Seasonal Roadway Deflection

Correlations with Climate

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16. Abstract

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Benkleman Beam deflection levels nearly always continued to rise until thaw depths reached three to four feet, with deflections declining toward summer levels as thawing increased beyond these depths. In both Fairbanks and Anchorage, the three foot thaw depth was reached after about 50 degree-days of thaw. Each roadway, however, will have it's own characteristic pattern of deflection level variations as thawing progresses. Some Fairbanks area roadways show very little thaw weakening, while others weaken drastically, and exhibit spring deflection levels in excess of 300% above the late summer and fall levels.

To determine the highest spring deflection level for a given roadway, a series of repeated deflection observations between two and six weeks after the start of thawing is recommended.

SEASONAL ROADWAY DEFLECTION CORRELATIONS WITH CLIMATE

Introduction

The Alaska Deportment of Highways customarily imposes restrictions on gross vehicle weights during the spring thawing season to prevent pavement damage during the period in which the roadway structure is at its lowest strength. Decisions as to when to begin and end these. weight restrictions have be23 made primarily on the basis of judgement) tempered by mechanical probing to determine the depth of thawing.

A study of seasonal variation in the deflections of roadways in the Fairbanks area was made in 1972 by the State Materials Laboraotory, using the Benkleman Beam test method to periodically measure the deflections of the pavement surfaces at selected locations. This study indicated that most newer roadways did not need seasonal load restrictions, while some thinly constructed road sections should not have been permitted to carry the maximum legal loads at any time during which they were not rigidly frozen. However, thaw depths were not measured during the course of the 1972 study, so information on a rational basis of predicting when to first impose spring load restrictions was lacking.

To study the progression of seasonal thawing through the various layers of the pavement system and the effects of this thawing on the roadway surface deflection levels, this study was instituted during the spring of 1975 and continued through the thawing season of 1976. Periodic deflection measurements were repeated at various locations in the Fairbanks area, while thaw depths beneath the roadway were determined fron thernocouple temperature measurements and frost tubes. Pavement temperatures were continuously recorded by thermographs, and comparisons have been made between deflection levels and that? depths at various locations. Some additional deflection studies and frost tube observations were made in the Anchorage area in 1976 and are also discussed in this report.

Description of Study Sections

Under the initial phase of this study) temperature instrumentation was installed in August of 1974 on Farmers Loop Road approximately 0.2 miles north of its intersection with College Road (Fig. 1). Three thermocouple strings were installed in borings made to depths of 10 *to* 25 feet, with thermocouples installed at 6 inch intervals in the upper 3 feet, and at greater intervals to the bottoms of the borings. A battery driven 31-day thermograph was also installed to measure air temperatures at a height of 1 :et and pavement temperatures at a depth of 3 inches, the bottom of the AC pavement and top of the base course layer, Locations of these thernocouples are shown by Figure 2.

The Farmers Loop study area was instrumented during its 1974 reconstruction from *o* two lane to a four lane roadway section. The adjacent terrain is a level muskeg area with grass, low brush and occasional stunted black spruce cover underlain by 4' to 6' of peat. The peat is perennially frozen below

a depth of one to two feet, and has a water table essentially at the ground surface. Beneath the peat is a deposit or ice-rich silt, extending down to underlying perennially frozen gravels at a depth of approximately twenty feet. The roadway embankment throughout the study area ranges from five to six feet in thickness, and was constructed Erom river deposited gravels having fines contents from 3% to 6% (passing #200 sieve) in the upper layers, and increasing to 10 to 15%at a depth of five feet. Moisture contents of the granular fill generally increased from 3 to 4% near the surface to 5 to 10% at the 5 foot depth.

After initial deflection measurements on tha Farmers Loop section indicated this roadway to have high strengths during the thawing season, a second roadway section was added to the study. This section consisted of Davis Road and University Avenue South of Airport Road (Fig. 1), and was selected for convenience of location and apparent low strengths as indicated by the presence of load related pavement "Alligator" cracking.

Temperature Instrumentation was not installed at the Davis-University Extension sire because of a lack of additional funds, but two shallow borings were made through the roadway in March of 1976, and 4' long frost tubes were installed to permit observations of thaw depths during the spring thawing period. The Frost tubes were constructed by filling ½" I.D. clear polyethylene plastic tubing with Ottawa sand and then saturating the sand with a fluorescein dye and water solution, which changes color from red to green upon thawing. The frost tubes were inserted into 7/8" I.D. plastic water pipe casings and reached through pipe bell and screw cap access ports in the pavement. The roadway throughout this study section vas of extremely marginal construction, and consisted of a thin Bituminous Surface Treatment (EST) placed on a 6" to 18" thick gravel layer overlying an embankment constructed of 4' to 6' of frost susceptible sandy organic silts and silty sands, which had been borrowed from the adjacent ditch areas. The embankment foundation soils generally consist of sandy gravels or fine sands, with the water table at 12' to 14' below the roadway surface. Permafrost appeared to be generally absent to depths of up to 20 feet.

Deflection Testing Program

Roadway deflection measurements were made with the "Benkleman Beam" testing apparatus, which measures the rebound of the pavementsurface between the rear dual wheels of a single axle truck with a rear axle loading of 18,000 lbs. This procedure was the same as that used and described previously in the "1972 Fairbanks Area Roadway Deflection Study". A copy of that report, including a detailed description of the testing procedures and equipment, is attached as Appendix A.

On each roadway study section, a series of 10 deflection testing points were established and permanently marked so that repeated readings could be taken at the same locations over the two year period of study.

On the Farmers Loop site, a 4-lane facility, five test points were located in the outer wheel paths of both inner and outer southbound driving lanes. This site had a total pavement width of 65 feet including the paved shoulders, and is representative of a high class high volume roadway, well protected from water infLltration.

The Davis,University-Extension site, by contrast, was a narrow 20' to 22' wide paved roadway without shoulders, subject to water ponding in the relatively shallow ditches during the snow melting period. On these sections, five deflection points were established in the outer wheel path of the westbound lane of Davis, and five in the outer path of the northbound lane of University Extension. Three additional test points were established on an access road to the lower library parking lot on the University of Alaska campus, a road having no heavy truck traffic and a relatively veak pavement structure.

Deflection testing was performed two to three times a week during the initial thawing season in 1975 and at progressively longer intervals after peak deflection levels had been reached. In 1976, the testing was continued only through the season of peak deflections, since summer levels had been previously established. The Farmers Loop section had such low deflections that minimal testing was done there in 1976. Deflection test results for 211 sections are presented in Figures 3 to 8. Unfortunately, in 1975 deflections were not taken on Davis Road at the first appearance of roadway thawing, because of expectations that Farmers Loop would provide the necessary thew weakening observations.

In 1976, deflections were again not obtained at the very start of roadway thawing because of the State Employees Supervisors Unit Strike. These absences of early data both years had some minor adverse effects on the aims of this study. During the spring of 1976, defledtion measurements made on some Anchorage area roadways were included in this study and correlated with frost tube thaw depths at Tudor Road and Victor Road.

Air & Favement Temperatures

Air temperatures at the study sites are fairly well represented by temperatures from the Fairbanks Airport Weather Bureau, which is located at less than four miles from all sites, and at approximately the same elevation. Temperatures at the bottom of the pavement layers were obtained from a thermograph installed at the Farmers Loop test site. Data from similar pavement temperature recording installations at rhe Canyon Creek permafrost study site located about 50 miles Southeast of Fairbanks, and from the Bonanza Creek permafrost study site located approximately 25 miles West of Fairbanks, were also included in this analysis to broaden the data base. Average daily air temperatures for the start of the '75 and '76 thawing seasons at both the Fairbanks and Anchorage Weather Bureaus ai-e presented in Figures 9 and 10. Air and top of base course temperatures from the Farmers Loop installation for 1976 are presented in Figure 11. The air temperature probe of the 3-pen thermograph utilized at this site vas enclosed in a white louvered weather station type enclosure at a height of five feet above the ground. The third probe at this site was used to record the temperature at a depth of 2" beneath the gravel covered west facing roadway side slope, and shoved temperatures slightly below, but always within 4°F of those recorded beneath the asphaltic pavement surface, once the shoulder snow cover had melted.

The unfortunate absence of data for April of 1976 for the Farmers Loop recorder was the result of interference between the 3 recorder pens, which cast doubt on the accuracy of any of the values for this month. Data from very similar pavement temperature recorders at the Bonanza Creek and Canyon Creek sites are presented in Figures 12 to 14. Again, these data show some difficulties with temperature recording during the seasonal thawing of the snow cover, caused by water entering the buried thermograph cases, and high humidity effects on the

paper charts used. All air temperatures on Figures 11 to 14 were measured adjacent to the pavement temperature locations.

Solar Heating Effects

In the Fairbanks area, pavement temperatures in March range above or bel.~~.: the air temperature, depending on the random variations in air temperatures, since the pavement will have *a* slower and weaker response to weather related temperature fluctuations than the air. In April the increasing elevation angle of the sun results in increased solar heating of the pavement. This causes the daily average pavement temperature to rise above the average air temperature, with the temperature differences between pavement and air increasing to maximums of approximately 25°F by inid-June, the time of maximum sun angle. This effect is even more pronounced in Kotzebue, as shown by data from the Kotzebue Airport runway, Figure 15.

To clarify the temperature relationships between the air and roadway surfaces, the daily differences between pavement and air temperatures are presented in Figures 16 and 17. The peak differences noted on April 14 and 15, 1976, (Fig. 16) were the result of a very sudden cold front causing a drop in air temperatures, and not excessive surface yarning. With this exception, these plots show the pavement to be very close to the average daily air temperature in early April, and to rise above the air temperature progressively after that tine,. Figure 18 was prepared to show the daily average pavement temperature difference for the Farmers Loop, Canyon Creek, and Bonanza Creek sites.

The effect of solar heating of a pavement above the ambient air temperature is primarily affected by the sky cover and the average wind velocity. Higher percentages of cloud cover or higher surface wind velocities both act to reduce the pavement temperature during the daytime hours, while a heavy cloud cover at night will retard pavement cooling through prevention of long wave radiation into space. An additional factor affecting roadway surfaces is the air movement created by passing vehicles. With high volume high speed traffic the air near the pavement surface will be in almost continual motion, even on a calm day. Ideal conditions for maximizing the pavement temperatures would be those of clear daytime skies, night time cloud cover, calx wind conditions, no traffic, and a pavement surface totally asphalt covered.

Average daily cloud covers for the Fairbanks Area for 1976 were obtained from the U. S. Weather Bureau records, and are presented in Figure 19. Comparisons between Figures 18 and 19 indicate fair agreement between the daily pavement to air temperature differences, and the daily sky cover, but many days of non-agreement are also obvious. This could be due to wind velocity variations or to the fact that the surface can be exposed to iirect sunlight for a sufficient period of time to create a high maximum pavement temperature even on a "mostly cloudy" day. Radiation recorders could be installed to obtain better information on solar heating effects on pavements and would probably permit better estimations of pavement temperatures from air temperature data. Wind velocity information at the project sites was not obtained in this study, and wind data at the more exposed Fairbanks Airport Weather Station location are probably not truly representative of the study sites. At the Airport site, the average monthly wind velocities during the two years of this study were 5.2, 6.5, 7.5 and 7.8 mph for the months of March through June, indicating relatively calm conditions.

To quantify the differences betweeen pavement and air temperatures which were observed in the Fairbanks area during the period of this study, Table I has been prepared by averaging the differences at the Farmers Loop, Canyon Creek and Bonanza Creek sites during 1976. These differences were averaged over ten day periods to eliminate some effects of the scatter of the data from day to clay.

TABLE I

Time	April			May			June		
Interval	1-10	11.-20	21-30	1-10	11-20	21-30	1-10	11-20	21-30
(T pvmt-T Air)°F	-1	+5.3	+8.6	+7.7	+10.9	+12.5	+13.7	+17.4	+12.6
Average Cloud Cover - 1976	.59	.55	.66	.71	.60	.81	.69	.47	.84

Thaw Depths Versus Time

Thaw depths were determined primarily by temperature readings on thermocouples placed beneath the roadway at three locations on the Farmers Loop study site, Additional 1976 thaw depth data were obtained through frost tube installations on Farmers Loop and Davis Roads. Thaw data are presented for these sections by Figures 20 and 21. Anchorage area thaw depths for 1976 at Tudor and Victor Roads are presented in Figure 22. Occasional checks on thaw depths were made by hand tool excavations at the edges of the roadway pavement, and agreed very well with adjacent frost tube measurements,

Thawing of the pavement system proceeded rapidly in the Fairbanks area during the two years of this study. The differences in frost penetration rates at the different locations are apparently the result of the differences in moisture contents at the sites, the soils at Davis Road being much more silty and Frost Susceptible than at Farmers Loop. Air temperature thawing indices, calculated from Fairbanks and Anchorage Weather Bureau temperature data, are presented in Figures 20 through 22 for comparison with thaw depths. Thawing degree-days, calculated by summing the day to day differences between the average daily air temperatures and 32°F, are a commonly used measure of thawing potential. Comparisons from these figures indicate that when the average daily air temperatures begin to rise above 32°F, thawing beneath roadway surfaces may already have reached to depths of roughly one foot, and that maximum thaw depths of approximately three feet were attained after only fifty degree-days of thawing. Thawing generally progressed at a rate of ½' to 1' per week after the start of thawing, depending on soil types and water contents.

Deflection - Thaw Depth Relationships

One major question investigated in this study was the depth of thaw at the time of maximum deflections and at the time when deflections decreased to near summer levels. At the Davis Road site, average 1976 deflection levels were at half of the maximum level at a thaw depth of 1.4 feet and peaked at a thaw depth of 3.S. feet. Deflections declined to near summer levels at a thaw depth of approximately 4 feet. As previously mentioned, this site typifies a very weak subgrade condition.

Deflections at the Farmers Loop site reached half of the spring maximum at a thaw depth of 1.0 feet, peaked at a thaw depth of 4.5 feet, ancl declined slowly thereafter. Deflections at this site never approached critical levels. Seasonal thaw weakening was minimal and no Spring Load Restrictions would have been required on this roadway *segment.*

In the Anchorage Area 1976 extension of this study, deflection measurements were made on nearly all Anchorage area State maintained roadways three to four times during the thawing season. Nearly all sections reached peak deflections between April 15 and 30, during which time the recorded thaw depths increased from 2.1 to *4.0* feet (Fig. 22). Six relatively new road segments, including C-Street, Seward Highway, Minnesota Drive, and Ingra and Gamble Streets, showed peak deflections between April 20 and 23, at which time the thaw depth ranged from 2.5 to 3.0 feet at the two frost tube sites. Soils and sun exposure at the frost tube sites may have led to slightly shallower indicated thaw depths than existed beneath the majority of the above routes, indicating again that peak deflections may be generally expected at thaw depths in the *3'* to *4'* range. With respect to air temperatures, peak deflections generally occurred after from 10 to 100 degree-days of thawing air temperatures.

Thermal Analysis .

A thermal analysis was made of the subsurface heat flows during the early part of the thawing season at the Farmers Loop Site. Temperature data for this analysis were taken from observations of thermocouple string #1 for six representative dates between mid-April and mid-June of 1976. The analysis was performed by using assumed soil thermal properties based on gravel at a dry density of 140 pcf and a moisture content of 4%. These properties included a latent heat of fusion of 800 Btu/ft^3, and thawed and frozen conductivities of 1.8 and 1.6 Btu/ft. hr. OF, respectively. Temperature gradients above and below the freezing front were measured from temperature versus depth plots and are presented in Table 2 as i_t and i_f (^{o}F/ft.).

Table 2

Date	i-thawed (^{o}F/ft.)	i-frozen (^{o}F/ft)	Q-in (Btu/wk)	Q-out (Btu-wk)	Q-thaw (Btu/wk)	Q into thaw %
4/14/76	8.0	*1.8*	*2419*	484	1935	*80*
4/20/76	6.5	1.6	1066	430	1536	73
4/25/76	3.3	1.6	998'	430	568	57
5/5/77	4.3	3.0	1300	*807*	493	*38*
5/13/77	5.2	3.25	1572	874	698	*44*
6/16/77	5.0	2.9	1512	780	732	48

The toal calculated heat flowing both into and away from the thawing front at the thermal gradients listed, over a one-week period, are shown as Q-in and Q-out (Btu/week). The difference between these two values represents heat absorbed in thawing the soil.

During the two month period covered by this analysis, it appears that on the average, about half of the solar heat energy entering the roadway was utilized in thawing the roadway soils, while the remainder of the heat went to warming the underlying frozen soils. Because of the extremely low winter temperatures common to Fairbanks and the rapid warming which occurs at the start of the thawing season, lower thawing rates would be expected in Fairbanks than in regions having warmer wintertime ground temperatures, assuming the same rate of varming during the thawing season.

Summary and Conclusions

Roadway surface deflection measurements were taken at frequent intervals in 1975 and 1976 during the early portion of the thawing season, on two roadway sections in the Fairbanks area. These sections represented a very strong and well constructed roadway, and a very thin, weak roadway structure over organic silts and sands. Air and pavement temperatures were continuously recorded, and periodic observations of thaw depths were made by thermocouple temperature measurements and by Frost Tubes. This permitted comparisons to be made between air temperatures, thawing rates, thaw depths, and deflection levels as measured by the Benkleman Beam test procedure. Additional deflection and thaw depth observations were made in the Anchorage area during 1976 to broaden the base of this study.

Temperature observations show that beginning around the first of April, the average daily temperature at the bottom of the asphaltic concrete pavement layer will begin to rise above the average daily air temperature, and will be around 8°F above the air by the end of April. Thawing of the roadway soils can commence in late April at average air temperatures above about 25°F. The actual timing of the start of roadway thawing is dependent on air temperatures, cloud cover, wind velocities, surface orientation, and other factors, and is probably as difficult to predict as the weather. During this study, the beginning of thawing occurred approximately two weeks earlier in 1976 than in 1975. In both years, thawing reached depths of around one foot by the time the daily average air temperature rose above 32°F.

After it commenced, thawing proceeded rather quickly through the pavement system layers, advancing at rates of 0.3 to 1.5 feet per week, depending on temperatures and soil properties. Maximum thaw depths of three feet were found to occur when the thawing index reached 50 degree-days. The most simple and consistent thaw depth observations were obtained by the use of the frost tube installations, and agreed very closely with test pits made at the edge of the pavement.

Benkleman Beam deflection levels, which are a measure of the distortion and potential distress of a pavement under wheel loadings, continued to increase on nearly all sections until thaw depths reached 3 to 4 feet, with deflections declining slowly toward summer levels as thawing increased beyond these depths. Peak deflection levels occurred at from two to six weeks after the start of thawing. All deflection tests were repeated at the same test points during the course of this study. Comparison of the deflection variations with time at the Davis Road site, for a single test point, did not show the same consistent pattern of deflections versus time as indicated by the average of all points. At some test points, the maximum

observed deflection occurred durin the summer or fall season, indicating the need to use the average of several test points to reliably determine the relative strength level of a roadway.

The data generated during this study was not sufficient to permit any definite conclusions regarding correlation of air temperatures and pavement deflections. Because of the lack of sufficient data to establish this relationship and the limited scope of the study, no conclusions were reached regarding improvements to the pavement system layers.

Implementation Recommendations

1) Measurements aimed at determining the maximum deflection level of a given roadway section should be performed weekly, starting one to two weeks after the start of roadway thawing, and continuing until at least six weeks have elapsed after the start of thawing.

2) Frost tubes approximately 5 feet in length should be installed at representative roadway locations, to permit observations of the thaw progression. Those observations would be very useful in estimating when load restriction periods should begin and end, once the maximum level and pattern of strength loss and recovery is known for the same roadway type and area.

3) Air temperatures can be used as an initial indication of the start of pavement thawing, using, at least in the Alaskan Interior, the average pavement to average air temperature relationships developed under this study. Thawing of the first granular layer beneath the pavement may be expected when average air temperatures exceed 32°F in March or early April. Initial thawing can occur at air temperatures as low as 25°F by early May, because the increasing sun angle causes surface temperatures to rise above air temperatures as Spring progresses.

4) As demonstrated by this study and the previous Fairbanks Area Deflection Study, there appears to be no substitute for actual measurements of deflection levels as a basis for setting the allowable level of Spring Load Restrictions. The Farmers Loop study segment demonstrated strengths adequate to carry full legal truck loadings at any time during the thawing season. The Davis Road site, by deflection criteria, should not be permitted to carry any large number of legal loads, except when rigidly frozen. Most Anchorage Area routes did not indicate a need for spring load restrictions during 1976. The rate of strength recovery will differ between roadway sections, and the removal of load restrictions should be determined by actual deflection measurements.

SEASONAL ROADWAY DEFLECTION STUDY

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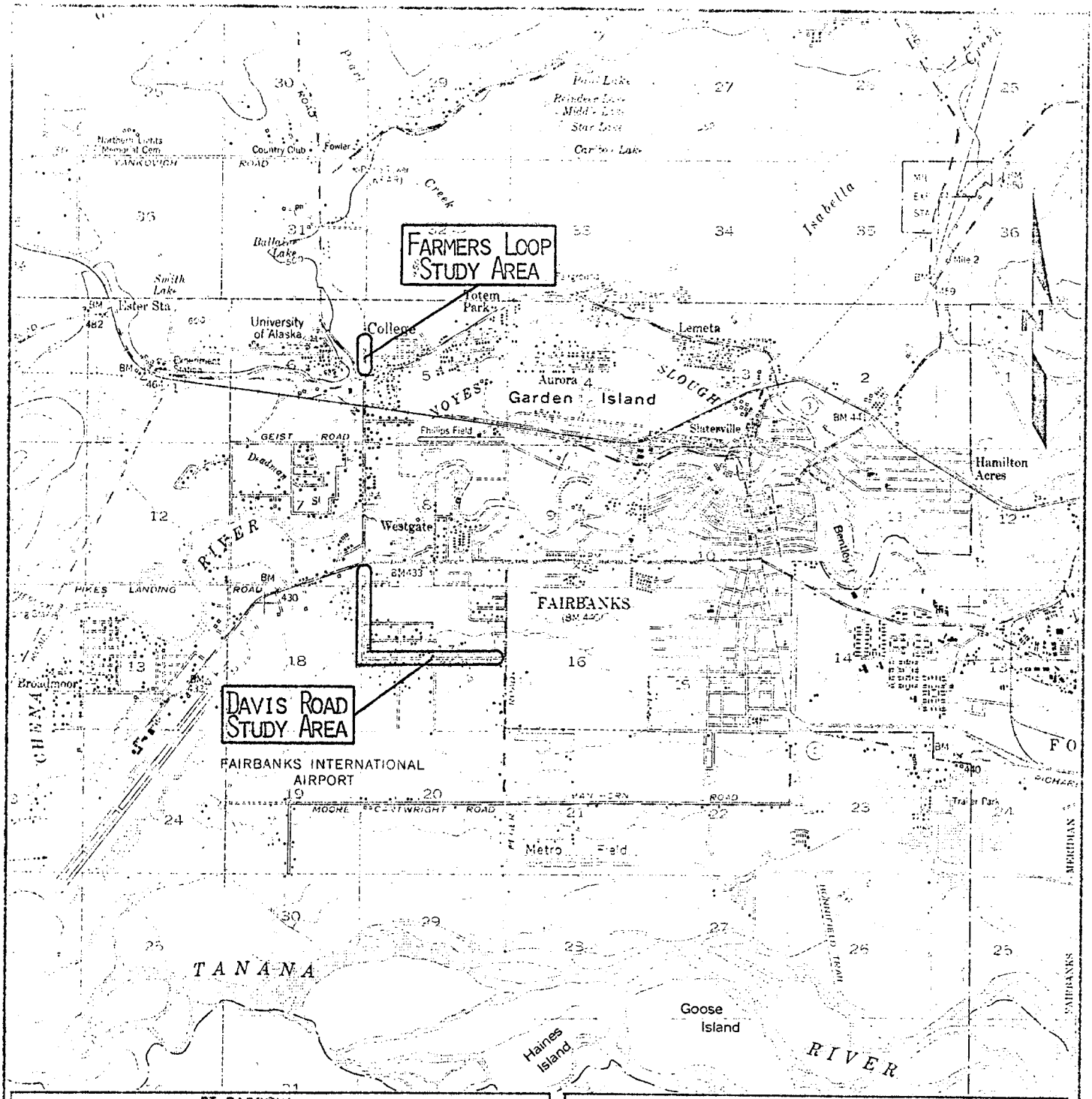
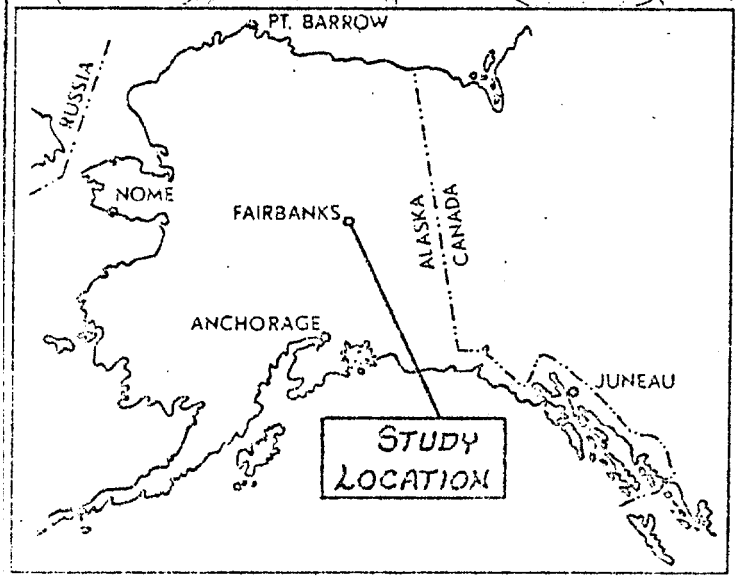




SEASONAL ROADWAY DEFLECTION CORRELATIONS WITH CLIMATE FAIRBANKS AREA STUDY SECTIONS

FIGURE 1

LOCATION MAP

Scale 1" = 1 MILE Data USGS

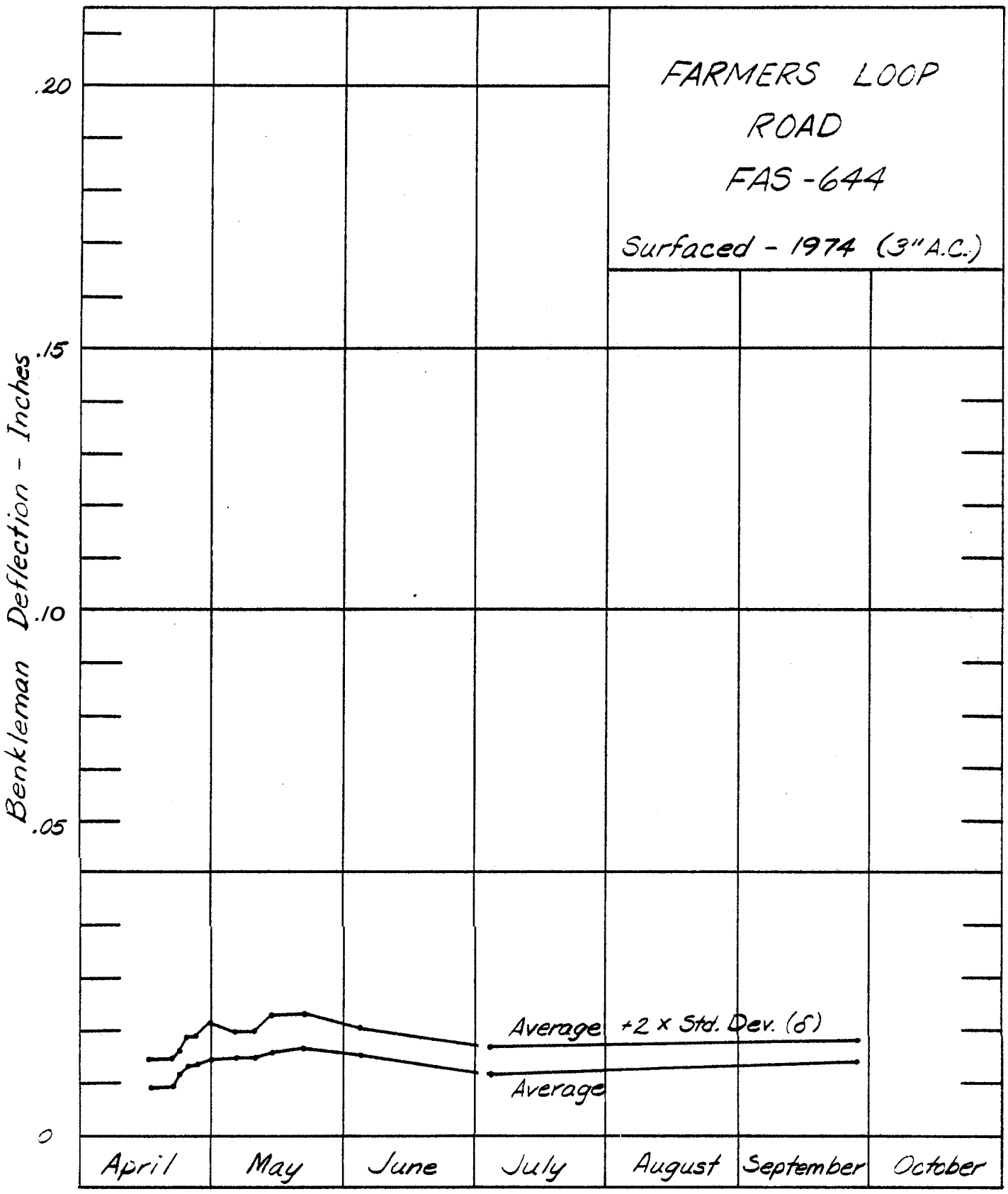
Note:
* Depths are from bottom of 3" AC Pavement
** Depths from top of Pavement

Farmers Loop Road - Ground Temp Data

Observers: _____ Air Temperature: _____ Date: _____

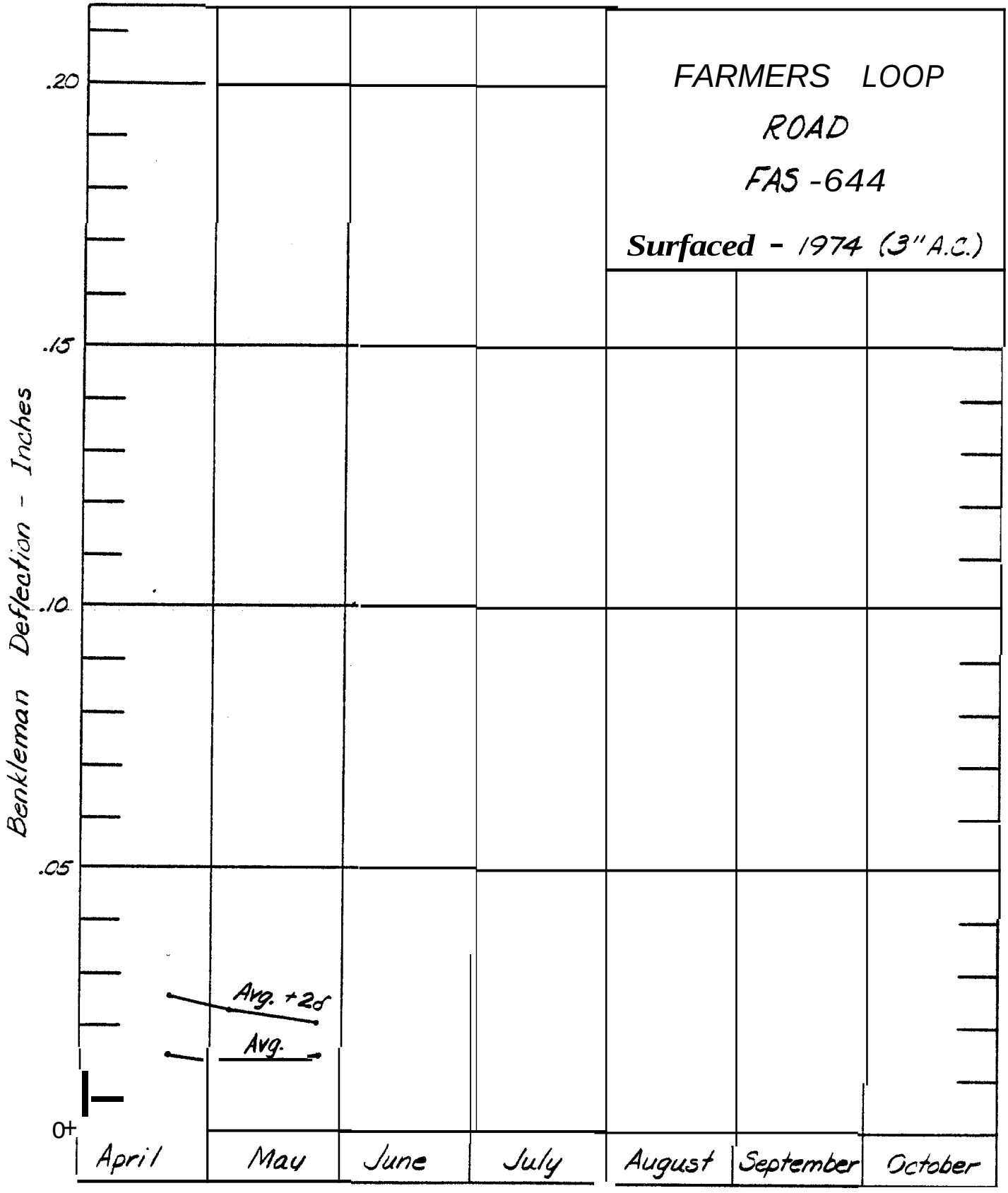
Station	9+00			9+00			14+00			8+95		
℄ Reference	4' Left			16' Left			4' Left			20' Left		
String No.	FLTC-1			FLTC-2			FLTC-3			FLTC-4		
Switch Pos.	μV	Temp °F	Depth*	μV	Temp. °F	Depth*	μV	Temp °F	Depth*	μV	Temp °F	Depth**
1			0			0			0			0.5'
2			0.25'			0.25'			0.25'			2.0'
3			0.5'			0.5'			0.5'			4.0'
4			0.75'			0.75'			0.75'			10.0'
5			1.0'			1.0'			1.0'			25.0'
6			1.25'			1.25'			1.25'			10.0'
7			1.5'			1.5'			1.5'			25.0'
8			1.75'			1.75'			1.75'	T.C. Ref. _____ = _____ °F		
9			2.0'			2.0'			2.0'	T_{FL1} _____ Ω/°F		0.5'
10			2.5'			2.5'			2.5'			
11			3.0'			3.0'			3.0'	T_{FL2} _____ Ω/°F		2.0'
12			3.5'			3.5'			3.5'			
13			4.0'						4.0'	T_{FL3} _____ Ω/°F		4.0'
14			6.0'						6.0'			
15			8.0'						8.0'	T_{FL4} _____ Ω/°F		10'
16			10.0'						10.0'			
Reference	T_{1065} @25', Ω =		= °F	T_{1066} @10' Ω =		= °F	T_{1070} @25' Ω =			T_{FL5} _____ Ω/°F		25'

Figure 2



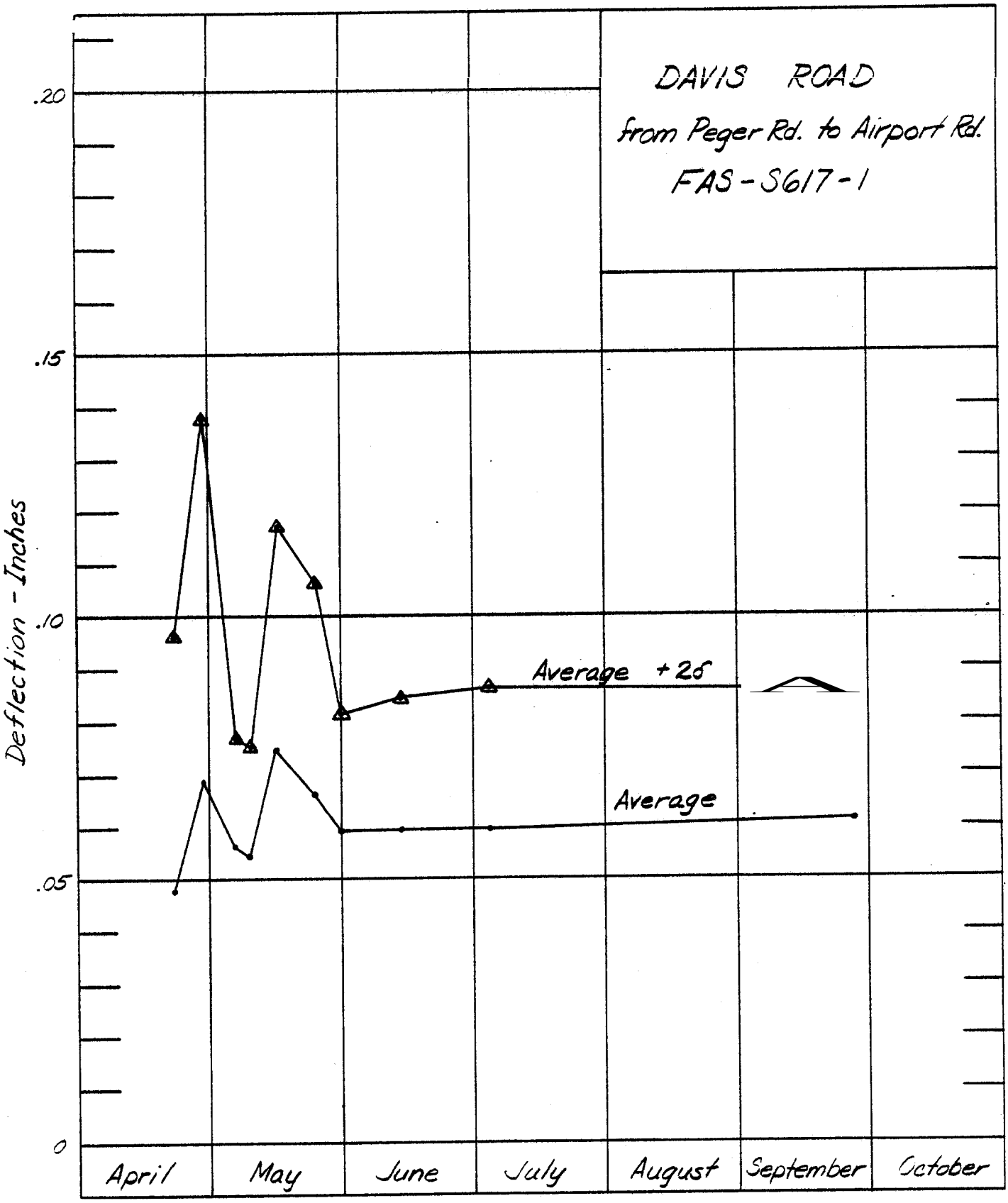
Date 1975

Figure 3



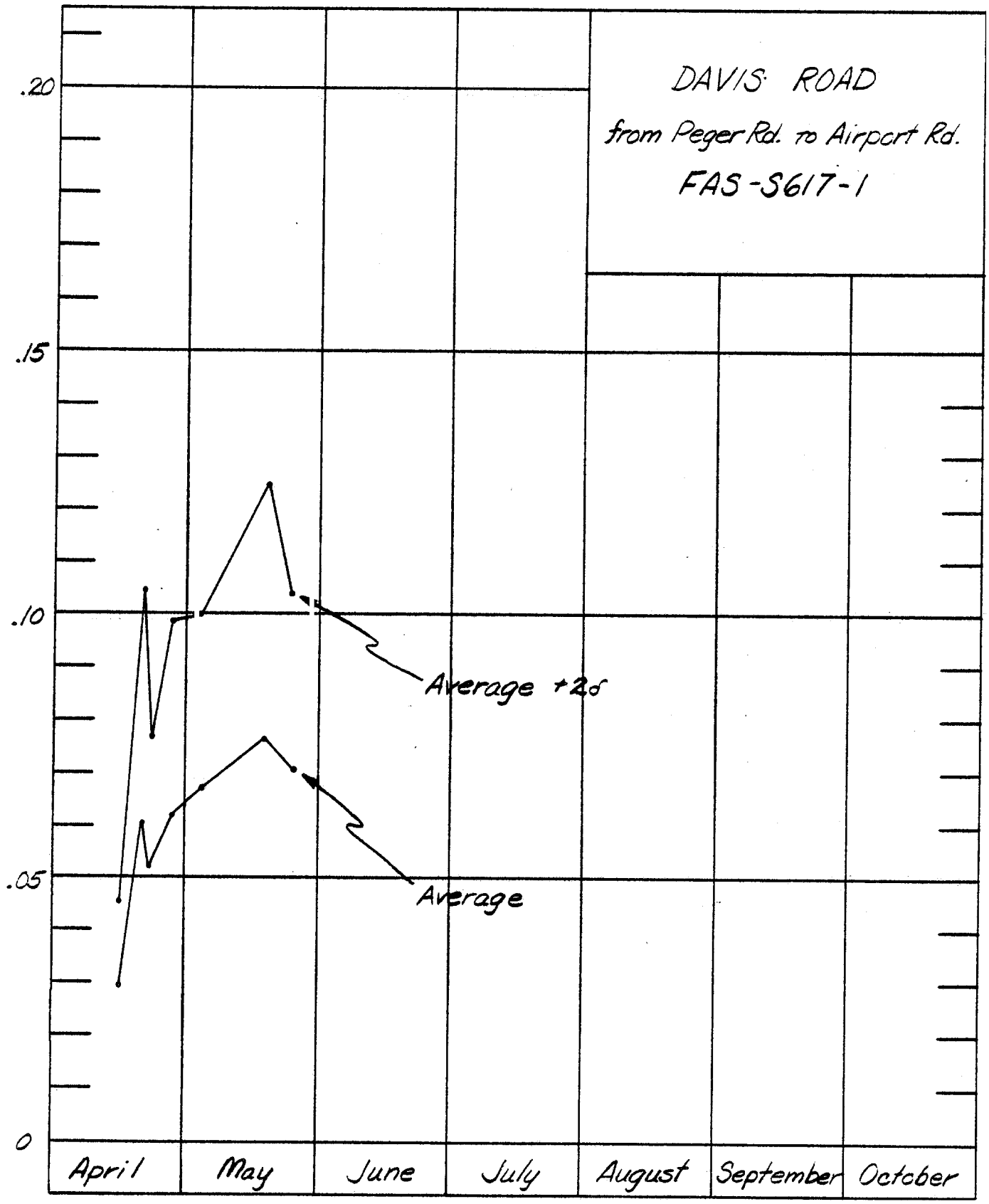
Date 1976

Figure 4



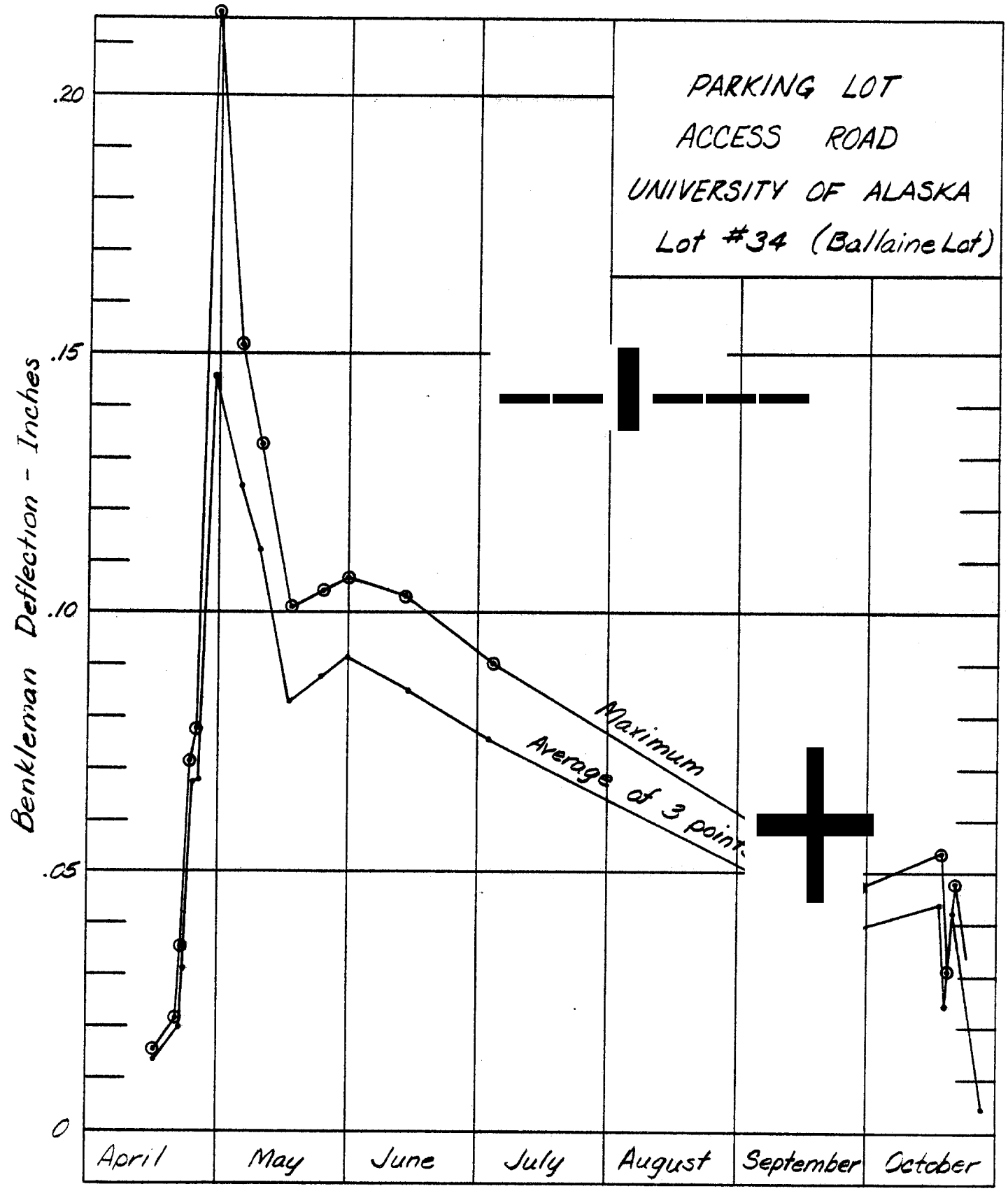
Date 1975

Figure 5



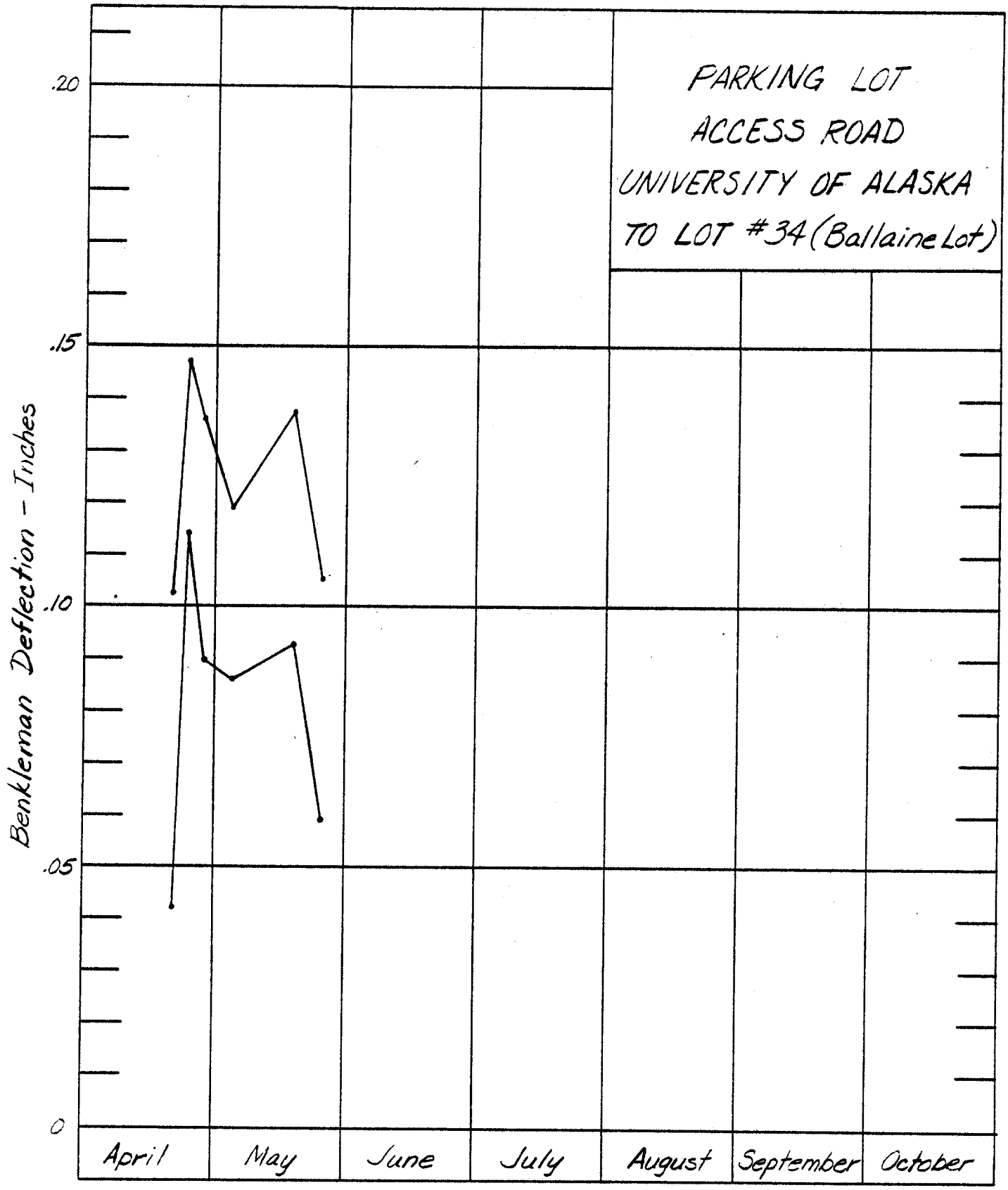
Date 1976

Figure 6



Date 1975

Figure 7



Date 1976

Figure 8

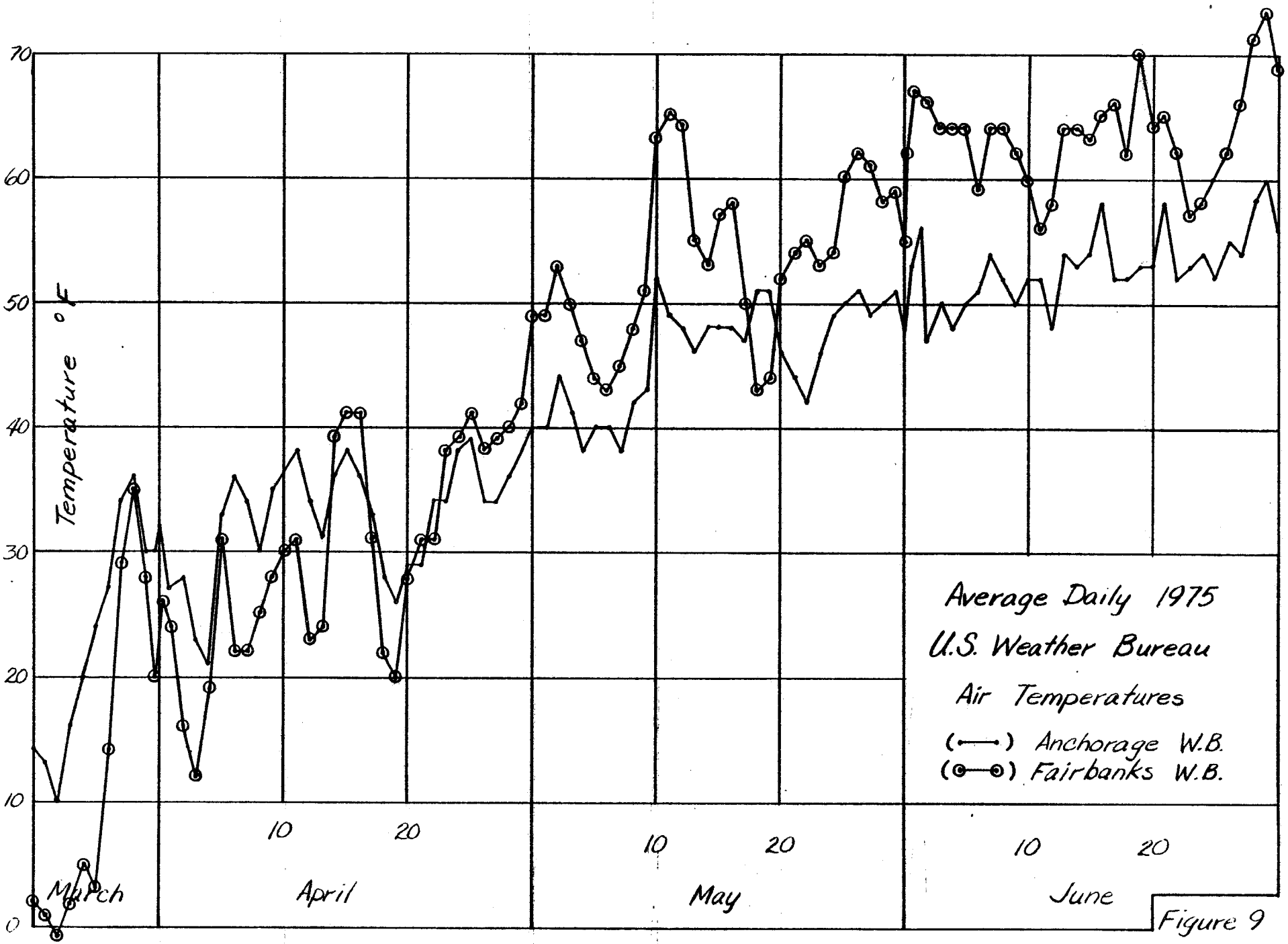

Temperature °F
70
60
50
40
30
20
10
0
March
April
May
June
10
20
10
20
10
20
Average Daily 1975
U.S. Weather Bureau
Air Temperatures
Anchorage W.B.
Fairbanks W.B.

Figure 9

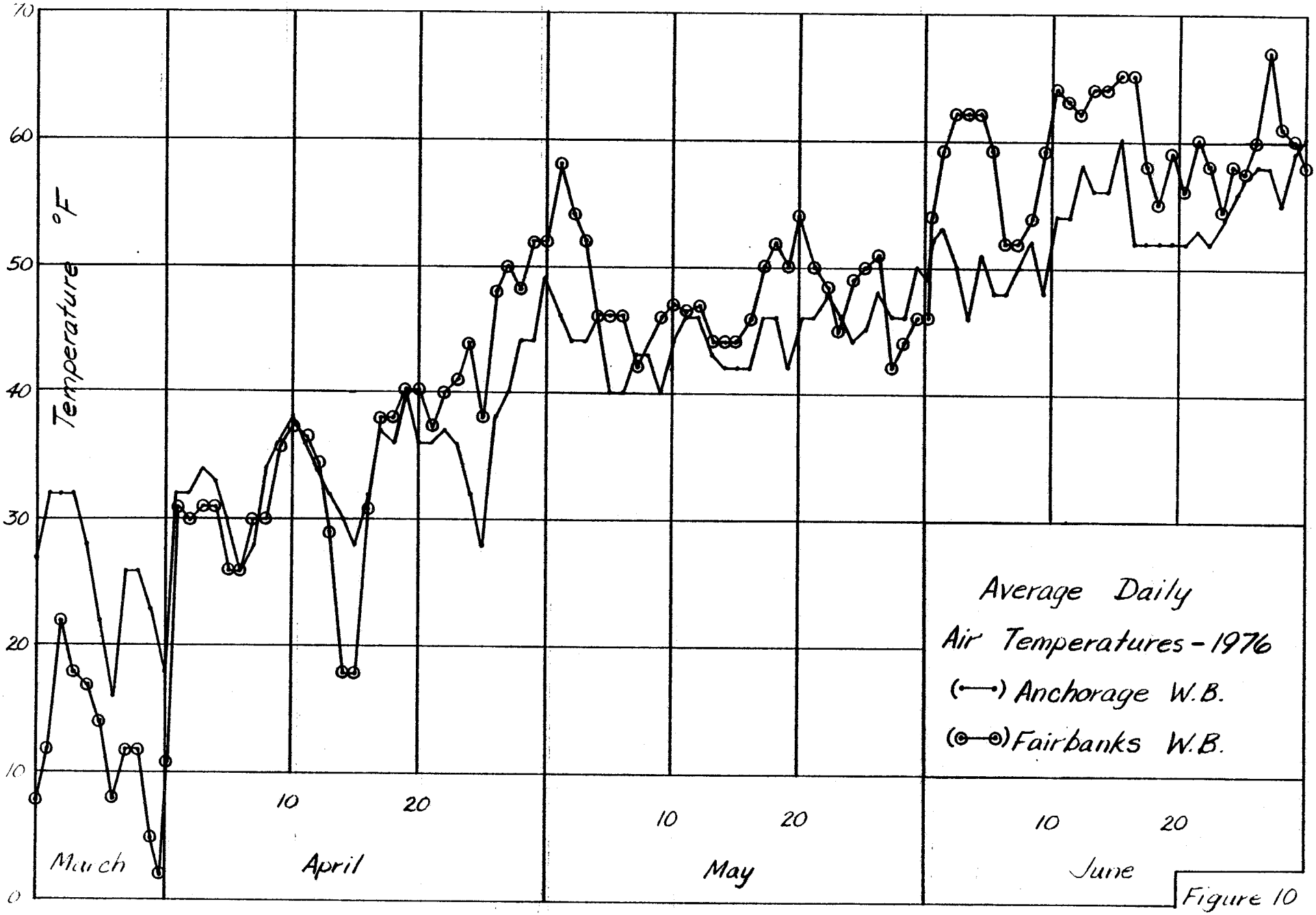

70
60
50
40
30
20
10
0
Temperature °F
March
April
May
June
10
20
10
20
10
20
Average Daily
Air Temperatures - 1976
Anchorage W.B.
Fairbanks W.B.

Figure 10

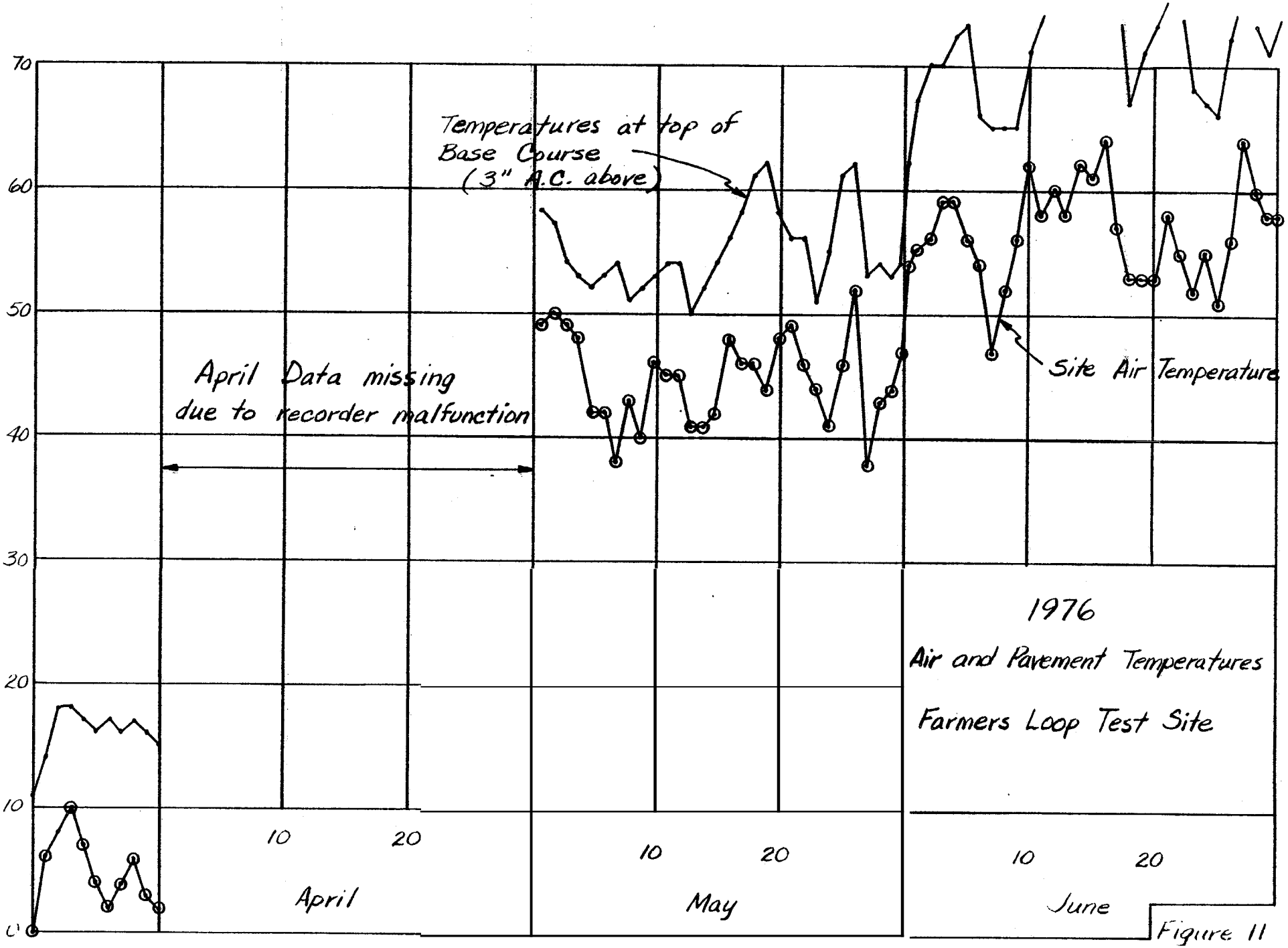

70
60
50
40
30
20
10
0
Temperatures at top of Base Course (3" A.C. above)
Site Air Temperature
April Data missing due to recorder malfunction
1976
Air and Pavement Temperatures
Farmers Loop Test Site
10
20
April
10
20
May
10
20
June

Figure 11

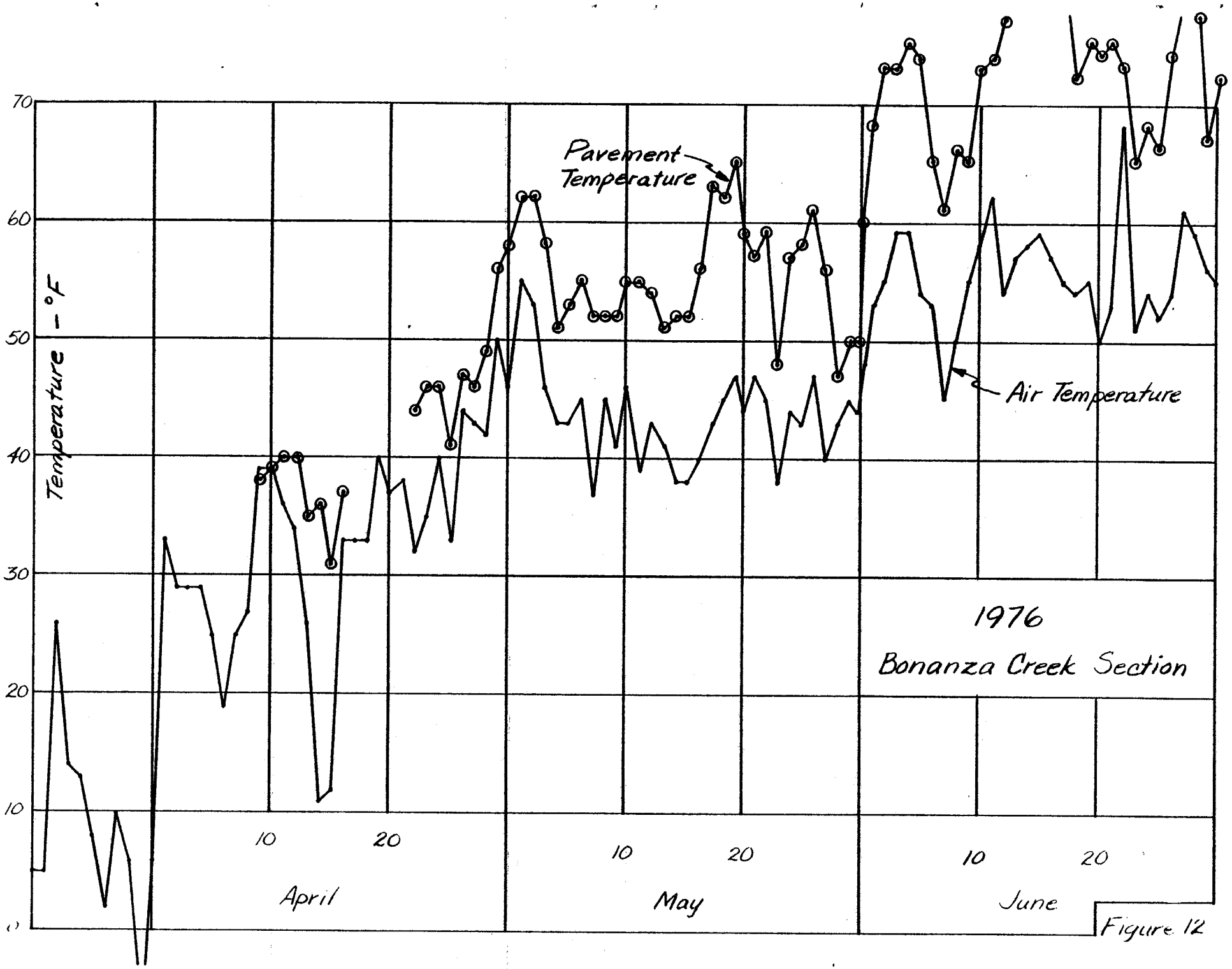

Pavement Temperature
Air Temperature
Temperature - °F
70
60
50
40
30
20
10
0
10
20
10
20
10
20
April
May
June
1976
Bonanza Creek Section

Figure 12

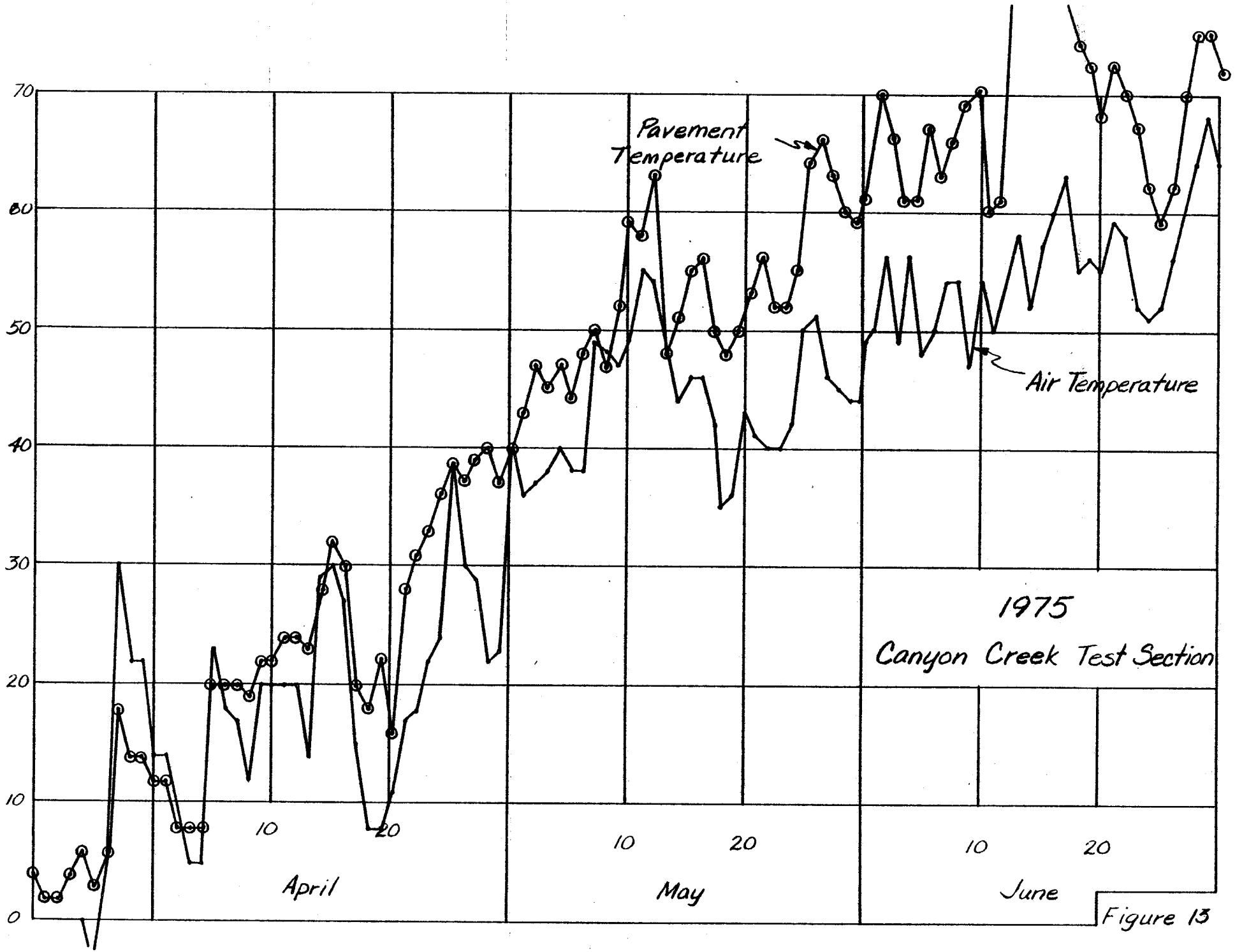

70
60
50
40
30
20
10
0
Pavement Temperature
Air Temperature
1975
Canyon Creek Test Section
10
20
April
10
20
May
10
20
June

Figure 13

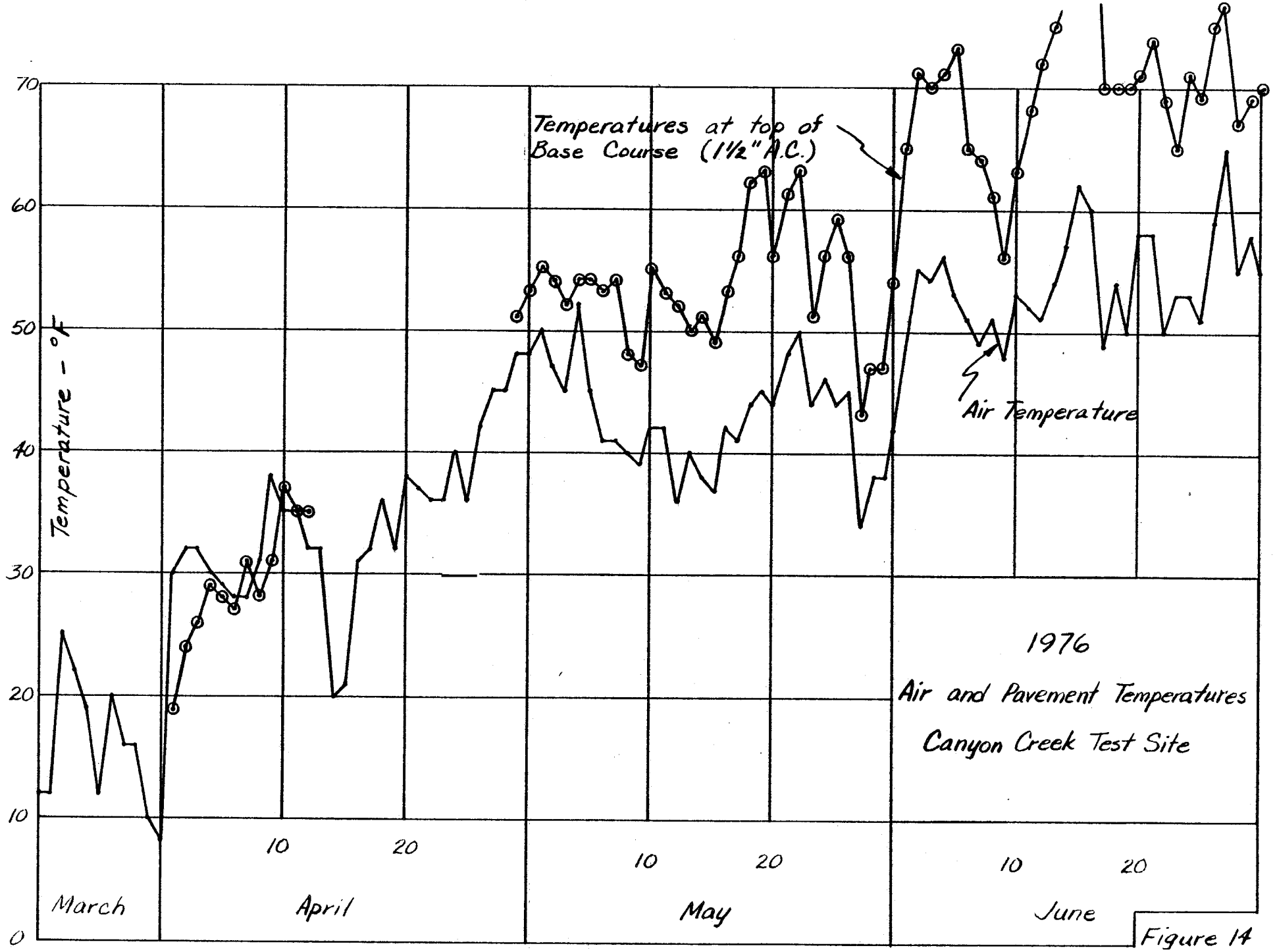

Temperatures at top of Base Course (1½" A.C.)
Air Temperature
Temperature - °F
70
60
50
40
30
20
10
0
10
20
10
20
10
20
March
April
May
June
1976
Air and Pavement Temperatures
Canyon Creek Test Site

Figure 14

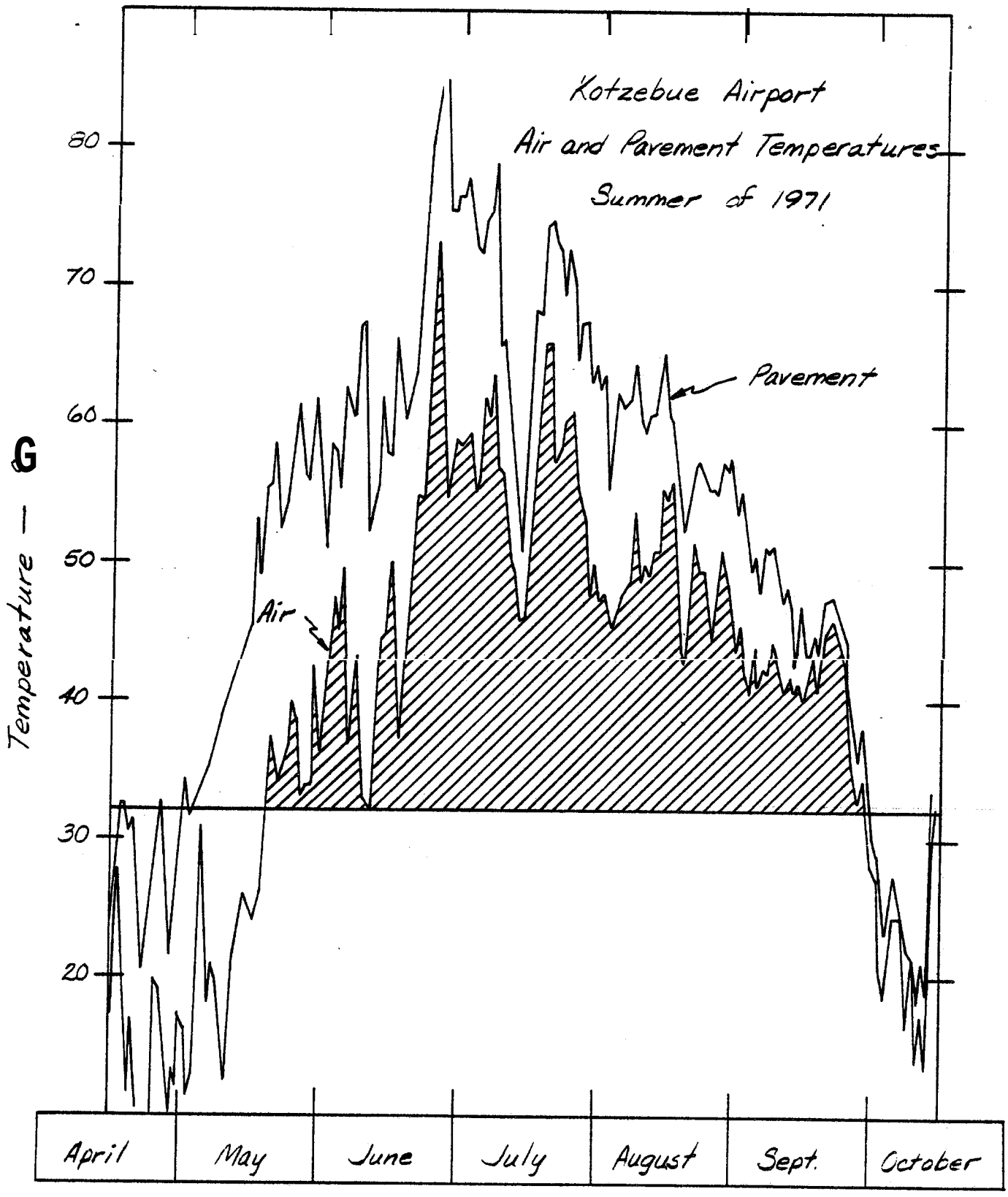

Kotzebue Airport
Air and Pavement Temperatures
Summer of 1971
Pavement
Air
Temperature — °F
80
70
60
50
40
30
20
April
May
June
July
August
Sept.
October

Figure 15

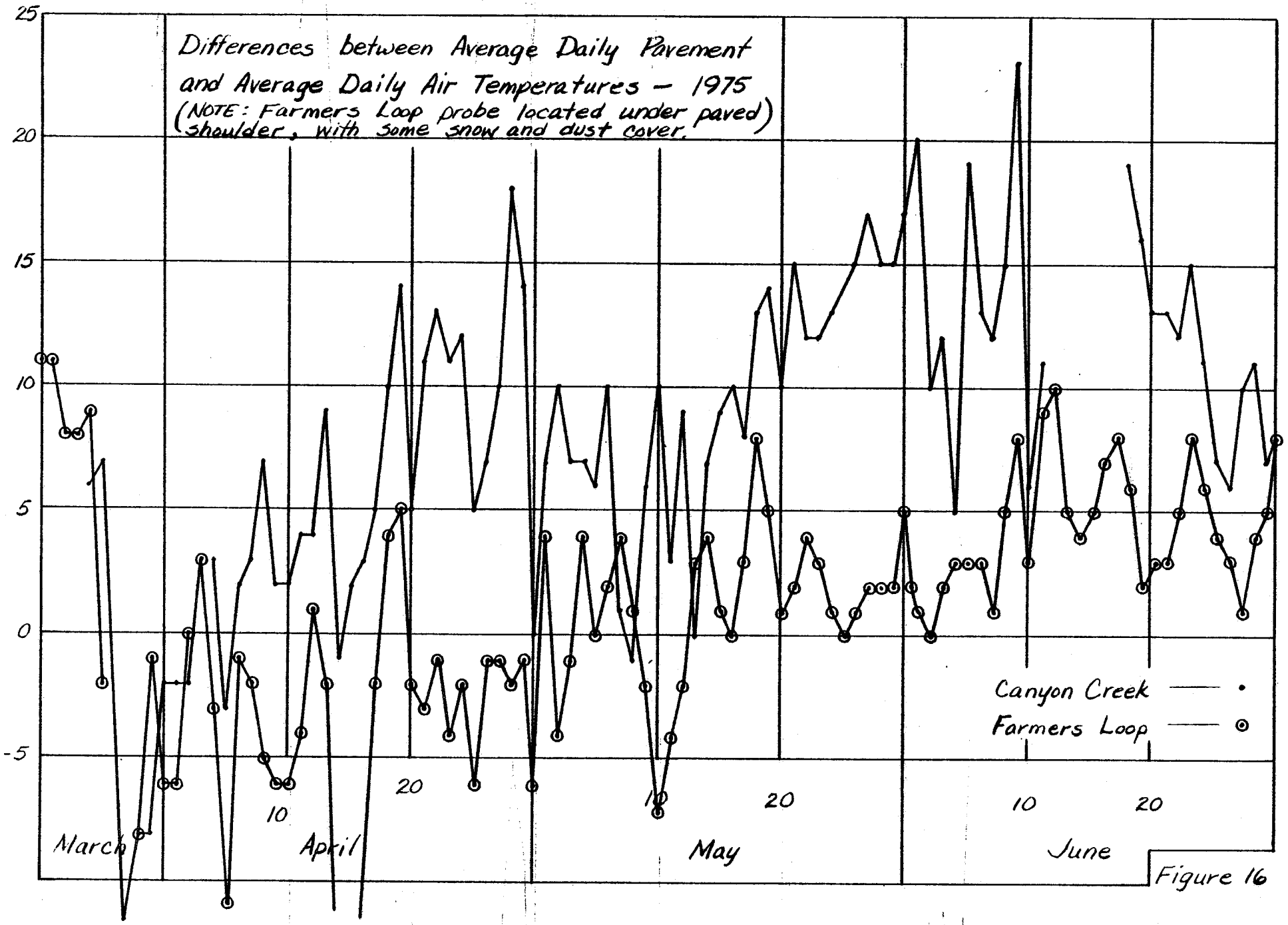

Differences between Average Daily Pavement and Average Daily Air Temperatures – 1975
(NOTE: Farmers Loop probe located under paved shoulder, with some snow and dust cover.)
25
20
15
10
5
0
-5
March
10
April
20
10
May
20
10
June
20
Canyon Creek
Farmers Loop

Figure 16

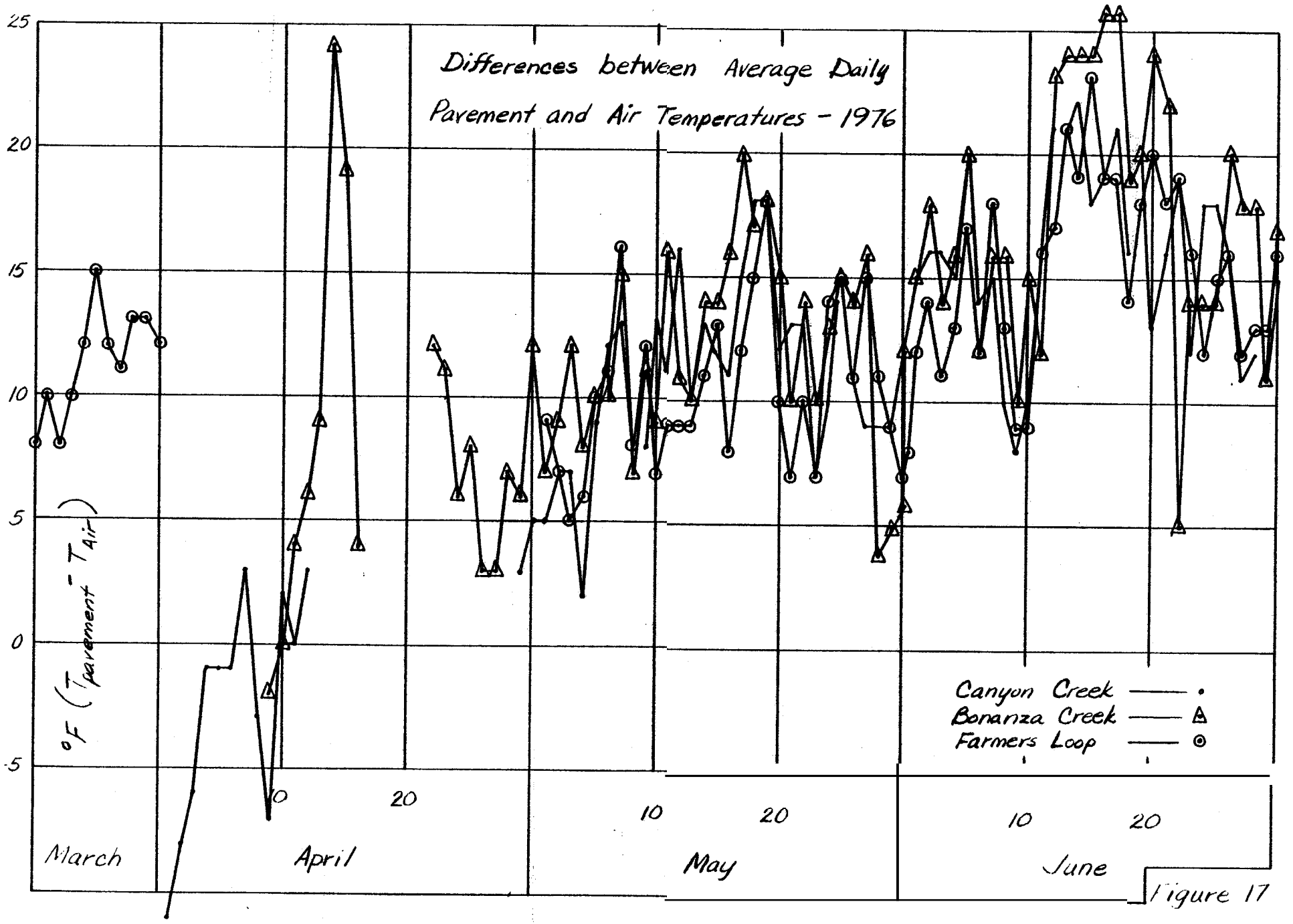

Differences between Average Daily
Pavement and Air Temperatures - 1976
°F (T_pavement - T_Air)
25
20
15
10
5
0
-5
March
April
May
June
10
20
10
20
10
20
Canyon Creek
Bonanza Creek
Farmers Loop

Figure 17

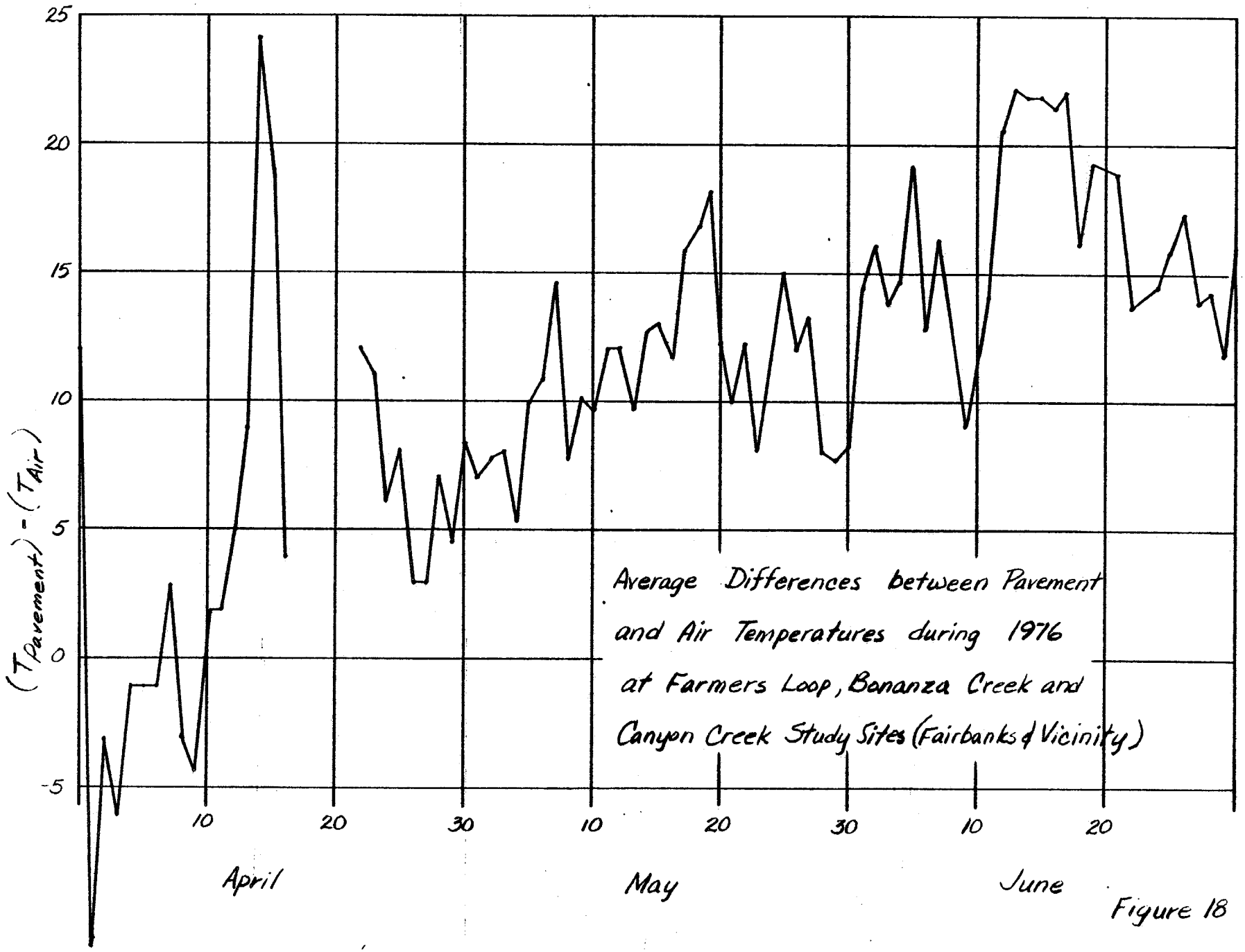

25
20
15
10
5
0
-5
$(T_{Pavement}) - (T_{Air})$
10
20
30
10
20
30
10
20
April
May
June
Average Differences between Pavement and Air Temperatures during 1976 at Farmers Loop, Bonanza Creek and Canyon Creek Study Sites (Fairbanks & Vicinity)

Figure 18

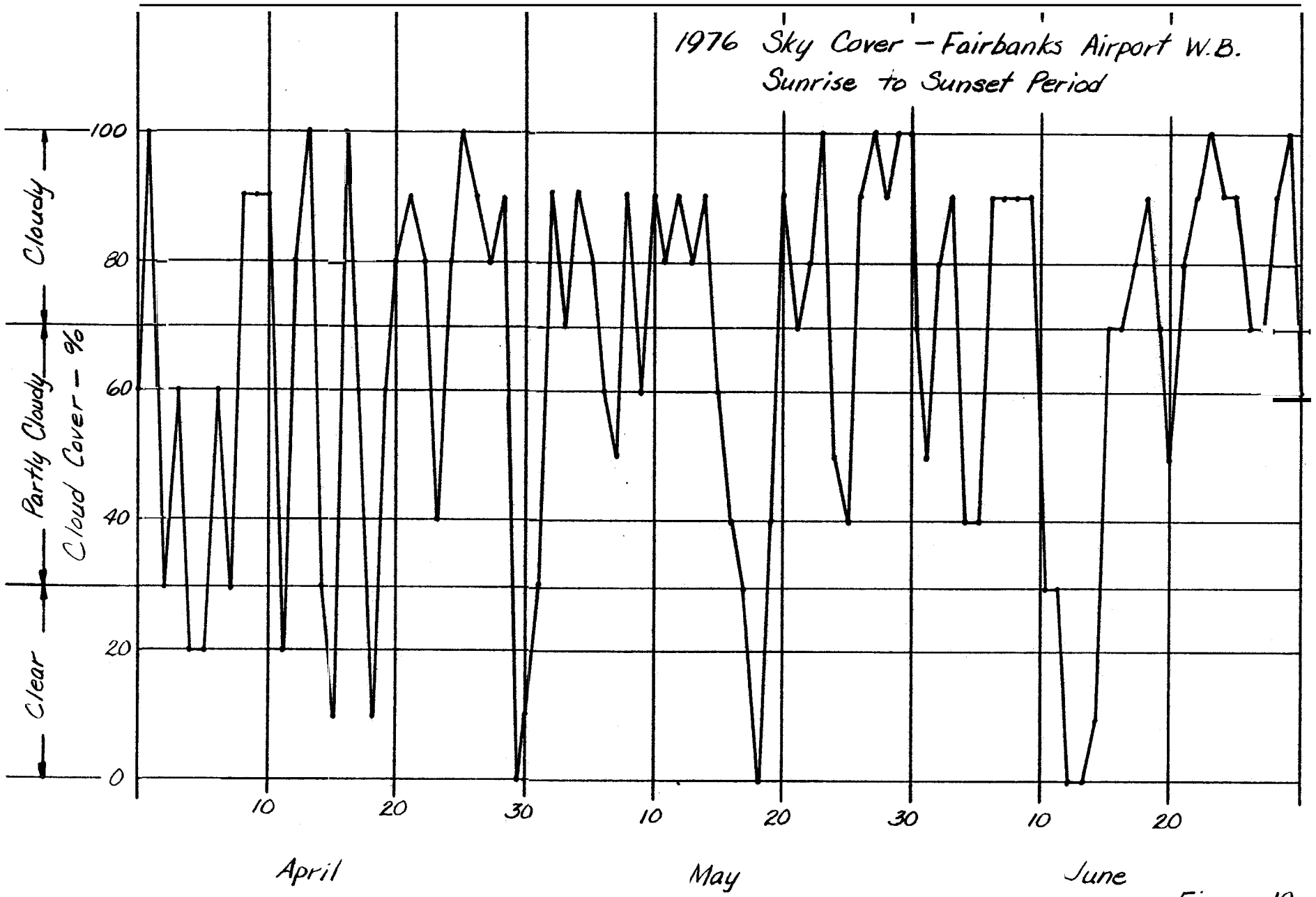
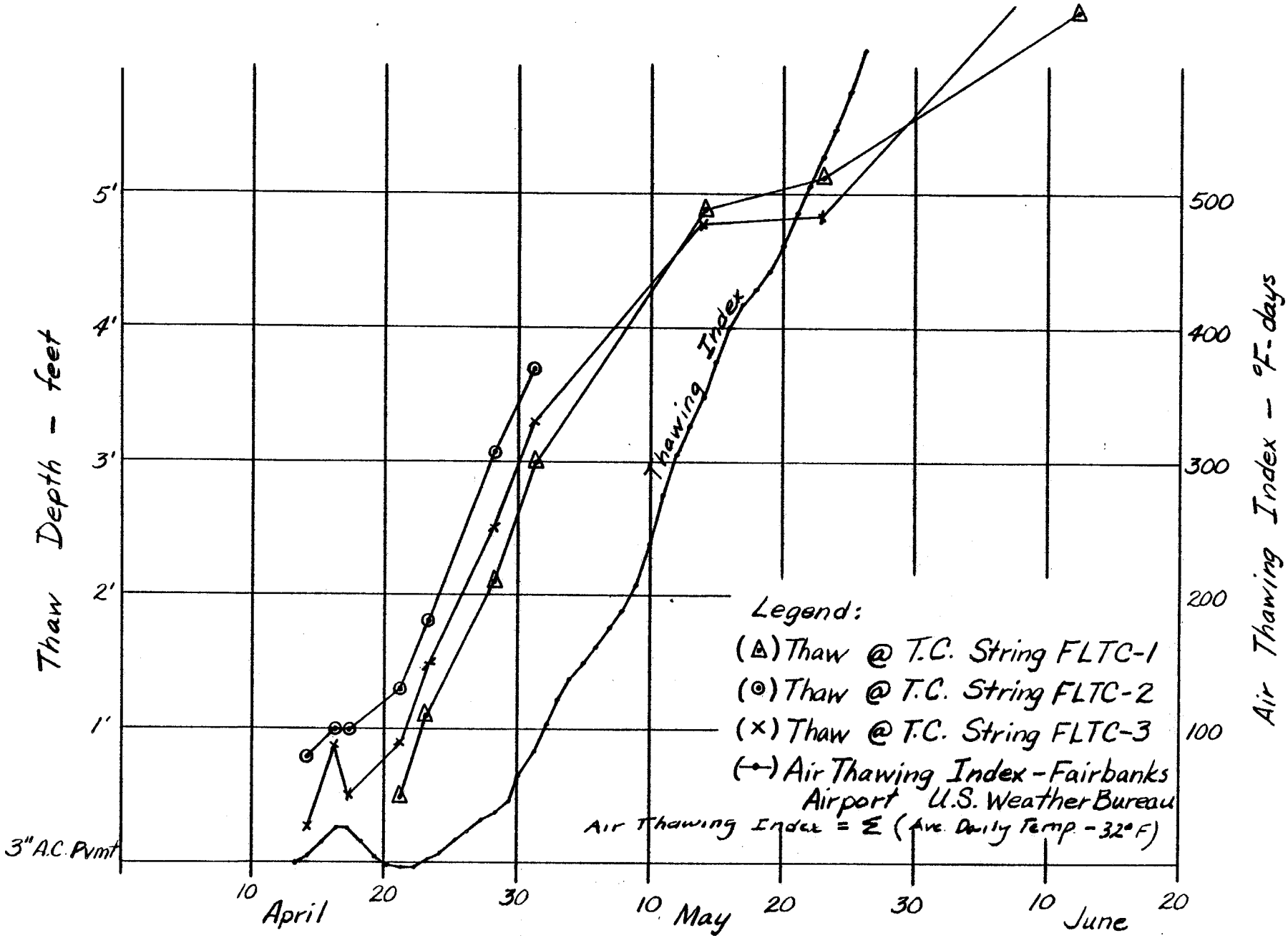
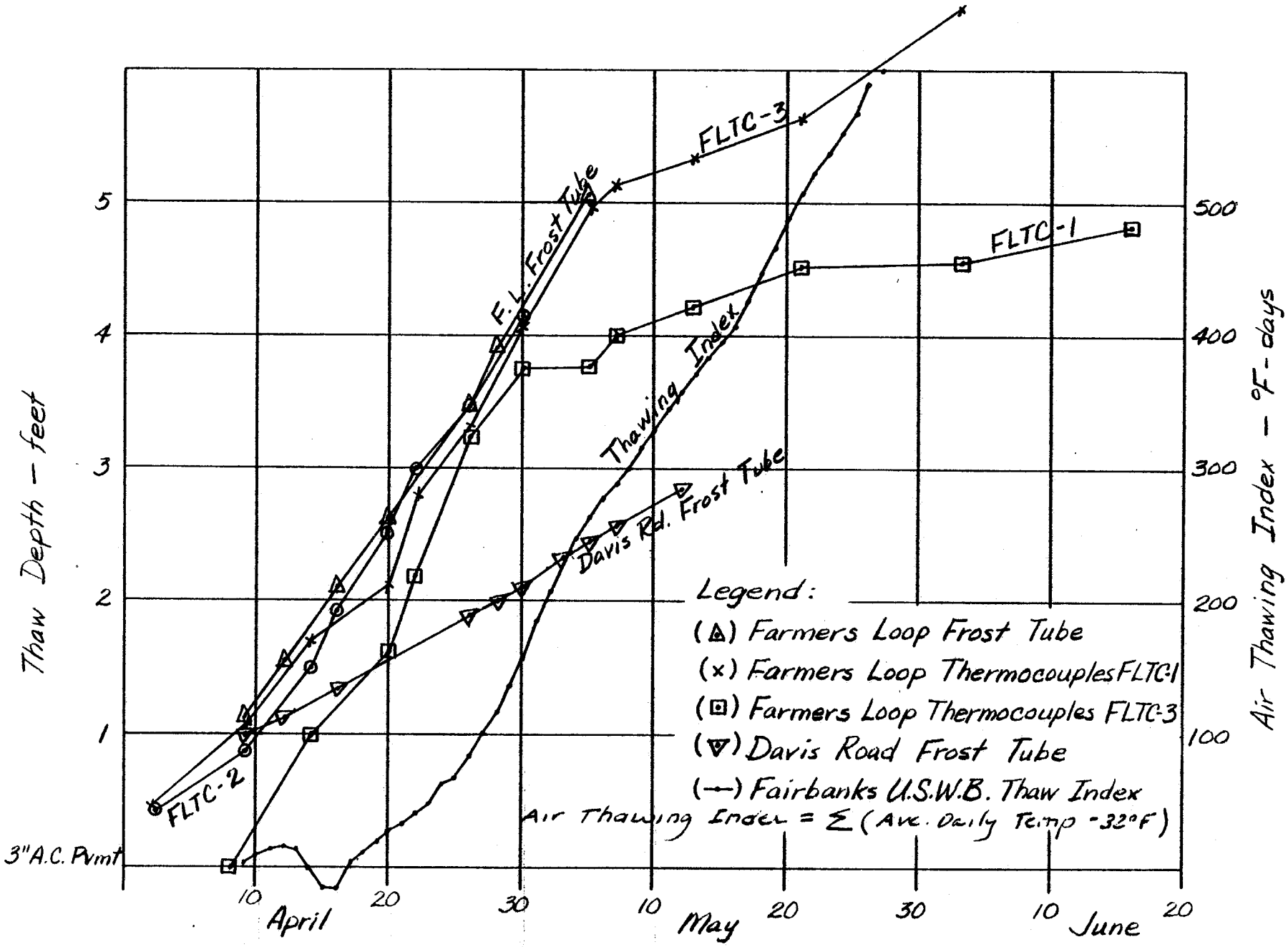

1976 Sky Cover – Fairbanks Airport W.B.
Sunrise to Sunset Period
Cloudy
Partly Cloudy
Clear
Cloud Cover – %
100
80
60
40
20
0
10
20
30
10
20
30
10
20
April
May
June

Figure 19



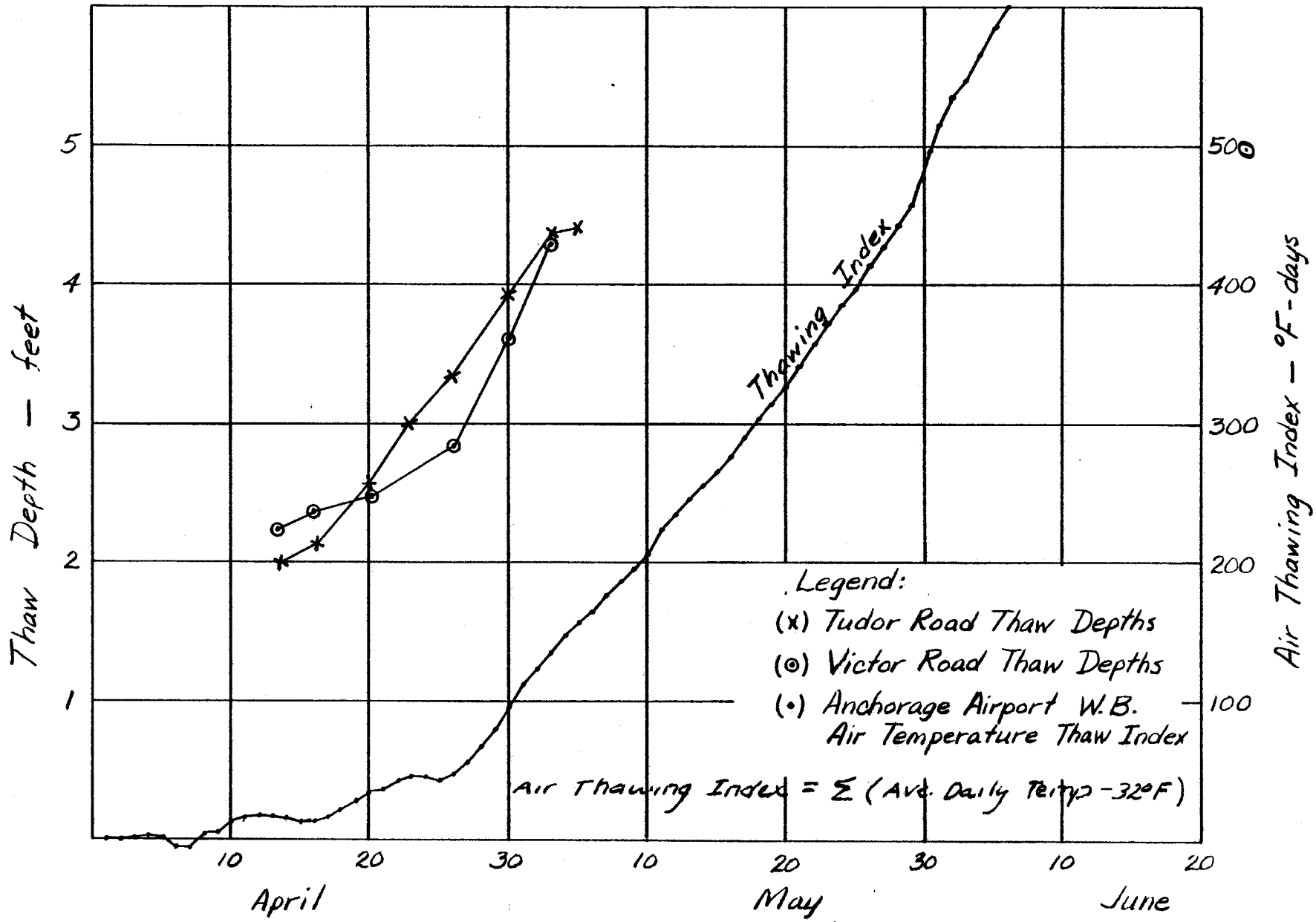
1975 - Farmers Loop Roadway Thaw Depths & Thawing Index

Figure 20



1976 – Fairbanks Area Roadway Thaw Depths & Thawing Index

Figure 21



1976 Anchorage Area — Thaw Depths & Thawing Index

Figure 22

1972 FAIRBANKS AREA ROADWAY DEFLECTION STUDY

by D. C. Esch, Engineer of Tests, Alaska Department of Highways

Introduction

During the spring and summer of 1972, personnel of the State Materials Laboratory, in cooperation with the Interior District Maintenance Division, ran periodic rebound deflection surveys of selected Fairbanks area roadways, using the Benkleman Beam test method. These surveys were made to determine the magnitudes and durations of roadway strength losses during the spring thawing period, and the general relationship between roadway deflection values and time of year.

Test Procedures

The Benkleman Beam test procedures and methods of analysis used were essentially those recommended by the Canadian Good Roads Association, as discussed in the publication, "A Guide to the Structural Design of Flexible and Rigid Pavements in Canada." The Benkleman Beam is a simple device consisting of a fixed base assembly and a twelve foot long pivoting beam. A dial indicator mounted on the base measures vertical movements at the reference end of the beam, which result from elevation changes in the roadway surface on which the opposite or probe end of the beam is resting (see Figure 1). In practice the beam is used to measure the "rebound" of the roadway, by placing the probe end of the beam on the roadway surface between the rear dual wheels of a single axle dump truck loaded with a gross rear axle loading of 18,000 pounds. Tests are always run in the outer wheel path because this area is most subject to moisture infiltration from the shoulder area. After the beam is positioned and the dial indicator zeroed, the truck is slowly driven away from the measurement point. The rebound of the roadway surface after the truck loading is removed, measured to the nearest .001 inch, and is recorded as the rebound deflection.

Each time a section of road was evaluated, a minimum of ten deflection measurements were obtained. The average deflection and the standard deviation from the average were calculated for each roadway section. The Canadian Good Roads Association (CGRA) rebound deflection was determined as the average deflection plus two times the standard deviation. According to probability statistics, the rebound deflections over a given section of roadway will not exceed the CGRA Benkleman Beam rebound deflection value more often than once in forty observations.

Readings on each roadway section were made weekly during the spring thawing period and twice more during the summer. To assure the most reliabie correlations between readings on a given section at different times, each test location was initially marked with paint, and subsequent readings were taken at the same locations.

A minimum crew of four men is needed to safely perform Benkleman Beam surveys on travelled roadways. This minimum includes the truck driver, beam operator, and two flagmen. In addition to the loaded test vehicle, a pickup truck or similar vehicle is needed to transport the Benkleman Beam unit and operator, and one of the flagmen. The overall rate of testing will vary considerably depending on distance between test points. Actual test and setup time at one location is roughly two to three minutes. A testing frequency of five to ten tests per mile is recommended to adequately evaluate a section of roadway. With this frequency the rate of testing will be approximately fifteen to thirty miles per day.

Test Significance

The Benkleman Beam test method was used extensively in evaluating pavement performance in the AASHO Road Test Program. It was learned that rebound deflections exceeding .050" were a good indicator that premature pavement failures by flexural fatigue would occur, a failure mode evidenced by alligator cracking of the pavement surface. When rebound deflections exceed 0.20", displacement and shear failures may occur, leading to rutting of the pavement and base system. Canadian research has shown that when the average daily traffic(ADT)per lane is less than 1000, deflections somewhat higher than .050" can be tolerated, but the exact relationships between low traffic volumes and tolerable deflection limits have not been adequately determined. Indications are that deflection levels consistently below the .050" limit will result in longer pavement life and freedom from roughness.

Deflection studies for a series of years after construction of a new roadway show that changes in deflection levels may occur over a two to three year period due to the combined effects of compaction by traffic and decreases in base and sub-base densities through frost action. Therefore, deflection testing shortly after construction may not reliably indicate the long-term performance of a given pavement.

Application to Spring Load Restrictions

One obvious application of Benkleman Beam deflection surveys is in determining when and where to impose or remove restrictions on gross axle loads during the spring thawing season.

Figures 2 to 8 show both average and CGRA rebound deflections plotted versus time of observations, for all road sections evaluated in this study, All sections showed peak deflection values occurring during May, with deflections decreasing during the summer.

Applying the recommended maximum allowable CGRA deflection limit of .050" leads to the conclusions that no spring load restrictions would have been needed on the Richardson Four-Lane, Farmers Loop, and College Road sections. The other four roadway sections showed excessive deflection levels for varying periods of time. Using the .050" maximum criteria indicates that the McGrath Road and Fairbanks-Anchorage Highway (Ester - Ten Miles West) sections were inadequate to support frequently repeated 18,000 pound axle loadings at any time during the spring or summer of 1972. This was also evidenced by the fact the BST pavement on the Fairbanks-Anchorage Highway section required frequent patching during 1972, since sections did break up under traffic loadings. McGrath Road, being a local service type road, is not commonly subjected to high axle loadings.

Results of the AASHO road test showed that deflections are directly proportional to axle loadings, at least in the range of axle loadings from 7,000 to 22,500 pounds. Therefore, if for a given roadway section the CGRA rebound deflection is 0.10", a 50% reduction in maximum axle loadings should be imposed to assure that actual field deflections do not exceed 0.05".

Air temperature data from Fairbanks International Airport, during the deflection observation period, is presented in Figure 9. This data may be useful in determining when to impose and remove "spring load restrictions." Because we have only one year of observations, covering only one geographic area, no firm conclusions can be reached in this regard. However, the data does show that peak spring deflections can occur very quickly after average daily air temperatures rise above 32°F. At the time of peak deflections on five of the seven sections studied, the average air temperatures had been above 32° for only four days, with a net thawing index of 31 degree-days. By the end of May, at which time the net thawing index was 480 degree-days, all sections had deflections which were at least 40% lower than the observed spring maximums. The two sections still having excessive deflections by this time continued to deflect excessively throughout the summer, as discussed previously.

For the various sections observed, the rates of decrease in deflections with time after the spring peak were quite variable, and appear to be related to the properties and locations of the specific sections in addition to air temperatures. Therefore, it appears that repeated observations with the Benkleman Beam are necessary to accurately determine whether load restrictions are required for a given section, the necessary percentage of reduction below maximum loadings, and the time after which restrictions can be removed.

Discussion

Berkleman Beam deflection surveys present a simple means of assessing the structural adequacy of an existing pavement system. This information is particularly useful in evaluating roadways prior to paving if the roadway is unpaved, or prior to reconstruction and repaving if the old roadway surfacing has deteriorated. Approximate additional thicknesses of granular base course materials required to reduce excessive Benkleman Beam deflections to various designated levels are shown by Figure 10, taken from "A Guide to the Structural Design of Flexible and Rigid Pavements in Canada," by the Canadian Good Roads Association. To determine the actual maximum deflection level for a given pavement it is necessary either to measure deflections at the time of maximum weakness of the pavement structure or to apply a correction factor to the deflection levels observed at some other time. At times when the base and subbase layers are frozen, deflection levels will be very low and no information can be gained. Through the thawing season, deflection levels will vary with time, as indicated by Figures 2 to 8. Because of the critical timing and very short period of extreme weakness during seasonal thawing, it is desirable to evaluate roadway deflections at some other time and to apply a correction factor to estimate the maximum spring deflection level. Canadian experience has led to the recommendation by the Canadian Good Roads Association that maximum spring deflections be estimated by observing the fall deflection levels and applying a correction factor of 2.5

The average spring to fall deflection ratio for Canada, according to the CGRA, was 1.63. The 2.50 value was selected as a reasonable upper limit. Canadian attempts to correlate this ratio with subgrade soil type, pavement structure thickness, or severity of freezing conditions have been unsuccessful. However, the ratio was found to vary from area to area, indicating that the overall climate is a significant factor.

For the Fairbanks area study, ratios of spring maximum deflections were calculated for the observation dates of July 14 and August 24, 1972, as shown by Figures 11 and 12. These ratios indicate that sections having relatively high deflections during the summer and early fall are also likely to have higher spring deflection ratios than areas with low summer deflections. The data also indicate that peak spring to mid-July deflection ratios are significantly less variable than the spring to late August ratios. August ratios show that, for the Fairbanks area, spring to fall ratios are significantly higher than those observed in Canada, possibly due to the extreme severity of the Fairbanks winters, combined with very low rainfall in the spring and early summer.

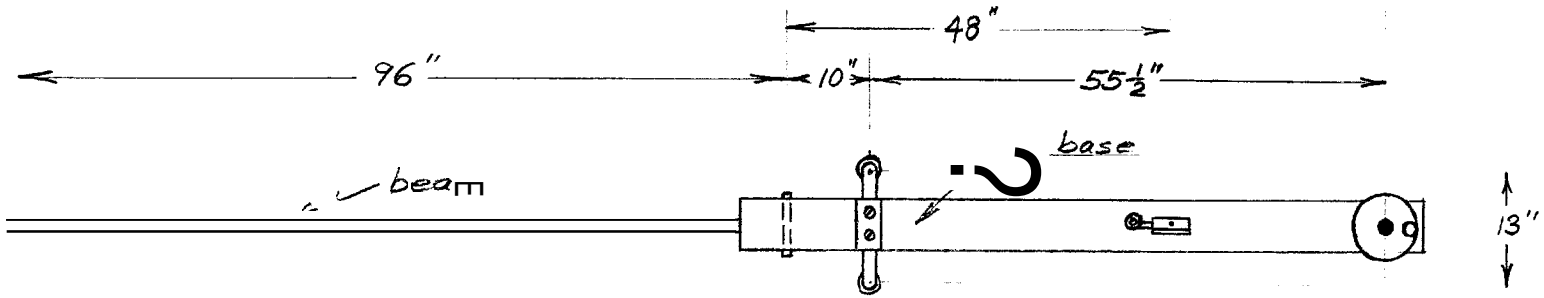
Conclusions

Based on the observations presented herein, estimates of the probable maximum Benkleman Beam deflection levels during spring thawing for Fairbanks and similar areas of the Alaskan interior, may be made most reliably by measuring deflection levels during mid-summer and applying a variable factor determined from the upper limit or "Design Value" line on Figure 12. This factor will vary roughly from 1.5 to 3.5, depending on the observed maximum summer deflection level, determined as the average of the measured deflections plus two standard deviations.

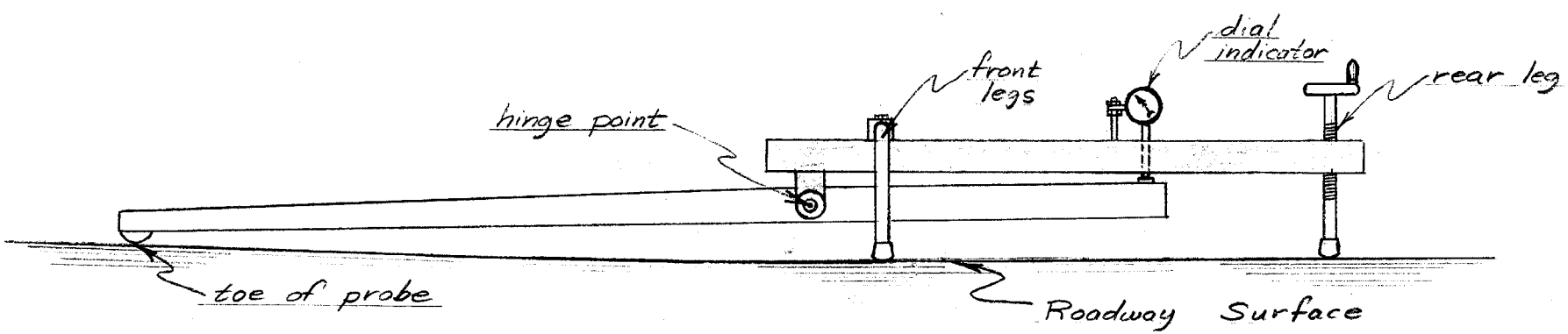
Because of the variability of spring to summer deflection ratios, observations of deflections at times other than the spring thawing period are not adequate to predict reliably whether spring loading restrictions should be imposed on a given roadway section. Weekly deflection studies, starting as soon as the average daily air temperatures rise above 32°F, appear to be an excellent basis of determining the need for load restrictions along with the percentage reductions required.

Climatic variations between the coastal and interior areas of Alaska, in addition to wide variations in coastal climate, can be expected to result in different spring to fall deflection patterns for different areas. Because of these variations it is recommended that the seasonal deflection variations be studied at various coastal locations in Alaska, over a one year period, by a pattern of deflection observations on selected roadways at one week intervals during the spring thawing season, followed by monthly observations until refreezing occurs. This data can then be used to determine appropriate factors for predicting whether any given roadway should receive an additional granular overlay to strengthen the pavement system prior to repaving, on the basis of a single deflection survey made during the summer or fall period.

Benkleman Beam Diagram



Top View



Side View

Fig e 1

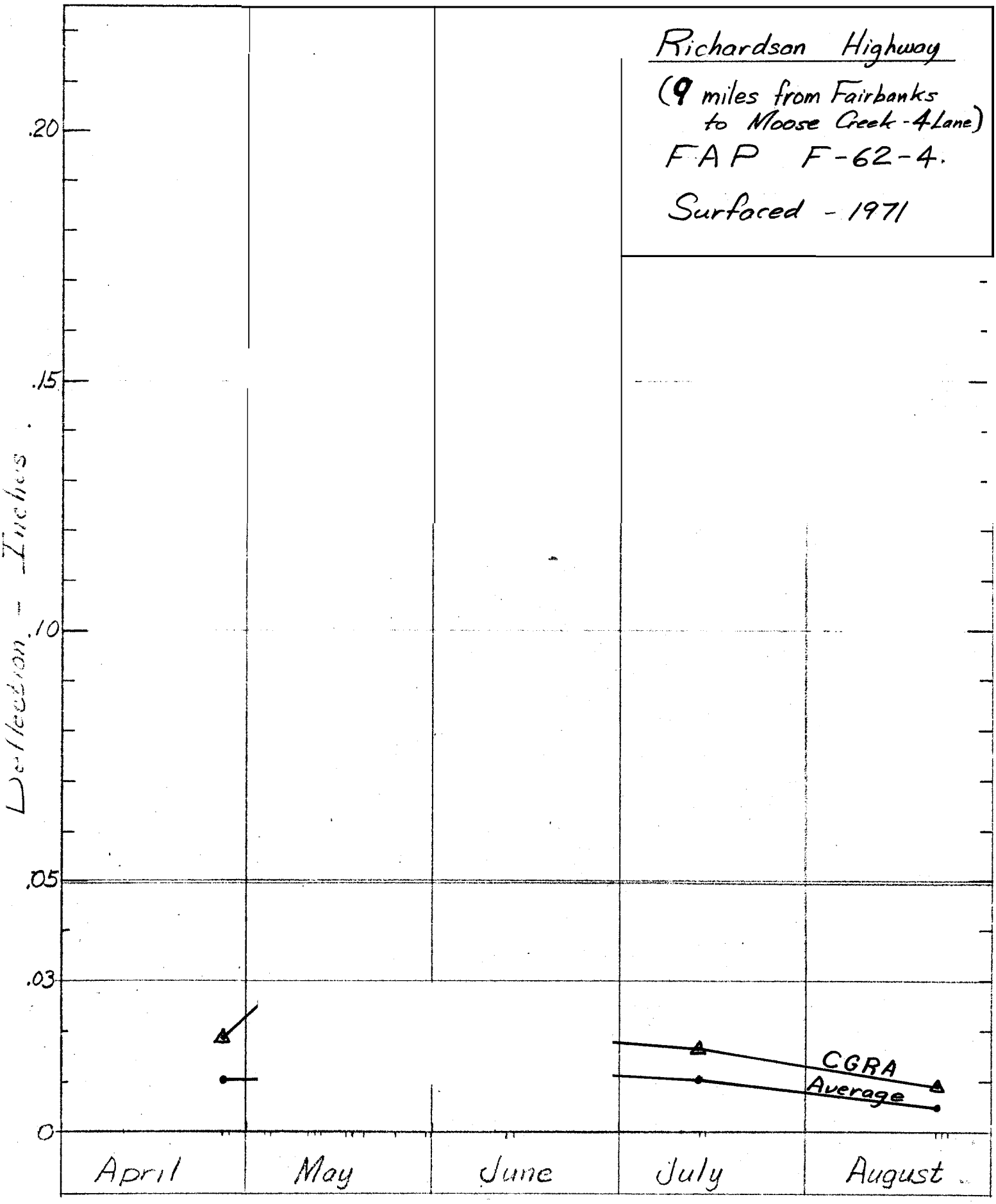

Richardson Highway
(9 miles from Fairbanks to Moose Creek - 4 Lane)
FAP F-62-4.
Surfaced - 1971
.20
.15
.10
.05
.03
0
Deflection - Inches
CGRA
Average
April
May
June
July
August
Observation Dates - 1972

Figure 2

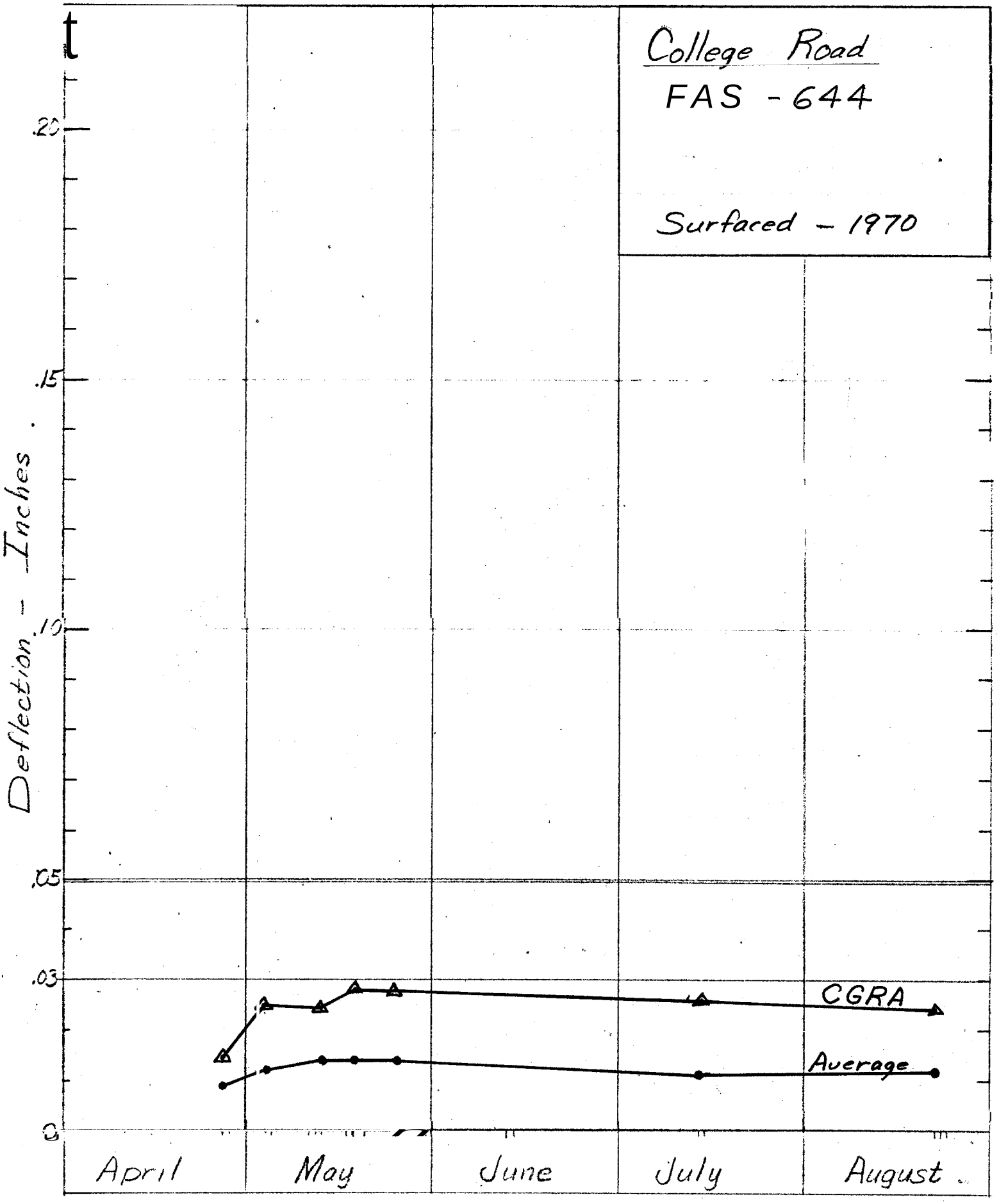

College Road
FAS - 644
Surfaced - 1970
.20
.15
.10
.05
.03
0
Deflection - Inches
CGRA
Average
April
May
June
July
August
Observation Dates - 1972

Figure 3

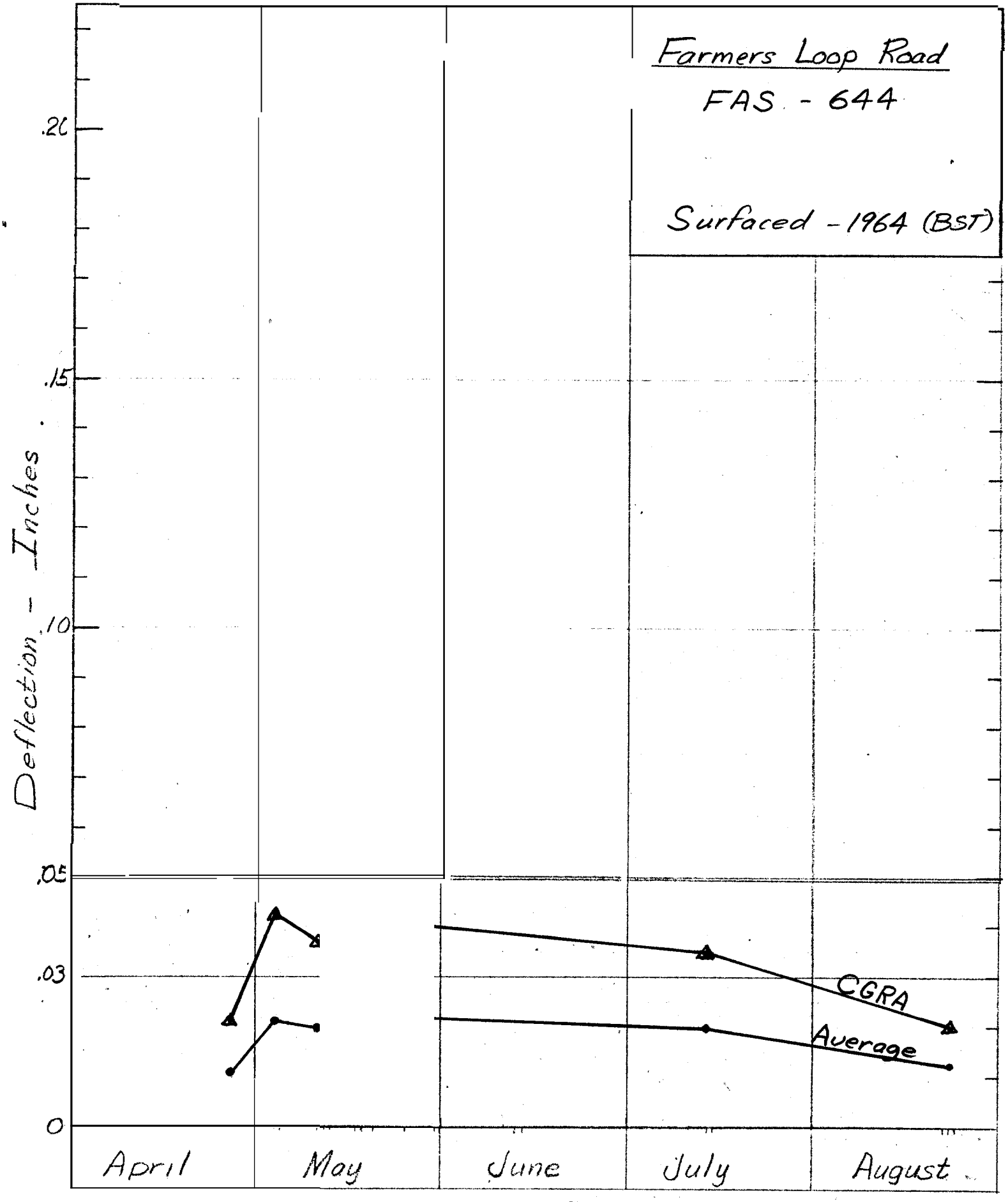

Farmers Loop Road
FAS - 644
Surfaced - 1964 (BST)
.20
.15
.10
.05
.03
0
Deflection - Inches
CGRA
Average
April
May
June
July
August
Observation Dates - 1972

Figure 4

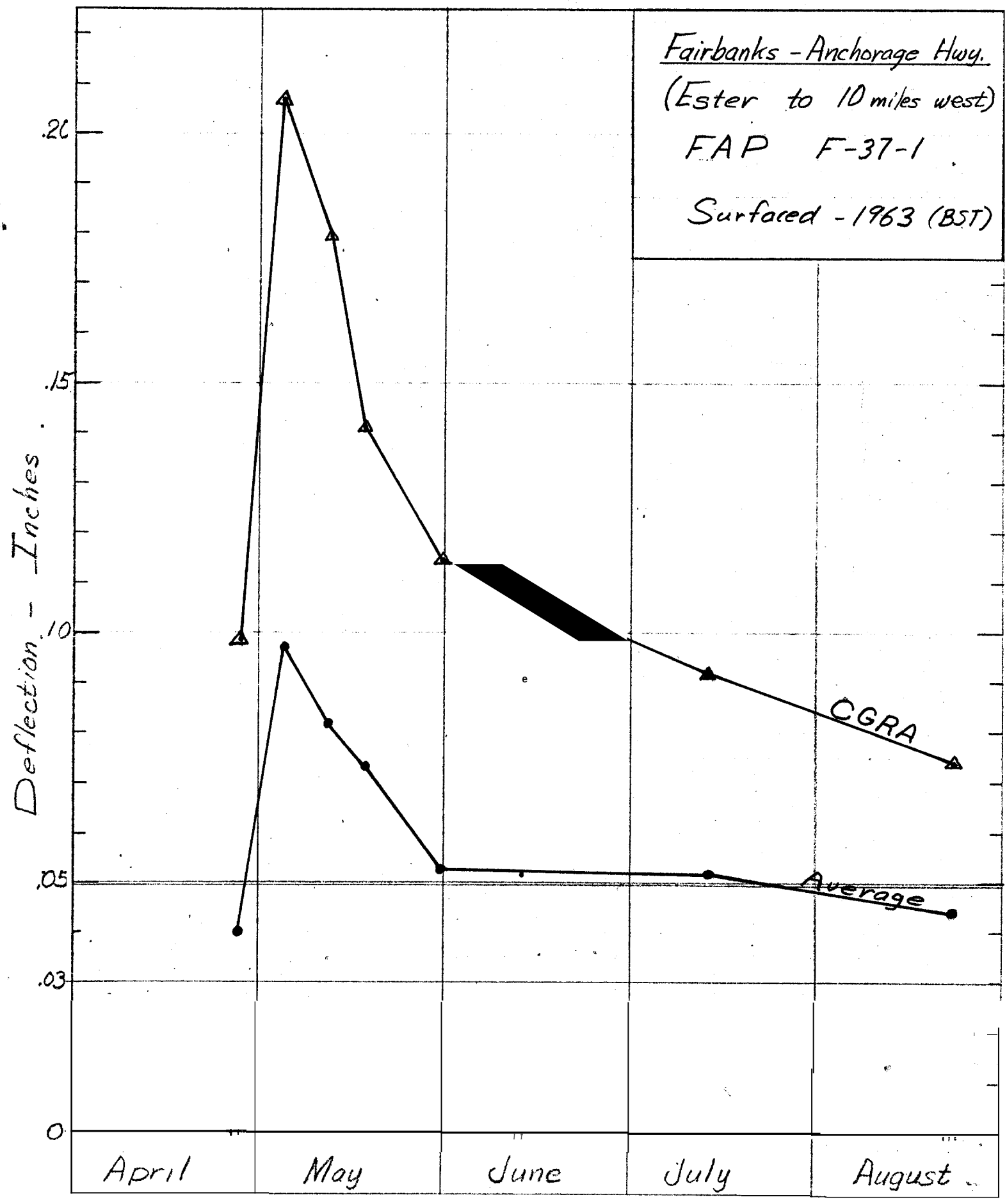

Fairbanks - Anchorage Hwy.
(Ester to 10 miles west)
FAP F-37-1
Surfaced - 1963 (BST)
.20
.15
.10
.05
.03
0
Deflection - Inches
CGRA
Average
April
May
June
July
August
Observation Date - 1972

Figure 5

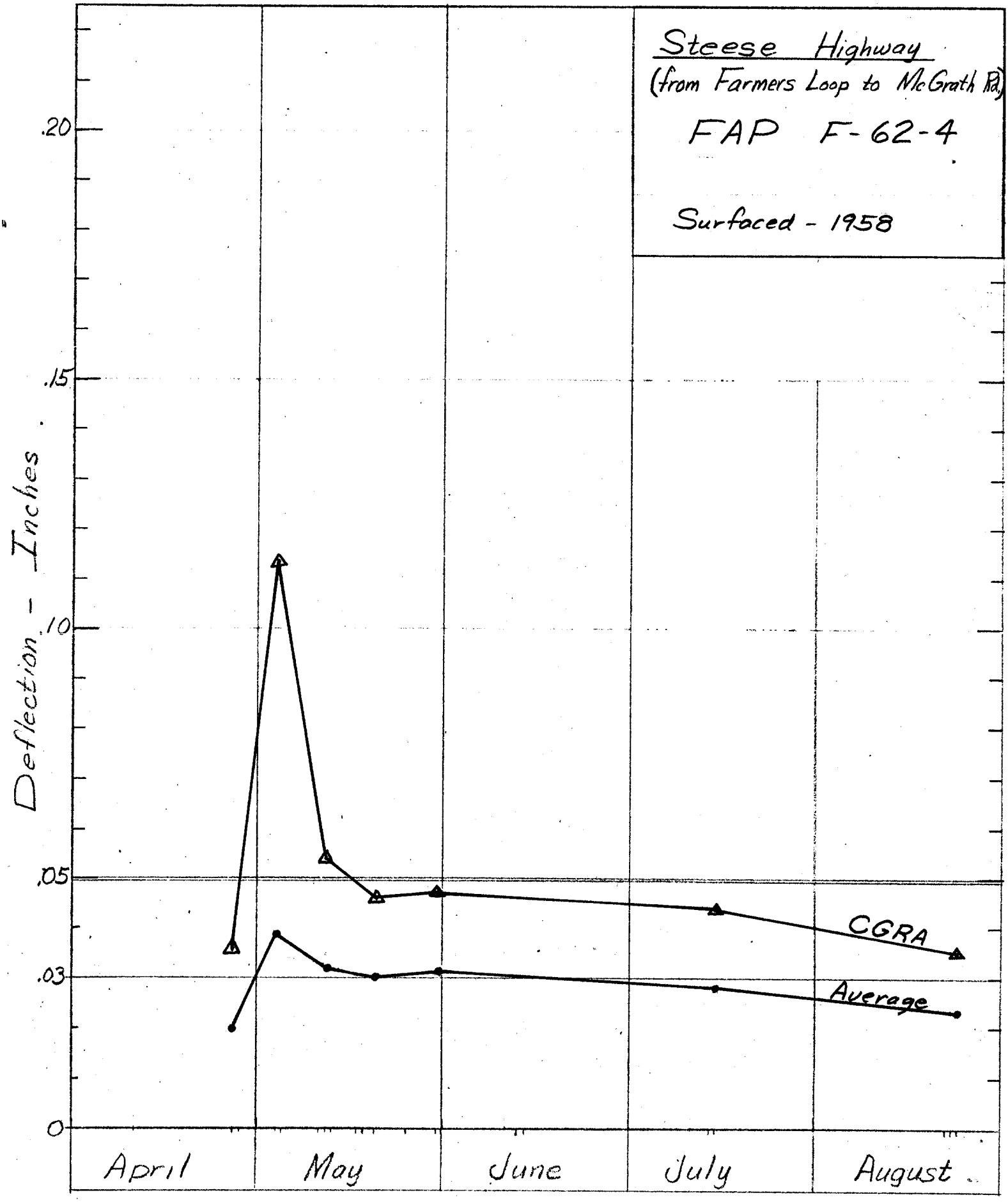

Steese Highway
(from Farmers Loop to McGrath Rd.)
FAP F-62-4
Surfaced - 1958
.20
.15
.10
.05
.03
0
Deflection - Inches
CGRA
Average
April
May
June
July
August
Observation Dates - 1972

Figure 6

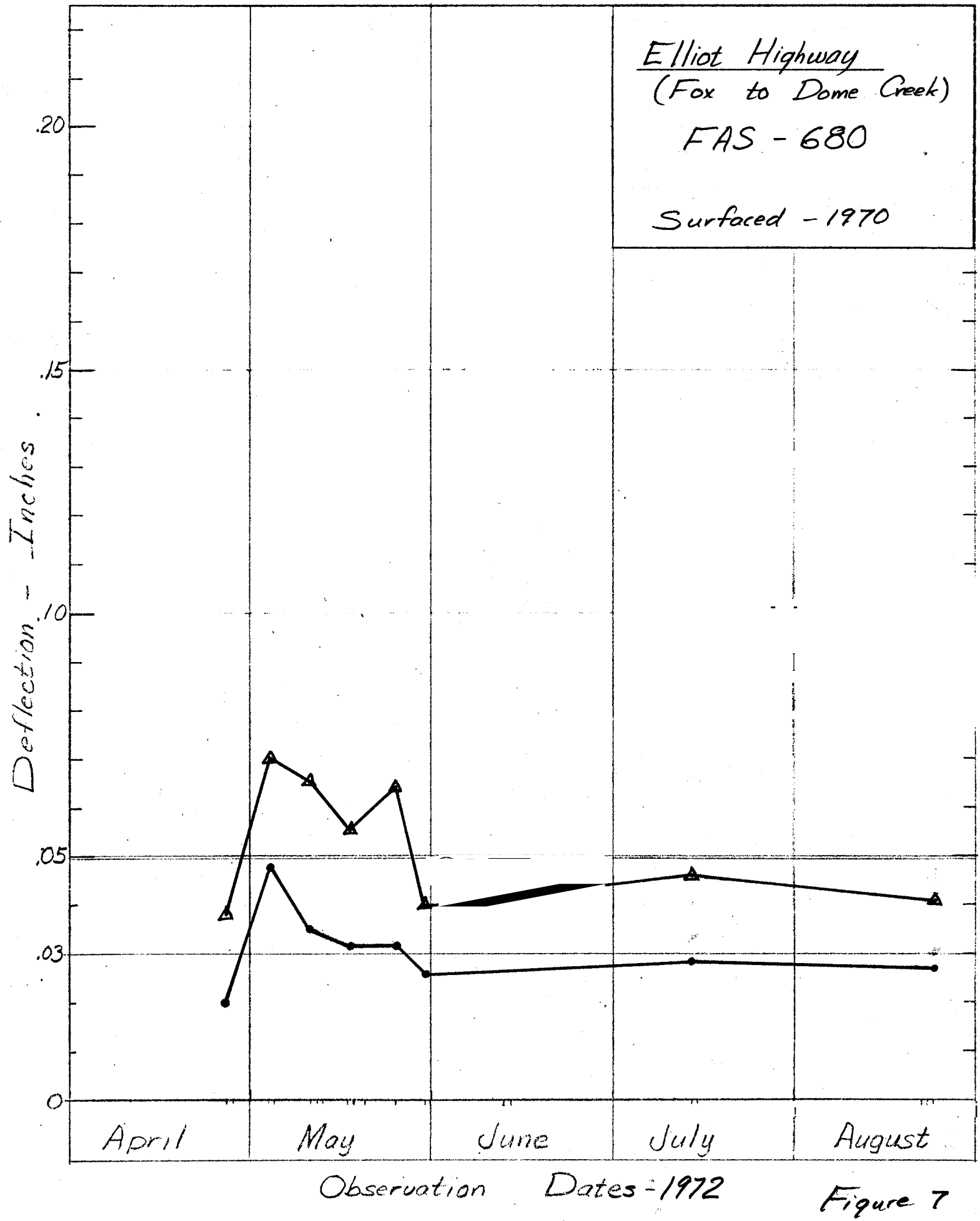

Elliot Highway
(Fox to Dome Creek)
FAS - 680
Surfaced - 1970
.20
.15
.10
.05
.03
0
Deflection - Inches
April
May
June
July
August
Observation Dates - 1972

Figure 7

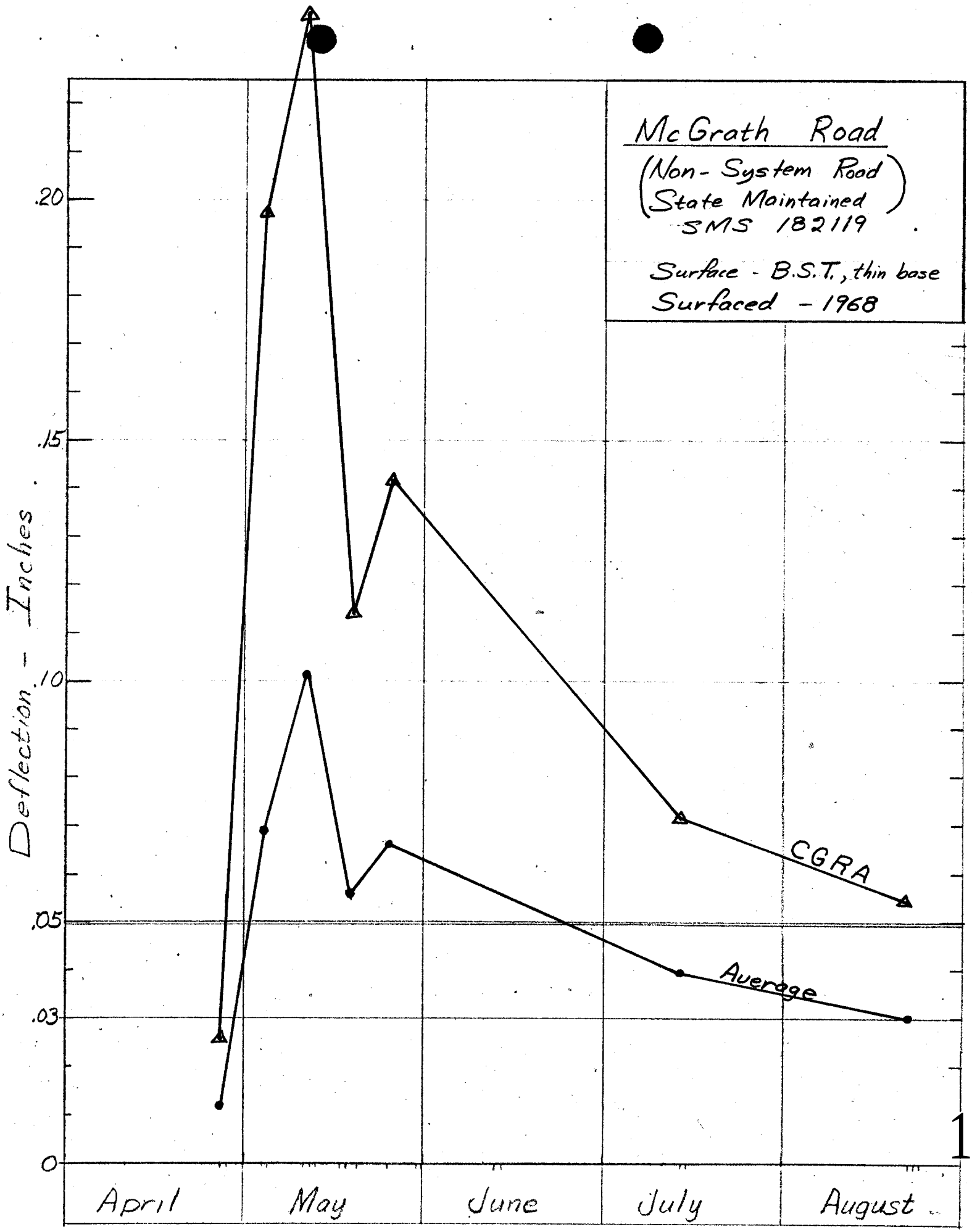

McGrath Road
(Non-System Road
State Maintained
SMS 182119)
Surface - B.S.T., thin base
Surfaced - 1968
.20
.15
.10
.05
.03
0
Deflection - Inches
CGRA
Average
April
May
June
July
August
Observation Dates - 1972

Figure 8

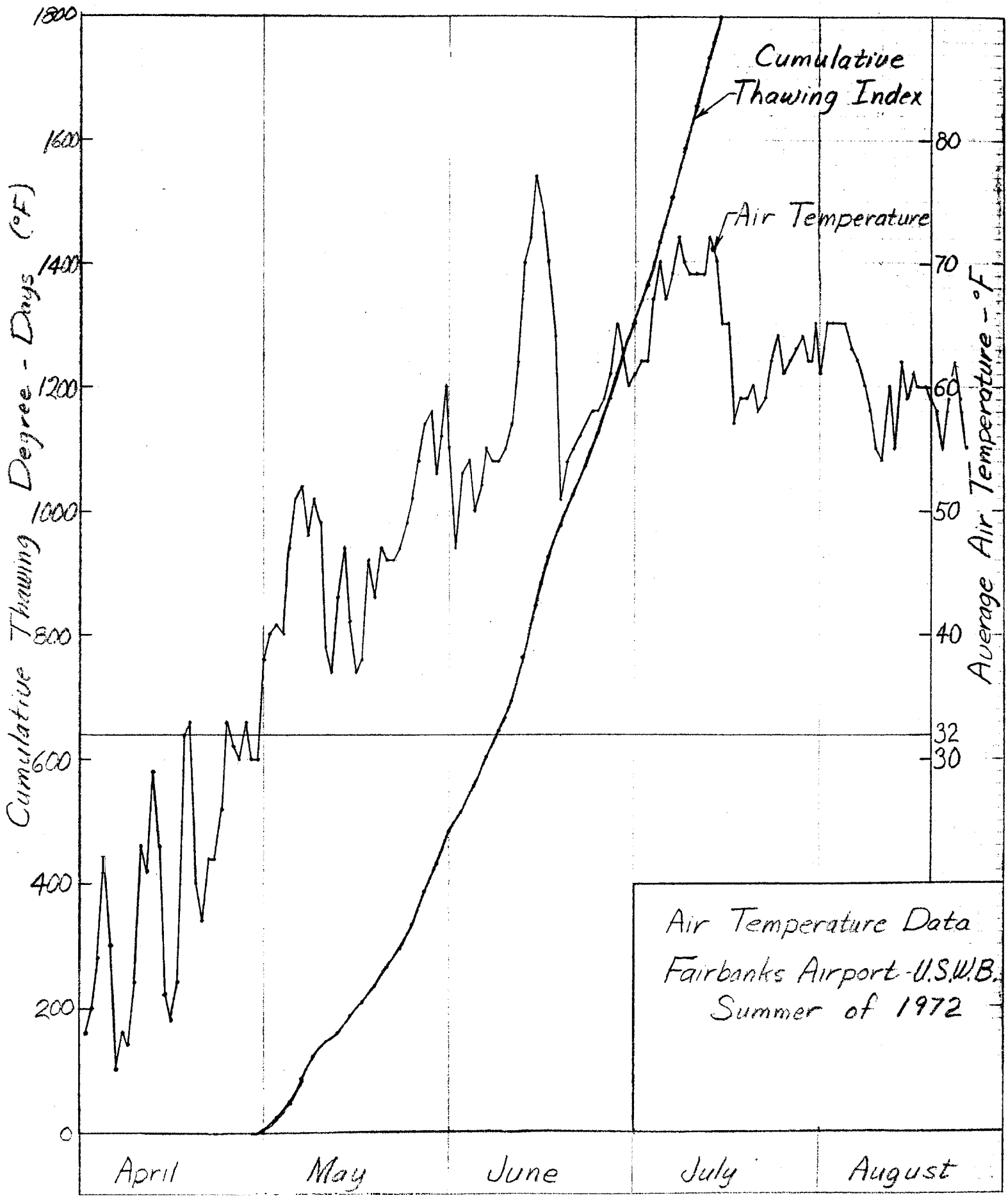

Cumulative Thawing Index
Air Temperature
Cumulative Thawing Degree - Days (°F)
Average Air Temperature - °F
1800
1600
1400
1200
1000
800
600
400
200
0
80
70
60
50
40
32
30
April
May
June
July
August
Air Temperature Data
Fairbanks Airport - U.S.W.B.
Summer of 1972

Figure 9

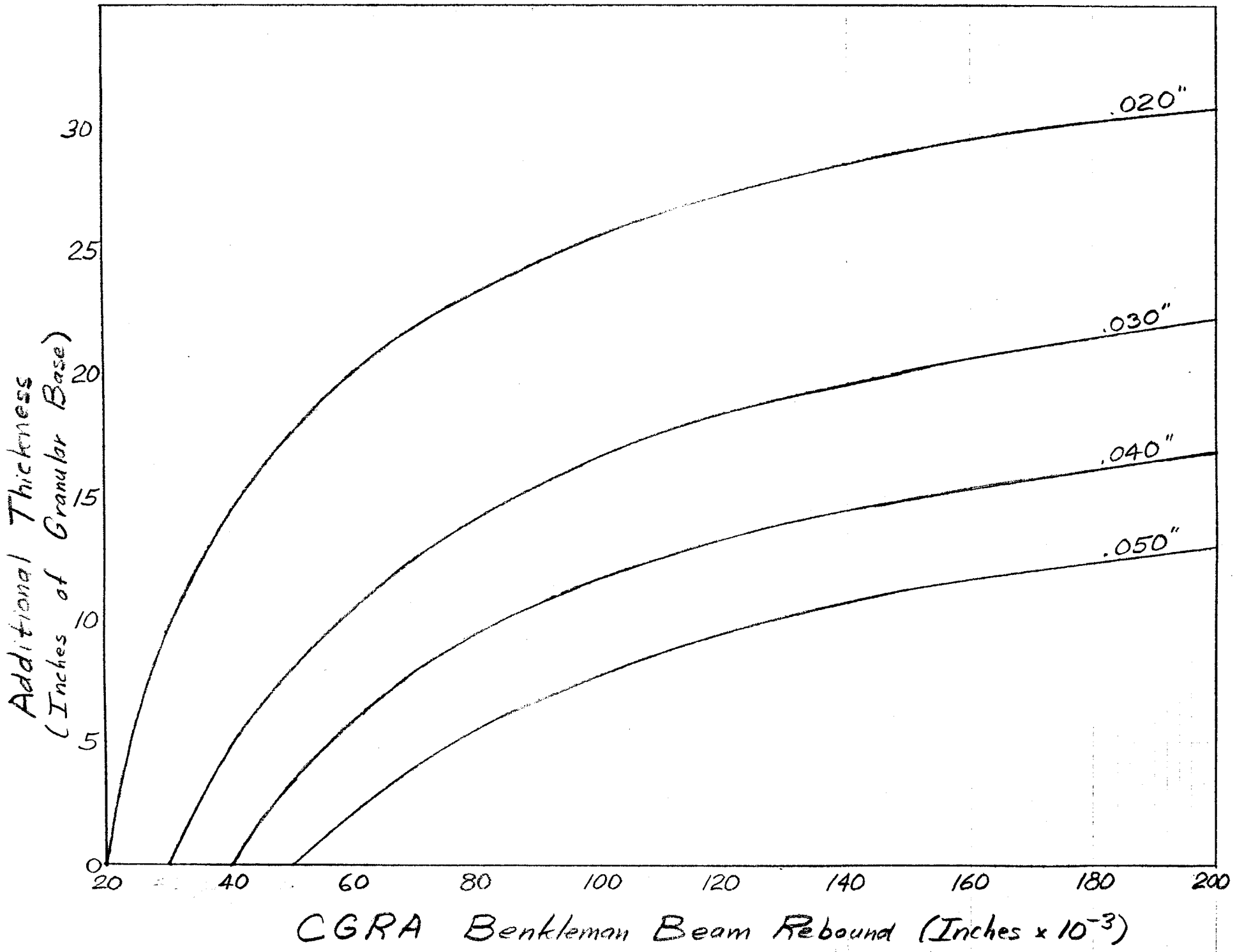

.020"
.030"
.040"
.050"
30
25
20
15
10
5
0
20
40
60
80
100
120
140
160
180
200
Additional Thickness
(Inches of Granular Base)
CGRA Benkleman Beam Rebound (Inches x 10^{-3})

Figure 10

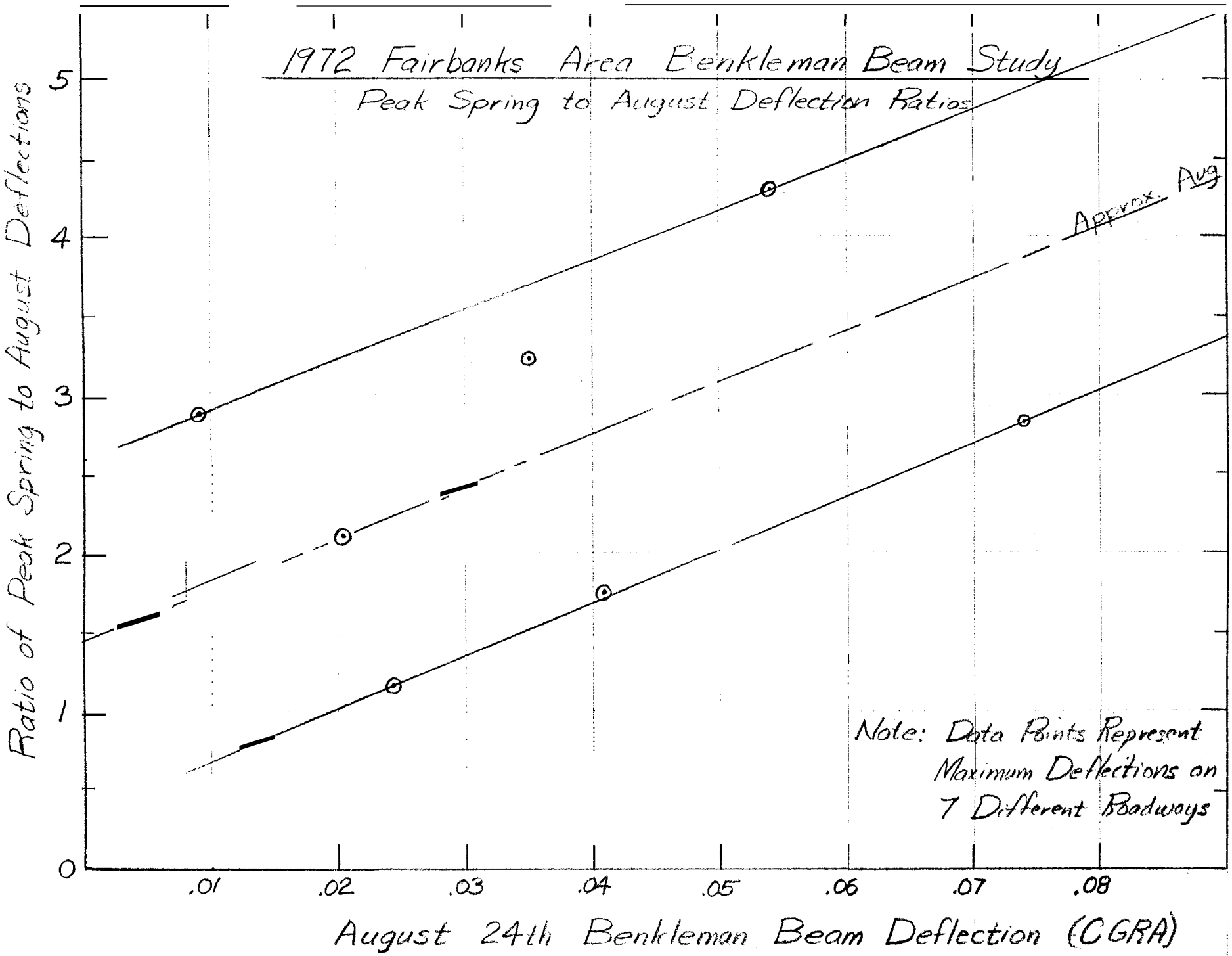

1972 Fairbanks Area Benkleman Beam Study
Peak Spring to August Deflection Ratios
Ratio of Peak Spring to August Deflections
0
1
2
3
4
5
.01
.02
.03
.04
.05
.06
.07
.08
Approx. Avg
Note: Data Points Represent Maximum Deflections on 7 Different Roadways
August 24th Benkleman Beam Deflection (CGRA)
Average + 2 · (Standard Deviation)

Figure 11

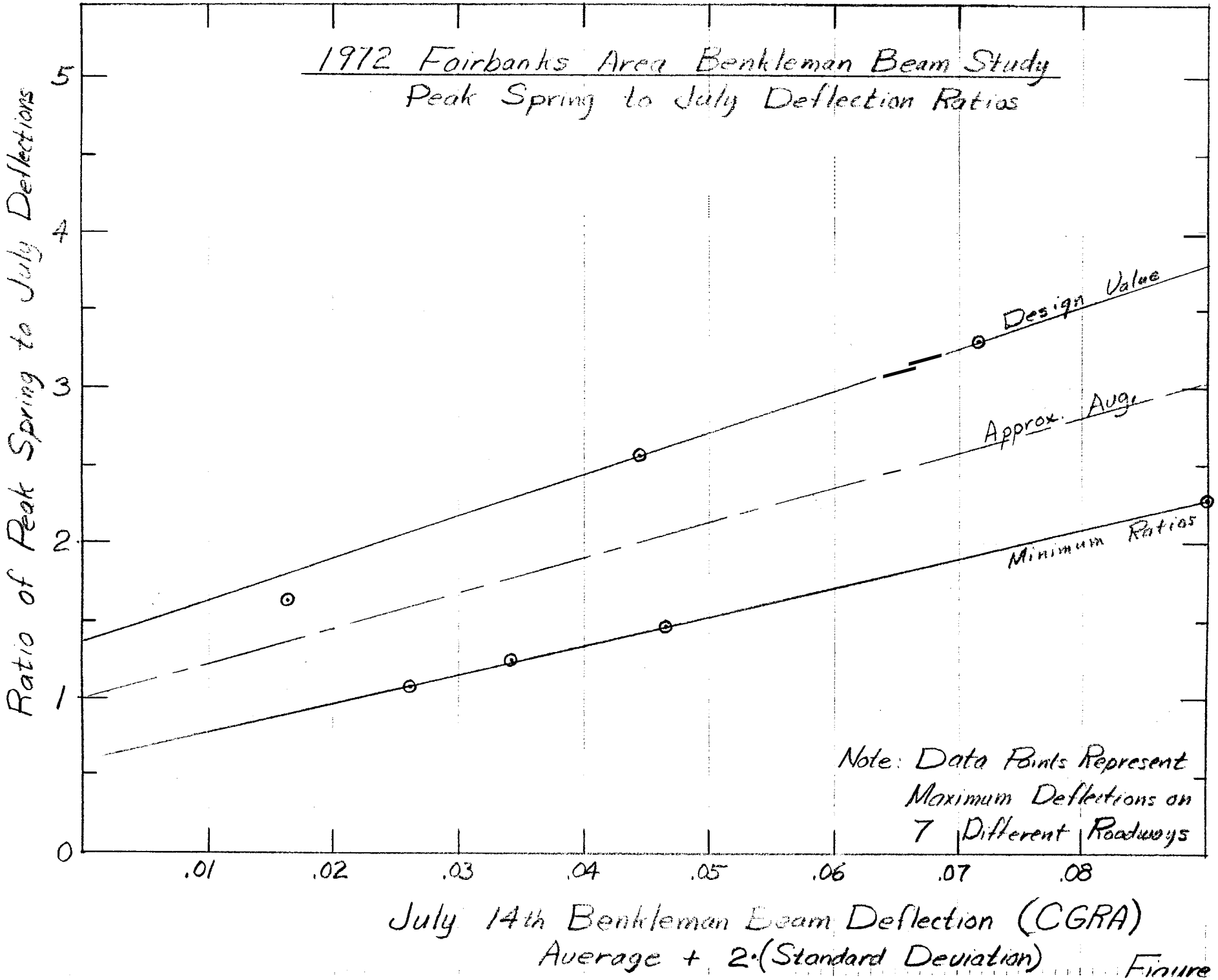

1972 Fairbanks Area Benkleman Beam Study
Peak Spring to July Deflection Ratios
Ratio of Peak Spring to July Deflections
0
1
2
3
4
5
.01
.02
.03
.04
.05
.06
.07
.08
Design Value
Approx. Avg.
Minimum Ratios
Note: Data Points Represent
Maximum Deflections on
7 Different Roadways
July 14th Benkleman Beam Deflection (CGRA)
Average + 2·(Standard Deviation)

Figure 12

EXAMPLE COMPUTATION

OF STANDARD DEVIATION

1. The 10 data points are reported in thousandths of an inch. (See next page.)

2. First the average of the data is found. Here, it is 33.7 thousandths.

3. Next, calculate the differences between the average and each data point. For example, for the first point the difference is 42 - 33.7 = 8.3, and for the second data point, 33.7 - 31 = 2.7 (see column 3, next page).

4. Each of these differences is squared. (See Column 4 on next page.)

5. The squared differences are then totaled. Here the total is 528.2.

6. To calculate the standard deviation, the total of the squared differences is divided by the number of data points minus one.

$$\frac{528.2}{10-1} = \frac{528.2}{9} = 58.7$$

7. The square root of this number is the standard deviation. S.D. = 7.7.

8. Calculate the CGRA Maximum Deflection Level : CGRA = Average + 2 (S. D.) in this case CGRA = 33.7 + 2(7.7) = 49.1.

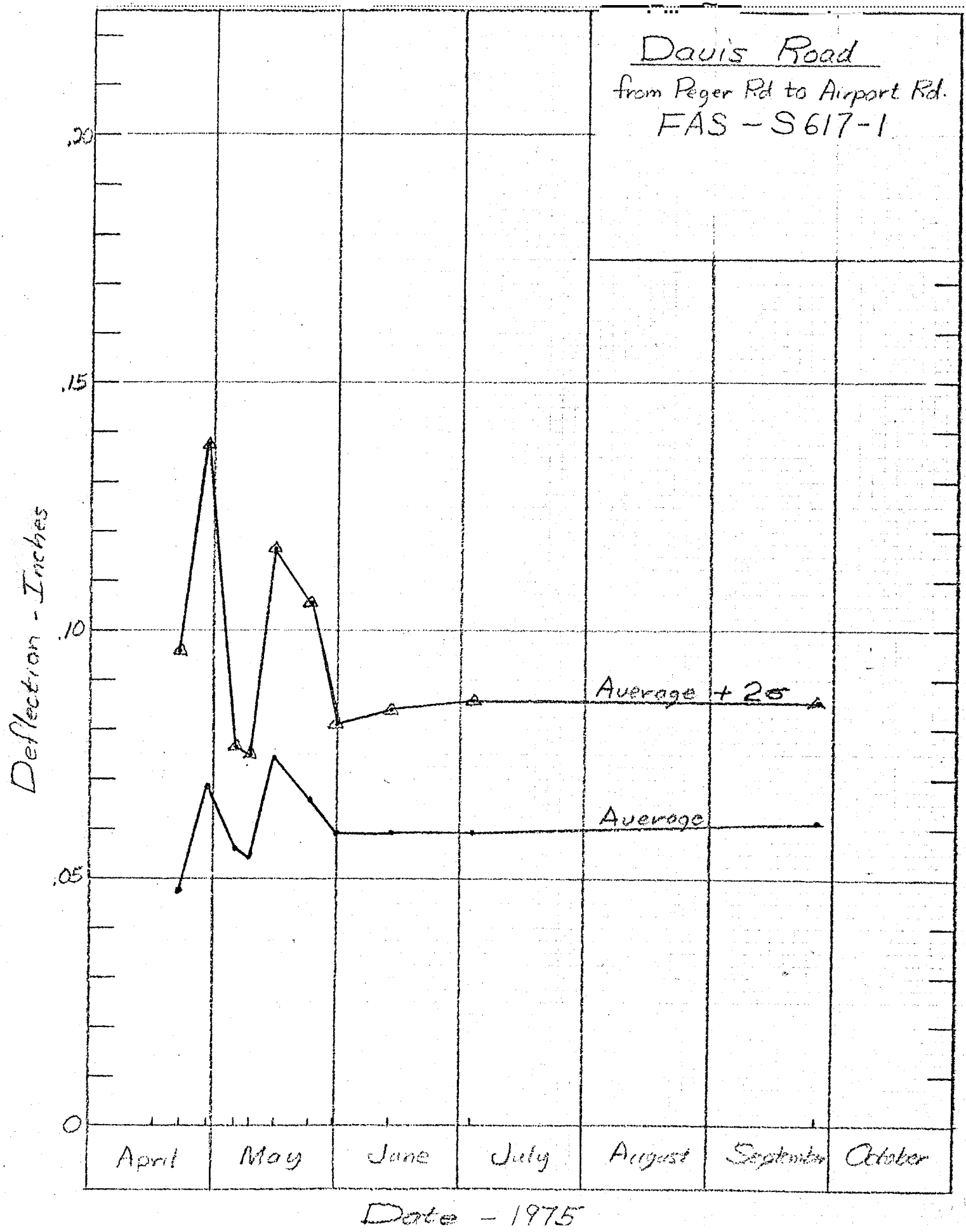
Data Number	Thou.	Diff.	Diff. Sqrd.
1	42	8.3	68.9
2	31	2.7	7.3
3	35	1.3	1.7
4	20	13.7	187.7
5	45	11.3	127.7
6	26	7.7	59.3
7	32	1.7	2.9
8	40	6.3	39.7
9	29	4.7	22.1
10	37	3.3	10.9

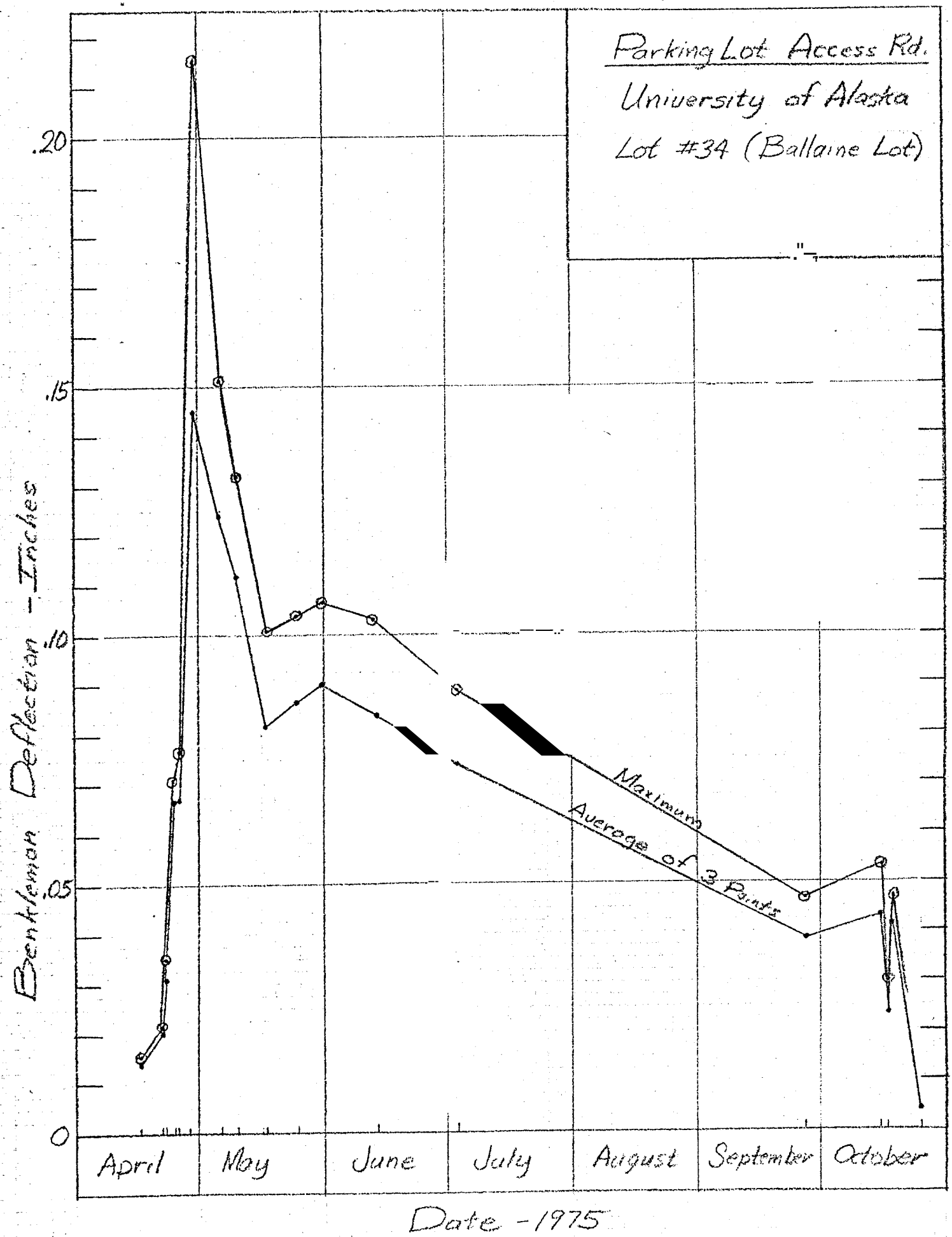
Average : 33.7 Total : 528.2

Standard Deviation = $\sqrt{\frac{528.2}{10-1}} = \sqrt{58.7} = 7.7$

BY..... DATE..... SUBJECT..... SHEET NO..... OF.....

CHKD. BY..... DATE..... JOB NO.....




Parking Lot Access Rd.
University of Alaska
Lot #34 (Ballaine Lot)
.20
.15
.10
.05
0
Benkelman Deflection - Inches
Maximum
Average of 3 Points
April
May
June
July
August
September
October
Date - 1975