Technical Report Documentation Page

1. REPORT No.
632509-3

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE
Movement Within Large Fills- Ridge Route Project

5. REPORT DATE
March 1969

6. PERFORMING ORGANIZATION

7. AUTHOR(S)
Smith, Travis W., and Weber, William G., Jr.

8. PERFORMING ORGANIZATION REPORT No.
632509-3

9. PERFORMING ORGANIZATION NAME AND ADDRESS
State of California
Business and Transportation Agency
Department of Public Works
Division of Highways

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

12. SPONSORING AGENCY NAME AND ADDRESS

13. TYPE OF REPORT & PERIOD COVERED
Interim Report

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The development of instrumentation for measuring the magnitude and direction of horizontal and vertical movements within embankments of up to 240 feet in height and the measurements obtained during construction are reported. Revisions to design of instrumentation and protection of reading devices are discussed. Data obtained during and immediately following construction of the embankments are presented and discussed. The use of cylindrical steel instrument shelters proved to be entirely effective in preventing damage to instrumentation placed on embankment slopes. Recommendations for improvement in design of instrumentation and reading methods are discussed. Collection of data will continue for three to five years following completion of the embankments and subsequently, a report will be published following analysis and evaluation of this long-term study.

17. KEYWORDS
Instrumentation, measurements, embankments, earth movements, movements, earth fills

18. No. OF PAGES:
54

19. DRI WEBSITE LINK
http://www.dot.ca.gov/hq/research/researchreports/1969-1970/69-19.pdf

20. FILE NAME
69-19.pdf

This page was created to provide searchable keywords and abstract text for older scanned research reports.
November 2005, Division of Research and Innovation

HIGHWAY RESEARCH REPORT

MOVEMENT WITHIN LARGE FILLS
RIDGE ROUTE PROJECT

69-19

INTERIM REPORT

STATE OF CALIFORNIA

BUSINESS & TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 632509-3

Prepared in Cooperation with the U.S. Department of Transportation, Bureau of Public Roads March, 1969

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, *Governor*

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

5900 FOLSOM BLVD., SACRAMENTO 95819

March 1969
Interim Report
M & R No. 632509-3
D-3-3

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

MOVEMENT WITHIN LARGE FILLS

RIDGE ROUTE PROJECT

TRAVIS SMITH
Principal Investigator

W. G. WEBER, JR.
Co-Investigator

Assisted by

L. R. Leech
C. A. Frazier
E. C. Wrye

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

REFERENCE: Smith, Travis W., and Weber, William G., Jr., "Movement Within Large Fills - Ridge Route Project," State of California, Department of Public Works, Division of Highways, Materials and Research Department. Research Report 632509-3, March, 1969.

ABSTRACT: The development of instrumentation for measuring the magnitude and direction of horizontal and vertical movements within embankments of up to 240 feet in height and the measurements obtained during construction are reported. Revisions to design of instrumentation and protection of reading devices are discussed. Data obtained during and immediately following construction of the embankments are presented and discussed. The use of cylindrical steel instrument shelters proved to be entirely effective in preventing damage to instrumentation placed on embankment slopes. Recommendations for improvement in design of instrumentation and reading methods are discussed. Collection of data will continue for three to five years following completion of the embankments and, subsequently, a report will be published following analysis and evaluation of this long-term study.

KEY WORDS: Instrumentation, measurements, embankments, earth movements, movements, earth fills.

ClibPDF - www.fastio.com

ACKNOWLEDGMENTS

The researchers wish to express their appreciation to the personnel of the District 07 Construction Department of the California Division of Highways for their assistance in this investigation.

This work was done under the HPR Work Program in cooperation with the U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

ClibPDF - www.fastio.com

TABLE OF CONTENTS

ClibPDF - www.fastio.com

LIST OF FIGURES

ClibPDF - www.fastio.com

INTRODUCTION

The California Division of Highways has, for several years, been conducting a research project concerning "Movement Within Large Fills." The San Luis Reservoir Relocation Project* in the Pacheco Pass-Los Banos area of District 10 was the first attempt by this Department to obtain measurement of both horizontal and vertical movement within large embankments. The second project chosen was a section of Interstate 5 in Los Angeles County, located within the San Andreas fault area approximately 12 miles north of the town of Castaic.

In this section, Interstate 5 is being constructed on new alignment spanning several canyons which require fills of over 200 feet in height. It was anticipated that very little foundation settlement would occur in the foundation materials consisting of partially exposed rock with a soil mantle up to several feet thick in some locations. Two embankments on this project were selected for instrumentation, Osito Canyon fill and No Name Canyon fill. This interim report concerns the instrumentation of these embankments and contains the data accumulated during the construction period. All conclusions and data in this report are thus based upon the action of the embankments during the loading period only. It is planned to continue readings of these installations for several years. A final report will be prepared approximately five years after completion of construction and will present data covering movements that occur under constant load over a long time interval.

A plan map of the construction project, together with plan, profile and cross-section drawings of Osito Canyon and No Name Canyon embankments are shown in Figures 1, 8 to 10, and 15 to 17. Instrument locations are detailed in these drawings.

CONCLUSIONS

This report is concerned primarily with the presentation of acquired data and the performance of the instrumentation. Analysis and correlation of the data from the various sites comprising the research project will be presented in a final report.

The use of instrument shelters has proved to be entirely effective in preventing extensive damage to instrumentation similar to that which occurred on the San Luis Reservoir Relocation project. Although several of the shelters suffered moderate to heavy damage during construction, all instrumentation remained operable.

Operation of the horizontal movement instrumentation on this project was not completely adequate. Improvements in this measurement technique have recently been made and are yielding more satisfactory data.

Although it is believed that reliable data may be obtained on settlement and horizontal strain for a long-term study, the maintenance and reliability of line survey reference points may prove to be a weak point in the collection of valid data for determining horizontal movement.

*Refer to Materials and Research Department Research Report No. 632509-1, "Movement Within Large Fills," December, 1966.

ClibPDF - www.fastio.com

RECOMMENDATIONS

It is recommended that a method be devised to insure that proper tensile force is applied to the horizontal movement cables when readings are taken. Although it would be preferred that these cables remain under constant tension, it appears that any reasonable method to accomplish this would require larger instrument shelters to house the mechanism. Because of the reasonable cost of the surplus missile containers used for shelters, it is not considered feasible to change the present shelter design.

Another approach to horizontal movement instrumentation utilizes short runs of very light wire rope. The rope is under constant five-pound tension and terminates in a potentiometer which is read remotely. It is felt that a standard line of instrumentation, as described in this report, should be duplicated in an embankment with this other type. If the electrical method is reliable, its use might result in more accurate readings and greater flexibility in installation.

DISCUSSION

SITE DESCRIPTION

The alignment of Interstate 5 northward from Los Angeles crosses the Tehachapi mountain range. Freeway construction standards in this steep terrain necessitated cuts and fills of large magnitudes. Osito Canyon fill in the vicinity of Station 234 has a maximum height of about 240 feet at centerline, a total length of 2100 feet, and a base width of approximately 1000 feet.

Bridge Department test borings for the arch culvert foundation beneath the fill indicated the underlying materials to be shale with some interbedded sandstone.

This fill was constructed with 2:1 side slopes. The embankment materials consist of sedimentary material resembling shale which breaks down into a silty clay soil. This material has the characteristic of losing strength upon weathering and exposure to moisture. Differential thermal analysis reveals that the identifiable clay mineral content in the material is quite small. Some interbedded sandstone of rather poor quality was also present in the adjacent cuts where these materials were excavated.

No Name Canyon fill is located approximately one-half mile south of Osito Canyon fill and was constructed under the same contract. This fill, also constructed with 2:1 side slopes, is approximately 200 feet in height and 1000 feet in length. During the winter rains of 1965-66, a portion of the partially completed culvert beneath this embankment was washed out. This resulted in the Contractor's decision to defer completion of the culvert for several months during which time the construction activity was concentrated at Osito Canyon fill. The embankment materials at No Name Canyon are basically the same as those used in the Osito Canyon embankment, and were also excavated from adjacent cuts.

In-place strength tests using the Menard device were made in the Liebre Gulch embankment which was constructed of materials similar to those used in the Osito and No Name Canyon fills. Triaxial tests were also performed on remolded samples of these embankment materials which were

ClibPDF - www.fastio.com

fabricated to a moisture-density state equal to 90 percent relative compaction at an optimum moisture content of about 12.5 percent. The quick undrained triaxial test values compared favorably with the in-place test results from the Menard pressuremeter device. However, another set of specimens was prepared and run under similar conditions except that they were allowed to saturate under the chamber pressure for several days prior to shearing. The strength values obtained on these saturated specimens were considerably less than the in-place strength values. For a detailed discussion of these tests and the strength values obtained, refer to Materials and Research Department Research Report No. 632509-2 "Embankment Testing with Menard Pressuremeter.", May, 1968.

INSTRUMENTATION METHODS

The instrumentation is basically the same as that used at the San Luis Reservoir Relocation Project with the exception of some changes brought about by experience gained from the initial installations. These include a cylindrical metal instrument shelter, a spring tensioning device for the horizontal movement cables in lieu of formerly used "dead weight" blocks of concrete or steel, and steel horizontal movement platforms with a settlement standpipe riser attached.

The 5-foot diameter by 6-foot long cylindrical metal instrument shelters, which are surplus U. S. Navy missile containers, were used on these installations to prevent the extensive damage to the indicating devices which occurred on the San Luis Reservoir Project. Figures 2, 3 and 4 illustrate the use of those shelters. Backfill material in the instrumentation line trenches consisted of a selected material devoid of sharp, angular rock which might damage the protective plastic pipe and instrument tubing.

HORIZONTAL MOVEMENT

Because of space limitations in the instrument shelters, it was necessary to provide springs in lieu of dead weights to hold the horizontal movement cables in tension. The plastic coated 3/16" wire ropes, after being pretensioned with a torque wrench to approximately 200 pounds as shown in Figure 5, were attached to springs anchored in the shelter. These spring lengths were adjusted to apply a nearly constant 50-pound tension on the cables. This tension is checked by stretching the spring to a predetermined length before each subsequent reading is observed and recorded.

The horizontal movement platforms consist of 12-inch square steel plates placed on edge at intervals of approximately 100 feet. The plates have a 2-inch hole in the center to facilitate passage of horizontal movement cables connected to other platforms in the same line of instrumentation (See Figures 6 and 7). Each horizontal movement platform has a cable attached which extends through a 1-1/2-inch polyvinyl chloride (PVC) plastic pipe to the outer edge of the embankment where it is secured to the tensioning spring inside the instrument shelter. The plastic pipe conduit provides a protective covering for the cables and reduces friction. An expansion joint is placed at intervals of 40 feet in the plastic pipe throughout the length of the horizontal movement installations.

ClibPDF - www.fastio.com

A permanent index is crimped onto each cable where it passes over a reading table in the instrument shelter. Readings are then taken by observing the location of the cable index relative to a scale permanently attached to the reading table. The reading table, scale, and cables with index attached can be seen in Figure 5.

VERTICAL MOVEMENT

The measurement of vertical movement within fills is accomplished by the use of water level type settlement platforms which are attached to the top of the horizontal movement platforms as shown in Figure 7. These settlement devices are the same closed system type utilizing air vent and drain lines which were used at Station 80+00 on the San Luis Reservoir Relocation project.

INSTALLATION

Four levels of instrumentation were placed in each of the two embankments. The first line of instrumentation was placed in the No Name Canyon embankment during October, 1965. Because of a flash flood in No Name Canyon during the following winter, work was suspended on this embankment until construction of the Osito Canyon embankment was completed. The first line of instrumentation was installed at Osito Canyon on March 27, 1966. Three subsequent instrumentation levels were installed at 40 to 47-foot vertical intervals during May, August and November of 1966. Osito Canyon embankment was completed to profile grade elevation on December 22, 1966.

Following the completion of Osito Canyon embankment, work was resumed at No Name Canyon. Three additional levels of instrumentation were installed in this embankment at 40- to 50-foot intervals during February, March, and May of 1967. Final grade elevation was reached on August 10, 1967.

Survey bench marks were set outside the fill slope in original ground at each instrumentation level to monitor the instrument shelters for movement. These lines are shown in Figures 8 and 15.

Figures 8 and 15 show the lines of instrumentation set normal to roadway centerline rather than parallel to the canyon floor. This difference in alignment is clearly shown in Figure 8 where the Osito Canyon Culvert follows the Canyon alignment. It is very possible that the data obtained at the lower levels of instrumentation were influenced by the effect of soil movement along the sides of these steep, V-shaped canyons.

HORIZONTAL MOVEMENT AND STRAIN DATA

The horizontal movement platforms were installed to measure the magnitude of horizontal strain occurring during loading operations and over a period of several years after completion of the embankment. These data, in conjunction with periodic line surveys made to correct for horizontal movement of the associated instrument shelter, provide information on the soil movement within the embankments. Tables 1 and 3 tabulate the horizontal movement observed after correcting for instrument shelter movement.

ClibPDF - www.fastio.com

As explained earlier, each horizontal movement cable was attached at one end to a horizontal movement platform and at the other end to a tensioning spring inside of the instrument shelter. Where possible, instrument shelters were placed on both sides of the embankment at each line of instrumentation permitting use of shorter cable lengths. When instrument shelters were placed on both slopes, a single cable was placed between the two instrument shelters and attached to the horizontal movement platform below roadway centerline. By using this method, movement readings were obtained on the central horizontal movement platform at both instrument shelters. As previously noted, on the San Luis project, a considerable discrepancy can exist between the two readings obtained for a centerline platform. The causes for these discrepancies can be numerous-- differential settlement within the fill, improper tension on the cables when readings are being taken, inaccuracies in line surveys, and improper operation of the instrumentation, to mention a few.

Since this area is within the influence of the San Andreas Fault, it is felt that surface movements could have caused the bench marks, used to establish the original survey line, to be displaced. The result of this displacement would be one source of error when horizontal movement of the instrument shelter was determined by offset from the survey line. Prior to a survey made in August 1967, it was found that most of the survey point "hubs" were loose and that some were missing. As a result, two survey lines were lost, i.e., right D level at No Name Canyon and left D level at Osito Canyon. It was necessary to establish new lines for these two locations and reset all reference points on concrete monuments.

It is also entirely possible that the present instrumentation is not functioning as anticipated. The measured strains are small and generally less than anticipated. Possible malfunctions might occur in cables which bind together, or whose coatings adhere, and/or in friction where cables pass through other platforms.

A review of the horizontal movement and strain data for Osito Canyon, shown in Figures 11 and 12, indicates a general trend for increasing horizontal movement with increasing height of fill as would normally be expected. The strain data presented in Figure 12, however, indicate two trends which merit some mention.

The first of these trends in horizontal strain is the development of increasing compressive strain, near the surface of the slope, with increased fill loading. These data would indicate that significant strain could develop within the embankment without appreciable dilation of the embankment. In Figure 12, for fill elevation 2730, a 0.06% compressive strain was recorded adjacent to the surface of the right and left slopes at instrumentation level B. As might be expected, the compressive strains were greater in magnitude and extent on the downhill side of the embankment. An expansive strain of 0.12% was recorded within the fill.

The second trend noted was that generally greater strains were observed across instrumentation level B than were obtained at the lower level. Although it would appear that greater strains would be developed with increasing fill loads, there is an apparent "keying" effect between the embankment and the assumed stable foundation which restrains the development of appreciable horizontal strain across instrumentation level A.

ClibPDF - www.fastio.com

Horizontal movement and strain data for No Name Canyon are shown in Figures 18 and 19. In general, the same general horizontal strain trends as discussed above can be seen in this figure. In No Name Canyon, however, it appears that if a "keying" effect exists, it has a tendency to restrain horizontal movement but allows greater strains to be developed in the bottom level of instrumentation. Again, significantly greater strains were developed within the embankment when compared with those near the surface. Although greater slope dilation was observed at No Name Canyon, this dilation may or may not be reflected in the magnitude of the localized internal strains.

The rates of horizontal movement compared with fill loading are shown in Figures 11 (Osito Canyon) and 18 (No Name Canyon). Regardless of the possible difficulties in determining horizontal movement which were discussed earlier, a review of these figures indicates that the data obtained thus far are relatively consistent and the instruments may be operating properly. Although both Osito Canyon and No Name Canyon embankments were constructed of essentially identical materials and by the same contractor, considerably greater horizontal movement and rate of movement have been recorded at No Name Canyon. The reason for this significant difference in data has not been determined, although configuration of the embankment foundation is thought to play an important part.

Horizontal movement readings obtained after Osito Canyon embankment was completed, define a continually lessening rate of movement.

Regardless of the greater observed movements and larger strains developed in No Name Canyon embankment, the magnitude of values obtained was less than anticipated.

FILL SETTLEMENT AND VERTICAL STRAIN DATA

Settlement platforms were installed as an integral part of the horizontal movement platforms at selected distances from centerline in both embankments. These platforms are used to determine the magnitude of vertical movement, occurring within the embankment. Readings must be corrected by elevation surveys before the data can be used.

Rate of settlement charts, Figures 13 and 20, indicate a cumulative settlement of about 3.9 feet on centerline upon completion of fill construction at both Osito and No Name Canyons. Subsequent readings at Osito Canyon indicate that the settlement-time curves are approaching a straight line as would be expected. Because of the lighter loads, due to decreasing fill height, settlement readings become less as the distance from centerline increases.

Settlement along lines of instrumentation as well as magnitude of vertical strains for various heights of fill are shown in Figure 14 for Osito Canyon and Figure 21 for No Name Canyon.

As expected, the greatest vertical strains generally occur in the lower and central portions of the embankment where loading is greatest. Because a number of the settlement platforms become inoperative within the period covered by this report, no interpretation of the strain distribution has been attempted.

ClibPDF - www.fastio.com

ADDENDA

A new type of horizontal movement platform, shown in Figures 22 and 23, has recently been developed and incorporated in the instrumentation of the Squaw Creek embankment, to be reported in the next interim report for this project. This new platform consists of two 8 x 12-inch steel plates welded to a 12-inch square plate to form an "X" shaped cross-section. The metal box attached to the platform shown in Figure 22 contains a potentiometer (Figure 24) to allow measurement of horizontal strain by analog resistance.

These new platforms are installed so that the 8 x 12 inch plates are flush with the bottom of the trench. They are then pinned to the ground through holes in the horizontal plates. Figure 23 shows a typical installation using the new platforms.

The potentiometer measuring device shown in Figure 24 has been used at four locations in the Squaw Creek embankment and results thus far look encouraging. The potentiometer is coupled to a spring motor providing a constant 5-pound tension on a cable which is, in turn, attached to a rod housed in PVC pipe and pinned to the soil at the other end. In this manner, horizontal strains of $\pm$ 2.5 feet over the distance between the platform and the point where the rod is pinned to the embankment can be measured electrically at a remote instrument shelter.

A field inspection of the instrument shelters and reading facilities at No Name and Osito Canyons was made during the month of September 1967. It was noted during this inspection that, although some of the instrument shelters had suffered slight to extensive damage from rocks or other debris rolling down the slope, the instrumentation inside of the shelters suffered no visible damage. It was noticed, however, that the springs loading the horizontal movement cables had considerably less than the intended 50 pounds of tension. Since these instruments had been read only one month earlier and had been checked for proper elongation at that time, it was concluded that a permanent set had occurred in the springs changing the predetermined stress-strain relationship. The effect of this reduced tension on readings can be of consequence. It was found that movement as large as 0.17 foot was obtained by firmly pulling on several of the cables. Upon releasing the cable, the index on the horizontal movement cable slowly returned to the original reading.

A standard method of reading cable type instrumentation was developed in November, 1967. This method precludes tensioning problems which previously occurred. It will be detailed in a later report.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

Table 1A

Horizontal Movement at Elevation 2537±

Osito Canyon

Date	HMI Line Survey	A-L Est. Value*	Horizontal Movement at HMP Feet 11	10	9	8	7	6	5	Fill Elevation
4-18-66		0	I	I	I	I	I	I	I	2541
4-28-66		0	0	0	0	0	0	0	0	2556
5-20-66	I	0								
5-26-66		.01	.02	.03	.03	.03	.03	.03	.02	2580
6-8-66		.02	.03	.04	.03	.03	.02	.03	.03	2592
6-25-66		.02	.03	.03	.03	.03	.04	.04	.04	2601
8-4-66		.04	.07	.07	.07	.07	.07	.07	.07	2611
8-24-66		.05	.11	.11	.10	.09	.09	.10	.09	2631
10-4-66		.06	.15	.15	.14	.14	.14	.14	.14	2646
10-20-66		.07	.15	.15	.15	.15	.15	.16	.15	2661
11-1-66		.07	.17	.17	.17	.17	.16	.17	.16	2675
12-14-66		.08	.18	.19	.19	.19	.19	.19	.19	2710
1-10-67	0.09	.09	.20	.21	.21	.21	.21	.21	.21	2730
2-6-67		.10	.20	.22	.22	.22	.22	.22	.23	↓
3-1-67	0.07	.10	.20	.22	.22	.22	.22	.22	.22	↓
3-30-67		.11	.22	.24	.23	.23	.23	.24	.23	↓
5-20-67		.12	.22	.24	.24	.23	.23	.24	.24	↓
5-26-67	0.13									↓
8-15-67		.13	.23	.25	.24	.24	.24	.25	.24	↓
8-24-67	0.17									↓
11-16-67	0.13	.15	.25	.27	.26	.26	.26	.26	.26	↓

"I" indicates initial reading.
* Estimated horizontal movement of HMI, in feet, obtained by interpolation of line survey data.
Positive values indicate movement toward downhill (left) side of embankment.

ClibPDF - www.fastio.com

Table 1B

Horizontal Movement at Elevation 2577±

Osito Canyon

Date	HMI B-L Line Survey	HMI B-L Est. Value*	Horizontal Movement at HMP, Feet: 22	21	20	16-L	16-R	17	18	19	HMI B-R Est. Value*	HMI B-R Line Survey
5-26-66		0	I	I	I	I	I	I	I	I	0	
6-1-66	I	0									0	I
6-8-66		0	.01	.01	.01	.01	0	.03	.01	.01	.02	
6-25-66		.01	.02	.03	0	.03	.02	.03	.02	.03	.03	
8-4-66		.04	.06	.06	.03	.06	.05	.08	.05	.05	.09	
8-24-66		.05	.06	.08	.05	.08	-	-	-	-	.10	
10-4-66		.07	.13	.14	.07	.12	.07	.07	.08	.15	.14	
10-20-66		.08	.11	.12	.10	.12	-	-	-	-	.15	
11-1-66		.09	.11	.12	.11	.13	.08	.12	.09	.21	.18	
12-14-66		.10	.14	.15	.13	.15	.05	.06	.13	.24	.19	
1-10-67	0.11	.11	.16	.17	.15	.16	0	.05	.17	.26	.20	0.20
2-6-67		.12	.19	.26	.19	.12	-.01	.09	.22	.31	.22	
3-1-67	0.14	.14	.21	.28	.21	.14	.03	.13	.25	.32	.23	0.25
3-30-67		.14	.22	.29	.21	.15	0	.13	.25	.33	.24	
5-20-67		.15	.22	.29	.21	.15	-.01	.13	.25	.33	.25	
5-26-67	0.16											0.25
8-15-67		.17	.25	.31	.23	.17	.02	.15	.26	.35	.27	
8-24-67	0.18											0.26
11-16-67	0.17	.17	.23	.33	.26	.16	.07	.15	.28	.37	.29	0.29

"I" indicates initial reading.
*Estimated horizontal movement of HMI, in feet, obtained by interpolation of line survey data.
Positive values indicate movement toward outside of fill.
Negative values indicate movement toward centerline of fill.

Table 1C

Horizontal Movement at Elevation 2629±

Osito Canyon

Date	HMI C-L Line Survey	HMI C-L Est. Value*	Horizontal Movement at HMP 29	30	31-L	31-R	32	33	HMI C-R Est. Value*	HMI C-R Line Survey
8-26-66		0	I	I	I	I	I	I		
10-4-66		0	.02	.02	.02	-.02	-.02	0		
10-20-66		0	.01	0	0	-	-	-		
11-1-66		0	.01	.01	0	-.02	-.03	-.03	0	I**
12-14-66		0	0	0	0	.01	.02	.03	.05	
1-10-67	I	0	0	0	0	.02	.02	.04	.07	0.10
2-6-67		.02	.02	.03	.02	.03	.04	.06	.09	
3-1-67	0.04	.04	.03	.04	.04	.05	.07	.08	.12	0.15
3-30-67		.04	.03	.04	.04	.05	.08	.10	.13	
5-20-67		.05	.03	.04	.04	.06	.09	.11	.15	
5-26-67	0.05									0.15
8-15-67		.07	.05	.05	.05	.08	.11	.13	.17	
8-24-67	0.07									0.09
11-16-67	0.10	.10	.07	.08	.08	.08	.11	.15	.19	0.19

"I" indicates initial reading.
*Estimated horizontal movement of HMI, in feet, obtained by interpolation of line survey data.
Positive values indicate movement toward outside of fill.
Negative values indicate movement toward centerline of fill.
**Initial survey 11-18-66.

ClibPDF - www.fastio.com

Table 1D

Horizontal Movement at Elevation 2679±

Osito Canyon

Date	HMI D-L Line Survey	HMI D-L Est. Value*	Horizontal Movement at HMP Feet 35	36-L	36-R	37	HMI D-R Est. Value*	HMI D-R Line Survey
11-14-66			I	I	I	I		
11-18-66	I	0					0	I
1-10-67	0	-.03	-.03	-.02	-.08	-.08	-.08	
2-6-67		-.04	-.04	-.03	-.11	-.11	-.11	
3-1-67	-0.05	-.05	-.04	-.04	-.13	-.13	-.13	-0.13
3-30-67		-.05	-.04	-.02	-.13	-.15	-.14	
5-20-67		-.05	-.04	-.03	-.16	-.18	-.16	
5-26-67	-0.04							-0.16
8-15-67		-.05	-.05	-.03	-.19	-.20	-.17	
8-24-67	-							-0.17
11-16-67	I**	-.05	-.05	-.03	-.18	-.20	-.17	-0.17

"I" indicates initial reading.

*Estimated horizontal movement of HMI, in feet, obtained by interpolation of line survey data. Positive values indicate movement toward outside of fill. Negative values indicate movement toward centerline of fill.

**New initial reading; original tie lost.

ClibPDF - www.fastio.com

Table 2A

Settlement at Elevation 2537±

Osito Canyon

Date	HMI Survey Elev.	A-L Est.* Value	Settlement at SP Feet 4	3	2	1	Fill Elevation
3-27-66	2534.53	0	I	I	I	I	2536
3-29-66		0	0.03	+0.03	0.02	0.04	2541
4-15-66		0.01	0.03	0.07	0.21	0.13	2543
4-28-66		0.01	0.08	0.15	0.39	0.20	2556
5-18-66	2534.41	0.01	0.11	0.37		0.31	2576
5-26-66		0.01	0.15	0.45	0.62	0.31	2580
6-8-66		0.02	0.20	0.59	0.77	0.37	2592
6-25-66		0.02	0.20	0.67	0.98	0.52	2601
8-4-66		0.02	0.22	0.95		0.68	2611
8-24-66		0.02	0.26	1.11		0.78	2631
10-4-66		0.03	0.31	1.50	1.95		2646
10-20-66		0.03	0.28	1.59	2.04	0.97	2661
11-1-66		0.03	0.28	1.69	2.10	1.07	2675
12-14-66		0.04	0.30			1.24	2710
1-10-67	2534.48	0.04	0.34	1.96		1.37	2730
3-1-67	2534.49	0.04	0.33	2.01		1.35	↓
5-20-67	2534.48	0.05	0.33	2.10		1.40	
8-19-67		0.06	0.33	2.15		1.44	
8-24-67	2534.47	0.06					
11-15-67	2534.46	0.07	0.41				

"I" indicates initial reading.

*Estimated settlement of SP, in feet, obtained by interpolation of survey data. Positive value indicates a rise in ground level.

ClibPDF - www.fastio.com

Table 2B

Settlement at Elevation 2577±

Osito Canyon

Date	HMI Survey Elev.	B-L Est.* Value	Settlement at SP Feet 24	23	15	HMI Est.* Value	B-R Survey Elev.
5-26-66	2575.02	0	I	I	I	0	2575.12
6-8-66	2575.03	0.04	-	0.08	-	0.01	2575.12
6-25-66		0.06	0.19	0.33	.09	0.01	
8-4-66		0.11	1.18	0.70	.37	0.02	
8-24-66		0.12	1.30	0.90	-	0.02	
10-4-66		0.15	1.75	1.48	.86	0.04	
10-20-66		0.16	-	1.68	-	0.04	
11-1-66		0.16		1.86	1.14	0.04	
12-14-66		0.18		2.37	1.38	0.05	
1-10-67	2574.84	0.19			1.51	0.05	2575.07
3-1-67	2574.84	0.19	OUT	2.76	1.57	0.06	2575.06
5-20-67	2574.83	0.20		2.88	1.59	0.07	2575.04
8-19-67		0.21			1.70	0.08	
8-24-67	2574.82						2575.04
11-15-67	2574.81	0.21			1.73	0.08	2576.05

"I" indicates initial reading.
*Estimated settlement of SP, in feet, obtained by interpolation of survey data.

ClibPDF - www.fastio.com

Table 2C

Settlement at Elevation 2629±

Osito Canyon

Date	HMI Survey Elev.	C-L Est.* Value	Settlement at SP Feet 26	27	28	HMI Est.* Value	C-R Survey Elev.
8-26-66	2625.83	0	I	I	I	0	2628.16
10-4-66		0.26	0.60	0.62	0.50	0.11	
10-20-66		0.32	.	0.80		0.16	
11-1-66		0.35			0.80	0.18	
11-13-66							2627.93
12-14-66		0.50	1.27	1.73	1.06	0.22	
1-10-67	2625.26	0.56		1.99	1.26	0.27	2627.85
3-1-67	2625.23	0.61	1.54		1.31	0.30	2627.85
5-20-67	2625.13	0.70	1.63	2.32	1.40	0.34	2627.80
8-19-67		0.74	1.70	2.32		0.37	
8-24-67	2625.09						2627.77
11-16-67	2625.06	0.77	1.72			0.39	2627.77

"I" indicates initial reading.
*Estimated settlement of SP, in feet, obtained by interpolation of survey data.
Positive value indicates a rise in ground level.

ClibPDF - www.fastio.com

Table 2D

Settlement at Elevation 2679±

Osito Canyon

Date	HMI D-L Survey Elev.	HMI D-L Est.* Value	Settlement at SP feet 34	HMI D-R Est.* Value	HMI D-R Survey Elev.
11-3-66		0	I	0	2675.96
11-13-66	2676.72				2675.81
12-14-66		0.42	0.86	0.40	
1-10-67	2676.32	0.52		0.50	2675.42
3-1-67	2676.27	0.60	1.42	0.59	2675.37
5-20-67	2676.18	0.69	1.58	0.68	2675.28
8-19-67		0.75		0.73	
8-24-67	2676.12				2675.21
11-15-67	2676.08	0.79	1.84	0.78	2675.20

"I" indicates initial reading.
*Estimated settlement of SP, in feet, obtained by interpolation of survey data.

ClibPDF - www.fastio.com

Table 3A

Horizontal Movement at Elevation 2558±

No Name Canyon

Date	HMI A-L Line Survey	HMI A-L Est.* Value	Horizontal Movement at HMP Feet 11	10	9	8	7	6	5	Fill Elevation
5-26-66		0	I	I	I	I	I	I	I	2583
6-26-66		0	.01	0	-.01	0	0	.02	.01	↓
8-1-66	I	0								
8-26-66		0	0	0	0	0	0	0	.01	
3-2-67	0.06									2635
3-30-67		.08	.09	.09	.09	.08	.08	.08	.09	2644
5-20-67		.13	.16	.15	.15	.14	.14	.14	.15	2685
5-23-67	0.13	.13								2686
8-15-67		.23	.33	.32	.32	.20	.21	.21		2725
8-24-67	0.30									↓
11-9-67	0.30									
11-15-67		.30	.40	.40	.40	.28	.28	.28	.29	

"I" indicates initial reading.
*Estimated horizontal movement of HMI, in feet, obtained by interpolation of line survey data. Positive values indicate movement toward downhill (left) side of embankment.

ClibPDF - www.fastio.com

Table 3B

Horizontal Movement at Elevation 2605±

No Name Canyon

Date	HMI Line Survey	B-L Est.* Value	Horizontal Movement at HMP Feet 21	20	19	18	17	16	15
2-6-67		0	I	I	I	I	I	I	I
2-8-67	I	0	-.02	0	0	.01	.01	0	0
3-1-67	0.02	.04	.04	.06	.06	.06	.06	.05	.05
3-30-67		.09	.11	.10	.10	.11	.12	.10	.11
4-17-67	0.05								
5-20-67		.19	-	.22	.17	.18	.19	.18	.18
5-23-67	0.19	.19							
8-15-67		.40	.45	.29	.44				
8-24-67	0.43								
11-9-67	0.44								
11-15-67		.44	.51	.36	.50	.16	.18	.18	.21

"I" indicates initial reading.
*Estimated horizontal movement of HMI, in feet, obtained by interpolation of line survey data.
Positive values indicate movement toward downhill (left) side of embankment.

ClibPDF - www.fastio.com

Table 3C

Horizontal Movement at Elevation 2645±

No Name Canyon

Date	HMI C-L Line Survey	HMI C-L Est.* Value	Horizontal Movement at HMP Feet 29	28	27L	27R	26	25	HMI C-R Est.* Value	HMI C-R Line Survey
3-30-67	I	0	I	I	I	I	I	I		
4-5-67									0	I
5-20-67		.03	.03	.04	.04				.04	.04
5-23-67	0.03									
8-15-67		.18	.17	.16	.09	.19	.11	.06	.05	
8-24-67	0.21									0.05
11-9-67	0.22									0.05
11-15-67		.23	.21	.20	.12	.22	.12	.06	.05	

"I" indicates initial reading.
* Estimated horizontal movement of HMI, in feet, obtained by interpolation of line survey data. Postive values indicate movement toward outside of fill.

ClibPDF - www.fastio.com

Table 3D

Horizontal Movement at Elevation 2685±

No Name Canyon

Date	HMI D-L Line Survey	HMI D-L Est.* Value	Horizontal Movement at HMP Feet: 32	31L	31R	30	HMI D-R Est.* Value	HMI D-R Line Survey
5-20-67	I	0	I	I	I	I	0	I
8-15-67		-.01	.02	.02	0	-.01		
8-23-67	-0.01						0	I**
11-9-67	-0.02							0.02
11-15-67		-.02	-.01	-.01	.02	-.08	.02	

"I" indicates initial reading.
*Estimated horizontal movement of HMI, in feet, obtained by interpolation of line survey data.
Positive values indicate movement away from centerline of fill.
**Original tie point lost - new initial reading established.

ClibPDF - www.fastio.com

Table 4A

Settlement at Elevation 2558±

No Name Canyon

Date	HMI Survey Elev.	A-L Est.* Value	Settlement at SP Feet 4	3	2	1	Fill Elevation
10-14-65		0	I	I	I	I	2583
5-26-66		0	.91		.28	.73	↓
6-26-66		0	1.02		.35	.83	
8-1-66	2556.26(I)	0					
8-26-66		0.01	.88		.40	.77	
2-8-67	2556.16	0.10					2624
3-2-67	2556.15	0.11					2635
3-30-67		0.12	1.21		1.87	1.57	2644
4-6-67	2556.14	0.12					-
5-20-67	2556.14	0.12	1.35			1.84	2685
8-19-67		0.13				2.12	2725
11-9-67	2556.15	0.14					↓
11-15-67		0.14	1.59			2.18	

"I" indicates initial reading.
*Estimated settlement of SP, in feet, obtained by interpolation of survey data.

ClibPDF - www.fastio.com

Table 4B

Settlement at Elevation 2605±

No Name Canyon

Date	HMI Survey Elev.	B-L Est.* Value	Settlement at SP Feet 14	Settlement at SP Feet 13	Settlement at SP Feet 12
2-1-67	2602.63(I)	0	I	I	I
2-8-67	2602.60	0.03	0.14	0.07	0.06
3-1-67	2602.41	0.22		0.42	0.30
3-30-67		0.30	0.91	0.61	0.49
4-6-67	2602.33	0.33			
5-20-67	2602.20	0.43	1.51	1.34	
8-19-67	2602.08	0.51	2.02	2.13	
11-9-67	2602.08	0.55			
11-15-67		0.56	2.12	2.23	1.19

"I" indicates initial reading.
*Estimated settlement of SP, in feet, obtained by interpolation of survey data.

ClibPDF - www.fastio.com

Table 4C

Settlement at Elevation 2645±

No Name Canyon

Date	HMI C-L Survey Elev.	HMI C-L Est.* Value	Settlement at SP Feet 24	Settlement at SP Feet 23	Settlement at SP Feet 22	HMI C-R Est.* Value	HMI C-R Survey Elev.
3-30-67	2643.17(I)	0	I	I	I	0	2643.09(I)
4-6-67	2643.15	0.02				0.11	2642.94
5-20-67	2642.77	0.36	0.74	1.11	0.79	0.33	2642.76
8-19-67	2642.50	0.59	1.31		1.31	0.47	2642.62
11-9-67	2642.47	0.70				0.49	2642.60
11-15-67		0.70	1.40	2.30	1.36	0.49	

"I" indicates initial reading.
*Estimated settlement of SP, in feet, obtained by interpolation of survey data.

ClibPDF - www.fastio.com

Table 4D

Settlement at Elevation 2685±

No Name Canyon

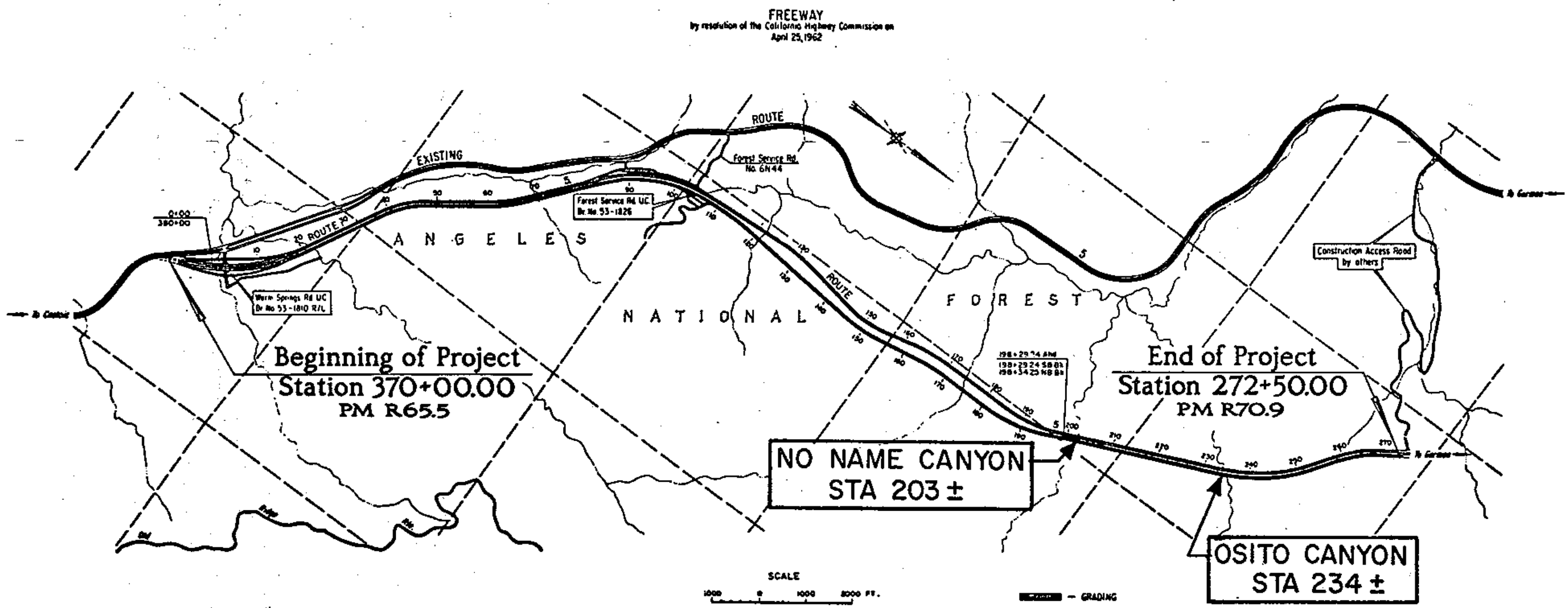
Date	HMI D-L		Settlement at SP	HMI D-R	
	Survey Elev.	Est.* Value	Feet 33	Est.* Value	Survey Elev.
5-25-67	2682.93(I)	0	I	0	2682.87(I)
8-19-67	2682.19	0.65		0.58	2682.49
11-9-67	2682.13	0.80		0.64	2682.43
11-15-67		0.80		0.64	

"I" indicates initial reading.
*Estimated settlement of SP, in feet, obtained by interpolation of survey data.

ClibPDF - www.fastio.com

FIGURE 1

In Los Angeles County between 6.9 and 12.3 miles north of Castaic



Length of Project = 5.4 miles

ClibPDF - www.fastio.com

Figure 2. Instrument shelter in place at Osito Canyon Fill.

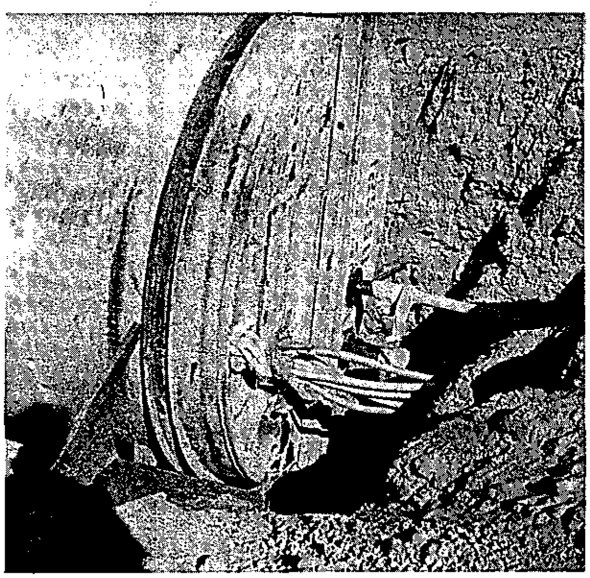


Figure 3. Rear view of instrument shelter. Instrumentation tubing and lines emerge from trench at right and enter rear of shelter.

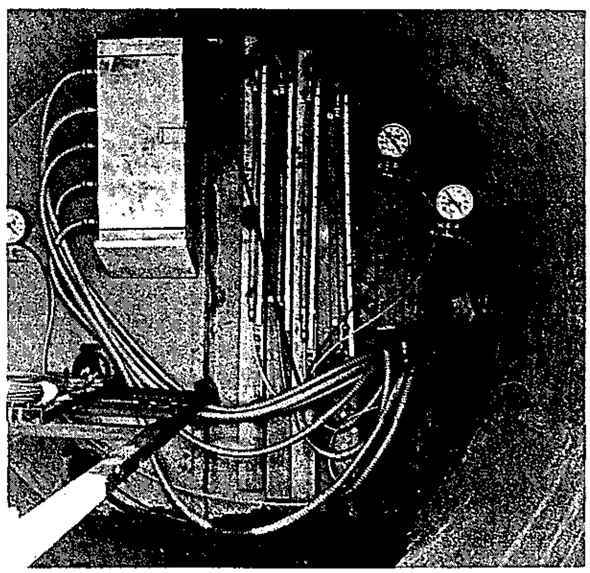
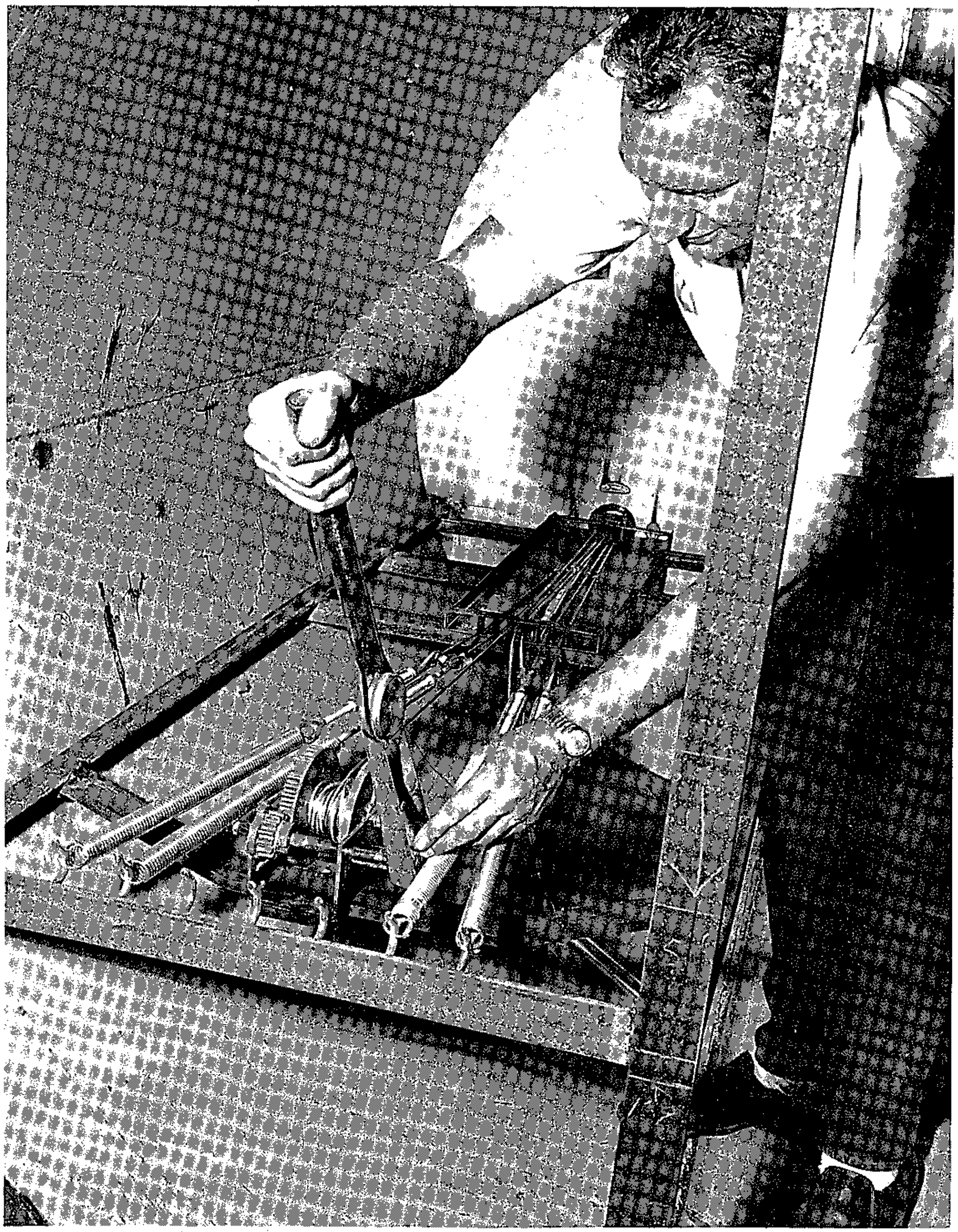


Figure 4. Interior of shelter. Metal frame at lower left supports horizontal movement cables tensioning device and foot-rule for reading purposes.

ClibPDF - www.fastio.com

Figure 5



Tension being applied to
horizontal movement cables.

ClibPDF - www.fastio.com

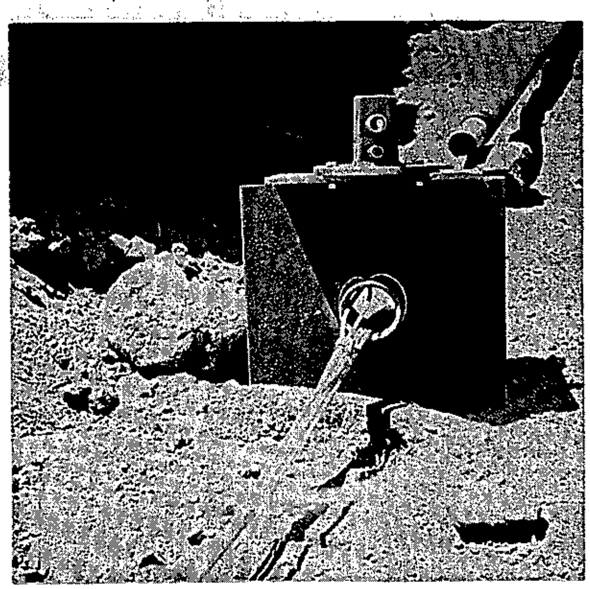
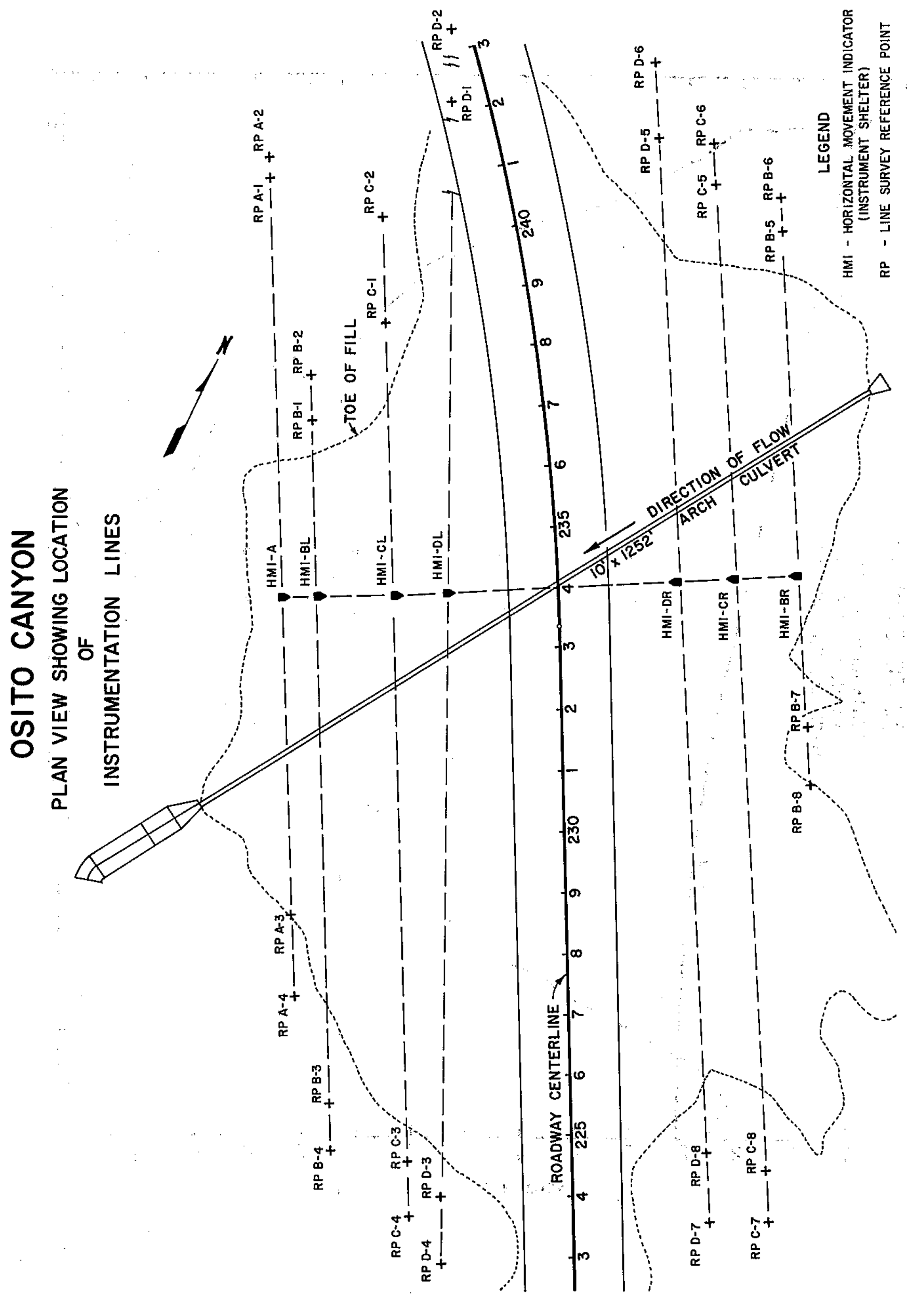


Figure 6. Horizontal movement platform with base of fluid-level type settlement platform riser attached.

Figure 7. Completed unit of horizontal movement platform and settlement platform ready to be backfilled with select rock-free material.

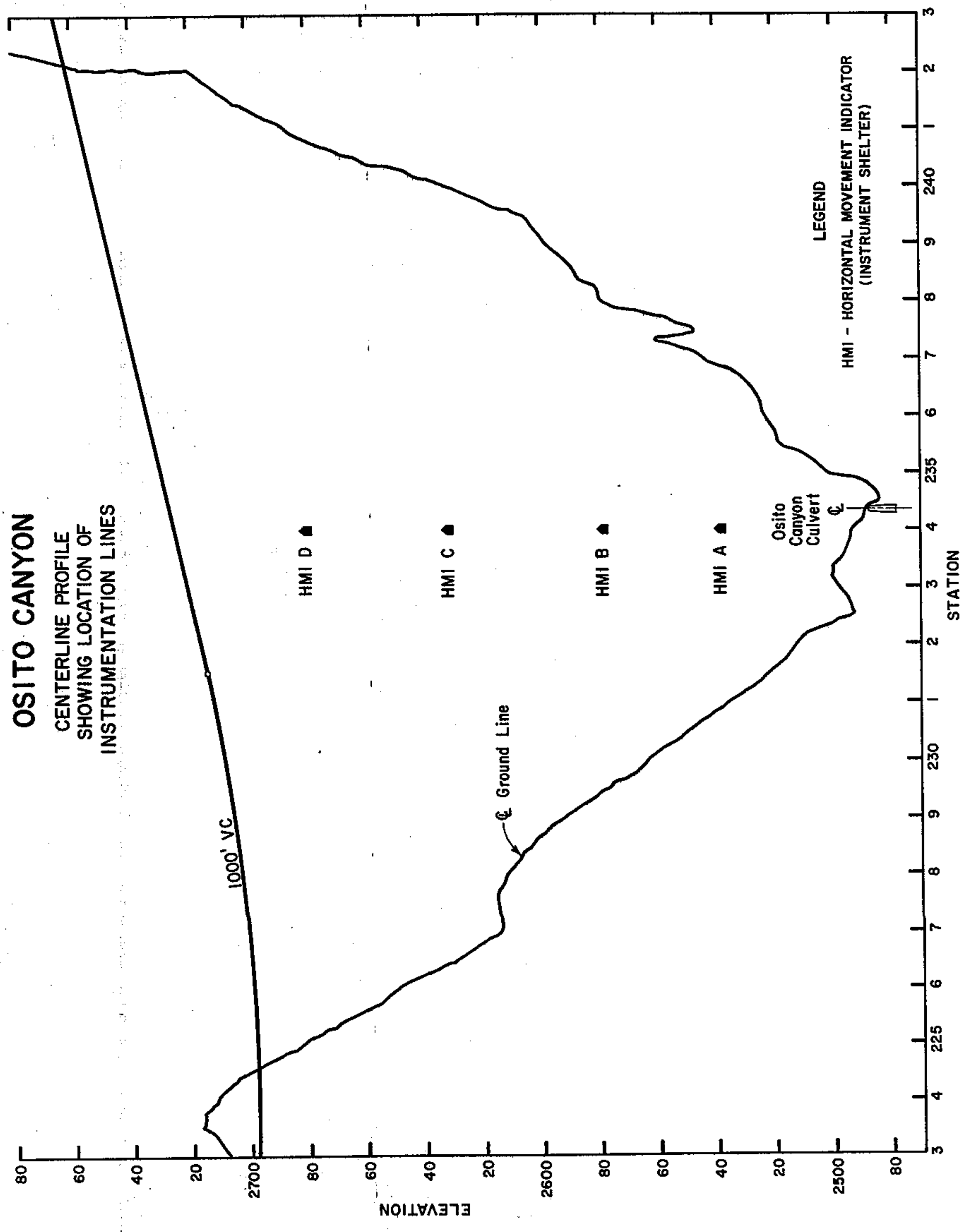
ClibPDF - www.fastio.com

Figure 8



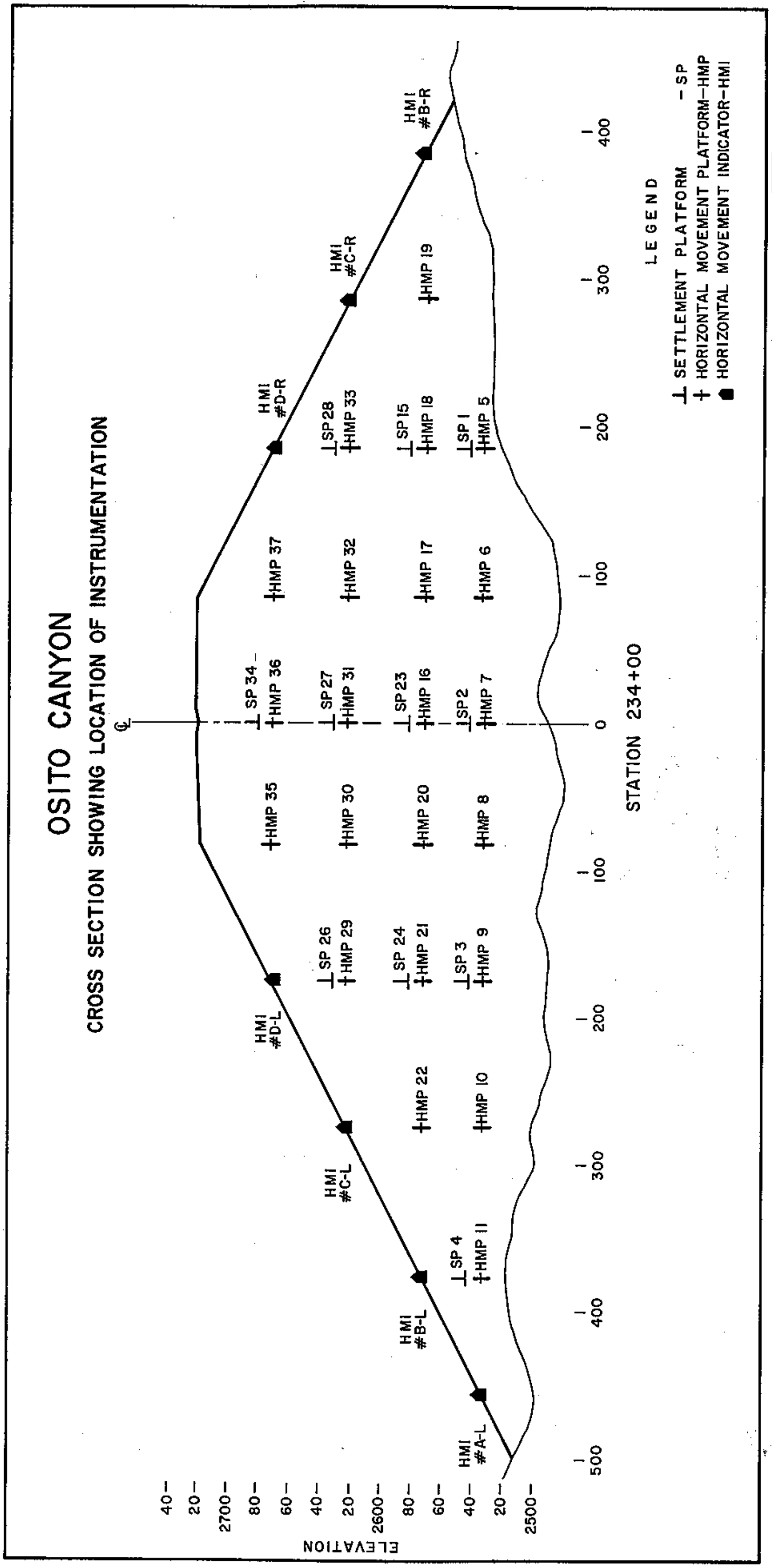
ClibPDF - www.fastio.com

Figure 9



ClibPDF - www.fastio.com

Figure 10



ClibPDF - www.fastio.com

Figure 11

OSITO CANYON
RATE OF HORIZONTAL MOVEMENT COMPARED WITH FILL LOADING

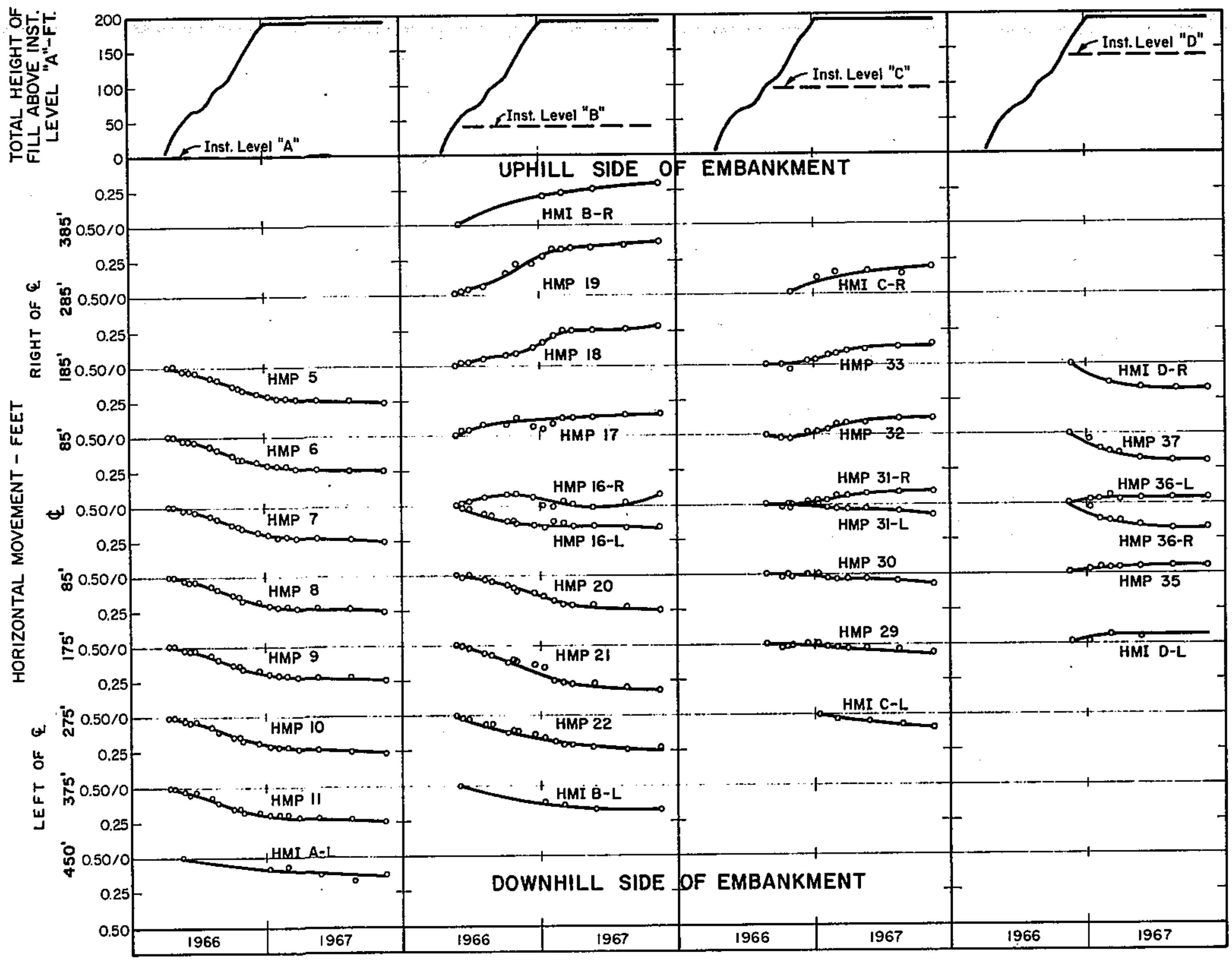


Figure 12

OSITO CANYON

HORIZONTAL MOVEMENT BETWEEN LINES OF INSTRUMENTATION
FOR VARIOUS HEIGHTS OF FILL

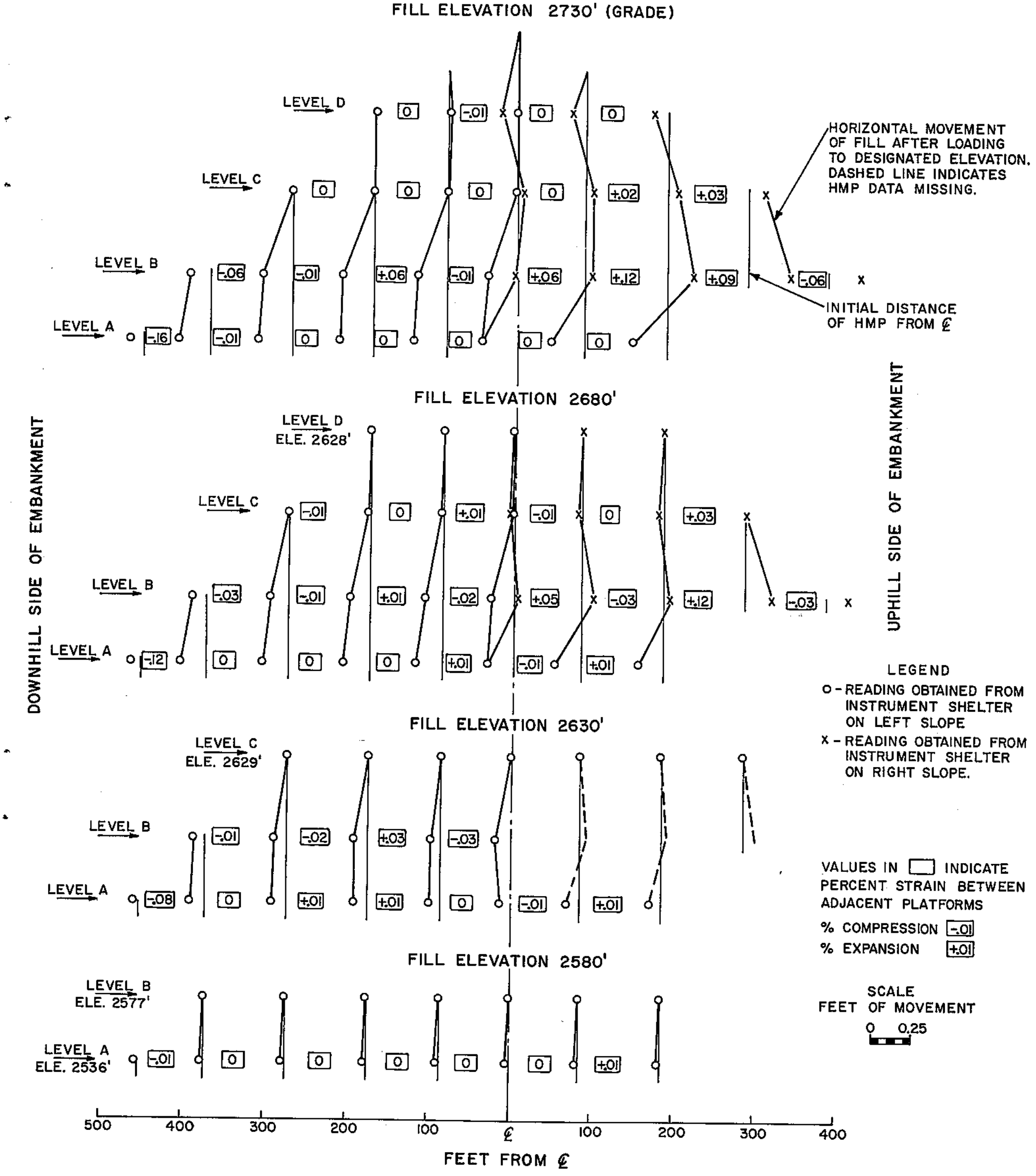
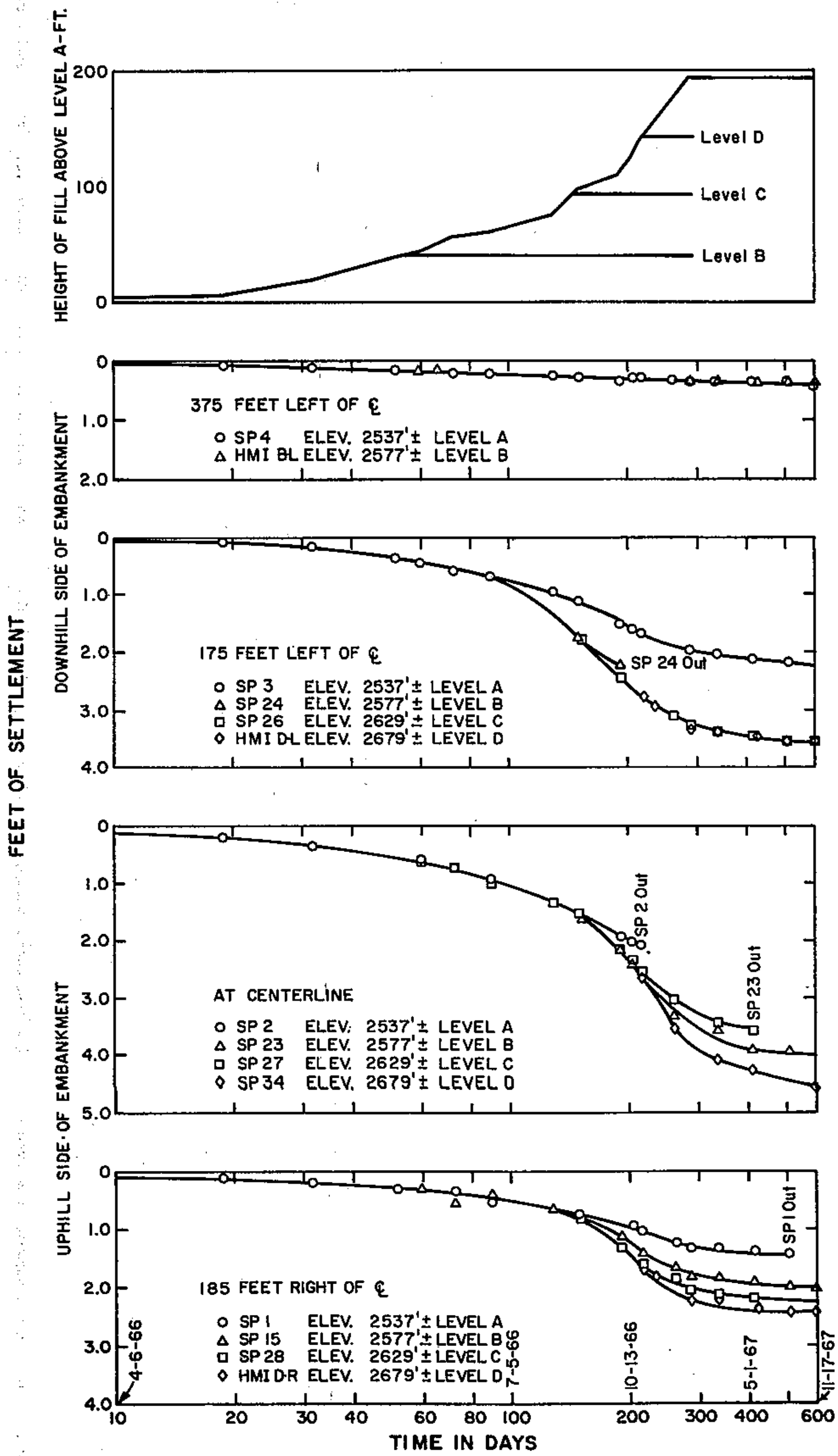


Figure 13

OSITO CANYON
RATE OF SETTLEMENT
COMPARED WITH FILL LOADING

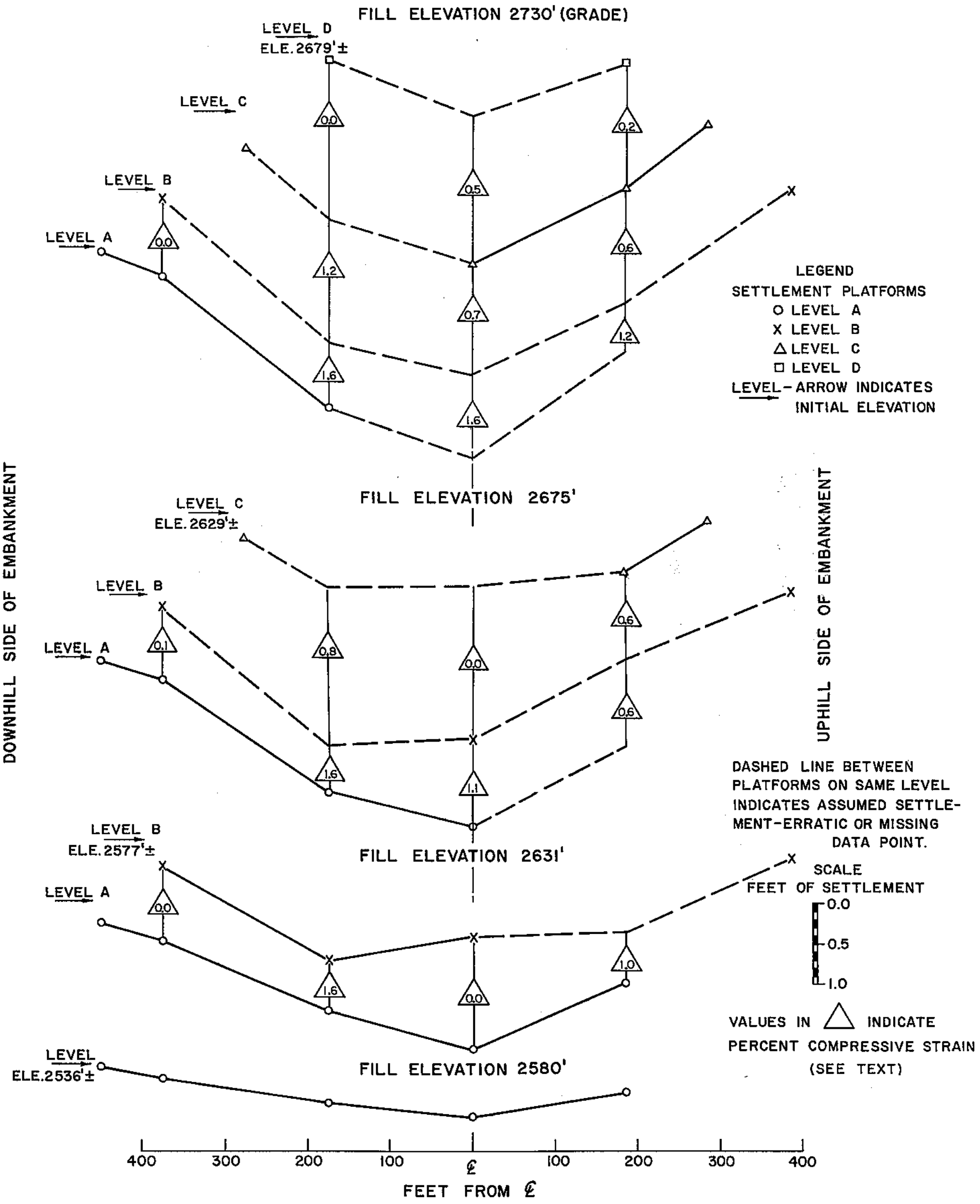


ClibPDF - www.fastio.com

Figure 14

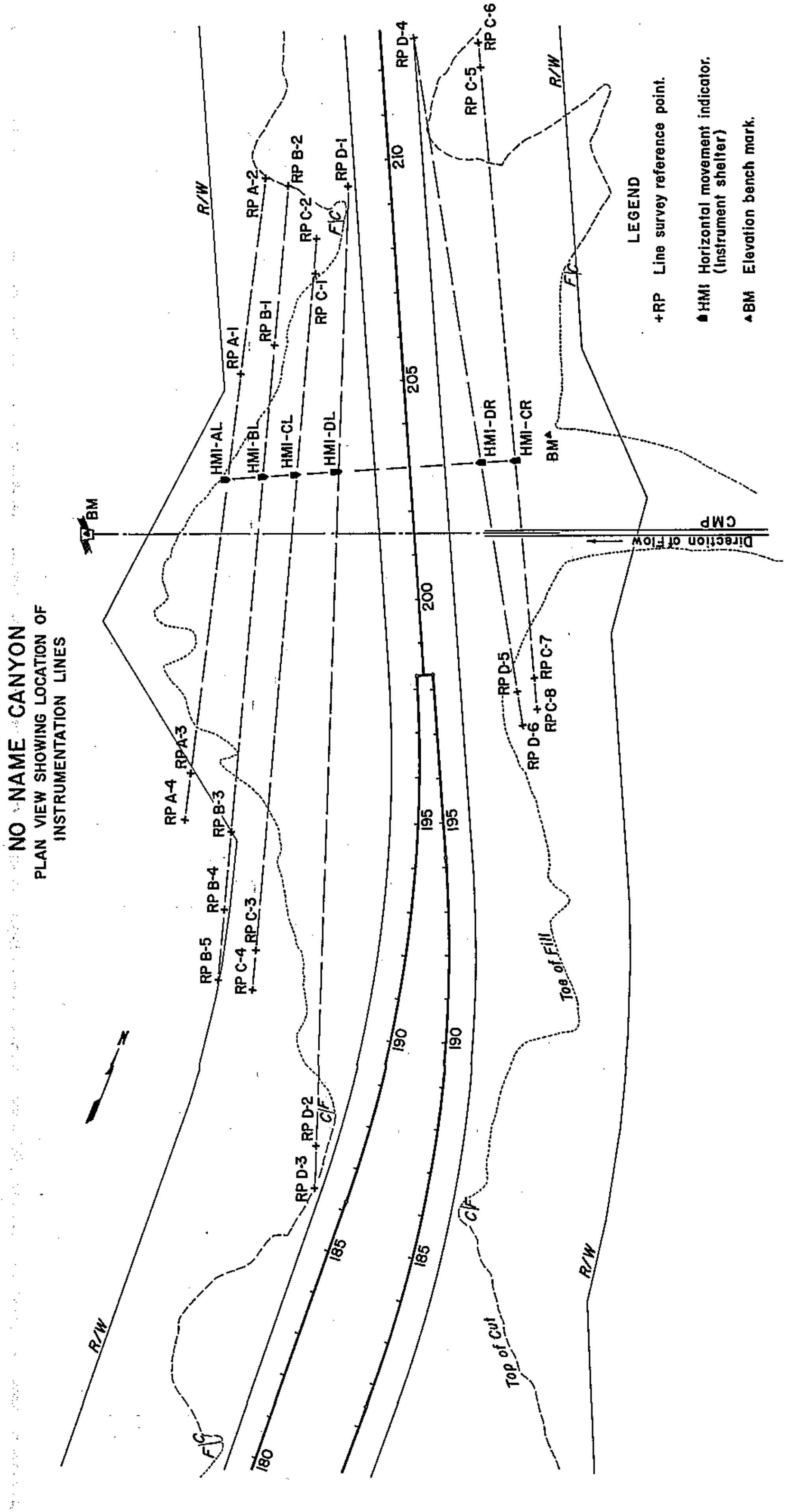
OSITO CANYON

SETTLEMENT ALONG LINES OF INSTRUMENTATION FOR VARIOUS HEIGHTS OF FILL



ClibPDF - www.fastio.com

Figure 15



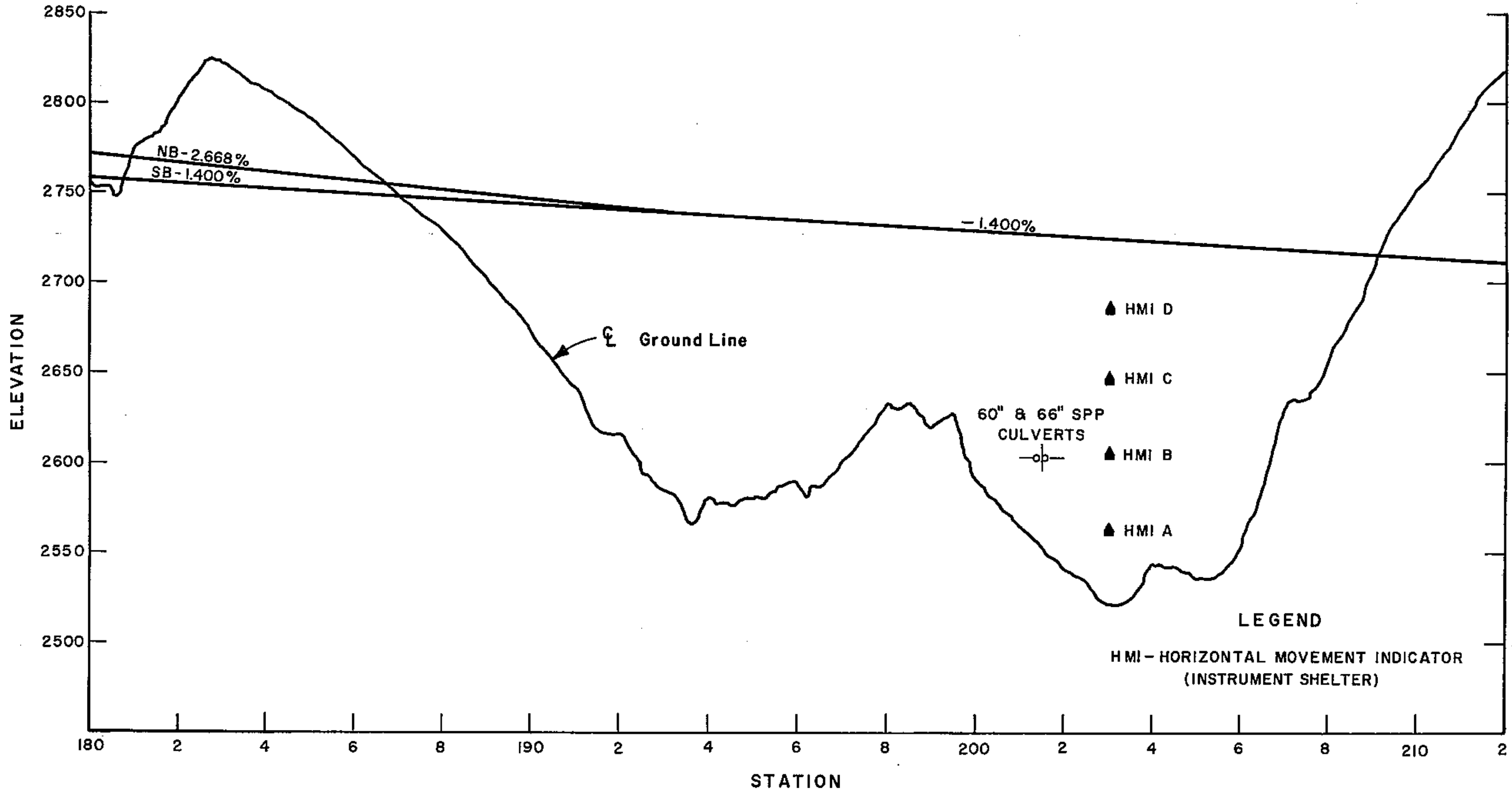
NO NAME CANYON
PLAN VIEW SHOWING LOCATION OF INSTRUMENTATION LINES

ClibPDF - www.fastio.com

Figure 16

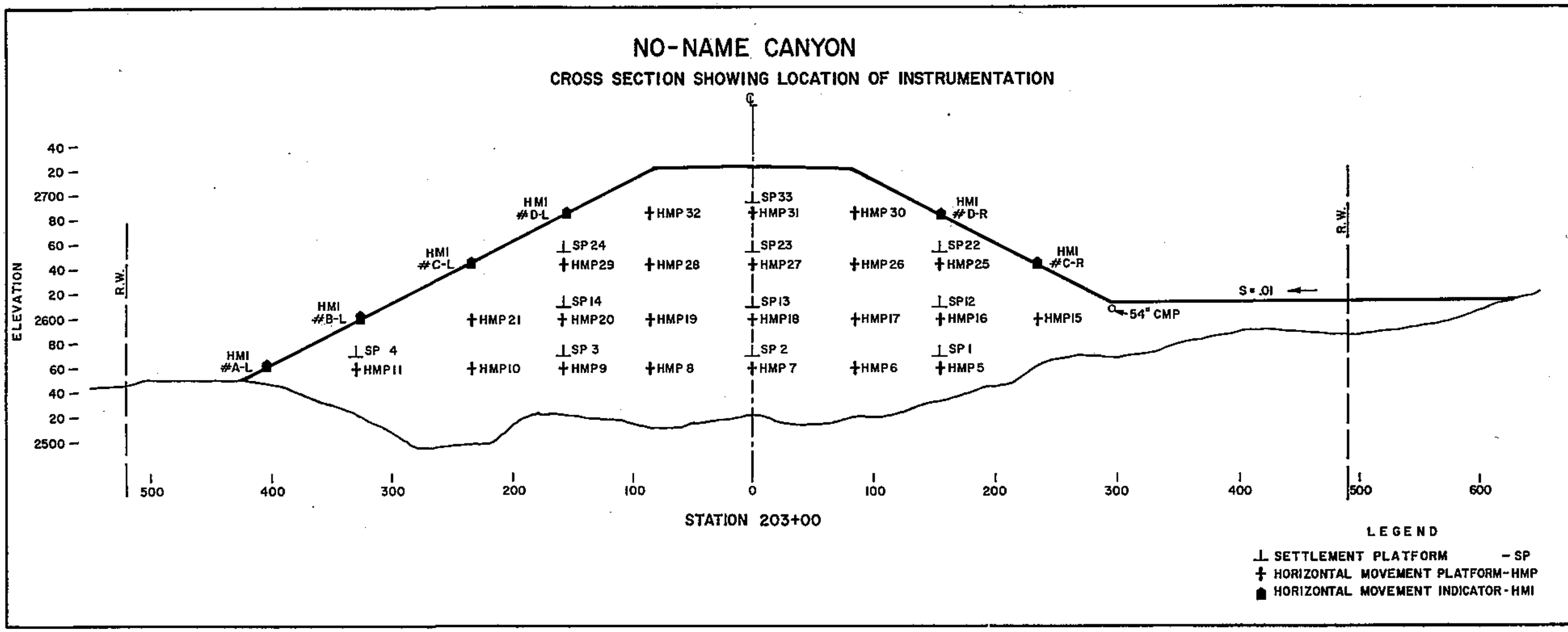
NO NAME CANYON

CENTERLINE PROFILE
SHOWING LOCATION OF
INSTRUMENTATION LINES



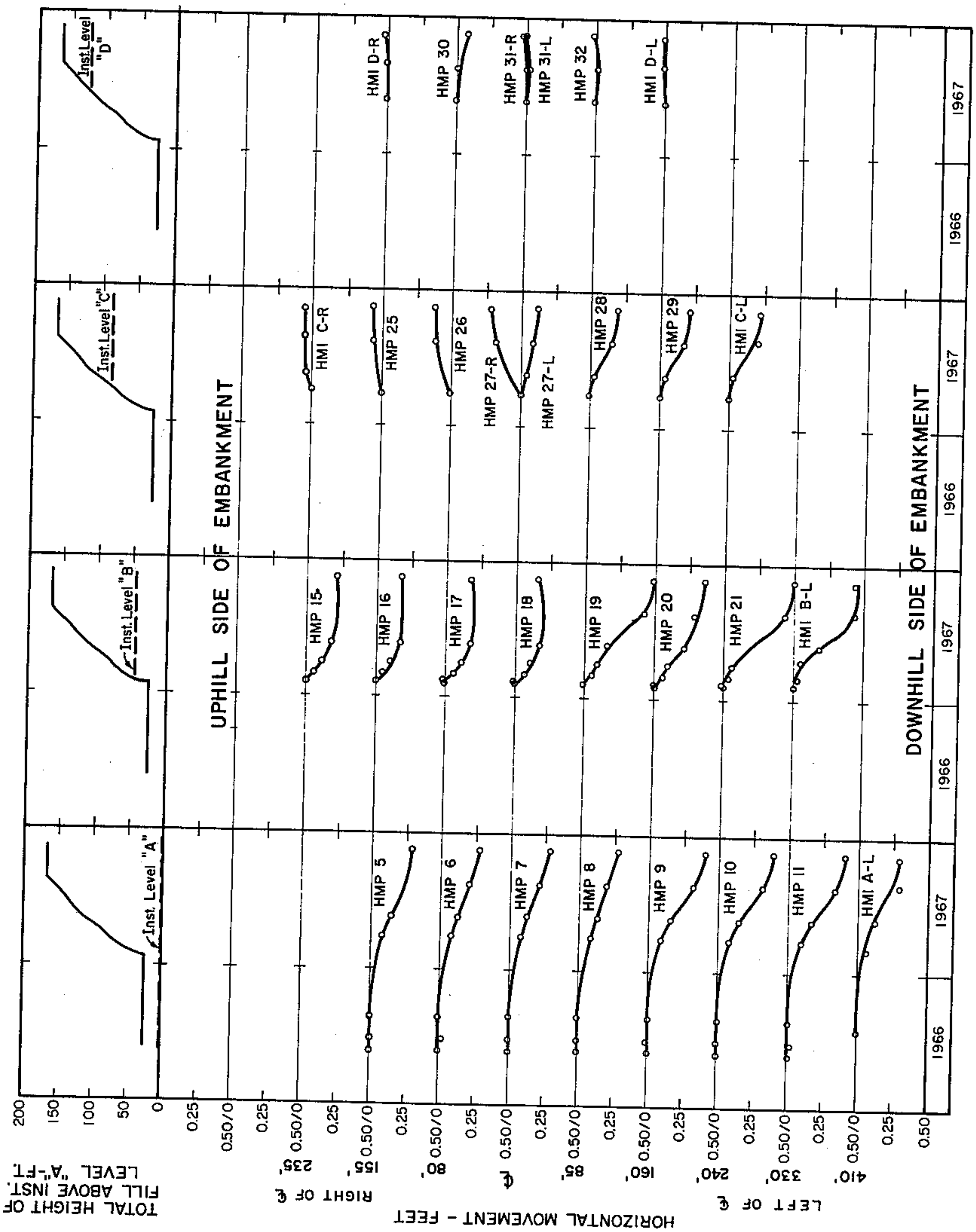
ClibPDF - www.fastio.com

Figure 17



NO-NAME CANYON
CROSS SECTION SHOWING LOCATION OF INSTRUMENTATION
ELEVATION
40
20
2700
80
60
40
20
2600
80
60
40
20
2500
R.W.
HMI #A-L
HMI #B-L
HMI #C-L
HMI #D-L
HMI #D-R
HMI #C-R
SP 4
HMP11
HMP10
HMP21
SP 3
HMP9
SP14
HMP20
SP24
HMP29
HMP 8
HMP19
HMP28
HMP32
SP33
HMP31
SP23
HMP27
SP13
HMP18
SP 2
HMP 7
HMP30
HMP26
HMP17
HMP6
SP22
HMP25
SP12
HMP16
SP 1
HMP5
HMP15
54" CMP
S = .01
R.W.
500
400
300
200
100
0
100
200
300
400
500
600
STATION 203+00
LEGEND
SETTLEMENT PLATFORM - SP
HORIZONTAL MOVEMENT PLATFORM - HMP
HORIZONTAL MOVEMENT INDICATOR - HMI

Figure 18

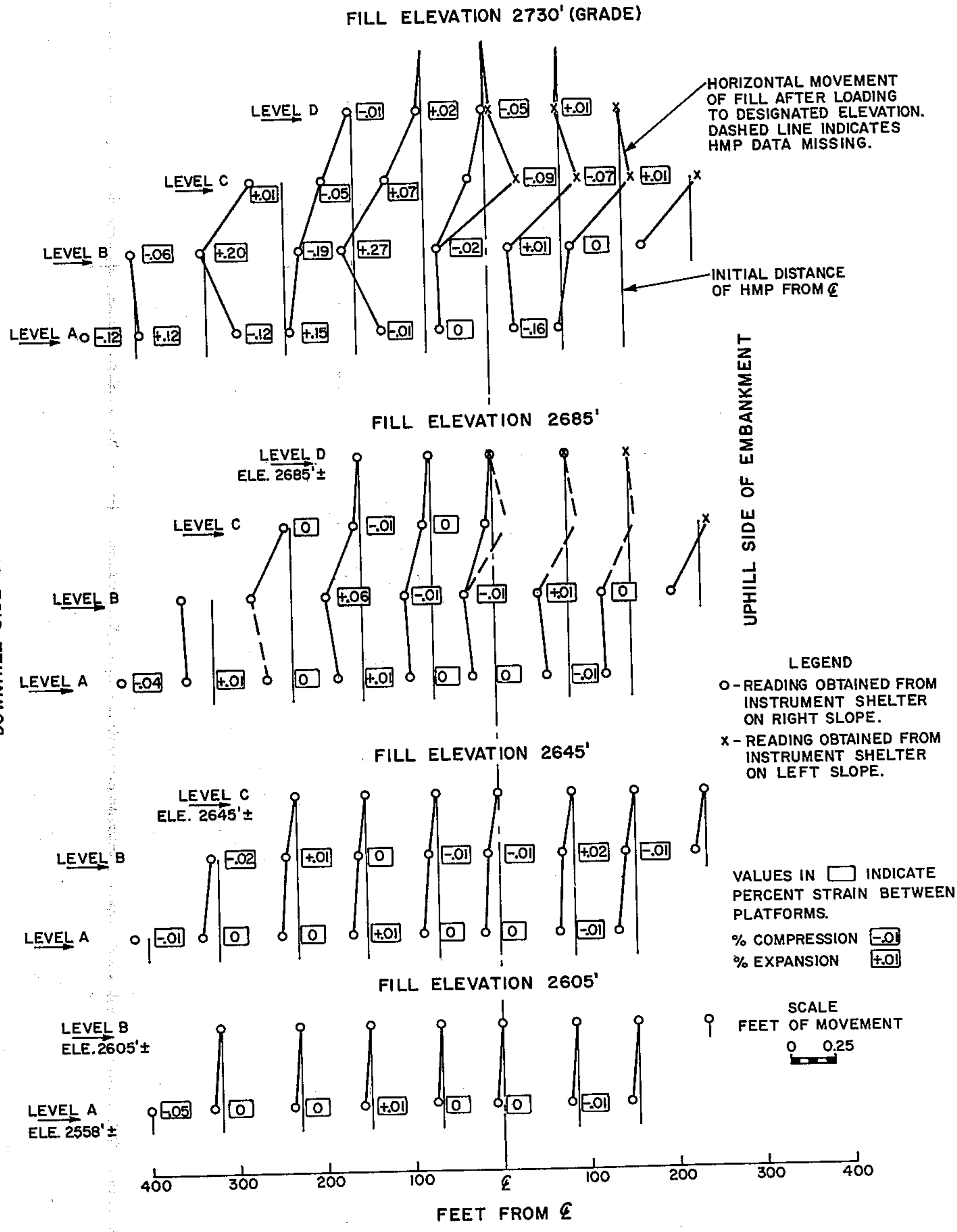


ClibPDF - www.fastio.com

Figure 19

NO-NAME CANYON

HORIZONTAL MOVEMENT BETWEEN LINES OF INSTRUMENTATION FOR VARIOUS HEIGHTS OF FILL



ClibPDF - www.fastio.com

Figure 20

NO NAME CANYON

RATE OF SETTLEMENT

COMPARED WITH FILL LOADING

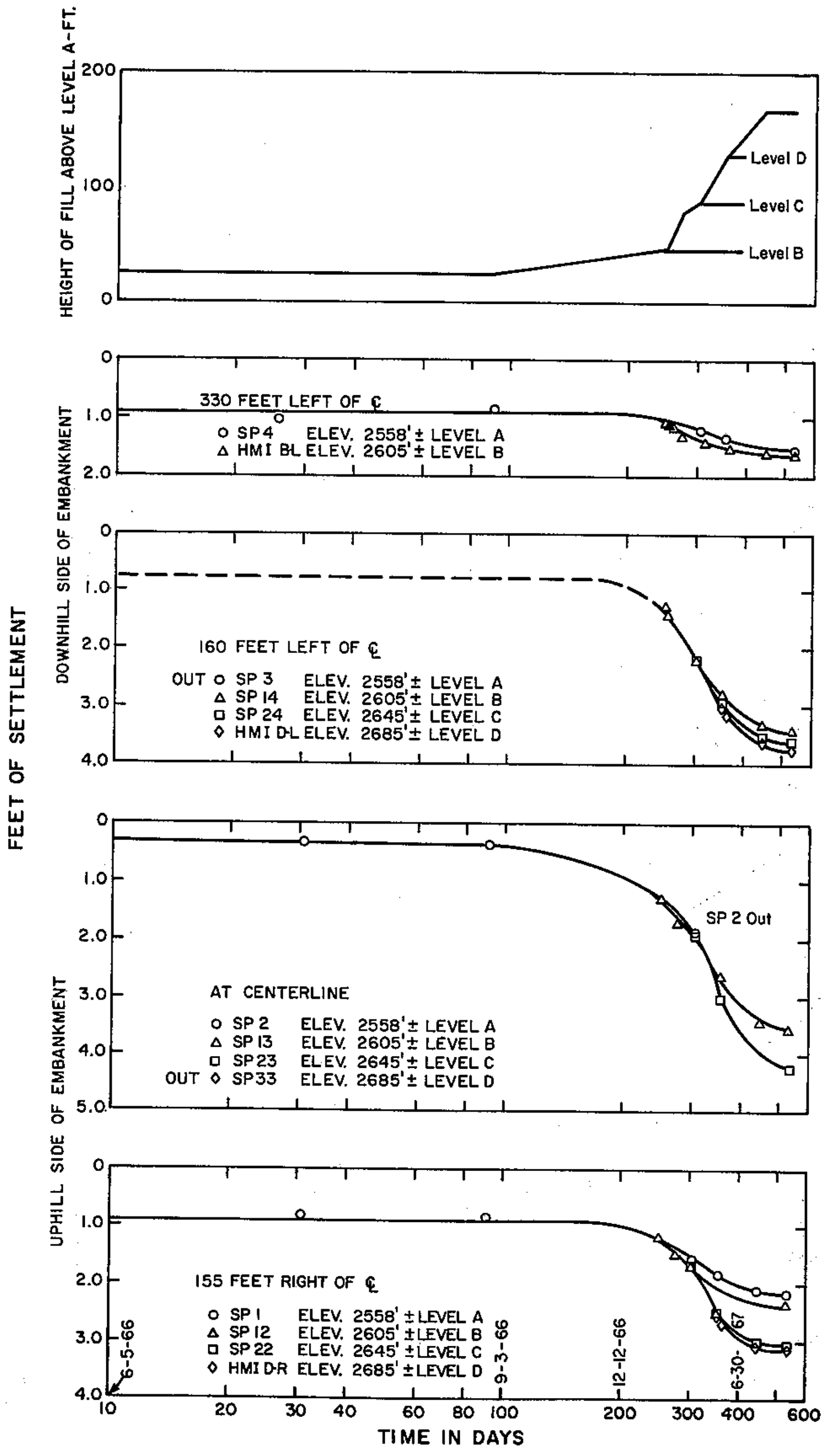
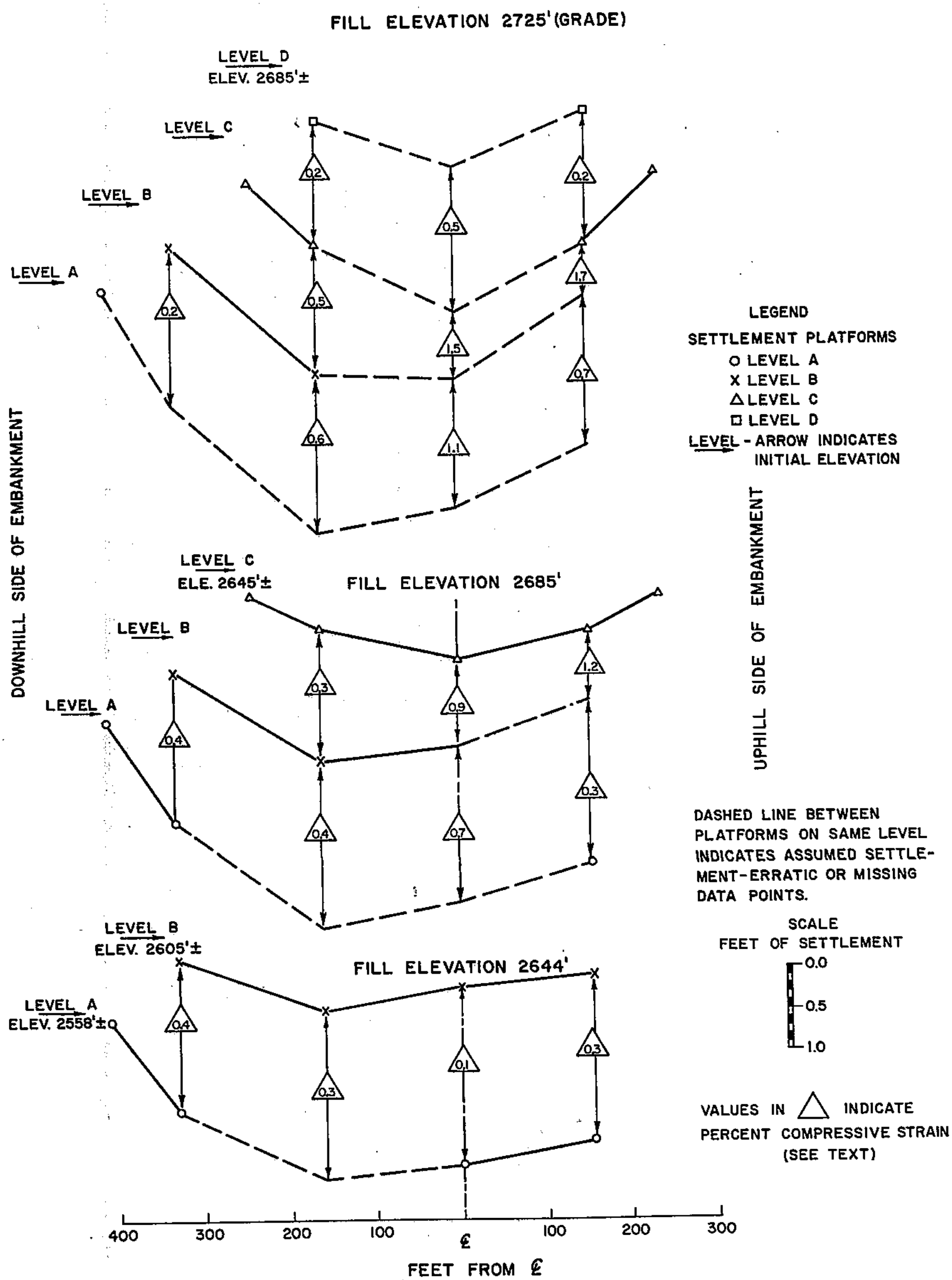


Figure 21

NO NAME CANYON

SETTLEMENT ALONG LINES OF INSTRUMENTATION
FOR VARIOUS HEIGHTS OF FILL



ClibPDF - www.fastio.com

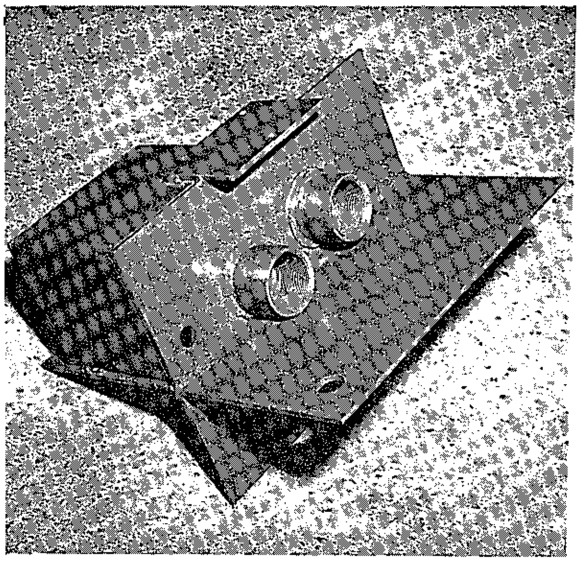


Fig. 22 - New type horizontal movement platform with box for housing potentiometer to measure horizontal strain by electrical resistivity.

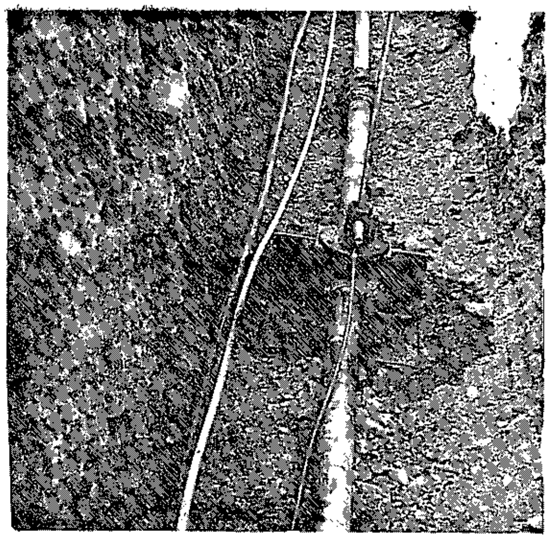


Fig. 23 - Typical installation of new type horizontal movement platform with settlement device partially assembled on top (electrical reading device omitted).

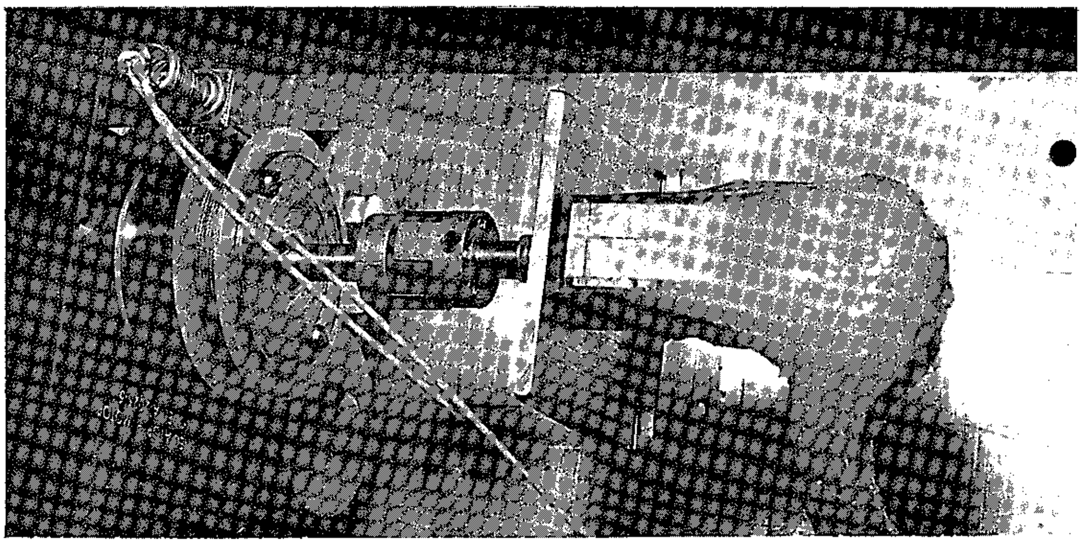


Fig. 24 - Potentiometer and associated equipment removed from horizontal movement platform.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com