COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT

January 21, 1959

ADDRESS REPLY TO
DEPARTMENT OF HIGHWAYS
MATERIALS RESEARCH LABORATORY
132 GRAHAM AVENUE
LEXINGTON 29, KENTUCKY

Ward J. Oates
COMMISSIONER OF HIGHWAYS

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J.1.4.2.

MEMO TO: D. V. Terrell
Director of Research

The attached research report, "17-Year Report on the Owensboro-Hartford Co-Operative Investigation of Joint Spacing in Concrete Pavements," was prepared as a result of a special request from Mr. Harold Allen, Chief of the Division of Physical Research, Bureau of Public Roads, to Mr. D. H. Bray, State Highway Engineer.

This is a co-operative project with the Bureau of Public Roads, and Kentucky was one of six states that installed test sections in 1940 or 1941. The report was presented before the Highway Research Board meeting on January 8, 1959, in answer to a request by the HRB Committee on Rigid Pavement Design. This committee of the Department of Design sponsored the report. The State of Michigan also reported on a similar test project at the same meeting.

The various sections of pavement are compared by a numerical system with each rating item given the same weight. Tables 9 and 10 list the rating items, and the over-all ratings. The designs of the sections are shown in Table 1. This system would be overly severe on the longer reinforced slabs in that any crack formed would be counted regardless of the amount of opening or its ability to transfer the load.

Table 3, following page 5, lists the average daily traffic classified into various vehicle types. This is not a heavy commercial traffic road. As was pointed out in the Michigan report, mentioned earlier, the traffic has not been heavy enough to rationally analyze the reinforced sections and some of the joint spacings. The design variables have not all been subjected to enough traffic to justify final conclusions.

We had expected this to be the final report on the project, however, discussions of the participants in the study indicate that probably an additional performance and analysis will be needed.

Respectfully submitted,

W. B. Drake

W. B. Drake
Associate Director of Research

WBD:dl
Enc.
cc: Research Committee
Bureau of Public Roads (3)

Commonwealth of Kentucky
Department of Highways

17-YEAR REPORT ON THE OWENSBORO-HARTFORD CO-OPERATIVE INVESTIGATION OF JOINT SPACING IN CONCRETE PAVEMENTS

by

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and

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Lexington, Kentucky

January, 1959

INTRODUCTION

In 1940, the Kentucky Department of Highways constructed an experimental concrete pavement which was one of a group of six built in co-operation with the Bureau of Public Roads by the States of Minnesota, California, Kentucky, Michigan, Missouri and Oregon. The purpose of these projects was to study and evaluate the performance of such pavements over a period of years with specific regard to types of joints and spacings. The Kentucky project, consisting of 6.27 miles, was constructed in Daviess County, beginning approximately 6 miles south of Owensboro on US Route 231 (formerly Ky. Route 71).

This report is a continuation of the 1940 joint-spacing and pavement-performance study. A complete discussion of the original scope, purpose, and early performance of this project has been given in previous reports (1, 2, 3, and 4).

The present report is essentially a 17-yr. performance report but includes some data obtained through 1958. Subgrade, traffic, riding quality, and over-all condition data are provided.

On the whole, the 7-in. uniform pavement had the poorest performance record. Of the other sections, which are all of 9-7-9-in. cross section, the pavement with expansion joints spaced 120 ft. apart with load transfer dowels and contraction joints spaced 20 ft. apart without load transfer dowels had the poorest performance record.

The results obtained from this project, representing specific aggregate and specific construction methods, permit the following important conclusions. Expansion joints less than 400 ft. apart are of little benefit and are probably detrimental to pavement performance.

Contraction joints, for best performance, should be closely spaced. Dowel bars for load transfer at contraction joints are of questionable value if the joints remain closed. Joints that open considerably and remain open benefit from load transfer dowels. The thickened edge pavement section is superior to that of uniform 7-in. thickness.

DESIGN FACTORS

The investigational pavement was constructed with the features, design and arrangement given in Table 1. It is composed of seven sections with variables prescribed in the general test program and an added section designated as Standard, representing the design used by Kentucky at that time. The Standard Section, for the most part, was constructed over poorly drained land which has proven to be undesire-able for experimental pavements .

The spacing of expansion joints in different sections varied from 60 ft. to 5,000 ft. with contraction joint spacing of 20 ft. Two exceptions were Section 6, where the joint interval was 60 ft. with alternating contraction and expansion joints, and the Standard Section, where the joint interval was 30 ft. with expansion joints every 120 ft.

Expansion joints were constructed to accomodate a 1-in. width of premolded bituminous fiber filler, and contraction joints were of the weakened plane type with a premolded bituminous fiber filler.

Where dowel bars were installed for load transfer, they were preassembled in a metal support designed to hold the bars rigidly in proper spacing and alignment. Dowels were 3/4-in. plain round bars. In sections where wire mesh reinforcing was installed, the initial pour of concrete was struck off 2 in. below grade to permit placing of the mesh.

TABLE 1
DESIGN OF EXPERIMENTAL JOINT SECTIONS

Section No.	Length	Design Section	Wire Mesh Reinf.	Expansion Joints		Contraction Joints	
				Spacing	Load Transfer	Spacing	Load Transfer
	ft.	in.		ft.		ft.	
7	1250	7-7-7	None	120	None	20	None
6	1500	9-7-9	70 lb.	60 alt.	Dowels	60 alt.	Dowels
5	1500	9-7-9	None	120	Dowels	20	Dowels
4	1500	9-7-9	None	120	Dowels	20	None
3	2500	9-7-9	None	400	Dowels	20	None
2	3000	9-7-9	None	800	Dwoels	20	None
1	5000	9-7-9	None	None	None	20	None
Std.	7000	9-7-9	44 lb.	120	Dowels	30	Dowels
2R	2500	9-7-9	None	800	Dowels	20	None
3R	2500	9-7-9	None	400	Dowels	20	None
4R	1500	9-7-9	None	120	Dowels	20	None
5R	1500	9-7-9	None	120	Dowels	20	Dowels
6R	1500	9-7-9	70 lb.	60 alt.	Dowels	60 alt.	Dowels
7R	1200	7-7-7	None	120	None	20	None

R - Repeat Sections. Section No. 1 was not repeated.

Soil Conditions

The major part of the project lies on general upland terrain where the soils are predominantly wind-blown silt and fine sand. Underlying these materials is a shale formation which is below sub-grade elevation in nearly every case. Soils throughout the project were quite uniform in textural and plasticity characteristics and were predominately HRB A-4 or approximately A-4-6 materials. Generally speaking, they were of a fine sand or silty texture with the clay content in all but a few cases lower than 20 percent. Tests were made on samples representing material at subgrade level regardless of cut or fill. Residual soils, having a greater percentage of finer particles, entered the subgrade from below at a few locations. This affected the plasticity relationships which are typical of sorted and wind-blown materials only slightly. Tests of soil samples show that in the Standard Section there was a slightly greater percentage of fine sand; and, in the "Repeat" or R sections, there was a slight tendency toward reduction in silt and sand and an increase in finer particles.

In the determination of moisture-density relations for compaction control, the samples were divided into six different groups according to their common characteristics, and standard proctor tests were run. Differences among the compaction curves were slight and the average density and optimum moisture content were chosen for use in construction of the subgrade. All embankments were constructed in successive horizontal layers 12 in. in thickness and each layer compacted with a sheepsfoot roller.

Examination of the construction records for subgrade descriptions disclosed that in the repeat sections and the Standard Section the subgrade was frequently found to be soft and spongy. These records also show that in the initial sections, 1 through 7, the subgrade was found to be consistently firm and uniform. Taking these differences into account, it appears that the performance of the repeat sections, 2R through 7R, and the Standard Section might be erratic because of varying soil conditions.

Data include performance factors and information concerning the initial sections, the Standard Section, and the repeat sections. Evaluations are made separately for the initial sections, 1 through 7, and for the Standard and repeat sections. Where trends found by comparing initial sections are not validated by trends found in the repeat sections, variance in subgrade appears to be the cause. However, the performance of the repeat sections, with 2 exceptions, generally bears out the performance of the initial sections.

Physical Properties of Concrete

The constituents of the concrete used in this project were fine and coarse aggregates dredged from the Boone Bar in the Ohio River about 8 miles upstream from Owensboro, and a single brand of Type I portland cement.

The average 28-day compressive strength for 68 specimens, representing one cylinder for each 500 ft. of pavement, was 4,910 psi Maximum and minimum strengths were 6,200 and 3,890 psi respectively, and 71 percent of the strengths were within 10 percent of the average strength. The average modulus of rupture for 42 beams was 1,000 psi at 28 days. Maximum and minimum values were 1,200 and 815 psi respectively, with 77 percent of the strengths falling within 10 percent of the average.

The 34 core specimens, one for each 1,000 ft. of pavement, varied in age from 41 to 80 days and had an average compressive strength of 4,855 psi. Maximum and minimum strengths were 6,735 and 3,245 respectively, and 47 percent of the strengths were within 10 percent of the average.

Climate

Climatological data were obtained from the US Weather Bureau's special observer station 1/2 mile west of Owensboro in Daviess County, and are presented in Table 2. These data represent the average temperature and precipitation for each month of the year.

As is typical of Kentucky, there were frequent changes from freezing to thawing and vice versa within a normal winter. However, few severe changes in temperature occurred. Past calculations (5) based on air temperatures, at a station in the central part of the state, show that there are about 55 freeze-thaw cycles in a representative year.

Mean annual precipitation for the 18-yr. period at Owensboro was 44.9 in. and is generally representative of the entire state.

Traffic

The average daily traffic, by number and type, for each year throughout the life of the project is given in Table 3. The traffic is

TABLE 2
TEMPERATURE AND PRECIPITATION DATA
July 1940 to July 1958*

Month	Temperature Average	Avg. Max.	Abs. Max.	Avg. Min.	Abs. Min.	Precipitation Average	Snowfall Average
	°F	°F	°F	°F	°F	In.	In.
December	37	56	72	20	-6	3.3	1.4
January	35	53	76	17	-15	4.4	3.7
February	38	56	73	18	-21	3.9	2.2
Winter	37	55	76	18	-21	3.9	7.3
March	47	65	85	29	0	5.0	1.8
April	57	77	90	38	25	4.2	0.0
May	66	84	95	48	33	3.5	0.0
Spring	57	75	95	38	0	4.2	1.8
June	75	92	107	58	42	3.8	0.0
July	78	94	106	61	44	3.2	0.0
August	77	94	105	59	42	3.2	0.0
Summer	77	93	107	59	42	3.4	0.0
September	68	89	104	50	32	3.2	0.0
October	60	80	95	38	21	2.1	0.0
November	46	66	85	26	-7	4.1	0.4
Fall	58	78	104	38	-7	3.1	0.4
Annual	57	76	107	39	-21	43.9	9.5

* From Special Observer Station, U.S. Weather Bureau, 1/2 mile west of Owensboro, Daviess County, Kentucky.

TABLE 3
AVERAGE DAILY TRAFFIC

Year	A.D.T.	Pass. Car	Light Trucks Under 1.5 T	Med. Trucks 1.5-5 T	Tractor-Semi Over 5 T	Busses
1940	675	511	150	0	6	8
1941	840	584	237	0	8	11
1942	649	207	413	4	8	17
1943	648	264	300	64	11	9
1944	700	290	325	63	12	10
1945	750	360	333	29	16	12
1946	1003	590	363	7	28	15
1947	1068	670	300	61	22	15
1948	1140	675	282	149	18	16
1949	1066	681	194	175	2	14
1950	1400	895	255	230	3	18
1951	1700	1233	221	181	49	16
1952	1850	1342	241	196	53	18
1953	1900	1378	247	202	55	18
1954	1950	1415	253	207	56	19
1955	2000	1451	260	212	57	20
1956	2200	1596	286	234	63	21
1957	2400	1740	311	255	69	23
1958	3000	2177	389	319	86	29

moderate and has increased gradually throughout the life of this project. Average daily traffic in 1940 was 675 vehicles and in 1950 it was 1400 vehicles. Comparatively, the average daily traffic increased to 3000 vehicles in 1958. These figures show that traffic volume doubled during the first 10-yr. period and has more than doubled during the succeeding 8 years. The number of trucks for each of the three classifications has increased at a rapid rate. The percentage of trucks to total traffic is 27.5 for the 1958 survey.

This evaluation depends in large measure on the amount and type of traffic which the pavement has withstood. Therefore, the fact that traffic has been only moderate is a prime consideration.

JOINT WIDTHS AND PAVEMENT ELEVATIONS

A representative number of joints were selected in each initial section for daily, seasonal, and permanent width measurements. Brass inserts, as shown in Fig. 6, were installed on each side of the joints selected for caliper measurements. Table 4 gives the number and type of joints measured in each section.

Also, a representative number of joints were selected in each section for periodic elevation measurements. Steel points were set on each side of the joints as shown in Fig. 8. The first column of Table 6 gives the number of these joints. Points were also placed at some of the midpoints in order to measure warping.

Daily Measurements

The average daily change in joint width for each section is given in Fig. 1 and Fig. 1A. Expansion and contraction joints are treated separately. Daily movements of the expansion joints within each section were somewhat erratic and varied greatly among the

TABLE 4
NUMBER OF JOINTS SELECTED FOR WIDTH MEASUREMENTS

Section No.	Joint Width Measurements Daily Exp.	Daily Contr.	Seasonal Exp.	Seasonal Contr.	Permanent Exp.	Permanent Contr.
7	2	5	4	10	2	5
6	3	2	6	5	4	3
5	2	5	4	10	2	5
4	0*	0*	4	10	0*	0*
3	2	5	3	10	0	7
2	2	8	2	20	2	14
1	0**	8	0**	21	0**	7
Standard	3	6	5	24	3	6

* No measurement schedule
** No expansion joints within the section

TABLE 5
PERCENT OF TOTAL JOINTS FAULTING

Measurement date	Amount of Faulting 0 in.	0.06 in.	0.12 in.	0.18 in.	0.24 in.	0.36 in.	0.42 in.
	%	%	%	%	%	%	%
March, 1942	53.10	41.09	5.81	0	0	0	0
July, 1944	49.22	44.19	6.59	0	0	0	0
August, 1948	47.67	40.31	9.69	1.94	0.39	0	0
February, 1949	40.70	41.86	15.50	1.16	0.78	0	0
July, 1958	22.48	41.09	25.97	5.04	4.26	0.77	0.39

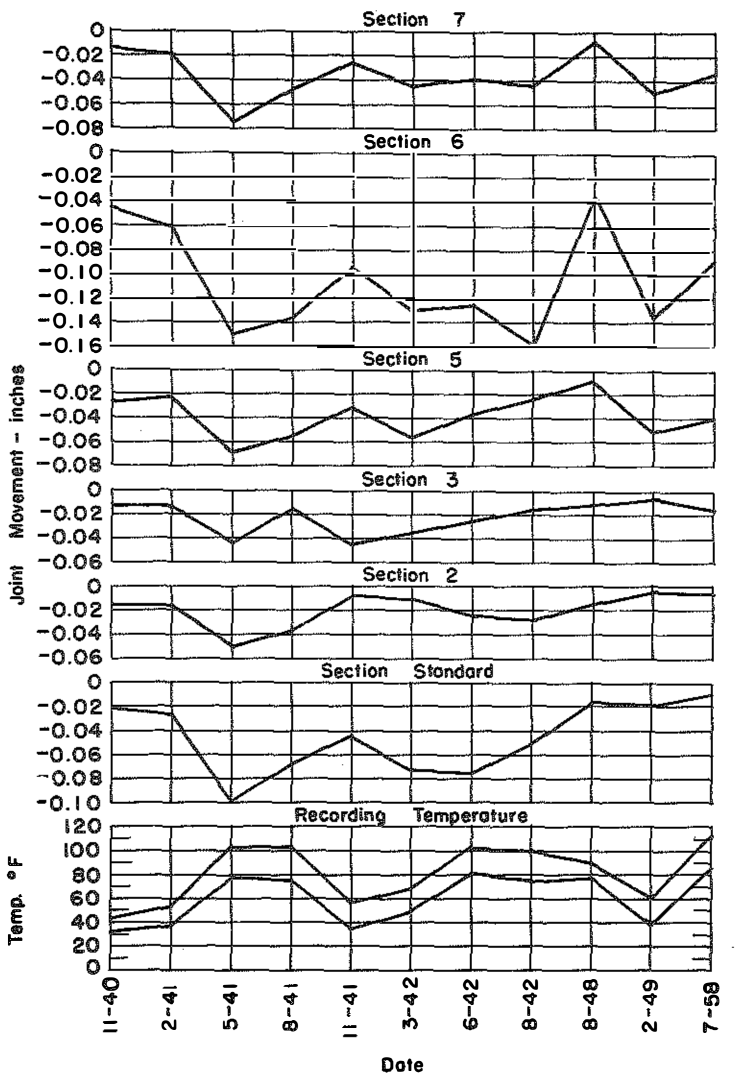

Figure 1. Average Joint Width Change - Daily. Expansion Joints

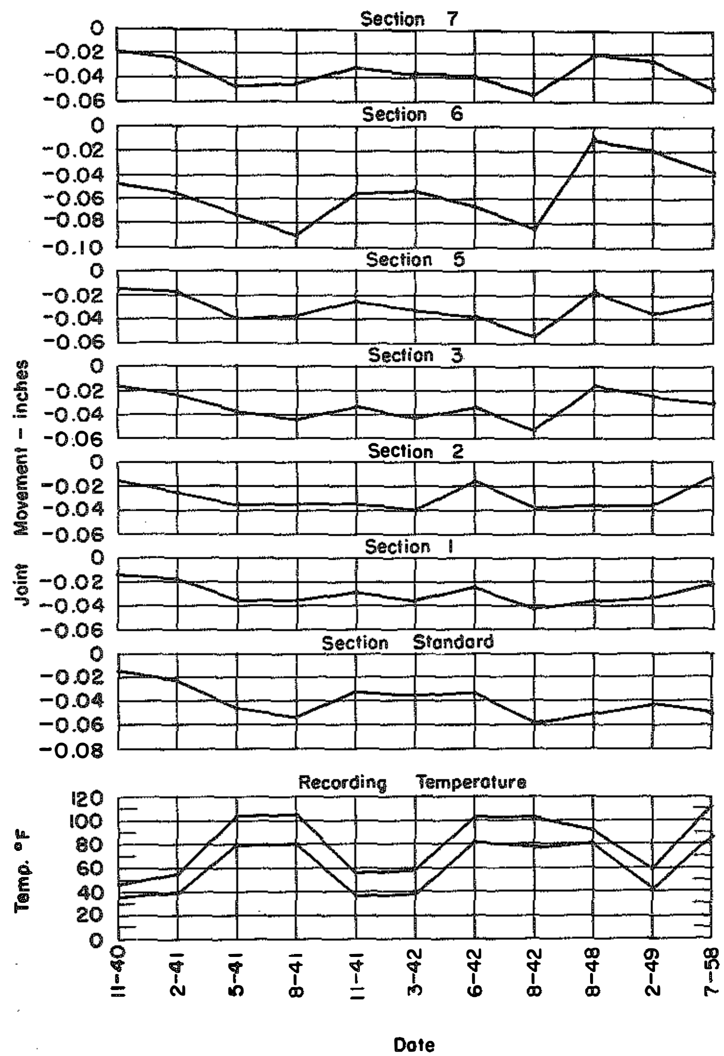

Figure 1A. Average Joint Width Change - Daily. Contraction Joints.

sections. The unit change* in widths of the contraction joints was relatively uniform regardless of section or date of measurement. In sections having 120-ft. intervals between expansion joints, there was greater movement in expansion joints than contraction joints. However, the opposite was true where this interval was 400 ft. or greater. This suggests that the sections with the longer joint interval reached a permanent set in expansion joint closure. The joints spaced at long intervals showed practically no seasonal changes, whereas the joints spaced at shorter intervals showed considerable change.

The 60-ft. spacing in Section 6 and the 30-ft. spacing in the Standard Section, both of which are greater than in any of the other sections, showed the least unit change in width of the contraction joints. Section 6 showed less unit change than the Standard Section. However, Section 6 had the most transverse cracks, and it is probable that much of the movement was taken up by them.

Seasonal Measurements

The average seasonal joint width change for each section is given in Figs. 2 and 2A for expansion and contraction joints respectively.

Expansion joints in Sections 2 and 3 reached a "closed set" at an early age and remained closed thereafter. Section 6 was the most variable in this respect.

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* Total closure converted to closure per 10° temperature increase per 20 ft. of pavement.

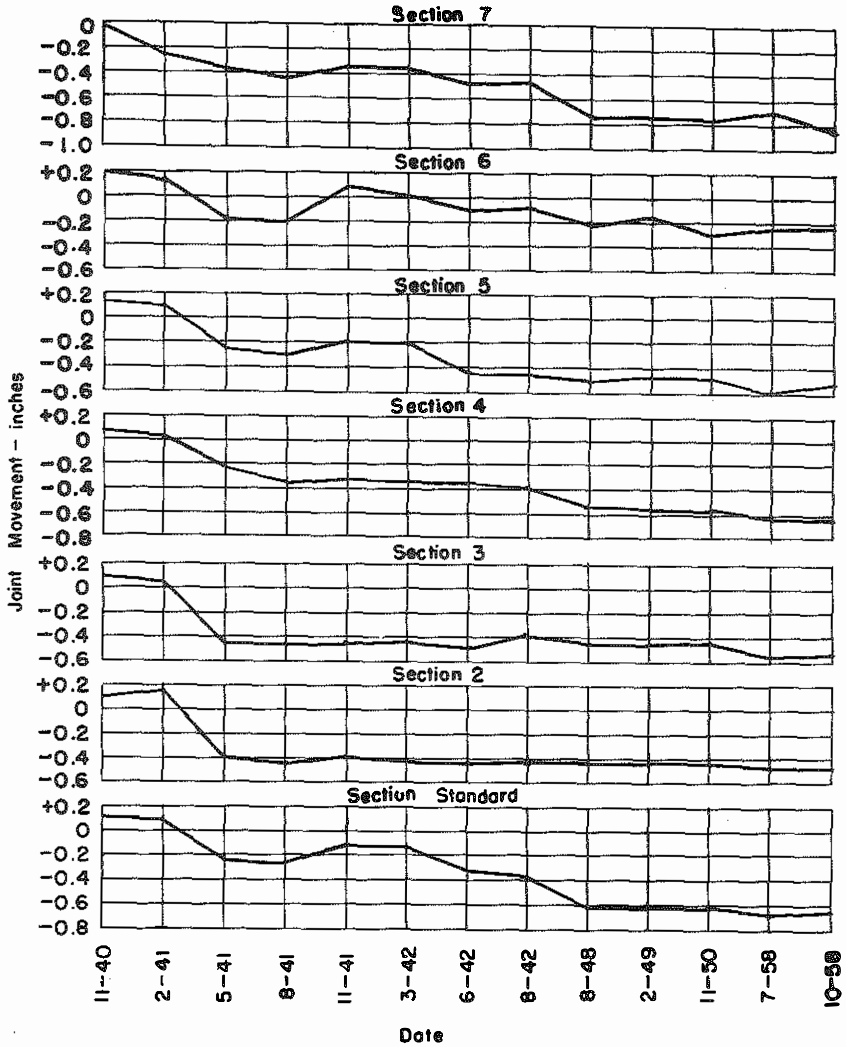


Figure 2. Average Joint Width Change - Seasonal. Expansion Joints.

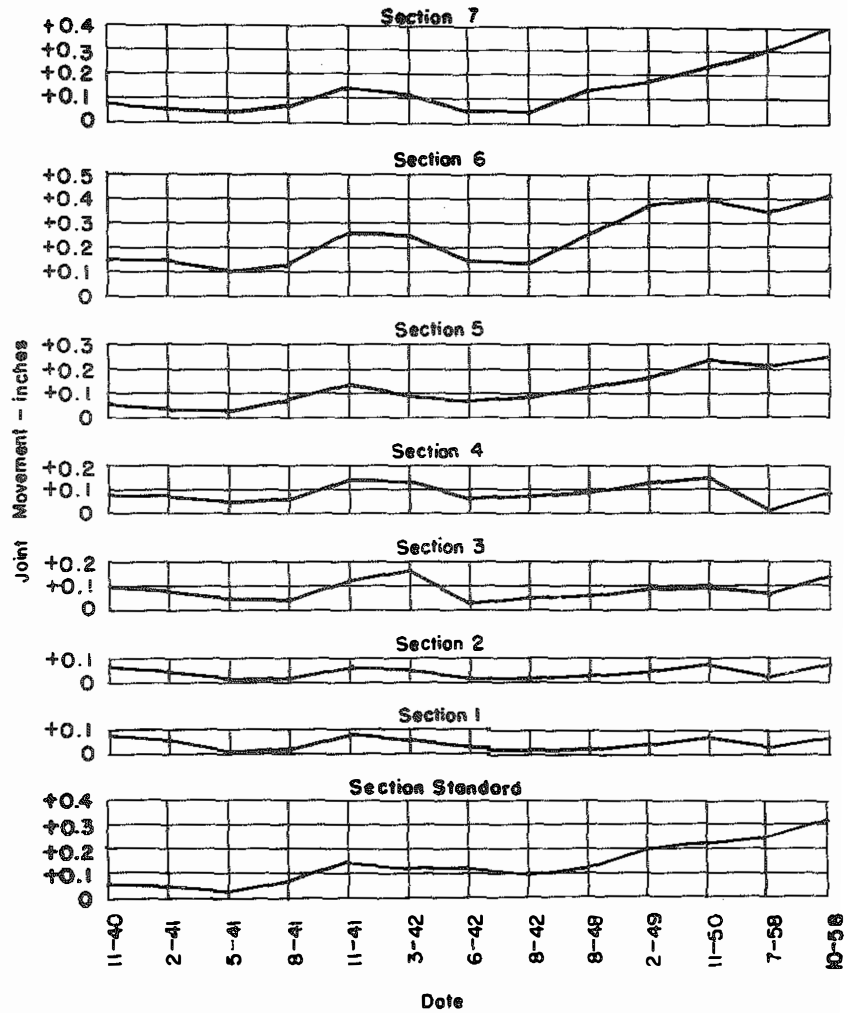


Figure 2A. Average Joint Width Change - Seasonal. Contraction Joints.

Contraction joints in Sections 1 and 2 almost invariably regained their original widths at summer temperatures. The contraction joints in Section 6 showed the greatest tendency to open and remain open regardless of season. After the first year, the seasonal width change for all joints of a given type in each section has been somewhat uniform.

Permanent Measurements

The average permanent change in joint widths for each section is given in Figs. 3 and 3A for expansion and contraction joints respectively.

Section 2 showed practically no permanent change in joint widths for either expansion or contraction joints beyond the initial set. Contraction joints showed little change in Sections 1, 3, and 5. No permanent measurements were scheduled for Section 4, and those taken for Section 6 were too erratic for evaluation. Expansion joints in Section 7 and the Standard Section showed a slight increase in the amount of closure each year whereas contraction joints in these sections have gradually opened.

Change in Elevation

Table 5 gives the percent of joints faulted within each section on specific dates. Variations in pavement elevations and the extent to which faulting has occurred are given in Table 6.

Original pavement elevations, to .005 of a foot, were established in September 1940, by means of a standard level. Subsequent elevation measurements were taken in March 1942, July 1944, August

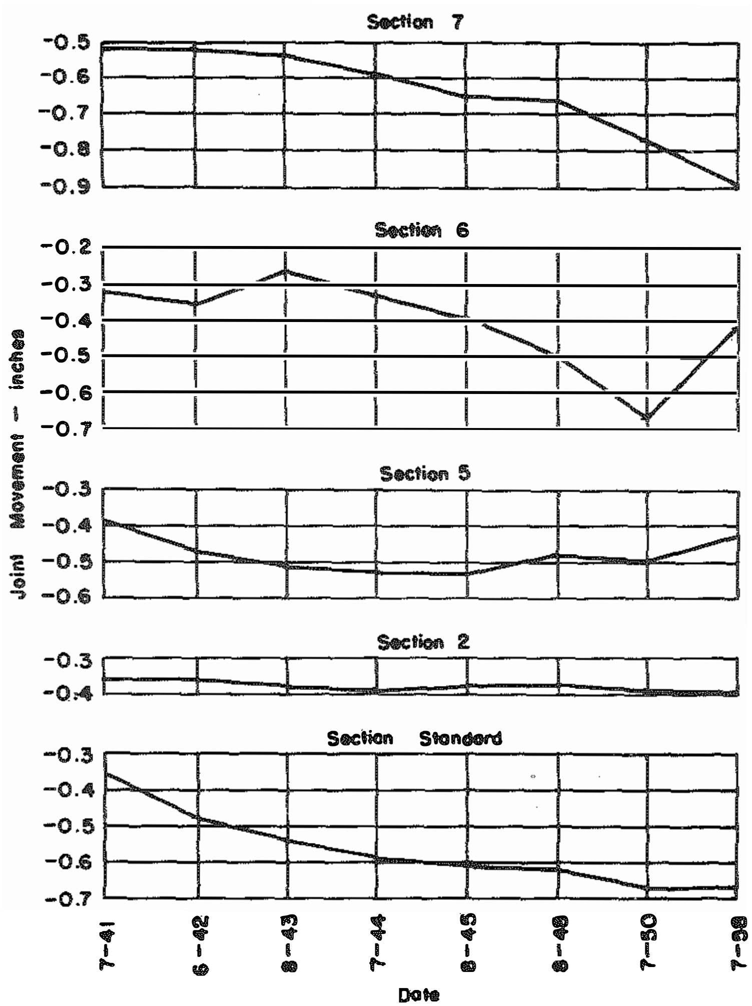


Figure 3. Average Joint Width Change - Permanent. Expansion Joints.

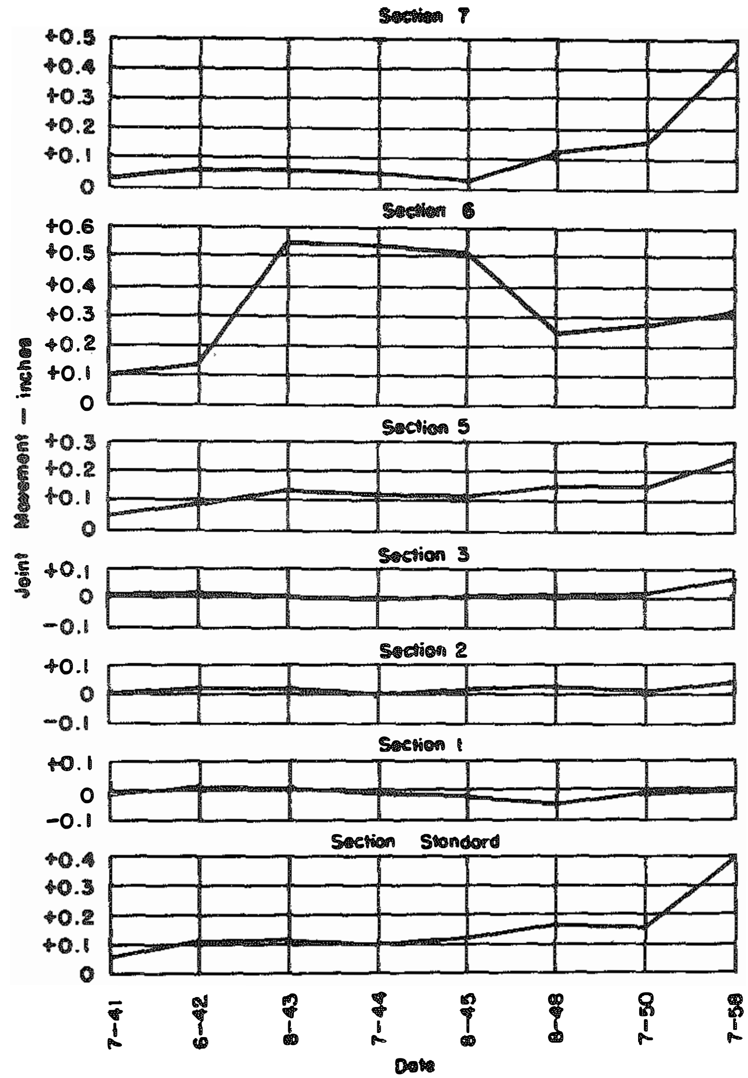


Figure 3A. Average Joint Width Change - Permanent. Contraction Joints.

TABLE 6
DIFFERENCE IN ELEVATION FROM ORIGINAL ELEVATIONS

Section No. (Joints)	Measurement Date	Change in Elevation-In. Max.	Change in Elevation-In. Avg.	No. Joints Faulting 0.12 In.	No. Joints Faulting 0.24 In.	No. Joints Faulting 0.36 In.	No. Joints Faulting 0.42 In.
	March, 1942	0.36	0.17	1	0	0	0
7	July, 1944	0.36	0.17	4	0	0	0
(31)	August, 1948	0.66	0.33	6	0	0	0
	February, 1949	0.72	0.25	7	1	0	0
	July, 1958	1.62	0.39	9	4	1	1
	March, 1942	0.40	0.23	0	0	0	0
6	July, 1944	0.48	0.25	0	0	0	0
(11)	August, 1948	0.60	0.34	1	0	0	0
	February, 1949	0.72	0.29	2	1	0	0
	July, 1958	0.84	0.50	3	0	0	0
	March, 1942	0.48	0.27	0	0	0	0
5	July, 1944	0.42	0.22	2	0	0	0
(31)	August, 1948	1.14	0.90	3	0	0	0
	February, 1949	1.26	1.01	5	0	0	0
	July, 1958	1.20	0.96	6	0	0	0
	March, 1942	0.54	0.30	1	0	0	0
4	July, 1944	0.84	0.23	2	0	0	0
(31)	August, 1948	1.08	0.41	1	0	0	0
	February, 1949	0.96	0.32	3	0	0	0
	July, 1958	1.08	0.19	6	0	1	0
	March, 1942	0.66	0.40	5	0	0	0
3	July, 1944	0.48	0.25	2	0	0	0
(41)	August, 1948	0.90	0.46	5	0	0	0
	February, 1949	0.66	0.31	7	0	0	0
	July, 1958	0.66	0.35	9	4	0	0
	March, 1942	0.84	0.38	2	0	0	0
2	July, 1944	0.72	0.25	4	0	0	0
(41)	August, 1948	1.14	0.48	6	0	0	0
	February, 1949	0.66	0.16	8	0	0	0
	July, 1958	1.62	0.96	15	1	0	0
	March, 1942	0.90	0.53	2	0	0	0
1	July, 1944	0.60	0.40	3	0	0	0
(31)	August, 1948	0.96	0.70	0	1	0	0
	February, 1949	0.78	0.48	3	0	0	0
	July, 1958	1.02	0.74	10	2	0	0
	March, 1942	0.60	0.30	4	0	0	0
Std.	July, 1944	0.60	0.24	0	0	0	0
(41)	August, 1948	1.02	0.43	3	0	0	0
	February, 1949	0.78	0.32	5	0	0	0
	July, 1958	0.96	0.30	9	0	0	0
	March, 1942	0.90	0.32	15	0	0	0
Total	July, 1944	0.84	0.25	17	0	0	0
(258)	August, 1948	1.14	0.45	25	1	0	0
	February, 1949	1.26	0.39	40	2	0	0
	July, 1958	1.62	0.55	67	11	2	1

Note: .42 in. Maximum Faulting Observed

1948, February 1949, and July 1958. Measurements and observations during this period suggest that changes in elevation of the joints do not particularly reflect or indicate structural failure of the concrete. The maximum variation in adjacent slab elevations in all the sections was 0.42 in. Generally, the variation was less than 0.24 in.

Pavement Condition

Surveys were conducted and reported twice yearly between 1940 and 1945, between 1948 and 1950, and once in 1958. Generally, service characteristics of the pavement have been considered satisfactory from the standpoint of existing traffic and particularly so with respect to initial design expectations.

Faulting and Pumping

Faulting, though not infrequent, exists in such magnitude as to defer any particular emphasis on relative merits of design or imply definite association with particular construction features. Additionally, neither the presence of expansion joints nor their spacing as compared with contraction joints, had any measurable effect on faulting or differentials in pavement elevations in adjacent slabs. Little or no significant evidence of pumping was observed to have occurred in any of the sections during the 17-yr. period.

Cracking, Corner Breaks and Joint Deterioration

A summary of cracks in each section is given in Table 7. More transverse cracking has occurred in the initial test sections than in the corresponding "Repeat" sections, whereas more longitudinal cracking has occurred in the "Repeat" than in the initial sections.

TABLE 7
CRACK SUMMARY BY TYPE PER SECTION

Section No.	Length (ft.)	No. of Transverse Cracks		No. of Longitudinal Cracks		No. of Outside Corner Breaks		No. of Inside Corner Breaks		No. of Spalling Joints	
		Per Section	Per Mile	Per Section	Per Mile	Per Section	Per Mile	Per Section	Per Mile	Per Section	Per Mile
7	1250	25	105.5	17	71.7	11	46.4	12	50.6	11	46.5
6	1500	32	112.6	3	10.6	6	21.1	7	24.6	5	17.6
5	1500	15	52.8	5	17.6	4	14.1	2	7.0	2	7.0
4	1500	24	84.5	24	84.5	7	24.6	8	28.2	5	17.6
3	2500	4	8.4	6	12.7	4	8.4	3	6.3	5	10.6
2	3000	2	3.5	23	40.5	7	12.3	6	10.6	6	10.6
1	5000	20	21.2	19	20.1	7	7.4	5	5.3	5	5.3
Std.	7000	45	33.9	6	4.5	13	9.8	10	7.5	80	60.3
2R	2500	12	25.3	25	52.8	9	19.0	7	14.7	14	29.6
3R	2500	10	21.1	24	50.6	6	12.7	5	10.6	25	52.8
4R	1500	7	24.6	12	42.2	4	14.1	7	24.6	17	59.8
5R	1500	18	63.4	17	59.8	10	35.2	8	28.2	13	45.8
6R	1500	27	95.0	2	7.4	4	14.1	5	17.6	17	52.8
7R	1200	9	39.7	10	44.0	3	13.2	4	17.6	2	8.8

Corner breaks were somewhat equally distributed in both the initial and "Repeat" sections except for Section 7 which showed more corner breaks than any of the other sections and Section 7R which showed less than any of the repeat sections.

According to the description of the soils given in this report, there may be significant differences in the subgrade on which the initial sections were constructed and the subgrade on which the repeat and Standard Sections were constructed. The crack summary also points to some major variable other than the design variables. Therefore, it was necessary to evaluate the performances of the initial sections separately and look for verification of trends thus established in the repeat sections. It is believed that where there is a lack of agreement between performance factors for the initial and repeat sections, the information for the initial sections is more reliable. Also, there are more data on the initial sections available for evaluation.

Pavement Roughness

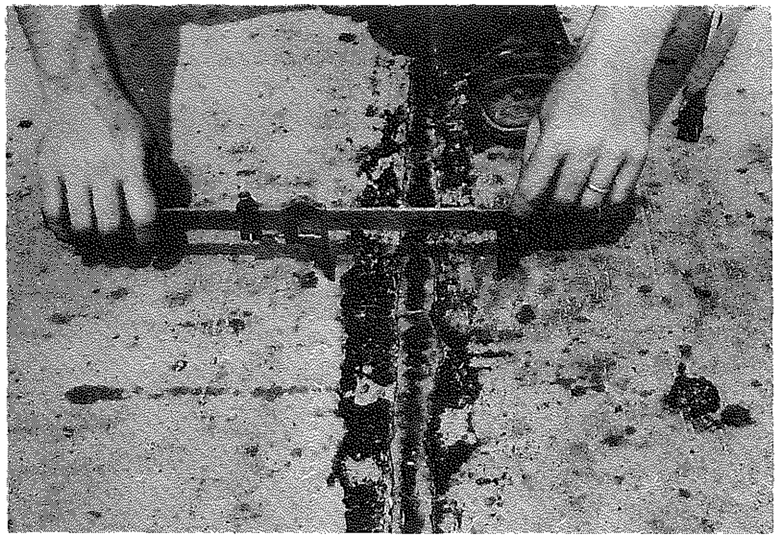
Pavement roughness measurements were made by recording the vertical accelerations imparted to a passenger in a 1957 Ford, driven at 55 mph.(6). A CE Recording Oscillograph recorded the occuring phenomena on a strip chart (Fig. 4) which was analyzed to determine the over-all pavement roughness in terms of ft./sec^3. or g's/sec.

The area under the acceleration curve was measured with a compensating polar planimeter and expressed in ft./sec^2. x sec. Average acceleration was obtained by expressing the length of chart in terms of elapsed time, in seconds, and then dividing time into the area under the acceleration curve to obtain ft./sec^2. or g's. The inverse of the frequency of the fluctuations divided into the average acceleration produced a mathematical parameter in terms of ft./sec^2. or g's/sec. which was used as a basis for comparing sections of road. This parameter for each section is given in Table 8 and is plotted on Fig. 5. The initial sections, ranked from smoothest to roughest, are: 5, 2, 6, 1, 3, Std., 7 and 4. The repeat sections, ranked from smoothest to roughest, are: 2R, 6R, 3R, 4R, 7R and 5R. The indications were that the smoother sections were generally those with dowels in the joints and those in which the expansion joints were widely spaced.

TABLE 8
RIDING QUALITY OF TEST SECTIONS

Section	gs per sec.		
	Northbound	Southbound	Average
7	.0317	.0272	.0294
6	.0283	.0230	.0256
5	.0246	.0234	.0240
4	.0354	.0275	.0314
3	.0285	.0232	.0258
2	.0265	.0229	.0247
1	.0279	.0237	.0258
Std. Section	.0288	.0275	.0281
2R	.0281	.0300	.0290
3R	.0282	.0320	.0301
4R	.0296	.0338	.0317
5R	.0420	.0470	.0445
6R	.0285	.0308	.0296
7R	.0314	.0335	.0324

Fig. 6: A Measurement Being Taken Between Caliper Points for Joint Width Change Determinations.



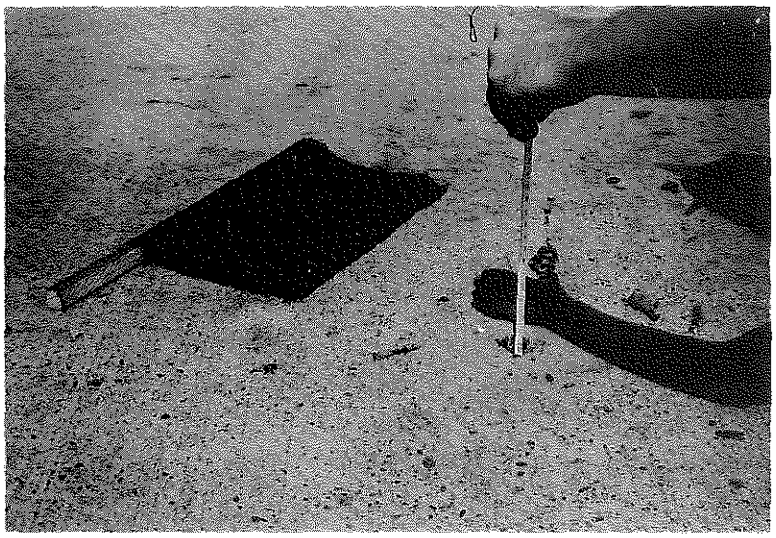


Fig. 7: Pavement Temperature Being Taken in a Thermometer Well.

Fig. 8: Elevation Points Used to Determine Amount of Faulting at Joints.

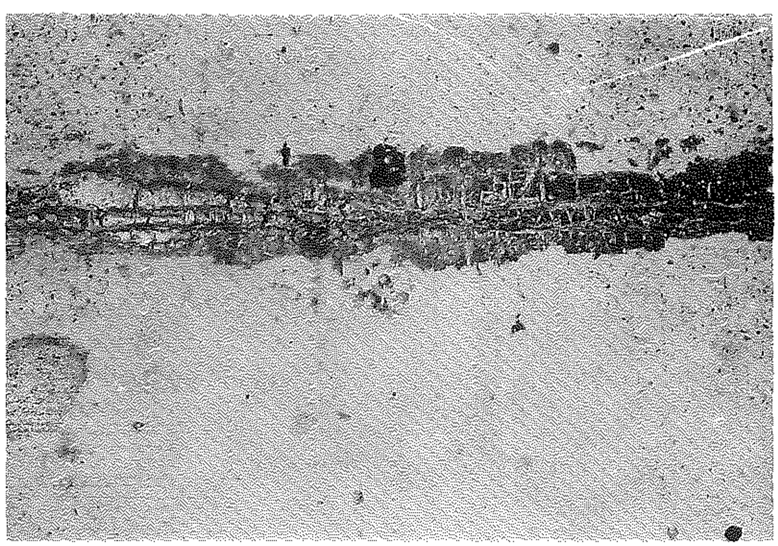


Fig. 9: View to the North in Section 3 Showing a Faulted Joint in Foreground.

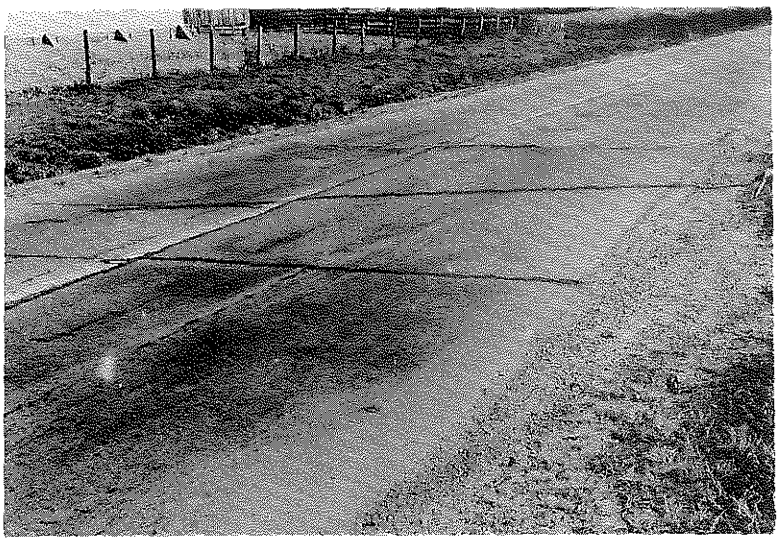


Fig. 10: A Joint Failure in Section 1 Where Expansion of the Slabs Forced the Joint up.

Fig. 11: View to the North in Section 4R.

SUMMARY

The 1958 data, when compared with previous data reported in Highway Research Board Research Report 17-B(4), bear out trends noted at that time. The several differences among the sections and the effect of different variables noted in 1950 are discussed.

Expansion Joints

1. With few exceptions, changes in joint widths were uniform for each type of joint within each section on each date. However, there were greater differences among the different sections, particularly for expansion joints as compared with contraction joints,

2. The expansion joints continued to close and retain an increasing amount of closed set. Only Section 5, short slab lengths, and Section 6, long slab lengths, both having expansion joints spaced every 120 ft., show any notable reversal of this tendency. However, closure has increased very little during the past 10 years, which indicates that nearly maximum closure has been attained.

3. Expansion joint spacing has shown no appreciable effect upon the tendency of these joints to assume and retain a closed set.

4. The influence of temperature on changes in width of expansion joints is greater when the spacing is relatively short, 120 ft., than when it is 400 ft. or greater.

5. The unit movement of expansion joints with changes in temperature has been generally greater than that of contraction joints in those sections having 120-ft. intervals between expansion joints. The reverse was true where this interval is 400 ft. or greater; and,

in sections with the 120-ft. spacing of the expansion joints, contraction joints opened more and tended to stay open more than in sections where the expansion joint interval was 400 ft. or more.

6. In sections having longer spacings of expansion joints or having no expansion joints, there are fewer transverse cracks in slabs of equal length.

7. Expansion joint spacing or even the existence of expansion joints shows no measurable relationship to faulting or differences in slab elevations.

Contraction Joints

8. In the two sections where the contraction joint spacing was greater than 20 ft., the expansion joints show the greatest tendency to return to their original width with reduction in temperature. This was more pronounced in Section 6 than in the Standard Section.

9. The extent of opening of most contraction joints increased in approximate proportion to slab length. Joints in sections having the longest joint interval assumed and retained the largest opening regardless of changes in temperature.

10. Pavement elevations show that the greater the slab length the greater the differences in elevation between the ends and centers of slabs. However, the average difference in elevation per foot of slab is about the same regardless of slab lengths. All sections had some warped slabs, but no general tendency toward warping was noted with increased age.

11. All sections had tilted slabs, but in Section 6 (60-ft. slab length) there were fewer instances of tilted slabs to total number of slabs.

12. The survey has shown no definite relationship between contraction joint spacing and the development of cracks in pavement.

13. The data show no evidence that dowels resist the closure of expansion joints or the opening of contraction joints.

14. Interlock in contraction joints, where maintained, in the absence of load transfer, has tended to prevent cracks and corner breaks.

15. Generally the sections having load transfer dowels in all joints have shown less faulting of the joints.

16. The high frequency of transverse cracks in Section 6 and Section 6R indicates that the 70-lb. mesh failed to prevent more cracking in slabs 60 ft. in length than in slabs 20 ft. in length, whereas the combination of 44-lb. mesh and a 30-ft. slab length in the Standard Section resulted in a transverse crack interval that is about the same as for sections with 20-ft. slab lengths.

Pavement Section

17. Section 7, of uniform 7-in. cross section, has shown more faulting and corner breaks than any of the other sections, and is one of the sections with the largest amount of transverse cracking. It appears that the excessive corner breaking and perhaps the high frequency of transverse cracking may be attributed to the lesser pavement cross section. It also appears that the absence of load transfer devices in any of the joints contributed to the cracking and faulting.

Riding Quality

18. The whole test project is relatively smooth when compared with other pavements of similar age. Generally, the sections having

load transfer devices or widely spaced expansion joints, and no transfer devices in contraction joints showed better riding qualities.

General

In order to better describe the relative performance of the various sections, numerical ratings were given to the sections according to each performance factor. The initial sections, 1 through 7, have been treated as a group on the assumption that the subgrade conditions throughout these sections were uniform. Table 9 summarizes the ratings of the initial sections. Ratings were made according to the following factors: transverse cracks per mile, longitudinal cracks per mile, outside corner breaks per mile, inside corner breaks per mile, spalled joints per mile, road roughness indications for each section, percent of joints faulted in each section, and the average faulted joints in each section. By assigning each section a rank according to each of these factors, sections were compared according to individual factors. By totaling these numerical ranks, a total performance rating was given to each section.

The repeat sections, 2R through 7R, and the Standard Section have been treated as a separate group because, according to construction records, subgrade conditions during construction were not uniform within the sections or with respect to their companion sections in the first group.

On this basis (See Table 9), Section 5 has the best over-all rating; and the remaining sections rated in declining order are: Section 1, Section 3, Section 2, Section 6, Section 4 and Section 7.

TABLE 9
SUMMARY OF PERFORMANCE DATA AND SECTION PERFORMANCE RATINGS FOR THE INITIAL SECTIONS

Section No.	1		2		3		4		5		6		7	
	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank
Transverse Cracks/Mi.	21.2	3	3.5	1	8.4	2	84.5	5	52.8	4	112.6	7	105.5	6
Logitudinal Cracks/Mi.	20.1	4	40.5	5	12.7	2	84.5	7	17.6	3	10.6	1	71.7	6
Outside Corner Breaks/Mi.	7.4	1	12.3	3	8.4	2	24.6	6	14.1	4	21.1	5	46.4	7
Inside Corner Breaks/Mi.	5.3	1	10.6	4	6.3	2	28.2	6	7.0	3	24.6	5	50.6	7
Spalled Joints /Mi.	5.3	1	10.6	3	10.6	3	17.6	4	7.0	2	17.6	4	46.5	5
Road Roughness /Section	.0258	4	.0247	2	.0258	4	.0314	6	.0240	1	.0256	3	.0294	5
Joints Faulted (Percent)	38.7	5	39.0	6	31.7	4	22.6	2	19.4	1	27.3	3	48.4	7
Average Fault Displacement	.14"	3	.13"	2	.16"	5	.15"	4	.12"	1	.12"	1	.19"	6
Total Performance Rating		22		26		24		40		19		29		49
Rank		2		4		3		6		1		5		7

Generally, the repeat sections (Table 10) bear out these performance ratings. However, it is obvious that there is a discrepancy between the performance ratings of the initial and repeat sections. Section 5, showing the poorest performance in the repeat group, has the best rating in the first group. Another discrepancy may be noted by comparing Section 7 which shows the poorest performance with Section 7R which shows moderate performance. With these two discrepancies in mind, the only assumption that can be made is that an extraneous factor affected performance of these companion sections more than the design variables. It appears that this factor was variation in subgrade. Section 5R, by visual examination, showed signs of poor drainage and excessive deterioration. Likewise, Section 7R shows moderate deterioration because of subgrade and drainage problems. By discounting Sections 5R and 7R, the ratings of the rest of the repeat sections given in Table 10 generally check the ratings of the initial sections.

From the performance data in Table 9, the sections, from best to poorest, can be described as follows. The best section performance-wise is Section 5 (9-7-9 cross section, 120-ft. expansion joint spacing, 20-ft. contraction joint spacing, and dowels in all the joints). Second in performance is Section 1. This section, also 9-7-9-in. pavement, differs from Section 5 in that there are no expansion joints and no load transfer dowels. Next in performance is Section 3 which is also a 9-7-9-in. pavement with a 20-ft. contraction joint interval, but which has a 400-ft. expansion joint interval and load transfer dowels only in the expansion joints. The only difference between Section 3 and Section 2, which is next in performance, is the 800-ft. expansion joint

TABLE 10
SUMMARY OF PERFORMANCE DATA AND SECTION PERFORMANCE RATINGS FOR THE STANDARD AND REPEAT SECTIONS

Section	Std.		2R		3R		4R		5R		6R		7R	
	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	Rank
Transverse Cracks/Mi.	33.9	4	25.3	3	21.1	1	24.6	2	63.4	6	95.0	7	39.7	5
Longitudinal Cracks/Mi.	4.5	1	52.8	6	50.6	5	42.2	3	59.8	7	7.4	2	44.0	4
Outside Corner Breaks/Mi.	9.8	1	19.0	5	12.7	2	14.1	4	35.2	6	14.1	4	13.2	3
Inside Corner Breaks/Mi.	7.5	1	14.7	3	10.6	2	24.6	5	28.2	6	17.6	4	17.6	4
Spalled Joints /Mi.	60.3	6	29.6	2	52.8	4	59.8	5	45.8	3	52.8	4	8.8	1
Road Roughness /Section	.0281	1	.0290	2	.0301	4	.0317	5	.0445	7	.0296	3	.0324	6
Total Performance Rating		14		21		18		24		35		24		23
Rank		1		3		2		5,6		7		5,6		4

CRACK SURVEY

for

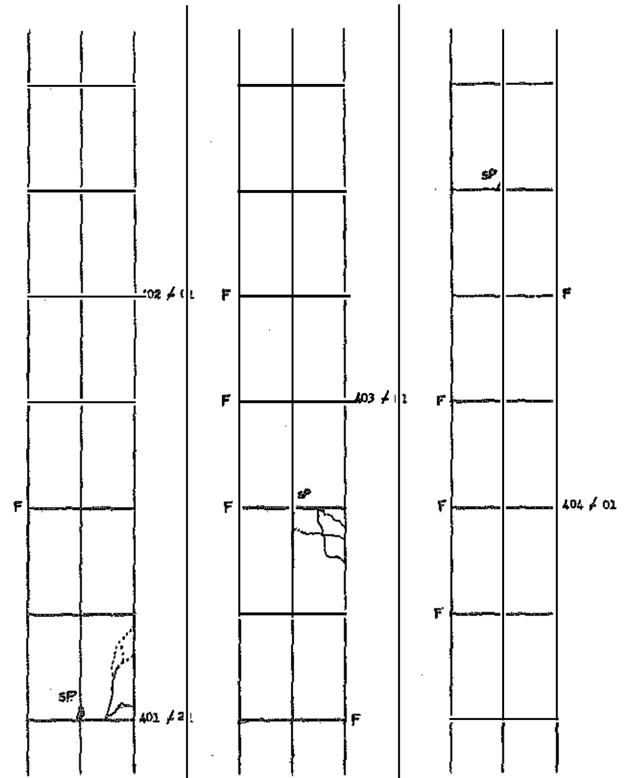
17-YEAR REPORT ON THE OWENSBORO-HARTFORD CO-OPERATIVE INVESTIGATION OF JOINT SPACING IN CONCRETE PAVEMENTS

June, 1958

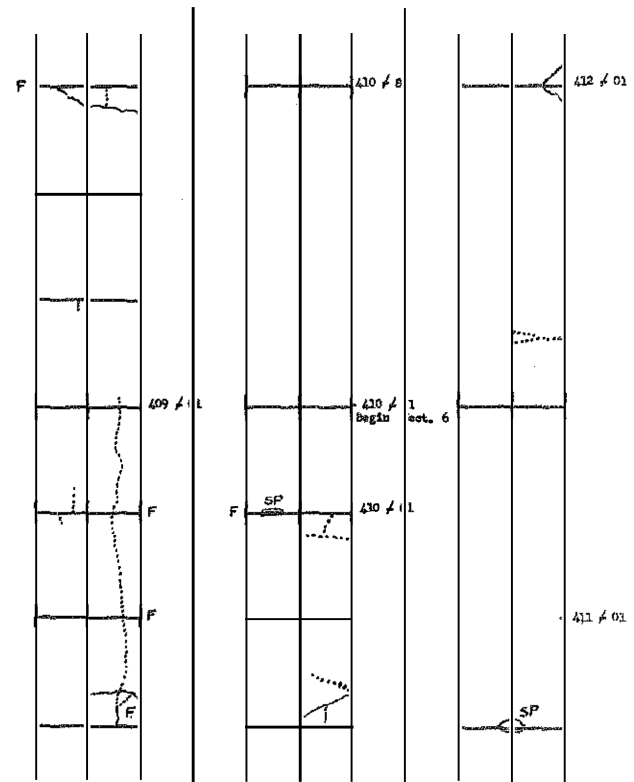
LEGEND

F.	Faulting
P.	Pumping
SP.	Spalling
SC.	Scaling
CON.	Construction Joint

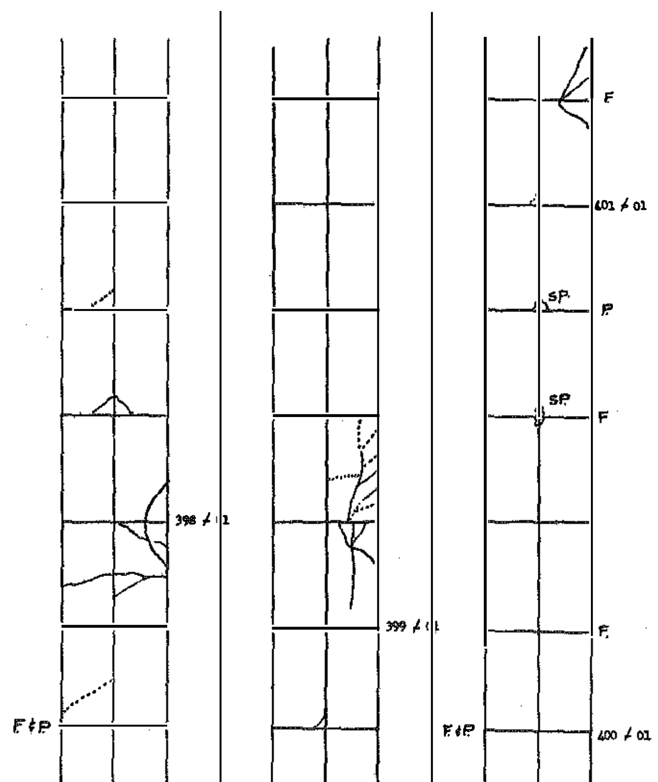
———	Old Cracks
. . . . . .	New Cracks
//////	Asphalt Patch
⊞	Catch Basin



Section 7
Sta. 401 + 21 to 404 + 81



Section 7 + 6
Sta. 408 + 41 to 412 + 01



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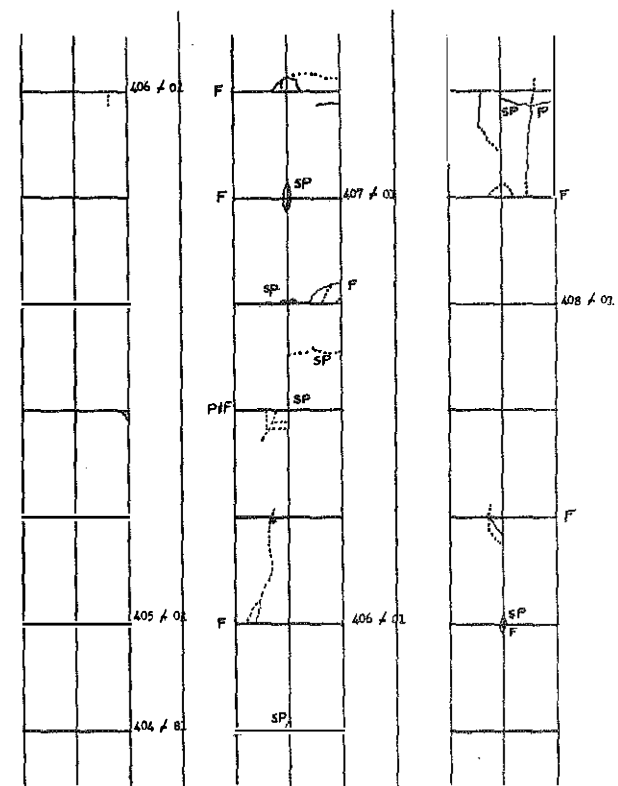

Section 7
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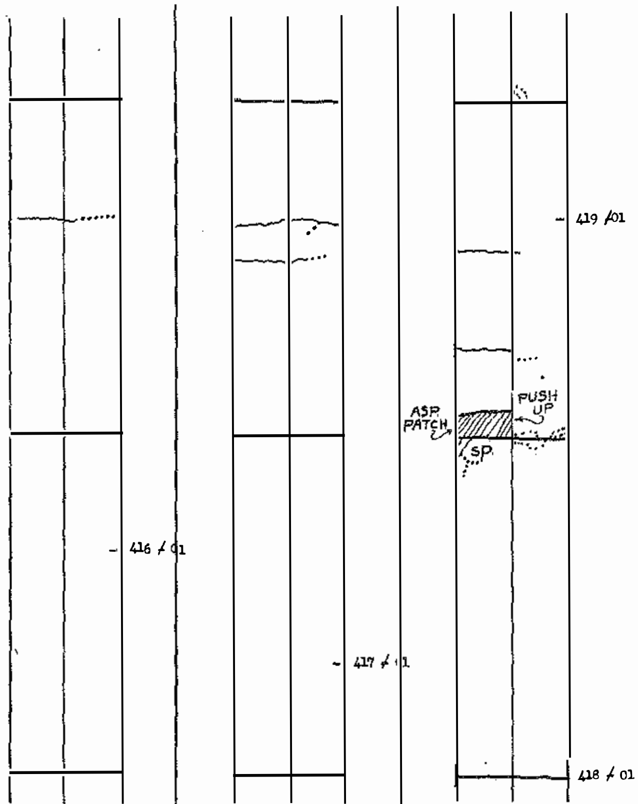

Section 6
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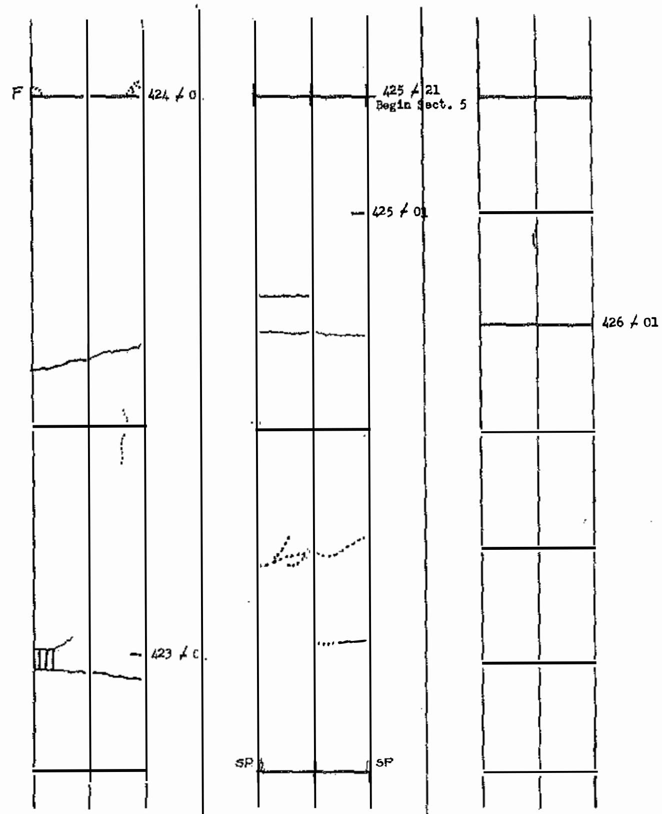

Section 6 + 5
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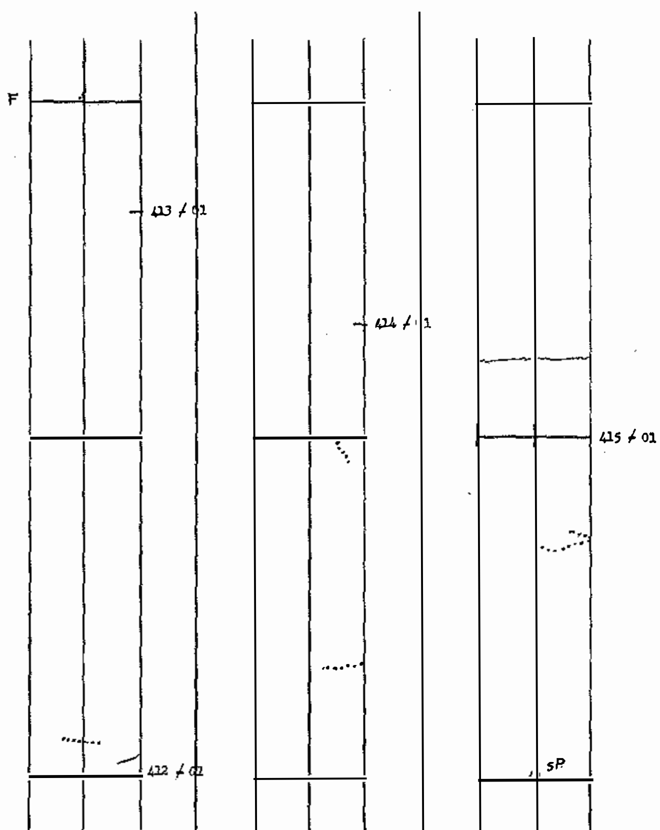

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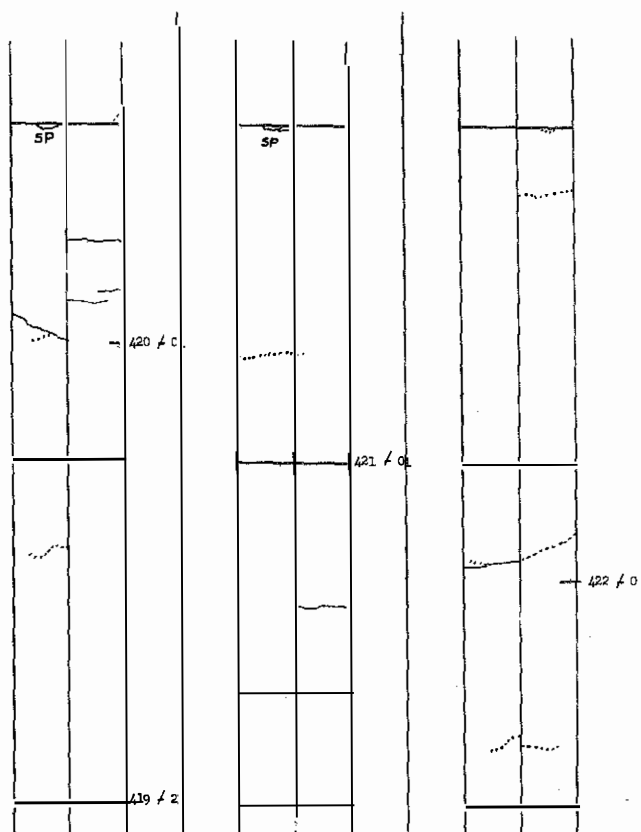

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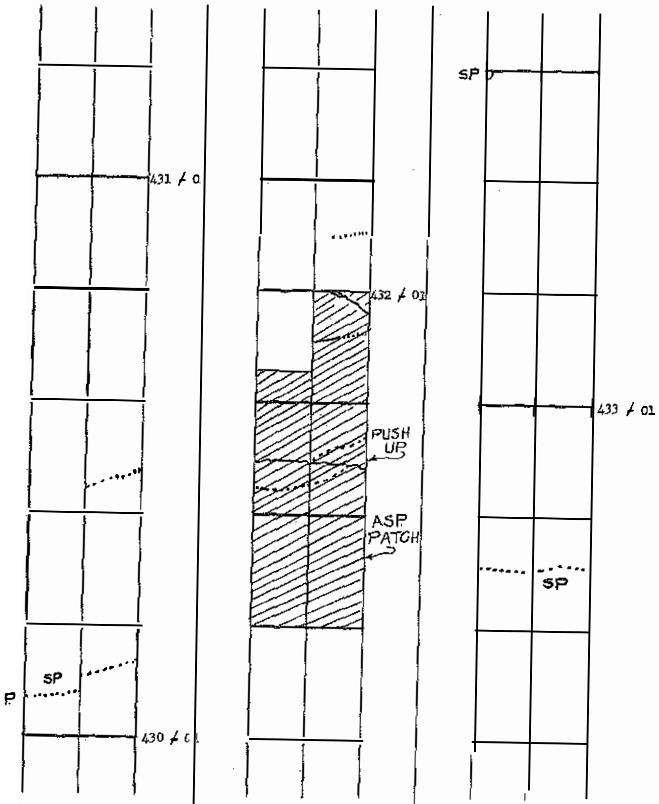

Section 5
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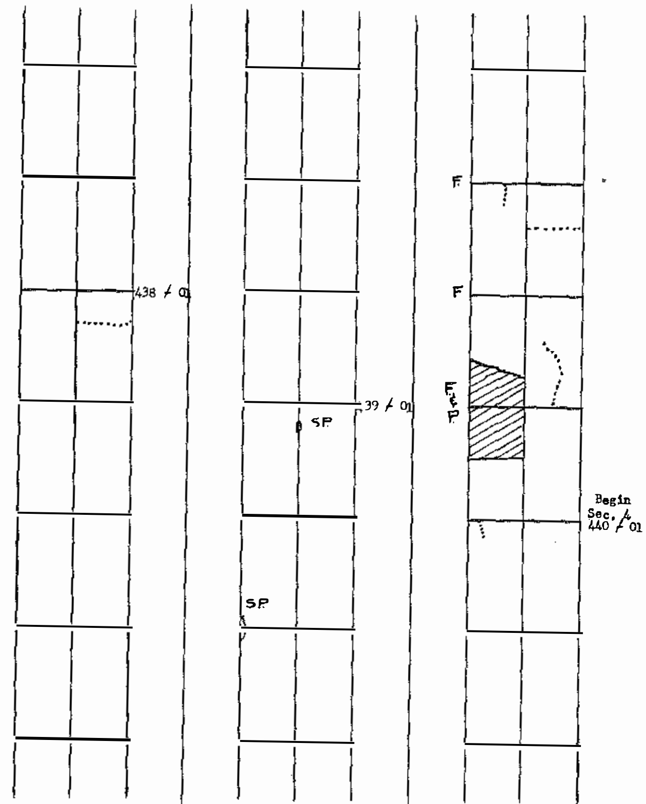

Section 5 & 4
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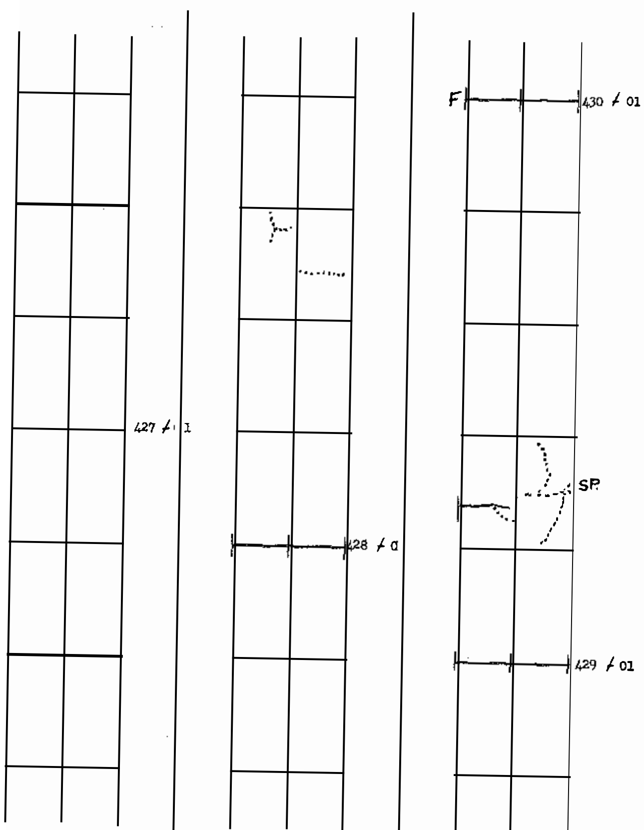

Section 5
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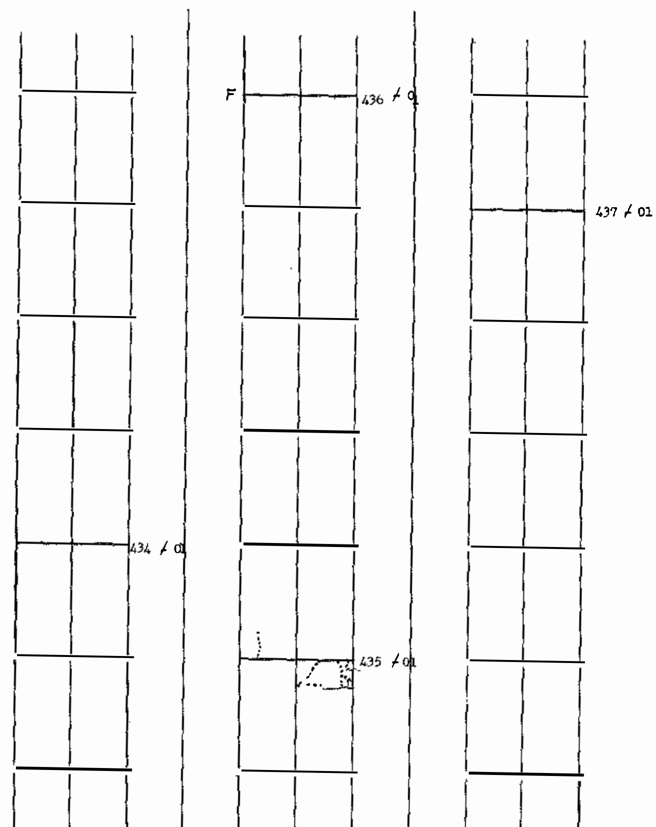

Section 5
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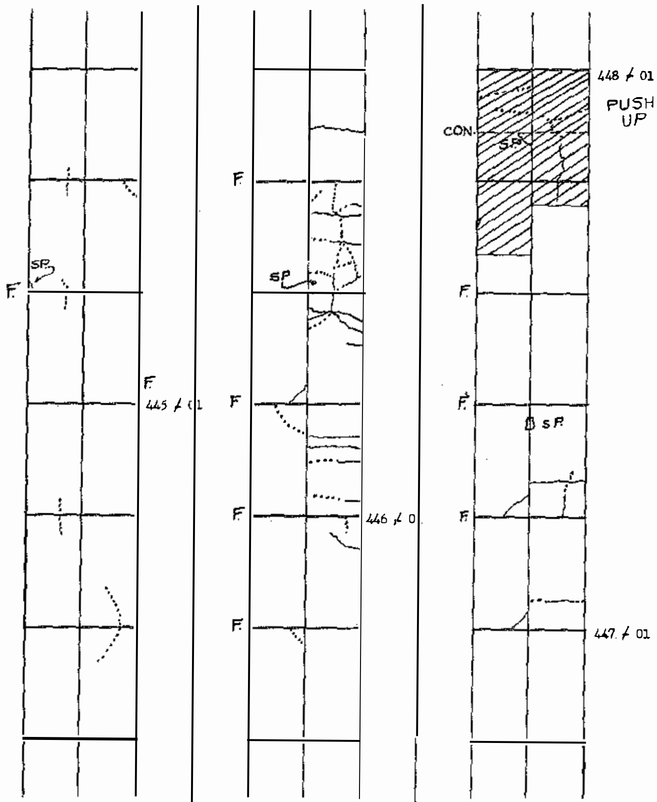
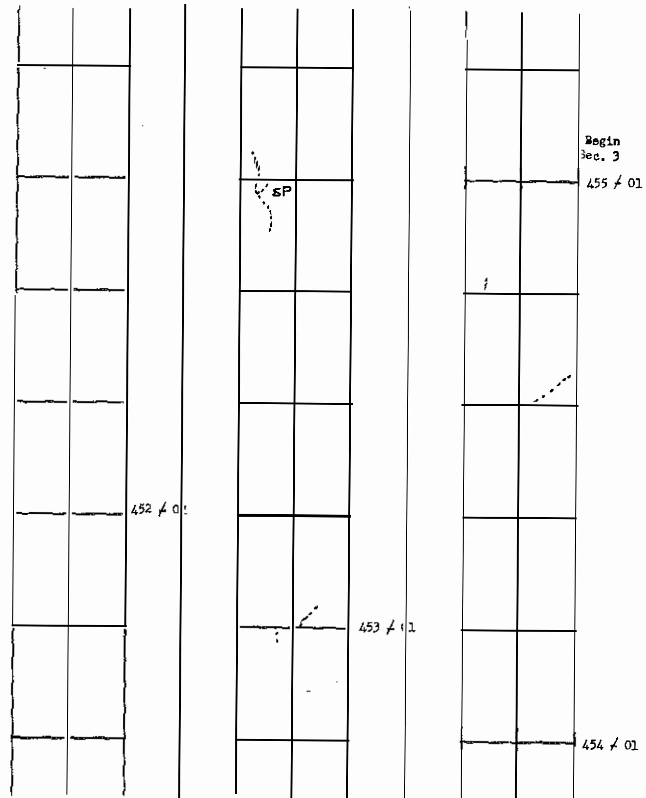


Section 4
Sta. 444 + 41 to 448 + 01



Section 4 & 3
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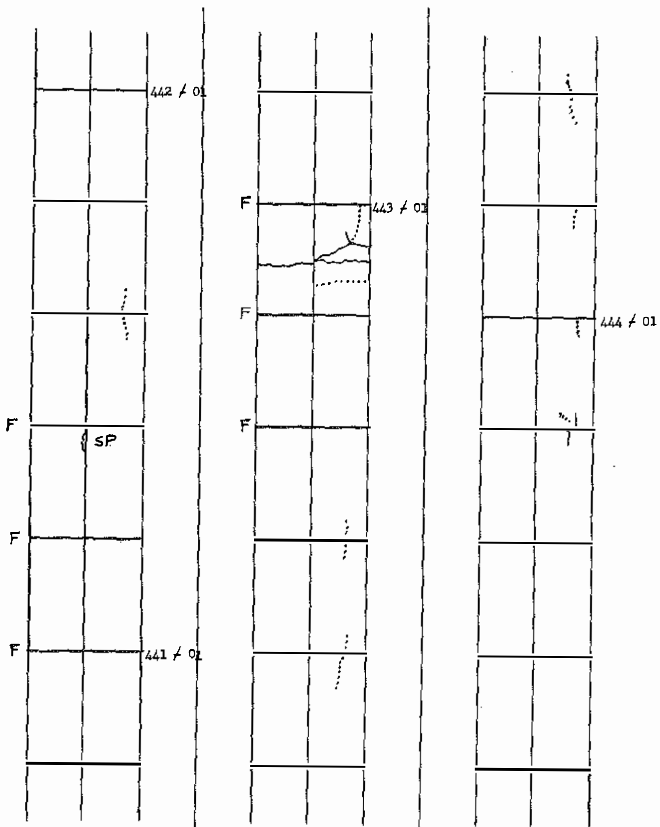

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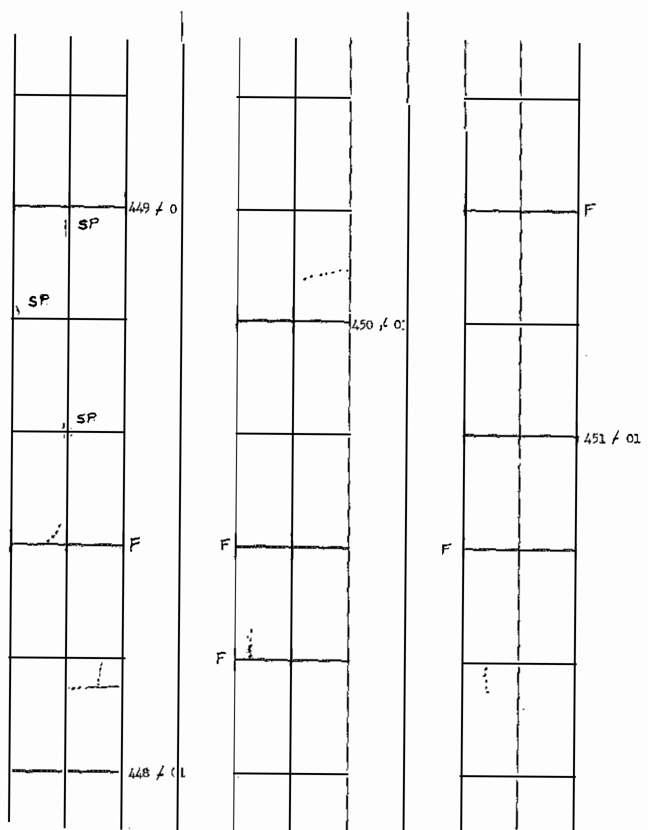

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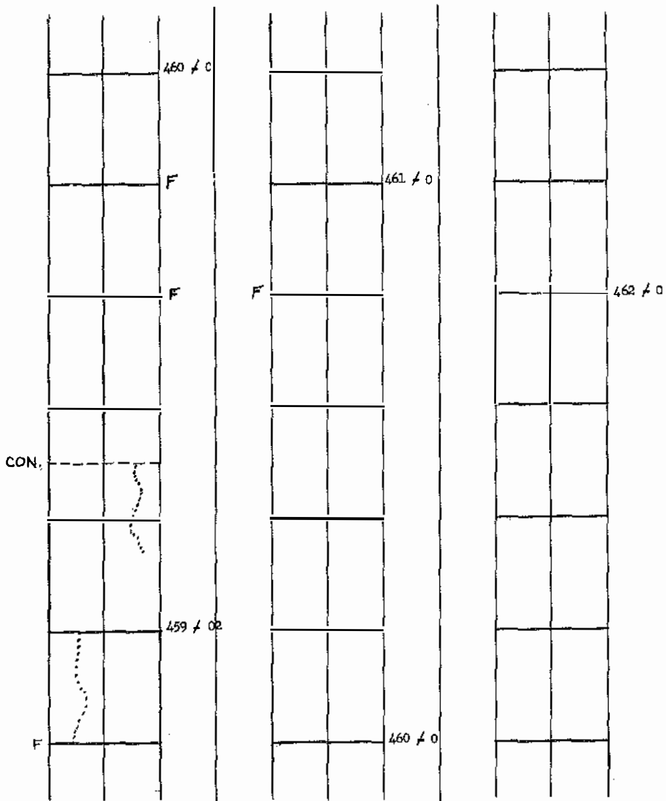
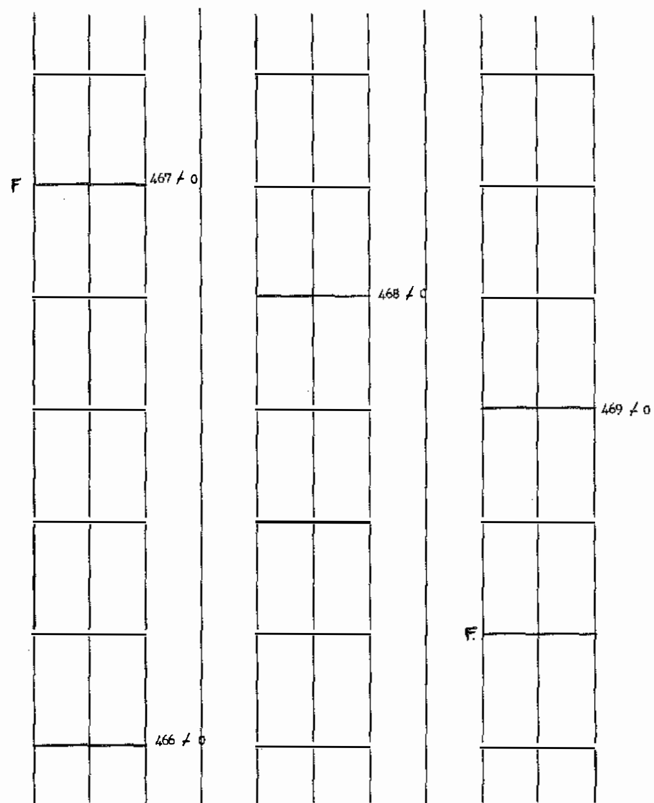


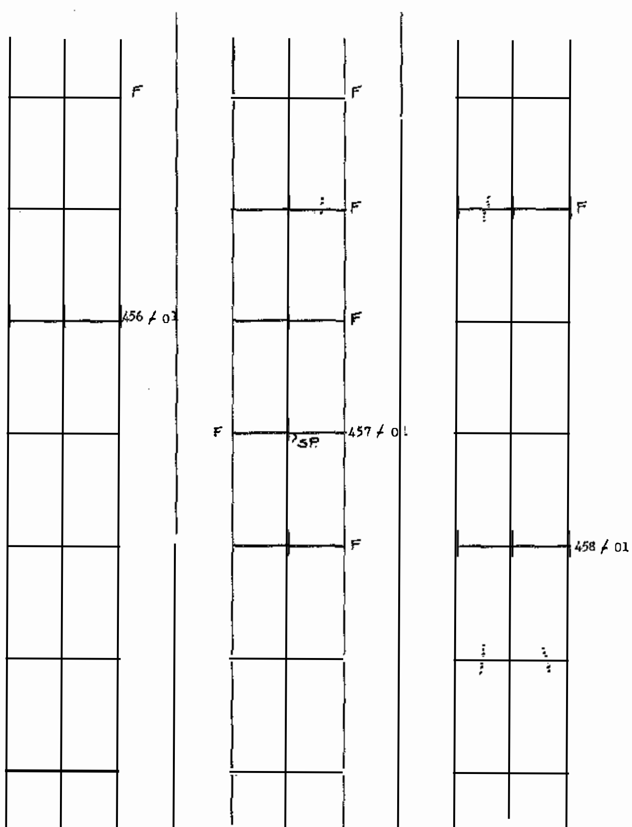
Section 3

Sta. 458 + 81 to 462 + 40



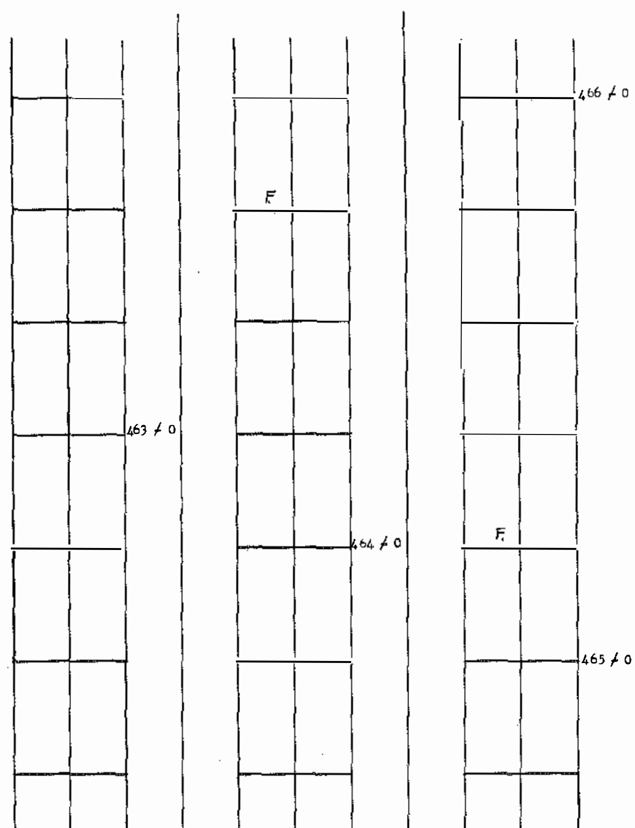
Section 3

Sta. 466 + 0 to 469 + 60



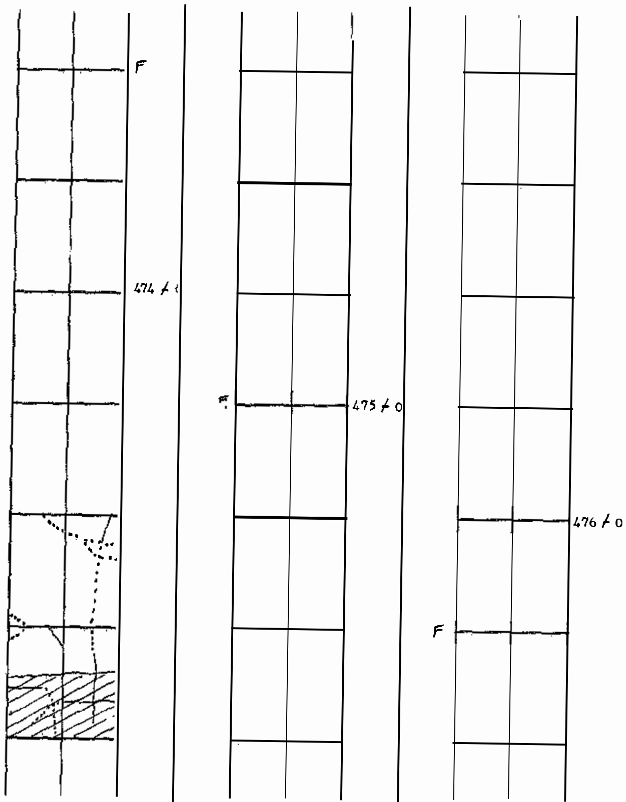
Section 3

Sta. 455 + 21 to 458 + 81



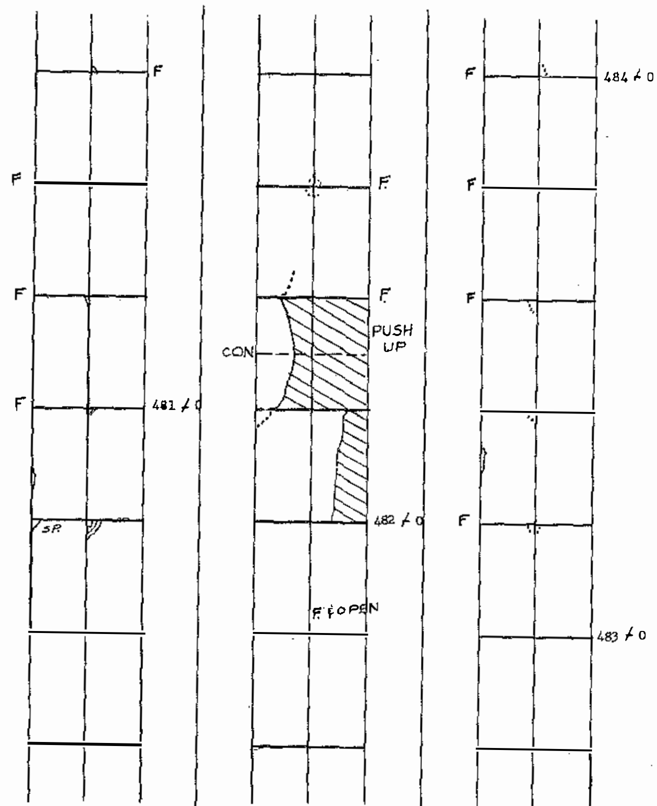
Section 3

Sta. 462 + 40 to 466 + 0



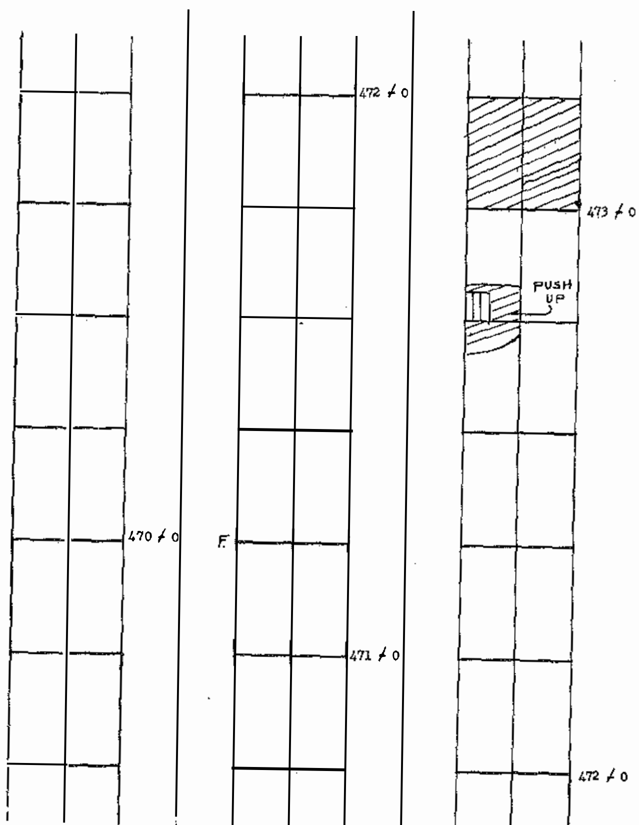
Section 3

Sta. 473 + 20 to 476 + 80



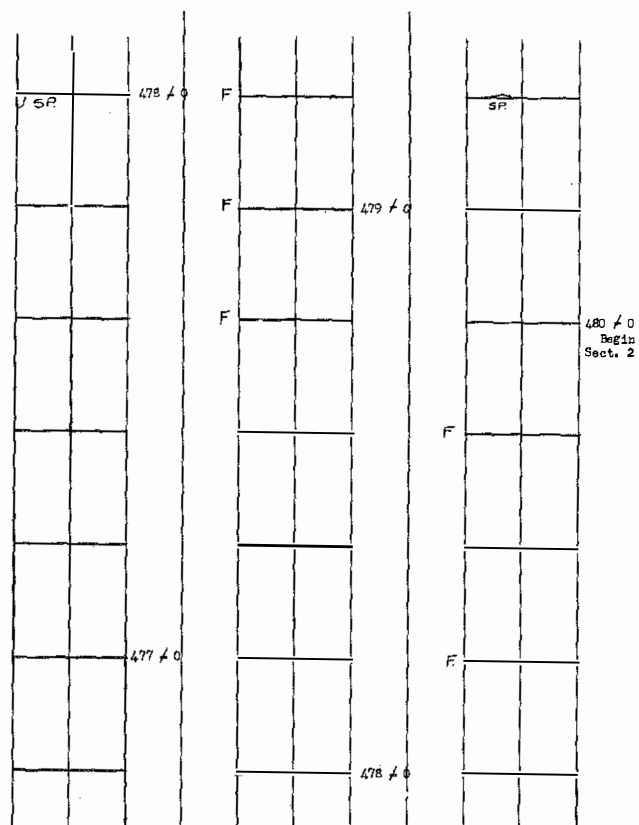
Section 2

Sta. 480 + 40 to 484 + 0



Section 3

Sta. 469 + 60 to 473 + 80



Section 3& 2

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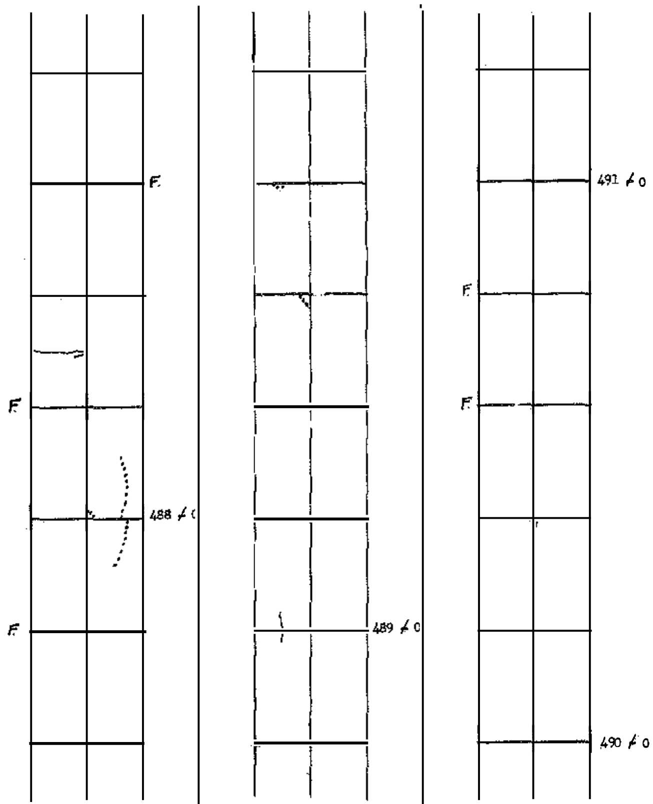

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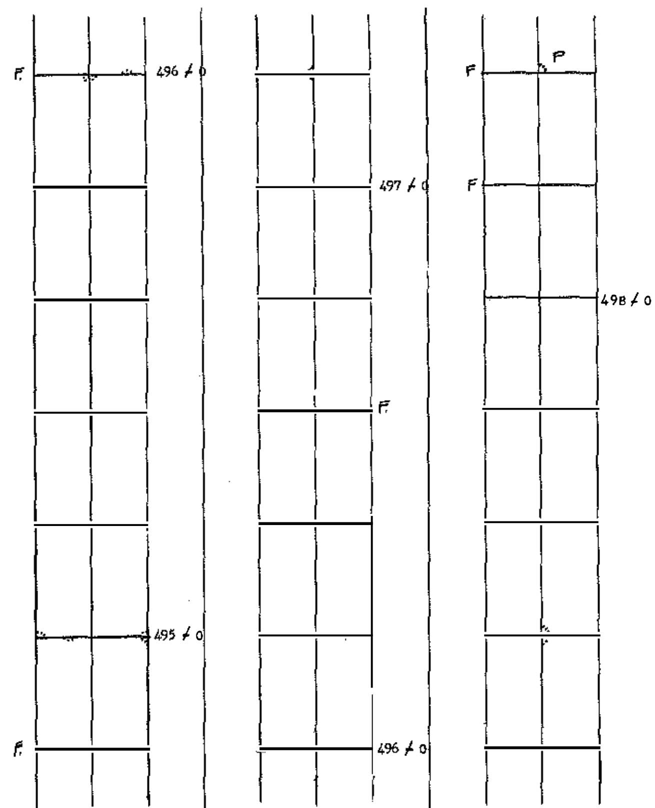

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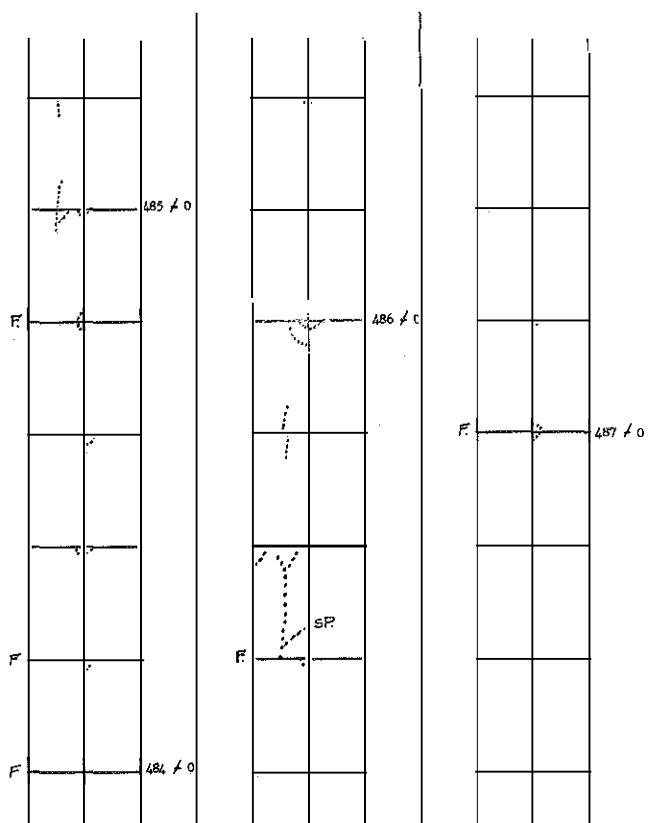

Section 2
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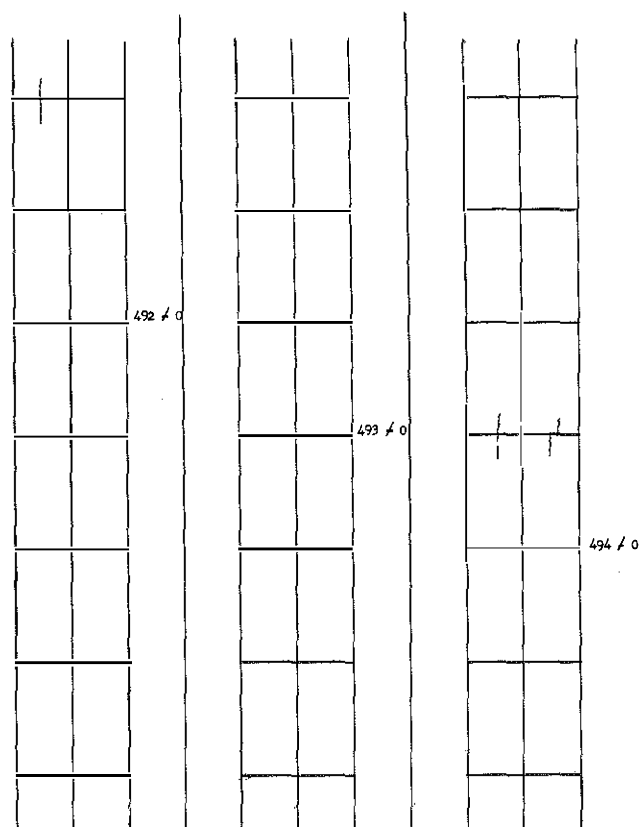

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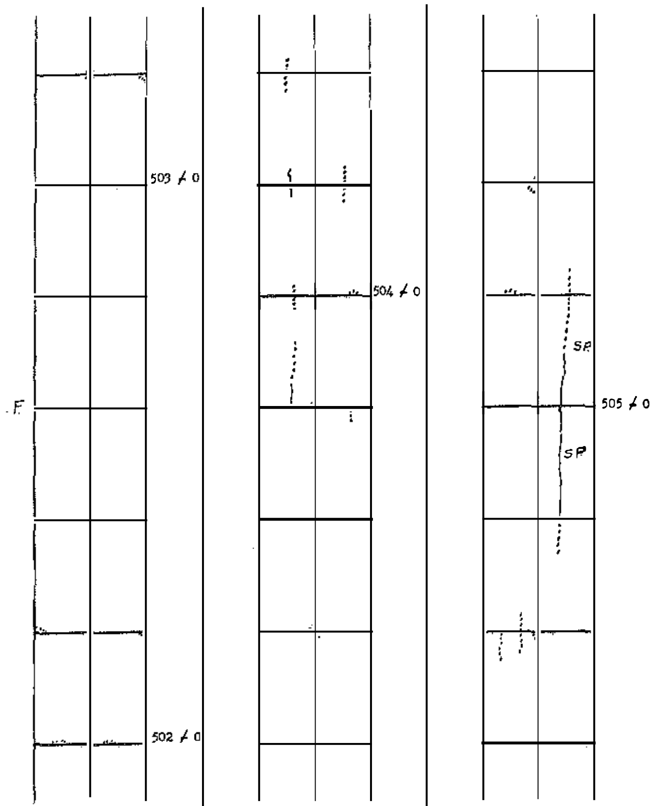
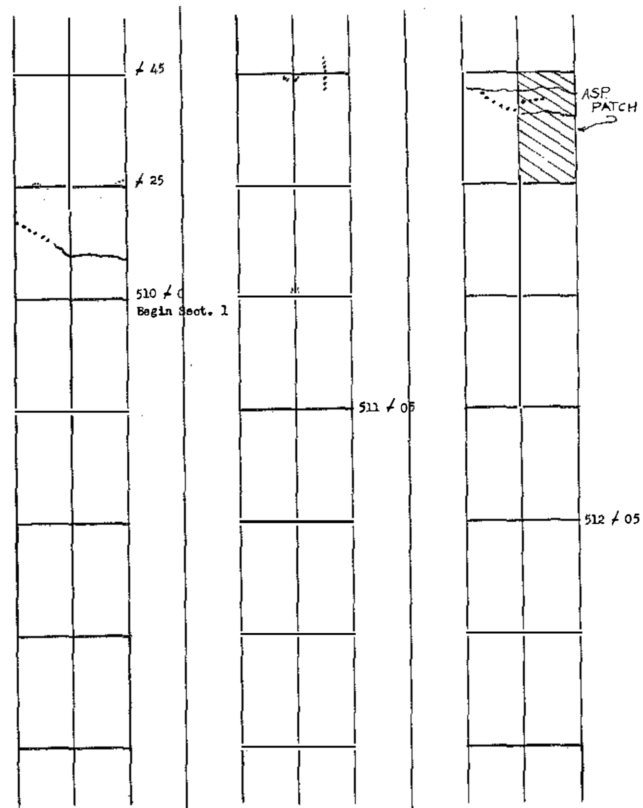


Section 2
Sta. 502 + 0 to 505 + 60



Section 2 & 1
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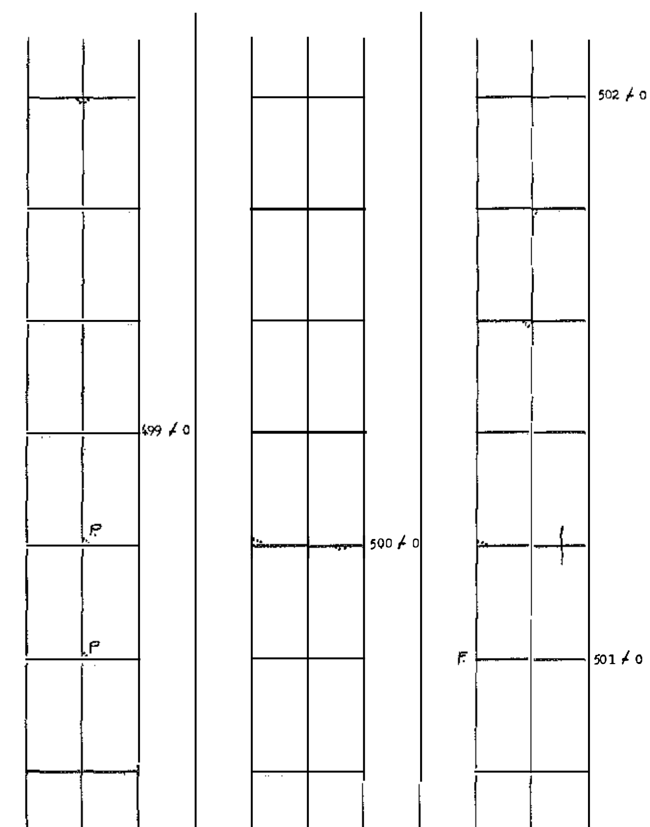

Section 2
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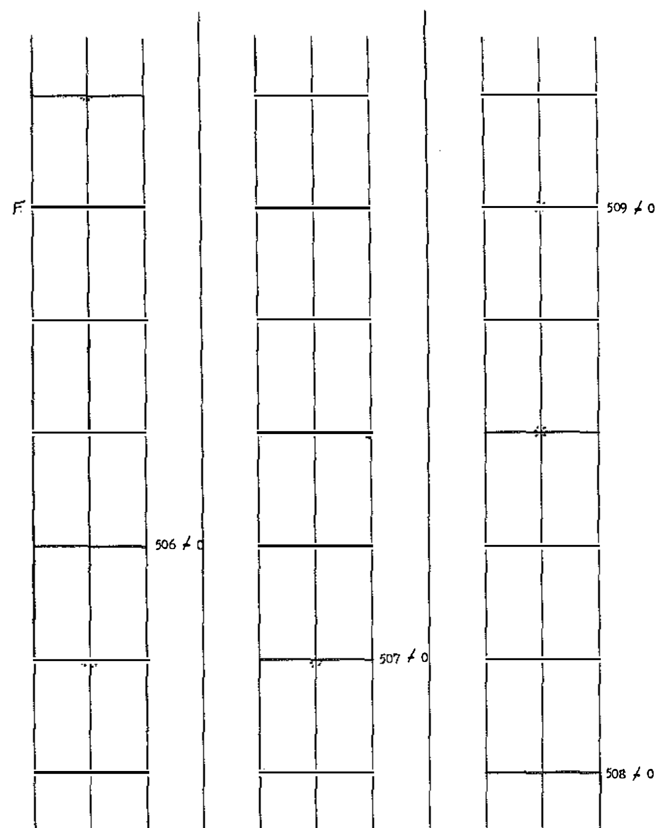

Section 2
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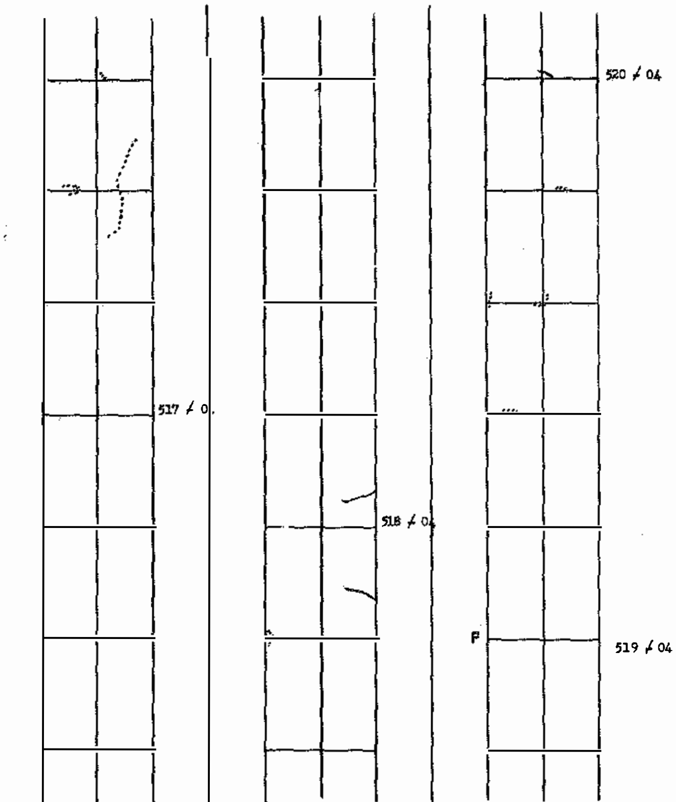
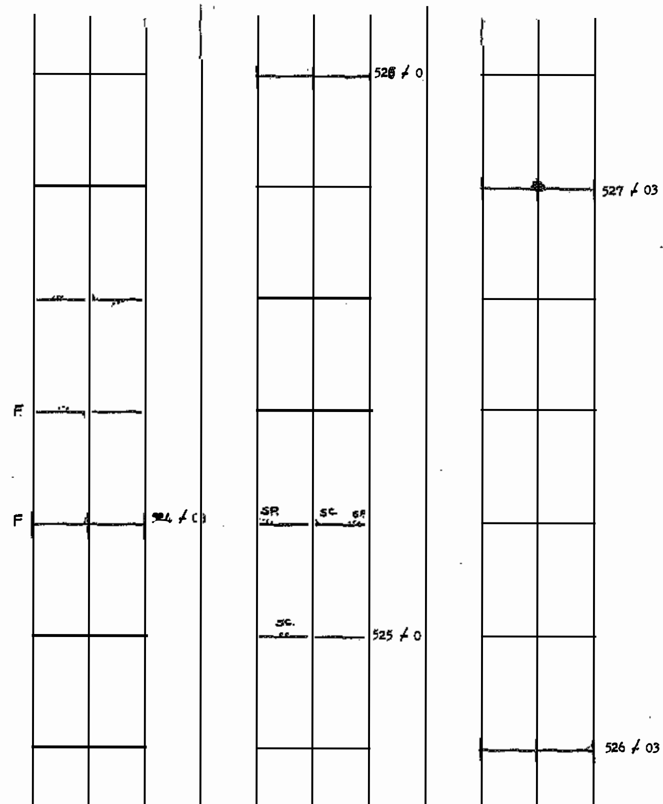
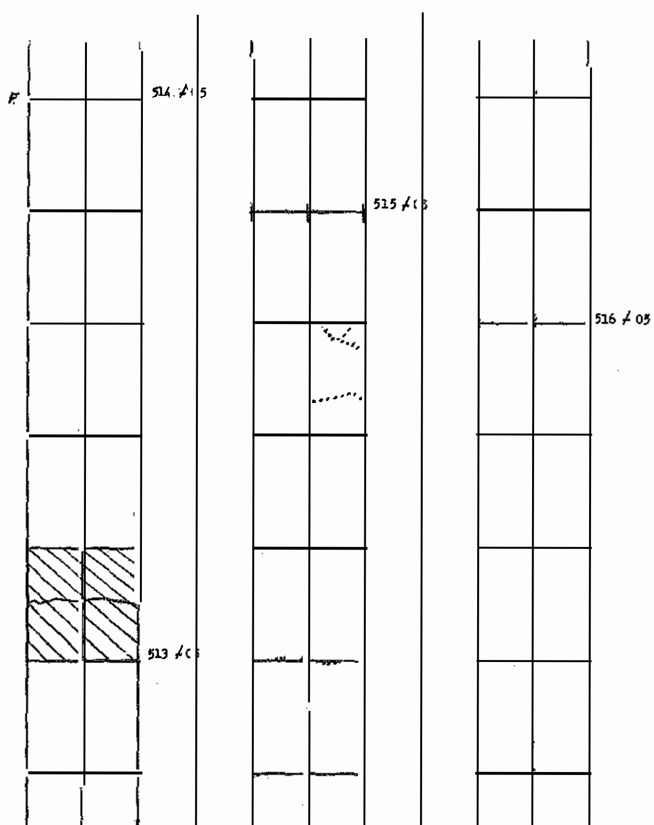


Section 1
Sta. 516 + 44 to 520 + 04



Section 1
Sta. 523 + 63 to 527 + 23



Section 1
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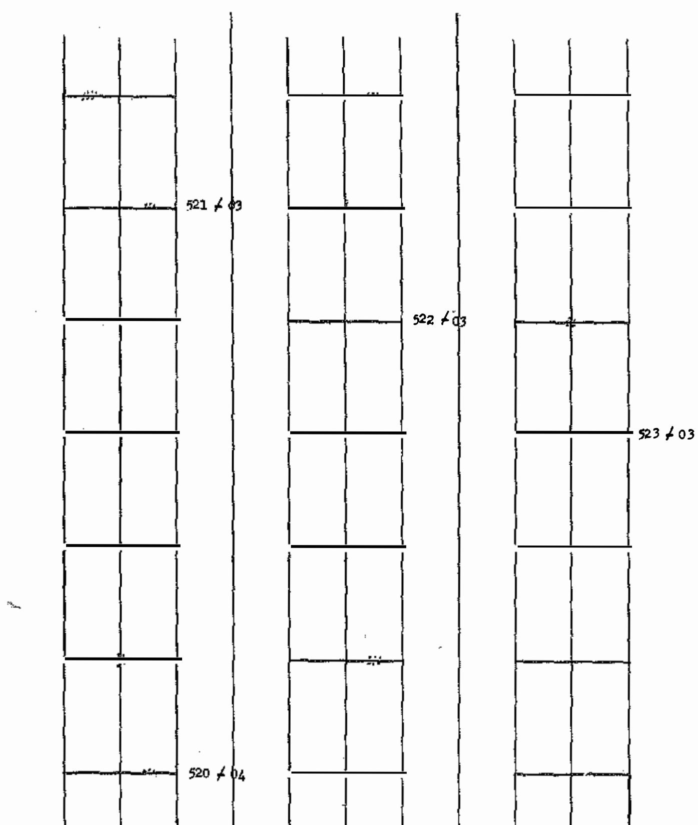

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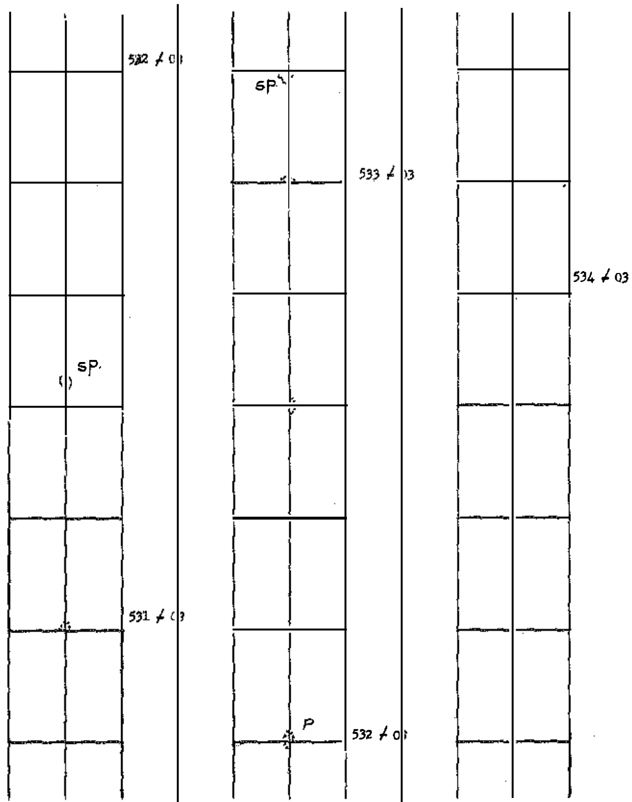

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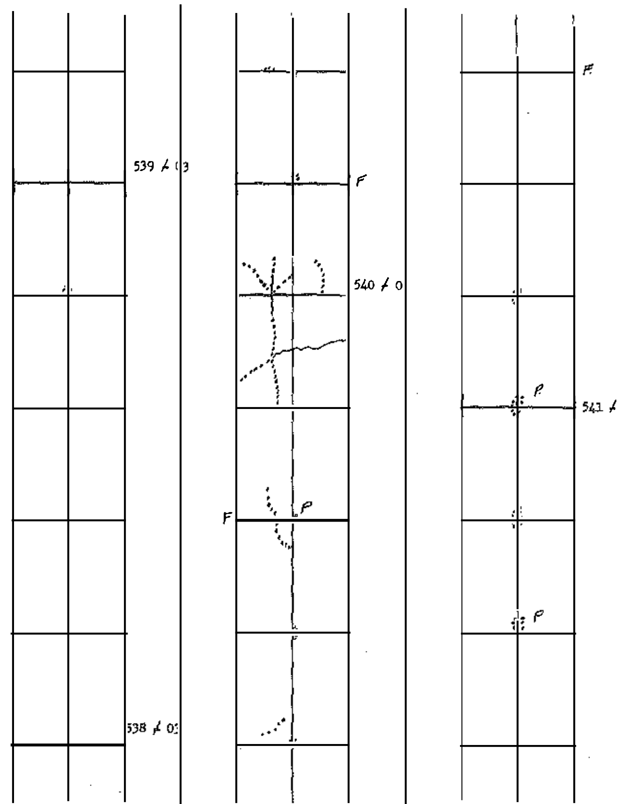
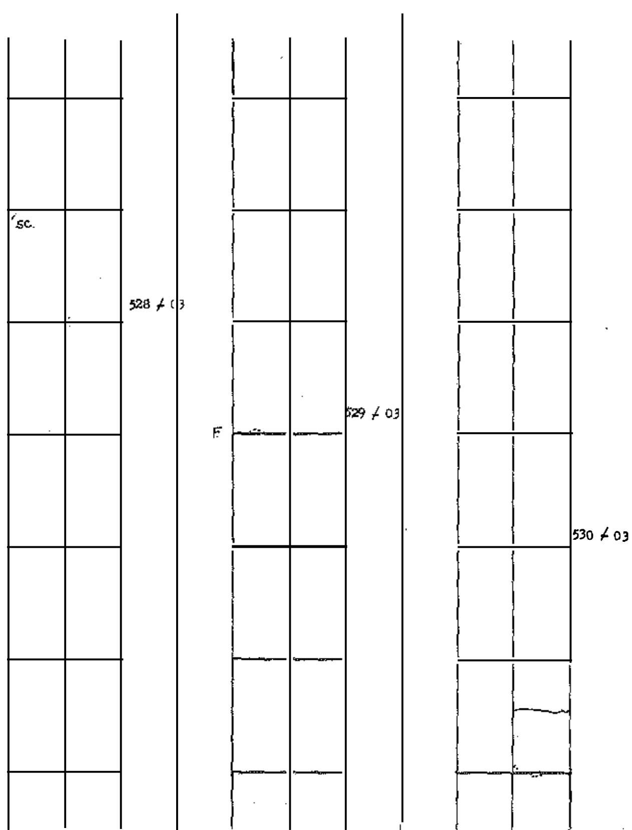
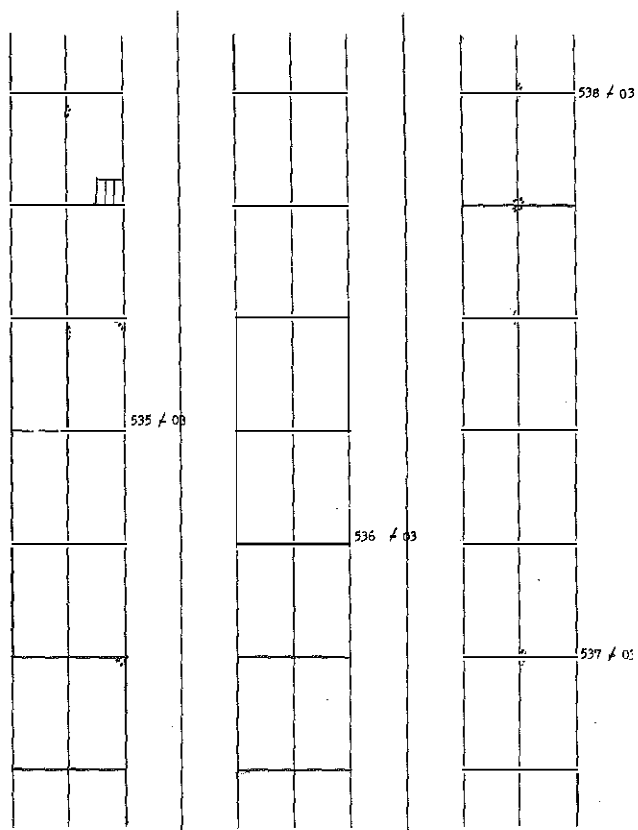


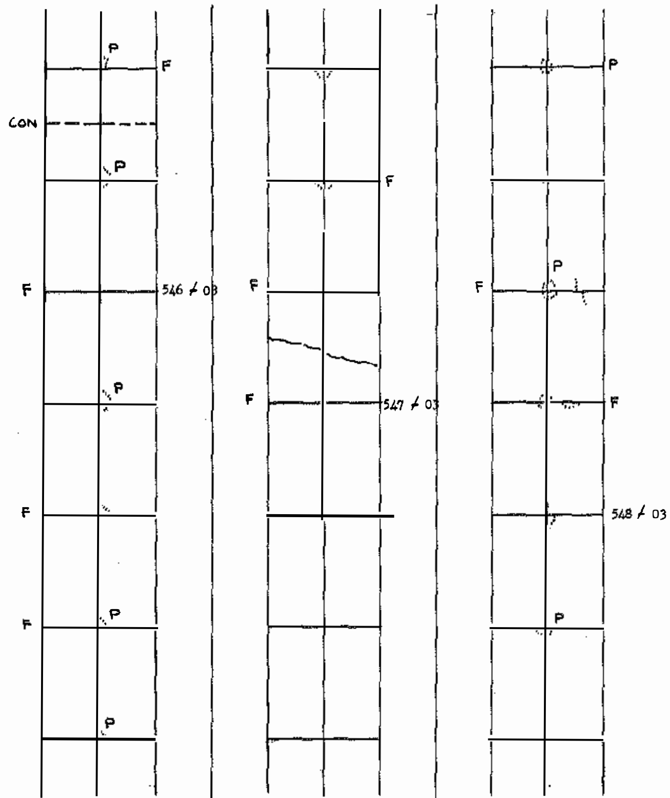
Section 1
Sta. 538 + 03 to 541 + 63



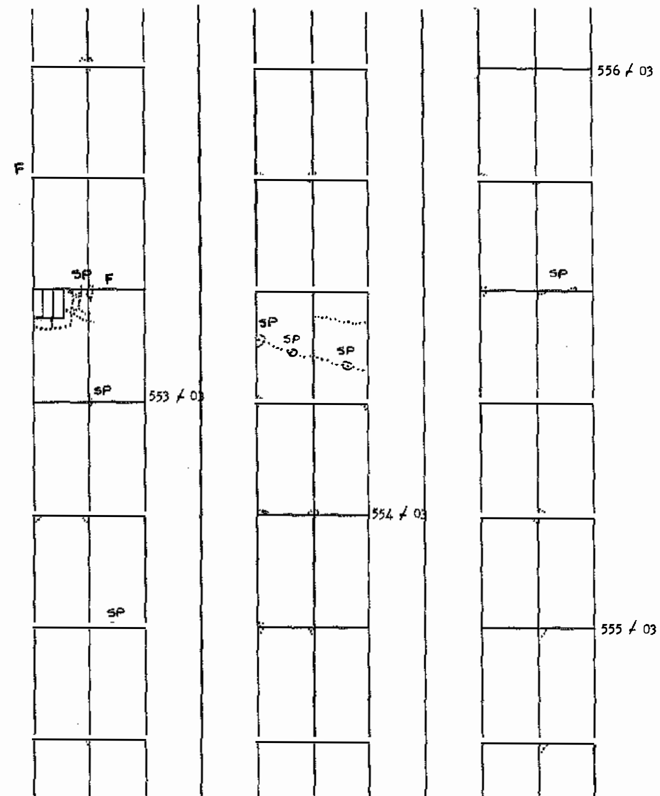
Section 1
Sta. 527 + 23 to 530 + 83



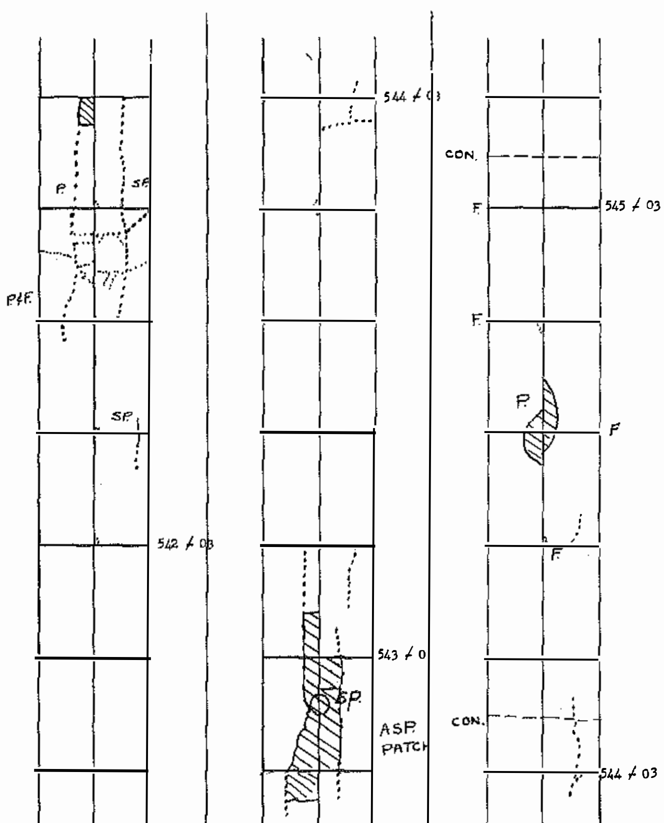
Section 1
Sta. 534 + 43 to 538 + 03



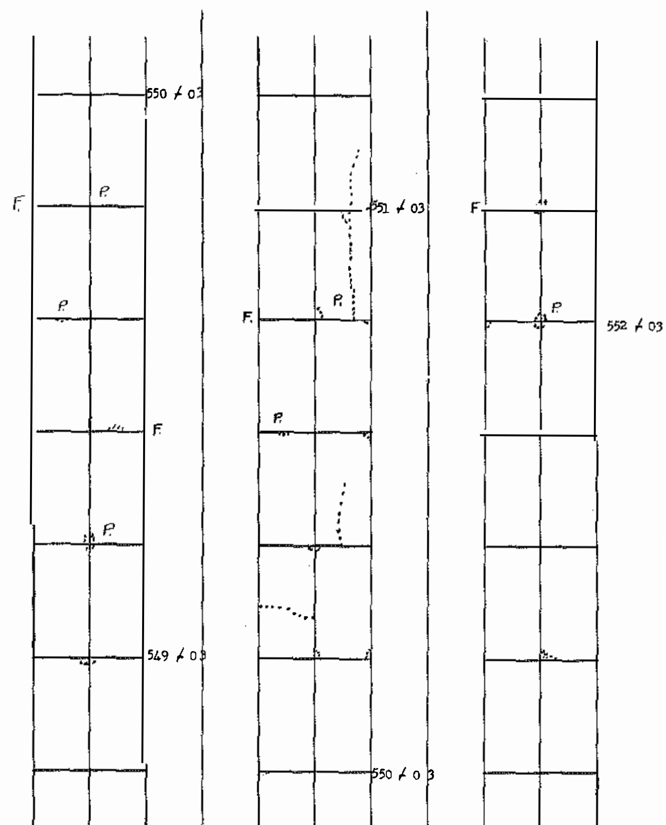
Section 1
Sta. 545 ≠ 23 to 548 ≠ 83



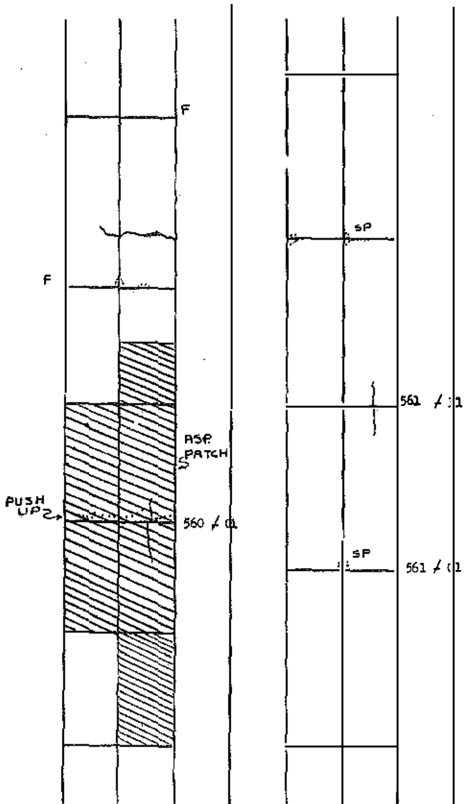
Section 1
Sta. 552 ≠ 43 to 556 ≠ 03



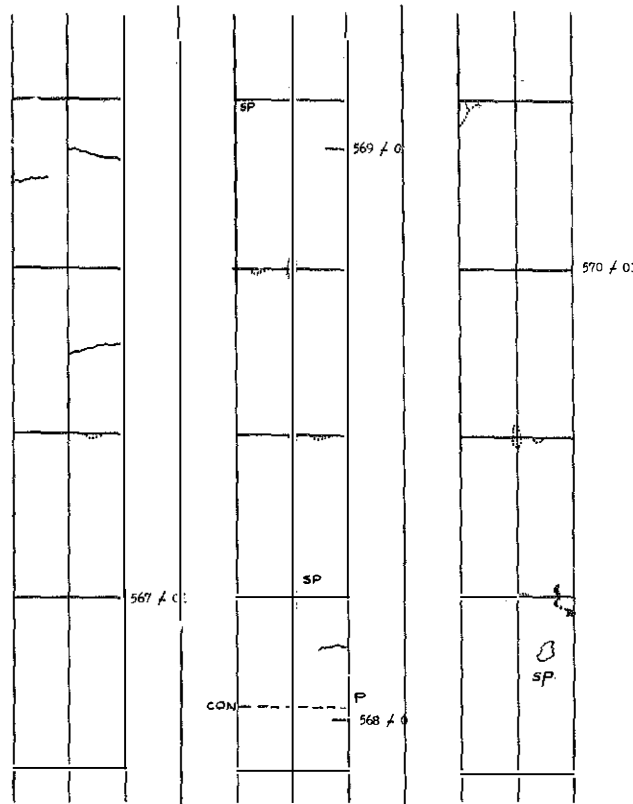
Section 1
Sta. 541 ≠ 63 to 545 ≠ 23



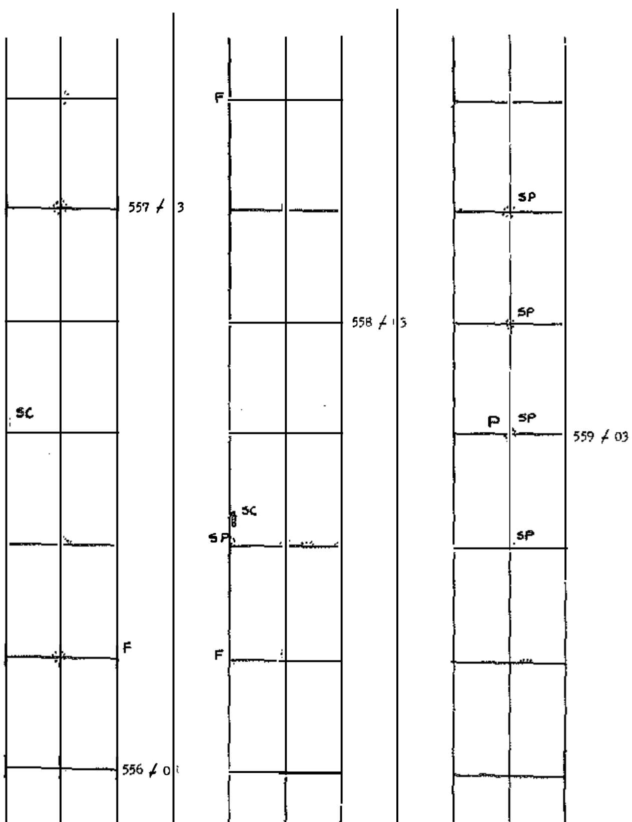
Section 1
Sta. 548 ≠ 83 to 552 ≠ 43



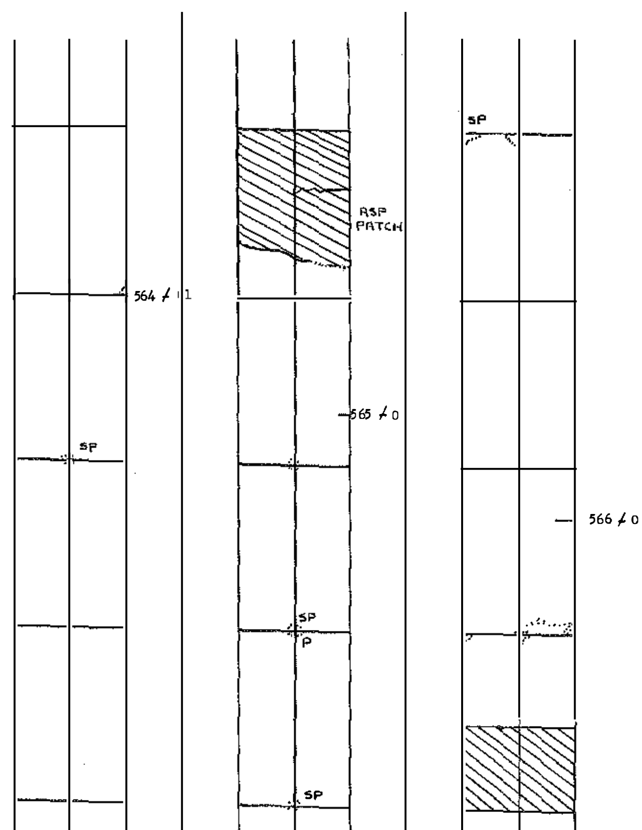
Section 1 + STD.
Sta. 559 + 63 to 563 + 71



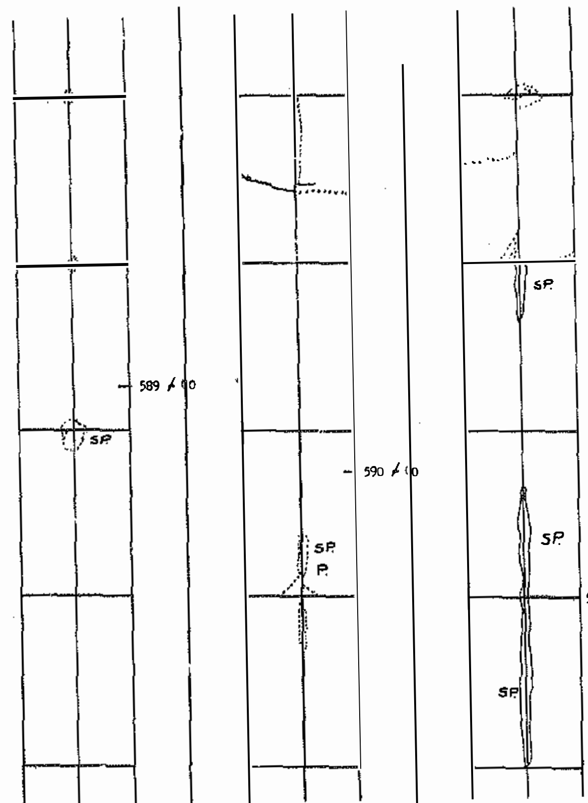
Section STD.
Sta. 566 + 71 to 570 + 31



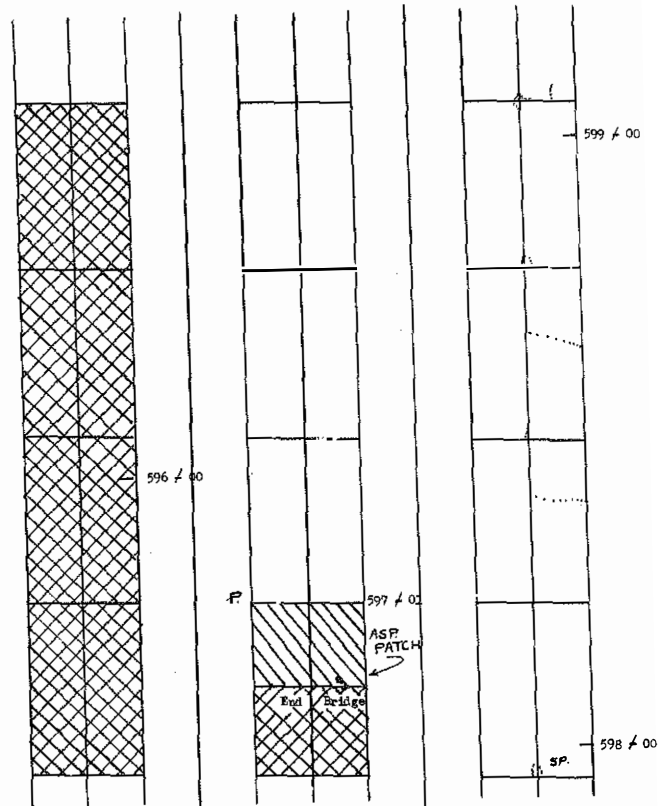
Section 1
Sta. 556 + 03 to 559 + 63



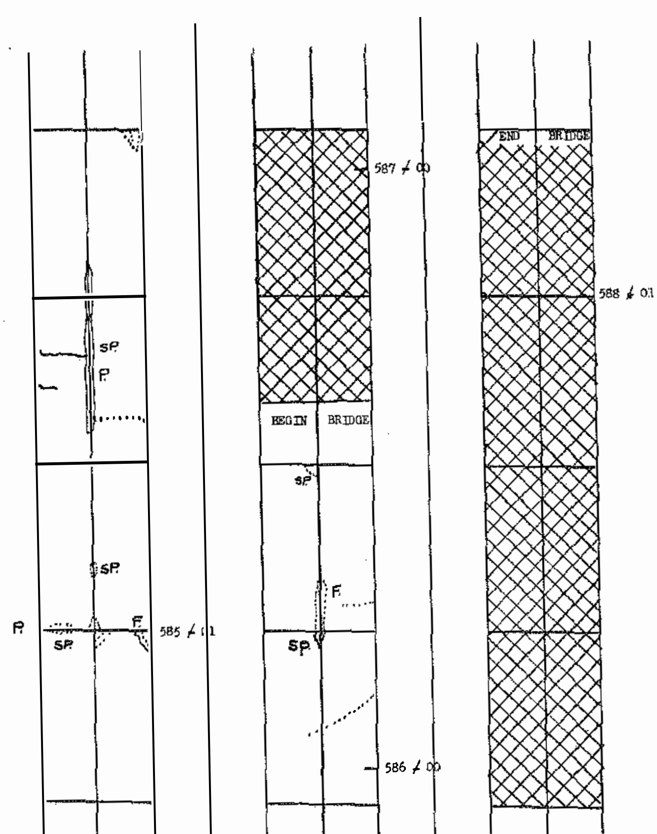
Section STD.
Sta. 563 + 11 to 566 + 71



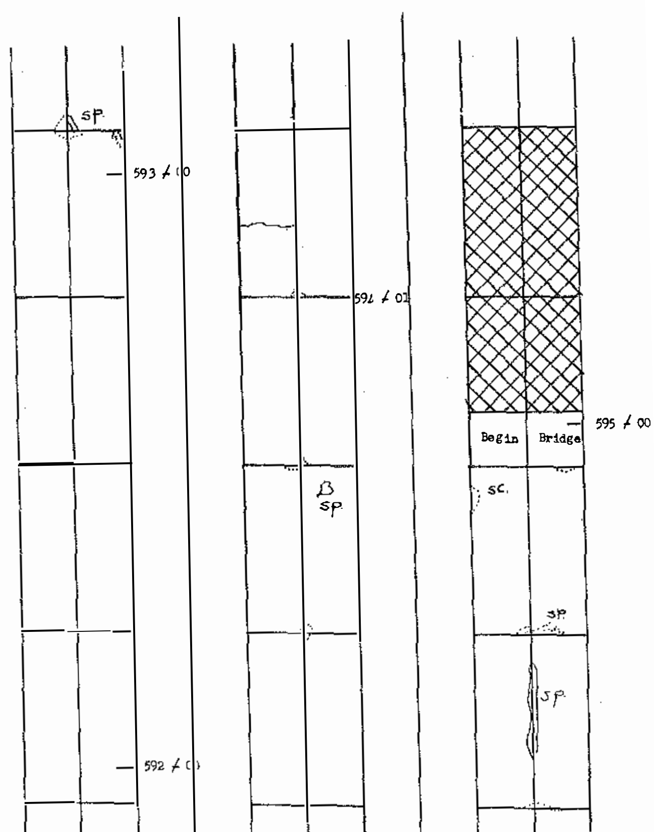
Section STD.
Sta. 588 + 31 to 591 + 91



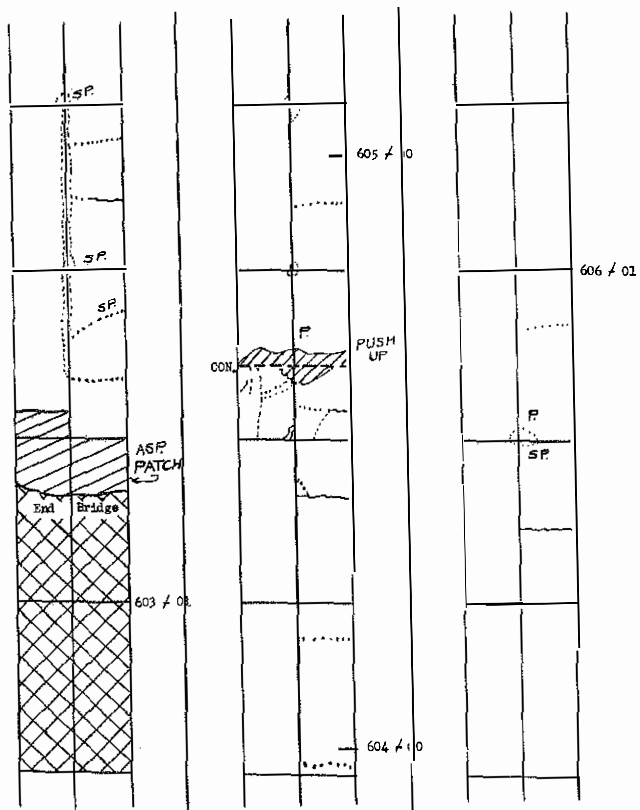
Section STD.
Sta. 595 + 51 to 599 + 11



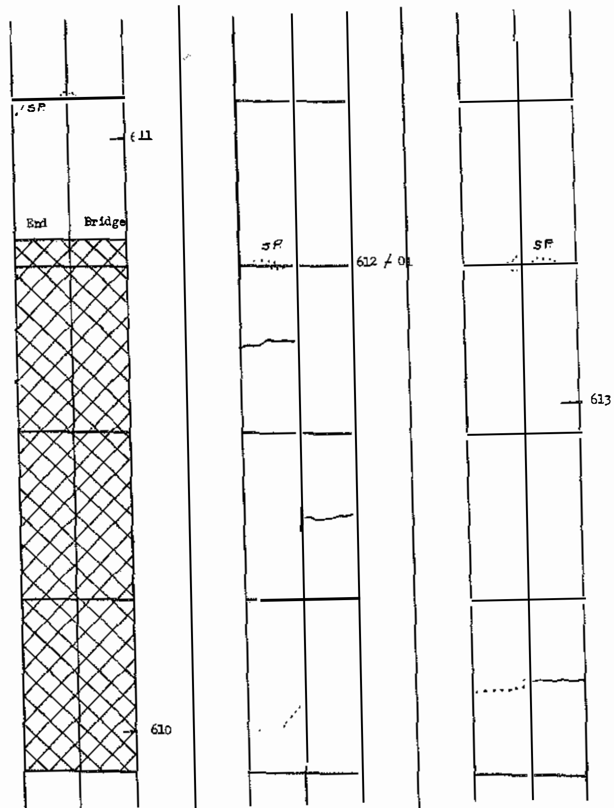
Section STD.
Sta. 583 + 71 to 588 + 31



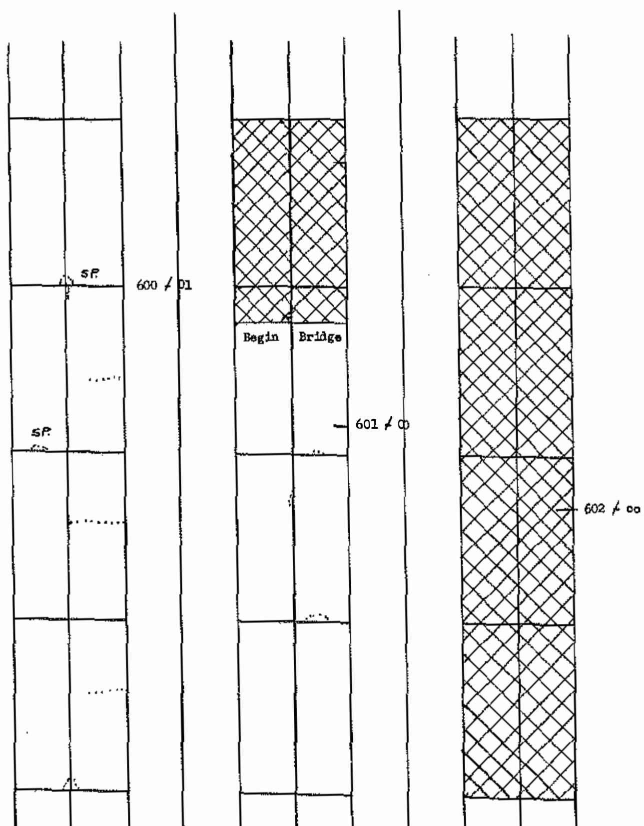
Section STD.
Sta. 591 + 91 to 595 + 51



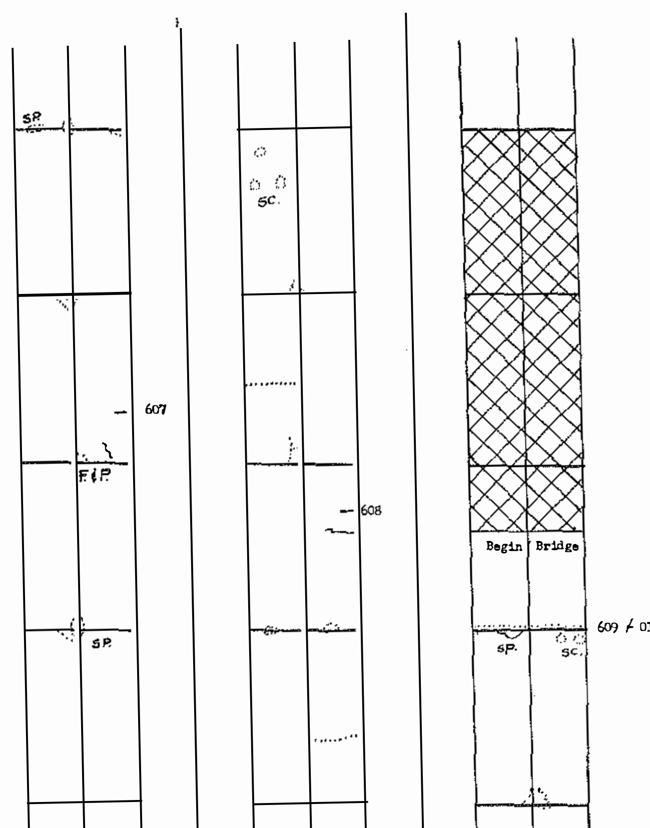
Section STD.
Sta. 602 + 71 to 606 + 31



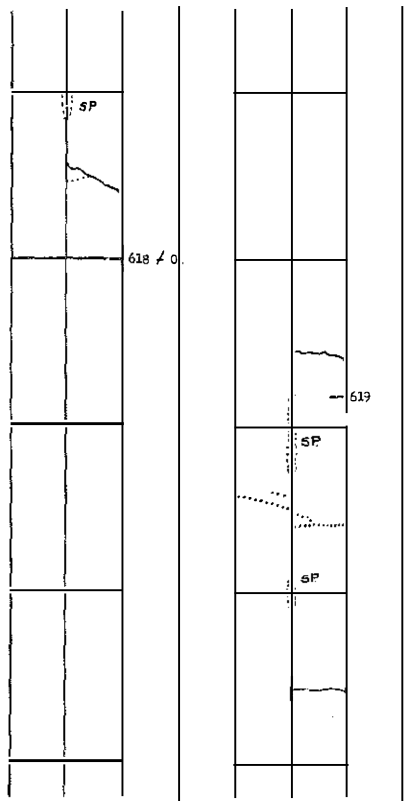
Section STD
Sta. 609 + 91 to 613 + 51



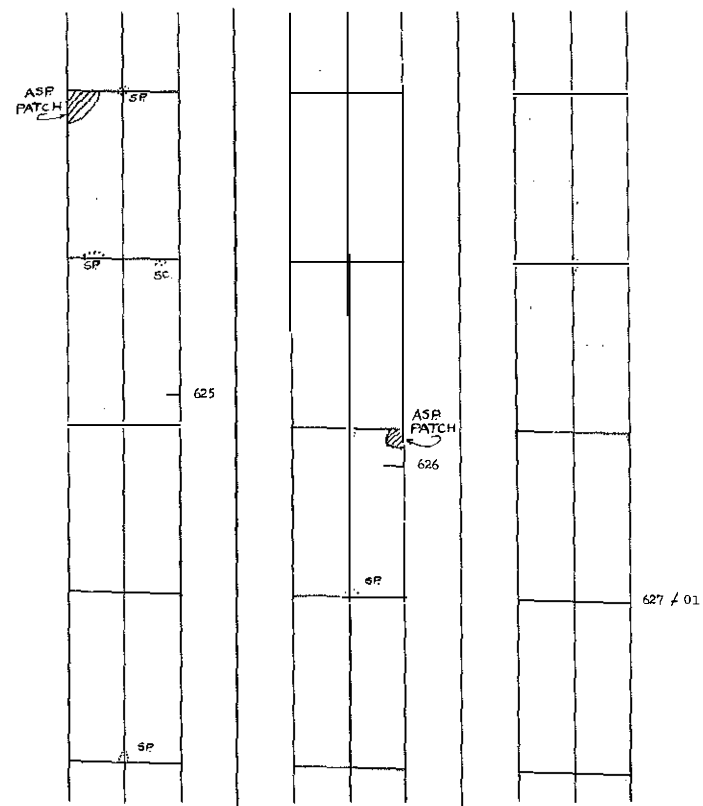
Section STD
Sta. 599 + 11 to 602 + 71



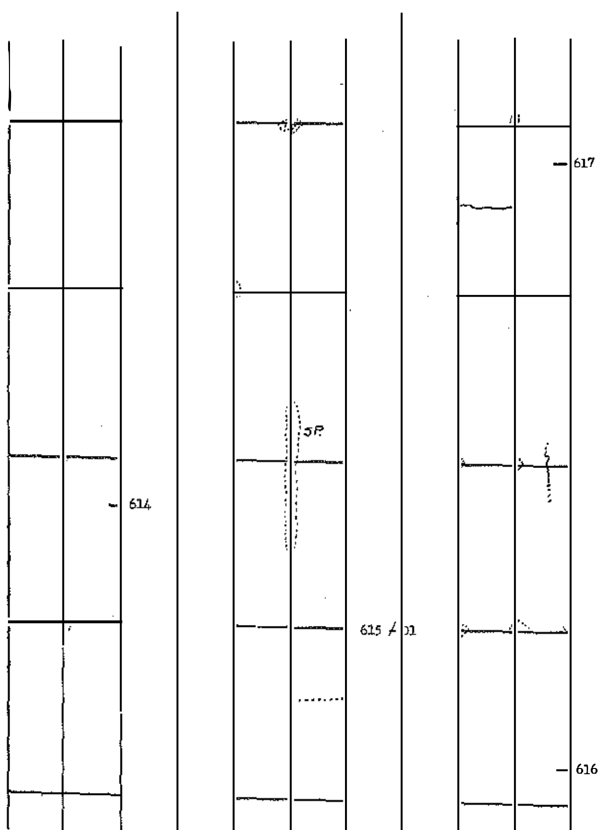
Section STD.
Sta. 606 + 31 to 609 + 91



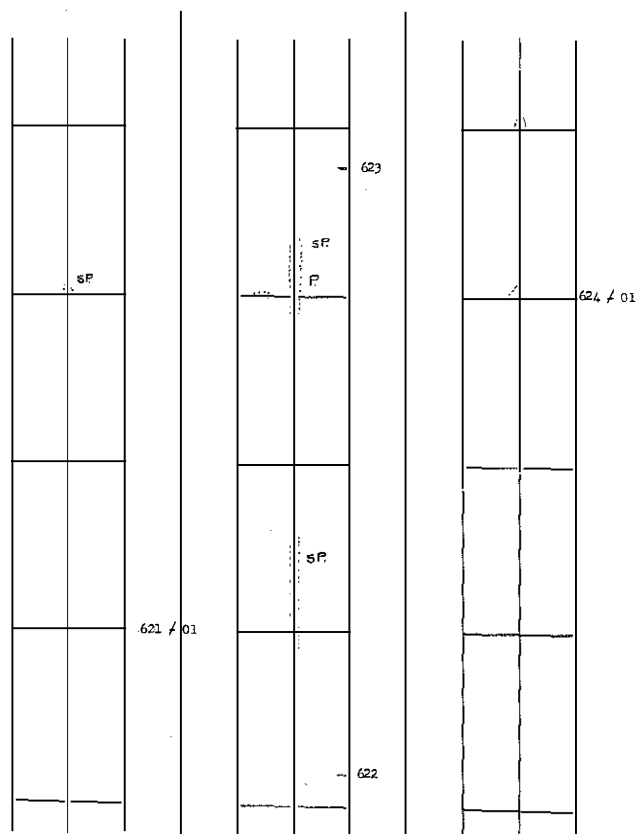
Section STD.
Sta. 617 + 11 to 620 + 71



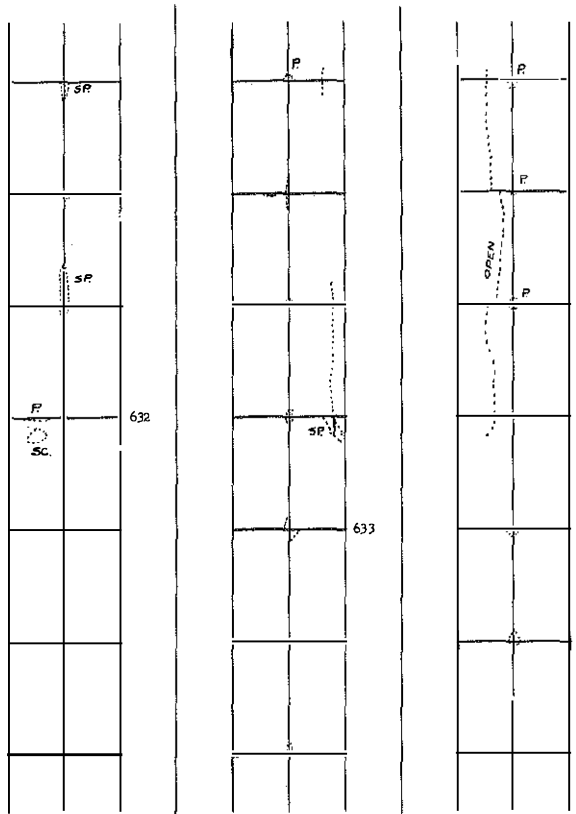
Section STD.
Sta. 624 + 31 to 627 + 91



Section STD.
Sta. 613 + 51 to 617 + 11

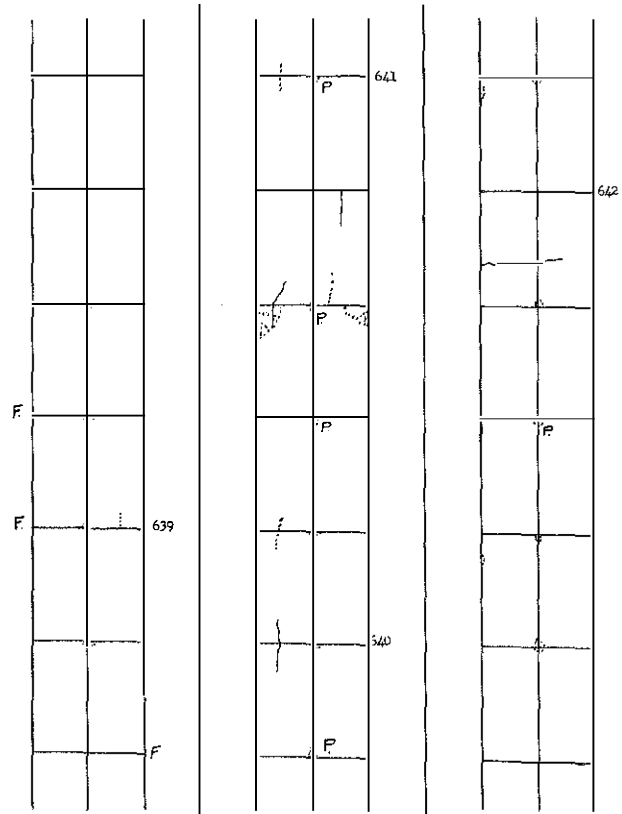


Section STD.
Sta. 620 + 71 to 624 + 31



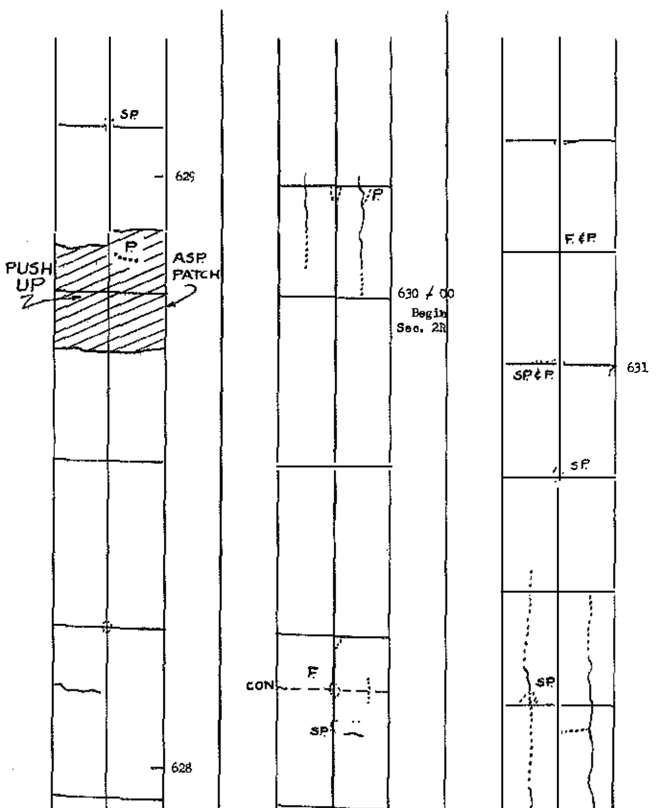
Section 2R

Sta. 631 + 20 to 635 + 00



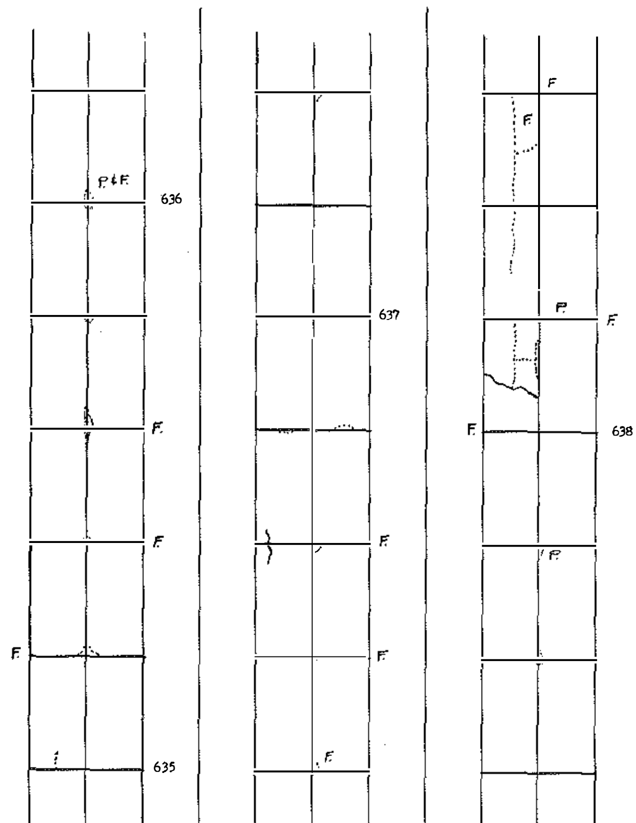
Section 2R

Sta. 638 + 60 to 642 + 20



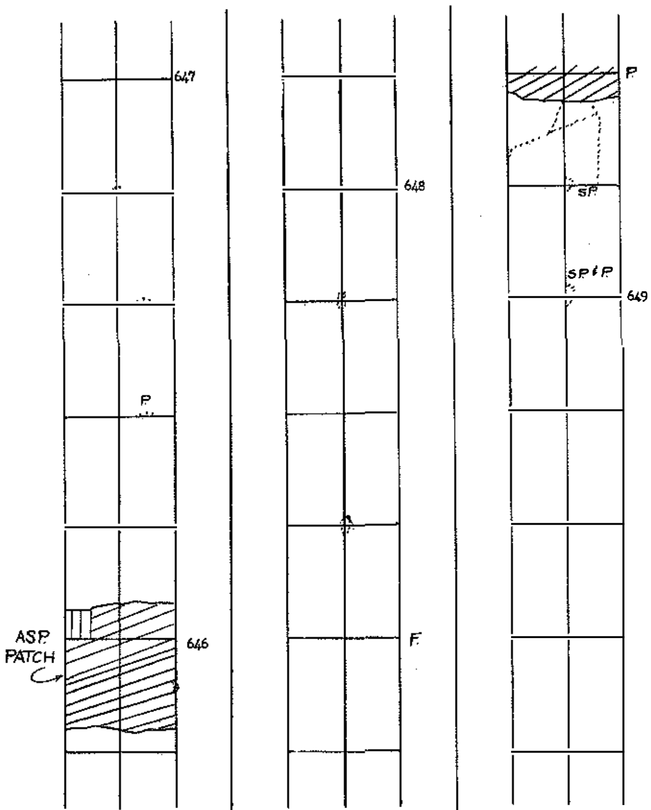
Section STD. + 2R

Sta. 627 + 91 to 631 + 20

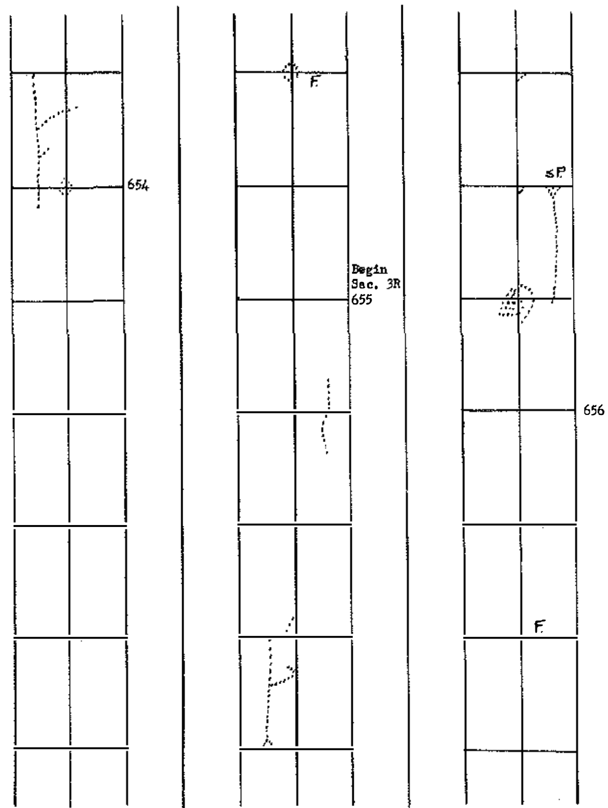


Section 2R

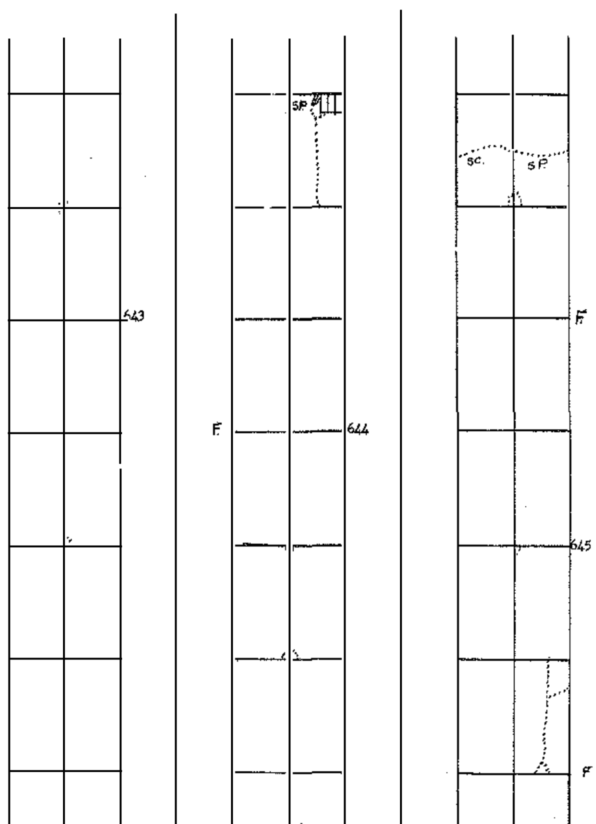
Sta. 635 +00 to 638 + 60



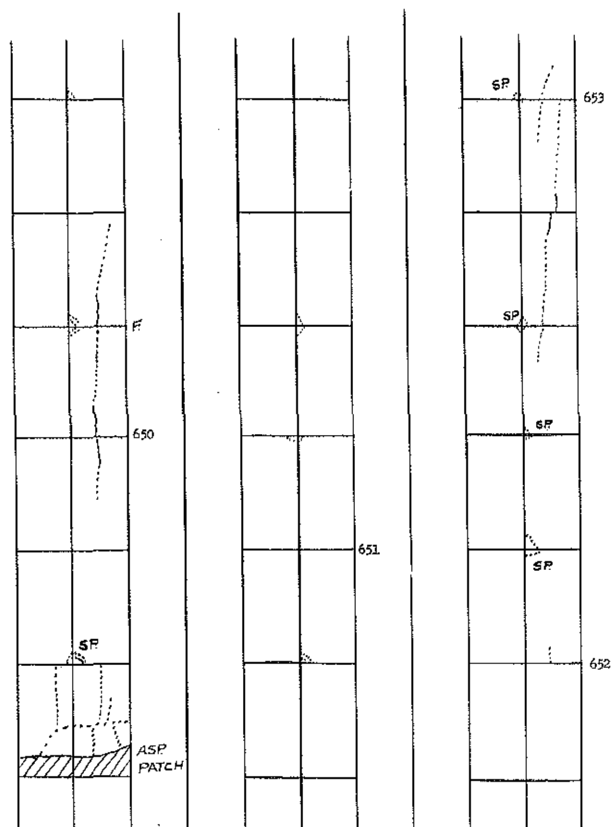
Section 2R
Sta. 645 + 80 to 649 + 40



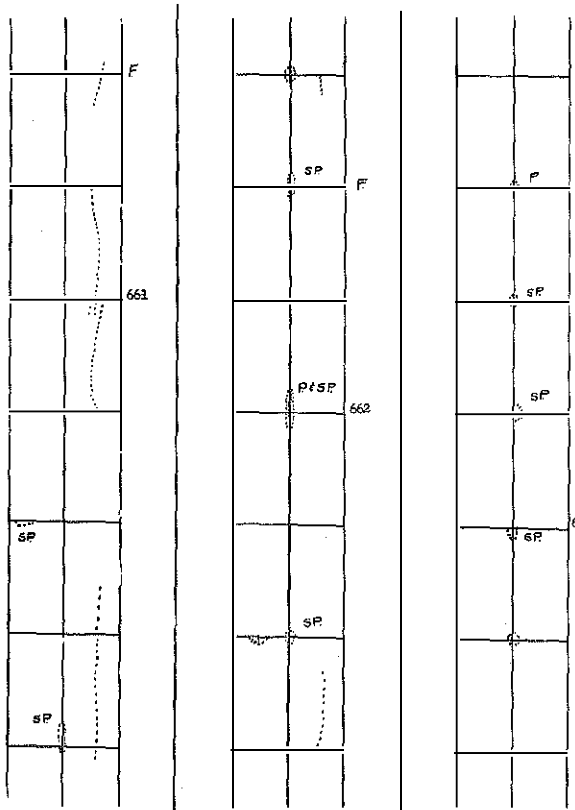
Section 2R + 3R
Sta. 653 + 00 to 656 + 60



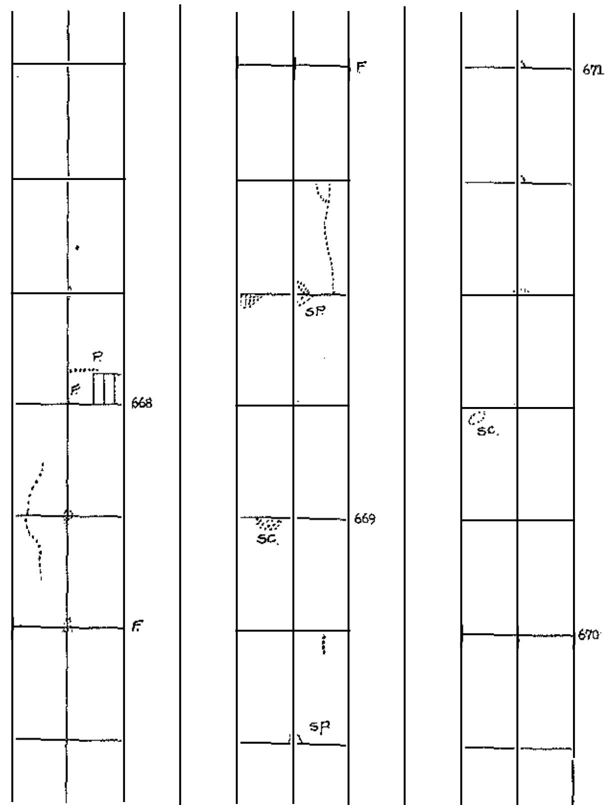
Section 2R
Sta. 642 + 20 to 645 + 80



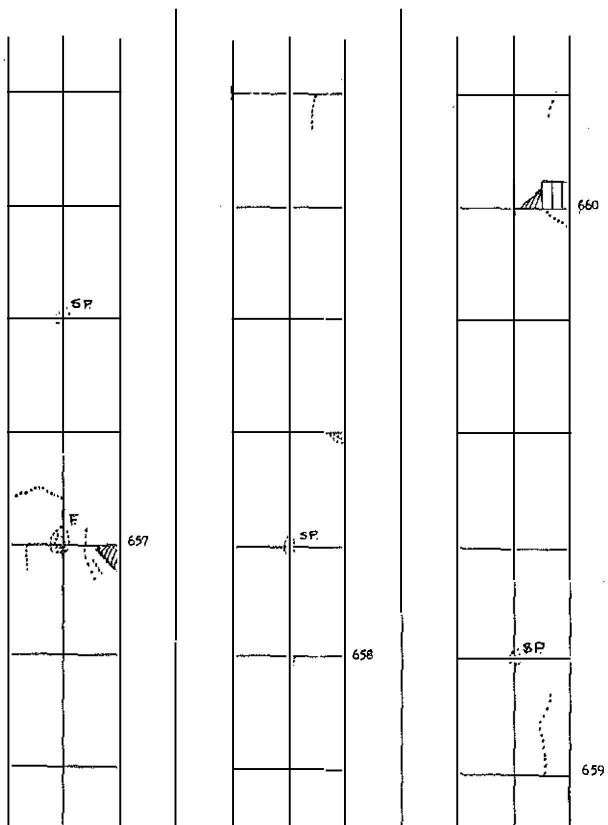
Section 2R
Sta. 649 + 40 to 653 + 00



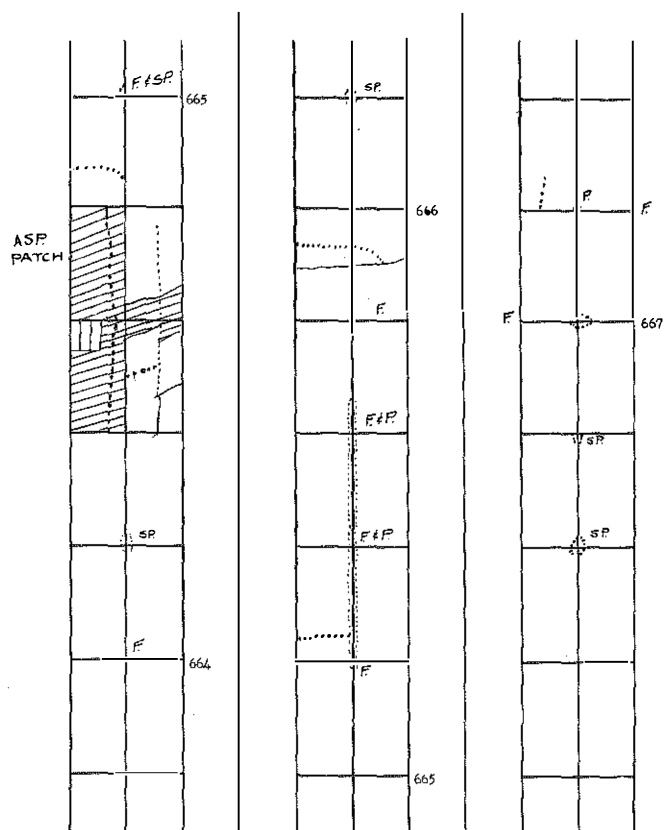
Section 3R
Sta. 660 + 20 to 663 + 80



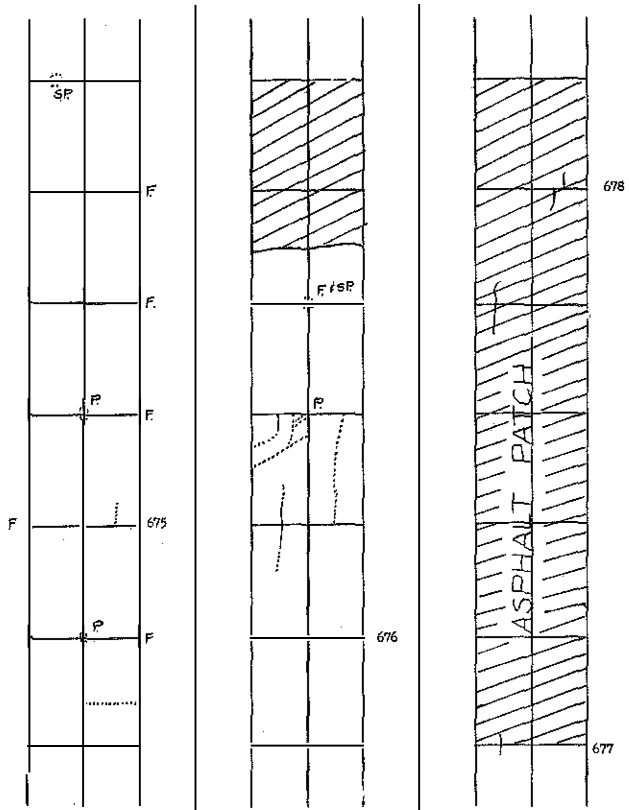
Section 3R
Sta. 667 + 40 to 671 + 00



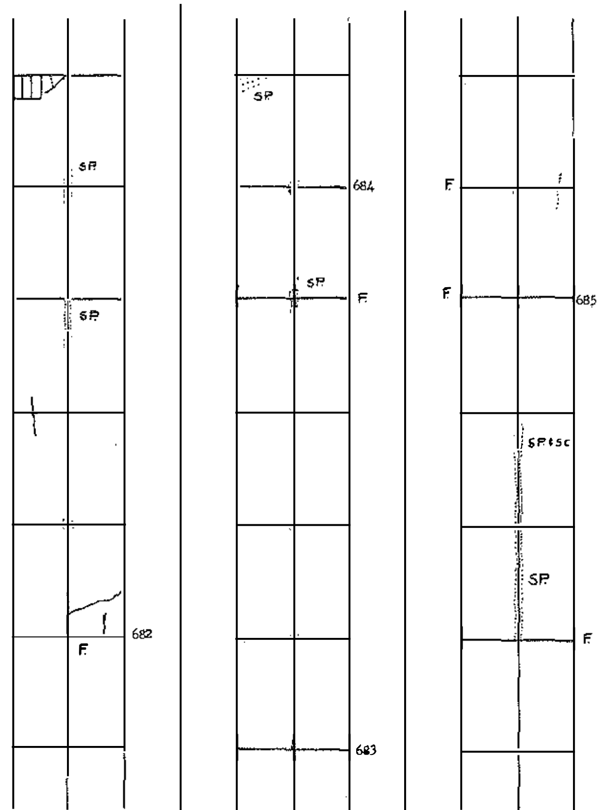
Section 3R
Sta. 656 + 60 to 660 + 20



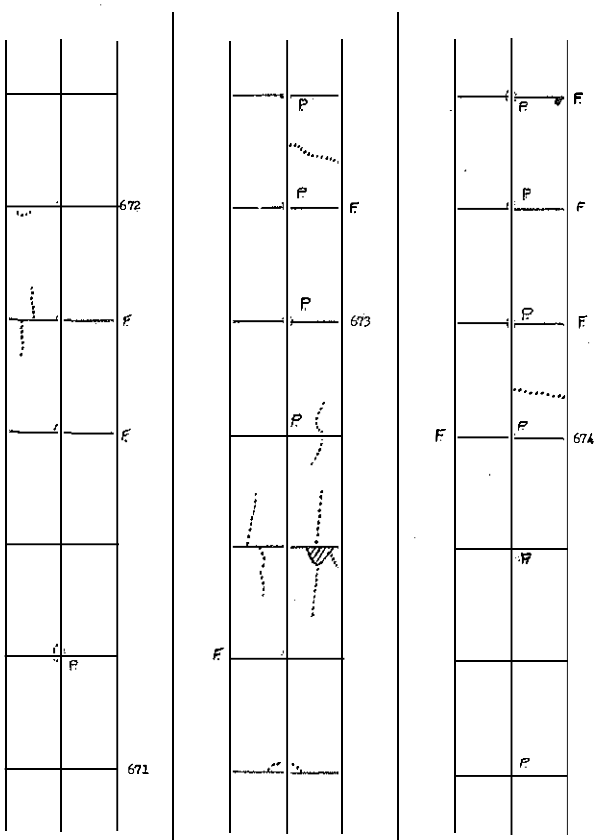
Section 3R
Sta. 663 + 80 to 667 + 40



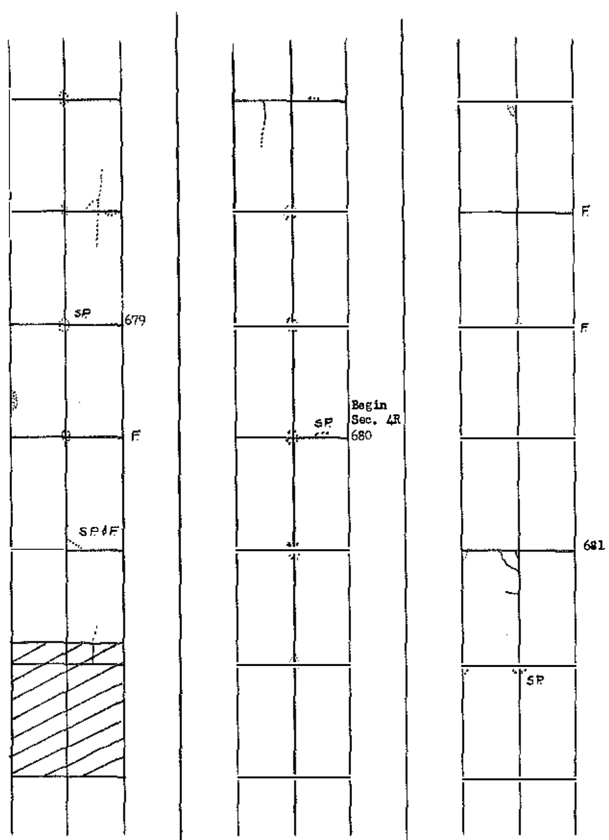
Section 3R
Sta. 674 ⁄ 60 to 678 ⁄ 20



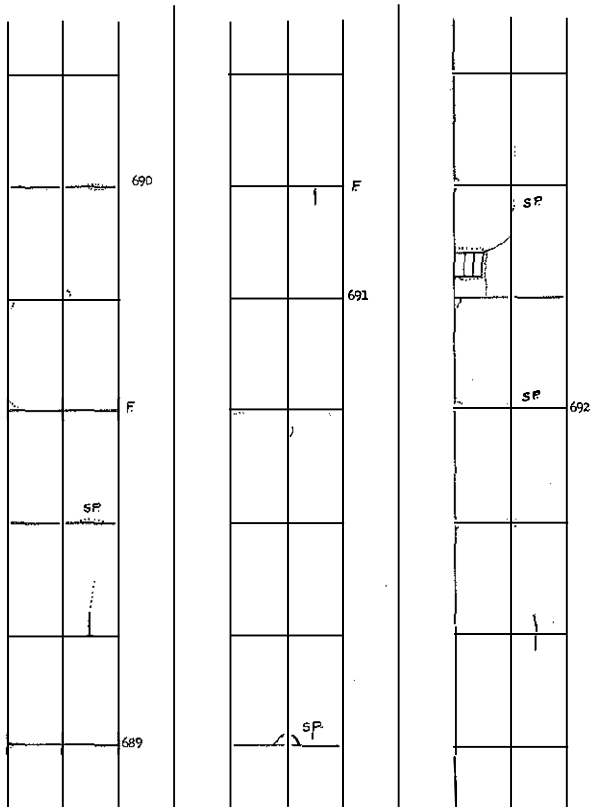
Section 4R
Sta. 681 ⁄ 80 to 685 ⁄ 40



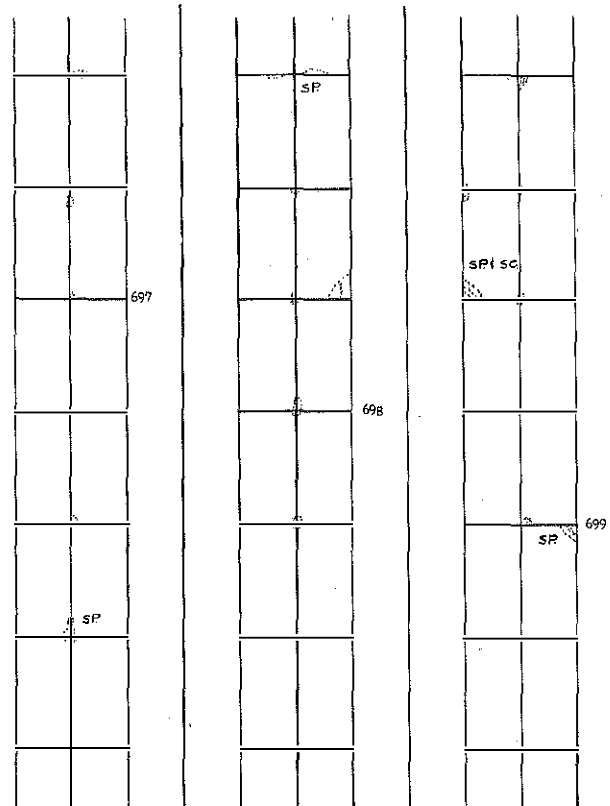
Section 3R
Sta. 671 ⁄ 00 to 674 ⁄ 60



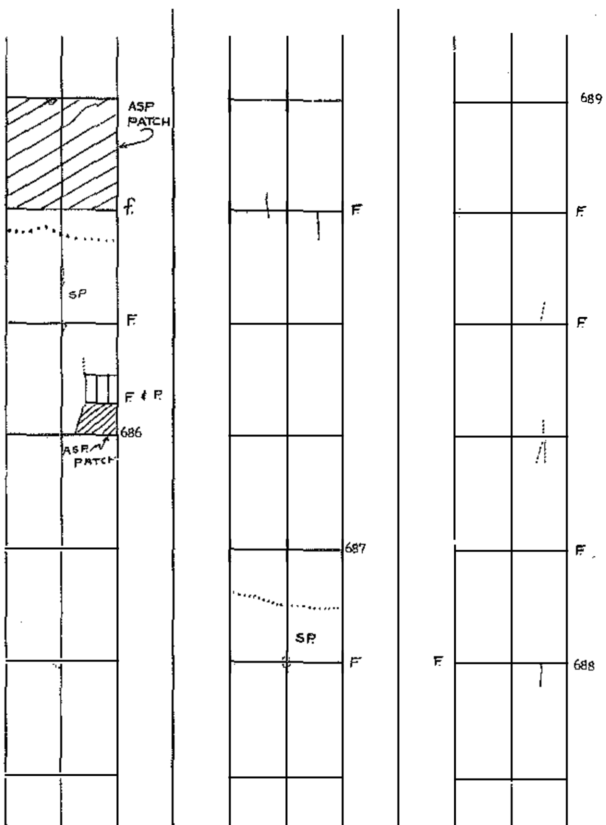
Section 3R ⁄ 4R
Sta. 678 ⁄ 20 to 681 ⁄ 80



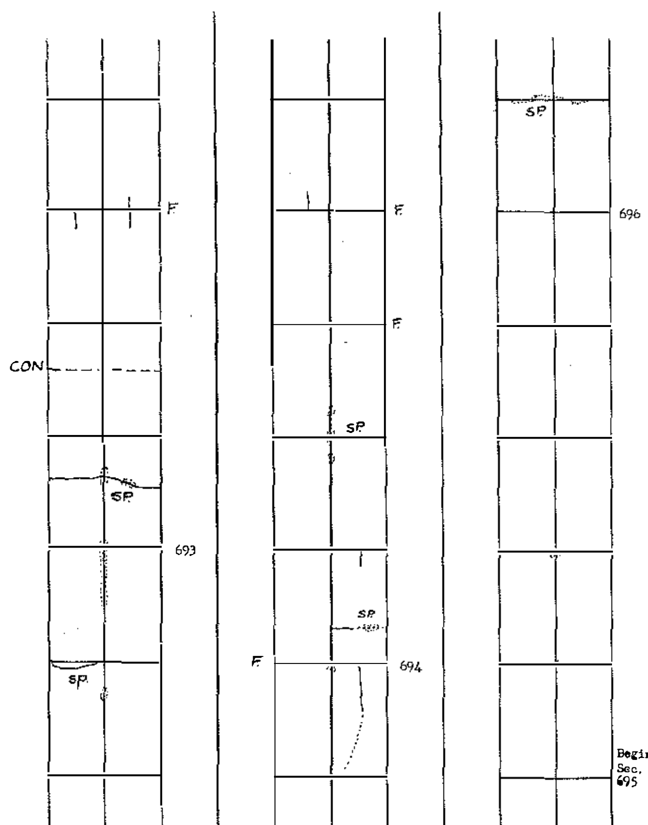
Section 4R
Sta. 689 ⁄ 00 to 692 ⁄ 60



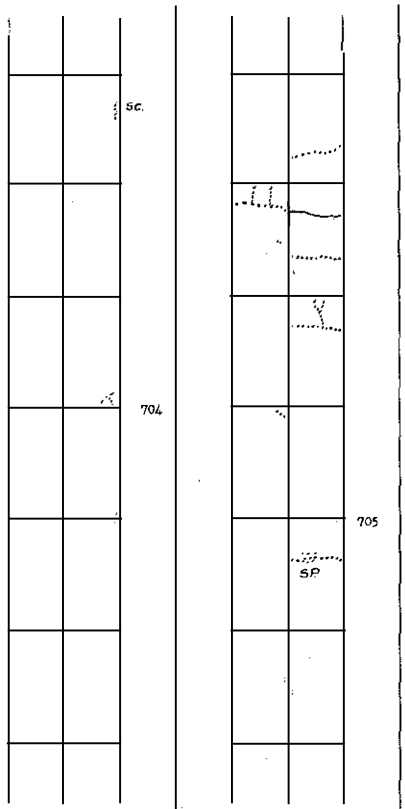
Section 5R
Sta. 696 ⁄ 20 to 699 ⁄ 80



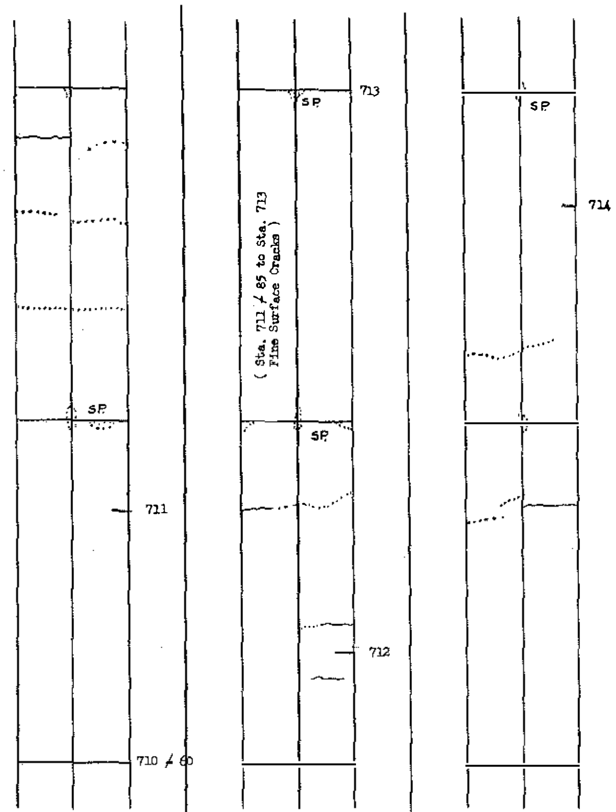
Section 4R
Sta. 685 ⁄ 40 to 689 ⁄ 00



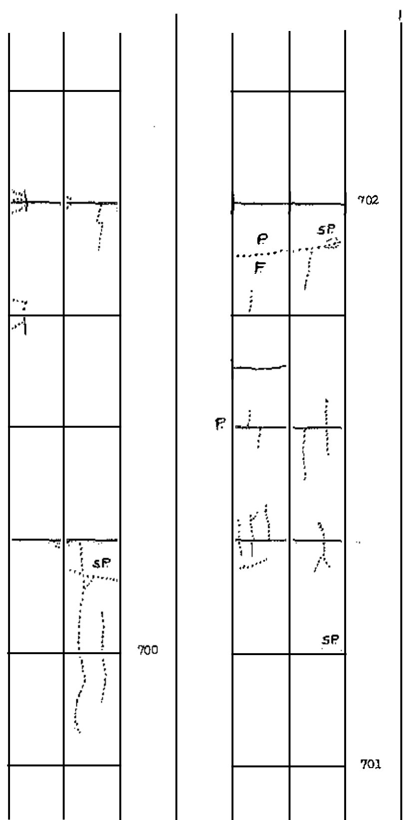
Section 4R ⁄ 5R
Sta. 692 ⁄ 60 to 696 ⁄ 20



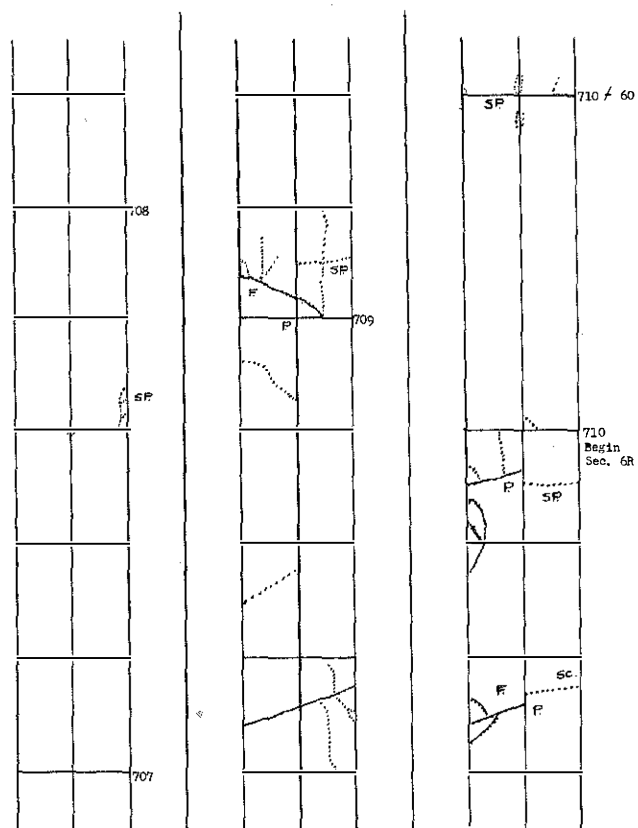
Section 5R
Sta. 703 + 40 to 707 + 00



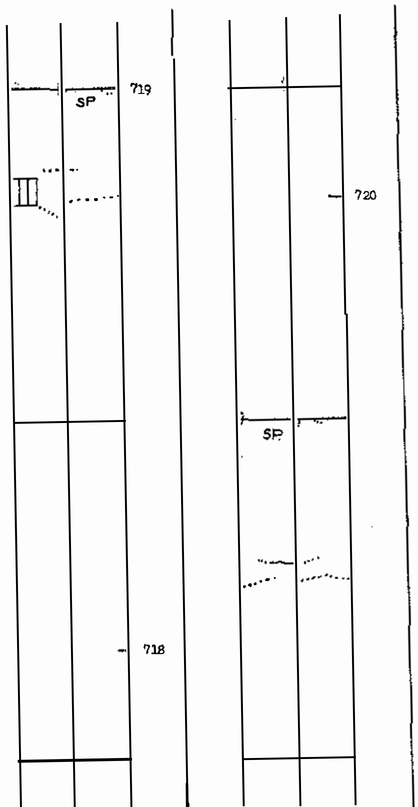
Section 6R
Sta. 710 + 60 to 714 + 20



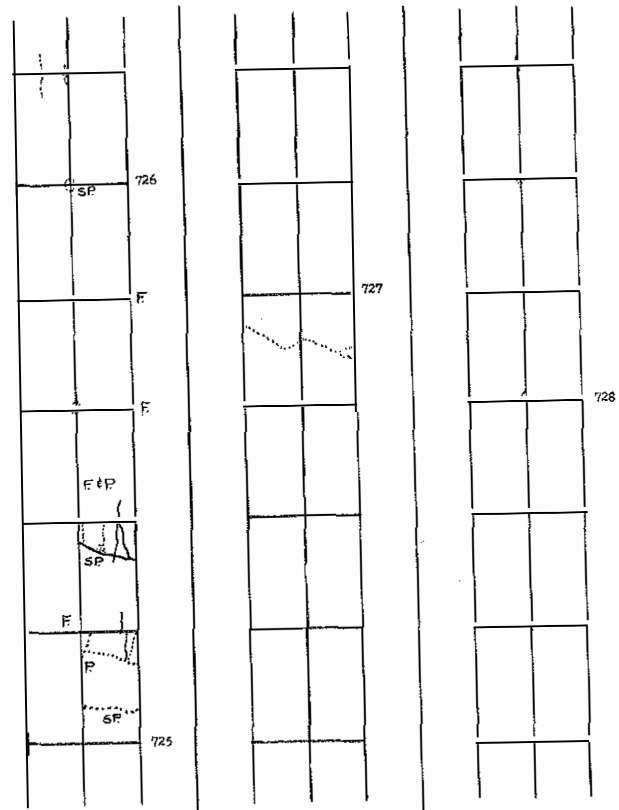
Section 5R
Sta. 699 + 80 to 703 + 40



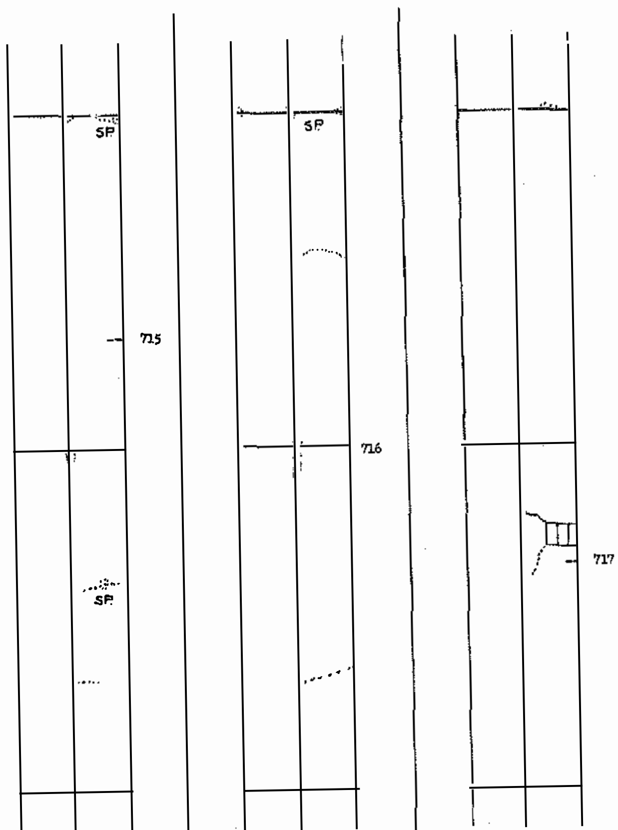
Section 5R & 6R
Sta. 707 + 00 to 710 + 60



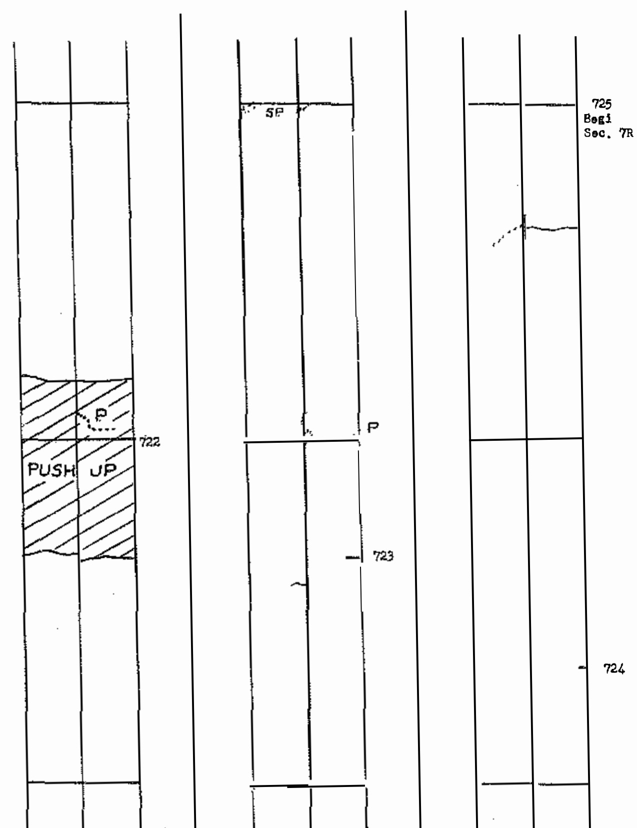
Section 6R
Sta. 717 ∔ 60 to 721 ∔ 40



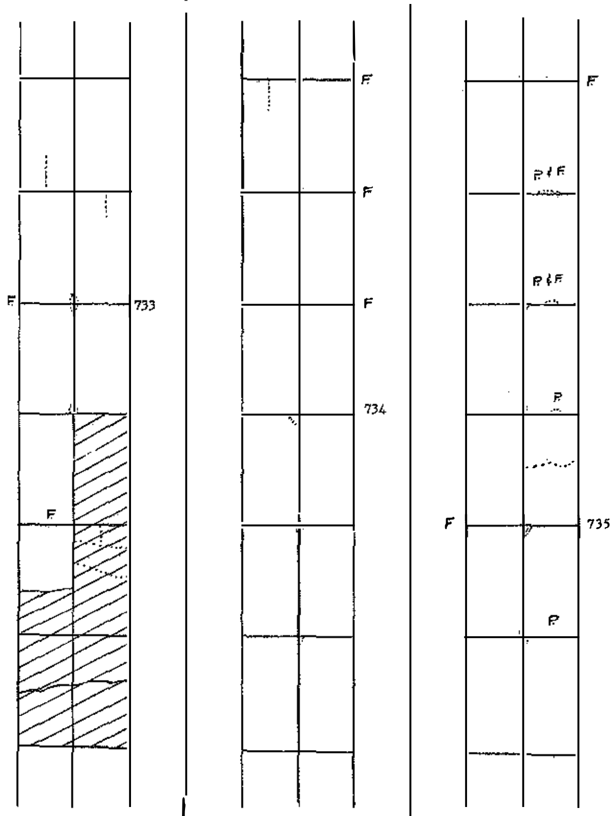
Section 7R
Sta. 725 ∔ 00 to 728 ∔ 60



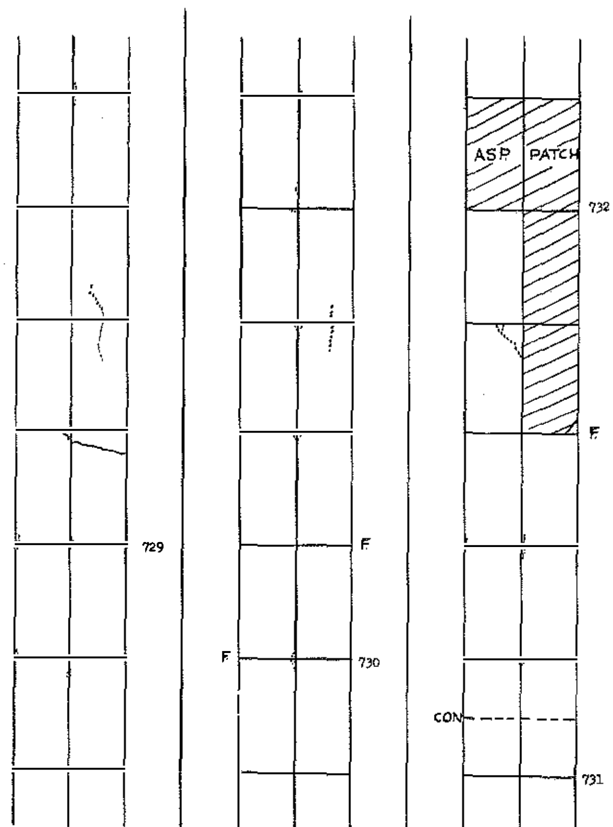
Section 6R
Sta. 714 ∔ 20 to 717 ∔ 80



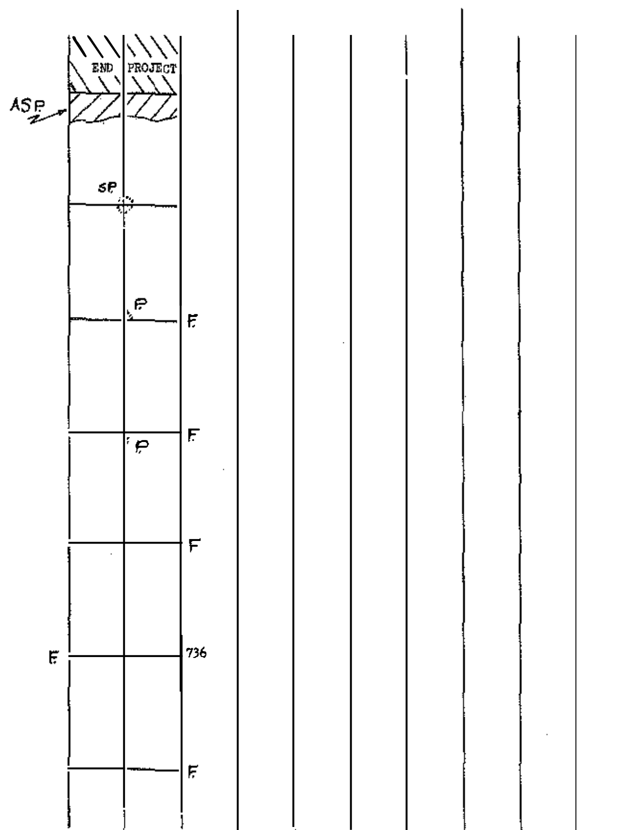
Section 6R ∔ 7R
Sta. 721 ∔ 40 to 725 ∔ 00



Section 7R
Sta. 732 + 20 to 735 + 80



Section 7R
Sta. 728 + 60 to 732 + 20



Section 7R
Sta. 735 + 80 to 737 + 00