EVALUATION OF THE GILCREASE EXPRESSWAY DYNAMIC COMPACTION

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FINAL REPORT

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16. ABSTRACT

This is the final evaluation report on the dynamic compaction project that was completed in 1985 on an abandoned strip mine and landfill. Since that time, the area has been monitored with instrumentation for lateral movement and horizontal settlement.

Evaluation of the test data obtained from seven years of monitoring indicated no appreciable settlement of the embankment. The dynamic compaction of the abandoned strip mine and land fill apprears to have worked effectively. The instrumentation that was used, performed well and provided the necessary data to evaluate the dynamic compaction.

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

VOLUME

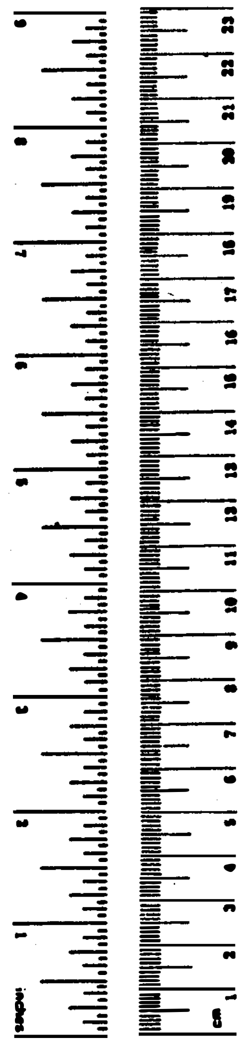
Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* SI is the symbol for the International System of Measurements



APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectares (10 000 m^2)	2.53	acres	ac

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

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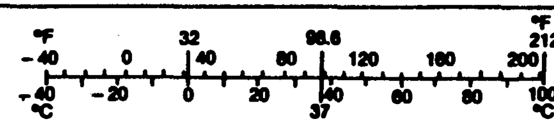
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

This is a final evaluation report. It concerns the performance of the dynamic compaction that was completed in 1985 on strip mine spoils and landfill. Since that time, the area has been monitored with instrumentation for lateral and horizontal movement.

In 1985, the Oklahoma Department of Transportation (ODOT), with the aid of W.R. Holway and Associates Consultants, Wise Sullivan Construction Company, and the Federal Highway Administration (FHWA), completed the dynamic compaction project. Dynamic compaction is the process of soil densification by means of repeatedly dropping a heavy weight on the ground surface.

The project was located on the Gilcrease Expressway in the vicinity of Yale Avenue in Tulsa, Oklahoma. Dynamic compaction was conducted so that a four lane expressway with a 40 foot median could be constructed over an abandoned strip mine and land fill. The area was 0.5 miles long and covered 22 acres. The abandoned strip mine was used as a public trash dump during the years after the mining operation was shut down. Alternate design methods were considered, but the advantages of dynamic compaction outweighed them.

Three test sections representing three different mine spoil and trash compositions provided guidance for subsequent compaction effort. This information can be obtained in the construction report entitled: "Evaluation of Dynamic Compaction in Tulsa, Oklahoma", by Oklahoma State University (OSU) and the Research and Development Division, FHWA/OK 86(3). Also, a video tape entitled: "Dynamic Compaction: A Case Study" was produced by the Research Division and Oklahoma State University on the construction phase. A copy of the video is available on request from the Research and Development Division.

BACKGROUND

Once the dynamic compaction was completed, the plans called for the construction of a large fill for the Gilcrease-Yale interchange. The fill was to be as much as 30 feet above the grade of the dynamic compaction.

In the interest of seeing how well the dynamic compaction process worked, the ODOT Research Division installed 5 pneumatic settlement plates. These settlement plates, along with 7 piezometers left from previous OSU work, were to be the first part of a long term study of the dynamic compaction process used in Tulsa.

Following settlement plate installation, the highway embankment was constructed. Research monitored the site throughout construction by taking pore pressure and settlement measurements. Following the completion of the grading, drainage, and bridge contract, Research Division personnel installed inclinometers and heave anchors at the toe of the fill.

Since there were three types of material encountered at the site, instrumentation was installed so that each area could be monitored. Consult Figure 1 to see the instrumentation layout relative to the test sections. Test Section No. 1 represents the conditions that exist between Stations 172+00 and 181+00. Borings from Test Section No. 1 indicated the presence of mine spoil, consisting of a silty clay with shale fragments, from the surface down to bedrock in this area. The water table was not encountered in the borings.

Test Section No. 2 was located between Stations 182+00 and 192+00. In Test Section No. 2, the top 2 or 3 feet at this test site consisted of clay, shale fragments and mine spoil. Debris consisting of paper, wood, metal, rubber, etc., was found to a depth of about 20 feet. Beneath the debris there was a two or three foot layer of the mine spoil overlying the hard weathered shale. The water table was not encountered in the borings.

Test Section No. 3 was located between Stations 164+00 and 171+00. At Test Section No. 3, the top 5 or 6 feet consisted of clay and shale fragment mine spoils. This was underlain by approximately 12 feet of silty clay and shale fragments mixed with some trash. Beneath this material was 2 to 3 feet of stiff silty clay and shale fragments which rested on the hard weathered shale. In Test Section No. 3, the ground water table at the time of exploration was approximately 4 feet below the ground surface.

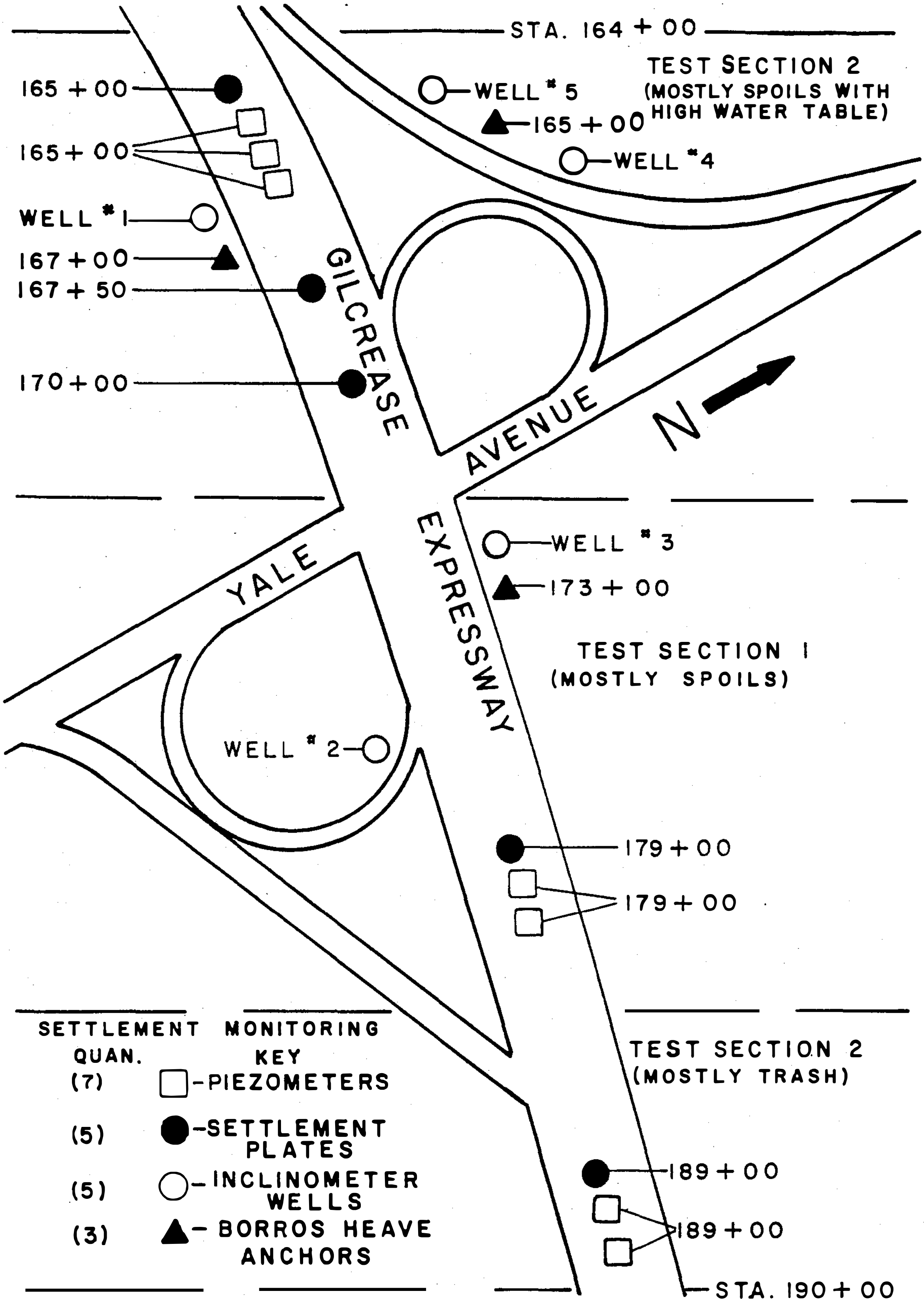

Figure 1. Location of the Instrumentation

MATERIALS AND METHODS

Piezometers

Piezometers are used to measure pore water pressure. Seven piezometers, produced by the Slope Indicator Company (SINCO), were originally installed at the site. Figure 2 shows a diagram of the piezometer set-up. Standard methods were used to install the casing.

The electrical piezometer system consisted of the digital indicator (Model 56449), the transducer, and the interconnecting electrical cable. As was indicated, the piezometers were used in the preliminary testing conducted by OSU and the Research Division. After the completion of the compaction, and during the embankment construction, the piezometer cables were brought up to grade by using Schedule 40, PVC casing, 2 inch diameter pipe with 2 inch Schedule 40, PVC couplings.

Pneumatic Settlement Plates

Settlement plates are designed to measure and monitor settlement in areas inaccessible during construction. Five pneumatic settlement plates were installed and monitored. The settlement plate operates on the principle that the pressure at the bottom of a column of fluid increases as the column of fluid gets higher. The settlement plate system installed uses pressurized nitrogen to amplify the pressure from the bottom of a simple column of water. Pressure readings are taken and are converted into vertical elevation. Then, based on the initial elevation of the plate, a determination of any plate movement can be made.

Standard practices were used to install the settlement plates. At the location of the settlement reservoir, a 4 x 4 inch x 8 foot treated post was set in Portland cement concrete, as nearly vertical as possible. Stability and permanence of the treated post is important to the success of the settlement plate system.

The settlement plate consists of the Pneumatic Pressure Indicator (Model 51411-A), the transducer, and the electrical cable. The cable contained 5 tubes, three were pneumatic and two were liquid filled. The cable was laid in an "S" pattern as depicted in the Settlement Plate Installation in Figure 2 to allow ample slack for movement of the transducer.

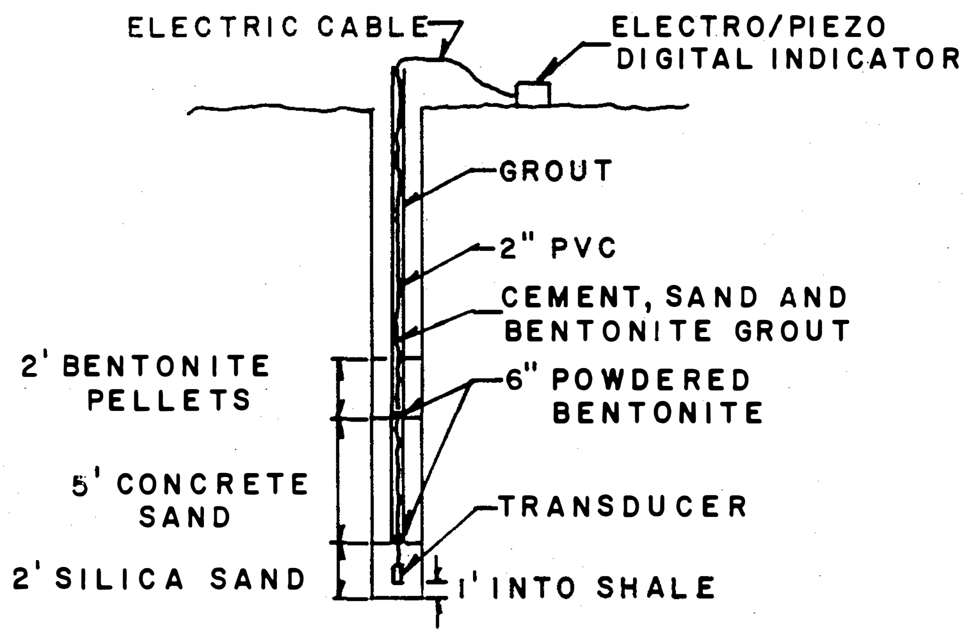

Figure 2. Piezometer Set-Up

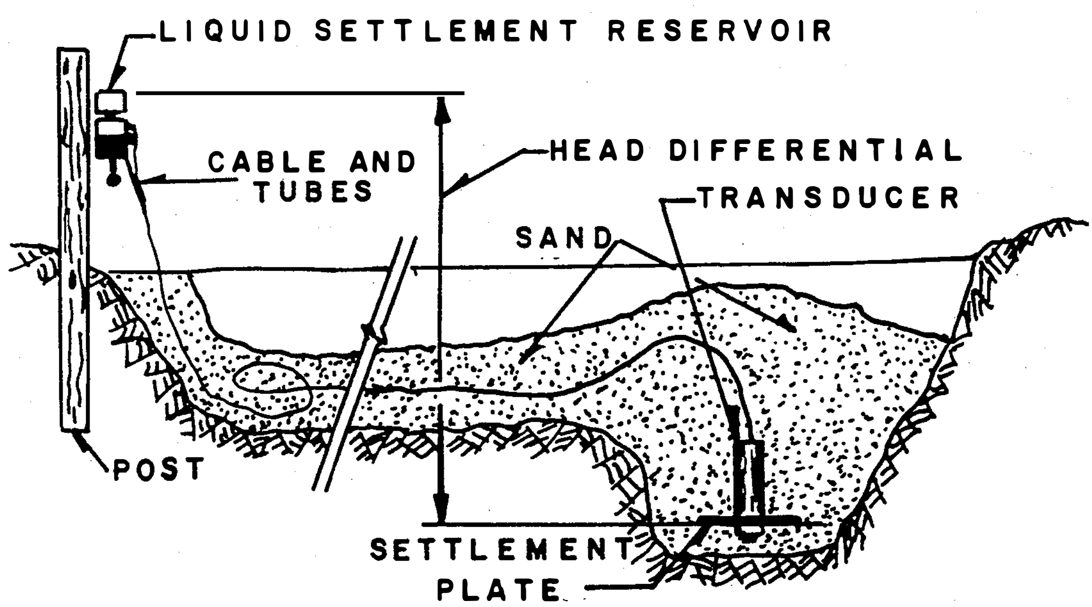

Figure 3. Settlement Plate Set-Up

Inclinometers

Inclinometers measure lateral embankment movement with depth. Five inclinometers were installed and monitored following completion of the embankment. Figure 4 shows a diagram of the inclinometer set-up. Aluminum epoxy coated, 2.97 inch O.D. 10 foot and 5 foot sections were used as inclinometer guide casing. These were permanently installed in the ground. Aluminum epoxy coated, 2.97 inch O.D. couplings were used to connect the casing. Standard boring methods were used to install and grout the casing.

The inclinometer equipment used for this project was manufactured by SINCO. The Digitilt Recorder-Processor-Printer (RPP) Inclinometer System consists of a Digitilt sensor probe, a portable RPP indicator (Model 50368), and interconnecting electrical cable.

Heave Anchors

The borros type heave anchors measure vertical movements in the foundation soil. Three heave anchors were installed and monitored. The idea was that if settlement or slumping of the embankment did occur, heaving would result.

The heave anchor consists of a three prong anchor, a 0.25 inch inner pipe, and the 1 inch outer pipe. The pipes are assembled in sections and fastened together with couplings to the required anchor depths. The heave anchors were installed using standard methods. A diagram of the heave anchor set-up can be seen in Figure 5.

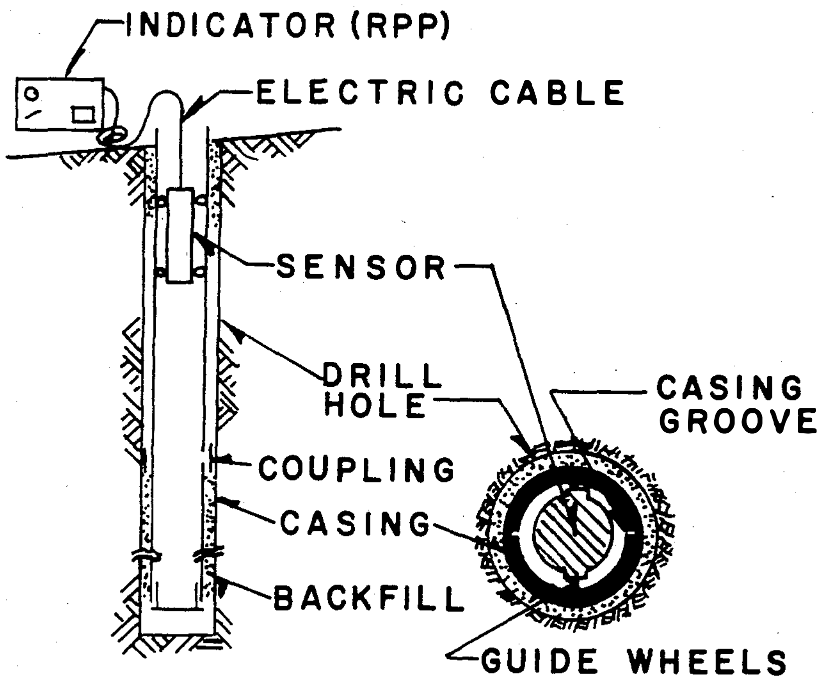

Figure 4. Inclinometer Set-Up

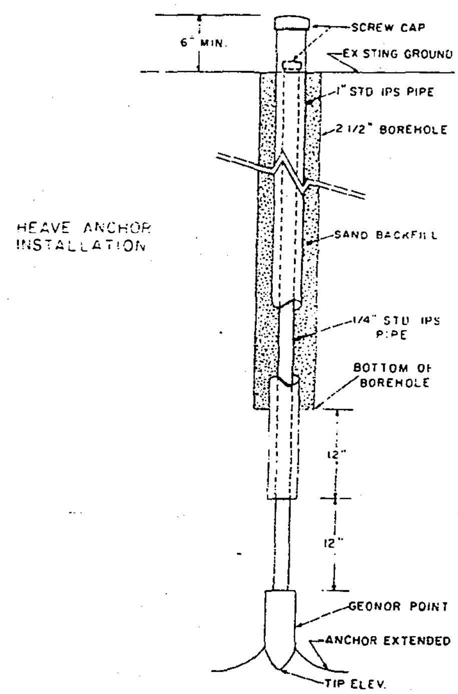

Figure 5. Heave Anchor Set-Up

EVALUATION

The instrumentation was placed in specific locations depending on the anticipated movement. Data was collected annually after the installation date. The piezometer data was recorded beginning April of 1986, once every two weeks until 1987. Then the data was recorded every other month until eventually the piezometers failed. The settlement plate data was collected in a similar fashion. Data was collected beginning March 1986 once every two weeks until March 1987. Then the data was collected every other month until the middle of 1988. Then once a year thereafter. This method of recording data was conducted anticipating the greatest amount of settlement to be during construction of the embankment. If there were continued settlement with time, that settlement would also be indicated by the data.

The inclinometers were installed in September 1986 after the completion of the embankment. The data was collected once every month until 1987 and every other month in 1988. Then the data was collected every six months to the present. The graphs presented in the report show the movement for each year. Data was collected for the heave anchors, beginning October 1986. Then once every month until the middle of 1987. Then the data was collected every six months thereafter. The total rise in elevation was determined using the average of the four beginning and ending elevation readings.

Piezometers

Five of the 7 piezometers that were installed in 1986 to measure the pore water pressure, worked effectively. Piezometers No. 2 and 7, located at Stations 165+00 and 189+00, showed inconsistent data and were abandoned. The pore water pressures of the working instruments were constant throughout construction. No indication of change in the pore water pressure was noted. Even the piezometers located in the high water table (Test Section No. 3), showed no appreciable change. Figures 6 to 11 show graphs of the pore water pressures vs. time for the five working installations. Day zero was when embankment construction began. By day 180, the construction of the embankment was completed. Traffic was allowed on the expressway 867 days (August 22, 1988) after the beginning of data collection.

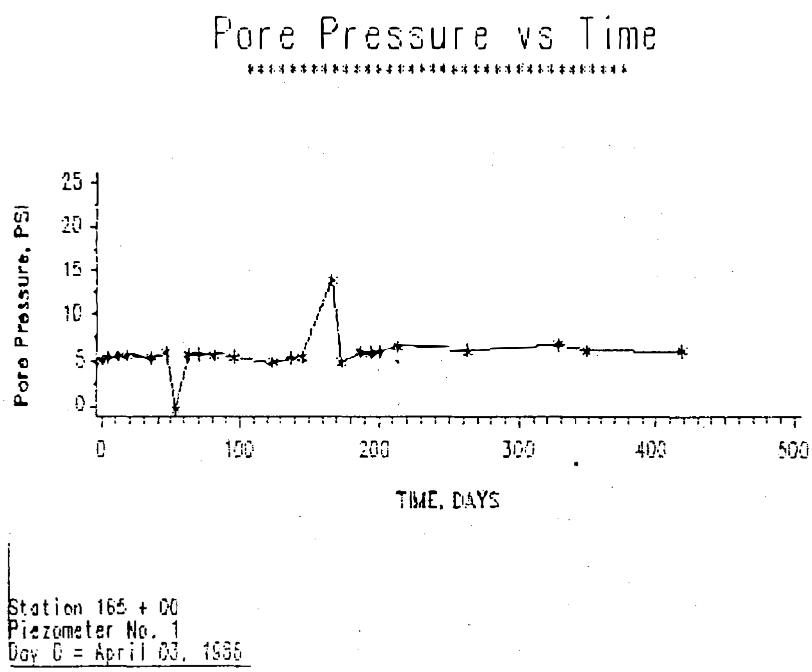

Figure 6. Piezometer No. 1, Station 165+00

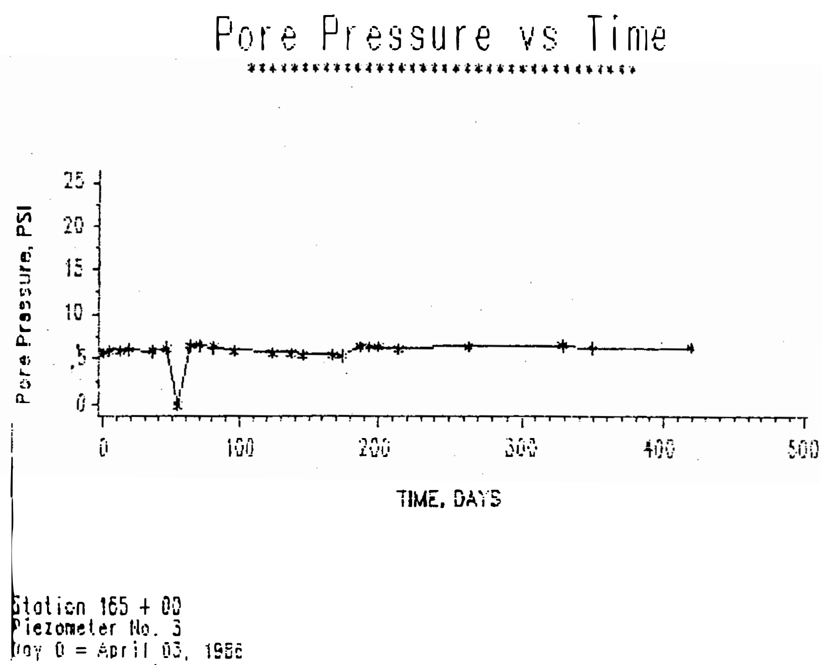

Figure 7. Piezometer No. 3, Station 165 + 00

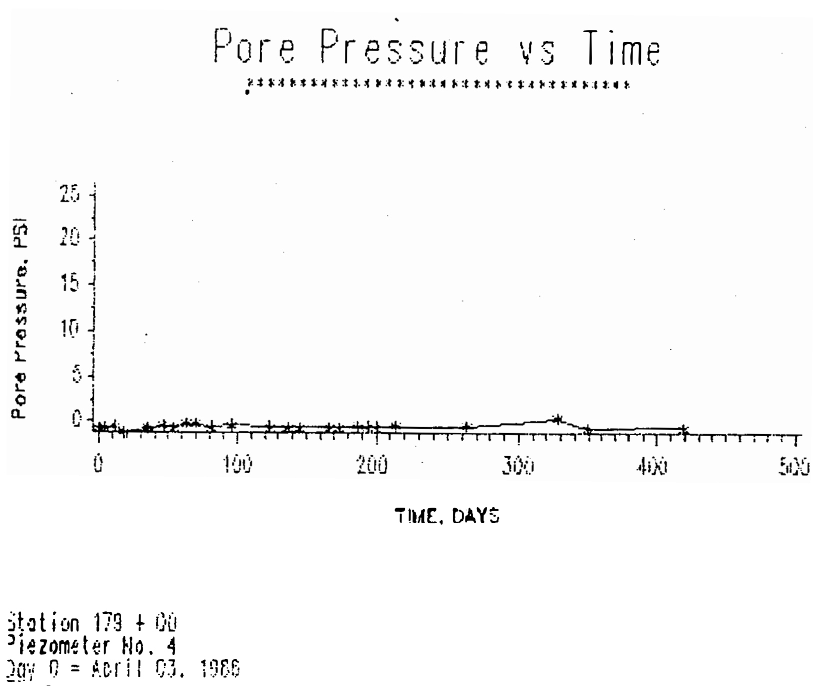

Figure 8. Piezometer No. 4, Station 179 + 00

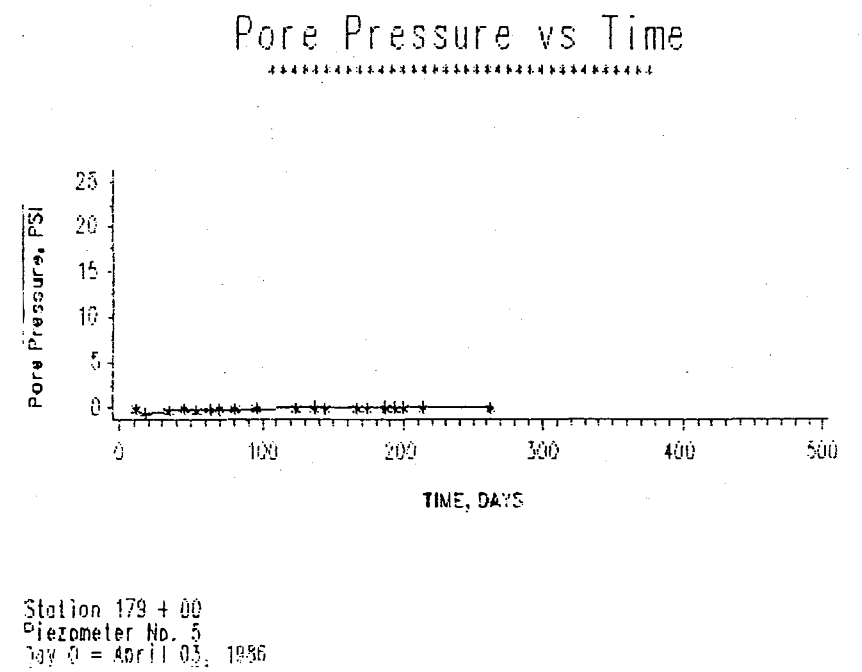

Figure 9. Piezometer No. 5, Station 179 + 00

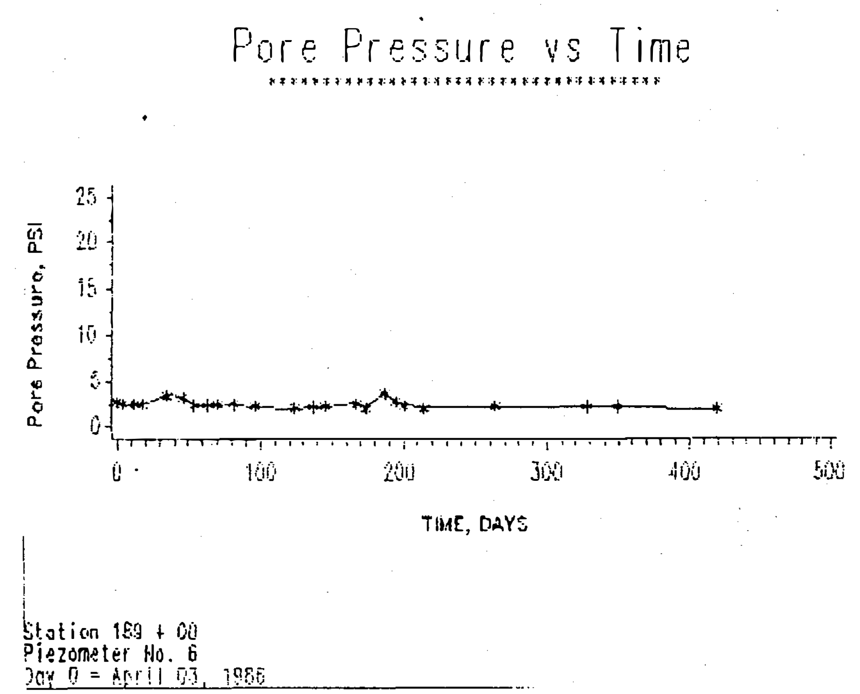

Figure 10. Piezometer No. 6, Station 169 + 00

Pneumatic Settlement Plates

Four of the 5 settlement plates that were installed in 1986 to measure settlement worked effectively. The settlement plate reservoir and tubing at Station 179 + 00 were damaged during embankment construction and were abandoned. The 4 plates that operated correctly, indicated settlement.

Roughly 0.4 to 0.6 tenths of a foot of settlement occurred during and shortly after construction of the fill. On the average, 105 days after the start of embankmment construction, the settlement had stopped, although two of the plates indicate continuing creep-like settlement. No appreciable settlement has occurred since that time. By day 180, the embankment was completed. Figures 11 to 14 show graphs of the settlement plate data that was recorded through 1987. Data has been recorded since then, but has shown no further settlement.

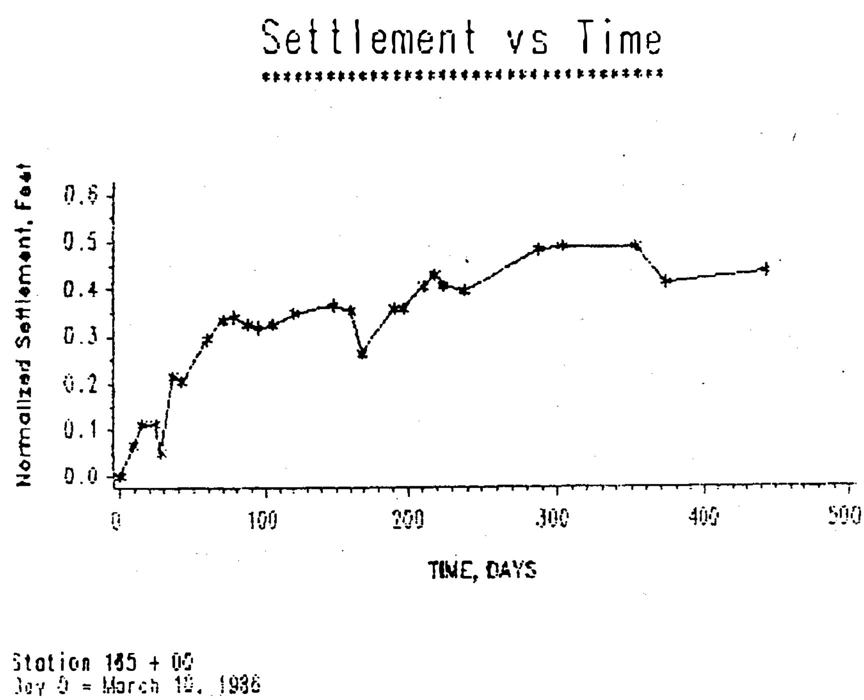

Figure 11. Settlement Plate, Station 165 + 00

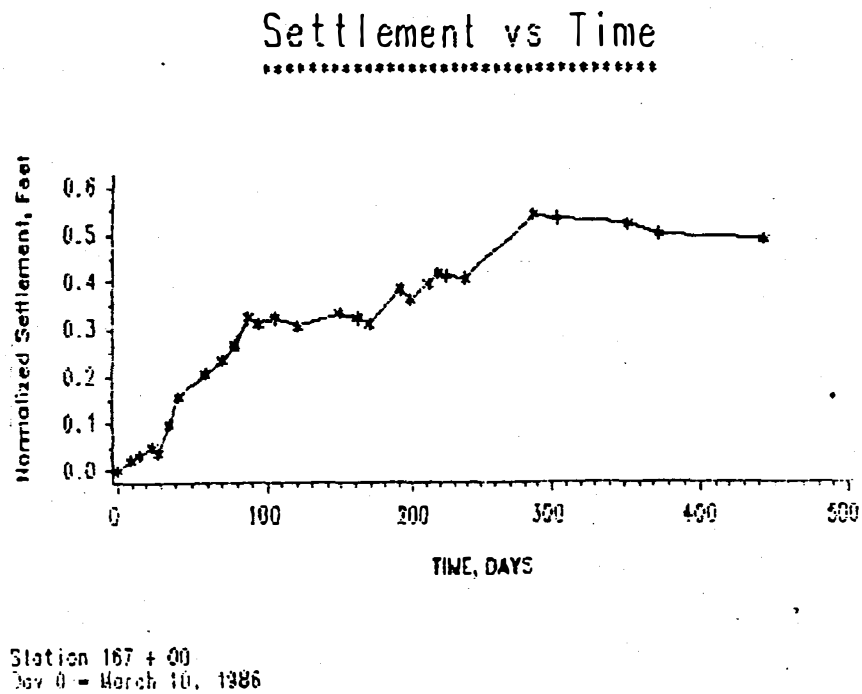

Figure 12. Settlement Plate, Station 167+50

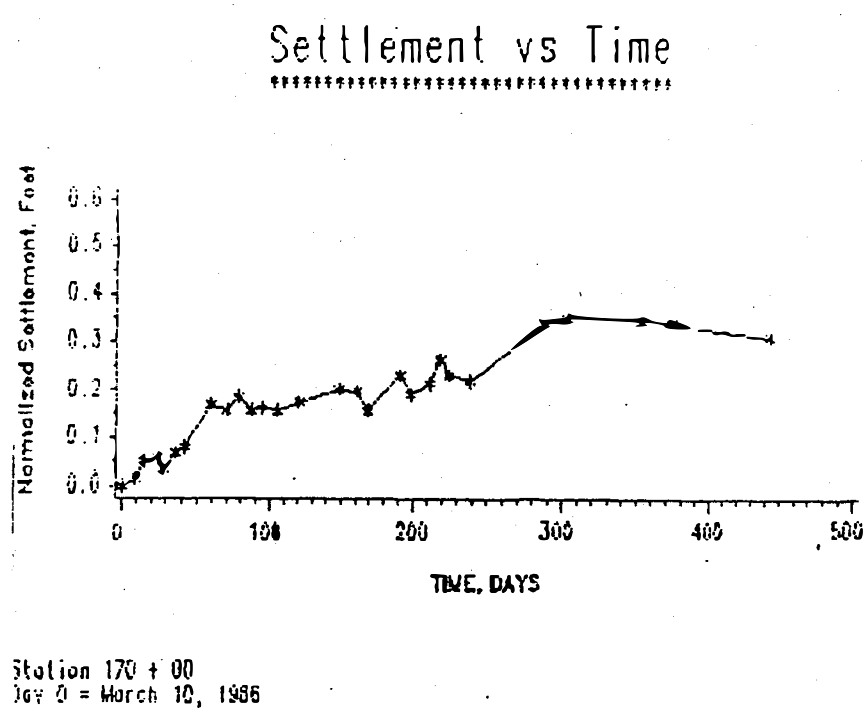

Figure 13. Settlement Plate, Station 170+00

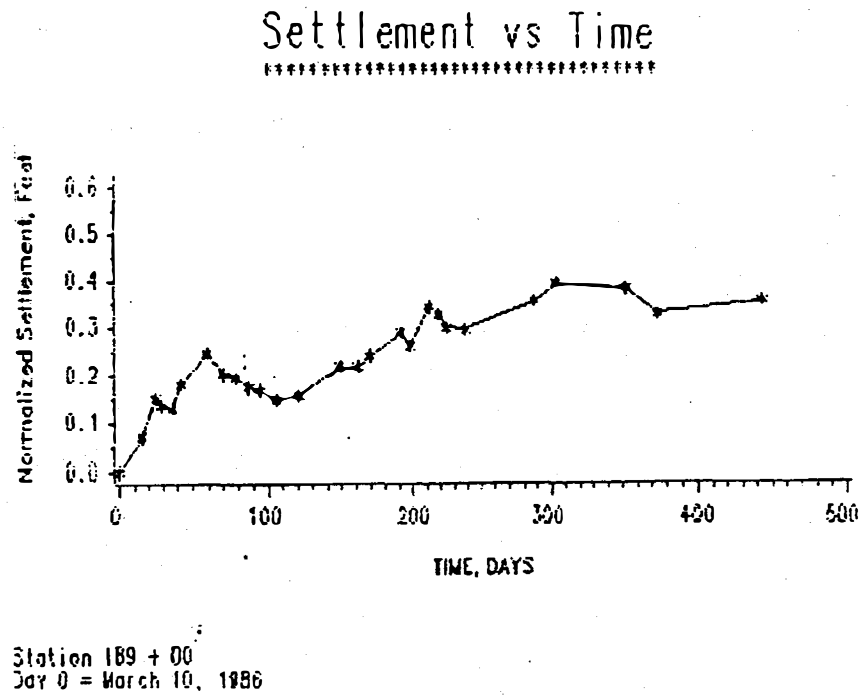

Figure 14. Settlement Plate, Station 189 + 00

Inclinometers

Four of the 5 inclinometer wells worked throughout the investigation. Well No. 3 (Test Section 1) was left inoperable after being crushed by a vehicle. The remaining 4 wells functioned properly. Since the inclinometer wells were installed in 1985, there has been virtually no significant movement. Well No. 2 (Test Section 1) has shown little movement. The inclinometers located in Test Section No. 3 (Wells No. 4, 5 and 1) have shown some slight movement.

Inclinometer wells No. 4 and 5 are located north of the expressway. Consult Figure 1 for the locations of the wells. Inclinometer Well No. 4 has shown a maximum movement of 0.75 inch outward from the embankment. Well No. 5 has had a maximum movement of 1.0 inch outward. This slight movement may be the result of two things. The first being that the water table is higher north of the expressway, averaging 4 feet below the surface. Secondly, the wells are placed at the toe of the embankment, which is the outer limit of the compacted area. The soft, wet, clayey soils adjacent to the 30 foot embankment, appears to be yielding due to the stresses applied by the embankment weight.

Well No. 1, also in Test Section No. 3, is located on the south side of the expressway in an area of compaction. The densification process extended 15 feet beyond the embankment toe. Well No. 1 indicates 0.25 inch of lateral movement outward from the embankment. Figures 15 to 18 show graphs of the inclinometer well data taken from 1986 to 1991.

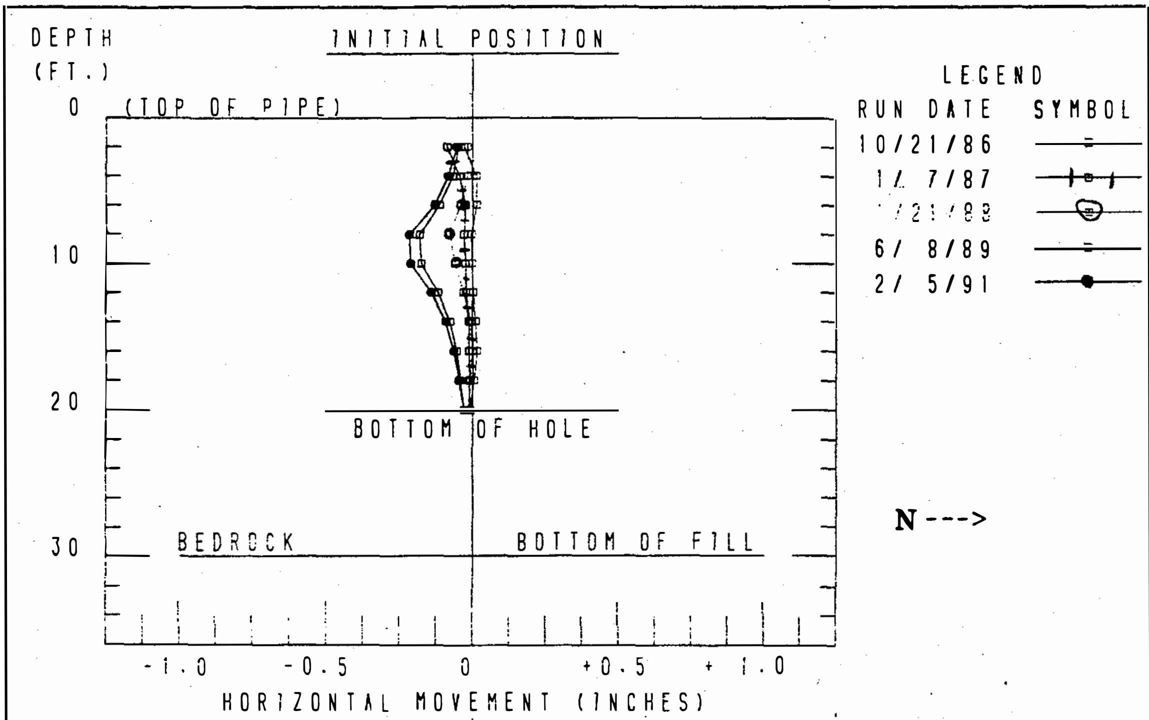

Figure 15. Inclinometer Well No. 1, A Axis

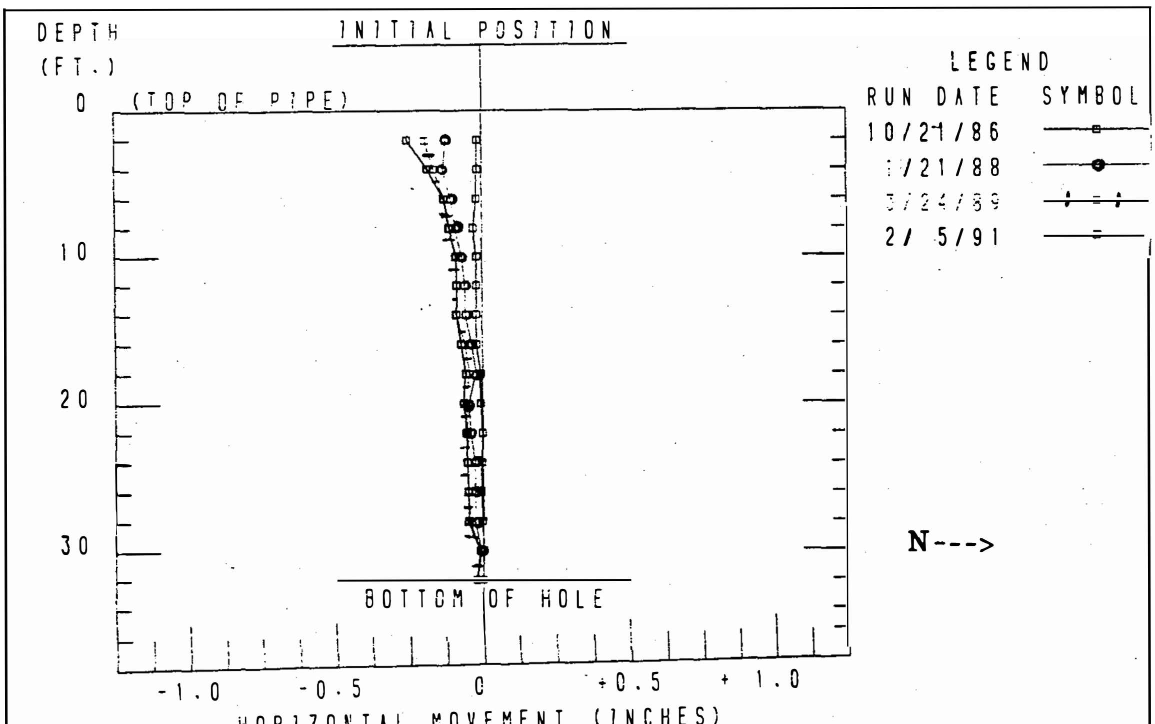

Figure 16. Inclinometer Well No. 2, A Axis

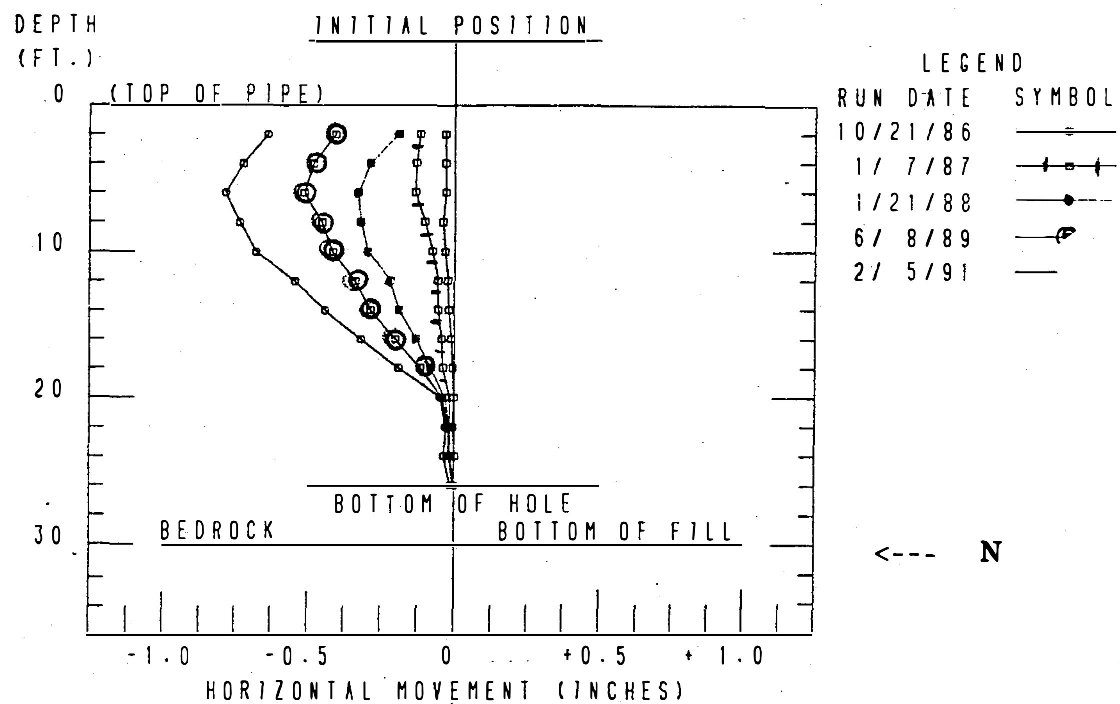

Figure 17. Inclinometer Well No. 4, A Axis

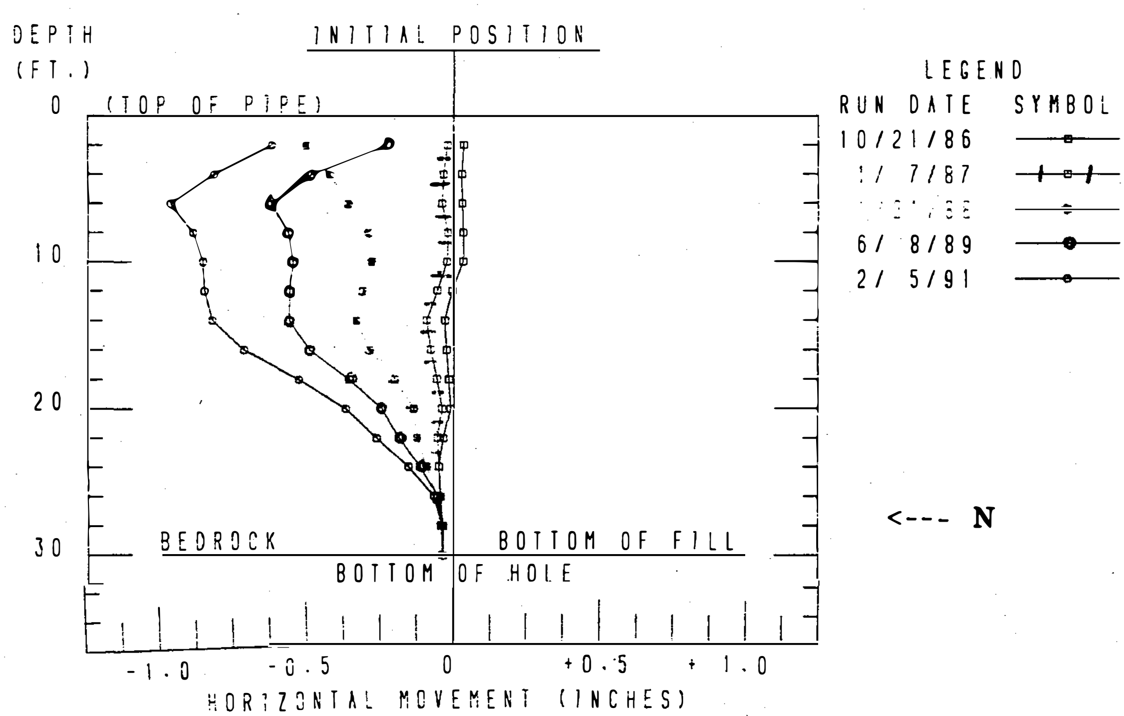

Figure 18. Inclinometer Well No. 5, A Axis

Heave Anchors

The three heave anchors installed in 1986 appeared to work well throughout the investigation. Heave anchors were placed at Stations 167+00, 173+00 and 165+00, which were in close proximity to the inclinometer wells No.'s 1, 3, and 4 respectively. No appreciable movement was detected.

At Station 167+00 in Test Section 3, the heave anchor elevation has increased (raised) approximatley 0.2 foot since 1986. At Stations 173+00 and 165+00 in Test Sections 1 and 2 respectively, the heave anchor elevations have increased approximately 0.1 foot since 1986.

DISCUSSION

After the construction of the embankment, the instrumentation revealed no appreciable movement. The pore water pressures were constant and showed no change throughout the project in all test sections.

As the map of the instrumentation locations indicates, the majority of the instrumentation was located in Test Section 3. This was considered the most vulnerable area. The 3 settlement plates in Test Section 3 revealed 0.40 to 0.60 foot settlement. The plates were all consistent with regards to the data. As the report indicates, the inclinometer wells located in the area of consolidation had 0.10 to 0.25 inches of lateral movement. The heave anchors showed 0.20 foot of heave. The wells located in the area of unconsolidated material saw 0.50 to 1.00 inches of lateral movement, while the heave anchors showed 0.10 foot of heave.

Test Section 2 contained only 1 settlement plate. It showed 0.40 foot settlement.

In Test Section 1 the settlement plate and inclinometer well No. 3 were not operational. Inclinometer well No. 2 showed 0.25 inch of lateral movement. The heave anchor, which was close to inclinometer well No. 3, showed 0.10 foot of heave.

Detailed reconnaissance shows no slumping, evidence of appreciable settlement or distress cracking of the pavement or in the embankment at this time.

The instrumentation worked well throughout the evaluation. As with all instrumentation, the installation is critical. Considerable time and effort was required to install the instrumentation properly. The only problems encountered were due to damage of the installation by construction vehicles. One inclinometer well was left inoperable after being crushed. One Settlement plate was inoperable after the post was runover and a cable was severed. Eventually all the piezometers failed, but not until the end of the project.

CONCLUSIONS

1. The dynamic compaction of the landfill and mine spoil appears to have worked. The greatest amount of settlement occurred during embankemnt construction. No appreciable movements have been recorded since.
2. The instrumentation devices that were utilized, have shown no significant movement.
3. The instrumentation devices worked well throughout the investigation.

RECOMMENDATIONS

1. In special cases, dynamic compaction can be used in large areas to compact unstable material. Types of unstable material would include trash, mine spoils or other loose soil/rock conditions.
2. ODOT should consider using dynamic compaction to consolidate underlying soft clay foundation soils prior to the constructing of high embankments.
3. Instrumentation, such as piezometers, pneumatic settlement plates, inclinometers and heave anchors should be used on subsequent geotechnical research, e.g. with retaining wall structures.