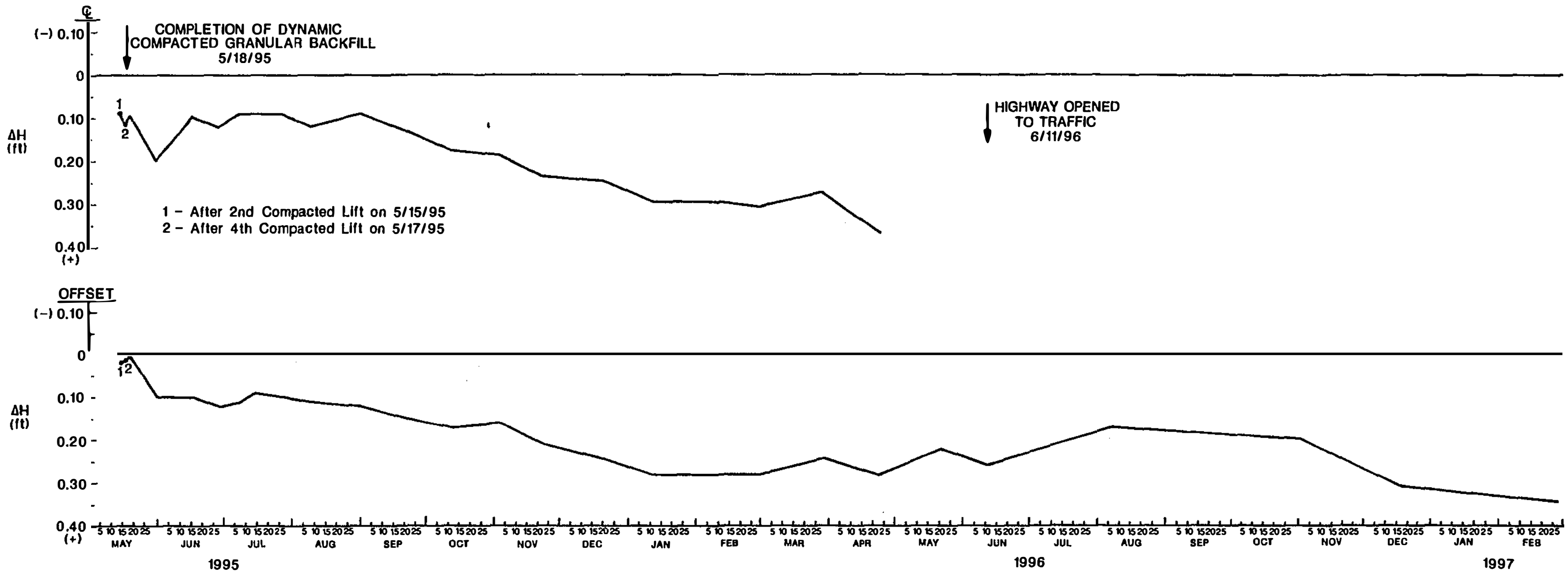
Data Plots for Approach Embankment C1



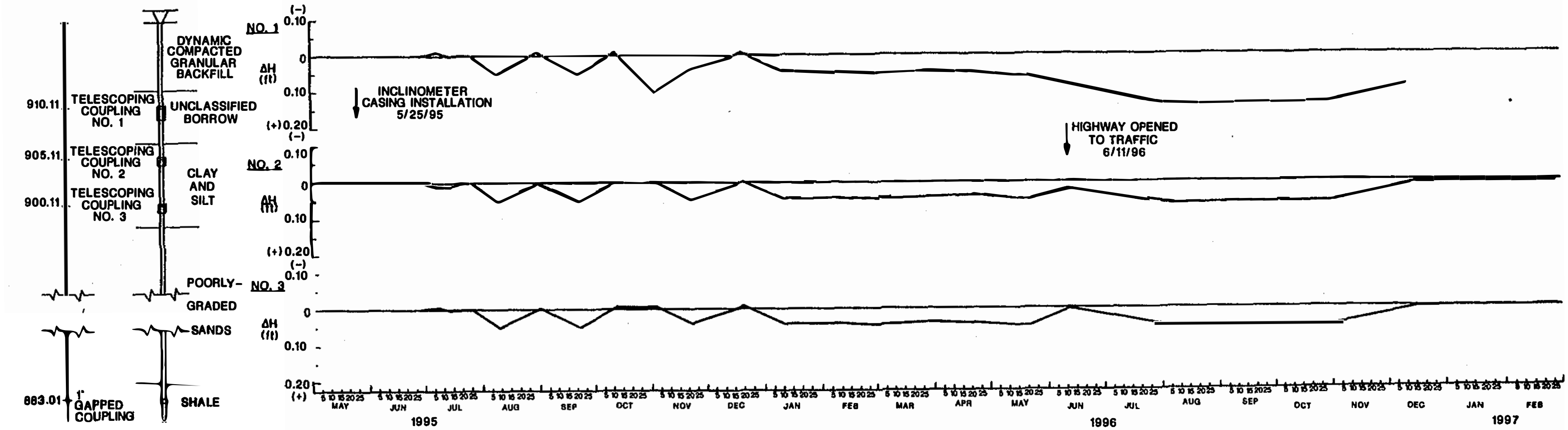
TOTAL PRESSURE CELL DATA (TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE C



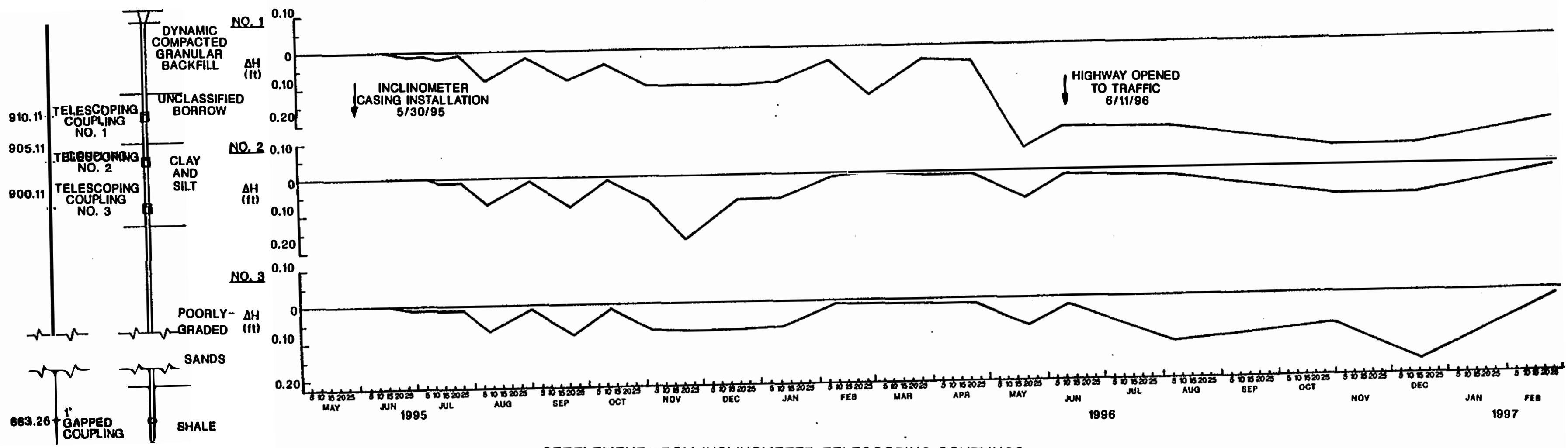
TOTAL PRESSURE CELL DATA (PROFILE) SOUTH ABUTMENT WALL, BRIDGE C



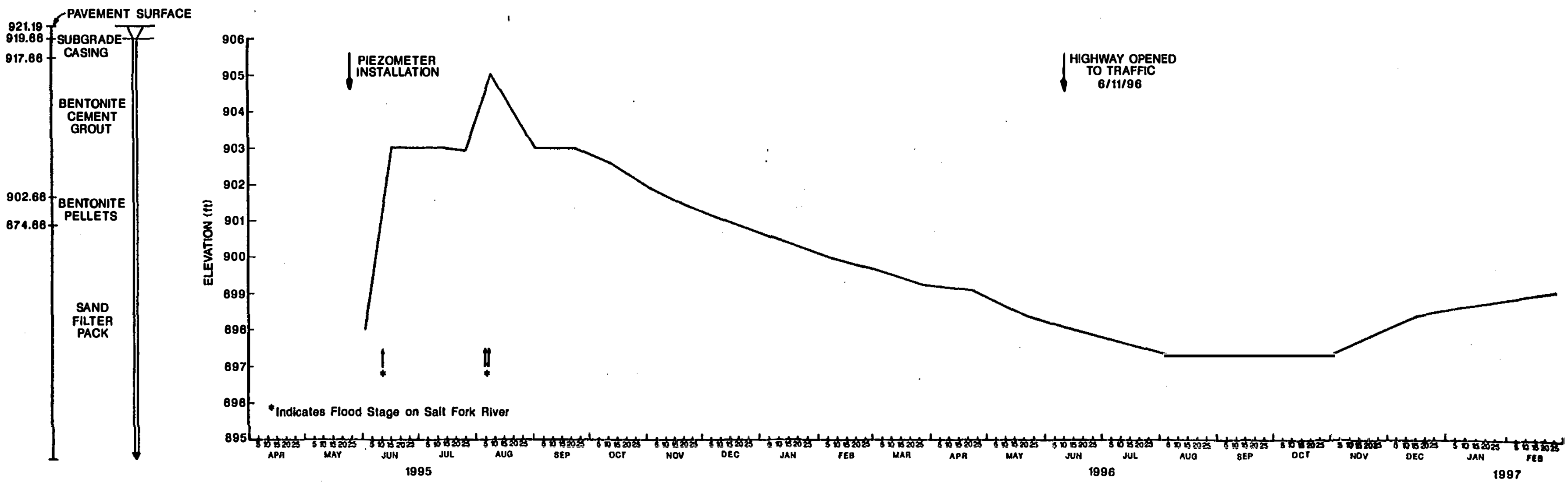
SETTLEMENT FROM AMPLIFIED LIQUID SETTLEMENT
GAGES SOUTH ABUTMENT WALL, BRIDGE C



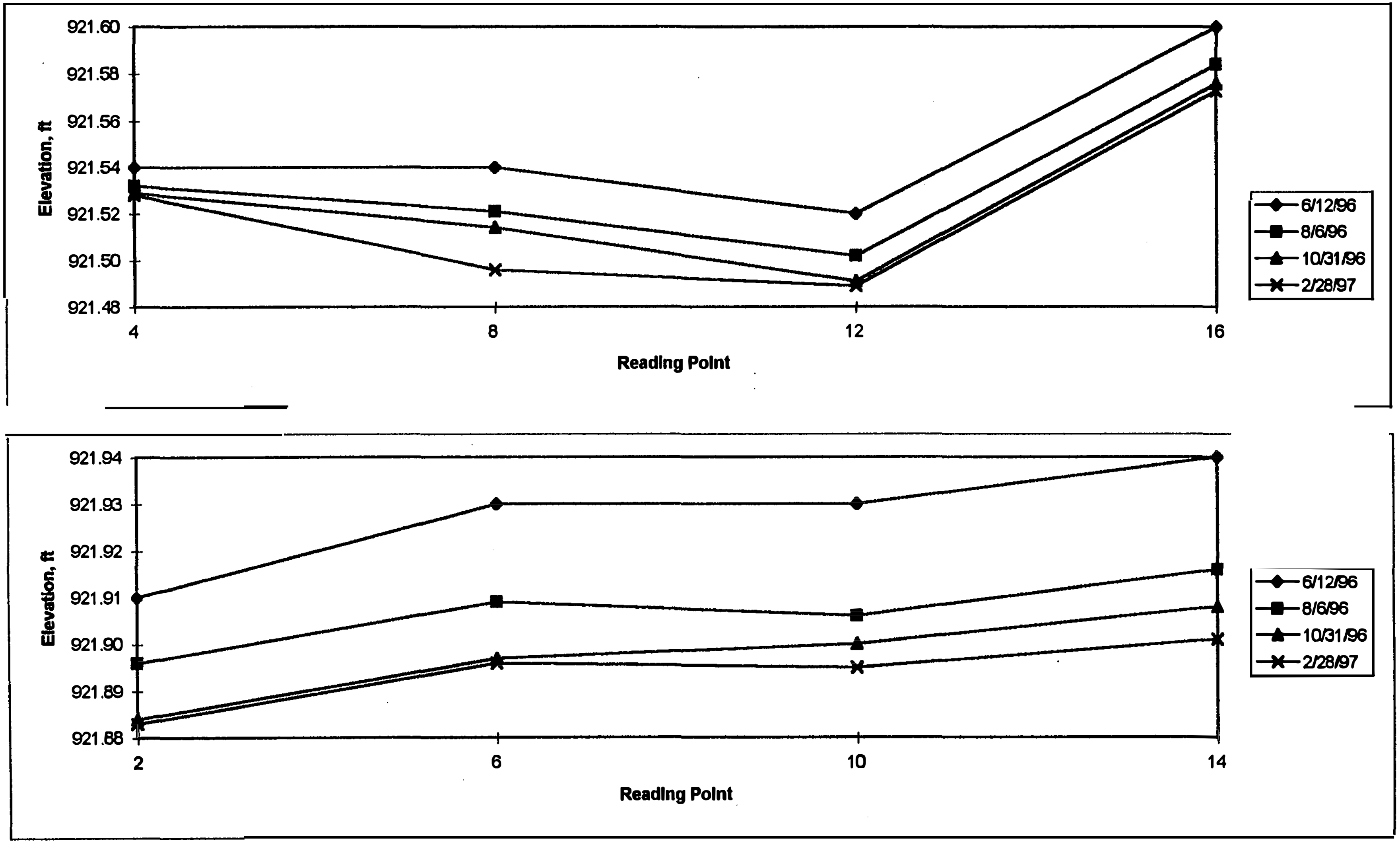
SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) CENTERLINE, SOUTH ABUTMENT WALL, BRIDGE C



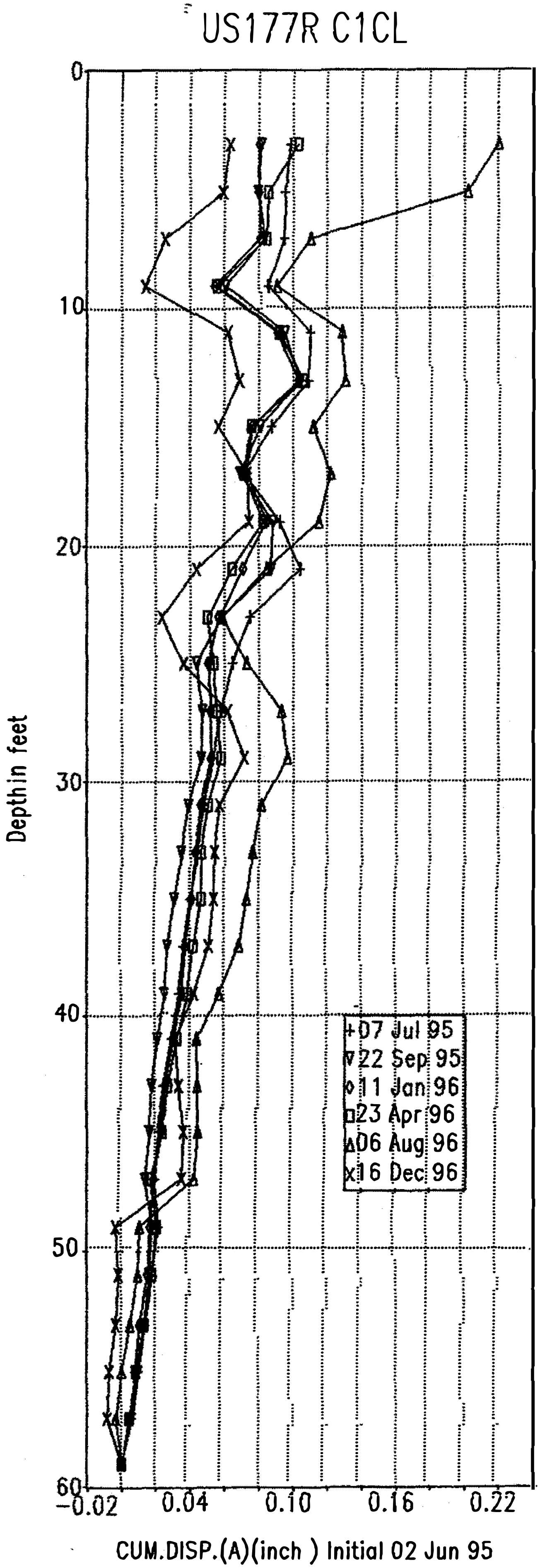
SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) OFFSET, SOUTH ABUTMENT WALL, BRIDGE C

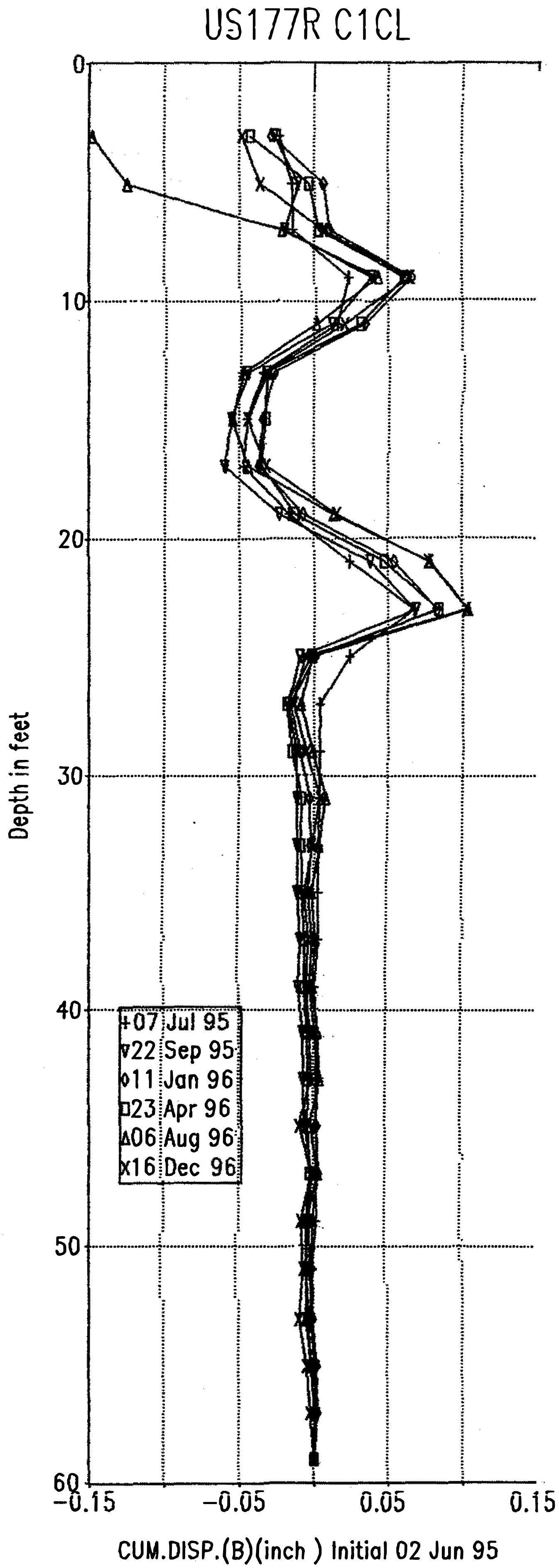


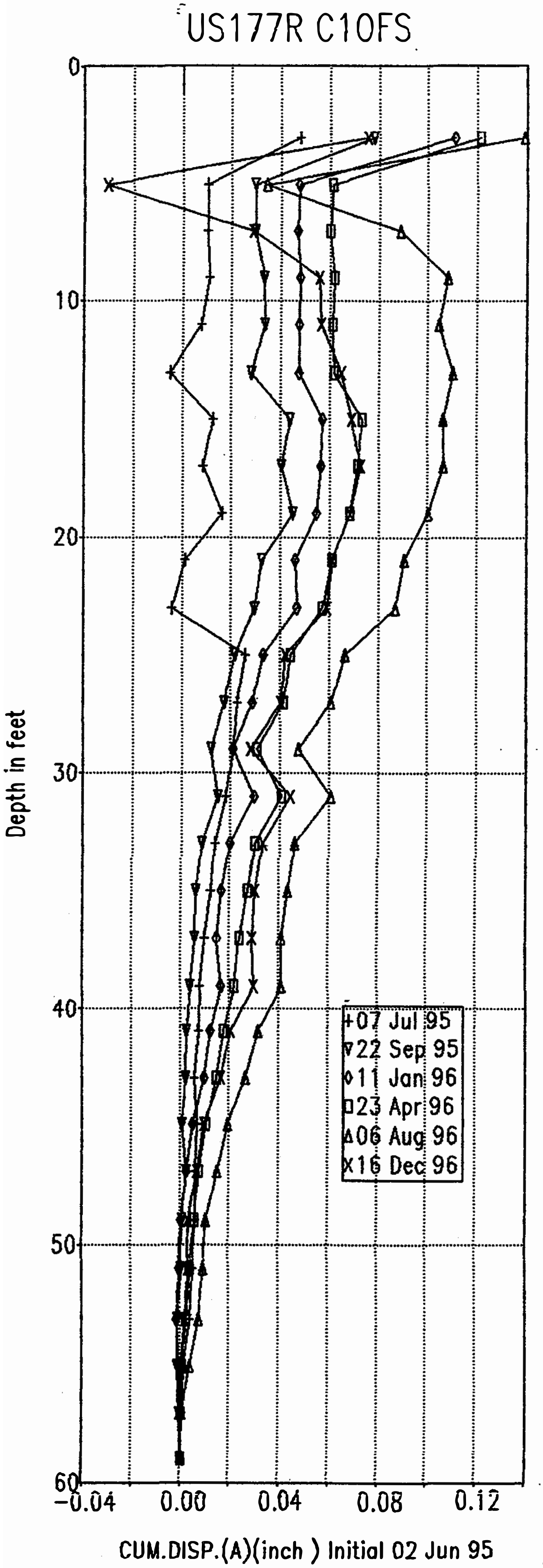
GROUNDWATER TABLE ELEVATION (TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE C

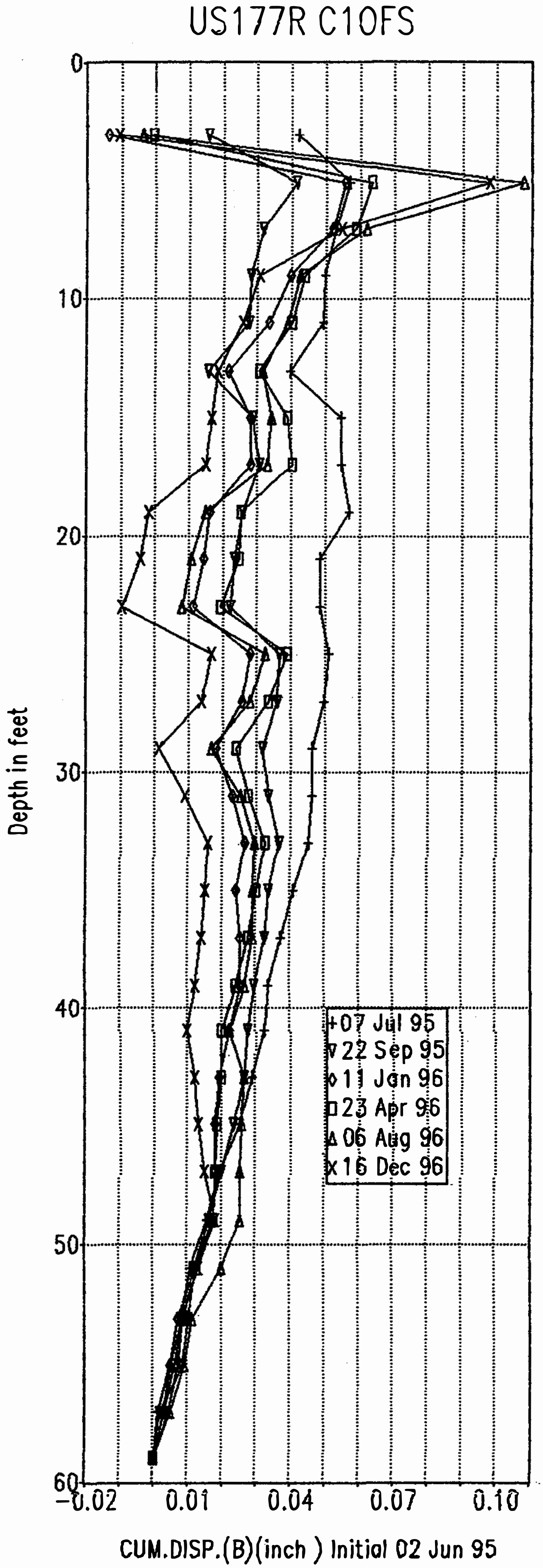


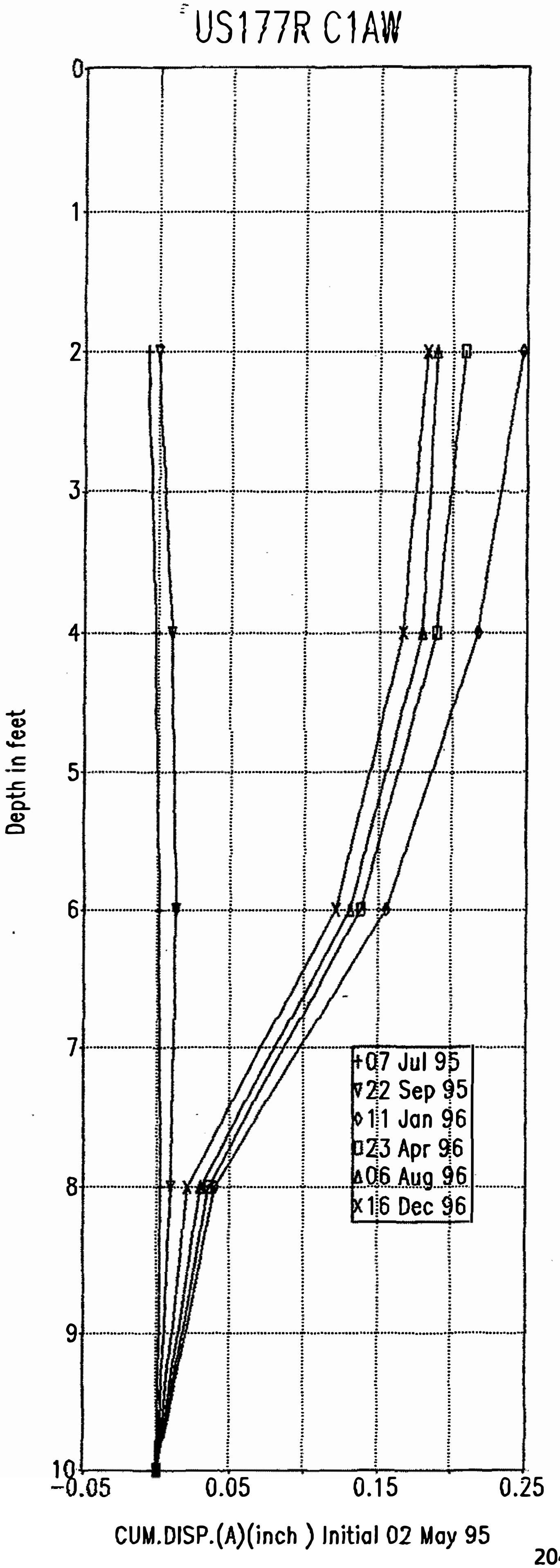
Surface Settlement Point Data, South Abutment Wall, Bridge C

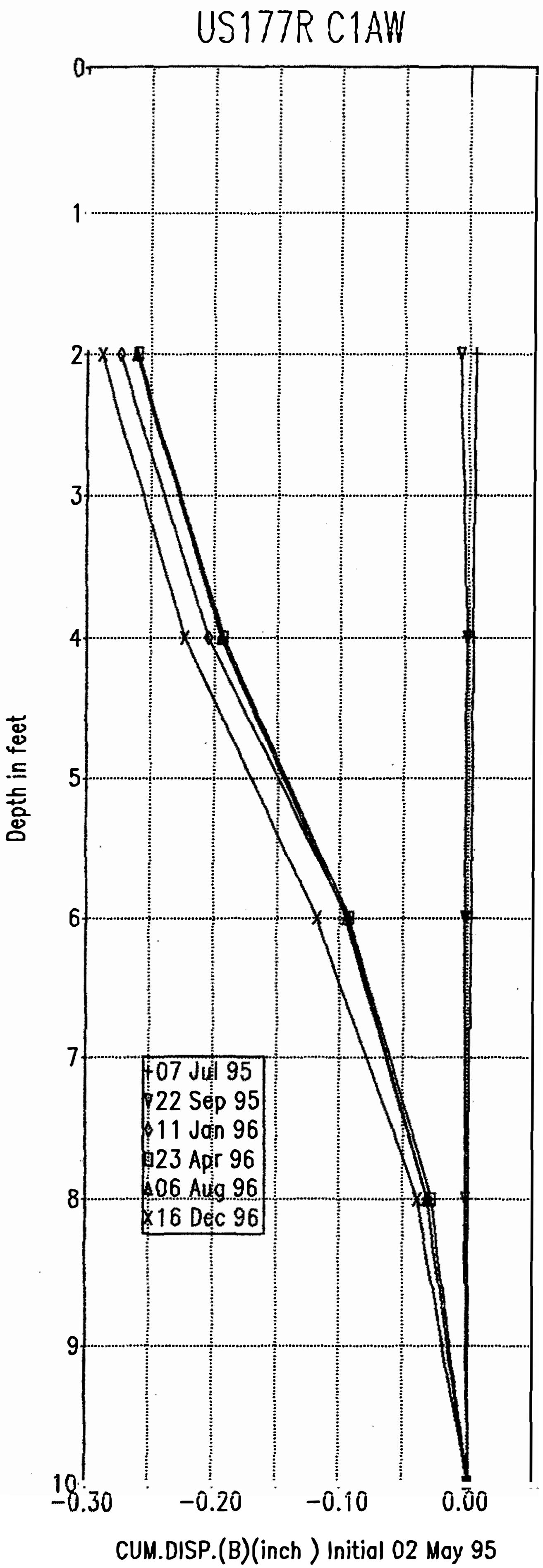

US177R C1CL
Depth in feet
0
10
20
30
40
50
60
-0.02
0.04
0.10
0.16
0.22
+07 Jul 95
∇22 Sep 95
◊11 Jan 96
□23 Apr 96
Δ06 Aug 96
x16 Dec 96
CUM.DISP.(A)(inch) Initial 02 Jun 95


US177R C1CL
Depth in feet
0
10
20
30
40
50
60
-0.15
-0.05
0.05
0.15
+07 Jul 95
∇22 Sep 95
◊11 Jan 96
□23 Apr 96
Δ06 Aug 96
x16 Dec 96
CUM.DISP.(B)(inch) Initial 02 Jun 95


US177R C10FS
Depth in feet
0
10
20
30
40
50
60
−0.04
0.00
0.04
0.08
0.12
CUM.DISP.(A)(inch) Initial 02 Jun 95
+07 Jul 95
▽22 Sep 95
◊11 Jan 96
□23 Apr 96
△06 Aug 96
x16 Dec 96

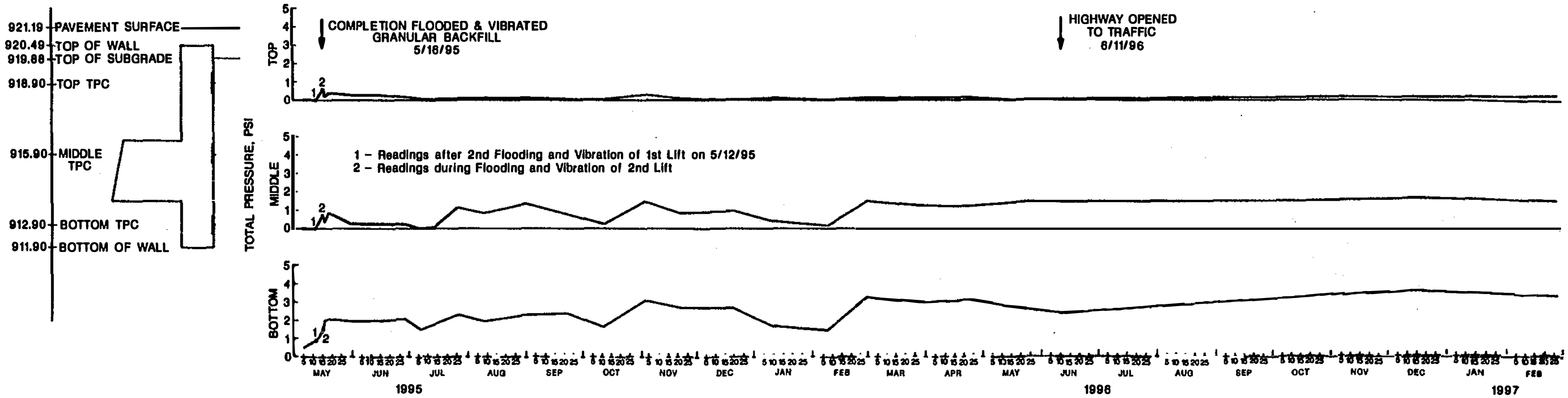

US177R C10FS
Depth in feet
0
10
20
30
40
50
60
−0.02
0.01
0.04
0.07
0.10
CUM.DISP.(B)(inch) Initial 02 Jun 95
+07 Jul 95
▽22 Sep 95
◊11 Jan 96
□23 Apr 96
△06 Aug 96
x16 Dec 96


US177R C1AW
Depth in feet
0
1
2
3
4
5
6
7
8
9
10
−0.05
0.05
0.15
0.25
+07 Jul 95
▽22 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96
CUM.DISP.(A)(inch) Initial 02 May 95

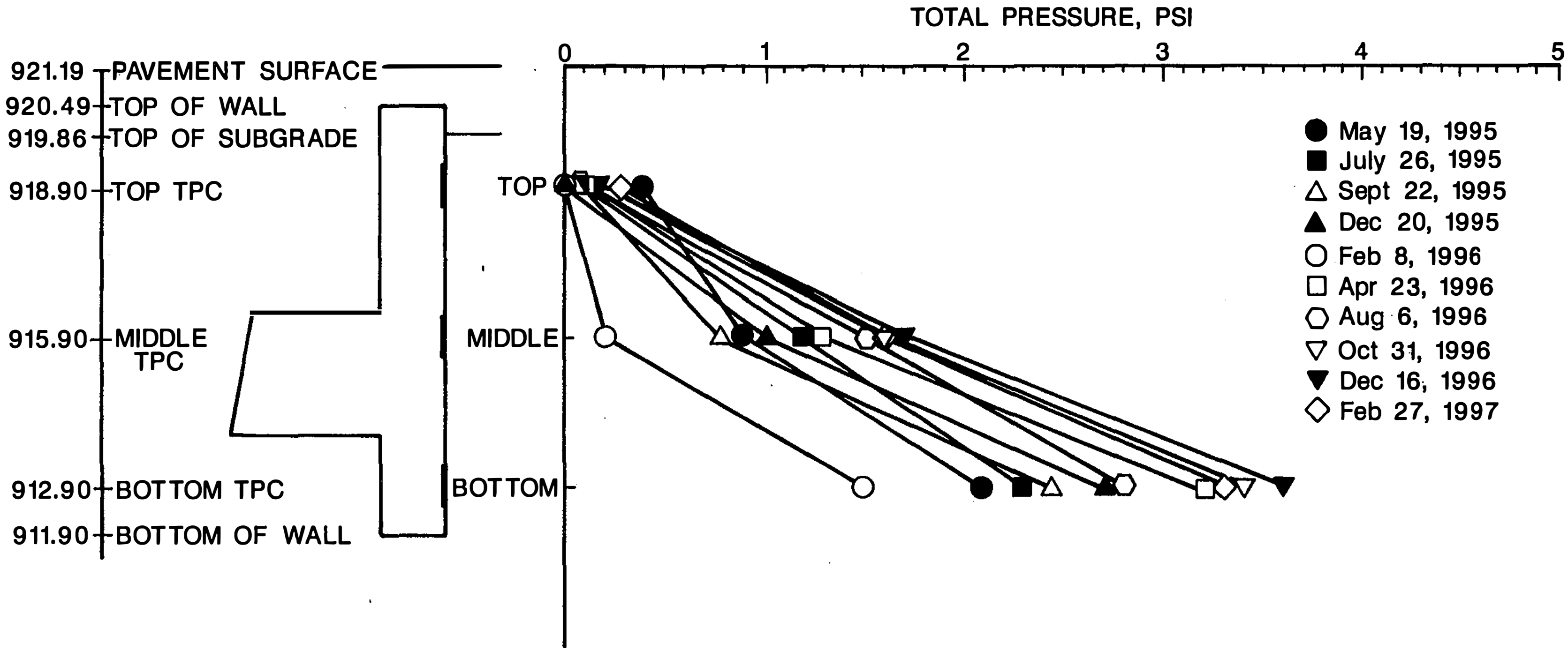

US177R C1AW
Depth in feet
0
1
2
3
4
5
6
7
8
9
10
−0.30
−0.20
−0.10
0.00
+07 Jul 95
▽22 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96
CUM.DISP.(B)(inch) Initial 02 May 95

APPENDIX C6

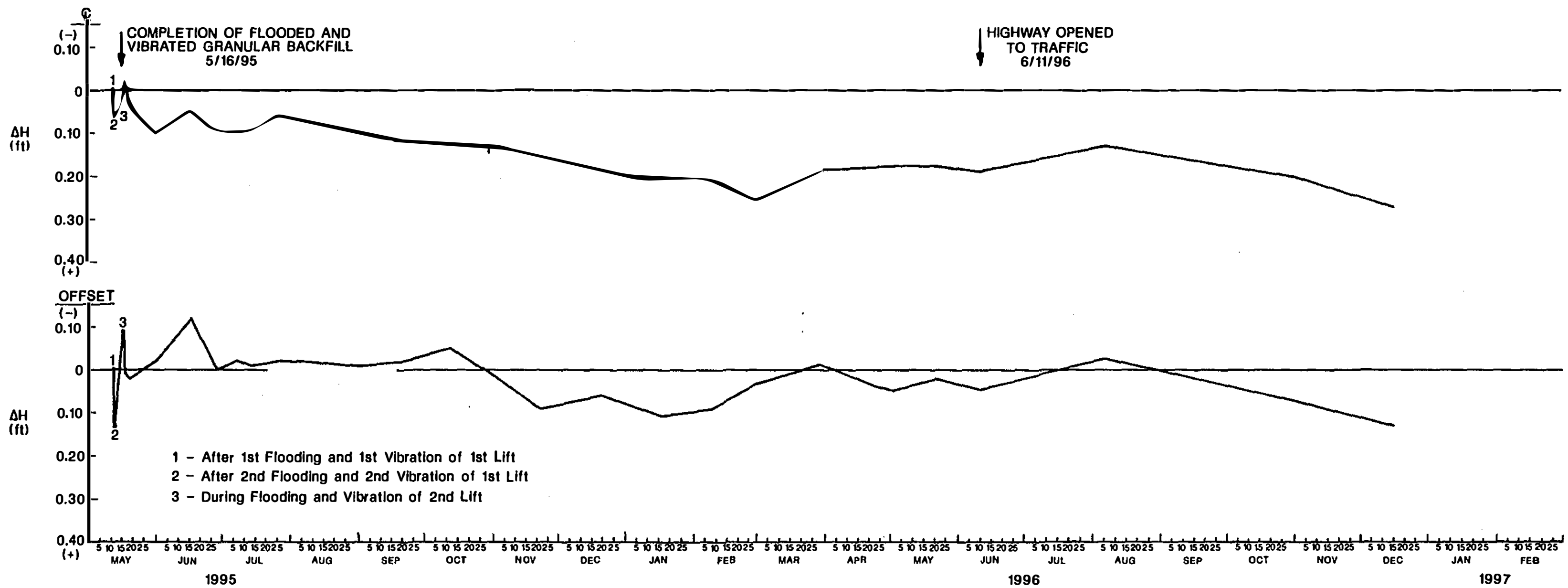
Data Plots for Approach Embankment C2



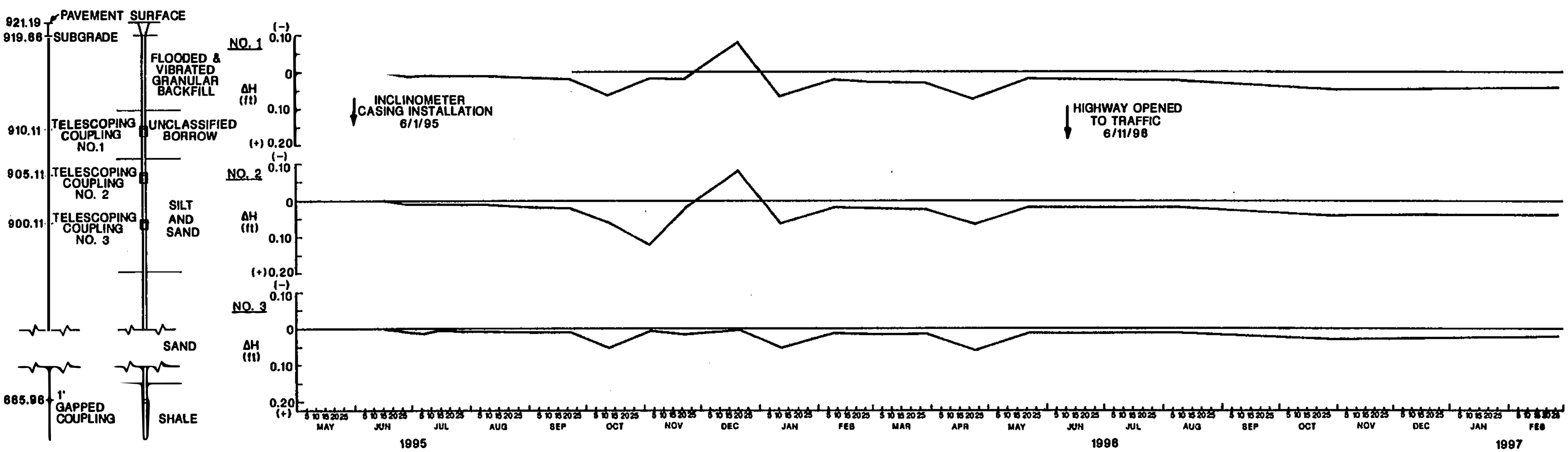
TOTAL PRESSURE CELL DATA (TIME PLOT) NORTH ABUTMENT WALL, BRIDGE C



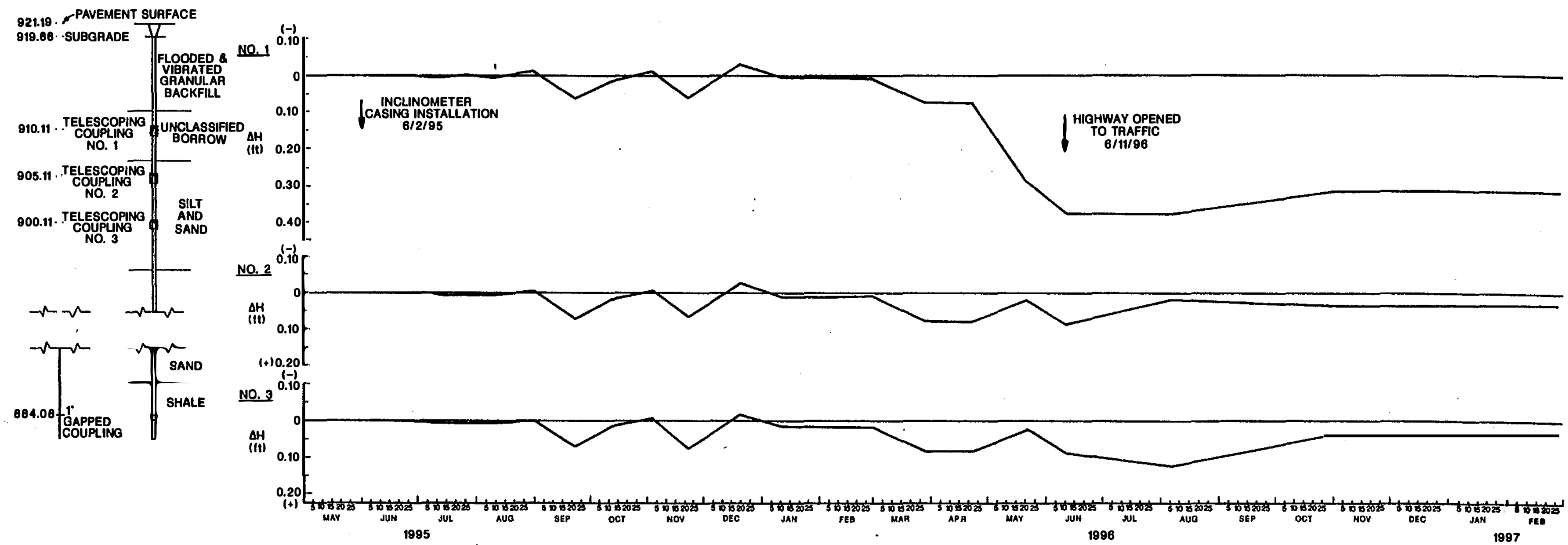
TOTAL PRESSURE CELL DATA (PROFILE) NORTH ABUTMENT WALL, BRIDGE C



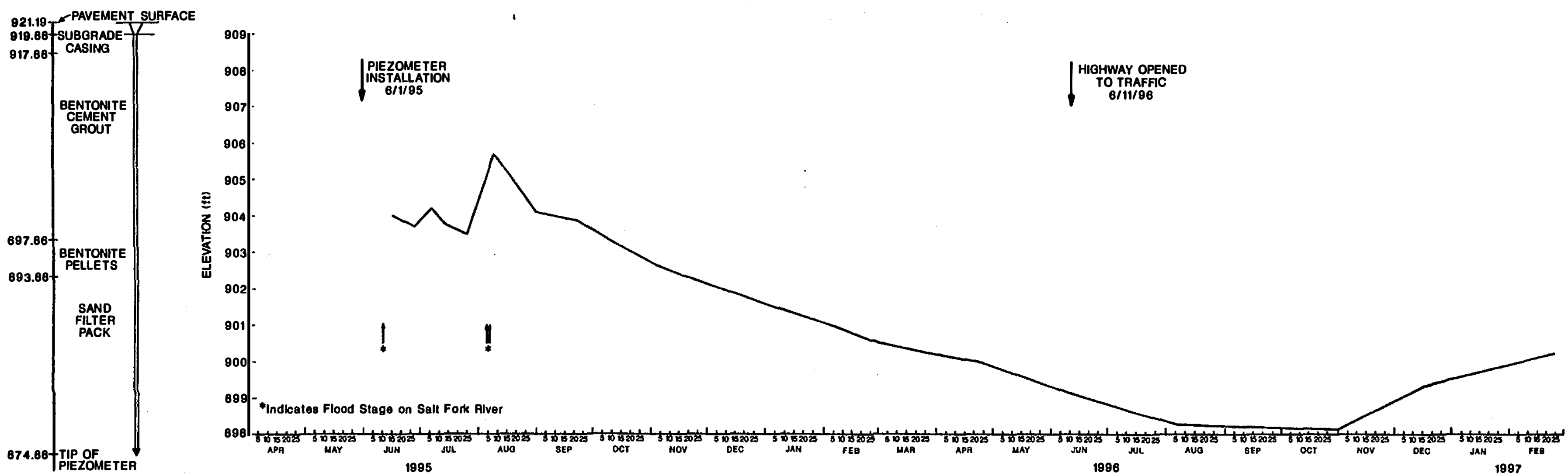
SETTLEMENT FROM AMPLIFIED LIQUID SETTLEMENT
GAGES NORTH ABUTMENT WALL, BRIDGE C



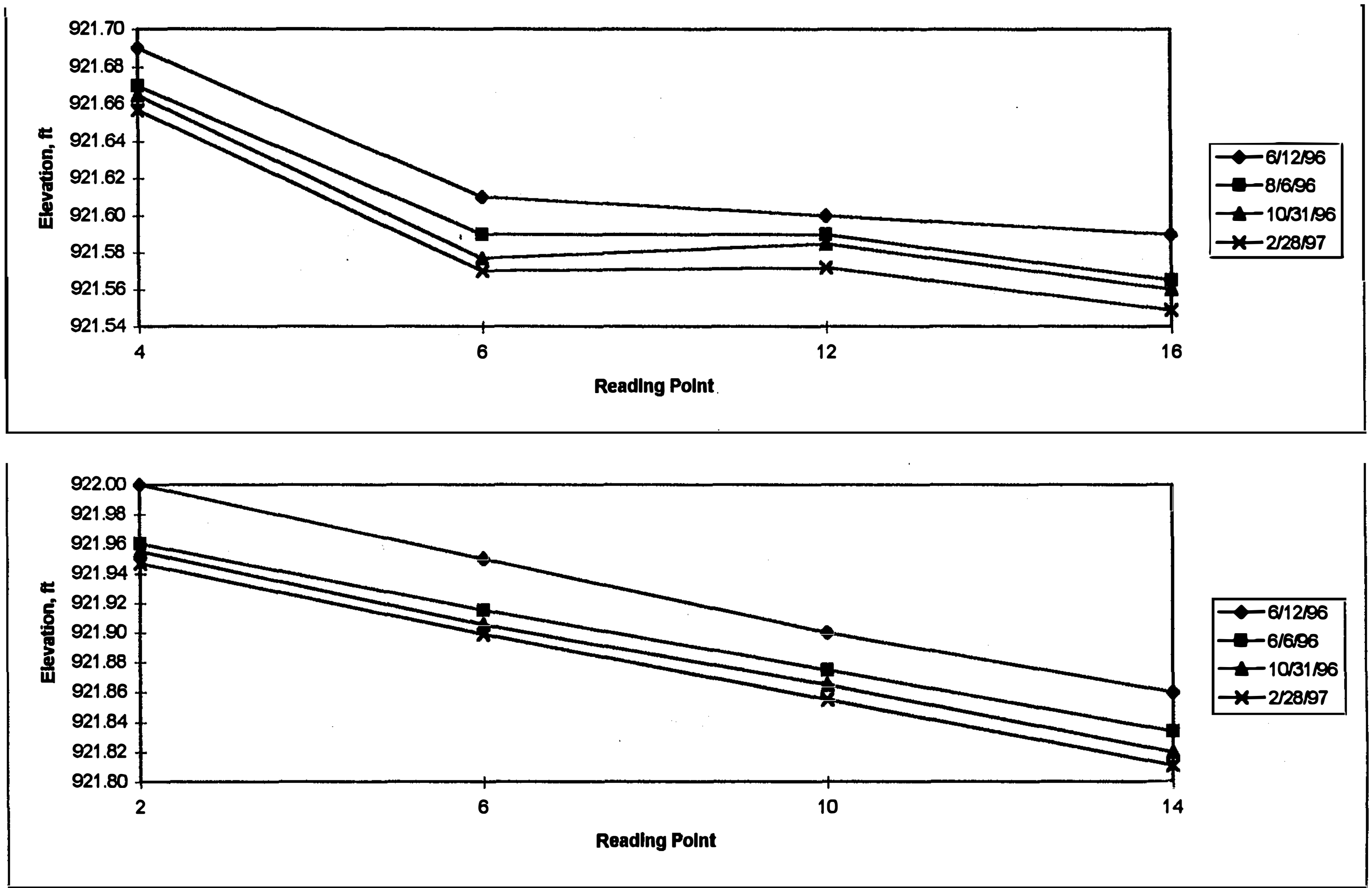
SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) CENTERLINE, NORTH ABUTMENT WALL, BRIDGE C



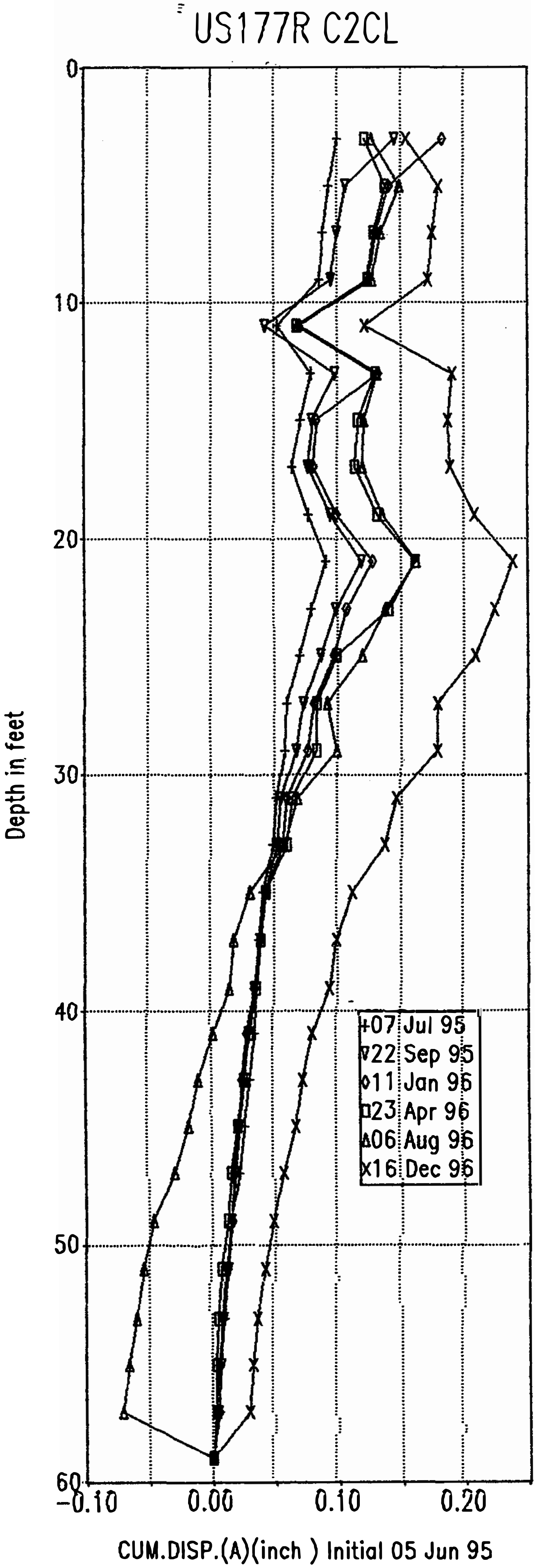
SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) OFFSET, NORTH ABUTMENT WALL, BRIDGE C

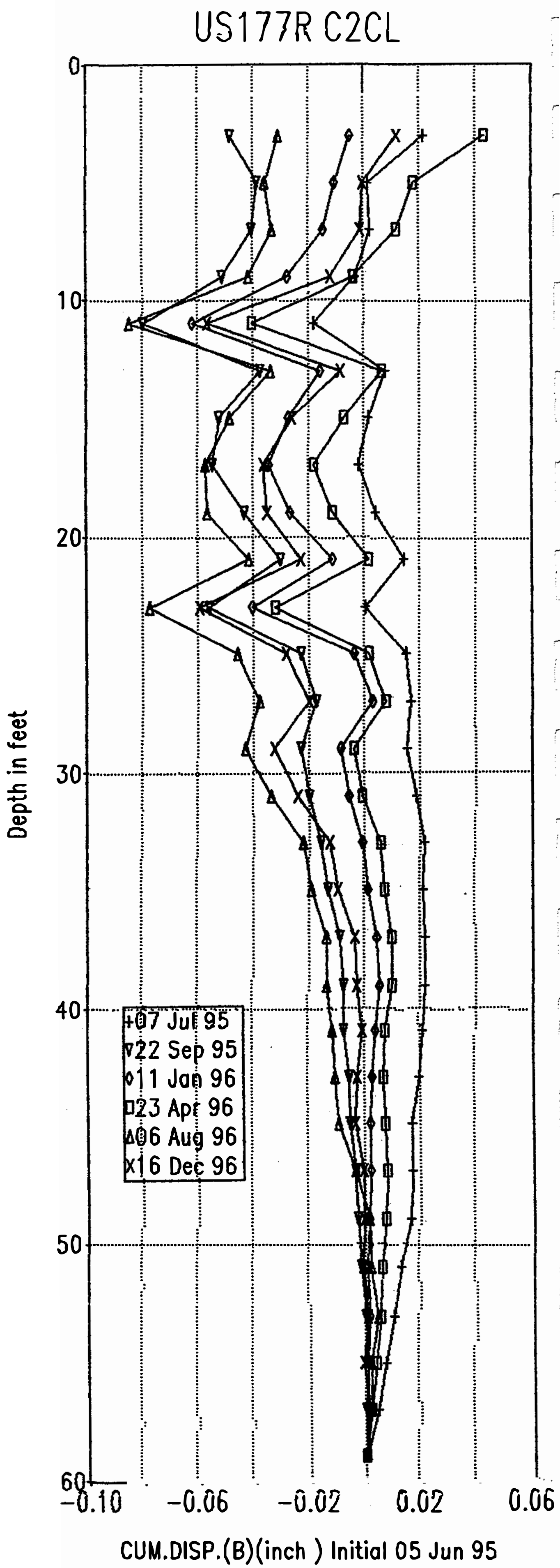


GROUNDWATER TABLE ELEVATION (TIME PLOT) NORTH ABUTMENT WALL, BRIDGE C



Surface Settlement Point Data, North Abutment Wall, Bridge C


US177R C2CL
Depth in feet
CUM.DISP.(A)(inch) Initial 05 Jun 95
+07 Jul 95
▽22 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96


US177R C2CL
Depth in feet
CUM.DISP.(B)(inch) Initial 05 Jun 95
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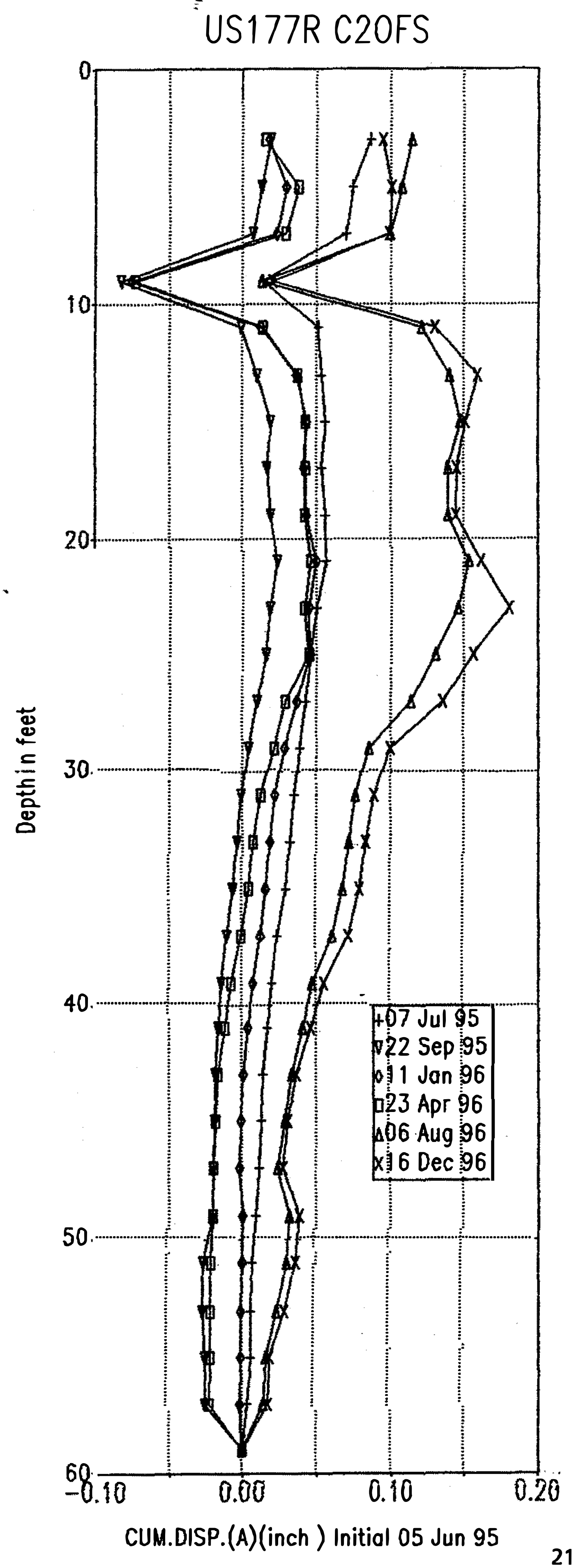
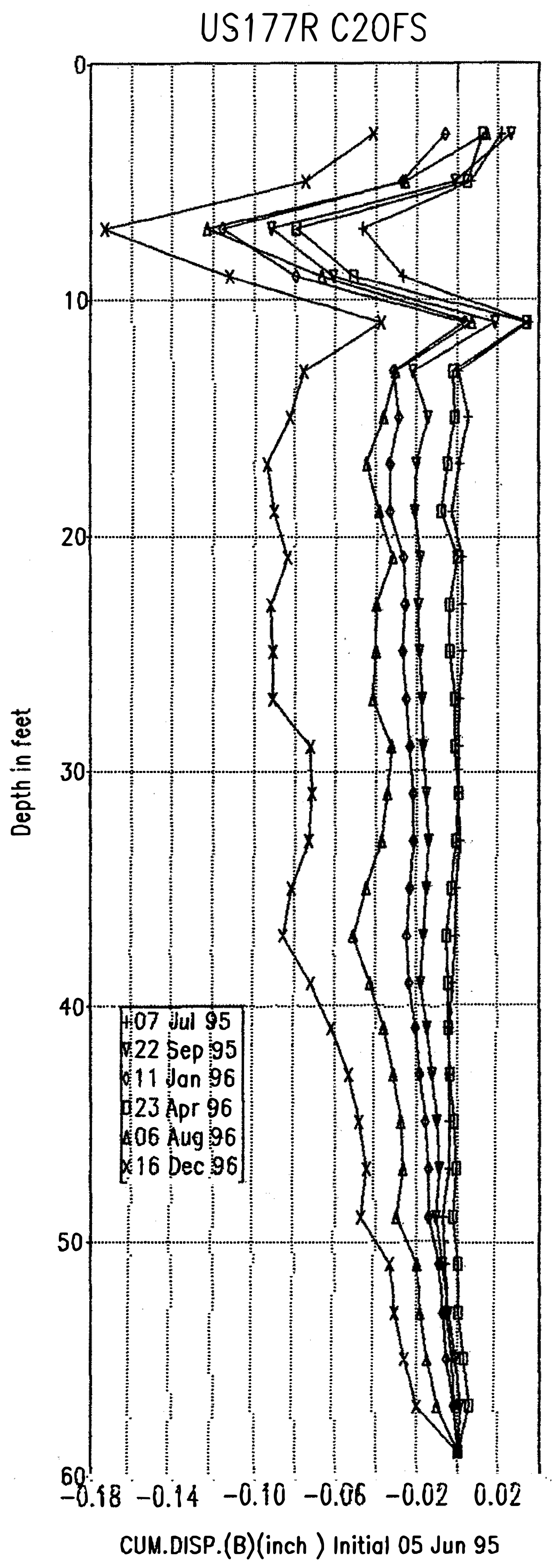
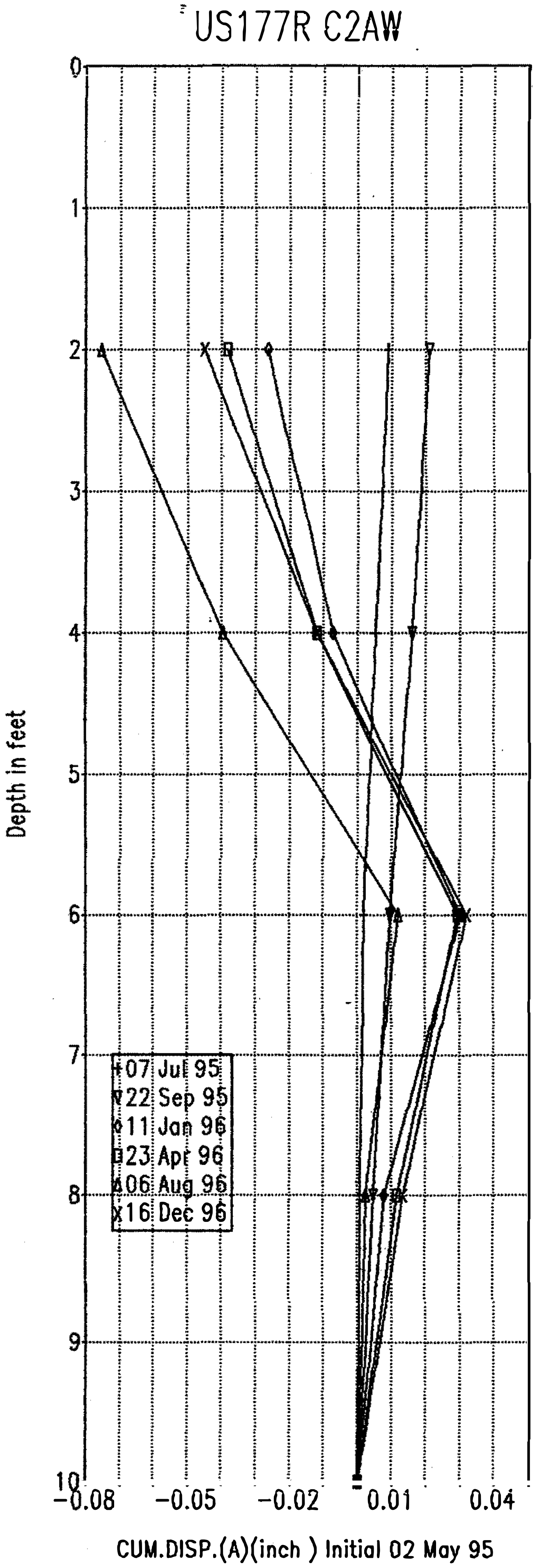
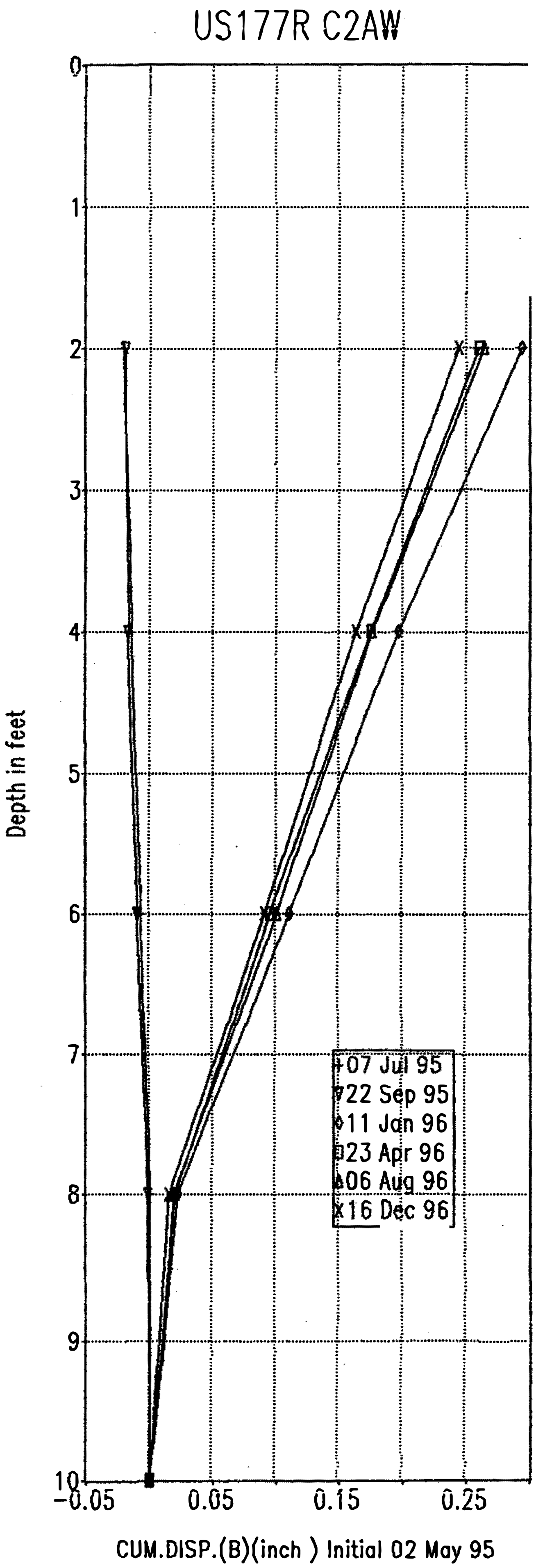
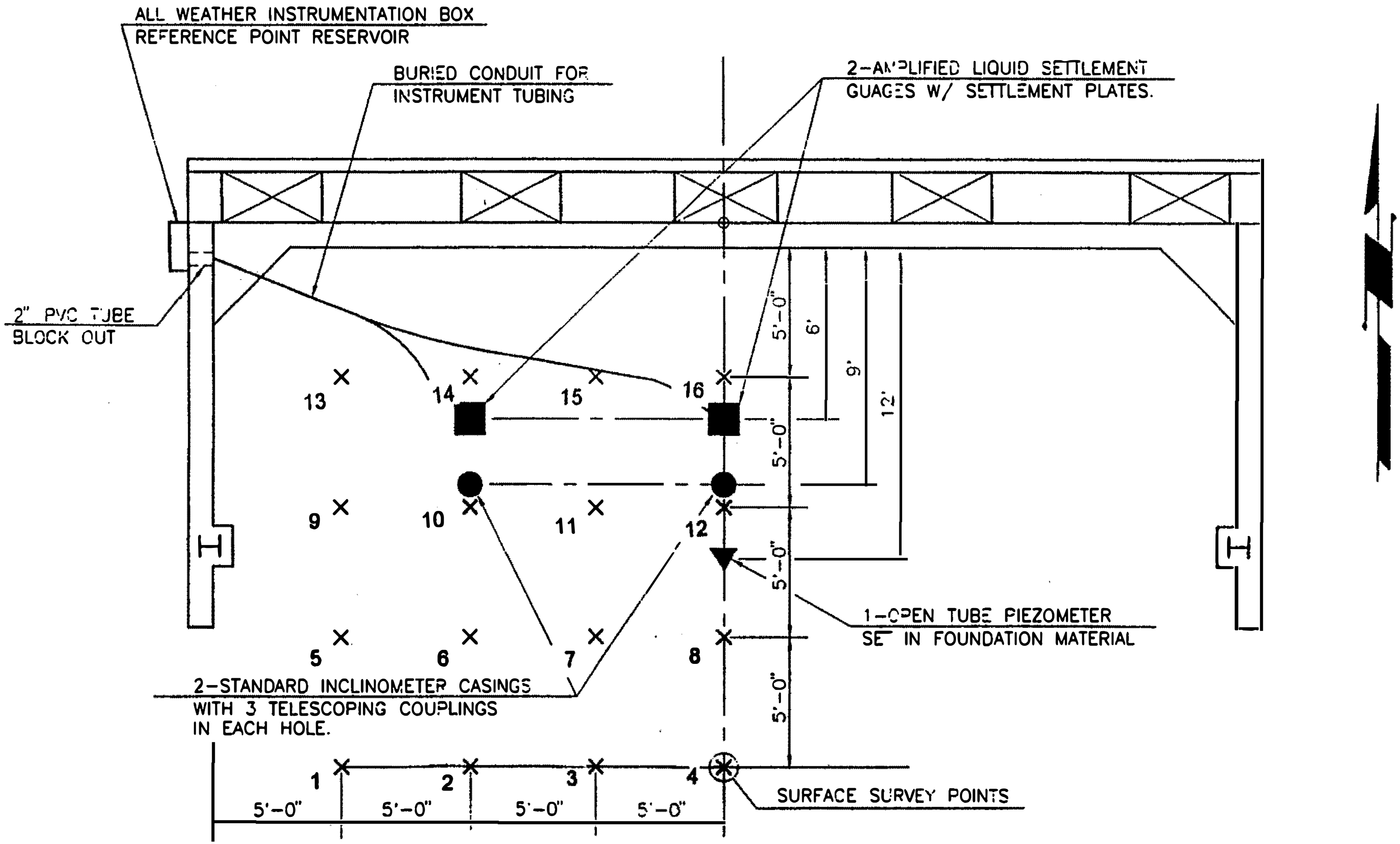
▽22 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96


US177R C20FS
Depth in feet
0
10
20
30
40
50
60
-0.10
0.00
0.10
0.20
+07 Jul 95
▽22 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
×16 Dec 96
CUM.DISP.(A)(inch) Initial 05 Jun 95


US177R C20FS
Depth in feet
0
10
20
30
40
50
60
-0.18
-0.14
-0.10
-0.06
-0.02
0.02
+07 Jul 95
▽22 Sep 95
◇11 Jan 96
□23 Apr 96
△06 Aug 96
×16 Dec 96
CUM.DISP.(B)(inch) Initial 05 Jun 95


US177R C2AW
Depth in feet
0
1
2
3
4
5
6
7
8
9
10
-0.08
-0.05
-0.02
0.01
0.04
+07 Jul 95
∇22 Sep 95
◊11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96
CUM.DISP.(A)(inch) Initial 02 May 95


US177R C2AW
Depth in feet
0
1
2
3
4
5
6
7
8
9
10
-0.05
0.05
0.15
0.25
+07 Jul 95
∇22 Sep 95
◊11 Jan 96
□23 Apr 96
△06 Aug 96
X16 Dec 96
CUM.DISP.(B)(inch) Initial 02 May 95



Surface Settlement Point Locations, South Abutment Wall, Bridge C