Research Report
KTC-89-61

EVALUATION OF WICK DRAIN STABILIZATION OF APPROACH FILL FOUNDATION (CARROLL COUNTY)

by

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16. Abstract

The purpose of this study was to document construction procedures and evaluate the effectiveness of wick drains as a foundation stabilization method. This effort was executed by use of field inspections, photologs, and instrumentation to monitor foundation and field response. Instrumentation included a multipoint settlement gage, settlement platforms, and vertical slope inclinometers.

This procedure was judged to be successful in that 90 percent consolidation of the deep foundation occurred within approximately 100 days. Construction procedures were generally satisfactory.

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EXECUTIVE SUMMARY

In 1984, construction on a replacement bridge and bridge approaches for US 42 in Carroll County were initiated. A settlement analysis indicated an unacceptable time requirement for 90 percent consolidation of the foundation. Ninety percent foundation consolidation prior to pile driving was considered essential to reduce negative friction loading and lateral movement of the piling. Prefabricated wick drains were installed to accelerate foundation consolidation.

This procedure was successful in that 90 percent consolidation of the west foundation, where large settlement was anticipated, was achieved within approximately 100 days after completion of the embankment. This procedure was completed, including all materials, for approximately $83,000.

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INTRODUCTION

In November 1984, construction of a replacement bridge and bridge approaches for US 42 over the Little Kentucky River was initiated. The site lies in Carroll County approximately 0.5 mile west of Carrollton (Figure 1). Embankment heights are up to 28 feet for the west approach and 16.5 feet for the east approach. Foundation soil depths to rock are roughly 75 feet for the west and 85 feet for the east approaches. A plan view and a centerline profile of the site are shown in Figures 2 and 3.

A geotechnical investigation by Kentucky Department of Highways' personnel indicated that the approach foundations generally consist of three strata. Beneath Abutment 1 (west foundation), the foundation consists of a relatively soft, highly compressible clay extending from original ground to a depth of 25 feet. The clay is underlain by a loose to dense sand extending from 25 to 45 feet below original ground. Below the sand layer, a relatively stiff, silty clay extends to rock at about 75 feet below original ground. Beneath Abutment 2 (east foundation), the upper clay layer extends 15 feet below original ground and is underlain by a medium dense sand extending to a depth of 65 feet. A silty clay extends from the sand to rock at a depth of 85 feet. Foundation conditions and soils data are shown in Figure 4.

Settlement analysis indicated total settlements of 32 inches at Abutment 1 and 18 inches at Abutment 2. Time required for 90 percent consolidation would be 3 years for Abutment 1 and 4 months for Abutment 2. Negative friction pile loading introduced by foundation settlement at the abutments would be unacceptably high unless 90 percent consolidation of the deep clays was accomplished prior to pile driving. Lateral squeeze resulting from settlements of this magnitude could produce unacceptable pile movement.

Due to these factors, pile driving would need be delayed until 90 percent consolidation of the deep clay layer was accomplished. Aside from the pile problem, settlement of this magnitude would also delay placement of the

pavement. Clearly, acceleration in consolidation was considered essential. The method chosen to accomplish this was to install prefabricated wick drains in the foundation. Drainage paths are decreased thus permitting more rapid drainage of the foundation and accelerated foundation consolidation.

Surcharging the approach was considered but was not chosen as an alternative. A 10-foot surcharge would reduce the time required for 90 percent consolidation of the west foundation to 2.8 years.

STUDY OBJECTIVES

Prefabricated wick drains have been used to reduce consolidation time in other areas but have not been used extensively in Kentucky. For this reason, a research study was initiated to monitor the installation and performance of the wick drains. The objectives of the study were;

1. to document construction procedures and obtain experimental data on wick drain effectiveness,
2. to analyze field behavior by using various instrumentation, and
3. to make recommendations as to the effectiveness and future use of wick drains.

WICK DRAIN LAYOUT

As a result of the Department of Highways analysis, wick drains were installed in both approach foundations. In the east foundation, the drains were primarily used to reduce lateral squeeze. In the west foundation the drains were needed to address all the factors relating to the foundation problem. It was decided to install the drains from Station 28+00 to 32+50 in the west foundation and from Station 35+30 to 36+20 in the east foundation. From Station 30+00 to 32+25, under the highest part of the embankment, the drains were placed 6.5 feet on center. The remainder of the west foundation drains were placed 9 feet on center. East foundation drains were placed 11 feet on center. The wick drain layout is shown in Figure 5.

Drains in the west foundation were designed to extend to rock and ranged

from 51 to 73 feet in length. Drains in the east foundation were to extend through the upper clay layer and were 25 feet in length.

The prefabricated wick drain used was "AMERDRAIN 407" supplied by International Construction Equipment,Inc. This drain consists of a corrugated polypropylene core wrapped in a polypropylene fabric. The drain is 4 inches wide and 0.125 inch thick. Physical properties of the drain are shown in Table 1.

PROCEDURES

The procedure involves pushing a prefabricated wick drain through the soil to a desired depth and extending the top of the drain into a drainage blanket. This is accomplished by threading the wick drain through a hollow mandrel and driving the mandrel into the soil. The wick drain is looped around an anchor plate or pin at the leading end. Figure 6 shows the drain being looped and inserted into the leading tip of the mandrel. Figure 7 shows the mandrel with the wick drain and anchor pin in place being placed at the next location. A crane is used to place the mandrel at a previously flagged drain location and the mandrel is driven with a vibratory force. In Figure 8, a reel of drain may be seen mounted on the bottom of the tower and extending to the top of the mandrel. When the desired depth is reached, the mandrel is withdrawn with the anchor device holding the wick drain at that depth. The wick drain is severed at the surface and the process is repeated at the next drain location. An installed wick drain extending through the sand drainage blanket is shown in Figure 9.

The drainage blanket is typically constructed by placing a layer of geotextile fabric on the existing foundation and placing a free draining material (sand or gravel) on the fabric. A second layer of fabric is placed on the drainage blanket before embankment construction begins if the embankment material is not free draining. The geotextile fabric is used as a filter to inhibit the intrusion of fine particles from the foundation or embankment into the drainage blanket.

CONSTRUCTION

Clearing and grubbing commenced in November of 1984. Piezometers were installed in January of 1985. A geotextile fabric was placed on the west approach foundation and a sand drainage blanket, approximately one foot thick, was placed on the fabric in February 1985. This procedure was repeated on the east approach. High water level of the Little Kentucky River delayed completion of drainage blanket construction until mid March. Wick drain locations were flagged in accordance with the design layout after the sand was in place. Figure 10 shows a portion of the west approach with wick drain locations flagged on the sand drainage blanket.

Placement of the wick drains was initiated in mid March and was completed in approximately 20 days. Up to 4,700 feet of wick drain was placed per day on days when weather or other unforseen conditions did not present problems. Normal per-day construction was from 2,000 to 3,000 feet of drain.

A second layer of geotextile fabric was placed on the sand to complete the drainage blanket after the drains were in place. The edges of the bottom layer of fabric were pulled over the sand and lapped by the top layer of fabric. The sand drainage blanket was cleaned of deleterious material and returned to a minimum thickness of one foot prior to placement of the top fabric. Settlement monitoring instrumentation was placed on the completed drainage blanket. In Figure 11, the top layer of fabric is being placed on the sand blanket and the embankment material is being placed on the fabric. The bottom layer of fabric lapped over the top fabric and the tubes extending from the embankment house settlement monitoring instrumentation may be seen in the left foreground.

The initial subsurface report indicated the top layer of clay was underlain by a loose to dense sand layer. This sand layer resisted penetration of the mandrel and drain while attempting to install the wick drains in the west

approach. Two alternatives were presented to the contractor after additional boring in the problem area. One alternative was to auger through the obstructing layer and install the drains as designed. Augering was to be performed at no additional cost. The second alternative was to install drains through the upper clay layer but not through the underlying layers. This would necessitate delaying construction of the embankment until 90 percent consolidation of the foundation had been achieved. The second alternative (installation of drains in the upper layer only) was chosen.

A total of 18,850 feet of the design total of 32,600 feet of wick drain was installed at $2.10 per linear foot. A total of 15,098 square yards of geotextile fabric was placed at $1.10 per square foot. Together with 3,381 tons of sand drainage blanket at $8.00 per ton, construction costs for this procedure totaled approximately $83,000.

PROBLEMS

Only two significant problems relating to the wick drains or drainage blanket were encountered. Flooding of part of the area that was to have wick drains delayed construction (Figure 12). This problem could not be avoided because of a rise in the river level. The other problem was the previously discussed subsurface conditions which restricted installation of wick drains to the upper clay layer.

INSTRUMENTATION

Instrumentation at the site included piezometers, settlement platforms, a settlement gage, and slope inclinometers. Piezometers were used to monitor pore water pressure. Settlement platforms and gages were used to monitor foundation settlement. Slope inclinometers were used to monitor lateral squeeze. Instrumentation locations are shown in Figures 13 and 14.

Eight piezometers were installed in four borings. At each boring, a piezometer was placed near the center of the upper clay layer and one was placed in the lower clay layer. Piezometer Numbers 1 and 2 were located at

Station 31+90, at centerline. Number 1 was installed in the lower clay layer. Piezometer Numbers 3 and 4 were placed at Station 31+90, 30 feet right of centerline. Number 3 was placed in the lower layer. Piezometer Numbers 5 and 6 were at Station 30+70, 6 feet left of centerline. Number 5 was placed in the lower layer. Piezometer Numbers 7 and 8 were at Station 29+50, at centerline. Number 7 was placed in the lower layer. Each piezometer was placed in sand and sealed above and below with bentonite clay.

Settlement platforms were placed on the foundation at Stations 31+94 (18 feet right) and 35+89 (18 feet left).

Piezometer installation was initiated on January 15, 1985 with Piezometers 1 and 2. Installation was completed on January 29, 1985 with Piezometers 7 and 8.

Slope inclinometers were placed at the toe of each approach embankment near centerline. Inclinometer 1 was in the west foundation (Station 33+00) and Inclinometer 2 was in the east foundation (Station 35+00). Inclinometer 1 failed due to excessive movement in May 1986. Additional inclinometers (Number 3 at 35 feet right of Station 32+18, Number 4 at 64 feet right of Station 32+50, and Number 5 at 29 feet left of Station 32+93) were installed in June 1986.

A settlement gage and a horizontal inclinometer were installed at Station 30+86. Both instruments extended from the right toe of the fill to 15.5 feet left of centerline. These instruments were installed in April 1985.

Due to the much larger area utilizing wick drains and the fact that more settlement was anticipated in the west approach than in the east approach, the west approach received most of the instrumentation and monitoring effort.

FIELD DATA

Settlement

The settlement platform at Station 31+94 (west approach) indicated total foundation settlement of 12.0 inches by September 1986 or approximately 450 days after completion of embankment construction. Plotting measured

settlement versus the square root of time, 90 percent consolidation occurred within approximately 100 days of embankment completion (Figure 15). Predicted foundation settlement for the west approach was 32 inches. Much of the predicted settlement apparently occurred prior to installation of the settlement platform. Prior to the placement of the settlement platforms, heavy equipment was constantly moving about the site while involved in clearing, drainage blanket placement and installation of the wick drains. It is suspected that the dynamic action of the equipment and dewatering resulting from placement of the wick drains resulted in significant foundation settlement. Settlement platform data and embankment heights are plotted versus time in Figure 16.

Settlement of the east foundation, as indicated by the settlement platform, totaled 2.04 inches as of September 1986, approximately 460 days after completion of the embankment (Figure 17). For the east foundation, 90 percent consolidation was achieved approximately 220 days after completion of the embankment (Figure 18).

Settlement gage data from Station 30+86 are inconsistent but indicate that little settlement occurred at that location after installation of the gage. The gage was installed after the wick drains, drainage blanket, and some fill was in place. The embankment height was 15 to 16 feet at the settlement gage location. Settlement gage data are plotted in Figure 19.

Foundation Pore Pressure

Foundation pore pressure, as indicated by piezometers, generally remained higher in the lower clay layer and dropped rapidly in the upper clay layer. Piezometers 2, 4, 6, and 8 are in the upper clay layer. The elevations of these piezometers increase from 421.4 feet at Piezometer 2 and to 439.2 feet at Piezometer 8. Piezometer 2 indicates a residual pore pressure of 8 psi. Piezometers 4 and 6 indicated zero pore pressure 70 to 80 days after installation. Piezometer 8 never indicated the presence of pore pressure.

Piezometers 1, 3, 5, and 7 are located in the lower clay layer with 1 and

3 being nearer the river (an elevation of approximately 377 feet). Piezometer 5 was installed at an elevation of 380 feet. Piezometer 7 was installed at a depth of 70 feet which was the depth to rock. This is an elevation of 373 feet. Piezometer 7 ceased functioning after approximately 120 days.

Piezometer data are graphically displayed in Figures 20 through 24. Pore pressure as indicated by these data fluctuates. However, as seen in Figure 25, the fluctuations in pressure in the lower clay layer occur approximately at the same time. Much of this fluctuation is traceable to precipitation and river pool level. Pool level of the river is plotted with Piezometer 3 data in Figure 26. Many of the pressure increases reflect river pool elevation increases.

Precipitation, water table changes, and embankment construction are reflected in pore pressure data. At the time that significant amounts of material were placed on the foundation (April 11, 1985), pore pressure in the lower clay layer rose from the equivalent of 4 feet of water (Piezometer 7) to the equivalent of 8 feet of water (Piezometer 5). Little material was placed until May 29, 1985. Pore pressures decreased the equivalent of 5 to 8 feet of water during this time. Placement of additional embankment again was reflected in a pore pressure rise of 2 to 3.5 feet of water on May 19, 1985. This pattern continued until the embankment was complete. Embankment heights and pore pressure (during the embankment construction period) are shown in Figure 27.

Pore pressure in the upper clay layer tended to decrease soon after installation of the piezometers. While reflecting embankment construction to some degree, upper clay layer pore pressure remained much more constant (Piezometer 2) than in the lower layer. Piezometers further from the river and higher in elevation ceased indicating foundation pore pressure soon after installation (Piezometers 4, 6, and 8).

Lateral Movement

Slope inclinometer 1 was installed at Station 33+00 on centerline. This placed the inclinometer on the river bank near the water line. A slope failure

occurred on the river bank, resulting in the closing of the inclinometer 23 feet from the surface during the winter of 1985 and 1986. The failure was outside the area receiving wick drains, however data from the instrument indicated an area of lateral displacement at a depth of 45 to 69 feet. This would be the approximate depth of the lower clay layer. Total lateral movement as of October 10, 1985 was roughly 0.5 inch. Data for inclinometer 1 are shown in Figure 28.

After Inclinometer 1 closed, Inclinometers 3 through 5 were installed in June 1986. Inclinometer 5 was destroyed 3 months after installation with approximately 0.2 inch of movement near the surface. Inclinometer 3 indicates continuing movement with approximately 1.5 inches of movement in the upper clay layer and an additional 0.9 inch in the top 6 feet of the embankment. Inclinometer 4 closed approximately 24 feet below the surface within a year of installation. A total of 9.5 inches of lateral movement had occurred. Data for Inclinometers 3, 4, and 5 are shown in Figures 29, 30, and 31.

CONCLUSIONS

Construction procedures and materials were satisfactory for this job. Experience gained in efforts such as this used in conjunction with in-depth subsurface investigations should result in more precise planning of the amount of wick drains required.

Only the upper clay layer, rather than both clay layers, in the foundation was drained by wick drains due to the underlying sand. The sand layer presented too much resistance to penetration of the mandrel which carried the wick drain. The contractor chose to drain only the top layer and wait for Department of Highways' officials' acceptance of consolidation before continuing work. This aspect of performance was successful in that 90 percent consolidation occurred within the anticipated 100 days.

The slope failure that closed Inclinometer 1 was outside the wick drain area. This failure was not an indication of the failure of the wick drains to

perform adequately but rather was a possible indication of their effectiveness. The foundation at the site is of a nature to permit this failure yet the wick drained foundation is presently stable. The slope failure that closed Inclinometer 1 was probably due to rapid drawdown when the native soils did not drain quickly. This same soil comprises the approach foundation upper clay layer and where drains were installed the foundation soil drains quickly. Slope inclinometer data indicate that some instability along the river bank still exists.

The utilization of prefabricated wick drains to dewater the foundation and speed consolidation at this site was successful. This procedure should be considered for similar uses in the future.

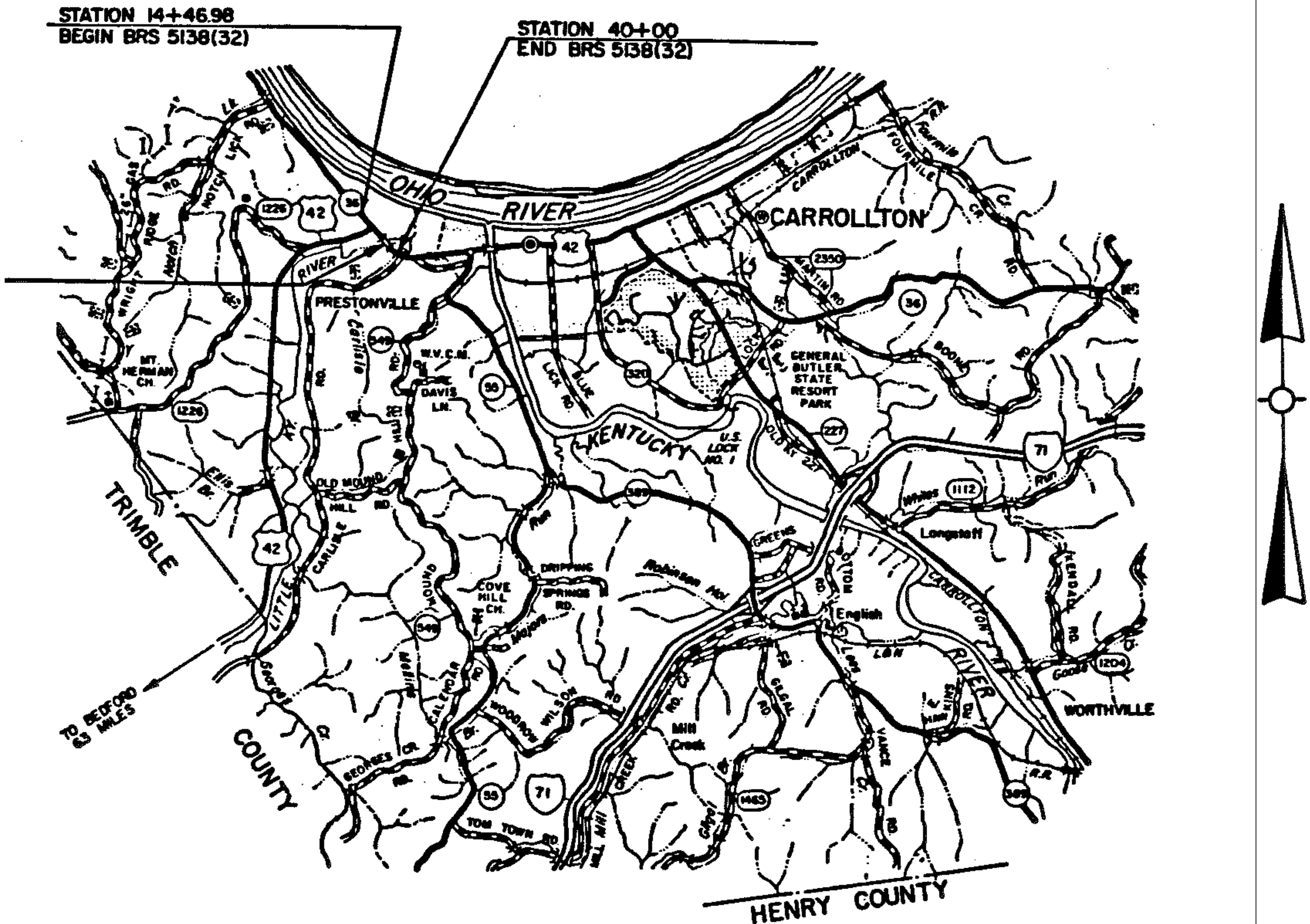

Figure 1. Site Location.

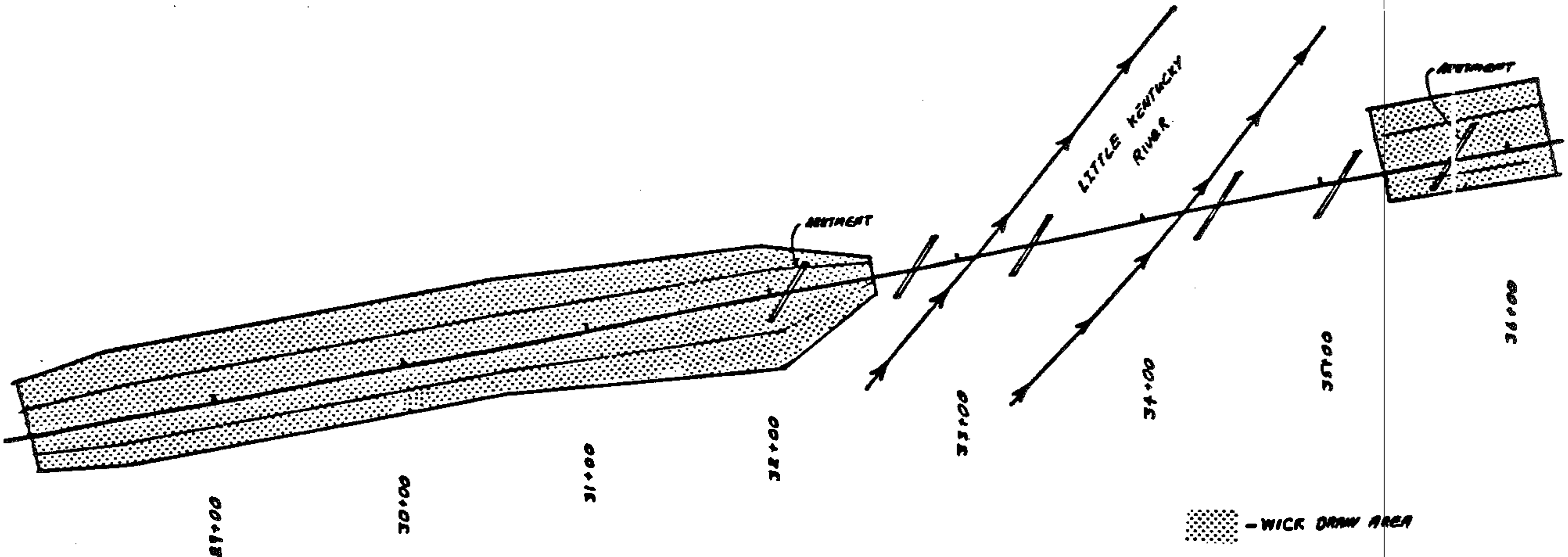

Figure 2. Plan View of Site.

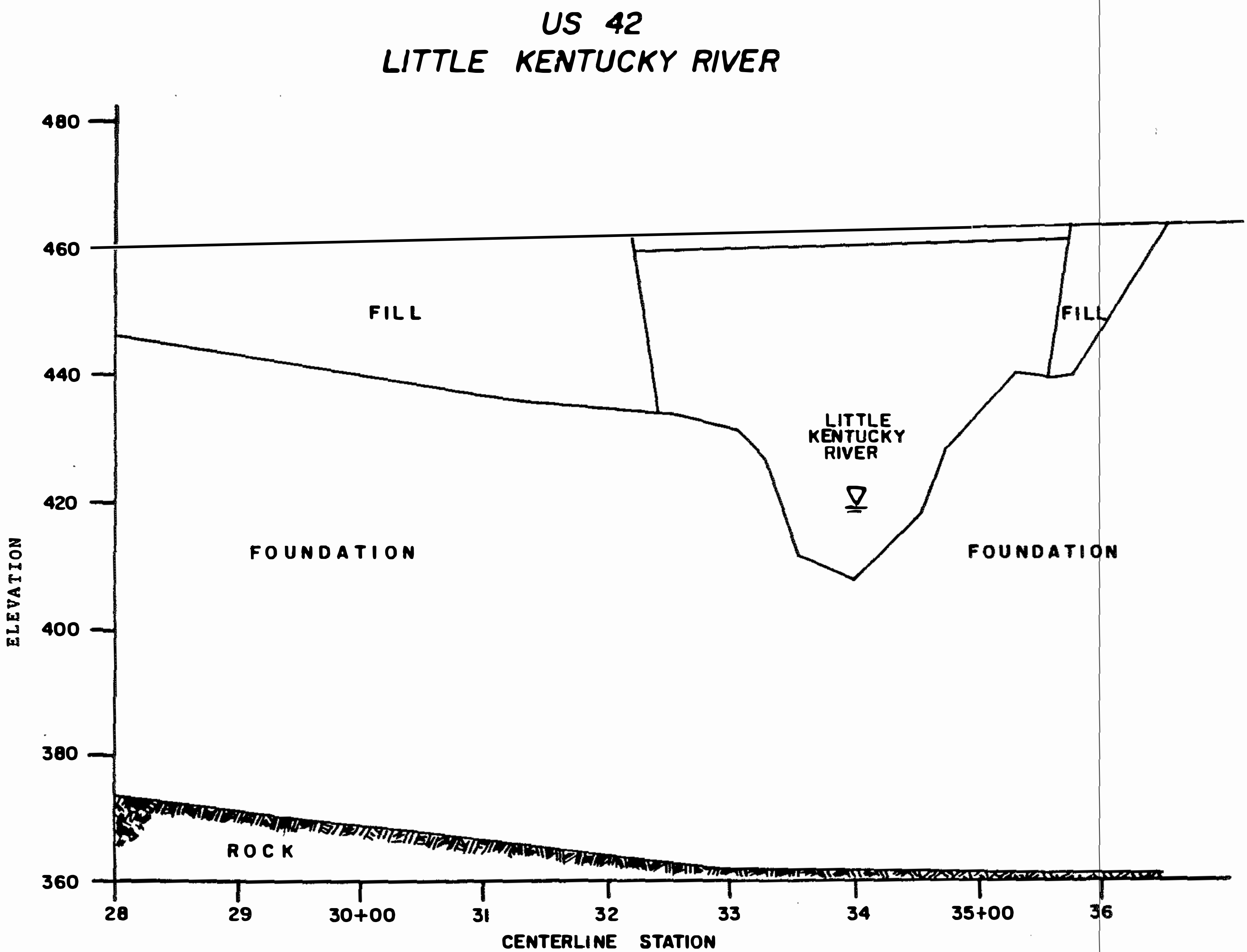

Figure 3. Centerline Profile of Site.

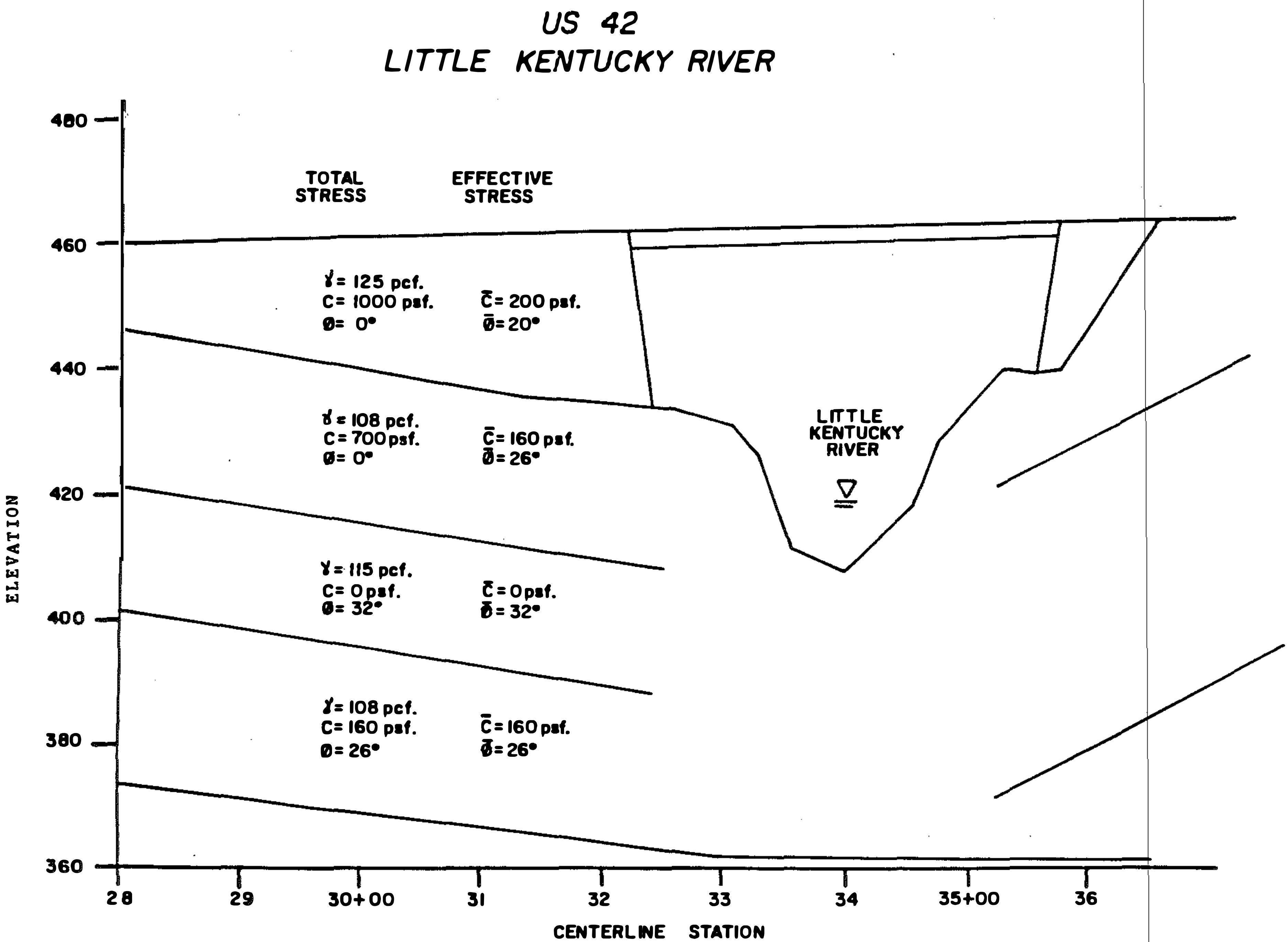

Figure 4. Subsurface and Soil Data.

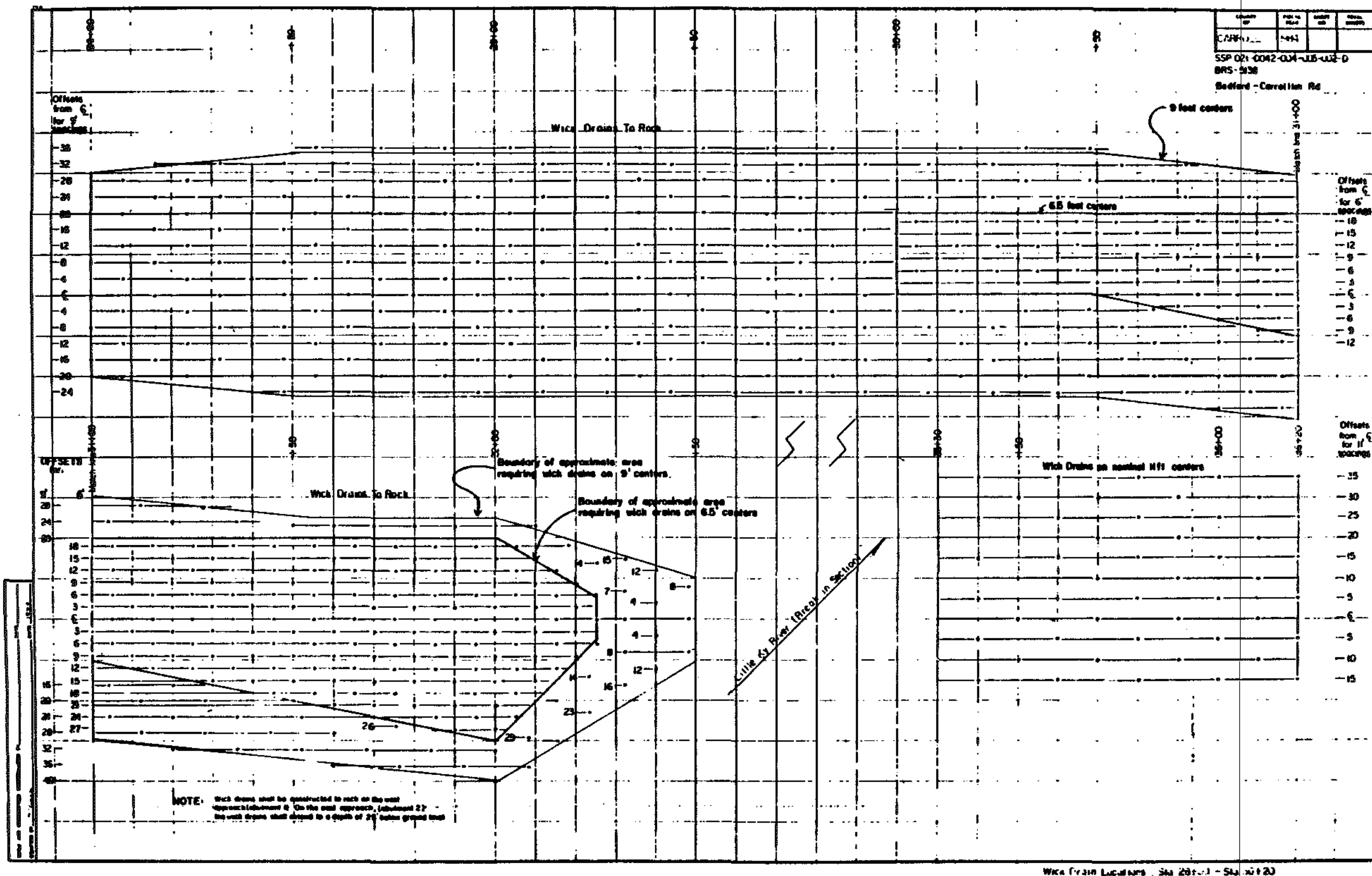

Figure 5. Wick Drain Layout.

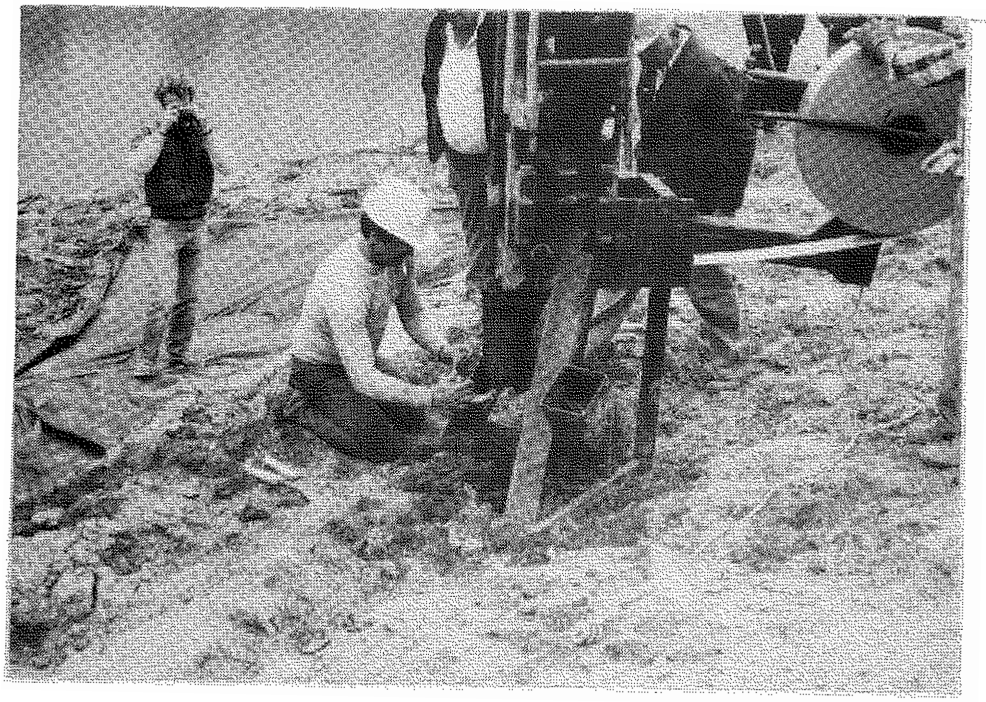

Figure 6. Photo of Wick Drain Being Prepared for Installation.

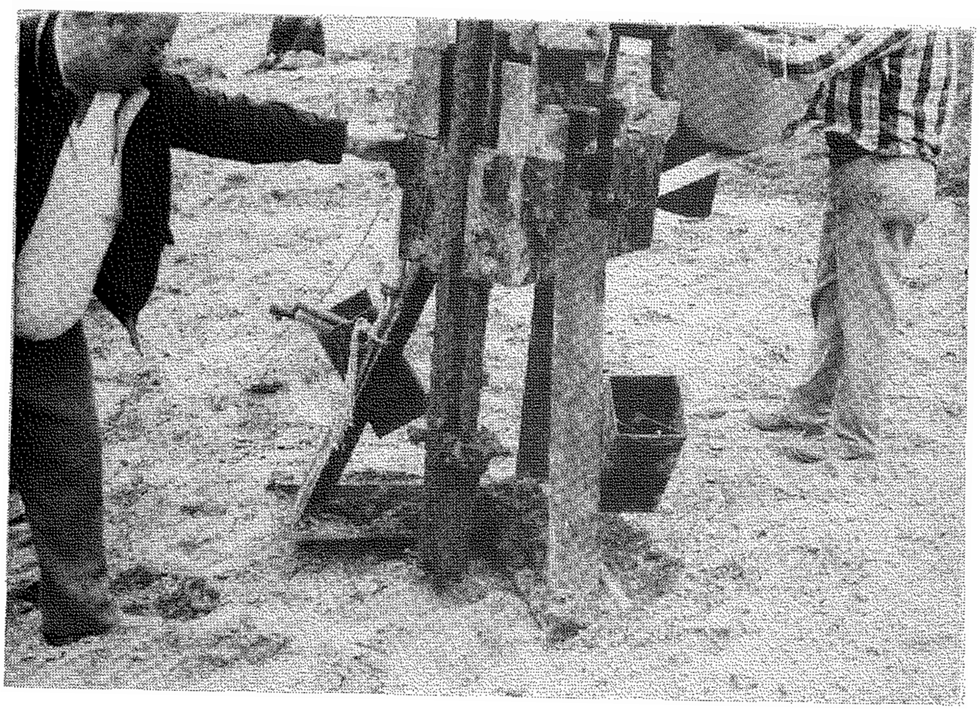

Figure 7. Wick Drain Being Located at Flagged Spot.

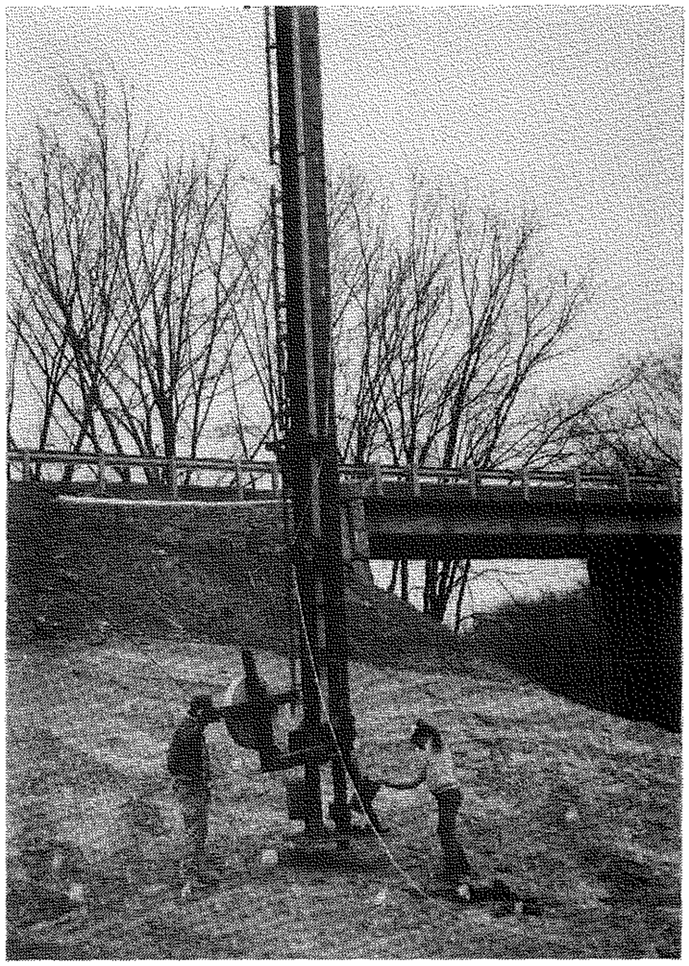

Figure 8. Tower and Mandrel with Reel of Wick Drain Showing.

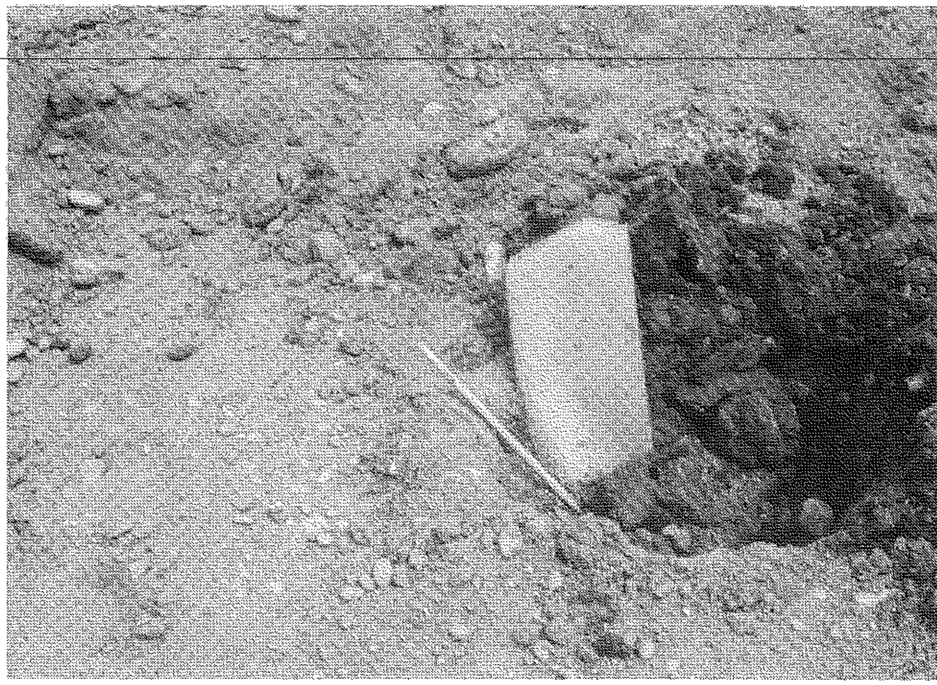

Figure 9. Installed Wick Drain Extending through Drainage Blanket.

Figure 10. Flagged Wick Drain Layout.

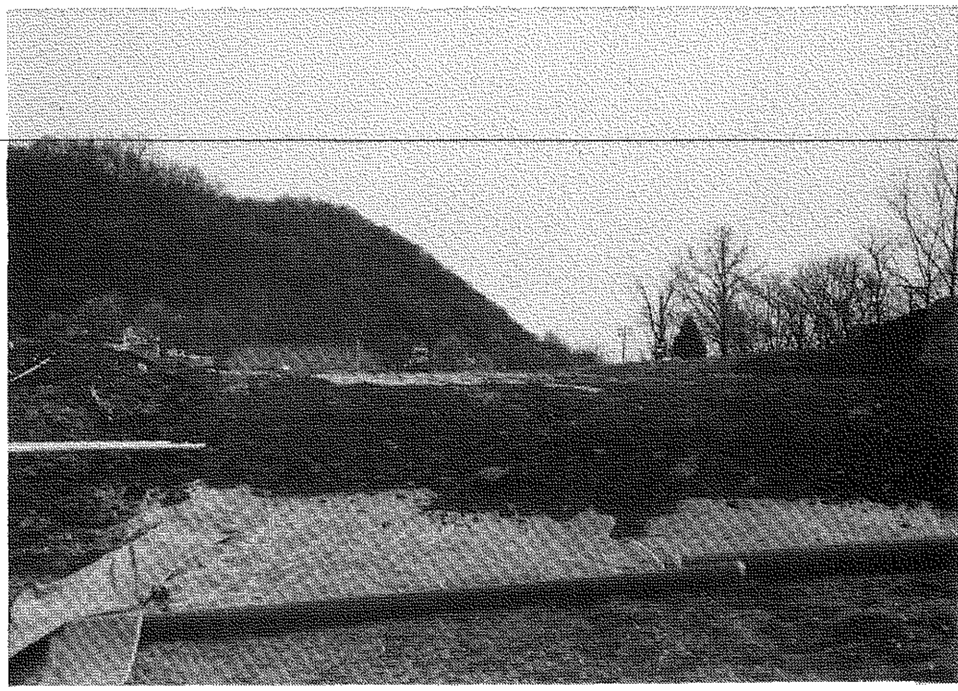

Figure 11. Drainage Blanket Separated by Filter Fabric from Embankment.

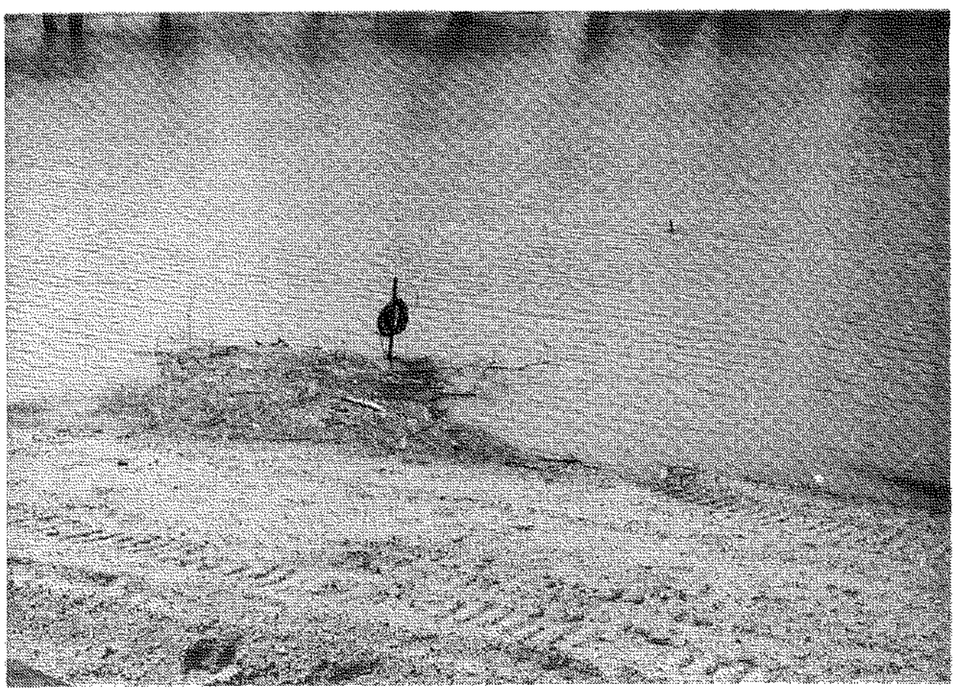

Figure 12. Spring Flooding of the Site.

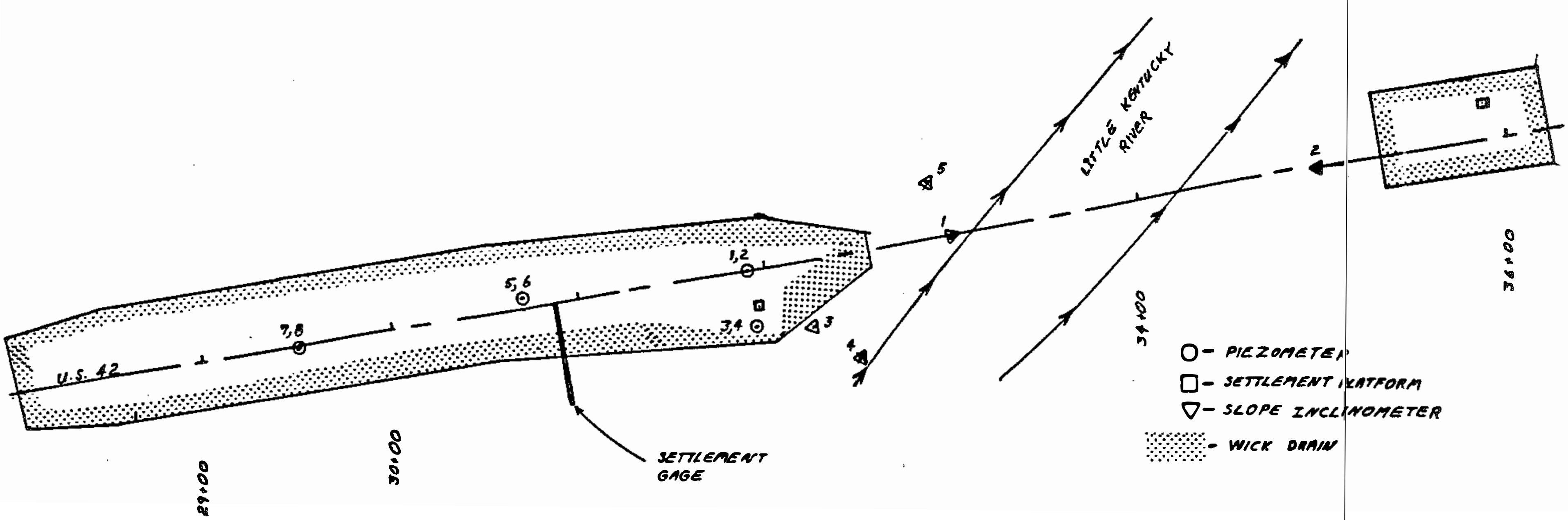

Figure 13. Plan View of Site with Instrumentation Locations.

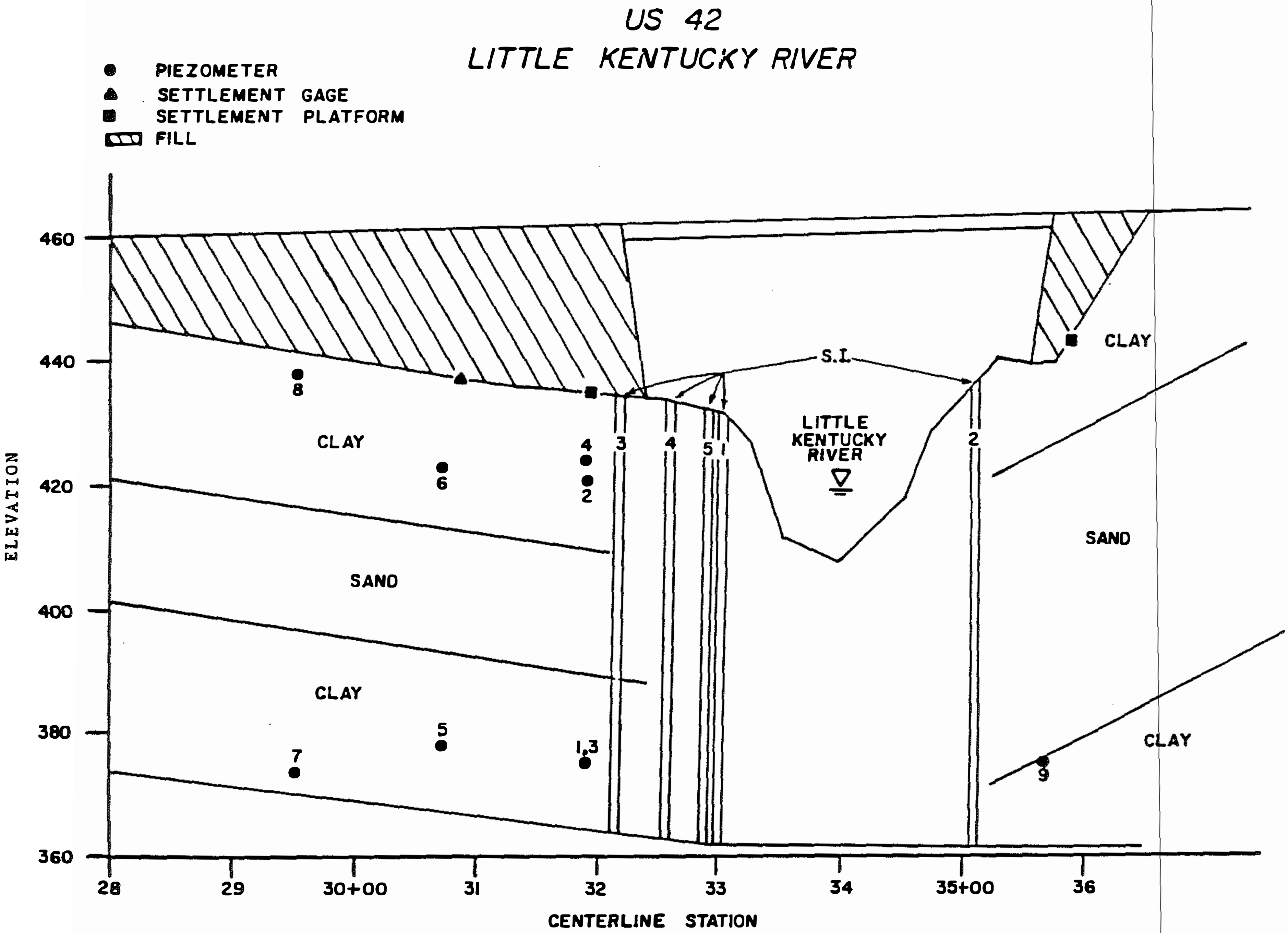

Figure 14. Centerline Section with Instrumentation Locations.

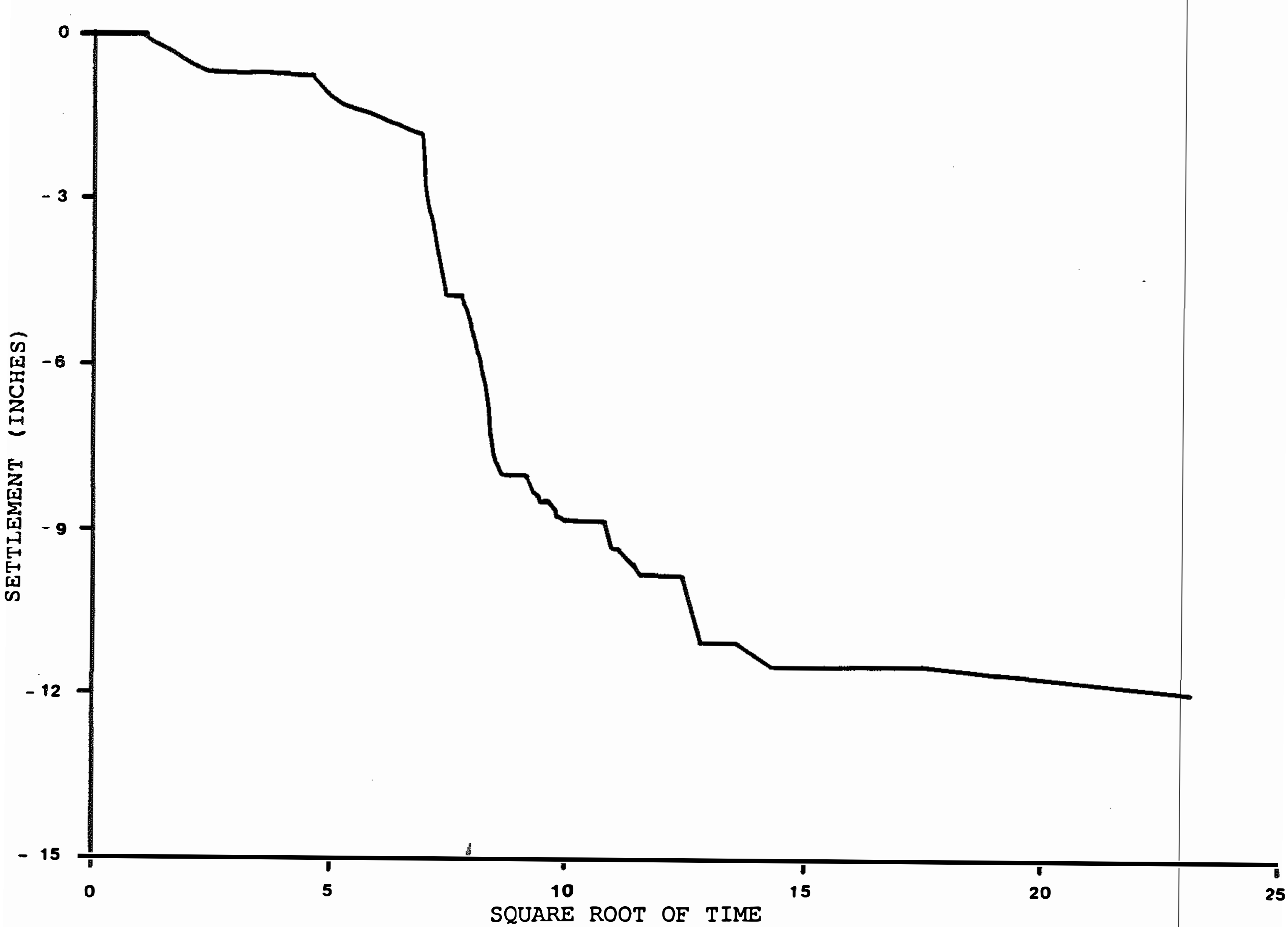

Figure 15. West Foundation Settlement Versus Square Root of Time (Station 31+94).

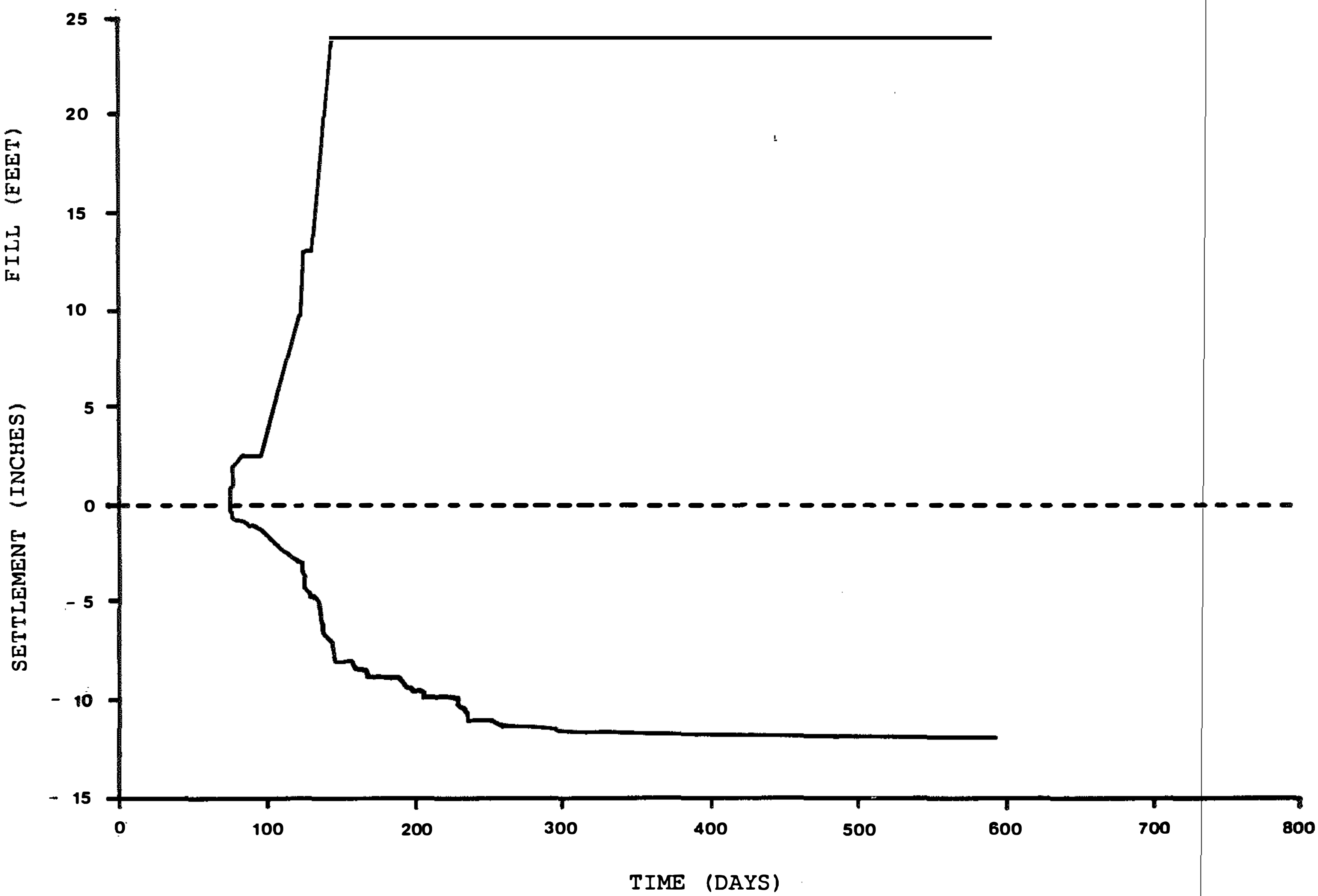

Figure 16. West Foundation Settlement and Embankment Height Versus Time (Station 31+94).

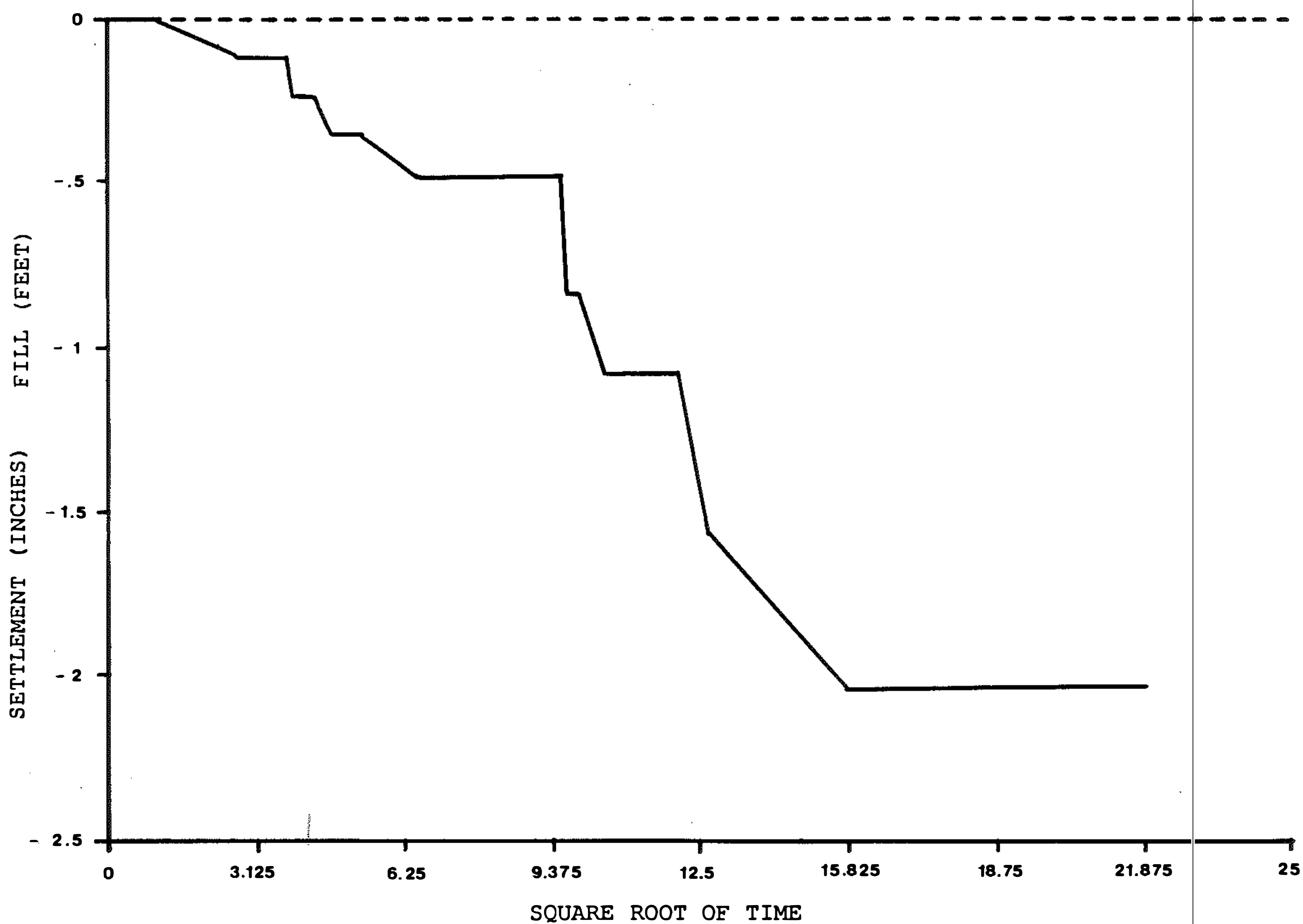

Figure 17. West Foundation Settlement Versus Square Root of Time (Station 35+00).

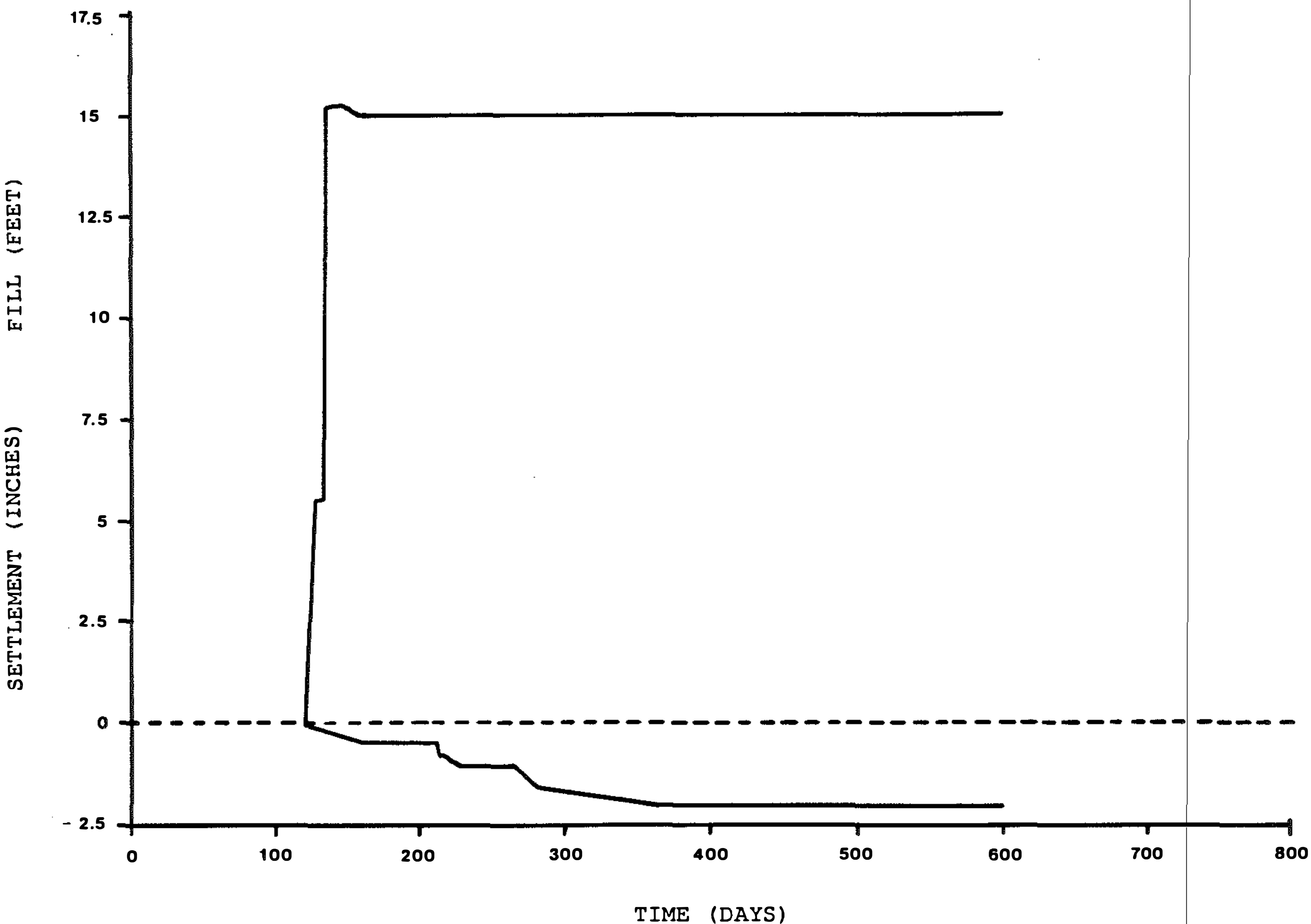

Figure 18. West Foundation Settlement and Embankment Height Versus Time (Station 35+00).

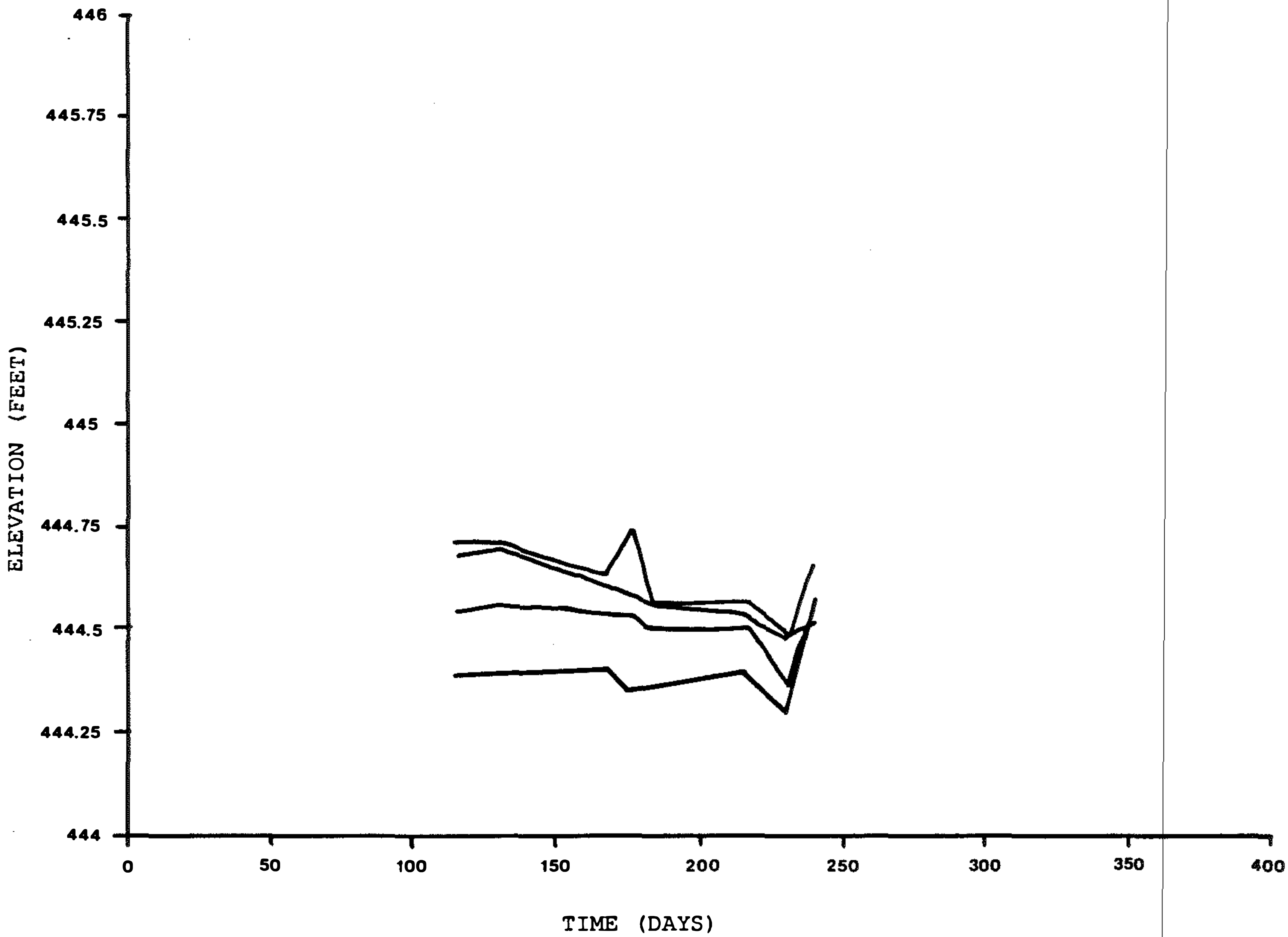

Figure 19. Settlement Gage on West Foundation.

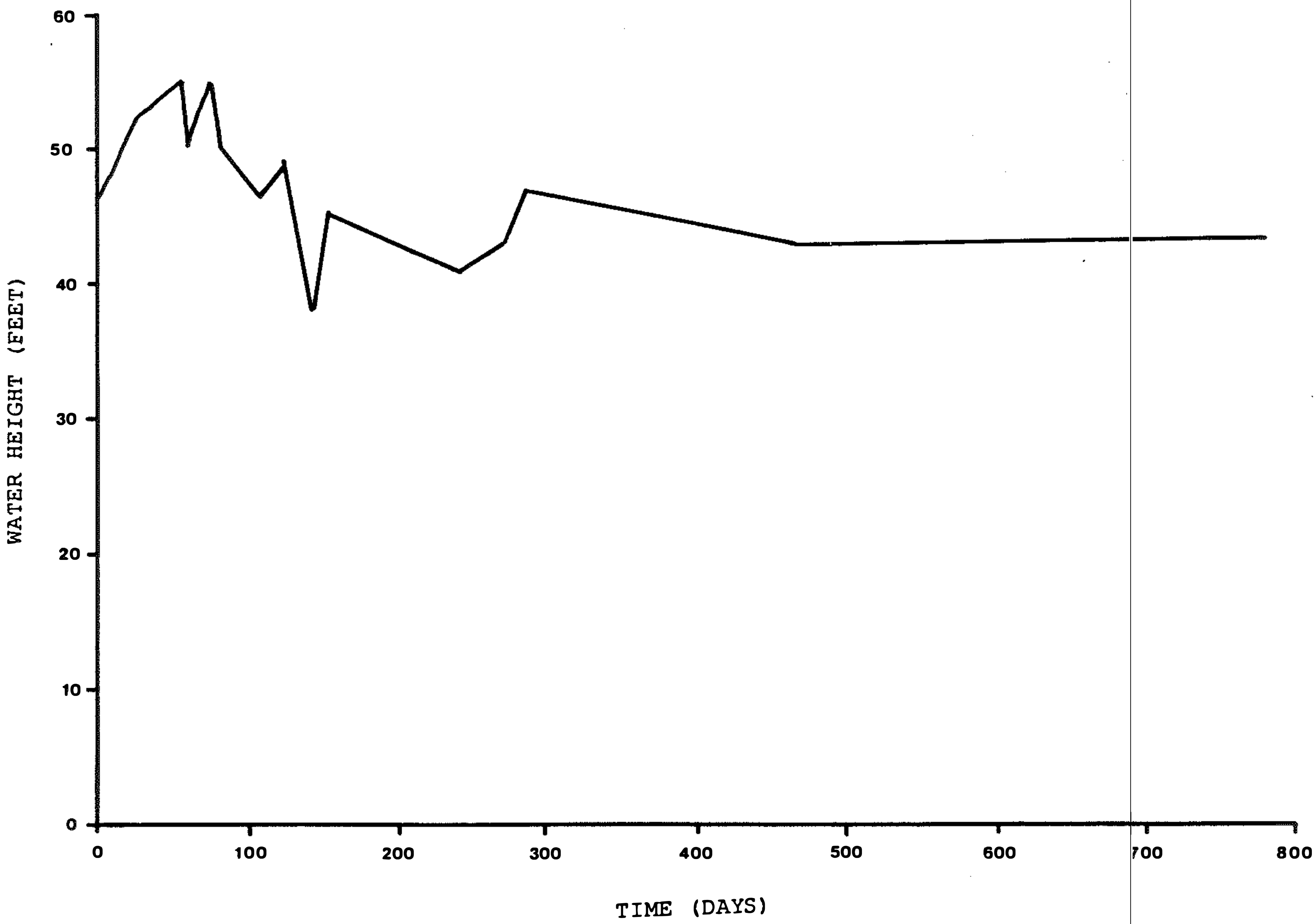

Figure 20. Foundation Pore Pressure at Piezometer 1.

5.

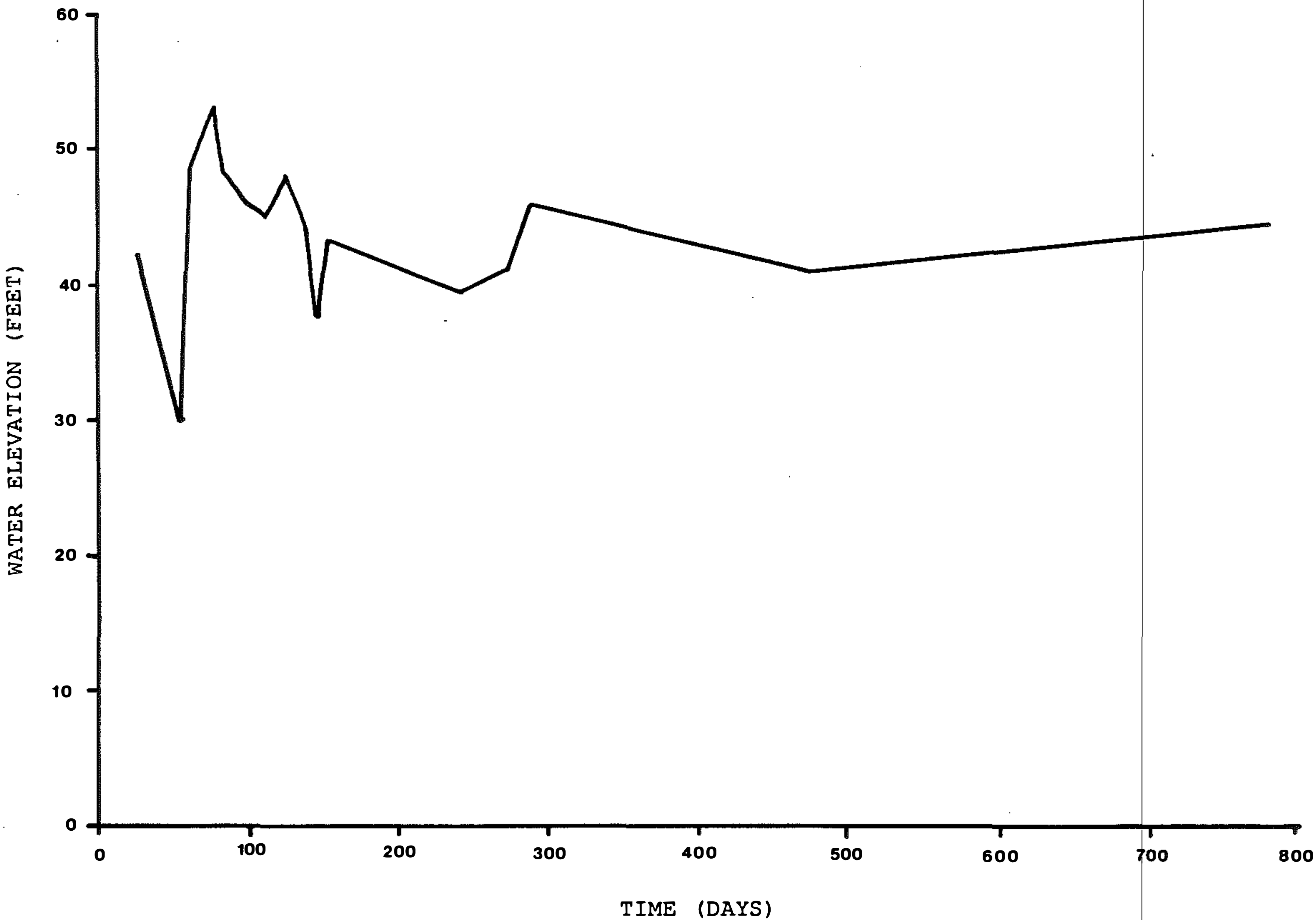

Figure 21. Foundation Pore Pressure at Piezometer 3.

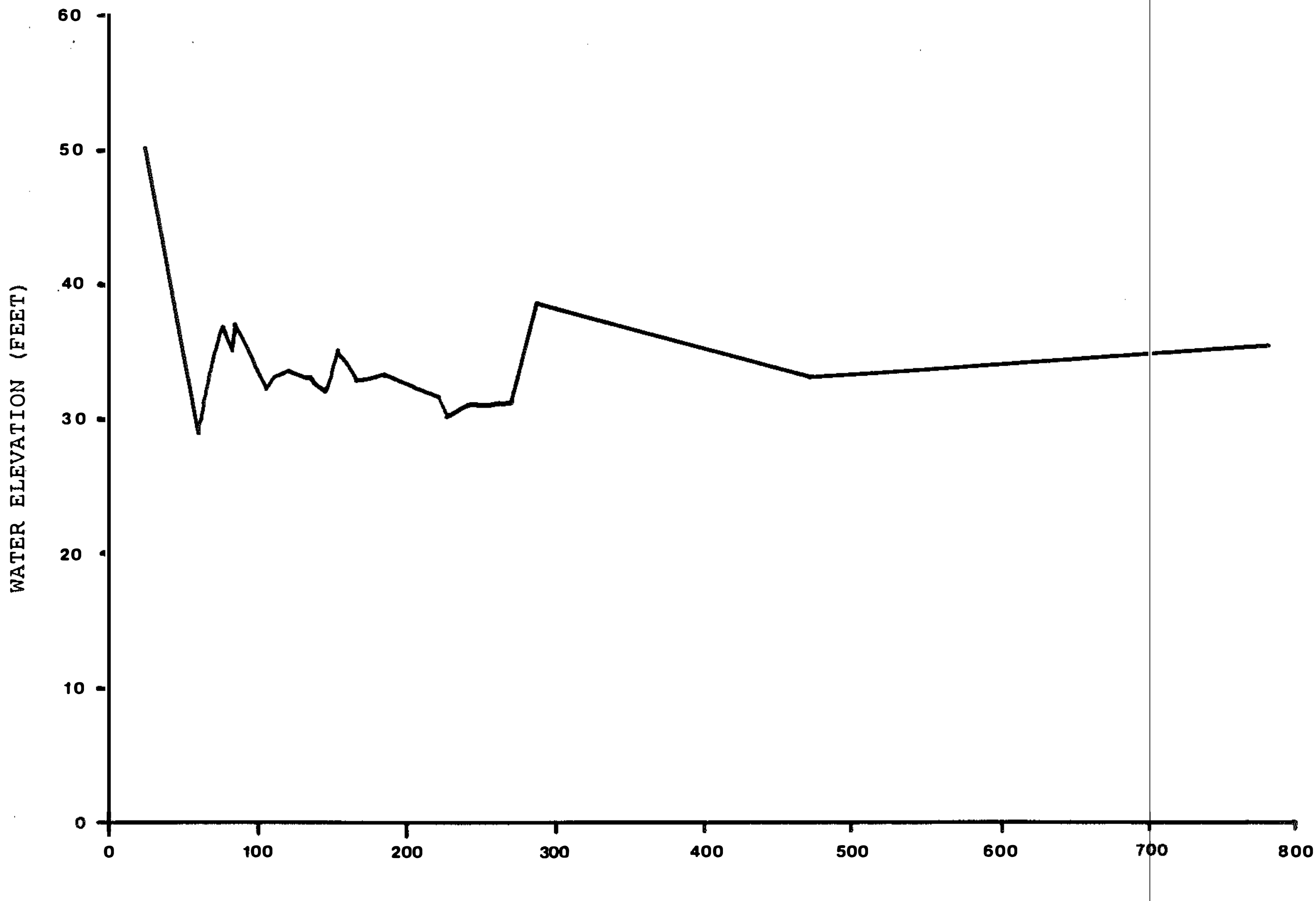

Figure 22. Foundation Pore Pressure at Piezometer 5.

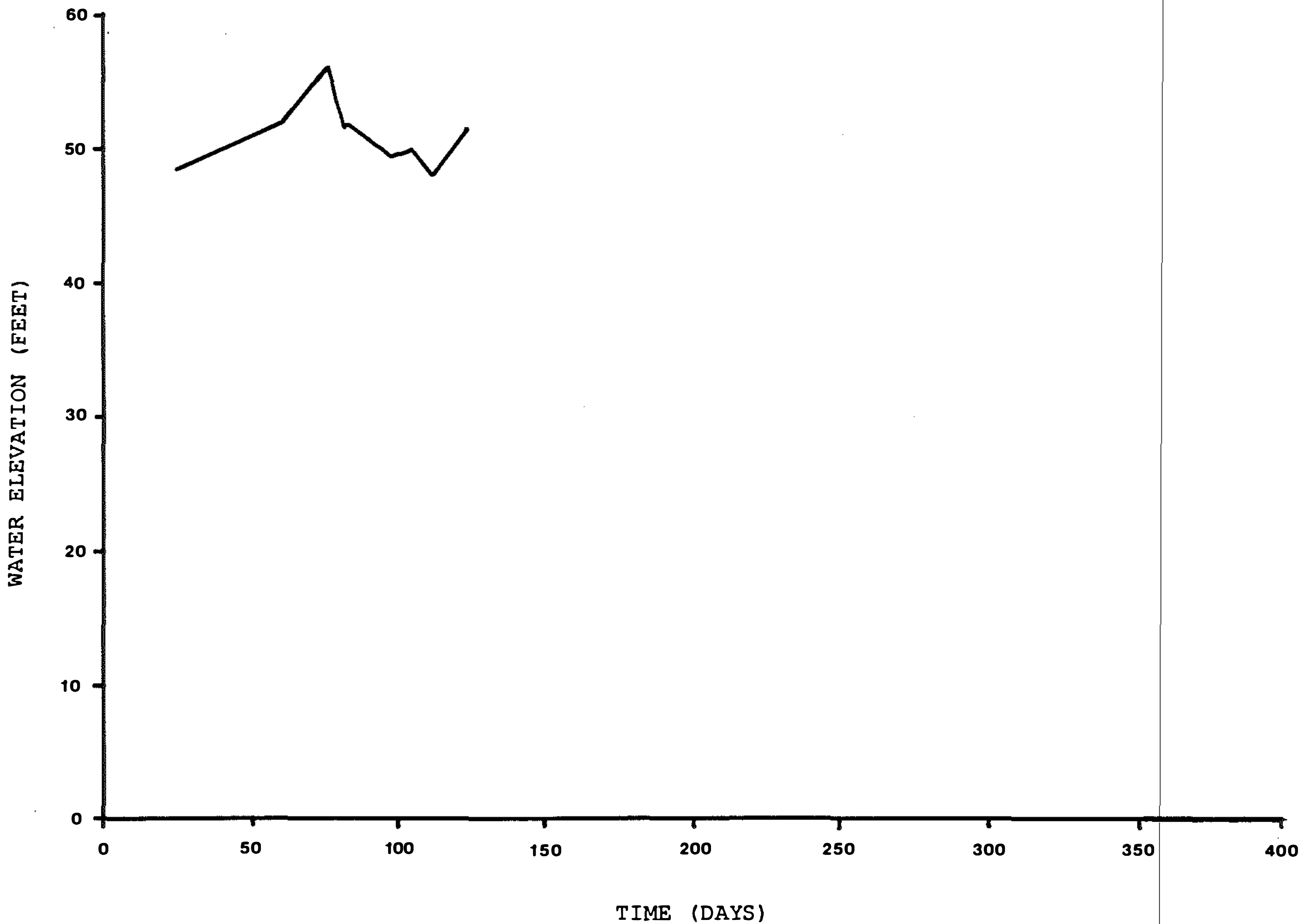

Figure 23. Foundation Pore Pressure at Piezometer 7.

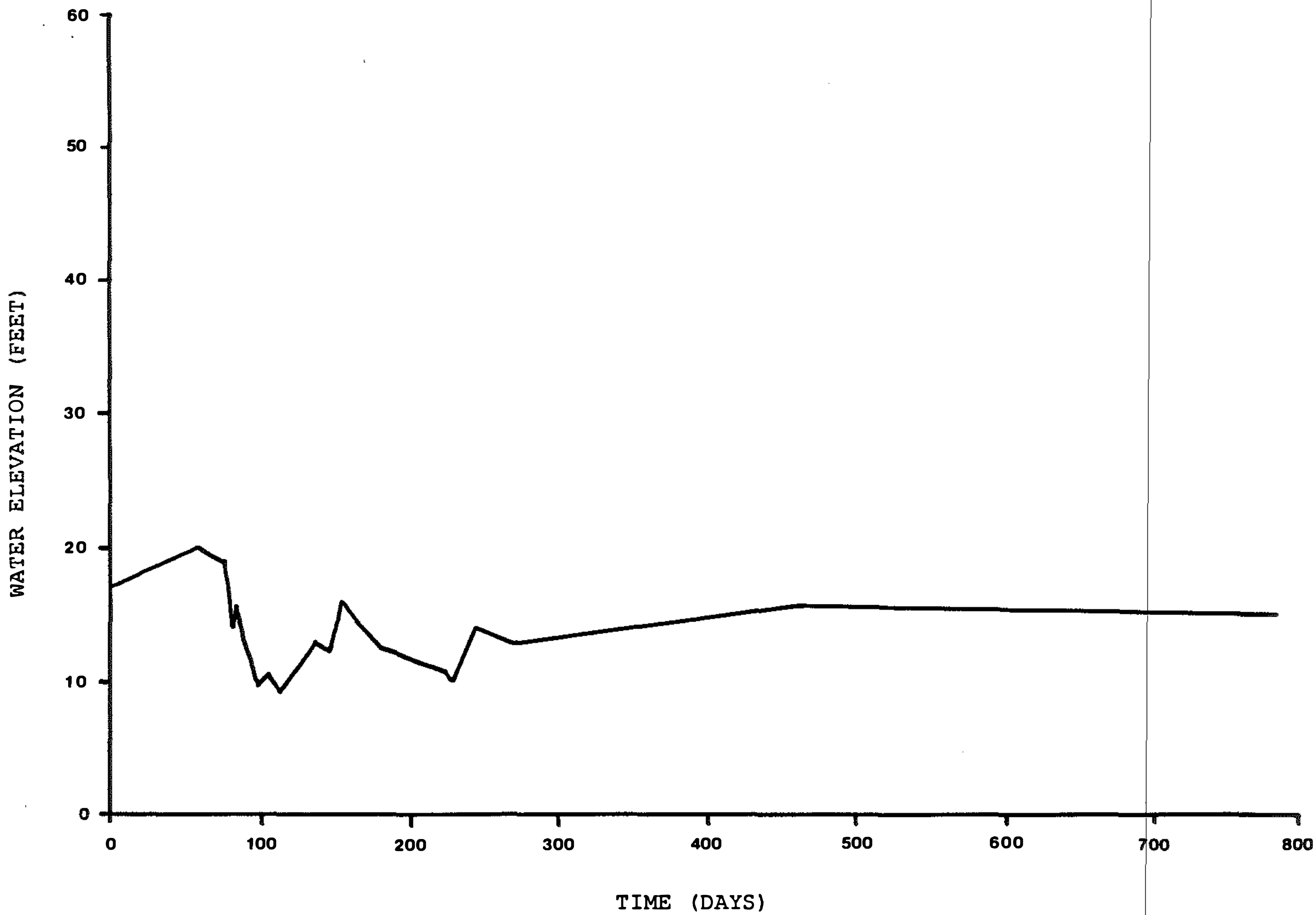

Figure 24. Foundation Pore Pressure at Piezometer 2.

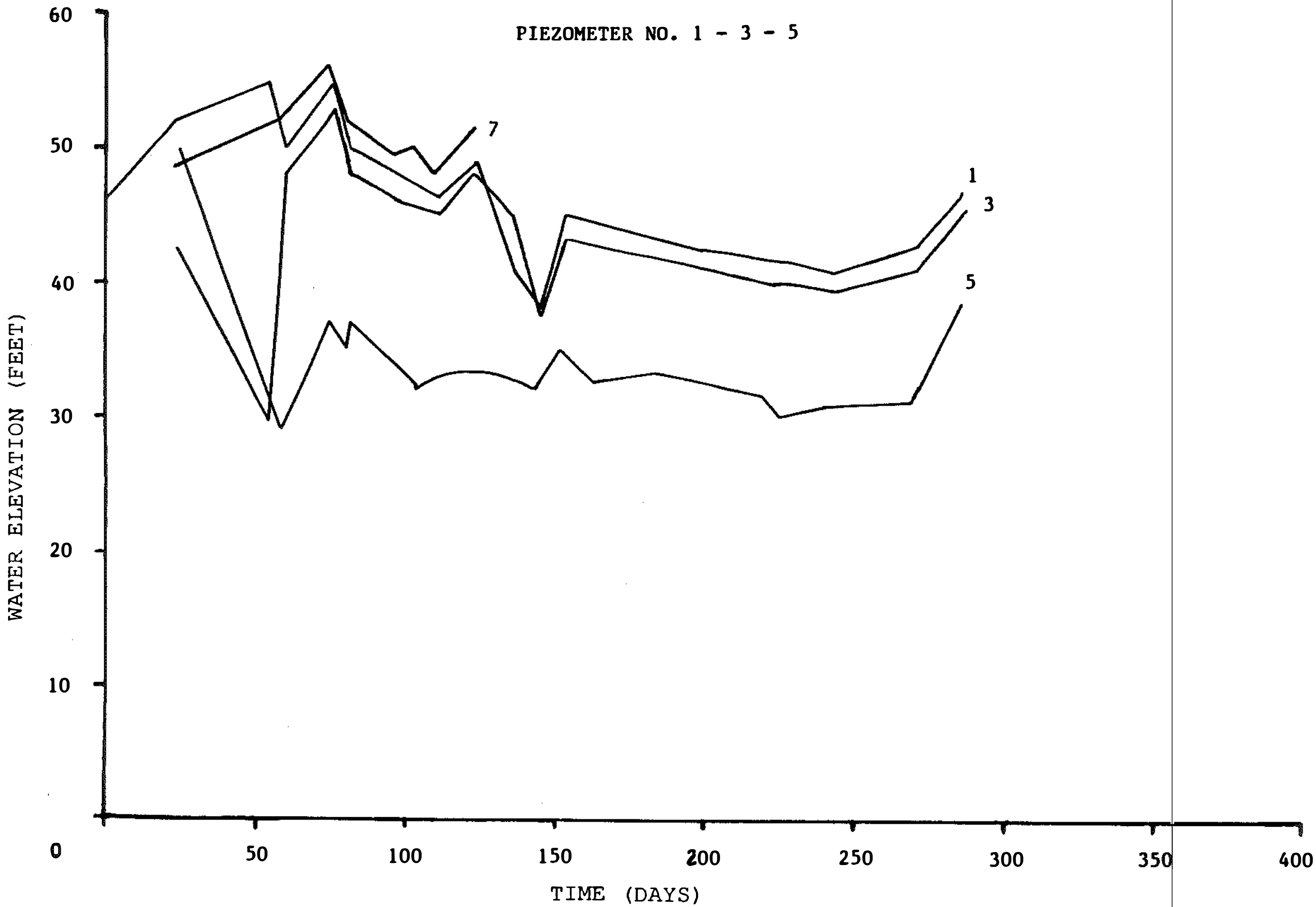

Figure 25. Pore Pressure In the Lower Clay Layer.

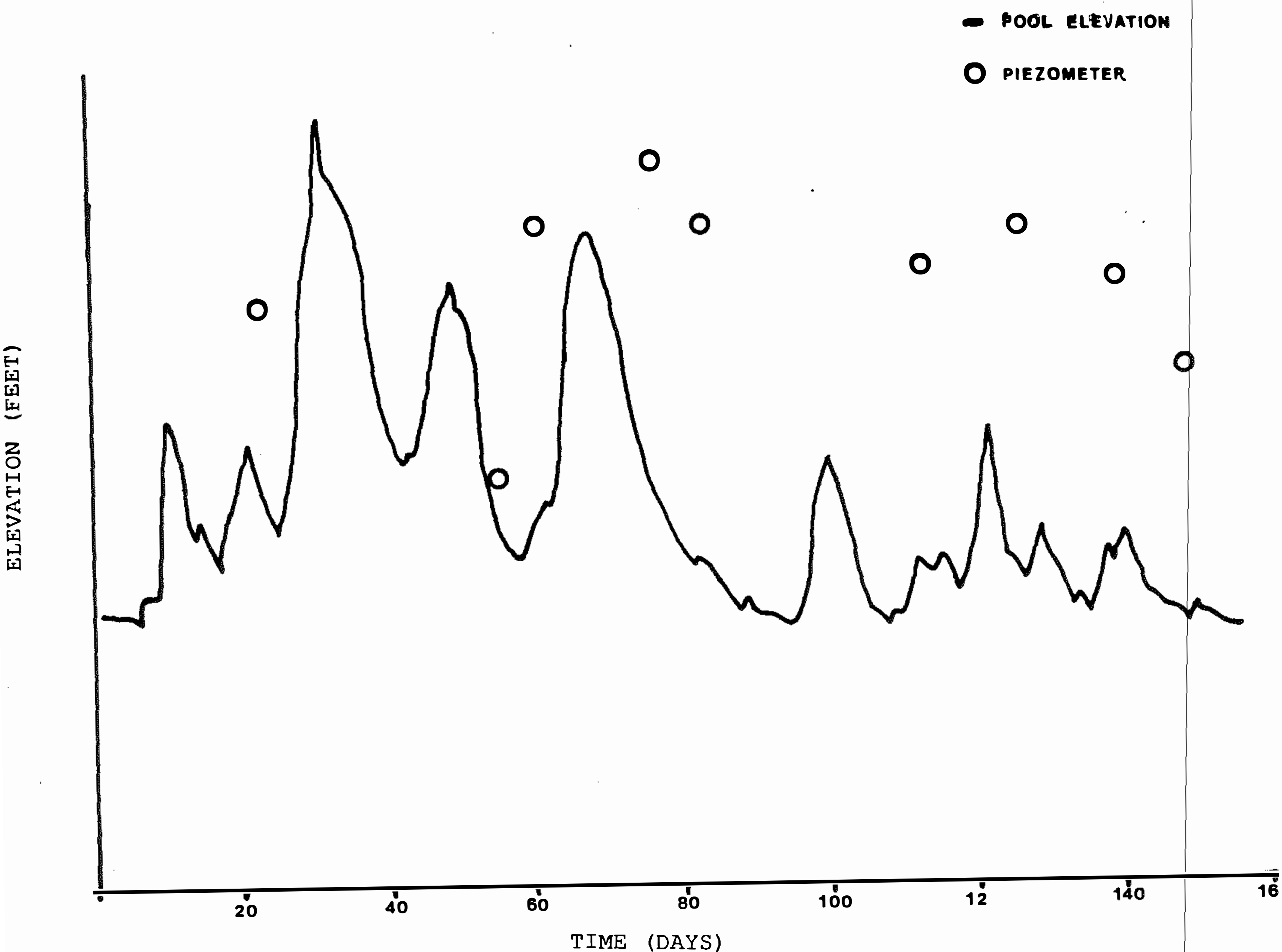

Figure 26. Piezometer 3 and Little Kentucky River Pool Elevation.

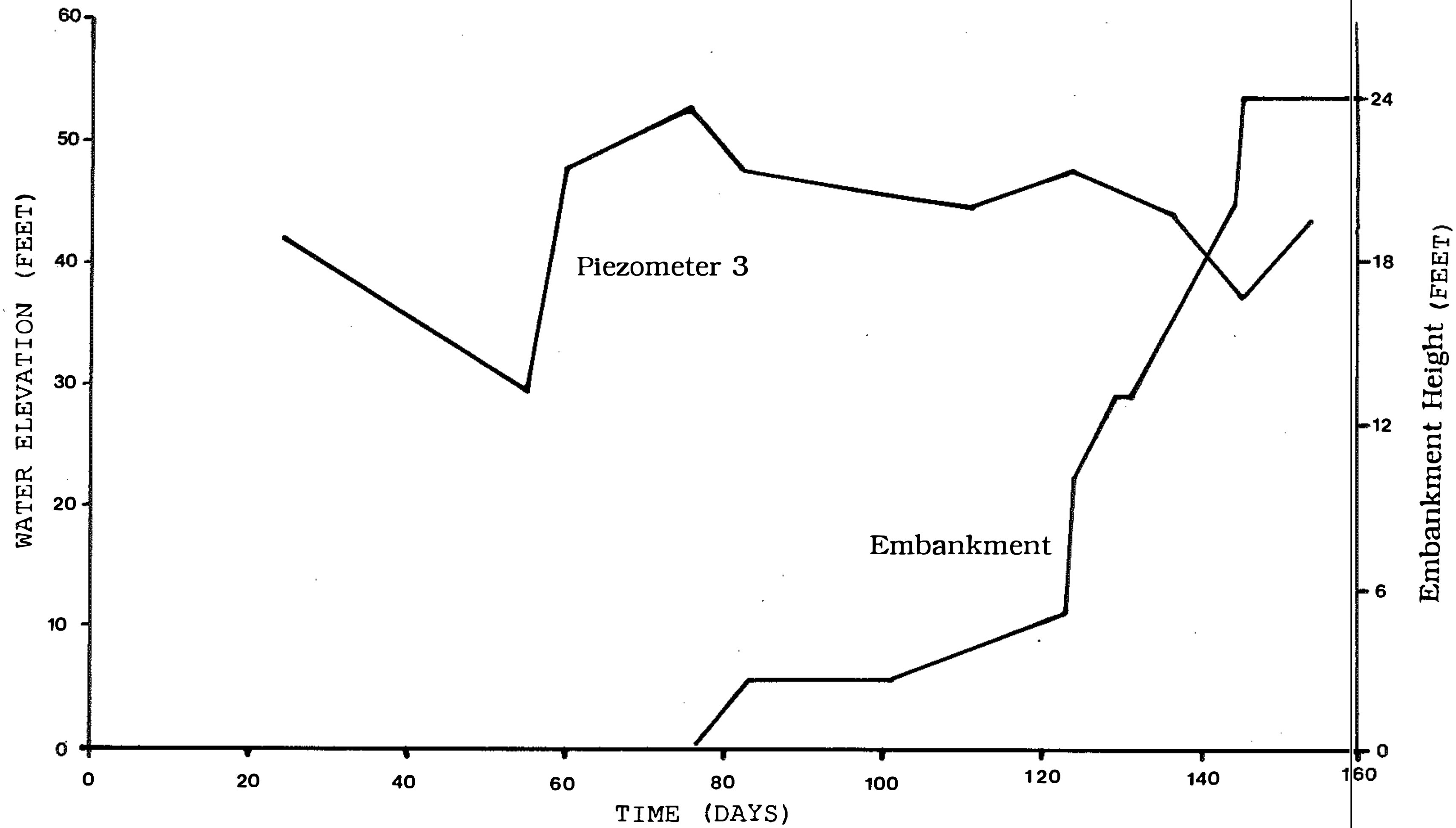

Figure 27. Pore Pressure at Piezometer 3 Compared to West Embankment Height.

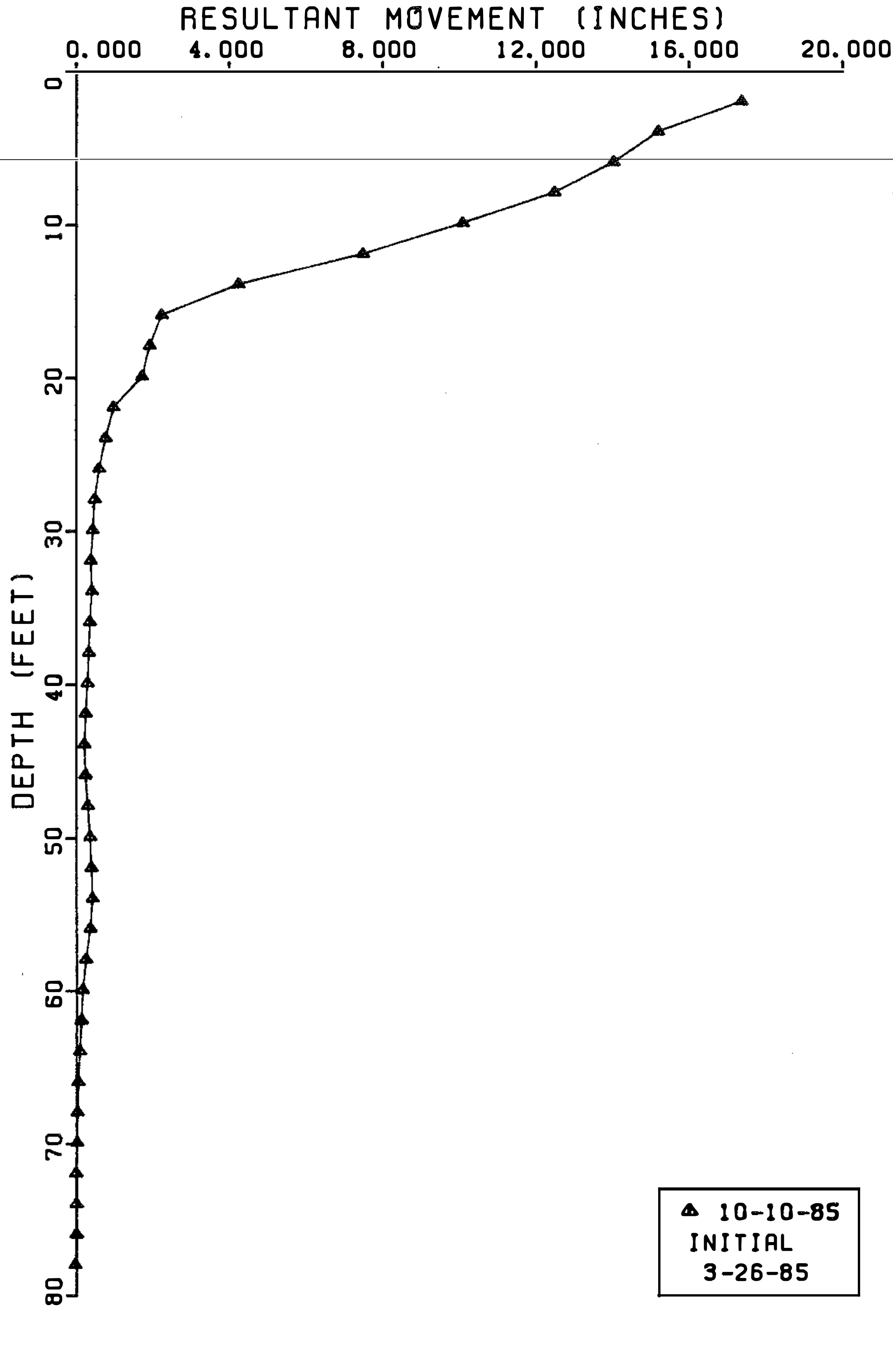

Figure 28. Lateral Movement at Slope Inclinometer 1.

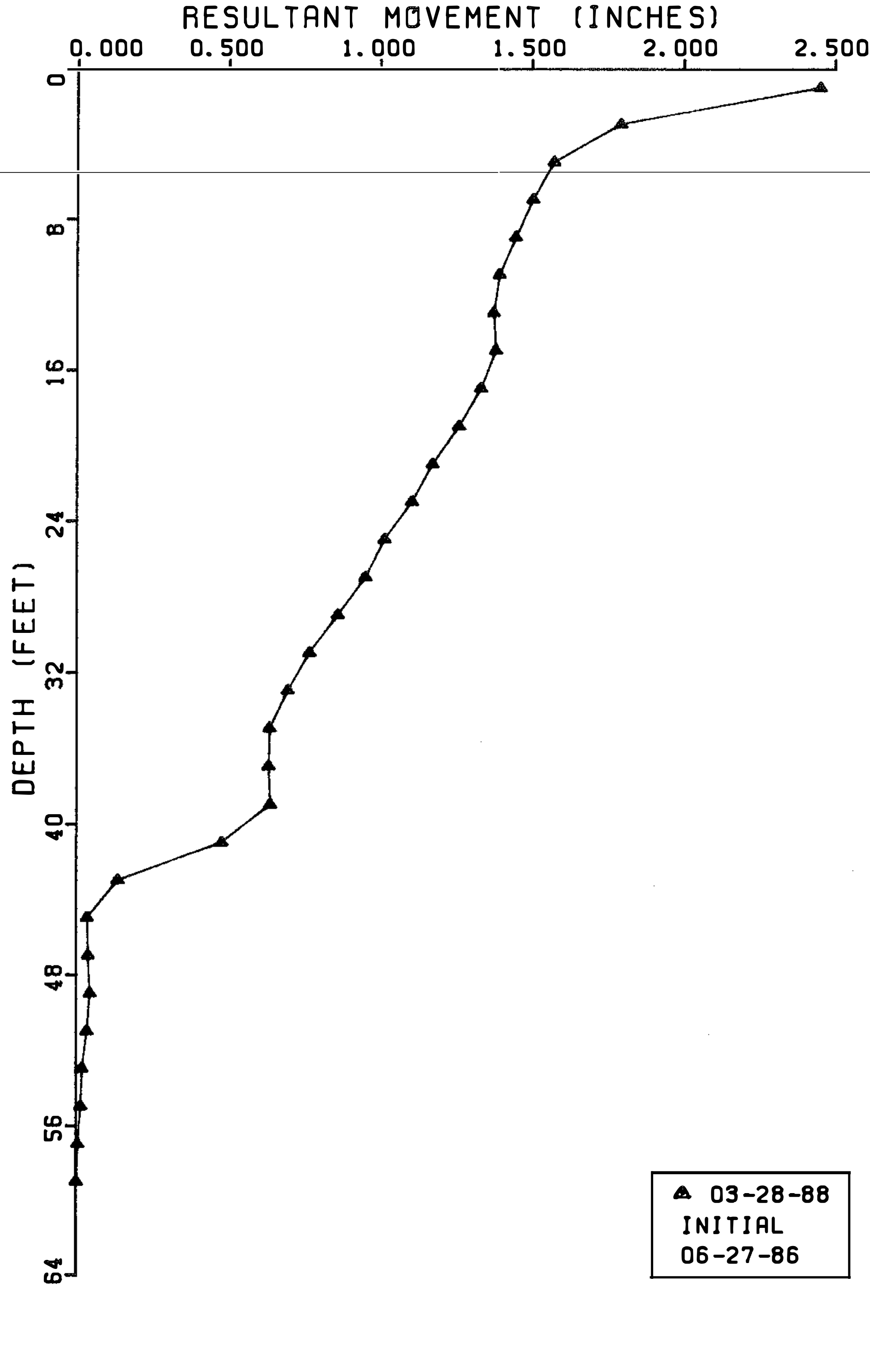

Figure 29. Lateral Movement at Slope Inclinometer 3.

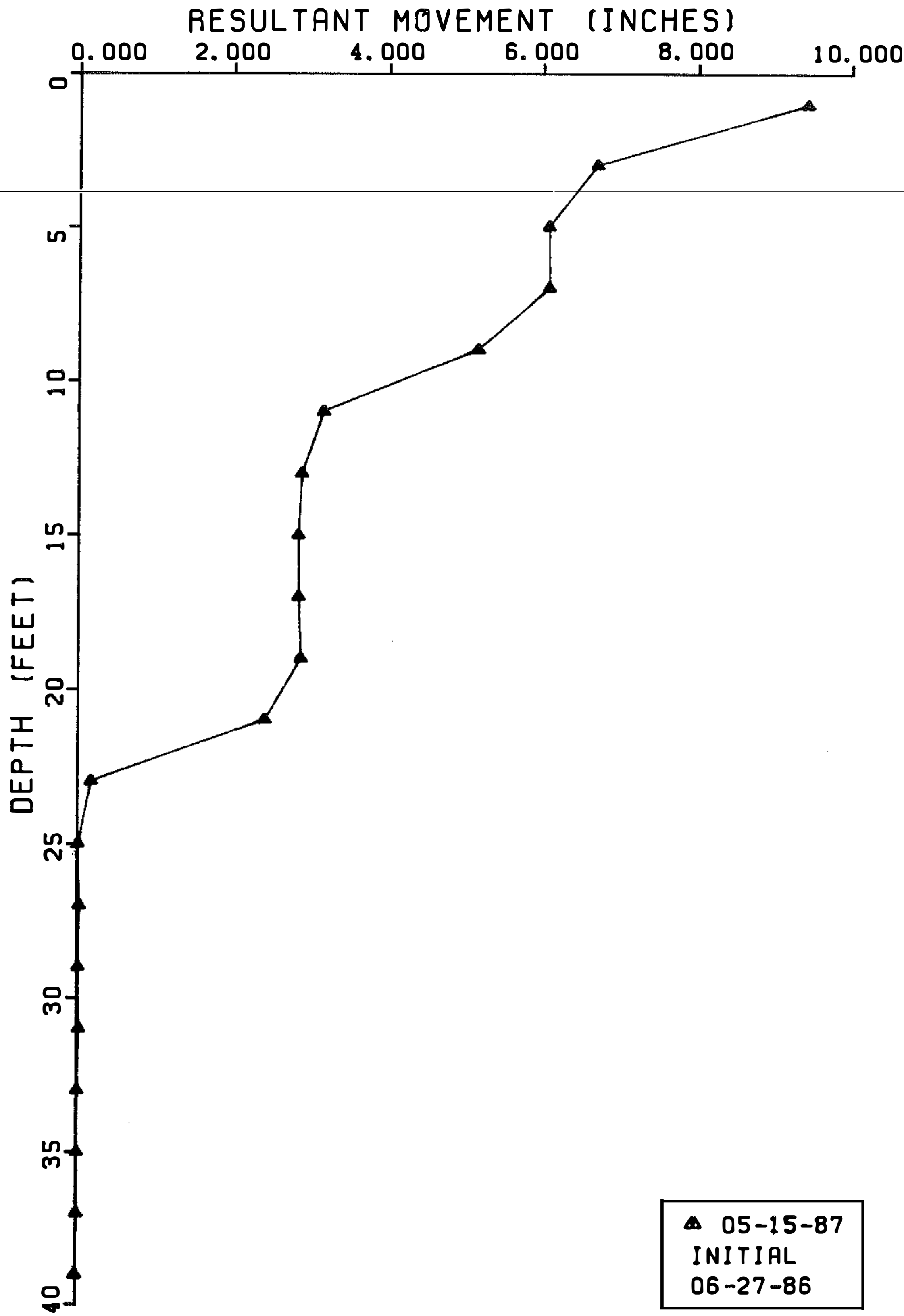

Figure 30. Lateral Movement at Slope Inclinometer 4.

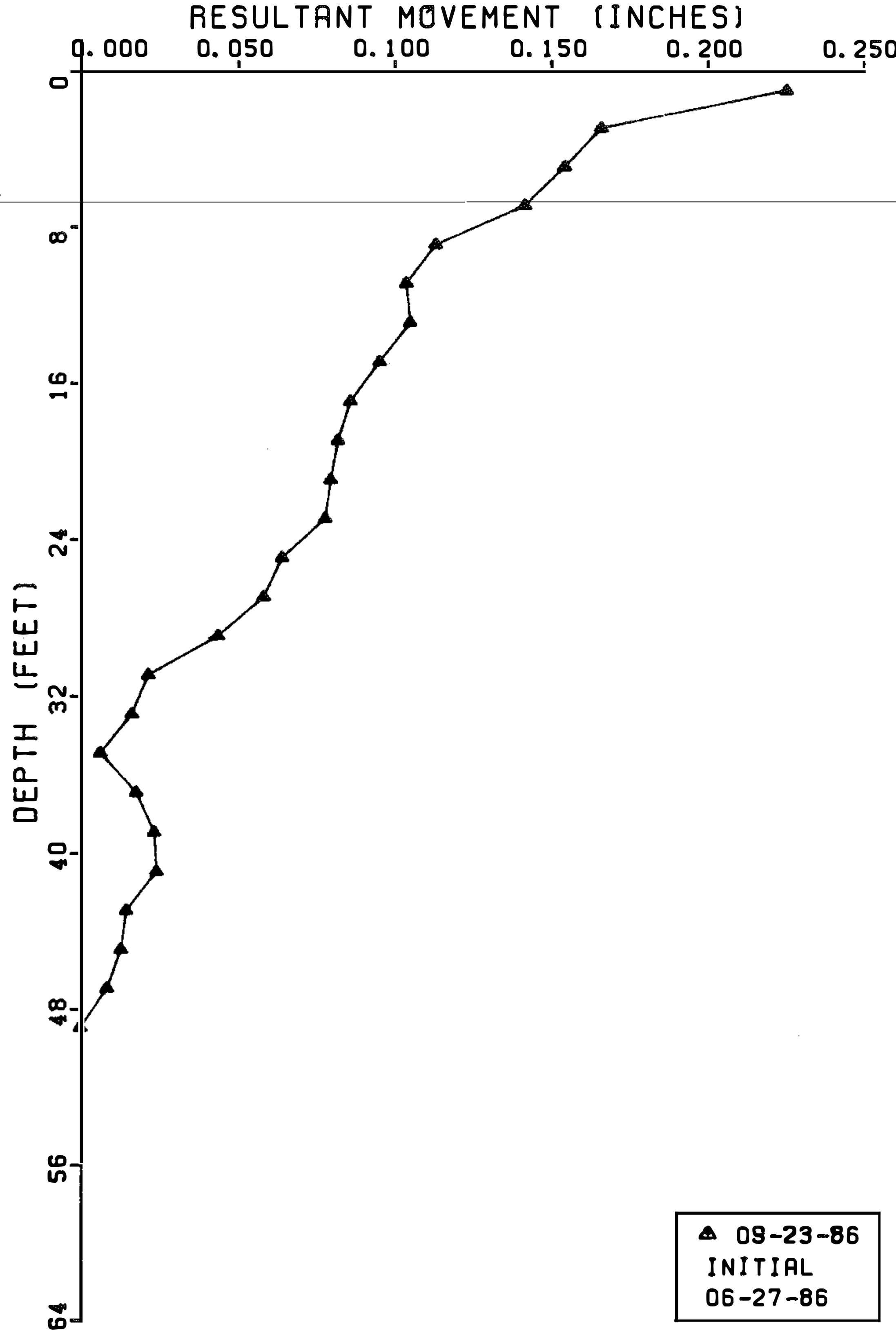

Figure 31. Lateral Movement at Slope Inclinometer 5.

TABLE 1 Physical Properties of the Wick Drain.

AMERDRAIN 407	VALUES	TEST METHODS
Drain Core	Polypropylene	
Filter Fabric	Polypropylene	
Weight	93 gm/m (1 oz/ft)	
Width	100mm (4 in)	
Thickness	3mm (1/8 in)	
Tensile Strength*	65 kg (145 lbs)	ASTM D1682-64
Elongation at Break*	116%	ASTM D1682-64
Mullen Burst Strength*	12.3 kg/cm² (175 psi)	ASTM D751
Puncture Strength*	25 kg (57 lbs)	ASTM D751 Mod.
EOS (AOS)*	70/100	COE CW-02215
Modulus at 10% Elongation*	358 kg (790 lbs)	ASTM D1682-64
Trapezoidal Tear*	34 kg (75 lbs)	ASTM D2263
Specific Gravity	0.95	
Coefficient of Permeability*	0.031 cm/sec	ASTM D737
Permittivity*	0.8/sec	ASTM D4491-85
Flux*	2525 l/min/m² (62 gal/min/ft²)	ASTM D4491

*Data for filter fabric only.