Research Report
KTC-90-5

INVESTIGATION OF PREMATURE CRACKING ON THE NATIONAL TURNPIKE, JEFFERSON COUNTY

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Commonwealth of Kentucky

and

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16. Abstract

This report discusses the investigation of the premature cracking that occurred on the National Turnpike, Jefferson County (1989). A detailed distress survey was performed evaluating each slab throughout the project site. Falling Weight Deflectometer testing was performed on every third slab. In addition subgrade samples were taken, along with the installation of three water monitoring wells. Laboratory test were conducted on the subgrade samples.

Damage that occurred near the curb inlets and manholes is probably due to insufficient compaction. The remaining damage is most likely related to the combined effects of a very soft subgrade, high water tables, and traffic loads that are applied to the saturated or near-saturated subgrade.

Because complete reconstruction of this project is economically unfeasible, an intense maintenance program is recommended.

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INTRODUCTION

The National Turnpike, in Jefferson County (Project No. F 841-1(39)) was completed on May 3, 1989. At the recommendation of the Department of Highways' Geotechnical Branch, a considerable amount of subgrade stabilization was performed during construction. However, pavement cracking and settlement have occurred throughout the project since completion. On September 27, 1989 the Transportation Cabinet and FHWA requested that the Transportation Center investigators be involved in an attempt to determine the cause of the premature pavement failure and suggest possible remedial actions.

The original design section for the new lanes was to be eight inches of unreinforced Portland cement concrete on three inches of dense-graded aggregate. The existing portion of the road where widening was to be done was to have been eight inches of asphaltic concrete base and surface on ten inches of dense-graded aggregate. Early in the construction of the project a number of problems developed. The following information on those problems, construction procedures, and sequences was obtained from conversations with personnel from the Department of Highways. Construction personnel indicated there were two swampy locations where heavy equipment had trouble operating. These areas were at the South Park Drive Inn and at the intersection of National Turnpike and Sinclair Street. The Geotechnical Branch of the Division of Materials recommended the subgrade be undercut and replaced with 12 or 24 inches of crushed limestone aggregate (No. 3's). During placement of the No. 3 aggregate, a roller could not be used because of the soft subgrade. A grader was pulled across the area to place the stone. Construction personnel also indicated there were problems with the dense grade aggregate (DGA) settling down into the No. 3 stones during placement. The DGA could not be properly compacted because it tended to aggravate the problem of filtering into the stabilized rock layer. Pumping of the DGA under heavy loading was observed prior to the placement of the portland cement concrete. Some grinding was performed because the concrete slabs had settled before the road was open to traffic.

CONSTRUCTION SEQUENCE

The National Turnpike was constructed in two phases. The exiting road remained in service while the median and northbound driving lanes were constructed. The exiting pavement was then removed and the southbound lanes were constructed while traffic was routed onto the new northbound lanes.

On May 31, 1988, the first concrete placement was initiated in the northbound lanes south of the Southern Ditch Bridge. The northbound mainline was completed June 1, 1988. Several small placements such as curbs and gutters were made on the northbound lanes until July 1, 1988. The northbound lanes were opened to traffic on July 8, 1988. Concrete placement on the southbound lanes initiated August 11, 1988 and was completed August 12, 1988. The southbound lanes were opened to traffic December 14, 1988.

FIELD INSPECTION

On October 11, 1989, Transportation Center personnel inspected the National Turnpike between the Outer Loop and Fairdale Road. From that visual inspection, it appeared there where isolated areas where severe premature cracking had occurred. On October 19, 1989, a detailed inspection was performed on each slab starting at the Southern Ditch Bridge and continuing south to Fairdale Road (approximately 4,937 feet). All surface distress was logged on inspection sheets which are contained in Appendix A. Information gathered from the inspection revealed cracking in the area of the intersection of Sinclair Street and the National Turnpike (STA 84+66 to STA 85+15), and in an area starting north of the drive-in theater (STA 106+25) continuing south to Fairdale Road (STA 117+38).

FIELD TESTING

Falling Weight Deflectometer

Falling Weight Deflectometer (FWD) Tests were performed on every third joint, in both lanes, and in both directions. These tests were conducted between the Southern Ditch Bridge and Fairdale Road. Testing was conducted between October 19, 1989 - October 24, 1989. Estimations of load transfer and subgrade stiffness values were derived from the FWD test data. The efficiency of load transfer at a joint was determined by placing the loading plate of the FWD on one side of the joint and positioning the joint between the No.2 and No.3 sensors. The efficiency of load transfer was estimated as the ratio of the difference between the deflection at the No. 3 and No. 2 sensors. Theoretically, a dowel at a joint is considered 100 percent efficient when the dowel transfers one-half of the applied load from one slab to an adjoining slab. Subgrade stiffness values were estimated by dividing the applied load by the No. 1 sensor deflection. Load transfer and subgrade stiffness values are contained in Figures 1 through 4. Stiffness contour maps are contained in Appendix B. It appears that there is some correlation between the areas of low stiffness and those areas which are severely cracked. Cracking was most severe at the intersection of Sinclair Street and the National Turnpike (STA 84+66 to STA 85+15), and in an area starting north of the drive-in theater (STA 106+25) continuing south to Fairdale Road (STA 117+38). Low stiffness values were also determined for these areas.

Subgrade Investigation

Six inspection holes were drilled on November 2, 1989. The first three holes were drilled adjacent to the drive-in theater in the northbound, outside lane (Station 109+34). The concrete was approximately 8.5 inches thick. The underlying DGA varied from three inches to six inches, and the stabilized rock blanket was approximately 24 inches. The stabilized rock appeared to be very loose (There were problems with the No. 3 stone caving back into the open inspection hole). Hollow stem augers were used on the third hole to reach the subgrade. Thin-wall tube sample were obtained from depths of 34.5 inches to 64.5 inches and from 64.5 inches to 94.5 inches.

A forth hole was drilled at Station 91+46 in the northbound, outside lane. The concrete was 8.5 inches thick, and the boundary between the DGA and the stabilized rock was not distinguishable. The total thickness of the DGA and the stabilized stone layer was 17 inches thick. The stabilized rock was sufficiently loose to be removed by hand. One thin-walled tube sample was obtained from 28.5 inches to 58.5 inches.

The fifth hole was drilled at Station 75+64 in the northbound, outside lane. The concrete was 8.5 inches thick and the combined DGA and the stabilized rock was approximately 16 inches thick. A thin-walled tube sample was collected from a depth of 25 inches to 55 inches.

The sixth hole was drilled at Station 74+77 in the southbound, outside lane. The concrete was 6.5 inches in thickness, and the underlying DGA was 5.5 inches thick. The DGA was placed directly on the subgrade.

Water Monitoring Wells

Three water monitoring wells were placed in the study area on November 9, 1989. One well was placed in front of the drive-in theater, in the center turning lane of the National Turnpike (Well 1). Well 1 was drilled to a depth of 13.4 feet. The subgrade was moist but no free water was encountered at the time of installation.

Two wells were placed in the vicinity of Sinclair Street, in the center turning lane of the National Turnpike. The first well was installed to a depth of 13.6 feet (Well 2). At Well No. 2, the subgrade appeared to be saturated. Water was observed rising in the well immediately after installation. The water stabilized at a depth of 2.2 feet below the surface. An additional hole (Well No. 3) was drilled approximately five feet north of Well 2. A thin-walled tube sample was collected from a depth of 31 inches to 73 inches. Well No. 3 was further augered to a depth of 8.5 feet. No free water was encountered. Figure No. 5 shows the well readings since installation. Information gathered from the monitoring wells indicates that the water table reaches the base of the stabilized stone layer. During periods of heavy rain, it is probable the water table is penetrating the stabilized stone layer.

Slab Elevations

On November 16, 1989, elevations were obtained at the center of every third slab throughout the study area. Elevations were confined to the outside lanes (northbound and southbound) and the northbound turning lane. Elevations were obtained again on September 19, 1990 at the same locations. Figure 6 shows the change in elevation that has occurred in the north and southbound lanes since the initial elevations were obtained. The greatest amount of settlement has occurred in the southbound lanes in the area of Sinclair Street and in the northbound and southbound lanes form approximately Station 71+00 to Station 79+00. This latter location is in the area of a small five-foot high fill, which has apparently settled.

Joint Inspection

Five joints were inspected throughout the site at locations where FWD tests indicated the possibility of poor load transfer. Six inch cores were obtained approximately six inches from the joints. No damage or cracking was noticeable at the bottom of the slabs. It appears the poor load transfer was not due to damaged slabs but was due to a stiffer subgrade which did not permit the loaded slab to deflect enough to transfer a significant portion of the load to the unloaded slab. A more detailed discussion of this phenomenon will be discussed under the section entitled "Discussion and Conclusions".

Cone Penetrometer Data

Cone penetrometer readings obtained by Cabinet personnel indicate there are three areas of weak subgrade at Station 86+47, Station 95+47 and Station 99+97 (Figure 7). The cone penetrometer data are scattered but the values indicate soft to very soft subgrade soils are present.

COMPUTER / STRUCTURE ANALYSIS

A structural analysis of the pavement was performed using ELSYM5. ELSYM5 is a linear elastic computer program. A modulus of 3 million, poisson ratio of 0.15 and an 8-inch thickness was assumed for the concrete pavement. A modulus of 25,000, poisson ratio of 0.35 and a 4-inch thickness was assumed for the DGA. A modulus of 50,000, poisson ratio of 0.35 and 12-inch and 24-inch thickness were assumed for the stabilized rock zone. For the subgrade, a modulus of 2,000 and a poisson's ratio of 0.45 was assumed. A 40-kip tandem with eight tires and a tire pressure of 100 psi was assumed to be the typical load.

Results of the analysis were used to determine the state of stress at the surface of the soil subgrade for the given load. Using the above mentioned variables and a 24-inch stabilized rock zone, approximately one to two psi was estimate to be exerted at the top of the soil subgrade. This information was used to determine the magnitude of load to be used on a repeated-load test performed in the laboratory.

LABORATORY SOIL TESTS

Soil classification tests were performed on soil specimens from three areas on the National Turnpike. The laboratory tests indicated the soil was fairly uniform throughout the study area. Under the USC (Unified Soil Classification) System, the soil classifies as a CL or a ML-CL. Laboratory test results are contained in Appendix C.

A saturated, unconfined, repeated load compression test was performed on an undisturbed subgrade specimen. The specimen was loaded for one second and allowed to relax for one second at a deviator stress level of 2.0 pounds per square inch for 1,000 cycles. Results of the test are shown in Figure 8. Assuming 10,000 vehicles per day (2-way), and assuming five percent trucks (total weight equal to 80,000 pounds), results of Figure 8 indicate as much as 0.30 of permanent deformation could occur in the upper portion of the subgrade in one year. This confirms the fine-grained and somewhat plastic nature of the subgrade, as determined from the soil classification tests. This further indicates that slab settlement and movement may continue indefinitely.

DISCUSSION AND CONCLUSIONS

There are five locations where cracks in the slabs are associated with adjacent curb inlets and manholes. It is suspected that compaction around these inlets probably was not sufficient and did not provide proper support for the slabs.

However, there are two major areas where pavement damage appears to be concentrated. The first is from Station 84+50 to approximate Station 86+00. This is in the vicinity of Sinclair Street. The second major area of damage is from Station 108+20 to Station 113+20. This is near the south end of the project. There was no cone penetration data for the second major area of damage. However, Figure 7 indicates in the vicinity of Sinclair Street the subgrade is weaker than at any other location where cone data are available. This is true at all depths of penetration. The two figures in Appendix B (contours of stiffness) also show relatively weak areas in the vicinity of Sinclair Street and on the south end of the project.

Figures 1 through 4 show the stiffness of the pavement structure was greater in the southbound lanes than in the northbound lanes. As mentioned previously, the southbound lanes were constructed largely on the old roadbed. This may indicate the subgrade under the old structure had consolidated and was probably stiffer, and consequently, provided better support to the new structure.

Although not true in every case, in many instances, at locations where the stiffness curves in Figures 1 through 4 showed small peaks, there was a corresponding "valley" in the load transfer curves. The thin vertical lines in those figures illustrate that relationship. This may suggest that a stiffer base and subgrade do not permit the slab to deflect as much as a weaker base and subgrade. Therefore the slab that is under load cannot transfer as much deflection to the adjacent slab. These locations appeared to be distributed throughout the project with a noticeable number of these occurring at the south end of the project in the northbound lanes. However, it does not appear that a definitive statement can be made concerning the location of particularly weak areas when using this relationship.

A comparison of the variation of the slab from the design grade with stiffness (Figures 9 and 10) does not reveal a good correlation. However, there are dips in the slab elevation in the area near Sinclair Street and near the south end of the project. Again, these are the areas where most distress was noted.

Figures 11 and 12 show the locations of the 12-inch layer and the 24-inch layers of No. 3 stone. There appears to be little or no difference in behavior between the 12-inch sections and the 24-inch sections. However, Figure 6 indicates from Station 72+00 to 78+00 considerable settlement occurred in one year (from 1989 to 1990). This area of the project had no stone layer. It appears that the addition of at least 12 inches of stone was beneficial.

The No. 3 stone does not meet the filter requirement for the DGA; therefore, it is possible that fines from the DGA may be filtering into the stone. The filter requirements that must be satisfied to prevent the fine particles of the material being filtered (DGA) from intruding into the filter material (No. 3 stone) were developed by Terzaghi and later extended by the Army Corps of Engineers. Those requirements are illustrated by the following:

1. D_{15} Filter (No. 3 stone)/D_{85} Soil (DGA) < 5

   25 mm/20 mm = 1.25 (passes first requirement)

2. 4 < D_{15} Filter No. 3 stone)/D_{15} Soil (DGA) < 20

   25 mm/0.27 mm = 92 (fails second requirement)

3. D_{50} Filter (No. 3 stone)/D_{50} Soil (DGA) < 25

   40 mm/6 mm = 6.7 (passes third requirement)

The particle sizes were assumed to be the median gradation for the DGA and the No. 3 stone. The No. 3 stone fails the second filter requirement, thus indicating the possibility of DGA fines intruding into the No. 3 stone. However, when coring, research personnel could not determine if this was, in fact, occurring. If this were occurring, it is unlikely this would significantly affect pavement behavior, since the large particle sizes in the DGA would continue to support traffic loads.

The subgrade soils consisted largely of silts with a large proportion of clay (25 to 35 percent). The shear strength characteristics of these soils are undoubtedly adversely affected by increased degrees of saturation. The results of the repeated-load test show that extremely small stresses in the saturated subgrade may produce significant deformations in the subgrade that could be reflected in settling of the slabs.
The northbound lanes were opened to traffic on July 8, 1988. Figure 13 indicates the months of July and August of that year received abnormally high amounts of rainfall. The southbound lanes were opened to traffic on December 14, 1988. The previous month (November 1988) received well above the normal rainfall. It is suspected this excess moisture may have saturated and weakened the subgrade of the new pavement.

The last reading on the water wells installed during this study indicated the water table was as close as 30 inches to the surface (Figure 5) and this was in a relatively dry period. Also, during the spring of 1990, the entire pavement was flooded for a short period. These facts indicate the subgrade is probably in a state of near saturation for a large portion of the year.

Figure 6 shows that settlement and some shifting of the slabs occurred from 1989 to 1990. In general, the northbound lanes settled more than the southbound lanes. Most settlement occurred from Station 72+00 to Station 78+00. This is the area that has no stone layer. A second area where considerable settlement has occurred is from Station 85+00 to Station 95+00. This is in the area of Sinclair Street. It is expected that settlement from consolidation of the subgrade resulting from traffic loading will continue. It would be difficult to predict the amount of settlement because of the complexity of factors involved.

In summary, damage that has occurred near the curb inlets and manholes is probably due to insufficient compaction. The remaining damage is most likely related to the combined effects of a very soft subgrade, high water tables, and traffic loads that are applied to the saturated or near-saturated subgrade. Again, It is expected that consolidation of the subgrade will continue, although the rate cannot not be predicted with any degree of accuracy.

RECOMMENDATIONS

It is recommended that pavement distresses continue to be monitored on a frequency of every six months.

Longitudinal edge drains placed at the back of the curbs would help to intercept any surface water that infiltrated through the joints of the pavement and would otherwise become trapped at the interface between the DGA and the base of the slab. The edge drains would probably help to reduce pumping of the slab and the consequent loss of DGA fines. These edge drains are recommended. However, in all likelihood, this would alleviate only part of the problem. Edge drains would not significantly help the weak subgrade because the drains could not be placed sufficiently deep to effectively drain the subgrade.

Because complete reconstruction of this project is economically unfeasible, it is recommended a number of slabs be replaced. These slabs are located as follows:

STATION	DIRECTION	LANE
78+14	Northbound	Both Lanes
79+95	Northbound	Both Lanes
82+12	Northbound	Outside Lane
84+79	Southbound	Both Lanes, Plus Turning Lanes
84+98	Southbound	Outside Lane
85+58	Southbound	Both Lanes
91+46	Southbound	Outside Lane
103+07	Southbound	Outside Lane
104+33	Southbound	Both Lanes
106+02	Southbound	Both Lanes
106+19	Southbound	Outside Lane
108+19 - 108+62	Southbound	Outside Lane
108+80 - 108+94	Southbound	Inside Lane
108+62	Southbound	Inside Lane
108+45 - 108+80	Northbound	Outside Lane
108+80	Northbound	Inside Lane
109+25	Northbound	Both Lanes
109+68	Northbound	Outside Lane

STATION	DIRECTION	LANE
109+25	Southbound	Both Lanes, Plus Turning Lane
110+03	Northbound	Outside Lane
110+16	Northbound	Inside Lane
111+06	Northbound	Both Lanes
112+09	Northbound	Outside Lane
112+70 - 112+89	Northbound	Inside Lane
113+06	Northbound	Outside Lane
116+83	Northbound	Inside Lane
117+12 - 117+30	Northbound	Inside Lane

An intensive and aggressive maintenance program is also recommended. Any future faulting at joints and/or new cracks should be maintained by grinding. Pavement undersealing could be used to help maintain grade. In some instances, as slabs and joints deteriorate, complete replacement is recommended. If a comprehensive maintenance program is implemented, the pavement may provide most of its original design life.

FIGURE 1. NATIONAL TURNPIKE SOUTHBOUND
5 PT FLOATING AVERAGE
OUTSIDE LANE

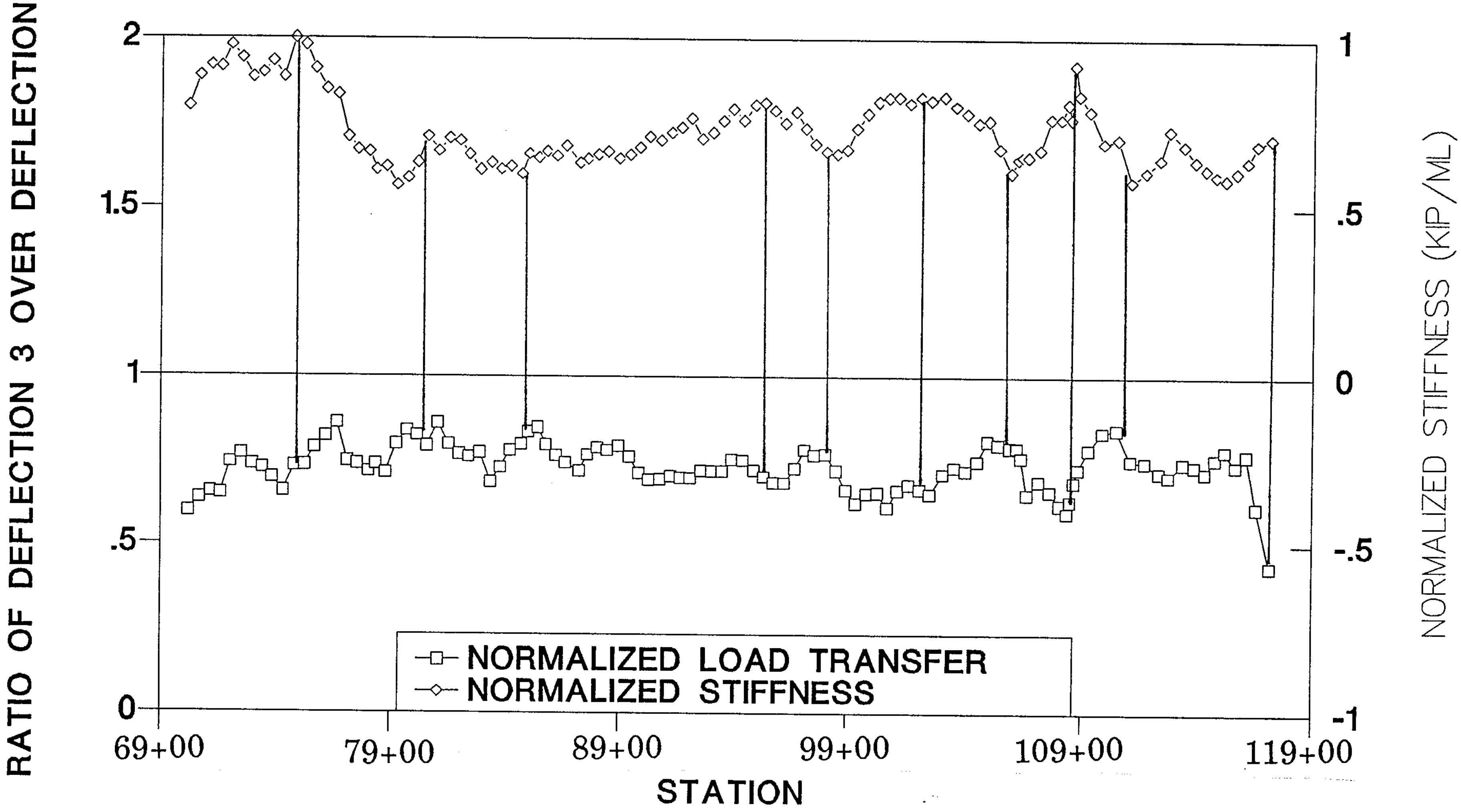

FIGURE 2. NATIONAL TURNPIKE SOUTHBOUND
5 PT FLOATING AVERAGE
INSIDE LANE

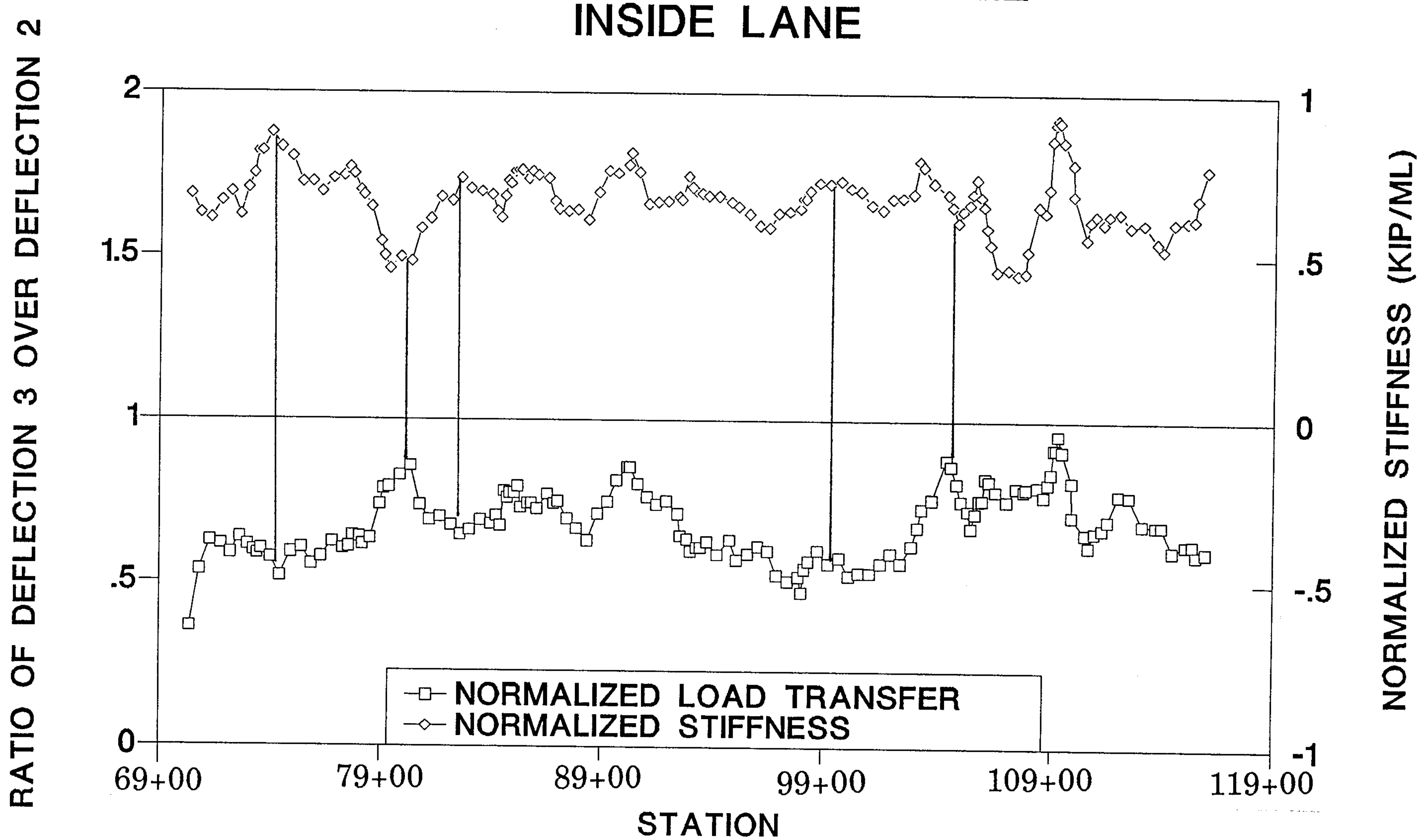

FIGURE 3. NATIONAL TURNPIKE NORTHBOUND
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OUTSIDE LANE

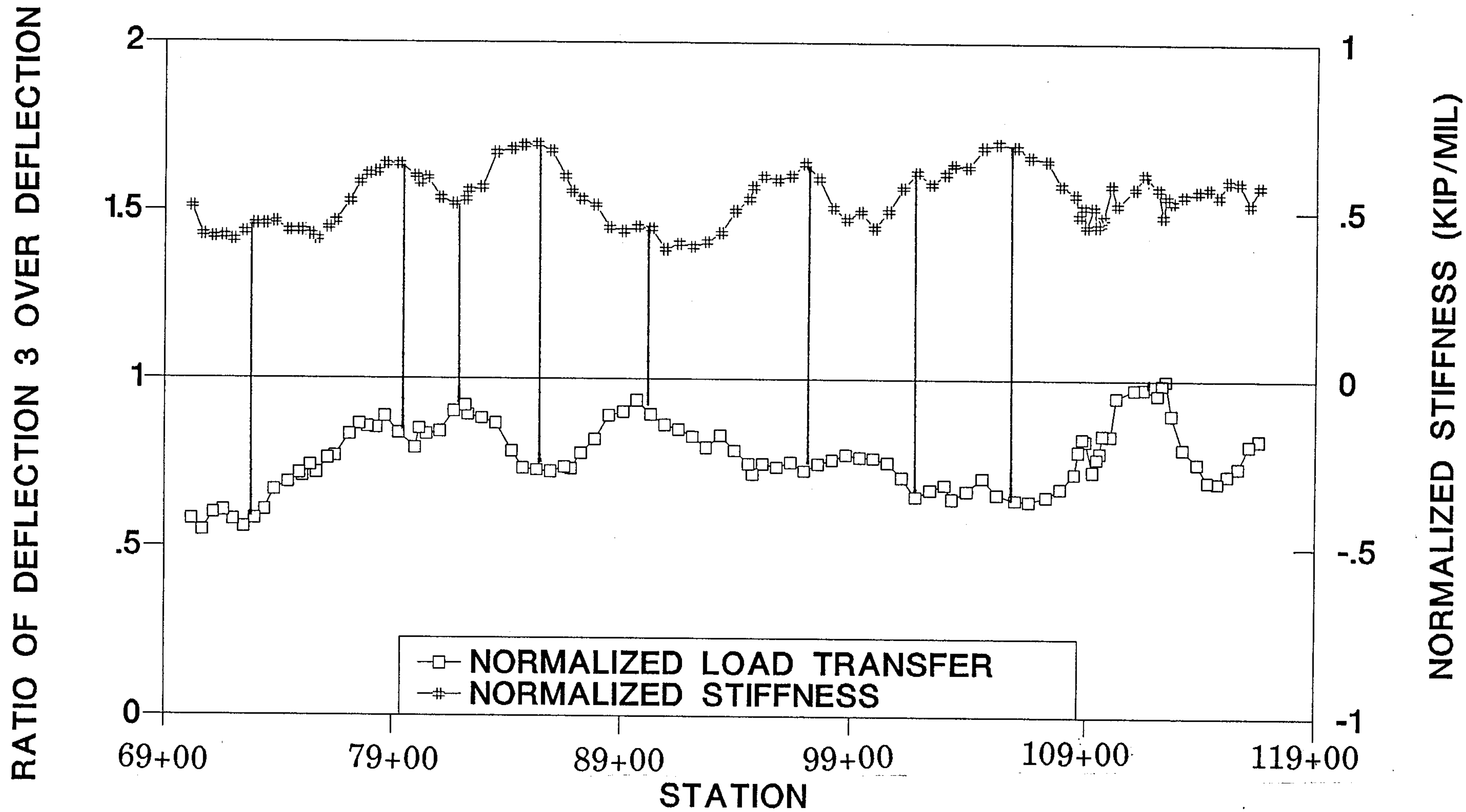


FIGURE 4. NATIONAL TURNPIKE NORTHBOUND
5 PT FLOATING AVERAGE
INSIDE LANE

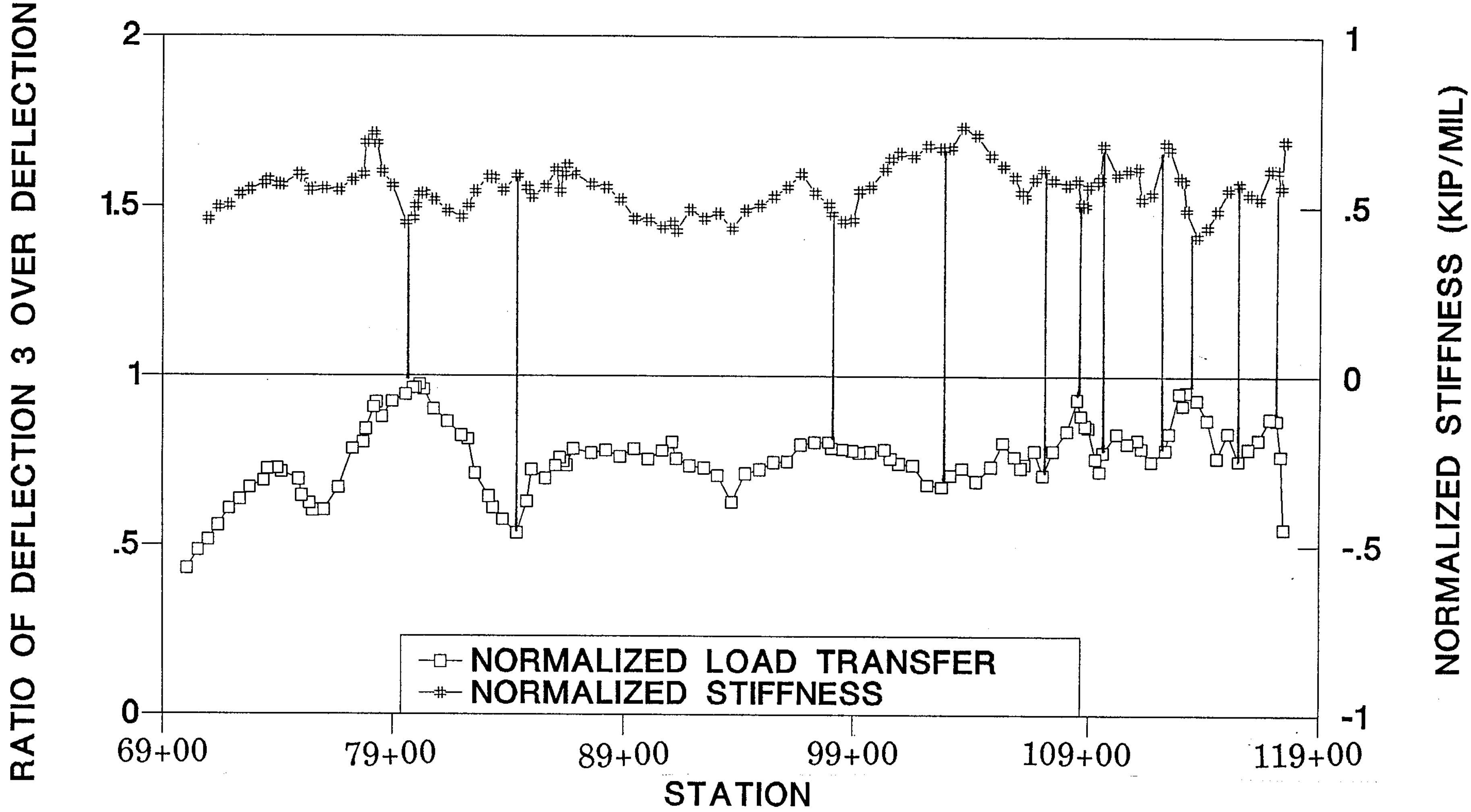


Figure No. 5. National Turnpike Water Monitoring Wells

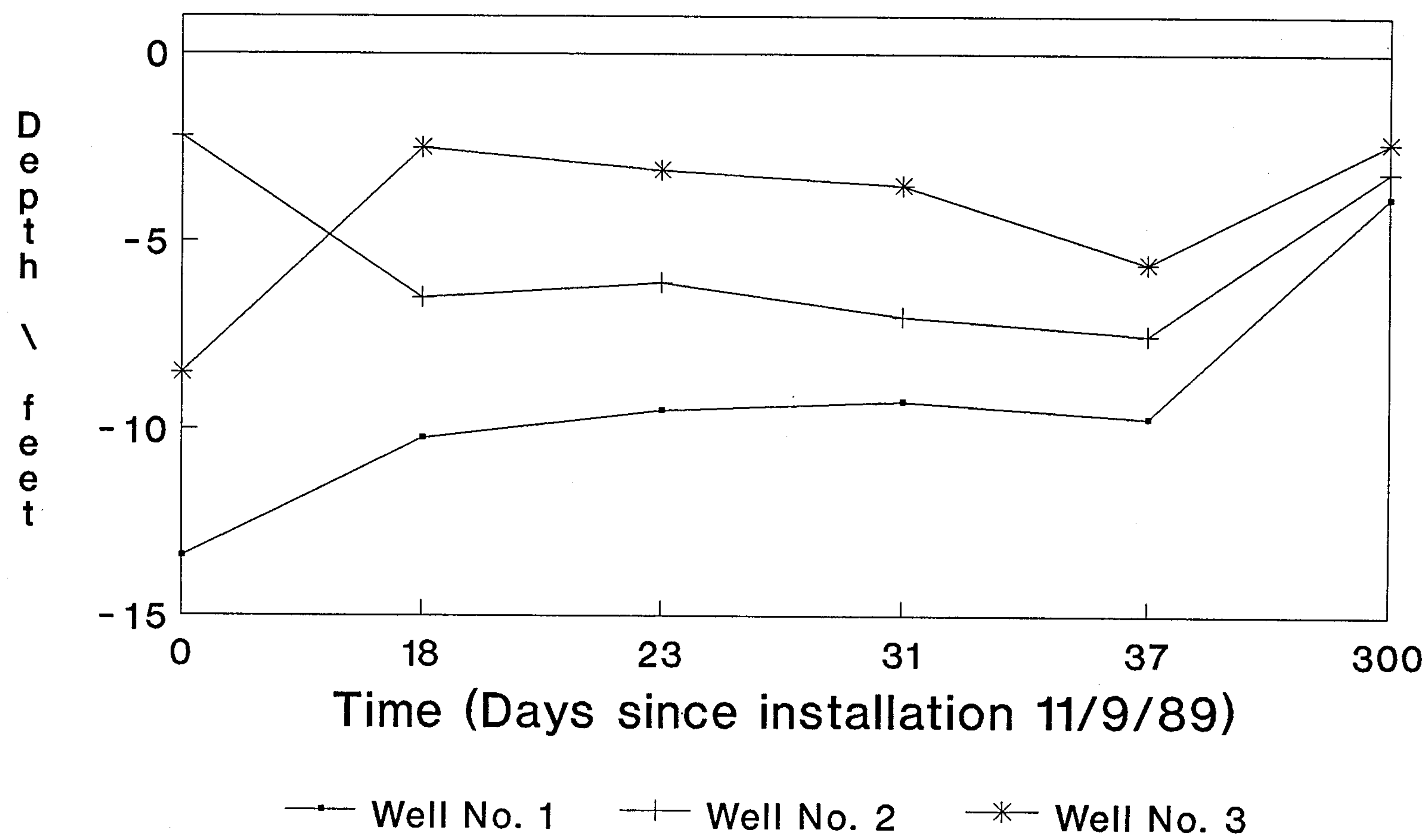
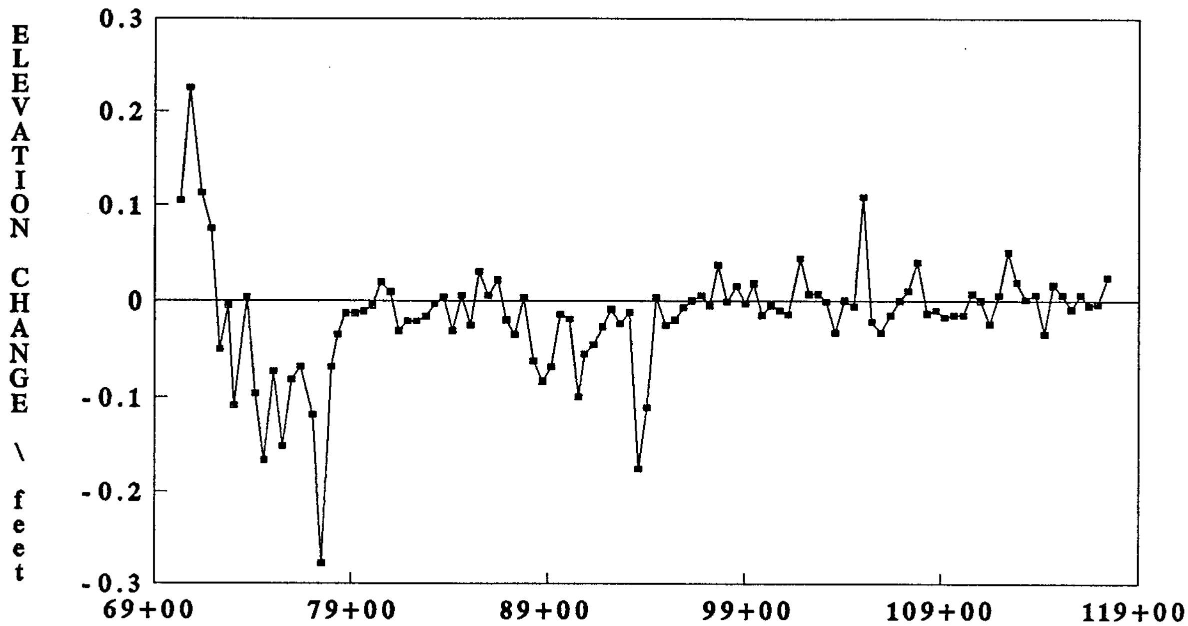


FIGURE 6. CHANGE IN ELEVATION (1989-1990)

NORTHBOUND



SOUTHBOUND

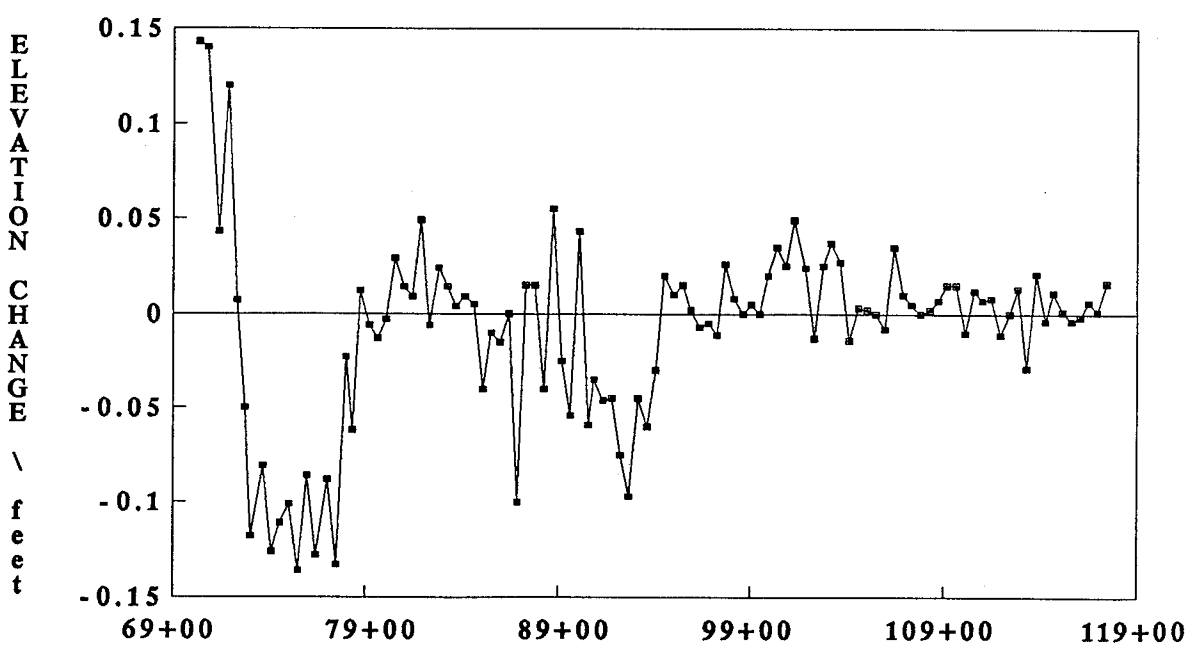


Figure 7. Cone Penetrometer Data

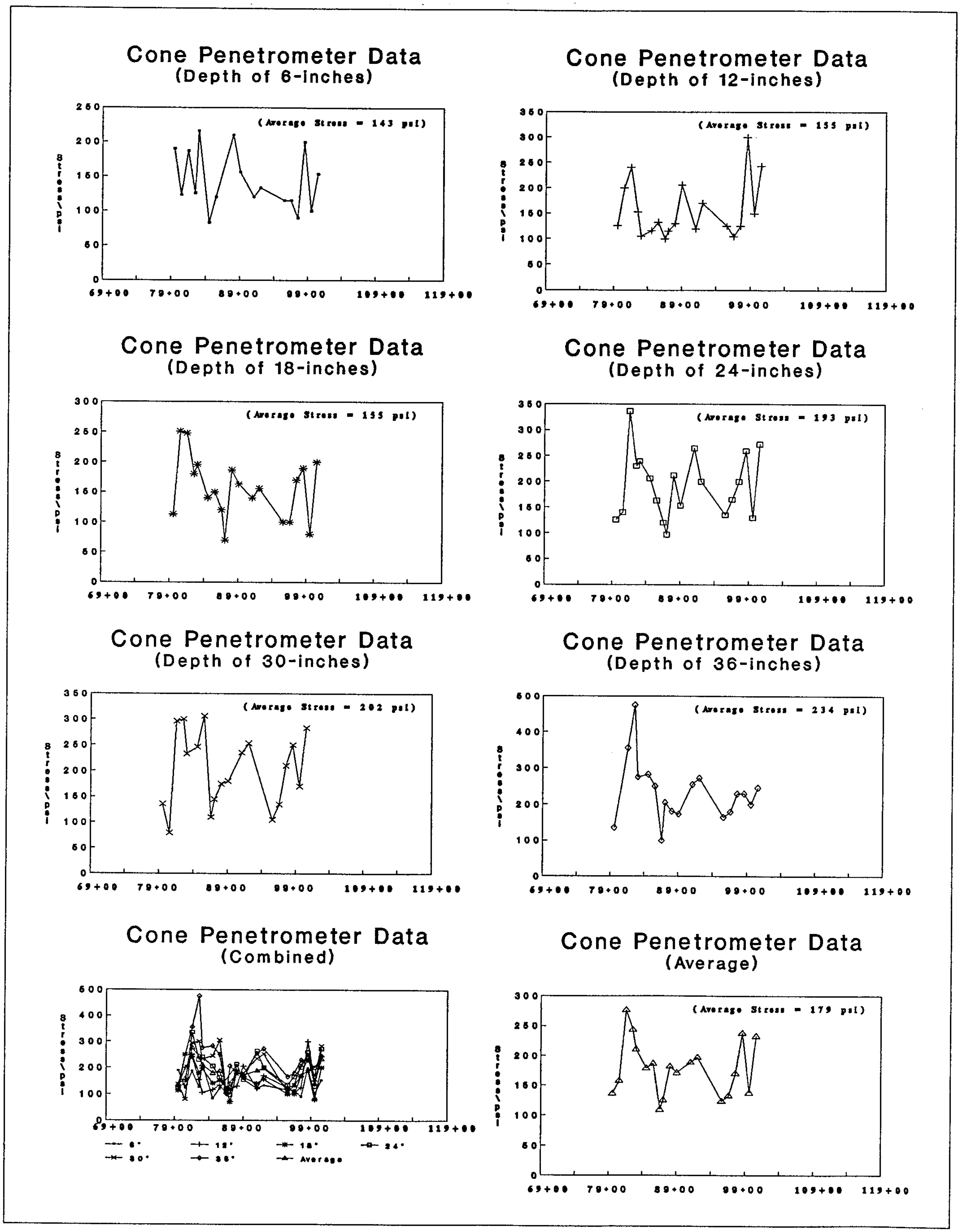


FIGURE 8. REPEATED LOAD TEST
Hole No. 182 (34.5"-40.5")
(Sample was tested saturated)

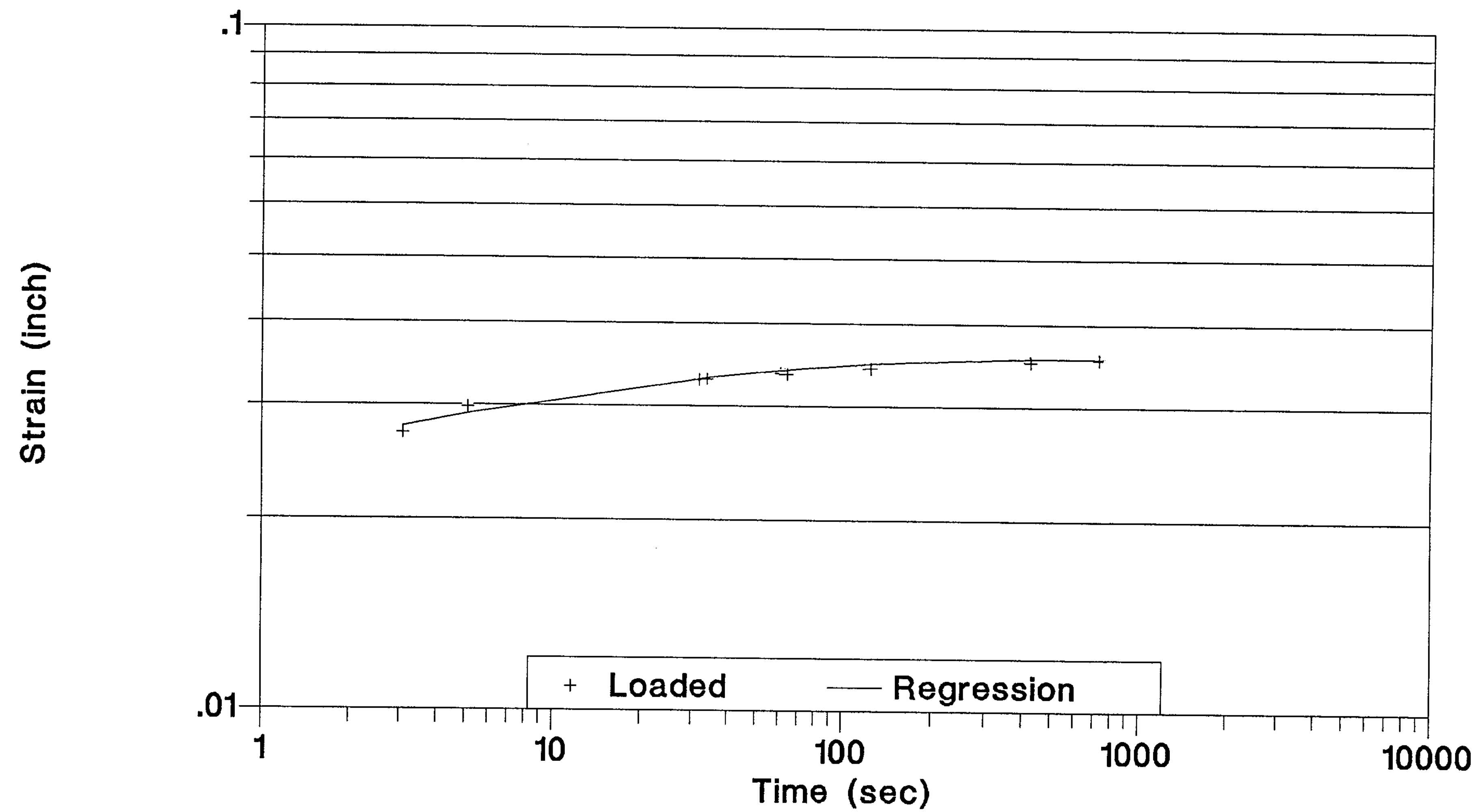


Figure 9. National Turnpike, Stiffness/Slab Variation Southbound Outside Lane

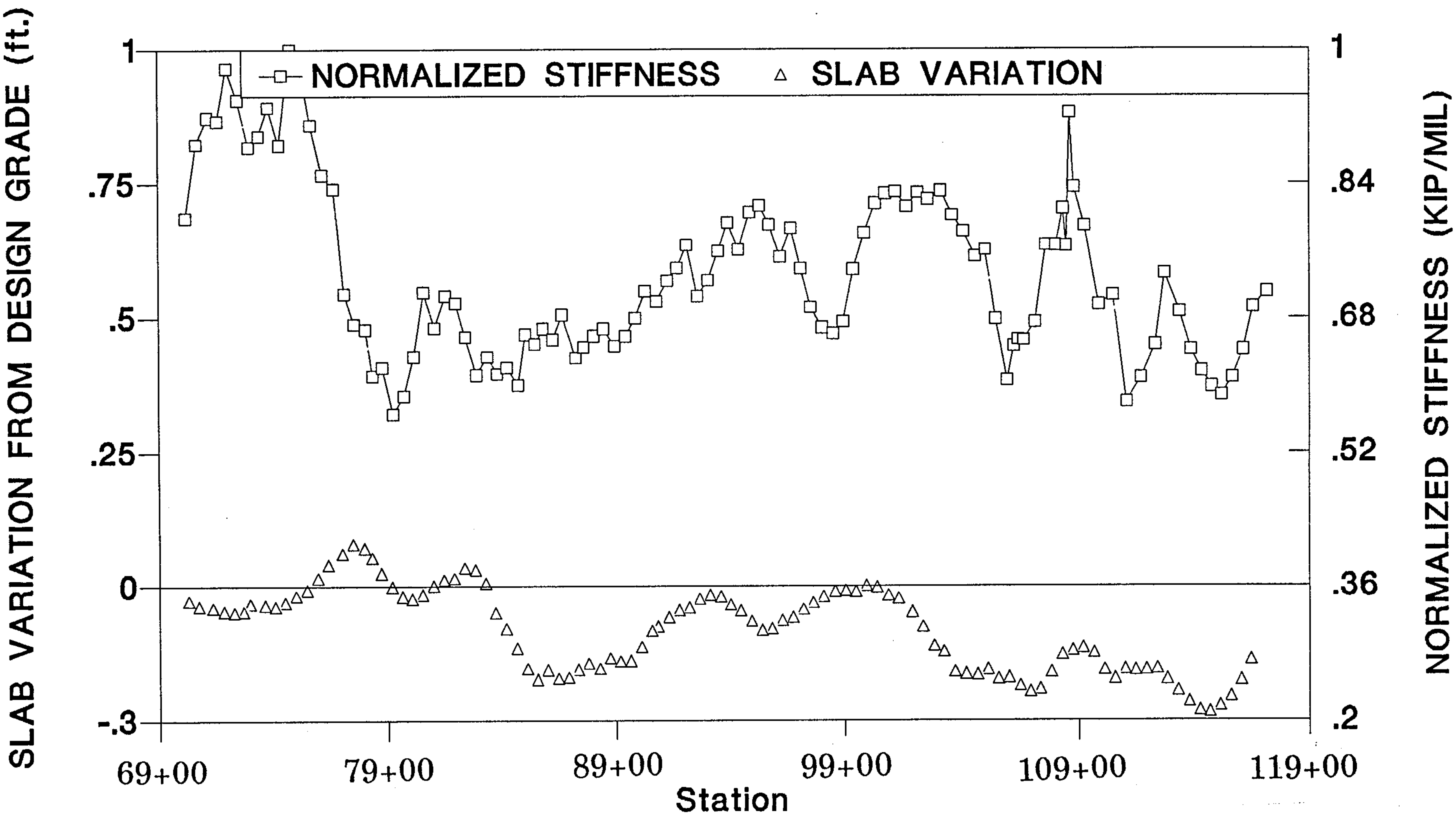


Figure 10. National Turnpike Stiffness/Slab Variation
Northbound Outside Lane

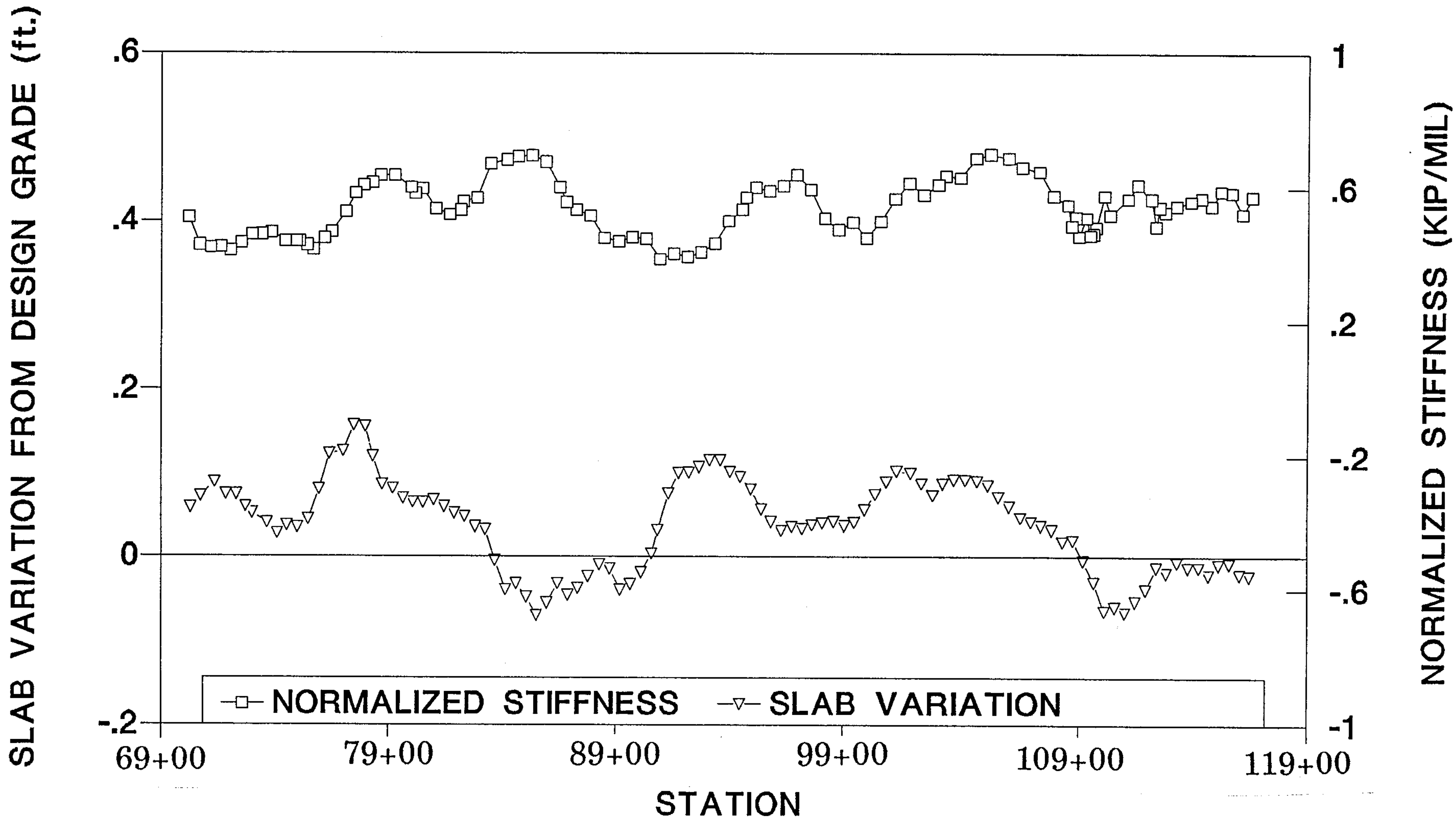


Figure 11. National Turnpike, Slab Variation/Rock Stabilization
Northbound Outside Lane

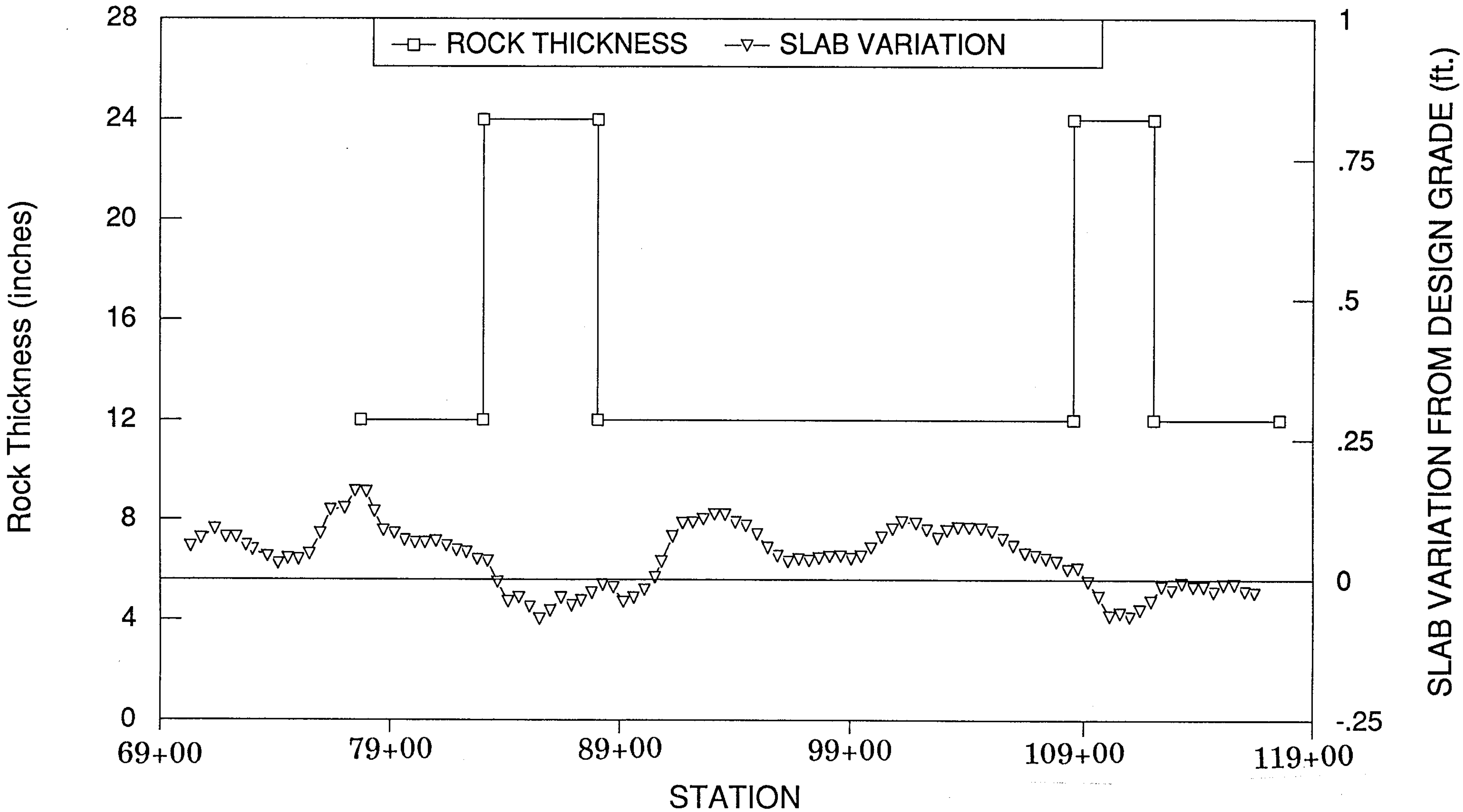


Figure 12. National Turnpike, Slab Variation/Rock Stabilization
Southbound Outside Lane

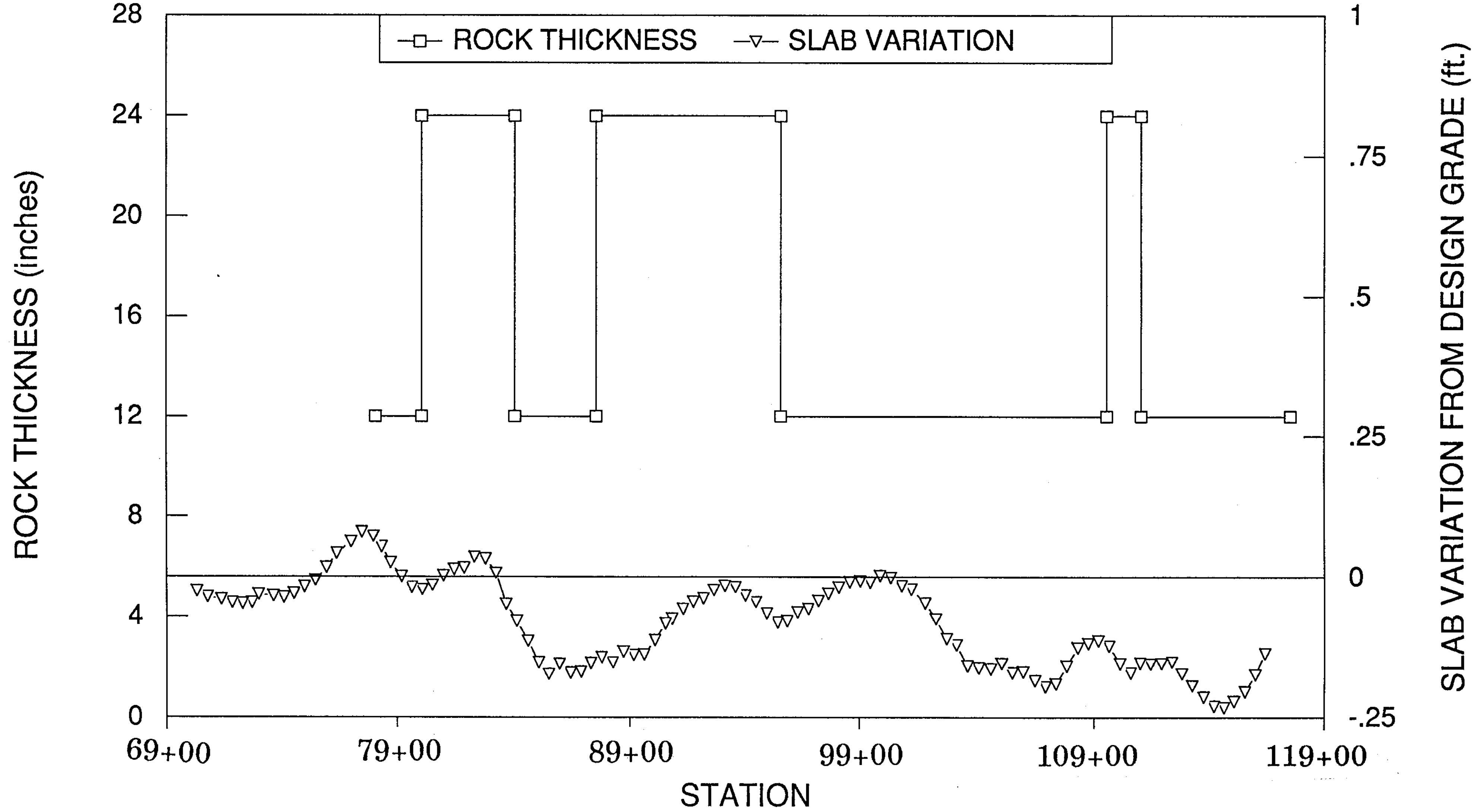
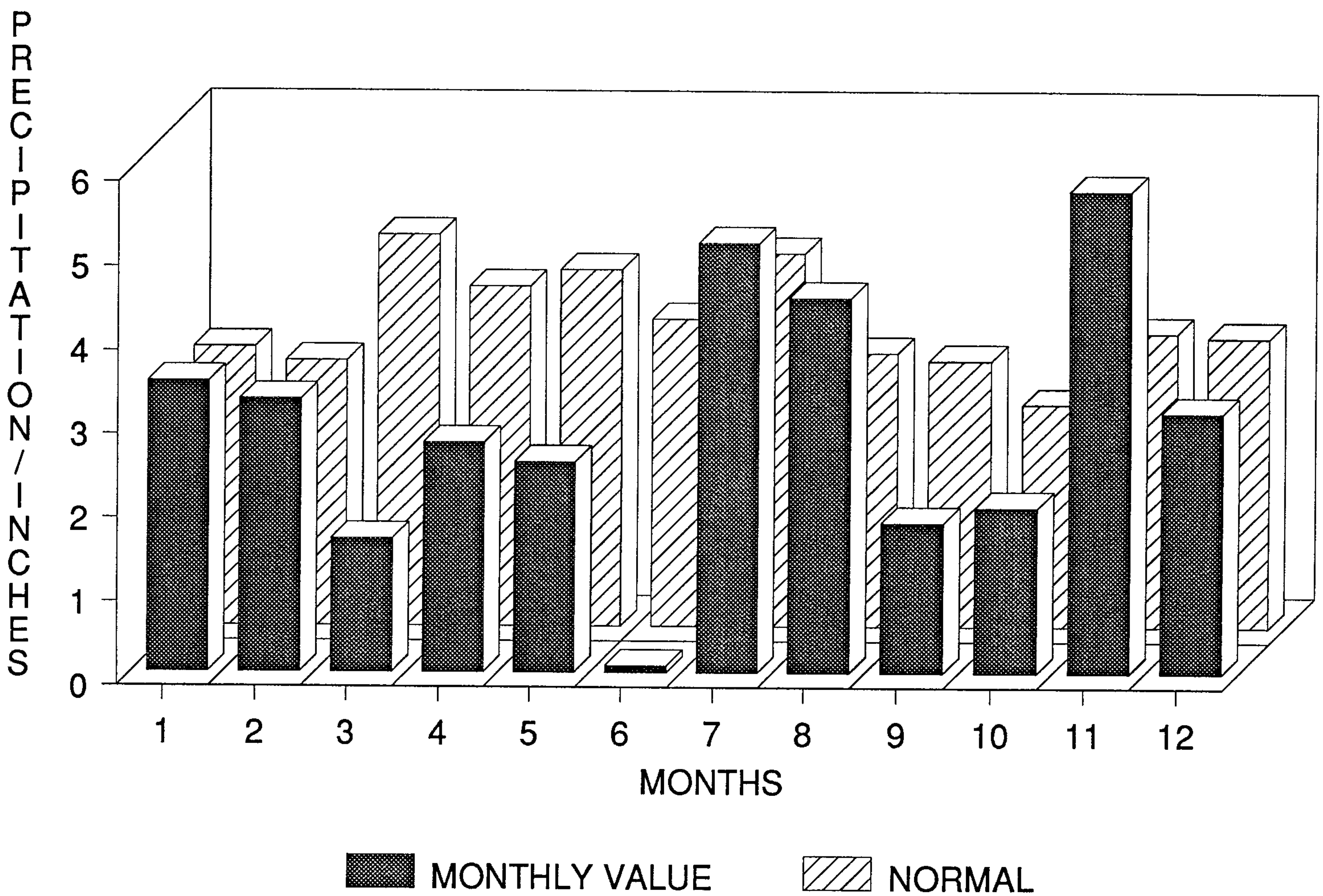
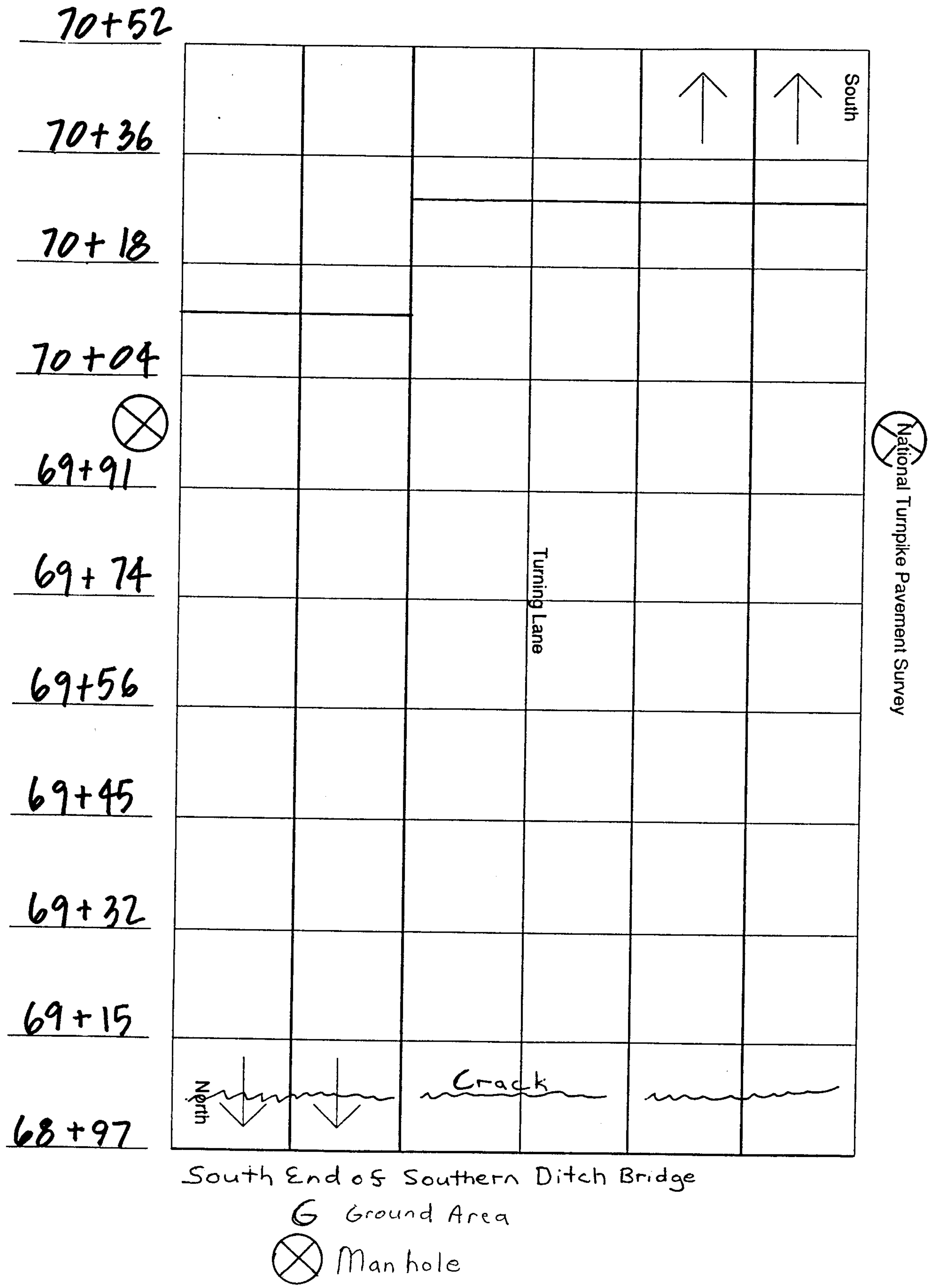
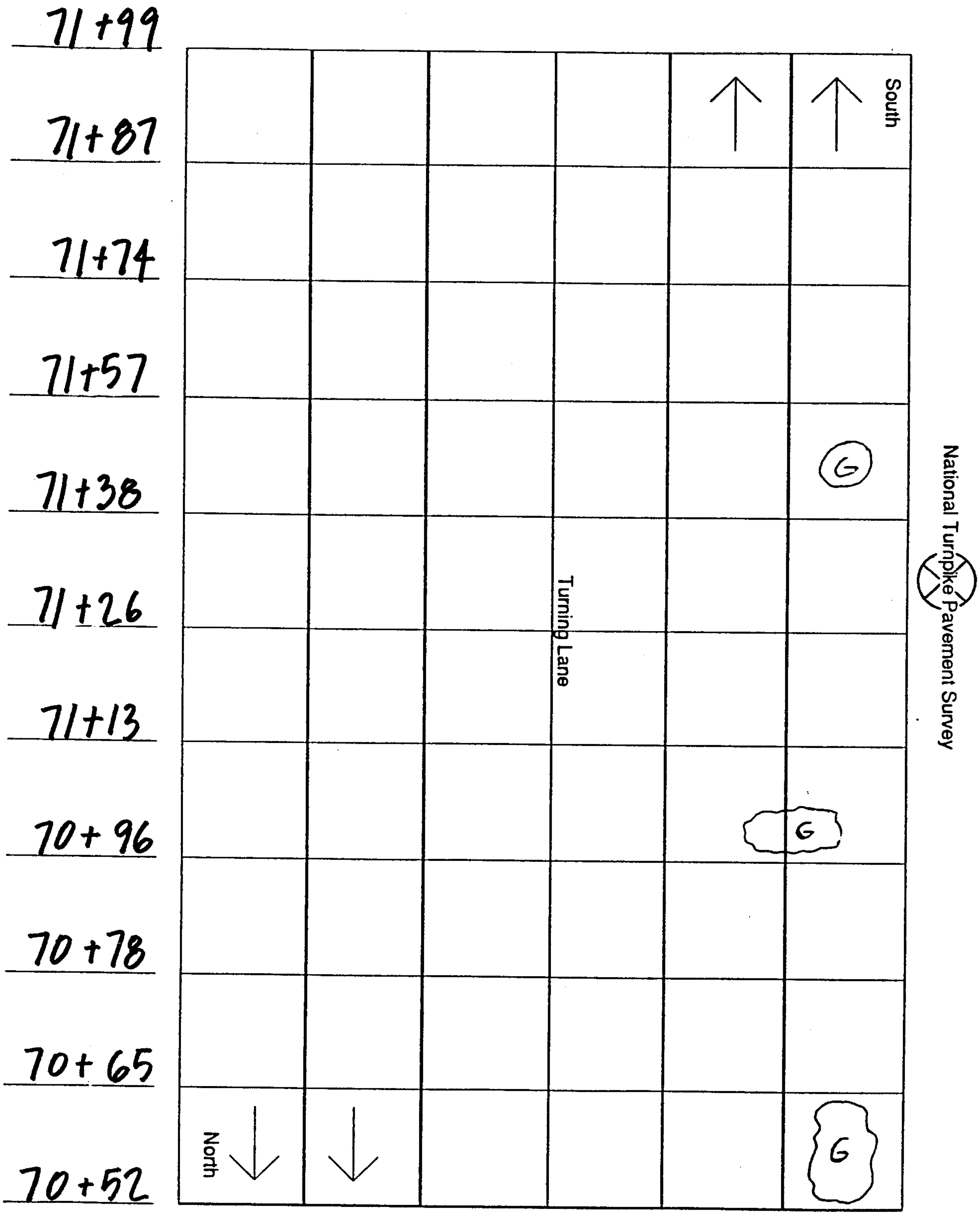


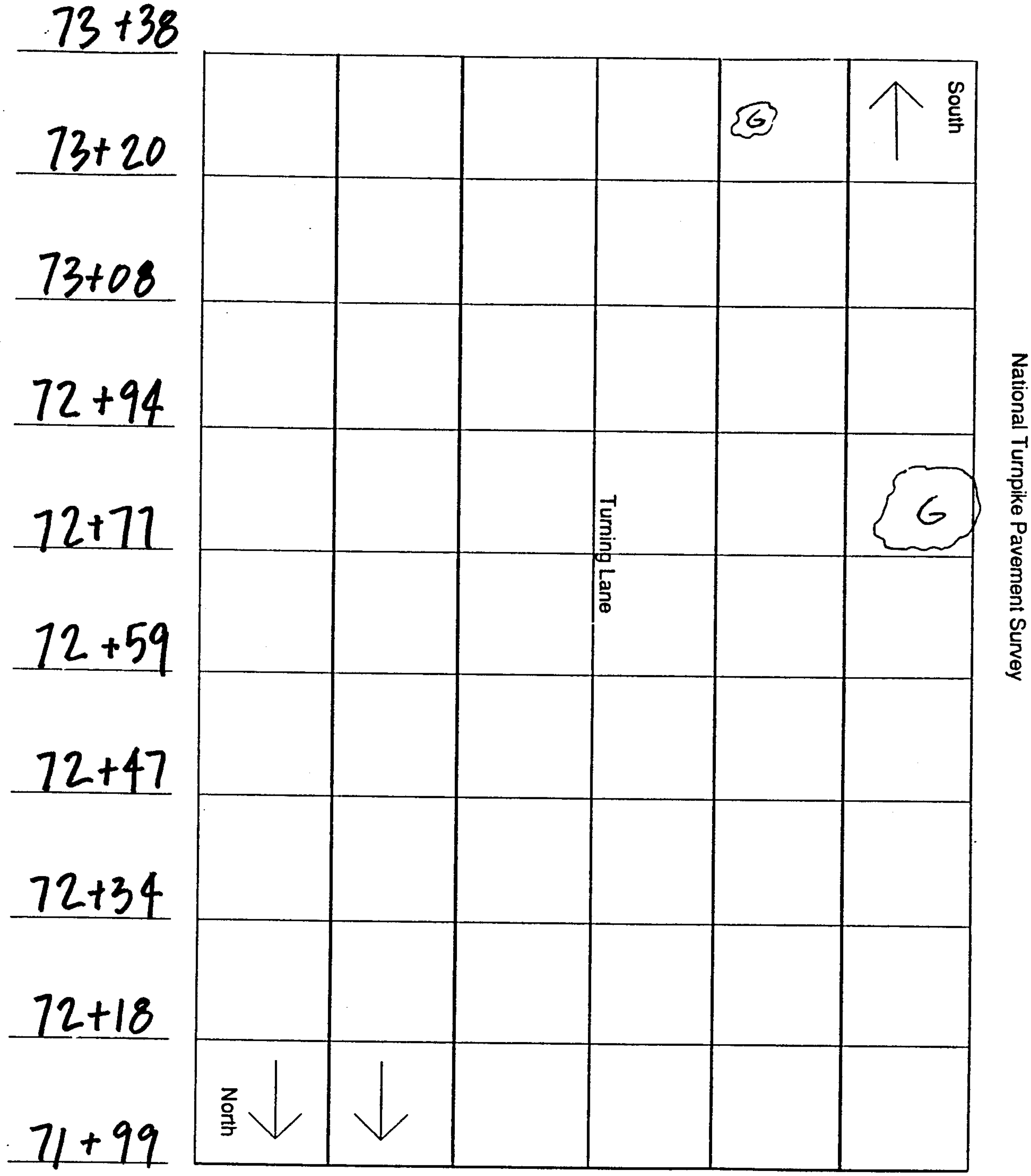
FIGURE 13. MONTHLY PRECIPITATION AND DEPARTURES FROM NORMAL (1988)



Appendix A
Concrete Slab Inspection
October 19, 1989


70+52
70+36
70+18
70+04
69+91
69+74
69+56
69+45
69+32
69+15
68+97
South
National Turnpike Pavement Survey
Turning Lane
North
Crack
South End of Southern Ditch Bridge
G Ground Area
Man hole


71+99
71+87
71+74
71+57
71+38
71+26
71+13
70+96
70+78
70+65
70+52
South
North
Turning Lane
G
G
G
National Turnpike Pavement Survey


National Turnpike Pavement Survey
South
North
Turning Lane
G
G
73+38
73+20
73+08
72+94
72+71
72+59
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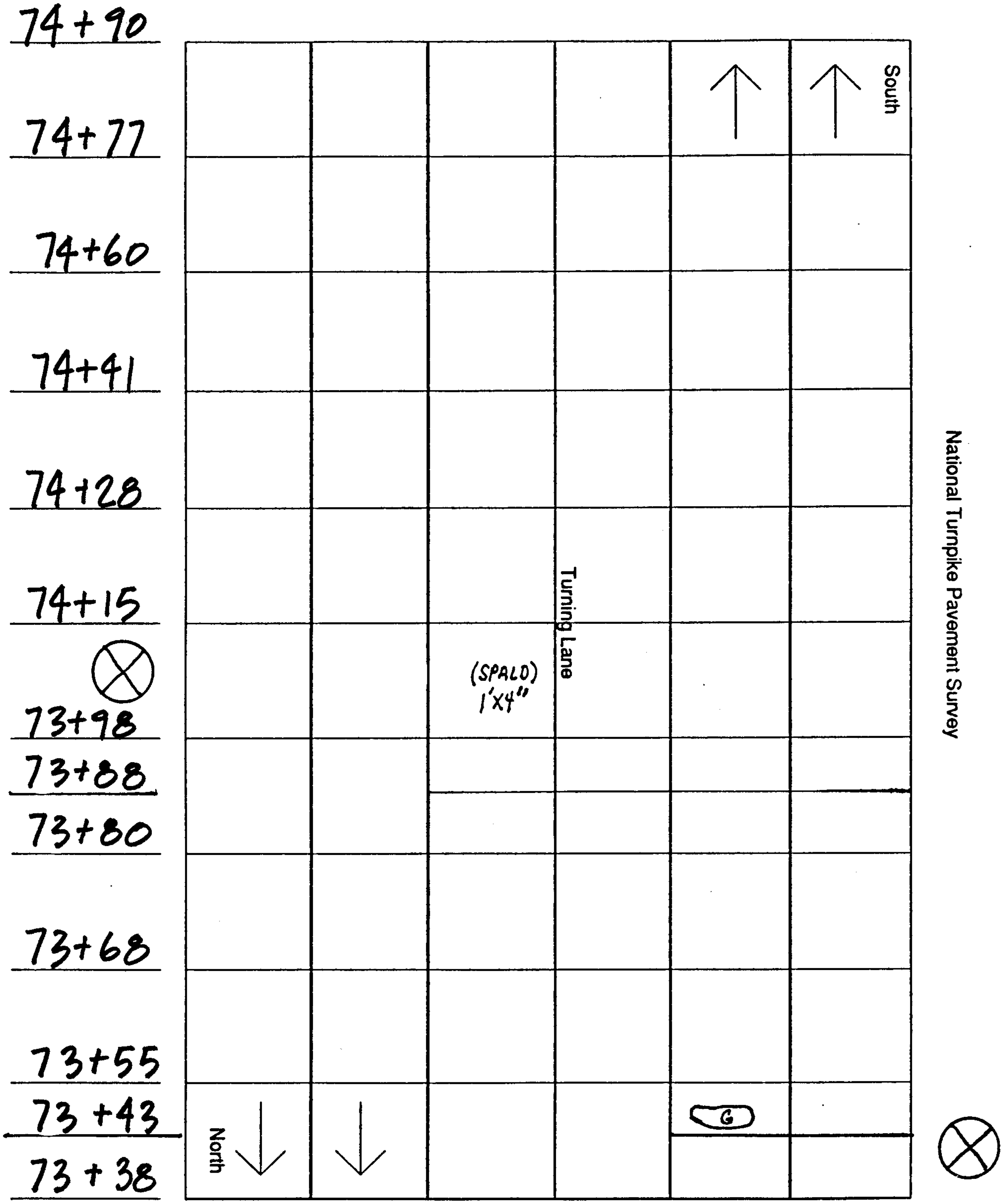
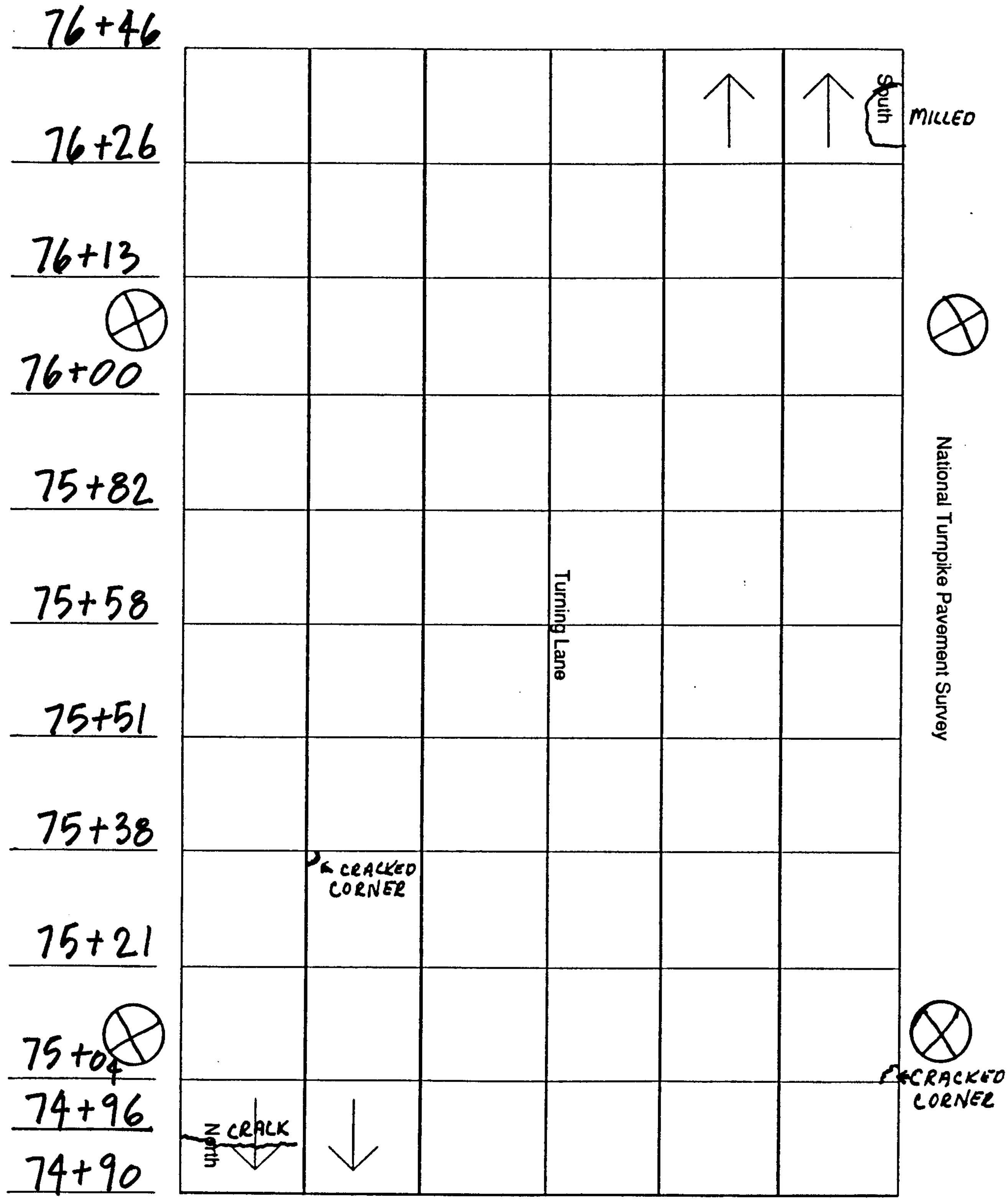
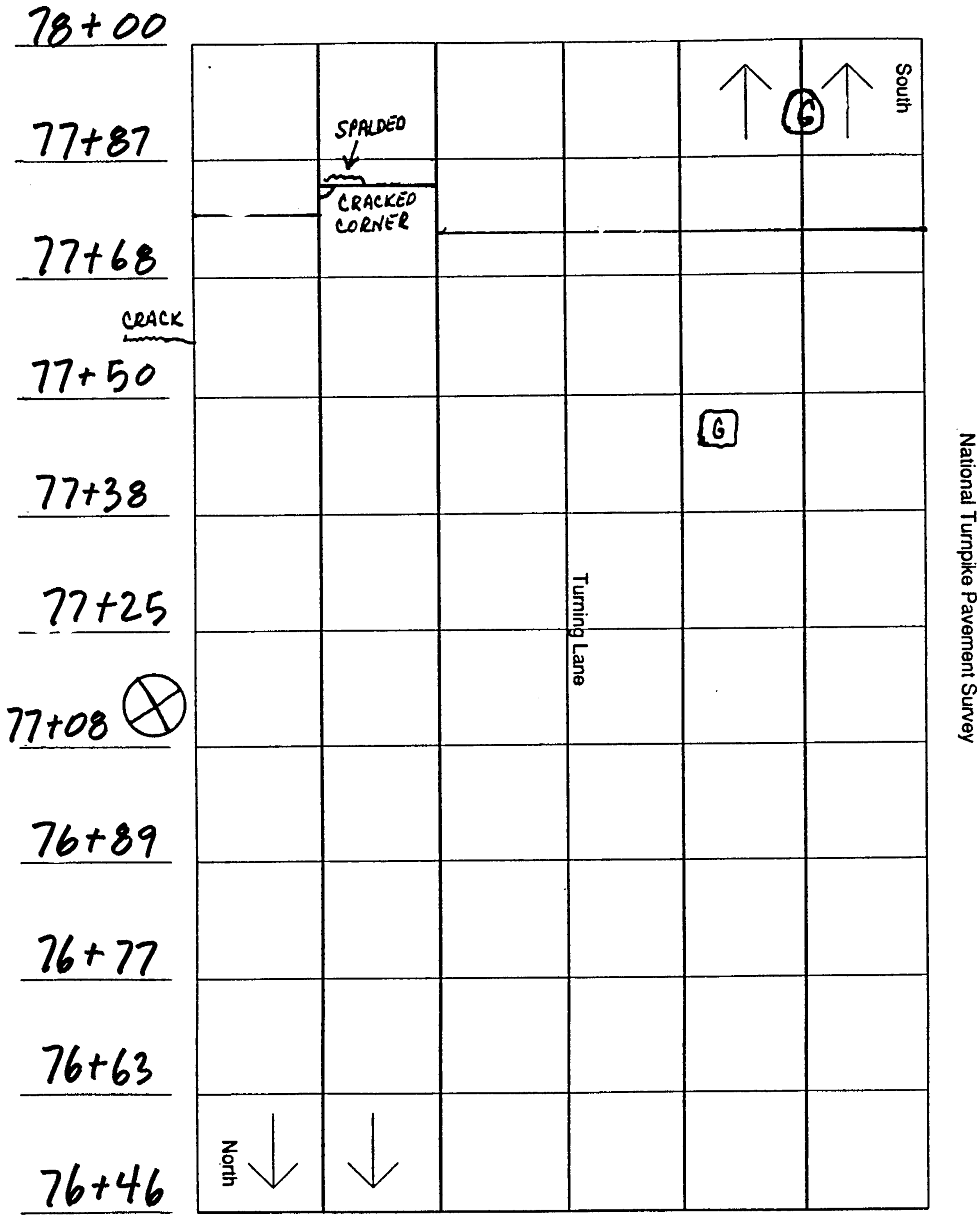
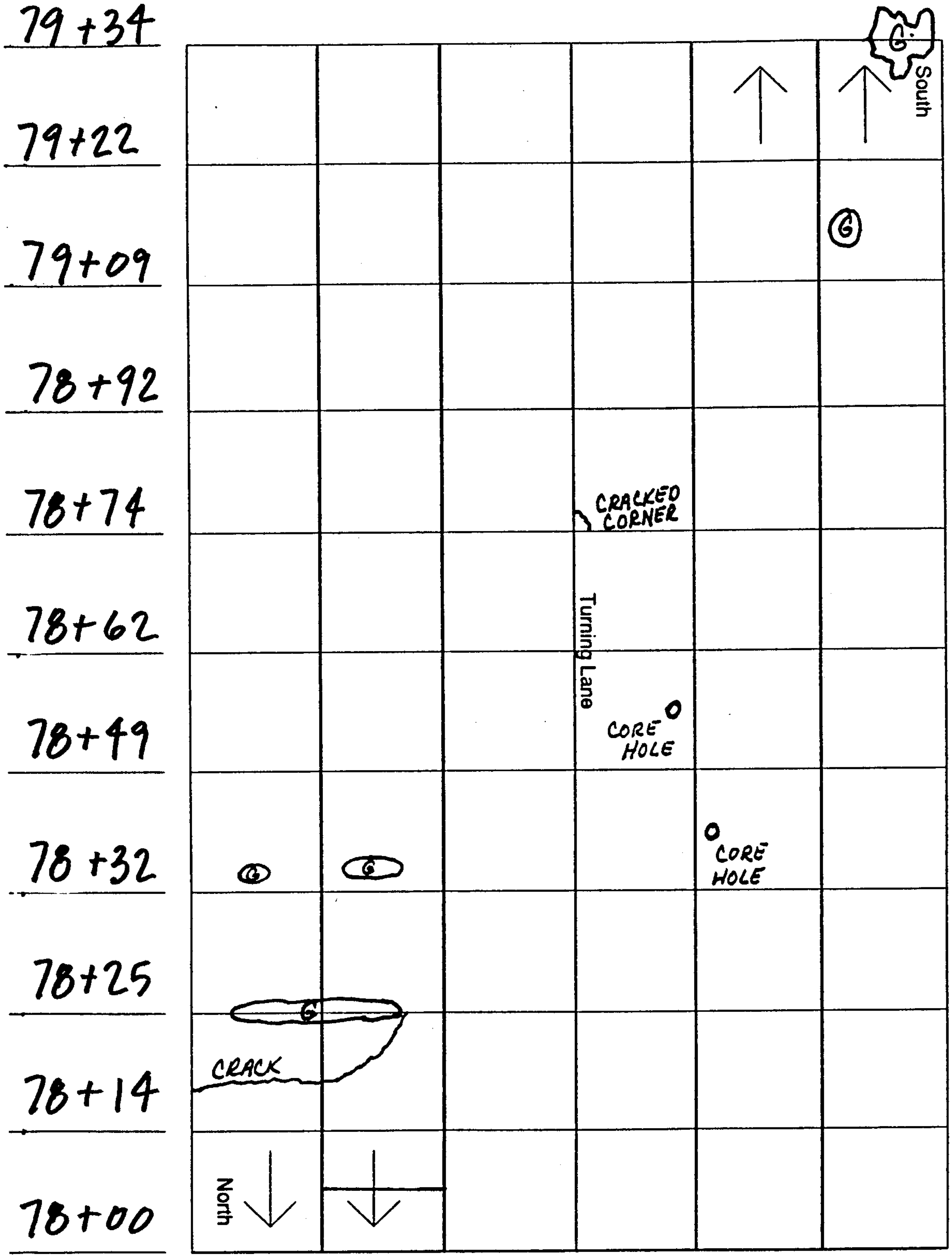
72+34
72+18
71+99

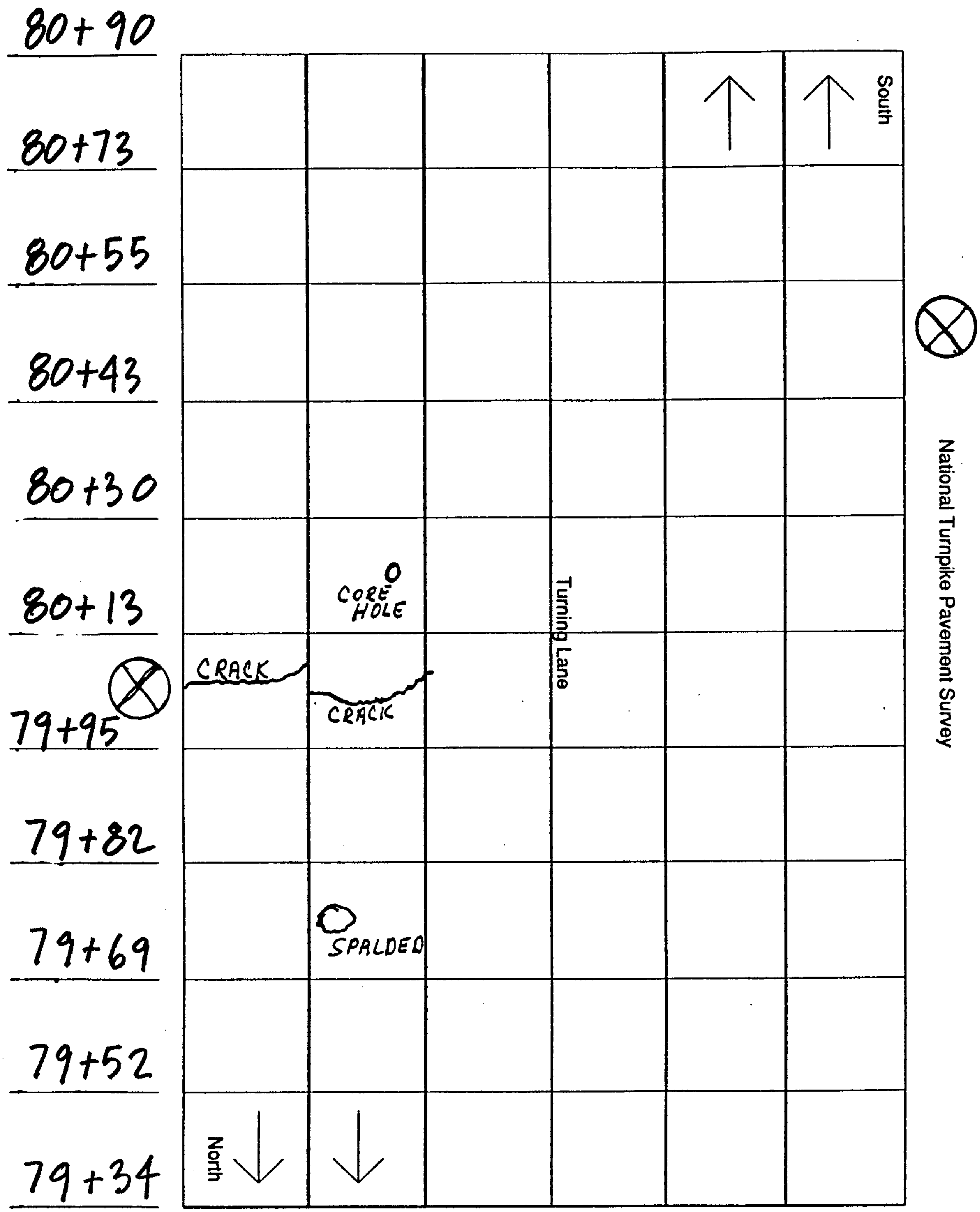

74+90
74+77
74+60
74+41
74+28
74+15
73+98
73+88
73+80
73+68
73+55
73+43
73+38
South
North
Turning Lane
(SPALD)
1'X4"
G
National Turnpike Pavement Survey

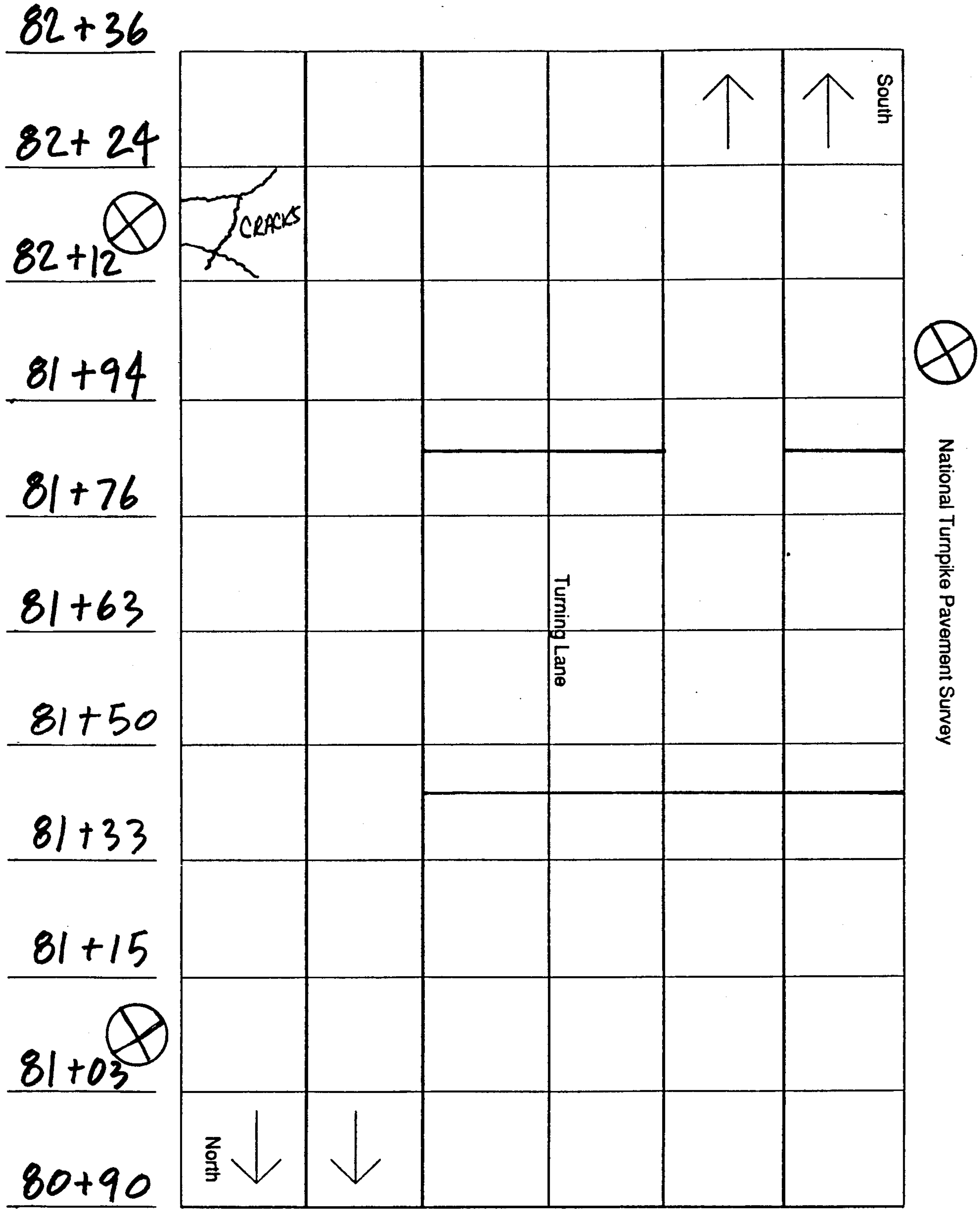

76+46
76+26
76+13
76+00
75+82
75+58
75+51
75+38
75+21
75+04
74+96
74+90
South
MILLED
Turning Lane
National Turnpike Pavement Survey
CRACKED CORNER
CRACKED CORNER
CRACK
North

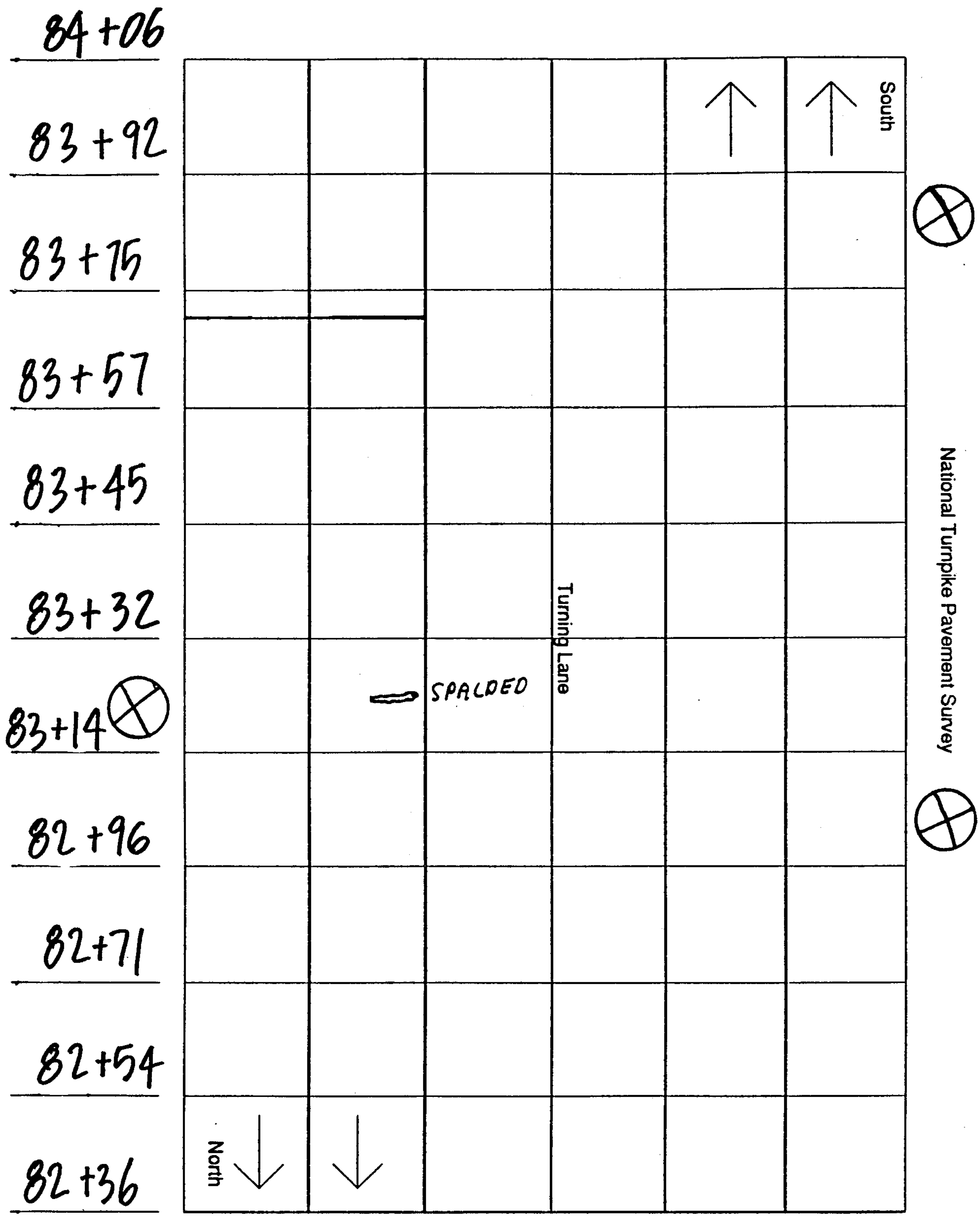

78+00
77+87
77+68
77+50
77+38
77+25
77+08
76+89
76+77
76+63
76+46
CRACK
SPALDED
CRACKED CORNER
G
G
South
North
Turning Lane
National Turnpike Pavement Survey

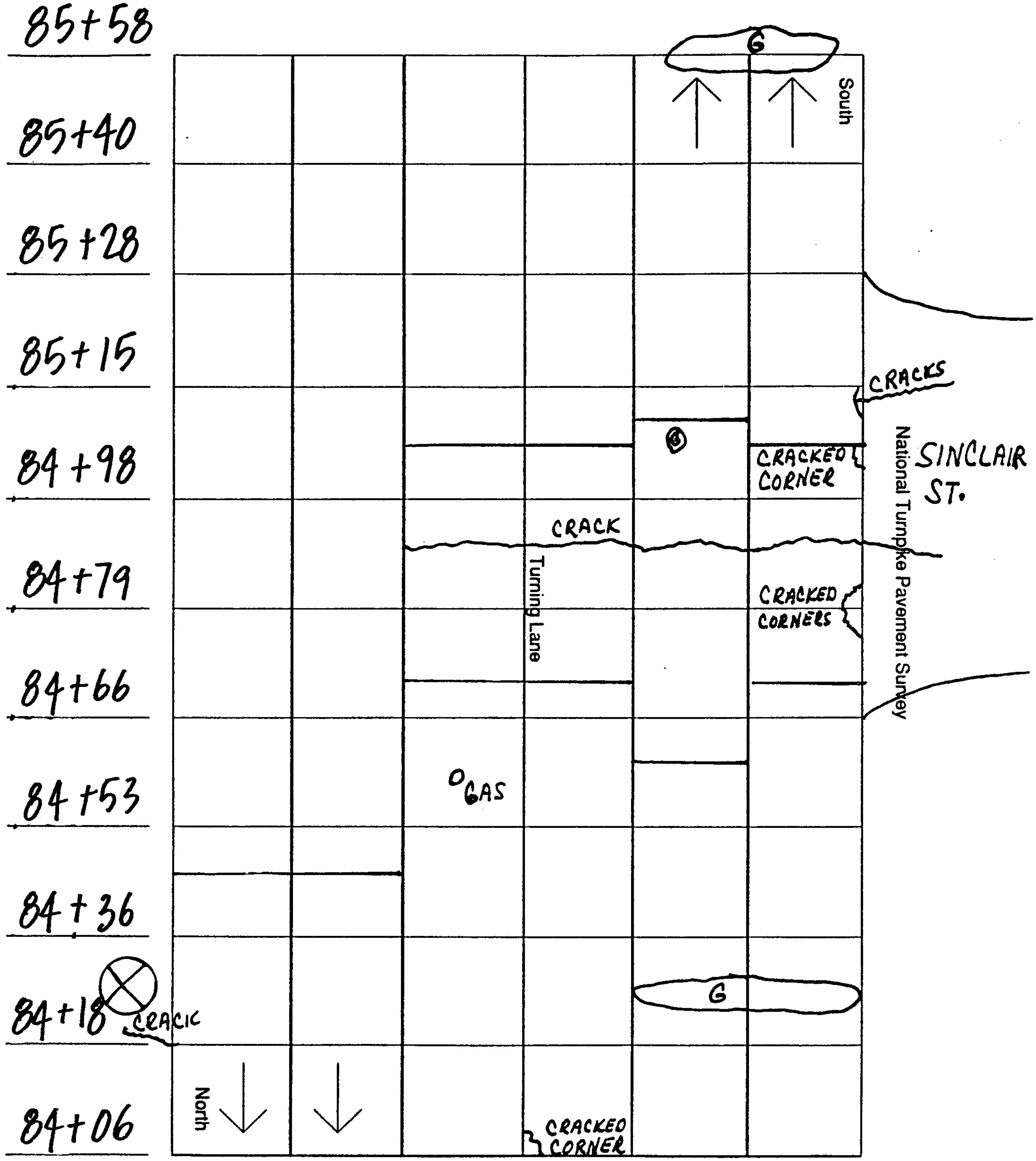


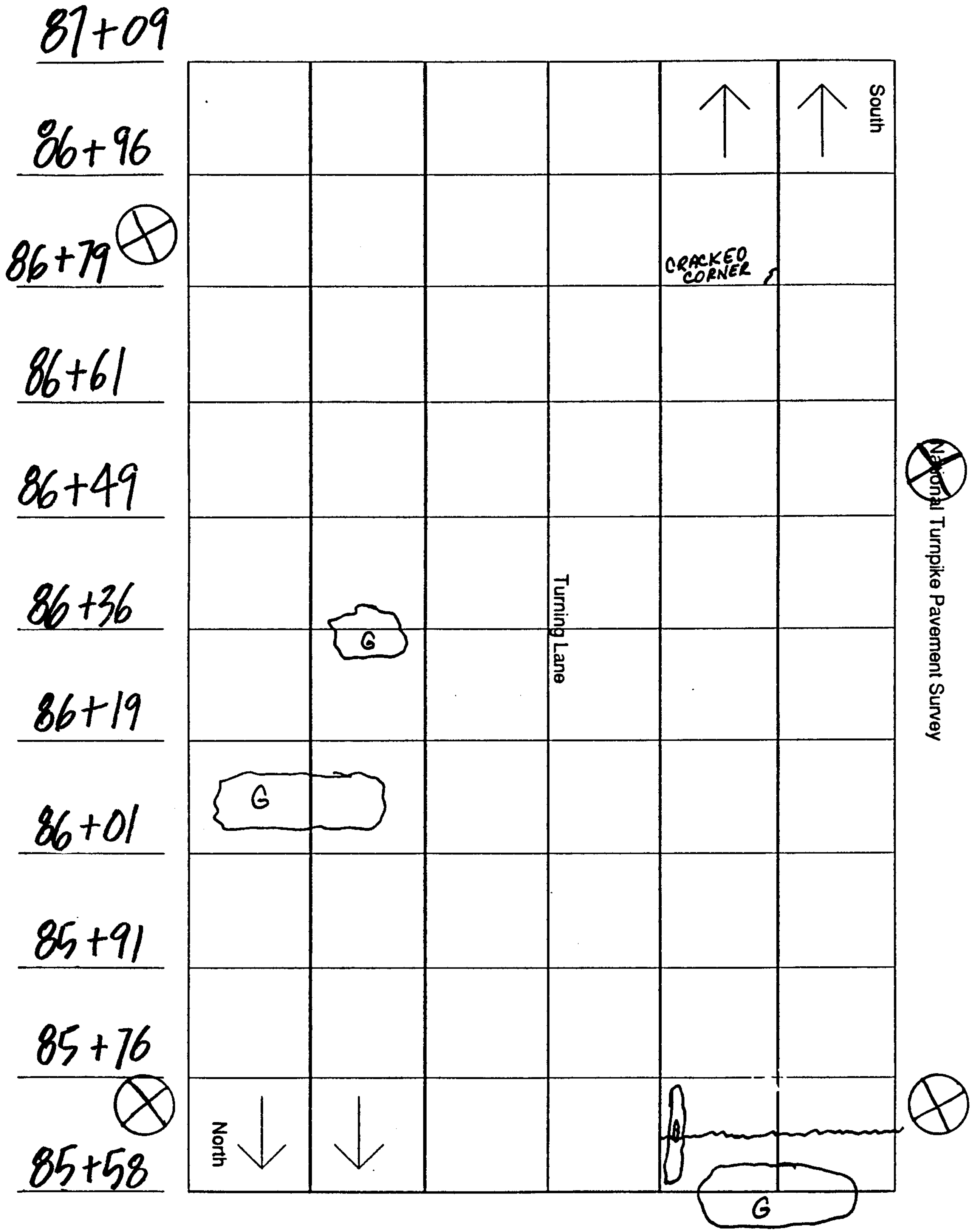
National Turnpike Pavement Survey

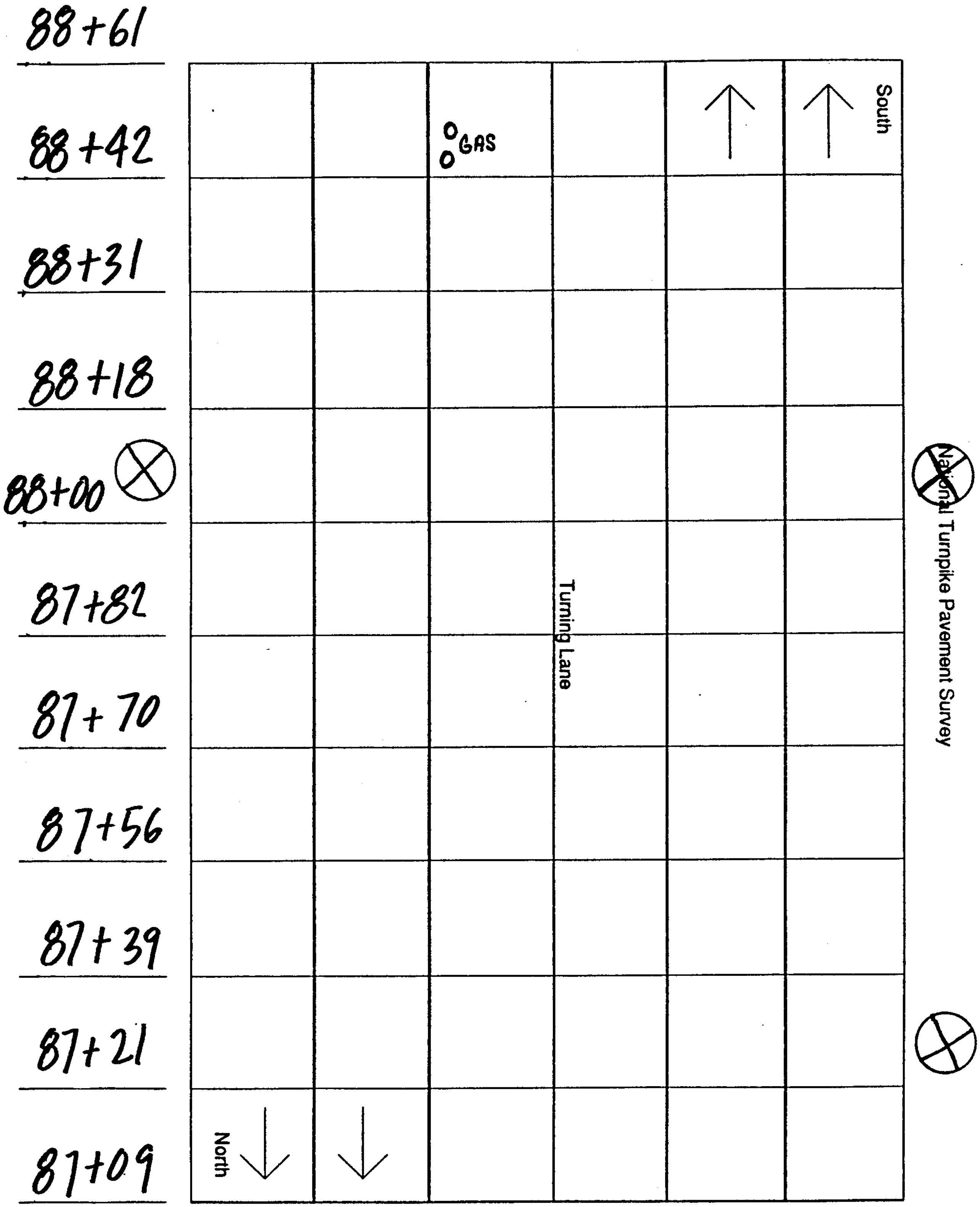

National Turnpike Pavement Survey
South
North
Turning Lane
80+90
80+73
80+55
80+43
80+30
80+13
79+95
79+82
79+69
79+52
79+34
CORE HOLE
CRACK
CRACK
SPALDED

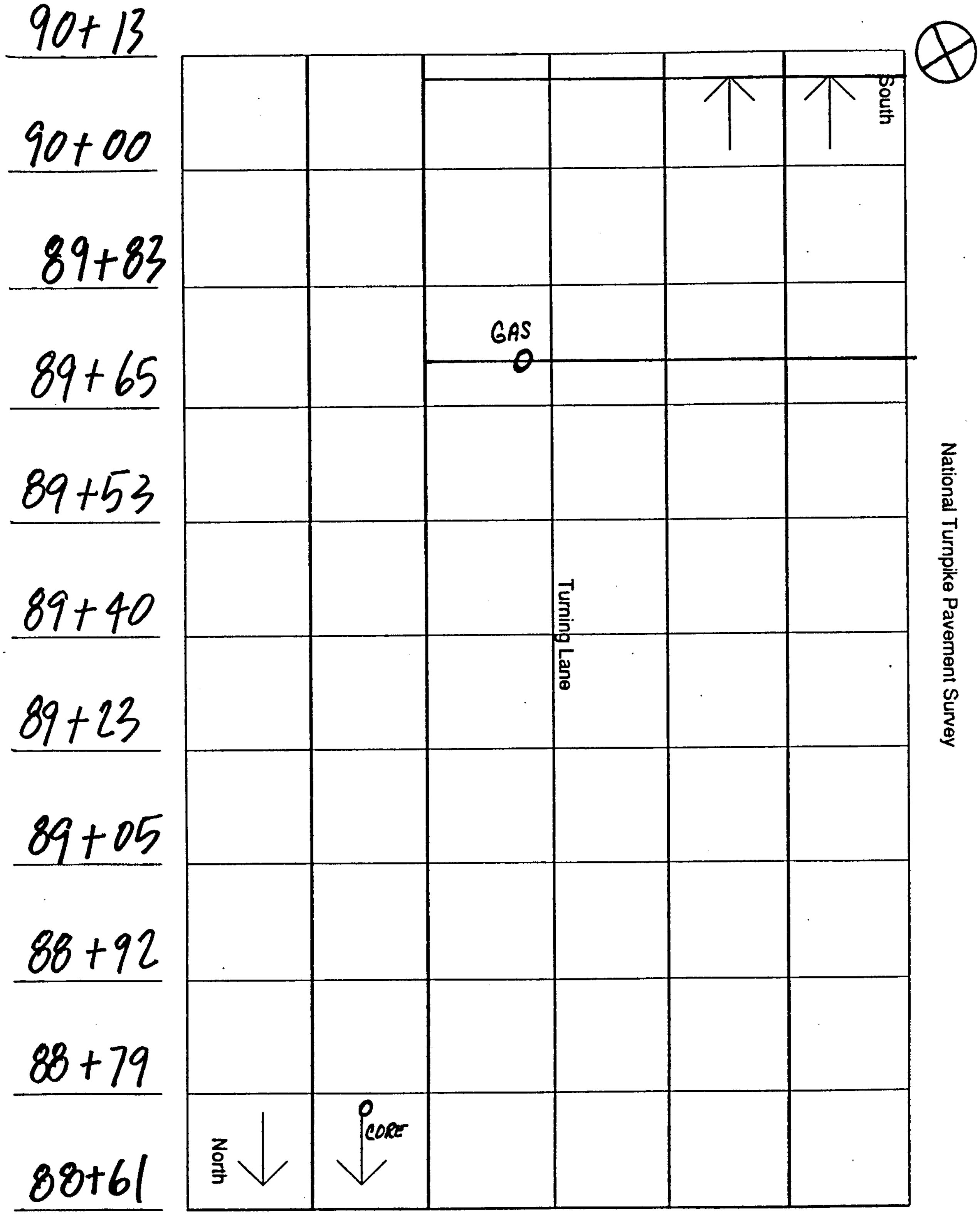

82+36
82+24
82+12
81+94
81+76
81+63
81+50
81+33
81+15
81+03
80+90
CRACKS
South
North
Turning Lane
National Turnpike Pavement Survey

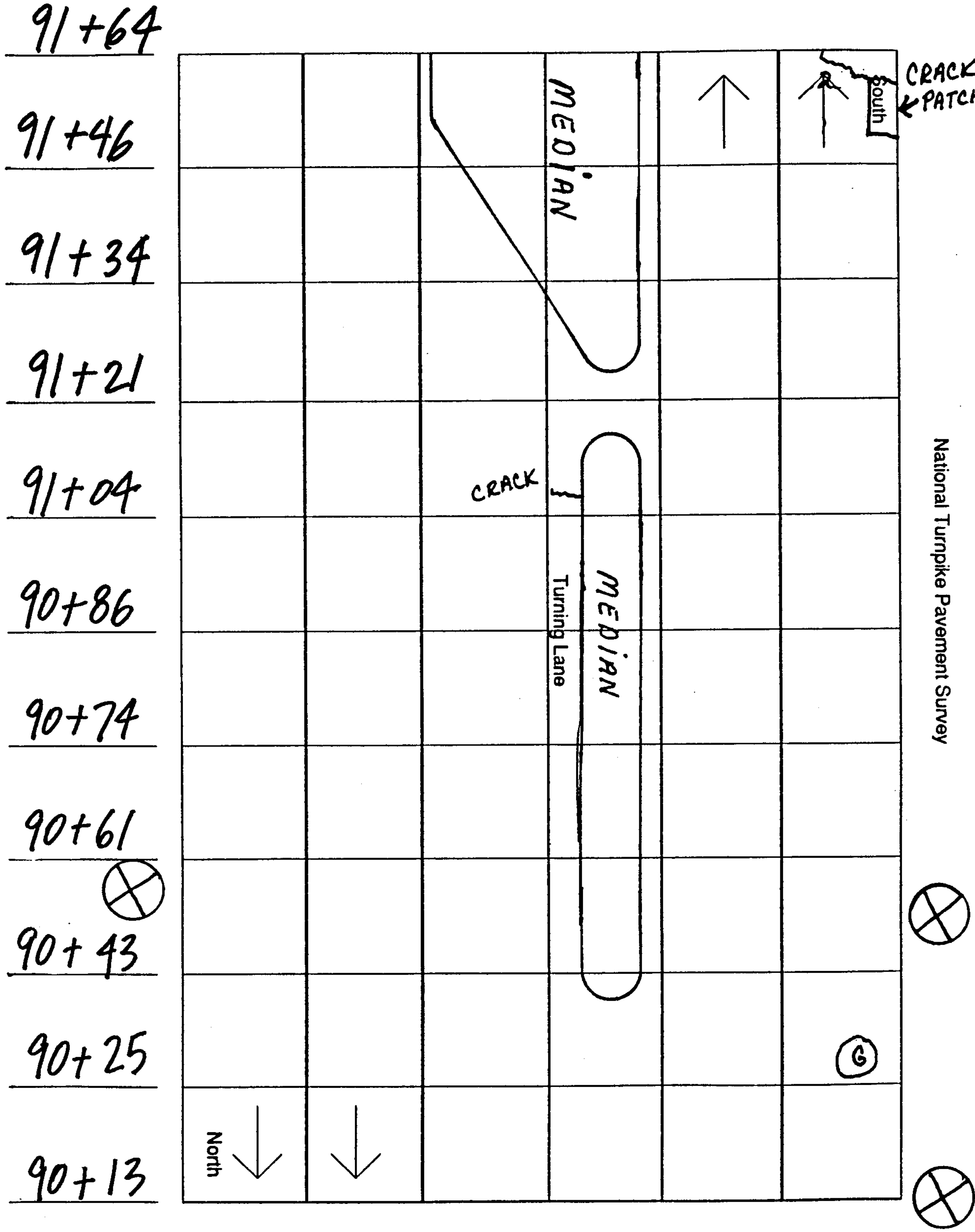

84+06
83+92
83+75
83+57
83+45
83+32
83+14
82+96
82+71
82+54
82+36
South
National Turnpike Pavement Survey
Turning Lane
SPALDED
North

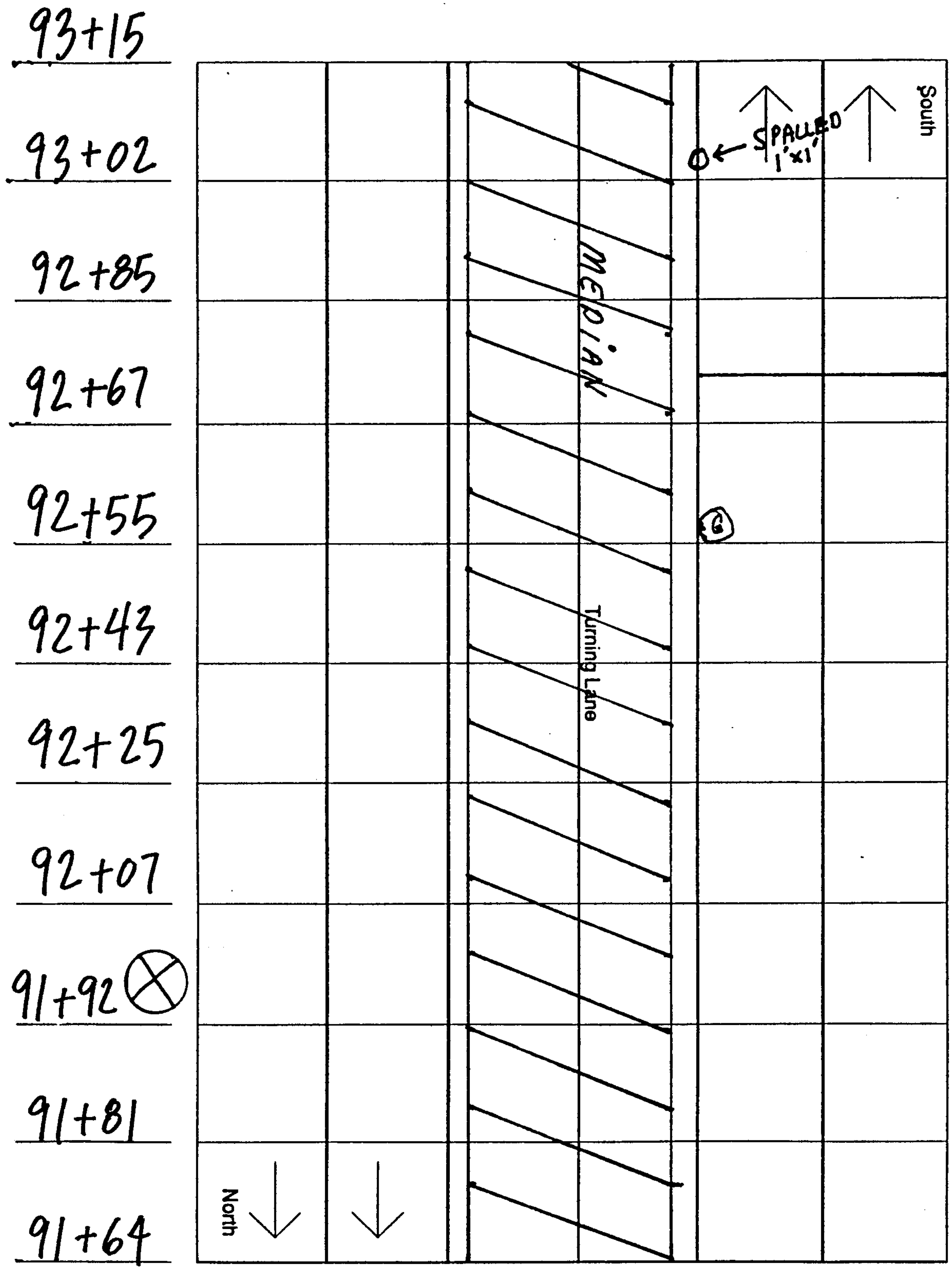

85+58
85+40
85+28
85+15
84+98
84+79
84+66
84+53
84+36
84+18
84+06
South
North
G
CRACKS
CRACKED CORNER
SINCLAIR ST.
National Turnpike Pavement Survey
CRACK
Turning Lane
CRACKED CORNERS
GAS
CRACK
CRACKED CORNER


87+09
86+96
86+79
86+61
86+49
86+36
86+19
86+01
85+91
85+76
85+58
South
North
Turning Lane
National Turnpike Pavement Survey
CRACKED CORNER
G
G
G

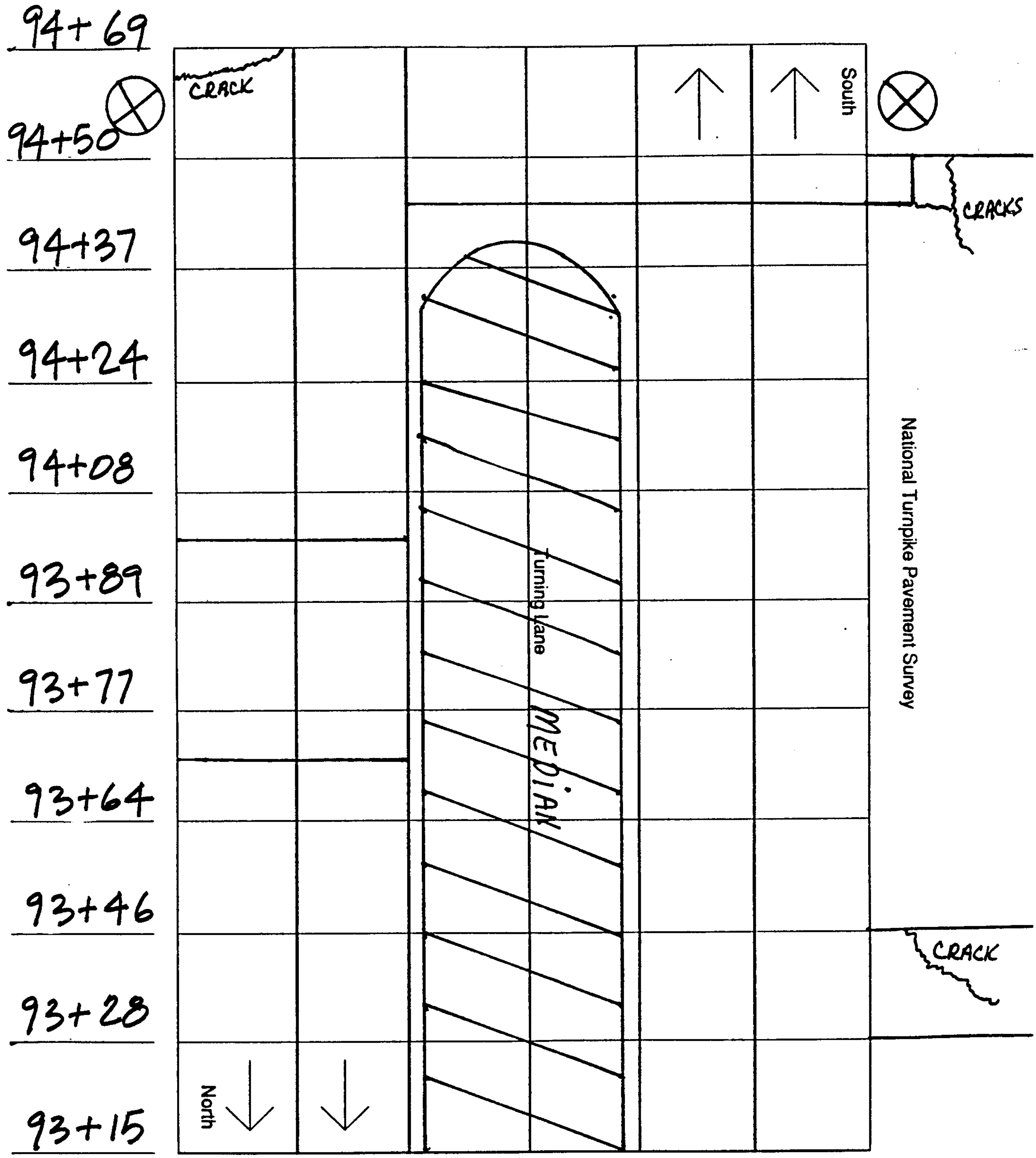

88+61
88+42
88+31
88+18
88+00
87+82
87+70
87+56
87+39
87+21
87+09
GAS
South
North
Turning Lane
National Turnpike Pavement Survey

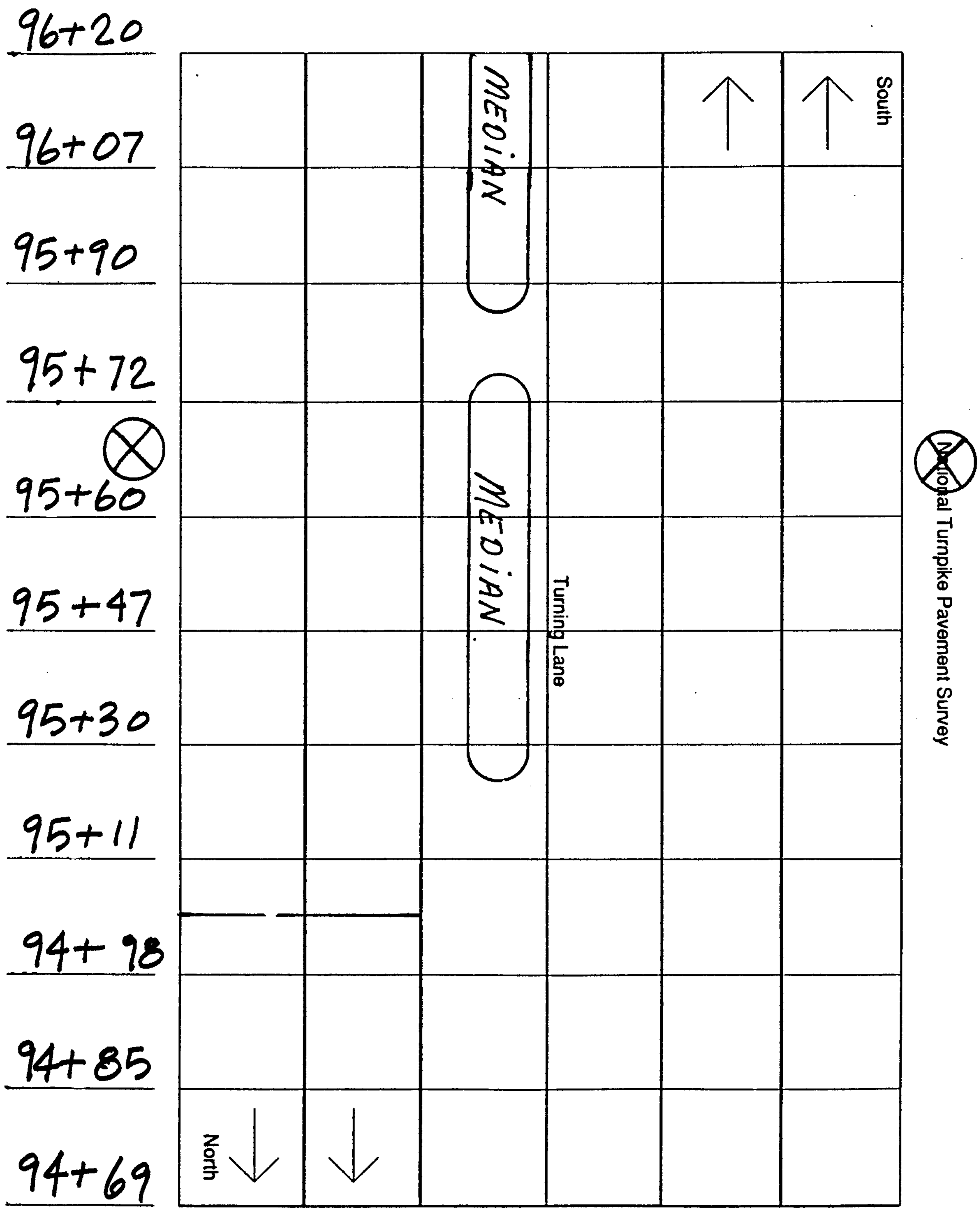

90+13
90+00
89+83
89+65
89+53
89+40
89+23
89+05
88+92
88+79
88+61
South
GAS
Turning Lane
North
CORE
National Turnpike Pavement Survey

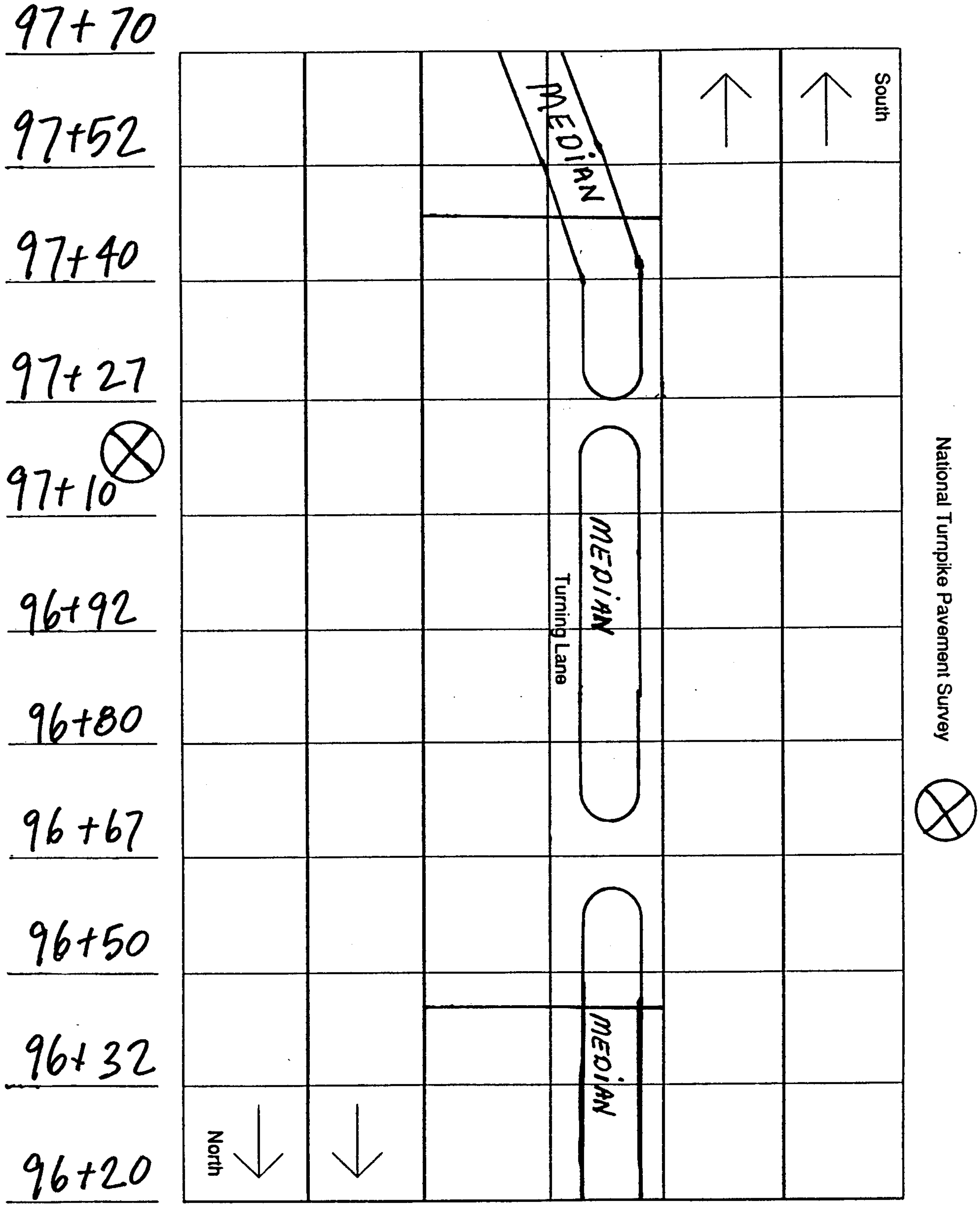

91+64
91+46
91+34
91+21
91+04
90+86
90+74
90+61
90+43
90+25
90+13
MEDIAN
South
CRACK
PATCH
CRACK
Turning Lane
MEDIAN
North
G
National Turnpike Pavement Survey

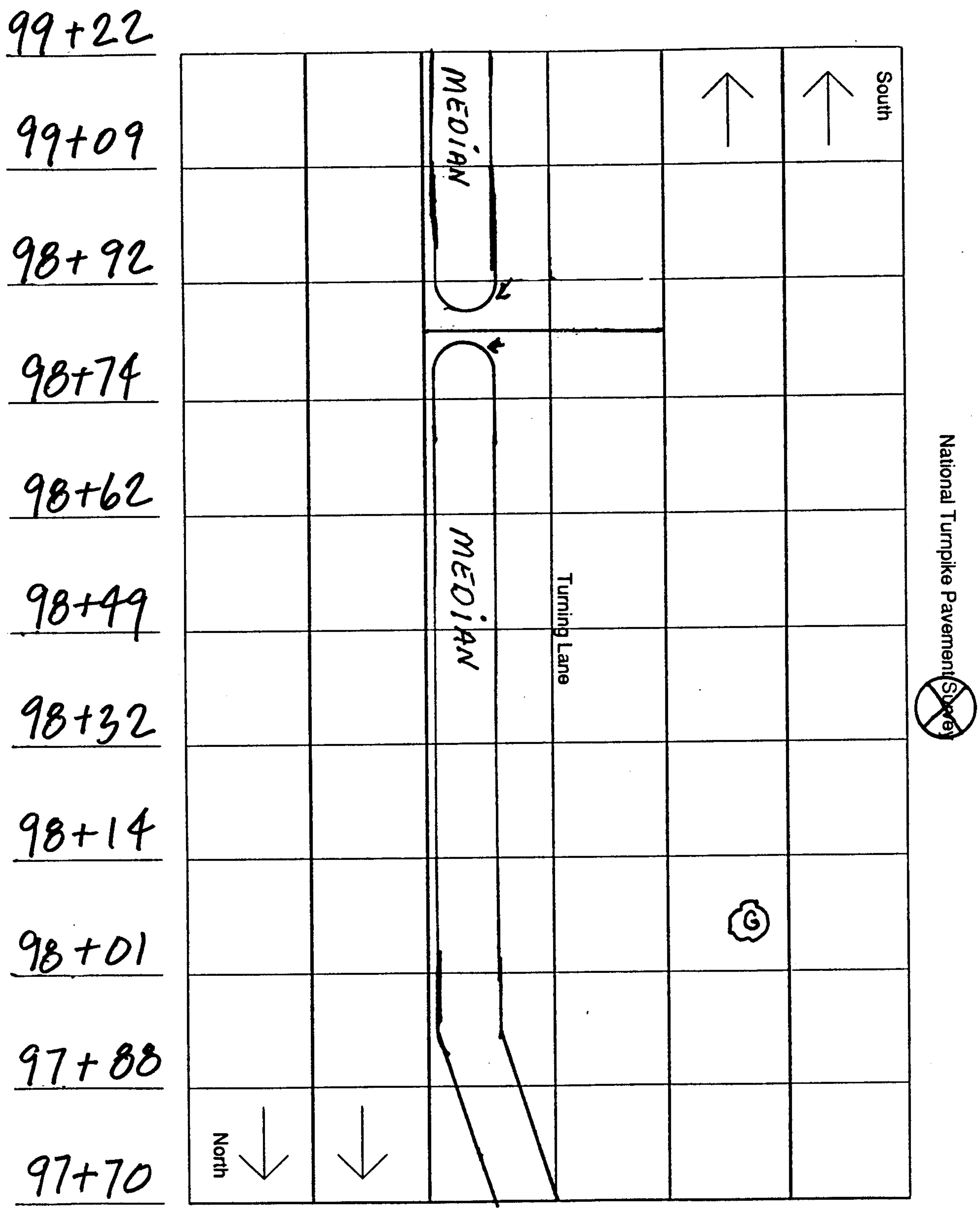


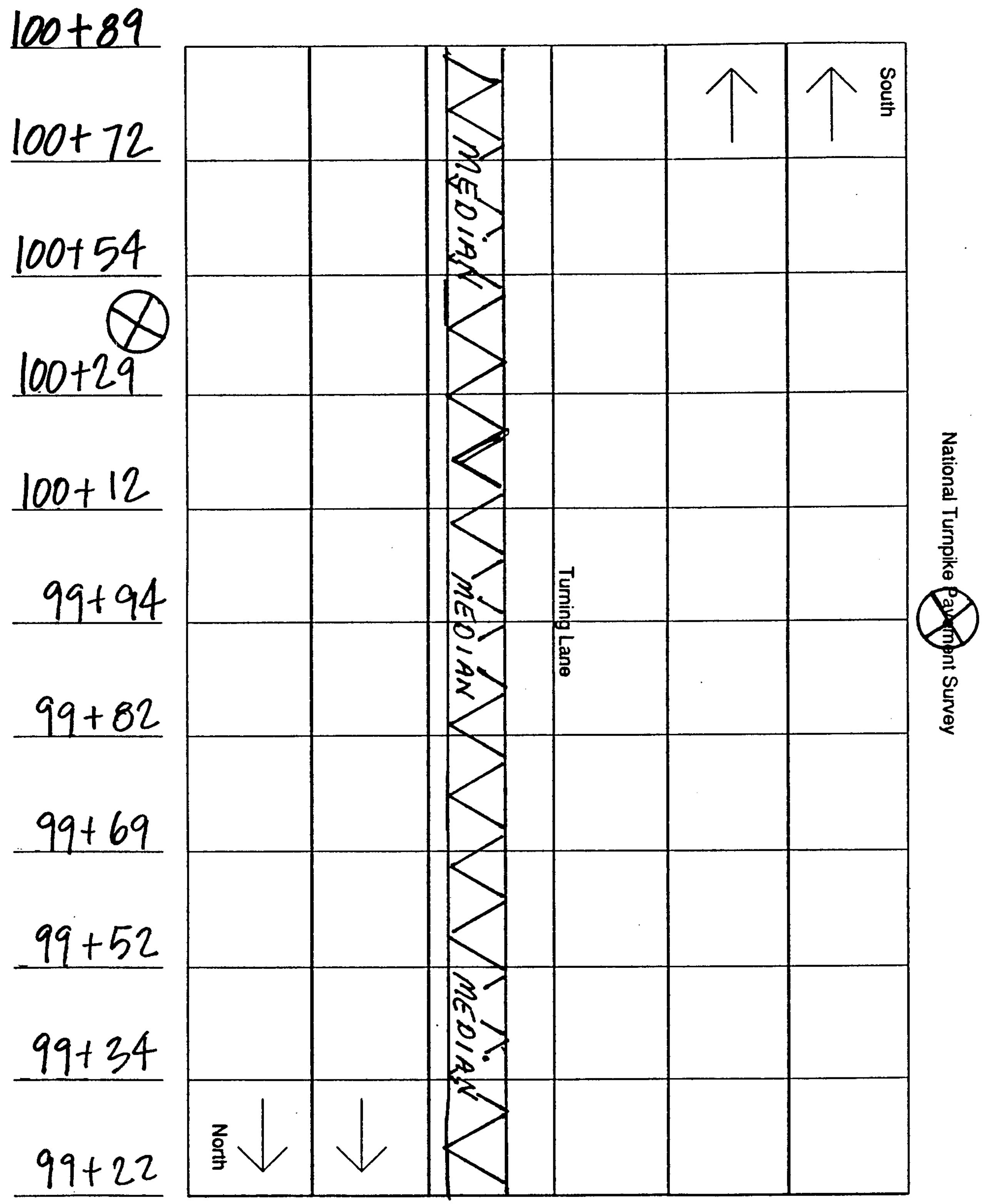
93+15
93+02
92+85
92+67
92+55
92+43
92+25
92+07
91+92
91+81
91+64
South
SPALLED
1'x1'
MEDIAN
Turning Lane
North

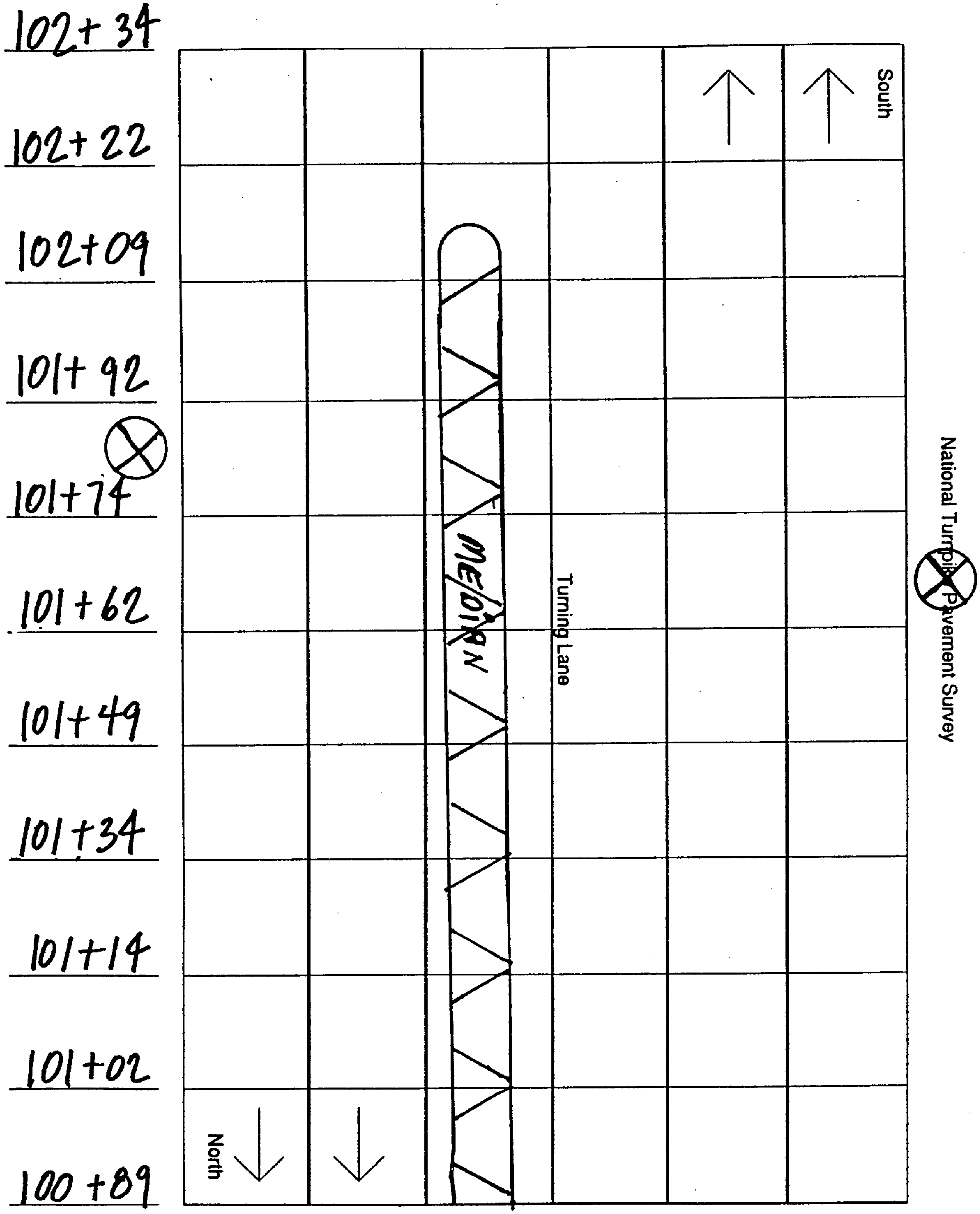

94+69
94+50
94+37
94+24
94+08
93+89
93+77
93+64
93+46
93+28
93+15
CRACK
South
CRACKS
Turning Lane
MEDIAN
National Turnpike Pavement Survey
CRACK
North


96+20
96+07
95+90
95+72
95+60
95+47
95+30
95+11
94+98
94+85
94+69
MEDIAN
MEDIAN
Turning Lane
South
North
Turnpike Pavement Survey

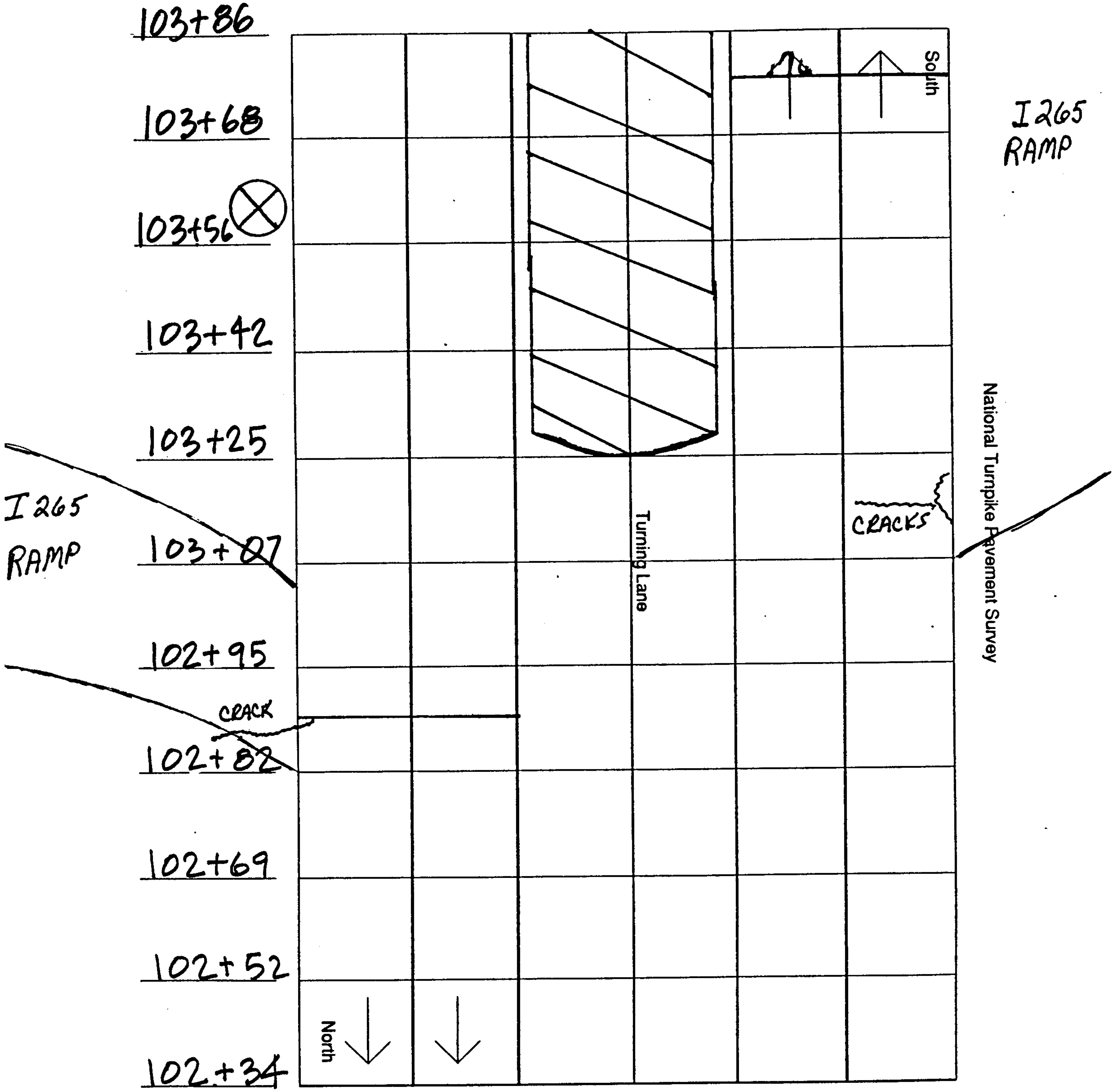

97+70
97+52
97+40
97+27
97+10
96+92
96+80
96+67
96+50
96+32
96+20
South
North
MEDIAN
MEDIAN
MEDIAN
Turning Lane
National Turnpike Pavement Survey


99+22
99+09
98+92
98+74
98+62
98+49
98+32
98+14
98+01
97+88
97+70
South
MEDIAN
MEDIAN
Turning Lane
North
National Turnpike Pavement Survey
G

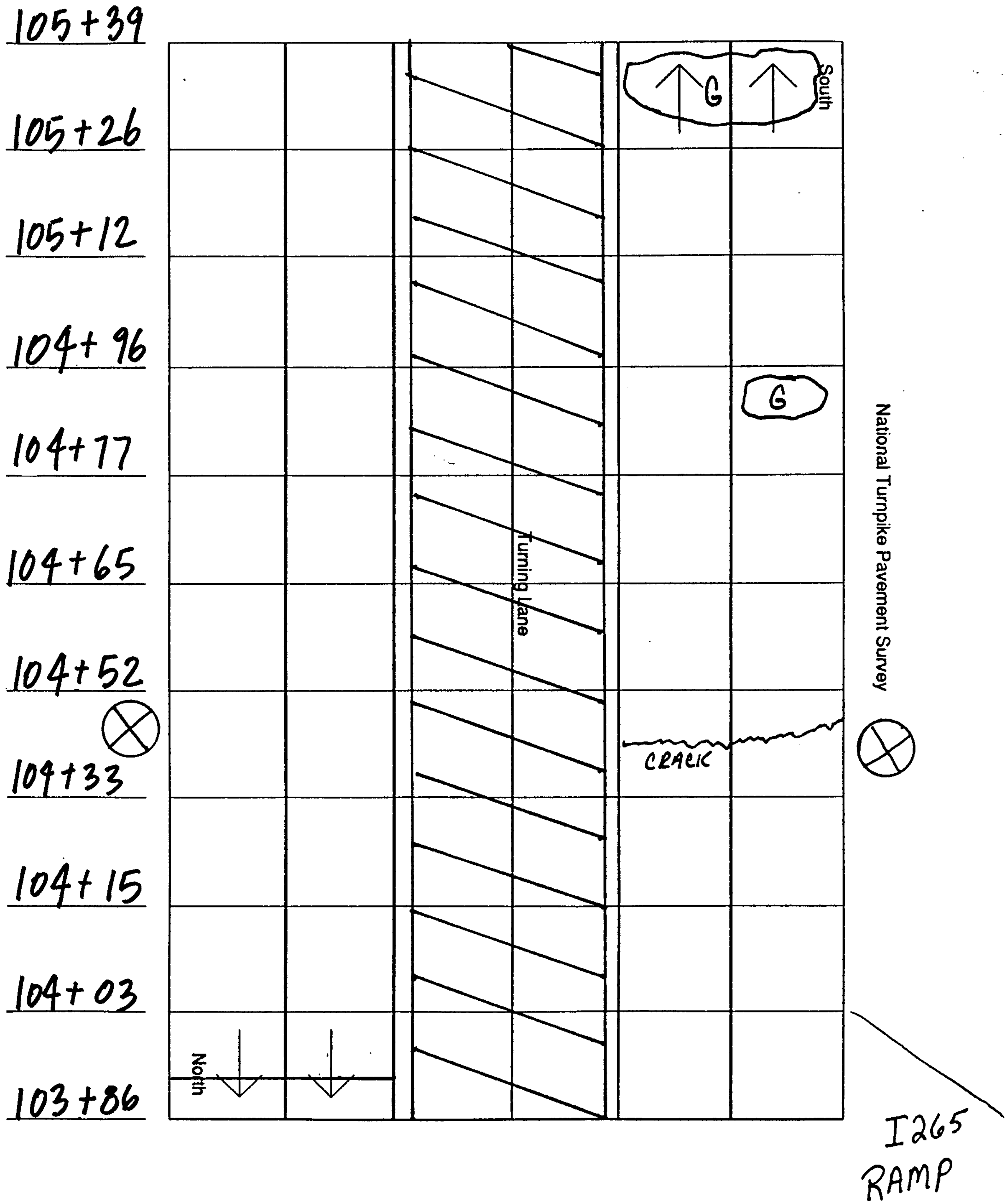

100+89
100+72
100+54
100+29
100+12
99+94
99+82
99+69
99+52
99+34
99+22
South
North
MEDIAN
MEDIAN
MEDIAN
Turning Lane
National Turnpike Pavement Survey

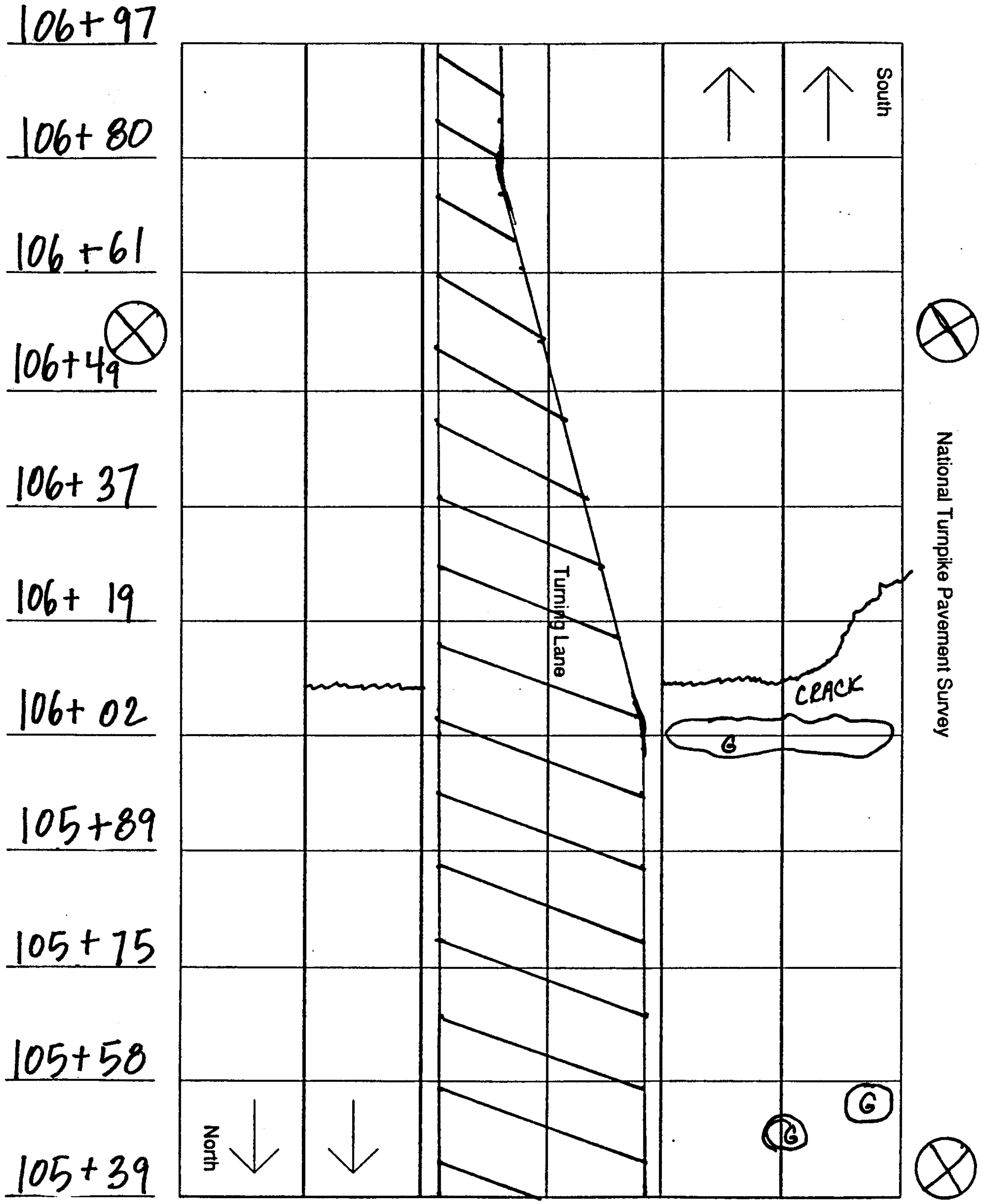


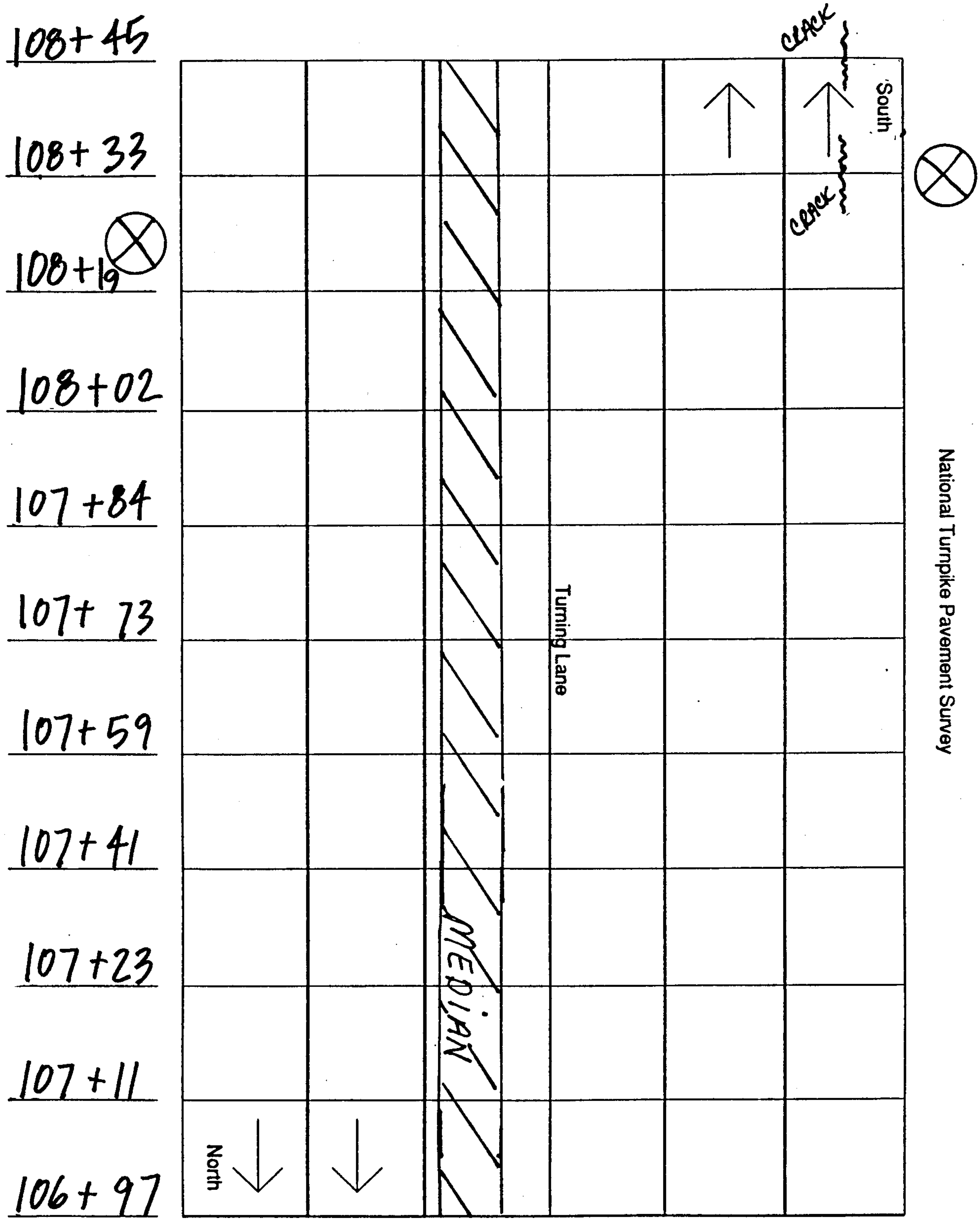
102+34
102+22
102+09
101+92
101+74
101+62
101+49
101+34
101+14
101+02
100+89
South
North
Turning Lane
MEDIAN
National Turnpike Pavement Survey



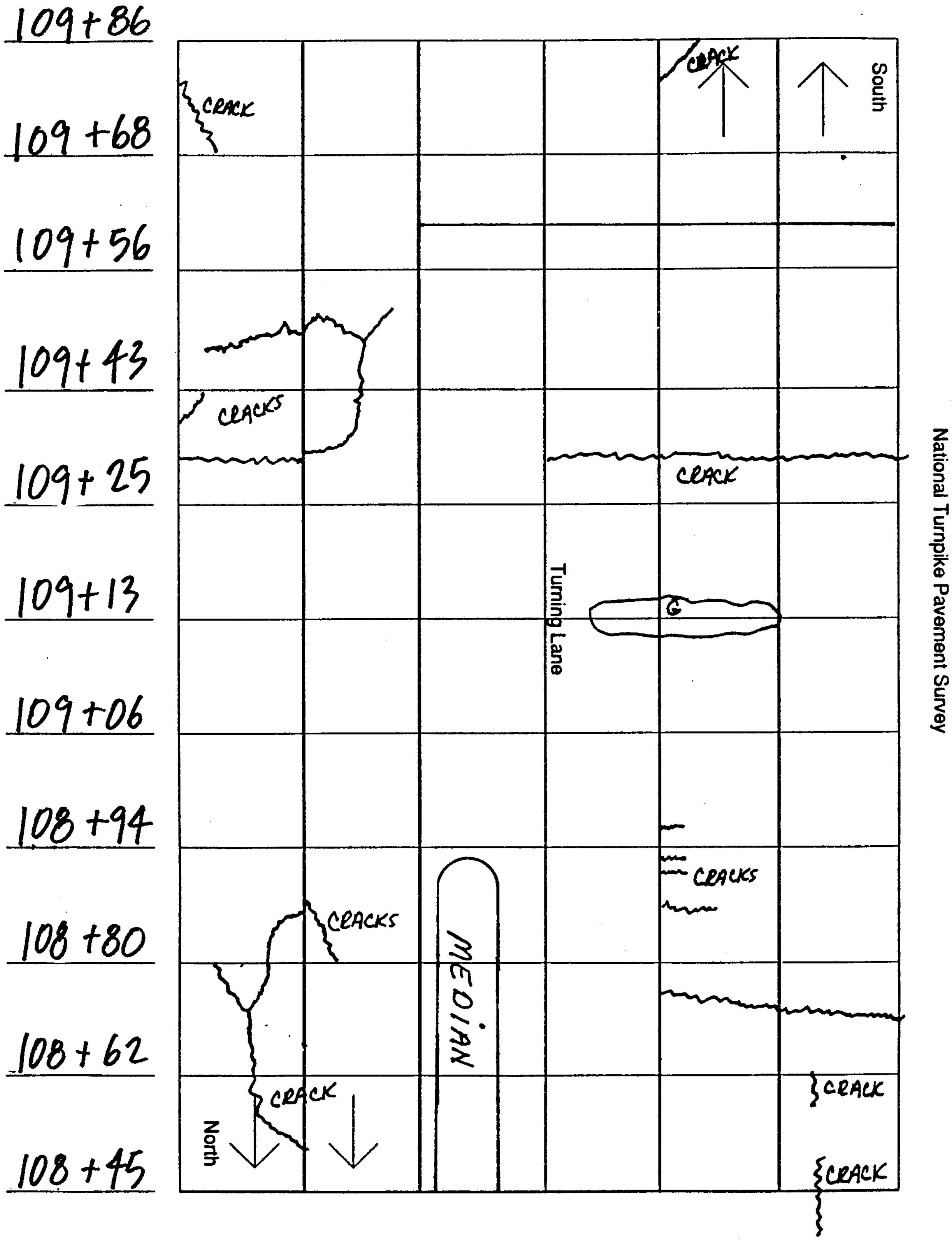
103+86
103+68
103+56
103+42
103+25
103+07
102+95
102+82
102+69
102+52
102+34
I265 RAMP
I265 RAMP
CRACK
CRACKS
South
North
Turning Lane
National Turnpike Pavement Survey


105+39
105+26
105+12
104+96
104+77
104+65
104+52
104+33
104+15
104+03
103+86
South
G
G
Turning Lane
CRACK
North
National Turnpike Pavement Survey
I265
RAMP


106+97
106+80
106+61
106+49
106+37
106+19
106+02
105+89
105+75
105+58
105+39
South
North
Turning Lane
CRACK
G
G
G
National Turnpike Pavement Survey

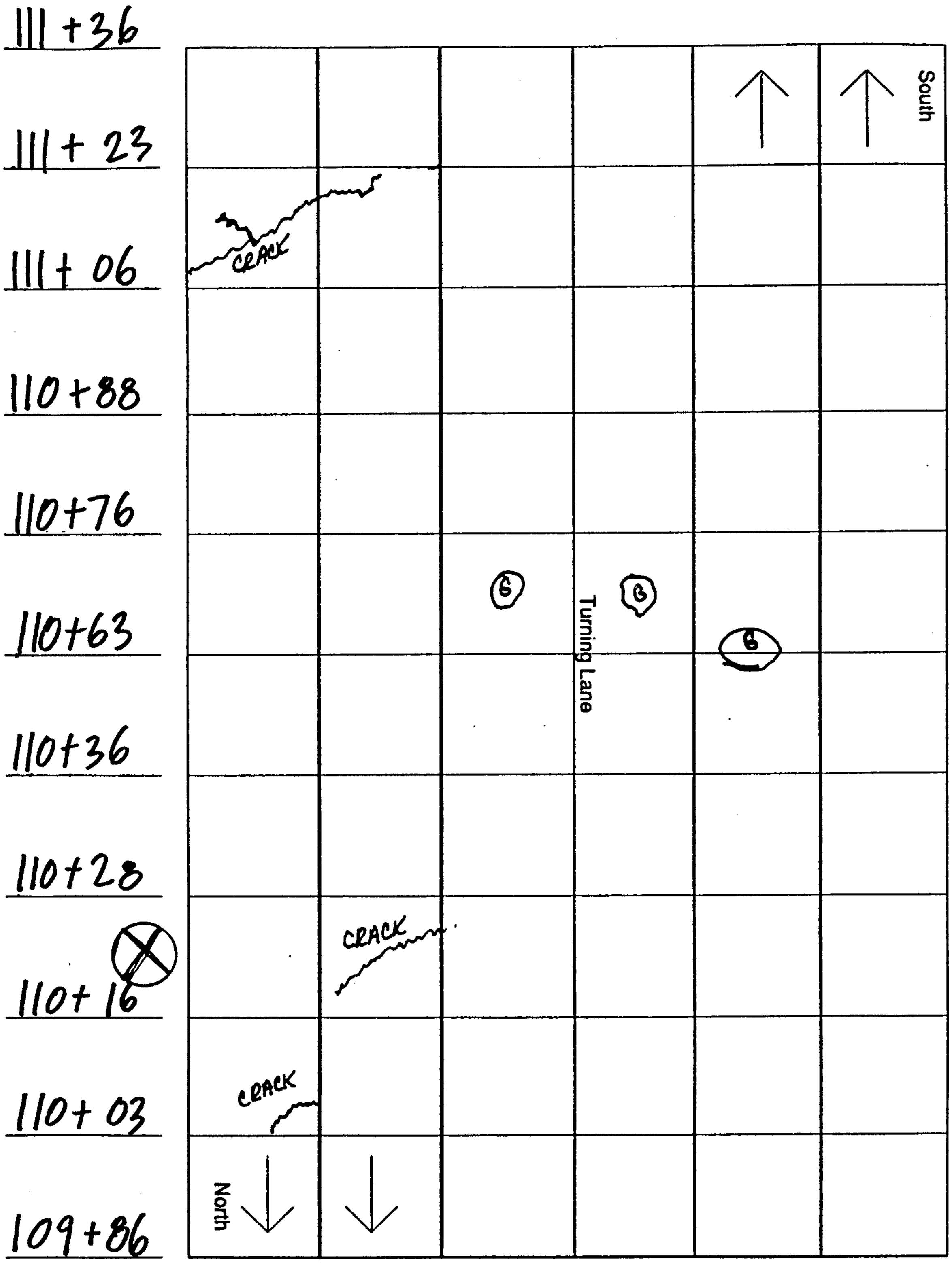


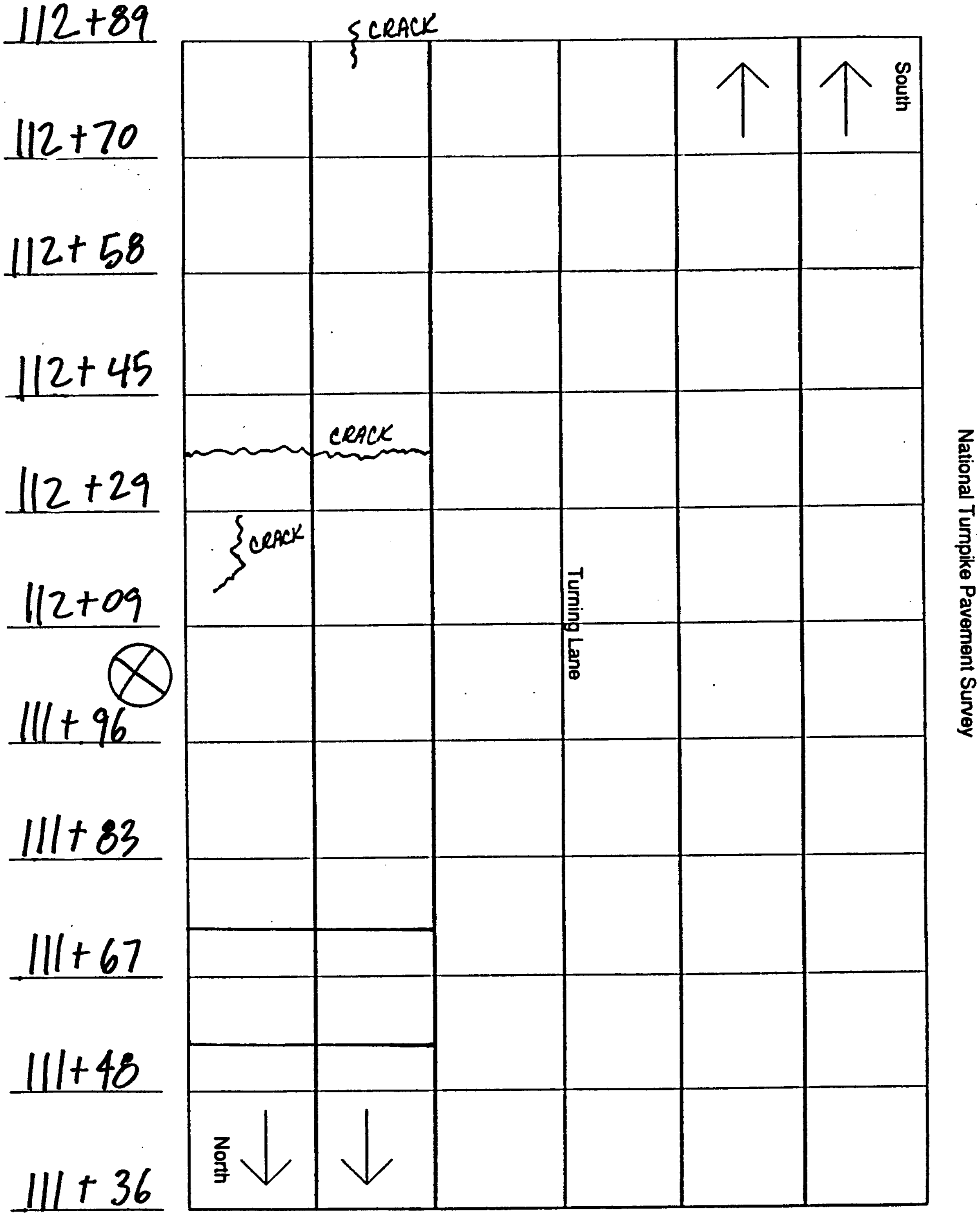
108+45
108+33
108+19
108+02
107+84
107+73
107+59
107+41
107+23
107+11
106+97
North
MEDIAN
Turning Lane
South
CRACK
CRACK
National Turnpike Pavement Survey

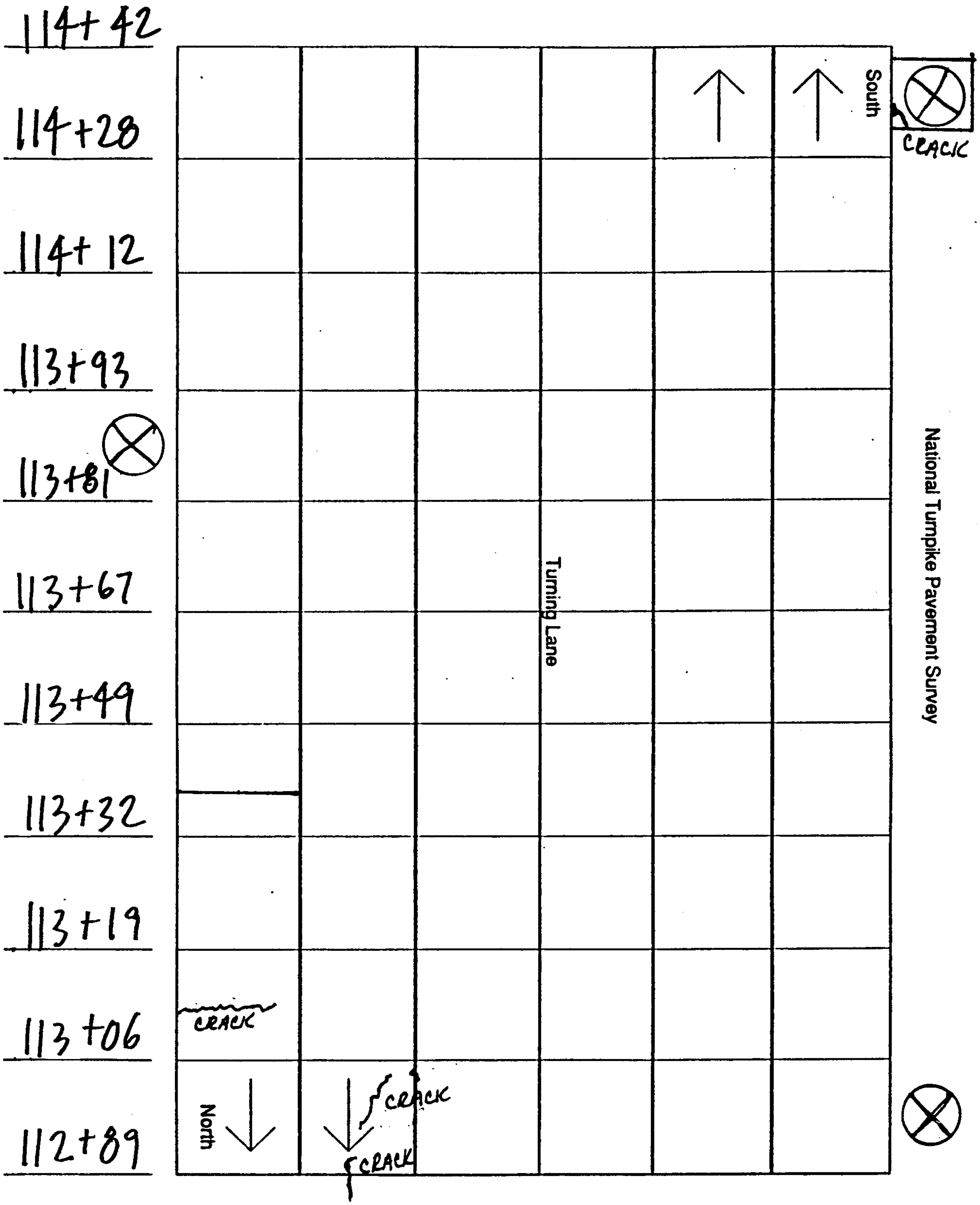


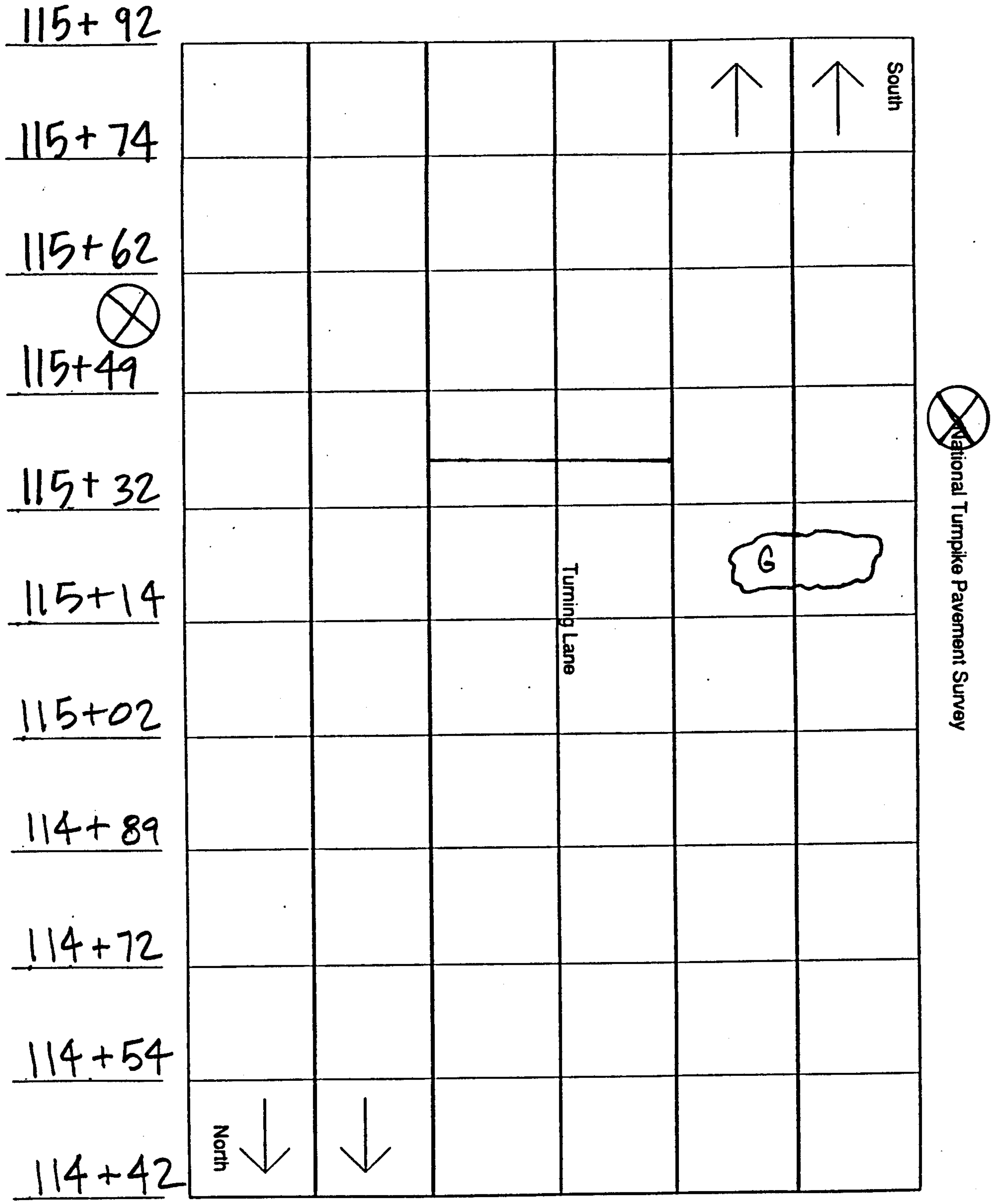
109+86
109+68
109+56
109+43
109+25
109+13
109+06
108+94
108+80
108+62
108+45
CRACK
CRACK
South
CRACKS
CRACK
G
Turning Lane
National Turnpike Pavement Survey
CRACKS
CRACKS
MEDIAN
CRACK
North
CRACK
CRACK

National Turnpike Pavement Survey

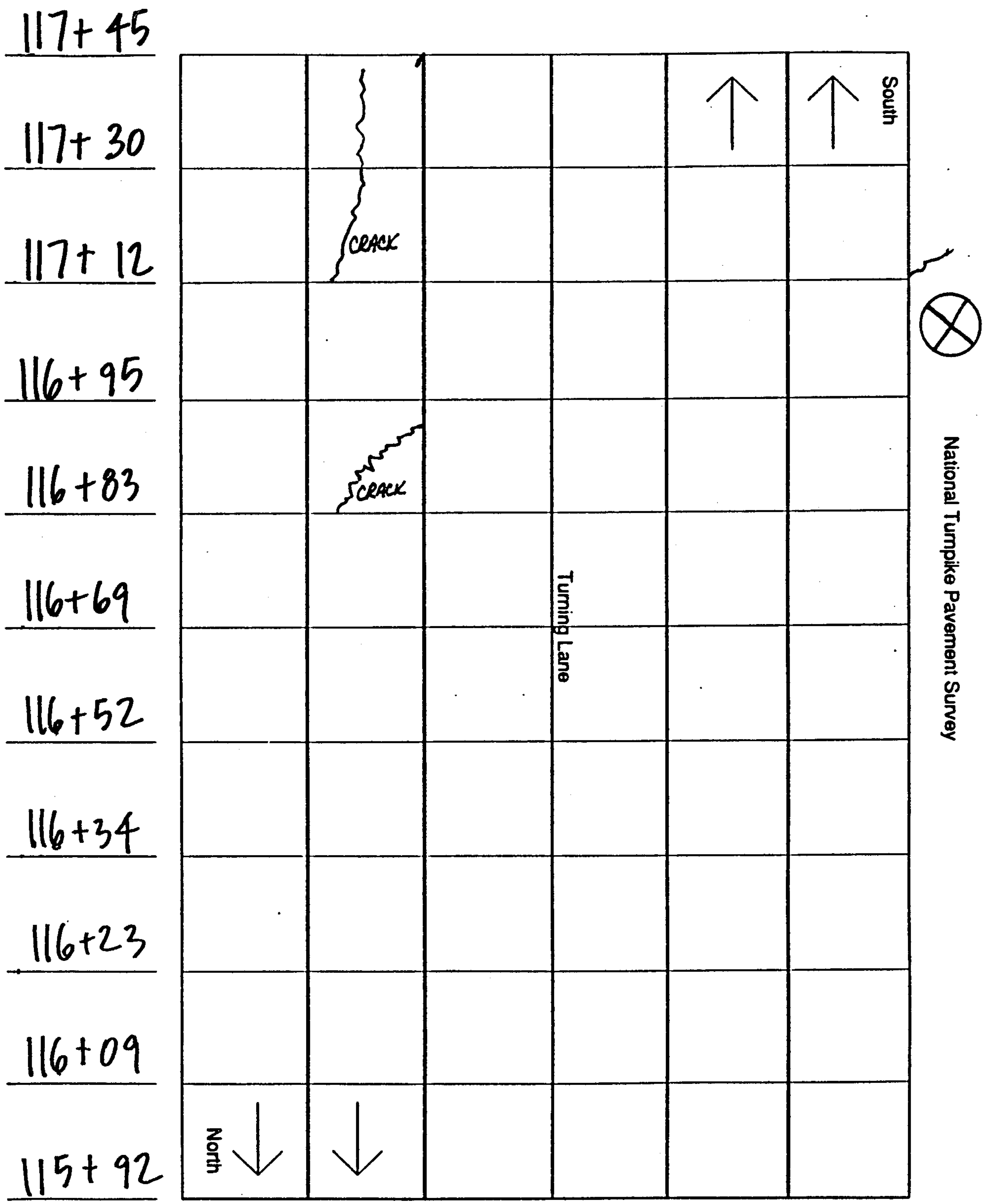



112+89
CRACK
South
112+70
112+58
112+45
CRACK
112+29
CRACK
112+09
Turning Lane
111+96
111+83
111+67
111+48
North
111+36
National Turnpike Pavement Survey


114+42
114+28
114+12
113+93
113+81
113+67
113+49
113+32
113+19
113+06
112+89
South
CRACK
National Turnpike Pavement Survey
Turning Lane
CRACK
North
CRACK
CRACK



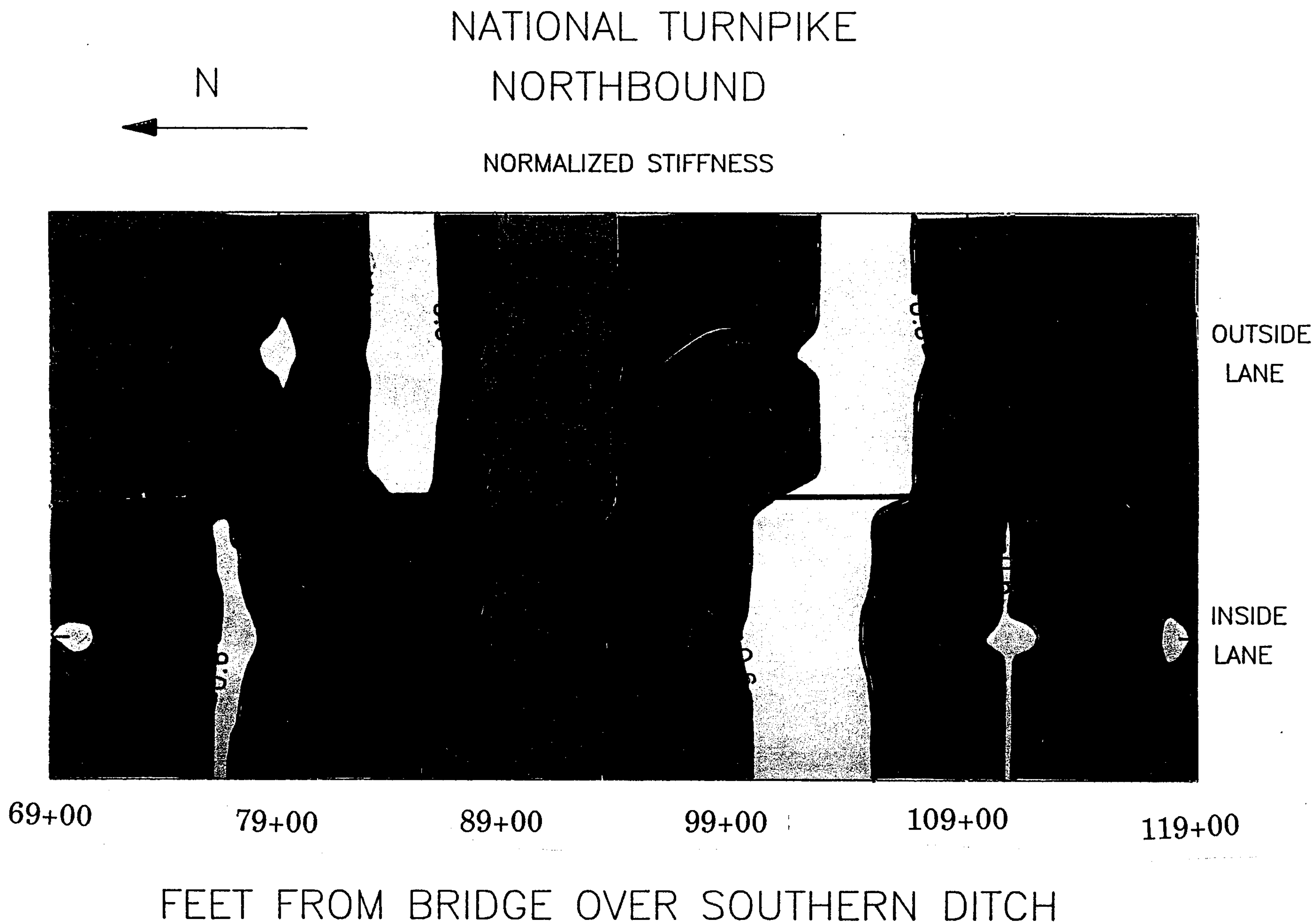
115+92
115+74
115+62
115+49
115+32
115+14
115+02
114+89
114+72
114+54
114+42
South
North
Turning Lane
G
National Turnpike Pavement Survey


117+45
117+30
117+12
116+95
116+83
116+69
116+52
116+34
116+23
116+09
115+92
South
North
CRACK
CRACK
Turning Lane
National Turnpike Pavement Survey

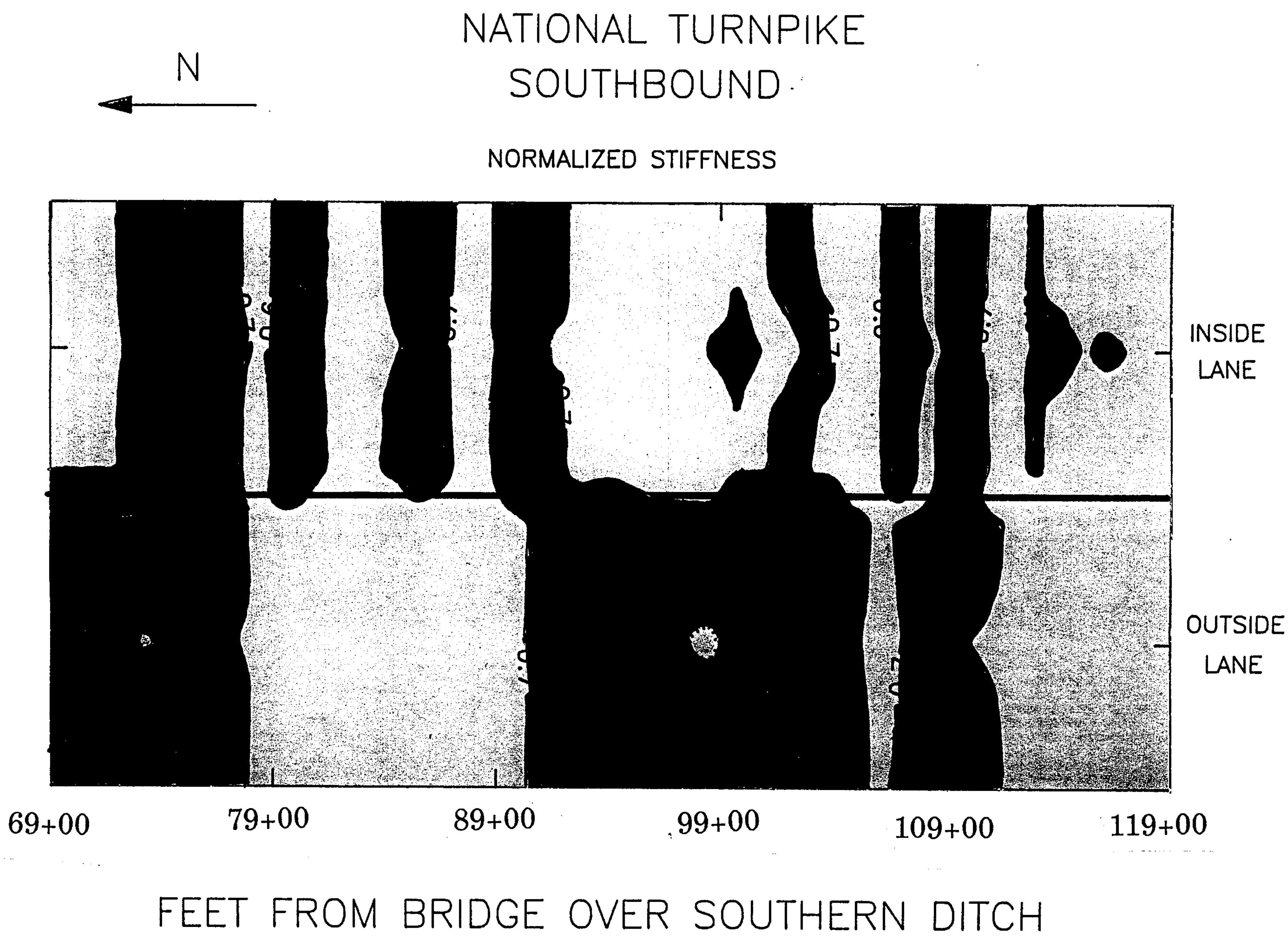
National Turnpike Pavement Survey

					↑	↑ South
	FAIRDALE	RD.				
118+34						
118+16						
118+09				Turning Lane		
118+04						
117+91						
117+74						
117+56	CRACK					
117+45	North ↓	↓				

Appendix B
Normalized Stiffness Contours



NATIONAL TURNPIKE
NORTHBOUND
N
NORMALIZED STIFFNESS
OUTSIDE LANE
INSIDE LANE
69+00
79+00
89+00
99+00
109+00
119+00
FEET FROM BRIDGE OVER SOUTHERN DITCH


NATIONAL TURNPIKE
SOUTHBOUND
N
NORMALIZED STIFFNESS
INSIDE LANE
OUTSIDE LANE
69+00
79+00
89+00
99+00
109+00
119+00
FEET FROM BRIDGE OVER SOUTHERN DITCH

Appendix C
Laboratory Record Of Soil Test Data

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO	GI	USC
Station 40+37 Northbound Lane Depth (48"-51")	31.0	21.0	10.0	2.75	A-4	(10)	CL

MECHANICAL SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
1 IN	0.00	100.00
3/4 IN	0.00	100.00
1/2 IN	0.00	100.00
3/8 IN	0.00	100.00
NO. 4	0.00	100.00
NO. 10	0.00	100.00

HYDROMETER SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 20	0.00	100.00
NO. 40	0.00	100.00
NO. 60	0.02	99.97
NO. 200	0.12	99.76

HYDROMETER ANALYSIS

TIME (MIN)	TEMP	HYD READING	PERCENT FINER	PARTICLE DIAMETER-M/M
1.00	68.00	61.00	95.59969	0.03278
2.00	68.00	60.00	93.95045	0.02349
5.00	68.00	54.00	84.05479	0.01597
15.00	68.00	44.00	67.56206	0.01021
31.00	70.00	36.00	54.76711	0.00750
59.00	71.00	31.00	46.65222	0.00562
245.00	75.00	19.00	27.99707	0.00291
1432.00	75.00	13.00	18.10144	0.00125

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO	GI	USC
Station 16+01 Center Median Sinclair Street	28.0	21.0	7.0	2.72	A-4	(6)	ML-CL

MECHANICAL SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
1 IN	0.00	100.00
3/4 IN	0.00	100.00
1/2 IN	0.00	100.00
3/8 IN	0.00	100.00
NO. 4	0.00	100.00
NO. 10	0.00	100.00

HYDROMETER SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 20	0.00	100.00
NO. 40	0.01	99.98
NO. 60	0.01	99.97
NO. 200	0.04	99.90

HYDROMETER ANALYSIS

TIME (MIN)	TEMP	HYD READING	PERCENT FINER	PARTICLE DIAMETER-M/M
1.00	67.00	61.00	98.46545	0.03463
2.00	67.00	56.00	89.95410	0.02607
5.00	67.00	49.00	78.03824	0.01780
15.00	67.00	39.00	61.01553	0.01127
29.00	69.00	34.00	52.91628	0.00832
62.00	70.00	27.00	41.20644	0.00595
274.00	75.00	20.00	30.59894	0.00287
1461.00	75.00	14.00	20.38531	0.00129

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO	GI	USC
Station 22+49 Northbound Lane Depth (46.5"-52.5")	35.0	22.0	13.0	2.75	A-6	(14)	CL

MECHANICAL SIEVE ANALYSIS

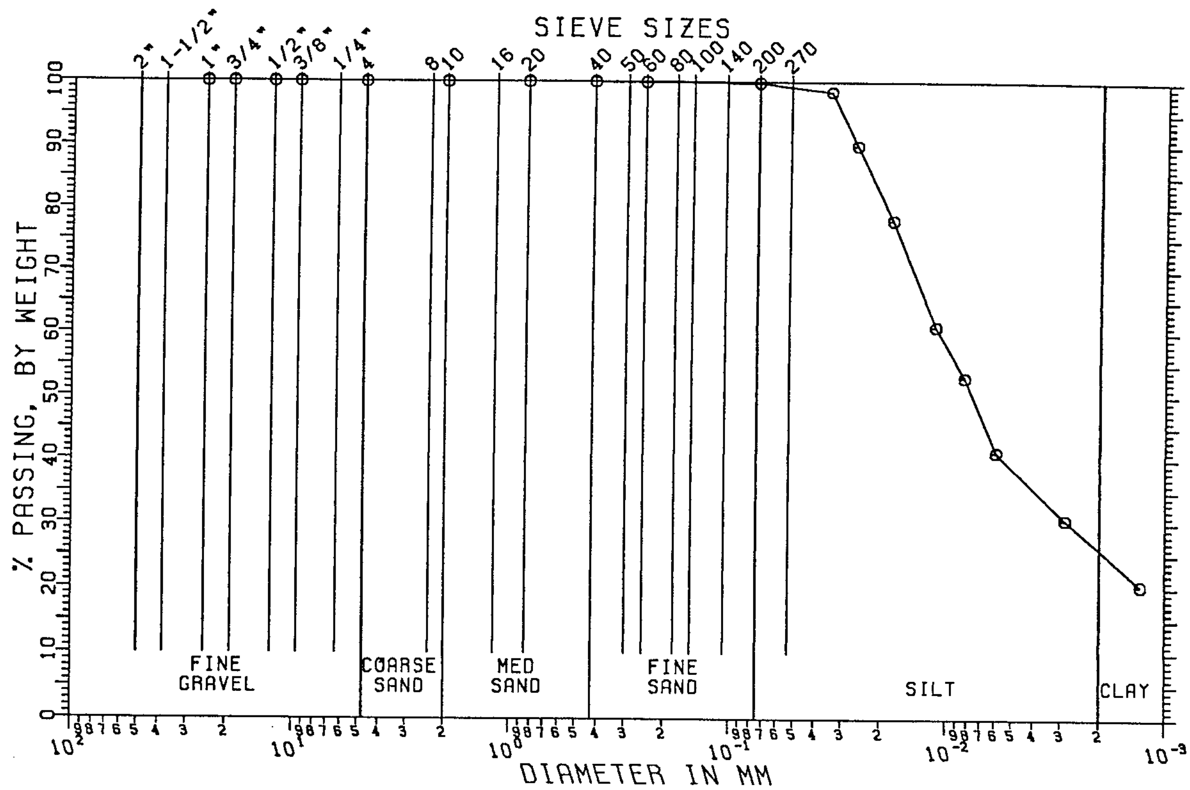
SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
1 IN	0.00	100.00
3/4 IN	0.00	100.00
1/2 IN	0.00	100.00
3/8 IN	0.00	100.00
NO. 4	0.00	100.00
NO. 10	0.00	100.00

HYDROMETER SIEVE ANALYSIS

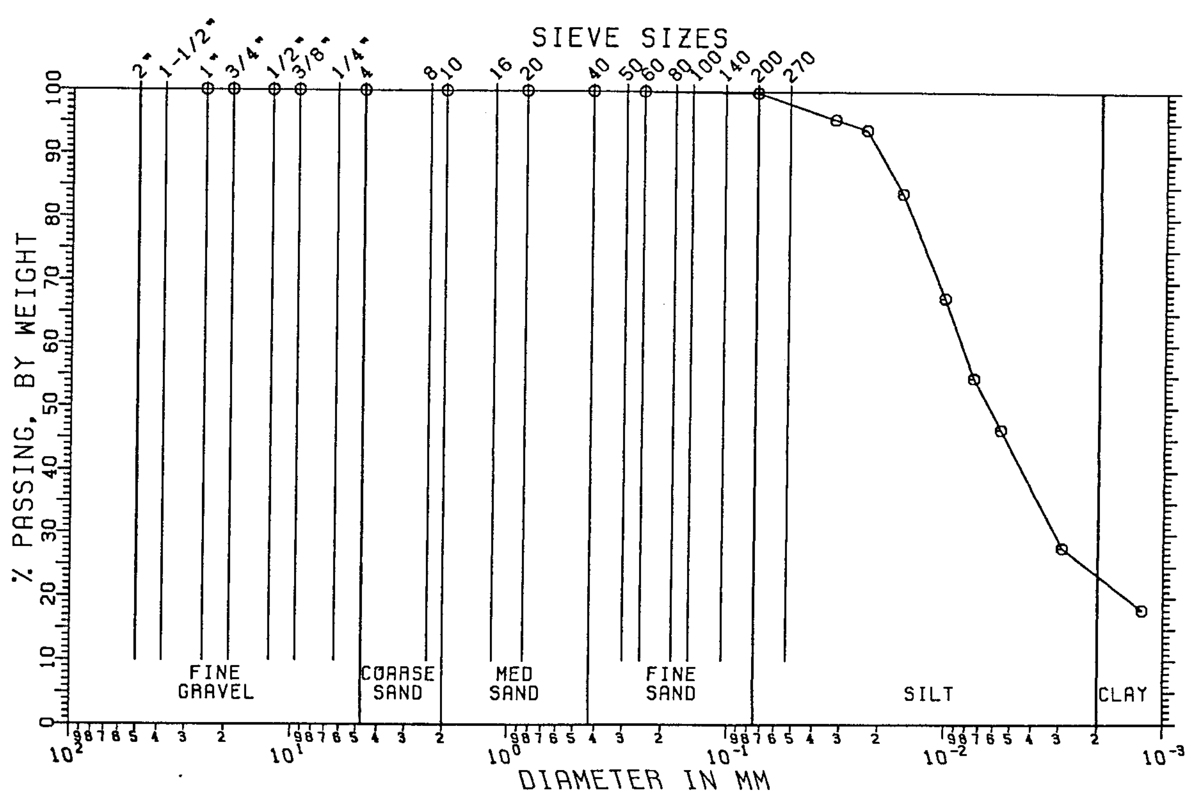
SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 20	0.02	99.96
NO. 40	0.00	99.96
NO. 60	0.02	99.93
NO. 200	0.14	99.68

HYDROMETER ANALYSIS

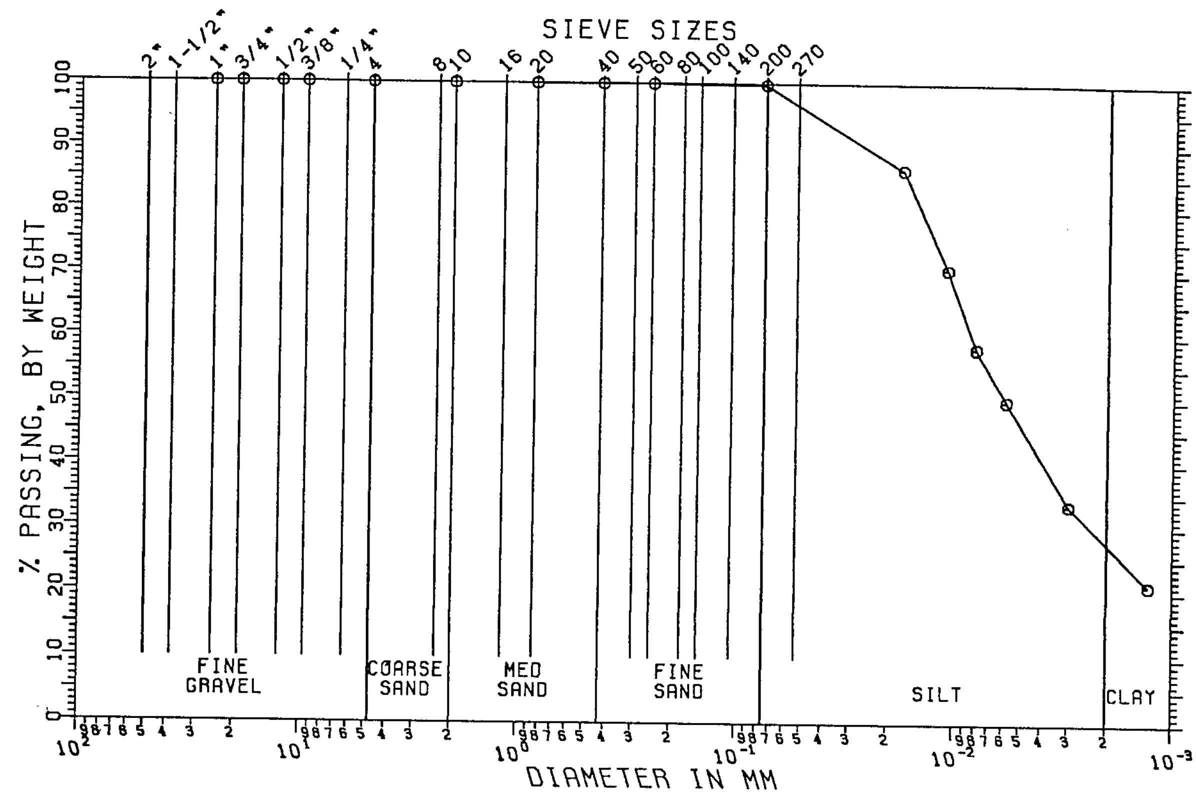
TIME (MIN)	TEMP	HYD READING	PERCENT FINER	PARTICLE DIAMETER-M/M
1.00	67.00	60.00	99.42303	0.03345
2.00	67.00	57.00	94.17589	0.02456
5.00	67.00	52.00	85.43057	0.01644
15.00	68.00	44.00	71.64980	0.01021
30.00	68.00	38.00	61.15543	0.00761
60.00	71.00	34.00	54.72198	0.00544
231.00	75.00	24.00	38.43629	0.00290
1418.00	75.00	16.00	24.44380	0.00123



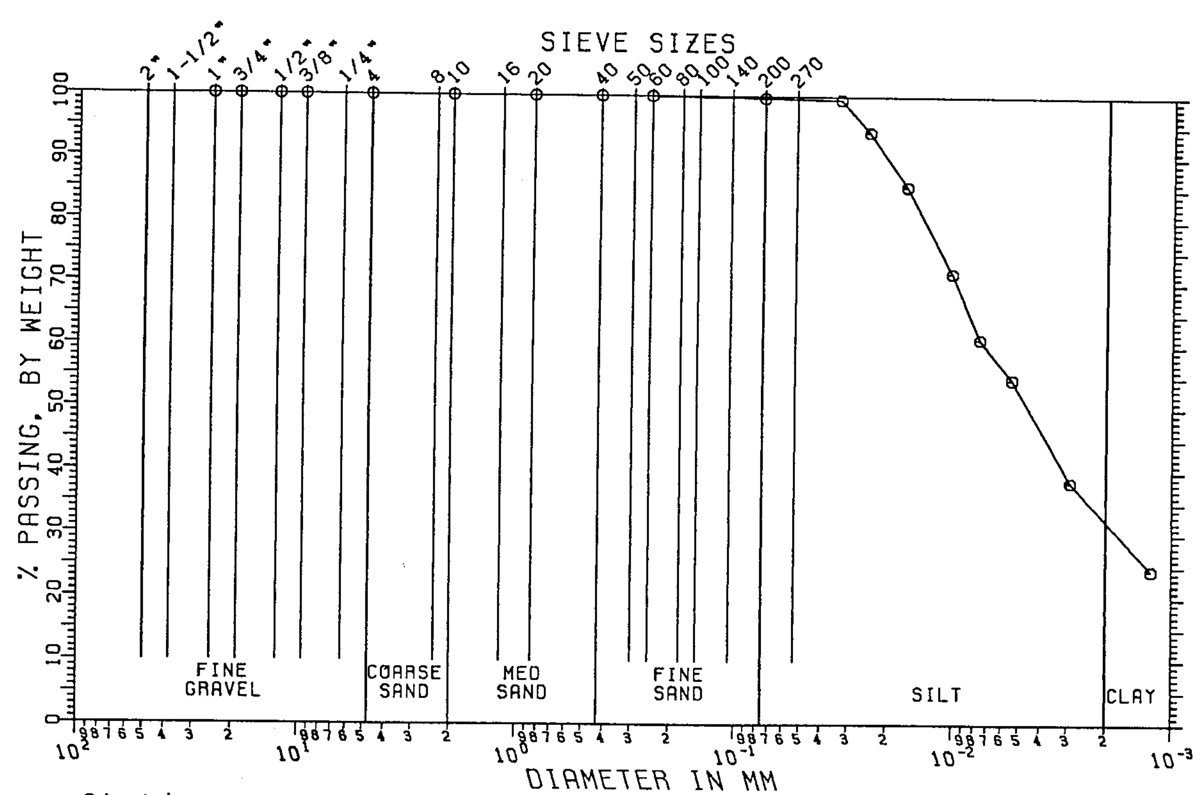
Station 16+01
Center Median
Sinclair Street



Station 40+37
Northbound Lane
Depth (48"-51")



Station 40+37
Northbound Lane
Depth (85"-90")



Station 22+49
Northbound Lane
Depth (46.5"-52.5")