Technical Report Documentation Page

1. REPORT No.
FHWA-CA-TL-78-05

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE
Long Term Field Behavior of A Reinforced Earth Wall

5. REPORT DATE
February 1978

6. PERFORMING ORGANIZATION

7. AUTHOR(S)
Jerry C. Chang

8. PERFORMING ORGANIZATION REPORT No.
19202-632166

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Office of Transportation Laboratory
California Department of Transportation
Sacramento, California 95819

10. WORK UNIT No.

11. CONTRACT OR GRANT No.
D-4-143

12. SPONSORING AGENCY NAME AND ADDRESS
California Department of Transportation
Sacramento, California 95807

13. TYPE OF REPORT & PERIOD COVERED
Interim

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration for the research project "Continue Monitoring the Field Instrumentation in the Reinforced Earth Fill on Route 39 (Type B Study)".

16. ABSTRACT
This interim report presents the additional field data observed from November 1974 through June 1977 at the reinforced earth wall on Route 39 in Los Angeles County. The field instrumentation was installed between August and October 1972 for a previous research project titled "Earthwork Reinforcement Techniques" which was reported in November 1974 for the field data obtained through June 1973. The additional data collected since November 1974 indicated that the south wing of the reinforced earth wall has moved continuously outward. The strains in some of the steel strips have also increased continuously and now exceed the proportional limit. It is believed that this excessive straining is related to the following factors:

1. Additional load from the continuous deposit of slide debris on top of and behind the wall.
2. Additional seepage pressure behind the wall because the subsurface drainage system may have been disrupted due to large vertical and horizontal movements of the foundation slide debris and percolation of surface runoff from behind the wall directly through the fill rather than the cross drain.
3. Portions of the toe berm for the south wind of the reinforced earth wall and the embankment slope below the wall have been eroded by several winter storms.

17. KEYWORDS
Reinforced earth, reinforcing strip, stress-strains, movement, stability

18. No. OF PAGES:
75

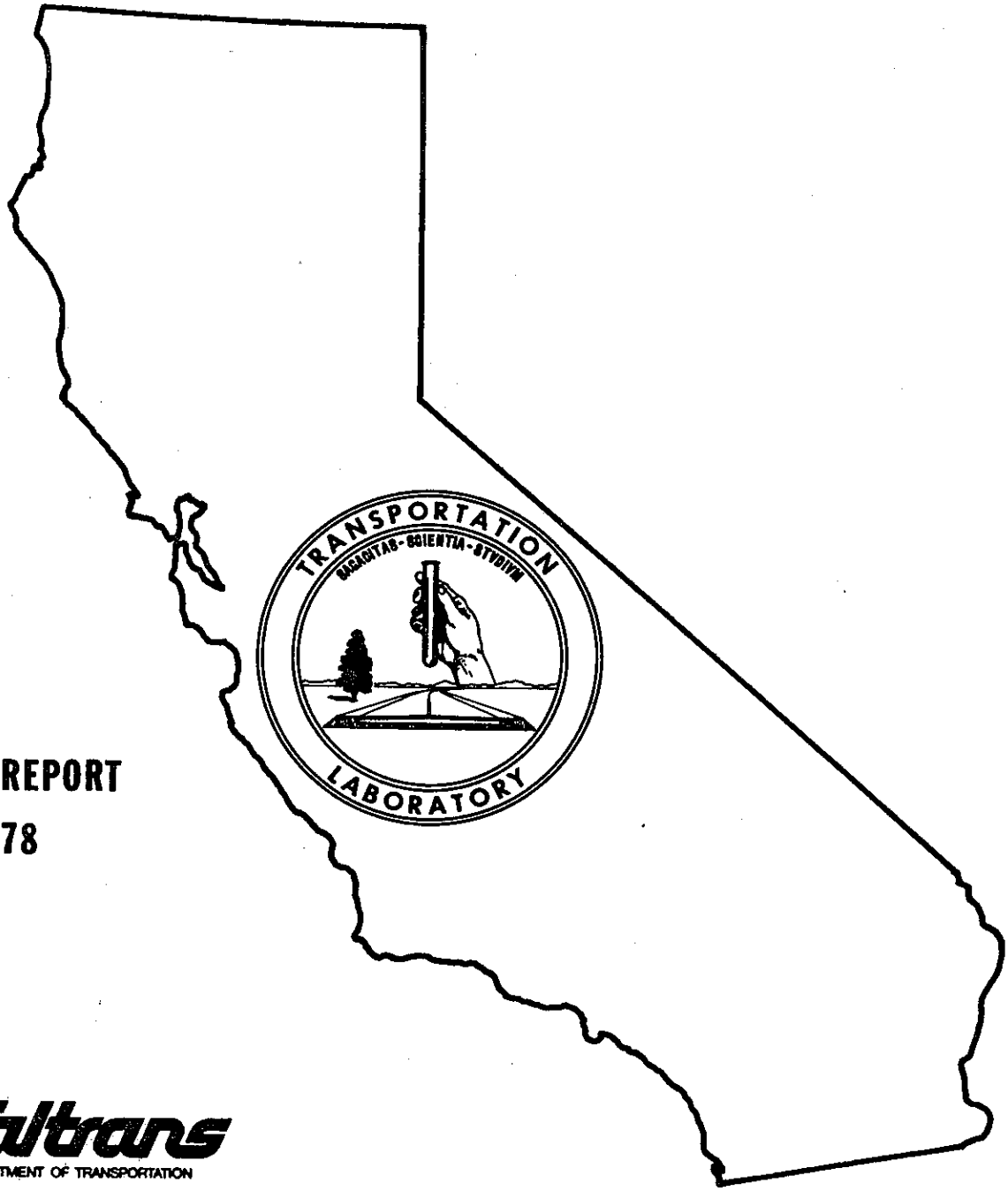
19. DRI WEBSITE LINK
http://www.dot.ca.gov/hq/research/researchreports/1978-1980/78-05.pdf

20. FILE NAME
78-05.pdf

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

REPORT NO. FHWA-CA-TL-78-05

LONG TERM FIELD BEHAVIOR OF A REINFORCED EARTH WALL



INTERIM REPORT

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TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO
FHWA-CA-TL-78-05		

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LONG TERM FIELD BEHAVIOR OF A REINFORCED EARTH WALL	February 1978
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Office of Transportation Laboratory California Department of Transportation Sacramento, California 95819	11. CONTRACT OR GRANT NO D-4-143
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT & PERIOD COVERED
California Department of Transportation Sacramento, California 95807	Interim
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17. KEY WORDS	18. DISTRIBUTION STATEMENT
Reinforced earth, reinforcing strip, stress-strains, movement, stability.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. SECURITY CLASSIF. (OF THIS REPORT)	20. SECURITY CLASSIF. (OF THIS PAGE)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	75	

DH-TL 1242 (Rev. 3-74)

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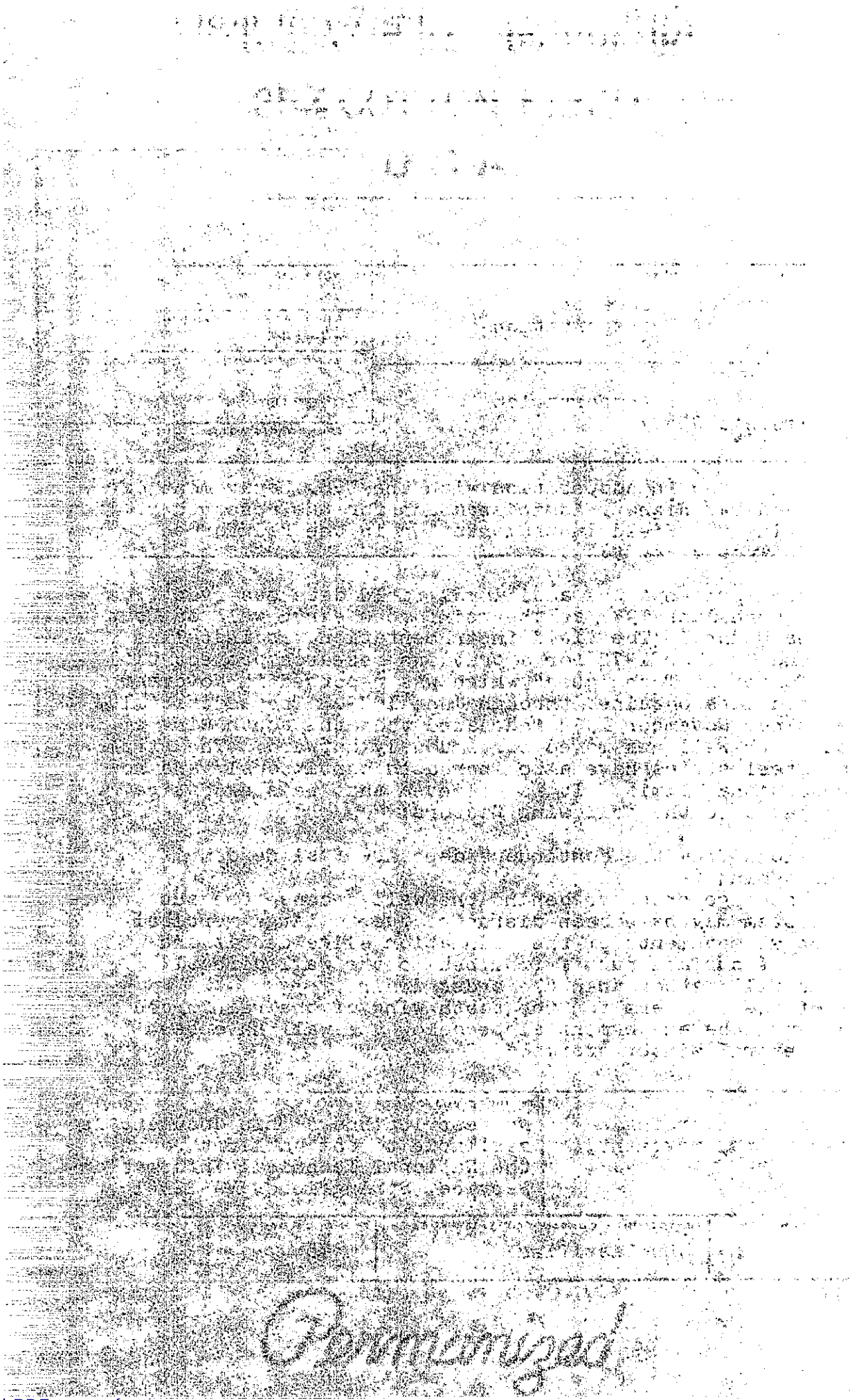

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

February 1978

FHWA No. D-4-143
TL No. 632166

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this interim research project report titled:

LONG TERM FIELD BEHAVIOR OF
A REINFORCED EARTH WALL

Study made by ..... Geotechnical Branch

Under the Supervision of ..... Raymond A. Forsyth, P.E.

Principal Investigator ..... Jerry C. Chang, P.E.

Co-Investigators ..... Joseph B. Hannon, P.E.
and
Bobby L. Lister

Report Prepared by ..... Jerry C. Chang, P.E.

Very truly yours,

George A. Hill

GEORGE A. HILL
Chief, Office of Transportation Laboratory

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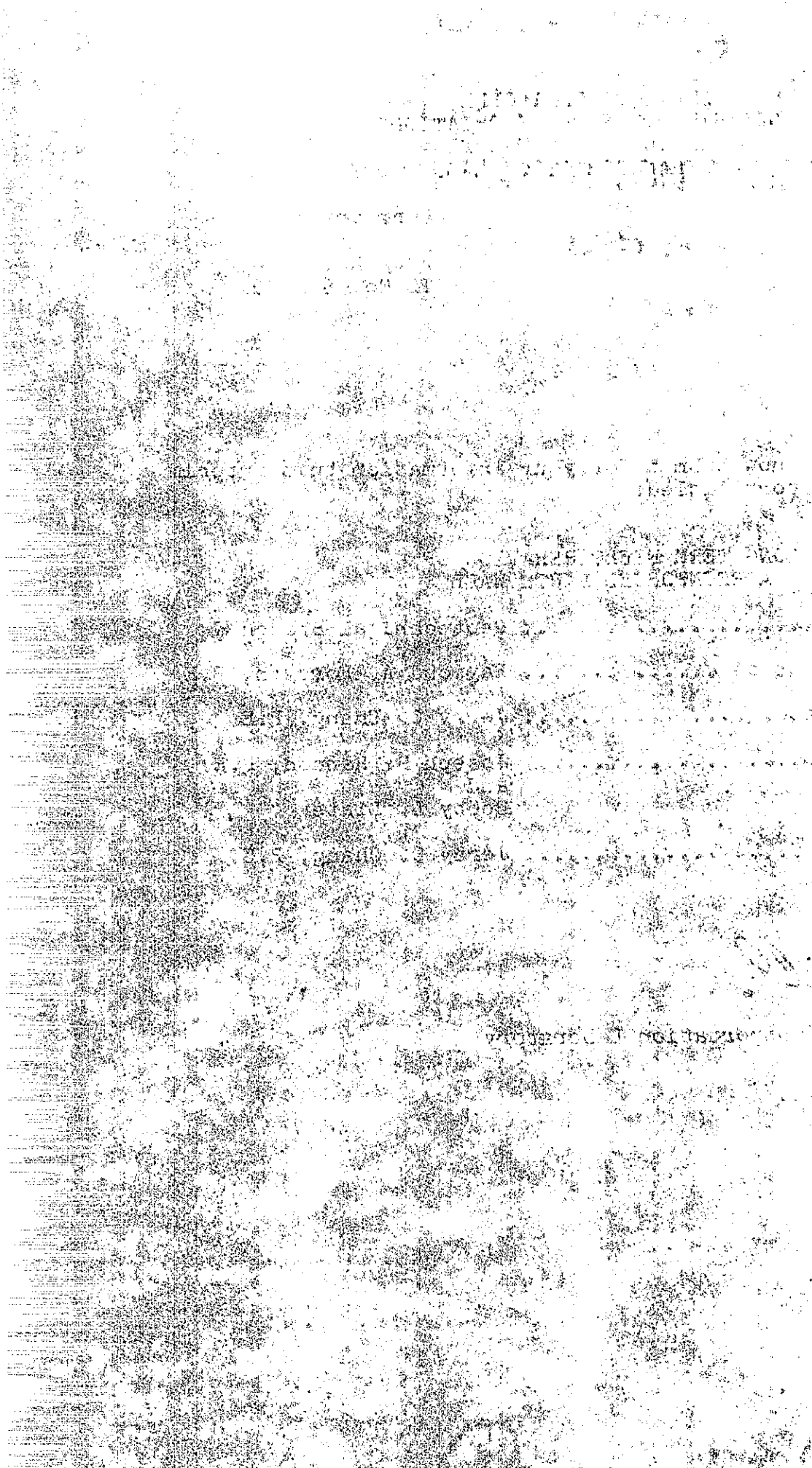

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ACKNOWLEDGEMENTS

The work reported herein is part of a research project authorized under work program HPR-1(13), D-4-143, in cooperation with the Federal Highway Administration, U. S. Department of Transportation.

The field data were read, plotted, and analyzed by Ronald Thompson and David Castanon.

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I. INTRODUCTION

Comprehensive field instrumentation financed under Project T.L. 632115, D-4-93, titled "Earthwork Reinforcement Techniques" was installed in the reinforced earth fill on Route 39 in Los Angeles County during its construction between August and October 1972. Readings of field data began immediately after installation of the instrumentation and were continued periodically thereafter through July 1973.

The final report for that research project (T.L. 632115, D-4-93) was published in November 1974. It presented the data observed through June 1973. A separate Type "B" study was then proposed (T.L. 632166, D-4-143) to continue monitoring the field instrumentation in order to monitor the long-term performance of the Rte. 39 reinforced earth fill. The proposal was initiated in January 1975 and was approved by FHWA on March 25, 1975. Four more sets of readings of the field instrumentation have been obtained from November 1974 through June 1977. The additional data indicates that the south wing of the reinforced earth wall has moved continuously outward. The strain measurements on some of the steel strips have also increased continuously and now exceed their proportional limit of 35,000 pounds per square inch (241,317 kN/m^2).

It is believed that this excessive straining is related to the following:

1. Deposition of slide debris on top of and behind the wall during each winter storm.

2. The original design thickness of the south wing wall section was reduced during construction to limit the excavation into the rock slope. In addition, the end portions of the steel reinforcements were bent up along the rock slope. This construction revision may have reduced the stability to some extent.

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3. Seepage forces may have developed behind the wall and the embankment during winter storms as a result of possible disruption of portions of the subsurface drainage system during the large vertical settlements and horizontal movements of the slide debris foundation.

4. Portions of the toe berm for the north wing of the reinforced earth wall and the embankment slope below the wall have been eroded by several winter storms, the most severe of which occurred during September 1976.

The results of a stability analysis using recent surveyed cross-sections, has led to the recommendations that the toe berm be raised at least 5 feet (1.53 m) and the embankment be flattened from the badly eroded existing 1.5 on 1.0 to 1.75 on 1.0 in order to enhance the stability of the north wing wall. Additional remedial measures have also been recommended to intercept and divert surface runoff behind the wall into the existing crossdrain and to remove portions of the slide debris atop and behind the wall. All of the recommended remedial work will be carried out by District 07.

It was also proposed to continue monitoring the field instrumentation for an additional two years to evaluate the effectiveness of the remedial measures and to study the long term performance of the reinforced earth wall under the above overstressed conditions. To accomplish this work it was also proposed to change the existing Type "B" study to a Type "A" project. A revised work plan for the accomplishment of these objectives was approved by FHWA in December 1977.

This interim report presents the field data observed from November 1974 through June 1977, and concludes the Type "B" study.

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II. CONCLUSIONS

The large increase in horizontal movements of the south wing wall and the excessive strains of the steel reinforcement were probably due to:

1. Additional overburden load from the continuing deposit of slide debris atop and behind the wall.

2. Reduced thickness of the reinforced earth wall section along the south wing alignment after revision during construction to minimize excavation into the rock slope.

3. Seepage pressure behind the wall during winter storms caused by probable rupture of the underdrain collector system as a result of large vertical and horizontal movement of the foundation slide debris and percolation of surface runoff from behind the wall directly through the fill rather than the crossdrain.

4. Erosion of the toe berm at the base of the wall and erosion of the down slope embankment below the south wing wall.

5. Possible creep of the steel strips or the wire of the strain gages when the steel strain is beyond its proportional limit.

Even though the strains of some of the steel reinforcements now exceed the proportional limit and excessive horizontal movements have occurred along the south wing wall, the entire reinforced earth wall maintains its integrity without local failure. The stability of the entire reinforced earth wall, which was constructed over a slide debris foundation, is probably due to the monolithic nature and flexibility of the reinforced soil mass. The reinforced earth wall was built in three cords along a circular arc and the skin plates were continuously linked together. If the facility had been constructed with concrete facing, severe cracking of the concrete members would probably have occurred.

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III. RECOMMENDATIONS

The remedial measures outlined in the introduction should be accomplished as soon as possible to enhance the stability of the reinforced earth wall. Continuous monitoring of the existing field instrumentation for an additional two years after completion of the remedial work is also recommended. This would allow study of the long term performance of the reinforced earth wall under overstressed conditions.

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IV. DISCUSSION

The Rte. 39 reinforced earth wall was built between August 1 and October 18, 1972. Figure 1 shows the plan and section of the reinforced earth wall and the embankment. Figure 2 shows the instrumentation sections. All of the field instruments were read during and after construction between August 1972 and July 1973 for the preceeding research project entitled "Earthwork Reinforcement Techniques". The final report of that project(1) presented the state-of-the-art of reinforced earth, the basic theory, the design information, the construction operation, the instrumentation program, and the field data. Theoretical analysis by finite element method was also included in the final report. Subsequently, several articles were written by Chang and Forsyth(2,3,4,5) and Romstad, et al, (6,7) to provide additional interpretation of the information contained in the final report.

The field data continuously monitored from December 1973 through July 1977 are presented and discussed as follows:

A. Horizontal and Vertical Movement of Reinforced Earth Wall

Figure 3, shows the cross-section of the reinforced earth wall and the location of the Series "A" and Series "C" survey monuments on the berm along the toe of the wall and at the top of wall, respectively. The field data of horizontal movements are shown in Table 1 and Figures 4 and 5 for the Series "A" and Series "C" monuments, respectively. Horizontal movements totaling as much as 7.8 inches (198 mm) and 11.3 inches (287 mm) were observed at the toe berm and at the top of wall, respectively, from the initial readings during construction to July 1977.

The maximum change in horizontal movement was about 4.3 inches (109 mm) and 2.5 inches (64 mm), respectively, at the top and

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bottom of the wall from December 1973 through July 1977; and 0.92 inches (23 mm) and 1.08 inches (27 mm) respectively, from September 1976 through July 1977. As shown in Figures 4 and 5 and Table 1, the greatest movement occurred at the south wing wall.

Vertical settlements measured on Series "A" and "C" monuments are shown in Figures 6 and 7, respectively. The maximum settlement was approximately 1.6 feet (0.49 m) at both level A and C, from the initial readings after embankment placement to July 1977. The maximum increase in settlement, about 0.45 foot (0.14 m) and 0.3 foot (0.09 m), respectively, on the top and bottom of wall at the center chord, occurred between September 1973 and July 1977. These long-term settlements probably represent the creep behavior of the soil mass.

B. Settlements Within Reinforced Earth Fill

Settlements measured from the settlement platforms installed within the reinforced earth fill are shown by Figures 8 and 9 for Station 550+25, and Figures 10 and 11 for Station 551+75. Almost every settlement platform has continued to show additional settlement for the period between 1973 and 1975. Settlement platform SP-20 has settled about 0.75 foot (0.23 m) since 1973 (Figure 8). Other platforms have settled between 0.25 and 0.50 foot (0.08 and 0.15 m) during the same period. From 1975 to 1977, most of the settlement platforms show very little additional settlement, except for platform SP-17, where additional settlement of 0.9 foot (0.27 m) was measured between 1975 and 1977.

At Station 551+75, the readout gauges for the level A settlement platforms were destroyed in 1973. Only those settlement platforms on Level B and Level C were observed. The settlements between 1973 and 1975 are in the range of 0.25 to 0.35 foot (0.08 to 0.11 m). From 1975 to 1977, settlement was almost nil.

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C. Internal Movement of Embankment

The internal horizontal movements of the embankment measured by slope indicators SI-1, SI-2, and SI-3, are shown in Figures 12 through 17. Slope indicator SI-1, located on the slope of the toe buttress of the embankment, indicates a small movement in the south-west direction (Figures 12 to 13). Slope indicator SI-2, located at the top of the embankment toe buttress, moved in the south-west direction (Figures 14 and 15); whereas SI-3, located on the embankment slope, moved slightly to the north-west direction (Figures 16 and 17).

D. Stresses and Strains of Soil

The vertical and horizontal soil stresses measured by soil pressure cells at both Station 550+25 and 551+75 are shown in Tables 2 and 3. At Station 550+25, the distribution of vertical and horizontal soil stresses on the horizontal plane are shown in Figures 18 and 19, respectively; and on the vertical sections in Figures 20 and 21, respectively. At Station 551+75, the distribution of vertical and horizontal soil stresses on the horizontal plane are shown in Figures 22 and 23, respectively; on the vertical sections in Figures 24 and 25, respectively. The average axial steel stresses measured by strain gages on the top and bottom faces of the steel strip are also superimposed on Figures 18, 20, 22, and 24 for comparison purposes, since the steel stresses are theoretically proportional to the vertical soil stresses.

The data indicate that the pattern of stress distribution on the horizontal plane in 1977 was similar to that for 1973. However, the magnitude of both horizontal and vertical soil stress decreased slightly in 1977.

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The distribution patterns of stresses on vertical sections also indicate similarity for 1973 and 1977. Both vertical and horizontal soil stresses increased from the upper level to the lower level. The rate of increase in stress is much larger between level B and A than between level C and B.

The distributions of steel stresses on both the horizontal plane and the vertical section are not compatible with the vertical soil stresses as shown in Figures 18, 20, 22, and 24. This is due to the complex geometry of the facility, and also to the foundation conditions at the site.

Horizontal soil strains registered by extensometer installations are shown in Table 4. Distribution of horizontal strains are shon in Figures 26 and 27, respectively, for Station 550+25 and 551+75. In Figures 26 and 27, distributions of steel strains are also shown for comparison. Figure 26 shows an increase at Station 550+25 in both soil strains and steel strains between 1973 and 1977. However, the steel strains exhibited larger increases than did the soil strains. At Station 551+75, the soil strains increased slightly, while the steel strains again exhibited a considerable increase between 1973 and 1977 (Figure 27).

E. Stress-Strain Relationship of Reinforcing Steel Strip

In order to determine the physical properties of the galvanized reinforcing steel strip imported from France, a standard laboratory tension test was conducted in 1971 on a sample of the steel strip. The stress-strain curve obtained from that test is shown in Figure 28. The test results indicate a Youngs modulus of elasticity of 30.3×10^6 psi (209×10^6 kN/m^2), a proportional limit of 30,000 psi (206,843 kN/m^2), a yield strength of 37,000 psi (255,108 kN/m^2), and an ultimate strength of 50,000 psi (344,740 kN/m^2).

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For the purpose of determining Poisson's ratio, another standard tension test was conducted in 1972 using strain gages installed on the steel strip specimen to measure the longitudinal and lateral strains. This test was conducted with a tensile load up to 9,000 pounds (4082 kg) corresponding to a stress of approximately 33,000 psi (227,528 kN/m^2). The stress-strain curve obtained from this test is also shown in Figure 28. The results of this test indicates a Young's modulus of elasticity of 28.5 x 10^6 psi (196 x 10^6 kN/m^2) and a Poisson's ratio of 0.28.

Four additional standard tension tests were conducted in 1977 to define the stress-strain relationship in the plastic range. A typical stress-strain curve obtained from these four tests is also shown in Figure 28. A summary of all test results of Young's modulus of elasticity, yield strength, and ultimate strength are shown in Table 5. The typical stress-strain curves obtained from the four tests in 1977 were utilized for interpreting the field stresses in the steel strip, based on field strain measurements as described in the subsequent section.

F. Stresses in Steel Strips

The stresses in the steel strips were determined from strain measurements made between December 1973 and November 1977 utilizing the typical stress-strain relation curve obtained from standard tensile tests conducted in 1977 (Figure 28). The results of steel strains are shown in Table 6 and results of stresses in Table 7, for both Stations 550+25 and 551+75. Figures 29, 30, and 31 show the daily history of stresses and strains in steel strip for Levels A, B, and C, respectively, at Station 550+25. In Figures 29 through 31, the scale at the left shows steel stresses in kips per square inch up to the proportional limit only. The scale at the right shows the steel strain in micro inches per inch. It can be seen from these plots that the steel strain continuously increases from 1973 through 1977. Most of the steel strips have

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stressed beyond the proportional limit. Figures 32 through 34 show the daily history of stresses and strains observed at Station 551+75 for level A through C. Again, a number of the steel strips had strains above the proportional limit after 1976. Figures 35 through 40 show the distribution of steel strains on the vertical section at Station 550+25 (Figures 35 through 37) and at Station 551+75 (Figures 38 through 40). The proportional limit is also shown in these figures. At Station 550+25, the steel strips at one foot (0.305 m) from the wall face (Figure 35) exhibit higher strain on the upper level (level C) than those on the lower level (levels A and B). The steel strips at 15 feet (4.6 m) from the wall face have almost equal strain on B and C level, and less strain on the A level (Figure 36). The steel strips at 25 feet (7.6 m) from wall face exhibit much higher strain on A level than those at B and C level (Figure 37).

At Station 551+75, the steel strips at one foot (0.305 m) from wall face developed higher strains on the middle level (level B) than those on the lower level A and upper level C (Figure 38). The steel strip at 15 feet (4.6 m) from wall face developed much higher strains on upper level C than those on the lower levels A and B (Figure 39). The steel strip at 30 feet (9.2 m) from the wall face also developed higher strains on the upper level C than those on lower level A (Figure 40).

G. Stresses and Strains in Skin Plate

Strain gages were installed on several skin plates during construction. The locations and the identification numbers of the strain gages are shown on Figures 41 through 46. Gages 1, 5, and 9 measure strains on the front face in the axial direction; Gages 3, 7, and 11 measure strains on the inner face in the axial direction; Gages 2, 6, and 10 measure the circumferential strain on the front face; and Gages 4, 8, and

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12 measure the circumferential strain on the inner face. The stresses and strains observed in the skin plate at both Stations 550+25 and 551+75 are shown in Tables 8 and 9, respectively. Figures 41, 42, and 43 show the daily history of stresses and strains on levels A, B, and C, respectively, at Station 552+25. At Station 552+25, all three skin elements No. 46 (level A), No. 57 (level B), and No. 69 (level C), developed tensile axial stresses and bending circumferential stresses with tension on outer face and compression on inner face. On Station 551+75 the stresses and strains of the skin plate are shown in Figures 44 through 46. Skin element No. 8 (level A) shows compressive axial stresses and tensile circumferential stresses on the outer face and compressive circumferential stresses on the inner face. The tensile and compressive circumferential stresses are almost symmetrical (Figure 44). From the circumferential stress pattern developed in skin element No. 8, it can be concluded that the circumferential stresses are bending stresses due to vertical compression under the gravity load of the fill material. This was the case assumed in developing the design equations in the final research report(1). In skin element No. 25 (on level B) and No. 43 (on level C) considerable change in stresses have occurred from 1973 to 1977 (Figures 45 and 46), possibly due to localized deformation of the skin plate at these instrument locations.

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TABLE 1: TOTAL HORIZONTAL MOVEMENT IN INCHES ON LEVELS A AND C

Sta.	LEVEL A: Along Bottom of Wall on the Berm					LEVEL C: Along Top of Wall on the Fill				
	DATE READ					DATE READ				
	12-17-73	11-20-74	6-5-75	9-22-76	7-1-77	12-17-73	11-20-74	6-5-75	9-22-76	7-1-77
10+84	-	-	-	-	-	3.24	-	-	4.84	5.28
11+00	-	-	-	-	-	3.60	5.50	5.50	6.20	6.36
11+25	2.76	3.84	3.96	3.96	3.96	-	-	-	-	-
11+50	2.28	3.48	3.48	3.48	3.48	-	-	-	-	-
11+75	-	-	-	-	-	2.28	-	-	3.88	-
12+00	0.48	-	-	1.32	1.92	-	-	-	-	-
12+75	3.12	3.36	5.16	5.16	5.28	-	-	-	-	-
13+00	5.52	7.08	7.08	7.68	7.80	4.20	5.80	-	7.30	7.68
13+25	-	-	-	-	-	7.32	9.02	9.12	10.42	10.56
14+00	4.08	5.40	5.76	5.76	6.60	6.96	8.36	8.76	10.36	11.28
14+75	1.92	3.36	3.36	3.36	4.44	-	-	-	-	-

NOTE: 1 inch = 25.4 mm

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TABLE 2: VERTICAL SOIL STRESSES IN POUNDS PER SQUARE INCH (PSI)

LEVEL	STATION 550+25							STATION 551+75						
	Gage Distance From Wall Face (ft)	DATE READ						Gage Distance From Wall Face (ft)	DATE READ					
		12-17-73	11-20-74	6-5-75	11-18-75	9-22-76	6-2-77		12-17-73	11-20-74	6-5-75	11-18-75	9-22-76	6-2-77
A	7	21.0	18.5	17.0	17.0	17.5	17.5	5	70.5	72.0	70.0	70.0	71.0	72.0
	18	30.5	28.0	27.0	27.5	28.0	28.5	17	67.0	70.0	68.0	69.0	74.0	-
	27	39.0	38.5	37.0	38.0	37.0	38.0	33	40.0	39.5	37.0	37.0	40.5	40.5
	41	43.5	41.0	40.0	41.0	41.0	42.5	44	36.5	34.0	33.5	34.5	36.0	35.0
B	8	14.5	13.0	11.0	11.5	12.6	12.0	8	56.5	57.0	54.0	54.0	57.0	53.0
	18	26.0	24.5	22.5	23.5	22.5	23.0	17	36.5	34.5	32.0	32.5	32.2	29.5
	31	30.0	28.5	25.5	26.0	25.5	24.5	33	35.0	34.0	30.0	30.5	31.5	31.5
	41	30.0	28.0	27.0	27.0	28.0	28.0	46	17.5	14.5	13.0	13.5	13.5	12.5
C	7	11.5	10.0	8.0	8.0	8.0	9.5	7	34.0	34.0	33.0	34.0	34.0	35.5
	17	15.0	12.5	10.0	10.5	10.0	9.0	17	20.0	20.0	17.0	19.0	18.0	19.0
	27	18.0	17.0	15.5	16.0	15.5	15.5	33	25.0	23.5	21.5	22.5	23.5	24.0
	36	9.0	7.5	4.5	5.5	5.0	4.5	47	28.0	26.0	24.0	24.5	25.5	26.5

NOTE: 1 foot = 0.305 m
1 psi = 6.89 kN/m^2

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TABLE 3: HORIZONTAL SOIL STRESSES IN POUNDS PER SQUARE INCH (PSI)

LEVEL	STATION 550+25							STATION 551+75						
	Gage Distance From Wall Face (ft)	DATE READ						Gage Distance From Wall Face (ft)	DATE READ					
		12-17-73	11-20-74	6-5-75	11-18-75	9-22-76	6-2-77		12-17-73	11-20-74	6-5-75	11-18-75	9-22-76	6-2-77
A	4	3.5	2.0	0.5	14.0	1.5	2.5	6	37.0	47.0	45.0	46.0	48.0	47.0
	16	12.5	12.0	11.0	13.5	12.5	13.0	18	26.5	28.0	25.5	26.5	27.5	27.5
	24	15.0	14.0	13.0	11.5	13.5	14.0	35	19.5	15.5	13.5	13.0	13.5	12.5
	37	18.5	16.0	13.5	1.5	13.5	13.5	46	10.5	9.5	8.5	8.5	9.5	9.0
B	6	5.0	5.0	3.5	4.0	4.0	4.0	6	15.5	15.0	12.5	12.5	12.0	13.0
	16	8.0	7.5	5.5	6.5	6.5	6.5	15	24.0	24.0	22.0	23.0	23.0	24.0
	28	12.0	11.5	10.0	11.0	10.0	11.0	31	20.5	20.5	18.5	19.5	19.7	20.0
	38	4.0	3.0	1.0	2.0	0.5	1.0	45	11.5	11.5	10.5	11.0	10.5	10.5
C	4	4.0	2.5	0.5	0.5	0.5	1.0	5	7.5	7.5	5.5	6.5	5.5	6.5
	15	5.5	5.0	2.0	4.0	3.0	4.0	15	19.0	19.0	17.0	18.5	19.0	19.0
	25	8.0	7.0	5.0	6.0	6.5	6.0	30	21.0	21.0	19.0	20.0	17.0	20.0
	35	3.0	1.0	0.5	-	-	-	46	16.0	16.0	14.0	14.0	15.5	-

NOTE: 1 foot = 0.305 m

1 psi = 6.89 kN/m^2

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TABLE 4: HORIZONTAL SOIL STRAIN IN INCH PER INCH X 10^{-4}

LEVEL	STATION 550+25							STATION 551+75						
	GAGE DISTANCE FROM WALL FACE (FT.)	DATE READ						GAGE DISTANCE FROM WALL FACE (FT)	DATE READ					
		12-17-73	11-20-74	6-5-75	11-18-75	9-22-76	6-27-77		12-17-73	11-20-74	6-5-75	11-18-75	9-22-76	6-27-77
A	8	8	8	8	9	9	10	8	1	2	2	2	2	15
	12	−1	0	1	0	0	4	11	0	1	1	1	0	2
	28	2	2	4	3	3	2	27	−1	−1	−1	0	—	8
	33	18	22	26	26	27	10	32	−1	0	−1	0	0	2
								43	2	3	3	3	3	4
								46	15	19	20	21	22	12
B	8	6	7	8	8	8	9	12	7	8	8	9	8	5
	12	4	5	6	5	5	6	16	3	3	3	4	3	2
	29	2	2	0	3	2	3	27	3	2	2	3	3	2
	33	8	8	8	10	9	10	32	2	2	2	2	2	3
								43	2	2	2	2	2	3
								47	4	5	5	6	5	8
C	8	—	—	—	—	—	—	7	9	10	10	11	12	23
	12	3	3	7	7	4	4	13	3	3	3	4	4	3
	28	2	2	3	2	2	2	27	2	2	2	3	2	—
	33	7	8	10	9	9	9	32	7	7	7	8	8	—
								43	1	1	1	2	2	0
								47	12	14	14	15	15	2

NOTE: 1 inch = 25.4 mm

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TABLE 5 SUMMARY OF LABORATORY TEST RESULTS OF PHYSICAL PROPERTIES OF STEEL STRIPS

TEST DATE	TEST NUMBER	READOUT NUMBER	PROPORTIONAL LIMIT (KSI)	YIELD STRENGTH(KSI)	MODULUS OF ELASTICITY(KSI)	ULTIMATE STRAIN in/in x 10-6	ULTIMATE STRENGTH (KSI)
1971	1	1	30.0	37.150	30.25×10^3	--	49.8
1972	1	1	-	-	28.5×10^3	--	-
1977	1	1	35.00	44.85	30.50×10^3	--	50.0
		2	33.89	45.33	25.0×10^3	--	50.0
1977	2	1	33.89	46.69	25.7×10^3	--	50.0
		2	33.89	46.69	25.7×10^3	--	50.0
1977	3	1	42.37	46.6	29.7×10^3	--	50.0
		2	42.37	46.6	29.7×10^3	--	50.0
1977	4	1	33.89	-	27.7	--	48.0
			-	-	-	--	-

NOTE: Test conducted in 1972 with tensile load up to 9,000 lbs or 15.25 KSI.

1 KSI = 6.89 MN/m^2
1 Inch = 25.4 mm

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TABLE 6: STRAIN IN STEEL STRIPS IN INCH PER INCH X10^{-6}

NOTE: The longest gage distance at Sta 551+75 is 30 feet instead of 25 feet as indicated in Table.

STATION	DATE	LEVEL C			LEVEL B			LEVEL A		
		GAGE DISTANCE FROM WALL FACE IN FEET			GAGE DISTANCE FROM WALL FACE IN FEET			GAGE DISTANCE FROM WALL FACE IN FEET		
		1	15	25	1	15	25	1	15	25
550+25	12-17-73	129.5	186.85	184.63	44.77	116.92	285.27	-120.99	396.27	232.36
	11-20-74	213.12	310.8	222.0	174.27	254.56	424.76	-59.94	649.72	475.45
	6-5-75	190.18	355.57	290.08	178.34	349.28	499.6	-97.68	804.75	666.0
	11-18-75	375.92	336.33	311.91	365.93	367.41	469.0	-62.53	892.07	774.41
	9-22-76	652.98	593.33	381.75	451.58	736.84	568.07	-20.0	1252.28	1203.51
	6-2-77	1096.31	1428.2	487.72	364.91	1438.60	712.28	154.29	1719.76	1441.52
	11-2-77	1177.34	1752.69	492.47	543.16	out	779.96	432.53	1944.72	1525.51
551+75	12-17-73	-27.01	761.40	589.78	203.87	438.08	283.51	-7.4	2.22	70.3
	11-20-74	157.25	1066.71	895.03	431.79	626.41	588.3	301.55	297.85	352.98
	6-5-75	169.46	1132.57	1057.83	475.08	718.91	819.55	451.03	388.87	592.0
	11-18-75	298.22	1207.31	1077.44	821.40	719.65	907.24	517.26	385.91	703.0
	9-22-76	574.39	1539.30	1370.18	1255.44	856.42	1381.75	767.37	501.40	1040.70
	6-2-77	680.70	1894.74	1796.49	1736.84	1073.68	1498.25	106.39	501.35	1217.3
	11-2-77	811.78	2050.17	1913.27	1950.64	1145.89	1583.97	1118.88	669.33	1277.98

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TABLE 7: STRESSES IN STEEL STRIPS IN KSI

NOTE: The longest gage distance at Sta. 551+75 is 30 feet instead of 25 feet as indicated in Table.

STATION	DATE	LEVEL C			LEVEL B			LEVEL A		
		GAGE DISTANCE FROM WALL FACE IN FEET			GAGE DISTANCE FROM WALL FACE IN FEET			GAGE DISTANCE FROM WALL FACE IN FEET		
		1	15	25	1	15	25	1	15	25
550+25	12-17-73	3.5	5.6	5.5	1.1	3.4	8.6	-3.5	11.9	6.7
	11-20-74	6.3	9.2	6.5	5.0	7.5	12.5	-1.7	19.4	14.3
	6-5-75	5.6	10.7	8.6	5.4	10.4	14.9	-2.8	24.0	20.0
	11-18-75	11.3	10.2	9.3	10.9	10.9	14.5	-1.7	26.7	23.0
	9-22-76	19.3	17.6	11.3	13.4	21.7	16.9	-0.5	35.5	35.7
	6-27-77	32.7	40.9	14.6	11.0	41.0	21.2	-4.4	44.0	41.0
	11-2-77	35.3	44.3	14.6	16.1	N.F.	23.4	12.7	44.9	42.4
551+75	12-17-73	-0.6	22.9	17.6	6.0	13.1	8.4	0.0	0.0	2.0
	11-20-74	4.7	31.9	26.9	12.3	18.6	17.6	8.9	8.9	10.4
	6-5-75	5.0	33.8	31.6	14.2	21.5	24.6	13.4	11.5	17.6
	11-18-75	8.9	36.0	32.3	24.6	21.5	27.3	15.5	11.5	20.9
	9-22-76	17.0	42.5	39.6	37.3	25.7	39.9	23.0	15.0	31.1
	6-27-77	20.2	44.9	44.5	44.3	32.0	41.9	30.5	14.9	36.3
	11-2-77	24.3	45.0	44.9	44.9	34.4	43.0	33.5	20.0	37.6

NOTE: 1 ft. = 0.305 m, 1 KSI = 6.89 MN/m^2

TABLE 8: STRESSES IN SKIN PLATE IN KSI

LEVEL	GAGE NUMBER	STATION 550+25						STATION 551+75					
		SKIN ELEMENT NUMBER	DATE READ					SKIN ELEMENT NUMBER	DATE READ				
			12-17-73	11-24-74	11-18-75	9-22-76	6-27-77		12-17-73	11-24-74	11-18-75	9-22-76	6-27-77
A	1	46	0.1	3.2	- 0.6	-0.6	0.2	8	-9.7	-5.9	-6.2	-4.4	-3.2
	3		1.4	3.7	1.5	2.7	5.8		- 0.5	-2.5	- 4.5	-3.6	-7.5
	2		9.2	12.7	12.2	14.5	16.4		24	30.5	30.0	31.3	31.4
	4		-9.8	- 8.6	-11.0	-1.9	-2.3		-22.7	-20.0	-22.0	-23.3	-26.0
	5		8.9	9.0	8.0	6.5	4.2		- 3.3	0.4	-1.4	0.6	0.7
	7		8.9	9.0	9.5	11.0	9.0		- 1.6	2.0	-0.8	1.2	1.6
	6		6.6	11.9	7.2	9.0	10.2		-24.3	29.0	26.0	28.0	27.3
	8		-7.4	-2.5	-3.3	1.7	-10.9		-28.0	-23.4	-27.1	-27.2	-27.0
	9		9.2	8.4	8.0	7.7	8.3		- 4.2	- 0.6	- 3.8	- 3.3	- 3.2
	11		8.0	9.5	15.6	23.4	25.0		- 1.9	1.5	- 1.8	0	1.6
	10		7.7	12.2	7.8	10.1	10.2		16.6	19.9	17.0	18.8	18.5
	12		-10.0	- 6.5	- 8.6	- 2.1	3.9		-19.1	-14.4	-17.5	-16.4	-16.6
B	1	57	8.01	6.1	6.8	5.7	4.3	25	- 0.4	- 2.9	- 1.8	- 7.2	-11.2
	3		6.0	2.2	12.3	30.2	39.4		- 0.6	- 4.5	- 2.2	- 7.8	- 5.0
	2		6.3	12.3	8.9	11.6	14.9		12.1	21.2	23.0	30.4	32.4
	4		- 6.8	- 0.2	3.9	3.9	25.0		-13.1	-13.0	-15.2	1.4	23.4
	5		5.0	3.6	3.5	3.6	0.1		2.9	1.5	2.3	- 1.9	- 6
	7		4.7	3.5	5.3	10.0	15.4		3.5	2.5	4.7	2.2	0.5
	6		14.7	19.5	12.6	14.0	15.9		9.5	19.9	23.2	32.8	35.0
	8		-13.6	-10.3	-14.6	-12.5	-10.2		-11.5	-11.0	-26.1	-27.1	-26.7
	9		4.0	2.9	1.6	1.6	- 1.0		6.1	4.4	5.6	1.3	- 2.9
	11		3.3	2.9	6.1	11.4	18.5		5.9	4.2	5.5	1.3	- 1.6
	10		9.3	15.6	9.2	4.9	12.8		12.6	20.4	21.2	29.0	28.7
	12		- 9.4	- 8.3	-10.4	- 5.9	0.7		-18.5	-13.3	7.5	8.8	26.9
C	1	69	7.2	7.5	7.5	6.3	5.5	43	3.8	3.7	6.8	2.5	1.3
	3		6.5	4.7	7.1	7.7	7.2		2.9	2.1	5.5	0.9	1.1
	2		2.0	6.6	1.2	3.0	8.1		- 0.4	2.7	- 3.7	- 0.2	1.7
	4		- 4.2	- 1.7	- 3.4	- 1.1	0.8		- 1.5	3.1	1.0	6.9	12.5
	5		3.8	4.3	2.9	3.8	3.8		4.6	- 13.6	-30.1	-45.0	-44.7
	7		1.7	1.1	- 0.3	1.8	1.4		4.2	- 13.7	-29.5	-42.2	-44.0
	6		5.0	9.6	4.2	7.0	9.3		- 5.2	-18.8	-41.3	-44.2	-45.0
	8		- 2.3	5.0	5.7	9.3	10.0		- 2.0	- 1.5	-36.3	-42.5	-44.0
	9		3.1	5.7	3.5	2.1	5.0		4.4	-15.3	-31.5	-43.0	-45.0
	11		2.0	- 0.8	0.4	2.9	2.2		2.9	-16.4	-31.8	-42.5	-44.5
	10		4.1	6.0	- 3.3	2.5	3.3		- 6.5	-20.3	-44.0	-44.5	-45.1
	12		- 5.3	- 3.3	- 5.0	4.1	7.4		- 1.4	-13.7	-33.5	-38.3	-42.0

NOTE: 1 KSI = 6.89 MN/m^2

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TABLE 9: STRAIN IN SKIN PLATE IN INCHES PER INCH $X10^{-6}$

LEVEL	GAGE NUMBER	STATION 550+25						STATION 551+75					
		SKIN ELEMENT NUMBER	DATE READ					SKIN ELEMENT NUMBER	DATE READ				
			12-17-73	11-24-74	11-18-75	9-22-76	6-27-77		12-17-73	11-24-74	11-18-75	9-22-76	6-27-77
A	1	46	4	112	-28	-29	14	8	-333	-197	-214	-151	-112
	3		49	133	50	99	197		-21	-84	-147	-116	-253
	2		312	428	407	485	554		804	1018	1014	1061	1046
	4		-330	-291	-368	-234	-77		-761	-674	-744	-778	-870
	5		295	302	270	257	144		-109	18	-53	21	28
	7		295	305	323	370	309		-56	67	-39	42	56
	6		221	404	239	302	344		811	968	870	957	905
	8		-249	-88	-105	60	-365		-933	-786	-909	-907	-905
	9		305	288	274	261	109		-144	-28	-130	-112	-105
	11		270	319	526	788	835		-67	49	-60	0	53
	10		256	407	260	337	340		554	663	568	626	618
	12		-333	-218	-288	-70	130		-635	-481	-583	-546	-554
B	1	57	267	204	225	190	144	25	-14	-98	-60	-239	-372
	3		200	74	411	1008	1361		-21	-151	-74	-259	-168
	2		211	411	295	386	498		404	705	768	1014	1081
	4		-225	-7	130	130	832		-435	-432	-505	48	779
	5		168	117	116	120	4		98	49	77	-62	-200
	7		158	116	175	333	512		116	84	158	74	18
	6		491	649	421	466	530		316	663	772	1094	1168
	8		-453	-344	-488	-415	-340		-383	-365	-870	-902	-891
	9		133	95	53	52	-32		204	147	186	42	-95
	11		109	95	204	380	618		197	140	183	43	-53
	10		309	519	305	162	428		421	681	709	965	958
	12		-312	-275	-345	-198	24		-618	-442	249	292	898
C	1	69	239	249	249	209	183	43	126	123	225	84	42
	3		218	158	235	258	239		98	70	183	29	35
	2		70	221	39	99	270		-14	91	-123	-5	56
	4		-140	-56	-112	-38	28		-49	102	32	203	418
	5		126	144	95	127	126		154	-453	-1004	-1959	-1895
	7		56	35	-11	59	46		140	-456	-983	-1453	-1695
	6		168	319	140	233	309		-172	-625	-1463	-1731	-1997
	8		-77	168	190	311	333		-67	-49	-1218	-1555	-1698
	9		102	190	116	170	168		147	-509	-1049	-1589	-1960
	11		67	-28	14	97	74		95	-547	-1060	-1545	-1790
	10		137	200	-109	82	109		-218	-677	-1523	-1808	-2081
	12		-175	-109	-165	138	246		-46	-456	-1116	-1309	-1505

NOTE: 1 inch = 25.4 mm

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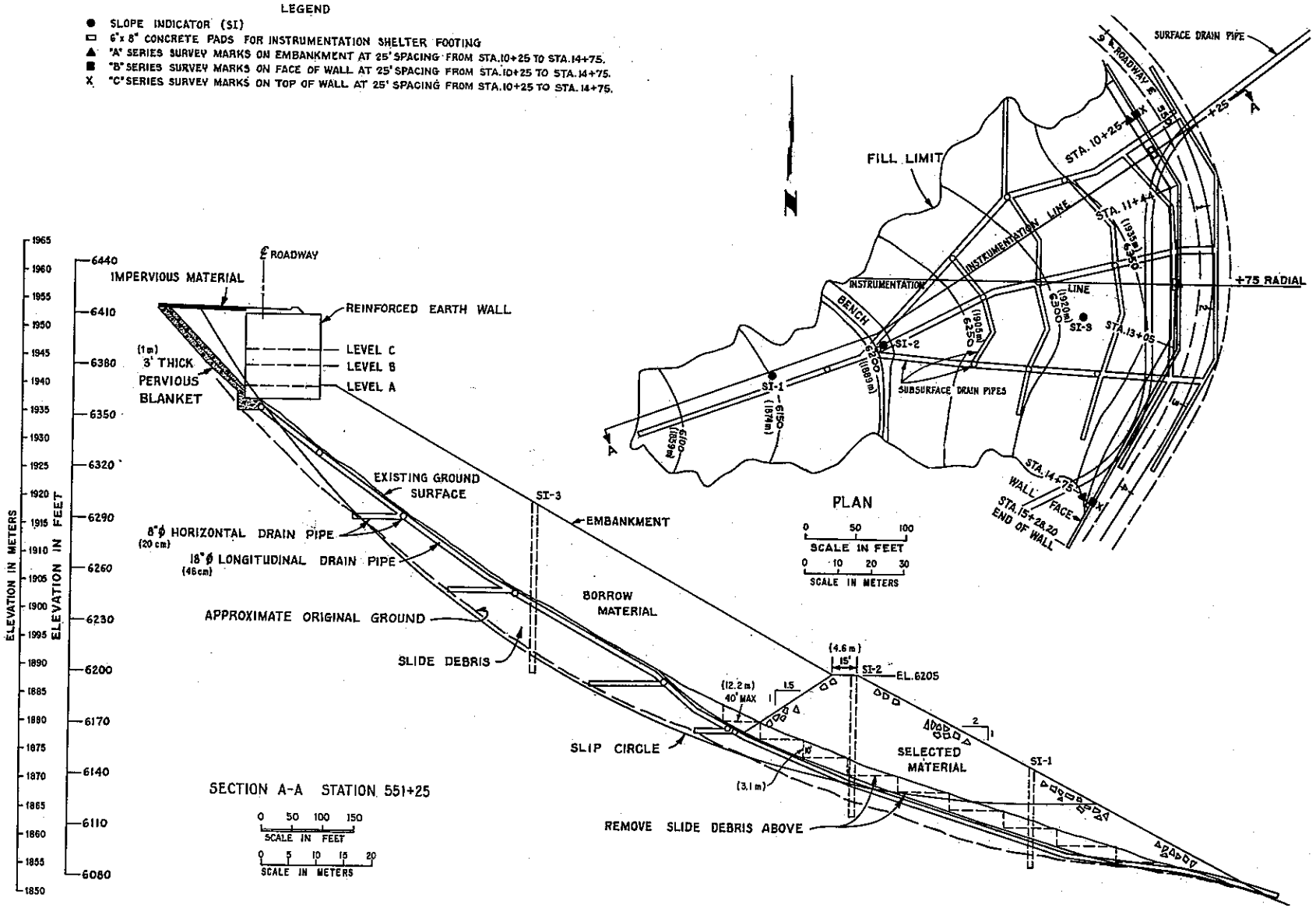

PLAN AND PROFILE

FIGURE 1

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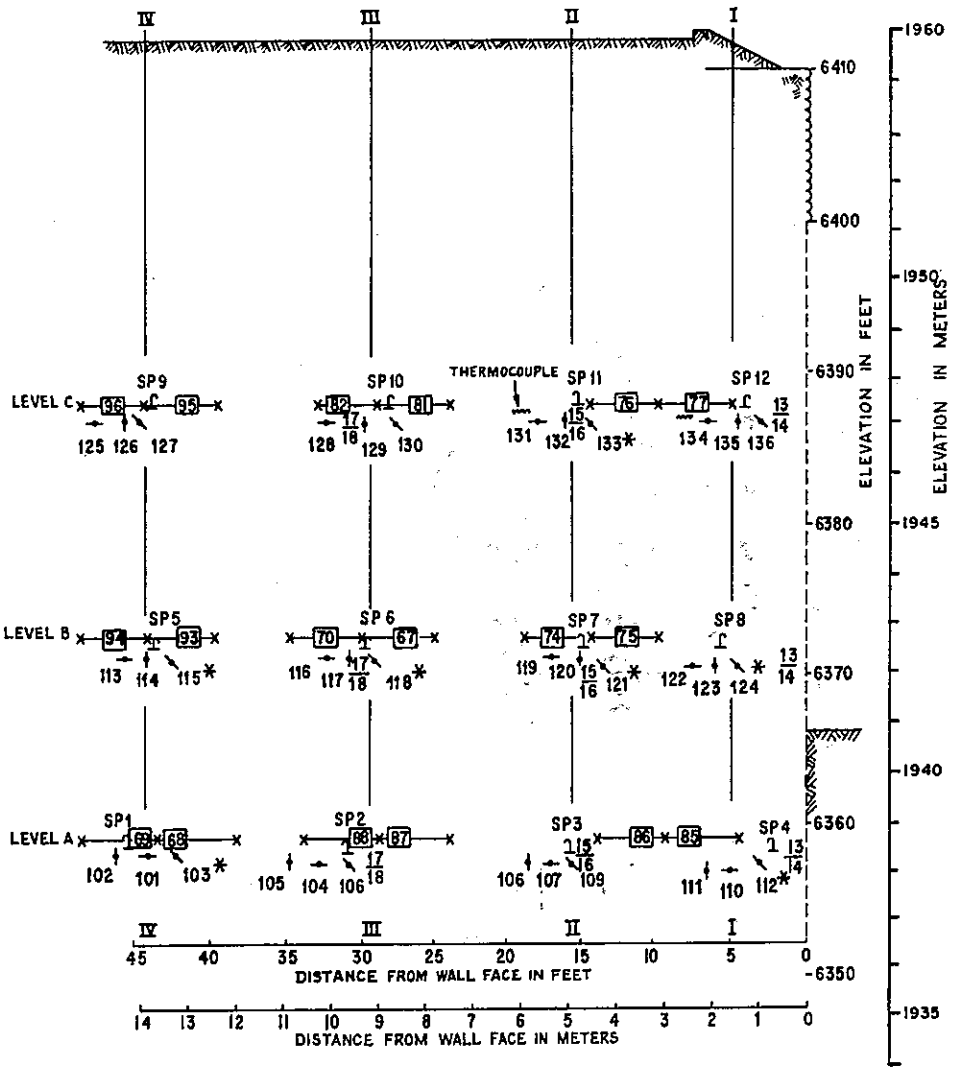
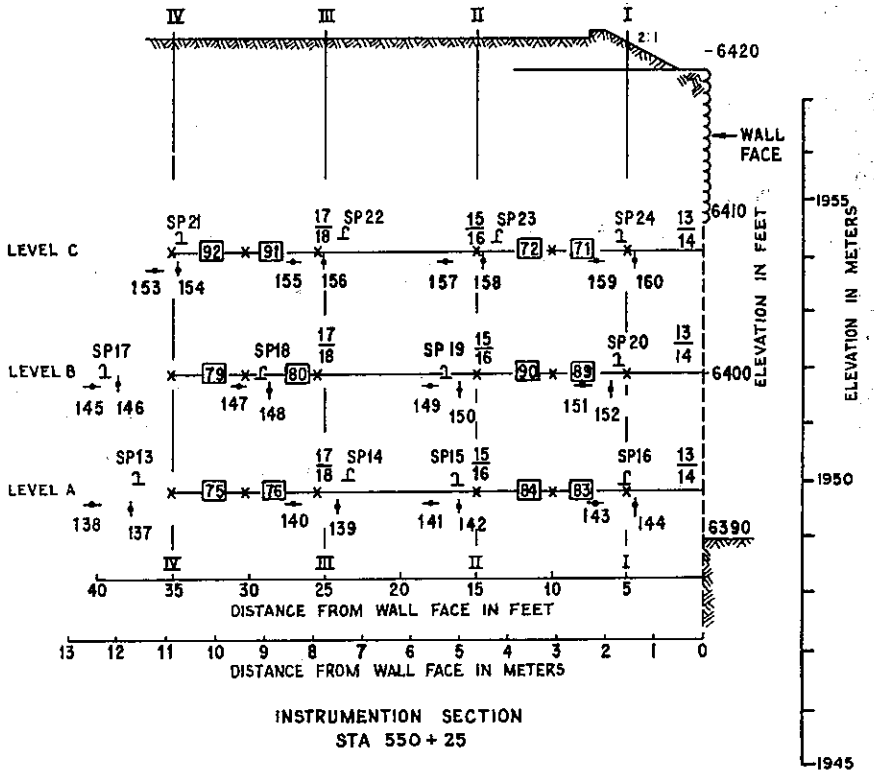


INSTRUMENTION SECTION
STA 551 + 75



INSTRUMENTION SECTION
STA 550 + 25

LEGEND

SP9 — SETTLEMENT PLATFORM

95 — EXTENSOMETER

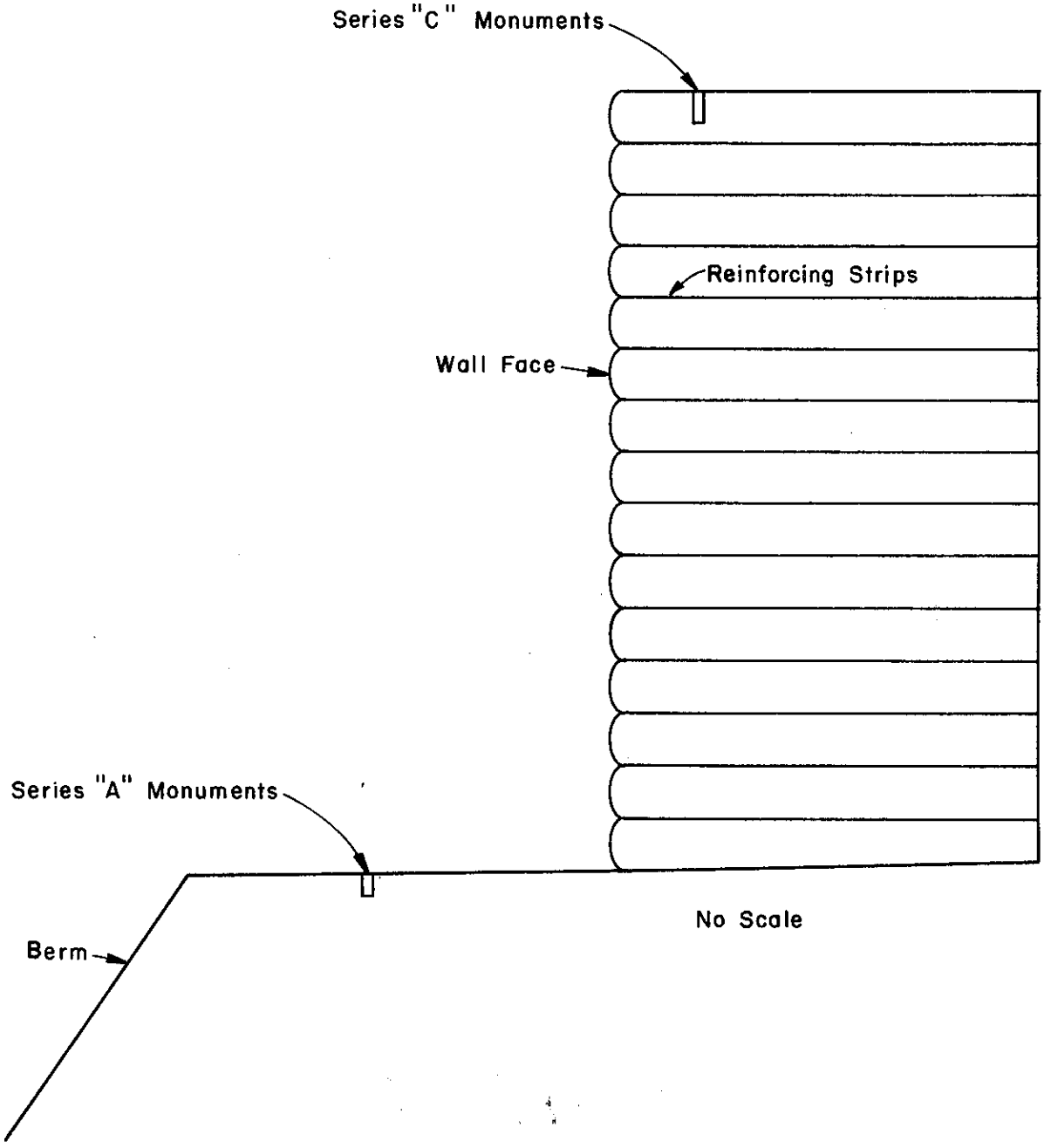
17/18 — STRAIN GAGE ON STRIP

PRESSURE CELLS WITH CORRESPONDING INDENTIFICATION NUMBER BENEATH THE CELL. CELL I.D. NUMBERS WITH ASTORISK (*) INDICATES A GENTRAN PRESSURE CELL. ALL OTHERS ARE GLOETZL PRESSURE CELLS

116 117 118

INSTRUMENTATION SECTIONS

FIGURE 2



CROSS SECTION OF REINFORCED EARTH WALL

Figure 3

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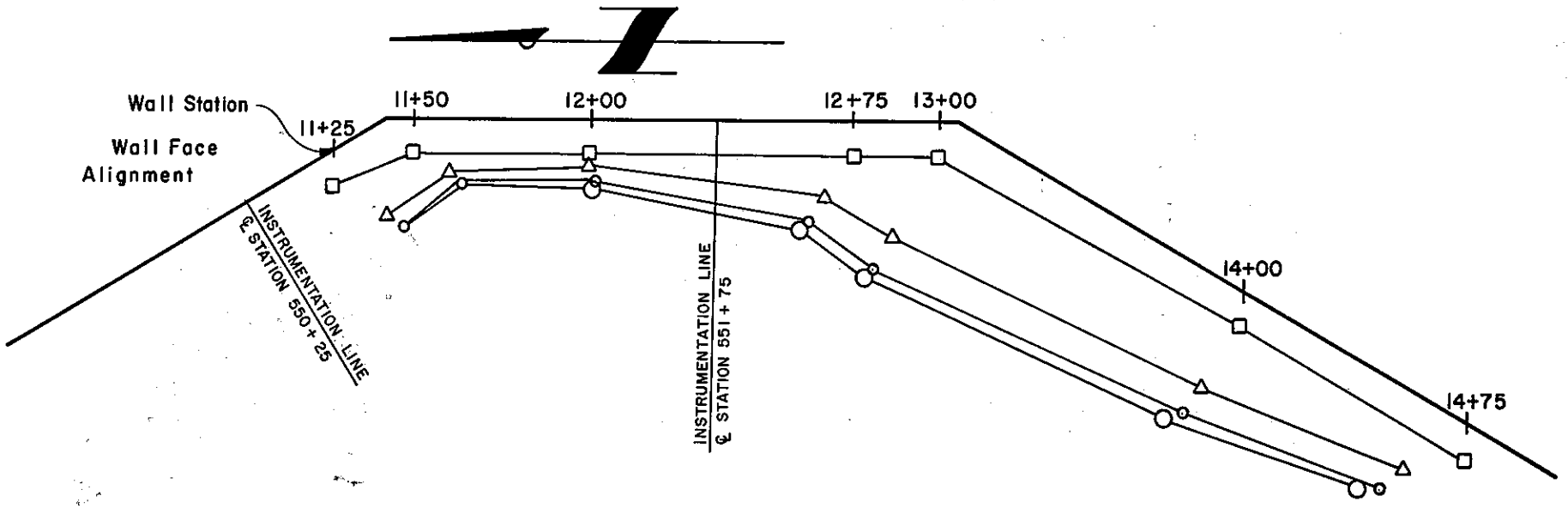

□ — INITIAL MONUMENT ALIGNMENT
△ — 1973 SURVEYED "
o — 1976 " "
○ — 1977 " "

0 50' 100' WALL ALIGNMENT SCALE

0 0.5 1.0' HORIZONTAL MOVEMENT SCALE

NOTE: 1 FOOT = 0.305 m

HORIZONTAL MOVEMENTS AT SERIES "A" MONUMENTS

Figure 4

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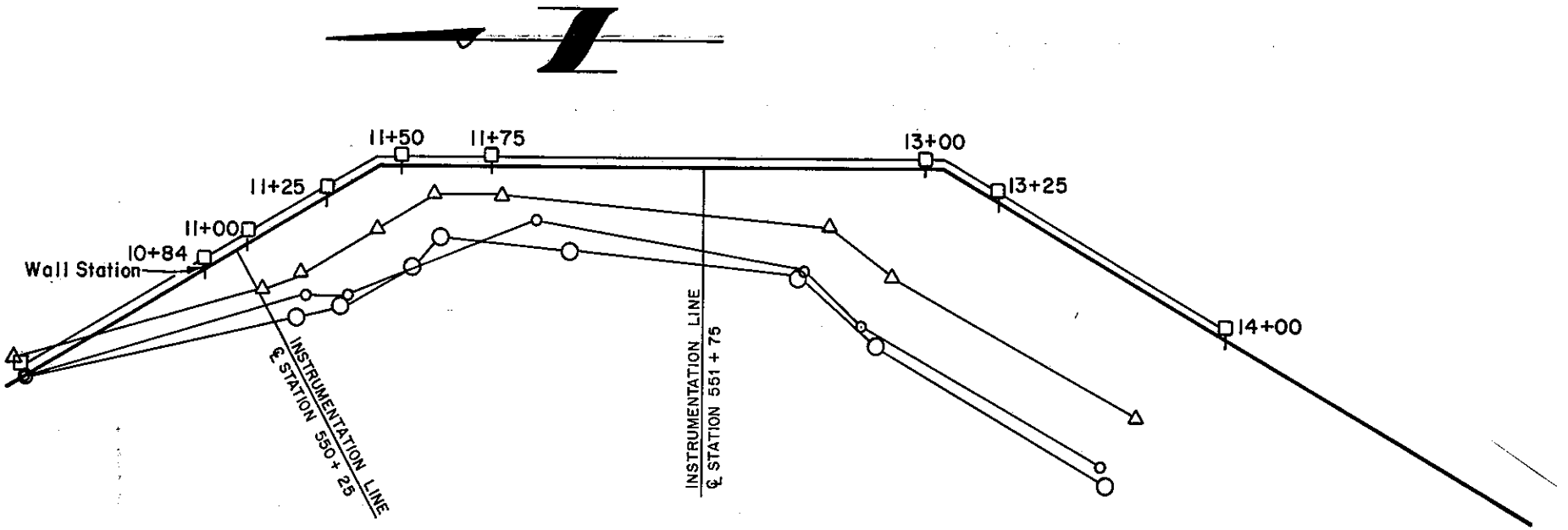

□ – INITIAL MONUMENT ALIGNMENT
△ – 1973 SURVEYED "
o – 1976 " "
○ – 1977 " "

0 50' 100' WALL ALIGNMENT SCALE
0 0.5 1.0' HORIZONTAL MOVEMENT SCALE

NOTE: 1 FOOT = 0.305 m

HORIZONTAL MOVEMENTS AT SERIES "C" MONUMENTS

Figure 5

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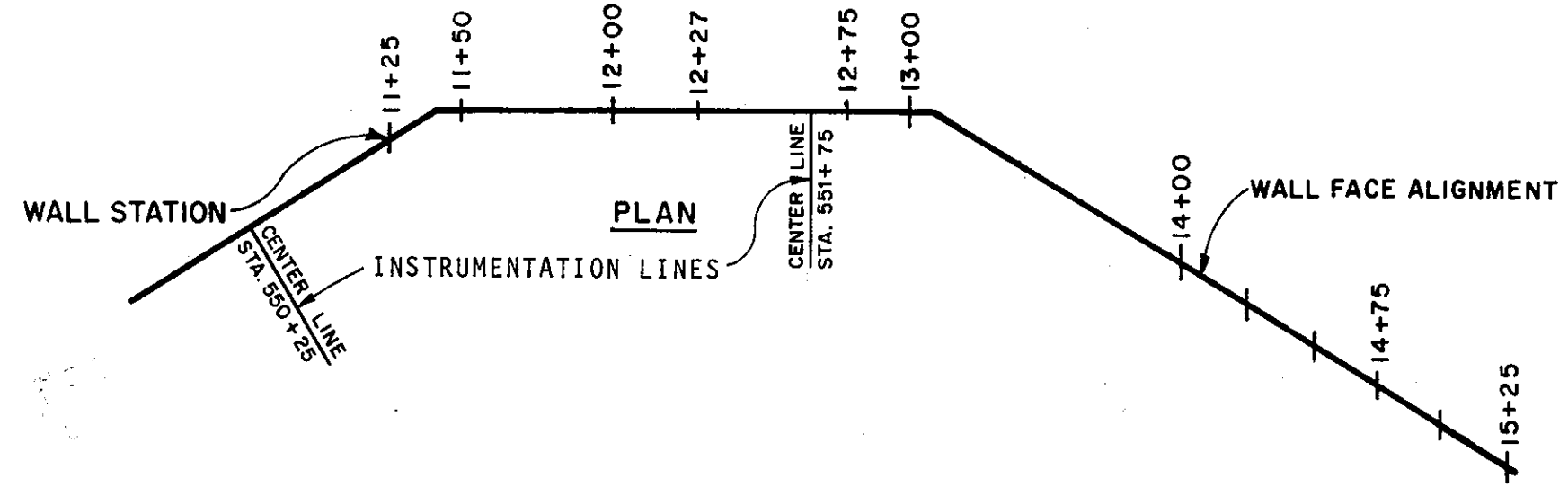

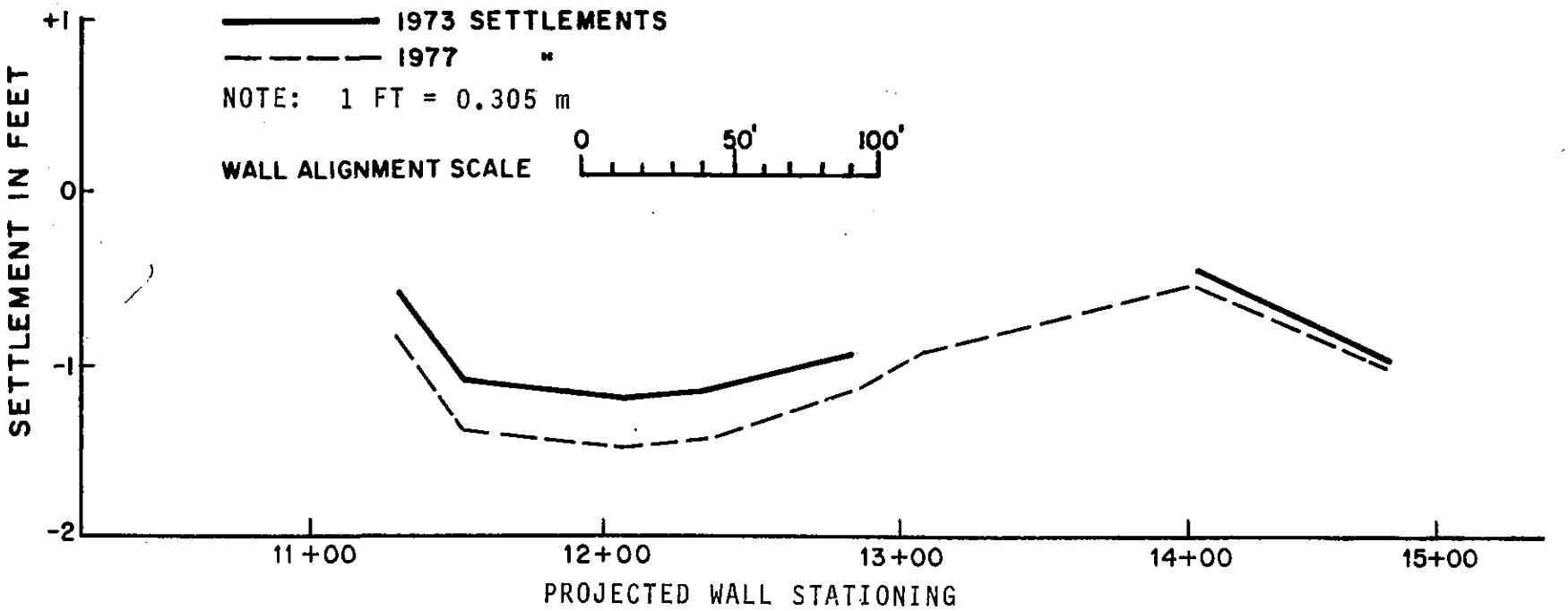

SETTLEMENTS AT SERIES "A" MONUMENTS

Figure 6

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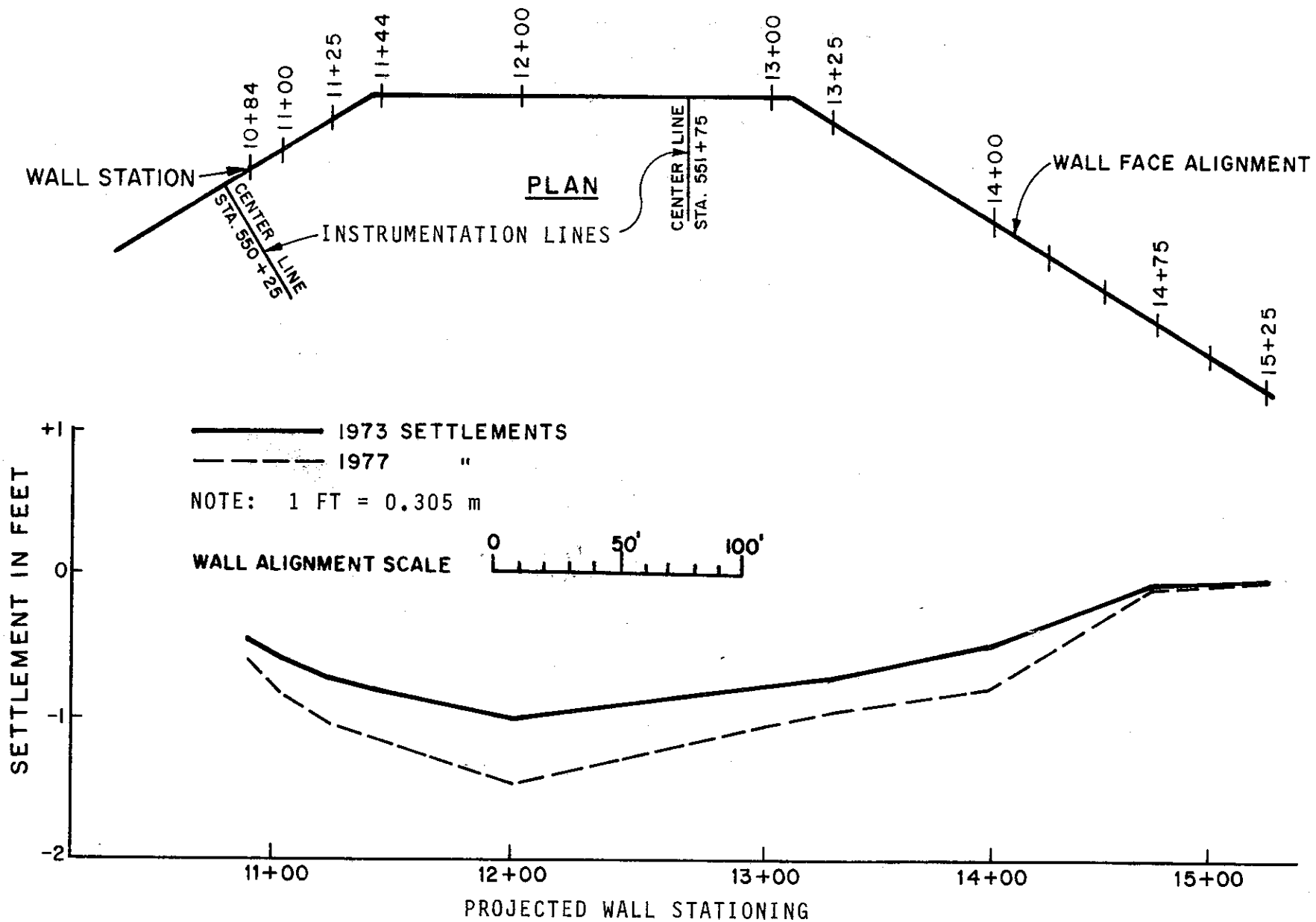
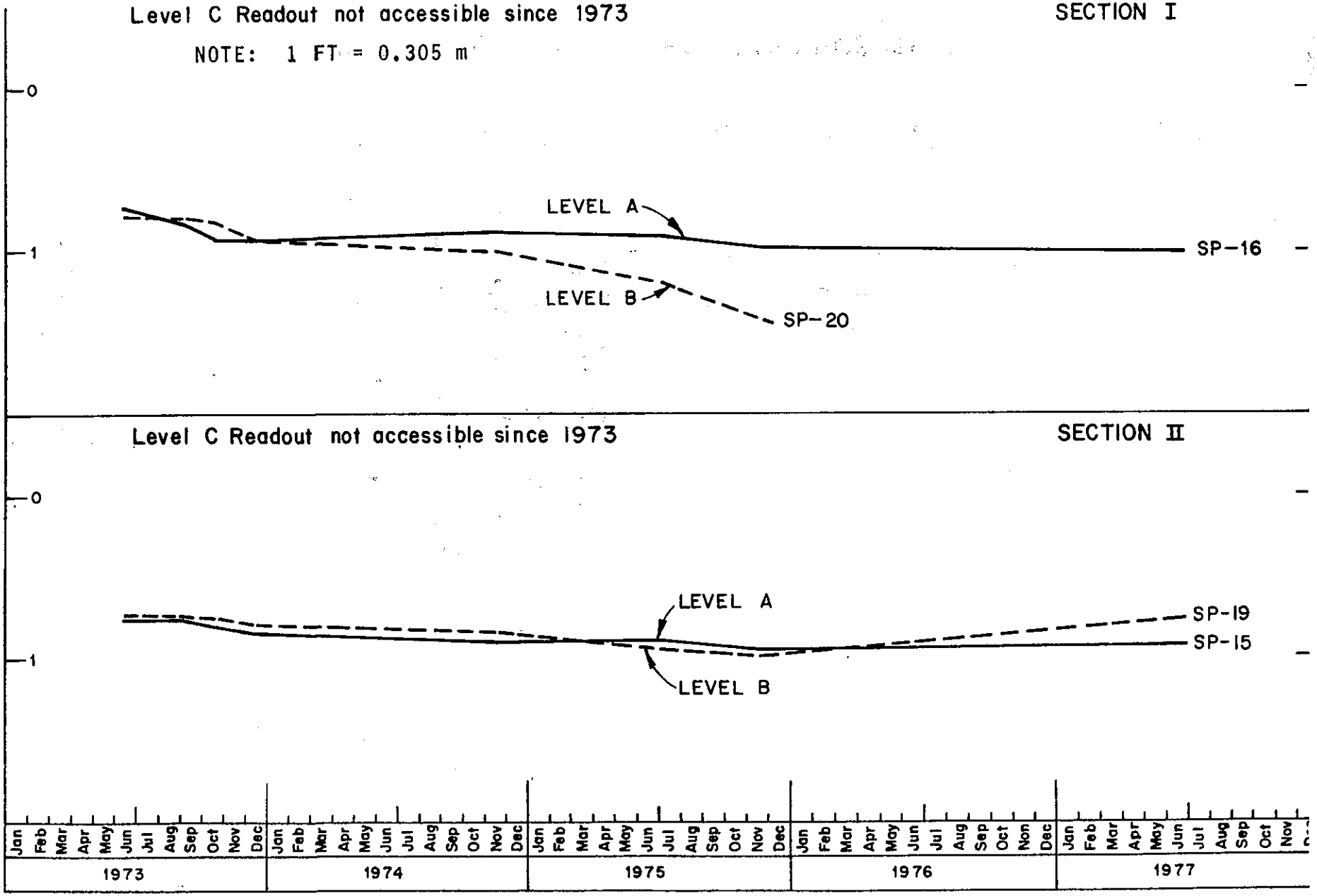


SETTLEMENTS AT SERIES "C" MONUMENTS

Figure 7

ClibPDF - www.fastio.com



STATION 550+25

DAILY HISTORY OF SETTLEMENT

Figure 8

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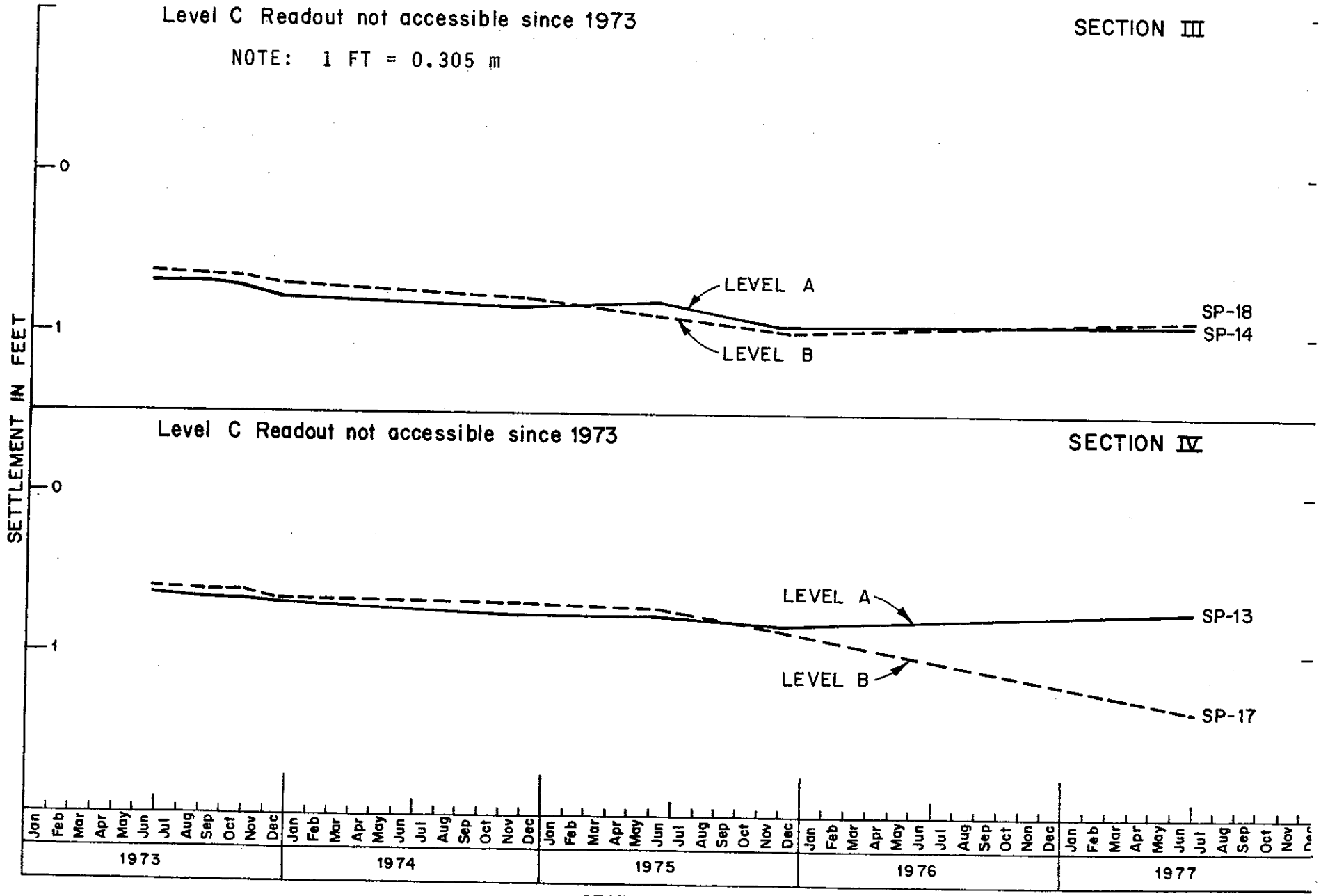
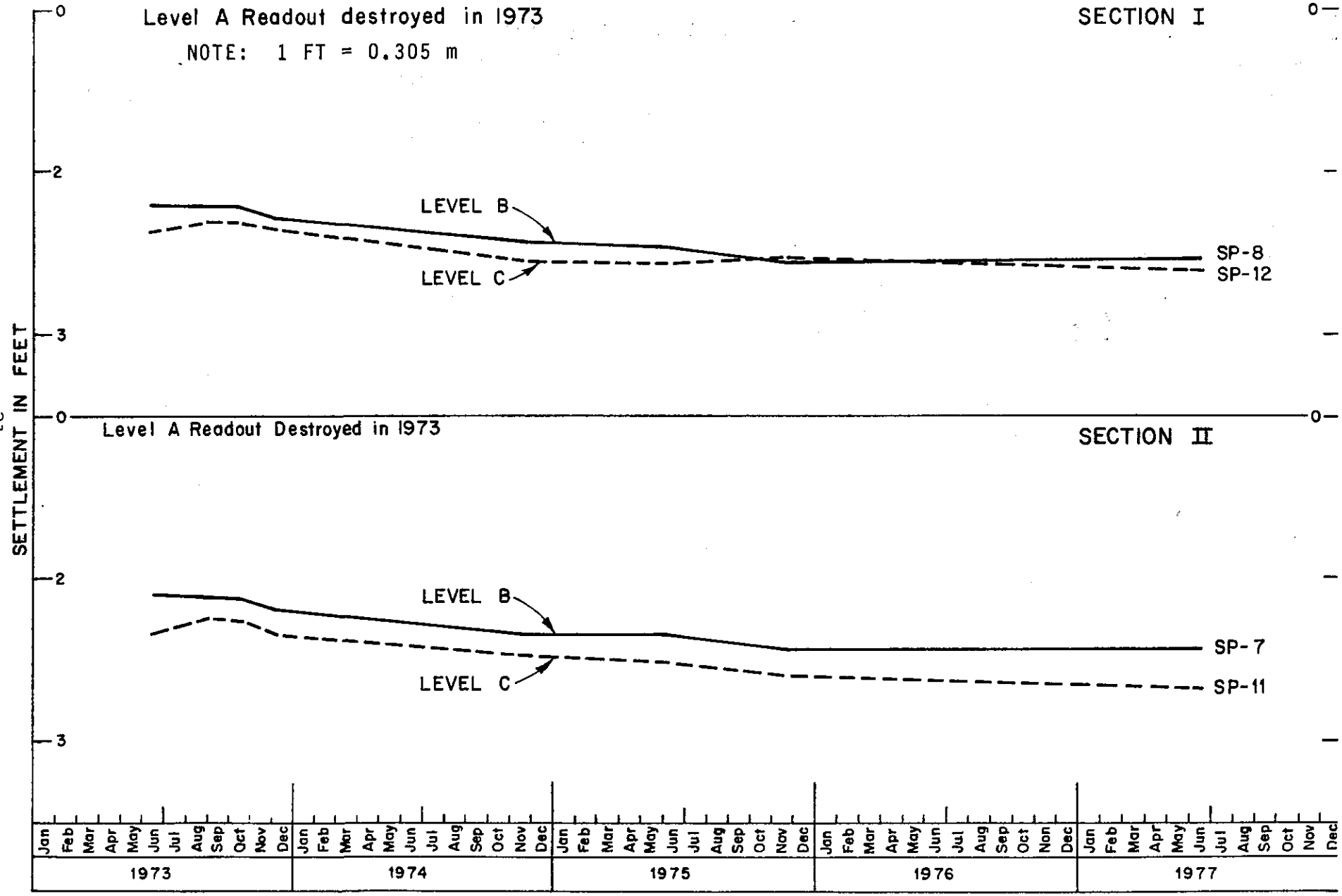


STATION 550+25

DAILY HISTORY OF SETTLEMENT

Figure 9

ClibPDF - www.fastio.com

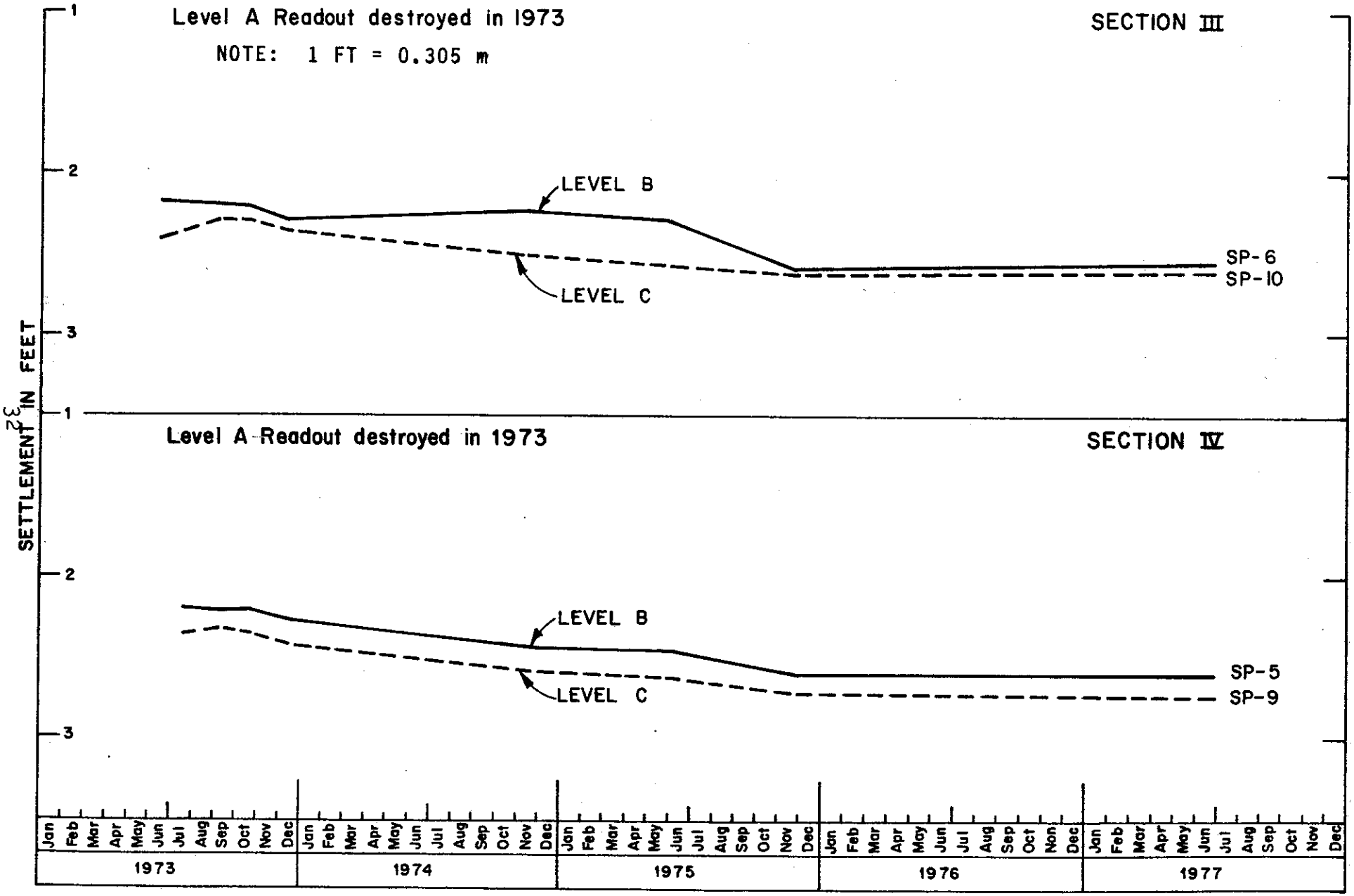


STATION 551+75

DAILY HISTORY OF SETTLEMENT

Figure 10

ClibPDF - www.fastio.com



STATION 551+75

DAILY HISTORY OF SETTLEMENT

Figure 11

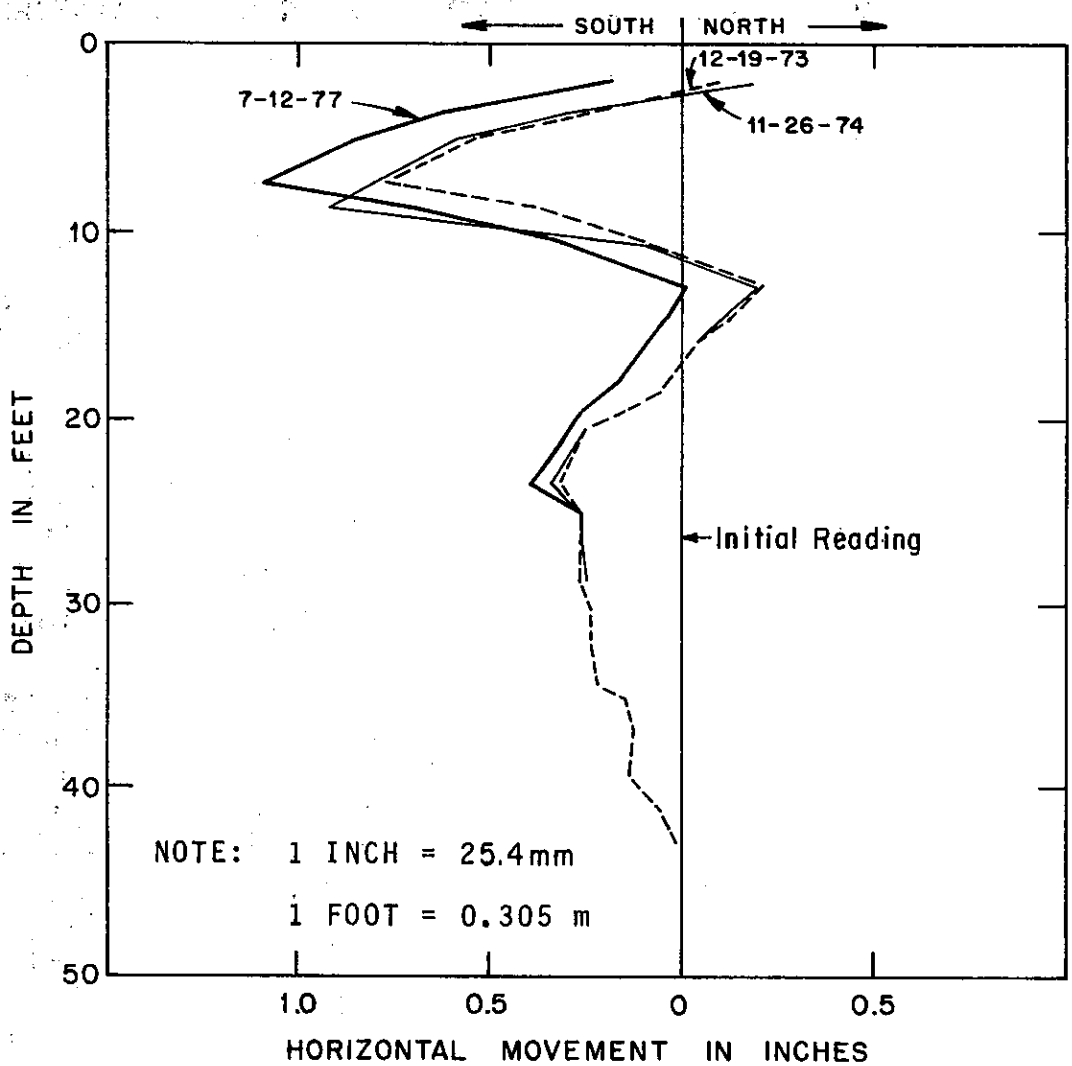


Figure 12, HORIZONTAL MOVEMENT IN THE N-S DIRECTION MEASURED BY SLOPE INDICATOR SI-1

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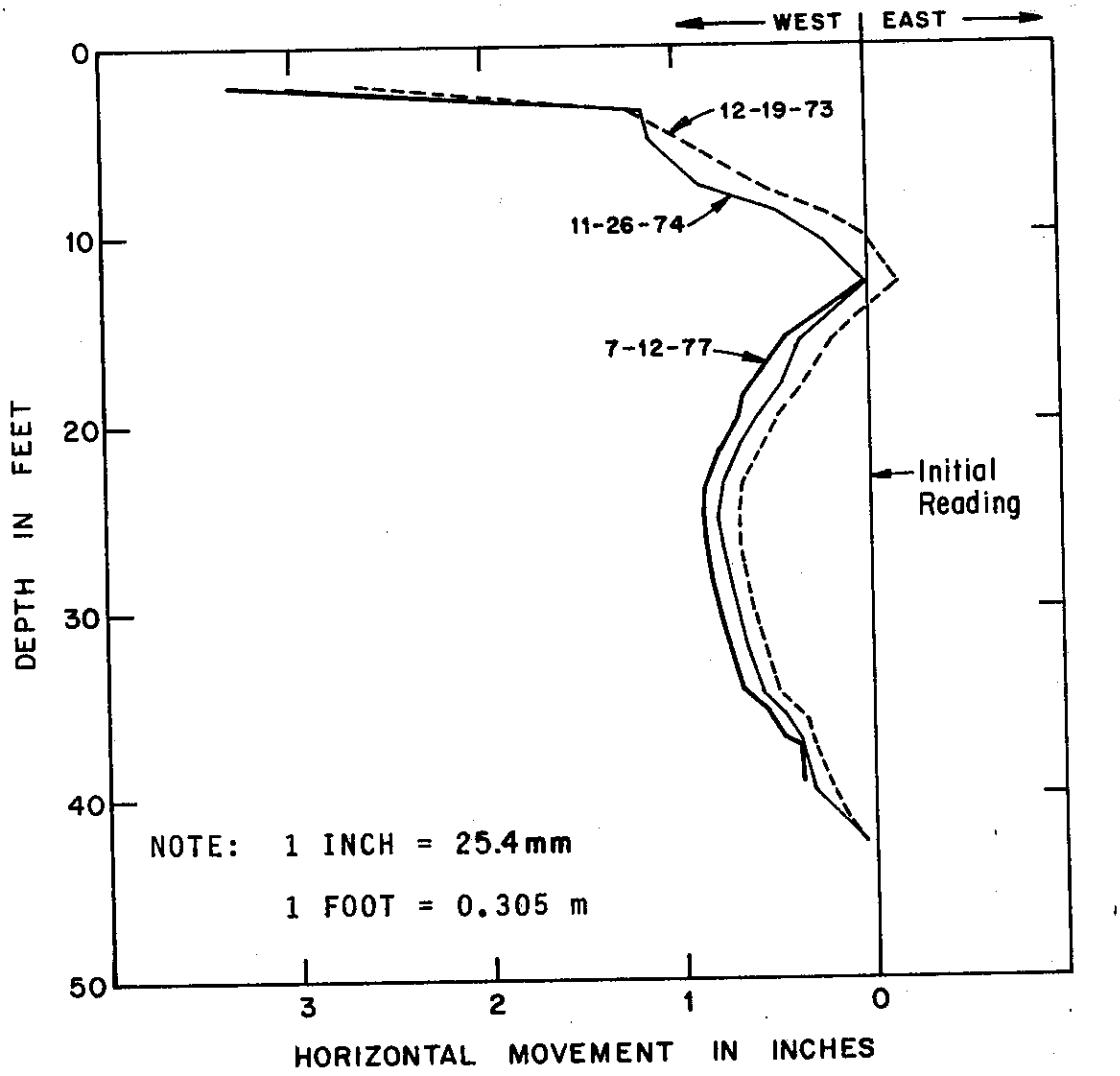

Figure 13, HORIZONTAL MOVEMENT IN THE E-W DIRECTION MEASURED BY SLOPE INDICATOR SI-1

ClibPDF - www.fastio.com

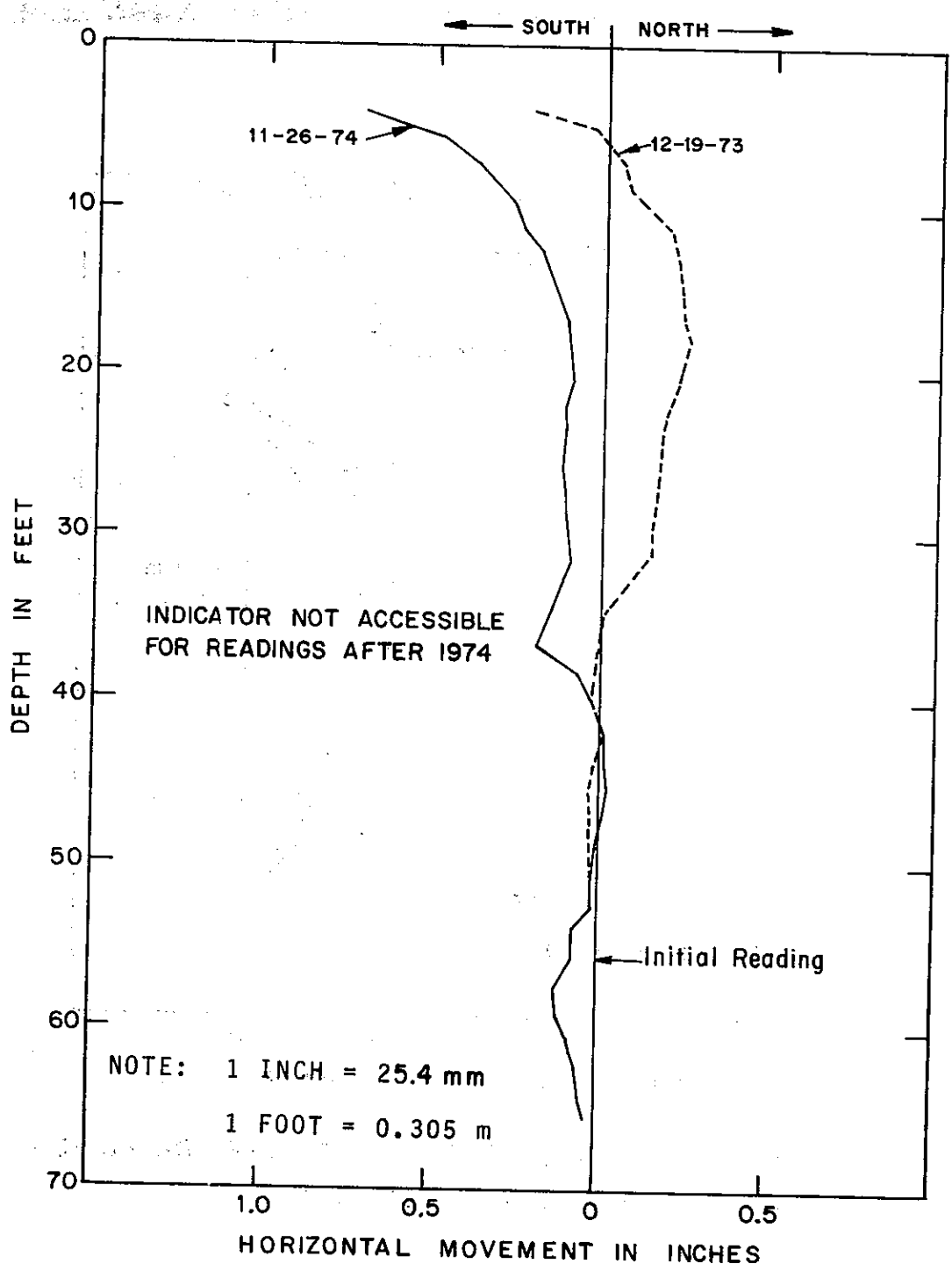

Figure 14, HORIZONTAL MOVEMENT IN THE N-S DIRECTION MEASURED BY SLOPE INDICATOR SI-2

ClibPDF - www.fastio.com

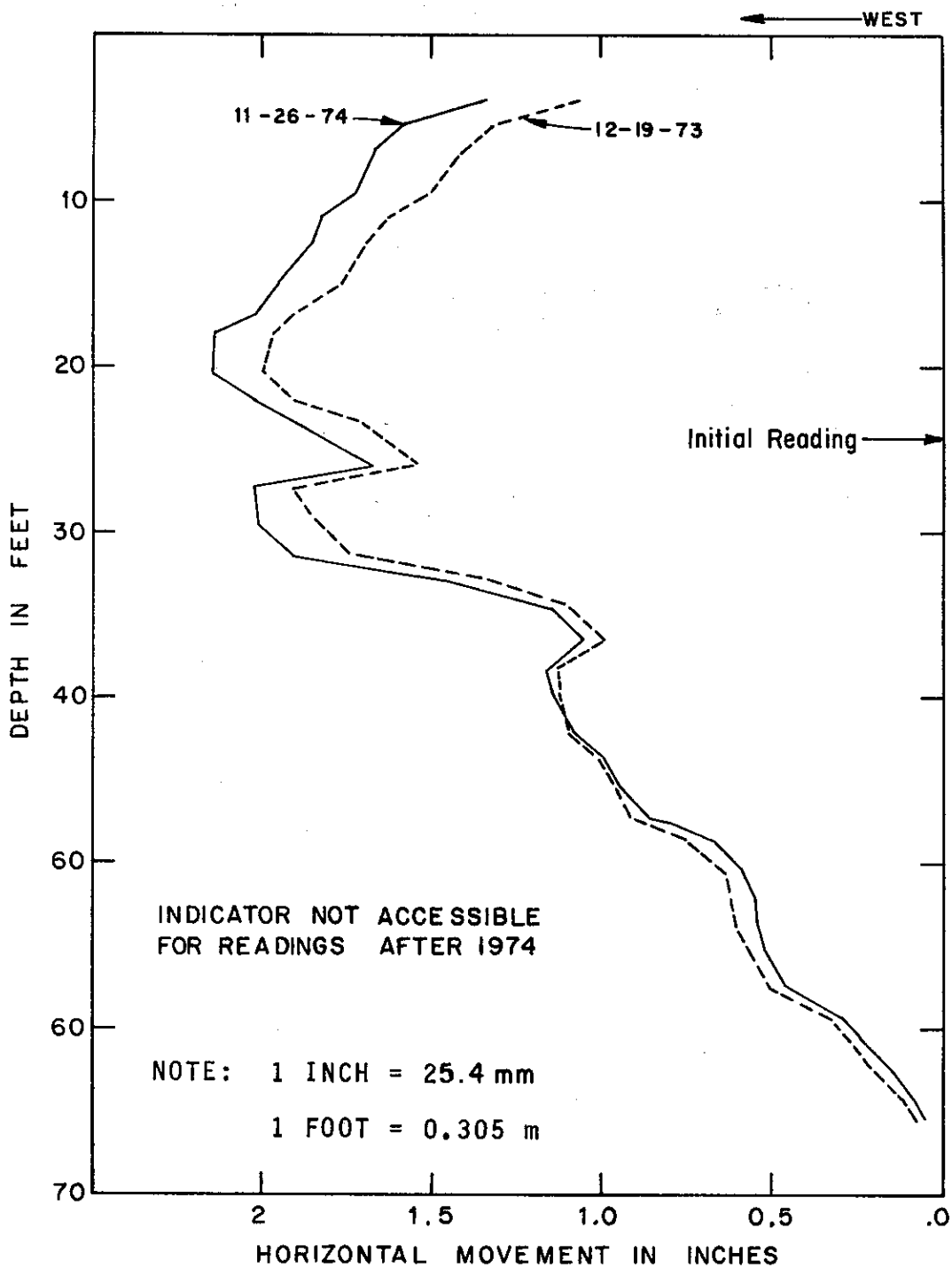

Figure 15, HORIZONTAL MOVEMENT IN THE E-W DIRECTION MEASURED BY SLOPE INDICATOR SI-2

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Permanized

PLOVER BOND

25% COTTON FIBER

U.S.A.

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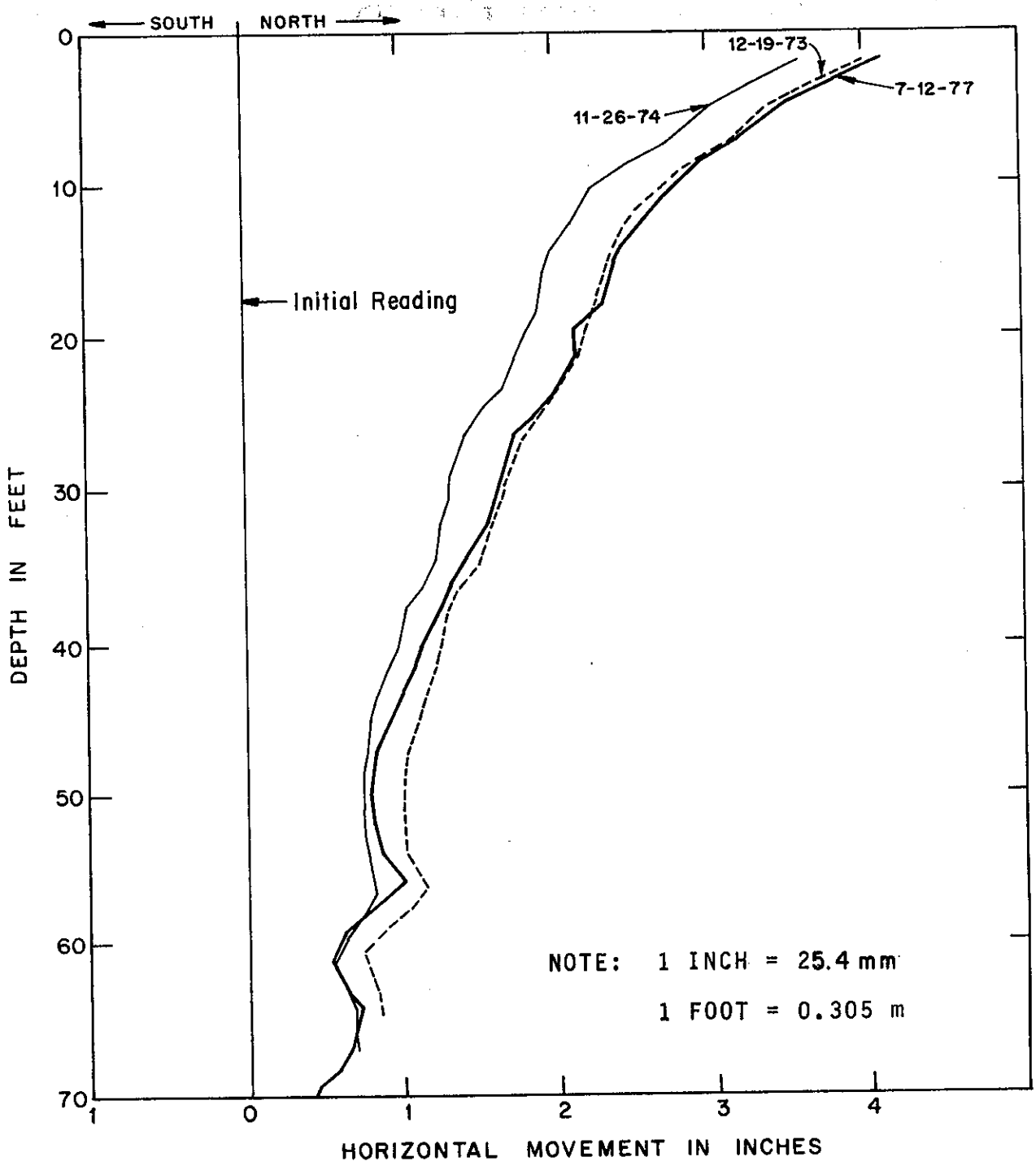

Figure 16, HORIZONTAL MOVEMENT IN THE N-S DIRECTION MEASURED BY SLOPE INDICATOR SI-3

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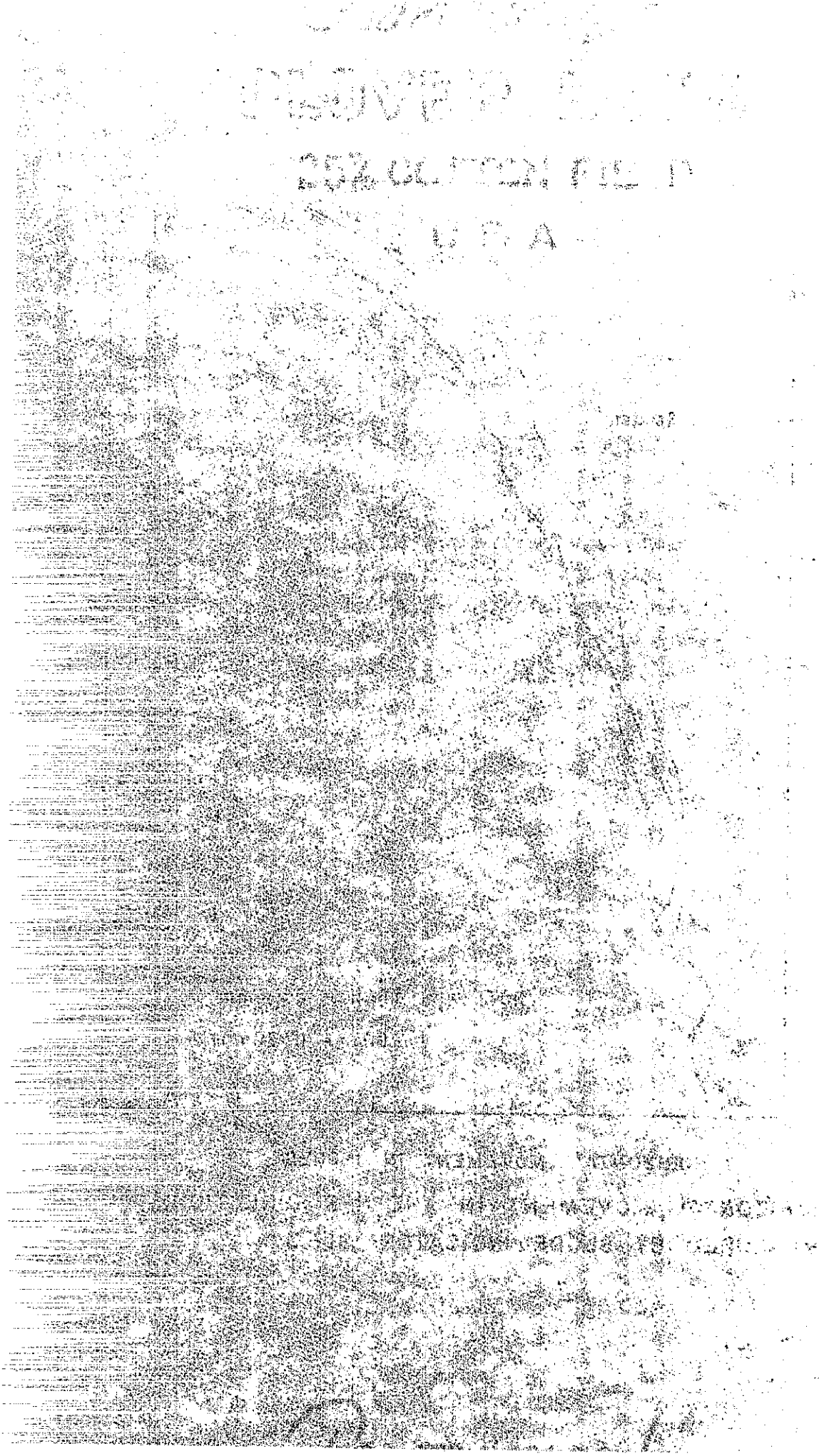

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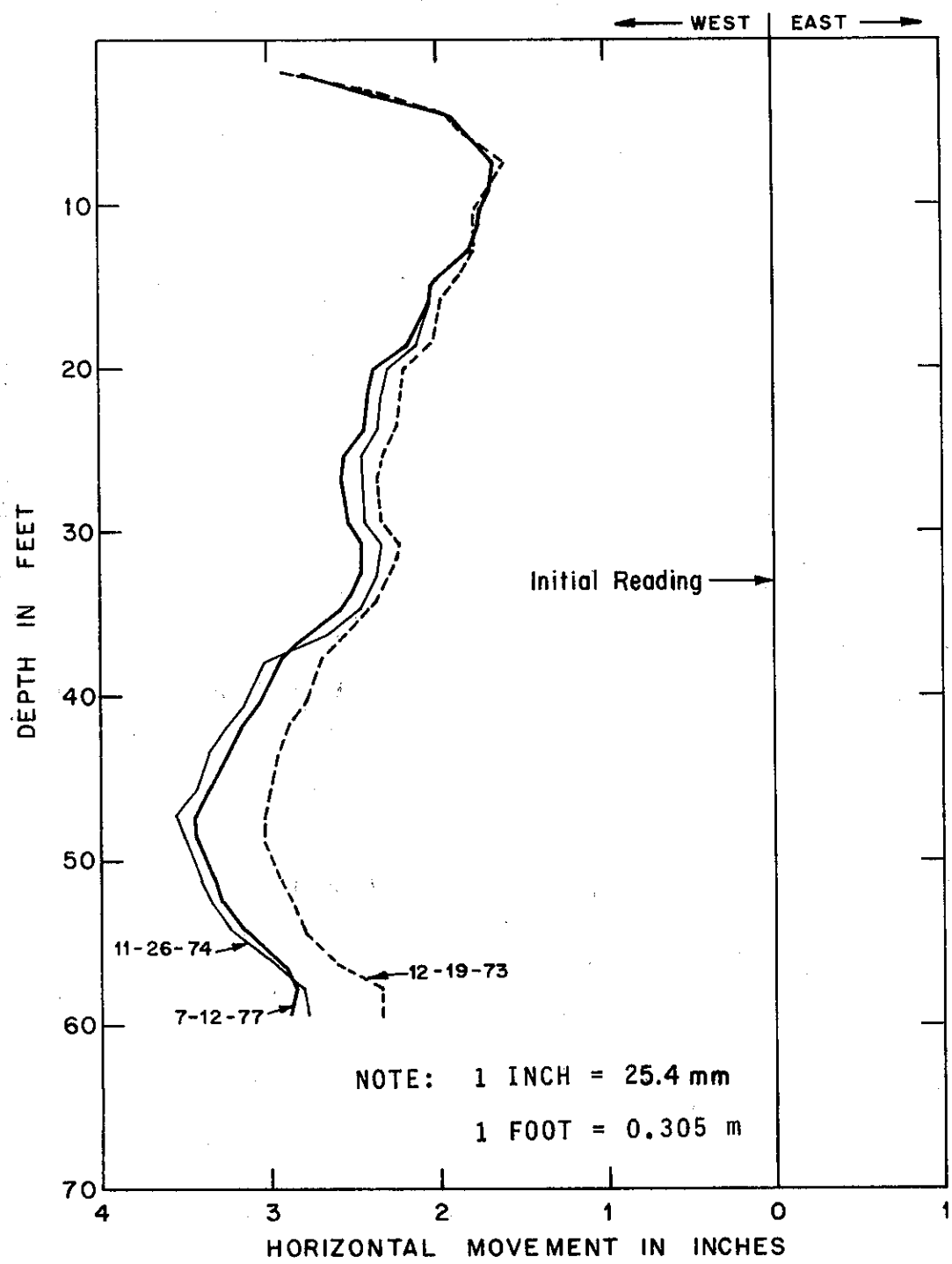

Figure 17, HORIZONTAL MOVEMENT IN THE E-W DIRECTION MEASURED BY SLOPE INDICATOR SI-3

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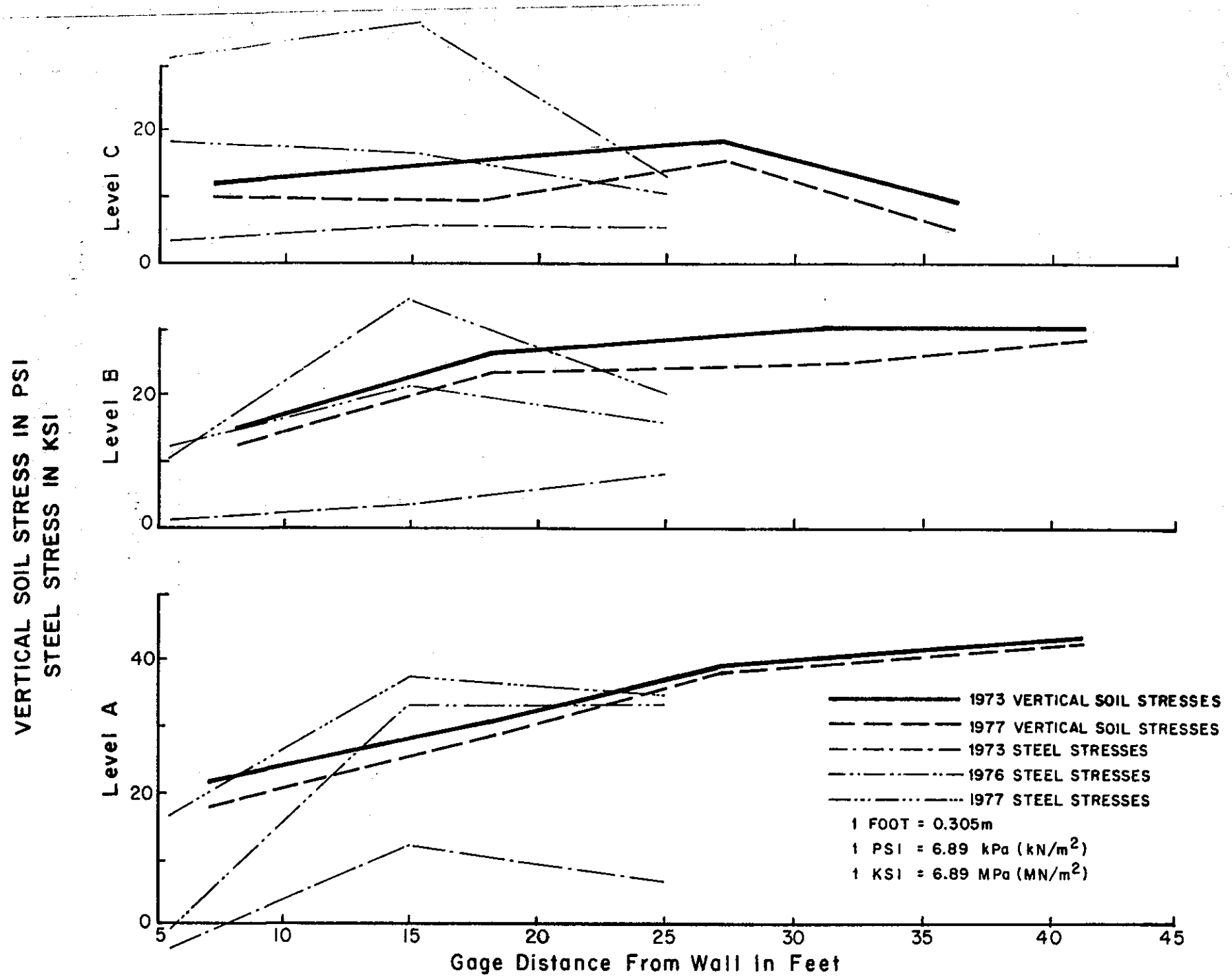
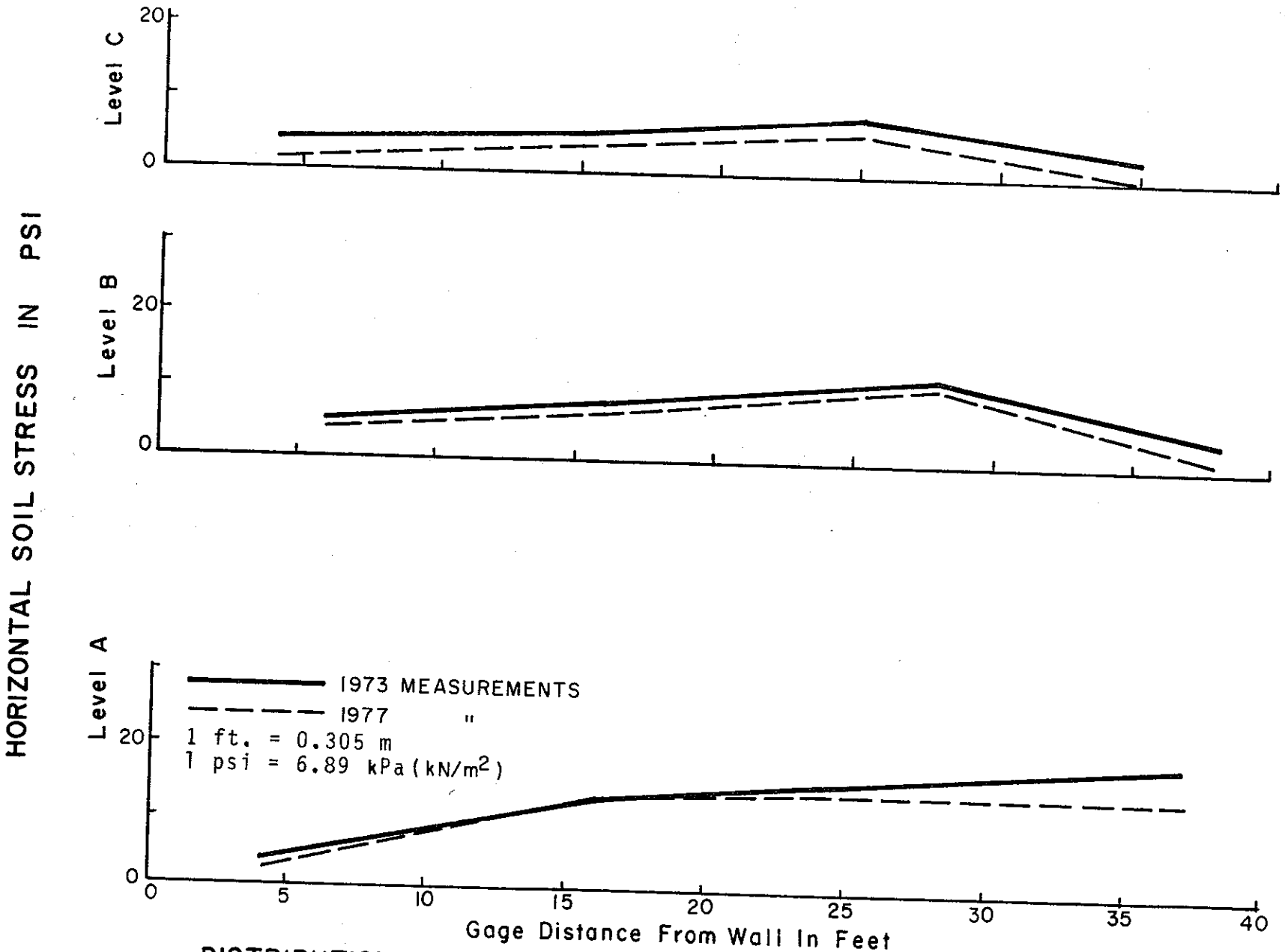
ClibPDF - www.fastio.com



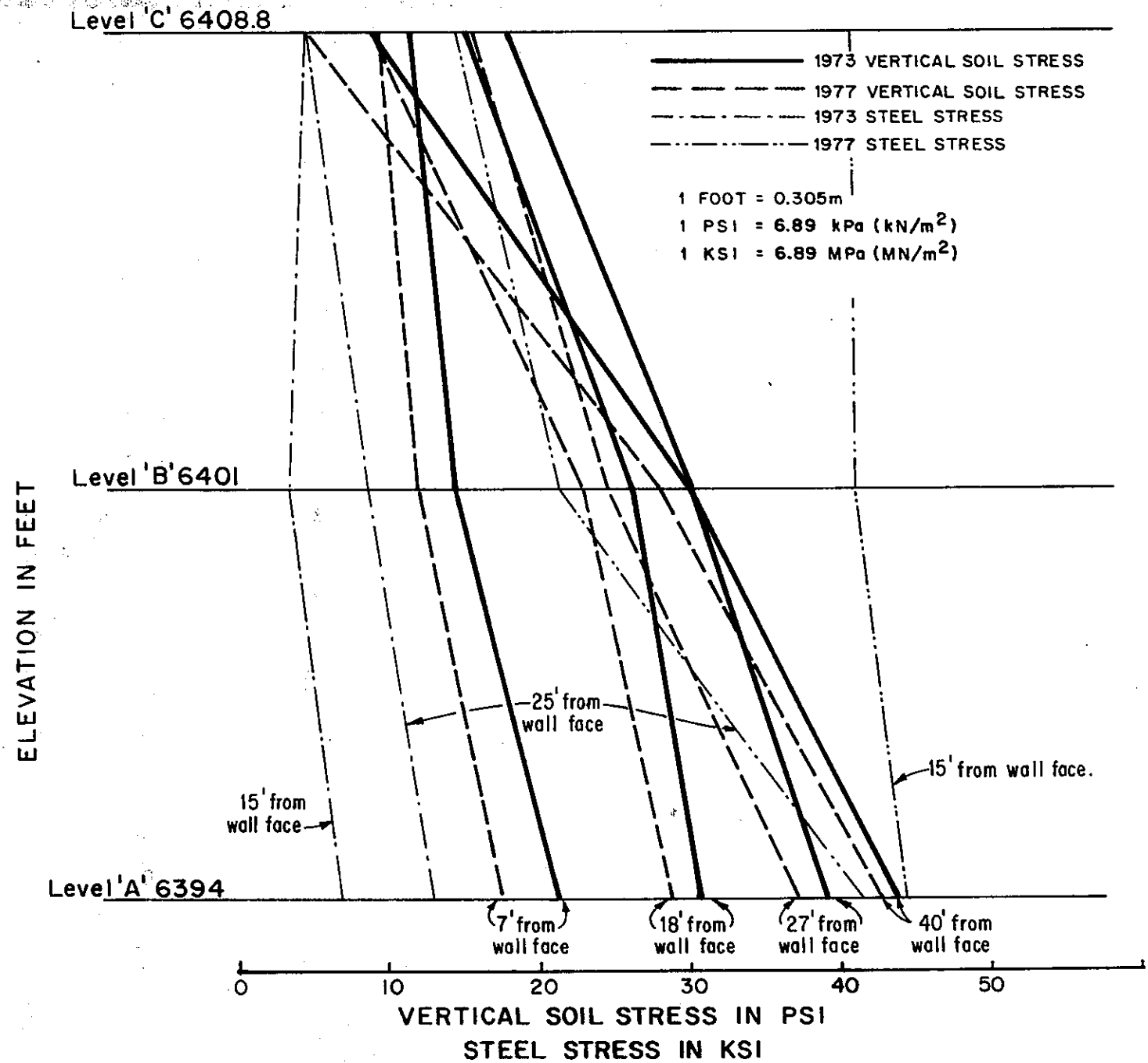
DISTRIBUTION OF STEEL STRESSES & VERTICAL SOIL STRESSES ON HORIZONTAL PLANE
STA.550+25

ClibPDF - www.fastio.com



DISTRIBUTION OF HORIZONTAL SOIL STRESSES ON HORIZONTAL PLANE
STA.550+25

Figure 19



DISTRIBUTION OF STEEL STRESSES &
VERTICAL SOIL STRESSES ON VERTICAL SECTIONS

STA. 550+25

Figure 20

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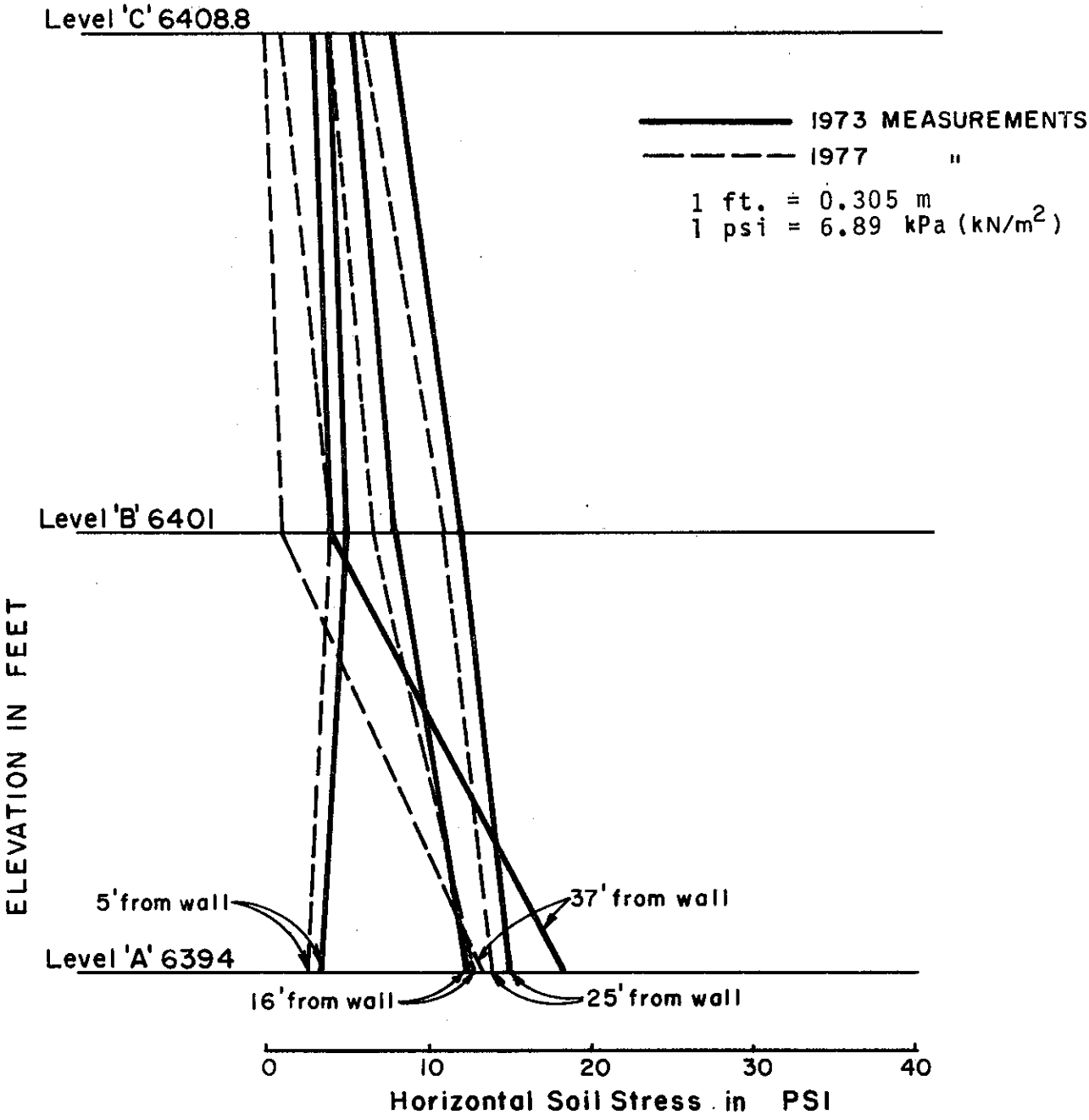

DISTRIBUTION OF HORIZONTAL SOIL STRESSES ON VERTICAL SECTIONS

STA. 550+25

ROUTE 07-LA-39

Figure 21

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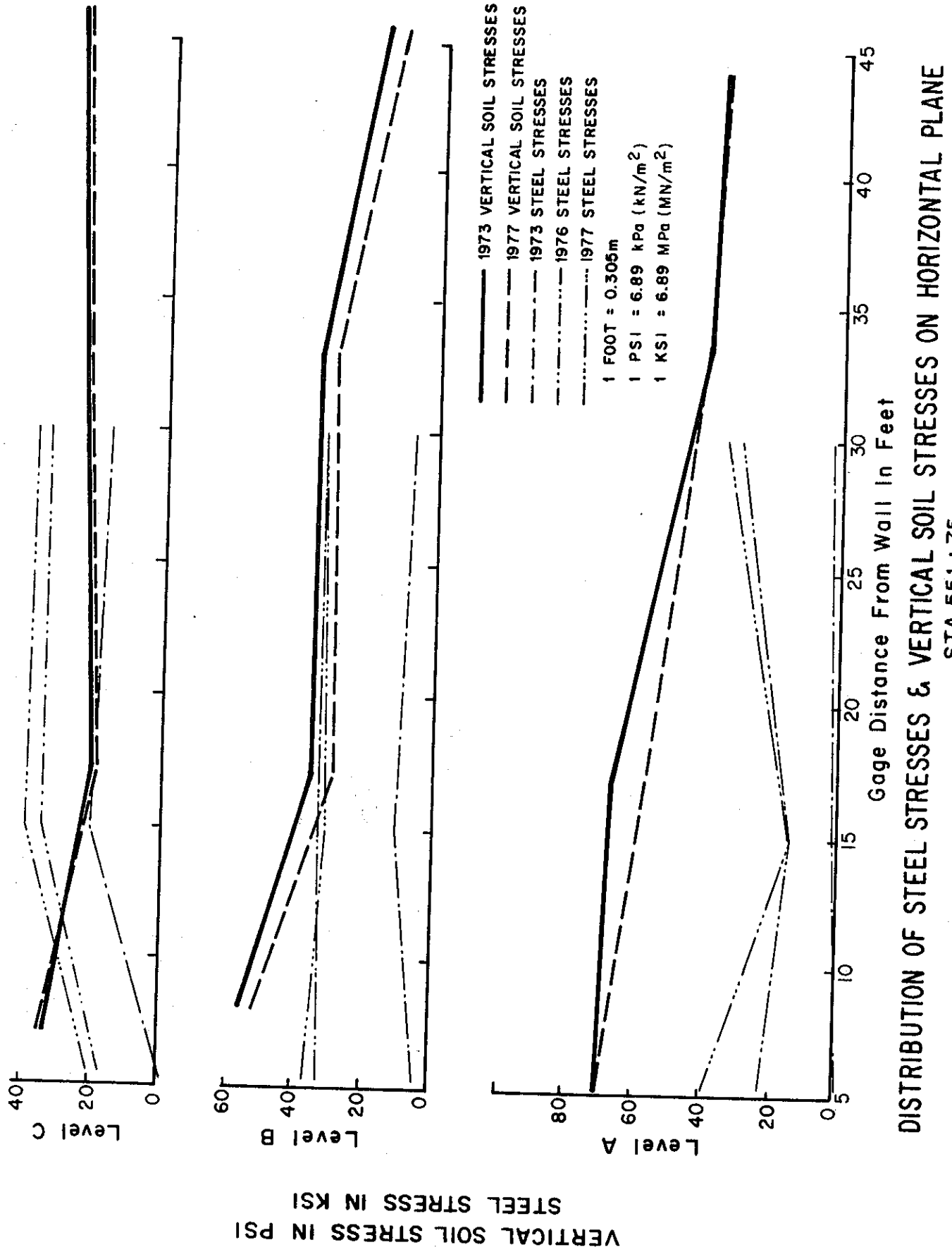

DISTRIBUTION OF STEEL STRESSES & VERTICAL SOIL STRESSES ON HORIZONTAL PLANE
STA.551+75

Figure 22

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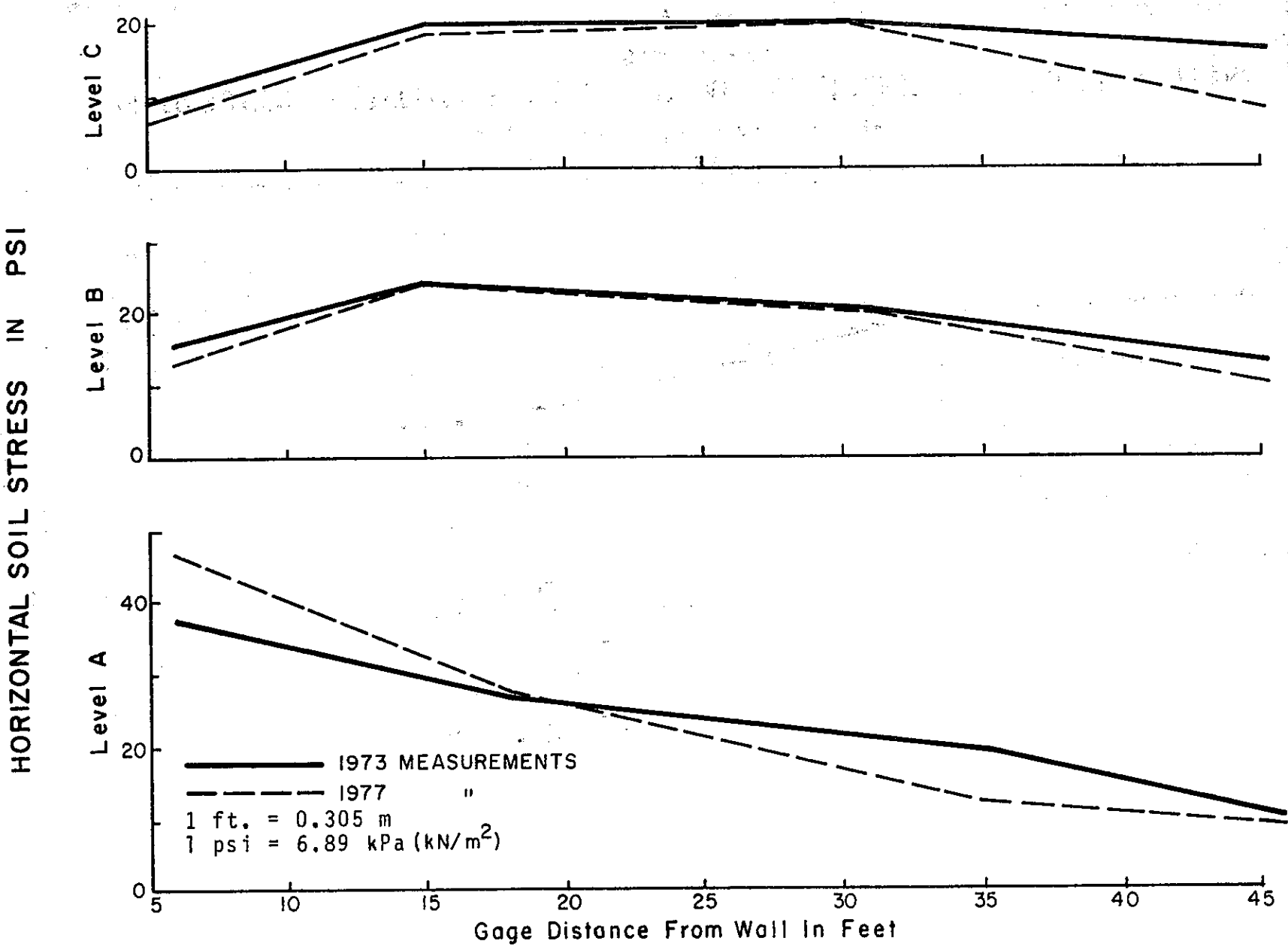
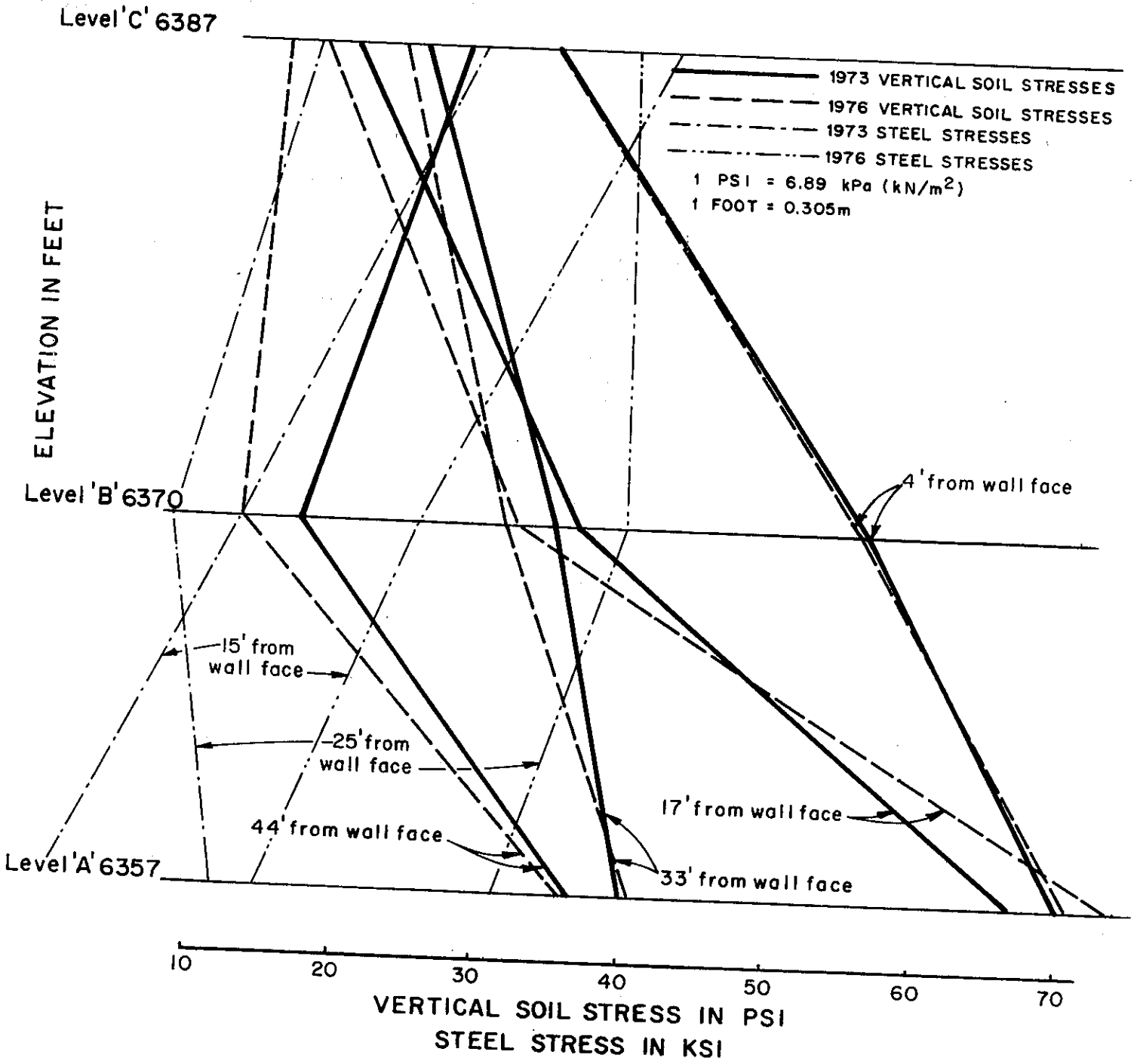


DISTRIBUTION OF HORIZONTAL SOIL STRESSES ON HORIZONTAL PLANE

STA.551+75

Figure 23



DISTRIBUTION OF STEEL STRESSES &
VERTICAL SOIL STRESSES ON VERTICAL SECTIONS

STA. 551 + 75

Figure 24

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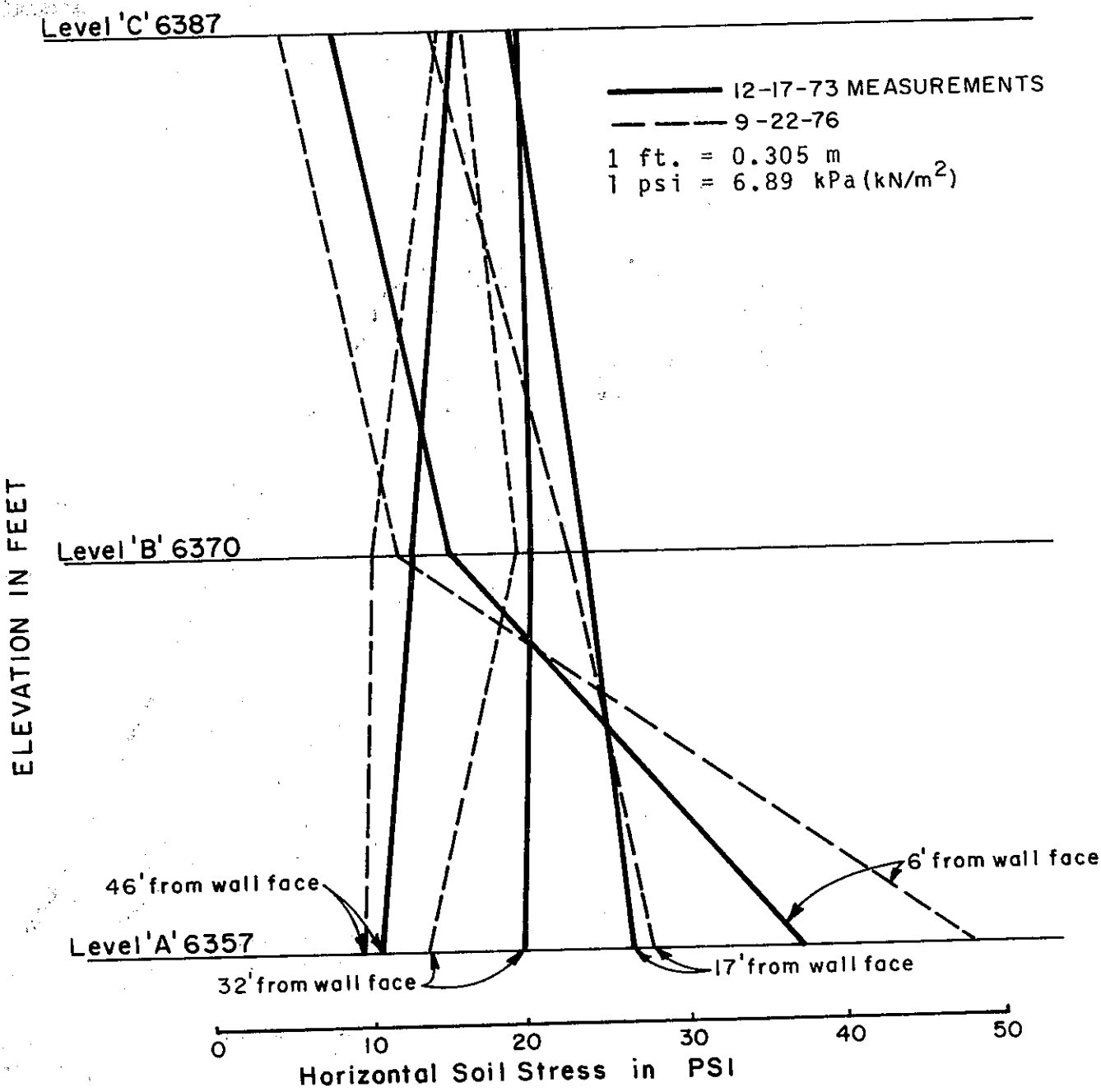

DISTRIBUTION OF HORIZONTAL SOIL STRESSES ON VERTICAL SECTIONS

STA. 551+75

Figure 25

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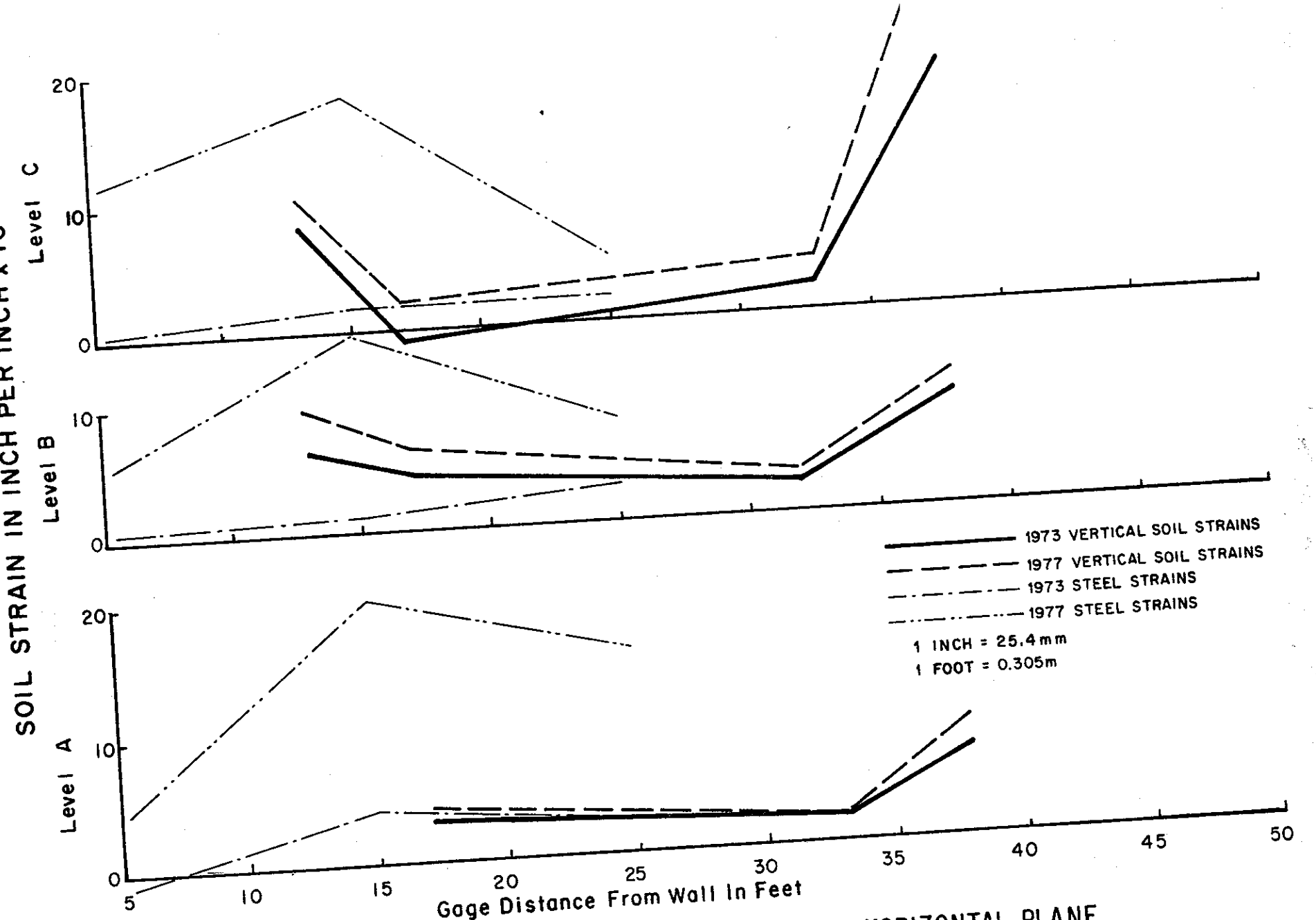

DISTRIBUTION OF SOIL STRAIN & STEEL STRAIN ON HORIZONTAL PLANE
STA. 550+25
Figure 26

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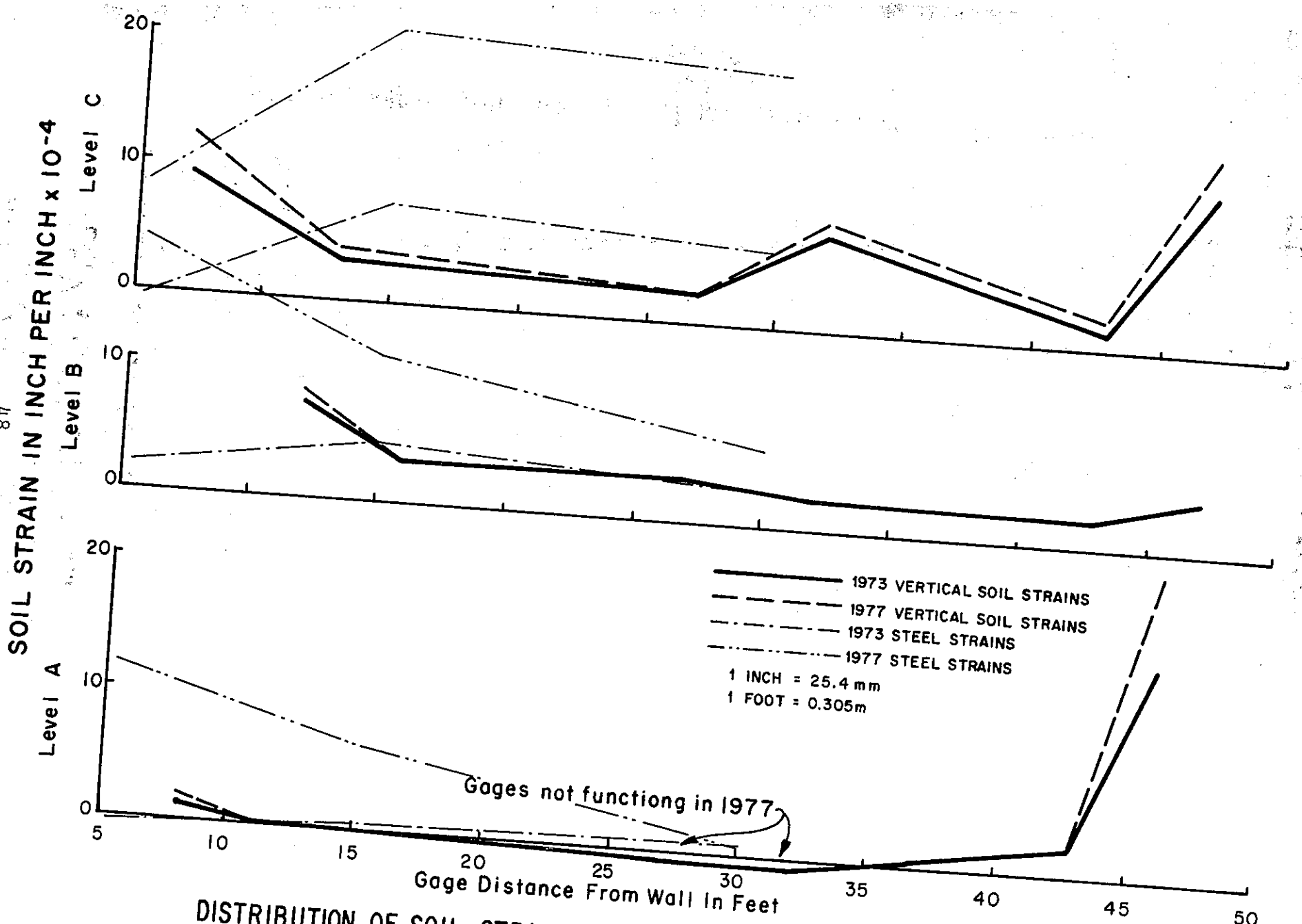

DISTRIBUTION OF SOIL STRAIN & STEEL STRAIN ON HORIZONTAL PLANE

STA. 551 + 75

Figure 27

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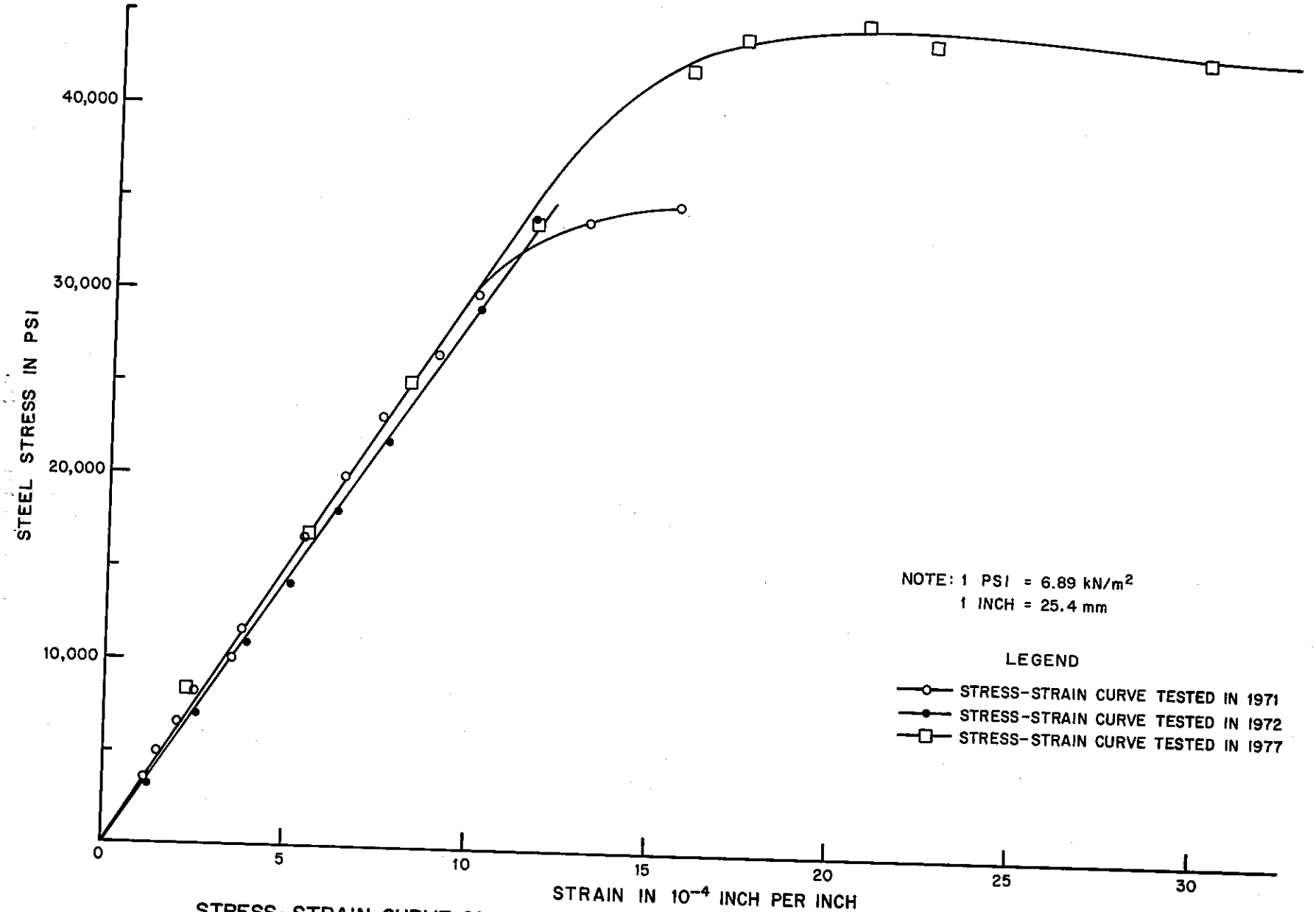

STRESS-STRAIN CURVE OF GALVANIZED STEEL STRIP - STANDARD TENSION TEST

FIGURE 28

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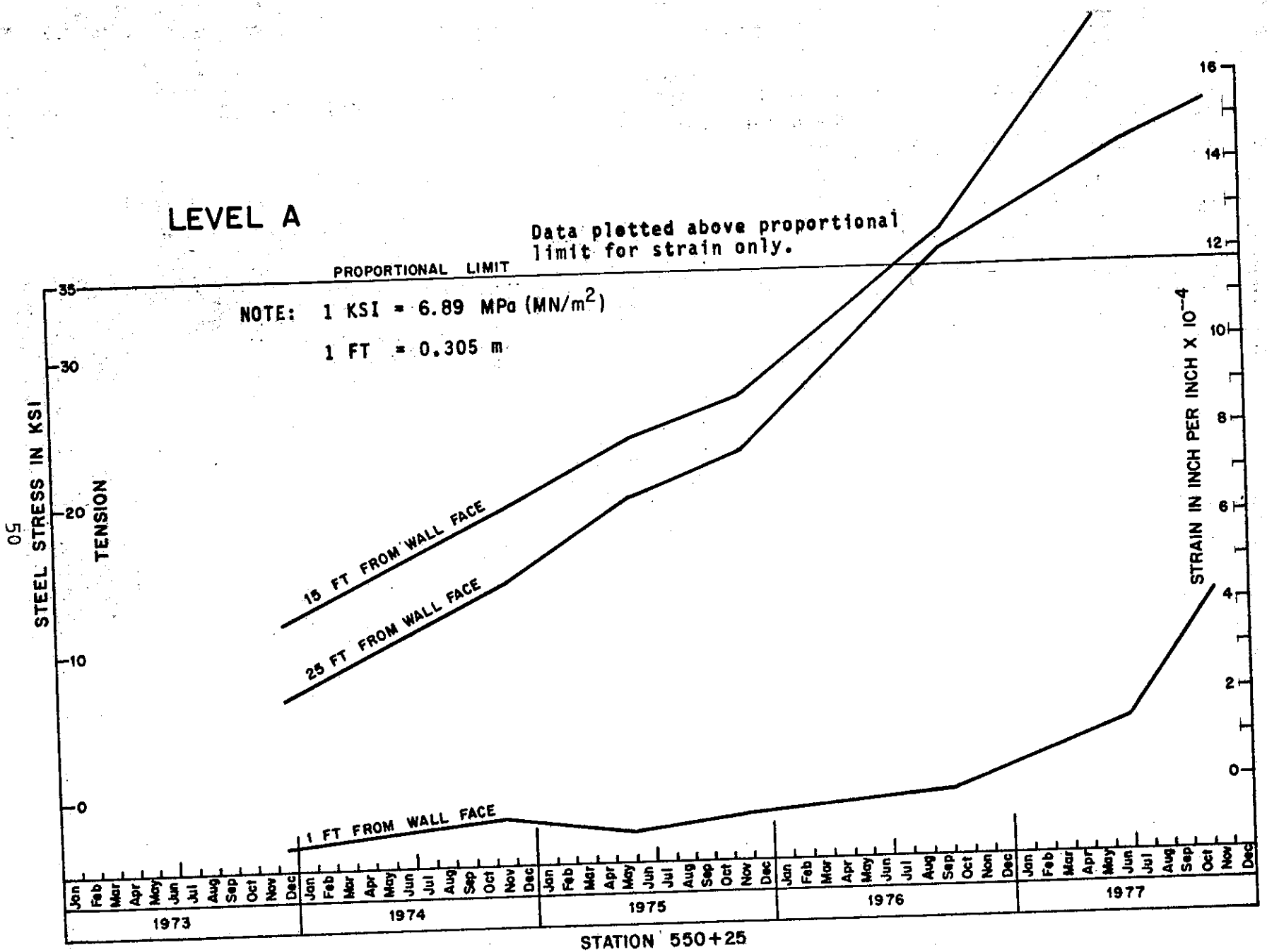
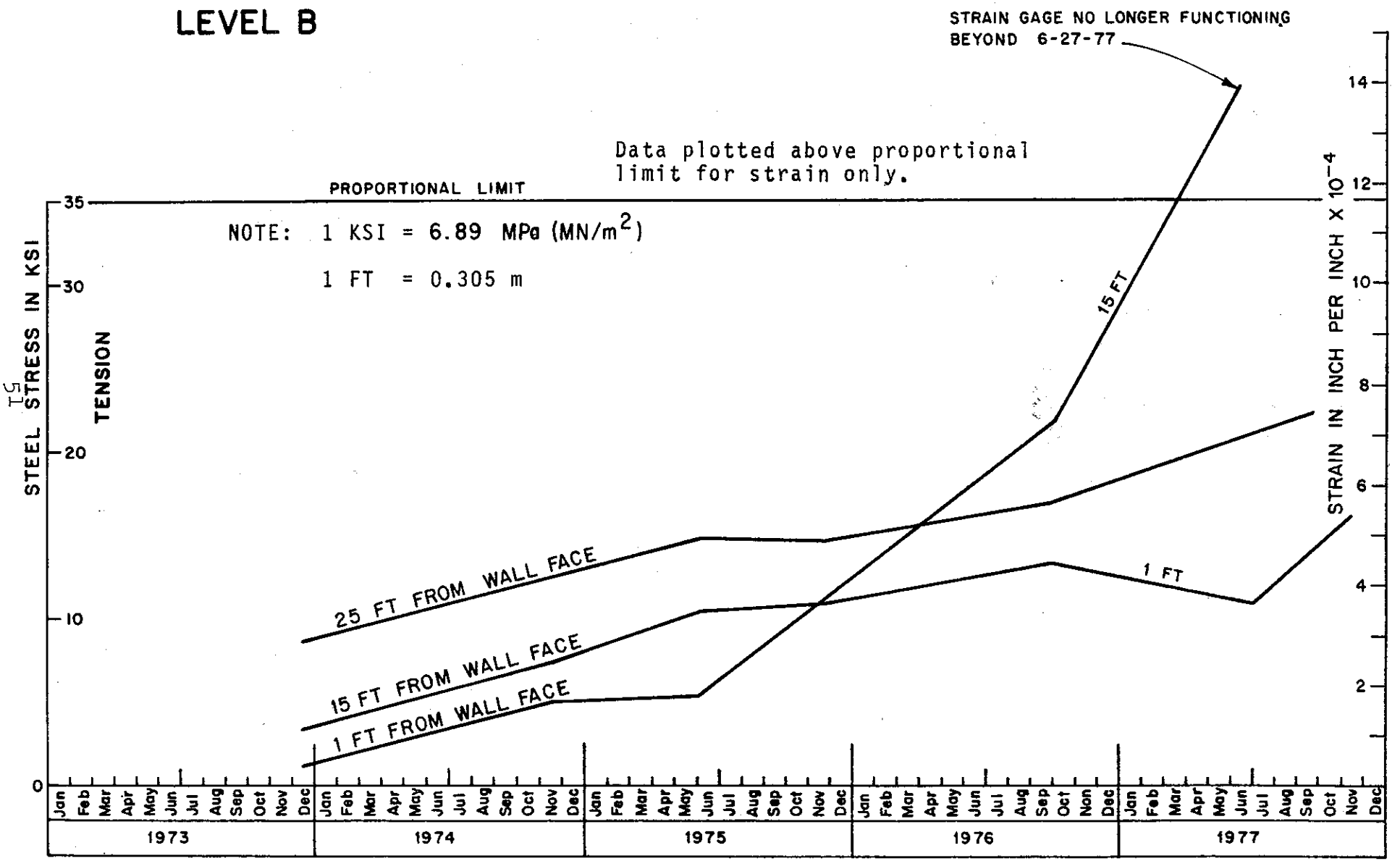


DAILY HISTORY OF STRESSES & STRAINS IN STEEL STRIP

Figure 29

ClibPDF - www.fastio.com

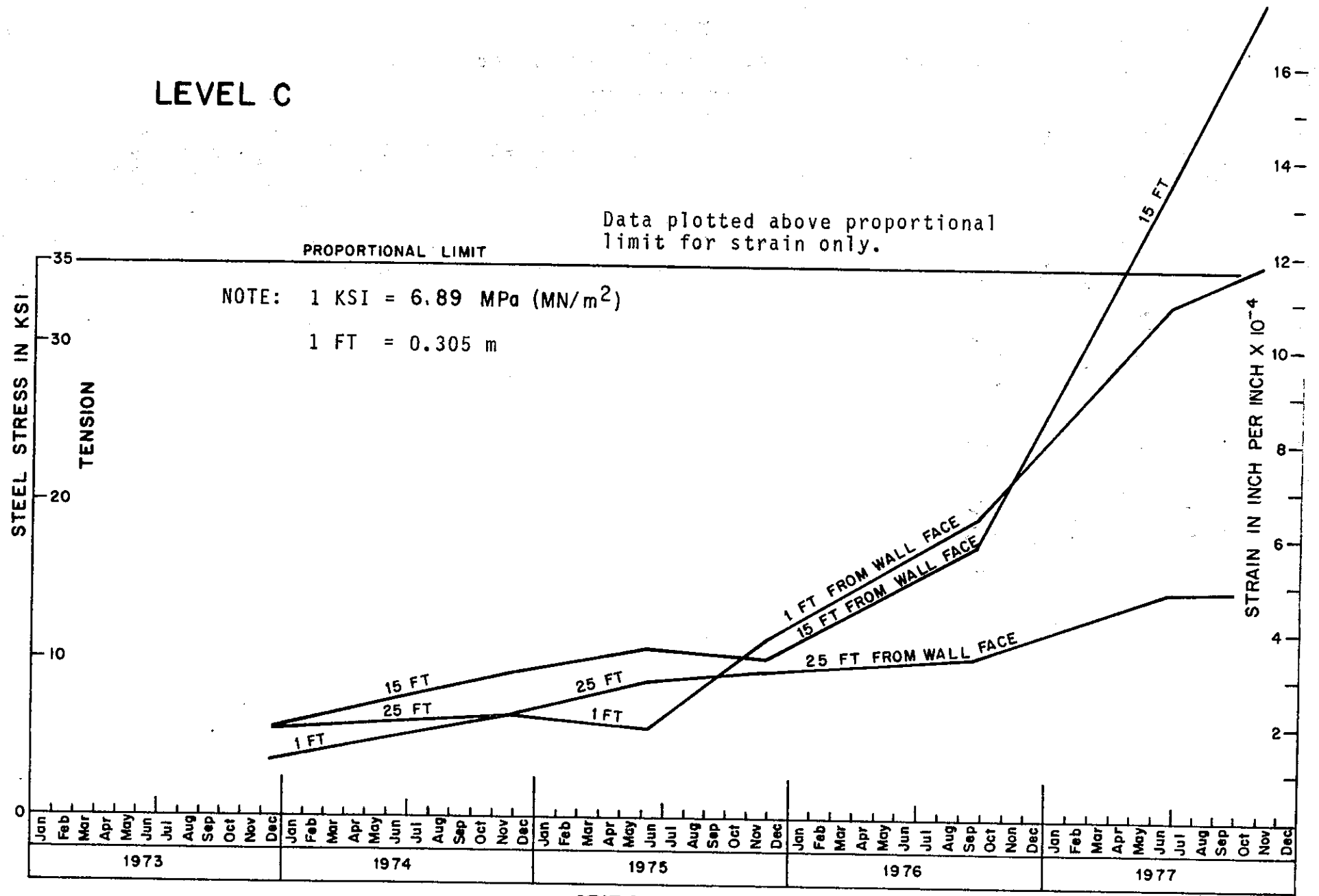


STATION 550+25

DAILY HISTORY OF STRESSES & STRAINS IN STEEL STRIP

Figure 30

ClibPDF - www.fastio.com



DAILY HISTORY OF STRESSES & STRAINS IN STEEL STRIP

Figure 31

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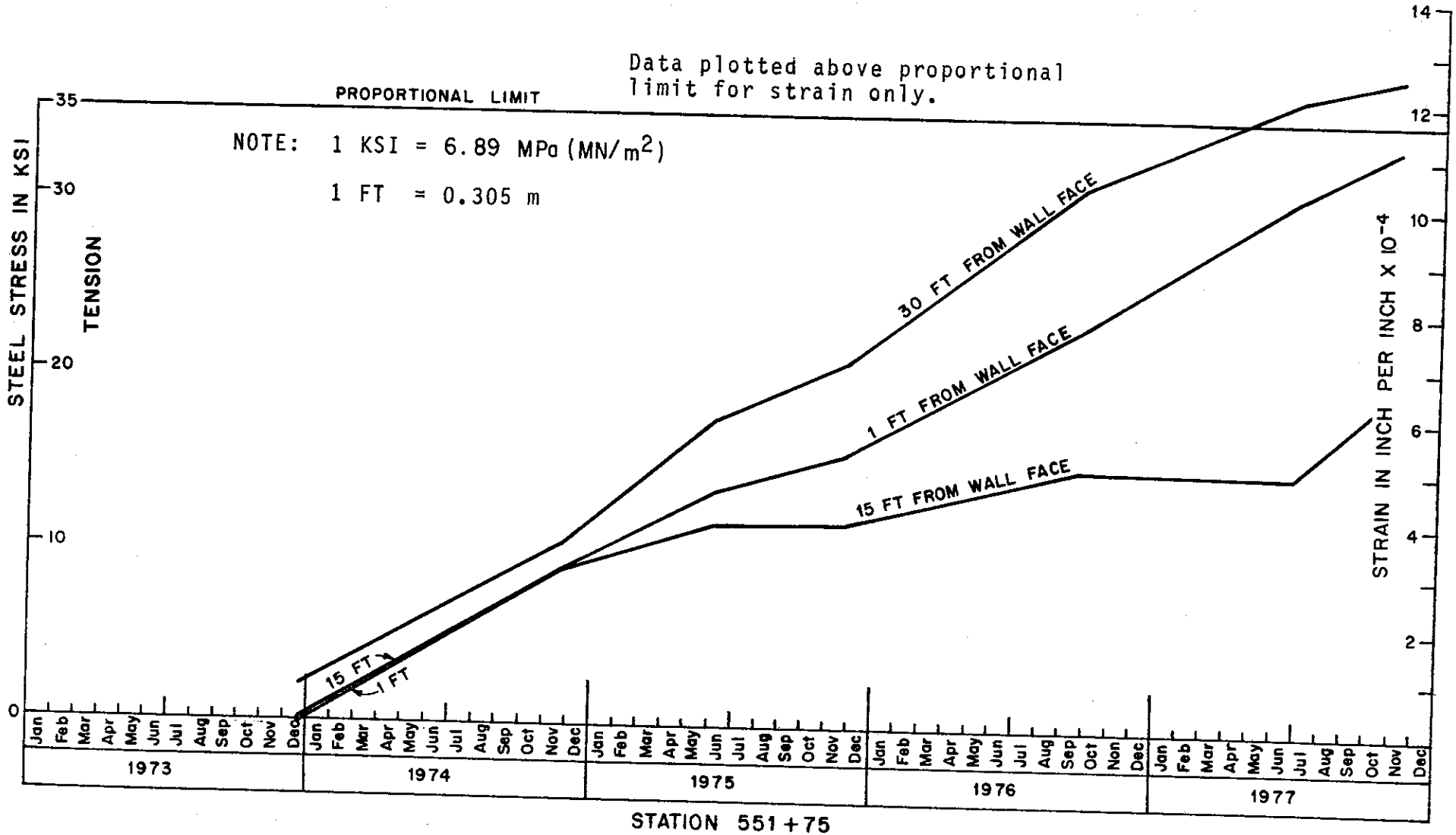
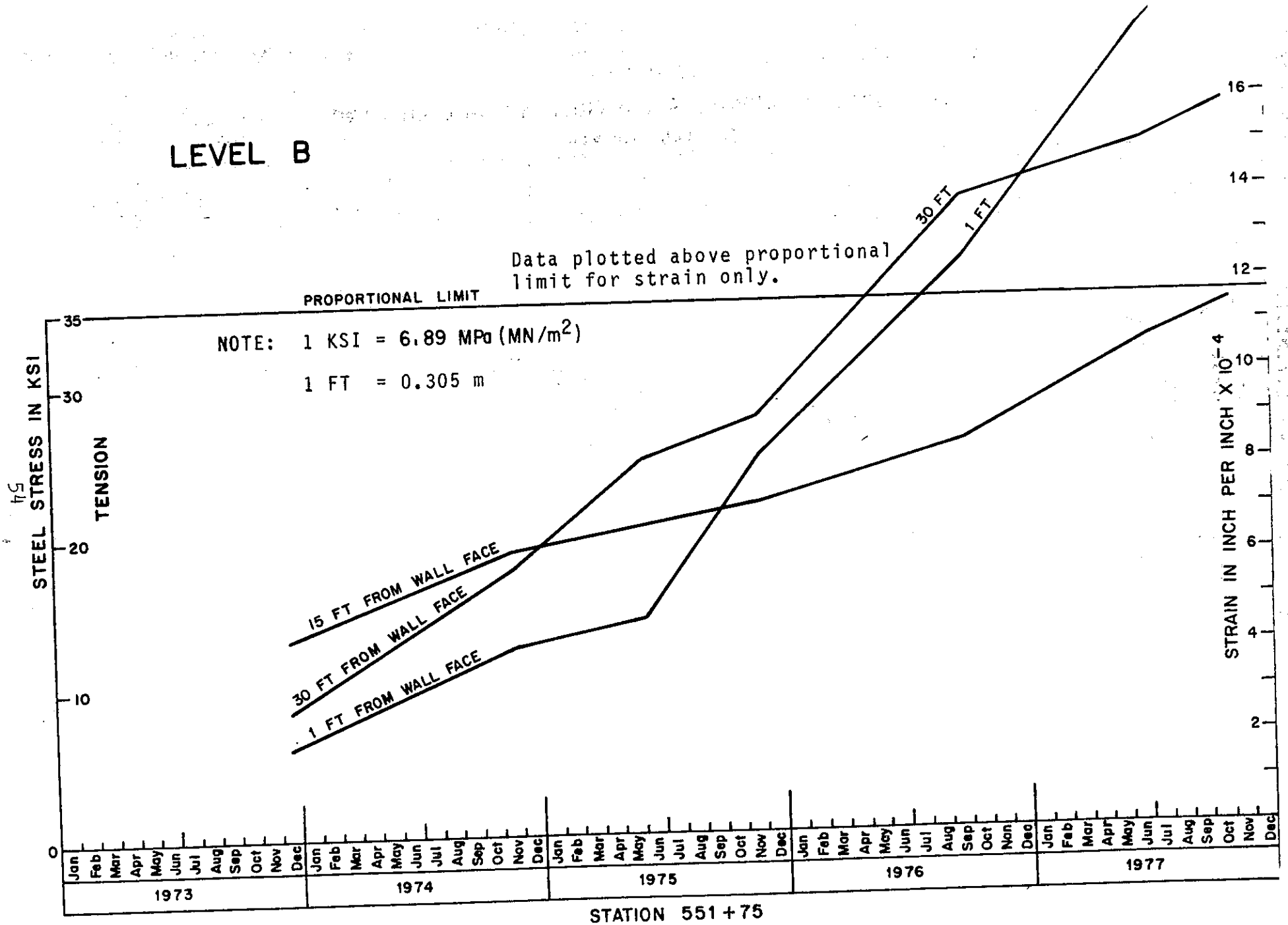
LEVEL A



DAILY HISTORY OF STRESSES & STRAINS IN STEEL STRIP

Figure 32

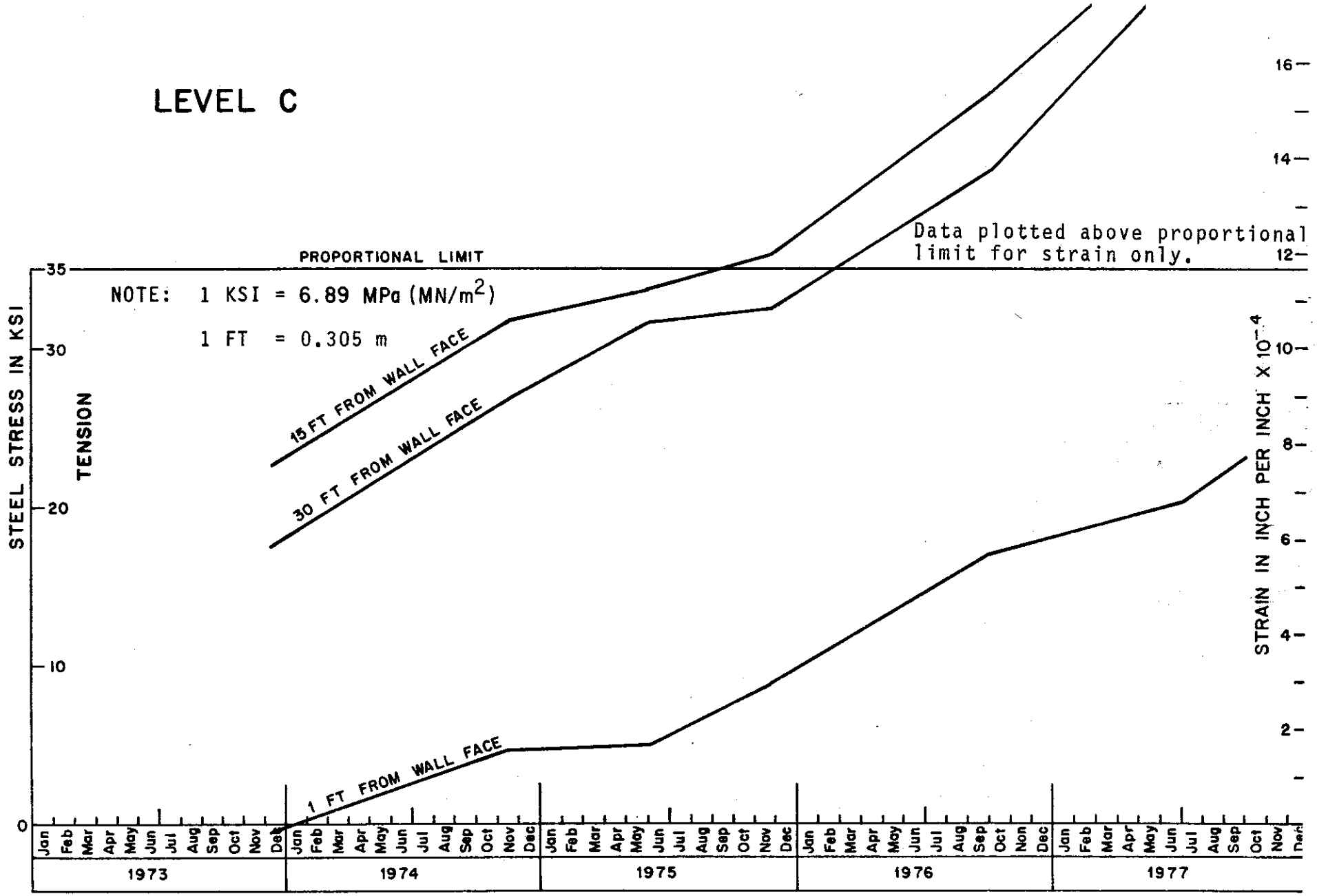
ClibPDF - www.fastio.com



DAILY HISTORY OF STRESSES & STRAINS IN STEEL STRIP

Figure 33

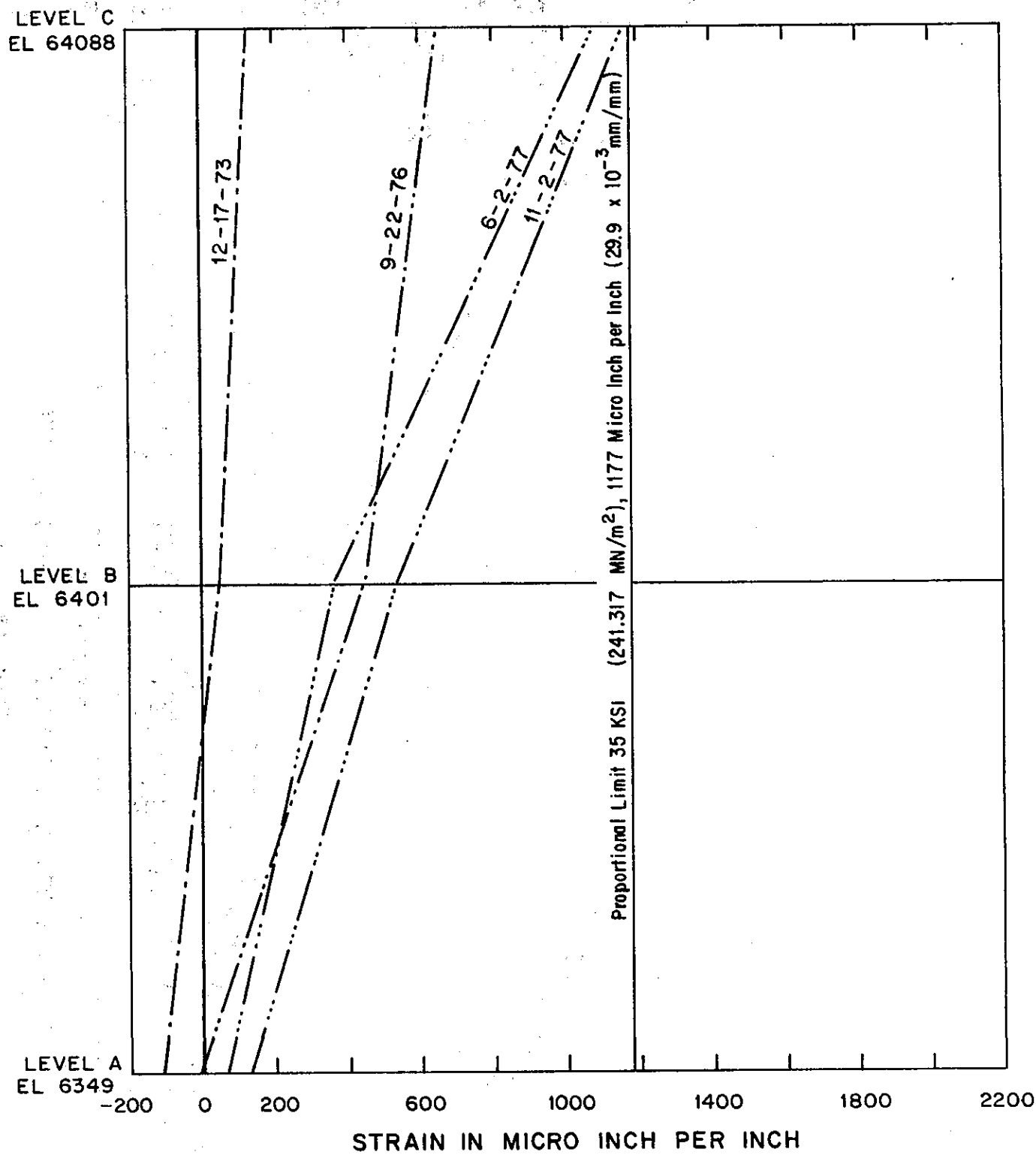
ClibPDF - www.fastio.com



STATION 551+75

DAILY HISTORY OF STRESSES & STRAINS IN STEEL STRIP

Figure 34

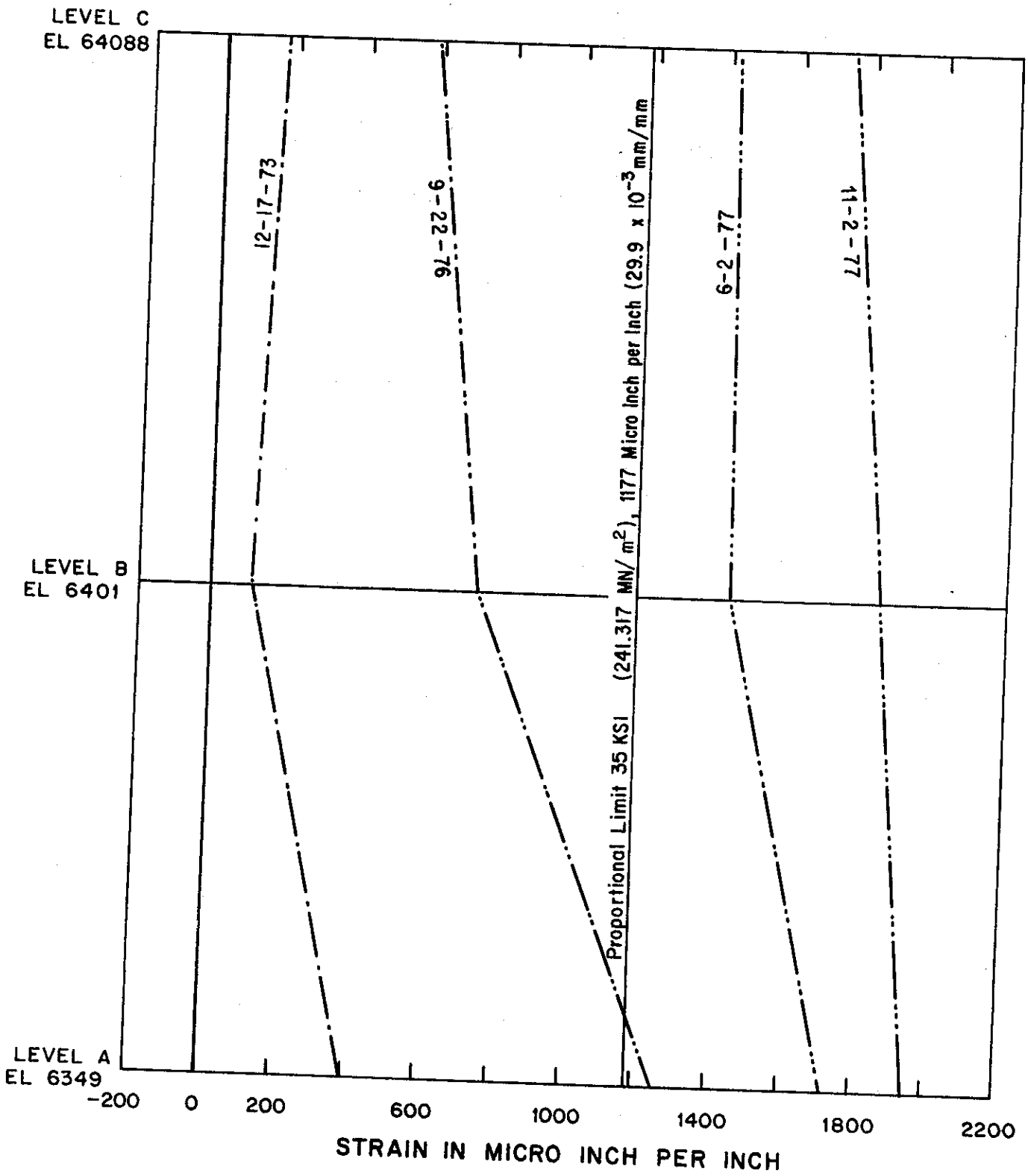


DISTRIBUTION OF STEEL STRAIN ON VERTICAL SECTION

1 FOOT (0.305m) FROM WALL FACE - STA 550+25

Figure 35

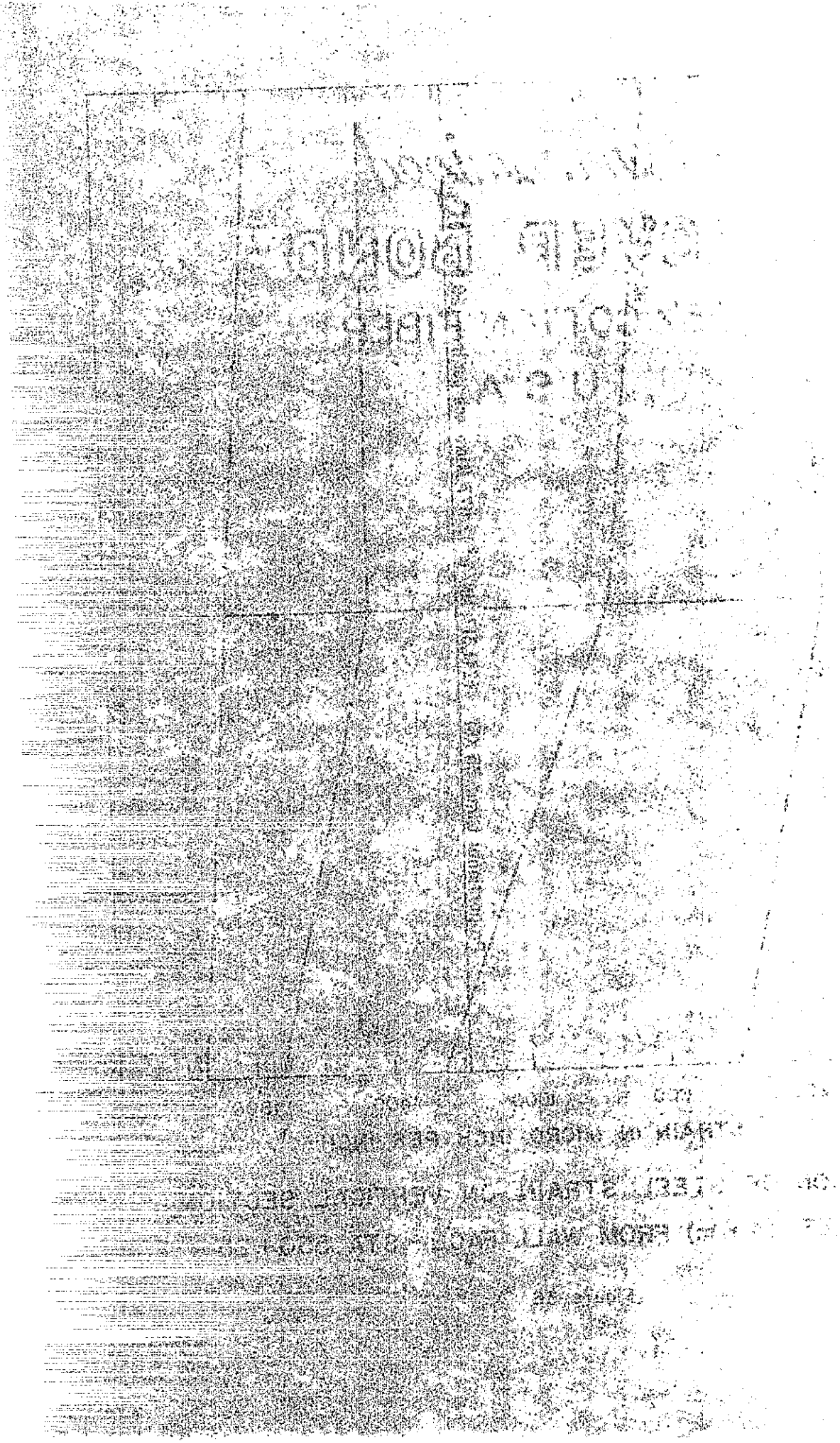
ClibPDF - www.fastio.com



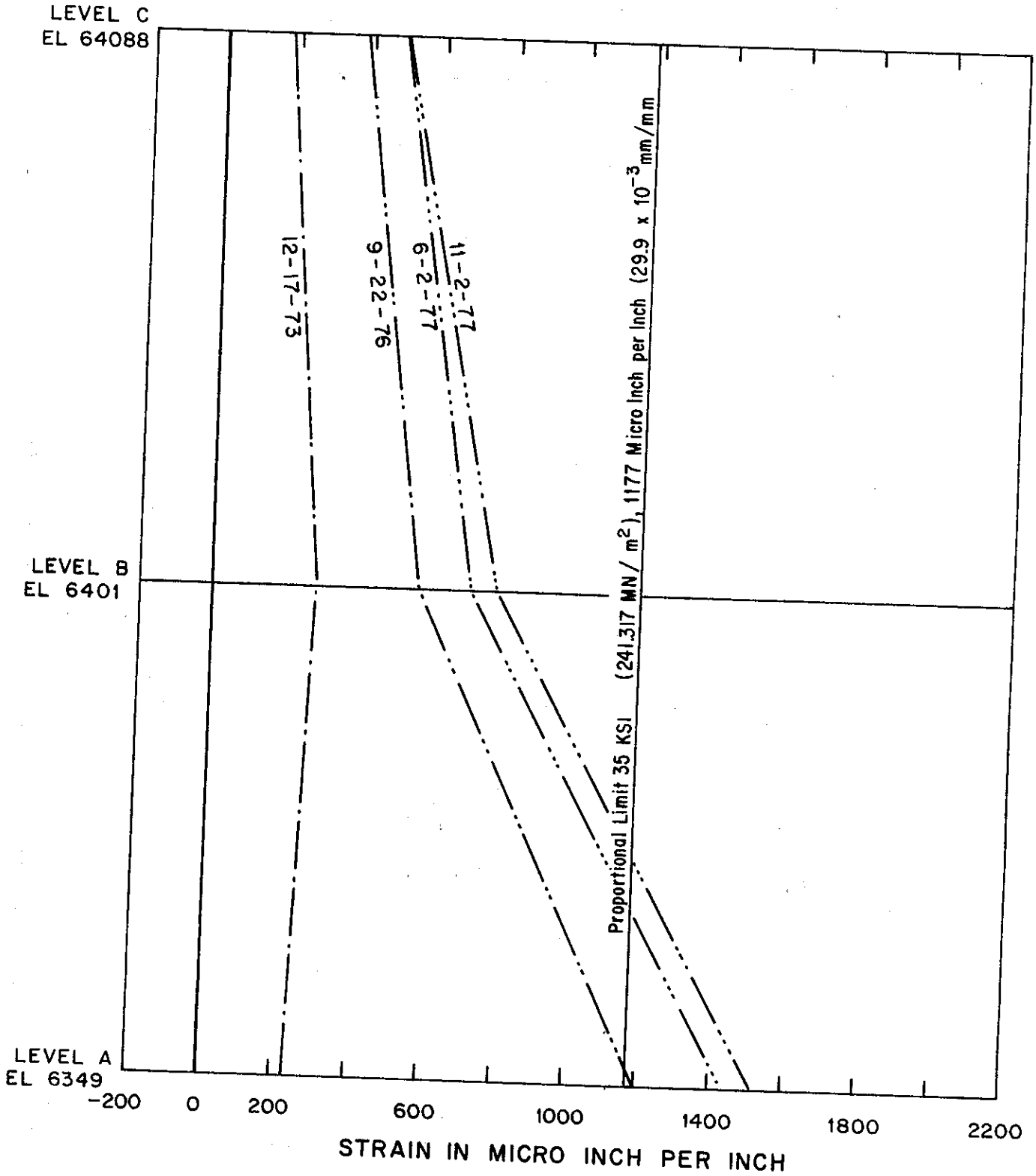
DISTRIBUTION OF STEEL STRAIN ON VERTICAL SECTION
15 FEET (4.6 m) FROM WALL FACE - STA 550+25

Figure 36

ClibPDF - www.fastio.com



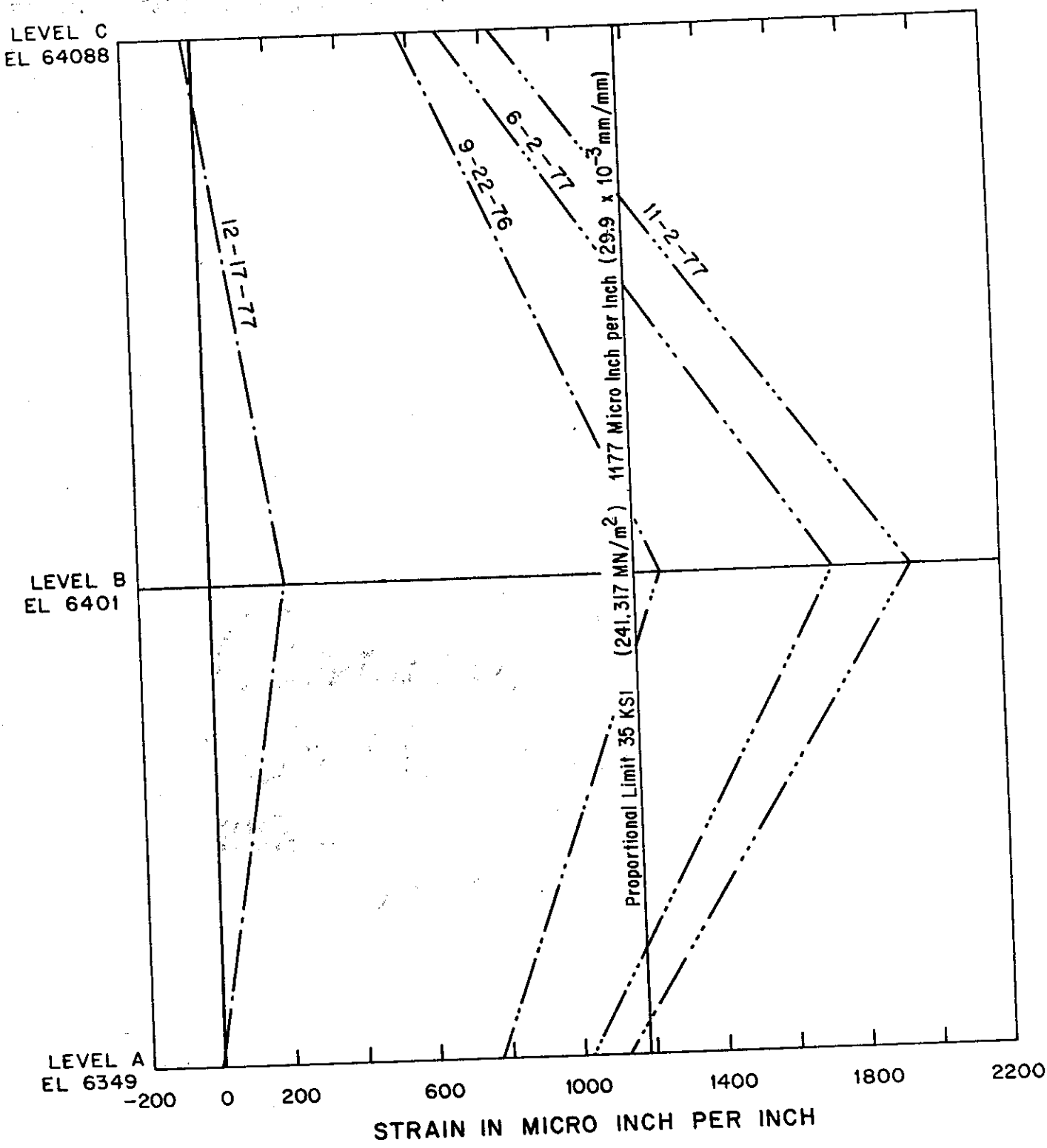
ClibPDF - www.fastio.com



DISTRIBUTION OF STEEL STRAIN ON VERTICAL SECTION
25 FEET (7.6 m) FROM WALL FACE - STA 550+25

Figure 37

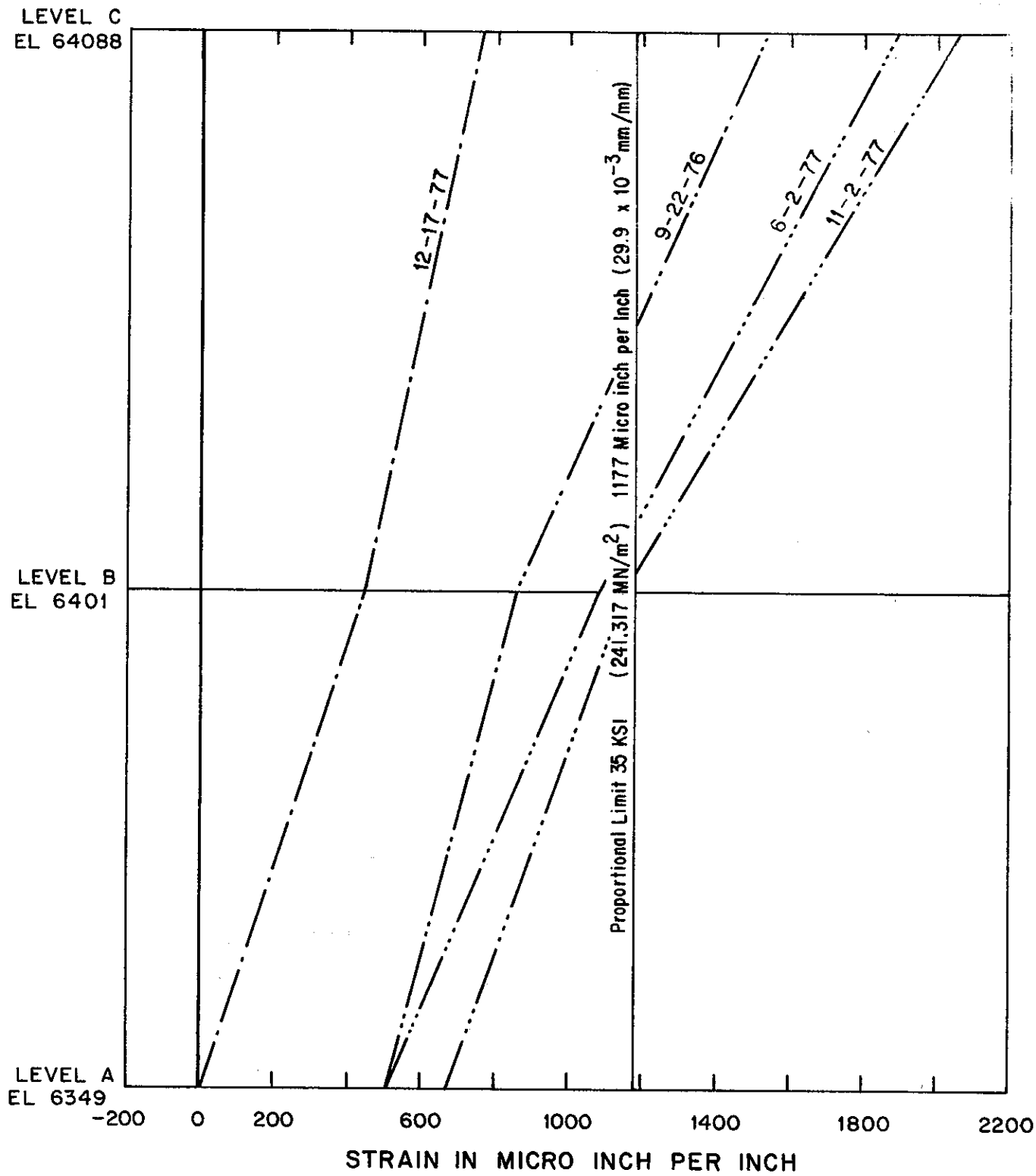
ClibPDF - www.fastio.com



DISTRIBUTION OF STEEL STRAIN ON VERTICAL SECTION
1 FOOT (0.305 m) FROM WALL FACE - STA 551 +75

Figure 38

ClibPDF - www.fastio.com



DISTRIBUTION OF STEEL STRAIN ON VERTICAL SECTION
15 FEET (4.6 m) FROM WALL FACE - STA 551 +75

Figure 39

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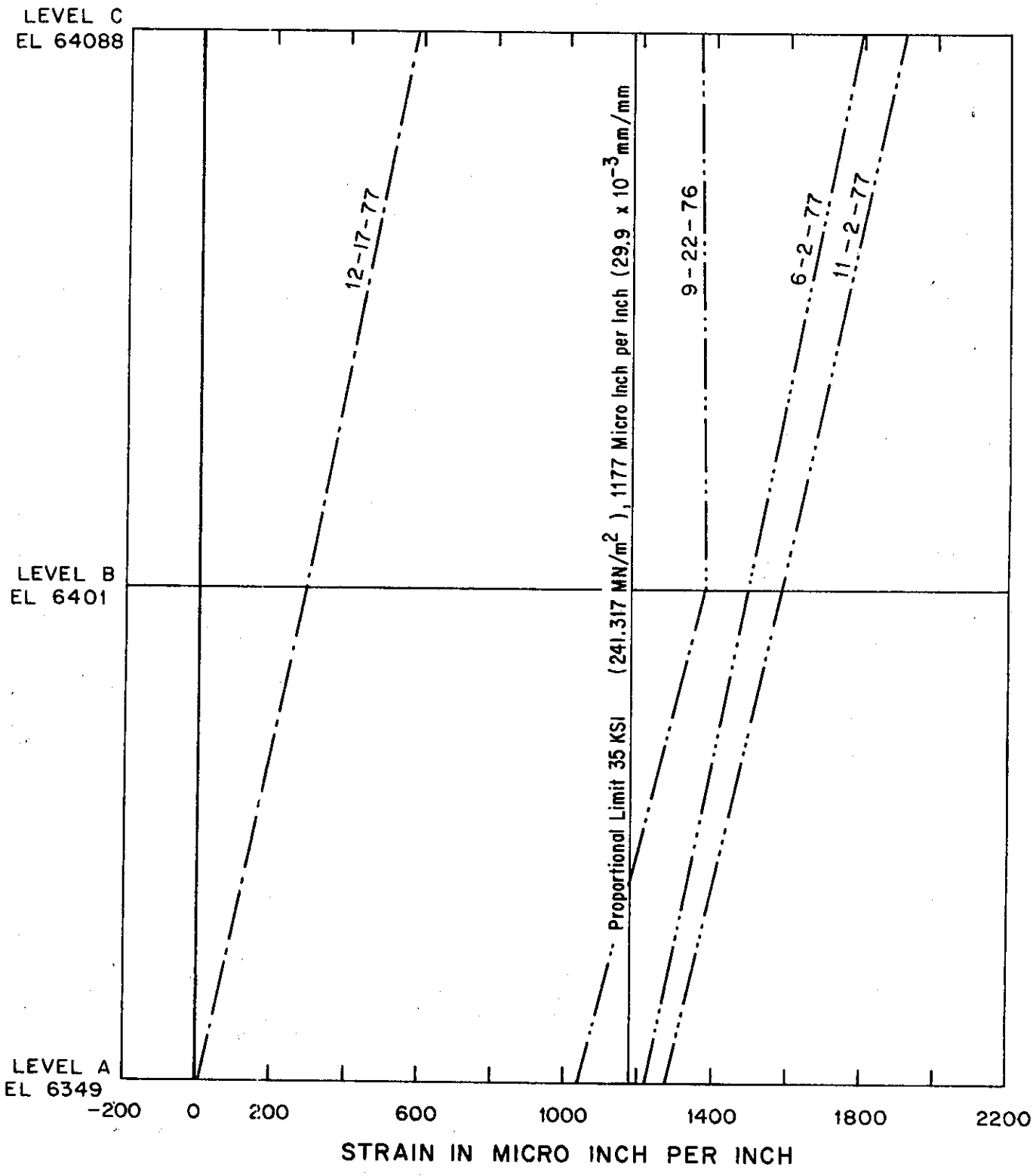
ClibPDF - www.fastio.com



DISTRIBUTION OF STEEL STRAIN ON VERTICAL SECTION
30 FEET (9.2m) FROM WALL FACE - STA 551 +75

Figure 40

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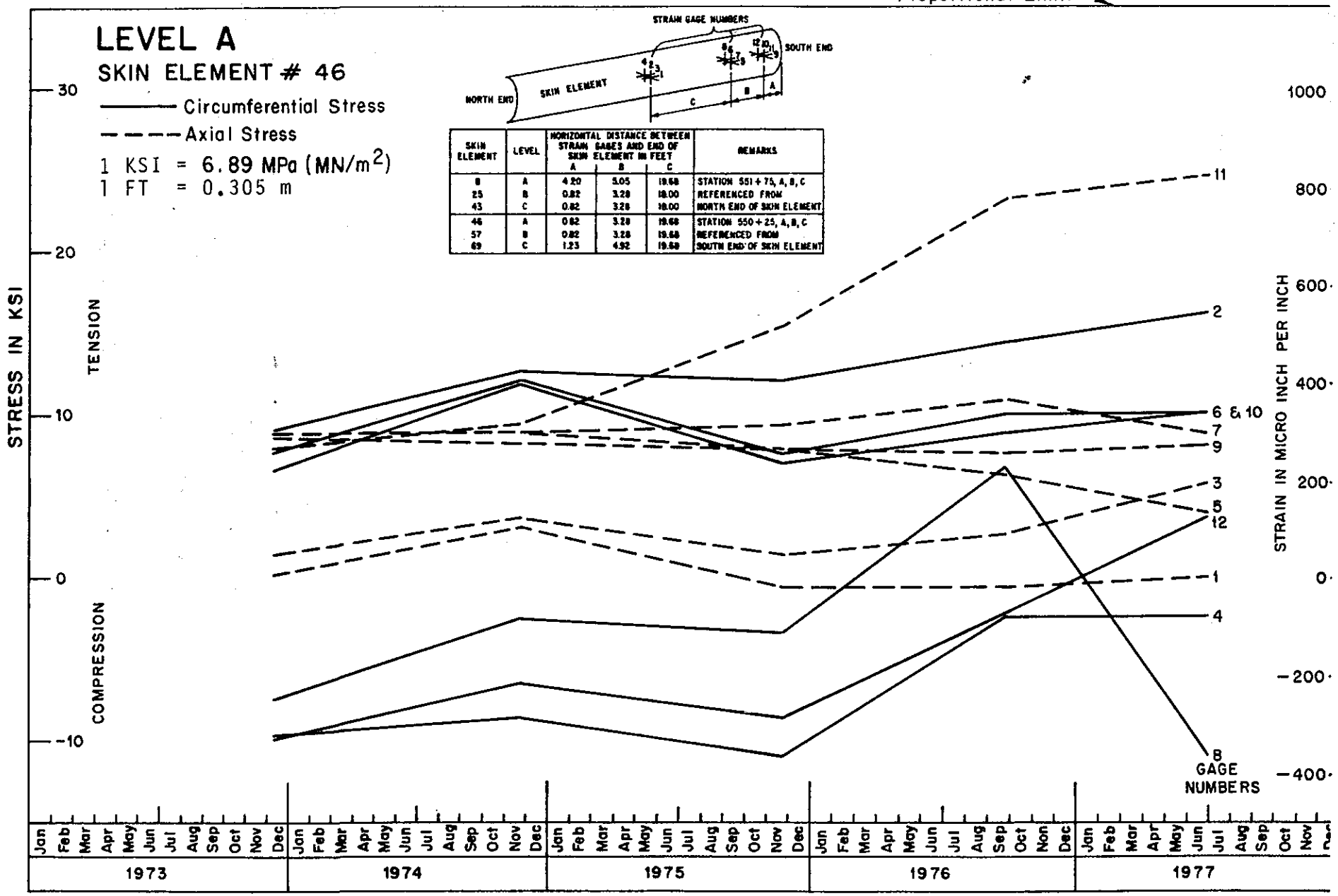

SKIN ELEMENT	LEVEL	HORIZONTAL DISTANCE BETWEEN STRAIN GAGES AND END OF SKIN ELEMENT IN FEET A	B	C	REMARKS
8	A	4.20	5.05	19.68	STATION 551+75, A, B, C
25	B	0.82	3.28	18.00	REFERENCED FROM
43	C	0.82	3.28	18.00	NORTH END OF SKIN ELEMENT
46	A	0.82	5.28	19.68	STATION 550+25, A, B, C
57	B	0.82	3.28	19.68	REFERENCED FROM
69	C	1.23	4.92	19.68	SOUTH END OF SKIN ELEMENT

STATION 550+25

DAILY HISTORY OF STRESSES IN SKIN ELEMENT

Figure 41

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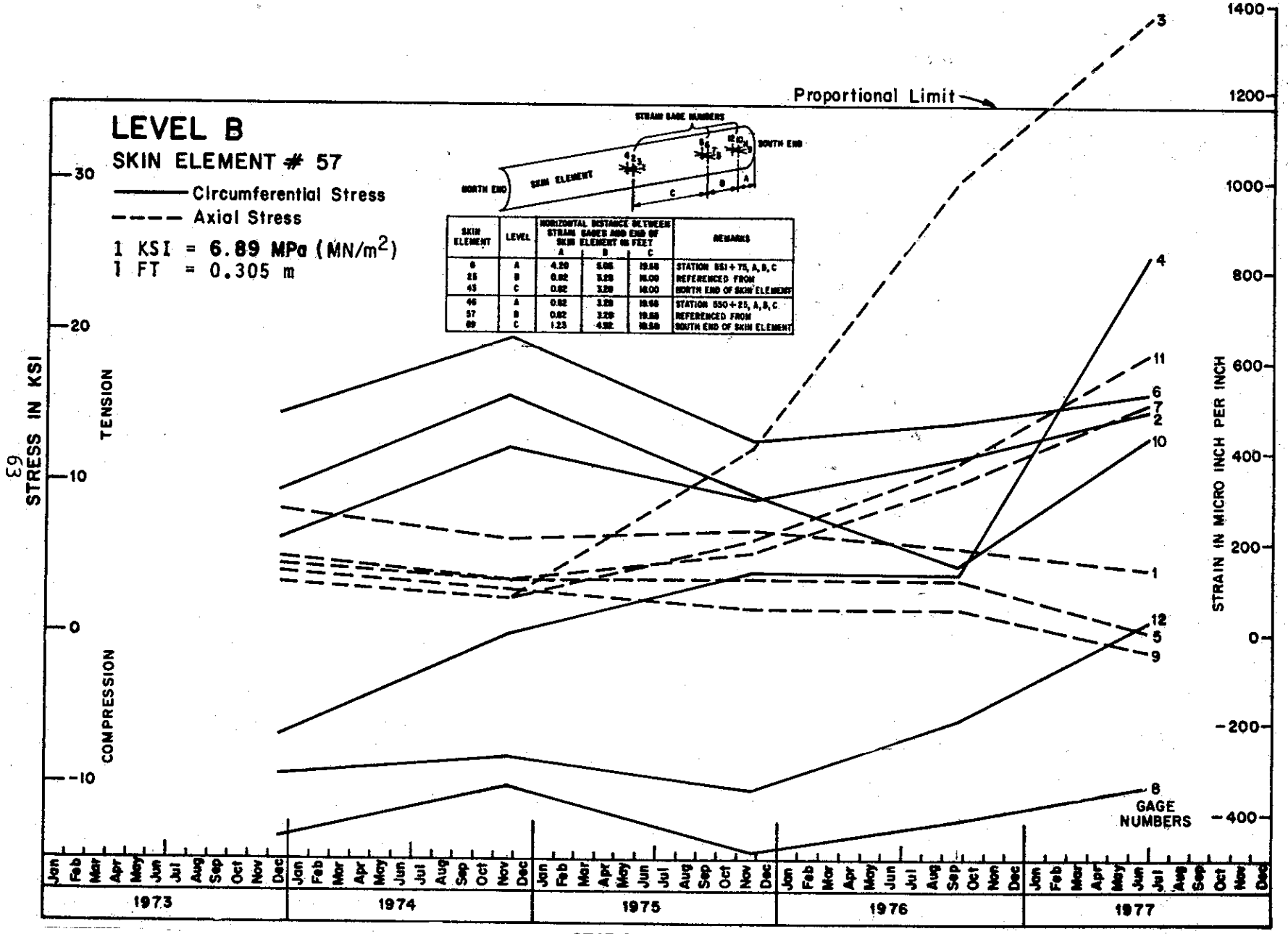

SKIN ELEMENT	LEVEL	HORIZONTAL DISTANCE BETWEEN STRAIN GAGES AND END OF SKIN ELEMENT IN FEET A	B	C	REMARKS
0	A	4.29	5.86	19.58	STATION 551+75, A, B, C
25	B	0.82	3.29	18.00	REFERENCED FROM
43	C	0.82	3.29	18.00	NORTH END OF SKIN ELEMENT
46	A	0.82	3.29	19.98	STATION 550+25, A, B, C
57	B	0.82	3.29	19.58	REFERENCED FROM
89	C	1.23	4.92	19.58	SOUTH END OF SKIN ELEMENT

STATION 550+25
DAILY HISTORY OF STRESSES IN SKIN ELEMENT
Figure 42

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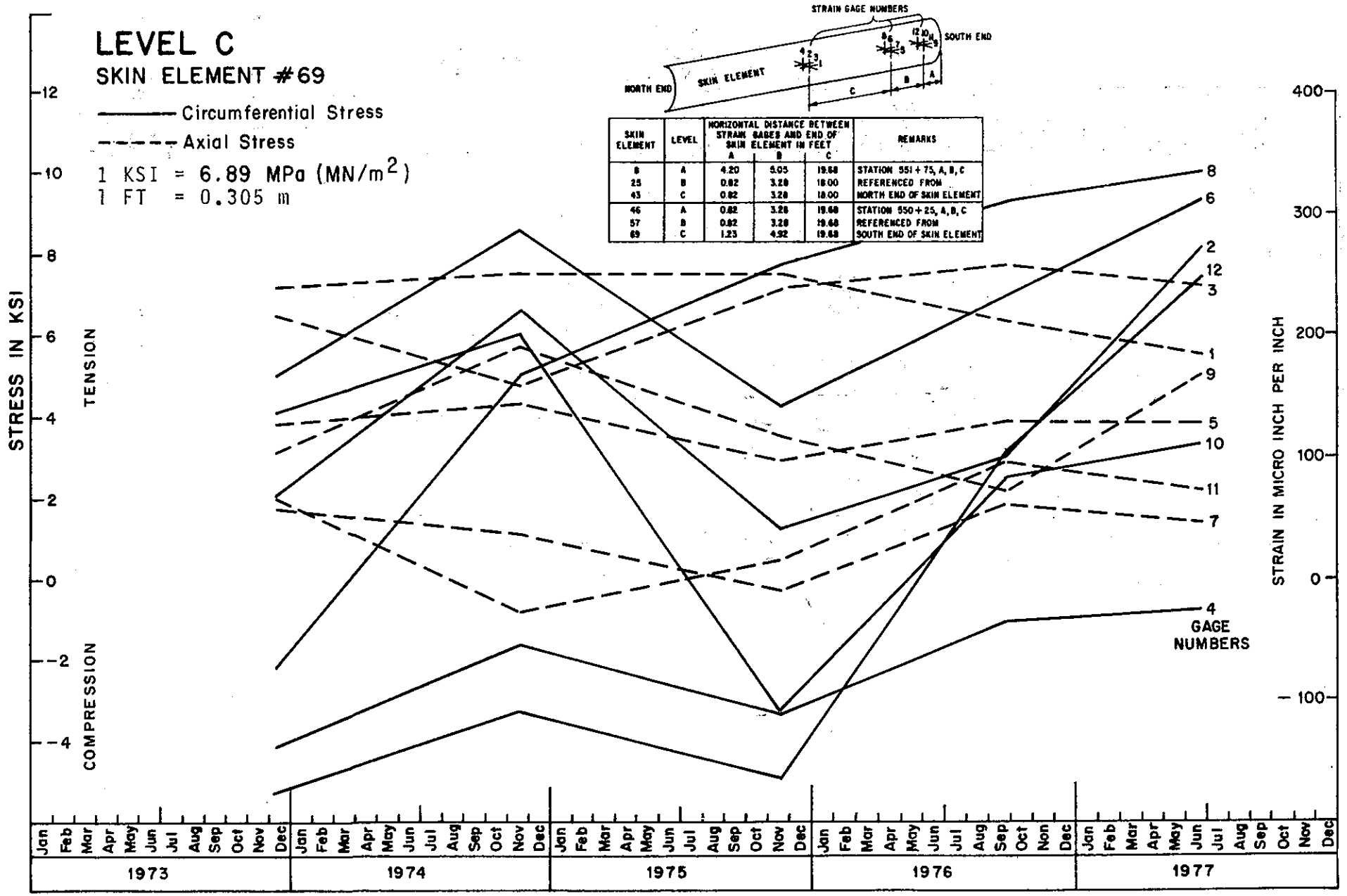

SKIN ELEMENT	LEVEL	HORIZONTAL DISTANCE BETWEEN STRAIN GAGES AND END OF SKIN ELEMENT IN FEET A	B	C	REMARKS
8	A	4.20	9.05	19.68	STATION 551+75, A, B, C
25	B	0.82	3.28	18.00	REFERENCED FROM
43	C	0.82	3.28	18.00	NORTH END OF SKIN ELEMENT
46	A	0.82	3.28	19.68	STATION 550+25, A, B, C
57	B	0.82	3.28	19.68	REFERENCED FROM
69	C	1.23	4.92	19.68	SOUTH END OF SKIN ELEMENT

STATION 550+25

DAILY HISTORY OF STRESSES IN SKIN ELEMENT

Figure 43

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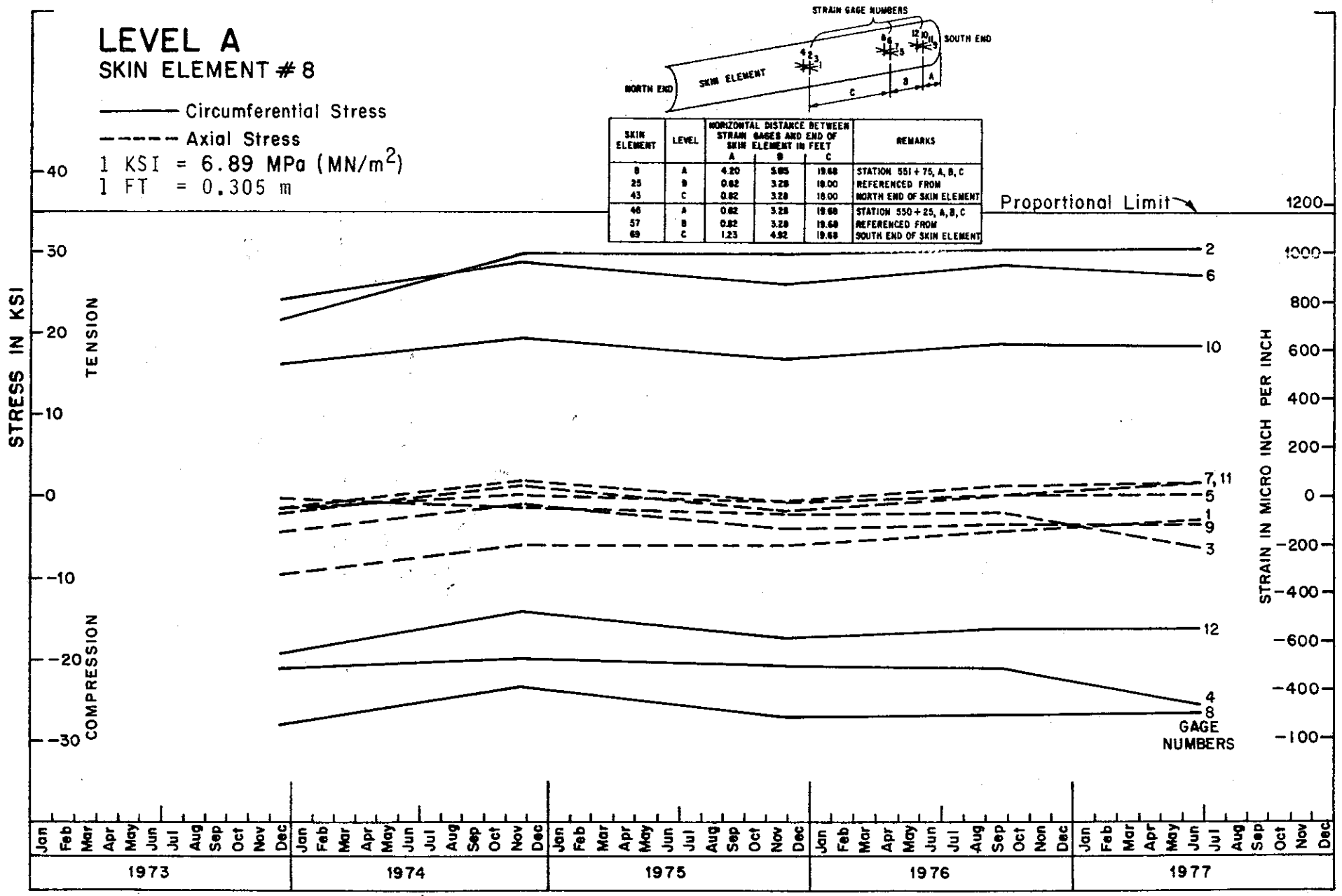

SKIN ELEMENT	LEVEL	HORIZONTAL DISTANCE BETWEEN STRAIN GAGES AND END OF SKIN ELEMENT IN FEET A	B	C	REMARKS
8	A	4.20	5.85	19.68	STATION 551+75, A, B, C
25	B	0.82	3.28	18.00	REFERENCED FROM
43	C	0.82	3.28	18.00	NORTH END OF SKIN ELEMENT
46	A	0.82	3.28	19.68	STATION 550+25, A, B, C
57	B	0.82	3.28	19.68	REFERENCED FROM
69	C	1.23	4.92	19.68	SOUTH END OF SKIN ELEMENT

STATION 551+75
DAILY HISTORY OF STRESSES IN SKIN ELEMENT
Figure 44

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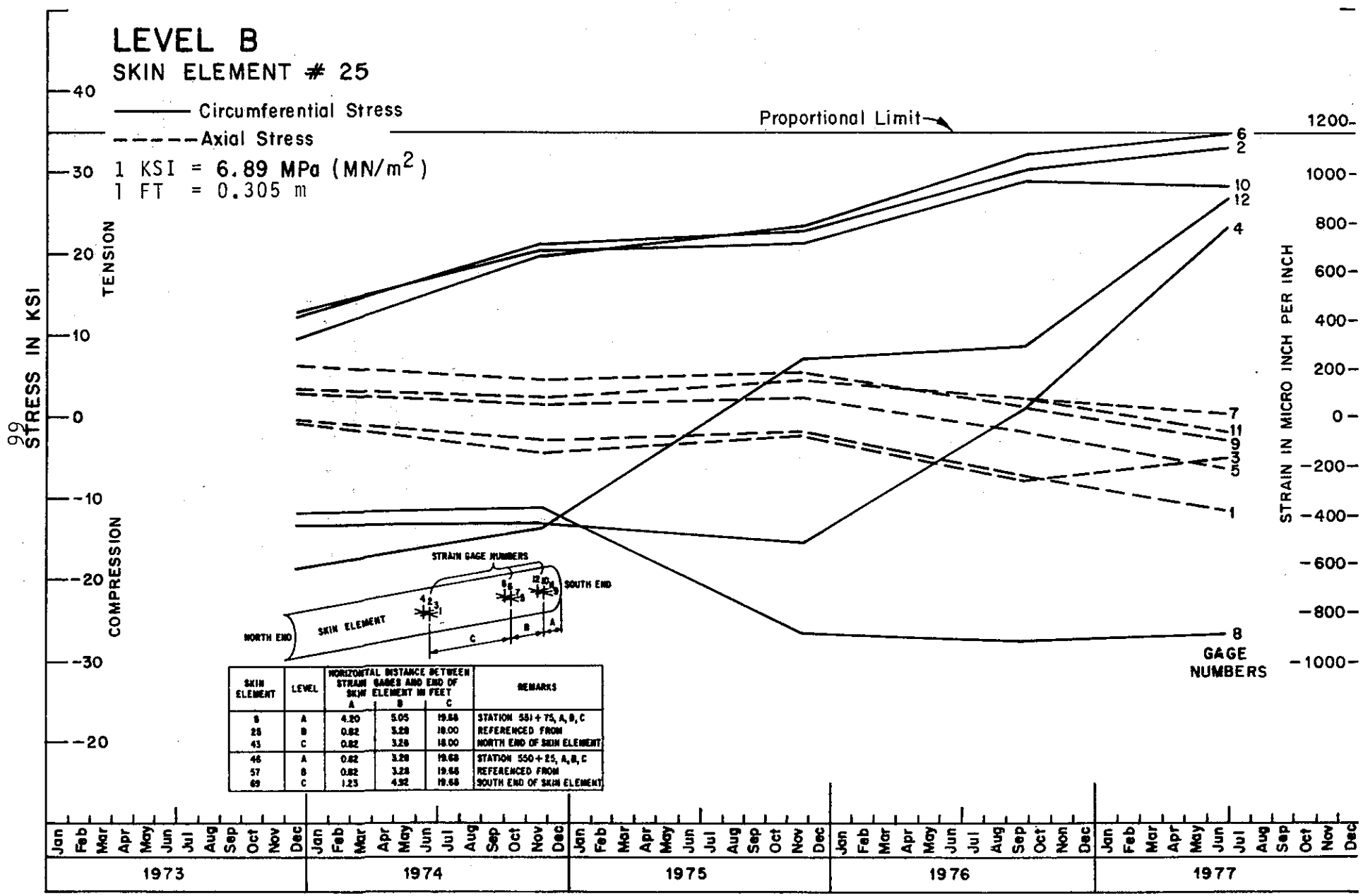

SKIN ELEMENT	LEVEL	HORIZONTAL DISTANCE BETWEEN STRAIN GAGES AND END OF SKIN ELEMENT IN FEET A	B	C	REMARKS
9	A	4.80	5.05	19.68	STATION 551+75, A, B, C
25	B	0.82	3.28	18.00	REFERENCED FROM
43	C	0.82	3.28	18.00	NORTH END OF SKIN ELEMENT
46	A	0.82	3.28	19.68	STATION 550+25, A, B, C
57	B	0.82	3.28	19.68	REFERENCED FROM
69	C	1.23	4.92	19.68	SOUTH END OF SKIN ELEMENT

STATION 551+75

DAILY HISTORY OF STRESSES IN SKIN ELEMENT

Figure 45

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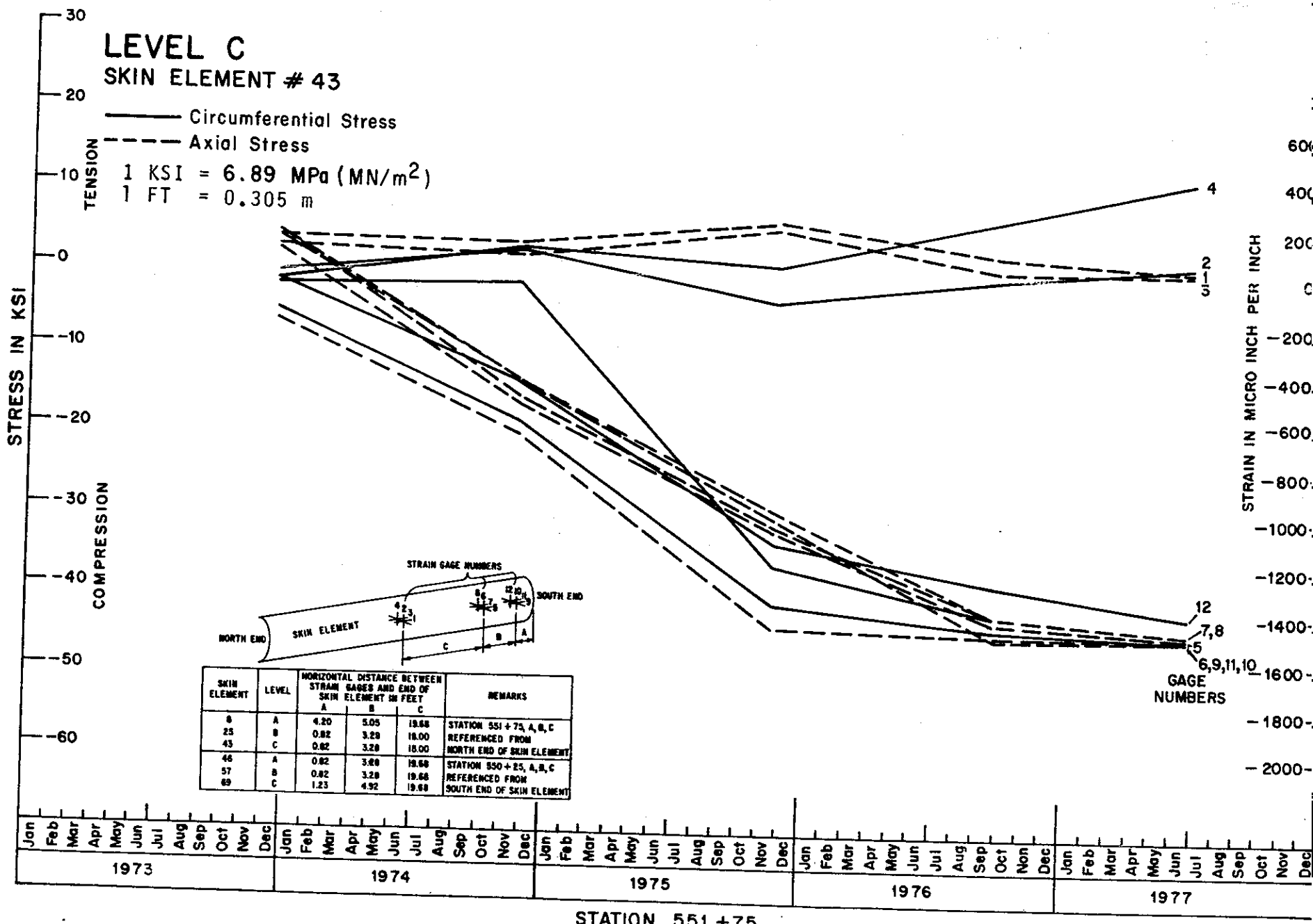

SKIN ELEMENT	LEVEL	HORIZONTAL DISTANCE BETWEEN STRAIN GAGES AND END OF SKIN ELEMENT IN FEET A	B	C	REMARKS
8	A	4.20	5.05	19.68	STATION 551+75, A, B, C
25	B	0.82	3.28	18.00	REFERENCED FROM
43	C	0.82	3.28	18.00	NORTH END OF SKIN ELEMENT
46	A	0.82	3.28	19.68	STATION 550+25, A, B, C
57	B	0.82	3.28	19.68	REFERENCED FROM
69	C	1.23	4.92	19.68	SOUTH END OF SKIN ELEMENT

DAILY HISTORY OF STRESSES IN SKIN ELEMENT

Figure 46

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